

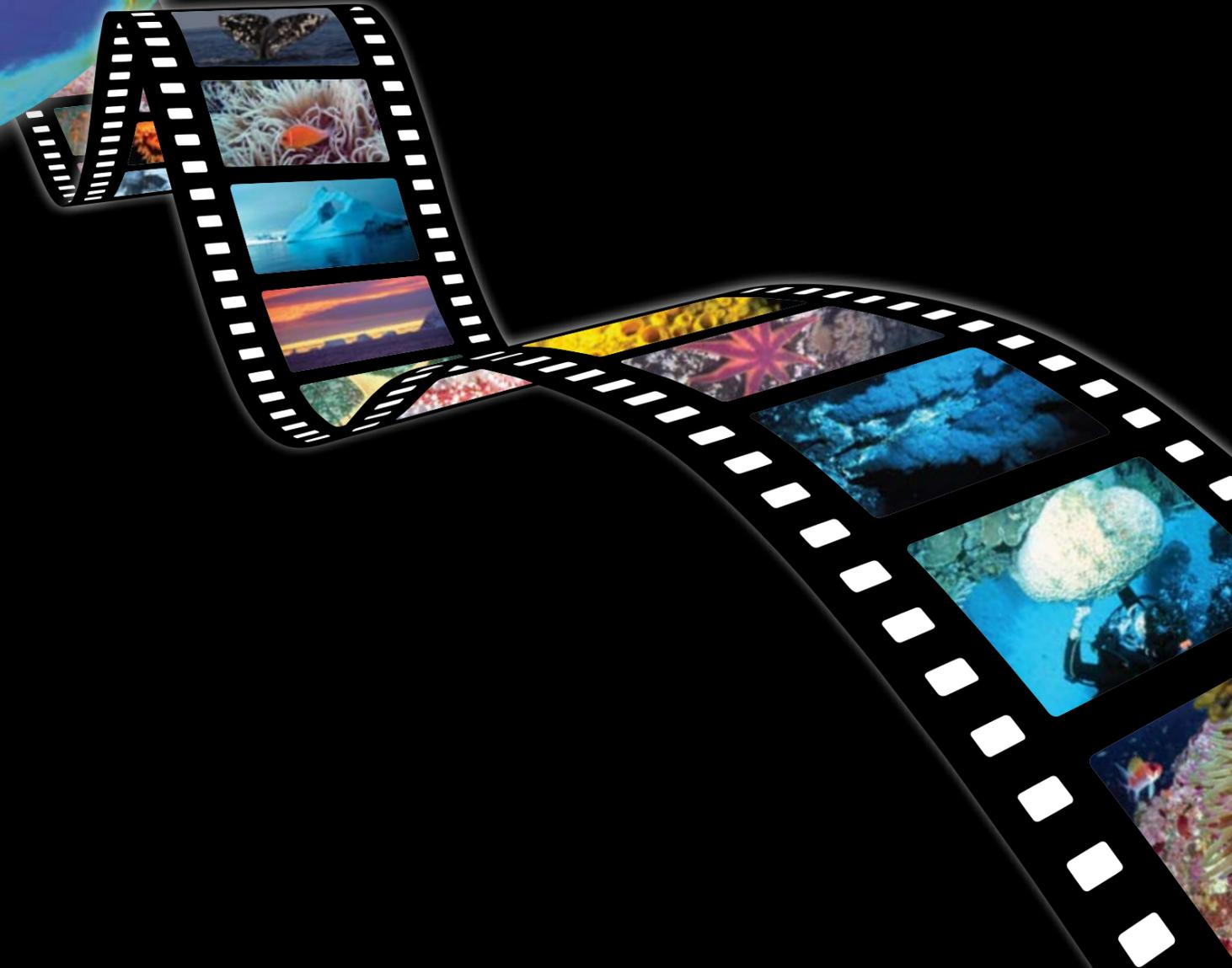


Effects of Climate Change on the World's Oceans

# Effects of Climate Change on the World's Oceans

## International Symposium Program and Abstracts

May 19-23, 2008  
Gijón, Spain



*Images generously supplied by ANSC, NOAA, and Y. Yakovlev*

Prepared and published by:

PICES Secretariat  
P.O. Box 6000, Sidney, BC, V8L 4B2  
Canada  
Tel: 1-250-363-6366  
Fax: 1-250-363-6827  
E-mail: [secretariat@pices.int](mailto:secretariat@pices.int)  
Website: [www.pices.int](http://www.pices.int)

GLOBEC IPO  
Prospect Place, Plymouth PL1 3DH  
United Kingdom  
Tel: 44-1752-633401  
Fax: 44-1752-633101  
E-mail: [globec@pml.ac.uk](mailto:globec@pml.ac.uk)  
Website: [www.globec.org](http://www.globec.org)



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# **Effects of Climate Change on the World's Oceans**

**19-23 May 2008**

**Gijón, Spain**



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## Welcome

On behalf of the scientific committee, the organising team and the Instituto Español de Oceanografía – C.O. de Gijón, and in my own name, I want to welcome all of you to this warm, friendly and beautiful city of Gijón.

The event we have the opportunity to enjoy over these days is the culmination of an intensive, interactive and long process in which many very professional people of PICES, IOC, ICES, GLOBEC and the IEO have been involved. The scientific committee hand in hand with the organising team have worked for almost three years to make this event a success and as enjoyable and productive as possible for everyone.

The symposium is convened to address a global issue of high scientific and social relevance “Effects of Climate Change on the World’s Oceans”. We have gathered contributions from all over the world (attendance of approximately 450 scientists from over 60 countries is expected) arranged in 10 theme sessions and 4 workshops, over 200 oral communications and 150 posters. The selection and preparation processes have turned out to be an arduous and long task but also very rewarding. This preliminary work shows without any doubt the outstanding dynamism and high quality of oceanographic research at a global scale, and has demonstrated the importance of the resources that it is possible to mobilise through international collaborative research.

I would like to encourage all the participants to take part in this symposium. During five days we will have the opportunity to exchange experiences, share new ideas, identify synergies, and build new bridges, and I hope that the result of the discussions will be successful and the conclusions important. The symposium will not conclude this week but it will be continued and perpetuated in a special volume of the ICES Journal Marine Science, in which the best contributions from the symposium will be published in 2009.

I want to thank all the institutions for the trust they placed in us when we asked for support in the organisation of this symposium. Without their committed and decisive support our aims would have been impossible to achieve. My sincere thanks and congratulations must also go to the scientific committee for their work in mobilising the wide representation of scientific teams attending the meeting and to all my collaborators in the organising team for the hard work done in the preceding months. Today, we all start to see the fruits of our effort.

As Albert Einstein said “Life is like riding a bicycle. To keep your balance you must keep moving”. This is what we are all trying to do in our discussions here in Gijón: to get things moving to be able to adapt ourselves to climate change.

Dr. Luis Valdés  
Director IEO-CO Gijón  
ICES Convenor, Effects of Climate Change on the World’s Oceans symposium



## **Background**

Climate change is the most important threat to the earth. Even if we stabilise CO<sub>2</sub> concentrations, the 2007 IPCC (Intergovernmental Panel on Climate Change) assessment confirms that warming will continue for decades and sea level will continue to rise for centuries. Some direct effects of climate change in the marine environment are already visible, but others need to be defined by enhanced observations, analysis and modelling. We have a rudimentary understanding of the sensitivity and adaptability of natural and managed ecosystems to climate change. An assessment of the consequences of climate change on the world's oceans has a high scientific and social relevance and is urgently needed.

Although we are beginning to document the local effects and consequences of climate change on the functioning of marine ecosystems, there is no comprehensive vision at the global scale, and only limited ability to forecast the effects of climate change. To close this gap, the symposium will focus on the major issues of climate change that affect the oceans: oceanic circulation, climate modelling, cycling of carbon and other elements, acidification, oligotrophy, changes in species distributions and migratory routes, sea-level rise, coastal erosion, etc. The symposium will bring together results from observations, analyses and model simulations, at a global scale, and will include discussion of the climate change scenarios and the possibilities for mitigating and protecting the marine environment and living marine resources.



## **Acknowledgements**

This Book of Abstracts, together with many other aspects of the Symposium preparation, is the product of the hard work, attention to tight deadlines, and high professional standards of the organising team. In particular the contribution of Alex Bychkov (PICES: Symposium coordinator), Julia Yazvenko (PICES: Symposium logistics, webpage design and support), Dawn Ashby (GLOBEC: Symposium “Book of Abstracts”), and the staff of IEO-CO Gijón (local organisation) is gratefully acknowledged. Their work, together with that of their colleagues, has ensured that the Symposium on the “Effects of Climate Change on the World’s Oceans” is organised to the highest of standards.



## The organisation and sponsors

### Symposium Convenors

John Church (IOC)  
William Peterson (PICES)  
Luis Valdés (ICES)

### Scientific Steering Committee

Richard Feely (USA)	Ove Hoegh-Guldberg (Australia)	Jorge Sarmiento (USA)
Michael Foreman (Canada)	Harald Loeng (Norway)	Martin Visbeck (Germany)
Roger Harris (UK)	Liana McManus (USA/Philippines)	Akihiko Yatsu (Japan)

### Primary international sponsors



International Council for the Exploration of the Sea (ICES)



North Pacific Marine Science Organization (PICES)



Intergovernmental Oceanographic Commission (IOC)

### Co-sponsoring international organisations



World Climate Research Programme



Global Ocean Ecosystem Dynamics (GLOBEC)

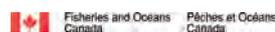


Scientific Committee on Oceanic Research (SCOR)

### With additional support from



Ayuntamiento de Gijón



Fisheries and Oceans Canada



Korea Ocean Research and Development Institute



National Aeronautics and Space Administration



National Oceanic and Atmospheric Administration



Port Authority of Gijón



Asturias Science Plan 2006-2009



Sociedad Mixta de Turismo de Gijón

### Local organiser



Instituto Español de Oceanografía (IEO)  
Centro Oceanográfico de Gijón



## **Notes for guidance**

### **Venue**

The Symposium will be held at the Congress Center in Gijón, Spain. This is a modern building complex with rooms for scientific sessions, workshops and poster exhibition, offices for the Scientific and Organising Committee, and facilities for press-conferences and communication with media.

Sessions will be held at the Conference center:

Palacio de Congresos de Gijón, Paseo del Dr. Fleming 481, 33203 Gijón, Spain.

### **Registration**

The registration desk will be located in the foyer of the Congress Centre. Next to the registration desk there will be a notice board for announcements and messages.

### **Symposium secretariat**

The symposium secretariat and the office of the editorial committee will be located in Room 1 on the 1st floor. Two rooms for parallel meetings will be available on the 1st and 2nd floors. They can be used under request.

### **Oral presentations**

In order to allow the sessions to run smoothly and in fairness to other speakers, please note that all presentations are expected to adhere strictly to the time allocated. The time for your presentation can be found in the agendas. CDs or memory sticks with the electronic presentations should be given to the symposium secretariat one day before the talk. The oral speakers will have the Mirador Hall on the 2nd floor at their disposal to prepare their presentation.

### **Posters**

Posters will be displayed in the Exhibition room throughout the symposium. Two poster sessions will be held there on Tuesday, 20 May and Thursday, 22 May between 5 pm and 8.30 pm with an informal wine and tapas reception. All posters contributors are requested to be present to answer questions.

### **Internet access**

Free access to the internet for all participants will be available on computers located in the foyer. There will be also Wi-Fi access in the Mirador Hall on the 2nd floor.

### **Simultaneous interpretation**

Simultaneous interpretation (English and Spanish) will be served during the opening ceremony. Headsets will be available.

### **Refreshments**

Complimentary refreshments (tea and coffee) will be served during the coffee break in the Exhibition room. Smoking is only permitted in the foyer.

### **Lunch**

There is a small cafeteria at the Congress Centre. You can also have a quick meal in one of the restaurants next to the Congress Centre (list of restaurants will be available at the registration desk).

### **Social activities**

#### ***Welcome Reception***

The Major of Gijón will hold a General Reception for all participants on Monday 19 May, from 7.30 pm to 11.00 pm in the "Llagar El Trole". Buses will leave the Congress Centre at 7.00 pm.

#### ***Symposium Dinner***

The Conference Dinner will be held on Wednesday, 21 May, in the restaurant of Gran Hotel Jovellanos from 8.30 pm to 12.00 pm. Buses will leave from hotels at 8 pm (information on the list of hotels with bus stops will be available at the registration desk).

#### ***Excursions***

There will be optional excursions organised on the afternoon of Wednesday, 21 May and Saturday, 24 May. Their organisation requires a minimum of participants. For further information please contact the symposium desk.



## General programme

Time		Events		
<b>Sunday 18 May</b>	09:30	Workshop 1	Workshop 2/3	Workshop 6
	13:00	Lunch		
	14:30-18:30	Workshop 1	Workshop 2/3	Workshop 6
<b>Monday 19 May</b>	08:30	Opening session		
	09:15	Plenary talk: Theme 1.1		
	10:00	Plenary talk: Theme 4.2		
	10:45	Coffee break		
	11:15	Session 1.1	Session 4.2	
	13:10	Lunch		
	14:30	Session 1.1	Session 4.2	
	16:00	Coffee break		
	16:30-18:15	Session 1.1	Session 4.2	
	19:30-23:00	Welcome reception		
<b>Tuesday 20 May</b>	08:30	Plenary talk: Theme 1.2		
	09:15	Plenary talk: Theme 2.1		
	10:00	Coffee break		
	10:30	Session 1.2	Session 2.1	
	13:10	Lunch		
	14:30	Session 1.2	Session 2.1	
	17:00-20:30	Wine and tapas poster session		
	<b>Wednesday 21 May</b>	08:30	Plenary talk: Theme 2.2	
09:15		Plenary talk: Theme 5.1		
10:00		Coffee break		
10:30		Session 2.2	Session 5.1	
14:00-18:00		Excursions		
14:30-18:00		Workshop 4	Poster session	
20:30-00:00		Symposium dinner		
<b>Thursday 22 May</b>	08:30	Plenary talk: Theme 3.1		
	09:15	Plenary talk: Theme 4.1		
	10:00	Coffee break		
	10:30	Session 3.1	Session 4.1	
	13:10	Lunch		
	14:30	Session 3.1	Session 4.1	
	17:00-20:30	Wine and tapas poster session		
	<b>Friday 23 May</b>	08:30	Plenary talk: Theme 3.2	
09:15		Plenary talk: Theme 5.2		
10:00		Coffee break		
10:30		Session 3.2	Session 5.2	
13:10		Lunch		
14:30		Session 3.2	Session 5.2	
15:45		Coffee break		
16:10-17:30		Panel discussion/closing ceremony		

- S1.1 Observed climate changes
- S1.2 Climate model projections
- S2.1 Marine carbon cycling and other biogeochemical cycles
- S2.2 Ocean acidification and coral reef bleaching
- S3.1 Natural hazards, sea level rise and coastal erosion
- S3.2 Estuarine and wetland ecosystem functioning
- S4.1 Impacts on lower trophic levels
- S4.2 Impacts on higher trophic levels
- S5.1 Scenarios for polar, mid-latitude, sub-tropical, and tropical environments and ecosystems
- S5.2 Adaptation and mitigation of impacts on the marine environment and ecosystems
- W1 Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels
- W2/3 Linking global climate model output to (a) trends in commercial species productivity and (b) changes in broader biological communities in the world's oceans
- W4 Prospects for multidisciplinary long-term ocean observations
- W6 Storm surges and flooding in the Baltic Sea



## Agendas by session/workshop

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<b>S1.1</b>	<b>Observed climate changes .....</b>	<b>4</b>
<b>S1.2</b>	<b>Climate model projections.....</b>	<b>9</b>
 <i>Theme 2. Interactions between climate variability and change and biogeochemical cycles</i>		
<b>S2.1</b>	<b>Marine carbon cycling and other biogeochemical cycles .....</b>	<b>11</b>
<b>S2.2</b>	<b>Ocean acidification and coral reef bleaching.....</b>	<b>15</b>
 <i>Theme 3. Impacts of climate variability and change on the coastal environment</i>		
<b>S3.1</b>	<b>Natural hazards, sea level rise and coastal erosion.....</b>	<b>17</b>
<b>S3.2</b>	<b>Estuarine and wetland ecosystem functioning .....</b>	<b>20</b>
 <i>Theme 4. Impacts of climate change on marine ecosystems: present status of our understanding</i>		
<b>S4.1</b>	<b>Impacts on lower trophic levels .....</b>	<b>22</b>
<b>S4.2</b>	<b>Impacts on higher trophic levels.....</b>	<b>26</b>
 <i>Theme 5. Scenarios-mitigation-reduction of impact of future climate change on the marine environment: from the regional to global scale</i>		
<b>S5.1</b>	<b>Scenarios for polar, mid-latitude, sub-tropical, and tropical environments and ecosystems.....</b>	<b>30</b>
<b>S5.2</b>	<b>Adaptation and mitigation of impacts on the marine environment and ecosystems.....</b>	<b>32</b>
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<b>W6</b>	<b>Storm surges and flooding in the Baltic Sea .....</b>	<b>39</b>



## Plenary talks

### Monday 19 May

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**Theme 1.1**  
09:15-10:00      **Lynne D. Talley**  
Observed ocean climate changes: a review based on the IPCC AR4 and subsequent works

**Theme 4.2**  
10:00-10:45      **Patrick Lehodey, Inna Senina, John Sibert, Laurent Bopp and Beatriz Calmettes**  
Forecasts of population trends for two species of tuna under an IPCC scenario

### Tuesday 20 May

---

**Theme 1.2**  
08:30-09:15      **Ronald J. Stouffer**  
Oceans role in climate change

**Theme 2.1**  
09:15-10:00      **Corinne Le Quéré, Taro Takahashi, Christian Rödenbeck, Erik T. Buitenhuis and Steward C. Sutherland**  
Recent trend in the global oceanic CO<sub>2</sub> sink

### Wednesday 21 May

---

**Theme 2.2**  
08:30-09:15      **Ove Hoegh-Guldberg**  
Coral reef ecosystems as casualties of rapid climate change

**Theme 5.1**  
09:15-10:00      **Eddy C. Carmack**  
The changing Northern Ocean

### Thursday 22 May

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**Theme 3.1**  
08:30-09:15      **Jason A. Lowe, T. Howard, A. Pardaens and K. Horsburgh**  
Can we quantify the risk of large increases in sea level extremes?

**Theme 4.1**  
09:15-10:00      **Joaquim I. Goes, Helga R. Gomes, Prasad G. Thoppil, Prabhu Matondkar, Adnan Al-Azri and John T. Fasullo**  
Shrinking snowcaps and rising productivity: response of the Arabian Sea ecosystem to recent climate change

### Friday 23 May

---

**Theme 3.2**  
08:30-09:15      **Dan Baird**  
An assessment of the functional variability of coastal ecosystems in the context of environmental changes

**Theme 5.2**  
09:15-10:00      **Jane Lubchenco**  
Managing for resilience in ocean ecosystems

## Theme 1. Past and future variability and change in ocean climate

Dramatic changes have been observed in the circulation and physical characteristics of the oceans over the past century. These changes are projected to continue over the next century based on the analyses and summaries recently presented in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). In this topic, we solicited presentations that address past and future climate variability and change in the ocean, and the role that the ocean plays in these changes. Papers related to changes in forcing mechanisms such as wind fields, air-sea heat exchange, the freshwater budget, and the impact that changes in these forcing fields have had, and will have, on ocean circulation, large-scale sea level, heat and freshwater content and transport, ventilation and upwelling, sea-ice, and surface waves were welcomed. Presentations using: i) analyses of global and regional data sets arising from observations alone and/or state estimation; ii) idealised and conceptual models of observed climate change; iii) analyses of global climate models projections or results from higher-resolution regional ocean, or coupled atmosphere-ocean, models that are forced by, and take their boundary conditions from, global climate models; iv) uncertainties in model projections and how they might be improved; and v) the ability of models to predict abrupt change and extreme events, were encouraged.

### S1.1 Observed climate changes

**Convenors:** *Lynne D. Talley (Scripps Institution of Oceanography, San Diego, USA)*  
*Martin Visbeck (IFM-GEOMAR, Germany)*

**Invited speakers:** *Nathan Bindoff (University of Tasmania, Australia)*  
*Ruth Curry (Woods Hole Oceanographic Institution, USA)*

This session will present observations of climate change in the ocean's physical characteristics, including circulation, water mass properties (heat, salinity, and tracers of water masses), sea level and surface waves; and change in the associated forcings, such as winds, air-sea heat flux, freshwater flux and sea-ice. Papers were encouraged that describe emerging methodologies for observing and quantifying ocean climate change, including new observing networks and state estimation. Model studies that explore the causes of observed climate change in the ocean were also welcome.

**Monday 19 May 2008 11:15 - 18:15**

- 11:15 Introduction by Convenors
- 11:20 **Ruth Curry (Invited)**  
Evolution of Atlantic Ocean properties and circulation from the tropics to the Arctic (S1.1-4813)
- 11:45 **Martin Visbeck, Jürgen Fischer, Rainer Zantopp, Lothar Stramma, Peter Brandt and Friedrich Schott**  
Is the Atlantic thermohaline circulation slowing? Results from Deep Western Boundary Current observations at the exit of the Labrador Sea (S1.1-4891)
- 12:10 **Eugene B. Colbourne, K.F. Drinkwater, H. Loeng and S. Sundby**  
Ocean climate variability in the North Atlantic: the importance of large-scale atmospheric forcing (S1.1-4725)

- 12:25 **Cesar M. González-Pola, Alicia Lavín, José Luis López-Jurado, Carmen Rodriguez, Raquel Somavilla, Manuel Ruiz-Villareal, Guillermo Díaz del Rio and Ricardo Sánchez**  
The recent warming of intermediate waters at the eastern North Atlantic: insights from a monthly hydrographical time series in the Bay of Biscay (S1.1-4840)
- 12:40 **N. Penny Holliday, S.L. Hughes, S. Bacon, A. Beszczynska-Möller, B. Hansen, A. Lavín, H. Loeng, K.A. Mork, S. Østerhus, T. Sherwin and W. Walczowski**  
Reversal of the 1960s-1990s freshening trend in the upper ocean of the north-east North Atlantic and Nordic Seas (S1.1-4750)
- 12:55 **Julio M. Morell, Julian Morell and Jorge E. Corredor**  
Responsiveness of water mass properties to climate forcing at the Caribbean Time series station in the northeastern Caribbean basin (S1.1-4731)
- 13:10 ***Lunch***
- 14:30 **Matthew H. England and Willem P. Sijp**  
Southern hemisphere westerly wind control over the ocean's thermohaline circulation (S1.1-4951)
- 15:00 **Douglas G. Martinson**  
Increased ocean heat along the continental margin of west Antarctica (S1.1-4759)
- 15:15 **Claus W. Böning, Astrid Dispert, Martin Visbeck, Steve R. Rintoul and Franziska Schwarzkopf**  
Multi-decadal warming and freshening of the Antarctic Circumpolar Current (S1.1-4899)
- 15:30 **Skip McKinnell and Nate Mantua**  
A high resolution Pacific Decadal Oscillation and some of its novel characteristics (S1.1-4709)
- 15:45 **Igor A. Zhabin and Svetlana N. Taranova**  
Influence of rapid regional climate warming on the water mass formation in the Japan/East Sea (S1.1-4543)
- 16:00 ***Tea/coffee break***
- 16:30 **Nathaniel L. Bindoff, Kieran P. Helm and John A. Church (Invited)**  
Global changes of the hydrological cycle and ocean renewal inferred from ocean salinity, temperature and oxygen data (S1.1-4863)
- 17:00 **Simon A. Josey, Jeremy P. Grist, Robert Marsh and Bablu Sinha**  
Impacts of air-sea flux variability on the mid-high latitude North Atlantic Ocean (S1.1-4762)
- 17:15 **Ming Feng, Arne Biastoch, Claus W. Böning, Nick Caputi and Gary Meyers**  
Variability and trend of the heat balance in the southeast Indian Ocean (S1.1-4827)
- 17:30 **Juliet C. Hermes and Chris J.C. Reason**  
Climate variability and change in the Seychelles-Chagos thermocline ridge of the south west Indian Ocean (S1.1-4562)
- 17:45 **Chikka Kalyani Devasena, P.S. Swathi and M.K. Sharada**  
Upper ocean variability in the equatorial Indian Ocean and the influence of monsoon circulation (S1.1-4640)
- 18:00 **Gaël Alory and Gary Meyers**  
Warming of the upper equatorial Indian Ocean and changes in the heat budget (1960-2000) (S1.1-4528)

**S1.1 Posters**

- S1.1-4538 **Artem A. Sarafanov, Alexey V. Sokov and Anastasia S. Falina**  
Warming and salinification of intermediate and deep waters in the Irminger Sea and Iceland Basin in 1997-2006
- S1.1-4566 **Simón Ruiz, Damià Gomis, Marcos G. Sotillo and Simon A. Josey**  
Seasonal and interannual heat fluxes variability in the Mediterranean Sea from a 44-year high-resolution atmospheric data set
- S1.1-4572 **U.K. Singh and P.S. Salvekar**  
Large scale circulation over the west Indian Ocean and the south west monsoon
- S1.1-4583 **Marcos Llope and Ricardo Anadón**  
Sea surface warming in the southern Bay of Biscay modulated by oceanic advection
- S1.1-4600 **Enrique Vidal-Vijande, A. Pascual, D. Gomis, B. Barnier and J. Tintoré**  
Analysis of a 44-year hindcast for the Mediterranean Sea: comparison with altimetry and climatology
- S1.1-4606 **Shusaku Sugimoto and Kimio Hanawa**  
Decadal and interdecadal variations of the Aleutian Low activity and their relation to atmospheric teleconnection patterns
- S1.1-4607 **Maite de Castro, Moncho Gómez- Gesteira, Inés Álvarez, María N. Lorenzo, José L.G. Gesteira and Alejandro J.C. Crespo**  
Spatio-temporal upwelling trends along the Canary Upwelling System (1967-2006)
- S1.1-4609 **Olanrewaju B. Oyewole**  
Establishing research objectives to address issues of climate-change
- S1.1-4610 **José Quereda-Sala, Enrique Montón-Chiva and José Escrig-Barberá**  
A “trojan” in climatic change: the urban effect
- S1.1-4616 **Raquel Niclòs, María J. Estrela, Jose A. Valiente, Vicente Caselles and César Coll**  
A new satellite algorithm for accurate determination of sea surface temperature for climate and meteorological studies
- S1.1-4627 **Sergey K. Gulev**  
Reconstruction of interdecadal variability of air-sea interaction in the Atlantic 1880-2004
- S1.1-4635 **Torbjørn Lorentzen**  
Global warming - stationarity in sea temperature data
- S1.1-4638 **Roman Yu. Tarakanov**  
Geostrophic currents variability in the Drake Passage
- S1.1-4652 **Hyacinth C. Nnamchi and Raymond N.C. Anyadike**  
Rainfall variations and trends along the coast of the Gulf of Guinea
- S1.1-4657 **Vladimir I. Ponomarev and Elena V. Dmitrieva**  
Climatic tendencies and changing global-regional linkages in the North Pacific SST
- S1.1-4680 **Aránzazu Lana, Sergio Vallina and Rafel Simó**  
Atmospheric variables potentially affected by DMS
- S1.1-4687 **Fernando González and Ricardo Anadón**  
Decoupling of sea surface temperature variation during the last two decades and its effect on remotely sensed phytoplankton biomass in the North Atlantic

- S1.1-4712 **Nina I. Savelieva, E.V. Dmitrieva and V.I. Ponomarev**  
Climatic oscillations in the Asian Pacific in terms of cluster analyses of aggregated observation data
- S1.1-4715 **Irina V. Sakova, Gary Meyers, Nerilie J. Abram and Richard Coleman**  
Analysis of the 18-month variability in the Indian Ocean based on historical data and proxy climate records
- S1.1-4729 **Vladislav E. Tymofeiev**  
ENSO and climate change in the West Antarctic Sector
- S1.1-4730 **Philip C. Reid and Astrid C. Fischer**  
The impact of the oceans on climate change
- S1.1-4752 **Jan Aure, Didrik S. Danielssen and Einar Svendsen**  
Climatic changes in the deep Norwegian coastal waters and Skagerrak 2000 - 2005 in relation to previous decades
- S1.1-4769 **Manuel González, Luis Ferrer, Almudena Fontán, Julien Mader, Adolfo Uriarte and Ganix Esnaola**  
Trend analysis of sea surface temperature at the aquarium of Donostia-San Sebastián (1946-2007)
- S1.1-4776 **Anna I. Ginzburg, Andrey G. Kostianoy and Nickolay A. Sheremet**  
Long-term variability of sea surface temperature in the Black and Marmara seas and its response to global atmospheric forcing
- S1.1-4792 **Heather Cannaby, G. Nolan, I. Nardello, G. Westbrook and K. Lyons**  
Analysis of an Irish coastal sea temperature time series: interannual variability and sensitivity to global influence (1958-2007)
- S1.1-4801 **Alexander N. Demidov, Sergey A. Dobrolyubov, Roman Yu. Tarakanov and Artem A. Sarafanov**  
Recent intra-decadal changes in the water mass temperature, salinity and transport in the 60°N transatlantic section
- S1.1-4812 **Gema Martínez-Méndez, Rainer Zahn, Ian R. Hall, Frank Peeters, Leopoldo D. Pena and Isabel Cacho**  
Palaeoceanography of the Agulhas current and ensuing Indian-Atlantic water exchange as a leading component of Atlantic MOC shifts
- S1.1-4823 **Olga O. Trusenkova**  
Variability and forcing of the subarctic front in the northwestern Japan/East Sea
- S1.1-4849 **Tiziana Peluso, Giorgio Budillon, Giannetta Fusco and Daniele Iudicone**  
Mixed layer variability and its relation to ice cover and distribution of chlorophyll *a* in the Weddell Sea (Southern Ocean)
- S1.1-4878 **Anastasia S. Falina, Artem A. Sarafanov, Alexey V. Sokov and Alexander N. Demidov**  
Warming and salinification of intermediate waters of southern origin in the eastern subpolar North Atlantic in the 1990s – mid-2000s
- S1.1-4894 **Belén Rodríguez-Fonseca, Irene Polo, Javier García-Serrano and Carlos R. Mechoso**  
Recent trends in the tropical Pacific-Atlantic connection
- S1.1-4898 **Vadim Navrotsky**  
Effects of the world's oceans on climate change
- S1.1-4911 **Eva Calvo, Carles Pelejero, Leopoldo D. Pena and Isabel Cacho**  
Eastern equatorial Pacific climate variability for the last glacial cycle

- S1.1-4915 **Sarah L. Hughes and members of the ICES Working Group on Oceanic Hydrography**  
Comparison of *in situ* time series of temperature with gridded sea-surface temperature data sets in the North Atlantic
- S1.1-4916 **Verónica M. Benítez-Barrios, Alonso Hernández-Guerra, Pedro J. Vélez-Belchí, Francisco J. Machín and Eugenio Fraile-Nuez**  
Recent changes in temperature and salinity in the Canary region
- S1.1-4948 **Archibong O. Ediang, L.E. Edaefinene and A.A. Ediang**  
The teleconnection between sea surface temperature analysis from *in situ* data at East Mole, Lagos and global warming
- S1.1-4957 **Larissa A. Gayko**  
Variations of water and air temperature in coastal areas of the north-west Japan/East Sea
- S1.1-4963 **Oscar Pizarro**  
Low-frequency changes in sea surface temperature in the eastern South Pacific
- S1.1-4979 **Thamer B. Al-Rashidi, Carl L. Amos, Hamdy I. El-Gamily and Karim A. Rakha**  
Effects of regional drivers on the sea water temperature in Kuwait Bay, northern Arabian Gulf

## S1.2 Climate model projections

**Convenors:** Michael G. Foreman (*Institute of Ocean Sciences, Fisheries and Oceans Canada*)  
Richard Wood (*Hadley Centre for Climate Prediction and Research, UK*)

**Invited speakers:** Seita Emori (*Center for Global Environmental Research, National Institute for Environmental Studies, Japan*)  
Hans von Storch (*Institute for Coastal Research, GKSS Research Center, Germany*)

This session will extend the observational evidence of oceanic climate change and variability described in Theme 1.1 to future projections. Presentations that summarise or analyse oceanographic characteristics or features simulated by global climate models, as well as those that downscale (statistically or dynamically) results from these models to specific regions, were encouraged. Though the focus is on change and variability in large scale physical variables, processes, and patterns, talks that draw links to biogeochemistry and impacts were also welcomed.

**Tuesday 20 May 2008 10:30 - 16:45**

- 10:30 **Hans von Storch, Eduardo Zorita and Fidel J. González-Rouco (Invited)**  
Comparing past variability of coastal currents and upwelling regimes with plausible future anthropogenic signals – in the framework of millennial AOGCM simulations (S1.2-4802)
- 10:55 **Seita Emori (Invited)**  
Future projection of extreme events (S1.2-4955)
- 11:20 **Markus Scheinert, Claus W. Böning and Arne Biastoch**  
Freshening of the subpolar North Atlantic: causes and consequences (S1.2-4839)
- 11:35 **Nicholas A. Bond, James E. Overland and Muyin Wang**  
A method for using IPCC model simulations to project changes in marine ecosystems (S1.2-4622)
- 11:50 **Robert Marsh, Beverly A. de Cuevas, Andrew C. Coward and Simon A. Josey**  
Recent warming and changes of circulation in the North Atlantic simulated with eddy-permitting and eddy-resolving ocean models (S1.2-4766)
- 12:05 **Talgat R. Kilmatov and Vera A. Petrova**  
A variational model of jet current applied to the Kuroshio Extension (S1.2-4642)
- 12:20 **John C. Fyfe and Oleg A. Saenko**  
Anthropogenic speed-up of oceanic planetary waves (S1.2-4697)
- 12:35 **Alexander Sen Gupta, Agus Santoso, Andrea Taschetto, Caroline Ummenhofer and Matthew H. England**  
Fidelity in the present-day simulation and projected changes to the southern hemisphere extratropical ocean/sea-ice system in the AR4 coupled climate models (S1.2-4714)
- 12:50 **Didier Swingedouw, T. Fichefet, P. Huybrechts, H. Goosse, E. Driesschaert and M.-F. Loutre**  
Antarctic ice-sheet melting provides negative feedbacks on future climate warming (S1.2-4603)
- 13:05 **Lunch**
- 14:30 **Jason Holt, Sarah Wakelin, Graham Tattersall, Roger Proctor, Icarus Allen, Jerry Blackford, Tim Smyth, Jason A. Lowe, Mark Gallani and Mike Ashworth**  
The sensitivity of the circulation, stratification and primary production of the northwest European continental shelf to climate change (S1.2-4667)

- 14:45 **Francisco Álvarez-García, William Cabos-Narváez and María J. Ortiz-Beviá**  
The Atlantic Multidecadal Oscillation in IPCC coupled model control and climate change simulations (S1.2-4691)
- 15:00 **Marisa Montoya and Anders Levermann**  
Surface wind-stress threshold for glacial Atlantic overturning (S1.2-4807)
- 15:15 **Pablo Ortega, Marisa Montoya and Fidel J. González-Rouco**  
The AMOC in millennial ECHO-g climate simulations and future climate change scenarios (S1.2-4809)
- 15:30 **Paulo Nobre, Emanuel Giarolla, Domingos Urbano, Roberto de Almeida and Marta Malagutti**  
Biosphere-atmosphere-ocean interactions and climate change: the case of Amazon deforestation (S1.2-4695)
- 15:45 **Maria Nieves Lorenzo, Isabel Iglesias and Juan Jose Taboada**  
Influence of coloured noise in the ocean coupling on the thermohaline circulation (S1.2-4598)
- 16:00 **William J. Merryfield, Badal Pal and Michael.G. Foreman**  
Future winds off the Pacific coast of Canada (S1.2-4579)
- 16:15 **Richard E. Thomson and Isaac V. Fine**  
A diagnostic model of mixed layer depth variability with application to Ocean Station “P” in the northeast Pacific (S1.2-4855)
- 16:30 **Enrique E. Aguirre**  
Study of the wind variation effects in the upwelling system along the Peruvian coast and consequences of climate change through numerical modelling (S1.2-4745)

## S1.2 Posters

- S1.2-4539 **Rodrigo Kerr, Ilana Wainer and Mauricio M. Mata**  
Representation of the Weddell Sea deep water masses in the ocean component of the NCAR-CCSM model
- S1.2-4808 **Pablo Ortega, Fidel J. González-Rouco, Marisa Montoya and Hugo Beltrami**  
Heat content through the last millennium and in future climate change scenarios: an assessment using ECHO-g AOGCM simulations
- S1.2-4889 **Huaming Yu, Xianwen Bao and Xueen Chen**  
A global ocean current and tidal model with varying unstructured grids: application to the East China Shelf

## Theme 2. Interactions between climate variability and change and biogeochemical cycles

Carbon dioxide is one of the most important “green-house” gases in the atmosphere affecting the heat balance of the earth. As a direct result of the industrial and agricultural activities of humans over the past two centuries, atmospheric CO<sub>2</sub> concentrations have increased by about 100 ppm. The atmospheric concentration of CO<sub>2</sub> is now higher than experienced on Earth for at least the last 650,000 years, and is expected to continue to rise, leading to significant temperature and CO<sub>2</sub> increases in the atmosphere and oceans by the end of this century. The ocean carbon cycle is closely linked to climate because the oceanic uptake of anthropogenic CO<sub>2</sub> helps to regulate atmospheric CO<sub>2</sub> and, furthermore, the rate of uptake of CO<sub>2</sub> is affected by climate-induced changes in biogeochemical and physical processes in the oceans.

### S2.1 Marine carbon cycling and other biogeochemical cycles

**Convenors:** *Corinne Le Quere (British Antarctic Survey, UK)*  
*Jorge L. Sarmiento (Princeton University, USA)*

**Invited speakers:** *Christopher L. Sabine (Pacific Marine Environmental Laboratory, NOAA, USA)*  
*Andrew J. Watson (University of East Anglia, UK)*

Global surveys over the past several decades now allow scientists to examine decadal time-scale variations in ocean biogeochemical processes in unprecedented detail. This session invites observational and modelling papers that describe these changes from many different angles, including physical, biological, biogeochemical and carbon cycle perspectives. Emphasis is placed on decadal changes in carbon cycling, e.g. anthropogenic carbon, air-sea exchange of carbon dioxide, the biological pump, nutrient and oxygen cycling, impacts of increasing levels of carbon dioxide on carbonate chemistry, and changes in the distribution of natural carbon in mode and deep waters. Contributions that make use of a broad palette of interdisciplinary tools were encouraged.

**Tuesday 20 May 2008 10:30 - 17:00**

- 10:30 Introduction by Convenors
- 10:35 **Christopher L. Sabine, Richard A. Feely, Frank J. Millero, Andrew G. Dickson, Rik Wanninkhof, Dana Greeley and Esa Peltola (Invited)**  
Decadal changes in the Atlantic, Pacific and Indian Ocean inorganic carbon inventories (S2.1-4817)
- 11:00 **Andrew J. Watson, P.J. Brown and U. Schuster (Invited)**  
The changing uptake of CO<sub>2</sub> by the North Atlantic Ocean (S2.1-4954)
- 11:25 **Nicolas Metzl and Andrew Lenton**  
What can surface fCO<sub>2</sub> measurements tell us about the evolution of the Southern Ocean CO<sub>2</sub> sink? (S2.1-4670)
- 11:40 **Kirsten Zickfeld, John C. Fyfe, Michael Eby and Andrew J. Weaver**  
Negative feedback of poleward intensifying southern hemisphere winds on atmospheric CO<sub>2</sub> in the 21st century (S2.1-4701)
- 11:55 **Andrew Lenton, Laurent Bopp Francis Codron, Nicolas Metzl and Patricia Cadule**  
The combined effects of rising atmospheric CO<sub>2</sub> and declining stratospheric ozone on the past and future uptake of CO<sub>2</sub> by the Southern Ocean (S2.1-4708)

- 12:10 **Claire Lo Monaco, Andrew Lenton, Nicolas Metzl and Keith B. Rodgers**  
Natural and anthropogenic carbon changes in mode waters of the south west Indian Ocean (S2.1-4854)
- 12:25 **Galen A. McKinley, David Ullman, Val Bennington, Stephanie Dutkiewicz and Nicolas R. Bates**  
Advective impacts on North Atlantic carbon sink variability (S2.1-4861)
- 12:40 **Keith B. Rodgers, Anand Gnanadesikan, Robert Key and Jorge L. Sarmiento**  
Altimetry helps to explain patchy changes in repeat hydrography carbon measurements (S2.1-4928)
- 12:55 **Jill A. Peloquin, Zouhair Lachkar and Nicolas P. Gruber**  
Understanding the impact of physical forcing on Southern Ocean phytoplankton and primary production (S2.1-4832)
- 13:10 *Tea/coffee break*
- 14:30 **Michio Aoyama, M. Fukasawa, T. Kawano, S. Kouketsu, Y. Kumamoto, A. Murata, K. Sato and H. Uchida**  
An increase of silicic acid and nitrate concentrations along the pathway of Lower Circumpolar Deep Water in the Pacific Ocean: results of snapshot comparisons (S2.1-4601)
- 14:45 **Tsuneo Ono, Akihiro Shiomoto and Toshiro Saino**  
Recent decrease of summer time nutrients in the mixed layer of the North Pacific HNLC region (S2.1-4643)
- 15:00 **Kazuaki Tadokoro, Tsuneo Ono, Ichiro Yasuda, Satoshi Osafune, Yuji Okazaki, Akihiro Shiomoto and Hiroya Sugisaki**  
Possible mechanism of decadal-scale variation in PO<sub>4</sub> concentration in the western north Pacific, and the influence on ocean productivity (S2.1-4820)
- 15:15 **Masahiko Fujii, Fei Chai, Lei Shi, Hisayuki Y. Inoue and Masao Ishii**  
Seasonal and interannual variation of ocean carbon cycling in the western and eastern tropical-subtropical Pacific: a physical-biogeochemical modelling study (S2.1-4711)
- 15:30 **Julia Wohlers, Anja Engel, Eckart Zöllner, Ulrich Sommer and Ulf Riebesell**  
The impact of rising sea surface temperature on the cycling of organic matter: an indoor mesocosm study (S2.1-4777)
- 15:45 **Richard B. Rivkin and Louis Legendre**  
Microbial dynamics and response to a changing polar ocean climate (S2.1-4965)
- 16:00 **Martin A. Montes-Hugo, Oscar Schofield, Hugh W. Ducklow, Douglas G. Martinson and Ray Smith**  
Climate mediated changes in phytoplankton productivity and air-sea CO<sub>2</sub> exchange on the western shelf of the Antarctic Peninsula over the last 30 years (S2.1-4938)
- 16:15 **Marie-Fanny Racault, Corinne Le Quéré, Erik T. Buitenhuis and Trevor Platt**  
Characterisation of phytoplankton blooms and their contribution to export production (S2.1-4816)
- 16:30 **Maya Robert and Uta Passow**  
Formation of POC through interactions between TEP and mineral ballast (S2.1-4686)
- 16:45 **Ian J. Totterdell**  
Comparing the carbon cycle response of two ocean ecosystem models to climate change (S2.1-4909)

**S2.1 Posters**

- S2.1-4531 **Naveen Gandhi and R. Ramesh**  
Input of 'new' nitrogen by *Trichodesmium* in the Arabian Sea
- S2.1-4568 **Valeriy N. Khokhloy, Alexander V. Glushkov, Nataliya S. Loboda and Tatiana V. Solonko**  
Phytoplankton influence on atmospheric carbon dioxide under global climate change
- S2.1-4639 **Nayrah A. Shaltout, Thanaa H. Mahmoud and Mamdouh S. Masoud**  
The distribution of CO<sub>2</sub> surface partial pressure and air-sea CO<sub>2</sub> flux in El Mex Bay Alexandria, Egypt
- S2.1-4648 **Marta Álvarez, Claire Lo Monaco, Toste Tanhua, Andrew Yool, Andreas Oschlies, John L. Bullister, Catherine Goyet, Frank Touratier, Rik Wanninkhof, Dave Wisegarver, Elaine McDonagh and Harry L. Bryden**  
A higher storage of anthropogenic carbon in the Indian Ocean?
- S2.1-4660 **Ricardo González Gil, Juan Höfer, Fernando González and Ricardo Anadón**  
*Trichodesmium* sp. population structure along the North Atlantic subtropical gyre
- S2.1-4673 **Paola Rivaro, Serena Massolo, Roberta Messa, Pasquale Castagno, Giorgio Budillon and Andrea Bergamasco**  
Dissolved oxygen and nutrient export by new Antarctic Bottom Water in the Ross Sea
- S2.1-4688 **Nicholas Stephens and Olivier Aumont**  
Marine system sensitivity to iron speciation and organic complexation
- S2.1-4690 **Nicholas Stephens, Corinne Le Quéré and Erik T. Buitenhuis**  
Nitrogen fixation and nitrogen cycles in a Plankton Functional Type model
- S2.1-4693 **Róisín Moriarty, Erik T. Buitenhuis and Corinne Le Quéré**  
Macrozooplankton in the global ocean biogeochemical model PlankTOM10
- S2.1-4700 **Mohammad Badran**  
Importance of organic matter in nutrient cycles and carbon dioxide sequestration in the oligotrophic waters of the Gulf of Aqaba: open water versus fish farms
- S2.1-4722 **Juan Höfer and Florentina Alvarez-Marques**  
Mesozooplankton respiration in the North Atlantic subtropical gyre and its implications for the carbon cycle
- S2.1-4724 **Stefano Ciavatta, Giorgio Ferrari and Roberto Pastres**  
Estimation of the seasonal pattern of carbon dioxide in a coastal lagoon
- S2.1-4738 **Joannie Ferland, Michel Gosselin, Michel Starr and François Saucier**  
Spatial distribution of phytoplankton production and biomass in the Hudson Bay Complex during summers 2004 to 2006
- S2.1-4744 **Kazuhiro Misumi, Daisuke Tsumune, Takeshi Yoshimura, Jun Nishioka, Frank O. Bryan, Keith Lindsay, J. Keith Moore and Scott C. Doney**  
Effects of two different iron sources on the iron cycle in the subarctic North Pacific
- S2.1-4764 **Ana Paula Oliveira, Graça Cabeçadas and Marta Nogueira**  
Mechanisms underlying coastal waters CO<sub>2</sub> emissions
- S2.1-4781 **Thomas W. Trull, A.R. Bowie, A. Davidson, F.B. Griffiths, P. Thomson, S.R. Rintoul, B. Tilbrook, S. Wright and the SAZ-SENSE team**  
The Australian SAZ-SENSE study of the sensitivity of the Sub-Antarctic Zone to climate change: an introduction
- S2.1-4787 **Mario Lebrato, Darryl Green, Nadia Suárez-Bosche and M. Débora Iglesias-Rodríguez**  
Uncertainties in the global carbon budget: the contribution of echinoderms to the shelf/neritic export at present

- S2.1-4811 **Jock C. Currie, Mike I. Lucas, Larry Hutchings and Howard N. Waldron**  
Long-term nutrient changes in the southern Benguela: intensified upwelling due to global climate change?
- S2.1-4844 **María Aranguren-Gassis and the CARPOS team**  
Net metabolic balance in the eastern and central North Atlantic subtropical gyre in October-November 2006
- S2.1-4847 **Meike Vogt, Sergio Vallina, Laurent Bopp, Erik T. Buitenhuis and Corinne Le Quéré**  
The dynamics of dimethylsulphide and dimethylsulphoniopropionate in a global prognostic model
- S2.1-4872 **Cosimo Solidoro, Gianpiero Cossarini, Simone Libralato, Stefano Salon and Filippo Giorgi**  
Testing potential impacts of changes in precipitation temporal patterns on biogeochemical properties of a coastal marine ecosystem
- S2.1-4875 **Akio Ishida, Maki N. Aita and Yasuhiro Yamanaka**  
Interannual to decadal variability of the carbon cycle in the Pacific simulated in a 3-dimensional model
- S2.1-4880 **Toru Miyama and Michio Kawamiya**  
Estimation of ocean carbon uptake with an Earth system model under CO<sub>2</sub> stabilisation scenario projection
- S2.1-4893 **Ferial Louanchi, M. Boudjakdji, M. Belounis, A. Taalba and L. Nacef**  
A coupled approach data/model to infer the decadal changes of the surface carbon dioxide and related parameters in the Mediterranean Sea
- S2.1-4939 **Sergio Vallina, Meike Vogt, Erik T. Buitenhuis and Corinne Le Quéré**  
Evaluation of DMS concentrations under global warming conditions by means of a mechanistic global ocean biogeochemistry model (PlankTOM5)

## S2.2 Ocean acidification and coral reef bleaching

**Convenors:** Ove Hoegh-Guldberg (University of Queensland, Australia)  
Richard A. Feely (Pacific Marine Environmental Laboratory, NOAA, USA)

**Invited speakers:** James C. Orr (Marine Environment Laboratories, Monaco, France)  
Hans-Otto Pörtner (Alfred-Wegener Institute for Polar and Marine Research, Germany)

The global oceans are the largest natural long-term reservoir for this excess heat and CO<sub>2</sub>, absorbing approximately 85% of the heat and 26% of the combined carbon sources from deforestation and fossil fuel burning. Recent studies have demonstrated that both the temperature increases and the increased concentrations of CO<sub>2</sub> in the oceans are causing significant changes in marine ecosystems. Many marine organisms are already affected by these anthropogenic stresses, including impacts due to coral bleaching and ocean acidification. The goal of this session is to review recent data on the physical, chemical, biological and geological impacts on marine ecosystems due to effects of ocean warming and acidification. Conceptual, experimental and modelling contributions at a variety of spatial and temporal scales are welcome.

Wednesday 21 May 2008 10:30 - 13:55

- 10:30 Introduction by Convenors
- 10:35 **Hans O. Pörtner (Invited)**  
Ecosystem effects of ocean acidification in times of ocean warming: a physiologist's view (S2.2-4800)
- 11:00 **James C. Orr, Sara Jutterström, Laurent Bopp, Leif G. Anderson, Victoria J. Fabry, Thomas Frölicher, Peter Jones, Fortunat Joos, Ernst Maier-Reimer, Joachim Segsneider, Marco Steinacher and Didier Swingedouw (Invited)**  
Acidification of the Arctic Ocean (S2.2-4860)
- 11:25 **Chris Langdon, Sarah Cullison, Michael DeGrandpre, Wade McGillis, David Kadko and Jorge E. Corredor**  
Detecting climate change impacts in coral reef calcification (S2.2-4786)
- 11:40 **John Guinotte, J.C. Orr, S. Cairns, A. Freiwald, L. Morgan and R. George**  
Potential effects of ocean acidification on deep-sea coral ecosystems (S2.2-4961)
- 11:55 **Simone Russo, Paolo Montagna, Malcolm McCulloch, Sergio Silenzi, Claudio Mazzoli, Stefano Schiaparelli and Rossella Baldaconi**  
More effective time grid reconstruction in the calibration of geochemical proxies from coral skeletons (S2.2-4834)
- 12:10 **Jon Havenhand, Fenina Buttler, Michael C. Thorndyke and Jane E. Williamson**  
Near-future levels of ocean acidification impair fertilisation and development in a sea urchin (S2.2-4794)
- 12:25 **Richard A. Feely, Christopher L. Sabine and Dana Greeley**  
Decadal changes in the carbonate system of the North Pacific Ocean (S2.2-4570)
- 12:40 **M. Debora Iglesias-Rodríguez, Paul R. Halloran, Rosalind E.M. Rickaby, Ian R. Hall, Elena Colmenero-Hidalgo, John R. Gittins, Darryl R.H. Green, Toby Tyrrell, Samantha J. Gibbs, Peter von Dassow, Eric Rehm, E. Virginia Armbrust and Karin P. Boessenkool**  
Marine calcification in a high CO<sub>2</sub> world: changes in coccolithophore calcification since pre-industrial times (S2.2-4671)

- 12:55 **Jörg Dutz**  
Effects of CO<sub>2</sub> induced acidification on diatom food quality and copepod reproduction (S2.2-4718)
- 13:10 **Takeshi Yoshimura, Jun Nishioka, Koji Suzuki, Hiroshi Hattori, Hiroshi Kiyosawa, Daisuke Tsumune, Kazuhiro Misumi and Takeshi Nakatsuka**  
Responses of phytoplankton assemblages and organic carbon dynamics to CO<sub>2</sub> increase (S2.2-4779)
- 13:25 **Laura M. Parker, Pauline M. Ross and Wayne A. O'Connor**  
The effect of ocean acidification and temperature on the fertilisation and development of the Sydney rock oyster, *Saccostrea glomerata* (Gould, 1850) (S2.2-4547)
- 13:40 **Knut Yngve Børsheim**  
Increased CO<sub>2</sub> levels in the ecosphere may modify the structure of marine plankton (S2.2-4698)

## S2.2 Posters

- S2.2-4541 **Kim S. Bernard and P. William Froneman**  
Implications of the potential removal of a keystone sub-Antarctic species due to ocean acidification
- S2.2-4593 **Evan Weller, Manuel Nunez and Gary Meyers**  
Ocean-atmosphere heat flux estimates over the Great Barrier Reef and Coral Sea: implications for recent mass coral bleaching events
- S2.2-4615 **Sam Dupont, Jon Havenhand and Michael C. Thorndyke**  
CO<sub>2</sub>-driven acidification radically affects larval survival and development in marine organisms
- S2.2-4629 **Suchana A. Chavanich, Voranop Viyakarn and Thepsuda Loyjiw**  
Mass bleaching of a soft coral, *Sarcophyton* sp., in Thailand: is this related to climate change?
- S2.2-4669 **Nadia Suárez-Bosche, Mario Lebrato, M. Débora Iglesias-Rodríguez and Darryl Green**  
Effect of changes in carbonate chemistry on larval development of echinoderms
- S2.2-4675 **Carles Pelejero and Eva Calvo**  
Reconstructing past seawater pH from boron isotopes in carbonates
- S2.2-4810 **Juancho Movilla, Eva Calvo, Carles Pelejero, Marta Ribes and Rafel Coma**  
A multi-temporal approach to tackle the ocean acidification problem: insights from coral cultures and instrumental time series of pH
- S2.2-4972 **Sue-Ann Watson, Paul A. Tyler and Lloyd S. Peck**  
Calcified marine invertebrates: Latitudinal variation and ocean acidification

## Theme 3. Impacts of climate variability and change on the coastal environment

Climate change will profoundly shape the global coast. Changes in weather patterns (temperature, rainfall and coastal winds) and extreme events could impact coastal ecosystems as well as societal use of coastal regions. A key factor is likely to be change in availability of fresh water during both flooding and drought periods. Long-term impacts such as sea-level rise and changes in the intensity and frequency of hurricanes and storms could lead to changes in shoreline migration and extent of coastal flooding, salinisation of aquifers, and changes in sediment and nutrient transport. Changes in the production and integrity of coastal ecosystems in response to altered climate and physical regimes could decrease the ecosystem goods and services they provide. Because human populations are increasing most rapidly in coastal areas, mitigating the impacts of anticipated climate change is a key determinant in reducing the vulnerability of coastal populations and ecosystems to change and increasing resilience in both urban and rural coastal regions.

### S3.1 Natural hazards, sea level rise and coastal erosion

**Convenors:** Kevin Horsburgh (*Proudman Oceanographic Laboratory, UK*)  
Iñigo J. Losada (*Instituto de Hidráulica Ambiental, Universidad de Cantabria, Spain*)

**Invited speakers:** John Rees (*British Geological Survey, UK*)  
Hans von Storch (*Institute for Coastal Research, GKSS Research Center, Germany*)

Many coastal areas around the world are experiencing an increased impact of natural hazards. The impact of climate change to the coastal systems, resulting from increasing sea level rise, storms surges and wave heights can cause severe coastal erosion and flooding with further consequences on infrastructure and human life, especially in underdeveloped countries. A precise knowledge on the magnitude of these impacts and the factors controlling them is a prerequisite to perform any decision making process related to mitigation and adaptation policies. Papers are invited exploring linkages between climate change and coastal natural hazards. Studies may also address climate change impacts on the coast including altered hydrology and sea-level rise, changes in surface waves, storm surges, altered ocean-meteorological weather patterns and frequency of extreme events. In particular, research that improves our understanding of sea-level rise and variability, including the different factors influencing the observed sea level, observational systems and requirements needed to refine this, and future projections and uncertainties, were especially welcomed.

**Thursday 22 May 2008 10:30 - 16:45**

- 10:30 Introduction by Convenors
- 10:35 **John G. Rees (Invited)**  
Coastal erosion under changing climates (S3.1-4964)
- 11:00 **Katja Woth and Hans von Storch (Invited)**  
Storm surges, perspectives and options (S3.1-4799)
- 11:25 **John A. Church, C.M. Domingues, N.J. White, P.J. Gleckler, S.E. Wijffels, P.M. Barker and J.R. Dunn**  
Improved ocean-warming estimates: implications for climate models and sea-level rise (S3.1-4592)
- 11:40 **Alejandro Cearreta, Eduardo Leorri, Roland Gehrels and Benjamin Horton**  
Two hundred years of sea-level rise reconstruction by combining instrumental and geological data from the southern Bay of Biscay (S3.1-4553)

- 11:55 **Damià Gomis, Enrique Álvarez-Fanjul, Michael N. Tsimplis, Marta Marcos, Ananda Pascual, Simón Ruiz, Sebastià Monserrat, Francisco M. Calafat, Gabriel Jordà, Marcos G. Sotillo, Begoña Pérez, Immaculada Ferrer, Roland Aznar, Simon A. Josey, Gilles Larnicol and Samuel Somot**  
The VANIMEDAT project: decadal and interdecadal sea-level variability in the Mediterranean Sea and the northeastern sector of the Atlantic Ocean (S3.1-4546)
- 12:10 **Francisco M. Calafat, Damià Gomis, Ananda Pascual, Marta Marcos and Simón Ruiz**  
Recovery of sea level fields of the last decades from altimetry and tide gauge data (S3.1-4662)
- 12:25 **Marta Marcos and Michael N. Tsimplis**  
Sea level change and extreme events in the Mediterranean Sea (S3.1-4559)
- 12:40 **Sommart Niemnil, Marc Naeiji and Itthi Trisirisatayawong**  
Sea level trend in Gulf of Thailand using satellite altimetry data (S3.1-4573)
- 12:55 **Ademilson Zamboni and João Luiz Nicolodi**  
An analysis of Brazilian coastal erosion (S3.1-4758)
- 14:30 **Melisa Menéndez, Fernando J. Méndez and Inigo J. Losada**  
Forecasting the seasonal to interannual variability of extreme sea levels (S3.1-4588)
- 14:45 **Wataru Sasaki and Toshiyuki Hibiya**  
Interannual variability and recent increase in the summertime significant wave heights in the western North Pacific (S3.1-4895)
- 15:00 **Jennifer L. Irish, Mir Emad Mousavi, Billy L. Edge, Francisco Olivera and Ashley E. Frey**  
Quantification of climate change impacts on hurricane flooding (S3.1-4557)
- 15:15 **Il-Ju Moon, Seok Jae Kwon and S.K. Kang**  
Growing intensification of landfalling typhoon at higher latitude (S3.1-4825)
- 15:30 **Tetyana L. Kuchma**  
Contribution of remote sensing data to ocean hazards monitoring and emergency system development (S3.1-4829)
- 15:45 **José A. Jiménez, Vicenç Gracia and Herminia I. Valdemoro**  
The Ebro delta coastal response during 2001-2004: a proxy of the potential effects of an increase in storminess (S3.1-4554)
- 16:00 **Fernando J. Méndez, Inigo J. Losada, Raul Medina, Maitane Olabarrieta, Melisa Menéndez and Paula Camus**  
A methodology to evaluate the impacts of climate change in a coastal system (S3.1-4587)
- 16:15 **Carlos Coelho, Raquel Silva, F. Veloso-Gomes and F. Taveira-Pinto**  
Potential impacts of climate change on NW Portuguese coastal zones (S3.1-4798)
- 16:30 **António Jorge da Silva, Inês Martins, Ana Santos and Luísa Bastos**  
NW Iberian coastal current: a feature of extreme freshwater and wind conditions (S3.1-4902)

**S3.1 Posters**

- S3.1-4550 **Pessiezoum D. Adjoussi and Adoté Blivi**  
Moving of the Togo shoreline detected by remote sensing. An example of coastal vulnerability to sea level rise
- S3.1-4578 **Mohamed Ahmed Sidi Cheikh and Yelli Diawara**  
Using GIS for vulnerability assessment to climate change: a case study National Park of Banc d'Arguin (Mauritania)
- S3.1-4614 **Francisco Pastor, María J. Estrela, Javier Miró, Igor Gómez, Jose A. Valiente and Raquel Niclòs**  
Torrential rains: using satellite-retrieved sea surface temperature as a forecast input data
- S3.1-4713 **Wataru Sasaki, Koji Dairaku and Satoshi Iizuka**  
Toward future projections of wind and wave climate in the northwestern Pacific Ocean using three different regional climate models
- S3.1-4789 **Saverio Devoti, Luca Parlagreco, Pasquale Di Pace and Sergio Silenzi**  
Predicting of coastal flooding in Latium coast (central Italy)
- S3.1-4828 **Seok Jae Kwon, Eunil Lee and Il-Ju Moon**  
Long-term variations of storm surge intensity along the Korean Coast and their connection with climate change

## S3.2 Estuarine and wetland ecosystem functioning

**Convenors:** Robert R. Christian (East Carolina University, USA)  
Nancy Rabalais (Defelice Center, Louisiana Universities Marine Consortium, USA)

**Invited Speakers:** Robert Diaz (Virginia Institute of Marine Science, USA)  
Pierluigi Viaroli (Parma University, Italy)

Climate change will potentially result in dramatic alterations for coastal ecosystems - affecting fluxes of water, sediments and nutrients; geomorphology; and societal use and management of coastal regions. Particularly sensitive are sea-level controlled wetlands and enclosed water bodies, such as estuaries and coastal lagoons. Manifestations of climate change include altered hydrology and sea-level rise, altered weather patterns and frequency of extreme events. The ability of coastal ecosystems to remain productive and functional within the complex interactions of landscape and human dependence relies on continued ecosystem processing of materials and energy. Human activities influence these functions and will modify the coastal ecosystem's ability to respond to (or even survive) climate change. Human impacts on ecosystem function are being addressed widely for natural resource management, and the effects of climate change on ecosystem functioning are receiving more attention. The challenge is to understand how the two interplay in management and sustainability of ecosystems that support the viable integration of humans and future coastal landscapes. This session invited papers that explore how the consequences of climate change may result in altered material fluxes, geomorphology, hydrology, habitats, ecosystem functioning, and societal functioning within coastal ecosystems.

**Friday 23 May 2008 10:30 - 15:45**

- 10:30 Introduction by Convenors
- 10:35 **Pierluigi Viaroli (Invited)**  
Assessing ecosystem properties and predicting responses of coastal lagoons to altered hydrology, nutrient cycling and direct anthropogenic pressures (S3.2-4756)
- 11:00 **Robert J. Diaz (Invited)**  
Future climate and oxygen depletion in coastal oceans (S3.2-4585)
- 11:25 **Prabhath Patabendi**  
Challenges and issues in managing marine ecosystems in Sri Lanka (S3.2-4523)
- 11:40 **Jonne Kotta, Ilmar Kotta and Helen Orav-Kotta**  
Identification of important spatial and temporal scales of ecological variables: the relative contribution of climate variables on a soft bottom invertebrate assemblage (S3.2-4877)
- 11:55 **José M. Gorostiaga, Nahiara Muguerza, Stéfani Novoa, Alberto Santolaria, Antonio Secilla and Isabel Díez**  
Changes in the benthic subtidal vegetation along the Basque coast (north Spain) and the probable relationship with climate change (S3.2-4852)
- 12:10 **Simone Libralato and Cosimo Solidoro**  
Effects of climate-driven changes on coastal food webs: the role of precipitation patterns (S3.2-4871)
- 12:25 **Tamara Cibic, Oriana Blasutto, Nicoletta Burba, Andrea Bussani, Cinzia Comici, Claus Falconi and Serena Fonda Umani**  
Benthic diatom response to changing environmental conditions (S3.2-4751)
- 12:40 **Lambini Sakab Kombat**  
Conservation of the Goaso watersheds in Ghana, a participatory approach to sustainability (S3.2-4732)

- 12:55 **Monika Kędra, Maria Włodarska-Kowalczyk and Jan Marcin Węślawski**  
Decadal change in soft-bottom community structure in high arctic fjord (Kongsfjorden, Svalbard) (S3.2-4604)
- 14:30 **Sonia Moreno and F. Xavier Niell**  
Temperature methanogenesis regulation in shallow temperate estuaries (S3.2-4734)
- 14:45 **Inés Álvarez, Moncho Gómez-Gesteira, Maite de Castro and João Miguel Dias**  
Changes in coastal upwelling conditions along the western coast of the Iberian Peninsula for the last 40 years (S3.2-4683)
- 15:00 **Georg Martin**  
Response of structure and distribution pattern of benthic littoral communities to climatic variation and eutrophication (S3.2-4892)
- 15:15 **Melanie J. Bishop and Brendan P. Kelaher**  
Compositional changes in aquatic macrophytes propagate through detrital food webs (S3.2-4555)
- 15:30 **Candida Savage, Peter R. Leavitt and Ragnar Elmgren**  
Effects of land use, urbanisation, and climate change on coastal eutrophication in the Baltic Sea (S3.2-4707)

### S3.2 Posters

- S3.2-4577 **Arturo Sousa, Pablo García-Murillo, Julia Morales and Leoncio García-Barrón**  
Anthropic and natural impacts upon the coastal lagoons in the SW of Spain (Doñana National Park)
- S3.2-4584 **Nancy N. Rabalais**  
Coastal hypoxia will be aggravated by climate change
- S3.2-4617 **Robert R. Christian, Mark M. Brinson, David M. Kunz, Enrique Reyes and Christine M. Voss**  
Changes in coastal wetland function with sea-level rise
- S3.2-4735 **Miriam Ruiz Nieto, Antonio Avilés and F. Xavier Niell**  
A series of data in water and sediment conditions (from 1980s to present) in a shallow temperate estuary (Palmones, Spain)
- S3.2-4775 **Guillermo Aravena, Fernando Villate, Arantza Iriarte, Ibon Uriarte and Berta Ibañez**  
Influence of different North Atlantic Oscillation indices on climatic factors and water temperature in Basque estuaries (Gulf of Biscay)
- S3.2-4896 **Liis Rostin and G. Martin**  
Prediction of variation in structure of benthic littoral community of offshore hardbottom banks in NE Baltic Sea related to changes in climatic conditions
- S3.2-4943 **Melissa K. Langridge, Craig E. Franklin and Greg A. Skilleter**  
Responses to thermal stress in the intertidal: Utilisation of refuge by a predatory whelk
- S3.2-4950 **Taehee Na, Tongsup Lee, Jung Hyun Oak, Jaeyoung Lee and Ik Kyo Chung**  
Estimation of seaweed carbon uptake as a CO<sub>2</sub> removal mechanism

## Theme 4. Impacts of climate change on marine ecosystems: present status of our understanding

Recent studies have documented the impacts of climate variability and change, on a range of ecosystems, over a range of time scales. While we can now begin to identify and monitor some of these impacts, many questions remain. These include how ocean processes will change in the future, the mechanisms involved, what effects such changes may have on ecosystems, and whether we can develop indicators for early detection of changes. This theme particularly encouraged comparative studies of relations between climate variability, climate change and marine ecosystems, as well as presentations which consider mechanisms that link physical forcing with ecosystem change. Central themes are: What are the key processes of ecosystem change and how might they be monitored? Can we predict shifts in species distributions and changes in productivity? Are there other limits that will constrain such global movements? What is the status of our knowledge of the ability of organisms to adapt to climate change? What are the options for managing marine ecosystems to sustain goods essential to societies? Such understanding is essential if we are to effectively manage global marine living resources such as fisheries and marine protected areas during this period of increased human impact. Studies from both shelf and open ocean areas were encouraged.

### S4.1 Impacts on lower trophic levels

**Convenors:** *Delphine Bonnet (University of Montpellier, France)*  
*Roger Harris (Plymouth Marine Laboratory, UK)*

**Invited speakers:** *Sanae Chiba (Frontier Research Center for Global Change, Japan)*  
*Angel Lopez-Urrutia (Centro Oceanográfico de Gijón, Instituto Español de Oceanografía, Spain)*

Physiological processes of planktonic organisms, such as nutrient uptake, photosynthesis, respiration, and reproductive development are highly sensitive to temperature as well as other environmental factors such as UV and CO<sub>2</sub>. Most plankton species are short lived, resulting in tight coupling between environmental effects and plankton dynamics. In contrast to higher trophic levels such as fish, few plankton species are commercially exploited so changes at lower trophic levels may be more easily attributed to climate variability and change. These characteristics make lower trophic levels good potential indicators of the global impacts of climate change. Impacts may include changes in distribution of individual species and communities, in the timing of important lifecycle events or phenology, in abundance and community structure, and through feed-backs to the climate system. In turn these climate impacts on plankton may have consequences for higher trophic levels and ecosystem structure and dynamics. In this session contributions on the impacts of climate change on all lower food web components of the plankton, from bacteria to mesozooplankton, were particularly encouraged.

**Thursday 22 May 2008 10:30 - 17:00**

- 10:30 Introduction by Convenors
- 10:35 **Ángel López-Urrutia (Invited)**  
Temperature rules the oceans biota (S4.1-4576)
- 11:00 **Sanae Chiba (Invited)**  
Anyway the wind blows... Scenario from climate to the lower trophic levels in the western North Pacific (S4.1-4624)
- 11:25 **Clara Ruiz-González, M. Galí, J.M. Gasol and R. Simó**  
Effects of increasing UV radiation on arctic bacterioplankton community structure and activity (S4.1-4843)

- 11:40 **Jeffrey J. Polovina, Evan A. Howell and Melanie Abecassis**  
Ocean's least productive waters are expanding (S4.1-4524)
- 11:55 **Violeta Saló, Rafel Simó and Albert Calbet**  
Role of microzooplankton grazing in the DMS cycle: laboratory and field studies (S4.1-4836)
- 12:10 **Severine Alvain, C. Le Quéré, L. Bopp, M.-F. Racault, Y. Dandonneau and C. Moulin**  
Shifts in phytoplankton ecosystem composition and large scale indices of climate variability (S4.1-4654)
- 12:25 **William K.W. Li**  
Propagation of an atmospheric climate signal to local phytoplankton in a small marine basin (S4.1-4590)
- 12:40 **Xosé Anxelu G. Morán, Ángel López-Urrutia, Alejandra Calvo-Díaz and William K.W. Li**  
Ocean warming and phytoplankton size (S4.1-4682)
- 12:55 **Stephanie Henson, J.P. Dunne and J.L. Sarmiento**  
Decadal changes in North Atlantic phytoplankton blooms (S4.1-4856)
- 13:10 **Lunch**
- 14:30 **Stephen Dye, Sonja Van Leeuwen, Naomi Greenwood and Liam Fernand**  
The future of shelf seas: Projections and observations of changes in the thermal structure and consequences for primary production and water quality (S4.1-4685)
- 14:45 **Mark D. Ohman, Michael R. Landry, Ralf Goericke, Peter J.S. Franks, Karen S. Baker, and the CCE LTER participants**  
A mechanistic perspective on ecosystem response to climate variability: the California Current Ecosystem LTER site (S4.1-4857)
- 15:00 **Andrew D. Barton, M. Follows and S. Dutkiewicz**  
How does climate change impact the biodiversity of marine phytoplankton communities in the North Atlantic Ocean? (S4.1-4903)
- 15:15 **Christian Möllmann, Janna Peters, Rabea Diekmann and Georgs Kornilovs**  
Ecosystem consequences of decadal changes in energy and carbon flows due to climate-induced changes in Baltic zooplankton (S4.1-4649)
- 15:30 **Fernando Gómez, Sami Souissi, Hervé Claustre and Bernard Queguiner**  
Microplankton response to climatic variability in the English Channel and western Mediterranean Sea (S4.1-4533)
- 15:45 **Antonio Bode, Maria Teresa Alvarez-Ossorio, Jose Manuel Cabanas, Ana Miranda and Manuel Varela**  
Surface warming, decreasing upwelling intensity and plankton off Galicia (NW Spain) (S4.1-4664)
- 16:00 **Anthony J. Richardson, Andrew Bakun and Mark J. Gibbons**  
The jellyfish joyride: can we stop oceans sliding down the slippery slope to slimy stingers? (S4.1-4881)
- 16:15 **Iaria Nardello, Russell W. Poole, Heather Cannaby, Caroline Cusack, Ciar O'Toole, Chris Lynam, Sinan Y. Husrevoglu, Joe Silke, Guy Westbrook, Leonie Dransfeld, Ken Whelan and G. Nolan**  
Effects of North Atlantic climate variations on the Irish marine ecosystem (S4.1-4653)
- 16:30 **Taketo Hashioka, Takashi T. Sakamoto and Yasuhiro Yamanaka**  
Impacts of global warming on lower-trophic level ecosystem projected by a 3-D high-resolution ecosystem model (S4.1-4848)
- 16:45 **SCOR WG Members, Associate Members, Data Collaborators and David Mackas**  
SCOR WG125 "Global comparison of zooplankton time series": A summary of results (S4.1-4760)

**S4.1 Posters**

- S4.1-4059 **Yuriy N. Tokarev, Viktor V. Melnikov and Alexandra V. Temnykh**  
Effect of climate changes on the aquatic ecosystem of the Black Sea: from planktonic communities to fish recruitment
- S4.1-4534 **Fernando Gómez**  
Phytoplankton invasive species: comments on the validity of the non-indigenous dinoflagellates and diatoms in the European Seas
- S4.1-4565 **Alexander Mikaelyan, Larisa Pautova and Vladimir Silkin**  
The long-term dynamics of coccolithophorids in the Black Sea with respect to environmental trends
- S4.1-4575 **Damien Cazamea-Catalan, Delphine Bonnet, Guy Charmantier and Mireille Charmantier-Daures**  
Biological cycle of *Sphaeroma serratum* (Isopoda) in the Thau lagoon: impact of global change from 1972 to 2006
- S4.1-4608 **Karina Stockmann, Ulrich Callies and Karen H. Wiltshire**  
Hydrographic changes and their connection to the phytoplankton spring bloom in the German Bight
- S4.1-4634 **Maria Grazia Mazzocchi**  
To what extent do coastal zooplankton reflect Mediterranean climate variability?
- S4.1-4650 **José-Abel Flores, Francisco J. Sierro, Elena Colmenero-Hidalgo, José M. Gravalosa, Miquel Canals, Jaime Frigola, Joan Grimalt, Serge Berne and Bernard Dennielou**  
Coccolithophore response to abrupt and short-term climate changes in the Gulf of Lions (western Mediterranean) for the last 25,000 years
- S4.1-4651 **Jordi Solé, Simón Ruiz, Ananda Pascual, Bruno Buongiorno Nardelli, Gianluca Volpe, Rosalia Santoleri, Alberto Alvarez, Guillermo Vizoso and Joaquín Tintoré**  
Study of potential effects of climatic forcing on the ecosystems of the western Mediterranean Sea
- S4.1-4656 **Luis Valdés, Gonzalo González-Nuevo, Maite Álvarez-Ossorio, Jesús Cabal and Enrique Nogueira**  
How will the ocean warming affect the planktonic diversity?
- S4.1-4672 **M. Varela and CLIGAL-Pelagic Working Group**  
Impact of climate change on the marine pelagic ecosystems off Galicia (NW Spain). I: Water characteristics and plankton
- S4.1-4677 **Marcos Llope and Priscilla Licandro**  
The effect of the North Sea regime shift on the distribution of plankton functional groups and biomass
- S4.1-4679 **Nunzio Penna, Fabio Ricci and Samuela Capellacci**  
Unusual mucilage event along Italian coasts in the northern Adriatic Sea
- S4.1-4689 **María Huete-Ortega, Manuel Varela, Antonio Bode and Emilio Maraón**  
Interannual variability in the size-abundance relationship of nano- and micro-phytoplankton in a coastal marine ecosystem
- S4.1-4694 **Vincent Vantrepotte and Frédéric Mélin**  
Temporal variability of 10-year global SeaWiFS time series of phytoplankton chlorophyll *a* concentration
- S4.1-4782 **Maki N. Aita, S. Lan Smith, Akio Ishida, Michio J. Kishi and Yasuhiro Yamanaka**  
Effects of iron on spatial and temporal phytoplankton distribution using a global 3-D ecosystem model (NEMURO)
- S4.1-4788 **Damiano Virgilio, Nicoletta Burba, Daniela Fornasaro, Benedetta Guardiani, Marina Cabrini and Serena Fonda Umani**  
Phytoplankton assemblages in the Gulf of Trieste (northern Adriatic Sea): are there signals of climate change? A twenty-year case study
- S4.1-4790 **Naoki Yoshie, Kosei Komatsu, Shin-ichi Ito, Tsuneo Ono, Kazuaki Tadokoro, Hiroaki Saito and Yasuhiro Yamanaka**  
Seasonal and interannual variation of the marine ecosystem in the western subarctic Pacific simulated by a 3D marine ecosystem model

- S4.1-4796 **Merja H. Schlueter, Agostino Merico, Karen H. Wiltshire and Wulf Greve**  
A statistical analysis of climate variability and ecosystem response in the German Bight
- S4.1-4835 **Grbec Branka, Mira Morović, Juan Carlos Molinero, Gordana Beg Paklar, Frano Matić, Ivona Marasović Jakov Dulčić and Sanja Matić-Skoko**  
The influence of northern hemisphere climate patterns on the Adriatic Sea pelagic ecosystem
- S4.1-4838 **Eva Teira, Sandra Martínez-García, Alejandra Calvo-Díaz, Xosé Anxelu G. Morán and Emilio Fernández**  
Impact of inorganic and organic nutrient inputs on bacterioplankton community composition along a latitudinal transect in the Atlantic Ocean
- S4.1-4842 **Sandra Martínez-García, Eva Teira, Emilio Fernández and Alejandra Calvo-Díaz**  
Response of open ocean microbial communities to inorganic and organic inputs: a microcosm approach along a latitudinal transect in the Atlantic Ocean
- S4.1-4865 **Kosei Sasaoka, Sanae Chiba and Toshiro Saino**  
Recent trends in the North Pacific chlorophyll and their controlling factor in relation to climatic forcing using satellite remote sensing
- S4.1-4868 **Roger Harris and WGZE**  
ICES Working Group on Zooplankton Ecology
- S4.1-4869 **Roger Harris (on behalf of the BASIN Steering Group: Peter Wiebe, Cisco Werner, Brad DeYoung, Pierre Pepin and Mike St. John)**  
BASIN: Basin-scale Analysis, Synthesis, and Integration: resolving the impact of climatic processes on ecosystems of the North Atlantic basin and shelf seas
- S4.1-4870 **Roger Harris and METAOCEANS students**  
METAOCEANS: training in advanced meta-analysis and comparative analysis techniques applied to marine ecosystems
- S4.1-4874 **Maria M. Sala, Jesús M. Arrieta, Dolores Vaqué, Julia Boras and Carlos M. Duarte**  
Effects of ice meltwater on Arctic bacterioplankton
- S4.1-4876 **Elena Arashkevich, Alexander Timonin, Alexander Kazmin and Andrei Zatsepin**  
Interactions among climate, circulation, and plankton distribution in the Black Sea
- S4.1-4914 **Renate Scharek, Mikel Latasa, Ramon Massana and Vanessa Balagué**  
Comparing microphytoplankton seasonality after 50 years at a coastal site in the northwest Mediterranean
- S4.1-4926 **Sei-Ichi Saitoh, Takahiro Iida, Kohei Mizobata and Mitsuhiro Toratani**  
Recent variability of coccolithophore blooms in the eastern Bering Sea shelf
- S4.1-4927 **Todd D. O'Brien**  
COPEPOD: a climate studies resource for historical plankton data
- S4.1-4931 **Muzzneena Ahmad Mustapha and Sei-Ichi Saitoh**  
Seasonal and interannual variability of primary production of scallop forming area in the Okhotsk Sea in relation to climate changes
- S4.1-4940 **Snejana P. Moncheva, Valentina G. Doncheva, Kremena B. Stefanova and Lyudmila T. Kamburska**  
Shifts in the Black Sea plankton communities: phenological response to climate forcing or nutrient alterations
- S4.1-4945 **E. Orlova, V. Guzenko, P. Dalpadado, T. Knutsen, V. Nesterova and O. Yurko**  
Reaction of dominant copepods to climatic changes in the Barents Sea

## S4.2 Impacts on higher trophic levels

**Convenors:** *Jürgen Alheit (Baltic Sea Research Institute, University of Rostock, Germany)*  
*Kenneth Drinkwater (Institute of Marine Research, Norway)*  
*Akihiko Yatsu (Hokkaido National Fisheries Research Institute, Japan)*

**Invited Speakers:** *Keith Brander (Technical University of Denmark, Denmark)*  
*Michio Kishi (Hokkaido University, Japan)*

Marine species, including many commercially-exploited stocks, have evolved species-specific life histories through adaptation to complex environmental conditions. They also clearly respond to ocean variability over a wide range of spatial and temporal scales and through various pathways. These responses are both direct, through regulating metabolic factors such as swimming speeds, activity rates, feeding rates and reproduction, and indirect, primarily through effects on the food web. They can result in changes in growth, recruitment, abundance, age of maturity, distribution, etc. The effects of fishing can also make populations more vulnerable to climate change and changes in higher trophic levels, in turn, can affect ecosystems through, for example, “top-down” or “wasp-waist” controls. In this session we encourage contributions on the impacts of climate variability and change (either direct or indirect) on trophic levels above mesozooplankton; ecosystem modelling that includes higher trophic levels; mechanistic linkages between climate change and population dynamics; the interaction between climate and fishing; and indicators that are useful for earlier detection of ecosystem changes. Contributions addressing perspectives on management of ecosystems and commercially-exploited stocks in the face of future climate change were also invited.

**Monday 19 May 2008 11:15 - 18:15**

- 11:15 Introduction by Convenors
- 11:20 **Keith Brander (Invited)**  
Predicting impacts of climate change on fisheries production (S4.2-4699)
- 11:45 **Michio J. Kishi, Yasunori Sakurai and Masahide Kaeriyama (Invited)**  
What will happen on the stock of chum salmon, walleye pollack, and common squid in the Northern Pacific? (S4.2-4596)
- 12:10 **Adriaan D. Rijnsdorp and Christian Möllmann**  
Marine fish and fisheries in a changing climate (S4.2-4719)
- 12:25 **Yury I. Zuenko, Elena I. Ustinova, Alexander N. Vdovin, Vladimir A. Nuzhdin and Natalia T. Dolganova**  
Impacts of climate shifts in the late 20th century on zooplankton and fishery resources in the Japan Sea (S4.2-4763)
- 12:40 **Jan-Olaf Meynecke**  
Effect of climate change on estuarine fish production in Queensland, Australia (S4.2-4960)
- 12:55 **Myron A. Peck, Ute Daewel and Corinna Schrum**  
Larval fish physiology and individual-based models: exploring climate impacts on early life stages of key species (S4.2-4897)
- 13:10 **Lunch**
- 14:30 **Frode B. Vikebø, T. Kristiansen, F.E. Werner, S. Sundby, R.G. Lough and E.G. Durbin**  
Temperature, light and food mediated growth for larval cod (*Gadus morhua*) at latitudinal extremes: a comparative study between the NW Atlantic and Norwegian Sea ecosystems (S4.2-4806)

- 14:45 **Ralf van Hal, Catherine L. Scott and Christine Röckmann**  
Variability in environmental factors affecting the recruitment of fish species in the North East Atlantic (S4.2-4646)
- 15:00 **Jürgen Alheit**  
Impact of climate variability on small pelagic fishes in the Atlantic and Pacific: a comparison (S4.2-4920)
- 15:15 **Akihiko Yatsu, Hiroshi Nishida, Ken Mori, Yasunori Sakurai and Sanae Chiba**  
Mechanisms of population dynamics of Japanese sardine and Japanese common squid in the Kuroshio/Oyashio current system, with a speculation on their future (S4.2-4626)
- 15:30 **Asit Mazumder, Marc Trudel, Ed Farley, Jamal Moss, Lisa Eisner and Jim Murphy**  
Shifting warm-water to cold-water conditions and food web dynamics of juvenile Pacific salmon in the eastern Bering Sea ecosystem (S4.2-4612)
- 15:45 **Kentaro Morita and Masa-aki Fukuwaka**  
Potential effect of rising temperature on growth performance and its influence on chum salmon (S4.2-4551)
- 16:30 **Catarina Vinagre, Telma Ferreira, Lélia Matos, Henrique N. Cabral and Maria José Costa**  
Latitudinal gradients in growth and spawning of sea bass: effect of temperature and photoperiod (S4.2-4625)
- 16:45 **Anne B. Hollowed, Z. Teresa A'mar, Richard Beamish, Nicholas A. Bond, James E. Overland, Michael J. Schirripa and Tom Wilderbuer**  
Fish population response to future climate drivers: A next step forward (S4.2-4815)
- 17:00 **Unai Ganzedo, Eduardo Zorita, Aldo Pier Solari, Guillem Chust, Angelo Santana Del Pino and Juan José Castro**  
What drives tuna captures between 1525 and 1756 centuries in southern Europe? (S4.2-4743)
- 17:15 **Earl G. Dawe, Donald G. Parsons and Eugene B. Colbourne**  
Effects of ocean climate variation on production, maturation, and recruitment of snow crab (*Chionoecetes opilio*) on the Newfoundland-Labrador shelf (S4.2-4739)
- 17:30 **Martin O. Lindegren and Christian Möllmann**  
The future of Baltic cod - modelling interactions between climate, food web dynamics and fisheries (S4.2-4605)
- 17:45 **Marc Trudel, David L. Mackas and Asit Mazumder**  
Climate-mediated changes in prey quality affect the production of wild Pacific salmon (S4.2-4628)
- 18:00 **Carmela Porteiro, Jose M. Cabanas, M.B. Santos and G.J. Pierce**  
The effect of environmental changes in the NE Atlantic sardine (*Sardina pilchardus*) fishery (S4.2-4728)

**S4.2 Posters**

- S4.2-4525 **Leonid Klyashtorin and Alexey Lyubushin**  
Cyclic climate changes and fish productivity in the past and at present
- S4.2-4595 **Yongjun Tian, Hideo Sakaji, Shingo Ino and Masahiro Kuno**  
Long-term changes in the abundance and population structure of yellowtail *Seriola quinqueradiata* in the Japanese waters and its relation to sea surface temperature over the last century
- S4.2-4613 **Oleg A. Bulatov**  
The influence of water temperature on abundance of walleye pollock and northeast arctic cod
- S4.2-4621 **Dale Haidvogel, Elizabeth J. Turner and David Mountain**  
Pan-regional synthesis in the US GLOBEC programme
- S4.2-4655 **Jesús Cabal, Gonzalo González-Nuevo, Jerónimo de la Hoz, Enrique Nogueira and Luis Valdés**  
Relationship between ocean warming and catches of Atlantic salmon (*Salmo salar*) at the southern boundary of the European geographical distribution
- S4.2-4665 **A. Bode and CLIGAL-Pelagic Working Group**  
Impact of climate change on the marine pelagic ecosystems off Galicia (NW Spain). II: Living resources
- S4.2-4674 **Elena Eriksen, Geir Odd Johansen, Randi Ingvaldsen and Jan Erik Stiansen**  
Impacts of climate variability on spatial distribution of 0-group fish in the Barents Sea
- S4.2-4696 **Kawser Ahmed and Shamima Sultana**  
Impact of climate change and variability on coastal water and fisheries resources of Bangladesh
- S4.2-4741 **Edmundo Casillas and W.T. Peterson**  
Impact of climate variability on the California Current ecosystem and Pacific salmon survival: linkages, ocean condition indicators, forecasting, and management perspectives
- S4.2-4748 **Michinobu Kuwae, Hidetaka Takeoka, Koji Omori, Narumi K. Tsugeki and Takashige Sugimoto**  
Sedimentary fish abundance records over the last 1500 yrs from the western North Pacific: Basin-scale link of sardine and anchovy abundance
- S4.2-4765 **Mark R. Payne, Emma M.C. Hatfield, Mark Dickey-Collas, Tone Falkenhaug, Alejandro Gallego, Joachim Gröger, Priscilla Licandro, Marcos Llope, Peter Munk, Christine Röckmann, Jörn O. Schmidt and Richard D.M. Nash**  
Is a changing North Sea environment making sustainable exploitation of herring more difficult?
- S4.2-4773 **Ángela M. Caballero-Alfonso and José J. Castro-Hernández**  
Evidence of North-east Atlantic tropicalisation
- S4.2-4780 **Helen Bailey, George Shillinger, Daniel Palacios, Steven J. Bograd, James Spotila, Frank Paladino, Scott Eckert, Graeme Hays and Barbara Block**  
Comparing Pacific and Atlantic leatherback turtle movements and oceanography using state-space modelling
- S4.2-4826 **Ulysses Madrid Montejo, Norvida Cruz Gatdula, Mirriam Formeloza Cayme and Valeriano Meneses Borja**  
Associating a fish kill event with seawater temperature in the Philippines
- S4.2-4830 **Victor A. Nadtochy, Yury I. Zuenko and Galina V. Moiseychenko**  
Impact of climate change in the 20th century on benthos communities in Peter the Great Bay (Japan Sea)
- S4.2-4833 **Didzis Ustups, Baerbel Karulis-Muller, Andrei Makarchouk and Maris Pliksh**  
The effect of the environmental variability on the early life stage of flounder *Platichthys flesus* in the Baltic Sea

- S4.2-4851 **Mira Morović, Branka Grbec, Juan Carlos Molinero, Gordana Beg Paklar, Jakov Dulčić, Mario Bone, Frano Matić and Živana Ninčević**  
Toward a better understanding of climate forcing on decadal changes in the Adriatic Sea ecosystem
- S4.2-4901 **Cesar Meiners, Lourdes Fernandez and Ana Ramos**  
Distribution dynamics of three hake species along the NW African coast: is climate variability a key factor?
- S4.2-4905 **Myron A. Peck, Helena Hauss and Laura Würzberg**  
Biophysical modelling of climate impacts on larval fish: testing parameterisations at the individual level
- S4.2-4933 **Yeonghye Kim, Sukgeun Jung, Jinkoo Kim and Young-Shil Kang**  
Influence of physical and biological oceanography on population fluctuations of the yellow croaker (*Larimichthys polyactis*) in the Yellow Sea/East China Sea
- S4.2-4944 **Oleg Titov, Boris Prishepa, Yuri. Lepesevich, Nikolay Tarasov and Andrey Pedchenko**  
Climate change and prospects of fisheries in the Barents Sea and adjacent Arctic seas
- S4.2-4956 **Larissa A. Gayko**  
Influence of a change in climate on the development of molluscs in marine farming (for Possyet Bay, Sea of Japan)
- S4.2-4966 **Henrique N. Cabral, J.L. Costa, C. Vinagre, J. Loff, J.J. Jacinto, N. Lopes, C. Freitas and M.J. Costa**  
Is there evidence of climate change impacts on Portuguese coastal fish assemblages?
- S4.2-4973 **Irene Mantzouni and Brian R. MacKenzie**  
Could warmer years mean good years for cod? A pan-Atlantic meta-analytic perspective
- S4.2-4980 **Kristina Raab, Mark Dickey-Collas and Adriaan D. Rijnsdorp**  
Anchovy as indicator of climatic regime shifts?

## Theme 5. Scenarios-mitigation-reduction of impact of future climate change on the marine environment: from regional to global scale

Marine ecosystems worldwide are changing as a result of climate variability and climate change. This session will consider potential impacts on and perturbations of ecosystem structure, function, goods and services using our current knowledge of ecosystem response to climate variability and the prognosis for future climate change. At present, our ability to make (even simple) predictions about coastal and oceanic ecosystem response to climate change may be hampered by an incomplete understanding of the linkages between them. We know that ecosystems in the Arctic are changing rapidly due to ice melting and resultant changes in habitat, thus we are interested in examples of scenarios for physical forcing and ecosystem change in the Arctic as well as in other geographical regions. Does our current knowledge of climate change allow us to predict shifts in distributions of organisms and/or changes in productivity? What do we know about the ability of organisms to adapt to climate change? What are the options for managing marine ecosystems to sustain goods and services essential to societies? We seek presentations that address these questions as well as regional examples of physical climate change scenarios and the resultant ecosystem responses. We expect that the information presented in this theme will lead to discussion of projected future changes and options for adaptation and mitigation.

### S5.1 Scenarios for polar, mid-latitude, sub-tropical, and tropical environments and ecosystems

**Convenors:** Sanae Chiba (*Frontier Research Center for Global Change, Japan*)  
Harald Loeng (*Institute of Marine Research, Norway*)

**Invited speakers:** Graham Hosie (*Department of the Environment and Water Resources, Australian Antarctic Division*)  
Gordon Kruse (*University of Alaska Fairbanks, USA*)

There are serious gaps in our understanding of the potential impacts of climate change on the marine ecosystems, and predicting ecosystem responses may prove challenging. Large, long-lived species tend to have very stable populations, so even dramatic changes in juvenile survivorship may not easily be detected for a considerable period of time. At the other end of the size range of organisms, natural variation in population size of phytoplankton is generally large and can mask detection of longer-term trends in abundance. This requires urgent attention in order to make significant progress toward predicting and understanding the impacts of climate change on the marine environment. This session will describe future changes in the marine ecosystem, including distribution, production and biodiversity due to changing climate. We seek papers that focus on ocean currents and transport pathways, vertical stratification and impact on nutrient distribution and phytoplankton production, identification of species sensitivity to climate change (sentinel species), indirect and non-linear effects on biological processes, match/mismatch between predators and prey, and competition when/if new species are introduced into the ecosystem. Ecosystem responses to the common, large scale climatic forcing could vary in respective latitudinal regions due to regionally-specific environmental/ecological characteristics. We hope to contrast especially the mechanisms of ecosystem changes in the polar, mid-latitude, sub-tropical, and tropical regions.

**Wednesday 21 May 2008 10:30 - 13:40**

10:30 Introduction by Convenors

10:35 **Graham W. Hosie (Invited)**  
Impacts of climate change on Antarctic marine ecosystems (S5.1-4770)

- 11:00 **Gordon H. Kruse, Jie Zheng and James E. Overland (Invited)**  
A scenario approach to forecast potential impacts of climate change on red king crabs in the eastern Bering Sea (S5.1-4778)
- 11:25 **Simon J. Walker, Greg A. Skilleter and Bernie M. Degnan**  
Predicting the effects of climatic change on the biodiversity of intertidal sessile fauna on coral reefs (S5.1-4631)
- 11:40 **Teruhisa Komatsu, Atsuko Mikami, Etienne Boisnier, Tatsuyuki Sagawa, Hideaki Tanoue, Tetsuro Ajisaka and Yoshihiko Sakanishi**  
Possible change in seaweed distribution in East Asia under a particular scenario of global warming (S5.1-4632)
- 11:55 **Clarence Pautzke, W. Wiseman and F. Wiese**  
North Pacific Research Board and National Science Foundation partner to study biological processes on eastern Bering Sea shelf ecosystem and impacts of climate change (S5.1-4959)
- 12:10 **Alistair J. Hobday, Elvira S. Poloczanska, Thomas J. Kunz, Tom A. Okey and Anthony J. Richardson**  
Getting hot and bothered about climate change impacts in Australian waters (S5.1-4819)
- 12:25 **Solfred Sætre Hjøllo, Morten Skogen and Einar Svendsen**  
Long term changes in North Sea physics and phytoplankton from NORWECOM (S5.1-4841)
- 12:40 **Xiuren Ning, Chuanlan Lin, Qiang Hao, Chenggang Liu and Fengfeng Le**  
Long-term environmental changes and the responses of the ecosystem in the northern South China Sea during 1976-2004 (S5.1-4864)
- 12:55 **Fabian Blanchard, Jean-Charles Poulard, Hicham Masski and Claude Roy**  
Predicting climate warming impact on marine fish communities from biogeography: example from tropical, subtropical and temperate case studies (S5.1-4919)
- 13:10 **Kenneth F. Drinkwater, Harald Loeng and S. Sundby**  
The ecosystem response of the Barents and Norwegian seas to future climate change with emphasis on the higher trophic levels (S5.1-4952)
- 13:25 **Bulent Acma**  
Climate changes and tourism: southeastern Anatolia region and southeastern Anatolia Project (GAP) in Turkey as a case study (S5.1-4515)

### S5.1 Posters

- S5.1-4548 **Jared O. Bosire**  
Resilience of mangroves to indirect effects of climate change
- S5.1-4845 **Anna V. Radovets and Nadezhda K. Khristoforova**  
Influence of climatic changes on density dynamics of boreal and subtropical bivalves larvae in plankton of Minonosok Bight (Possyet Bay, Japan/East Sea)
- S5.1-4922 **Fengfeng Le and Xiuren Ning**  
Effect of *El Niño* Southern Oscillation events on the distribution and abundance of phytoplankton in the northern South China Sea

## S5.2 Adaptation and mitigation of impacts on the marine environment and ecosystems

**Convenors:** *Jane Lubchenko (Oregon State University, USA)*  
*William T. Peterson (Hatfield Marine Science Center, National Marine Fisheries Service, USA)*

**Invited speaker:** *Marissa Baskett (National Center for Ecological Analysis and Synthesis, University California Santa Barbara, USA)*  
*Andrew A. Rosenberg (Institute for the Study of Earth, Oceans and Space, University of New Hampshire, USA)*

The recent reports of the Millennium Ecosystem Assessment and the IPCC Working Groups II and III included only a minimal discussion of climate impacts on marine ecosystems. This session invites papers that will expand our understanding of climate impacts on marine ecosystems, and on ecosystem services produced. Papers were sought that discuss adaptation, vulnerability, mitigation and the potential for reduction of impacts on coastal and oceanic ecosystems. What are our options for managing marine ecosystems to sustain critical services within both a climate change and an ecosystem management perspective? Will organisms be able to adapt to climate change? What tools are available to increase the likelihood that organisms will adapt and to enhance the resilience of ecosystems to detrimental impacts of changes? Coastal ecosystems such as wetlands, estuaries, intertidal and nearshore habitats, kelp forests, coral reefs and ecosystems surrounding small islands are particularly vulnerable to climate change due to global warming, sea level rise, increased freshwater runoff and storms, and influence of coastal winds. Changes in fish production are expected but may be mitigated by avoiding other ecological stressors such as overfishing and coastal pollution. Networks of marine protected areas and no-take marine reserves may enhance resilience of ecosystems. They may also counter selection pressures for reproduction at smaller size. Fishing practices may need to change to mitigate social and economic impacts of shifting availability of fishes as well as evolutionary changes. Aquaculture ventures will find that rising water temperatures are likely to increase growth rates of some species, but may be detrimental to others. What are the gaps in our knowledge that prevent us from making better assessments of likely outcomes under various climate change scenarios? Is it feasible and wise to consider the ocean as a depository for carbon dioxide either through pumping CO<sub>2</sub> into the deep sea or through massive iron fertilisation experiments?

**Friday 23 May 2008 10:30 - 15:45**

- 10:30 Introduction by Convenors
- 10:35 **Andrew A. Rosenberg (Invited)**  
How can fisheries adapt to a changing ocean climate: beyond ecosystem-based fishery management (S5.2-4949)
- 11:00 **Marissa L. Baskett (Invited)**  
Ecological and rapid evolutionary responses to climate change: implications for marine management (S5.2-4710)
- 11:25 **Benjamin S. Halpern, Shaun Walbridge, Kimberly A. Selkoe, Carrie V. Kappel, Fiorenza Micheli, Caterina D'Agrosa, John F. Bruno, Kenneth S. Casey, Colin Ebert, Helen E. Fox, Rod Fujita, Dennis Heinemann, Hunter S. Lenihan, Elizabeth M.P. Madin, Matthew T. Perry, Elizabeth R. Selig, Mark Spalding, Robert Steneck and Reg Watson**  
A global map of human impact on marine ecosystems (S5.2-4924)
- 11:40 **William T. Peterson, Edmundo Casillas, Cheryl Morgan, Hongsheng Bi and Hui Liu**  
Response and adaptation of salmon of the Pacific Northwest and the Columbia River region of the United States (Washington and Oregon) to climate change (S5.2-4921)

- 11:55 **Diana L. Stram and Chris Oliver**  
Fishery management responses to climate change in the North Pacific (S5.2-4529)
- 12:10 **Kelley D. Higgason and Maria Brown**  
Building local solutions to manage the effects of global climate change on a marine ecosystem: a process guide for place-based resource managers (S5.2-4853)
- 12:25 **Bayden D. Russell, Jo-Anne Thompson and Sean D. Connell**  
Managing local human impacts in marine systems under global climate change (S5.2-4594)
- 12:40 **Elvira S. Poloczanska and Anthony J. Richardson**  
Marine ecosystems: under resourced, overlooked and under threat? (S5.2-4818)
- 12:55 **Maria Rebecca A. Campos**  
Adaptation of fishing communities in the Philippines to natural risks (S5.2-4549)
- 13:10 ***Lunch***
- 14:30 **Ahsan U. Ahmed and S. Neelormi**  
Implications of changing sea surface temperature in the Bay of Bengal: livelihoods of coastal fisherfolks in jeopardy (S5.2-4636)
- 14:45 **Albrecht Götz, Russell Chalmers, Rhett Bennett, Sven Kerwath and Paul Cowley**  
Marine Protected Areas as a tool for long-term monitoring of marine biota: separating climate from anthropogenic influences (S5.2-4530)
- 15:00 **Felix L. Figueroa, N. Korbee and M. Segovia**  
Functional indicators monitoring ecological status and vulnerability of marine macroalgae to climate change (S5.2-4754)
- 15:15 **Dries Van den Eynde, Renaat De Sutter, José Ozer, Stéphanie Ponsar, Katrien Van der Biest, Els Vanderperren, Toon Verwaest and Annemie Volckaert**  
Evaluation of climate change impacts and adaptation responses for marine activities: the CLIMAR project (S5.2-4934)
- 15:30 **Barbaro V. Moya, Alfredo Cabrera, Lorenzo Castillo and Jose Rojo**  
Hicacos peninsula, face to future changes (S5.2-4057)

## **W1 Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels**

**Convenors:** *David L. Mackas (Institute of Ocean Sciences, Fisheries and Oceans Canada)*  
*Hans Verheye (Marine and Coastal Management, DEAT, South Africa)*

Evidence for climate-correlated variability of various components of marine ecosystems has accumulated rapidly over the past two decades. There is a growing recognition of the societal need to learn how climate and ocean environmental and biotic responses are linked, and the likely amplitude and steepness of future changes. Demographic characteristics of marine zooplankton make them especially suitable for examining variability at interannual to decadal time scales. Because zooplankton are rarely fished, their changes in abundance can greatly enhance our collective ability to evaluate the importance of and interaction between 'physical environment', 'food web', and 'fishery harvest' as causal mechanisms driving ecosystem level changes. A number of valuable within-region analyses of zooplankton time series have been published in the past decade, covering a variety of modes of variability including changes in total biomass, changes in size structure and species composition, changes in spatial distribution, and changes in phenology. But because most zooplankton time series are relatively short compared to the time scales of interest, the statistical power of individual local analyses is relatively low. Between-region and between-variable comparisons are needed, and are the mandate of SCOR's Working Group 125 on "Global comparison of zooplankton time series". This workshop will feature several presentations and discussions by WG125 members, but contributions from other investigators are also welcome.

**Sunday 18 May 2008 09:30 - 17:30**

- 09:30 Introduction by Convenors
- 09:40 **Todd D. O'Brien, David L. Mackas, Mark D. Ohman, Ángel López-Urrutia and SCOR WG125 Contributors**  
The SCOR WG125 toolkit: issues and methods for analysing zooplankton time series (W1-4768)
- 10:00 **Todd D. O'Brien, David Mackas, Hans M. Verheye and SCOR WG125 Contributors**  
SCOR WG125: global comparison of zooplankton biomass time series (W1-4767)
- 10:20 **Damien Eloire, Delphine Bonnet and Roger Harris**  
Temporal variations in the zooplankton community: a 20 year time-series analysis at station L4 in the English Channel (W1-4930)
- 10:40 **David L. Mackas, Anthony J. Richardson, Hans M. Verheye, William Peterson, Sanae Chiba, Gregory Beaugrand, Bertha Lavaniegos and SCOR WG125 Contributors**  
Climate-associated latitudinal shifts of zooplankton species and species assemblages (W1-4761)
- 11:00 *Tea/coffee break*
- 11:30 **Hans M. Verheye, Dave Checkley, Sanae Chiba, Young-Shil Kang, Webjørn Melle, Mark D. Ohman, Anthony J. Richardson and SCOR WG125 Contributors**  
Long-term changes in zooplankton community size structure: a global comparison (W1-4946)
- 11:50 **David Mackas, Wulf Greve, Martin Edwards, Sanae Chiba, Gregory Beaugrand, Elena Arashkevich and SCOR WG125 Contributors**  
Changing seasonal timing of zooplankton populations, and their link to ocean climate (W1-4704)
- 12:10 **Merja H. Schlueter, Agostino Merico, Karen H. Wiltshire and Wulf Greve**  
Long-term changes in zooplankton phenology at Helgoland Roads (W1-4968)

- 12:30 **Sanae Chiba, H. Sugisaki, K. Tadokoro, A. Kuwata, T. Kobari, A. Yamaguchi and D.L. Mackas**  
Pan-North Pacific synthesis of long-term variation of *Neocalanus* spp. based on stable isotope analysis (SCOR WG125 contribution) (W1-4633)
- 12:50 **Anthony J. Richardson, Patricia Ayon and SCOR WG125 Members**  
Are pelagic systems bottom-up or top-down controlled? (W1-4882)
- 13:10 **Lunch**
- 14:30 **Juha Flinkman, E. Arashkevich, M. Lehtiniemi and S. Viitasalo**  
Comparison of early stages of *Mnemiopsis leidyi* invasion into the Black, Caspian and Baltic Seas (W1-4975)
- 14:50 **Maria Grazia Mazzocchi, Lars Stemmann, Carmen Garcia Comas, Maurizio Ribera d'Alcala, Gregory Beaugrand, Stéphane Gasparini, Frederic Ibañez, Stéphane Pesant, Marc Picheral and Gabriel Gorsky**  
Retrospective analysis of zooplankton decadal time series in the western Mediterranean Sea using an automated imaging system (W1-4784)
- 15:10 **Maria Luz Fernandez de Puelles, Juan Carlos Molinero, Laura Vicente, Ana Morillas and Javier Jansá**  
Zooplankton time series related to North Atlantic climate changes in waters of the Balearic Sea: a case of boundary area in the central western Mediterranean (W1-4906)
- 15:30 **Alessandra Conversi, T. Peluso and S. Fonda-Umani**  
The Gulf of Trieste, 1970-2005: a changing ecosystem (W1-4666)
- 15:50 **Tea/coffee break**
- 16:20 **Isabelle Rombouts, G. Beaugrand, F. Ibañez and L. Legendre**  
Large-scale geographic variations in diversity of marine zooplankton: theories, environmental controls, and functioning of pelagic ecosystems (W1-4727)
- 16:50 **Chris Reason, Anthony J. Richardson and SCOR WG125 Contributors**  
Are there teleconnections among zooplankton time series within and between ocean basins? (W1-4883)
- 17:10 **Harold Batchelder, David Mackas, Todd D. O'Brien and SCOR WG125 Contributors**  
Global zooplankton time series comparisons: where is the synchrony? (W1-4859)

## **W2/3 Linking Global Climate Model output to (a) trends in commercial species productivity and (b) changes in broader biological communities in the world's oceans**

**Convenors (part a):** *Anne Hollowed (Alaska Fisheries Science Center, National Marine Fisheries Service, USA)*

*Richard Beamish (Pacific Biological Station, Fisheries and Oceans Canada),*

*Michael Schirripa (Northwest Fisheries Science Center, National Marine Fisheries Service, USA)*

**Convenor (part b):** *Thomas A. Okey (Bamfield Marine Sciences Centre, Canada)*

The goal of the combined workshop will be to facilitate a coordinated international research effort to forecast climate change impacts on the distribution and production of the world's major fisheries, and on the biological communities in which these fisheries are embedded. The specific objectives of the workshop are: (1) to review the activities of existing programmes within each nation, (2) to examine the evidence for climate impacts on production of commercial fish species and other marine life, (3) to discuss the feasibility of developing medium-term to long-term forecasts of climate impacts, (4) to discuss possible responses of commercial fisheries, human communities, and governments to climate-driven changes in marine life, and (5) to identify common or standard approaches to forecasting climate change impacts on commercial species and marine communities and ecosystems.

Workshop attendees will identify climate scenarios for use in forecasting and then discuss development of forecasting tools for use in predicting climate impacts on commercial fish production and broader marine ecosystems. The workshop will provide a forum for discussion of four components needed to complete the forecasts in a timely and coordinated fashion including: IPCC scenarios, predictions of oceanographic impacts, modelling approaches, and regional scenarios for natural resource use and enhancement. The ecosystem component of the workshop will survey a wide variety of approaches including vulnerability assessments for informing location choices for ecosystem modelling efforts and management prioritisation, trophodynamic fishery ecosystem modelling (i.e. Ecopath with Ecosim), climate envelope modelling, statistical approaches, and three dimensional high-resolution biogeochemical ecosystem modelling (i.e. CCC-NEMURO).

**Sunday 18 May 2008 09:30-18:00**

- 09:30 Introduction by Convenors
- 09:40 Round table discussion of existing or planned research
- 11:00 **Nicholas A. Bond, James E. Overland and Muyin Wang**  
A method for using IPCC model simulations to project changes in marine ecosystems (W2/3-4622)
- 11:30 **Mary E. Livingston**  
Climate change, oceanic response and possible effects on fish stocks in New Zealand waters (W2/3-4974)
- 11:45 **Jae Bong Lee, Anne B. Hollowed, Nicholas A. Bond, James E. Overland, Chang Ik Zhang and Dong Woo Lee**  
Forecasting climate change impacts on the distribution and abundance of jack mackerel around Korean waters (W2/3-4935)
- 12:00 **Sukyung Kang, Jae Bong Lee, Anne B. Hollowed, Nicholas A. Bond and Suam Kim**  
Techniques for forecasting climate-induced variation in the distribution and abundance of mackerels in the northwestern Pacific (W2/3-4925)

- 12:15 **Adriaan D. Rijnsdorp, Joep J. de Leeuw, Lorna R. Teal and Henk W. van der Veer**  
Effects of climate change on sole and plaice: timing of spawning, length of the growth period and rate of growth (W2/3-4720)
- 12:30 **Z. Teresa A'mar, André E. Punt and Martin W. Dorn**  
The impact on management performance of including indicators of environmental variability in management strategies for the Gulf of Alaska walleye pollock fishery (W2/3-4540)
- 12:45 **Michael J. Schirripa, Richard D. Methot and C. Phillip Goodyear**  
Simulation testing two methods of including environmental data in stock assessments (W2/3-4862)
- 13:00 **Alan Haynie**  
Climate change and changing fisher behaviour in the Bering Sea Pollock fishery (W2/3-4846)
- 13:15 **U.K. Singh and P.S. Salvekar**  
Large scale circulation over the west Indian Ocean and the south west monsoon (W2/3-4572)
- 13:30 **Lunch**
- 15:00 **Jorge L. Sarmiento, Patrick Schultz, Michael Hiscock and Stephanie Henson**  
Modelling the response of ocean biology to climate warming using an empirical approach (W2/3-4757)
- 15:15 **Taketo Hashioka, Takashi T. Sakamoto, Takeshi Okunishi and Yasuhiro Yamanaka**  
Future ecosystem changes projected by a 3-D high-resolution ecosystem model (W2/3-4793)
- 15:30 **William W.L. Cheung, Vicky W.Y. Lam and Daniel Pauly**  
Dynamic bioclimate envelope model to predict climate-induced changes in distribution of marine fishes and invertebrates (W2/3-4803)
- 15:45 **Alistair J. Hobday, Thomas J. Kunz, Thomas A. Okey, Elvira S. Poloczanska and Anthony J. Richardson**  
Informing location choices for ecosystem model development using a vulnerability index (W2/3-4805)
- 16:00 **Tea/coffee break**
- 16:30 **Simone Libralato, Cosimo Solidoro and Villy Christensen**  
Towards the integration of biogeochemical and food web models for a comprehensive description of marine ecosystem dynamics (W2/3-4913)
- 16:45 **Steven Mackinson, G. Daskalov, S.J.J. Heymans, S. Neira, H. Arancibia, M. Zetina-Rejón, D. Lecari, J. Hong, C. Hequin, M. Coll, F. Arreguin-Sanchez, L. Shannon and K. Lees**  
Which forcing factors fit? Using ecosystem models to investigate the relative influence of fishing and primary productivity on the dynamics of marine ecosystems (W2/3-4822)
- 17:00 **Sheila J.J. Heymans**  
The effects of climate change on the northern Benguela ecosystem (W2/3-4831)
- 17:15 Discussion of common approaches and workshop synthesis

## W4 Prospects for multidisciplinary long-term ocean observations

**Convenors:** *Ed Harrison (Pacific Marine Environmental Laboratory, NOAA/PMEL, USA)*  
*Richard Lampitt (Southampton Oceanography Centre, UK)*  
*Doug Wallace (IFM-GEOMAR, Germany)*

Motivated by the need to understand and measure the ocean's role for climate, the physical community has made great strides towards implementation of global and regional ocean observing systems both *in situ* and space-borne. Despite the introduction, three decades ago, of space-borne sensors for ocean colour, the observing systems for ocean biological and chemical properties are significantly less advanced. The motivation for such systems is strong and growing, given the pressures of marine ecosystems and the ocean's significance for carbon sources and sinks. The workshop will help to scope the prospects to allow similar progress concerning observation of biogeochemical properties in the oceans. The outcome of the workshop is intended to feed into a white paper to be presented at an international symposium, OCEANOBS09 (<http://www.oceanobs09.net/>), to be held in the autumn of 2009. The issues to be addressed follow directly from the principles and practices of GEOSS (Global Earth Observation System of Systems). The 10 year Implementation Plan (adopted February 16, 2005) clearly states that GEOSS "...builds on and adds value to existing Earth observation systems by coordinating their efforts, addressing critical gaps, supporting their interoperability, sharing information, reaching a common understanding of user requirements and improving delivery of information to users." GEO (Group on Earth Observations) includes 68 member countries, the European Commission, and 46 participating organizations working together to establish GEOSS. With these principles and needs in mind, interest groups, existing observing networks, and individuals are invited to exchange and share their visions for a global ocean observing system that addresses key biogeochemical properties of the marine realm.

Wednesday 21 May 2008 14:30 - 18:00

- 14:30 **D.E. Harrison**  
Ocean variability and trends, and the sustained Global Ocean Observing System (W4-4967)
- 14:50 **Christopher L. Sabine, Richard A. Feely, Stacy Maenner and Christian Meinig**  
High-resolution ocean and atmosphere  $p\text{CO}_2$  time series measurements from open ocean and coastal moorings (W4-4977)
- 15:10 **Martin Visbeck, Johannes Karstensen, Arne Körtzinger and Nicolas Gruber**  
Prospects for using profiling floats and gliders for biogeochemical sustained observations? (W4-4971)
- 15:30 **Richard A. Feely, Christopher L. Sabine and Rik Wanninkhof**  
Decadal  $\text{CO}_2$  uptake by the ocean deduced from the CLIVAR/ $\text{CO}_2$  Repeat Hydrography Program (W4-4970)
- 15:50 **R.S. Lampitt, K.E. Larkin, S.E. Hartman and M. Pagnani**  
The role of fixed-point deep ocean observatories in a global observing system (W4-4969)
- 16:10 Discussion

### W4 Posters

- W4-4536 **Juliet Hermes, Angus Paterson and Johan Pauw**  
Long term monitoring of oceans around Southern Africa

## **W6 Storm surges and flooding in the Baltic Sea**

**Convenors:** *Aleksander Toompuu (Tallinn University of Technology, Estonia)*  
*Evgueni Kulikov (Shirshov Institute of Oceanology of the Russian Academy of Sciences, Russia)*  
*Josef Cherniawsky (Institute of Ocean Sciences, Fisheries and Oceans Canada)*

The Baltic Sea water levels vary over a wide range of temporal and spatial scales. The prevailing winds and river runoff produce a mean sea-surface slope, while intense storms cause flooding in the eastern Baltic. This strong variability and flooding motivate investigations of the physical processes and of quantitative methods for more accurate predictions of extreme sea-level events in the Baltic Sea.

The strongest sea-level oscillations in the Baltic Sea and the most severe floods occur in the Eastern Gulf of Finland (EGF), as storm winds over the Baltic Sea drive large volumes of water into the shallow Neva Bay at the head of the Gulf. A major objective of the ongoing research is development of a reliable system for prediction of sea-level variations and storm surges along the EGF coast. The purpose of this workshop is to facilitate the exchange of information and ideas pertaining to this research, in particular on modelling of the effects of climate change and variability on water levels, storm surges and flooding in the Baltic Sea.

**Sunday 18 May 2008 09:30 - 18:00**

09:30 **Evgueni A. Kulikov, Aleksander Toompuu and Josef Y. Cherniawsky**  
Introduction: storm surges and flooding in the Baltic Sea

### **I. Observations and analyses of sea level data (Chair: K. Klevanny)**

- 09:50 **Aleksander Toompuu, Evgueni A. Kulikov and Germo Vali**  
Extreme sea level statistics along the Estonian coast (W6-4678)
- 10:20 **Alexander S. Averkiev and Konstantin A. Klevanny**  
Calculation of extreme water level rises along the western part of the Gulf of Finland (W6-4630)
- 10:50 **Oleg P. Nikitin and Andrey O. Koch**  
Sea level trends along the coast of the Gulf of Finland of the Baltic Sea (W6-4733)
- 11:20 *Tea/coffee break*
- 11:30 **Alexander B. Rabinovich and Evgueni A. Kulikov**  
On diurnal tidal resonance in the Baltic Sea and Gulf of Finland (W6-4885)
- 12:00 **Evgueni A. Kulikov, Oleg P. Nikitin and Aleksander Toompuu**  
Spectral analysis of sea level in the Gulf of Finland (W6-4681)
- 12:30 **Josef Y. Cherniawsky, Evgueni A. Kulikov and Oleg P. Nikitin**  
Sea level variability and trends from satellite altimetry and tide gauges in the eastern Baltic Sea (W6-4923)
- 13:00 *Lunch*

## **II. Modelling and forecasting of water level (Chair: E. Kulikov)**

- 14:30     **K. Klevanny and A. Rabinovich**  
Prof. Alexei Vsevolodovich Nekrasov (1933-2008)
- 14:50     **Alexey V. Nekrasov and Stanislav D. Martyanov**  
Influence of cyclone parameters upon the characteristics of storm surges in St. Petersburg (W6-4602)
- 15:20     **Andrey O. Koch and Natalia A. Tikhonova**  
Numerical study of wind-driven circulation in the Gulf of Finland with the Regional Ocean Modelling System (ROMS) (W6-4887)
- 15:50     *Tea/coffee break*
- 16:00     **Evgueni A. Kulikov and Isaac I. Fine**  
Numerical modelling of the Baltic sea-level variability (W6-4659)
- 16:30     **Martin Verlaan and Herman Gerritsen**  
Model development for flood forecast improvement in the Netherlands (W6-4976)
- 17:00     **Konstantin A. Klevanny and Suleiman-Mohammad W. Mostamandi**  
Recent improvements in automated flood forecasting system for St. Petersburg (W6-4581)
- 17:30     Discussion and summary

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# P

## Plenary

### Monday 19 May

**19 May, 09:15 (Theme 1.1)**

#### **Observed ocean climate changes: a review based on the IPCC AR4 and subsequent works**

Lynne D. **Talley**

Scripps Institution of Oceanography, UCSD, 9500 Gilman Drive, La Jolla, CA 92093-0230, USA. E-mail: ltalley@ucsd.edu

Changes in ocean temperature, salinity, oxygen and circulation over the past several decades, and their relation to changes in atmospheric forcing, were thoroughly synthesized in the Intergovernmental Panel on Climate Change's Fourth Assessment Report, published in February 2007. The conclusions of that synthesis were based on peer-reviewed materials published prior to 2006. Primary conclusions based on these published materials are as follows: from 1955 to 2003, the oceans were warming, with two-thirds of the heating in the upper 700 m. The warming was not uniform; the subpolar North Atlantic and North Pacific and tropical Pacific warm pool were cooling, but not enough to offset the global warming trend. Global mean sea level was rising, and the rate was increasing; like temperature, sea level changes also exhibited large regional variations. Salinity is changing regionally, with higher latitudes and the Pacific freshening, while lower latitudes and the Atlantic and Indian are becoming saltier, roughly consistent with a stronger atmospheric hydrological cycle, which is consistent with a warmer atmosphere and hence climate change. Oxygen had been decreasing in the pycnocline in subpolar regions, consistent with decreased ventilation at the base of the climatological pycnocline. On the other hand, circulation trends were not robust. The Atlantic meridional overturning circulation was of particular interest, but variability was dominated by interannual and decadal change; any trends were too weak in comparison to be apparent. The work reviewed in the IPCC was principally based on research ship-based observations and local experiments; climatologies were constructed by simple processing of these regional data sets. Many of the newer results that are brought together here are also based on direct regional observations. Newer products also include the growing body of distributed subsurface float profiles (Argo) as well as data assimilation for the Topex/Poseidon altimetry period. Ocean and climate models are also providing important information for interpreting the observed changes.

**19 May, 10:00 (Theme 4.2)**

#### **Forecasts of population trends for two species of tuna under an IPCC scenario**

Patrick **Lehodey**<sup>1</sup>, Inna Senina<sup>1</sup>, John Sibert<sup>2</sup>, Laurent Bopp<sup>3</sup> and Beatriz Calmettes<sup>1</sup>

<sup>1</sup> MEMMS (Marine Ecosystems Modelling and Monitoring by Satellites), CLS, Spatial Oceanography Division, 8-10 rue Hermes, Ramonville 31520, France. E-mail: PLehodey@cls.fr

<sup>2</sup> PFRP (Pelagic Fisheries Research Program), University of Hawaii at Manoa, 1000 Pope Road, MSB 313, Honolulu, HI 96822, USA.

<sup>3</sup> LSCE/IPSL, UMR 1572 CE Saclay, Gif sur Yvette, F-91191, France.

The spatial ecosystem and population dynamics model SEAPODYM includes a definition of habitat indices, movement, and accessibility of tuna predators to their forage at different vertical layers. The model was improved by implementing data assimilation techniques, and parameterisation was optimised by maximum likelihood estimation using historical fishing data (1985-2000). First optimised parameters were obtained for Pacific skipjack and bigeye, two tuna species with very different biological characteristics. Based on estimated parameters, hindcast simulations back to the early 1960s, i.e. the beginning of the industrial fishing period, predicted catch and tuna population abundance is in agreement with observation and stock assessment studies. We employed this model to forecast the future of skipjack and bigeye in the world's oceans under the A2 IPCC scenario. The simulation is driven by biophysical fields predicted from a global Earth system simulation coupling atmospheric, land surface, sea ice, physical and biogeochemical marine components. A preliminary simulation demonstrated the capacity of the model to predict plausible responses at global scale. However, due to overly coarse spatial resolution of the atmospheric model, the climate simulation produced a temperature cold anomaly in high latitudes. Given the key effects of temperature in the dynamics of both mid-trophic components and tuna populations, further simulations were conducted after the temperature fields were processed to remove this bias. Potential future changes in distribution and abundance of skipjack and bigeye under the IPCC scenario are presented. Populations' responses to the environmental changes are complex and differ between oceans. Though on average, the effect due to climate change is on the same order as the fishing effect, the combination of both effects result in spatially heterogeneous distributions.

## **Tuesday 20 May**

**20 May, 08:30 (Theme 1.2)**

### **Oceans role in climate change**

Ronald J. **Stouffer**

GFDL/NOAA, Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08542, USA. E-mail: ronald.stouffer@noaa.gov

First, an overview of the role of the oceans in climate change is given. For example, the ocean acts as a large reservoir for heat, water and other tracers. Changes in oceanic transports can also impact the climate. Projections of oceanic changes (e.g. temperature, salinity, circulation and sea level rise) from the IPCC 4th Assessment Report are presented. These projections show that the SSTs warm in most regions when greenhouse gases (GHG) increase in the atmosphere. However, the warming is minimal in high latitudes of the North Atlantic and around Antarctica. The warming only slowly penetrates to depth, indicating the long response time scales found in the ocean. The long temperature response time scales also lead to long response time scales for sea level rise. As GHG increase in the atmosphere, there is also the possibility that the earth will experience large scale abrupt climate changes. These could be related to changes in ocean circulation due to the warming or melting land ice. A discussion of the uncertainties associated with these projections will be presented. For example, the AR4 assessment states that it is *very unlikely* that the Meridional Overturning Circulation (MOC) found in the Atlantic Ocean will shut down this century. Finally some thoughts for discussion are presented. One issue is whether or not the MOC weakening (not an abrupt shutdown!) is good or bad for society; for example, a potentially good result of the MOC weakening as GHGs increase is that the North Atlantic region experiences less warming.

**20 May, 09:15 (Theme 2.1)**

### **Recent trend in the global oceanic CO<sub>2</sub> sink**

Corinne **Le Quéré**<sup>1,2</sup>, Taro Takahashi<sup>3</sup>, Christian Rödenbeck<sup>4</sup>, Erik T. Buitenhuis<sup>2</sup> and Steward C. Sutherland<sup>3</sup>

<sup>1</sup> British Antarctic Survey, High Cross, Madingley Rd, Cambridge CB3 0ET, UK. E-mail: c.lequere@uea.ac.uk

<sup>2</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK.

<sup>3</sup> Lamont Doherty Earth Observatory, Columbia University, 61 Route 9W, P.O. Box 1000, Palisades, NY 10964-8000, USA.

<sup>4</sup> Max Planck Institut für Biogeochemie, Postfach, Jena 011064, Germany.

In spite of the large increase in atmospheric CO<sub>2</sub> in recent decades, numerous studies have reported that long-term observations of seawater *p*CO<sub>2</sub> and sea-air *p*CO<sub>2</sub> difference are not always consistent with an increasing global oceanic sink for CO<sub>2</sub>. We analysed observations and models over the 1981-2007 time period to set constraints on the rate of increase of the global oceanic sink for CO<sub>2</sub>. Our analysis includes repeat surveys of oceanic *p*CO<sub>2</sub>, inversions of atmospheric CO<sub>2</sub> observations, and a process model forced by different combinations of observed atmospheric surface conditions. The observations and models show large temporal and spatial variability in the mean annual rate of change of seawater *p*CO<sub>2</sub>, including periods where it increases faster than atmospheric CO<sub>2</sub>. We show coherence between data and models that suggest a steady increase in the air-to-sea CO<sub>2</sub> flux in large sectors of the North and South Pacific oceans, and no change or a decrease in air-to-sea CO<sub>2</sub> flux in the sub-tropical North Atlantic, equatorial Pacific and Southern Oceans. Globally, the process model shows no increase in the oceanic CO<sub>2</sub> sink between 1981 and 2007 because of wind-driven changes in the physical transport, but this result remains only partly constrained by observations.

## **Wednesday 21 May**

**21 May, 08:30 (Theme 2.2)**

### **Coral reef ecosystems as casualties of rapid climate change**

Ove **Hoegh-Guldberg**

Centre for Marine Studies, University of Queensland, Gehrman Building, Level 7, St Lucia, Queensland 4072, Australia.  
E-mail: oveh@uq.edu.au

Coral reefs occupy less than 1% of the world's ocean yet are exquisite storehouses of biodiversity. They also underpin billion-dollar industries and are critically important to over 100 million people that forage on them daily for food. Rapid changes to the temperature and carbonate ion concentration of tropical/sub-tropical

oceans in response to anthropogenic greenhouse gas emissions have already produced major changes to coral reef ecosystems. These changes have affected reef-building corals by slowing their growth and eliminating them in large numbers during mass bleaching and mortality events. These impacts have had secondary effects on the estimated million species that live on and around reef-building corals, and have begun to affect the resources and ecological functions available to associated human societies. Most of the evidence suggests that this damage is likely to escalate under further changes to atmospheric CO<sub>2</sub>, and even under the most optimistic projections where atmospheric carbon dioxide stabilises at 450 ppm, carbonate coral reef ecosystems appear unviable. While corals may persist as minor members of tropical reef communities, tropical near-shore ecosystems will be vastly different to what they are today. The question of how we respond to this crisis in tropical/sub-tropical ecosystems (less than 30 years away at current rates of increase of atmospheric CO<sub>2</sub>) needs to drive the next set of research and management questions. Only by understanding the associated impacts on tropical fisheries, tourism and coastal protection, will we have a chance as a society to find ways to adapt to these major changes.

**21 May, 09:15 (Theme 5.1)**

### **The changing Northern Ocean**

Eddy C. **Carmack**

Institute of Ocean Sciences, Fisheries and Oceans Canada, 9860 W. Saanich Road, Sidney, BC, V8L 4B2, Canada.  
E-mail: [carmacke@dfo-mpo.gc.ca](mailto:carmacke@dfo-mpo.gc.ca)

It has long been argued that ocean climate change would occur first and fastest in the high-latitudes of the northern hemisphere; recent observations, reviewed here, now confirm this prediction to be true. Within the Arctic Ocean there have been pronounced changes in the properties and distribution of water masses derived from the Atlantic and Pacific Oceans, dramatic reductions in sea ice cover, and documented impacts on biota. However, our understanding of the full effects that a warming climate will have on subarctic and arctic seas remains fragmented - both regionally and among disciplines - and a panarctic perspective of these interconnected systems is urgently needed. In this talk I will attempt to (1) review the changes in the ocean and ice that have occurred in recent years; (2) discuss mechanisms of ice-ocean and physical-biological coupling; (3) present new observations of physical and biogeochemical structures in the three oceans surrounding northern North America; and (4) offer a conceptual model of climate change in subarctic and subarctic seas based on stratification typology and the ocean's hydrological cycle.

## **Thursday 22 May**

**22 May, 08:30 (Theme 3.1)**

### **Can we quantify the risk of large increases in sea level extremes?**

Jason A. **Lowe**<sup>1</sup>, T. Howard<sup>1</sup>, A. Pardaens<sup>1</sup> and K. Horsburgh<sup>2</sup>

<sup>1</sup> Met Office Hadley Centre for Climate Change, FitzRoy Road, Exeter EX1 3PB, UK. E-mail: [Jason.lowe@metoffice.gov.uk](mailto:Jason.lowe@metoffice.gov.uk)

<sup>2</sup> Proudman Oceanographic Laboratory, Joseph Proudman Building, 6 Brownlow Street, Liverpool L3 5DA, UK.

The impacts of future increases in sea level are potentially large and very costly. We assess the latest projections of 21st century sea level, focusing on results from the recent IPCC 4th assessment and new results produced by the Met Office Hadley Centre and the Proudman Oceanographic Laboratory. For time-average regional sea level we consider changes in ocean circulation and density, and the contribution from ice melt. For temporal extremes of sea level we also include the effects of changes in atmospheric storminess, using the impact on the European coastline as a case study. We conclude that whilst improvements in modelling techniques have led to a better understanding of some of the components of future sea level change there still remains considerable uncertainty. This is especially true for both the magnitude and risk of the physically plausible upper limit of 21st century sea level rise.

**22 May, 09:15 (Theme 4.1)**

**Shrinking snowcaps and rising productivity: response of the Arabian Sea ecosystem to recent climate change**

Joaquim I. **Goes**<sup>1</sup>, Helga R. Gomes<sup>1</sup>, Prasad G. Thoppil<sup>2</sup>, Prabhu Matondkar<sup>3</sup>, Adnan Al-Azri<sup>4</sup> and John T. Fasullo<sup>5</sup>

<sup>1</sup> Bigelow Laboratory for Ocean Sciences, P.O. Box 475, McKown Point Road, West Boothbay Harbor, ME 04575, USA.

E-mail: jgoes@bigelow.org

<sup>2</sup> University of Southern Mississippi and Naval Research Laboratory, Stennis Space Centre, MS 39529, USA.

<sup>3</sup> National Institute of Oceanography, Dona Paula, Goa 403004, India.

<sup>4</sup> Dept. of Marine Science and Fisheries, Sultan Qaboos University, Al-Khod 123, Oman.

<sup>5</sup> National Centre for Atmospheric Research, Boulder, CO 80305, USA.

Over the past eight years, the ecosystem of the Arabian Sea has been showing signs of rapid and profound changes. First seen in satellite images of chlorophyll *a* (Chl) as a year-on-year increase in summer-time phytoplankton Chl, this unusual escalation (>350%) in phytoplankton biomass was found to be the result of atypical strengthening of the southwest monsoon (SWM) winds and an intensification of wind-driven upwelling off the coasts of Somalia, Oman and Yemen. Our studies show that the changes taking place are not occurring in isolation, but are part of a sequence of events, whose origins can be traced to the warming trend over Eurasia and the decline in winter and spring-time snow over the Himalayan-Tibetan Plateau region. In recent studies we have been able to observe that the warming trend is undermining convective mixing responsible for nutrient enrichment during the boreal winter component of the monsoon cycle. Consistent with the weakening trend of winter convective mixing, winter-time concentrations of phytoplankton have been on the decline in the eastern Arabian Sea. In the western Arabian Sea however, Chl concentrations have been on the rise. We present data to show that this unusual increase in phytoplankton biomass seen in the ocean colour data is being caused by unprecedented blooms of *Noctiluca miliaris*, whose emergence appears to be tied to the uplift of subsurface, nutrient-rich and oxygen-poor waters off the coast of Oman.

**Friday 23 May**

**23 May, 08:30 (Theme 3.2)**

**An assessment of the functional variability of coastal ecosystems in the context of environmental changes**

Dan **Baird**

Department of Botany and Zoology, University of Stellenbosch, Private X1, Matieland, Stellenbosch 7602, South Africa.

E-mail: mpdb@sun.ac.za

The functioning of coastal ecosystems such as estuaries, wetlands, sea grass beds, shallow embayments, is greatly dependent on a wide variety of external pulses (e.g. tides, fresh water influx, seasonal trends in temperature, nutrient input, etc.). Assessments of the impact of a selection of environmental characteristics, thought to be driven by natural and/or anthropogenic forces on ecosystem function, are given using selected ecosystem properties such as total system throughput, system organisation, productivity, recycling, and trophic efficiency, derived from ecological network analysis (ENA) of several coastal ecosystems on intra-seasonal, seasonal, and inter-decadal scales. Results from ENA revealed considerable differences of the same property(ties) resulting from physical changes (e.g. temperature, salinity, oxygen, rate of fresh water inflow) over time. Each ecosystem was modelled based on existing quantified data of standing stocks, the flows between the constituent living (species, communities) and non-living (detritus) components in the system, exports, and imports. A small temperature increase in a Florida sea grass bed, for example, resulted in substantial increases in system throughput, the daily P/B ratio, and in the rate of carbon recycling, but also in a significant decrease in system organisation. The behaviour of C, N and P as derived from ENA is discussed for selected ecosystems. The impact of a potential increase in water temperature in the coastal zone, and the potential decrease/increase in river run-off are discussed. Examples are presented illustrating the possible effect of climate change on coastal ecosystem function, including elemental (C, N, P) behaviour in recycling processes.

**23 May, 09:15 (Theme 5.2)**

## **Managing for resilience in ocean ecosystems**

Jane **Lubchenco**

Department of Zoology, Oregon State University, 3029 Cordley Hall, Corvallis, OR 97331, USA. E-mail: [lubchenco@oregonstate.edu](mailto:lubchenco@oregonstate.edu)

Climate change is likely to result in numerous changes – both those that can be anticipated as well as others that will come as surprises. Many changes may act synergistically, e.g. higher ocean temperatures and lower pH creating ‘double jeopardy’ for many species. The fast pace and interaction of multiple changes may prove unfavourable for many species. Moreover climate impacts co-occur with other changes (nutrient and chemical pollution, overfishing, habitat destruction, invasive species). At risk are a wealth of ‘ecosystem services’ such as the provision of seafood, protection of shores from storms, control of pests and pathogens, nutrient cycling, primary production, climate regulation, detoxification, opportunities for recreation and more. As the impacts of climate changes on ocean ecosystems become more obvious, society will seek strategies to maintain key ecosystem services. The complex nature of ocean ecosystems and the interactions across multiple changes argue for holistic approaches to adaptation. One strategy is to choose policies that accomplish one or both of these goals: (1) minimise stresses that can be reduced (e.g. pollution, overfishing, invasive species), and (2) maximise genetic, species and habitat diversity (e.g. create networks of no-take marine reserves). Strategies will likely shift away from achieving specific targets such as fishery catches and toward maintaining resilience within ecosystems. The knowledge systems needed to inform such management and policy decisions are not currently in place. These needs present new challenges and opportunities to the marine science and policy communities.

## **S1.1** Observed climate changes

**19 May, 11:20 (S.1.1-4813) Invited**

### **Evolution of Atlantic Ocean properties and circulation from the tropics to the Arctic**

Ruth **Curry**

Department of Physical Oceanography, Woods Hole Oceanographic Institution, MS #21, 354 Clark Lab, Woods Hole, MA 02543, USA.  
E-mail: rcurry@whoi.edu

In the second half of the 20th century, the instrumental record revealed pronounced changes in Atlantic Ocean water mass properties and circulation. To first order, these changes were organised around the structure of the atmospheric NAO forcing – which evolved from an extreme negative phase in the late 1960s to its opposite extreme in the early 1990s. Through modulation of air-sea fluxes and surface wind patterns, the NAO gave rise to basin-scale anomalies of ocean temperature and salinity, altered the baroclinic strength of the gyres, and choreographed episodic exchanges of fresh and saline waters between the Arctic and North Atlantic. Despite a protracted 30-year period of freshening in the Nordic and subpolar seas, ocean measurements provided little, if any, evidence of persistent change in the strength of the Atlantic meridional overturning circulation (MOC). Redistribution of ocean temperature and freshwater anomalies by convection, entrainment, mixing and advection inhibited significant alterations of the density contrast that sustained the Atlantic MOC strength. Since the mid-1990s, Atlantic property distributions and anomalies have increasingly resembled the expected response to greenhouse forcing. From the equator to the Arctic, upper ocean thermal content has risen to record highs. Upper ocean salinities have also increased, particularly in the net evaporative regions of the Atlantic. The excess freshwater that caused salinities to plummet in previous decades at high latitudes has largely been exported to the deep subtropical basins via the lower limb of the MOC, while unusually warm and saline waters are presently flushing its upper limb and headwaters.

**19 May, 11:45 (S1.1-4891)**

### **Is the Atlantic thermohaline circulation slowing? Results from Deep Western Boundary Current observations at the exit of the Labrador Sea**

Martin **Visbeck**, Jürgen Fischer, Rainer Zantopp, Lothar Stramma, Peter Brandt and Friedrich Schott

IFM-GEOMAR Leibniz-Institut für Meereswissenschaften, Düsternbrooker Weg 20, Kiel 24105, Germany. E-mail: mvisbeck@ifm-geomar.de

Since 1993 moored current and temperature-salinity observations have been carried out in the western Labrador Sea near 56°N (western end of WOCE-AR7 line), 53°N (exit of the Labrador Sea) and east of the Grand Banks (at 43°N) as part of SFB 460. The time series at 53°N are continued under the German CLIVAR NORDATLANTIK project. All moored, shipboard and Argo observations are evaluated for transport and water mass variability of the different deep water layers. While altimetry and model studies have suggested a decline of the overall subpolar gyre circulation since the 1990s, direct current measurements at the 1500 m level along the western continental slope of the Labrador Sea show interannual variability of the order of 10-20% during the 1996-2007 period. At 43°N no significant change in the deep velocities was found between a Canadian moored array 1992/93 and the SFB array between 1999 and 2005. The relationship with other published records of transport variability is discussed.

**19 May, 12:10 (S1.1-4725)**

### **Ocean climate variability in the North Atlantic: the importance of large-scale atmospheric forcing**

Eugene B. **Colbourne**<sup>1</sup>, K.F. Drinkwater<sup>2</sup>, H. Loeng<sup>2</sup> and S. Sundby<sup>2</sup>

<sup>1</sup> Fisheries and Oceans Canada, P.O. Box 5667, St. John's, NL, A1C 5X1, Canada. E-mail: colbourn@dfo-mpo.gc.ca

<sup>2</sup> Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway.

The ocean climate in the North Atlantic has undergone dramatic changes throughout the last century. The warming event in northwestern areas during the 1920s to 1960s was followed by a 30-year period of extreme, near-decadal, variability with ocean climate trending towards cold-fresh conditions through to the early-1990s.

However, an examination of meteorological and oceanographic data from standard stations and sections reveals a remarkable out-of-phase thermal relationship between eastern and western areas of the North Atlantic during this period, confirming a well known phenomenon. When cold ocean conditions dominated the northwest Atlantic and Greenland, temperatures in the Nordic and Barents Seas were generally warmer-than-normal and conversely when conditions were warm. Since the mid-1990s the relationship between the two regions has shifted to a pan-Atlantic ocean warming response with record setting atmospheric and oceanic temperatures in many areas during recent years. In this presentation, we examine the extent and magnitude of ocean climate variability in the North Atlantic and the importance of large-scale atmospheric forcing based on historical and recent observations.

**19 May, 12:25 (S1.1-4840)**

### **The recent warming of intermediate waters at the eastern North Atlantic: insights from a monthly hydrographical time series in the Bay of Biscay**

Cesar M. **González-Pola**<sup>1</sup>, Alicia Lavín<sup>2</sup>, José Luis López-Jurado<sup>3</sup>, Carmen Rodríguez<sup>2</sup>, Raquel Somavilla<sup>2</sup>, Manuel Ruiz-Villareal<sup>4</sup>, Guillermo Díaz del Río<sup>4</sup> and Ricardo Sánchez<sup>2</sup>

<sup>1</sup> Instituto Español de Oceanografía, C.O. de Gijón, c/ Príncipe de Asturias 70 Bis, Gijón, CP 33212, Spain. E-mail: cesar.pola@gi.ieo.es

<sup>2</sup> Instituto Español de Oceanografía, C.O. de Santander, Promontorio de San Martín sn, Santander, CP 39080, Spain.

<sup>3</sup> Instituto Español de Oceanografía, C.O. de Baleares, Muelle de Poniente sn, Palma de Mallorca, CP 07080, Spain.

<sup>4</sup> Instituto Español de Oceanografía, C.O. de Coruña, Muelle de Animas s/n, Coruña, CP 15001, Spain.

In the early 1990s, the Spanish Institute of Oceanography began some ambitious programmes of continuous hydrographical and biological monitoring around the Iberian Peninsula. A monthly time series in the Bay of Biscay, eastern North Atlantic (NA), sampling the upper 1000 m, has shown local warming rates for the last 15 years that were much higher than the current long-term ocean warming trends, agreeing with other works reporting sustained warming at the mid-depths of the eastern NA. The relatively high frequency of sampling allows a precise description of the local interannual variability of two key water masses in the NA, East North Atlantic Central Water (ENACW) and Mediterranean Water (MW), timing any pronounced shift properly and making it possible to infer relationships with the air-sea fluxes in the areas of influence or large scale climatic indexes, like the NAO. This detailed description of interannual and interdecadal variability helps in the interpretation of the local warming record either as a consequence of sustained warmer conditions on a wide area (large-scale tendency) or relating it to local intense anomalies or basin-scale circulation changes. In the present work we will exploit the existence of a quarterly series, sampling the water column at the Balearic Sea (Western Mediterranean) to explore the character of local warming through the coherence in hydrographical signals among these different locations that are not directly connected but are affected by the same large-scale atmospheric patterns. The expected future behaviour of the different time series under global warming projections is also considered.

**19 May, 12:40 (S1.1-4750)**

### **Reversal of the 1960s-1990s freshening trend in the upper ocean of the north-east North Atlantic and Nordic Seas**

N. Penny **Holliday**<sup>1</sup>, S.L. Hughes<sup>2</sup>, S. Bacon<sup>1</sup>, A. Beszczynska-Möller<sup>3</sup>, B. Hansen<sup>4</sup>, A. Lavín<sup>5</sup>, H. Loeng<sup>6</sup>, K.A. Mork<sup>6</sup>, S. Østerhus<sup>7</sup>, T. Sherwin<sup>8</sup> and W. Walczowski<sup>9</sup>

<sup>1</sup> National Oceanography Centre, University of Southampton, Waterfront Campus, European Way, Southampton SO14 3ZH, UK. E-mail: [nph@noc.soton.ac.uk](mailto:nph@noc.soton.ac.uk)

<sup>2</sup> Fisheries Research Services, Marine Laboratory, Victoria Road, Aberdeen AB11 9DB, UK.

<sup>3</sup> Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, Bremerhaven 27570, Germany.

<sup>4</sup> Faroese Fisheries Laboratory, Tórshavn, Føroyar, Faroe Islands.

<sup>5</sup> Instituto Español de Oceanografía, C.O. de Santander, Promontorio de San Martín sn, Santander, CP 39080, Spain.

<sup>6</sup> Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway.

<sup>7</sup> Bjerknæs Centre for Climate Research and Geophysical Institute, Allégaten 55, NO-5007 Bergen, Norway.

<sup>8</sup> Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban, Argyll, PA37 1QA, UK.

<sup>9</sup> Institute of Oceanology PAS, Powstańców Warszawy 55, Sopot, 81-712, Poland.

Hydrographic time series in the north-east North Atlantic and Nordic Seas show that the freshening trend of the 1960s-1990s has completely reversed in the upper ocean. Since the 1990s, temperature and salinity have rapidly increased in the Atlantic Inflow from the eastern subpolar gyre to the Fram Strait. In 2003-2006 salinity values reached the previous maximum last observed around 1960, and temperature values exceeded records. The mean

properties of the Atlantic Inflow decrease northwards, but variations seen in the eastern subpolar gyre at 57°N persist with the same amplitude and pattern along the pathways to Fram Strait. Time series correlations and extreme events suggest a time lag of 3–4 years over that distance. This estimate allows predictions to be made; the temperature of Atlantic water in the Fram Strait may start to decline after 2007 or 2008, salinity a year later, but both will remain high at least until 2010.

**19 May, 12:55 (S1.1-4731)**

### **Responsiveness of water mass properties to climate forcing at the Caribbean Time series station in the northeastern Caribbean basin**

Julio M. Morell, Julian Morell and Jorge E. Corredor

Department of Marine Sciences, University of Puerto Rico, Road 304 end, Magueyes Island, La Parguera, P.O. Box 908, Lajas 00667, Puerto Rico. E-mail: jmorell@uprm.edu

Extended temporal coverage of the Caribbean Time series oceanographic station (CaTS), occupied at near-monthly periodicity since 1994, allows inference regarding responsiveness of Caribbean water mass properties to seasonal, interannual and long-term climate forcing revealing teleconnections of upper water mass properties to tropical and extratropical climatic oscillations. The Caribbean Surface Water (CSW) responds seasonally to continental climate. Surface salinity decreases under the influence of major river (Amazon and Orinoco) discharges and increases when riverine influence wanes. Salinity changes lag continental rainfall climatology by 3 to 4 months. Decreased rainfall during *El Niño* results in anomalously high surface salinity. While sea surface temperature (SST) oscillates seasonally between 25.5 and 30°C, anomalous warming occurs in response to *El Niño* events. Seasonal SST oscillations adjust well to a sinusoidal fit. Sinusoidal parameterisation of SST allows analysis of long-term temperature trends. Our analyses indicate an overall warming trend of about 0.0026 C/y, a trend that, if sustained would result in a SST increase of 2.6°C in 100 years. Similar analysis of the Reynolds ODI-SST-v2 data set in a 1x1 degree box encompassing CaTS yields a trend identical to that observed at CaTS. Properties of the Subtropical Underwater (SUW), a high-salinity water mass underlying the CSW formed in the subtropical North Atlantic, respond to the North Atlantic Oscillation with a time lag of 44 months, a period consistent with the expected transport time from the area of SUW formation. Water mass response is evident in depth of the salinity maximum, temperature and nutrient content.

**19 May, 14:30 (S1.1-4951)**

### **Southern hemisphere westerly wind control over the ocean's thermohaline circulation**

Matthew H. England and Willem P. Sijp

Climate Change Research Centre, University of New South Wales, Sydney, NSW 2052, Australia. E-mail: M.England@unsw.edu.au

Twentieth century climate change has forced a poleward contraction of the southern hemisphere (SH) subpolar westerly winds. The implications of this wind shift for the ocean's thermohaline circulation (THC) is analysed in models and, where available, observations. Substantial heat content anomalies can be linked to changes in the latitude and strength of the SH westerly winds. For example, the Southern Annular Mode projects onto sea surface temperature in a coordinated annular manner - with a conspiring of dynamic and thermodynamic processes yielding a strong SST signal. Subantarctic Mode Water (SAMW) change can be linked to fluctuations in the wind-driven Ekman transport of cool, low salinity water across the Subantarctic Front. Anomalies in air-sea heat fluxes and ice meltwater rates, in contrast, drive variability in Antarctic Surface Water, which is subducted along Antarctic Intermediate Water (AAIW) density layers. SAMW variations also spike T-S variability in AAIW, particularly in the southeast Pacific and southeast Indian Oceans. The location of zero wind stress curl in the SH can also control the distribution of overturning in the North Pacific/North Atlantic. A southward wind shift can force a stronger Atlantic THC and enhanced stratification in the North Pacific, whereas a northward shift leads to a significantly reduced Atlantic THC and the development of vigorous sinking in the North Pacific. This is because the distribution of wind stress over the Southern Ocean influences the surface salinity contrast between the Pacific and Atlantic basins. The implications of these findings for oceanic climate change are discussed.

**19 May, 15:00 (S1.1-4759)**

### **Increased ocean heat along the continental margin of west Antarctica**

Douglas G. Martinson

Lamont-Doherty Earth Observatory, Columbia University, 61 Route 9W, Palisades, NY 10964, USA. E-mail: dgm@ldeo.columbia.edu

The Antarctic Peninsula (AP) is undergoing extraordinary climate change, showing: (1) a significant *winter* warming trend during the past half century (~5.4 times the global average), (2) 87% of the glaciers in retreat; and on the western margin of the AP (wAP), (3) the sea ice season has decreased in length by >3 months in the last 2 decades, with complete loss of perennial sea ice, and (4) a southward expansion of the northern maritime system of the northern wAP displacing the continental polar system to the south. The only substantial source of heat in winter is the ocean (specifically, Upper Circumpolar Deep Water: UCDW). Our analysis of the first 12 years of the Palmer LTER project show that during the 1990s an increase in upwelling of UCDW onto the shelf explains over 80% of the estimated ocean heat flux, while another 20% or so can be attributed to increased heat content of the UCDW. Most impressive is comparison of LTER data to historical data in the region, which suggests that the heat content of the UCDW, supplied to the wAP via that Antarctic Circumpolar Current jumped by a tremendous amount near the end of the 1980s, equivalent to uniformly warming 300 m of shelf water by ~0.7°C throughout a 120 km x 500 km sample grid. This is a tremendous increase in the heat content supplied to the wAP, begging the question requiring a global perspective: what is the source of this increased heat content?

**19 May, 15:15 (S1.1-4899)**

### **Multi-decadal warming and freshening of the Antarctic Circumpolar Current**

Claus W. Böning, Astrid Dispert, Martin Visbeck, Steve R. Rintoul and Franziska Schwarzkopf

Ocean Circulation and Climate Dynamics, Leibniz Institute of Marine Sciences (IFM-GEOMAR), Düsternbrooker Weg 20, Kiel D-24105, Germany. E-mail: cboening@ifm-geomar.de

Studies of ocean observations show that a significant fraction of the increase in subsurface ocean heat storage during the last decades has been occurring in the vicinity of the Antarctic Circumpolar Current (ACC) south of 40°S. We have determined the meridional-vertical distribution of multi-decadal trends in the hydrographic properties across the ACC by utilising the rapidly expanding Argo network of profiling floats. In comparison to data collected between 1960 and 2000 the modern temperature and salinity fields exhibited coherent global-scale trends in water mass properties: averaged on isopycnal surfaces the dense water on the poleward side of the ACC has become warmer and more saline, while in the thermocline north of the Subantarctic Front, above the layer of minimum salinity, widespread cooling and freshening occurred. The observed pattern of trends on density surfaces is similar to the trends obtained in model simulations of climate change during the last century, representing a “fingerprint” of anthropogenic changes in the midlatitude southern hemisphere surface fluxes. The dichotomous trend pattern on density surfaces corresponds to uniform patterns of warming and freshening across the ACC, manifested in a general subsidence of isopycnal surfaces in the upper 1000 m of the water column.

**19 May, 15:30 (S1.1-4709)**

### **A high resolution Pacific Decadal Oscillation and some of its novel characteristics**

Skip McKinnell<sup>1</sup> and Nate Mantua<sup>2</sup>

<sup>1</sup> North Pacific Marine Science Organization (PICES), P.O. Box 6000, Sidney, BC, V8L 4B2, Canada. E-mail: mckinnell@pices.int

<sup>2</sup> School of Aquatic and Fisheries Sciences, University of Washington, P.O. Box 355020, Seattle, WA 98195-5020, USA.

A high resolution Pacific Decadal Oscillation (HR-PDO) Index for the ice-free regions of the North Pacific Ocean (20-60°N) was computed using monthly-averaged NOAA/OIv2SST data on a 1° grid obtained during the satellite era. While the PDO mode remains as the dominant feature over this period of years, some new and interesting temporal and spatial patterns emerge. Despite its short duration (~25 y), the HR-PDO is oscillatory but the dominant period is 10-11 years whether it is estimated by Fourier analysis or by a least squares fit of the data to a sine wave model. Furthermore, the time series bears a greater resemblance to a square wave than to a sine wave. This 10-11 year period (and its phase) is also a characteristic of the altimetry data in the northeast and tropical Pacific and of certain characteristics of the Kuroshio. The 10-11 year period is not a characteristic of SST data from the pre-satellite era and it does not appear in an index of the atmospheric Aleutian Low for the period 1900-2007. The spatial pattern of the HR-PDO features a broader zone of influence in the eastern North Pacific than the PDO with its greatest expression located offshore. Adjacent to the North American coast, only the region from about Oregon

to Pt. Conception is highly correlated with the HR-PDO. Month by month analyses of the OIv2SST data indicate that the strongest expression of a PDO-type pattern occurs in March, diminishing over the summer to the extent that in July and August the HR-PDO appears as EOF2 rather than EOF1. The HR-PDO pattern re-emerges as the dominant EOF in the late fall. The regularity of the phase shifts in the HR-PDO inspired a forecast.

**19 May, 15:45 (S1.1-4543)**

### **Influence of rapid regional climate warming on the water mass formation in the Japan/East Sea**

Igor A. **Zhabin** and Svetlana N. Taranova

V.I. Il'ichev Pacific Oceanological Institute, FEB RAS, 43 Baltiyskaya Street, Vladivostok 690041, Russia. E-mail: zhabin@poi.dvo.ru

The Japan/East Sea (JES) is often used as a “miniature” of the ocean to assess influences of global climate change on the marine environment. Sea surface temperatures in the JES have increased as much as three times the world average over the past century, partly due to global warming. As well as effects on ecosystems (e.g. by decrease of the ice cover area), warming could reduce the oceans ability to absorb CO<sub>2</sub>. Sea surface temperatures increase more in the winter. The wintertime circulation and water mass formation in the JES are thought to be strongly driven by surface fresh water and heat fluxes. Walin (1982) and Tziperman (1986) developed a theoretical frame to analyse the annual mean water mass formation rates from heat and fresh water fluxes at the ocean surface. The NCEP/NCAR reanalysis data from 1950 to 2000 are used to estimate the rate of water mass formation in the JES. The amount of surface water that sinks and forms the High Salinity Intermediate Water (HSIW) are defined. We found that the formation rate of water with density of the HSIW ( $\sigma_\theta > 27,3$ ) decreased (-0.11 Sv/decade) and the formation rate of water with density 26.9–27.3 $\sigma_\theta$  (subpolar winter surface mixed layer) increased (0.12 Sv/decade). The total formation rate (1.5 Sv) does not change. The formation of the HSIW is primarily influenced by the Arctic Oscillation (AO; negative correlation,  $r = -0.43$ ) and secondary influenced by the Siberian High (SH;  $r = 0.34$ ). The winter AO influences directly on surface air temperature over the JES region. The SH shows more direct and significant influences on winter northerly monsoon winds. The decreasing of the formation rate of more dense water during the last decade may be due to the combined effects of the winter sea surface warming (positive index phase of AO) and weakness of the East Asian Winter Monsoon (negative index phase of SH). The impact of subgrid mesoscale processes (eddies and upwelling) on the intermediate water formation are investigated using hydrographic data and a simple model of the mixed-layer evolution.

**19 May, 16:30 (S1.1-4863) Invited**

### **Global changes of the hydrological cycle and ocean renewal inferred from ocean salinity, temperature and oxygen data**

Nathaniel L. **Bindoff**<sup>1,2,3</sup> Kieran P. Helm<sup>2,3</sup> and John A. Church<sup>1,2,3</sup>

<sup>1</sup> CSIRO Marine Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: n.bindoff@utas.edu.au

<sup>2</sup> IASOS, University of Tasmania, Private Bag 77, Hobart, Tasmania 7001, Australia.

<sup>3</sup> ACE CRC, University of Tasmania, Private Bag 80, Hobart, Tasmania 7001, Australia.

Projections of climate change indicate increased precipitation in the equatorial region, and at high latitudes and decreased precipitation in the subtropics, and a general increase in ocean stratification. We use the available temperature, salinity and oxygen profile data for the period 1970 to 2005 to examine the evidence for such ocean changes. Here we report on results from the first global study to isolate changes of salinity and temperature on density surfaces between 1970 and 2005. Globally we find increased salinities near the upper-ocean salinity maximum and decreased salinities near the intermediate salinity minimum (~700 m deep). These salinity changes imply about a 1% decrease in the precipitation-minus-evaporation over the mid-latitude oceans and about a 5% increase in the precipitation-minus-evaporation at high latitudes since 1970. These new and independent ocean derived estimates of changes in precipitation-minus-evaporation extend the growing evidence for an acceleration of the Earth's water cycle. An analysis of oxygen changes throughout the global oceans shows a coherent decrease in zonal averages at almost all latitudes above 1500 m. Subducting mode and salinity minimum waters in both hemispheres have reduced oxygen concentration, and the upwelling circumpolar-deep water is also reduced (up to 10%). These changes cannot be explained by changes in oxygen saturation due to a warming ocean and are most simply explained by increased biological consumption resulting from reduced renewal rates. The inventories of oxygen, heat and sea-level show that the high latitude density surfaces are driving these decreases in oxygen and increases in heat and sea-level.

**19 May, 17:00 (S1.1-4762)**

### **Impacts of air-sea flux variability on the mid-high latitude North Atlantic Ocean**

Simon A. Josey, Jeremy P. Grist, Robert Marsh and Bablu Sinha

National Oceanography Centre, NOC, European Way, Southampton SO14 3ZH, UK. E-mail: Simon.A.Josey@noc.soton.ac.uk

Various processes by which variability in the air-sea fluxes of heat and freshwater at interannual to interdecadal timescales affect the mid-high latitude North Atlantic Ocean are discussed through a combination of observation based and model analyses. First, the impact of extreme Nordic Seas heat loss on Denmark Strait (DS) dense water transport is examined in a) control runs of the Hadley Centre HadGEM1 and HadCM3 coupled climate models, and b) perturbation experiments with the fast coupled model FORTE which allows heat flux effects to be isolated from wind stress. All three models show an approximately linear increase in southward DS transport of cold dense water with increasing Nordic Seas winter heat loss in the range  $-80$  to  $-250$   $\text{Wm}^{-2}$ . In addition, a common response time is found with the strongest decrease in DS temperature occurring within 8-12 months of the heat loss signal. Second, an extension of the surface-forced overturning stream function approach of Marsh (2000) is used to estimate the maximum value of the meridional overturning circulation (MOC) at  $48^\circ\text{N}$ . The method provides good agreement with model MOC variability when a past averaging window of 10 years is employed. This method is then applied with NCEP/NCAR reanalysis surface flux fields to reconstruct MOC strength over 1953-2007. Finally, observational data sets and atmospheric reanalyses are used to link freshening of the eastern subpolar gyre over the last 40 years to increases in the surface freshwater flux from the atmosphere to the ocean.

**19 May, 17:15 (S1.1-4827)**

### **Variability and trend of the heat balance in the southeast Indian Ocean**

Ming Feng<sup>1</sup>, Arne Biastoch<sup>2</sup>, Claus W. Böning<sup>2</sup>, Nick Caputi<sup>3</sup> and Gary Meyers<sup>4</sup>

<sup>1</sup> CSIRO Marine and Atmospheric Research, Underwood Avenue, Floreat, WA 6014, Australia. E-mail: ming.feng@csiro.au

<sup>2</sup> IFM-GEOMAR Leibniz-Institut für Meereswissenschaften, Düsternbrooker Weg 20, Kiel 24105, Germany.

<sup>3</sup> Department of Fisheries, Western Australian Fisheries and Marine Research Laboratories, PO Box 20, North Beach, WA 6920, Australia.

<sup>4</sup> CSIRO Marine Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia.

Enhanced surface warming in the Leeuwin Current, the anomalous poleward flowing eastern boundary current off the west coast of Australia in the southeast Indian Ocean, has been observed during the past decades. The warming trend is greater during the austral winter than the austral summer. By analysing the ORCA025 44-year simulation output, the heat budget in the Leeuwin Current region is found to be dominantly balanced by two terms, the Leeuwin Current heat advection and the air-sea heat loss, both of which are stronger during the austral winter. The interannual anomalies of both terms respond to the ENSO cycles, and on both annual and interannual time scales, the variations of the Leeuwin Current advection lead that of the air-sea flux by about two months. From the 1960s to 1990s, the modelled Leeuwin Current has had a 30% reduction of its volume transport, likely driven by the weakening of the trade winds and related thermocline anomalies since the mid-1970s. This leads to an almost  $20\text{Wm}^{-2}$  reduction of heat advection into the region, and likely also a reduction of surface heat loss. Although the model does not reproduce the warming trend in the region due to its forcing field, it may help explain the greater warming trend in the austral winter than summer. Long term changes in ocean circulation may play a significant role in re-distributing heat in the ocean, in both temporal and spatial domains.

**19 May, 17:30 (S1.1-4562)**

### **Climate variability and change in the Seychelles-Chagos thermocline ridge of the south west Indian Ocean**

Juliet C. Hermes and Chris J.C. Reason

Dept. of Oceanography, University of Cape Town, Private Bag X3, Rondebosch, 7701, South Africa. E-mail: Chris.Reason@uct.ac.za

The Seychelles-Chagos thermocline ridge is a region of doming of the thermocline located in the south west Indian Ocean in a more or less zonal orientation northeast of Madagascar. Previous research has shown that interannual variability in the depth of this thermocline ridge is related to the frequency of tropical cyclone occurrence in this ocean basin and to regional rainfall, sea surface temperature and phytoplankton anomalies. Strong intraseasonal cooling events also occur in this region during summer when the intertropical convergence zone is located south

of the equator. Despite its importance for regional ocean climate and rainfall over southeastern Africa, the forcing mechanism for the ridge or its sensitivity to changes in atmospheric or ocean conditions are not well understood. To address this issue, a regional ocean model is applied to better understand the annual cycle of the ridge, its generation mechanisms and its sensitivity to changes in the strength and location of the subtropical high pressure cell over the South Indian Ocean. Given that the latter is projected to shift further south and intensify in some climate change simulations, inferences about how the thermocline ridge might change in future climates may be made.

**19 May, 17:45 (S1.1-4640)**

### **Upper ocean variability in the equatorial Indian Ocean and the influence of monsoon circulation**

Chikka Kalyani **Devasena**, P.S. Swathi and M.K. Sharada

CSIR Centre for Mathematical Modelling and Computer Simulation (C-MMACS), Belur Campus Wind Tunnel Road, Bangalore 560 037 Karnataka, India. E-mail: kalyani@cmmacs.ernet.in

Studies using modelling and observations of Indian monsoon circulation reveal strong intra-seasonal to inter-annual variability. To study the upper ocean variability and its association with the Indian monsoon we have used ocean model simulations and observations. The semi annual reversal of the equatorial winds north of the equator and the associated changes in surface currents, the presence of a barrier layer throughout the year and the absence of equatorial upwelling makes the equatorial Indian ocean different from the Pacific and Atlantic equatorial regions. Our focus is on upper ocean variability with special emphasis on the seasonal heat budget variations and the influence of the monsoon circulation. Ocean General Circulation Model simulation (OGCM, MOM4p1 with sea ice interface, forcing: Quick-scat winds and NCEP reanalysis) from 1992-2006 have been used to study the seasonal variations of the heat budget. Argo and other observational programmes (Triton buoy data) gave a wider opportunity to understand the upper ocean variability of the equatorial Indian Ocean in detail.

**19 May, 18:00 (S1.1-4528)**

### **Warming of the upper equatorial Indian Ocean and changes in the heat budget (1960-2000)**

Gaël **Alory**<sup>1,2</sup> and Gary Meyers<sup>1,3</sup>

<sup>1</sup> Commonwealth Scientific and Industrial Research Organisation, Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7000, Australia. E-mail: gael.alory@csiro.au

<sup>2</sup> Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, 14, Avenue Edouard Belin, Toulouse 31400, France.

<sup>3</sup> Integrated Marine Observing System, University of Tasmania, Private Bag 110, Hobart, Tasmania 7001, Australia.

In the equatorial Indian Ocean, sea surface has warmed by 0.5°C to 1°C over the period 1960-2000, while waters have cooled at the thermocline depth and the net atmospheric heat flux has decreased. Among a set of 20th century climate simulations from 12 coupled models, the CNRM-CM3 model most realistically reproduces these observed changes. It is used to investigate changes in the heat budget of the upper equatorial Indian Ocean in order to identify mechanisms responsible for the surface warming. The heat budget can explicitly resolve interannual temperature variability with flux and advection terms only, but not the long-term temperature trend. However, by estimating diffusion as a residual term and comparing 20th century and control simulations, changes in the mean balance of the heat budget between the pre-industrial and the 1960-2000 period can be highlighted. There are significant shifts in the heat budget due to climate change. The decrease in the upwelling-related oceanic cooling is the main cause of the surface warming of the equatorial Indian Ocean, while the observed decrease in net heat flux is a feedback process mostly due to enhanced evaporation.

# S1.1

## Posters

### Poster S1.1-4538

#### Warming and salinification of intermediate and deep waters in the Irminger Sea and Iceland Basin in 1997-2006

Artem A. **Sarafanov**, Alexey V. Sokov and Anastasia S. Falina

P.P. Shirshov Institute of Oceanology, Polar Oceanology Group, 36 Nakhimovskiy Prospect, Moscow 117997, Russia. E-mail: sarafanov@mail.ru

The Labrador Sea Water (LSW), Iceland–Scotland Overflow Water (ISOW) and Denmark Strait Overflow Water (DSOW) are the main intermediate and deep water masses formed in the northern North Atlantic. These water masses inherit and transfer climate signals from the source regions to the deep ocean. Analysis of intra- and inter-decadal variability of these waters in vicinity to their source regions is thus essential for understanding and quantification of the oceanic response to the observed climate variations. In this study, recent intra-decadal changes in temperature and salinity of LSW and overflow-derived waters are quantified on the basis of the CTD data from four repeats of the zonal transatlantic section along  $\sim 60^\circ\text{N}$  carried out in 1997-2006. The changes revealed point to a rapid transition to warmer/saltier conditions at the intermediate and deeper levels in the Irminger Sea and Iceland Basin. In particular, substantial steady warming and salinification of ISOW is revealed in both basins. The latter result means an abrupt reversal or, at least, a decade-long interruption of the long-term freshening of this water lasted since the mid-1960s. The rate of the ISOW salinification in the Iceland Basin is more than twice as high compared to the rate of the preceding long-term freshening. In 2006, salinity in the ISOW core in the Iceland Basin reached the value of 34.99 being back to values typical for the 1970s. The LSW–ISOW–DSOW stratum at the section latitude became  $0.20^\circ\text{C}$  warmer and 0.029 saltier on average between 1997 and 2006. Causes of the observed tendency are discussed.

### Poster S1.1-4566

#### Seasonal and interannual heat fluxes variability in the Mediterranean Sea from a 44-year high-resolution atmospheric data set

Simón **Ruiz**<sup>1</sup>, Damià Gomis<sup>1</sup>, Marcos G. Sotillo<sup>2</sup> and Simon A. Josey<sup>3</sup>

<sup>1</sup> IMEDEA (CSIC-UIB), Natural Resources Department, C/Miquel Marqués, 21, Esporles, Islas Baleares 07190, Spain. E-mail: simon.ruiz@uib.es

<sup>2</sup> Puertos del Estado, Avda. del Partenón, 10, Campo de las Naciones, Madrid, 28042, Spain.

<sup>3</sup> National Oceanography Centre, European Way, Southampton SO14 3ZH, UK.

We examine 44 years (1958-2001) of model data with the aim of characterising the low frequency (seasonal cycle and lower) variability of surface heat fluxes. The data set was produced in the framework of the HIPOCAS project through a dynamical downscaling ( $1/2^\circ \times 1/2^\circ$ ) from the NCEP/NCAR global reanalysis using the atmospheric limited area model REMO. The added value of this data set is the better representation of regional and local aspects related to thermal and dynamical effects resulting from its higher resolution. The basin mean values of the heat fluxes have been estimated in  $168 \text{ W/m}^2$  for the solar radiation ( $Q_s$ ),  $73 \text{ W/m}^2$  for the longwave net radiation ( $Q_b$ ),  $8 \text{ W/m}^2$  for the sensible heat ( $Q_H$ ) and  $88 \text{ W/m}^2$  for the latent heat ( $Q_E$ ), giving a total heat budget of about  $1 \text{ W/m}^2$ . The total heat budget has an amplitude of  $164 \text{ W/m}^2$  and peaks by mid-June, in agreement with previous works and observations. The interannual variability of each component has been first quantified by the standard deviation of the annual mean values, obtaining  $\pm 2.0 \text{ W/m}^2$  for  $Q_s$ ,  $\pm 1.1 \text{ W/m}^2$  for  $Q_b$ ,  $\pm 4.7 \text{ W/m}^2$  for  $Q_E$  and  $\pm 1.1 \text{ W/m}^2$  for  $Q_H$ . From the evaluation analysis, HIPOCAS fluxes show stronger correlations with the observation based NOC fields than are obtained with the original NCEP/NCAR fluxes for the full set of interannually varying heat flux estimates. Thus, the downscaling has led to an improved representation of the interannual variability when compared with observations.

### Poster S1.1-4572

#### Large scale circulation over the west Indian Ocean and the south west monsoon

U.K. Singh and P.S. Salvekar

Indian Institute of Tropical Meteorology, Pune-08, India. E-mail: umesh@tropmet.res.in

The focus of this study is to document the role of the west Indian Ocean over the Indian monsoon during the last decade (1998-2007). Understanding the interannual variability of the southwest monsoon is an important and challenging factor. To date the relationship of the Mascarian high and the southwest monsoon has been well documented in the literature. However, the temporal variation of meteorological parameters, over the region east of Madagascar to the west coast of India, are not yet examined in detail. In the present study extensive analyses of daily outgoing longwave radiation (OLR), zonal wind (u) at 850 and 200 hpa and Global Precipitation Climatology Project (GPCP) rainfall over the region 50-80°E and 30S-30°N from April to September for all 10 years was carried out. In all cases, a 5-day running mean smoother was applied to the data to reduce the large day-to-day oscillations. We have prepared time-latitudinal plots averaged over longitude 50-80°E. Northward movement of large scale circulation and the core of maximum winds are clearly depicted and are found to be closely related with GPCP rainfall region. The study was very useful for understanding monsoon performance in the last decade. It is suggested that large scale circulation over the west Indian Ocean may be the dominating factor in the overall performance of southwest monsoon over India.

### Poster S1.1-4583

#### Sea surface warming in the southern Bay of Biscay modulated by oceanic advection

Marcos Llope<sup>1</sup> and Ricardo Anadón<sup>2</sup>

<sup>1</sup> Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Oslo, P.O. Box 1066, Blindern, 0316 Oslo, Norway. E-mail: marcos.llope@bio.uio.no

<sup>2</sup> Área de Ecología, Dep. Biología de Organismos y Sistemas, Universidad de Oviedo, Catedrático Valentín Andrés Álvarez, s/n, 33071 Oviedo, Spain.

One of the consequences of climate change is the world ocean warming. We address the issue of exploring how the rate of sea warming changes in relation to the central waters found in the Bay of Biscay area at any moment. We found that during the early 2000s, the advection of a large volume of cooler and less saline water from the inner part of the bay caused a general sinking of the isopycnals, thus reducing the rate of warming. During the last year, the process reversed due to the flow of warmer and saltier tropical waters which enhanced the warming. Based on these results, we propose a mechanism in which a wavering natural variability would superimpose on the steady global warming, thus modulating it. The combination of these two forcings results in the non linear warming observed in the area.

### Poster S1.1-4600

#### Analysis of a 44-year hindcast for the Mediterranean Sea: comparison with altimetry and climatology

Enrique Vidal-Vijande<sup>1</sup>, A. Pascual<sup>1</sup>, D. Gomis<sup>1</sup>, B. Barnier<sup>2</sup> and J. Tintoré<sup>1</sup>

<sup>1</sup> Instituto Mediterráneo de Estudios Avanzados, C./ Miquel Marqués, 21, Baleares, 07190 Esporles, Spain. E-mail: enrique.vidal@uib.es

<sup>2</sup> Laboratoire des Ecoulements Géophysiques et Industriels, BP53, 38041 Grenoble, France.

In this study we used the ORCA025-G70 simulation of the DRAKKAR model developed by Barnier *et al.* (2006) to perform a model assessment in the Mediterranean Sea by using altimetry and climatology data. ORCA025-G70 is a 1/4° resolution simulation of a global ocean numerical model aiming at the study of the ocean variability under realistic atmospheric conditions over the last half century (1958-2004). The model simulates the evolution of T, S, velocity, SSH, sea-ice characteristics, and oceanic concentrations of CFC11 and <sup>14</sup>C. Comparison of SSH given by the model and from altimetry in the Mediterranean Sea has shown that although the model overestimates the observed altimeter trends (possibly due to drift), the interannual variability is well reproduced, as well as the annual cycle both of which are well correlated, especially at the basin scale. Due to the model's low resolution it is incapable of correctly reproducing most mesoscale features. This is especially notable in the Alboran Sea and Algerian Current where the model is unable to reproduce the gyres and eddies that are formed in these regions.

There are certain cases where the model is incapable of reproducing important features such as the negative trend in the Ionian basin to the east of Sicily which is thought to be caused by a change in the deep water formation. Our aim for the following months is to continue this analysis in more depth and add the comparisons with the MEDAR climatology for the 1960-2004 period.

### Poster S1.1-4606

#### **Decadal and interdecadal variations of the Aleutian Low activity and their relation to atmospheric teleconnection patterns**

Shusaku Sugimoto and Kimio Hanawa

Department of Geophysics, Graduate School of Science, Tohoku University, 6-3 Aramaki-aza-Aoba, Aoba-ku, Sendai 980-8578, Japan.  
E-mail: sugi@pol.geophys.tohoku.ac.jp

We investigate long-term variation of the Aleutian Low (AL) which is defined by the sea level pressure minimum within the region of (30°N-60°N, 150°E-150°W) in winter. Time series of the latitude and longitude of the AL, and its intensity reveal different types of activities: the longitudinal shift accompanying intensity variation with an interdecadal (about 20 years) timescale and the latitudinal shift with a decadal (about 10 years) timescale. The AL intensity variation is strongly influenced by the Pacific/North American teleconnection pattern: In the strengthening (weakening) phase of the AL, the AL shifts east (west) in longitude, westerlies strengthen (weaken), and resultantly both subtropical and subpolar gyres are forced to spin-up (spin-down) simultaneously. The latitudinal shift is forced by the western Pacific teleconnection pattern, and is independent from the intensity variation. In the northward (southward) shift phase of AL, the westerlies move northward (southward), and resultantly the gyre boundary also shifts northward (southward).

### Poster S1.1-4607

#### **Spatio-temporal upwelling trends along the Canary Upwelling System (1967-2006)**

Maite de Castro<sup>1</sup>, Moncho Gómez- Gesteira<sup>1</sup>, Inés Álvarez<sup>1</sup>, María N. Lorenzo<sup>1</sup>, José L.G. Gesteira<sup>2</sup> and Alejandro J.C. Crespo<sup>1</sup>

<sup>1</sup> Grupo de Física de la Atmósfera y del Océano, Facultad de Ciencias, Universidad de Vigo, 32004 Ourense, Spain.  
E-mail: mdecastro@uvigo.es

<sup>2</sup> Area de Control y Gestión del Medio y los Recursos Marinos. Fundación CETMAR, c/ Eduardo Cabello s/n, 36208 Vigo, Spain.

Spatio-temporal trends in upwelling patterns were studied along the Canary Upwelling System for the period 1967-2006. The NW African coast from 20°N to 32°N is observed to be under a permanent upwelling regime characterised by coastal sea surface temperatures (SST) colder than the oceanic ones at the same latitude, the difference being named temperature upwelling index (UI<sup>SST</sup>). This regime is consistent with the wind derived Ekman transport (UI<sup>W</sup>) pointing offshore and observed near shore. This index shows the existence of upwelling-favourable conditions all year long, although with an annual cycle characterised by more upwelling-favourable conditions from April to September, with a peak in July, and less upwelling- favourable conditions from October to March, with a peak in December-January. Although both indices can be used to characterise the phenomenon, only UI<sup>W</sup> values were used to quantify upwelling change since this index is less sensitive to external factors than UI<sup>SST</sup>. A strong decrease in upwelling intensity has been observed in all seasons. In particular, the summertime (wintertime) decrease is around 45% (20%) of the mean amplitude of the upwelling cycle.

### Poster S1.1-4609

#### **Establishing research objectives to address issues of climate-change**

Olanrewaju B. Oyewole

Physics Department, Lagos State University, P.O. Box 2185, Ikeja, Lagos, Nigeria. E-mail: lanreoyewole@gmail.com

The implications of global climate change are enormous. However, there are major questions concerning whether climate change is occurring. If it is, subsequent questions should consider when and how the changes will affect society. There are numerous possible expensive research projects that could address each of the many facets of

these questions. Wise decision making about global climate change research is thus seen as important. This paper describes a systematic process to identify and structure the objectives of research on global climate change. The result is a hierarchy of 81 important research objectives. This hierarchy was constructed based on interviews with a diverse set of individuals knowledgeable about climate change, and on discussions at an international workshop on global climate research objectives. The participants in both exercises included scientists, policy analysts, and executives of utility companies and national agencies from Europe, Africa, Asia, and North America. The main uses of these objectives should be to promote constructive communication about research programmes designed to examine climate change issues, to stimulate the creation of potentially significant research tasks, and to provide a basis for evaluating and comparing research tasks.

### **Poster S1.1-4610**

#### **A “trojan” in climatic change: the urban effect**

José Quereda-Sala, Enrique **Montón-Chiva** and José Escrig-Barberá

Climate Laboratory, Universitat Jaume I, Climate Laboratory, Avda. Sos Baynat, s/n, 12071 Castellon, Spain. E-mail: quereda@his.uji.es

This paper sets out the preliminary results of an experimental research plan aimed at analysing the thermal processes inherent to the urbanisation effect. Although this effect is undeniable, the extent of its impact is a matter of controversy. In the present study, the urban thermal effect has been examined by installing three duly calibrated, automatic meteorological stations (Davis-Casella). These three stations were located in the Castellón city area, a city that has undergone marked demographic growth in recent years (from 93,000 inhabitants in 1970 to 205,000 inhabitants in 2007). The locations were chosen to record the temperature at the city centre (Casino Antiguo station, 51 m), at the Mediterranean Sea surface (marine station on the BP Oil Platform, 12 m), and on the western outskirts of the city (Universitat Jaume I (UJI) station, 80 m). The three stations are located on an E-W diagonal of just 10 km on the coastal plain. The results obtained in this study show both the nature of the phenomenon and its considerable magnitude. The notable differences in both the maximum and minimum temperatures between the city centre and the outskirts demonstrate the need for further analysis of the process. Failure to take this process into account might seriously bias any analysis of thermal evolution, the cornerstone of the climate change hypothesis.

### **Poster S1.1-4616**

#### **A new satellite algorithm for accurate determination of sea surface temperature for climate and meteorological studies**

Raquel **Niclos**<sup>1</sup>, María J. Estrela<sup>1</sup>, Jose A. Valiente<sup>1</sup>, Vicente Caselles<sup>2</sup> and César Coll<sup>2</sup>

<sup>1</sup> Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), 14 Charles Darwin (Parc Tecnologic), Paterna 46980, Spain.  
E-mail: niclos@ceam.es

<sup>2</sup> Earth Physics and Thermodynamics Department, University of Valencia, Spain.

Sea surface temperature (SST) is a key magnitude for climate and meteorological studies. A high-accuracy determination of SST would permit a better monitoring of climate change evolution and an improvement in the forecasting of natural hazards, such as torrential rain events (see poster S3.1-4614). The operational algorithms for the determination of SST from satellites do not use Sea Surface Emissivity (SSE) as input, since the sea surface is assumed to be similar to a blackbody surface. Only the algorithms for the retrieval of land surface temperature include emissivity-dependent terms. However, the variability of SSE within a satellite image, which depends on observation angle and surface wind speed, is similar to the emissivity variation for land surfaces. Therefore, SST determination can be improved by taking into account the effect of the SSE variation with angle and wind speed in SST algorithms, at least for image sections with large observation angles, for which the SSE differs greatly from unity. An angular and emissivity dependent split-window equation is now proposed with the aim of determining SST to a reasonable level of accuracy for any observation angle, including large viewing angles at the image edges of satellite sensors with wide swaths. This is the case for radiometers on board polar-orbiting satellites such as the MODIS, on both the EOS Terra/Aqua platforms, with observation angles of up to 65° at the surface, and especially for sensors such as the SEVIRI on board the geostationary METEOSAT Second Generation. Our algorithm takes into account the angular dependence of both the atmospheric correction (due to the increase in the atmospheric optical path with angle) and the emissivity correction (since sea surface emissivity decreases with observation angle). The proposed algorithm requires as input data: at-sensor brightness temperatures for the split-window bands, the observation angle at each

pixel, an estimate of the water vapour content and accurate SSE values for both channels. Simple methods are also proposed for estimating the required SSE and water vapour content data. Preliminary results using SEVIRI and MODIS satellite data show a good agreement between the SSTs estimated by the proposed equation and *in situ* SST measurements, even for off-nadir viewings: this proves the soundness of emissivity-dependent SST algorithms.

#### Poster S1.1-4627

### Reconstruction of interdecadal variability of air-sea interaction in the Atlantic 1880-2004

Sergey K. **Gulev**

P.P. Shirshov Institute of Oceanology, RAS, 36 Nakhimovsky Prospect, Moscow 117997, Russia. E-mail: gul@sail.msk.ru

Using 125 years (1880-2004) of Voluntary Observing Ship (VOS) observations from ICOADS we reconstructed monthly surface ocean-atmosphere heat fluxes over the North Atlantic with a 2-5° spatial resolution. The methodology is based on the homogenisation of sampling density, application of the double-exponential distributions of turbulent fluxes for minimising sampling errors and the use of specially adopted bulk-algorithms for incomplete data coverage. In particular, a multi-regressive approach is used to reconstruct atmospheric humidity, playing an important role in the estimation of surface fresh water fluxes. The methodology was first validated using the time series from VOS and reanalyses for the well sampled recent decades. Further analysis included computation of monthly anomalies of surface fluxes as well as estimation of the subpolar gyre heat and freshwater budgets. These were computed using two-dimensional distributions of surface fluxes of sea-air temperature difference and wind speed. Reconstructed fluxes reveal long-term trends, implying, for example, about 4 W/m<sup>2</sup> per decade growing sensible heat fluxes in the Labrador Sea and about 2 W/m<sup>2</sup> per decade secular increase in the central subpolar gyre. Non-secular signals are represented by the decadal-scale and multidecadal (about 40-50 years variability). Decadal scale signals have a clear association with the NAO-like atmospheric circulation variability during 1880-1915 and after 1955, but have little association with the NAO between 1915 and 1955. The approach formulated allows also for the derivation of heat energy budgets in different Atlantic regions. These budgets can be alternatively quantified from the oceanographic full-depth sections. Time series of the budget estimates were derived for 2 large regions (subpolar, mid latitudes) and their association with ocean dynamics and atmospheric circulation anomalies are discussed.

#### Poster S1.1-4635

### Global warming - stationarity in sea temperature data

Torbjørn **Lorentzen**

Bjerknes Centre for Climate Research (BCCR), Allégaten 55, NO-5007 Bergen, Norway. E-mail: torbjorn.lorentzen@Bjerknes.uib.no

According to the UN's Intergovernmental Panel of Climate Change (IPCC), the earth's climate is already changing. The objective of this paper is to analyse how the average yearly sea temperature has evolved at two different geographical spots along the coast of Norway during the period 1936-2003. The statistical analysis is related to the concept and properties of stationary time series, and the scientific objective is to analyse whether there is any indication of climate change in the time series. Augmented Dickey-Fuller and non parametric Phillips-Perron tests are applied in uncovering the data generation process behind the sea temperature.

#### Poster S1.1-4638

### Geostrophic currents variability in the Drake Passage

Roman Yu. **Tarakanov**

P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, 36 Nakhimovsky Prospect, Moscow 117997, Russia. E-mail: rtarakanov@gmail.com

The Drake Passage is the most suitable region for studying the easterly Antarctic Circumpolar Current (ACC) because here it passes between two coasts. The comparative analysis of two hydrographic sections, which were occupied across the Drake Passage during cruises of the Russian research vessels *Akademik Sergey Vavilov* and

*Akademik Ioffe* in December 2003 and November 2005, are realised. Both sections were located along the same track from Terra del Fuego to Elephant Island. Temperature, salinity, and velocity profiles in the entire water column were measured by a Sea-Bird 911 CTD profiler and Lowered Acoustic Doppler Profiler (LADCP) at each station. Satellite altimetry data (available at <http://www.jason.oceanobs.com>) and data of some other sections in the Drake Passage were also used in this investigation. Absolute geostrophic currents across these sections were calculated by correcting the geostrophic calculations using altimetry data and LADCP measurements. The distributions of hydrographic properties over the sections show a strong difference between synoptic situations in December 2003 and November 2005 resulting from ACC fronts splitting and subsequent eddy formation. Despite the differences in the structure, the integrated eastward flows calculated both by altimetry and LADCP corrections across both sections were very similar and approximately equal to 155 Sv. The boundaries between specific water masses were determined using the procedure, which was developed earlier by the author for the South Pacific. The procedure is based on the analysis of the vertical gradients of hydrographic properties. Mean properties and flows of water masses across the sections were assessed.

### **Poster S1.1-4652**

#### **Rainfall variations and trends along the coast of the Gulf of Guinea**

Hyacinth C. **Nnamchi** and Raymond N.C. Anyadike

University of Nigeria, Department of Geography, Nsukka, Enugu State 410001, Nigeria. E-mail: [nnamchy@yahoo.co.uk](mailto:nnamchy@yahoo.co.uk)

This paper examines the variations and trends in seasonal and annual rainfall along the coast of the Gulf of Guinea, West Africa based on a 99-year period, using the Hulme 98 data set. The rainfall series were extracted from the 2.5° latitude by a 3.75° longitude grid version of the data set for grid points within 2 degrees of latitude from the coast and south of latitude 10°N. Analyses of rainfall variability reveal that the annual rainfall of the area has a coefficient of variability of 11.77% and that rainfall is most variable in the peak of the dry season (59.19%), followed rather distantly by the peak of the rainy season (23.57%), while the variability coefficients for the transition seasons are generally lower. Furthermore, analysis of rainfall trends indicates that over the century, annual and seasonal rainfall along the coast of the Gulf of Guinea exhibited net decreases; although, these decreases are not significant. The implications of these findings are highlighted in the light of the Intergovernmental Panel on Climate Change (IPCC) predictions for the region.

### **Poster S1.1-4657**

#### **Climatic tendencies and changing global-regional linkages in the North Pacific SST**

Vladimir I. **Ponomarev** and Elena V. Dmitrieva

V.I.Ilichev Pacific Oceanological Institute, FEB RAS, 43 Baltiyaskya Street, Vladivostok 690041, Russia. E-mail: [pvi711@yandex.ru](mailto:pvi711@yandex.ru)

The climatic tendencies in the Pacific SST north of 30°S and statistical relationships between climatic indexes and SST anomalies are estimated for different periods of the observational records including first half of the 20th century and last 56 years using Hadley (1870/1900-2006) and other data sets. It is shown that SST cooling is typical for the subarctic northwest Pacific during last 56 years while the warming occupies most of the Japan - Okhotsk Sea area and Kuroshio region in the Pacific. It accompanies a decrease of the ice extent in the Okhotsk and Japan Seas from 1956 to 2006 and a change in the relationship between the Arctic Oscillation/NINO3, SSTA, Amur River discharge and ice Extent. The NW Pacific SSTA has significant unlagged or lagged correlations with most of northern hemisphere monthly/seasonal/annual mean different teleconnection indexes. The unlagged correlations between seasonal mean/SOI and SSTA/WP and SSTA in winter-spring show a significant inverse relationship being negative/positive in the subtropic and positive/negative in the subarctic NW Pacific. Correlation between winter AO and SSTA in spring-summer shows patterns which are similar to the NINO3/SOI-SSTA relationship in winter-spring with a shift of the subarctic core westward and subtropic core eastward. The winter AO-spring/summer SSTA correlation patterns are turned counterclockwise in the second half of the observational records in comparison with the first one. In recent decades the positive AO-SSTA lagged correlation pattern occupies the Okhotsk and Japan (East) Sea area.

## **Poster S1.1-4680**

### **Atmospheric variables potentially affected by DMS**

Aránzazu [Lana](#)<sup>1</sup>, Sergio Vallina<sup>2</sup> and Rafel Simó<sup>1</sup>

<sup>1</sup> Institut de Ciències del Mar, ICM-CSIC, Passeig Marítim de la Barceloneta, 37-49, Barcelona E-08003, Spain. E-mail: lana@cmima.csic.es

<sup>2</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK.

The CLAW hypothesis suggests a negative feedback between marine biota and climate through the emission of biogenic sulphur, its conversion into Cloud Condensation Nuclei (CCN), and its influence on the microphysics of clouds and the earth's albedo. Seawater dimethylsulfide (DMS) produced by plankton is the principal natural source of volatile sulfur to the atmosphere. The first part of the hypothesis postulates that an increase in solar radiation would produce an increase in the concentration and emission of DMS, a phenomenon that has been observed recently. Our current work focuses on the second part of the hypothesis—namely, that an increase in DMS concentration has consequences for cloud formation and microphysics. Our purpose is to analyse those atmospheric (aerosol and cloud-related) variables that may be affected by DMS emissions. We make global monthly data fields of different satellite-derived variables and calculate their temporal correlation with an oceanic DMS climatology obtained by extrapolation and interpolation of existing data). Our study begins with global distributions of crossed correlations, with the aim of exploring the geographic regions that deserve closer analysis, and at first investigating which atmospheric variables appear to be more sensitive to DMS concentrations, bearing in mind that correlation does not necessarily imply a causal relationship. Once the regions and variables with high correlation coefficients are defined, a detailed analysis of time series is conducted using satellite-derived data and the raw DMS concentrations from the Global Surface Seawater DMS database.

## **Poster S1.1-4687**

### **Decoupling of sea surface temperature variation during the last two decades and its effect on remotely sensed phytoplankton biomass in the North Atlantic**

Fernando [González](#) and Ricardo Anadón

Área de Ecología, Dpto Biología de Organismos y Sistemas, Facultad de Biología de la Universidad de Oviedo, C/ Catedrático Rodrigo Uría s/n, ES33071 Oviedo, Spain. E-mail: fgtaboada@gmail.com

Sea surface temperature has increased worldwide during the last century, especially in northern latitudes. The advent of borne on satellite sensors allow the monitoring of these changes with an unprecedented spatial and temporal resolution. Here, we use the time series derived from the Advanced Very High Resolution Radiometer to study the strength and spatial pattern in sea surface warming during the last two decades (1985-2006). Because of its influence on species distributions, we analysed the evolution of the magnitude of annual climate extremes and its timing, and the rates of northward migration of such extremes. A heuristic method was used to derive the length of the stratification period and the scales of the different responses were assessed by estimating geostatistical variograms. The results obtained support the main impacts predicted from climate modelling studies, but important heterogeneities were found both in physical and biological responses. Marked zonal contrasts on the response of the different parameters at northern latitudes suggest that changes were mainly mediated by the North Atlantic current, either through a strengthening of heat transport or a northward migration associated with the expansion of the subtropical gyre. Finally, changes in chlorophyll *a* concentration were derived from SeaWiFS images (1998-2006), and the timing of the spring phytoplankton bloom was assessed. In response to the above described changes a decrease in phytoplankton biomass in the North-east Atlantic occurred. Jointly, the responses observed depict a “black-box” scenario in which future biological responses will be highly nonlinear and difficult to mitigate.

### Poster S1.1-4712

#### Climatic oscillations in the Asian Pacific in terms of cluster analyses of aggregated observation data

Nina I. **Savelieva**, E.V. Dmitrieva and V.I. Ponomarev

V.I. Il'ichev Pacific Oceanological Institute, FEB RAS, 43 Baltiyskaya Street, Vladivostok 690041, Russia. E-mail: nina@poi.dvo.ru

The relationship between parameters of hydrosphere in northeast Asia and atmospheric indices of the Asian Pacific are estimated by cluster and spectral analyses. For 1930-2003 following time series were used: the seasonal anomalies of the Amur River discharge (ARD) and precipitation, ice extent and SST of adjacent area - Tatar Strait, Okhotsk Sea; AO, SOI, NPI, SLP anomalies in Siberian High, Hawaiian High, and Aleutian Low. The changing statistical relationships in the coupled atmosphere-hydrosphere system associated with well-known climatic regime shifts are found using cluster analysis of aggregated observational data for two periods: 1930-1969 and 1970-2003. The cluster tree was subdivided in two large branches, including: (1) atmospheric indices and SST/Ice Extent in Okhotsk Sea and winter precipitation; (2) AO, SOI, SST/Ice Extent in Tatar Strait, in Amur River Basin, and ARD. A change in correlation was observed between the atmospheric indices, AO, SST and ARD and data moved in clusters. Cluster and correlation analysis of time series for the two periods shows changes in the climate system. To understand, how the variables of the regional climatic system are interconnected, we determined the characteristics of the energy spectrum of each hydrosphere parameter and coherency and phases with reference to ice cover of Okhotsk Sea and Tatar Strait. There is a hierarchical connection between different components of regional climatic system. As a result of the influence of atmospheric factors the character of interrelations between hydrospheric components was observed.

### Poster S1.1-4715

#### Analysis of the 18-month variability in the Indian Ocean based on historical data and proxy climate records

Irina V. **Sakova**<sup>1,2</sup>, Gary Meyers<sup>3</sup>, Nerilie J. Abram<sup>4</sup> and Richard Coleman<sup>1,2,5</sup>

<sup>1</sup> CSIRO Marine and Atmospheric Research and Wealth from Oceans National Research Flagship, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: Irina.Sakova@csiro.au

<sup>2</sup> School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart, Tasmania, Australia.

<sup>3</sup> Integrated Marine Observing System, University of Tasmania, Private Bag 110, Hobart, Tasmania, Australia.

<sup>4</sup> British Antarctic Survey, Natural Environment Research Council, Cambridge CB3 0ET, UK.

<sup>5</sup> Antarctic Climate and Ecosystems CRC, Private Bag 80, Hobart, Tasmania, Australia.

The recent analysis of the interannual variability of the Indian Ocean found the existence of a strong 18-month signal. This signal was discovered based on satellite altimetry sea surface height measurements (1992-2004) and expendable bathythermograph temperature data (1989-2002). It is likely to be important for the dynamics of the Indian Ocean Dipole (IOD) mode; however, understanding of the connection between the 18-month signal and IOD events is difficult due to the small number of such events in the available time period. In this study we investigate the behaviour of the 18-month signal and its connection with IOD mode by wavelet and spectral analysis. We use long period time series from tide gauges and coral records extending back to ~1850 AD, as well as the reconstructed sea level and SST reanalysis data.

### Poster S1.1-4729

#### ENSO and climate change in the West Antarctic Sector

Vladislav E. **Tymofeiev**

Department of Climate Research and Long-Range Weather Forecast, Ukrainian Research Hydrometeorological Institute, Prospect Nauki 37, Kiev 03028, Ukraine. E-mail: tvvlad@mail.ru

This study aims to analyse a recent warming episode in the Antarctic Peninsula (AP) region and to find out how atmospheric circulation has changed in the West Antarctic Sector (WAS). The most accelerated warming in the AP has been observed from early 1980s to the turn of millennium, almost coherently with that in Alaska, and is related to well-known shift in PDO-ENSO conditions. Annual surface air temperature (SAT) records on many AP stations show clear ENSO-related sub-decadal oscillations (3-6 years). Anticyclonic MSLP and height anomalies

along with greater meridionality predominate in WAS under warm event whereas westerlies and depressions typically persist under *La Niña*. The AP lies at the boundary of main circulation systems whose behaviour has been changed after 1980s. Winter cold episodes have become less intensive than in the mid-20th century because anticyclones in the SE Pacific shifted north-or eastward allowing more frequent cyclogenesis at the Bellingshausen Sea with warmer and wetter air inflow to AP. The sign of the SAT anomaly on stations in the western coast of AP show the strongest correlation with the east Pacific SOI on a time shift from 3 to 9 months after mature ENSO episodes. Both SAT and sea-ice anomalies are responsible for live environmental anomalies at coastal area of AP determining conditions for krill development and setting up relationships in food chain.

#### **Poster S1.1-4730**

### **The impact of the oceans on climate change**

Philip C. **Reid** and Astrid C. Fischer

University of Plymouth, Marine Institute and Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK. E-mail: pere@sahfos.ac.uk

Comprising 97% of the Earth's water and covering ~71% of the surface the ocean plays a key role in climate change. As a main heat store for the world it has shown rapid and accelerating change in sea temperatures over the last few decades and is the likely modulator of many of the changes seen on land attributed to climate warming. It is the main store of carbon dioxide (CO<sub>2</sub>), each year taking in about 1.3 petagrams (1.3 x 10<sup>15</sup> g) from the atmosphere and exporting carbon via physical and biological processes to the deep ocean reservoir. Increases in sea temperature and changing planktonic systems may lead to a reduction in the uptake of CO<sub>2</sub>. These and other topics was discussed at a workshop of international experts held 13-14 March 2008 in London that will focus on the important role that the oceans, including Arctic and Antarctic seas, play in climate change. The meeting will address key feedback processes between the ocean and climate and include discussions on ocean acidification and ocean fertilisation. The report will also discuss the current woefully inadequate status of ocean observations and the need to implement as a high priority improved measurements of ocean processes through the development of a comprehensive, sustained and globally extensive ocean observing system. Initial sponsorship is being provided by WWF. A summary outline of the main conclusions and recommendations of the scientific report that is targeted for publication in July 2008 will be outlined in Gijón.

#### **Poster S1.1-4752**

### **Climatic changes in the deep Norwegian coastal waters and Skagerrak 2000 - 2005 in relation to previous decades**

Jan Aure, Didrik S. **Danielssen** and Einar Svendsen

Institute of Marine Research, Nordnesgaten 50, P.O. Box 1870, Bergen, N-5817 Nordnes, Norway. E-mail: jan.aure@imr.no

Climatic conditions in the deep Norwegian coastal water, from the Skagerrak to the Barents Sea, are to a large degree influenced by the Atlantic water. The seasonal variations are also much less than in the upper layer. Temperature and salinity are observed on a regular basis at a set of nine stations from Torungen (Skagerrak) to Ingøy (Finnmark). This takes place two or four times a month from surface to the bottom. The Torungen - Hirthals hydrographic section in the Skagerrak is observed regularly once a month. The decadal mean temperatures in the deep water (150 m) along the Norwegian coast and in the Skagerrak were quite stable in the period from 1950 to 1990. The mean decadal temperature in this period was about 7.2°C in the Skagerrak and along the Norwegian west coast. In the coastal areas off northern Norway the mean temperature was reduced to 6.1°C outside Lofoten (station Eggum) and to 4.7°C close to the North Cape (station Ingøy). In the 1990s the decadal mean temperature in the deep coastal water increased considerably and temperatures in the first part of the 1990s were the highest observed since observations along the Norwegian coast started in 1936. The temperature anomaly in 1990s was closely connected to an increase in the Atlantic inflow to the Norwegian Sea and warm winters (high level of North Atlantic Oscillations - NAO). After a certain temperature decrease in the late 1990s, the temperatures again increased to the same high levels as in early 1990s in the deeper layer of the coastal waters. In 2000 - 2005 the mean temperature in the deep water along the coast from Skagerrak to the North Cape was 0.7-1.0°C higher compared to the period 1960-1989. The mean temperature increase in 2000-2005 was considerable and related to the standard deviation 1960-1989 (diffT/stdev) and varied between 1.2 and 2.1, with the highest value at station

Ingøy. Higher temperatures in the North Sea during winters from the last part of the 1980s caused a lower density in this water mass. This seems to be the main reason for observed reduced inflow of North Sea water to the deepest part of the Skagerrak, resulting in lower oxygen content. During the same period Atlantic water flowing into the Skagerrak along the southern slope of the Norwegian trench also had a too low density (due to high temperatures) to replace the deep water in the Skagerrak. In contrast to the situation in the 1990s, the NAO index and the inflow of Atlantic water has been approximately normal between 2000 and 2005. The relatively high temperatures along the Norwegian coast from the Skagerrak to the Barents Sea must then have another explanation and are probably connected to both increased inflow from the warmer easterly branch of the North Atlantic current and reduced winter cooling.

#### Poster S1.1-4769

### Trend analysis of sea surface temperature at the aquarium of Donostia-San Sebastián (1946-2007)

Manuel González, Luis Ferrer, Almudena Fontán, Julien Mader, Adolfo Uriarte and Ganix Esnaola

Marine Research, AZTI-Tecnalia, Muelle de Herrera, s/n, Zona Portuaria de Pasaia, Gipuzkoa, 20110 - Pasaia, Spain.  
E-mail: mgonzalez@pas.azti.es

The results of the trend analysis of sea surface temperature, measured at the aquarium of Donostia-San Sebastian (43°19'N, 02°00'W), are described within this contribution. The time series extends from 2 July 1946 to 10 June 2007; representing almost 61 years of data (22,259 days), recorded daily at 10 am. The time series has gaps in the data, especially between 1967 and 1975; consequently, up to 23% of the total data set (5,121 days) is missing. Nevertheless, it has been proved that the distribution of the gaps is sufficiently homogeneous, so as not to distort the annual mean values. In order to remove fluctuations due to time-scales of less than a year (such as seasonal variability), a running annual mean has been calculated, taking into account missing data within the original time series. Subsequently, a trend analysis has been performed with the annual data. Globally, a very small cooling trend ( $-0.002^{\circ}\text{C}/\text{year}$ ) can be observed, for the whole of the time series. However, a change in the tendency is observed for the latter part of the series, 1991-2007, with a warming trend of  $0.040^{\circ}\text{C}/\text{year}$ . This positive tendency can be detected even if extreme periods of hot weather, such as the summer 2003 and the second half of 2006, are removed from the analysis.

#### Poster S1.1-4776

### Long-term variability of sea surface temperature in the Black and Marmara seas and its response to global atmospheric forcing

Anna I. Ginzburg, Andrey G. Kostianoy and Nickolay A. Sheremet

Department of Physical Oceanography, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, 36 Nakhimovsky Prospect, Moscow 117997, Russia. E-mail: ginzburg@ocean.ru

Monthly NOAA/NASA AVHRR Pathfinder data (1985-2006) with a spatial resolution of 4 km and available field measurements of different years were used to investigate seasonal and interannual variability of sea surface temperature (SST) in the Black and Marmara Seas and their individual regions. The character of the SST interannual variability in both seas was similar. Warming in 1985-2006 occurred during all the seasons, with general positive trends of the mean annual basin-averaged SSTs in the Black and Marmara Seas of about  $0.06$  and  $0.02^{\circ}\text{C year}^{-1}$ , respectively. Within the period the character of temperature changes and corresponding SST trends were significantly different: a slight negative trend of mean annual SST in 1985-1993, a marked increase in 1993-2001, and a tendency to decrease after 2001. A comparison was carried out between years of marked winter SST anomalies and the yearly phases of the *El Niño* – Southern Oscillation, North Atlantic Oscillation (NAO) and East Atlantic-West Russian (EAWR) pattern. The occurrence of most of the marked winter SST anomalies during the *El Niño* events or in the years immediately after them suggests an influence of the events on the temperature regime of the sea. The winter SST anomalies were better related to the winter indices of the EAWR or to particular combinations of the winter EAWR and NAO indices, which determine the predominance of cold or warm air masses over the Black Sea basin, than to the NAO winter indices. This study was supported by the Russian Foundation for Basic Research (Grant N 07-05-00141).

### Poster S1.1-4792

#### **Analysis of an Irish coastal sea temperature time series: interannual variability and sensitivity to global influence (1958-2007)**

Heather **Cannaby**, G. Nolan, I. Nardello, G. Westbrook and K. Lyons

Marine Climate Change Programme, Marine Institute, Rinville, Oranmore, Galway, Ireland. E-mail: heather.cannaby@marine.ie

The heat content of the world's oceans is estimated to have increased by  $14.2 \times 10^{22}$  J during the period 1961-2003. The overall temperature increase is superimposed on strong interannual and interdecadal variations, related to atmospheric teleconnection patterns. Understanding the nature of such patterns, and changes in their behaviour over time is central to understanding regional ocean dynamics and the potential impacts of future climate change. Here we describe interannual variability in a coastal sea temperature time series, recorded to the northwest of Ireland, and interpret this variability as the sum of global forcing and regional dynamics. The data reveals recent intense warming, exemplified by a linear trend of  $+0.85^\circ\text{C}$  over the period 1958-2006, and  $+1.26^\circ\text{C}$  over the period 1987-2006. Comparison with global SST data sets demonstrates that 74% of the variability in the data can be attributed to global temperature anomalies, 81% to northern hemispheric temperature anomalies and 85% to North Atlantic temperature anomalies. Relationships are demonstrated between the temperature time series and the dominant modes of climate variability in the northeast Atlantic (NAO and East Atlantic Pattern). The East Atlantic Pattern explains a greater proportion of variance in the data. Specific events in the temperature time series are also related to regional changes in ocean dynamics, specifically shifts in the reach of the sub-polar and subtropical gyre systems, shelf edge current dynamics and the Irish coastal current.

### Poster S1.1-4801

#### **Recent intra-decadal changes in the water mass temperature, salinity and transport in the $60^\circ\text{N}$ transatlantic section**

Alexander N. **Demidov**<sup>1</sup>, Sergey A. Dobrolyubov<sup>1</sup>, Roman Yu. Tarakanov<sup>2</sup> and Artem A. Sarafanov<sup>2</sup>

<sup>1</sup> Department of Oceanology, Moscow State University, GZ MGU, Lininskie Gory, Faculty of Geography, Moscow 119992, Russia. E-mail: tuda@mail.ru

<sup>2</sup> P.P. Shirshov Institute of Oceanology, 36 Nakhimovskiy Prospect, Moscow 117997, Russia

The study is based mostly on the data from the 7 repeats of the zonal transatlantic section along  $60^\circ\text{N}$  carried out on board Russian research vessels in 1997-2007 within the framework of the Russian research programme "Meridian-plus". In a recent study by Sarafanov *et al.*, the transition from the colder/fresher to the warmer/saltier conditions at the intermediate and deep levels in the subpolar North Atlantic during the past decade was reported. Here, the focus was on the water mass transport changes in the  $60^\circ\text{N}$  section. The meridional cross-sectional velocity was quantified as the sum of three components: geostrophic, drift and barotropic (from AVISO absolute sea level topography data). Transport estimates in all the section repeats provide high values (50-80 Sv) opposite in sign. The total transport in the surface layer does not differ significantly from year to year being 11-13 Sv (positive values indicate northward transport). The Iceland Intermediate Water transport ranges from 3 to 8 Sv. The Labrador Sea Water (LSW) leaves the region at rates of -5 to -10 Sv, contributing to the deep water export. Transport of the shallow LSW formed after 1995 is roughly two times higher than the transport of the deep LSW formed in the first half of the 1990s. The Iceland-Shetland Overflow Water and Denmark Strait Overflow Water supply the North Atlantic southward outflow with 9-11 and 2-6 Sv, respectively. The MOC intensity shows a substantial variability and does not reveal any distinct trend during the decade.

## Poster S1.1-4812

### Palaeoceanography of the Agulhas current and ensuing Indian-Atlantic water exchange as a leading component of Atlantic MOC shifts

Gema **Martínez-Méndez**<sup>1</sup>, Rainer Zahn<sup>1,2,3</sup>, Ian R. Hall<sup>4</sup>, Frank Peeters<sup>5,6</sup>, Leopoldo D. Pena<sup>7</sup> and Isabel Cacho<sup>6</sup>

<sup>1</sup> Universitat Autònoma de Barcelona, Institut de Ciència i Tecnologia Ambientals (ICTA), Cerdanyola, Barcelona E-08193, Spain.  
E-mail: gema.martinez@uab.cat

<sup>2</sup> Departament de Geologia, Edifici Cn Campus UAB, Bellaterra, E-08193, Spain.

<sup>3</sup> Institució Catalana de Recerca i Estudis Avançats, ICREA, Spain.

<sup>4</sup> School of Earth, Ocean and Planetary Sciences, Cardiff University, Main Building, Park Place, Cardiff CF10 3YE, UK.

<sup>5</sup> Department of Paleoecology and Paleoclimatology, Faculty of Earth and Life Sciences, Vrije Universiteit, de Boelelaan 1085, Amsterdam, 1081 HV, The Netherlands.

<sup>6</sup> Department of Marine Chemistry and Geology (MCG), Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands.

<sup>7</sup> GRC Geociències Marines, Departament d'Estratigrafia, P. i Geociències Marines, Universitat de Barcelona, C/ Martí i Franquès, s/n, Barcelona E-08028, Spain.

The Agulhas Current off South Africa plays a key role in the Atlantic Meridional Overturning Circulation (AMOC) as salty and warm Indian waters are transported to the Atlantic Ocean and influence its buoyancy budgets. Paleooceanographic records have revealed that enhanced transports of Agulhas water occurred near the end of glacial periods when the AMOC shifted to a vigorous interglacial mode. We present 350,000 year long palaeoceanographic profiles from a sediment core positioned in the Agulhas Corridor that monitors the Indian-Atlantic water transports. Sea surface temperature (SST, from planktonic foraminiferal Mg/Ca ratios), sea surface salinity (from SST and planktonic  $\delta^{18}\text{O}$ ) and abundance of Agulhas leakage fauna maximise during glacial terminations when the ventilation of the deep Atlantic increases, hence supporting stimulation of the AMOC. Surface warming is recorded during the penultimate glacial period (marine isotope stage 6) suggesting a narrowed near-shore flow of Agulhas water that vanished as the Agulhas corridor widened in the course of deglaciation. Benthic carbon isotopes ( $\delta^{13}\text{C}$ ) and Cd/Ca ratios document a continuous influence of deep water from the north during early glacial phases and a subsequent shift to a dominance of southern component water. Variations of the sortable silt index document strengthened near-bottom physical flow speeds during these times which is consistent with similar profiles from other southern hemisphere locations and supports the contention that the Southern Ocean in the past played an active role in the global AMOC.

## Poster S1.1-4823

### Variability and forcing of the subarctic front in the northwestern Japan/East Sea

Olga O. **Trusenkova**

Laboratory of Physical Oceanography, V.I. Ilyichev Pacific Oceanological Institute, FEB RAS, Russian Academy of Sciences, 43 Baltiyskaya Street, Vladivostok 690041, Russia. E-mail: trolia@poi.dvo.ru

Variability of the northwestern branch of the subarctic front (NWSF) in the Japan/East Sea (JES) is studied from two high resolution daily data sets of sea surface temperature: ew Generation (NG) SST from Tohoku University (July 2002-July 2006) and SST from the Japan Meteorological Agency (October 1993-November 2006). The NWSF index is proposed as a crossfrontal SST difference in the area off North Korea-Vladivostok where the front was documented. The NWSF manifests itself in the second Empirical Orthogonal Function of SST in the northwestern JES; reference locations for the NWSF index are based on its spatial pattern. High (low) index values correspond to the sharp (relaxed) NWSF off North Korea-Vladivostok. The NWSF index sharply increases with the onset of winter monsoon, usually in mid October, reaches its highest in the late November-early December and remains high until the end of a year or until the late winter in some cases, forced by local anticyclonic wind stress curl, as recognised from modelling studies. In the warm season, despite the decreased SST contrasts, the NWSF index reveals events of the NWSF sharpening alternated by the weakened NWSF (1-3 weeks). The NWSF index becomes low by late August-September. Forcings of the NWSF in the warm season are studied from numerical simulations with an oceanic model and shown to be related to a local anticyclonic wind stress curl and bathymetry.

### Poster S1.1-4849

#### Mixed layer variability and its relation to ice cover and distribution of chlorophyll *a* in the Weddell Sea (Southern Ocean)

Tiziana **Peluso**<sup>1</sup>, Giorgio Budillon<sup>2</sup>, Giannetta Fusco<sup>2</sup> and Daniele Iudicone<sup>3</sup>

<sup>1</sup> CNR - Consiglio Nazionale delle Ricerche, ISMAR - La Spezia, Forte S. Teresa, Loc. Pozzuolo, Lerici (SP), 19032, Italy. E-mail: tiziana.peluso@ge.cnr.it

<sup>2</sup> DiSAM, University of Naples 'Parthenope', Centro Direzionale, Isola C4, Naples 80143, Italy.

<sup>3</sup> SZN – Stazione zoologica 'Anthon Dorn', Villa Comunale, Naples 80121, Italy.

The ocean mixed layer depth (MLD) is one of most important quantities of the upper ocean because it defines the quasi-homogeneous surface region of density that directly interacts with the atmosphere and with CO<sub>2</sub> adsorption. In addition, the bulk of the biological productivity of the world oceans critically depends on the physical and chemical changes taking place within this layer. The scientific issue addressed in this study is the role of the mixed layer in the Weddell Sea - the most prominent area of water mass formation in the Southern Ocean - and its relationship with chlorophyll *a*. In an effort to reconstruction the variability of the mixed layer in the Weddell Sea, we used all public high vertical resolution data, available from 1940 to present, and vertical profiles of temperature measured on board the ice-breaker *A. Irizar* from 2004 to 2006 implementing a new method based on critical temperature. Causes of observed variations are investigated using an ocean mixed-layer model, the General Ocean Turbulence Model, forced with heat fluxes. Heat exchanges between the sea and atmosphere, whether ice cover was present or not, were calculated from climatological data obtained from ECMWF, while sea-ice data (ice concentration and thickness) were calculated by new algorithms from brightness temperature (SSM/I). Further, in order to investigate the linkage between the MLD, sea-ice concentration and chlorophyll *a* in the Weddell Sea, SeaWiFS derived chlorophyll *a* were also analysed.

### Poster S1.1-4878

#### Warming and salinification of intermediate waters of southern origin in the eastern subpolar North Atlantic in the 1990s – mid-2000s

Anastasia S. **Falina**, Artem A. Sarafanov, Alexey V. Sokov and Alexander N. Demidov

P.P. Shirshov Institute of Oceanology, RAS, Nakhimovskiy Prospect 36, Moscow 117997, Russia. E-mail: falina\_a@mail.ru

In addition to the quantification of the Labrador Sea Water (LSW) and Nordic overflow-derived waters temperature ( $\Theta$ ) and salinity (*S*) changes during the past decade (1997-2006), we have examined the  $\Theta$ -*S* changes in the layer of intermediate waters of southern origin (tentatively designated "IW" following van Aken and de Boer, 1995) in the eastern subpolar North Atlantic in the 60°N repeated section. Similarly to the positive trends in temperature and salinity of the LSW and deep waters, the IW layer steadily became warmer and saltier during the 1997-2005 time period at the section latitude. We have also inspected the  $\Theta$ -*S* changes in the IW layer at the upstream location, 52-53°N, and derived a similar trend for the 1992-2002 time period. The results are discussed in the context of the contemporary climate variations.

### Poster S1.1-4894

#### Recent trends in the tropical Pacific-Atlantic connection

Belén Rodríguez-Fonseca<sup>1</sup>, Irene **Polo**<sup>1</sup>, Javier García-Serrano<sup>1</sup> and Carlos R. Mechoso<sup>2</sup>

<sup>1</sup> Dpto. Geofísica y Meteorología, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, 28040 Madrid, Spain. E-mail: brfonsec@fis.ucm.es

<sup>2</sup> Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, CA, USA.

The Atlantic equatorial mode (or Atlantic *Niño*) is an important component of the Atlantic interannual variability, and is known for impacting regional rainfall over the coast of the Gulf of Guinea. It is also known that remotely forced variability affects very much the Atlantic *Niño*: several authors, using observations from the 1950s, have reported connections with a six-month lag between the Atlantic *Niño* and previous Pacific *Niño*. The present work revisits the relationship using an observational data set in the recent period (1979-2001) and comparing this with the first part of the twentieth century. The lead-lag correlation scores of the anomalous tropical SST and precipitation between these two tropical basins show a "Pacific-Atlantic wave-like relationship" with a 3-4

year period which is only significant from 1979. Possible explanations for this behaviour include the recent trends in warming rates of the individual ocean basins; stronger warming in the Atlantic from the 1980s and cooling in the eastern equatorial Pacific from 1975. Thus, in the recent period “a summer inter-basin SST gradient” trend is found that could suggest a relevant role of the equatorial Atlantic SST anomalies in the tropical belt anomalous circulation. For instance, the recent period is characterised by enhanced divergence in the central Amazon basin, representing a competitive action between basins, in comparison with the first period, when the Amazon cell splits. This also could imply that the Pacific, and in turn its global influence, could be modulated by the Atlantic.

## Poster S1.1-4898

### Effects of the world's oceans on climate change

Vadim Navrotsky

Department of General Oceanology, V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya Street, Vladivostok 690041, Russia. E-mail: navrotskyv@poi.dvo.ru

Recent decades have seen relatively quick changes in global climate although there has been a change in surface solar radiative forcing of only 0.1% and a very small change in global mean temperature. Considerable changes in space-time dispersions of temperature, pressure, humidity, wind velocity and other parameters have been observed and should be looked at as global climate change. Our analysis of the world's oceans role in climate change is based on the following statements derived from observations: 1) the world's oceans are the main accumulating and storing systems of the incoming solar energy, 2) solar energy income to the ocean surface and its assimilation depend on the atmospheric and ocean optical properties, which are affected by phytoplankton biomass and space structure, 3) primary production in the ocean is greatly influenced by different kinds of solar activity, 4) considerable biota changes can forestall the changes of climatic parameters. Basing on these facts and analysing interrelations between water leaving radiance and chlorophyll concentrations, we come to the conclusion that energy for global climate fluctuations can come from fluctuations of the world's oceans heat content via mechanisms of ocean-atmosphere interactions. Assimilation and accumulation of solar heat in the ocean is controlled by the ocean biota, where concentration and properties are greatly influenced by solar and geomagnetic activity. Using these observations we can derive methods for long-term prediction of global climate change.

## Poster S1.1-4911

### Eastern equatorial Pacific climate variability for the last glacial cycle

Eva Calvo<sup>1</sup>, Carles Pelejero<sup>2</sup>, Leopoldo D. Pena<sup>3</sup> and Isabel Cacho<sup>3</sup>

<sup>1</sup> Institut de Ciències del Mar, CSIC, Pg. Marítim de la Barceloneta 37-49, Barcelona 08003, Spain. E-mail: ecalvo@icm.cat

<sup>2</sup> ICREA and Institut de Ciències del Mar, CSIC, Pg. Marítim de la Barceloneta, 37-49, Barcelona 08003, Spain.

<sup>3</sup> GRC Geociències Marines, Dept. d'Estratigrafia, Paleontologia y Geociències Marines, Universitat de Barcelona. C/Martí i Franquès, s/n, Barcelona 08028, Spain.

The impact of the tropical ocean-atmosphere system on the global climate is well-recognised on interannual to decadal time scales because of the link to the *El Niño*-Southern Oscillation. On glacial and millennial time scales, however, the potential role of the tropics in driving or amplifying global climate is still not fully understood. The cold tongue of the eastern equatorial Pacific represents a key area if we are to understand some of the potential mechanisms driving global climate change as it is also the major oceanic source of carbon dioxide to the atmosphere. In this region, a marine sediment core was retrieved during ODP Leg 202 at the northern flank of the Carnegie Ridge (0°01.31'N, 86°27.76'W; 2,921 m water depth) in the Panama Basin. ODP Site 1240 is under the influence of the Equatorial Undercurrent (EUC), which flows eastward and transports cool thermocline waters from the western Pacific along the equator. We will present a multiproxy record of climate variability covering the last glacial cycle (~145,000 years) based on the analyses of molecular biomarkers and stable isotopes and trace elements in fossil foraminifera. These analyses will provide two independent methods to reconstruct past sea surface temperature (SST), namely the  $U_{37}^*$  index and foraminifera Mg/Ca ratios. Both glacial/interglacial and millennial SST variability will be evaluated in combination with terrestrial input and marine productivity changes over the last glacial cycle.

### Poster S1.1-4915

#### Comparison of *in situ* time series of temperature with gridded sea-surface temperature data sets in the North Atlantic

Sarah L. **Hughes**<sup>1</sup> and members of the ICES Working Group on Oceanic Hydrography

Fisheries Research Services, Marine Laboratory, Victoria Road, Aberdeen AB11 9DB, UK. E-mail: s.hughes@marlab.ac.uk

Analysis of the effects of climate variability and climate change on the marine ecosystem is difficult in regions where long-term observations of ocean temperature are sparse or unavailable. Gridded sea-surface temperature (SST) products, based on a combination of satellite and *in situ* observations, are often used to examine variability and long term trends as they provide better coverage on both spatial and temporal scales than the limited sets of long *in situ* time series. SST data from two gridded products (Reynolds/NCEP OISST and HadISST) are compared with long time series of *in situ* measurements from ICES standard sections in the North Atlantic and Nordic Seas. The long term variability and trends derived from these two data sources are compared and differences between the data sets are examined and discussed.

### Poster S1.1-4916

#### Recent changes in temperature and salinity in the Canary region

Verónica M. **Benítez-Barríos**<sup>1</sup>, Alonso Hernández-Guerra<sup>1</sup>, Pedro J. Vélez-Belchí<sup>2</sup>, Francisco J. Machín<sup>3</sup> and Eugenio Fraile-Nuez<sup>2</sup>

<sup>1</sup> Facultad de Ciencias del Mar, Universidad de Las Palmas de Gran Canaria, Sancho Panza 33, Puerto del Rosario, Fuerteventura, Las Palmas 35600, Spain. E-mail: veronica.benitez102@doctorandos.ulpgc.es

<sup>2</sup> Centro Oceanográfico de Canarias, Instituto Español de Oceanografía, Santa Cruz, Spain.

<sup>3</sup> Institut de Ciències del Mar, CSIC, Barcelona, Spain.

Based on hydrographic sections carried out during the last decade in the Canary region at 29°10'N, we show that there has been a statistically significant rise in temperature and salinity on isobars between 1500 and 2300 db. The maximum increase, found at 1600 db, is occurring at a rate of 0.29°C and 0.047 per decade. Isobaric change decomposition into changes on neutral surfaces and changes due to the vertical displacement of the isoneutrals was performed. Results reveal that the lower part of North Atlantic Central Water (NACW) cooled and freshened on neutral surfaces, suggesting changes in the freshwater fluxes at the outcropping region. However, the signal in deep waters (1500-2300 db) was principally due to a downward displacement of the isoneutrals, although water mass modification is observed in the range of Mediterranean Water (MW) influence.

### Poster S1.1-4948

#### The teleconnection between sea surface temperature analysis from *in situ* data at East Mole, Lagos and global warming

Archibong O. **Ediang**, L.E. Edaefinene and A.A. Ediang

Marine division, Nigerian Meteorological Agency, PMB1215, Oshodi, Lagos 23401, Nigeria. E-mail: Ediang2000@yahoo.com

Marine Weather Observers have since 1988 been making sea surface temperature observations at East Mole Station, about 2 kilometres from the coast. The station uses the rubber sea-temperature bucket thermometer and makes observations on an hourly basis. Sea surface temperature influences Lagos coastal weather and it is especially important for coastal fishermen, offshore oil and gas industries, shipping vessels, coastal recreational and port handling facilities. Some evidence of global warming in Nigeria has been observed using sea surface temperature (SST) for the period 1989-2006. Results show that the Nigerian coastal waters are warmest in April and coldest in August. The yearly mean SST during the period 1989-2000 shows some evidence of global warming. This paper attempts to highlight the features of sea surface temperature over the Lagos coastal waters, thus indicating that global warming is evident in the Nigerian coastal waters.

### **Poster S1.1-4957**

#### **Variations of water and air temperature in coastal areas of the north-west Japan/East Sea**

Larissa A. **Gayko**

V.I. Il'ichev Pacific Oceanological Institute, FEB RAS, Baltiyskaya Street 43, Vladivostok 690041, Russia. E-mail: gayko@yandex.ru

The tendencies of climate change, namely global warming are of great interest. It is an urgent problem to define the most vulnerable areas of the coastal zone by analysis of instrumental observations. We analysed the long-term series of observations of surface temperature of sea water and air temperature, conducted at the hydrometeorological stations on the coast of Primorski Krai from 1881 to 2006. For the last hundred years in Vladivostok water temperature has increased by 0.64°C, and air temperature, by 1.74°C. Our research confirms, that 1989-2000 is the warmest period of the twentieth century for the researched area but the warmest year for each station is different. Up until 1988 there is a fluctuation of temperature about norm, but since 1989 positive anomalies at all stations are marked.

### **Poster S1.1-4963**

#### **Low-frequency changes in sea surface temperature in the eastern South Pacific**

Oscar **Pizarro**

Department of Geophysics, University of Concepcion, Concepcion, Chile. E-mail: opizarro@udec.cl

Different IPCC model simulations have shown that the sea surface temperature (SST) increase over the eastern South Pacific is rather small compared to the global trends. This smaller regional trend may be associated with upwelling increasing along this region. Nevertheless, previous results have shown that at low frequencies (interannual and interdecadal time scales) SST and coastal air temperature fluctuations in the eastern South Pacific are closely correlated to changes in the equatorial Pacific and do not covary significantly with changes of the alongshore winds. In this work we analyse SST and sea level height (SLH) data along with winds data from the eastern South Pacific to evaluate long term changes of these variables. We evaluate the local relationships among low frequency fluctuations of SST, SLH and thermocline depth. We also explore possible mechanisms that could contribute to the observed trend and to the low frequency fluctuations in the different variables. In particular we focus on the relationship with the variability observed during the last decades over the equatorial Pacific and changes in the subtropical anticyclone over the eastern South Pacific. Our main hypotheses is that changes in thermocline depth along the Peruvian and Chilean coast are closely related to changes in the equatorial Pacific and those changes significantly impact the SST and SLH in this region. Despite limitations in the different data sets most of the evidence is consistent with the strong modulation of SST off Peru and Chile by the changes in the equatorial Pacific.

### **Poster S1.1-4979**

#### **Effects of regional drivers on the sea water temperature in Kuwait Bay, northern Arabian Gulf**

Thamer B. **Al-Rashidi**<sup>1</sup>, Carl L. Amos<sup>1</sup>, Hamdy I. El-Gamily<sup>2</sup> and Karim A. Rakha<sup>2</sup>

<sup>1</sup> National Oceanography Centre, European Way, Southampton SO14 3ZH, UK. E-mail: thamer22@noc.soton.ac.uk

<sup>2</sup> Kuwait Institute for Scientific Research, P.O. Box 24885, Safat 13109, Kuwait.

The water in the northern Arabian Gulf is well mixed by macrotidal semi-diurnal tides. Sea surface temperature (SST) is thus a good proxy of water mass temperature. MODIS (moderate resolution imaging spectroradiometer) satellite data collected over 5 years between 2003 and 2007 (750 SST images) show that SST in the Kuwait Bay has increased by 2.5°C. Regression analysis of a yearly average AVHRR (Advanced Very High Resolution Radiometer) data indicates that the SST in Kuwait Bay has increased by 1°C/decade over the last 20 years and 2°C/decade during the last 10 years. We propose that this rapid recent increase in SST is explained by drivers at global, regional and local scales. This study concentrates on the affect of the regional drivers on SST in Kuwait Bay. The regional drivers considered are: fresh water discharge from the Euphrates River, air temperature, wind speed and relative humidity. The fresh water discharge from the Euphrates is not available after 1994; therefore salinity data measured during 1983-1994 was correlated with discharge data in order to predict the discharge after 1994. Statistical analysis showed that only 30-40% of the variance in sea water temperature is explained by air temperature. We infer that 66-70% of the signal is driven by global and local drivers.

## S1.2 Climate model projections

**20 May, 10:30 (S1.2-4802) Invited**

### **Comparing past variability of coastal currents and upwelling regimes with plausible future anthropogenic signals – in the framework of millennial AOGCM simulations**

Hans von **Storch**<sup>1,2</sup>, Eduardo Zorita<sup>1</sup> and Fidel J. González-Rouco<sup>3</sup>

<sup>1</sup> Institute for Coastal Research, GKSS Research Center, P.O. Box, Geesthacht 215092, Germany. E-mail: hvonstorch@web.de

<sup>2</sup> KlimaCampus, Center for Marine and Atmospheric Sciences, Bundesstrasse 53, Hamburg 20146, Germany.

<sup>3</sup> Universidad Complutense de Madrid, Ciudad Universitaria, Madrid 28040, Spain.

For assessing the role of anthropogenic factors in changing climate at large, and of ocean features, detection (anthropogenic influenced developments) and attribution (to specific causes) studies are needed. For doing so, extensive data sets of past variability as well as scenarios of plausible future developments are needed. Obviously, such data sets hardly exist for many oceanic features such as the intensity of coastal currents and upwelling regimes. Thus, not surprisingly, only few detection and attribution studies have dealt with oceanic features, while the methodology has multiplied and been successfully applied to atmospheric variables. As a demonstration, we conduct detection and attribution exercises in the framework of millennial simulations (1000-2100), forced by estimated past volcanic, solar and greenhouse gas forcing - with the last 100 years using SRES scenarios. Statistics of coastal currents, of and coastal mean sea level and upwelling regimes are considered. Estimates of early detection times are derived.

**20 May, 10:55 (S1.2-4955) Invited**

### **Future projection of extreme events**

Seita **Emori**

National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba 305-8506, Japan. E-mail: emori@nies.go.jp

Research on extreme events in a future warmer climate has been accelerated in recent years partly because of social demand and partly because of the enhanced skill of climate models to represent extreme events. In this talk, I'd like to start by summarising what is written in IPCC AR4 about extreme events, especially on their changes in the future. Then I will continue by discussing general reliability issues on projected future changes in extreme events. For example, I'd like to demonstrate that high-resolution climate modelling is useful for realistically representing certain kinds of extreme events, but it is not sufficient. I hope also to mention what climate modellers should be careful about when projected changes in extreme events are used in impact assessment work.

**20 May, 11:20 (S1.2-4839)**

### **Freshening of the subpolar North Atlantic: causes and consequences**

Markus Scheinert, Claus W. **Böning** and Arne Biastoch

Ocean Circulation and Climate Dynamics, Leibniz Institute of Marine Sciences (IFM-GEOMAR), Düsternbrooker Weg 20, Kiel D-24105 Germany. E-mail: cboening@ifm-geomar.de

Recent studies of ocean observations show significant multi-decadal changes in the freshwater content (FW) for the subpolar North Atlantic (SNA), including a prominent freshening between the late 1960s and early 1990s. Two main mechanisms have been invoked to explain the changes in FW: a change in the surface freshwater fluxes, and changes in the export of freshwater out of the Arctic and Nordic Seas. Here we propose an alternative mechanism, which can explain not only the decadal variations in FW, but also its conspicuous, high negative correlation with heat content for the SNA. Our study is based on a sequence of hindcast and sensitivity experiments with a global ocean-sea ice model, using the bulk surface flux formulation for 1958-2000 (the "CORE" forcing protocol) developed by Large and Yeager (2004). The model simulation reproduces the observed changes in both the integrated SNA FW and heat content; it also captures other pertinent features of observed decadal SNA variability:

the salinity changes at OWS Bravo in the deep Labrador Sea; the freshwater flux anomalies associated with the “Great Salinity Anomalies”; and the Curry-McCartney index of North Atlantic Current (NAC) variability. The model output has been used to assess the changes in the components of the freshwater budget: it suggests that the largest contribution to the integral changes in the SNA has been due to the FW and heat exchanges with the subtropical gyre; in contrast to previous suggestions, it indicates a minor influence of variations in the surface fluxes, and also a secondary contribution to the SNA FW changes by freshwater exports from the Arctic. The variability in the subtropical-subpolar fluxes can be understood in terms of the response of the gyre circulation to atmospheric forcing variability associated with the North Atlantic Oscillation (NAO).

**20 May, 11:35 (S1.2-4622)**

### **A method for using IPCC model simulations to project changes in marine ecosystems**

Nicholas A. **Bond**<sup>1</sup>, James E. Overland<sup>2</sup> and Muyin Wang<sup>1</sup>

<sup>1</sup> Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, 7600 Sand Point Way NE, NOAA/PMEL, P.O. Box 354925, Seattle, WA 98195-4925, USA. E-mail: nicholas.bond@noaa.gov

<sup>2</sup> Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

In preparation for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, an international group of modelling centres carried out sets of global climate simulations. A total of 23 different coupled atmosphere-ocean general circulation models were employed under common emission scenarios. The objective of this paper is to describe a protocol for using these simulations towards the projection of the future states of marine ecosystems, drawing on examples from the North Pacific and Bering Sea. Our method relies on critical evaluation of the models' 20th century hindcasts of variables pertaining to the ecosystems of interest. Experience indicates that typically about one-half of the models are able to replicate the spatial pattern, temporal scale and magnitude of variance in the basin-scale climate forcing observed in the 20th century. Different models tend to have different strengths; a model's capability to hindcast an individual parameter such as sea ice does not guarantee it performs equally well for other parameters such as precipitation. Therefore, the subset of models used for projections into the 21st century should be tailored to the specific application. At the same time, it is desirable to retain as many independent simulations for the 21st century as possible (at least 5) in that an ensemble of simulations is required to ascertain the probable ranges of future extremes in the climate forcing, and the uncertainties in the projections in general.

**20 May, 11:50 (S1.2-4766)**

### **Recent warming and changes of circulation in the North Atlantic simulated with eddy-permitting and eddy-resolving ocean models**

Robert **Marsh**, Beverly A. de Cuevas, Andrew C. Coward and Simon A. Josey

National Oceanography Centre, University of Southampton, European Way, Southampton SO14 3ZH, UK. E-mail: rma@noc.soton.ac.uk

The role of ocean heat transport variations in recent warming of the North Atlantic is investigated using three different eddy-permitting ( $1/4^\circ$ ) simulations and one eddy-resolving ( $1/12^\circ$ ) simulation of the OCCAM global ocean model, forced with prescribed atmospheric boundary conditions since the mid-1980s. The first eddy-permitting simulation (spanning 1985-2003) is used to investigate links between surface warming and changes in regional heat budgets. Variability of model sea surface temperature compares favourably with satellite and *in situ* observations. Each data set reveals a similar pattern of significant surface warming across much of the North Atlantic since 1985. In the model, significant warming trends exceed  $0.1^\circ\text{C}$  per year across a large area of the northwest Atlantic. A second eddy-permitting simulation (1985-2004) includes several model improvements. Both of these eddy-permitting simulations, and an eddy-resolving simulation (1985-2004), are forced using blended NCEP re-analysis and satellite data. A third eddy-permitting simulation (1985-2000) is forced with a different data set, based on the ERA-40 re-analysis data. Inter-comparison of these simulations clarifies the relative importance of resolution and choice of forcing data set, for simulating the mean state and recent variability of ocean circulation. Two broad conclusions are reached: (1) the pattern of recent warming in the mid-latitude North Atlantic is largely due to anomalous convergence of ocean heat transport, associated with changes in overturning and horizontal components of the circulation, in the northern subtropics and the subpolar gyre respectively; and (2) recent changes in the structure of mid-latitude heat transport are more accurately represented if eddies are explicitly resolved.

**20 May, 12:05 (S1.2-4642)**

### **A variational model of jet current applied to the Kuroshio Extension**

Talgat R. Kilmatorov and Vera A. Petrova

Department of Physical Oceanography, V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya Street, Vladivostok 690041, Russia. E-mail: talgat\_k@mail.ru

The border between the subtropic and subarctic regions in the Northern Pacific is considered. There are two climatic fronts - the density front of the Kuroshio Extension and the thermohaline subarctic front. A variational stationary model is used, where a zonal channel on an  $f$ -plane with a fixed density difference on the southern and the northern borders is set. The geostrophic approach along the channel is carried out. The hydrostatics equation is applied to the vertical direction. Advection and turbulence forces across the channel are considered. The mathematical model is based on the variational functional of the minimum entropy production. Approximate analytical solutions are constructed by the direct variational method with the addition of the oceanographic information on the physical fields. Convergence across the channel is also set as a priority. The model shows that the existence of the Kuroshio Extension may be limited by climatic factors. There is a critical parity between the north-south difference of water density, convergence, turbulence intensity, when the current is not a jet current anymore.

**20 May, 12:20 (S1.2-4697)**

### **Anthropogenic speed-up of oceanic planetary waves**

John C. Fyfe and Oleg A. Saenko

Canadian Centre for Climate Modelling and Analysis, Environment Canada, University of Victoria, P.O. Box 1700 STN CSC, Victoria, BC, V8W 2Y2, Canada. E-mail: John.Fyfe@ec.gc.ca

We have analysed a suite of state-of-the-art climate model simulations, and show that anthropogenic warming of the upper ocean produces a detectable speed-up of low-latitude North Pacific oceanic planetary waves by the end of the 20th century. The projected percent increase in propagation speed for the end of the 21st century is about 35% (relative to pre-industrial) following one of the standard emission scenarios from the Intergovernmental Panel for Climate Change (IPCC). This remarkable simulated effect of oceanic warming on planetary wave propagation speed portends an important observed change in interannual climate variability.

**20 May, 12:35 (S1.2-4714)**

### **Fidelity in the present-day simulation and projected changes to the southern hemisphere extratropical ocean/sea-ice system in the AR4 coupled climate models**

Alexander Sen Gupta, Agus Santoso, Andrea Taschetto, Caroline Ummenhofer and Matthew H. England

Climate Change Research Centre, Faculty of Science, University of New South Wales, Sydney, NSW 2052, Australia.  
E-mail: a.sengupta@unsw.edu.au

The southern hemisphere extratropics boast one of the most profound and robust climate trends observed over the past few decades - a shift to an increasingly positive phase of the dominant mode of southern hemisphere (SH) extratropical variability, the Southern Annular Mode. This is characterised by a poleward shift and strengthening of the midlatitude jet. The surface signature of this atmospheric rearrangement has the potential to significantly modify characteristics of the ocean and sea-ice system. This is on the backdrop of, and intimately related to, unprecedented, large-scale increases in global temperatures and modifications to the hydrological cycle. Here we investigate the ability of the AR4 coupled climate models to realistically simulate the large-scale features of the SH extratropical ocean and sea-ice systems (for the end of the 20th century) pertaining to surface properties, mixed layer depths, water mass characteristics and lateral and overturning circulation. An assessment is further made of the projected changes to these properties over the next 100 years under the SRES A1B forcing scenario. Despite the existence of large inter-model differences many of the projected circulation changes are robust across the models. These changes are particularly associated with a poleward shift in the large-scale horizontal circulation, modifications to the SH overturning, a reduction in sea-ice extent and a shoaling of the deep mixed layers. Changes in oceanic circulation are consistent with a poleward shift in wind stress across the models. An investigation into the inter-model differences in surface forcing goes some way to explaining inter-model circulation variability.

**20 May, 12:50 (S1.2-4603)**

### **Antarctic ice-sheet melting provides negative feedbacks on future climate warming**

Didier **Swingedouw**, T. Fichet, P. Huybrechts, H. Goosse, E. Driesschaert and M.-F. Loutre

UCL, ASTR, Chemin du Cyclotron, 2, Louvain-la-Neuve, BE-1348, Belgium. E-mail: [swingedouw@astr.ucl.ac.be](mailto:swingedouw@astr.ucl.ac.be)

Anthropogenic greenhouse gas emissions are likely to affect climate for millennia, notably due to the large thermal inertia of the oceans and the long memory of the ice sheets. Archives of the past suggest noticeable Antarctic Ice-Sheet (AIS) melting contributions to sea-level changes during the last deglaciation and glaciation, illustrating the possibility of massive freshwater input into the Southern Ocean, which could have influenced the climate. Recent observations report an accelerated melting of the West Antarctic Ice Sheet. This ice melting may partly explain the observed freshening of the Ross Sea observed during the past four decades. Freshening also appears in the Antarctic Bottom Water (AABW) and could limit this deep-water formation in the future and affect climate. While none of the coupled climate models participating to the IPCC Fourth Assessment Report take into account the AIS melting, it is necessary to evaluate the potential effect of this melting on projected long-term global warming. Here we show by using a three-dimensional climate model, which includes a comprehensive representation of polar ice sheets, that AIS melting moderates warming in the southern hemisphere, by up to 10°C regionally, in a 4xCO<sub>2</sub> scenario of 3000 years. This behaviour stems from the formation of a cold halocline in the Southern Ocean, which limits sea-ice cover retreat under global warming and increases surface albedo, reducing surface warming. Furthermore, we show that AIS melting, by decreasing AABW formation, restrains the weakening of the Atlantic meridional overturning circulation, which is a new illustration of the effect of the bipolar oceanic seesaw. Consequently, it appears that AIS melting strongly interacts with climate and ocean circulation globally. It is therefore necessary to account for this coupling in future climate and sea-level rise scenarios.

**20 May, 14:30 (S1.2-4667)**

### **The sensitivity of the circulation, stratification and primary production of the northwest European continental shelf to climate change**

Jason **Holt**<sup>1</sup>, Sarah Wakelin<sup>1</sup>, Graham Tattersall<sup>1</sup>, Roger Proctor<sup>1</sup>, Icarus Allen<sup>2</sup>, Jerry Blackford<sup>2</sup>, Tim Smyth<sup>2</sup>, Jason A. Lowe<sup>3</sup>, Mark Gallani<sup>3</sup> and Mike Ashworth<sup>4</sup>

<sup>1</sup> Proudman Oceanographic Laboratory, 6 Brownlow Street, Liverpool L3 5DA, UK. E-mail: [jholt@pol.ac.uk](mailto:jholt@pol.ac.uk)

<sup>2</sup> Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK.

<sup>3</sup> Met. Office, Hadley Centre, FitzRoy Road, Exeter, Devon EX1 3PB, UK.

<sup>4</sup> STFC, Daresbury Laboratory, Warrington WA4 4AD, UK.

The physical and biological processes of shelf seas are strongly constrained by forcing from the atmosphere, ocean and land. Hence these regions might be expected to be highly sensitive to changing climatic conditions. Since these are regions of exceptionally high biological production and socio-economic importance, such changes may have wide ranging implications, e.g. for fisheries. Moreover, shelf seas have also been identified as playing a significant role in the Earth system as a whole, for example through their role in the global carbon cycle and water-mass formation and mixing. This opens up the possibility of feedbacks on longer time scales. We use multi-annual and multi-decadal model simulations of the Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) coupled to the European Regional Seas Ecosystem Model (ERSEM) to investigate how large scale modes of variability in the atmosphere and ocean propagate into the hydrodynamics of the northwest European continental shelf and then consequently to its ecosystem. The simulations are forced by both atmospheric re-analyses of the recent past (ERA-40) and by Met Office Hadley Centre regional climate model simulations of the late 20th century and the 21st century. Results from these two experiments are compared to investigate the variability of shelf-scale circulation, stratification and primary production, focusing on two periods: 1961-1990 and 2070-2100. Observations of hydrography, nutrients, chlorophyll and oxygen from the ICES database provide validation for the reference simulation.

**20 May, 14:45 (S1.2-4691)**

### **The Atlantic Multidecadal Oscillation in IPCC coupled model control and climate change simulations**

Francisco **Álvarez-García**, William Cabos-Narváez and María J. Ortiz-Beviá

Department of Physics, University of Alcalá, Ctra. Madrid-Barcelona, km. 33.6, Alcalá de Henares 28871, Spain.  
E-mail: franciscoj.alvarez@uah.es

Coherent variations in basin-wide North Atlantic sea surface temperature (SST) anomalies with a period of about 60-80 years constitute what is now generally referred to as the Atlantic Multidecadal Oscillation (AMO). These fluctuations, which influence distinct aspects of climate in the North Atlantic area, have been connected with changes in the thermohaline circulation and northward oceanic heat transport. The present study investigates the properties of the AMO in a set of global simulations with different coupled models whose output is available in the CMIP3 database. A Multichannel Singular Spectrum Analyses of the annual North Atlantic SST anomalies is used to extract the AMO signal. Its characteristics in different simulations and models are compared. The analysis is then extended to other atmospheric and oceanic fields in order to gain an insight into the physical mechanisms that might operate in different simulations and account for divergences among them.

**20 May, 15:00 (S1.2-4807)**

### **Surface wind-stress threshold for glacial Atlantic overturning**

Marisa **Montoya**<sup>1</sup> and Anders Levermann<sup>2,3</sup>

<sup>1</sup> Dpto. Astrofísica y Ciencias de la Atmósfera, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, Madrid 28040, Spain. E-mail: mmontoya@fis.ucm.es

<sup>2</sup> Earth System Analysis, Potsdam Institute for Climate Impact Research, Telegrafenberg A62, Potsdam 14473, Germany.

<sup>3</sup> Institute of Physics, Potsdam University, Am Neuen Palais 10, 14469 Potsdam, Germany.

Using a coupled model of intermediate complexity the sensitivity of the last glacial maximum (LGM) Atlantic Meridional Overturning Circulation (AMOC) to the strength of surface wind-stress is investigated. A threshold is found below which North Atlantic deep water formation takes place south of Greenland and the AMOC is relatively weak. Above this threshold, deep water formation occurs north of the Greenland-Scotland ridge, leading to a vigorous AMOC. This nonlinear behaviour is explained through enhanced salt transport by the wind-driven gyre circulation and the overturning itself. Both the pattern and magnitude of the Nordic Sea's temperature difference between strong and weak AMOC states are consistent with those reconstructed for abrupt climate changes of the last glacial period. Our results thus point to a potentially relevant role of surface winds in these phenomena.

**20 May, 15:15 (S1.2-4809)**

### **The AMOC in millennial ECHO-g climate simulations and future climate change scenarios**

Pablo **Ortega**, Marisa Montoya and Fidel J. González-Rouco

Dpto. Astrofísica y Ciencias de la Atmosfera, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, Madrid 28040, Spain. E-mail: portegam@fis.ucm.es

The main aim of this study is to analyse the Atlantic Meridional Overturning Circulation (AMOC) variability in one 1000-year long control simulation, two forced simulations of the last millennium and two IPCC climate change scenario simulations, all performed with the ECHO-g Atmosphere-Ocean General Circulation Model (AOGCM). Several Meridional Overturning Indices (MOI) are used to describe the behaviour of the ocean circulation in these simulations. Their evolution shows a weakening in the AMOC during the industrial era that intensifies through the 21st century. No complete collapse of the AMOC is observed in the future scenarios. Fourier and wavelet spectral analysis of the indices reveals an AMOC behaviour close to a red noise process and a tendency to present larger variability at interannual and multidecadal timescales. The short-term AMOC variability is similar in all the simulations, and is associated with atmosphere dynamics that force the ocean through changes in the wind stress. Low frequency forced and unforced AMOC variability responds to anomalies in ocean density. These are localised in the Atlantic basin in the control run, and develop at global-scales in the forced simulations.

**20 May, 15:30 (S1.2-4695)**

### **Biosphere-atmosphere-ocean interactions and climate change: the case of Amazon deforestation**

Paulo **Nobre**, Emanuel Giarolla, Domingos Urbano, Roberto de Almeida and Marta Malagutti

Centro de Previsão de Tempo e Estudos Climáticos (CPTEC), Instituto Nacional de Pesquisas Espaciais (INPE), Rodovia Presidente Dutra, Km 40, Cachoeira Paulista, SP 12630-000, Brazil. E-mail: pnobre@cptec.inpe.br

The Amazon rainforest is an important piece of the global climate system. With an annual mean precipitation in the order of 2 metres, it contributes to maintain the general circulation of the atmosphere and the oceans. One of the scenarios of future global warming present in the IPCC 4th Assessment Report is the gradual replacement of the exuberant Amazon rainforest for lower trees and bushes of savanna-type vegetation. This paper uses a suite of atmospheric and coupled biosphere-atmosphere-ocean general circulation models to study the impact of Amazon deforestation on global ocean circulation and climate. The results confirm early findings that Amazon deforestation leads to local increase of surface temperature and decrease of rainfall. In addition, this study suggests that global, ocean-atmosphere interactions are responsible for further Amazon rainfall reduction through the induction of enhanced ENSO-type ocean-atmosphere variability. Changes in tropical ocean temperature and circulation associated with the atmospheric response to the Amazon deforestation are also discussed.

**20 May, 15:45 (S1.2-4598)**

### **Influence of coloured noise in the ocean coupling on the thermohaline circulation**

Maria Nieves **Lorenzo**<sup>1</sup>, Isabel Iglesias<sup>1</sup> and Juan Jose Taboada<sup>2</sup>

<sup>1</sup> Department of Applied Physics, Faculty of Sciences, Campus de Ourense, University of Vigo, Ourense E-32004, Spain.  
E-mail: nlorenzo@uvigo.es

<sup>2</sup> Meteogalicia, X.E-15782 Santiago de Compostela, Spain.

In the last decades it has been established that the thermohaline circulation (THC) plays a major role in regulating the North Atlantic climate. Its formation is very sensitive to air-sea heat exchange and freshwater input in the North Atlantic. Therefore, many modelling studies have been performed in recent years in order to analyse the behaviour of the THC under a changing climate. Results show that the ocean-atmosphere system has more than one stable mode of operation and is very sensitive to different perturbations. In this work the effect of stochastic forcing in the coupling between an atmosphere and ocean system was considered. We have chosen a model where the ocean model couples to the atmospheric model through the restoring temperatures and the equivalent salt flux (differential net surface evaporation). In particular, previous analyses show that the equivalent salt flux presents considerable synoptic-scale variability with fluctuations about the seasonal mean in the order of 10-50%. Moreover, the equivalent salt flux should be related to the hydrological cycle, involving both river runoff (very important in the portion of the freshwater flux into the ocean basin) and the atmospheric meridional transport of water vapour. In this sense, we considered the study of the influence of stochastic forcing on  $Q_e$  and we considered a coloured noise such as was suggested by Hasselman. The results corroborate the necessity of considering stochastic forcing in climate models in order to minimise the uncertainty in the thresholds of possible abrupt change climate.

**20 May, 16:00 (S1.2-4579)**

### **Future winds off the Pacific coast of Canada**

William J. Merryfield<sup>1</sup>, Badal Pal<sup>1</sup> and Michael.G. **Foreman**<sup>2</sup>

<sup>1</sup> Canadian Centre for Climate Modelling and Analysis, Environment Canada, P.O. Box 1700, Victoria, BC, V8W 2Y2, Canada.

<sup>2</sup> Institute of Ocean Sciences, Fisheries and Oceans Canada, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada.  
E-mail: foremanm@pac.dfo-mpo.gc.ca

Global climate model output obtained from the Program for Climate Model Diagnosis and Intercomparison CMIP3 archive is used to examine projected changes in the winds off the Pacific coast of Canada. Extensive observations over the period of 1976 to 1995 at thirteen offshore buoys are first used to validate 10 m winds from eighteen models selected on the basis of data availability, and to establish baselines for statistical

downscaling. All models are shown to capture large scale aspects of the seasonal cycle. Magnitude and directional changes over the periods 2030-2049 and 2080-2099 under the SRES A1B scenario are then calculated for nearshore and offshore buoy groupings. Though the average changes are modest, the models do project a slight intensification and clockwise shift in summer winds at the offshore buoys. Winds from the Salathé *et al.* (2008) high-resolution climate model for the US Pacific Northwest are also obtained and used to demonstrate the limitations of statistical versus dynamical downscaling in regions with significant topographic variations.

**20 May, 16:15 (S1.2-4855)**

**A diagnostic model of mixed layer depth variability with application to Ocean Station “P” in the northeast Pacific**

Richard E. Thomson and Isaac V. Fine

Department of Fisheries and Oceans, Institute of Ocean Sciences, 9860 West Saanich Road, Sidney, BC, V8L 4B2, Canada.  
E-mail: Richard.Thomson@dfo-mpo.gc.ca

Direct determination of the surface mixed layer depth requires the measurement of turbulent mechanical mixing or observations from high precision temperature-conductivity profilers. Long-term measurements of these variables are difficult to sustain so that investigators typically seek estimators for mixed layer depth that can be derived from more readily available oceanic and meteorological time series. This study uses a simplified heat balance equation and remotely sensed surface data to formulate a simple diagnostic model for determining the depth of the mixed layer. Daily time series of mixed layer depth from early spring to late fall can be closely approximated using only records of the sea surface temperature and surface heat flux. A test of the diagnostic model using the 55-year series of oceanographic and meteorological data from Ocean Station “P” and recent data from Argo drifters for the northeast Pacific shows that the model provides more accurate estimates of mixed layer depth and is simpler to apply than established models. Application of the model to Station “P” shows that, contrary to what has been reported for late winter, there is no significant trend in the summer mixed layer depth at this mid-ocean location over the observation period 1951 to 2006 despite significant trends in the corresponding buoyancy and turbulent energy fluxes. The lack of trend has implications for studies of climate-induced changes in upper ocean productivity.

**20 May, 16:30 (S1.2-4745)**

**Study of the wind variation effects in the upwelling system along the Peruvian coast and consequences of climate change through numerical modelling**

Enrique E. Aguirre

Department of Fluid Mechanical Engineer, University National San Marcos, Alfonso Ugarte 408, San Cayetano, Lima 1 Peruvian, Lima 10, Australia. E-mail: Enrique.huaranga@gmail.com

Considering that the ocean and the atmosphere are a system that interact permanently, it is possible to observe at least two atmospheric forcings on the ocean. These forcings can be identified as wind stress on the sea surface and heat exchange flow: latent heat, absorption and refraction of the radiant sun. The eastern tropical and subtropical Pacific, particularly the coastal region of western South America, is affected by the *El Niño* Southern Oscillation (ENSO) event. In this work ERS-1 and ERS-2 scatterometer data of wind stress climatology are used to study Ekman pumping/suction and transport in the coastal ocean at 15°S and 5°S off Peru. I am tuning the Princeton Ocean Model (POM) to study oceanic circulation and Ekman dynamics along the Peruvian coast when the *La Niña* (1996-1997) and *El Niño* (1997-1998) events occurred. The model is forced by the wind stress and I use as initial conditions the temperature and salinity climatology. The analysis confirms that when strong *El Niño* events occur, the meridional wind stress has a dominant role in the intensity of coastal upwelling; the speed of Ekman pumping was nearly six times larger than the normal speed of Ekman suction and offshore Ekman transport nearly doubled.

# S1.2

## Posters

### Poster S1.2-4539

#### Representation of the Weddell Sea deep water masses in the ocean component of the NCAR-CCSM model

Rodrigo **Kerr**<sup>1</sup>, Ilana Wainer<sup>2</sup> and Mauricio M. Mata<sup>1</sup>

<sup>1</sup> Dept de Física Fundação Universidade Federal do Rio Grande, Av. Itália Km 8, Rio Grande, RS 96201-900, Brazil.  
E-mail: pgokerr@furg.br

<sup>2</sup> Instituto Oceanográfico, Dept. de Oceanografia Física Universidade de São Paulo, Praça do Oceanográfico 191, São Paulo, SP 05508-120, Brazil.

The Weddell Sea deep water mass distributions are examined with respect to the results from three different model runs using the oceanic component of the National Center for Atmospheric Research Coupled Climate System Model (NCAR-CCSM). One run is inter-annually forced by corrected NCAR/NCEP fluxes while the other two are forced with the annual cycle obtained from the same climatology. One of the latter runs includes an interactive ice-model. Optimum multiparameter analysis is applied to separate the deep water masses in the Greenwich meridian section (into the Weddell Sea only) to measure the degree of realism obtained in the simulations. First, the distribution of the simulated deep water masses are described using observed source water indices. Since the observed indices do not render an acceptable representation of the Weddell deep water masses as expected, these were specifically adjusted for each simulation. Differences between the water masses representation in the three simulations are quantified through their root-mean-square differences. Results here point out the need for better representation (and inclusion) of ice related processes in order to improve the oceanic characteristics and variability of dense Southern Ocean water masses on the outputs of the NCAR-CCSM model, and consequently in other ocean and climate models.

### Poster S1.2-4808

#### Heat content through the last millennium and in future climate change scenarios: an assessment using ECHO-g AOGCM simulations

Pablo **Ortega**<sup>1</sup>, Fidel J. González-Rouco<sup>1</sup>, Marisa Montoya<sup>1</sup> and Hugo Beltrami<sup>2</sup>

<sup>1</sup> Dpto. Astrofísica y Ciencias de la Atmosfera, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, Madrid 28040, Spain. E-mail: portegam@fis.ucm.es

<sup>2</sup> Environmental Sciences Research Centre, St. Francis Xavier University, P.O. Box 5000, Antigonish, NS, Canada.

This work analyses the ocean heat content (OHC) described by one 1000-year long control simulation, two forced simulations over the last millennium and two IPCC scenario simulations (A2 and B2), performed with the ECHO-g Atmosphere-Ocean General Circulation Model (AOGCM). Since the deepest layers of the ocean are stable, the heat content is integrated in the upper ocean. The forced experiments show a clear response to the external forcing at high and low-frequencies. A common result in all the simulations is that interannual variability of the OHC is found to be highest close to the equator, while the largest changes at interdecadal and secular timescales occur in the tropics. The amplitude of oscillations is considerably higher in the forced runs. In contrast with observations, our simulations exhibit the largest OHC changes in the Pacific basin, and the smallest in the Indian Ocean. In the future scenarios a gradual increase in the OHC is observed for the three basins, with maximum values above those simulated for the last millennium.

**Poster S1.2-4889**

**A global ocean current and tidal model with varying unstructured grids: application to the East China Shelf**

Huaming **Yu**, Xianwen Bao and Xueen Chen

College of Physical and Environmental Oceanography, Institute of Oceanography, Ocean University of China, 238 Songling Road, Qingdao, Shan Dong 266100, P.R. China. E-mail: huamingyu@gmail.com

In this paper a global ocean current and tide model (GOCTM) with varying unstructured grids was developed. The model is developed based on the philosophy of unstructured grids to conserve the water transported through model cells. The model takes advantage of the geometric flexibility of an unstructured triangular mesh system using a realistic global topography which also includes the Arctic. Thus, there is no open boundary condition to be considered. The first six partial tides were included as ephemerides forcing, and the model is fully baroclinic and 3-dimensional. As a general application, the model is first applied to the East China Shelf, which includes the Bohai Sea, Huanghai Sea and the East China Sea, and which has many marginal seas, channels and islands. In this application the model grids are globally refined over coastal areas, marginal seas and channels, especially those of the East China Shelf. The GOCTM is initialised by WOA05 climatological ocean temperature and salinity data, driven by surface heat flux and surface wind stress. Analysis of the model results indicates that the GOCTM reproduced the realistic global tidal harmonic constants well and the fundamental global general circulation fields, especially, those results over the East China Shelf were almost exactly reproduced. The transport of the Kuroshio and its sub-branches are in good agreement with observations. The seasonal variation of the Kuroshio extension and the main currents over the East China Shelf seems reasonable. The GOCTM provides a robust model to survey the interaction of the global ocean with coastal waters. This will allow us to more easily study the dynamic system and the ecosystem of the western Pacific under the climatic changes induced by the global warming.

## S2.1 Marine carbon cycling and other biogeochemical cycles

20 May, 10:35 (S2.1-4817) Invited

### Decadal changes in the Atlantic, Pacific and Indian Ocean inorganic carbon inventories

Christopher L. Sabine<sup>1</sup>, Richard A. Feely<sup>1</sup>, Frank J. Millero<sup>2</sup>, Andrew G. Dickson<sup>3</sup>, Rik Wanninkhof<sup>4</sup>, Dana Greeley<sup>1</sup> and Esa Peltola<sup>4</sup>

<sup>1</sup> Pacific Marine Environmental Laboratory, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: Chris.Sabine@noaa.gov

<sup>2</sup> Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, USA.

<sup>3</sup> Scripps Institution of Oceanography, University of California - San Diego, 9500 Gilman Drive, La Jolla CA 92093, USA.

<sup>4</sup> Atlantic Oceanographic and Meteorological Laboratory, NOAA, 4301 Rickenbacker Causeway, Miami, FL 33149, USA.

Discrete high-quality dissolved inorganic carbon and total alkalinity data were acquired as part of the international WOCE/JGOFS global CO<sub>2</sub> survey cruises in the early 1990s. These data provided a baseline global ocean carbon inventory. In 2003, the US CLIVAR/CO<sub>2</sub> Repeat Hydrography Program began reoccupying a subset of the WOCE/JGOFS lines on a ten year rotating schedule with the goal of quantifying the ocean uptake of anthropogenic CO<sub>2</sub> and the effects of natural variability and climate change on marine ecosystems and biogeochemistry. Although the survey is only half completed, cruises have been run in the Atlantic, Pacific and Indian Oceans allowing an initial comparison. We will discuss approaches for separating the anthropogenic CO<sub>2</sub> signal from variations in local circulation and biology using an extended multiple linear regression (eMLR) analysis. Anthropogenic CO<sub>2</sub> column inventory changes range from 0.25 to 0.75 mol m<sup>-2</sup> yr<sup>-1</sup> with some unexpected patterns. The largest inventory changes over the last 10 years were not found in the North Atlantic as suggested from changes since the preindustrial. Substantial DIC changes were observed in the North Pacific over the last decade, but as much as 80% of the change can be attributed to variations in circulation. The southern hemisphere oceans experienced the largest anthropogenic CO<sub>2</sub> inventory changes since the WOCE/JGOFS survey. We will examine the inventory change patterns and discuss the mechanisms leading to these changes. We also will discuss the total alkalinity results but find that there is insufficient evidence to conclude that there have been any measurable anthropogenic changes over the last 10-15 years.

20 May, 11:00 (S2.1-4954) Invited

### The changing uptake of CO<sub>2</sub> by the North Atlantic Ocean

Andrew J. Watson, P.J. Brown and U. Schuster

School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK. E-mail: a.watson@uea.ac.uk

The growing number of measurements over the last 10 years, both of surface *p*CO<sub>2</sub> and of subsurface parameters from repeat oceanographic sections, has begun to update our previously static “climatological” view of the ocean sink for CO<sub>2</sub>. In the North Atlantic we see that the uptake is very variable, changing coherently from year to year and by a factor of two from the mid-1990s to the early 2000s. The changes are due to altered rates of formation of sub-surface water masses such as the Labrador sea water. In transatlantic sections of calculated anthropogenic CO<sub>2</sub> we can see how its distribution is changing rapidly in the upper water column and the southward travelling deep western boundary current. These changes are in turn forced by climate variability, in particular, the North Atlantic Oscillation. Our conclusion that the uptake in the North Atlantic at least partly correlates with the NAO, is similar to our understanding of the equatorial Pacific, the other region where the time variability of air-sea flux is well-studied, and where it correlates closely with the ENSO. Most models of the sink for CO<sub>2</sub> in the North Atlantic do not reproduce the variability in uptake that we see, so it is difficult to forecast how it will evolve in the future. In particular, we cannot tell how much of the observed weakening of the sink is a response to anthropogenic climate change, and how much is due to natural variability – only a longer time series of measurements will answer this.

**20 May, 11:25 (S2.1-4670)**

## **What can surface fCO<sub>2</sub> measurements tell us about the evolution of the Southern Ocean CO<sub>2</sub> sink?**

Nicolas Metzl and Andrew Lenton

LOCEAN/IPSL, CNRS, Université P. et M. Curie, Case 100, 4 Place Jussieu, Paris, Cedex 05, 75252, France. E-mail: metzl@ccr.jussieu.fr

In this study trends of surface ocean CO<sub>2</sub> fugacity (fCO<sub>2</sub>) are estimated from observations conducted in 1991-2007 in the south-western Indian and Southern Oceans. These observed trends are also compared with recent ocean modelling and atmospheric inverse approaches that suggest that the Southern Ocean has experienced a reduction in carbon uptake over recent decades. In the latitudes 20°S-60°S we see that over the observational record the annually-averaged oceanic fCO<sub>2</sub> increased at a rate of 2.11 (±0.07) μatm/yr, i.e. about 0.4 μatm/yr faster than in the atmosphere. We also analyse the decadal variability in different regions (20-35°S, 35-40°S, 40-42°S and 50-55°S) and in different seasons. During the austral summer oceanic fCO<sub>2</sub> was seen to increase between +2.2 and +2.4 μatm/yr and was homogeneous across all regions. Conversely, during the austral winter, the growth rate is lower north of 40°S (+1.5 to +1.7 μatm/yr) in comparison to higher latitudes (+2.2 μatm/yr), broadly consistent with a Southern Annular Mode response. Our results show that *in situ* observations do suggest a reduction or near-stabilisation of the CO<sub>2</sub> sink in the Southern Ocean. To conclude we explore how well the trends can be simulated using an ocean biogeochemical model and how representative are these regional results of the greater Southern Ocean, over both the present and historical periods.

**20 May, 11:40 (S2.1-4701)**

## **Negative feedback of poleward intensifying southern hemisphere winds on atmospheric CO<sub>2</sub> in the 21st century**

Kirsten Zickfeld<sup>1</sup>, John C. Fyfe<sup>2</sup>, Michael Eby<sup>1</sup> and Andrew J. Weaver<sup>1</sup>

<sup>1</sup> School of Earth and Ocean Sciences, University of Victoria, P.O. Box 3055 STN CSC, Victoria, BC, V8W 3P6, Canada.

<sup>2</sup> Canadian Centre for Climate Modelling and Analysis, Environment Canada, University of Victoria, P.O. Box 1700 STN CSC, Victoria, BC, V8W 2Y2, Canada. E-mail: John.Fyfe@ec.gc.ca

An Earth System model is used to explore the response of the oceanic and terrestrial carbon sinks to strengthening and poleward shifting of the extratropical southern hemisphere winds, which is a robust feature of climate models' response to greenhouse gas forcing through the 20th and 21st centuries. We find that poleward intensifying southern hemisphere winds have an opposite effect on the uptake of natural and anthropogenic CO<sub>2</sub> in the Southern Ocean (90°S-40°S): altered winds lead to anomalous outgassing of natural CO<sub>2</sub> and anomalous uptake of anthropogenic CO<sub>2</sub>. As a result, uptake of total CO<sub>2</sub> (natural + anthropogenic) initially decreases and, from the end of the 20th century on, increases relative to the pre-industrial flux. On land, changing winds also lead to an enhanced efficacy of the CO<sub>2</sub> sink. We therefore suggest that poleward intensification of the southern hemisphere winds will likely provide for a negative feedback on atmospheric CO<sub>2</sub> in the 21st century. This feedback is found to be in the order of a few percent in 2100.

**20 May, 11:55 (S2.1-4708)**

## **The combined effects of rising atmospheric CO<sub>2</sub> and declining stratospheric ozone on the past and future uptake of CO<sub>2</sub> by the Southern Ocean**

Andrew Lenton<sup>1</sup>, Laurent Bopp<sup>2</sup>, Francis Codron<sup>3</sup>, Nicolas Metzl<sup>1</sup> and Patricia Cadule<sup>2</sup>

<sup>1</sup> LOCEAN/IPSL, Université Pierre et Marie Curie, Case 100, 4 Place Jussieu, 75252 Paris, Cedex 05, France.  
E-mail: andrew.lenton@locean-ipsl.upmc.fr

<sup>2</sup> LSCE/IPSL Orme des Merisiers, Bat 712, CEA/Saclay, 91198 Gif sur Yvette, France.

<sup>3</sup> LMD/IPSL, Université Pierre et Marie Curie, Case 99, 4 Place Jussieu, 75252 Paris, Cedex 05, France.

Recent observations suggest that the Southern Ocean is a decreasing sink of atmospheric CO<sub>2</sub>. This trend is linked to the Southern Annular Mode (SAM), the leading mode of climate variability in the Southern Ocean. The SAM in its positive phase increases wind speeds over the Southern Ocean decreasing the uptake of atmospheric CO<sub>2</sub>. The SAM is driven in equal parts by changes in both greenhouse gases (GHGs) and the Antarctic ozone hole. Coupled climate carbon models used to project the future response of the Southern Ocean have not been able

capture this decreasing trend in CO<sub>2</sub> uptake, nor the increasing wind speed. In this work we use the French IPSL coupled climate carbon model and prescribe an ozone hole in conjunction with GHGs, to reproduce the observed wind speed changes and hence the observed trend in CO<sub>2</sub> uptake over the historical period and thus project how under a higher wind speed regime the Southern CO<sub>2</sub> sink will respond in the future.

**20 May, 12:10 (S2.1-4854)**

### **Natural and anthropogenic carbon changes in mode waters of the south west Indian Ocean**

Claire **Lo Monaco**<sup>1</sup>, Andrew Lenton<sup>1</sup>, Nicolas Metz<sup>1</sup> and Keith B. Rodgers<sup>2</sup>

<sup>1</sup> LOCEAN-IPSL, Université Pierre et Marie Curie, Case 100, 4 place Jussieu, Paris, 75252 Cedex 05, France. E-mail: lomonaco@ccr.jussieu.fr

<sup>2</sup> AOS Program, Princeton University, Sayre Hall, Forrestal Campus, Princeton, NJ 08544, USA.

The CO<sub>2</sub> content in the present ocean is affected by both climate variability and anthropogenic CO<sub>2</sub> emissions. In an attempt to isolate the climate component in ocean carbon trends we evaluated jointly the change in total carbon (C<sub>T</sub>) and the accumulation of anthropogenic CO<sub>2</sub> (C<sub>ant</sub>). Mode waters are of particular interest here, both because they provide a privileged pathway for the transport of C<sub>ant</sub> into the ocean interior and because they are most sensitive to climate variability and change. Observations collected 15 years apart in the south-west Indian Ocean, a region where Subantarctic Mode Water is formed, show a small increase in mode waters C<sub>T</sub> (around 5 μmol/kg). The change in C<sub>ant</sub> estimated using three different methods is significantly higher (>10 μmol/kg over the 15-year period). The difference between changes in total and anthropogenic carbon must be explained by natural or climate change induced variability. We found that interannual variability has a relatively small impact on mode waters C<sub>T</sub>. Instead the small increase observed in C<sub>T</sub> as compared to the accumulation of C<sub>ant</sub> could result from a reduction in the biological activity as suggested by satellite data and/or decadal changes in ocean circulation. These different hypotheses will be discussed based on global ocean-carbon simulations.

**20 May, 12:25 (S2.1-4861)**

### **Advective impacts on North Atlantic carbon sink variability**

Galen A. **McKinley**<sup>1</sup>, David Ullman<sup>1</sup>, Val Bennington<sup>1</sup>, Stephanie Dutkiewicz<sup>2</sup> and Nicolas R. Bates<sup>3</sup>

<sup>1</sup> University of Wisconsin - Madison, Atmospheric and Oceanic Sciences and Center for Climatic Research, 1225 West Dayton Street, Madison, WI 53706, USA. E-mail: gamckinley@wisc.edu

<sup>2</sup> Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge MA 02139, USA.

<sup>3</sup> Bermuda Institute of Ocean Sciences, 17 Biological Lane, Ferry Reach, St. George's, GE 01, Bermuda.

Using a physical-biogeochemical model that is able to capture much of the seasonal variability in surface ocean pCO<sub>2</sub> across the North Atlantic and the interannual variability observed at Bermuda, we examine the impacts of changing horizontal advection on carbon sink variability across the basin. At Bermuda, preliminary results suggest that carbon sink variability that would be driven by the local atmospheric forcing is damped by anomalous advection of heat from the South Atlantic. Basin-wide, the net flux variability is small, but spatio-temporal variability in the carbon sink is due to decadal trends in the strength of gyre circulations. These results suggest that changes in the carbon cycle due to horizontal advection have first-order impacts on decadal variability in surface ocean pCO<sub>2</sub>, and thus on the spatial distribution of the North Atlantic carbon sink.

**20 May, 12:40 (S2.1-4928)**

### **Altimetry helps to explain patchy changes in repeat hydrography carbon measurements**

Keith B. **Rodgers**<sup>1</sup>, Anand Gnanadesikan<sup>2</sup>, Robert Key<sup>1</sup> and Jorge L. Sarmiento<sup>1</sup>

<sup>1</sup> AOS Program, Princeton University, Sayre Hall, Forrestal Campus, 300 Forrestal Road, Princeton, NJ 08544, USA.  
E-mail: krodgers@princeton.edu

<sup>2</sup> GFDL/NOAA, Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08542, USA.

Observations and models have been used to evaluate the relative amplitudes of natural variability and the anthropogenic perturbation in dissolved inorganic carbon (DIC) over the upper ocean. There are three main results: first, the amplitude of the natural variability of column inventories of DIC on seasonal to interannual

timescales is of the same order of magnitude as the anthropogenic transient signal as it changes over a decade. Second, the latitude/longitude pattern of natural variability is distinct from what is found for the decadal changes in anthropogenic DIC inventories. Third, that dynamically-driven variability constitutes at least a first-order component of the total background variability for DIC inventories. In particular, we focus here on the impact of local variability in circulation acting on background gradients in tracer concentrations in the ocean interior. Importantly, it is shown that natural DIC inventory variations are closely related to sea surface height variations over much of the ocean, with the North Atlantic being a notable exception. The underlying mechanisms and the implications for the detection of anthropogenic DIC using repeat hydrography measurements is presented.

**20 May, 12:55 (S2.1-4832)**

### **Understanding the impact of physical forcing on Southern Ocean phytoplankton and primary production**

Jill A. **Peloquin**, Zouhair Lachkar and Nicolas P. Gruber

Institute of Biogeochemistry and Pollutant Dynamics, ETH Zurich, Universitätstrasse 16, Zurich 8092, Switzerland.  
E-mail: jill.peloquin@env.ethz.ch

Phytoplankton in the Southern Ocean exist in a high nutrient, low chlorophyll regime where primary production rates and accumulation of large phytoplankton are often limited by seasonally and spatially heterogeneous interactions among light, iron and silicic acid. Uncertainty in the current controls of Southern Ocean phytoplankton impacts our understanding of how assemblages will respond under climate change scenarios. For instance, warmer temperatures and increased stratification will tend to favour higher rates of primary production while changes in windstress may alter upwelling of macro and micronutrients influencing regional patterns of primary production in complex ways. We regressed monthly mean climatology-corrected anomalies over time (1997-2007) in remotely-sensed and calculated fields of natural log-transformed chlorophyll *a* ( $\ln_{\text{chl } a}$ ), sea surface temperature, wind stress and primary production. Preliminary results indicate that the zonal mean  $\ln_{\text{chl } a}$  has increased in the Antarctic and Subantarctic Zones while phytoplankton biomass has decreased markedly in the Polar Front Zone and weakly in the Subtropical Zone. When zonal means are further decomposed by ocean basin or month (November-March), further complexity is introduced. In order to facilitate our understanding of Southern Ocean phytoplankton and the physical mechanisms that have significantly influenced them over the past decade, we will use self organising maps (SOM), a type of artificial neural network adept at pattern extraction from large and often non-linear data sets. Furthermore, we will compare our results with model output from a hindcast simulation with multiple phytoplankton functional groups (NCAR CCSM) coupled to the Parallel Ocean Program (POP) general ocean circulation model.

**20 May, 14:30 (S2.1-4601)**

### **An increase of silicic acid and nitrate concentrations along the pathway of Lower Circumpolar Deep Water in the Pacific Ocean: results of snapshot comparisons**

Michio **Aoyama**<sup>1</sup>, M. Fukasawa<sup>2</sup>, T. Kawano<sup>2</sup>, S. Kouketsu<sup>2</sup>, Y. Kumamoto<sup>2</sup>, A. Murata<sup>2</sup>, K. Sato<sup>3</sup> and H. Uchida<sup>2</sup>

<sup>1</sup> Geochemical Research Department, Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan.  
E-mail: maoyama@mri-jma.go.jp

<sup>2</sup> Institute of Observational Research for Global Change, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka 237-0061, Japan.

<sup>3</sup> Department of Marine Science, Marine Works Japan Ltd., 2-16-32 5F Kamariyahigashi, Kanazawa-ku, Yokohama, Kanagawa 236-0042, Japan.

Changes of nutrient concentrations and other hydrographic parameters such as temperature and dissolved oxygen concentration were observed when we compared WOCE revisited cruises in the 2000s and WOCE cruises in the 1980s and 1990s in the Pacific Ocean. A typical future of changes in nutrient concentrations are silicic acid concentration increased 1-2  $\mu\text{mol kg}^{-1}$  per decade, about 1% change per decade, if we can assume the changes are linear, along the pathway of Lower Circumpolar Deep Water (LCDW) in the North Pacific. We also found good positive correlation between silicic acid concentration and nitrate concentration, and negative correlation between silicic acid concentration and dissolved oxygen concentration. Since independent chemical measurements for nutrients and dissolved oxygen indicate the same direction of changes as water properties, these changes can be

thought to be much more reliable, although it is believed that there is less comparability of nutrient measurements at the present time. In the deeper layers in the eastern North Pacific, silicic acid concentration decreased in contrast with the areas of LCDW pathway. These findings showed that nutrient concentrations in the deeper layers might change systematically. These findings also suggest that northward LCDW and southward NPDW transport has decreased which is consistent with the previously reported warming of a few mK in the deep waters in the North Pacific Ocean by Fukasawa *et al.*, 2004 and Kawano *et al.*, 2006.

**20 May, 14:45 (S2.1-4643)**

### **Recent decrease of summer time nutrients in the mixed layer of the North Pacific HNLC region**

Tsuneo Ono<sup>1</sup>, Akihiro Shiimoto<sup>2</sup> and Toshiro **Saino**<sup>3,4</sup>

<sup>1</sup> Hokkaido National Fisheries Research Institute, 116 Katsurakoi, Kushiro 085-0802, Japan. E-mail: tono@fra.affrc.go.jp

<sup>2</sup> Faculty of Bio-industry, Tokyo Univ. of Agriculture, 196 Yasaka, Abashiri 099-2493, Japan.

<sup>3</sup> Hydrospheric Atmospheric Research Center, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan.

<sup>4</sup> Frontier Research Center for Global Change, JAMSTEC, Showa-cho, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.

Multi-decadal decreases of summer time nutrients in the mixed layer have been observed in various locations in the subarctic North Pacific, known as the third largest HNLC region in the world oceans. In this study we demonstrate, for the first time, that the decreasing trend is detectable over the entire subarctic North Pacific. We corrected 351 and 278 phosphate and silicate data, respectively, and these data were divided into two time groups before and after 1990 to investigate temporal changes. Area-averaged concentration decreased by  $0.07 \pm 0.05 \mu\text{M}$  and  $1.55 \pm 1.55 \mu\text{M}$  for phosphate and silicate, respectively, from the period 1975-1990 to 1991-2002. Close inspection of the time series data reveals that the differences are not the result of short-scale temporal variations such as *El Niño/La Niña* events. Instead, the decreasing trends are consistent with the linear trends observed in various time series stations, resulting from a multi-decadal SST increase. Our analysis indicates that the recent decrease of upward nutrient transport is larger than that of downward export production in the North Pacific HNLC region. This imbalance may have generated an oceanic carbon sink of  $12 \times 10^6$  ton C for the recent 30 years in the region. If we assume that this trend continues until the end of this century, 48% of the present subarctic North Pacific-HNLC region will change to a non-HNLC region as the result of nutrient decrease. This change may cause a considerable shift in the ocean ecosystem leading to significant changes in both the carbon cycle and fisheries of this region.

**20 May, 15:00 (S2.1-4820)**

### **Possible mechanism of decadal-scale variation in $\text{PO}_4$ concentration in the western north Pacific, and the influence on ocean productivity**

Kazuaki **Tadokoro**<sup>1</sup>, Tsuneo Ono<sup>2</sup>, Ichiro Yasuda<sup>3</sup>, Satoshi Osafune<sup>3</sup>, Yuji Okazaki<sup>1</sup>, Akihiro Shiimoto<sup>4</sup> and Hiroya Sugisaki<sup>5</sup>

<sup>1</sup> Tohoku National Fisheries Research Institute, 3-27-5 Shinhama, Shiogama Miyagi 985-0001, Japan. E-mail: den@affrc.go.jp

<sup>2</sup> Hokkaido National Fisheries Research Institute, 116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan.

<sup>3</sup> Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164-8639, Japan.

<sup>4</sup> Tokyo University of Agriculture, Faculty of Bio-Industry, 196 Yasaka, Abashiri, Hokkaido 099-2493, Japan.

<sup>5</sup> National Research Institute of Fisheries Science, 2-12-4, Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan.

Recent studies based on analyses of comprehensive ocean data sets have revealed decadal-scale variation in oceanographic conditions. Such variation has been attributed to trends associated with anthropogenically induced greenhouse warming and natural climate–oceanographic oscillations such as Pacific Decadal Oscillation. Variation in actual oceanographic conditions could be caused by a combination of both of these factors. Here, we suggest mechanisms of decadal-scale variation in  $\text{PO}_4$  concentration induced by these effects in the western North Pacific. Significant decreasing and increasing trends in  $\text{PO}_4$  have occurred in the surface and subsurface layers, respectively. Synchronous bidecadal-scale oscillations in  $\text{PO}_4$  were also found between the two layers. The differing relationships of the trend and oscillation between two layers suggests that these are driven by separate process. The trend component might be induced by attenuation of water exchange between the two layers due to a decrease in surface salinity in the North Pacific Ocean. On the other hand, the influence of the 18.6-year period nodal tidal cycle may cause the bidecadal-scale oscillation. The present process may be related

to decadal-scale variation in nutrient supply in a broad area of the North Pacific. *Neocalanus plumchrus* is a dominant mesozooplankton in the North Pacific. The biomass had a significant positive relationship with surface PO<sub>4</sub> in both waters. Variations in PO<sub>4</sub> supply might affect the biomass of *N. plumchrus* due to changes in primarily productivity.

**20 May, 15:15 (S2.1-4711)**

**Seasonal and interannual variation of ocean carbon cycling in the western and eastern tropical-subtropical Pacific: a physical-biogeochemical modelling study**

Masahiko **Fujii**<sup>1</sup>, Fei Chai<sup>2</sup>, Lei Shi<sup>2</sup>, Hisayuki Y. Inoue<sup>3</sup> and Masao Ishii<sup>4</sup>

<sup>1</sup> Sustainability Governance Project, Creative Research Initiative, Hokkaido University, N9W8, Kita-ku, Sapporo 060-0809, Japan  
E-mail: mfujii@sgp.hokudai.ac.jp

<sup>2</sup> School of Marine Sciences, 5706 Aubert Hall, University of Maine, Orono, ME 04469-5706, USA.

<sup>3</sup> Graduate School of Environmental Earth Science, Hokkaido University, N10W5, Kita-ku, Sapporo 060-0810, Japan.

<sup>4</sup> Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan.

A 3D physical-biogeochemical model is used to investigate spatiotemporal variations of the physical environment and oceanic carbon cycling in the tropical-subtropical Pacific. The physical model is based on the Regional Ocean Model System (ROMS) and the biogeochemical model is the Carbon Silicon Nitrogen Ecosystem (CoSiNE) model. The coupled physical-biogeochemical model is forced with the daily air-sea fluxes derived from the National Centers for Environmental Prediction (NCEP) reanalysis for the period of 1994 to 2004. The model results, of which performance was verified by two observations along 137°E and 155°W, show significant differences in seasonal and interannual variations of the water temperature, dissolved inorganic carbon (DIC), partial pressure of CO<sub>2</sub> in seawater ( $p\text{CO}_{2\text{sea}}$ ), and air-sea CO<sub>2</sub> flux, both longitudinally and latitudinally. The interannual variations, driven by various factors such as the global warming, ENSO and PDO, are more significant in the tropical regions than in the subtropical regions, and along 155°W than along 137°E, but the relative effect of each factor differs substantially with space. We identify a major cause of annual and interannual change in the  $p\text{CO}_{2\text{sea}}$ , by estimating the relative contribution of the water temperature, salinity, DIC and total alkalinity to the  $p\text{CO}_{2\text{sea}}$  change. The model results show that the cause of the interannual  $p\text{CO}_{2\text{sea}}$  increase is also different among the oceanic regions, and that the increase is primarily resulting from increase in the DIC along 155°W and the subtropical region of 137°E, and is mainly due to an increase in the water temperature in the tropical region along 137°E.

**20 May, 15:30 (S2.1-4777)**

**The impact of rising sea surface temperature on the cycling of organic matter: an indoor mesocosm study**

Julia **Wohlers**<sup>1</sup>, Anja Engel<sup>2</sup>, Eckart Zöllner<sup>1</sup>, Ulrich Sommer<sup>1</sup> and Ulf Riebesell<sup>1</sup>

<sup>1</sup> Leibniz Institute of Marine Sciences IFM-GEOMAR, Duesternbrooker Weg 20, Kiel 24105, Germany. E-mail: jwohlers@ifm-geomar.de

<sup>2</sup> Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, Bremerhaven 27570, Germany.

Recent climate models (e.g. the 4th IPCC report) predict an increase in global sea surface temperature of up to 6°C by the end of this century. Biological processes will respond differently to this, depending on their temperature-sensitivity. For instance, heterotrophic processes (e.g. bacterial degradation of organic matter) are expected to be more sensitive to temperature than autotrophic ones (e.g. photosynthesis), which are typically rate-limited by light or nutrient availability. As a consequence, global warming may affect the balance between production (source) and consumption (sink) of organic matter with possible feedbacks to climate change. To investigate the effect of rising temperature on the cycling and stoichiometry of organic matter during a phytoplankton spring bloom, we performed indoor mesocosm experiments using a natural Baltic Sea plankton community, and followed the build-up and decline of the bloom at four different temperature regimes. We observed significant temperature related effects on the uptake of dissolved inorganic carbon and on the production and fate of organic matter. Rising temperatures lead to an enhanced accumulation of dissolved organic matter and to a change in its C:N:P stoichiometry. In contrast, the concentration and elemental composition of particulate organic matter was less affected by changes in temperature. A sharp increase in transparent exopolymer particles was observed at elevated temperatures, potentially supporting the aggregation of organic matter. Based on these findings, the potential consequences of global warming for the cycling of organic matter in the surface ocean and the functioning of the biological pump will be discussed.

**20 May, 15:45 (S2.1-4965)**

### **Microbial dynamics and response to a changing polar ocean climate**

Richard B. **Rivkin**<sup>1</sup> and Louis Legendre<sup>2</sup>

<sup>1</sup> Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, NF, A1C 5S7, Canada. E-mail: rrvikin@mun.ca

<sup>2</sup> Laboratoire d'Océanographie de Villefranche, B.P. 28, 06234 Villefranche-sur-Mer Cedex, France.

Marine heterotrophic microbes (i.e. prokaryotic bacteria and eukaryotic protozoa) dominate the fluxes of organic carbon in the upper ocean, where they typically remineralise >75% of primary production back to CO<sub>2</sub>. Although these small organisms and their interactions are well studied in low latitudes, there is far less known about their distribution, community structure, activity and food web interactions, and their impact on upper open biogeochemistry in high latitudes. Despite the low temperatures, microbial processes are highly active and the rates of growth and elemental transformations are similar to those in lower latitudes. Profound climate changes are predicted for high latitude regions. These include altered temperatures, ice cover, mixing, and nutrient supply. These changes will influence the distribution of ice, physiochemical, biological and food web properties. In the present study, we report on a meta-analysis of a large database on heterotrophic microbes from the polar oceans. Using the results of database analyses, and conceptual and analytical models, we examine the influence of predicted changes in the climate in polar regions on microbial activity, their mediation of upper ocean biogeochemistry, and potential feedbacks on the cycling and flux of climate active properties.

**20 May, 16:00 (S2.1-4938)**

### **Climate mediated changes in phytoplankton productivity and air-sea CO<sub>2</sub> exchange on the western shelf of the Antarctic Peninsula over the last 30 years**

Martin A. **Montes-Hugo**<sup>1</sup>, Oscar Schofield<sup>1</sup>, Hugh W. Ducklow<sup>2</sup>, Douglas G. Martinson<sup>3</sup> and Ray Smith<sup>4</sup>

<sup>1</sup> Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley, New Brunswick, NJ 08901, USA.  
E-mail: montes@marine.rutgers.edu

<sup>2</sup> The Ecosystems Center, Marine Biological Laboratory, 7 MLB St., Woods Hole, MA 02543, USA.

<sup>3</sup> Lamont-Doherty Earth Observatory of Columbia University Palisades, NY 10964, USA.

<sup>4</sup> Department of Geography, University of California, Santa Barbara, Santa Barbara, CA 93106, USA.

Air temperatures along the Western Antarctic Peninsula have increased dramatically over the last 50 years which also corresponds with major retreats in the glaciers and disappearance of perennial sea ice. These changes will directly impact the phytoplankton productivity and associated elemental cycling, therefore we have been studying the time series changes in phytoplankton community composition and atmosphere-ocean differences in the CO<sub>2</sub> partial pressure ( $\Delta p\text{CO}_2 = p\text{CO}_{2,\text{sea}} - p\text{CO}_{2,\text{air}}$ ) over the western shelf of the Antarctic Peninsula (WAP) using ship and satellite data from 1978-2006. Satellite data shows the enhanced primary productivity (>2 mg Chl *a* m<sup>-2</sup>) in the southern sectors and declines in the offshore waters and in northern coastal waters. The satellite results were compared to an 18 year time series of phytoplankton pigments and discrete  $p\text{CO}_2$ . The January average (1993-2006) of  $\Delta p\text{CO}_2$  suggested a net 'sink' of CO<sub>2</sub> over the whole sampling grid however the size of the sink appeared to increase after the year 2000. Fucoxanthin (diatoms) explained >80% of the  $\Delta p\text{CO}_2$  variability, especially closer to the coast and in the southern part of the study area. A greater net 'sink' of atmospheric CO<sub>2</sub> during 2001-2006 with respect to 1997-2006 corresponded to increases in the contribution of larger diatom cells which presumably increased the efficiency of the carbon export flux. These results suggest that as the ice along the Western Antarctic Peninsula declined, the overall productivity and size of the biological CO<sub>2</sub> 'sink' has increased to the south.

**20 May, 16:15 (S2.1-4816)**

### **Characterisation of phytoplankton blooms and their contribution to export production**

Marie-Fanny **Racault**<sup>1</sup>, Corinne Le Quéré<sup>1,2</sup>, Erik T. Buitenhuis<sup>1,2</sup> and Trevor Platt<sup>3</sup>

<sup>1</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK. E-mail: m.racault@uea.ac.uk

<sup>2</sup> British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

<sup>3</sup> Bedford Institute of Oceanography, Dartmouth, NS, B2Y 4A2, Canada.

The oceans absorb one quarter of the fossil fuel CO<sub>2</sub> emitted to the atmosphere every year. Air-sea CO<sub>2</sub> flux is controlled by CO<sub>2</sub> solubility, physical processes and biological processes. One biological pathway that controls the draw down of CO<sub>2</sub> is the sinking of organic material following intense phytoplankton blooms. The current assumption is that

plankton blooms will continue into the future with the same level of activity as today. To estimate the contribution of phytoplankton blooms to export production, we used satellite chlorophyll data from the SeaWiFS sensor and the results of chlorophyll, primary production (PP) and export production (EP) from our global biogeochemistry model PlankTOM-5 that includes five plankton functional types. Phytoplankton blooms are characterised by their initiation dates, amplitudes and durations. Bloom initiation occurs earlier in the subtropics and propagates over a period of 10 weeks towards higher latitudes. Amplitudes of the bloom show increasing chlorophyll concentrations towards the north up to 2.5 mg Chl/m<sup>3</sup> in the northern hemisphere. In the Southern Ocean, maximum concentrations oscillate around 0.5 mg Chl/m<sup>3</sup>. Bloom durations range between 10-15 weeks in the subtropics to less than seven weeks at high-latitudes. In the northern hemisphere, between 30-60°N, cumulative PP during the bloom period is high compared to the southern hemisphere where PP values decrease towards the pole. Interestingly, the PP latitudinal trends observed in each hemisphere are coupled with both the variations in bloom amplitudes and durations. Spatial variations in PP and EP are shown to be associated with particular bloom characteristics.

**20 May, 16:30 (S2.1-4686)**

### **Formation of POC through interactions between TEP and mineral ballast**

Maya **Robert**<sup>1,2</sup> and Uta Passow<sup>1</sup>

<sup>1</sup> Biogeosciences Department, Alfred-Wegener-Institute for Polar and Marine Research (AWI), Am Handelshafen 12, Bremerhaven 27570, Germany. E-mail: Maya.Robert@awi.de

<sup>2</sup> Max Planck Institute for Marine Microbiology, Celsiusstrasse 1, Bremen 28359, Germany.

The reasons for the fairly constant ratio between particulate organic carbon and dry weight (POC: DW = 5%) observed globally in sinking matter below 1000 m are unclear. Possibly, these 5% POC represent a coating of organic carbon covering inorganic particles. We investigated the formation of POC from dissolved compounds in the presence of minerals during four 24-hour aggregation experiments. Exudates of diatom cultures (1.2 µm pre-filtered) were incubated with biogenic silica, smectite (clay) or CaCO<sub>3</sub> dust at concentrations ranging from 0 to 50 mg L<sup>-1</sup>. POC, DW and transparent exopolymer particles, TEP, which form abiotically from dissolved precursors, were measured. Microscopic aggregates formed everywhere, whereas macroscopic aggregates (> 0.5 mm) formed only in the smectite treatments. After 24 h, the POC: DW ratios of aggregates decreased exponentially with increasing biogenic silica, smectite and CaCO<sub>3</sub> concentrations, reaching minimum values of, 0.62%; 0.95% and 1.08%, respectively at a mineral concentration of 50 mg L<sup>-1</sup>. POC and TEP both increased with mineral concentration and were appreciably higher in smectite treatments compared to those with biogenic minerals. Microscopic observations revealed different attachment patterns between TEP and minerals, depending on the mineral. Our results show that the amount of organic matter coating minerals is ≤ 1%, too small to explain the 5% POC: DW found in traps. The carrying capacity of minerals for organic matter appears to depend on the mineral type and especially clays may enhance the transformation of dissolved material to POC.

**20 May, 16:45 (S2.1-4909)**

### **Comparing the carbon cycle response of two ocean ecosystem models to climate change**

Ian J. **Totterdell**

Met Office Hadley Centre for Climate Change, FitzRoy Road, Exeter EX1 3PB, UK. E-mail: ian.totterdell@metoffice.gov.uk

The uncertainty due to model structure in future ocean CO<sub>2</sub> uptake is examined. The natural carbon cycle in the ocean is strongly influenced by the “biological pump”: phytoplankton remove CO<sub>2</sub> from the surface waters for growth, some of which is exported to depth before returning to solution. This keeps the atmospheric CO<sub>2</sub> concentration much lower than it would be if it equilibrated with the high concentration in the deep ocean. The biological pump’s strength is determined by a number of factors, any or all of which may be affected by climate change, and it is expected to be a significant feedback on global warming. The size of this feedback is very uncertain however. In this study, two ocean ecosystem models of different complexities are used: the HadOCC model (a simple nutrient-phytoplankton-zooplankton-detritus model) and the Diat-HadOCC model (which additionally features two types of phytoplankton and the cycles of silicate and iron). Historical-future global warming scenario simulations are run with both models, and their climate change responses are compared in terms of the change in pattern and magnitude of CO<sub>2</sub> uptake from the atmosphere by the ocean, and in terms of the export flux of carbon. The inter-annual variabilities of these quantities in each model are compared to data and to each other. The effect of the additional processes in the Diat-HadOCC model (for example, those involving silicate and iron) is examined. Finally, a lower limit on our uncertainty in future ocean CO<sub>2</sub> uptake is deduced.

## S2.1

## Posters

### Poster S2.1-4531

#### Input of 'new' nitrogen by *Trichodesmium* in the Arabian Sea

Naveen **Gandhi** and R. Ramesh

Physical Research Laboratory, Planetary and Geosciences Division, Navrangpura, Ahmedabad, Gujrat, 380 009, India. E-mail: naveen@prl.res.in

*Trichodesmium*, an N<sub>2</sub>-fixer, provides 'new' nitrogen to the ocean waters and plays an important role in regulating marine productivity of the oceans which have traditionally been recognised as nitrogen limited. A *Trichodesmium* bloom occurs every year in the north-eastern Arabian Sea during the spring intermonsoon when winds are predominantly from the Arabian Peninsula and other parts of the Middle East. The wind-blown dust supplies bioavailable Fe which is the key element controlling the distribution and abundance of N<sub>2</sub>-fixers in ocean waters. The Arabian Sea is also known for intense denitrification, contributing ~60 TgN to the atmosphere annually. Therefore *Trichodesmium* plays a dominant role in nitrogen cycling, by supplying 'new' nitrogen in the Arabian Sea. Here we present an estimate of input of 'new' nitrogen by *Trichodesmium* during spring 2006 in the Arabian Sea. A cruise was undertaken in the northeastern Arabian Sea during April 2006 onboard FORV *Sagar Sampada*, (cruise #SS-244) where *Trichodesmium* presence was observed along the west coast of India. A bloom of *Trichodesmium* was ascertained at 20°31'N, 70°36'E. We detected excess nitrate (~35 mmol N m<sup>-2</sup>) in the top 20 m surface water at the bloom station. Nitrification of NH<sub>4</sub> released from the remineralisation of *Trichodesmium* could be the source of this excess nitrate. Our preliminary results show that the 'new' nitrogen input into the Arabian Sea in the form of excess nitrate (*Trichodesmium*-derived) appears to be comparable in magnitude to the estimated loss of nitrogen through denitrification.

### Poster S2.1-4568

#### Phytoplankton influence on atmospheric carbon dioxide under global climate change

Valeriy N. **Khokhlov**<sup>1</sup>, Alexander V. Glushkov<sup>2</sup>, Nataliya S. Loboda<sup>1</sup> and Tatiana V. Solonko<sup>2</sup>

<sup>1</sup> Hydrometeorological Institute, Odessa State Environmental University, Lvovskaya Street 15, Odessa 65009, Ukraine.  
E-mail: vkhokhlov@ukr.net

<sup>2</sup> Institute of Applied Mathematics, Odessa State Environmental University, Lvovskaya Street 15, Odessa 65009, Ukraine.

The carbon cycle dynamics in the atmosphere-ocean system are examined using a mathematical model consisting of ordinary differential equations. In the model, the oceanic CO<sub>2</sub> turnover is divided into 28 latitudinal belts with 5° width. The vertical ocean stratification includes the upper quasi-uniform layer (UQL), the thermocline layer, and the deep-sea layer (DL). The vertically uniform atmosphere is divided into the same zones as the ocean. The model variables are the molar concentration of non-organic carbon in each ocean block and carbon content as CO<sub>2</sub> in each atmospheric zone. The model considers the phytoplankton activity as both the rate of organic substance production in the UQL and the rate of organic substance decay in the UQL, thermocline, and DL. Our main results are the following. First, the maximal partial pressure of carbon dioxide dissolved in the UQL is registered at the equator whereas the minimal values of this variable are observed at the polar ocean. Another essential distinction of the polar ocean is that the largest differences between the results were obtained with and without taking into account the phytoplankton. Next, the tropical ocean is the CO<sub>2</sub> source for the atmosphere, whereas the carbon dioxide flows from the atmosphere into the ocean at high latitudes. Finally, the model outcomes for the adaptation time of the global climate system on the human economic activities show that if the ocean biota is taken into account then the adaptation time may be significantly decreased.

### Poster S2.1-4639

## The distribution of CO<sub>2</sub> surface partial pressure and air-sea CO<sub>2</sub> flux in El Mex Bay Alexandria, Egypt

Nayrah A. Shaltout<sup>1</sup>, Thanaa H. Mahmoud<sup>1</sup> and Mamdouh S. Masoud<sup>2</sup>

<sup>1</sup> Department of Marine Chemistry, National Institute of Oceanography and Fisheries, 1 Adeb Mouakad Street, Borg Aleman, Alsiouf Shamaa, Quitbay, Alexandria, 4020, Egypt. E-mail: Nayrahshaltout@yahoo.com

<sup>2</sup> Chemistry Department, Faculty of Science, Alexandria University, Alexandria, Egypt.

The partial pressure of CO<sub>2</sub> and air-sea fluxes were determined monthly during 2003-2004 in El-Mex Bay which is a shallow sheltered estuary west of Alexandria. Surface water partial pressure of CO<sub>2</sub> varied largely between 0.6 - 9464.2  $\mu\text{atm}$ . Its distribution was controlled by complex combinations of different factors such as volume and water quality of discharged waste water from different land based sources, biological activity, physical mixing processes, and fresh water residence time. El-Mex Bay surface water was found in most cases to be oversaturated with respect to the atmosphere and saturation percentages ranged between 0.16-2487.85%. The calculated water-atmosphere CO<sub>2</sub> flux showed a clear dependence on salinity. Water type L (brackish water with  $S < 10$ ) showed an annual average CO<sub>2</sub> flux to the atmosphere 148.54  $\text{mmol m}^{-2}\text{day}^{-1}$ , while the flux in water type M (mixed sea water with land drainage water type with salinity ranges  $10 < S < 30$ ) was 19.2  $\text{mmol m}^{-2}\text{day}^{-1}$ . The more saline zone which is water type D (diluted sea water with salinity  $30 < S < 35$ ) had the lowest annual average flux to the atmosphere of 2.94  $\text{mmol m}^{-2}\text{day}^{-1}$ . Different statistical studies, correlations and step wise regression analysis, were applied to evaluate the effect of phytoplankton standing stock, salinity, sea surface temperature, dissolved oxygen, and pH on sea water  $p\text{CO}_2$  distribution. These studies reflect the great effect of the El-Umum Drain and other land based sources on the carbon cycle in the bay.

### Poster S2.1-4648

## A higher storage of anthropogenic carbon in the Indian Ocean?

Marta Álvarez<sup>1</sup>, Claire Lo Monaco<sup>2</sup>, Toste Tanhua<sup>3</sup>, Andrew Yool<sup>4</sup>, Andreas Oschlies<sup>3</sup>, John L. Bullister<sup>5</sup>, Catherine Goyet<sup>6</sup>, Frank Touratier<sup>6</sup>, Rik Wanninkhof<sup>7</sup>, Dave Wisegarver<sup>5</sup>, Elaine McDonagh<sup>4</sup> and Harry L. Bryden<sup>4</sup>

<sup>1</sup> Department of Biogeochemistry, IMEDEA (CSIC-UIB), C/ Miquel Marqués 21, Esporles, Mallorca 07190, Spain  
E-mail: marta.alvarez@uib.es

<sup>2</sup> LOCEAN/IPSL - Université Paris 6 - place Jussieu 4, 75252 Paris, France.

<sup>3</sup> IFM-GEOMAR, Düsternbrooker Weg 20, 24105, Kiel, Germany.

<sup>4</sup> NOCS, Waterfront Campus European Way, Southampton SO14 3ZH, UK.

<sup>5</sup> NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, USA.

<sup>6</sup> IMAGES, Université de Perpignan, 52 avenue Paul Alduy, 66860 Perpignan, France.

<sup>7</sup> NOAA/AOML/PHOD, 4301 Rickenbacker Causeway, Key Biscayne, FL 33149, USA.

For the first time in March-April 2002 a full-depth high-resolution 32°S trans-Indian Ocean section was sampled for CO<sub>2</sub> variables: pH, alkalinity (TA) and some total inorganic carbon (TIC) for internal consistency control. The main goal of this project was to measure the meridional overturning circulation in the southern boundary of the Indian Ocean. On the other hand, the 2002 CO<sub>2</sub> data will allow the first direct estimation of anthropogenic carbon (CANT) in the subtropical Indian Ocean and eventually enable us to close the CANT budget in this ocean. In this work we present, compare and discuss the CANT inventory along 32°S following different techniques: three back-calculation techniques, Sabine *et al.* (1999), Lo Monaco *et al.* (2005) and the TrOCA method (Touratier *et al.*, 2007). We present two modifications to the Sabine *et al.* (1999) method which improved the preformed TA and the preindustrial preformed TIC estimation. The Lo Monaco *et al.* method yields higher CANT specific inventories than the Sabine *et al.*, and finally the TrOCA method. The inventories will be discussed by water masses, as deep waters with a southern origin could have some CANT signal as pointed out by tracers. The discrepancies arise from the assumptions in each method to estimate the biological contribution and the preindustrial preformed TIC or in the case of Sabine *et al.*, the so called disequilibrium. We will be comparing the transient time distribution (TTD) method applied to CFC-11, 12 and CCl<sub>4</sub> and the results from a general circulation ocean model to estimate CANT. One of the main questions is whether the CANT inventory in the Indian Ocean has been previously underestimated and what are the strengths and drawbacks of each method.

### Poster S2.1-4660

#### ***Trichodesmium* sp. population structure along the North Atlantic subtropical gyre**

Ricardo **González Gil**, Juan Höfer, Fernando González and Ricardo Anadón

Área de Zoología, del Dpto. de Biología de Organismos y Sistemas, Facultad de Biología de la Universidad de Oviedo, C/ Catedrático Rodrigo Uría s/n, Oviedo E33071, Spain. E-mail: rgonzalezgil@gmail.com

The role of *Trichodesmium* sp. in the cycle of nitrogen remains one of the main objectives on the climate change research agenda. Because of its potential to fix atmospheric N<sub>2</sub>, these species play an important role in the patterns of marine primary productivity in the subtropical zones and thus, also in the global carbon cycle. In this work, building on data collected along a transect in the North Atlantic subtropical gyre during the CARPOS cruise (planktonic carbon fluxes in subtropical oligotrophic environments: a lagrangian approach, October-November 2006), we describe population level patterns of abundance and size structure for this important organism. Samples were obtained using 53 µm mesh triple WP2 nets towed vertically from 200 m to the surface. In the laboratory, *Trichodesmium* trichomes were counted and measured. We differentiate between free trichomes and those forming colonies (puffs and tufts). Strong spatial variation was detected; previous abundance patterns were confirmed and variation in size-structure was also detected. These changes were related to physical variation as well as to community wide patterns like chlorophyll *a* and zooplankton biomass. Finally, we assessed the implications of population heterogeneity on nitrogen fixation rates obtained from existing size-based, physiological relationships, in order to disentangle the contribution of such patterns to nutrient cycles.

### Poster S2.1-4673

#### **Dissolved oxygen and nutrient export by new Antarctic Bottom Water in the Ross Sea**

Paola **Rivaro**<sup>1</sup>, Serena Massolo<sup>1</sup>, Roberta Messa<sup>1</sup>, Pasquale Castagno<sup>2</sup>, Giorgio Budillon<sup>2</sup> and Andrea Bergamasco<sup>3</sup>

<sup>1</sup> Department of Chemistry and Industrial Chemistry, University of Genoa, via Dodecaneso 31, 16146 Genoa, Italy. E-mail: rivaro@chimica.unige.it

<sup>2</sup> Department of Environmental Sciences, Parthenope University, Naples, Italy.

<sup>3</sup> National Research Council, Institute of Marine Sciences, CNR-ISMAR Castello 1364/A 30122, Venice, Italy.

The Ross Sea is one of the major contributors to the Antarctic Bottom Water (AABW). Two shelf waters (SW) participate in the formation of AABW: the High Salinity Shelf Water (HSSW), characterised by salinities between 34.75 and 34.85, and the Deep Ice Shelf Water (DISW), defined by temperatures below the freezing point. Circumpolar Deep Water (CDW) is a relatively warm ( $\theta > 1^\circ\text{C}$ ), low oxygen and nutrient rich water mass, transported onto the shelf in a pulsing but persistent way at specific locations. Intense tidal vertical mixing of SW with the local CDW intrusion near the shelf break produces new AABW. Dissolved oxygen and nutrient data were collected across the shelf break off Cape Adare (Victoria Land) and off the Glomar Challenger Basin during the 2005-2006 austral summer by the CLIMA (Climatic Long-term Interaction for the Mass-balance in Antarctica) and PolarDOVE (Polar Deep Ocean Ventilation) projects within the XXI Italian Antarctic Expedition. The thermohaline measurements were performed using a SBE 9/11 plus CTD and water samples for chemical analyses were collected from 12 litre Niskin bottles. Dissolved oxygen was measured by the Winkler method, while nutrients were determined using an Autoanalyser Technicon II. Two separate 300 kHz RDI Workhorse ADCP heads were used as a lowered ADCP system to measure the dynamical field. In this work we estimated and compared the export of nutrients and oxygen ventilating the bottom layers at the two areas. A comparison with data collected in the 1998-2003 surveys is also presented to evaluate the variability of the properties of the new AABW.

### Poster S2.1-4688

#### **Marine system sensitivity to iron speciation and organic complexation**

Nicholas **Stephens**<sup>1</sup> and Olivier Aumont<sup>2</sup>

<sup>1</sup> CNRS, Laboratoire des Sciences de l'Environnement Marin, Institut Universitaire Européen de la Mer, Place Nicolas Copernic, Technopôle Brest Iroise, Plouzané 29280, France. E-mail: nicholas.stephens@univ-brest.fr

<sup>2</sup> Laboratoire d'Océanographie et de Climatologie: Expérimentations et Approches Numériques IRD/IPSL, Plouzané 29280, France.

A number of recent studies have elucidated some of the complicated reactions of marine iron biogeochemistry. The present study uses one dimensional models to investigate and parameterise a series of different model representations based on these recent studies and data sets. The one-dimensional models will investigate the role

of iron speciation and organic complexation with respect to biogeochemical modelling. The one dimensional models also allow us to investigate parameter sensitivity and are used as an initial step for inclusion into a three dimensional model. Here we show results that address questions concerning the role of different iron species and the role of iron complexing with differing organic compounds. The iron representation is embedded in a NEMO-PISCES, physical-biogeochemical coupled model. This allows the investigation of questions concerning iron chemistry, biological iron availability, and in particular marine system sensitivity due to changes in iron biogeochemistry.

## Poster S2.1-4690

### Nitrogen fixation and nitrogen cycles in a Plankton Functional Type model

Nicholas **Stephens**<sup>1</sup>, Corinne Le Quéré<sup>2,3</sup> and Erik T. Buitenhuis<sup>3</sup>

<sup>1</sup> CNRS, Laboratoire des Sciences de l'Environnement Marin, Institut Universitaire Européen de la Mer, Place Nicolas Copernic, Technopôle Brest Iroise, Plouzané 29280, France. E-mail: nicholas.stephens@univ-brest.fr

<sup>2</sup> The British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0BT, UK.

<sup>3</sup> School of Environmental Sciences, University of East Anglia, Norwich NR7 4TJ, UK.

A number of approaches are being developed to address ocean nutrient dynamics in terms of chemistry, ocean physics and biology. One such approach is to use models based on the representation of Plankton Functional Types (PFT's) and the associated geochemistry, coupled to a physical ocean model. These PFT based models, in addition to enabling us to more adequately evaluate biogeochemical responses of marine systems, allow the investigation of multi-nutrient limitation (light, nitrogen (N), phosphorus (P), iron, silicon), the response of external N:P concentrations, and changes in community structure due to changing nutrient and physical conditions. The focus of this presentation is on results from present studies evaluating the response of N<sub>2</sub> fixation to the changing community structure, fluxes of N<sub>2</sub> fixation and denitrification (including aspects of anammox), subsequent implications for N:P concentrations, and responses in air-sea gas exchange. Of particular relevance is the response of the nitrogen cycle, community structure, primary productivity and export to changing physical conditions (such as warming, stratification and changes in circulation) that are used to evaluate marine system sensitivity and potential feedbacks on climate.

## Poster S2.1-4693

### Macrozooplankton in the global ocean biogeochemical model PlankTOM10

Róisín **Moriarty**<sup>1,2</sup>, Erik T. Buitenhuis<sup>2</sup> and Corinne Le Quéré<sup>1</sup>

<sup>1</sup> British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK. E-mail: roim@bas.ac.uk

<sup>2</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK.

Macrozooplankton play an important part in the removal of carbon from the surface layers of the ocean to the deep ocean. Their role in the export of large particulate organic carbon distinguishes them from other types of zooplankton. The explicit representation of macrozooplankton in a Plankton Functional Type (PFT) model is essential to capture the effect they have on the natural carbon cycle. Especially synthesised data sets for process rate measurements allow macrozooplankton to be represented in such a biogeochemical model - PlankTOM10. This model has been developed to include 10 PFTs. Process rate data are used to constrain macrozooplankton parameters. Preliminary runs show realistic values for primary production, export, air-sea CO<sub>2</sub> flux, and phytoplankton biomass. However, the group is overly abundant when compared to an independent validation data set of macrozooplankton biomass. Sensitivity analysis on well-populated data sets will allow these rates to be better constrained. The more poorly constrained parameters such as food preference will be investigated using the model. Little is known about the influence of macrozooplankton on the carbon cycle. PlankTOM10 will allow investigations into their interannual variability, links between macrozooplankton and fisheries and *vice versa*, and their vulnerability to climate change.

### **Poster S2.1-4700**

#### **Importance of organic matter in nutrient cycles and carbon dioxide sequestration in the oligotrophic waters of the Gulf of Aqaba: open water versus fish farms**

Mohammad **Badran**

Marine Science Station, University of Jordan/Yarmouk University, P.O. Box 195, Aqaba 7722, Jordan. E-mail: abudam@ju.edu.jo

Three years of observations (2004-2007) on inorganic and organic nutrients in the open water column and recent observations (1 year) at a floating cages on a fish farm site are discussed. Three distinctive dissolved inorganic nutrient (DIN) pools are observed in the open water column. First is the shallow DIN pool (photic zone), where DIN concentrations rise during winter mixing, and drop to undetectable levels during summer stratification. Second is the deep water pool, where the DIN inventory is generally steady except for sharp variations as a direct response to water column stability alteration. Third is an intermediate water pool, where an extensive decrease in the DIN reservoir is observed during mixing, similar to deep water, however the recovery is relatively slow and can last throughout the whole period of stratification. Net decomposition of organic matter in the case of the open water column occurs in two major areas, on the sediment and in intermediate water (200-400 m). After the winter and spring productivity bloom, the Particulate Organic Matter (POM) either sinks to the bottom or suspends in the water column and recycles back to DIN through dissolved organic compounds (DON). The rate of POM remineralisation is dependant on the persistence of the DON produced in this process. While labile DON molecules are oxidized on a scale of days, semi-labile DON has a half life of months. Thus the more labile DON forms the faster DIN concentration boost after stratification; and the more semi labile DON forms the more carbon is sequestered and driven to the bottom. Fish farms are a major source of POM and DON. A detailed budget of organic and inorganic nutrients in the water column under fish cages (20 m-40 m) and in the bottom sediments has been generated; and DON persistence compared to that naturally produced in the open water column. This is to assess floating cage fish farms effects on carbon dioxide recycling in waters of the Gulf of Aqaba as a model of oceanic water.

### **Poster S2.1-4722**

#### **Mesozooplankton respiration in the North Atlantic subtropical gyre and its implications for the carbon cycle**

Juan **Höfer** and Florentina Alvarez-Marques

Area de Ecología del Dpto. de Biología de Organismos y Sistemas, Facultad de Biología de la Universidad de Oviedo, C/ Catedrático Rodrigo Uría s/n, Oviedo 33071, Spain. E-mail: juanhofer@gmail.com

Nowadays one of the most challenging tasks in environmental sciences is the quantification of the ocean's role in the carbon cycle, because of its potential impact in the cycle and in climate change. The biological pump could be an important factor in the withdrawal capacity of the ocean, especially in regions where zooplankton cover hundreds of metres in their diel vertical migration (DVM). In this work, we build on data taken during the CARPOS cruise (Planktonic carbon fluxes in subtropical oligotrophic environments: a lagrangian approach, October-November 2006), and describe the mesozooplankton community and its diel vertical migration. Samples were obtained with LHPR (200 µm mesh size) hauls from 700 m, where the deep scattering layer was found, to surface. Finally we estimate the whole community respiration rate using the existing size-based physiological relationships for the different zooplankton groups, in order to assess the amount of carbon removed and transported by the mesozooplankton community.

### **Poster S2.1-4724**

#### **Estimation of the seasonal pattern of carbon dioxide in a coastal lagoon**

Stefano **Ciavatta**<sup>1,2</sup>, Giorgio Ferrari<sup>3</sup> and Roberto Pastres<sup>2</sup>

<sup>1</sup> EuroMediterranean Centre for Climate Change (CMCC) c/o Consorzio Venezia Ricerche, Via della Libertà 12, Venice 30175, Italy. E-mail: ciavatta@unive.it

<sup>2</sup> Department of Physical-Chemistry, University of Venice, Dorsoduro 2137, Venice 30123, Italy.

<sup>3</sup> Magistrato alle Acque di Venezia, 19 San Polo-Rialto, Venice 30125, Italy.

A carbonate system model was applied to investigate the seasonal pattern of carbon dioxide in the Lagoon of Venice, Italy, as a function of the temporal evolution of photosynthesis and respiration. Carbonate speciation was estimated on the basis of hourly pH data, collected by a real-time monitoring network, and of alkalinity

data. The model was applied to estimate the hourly evolution of the inorganic carbon species at different lagoon sites characterised by the presence of different communities of primary producers at different time windows in the period 2002-2005. The model outputs are consistent with the short-term evolution of the dissolved oxygen time series observed at the same sites. The statistical analysis of the simulated time series shows that the fluctuations of the carbon species can be explained by circadian cycles and are strongly influenced by climate forcing, e.g. temperature and solar radiation, and the community being considered. Carbon budgets based upon the model outputs obtained at different time windows highlighted that the lagoon may act as a carbon source for the atmosphere, depending upon the season and the site. Because our analysis can be easily implemented and applied to other case studies, we think that it could represent a straightforward way to extract valuable information about marine ecosystem functioning and to compute carbon budgets on the basis of data being collected in many estuaries as part of routine monitoring programmes.

## Poster S2.1-4738

### Spatial distribution of phytoplankton production and biomass in the Hudson Bay Complex during summers 2004 to 2006

Joannie **Ferland**<sup>1,2</sup>, Michel Gosselin<sup>1</sup>, Michel Starr<sup>2</sup> and François Saucier<sup>1</sup>

<sup>1</sup> Institut des sciences de la mer de Rimouski, Université du Québec à Rimouski, 301 allée des Ursulines, Rimouski, QC, G5L 3A1, Canada

<sup>2</sup> Maurice Lamontagne Institute, Ocean and Environmental Science Branch, Fisheries and Oceans Canada, Mont-Joli, QC, G5H 3Z4, Canada.  
E-mail: joannie.ferland@uqar.qc.ca

The spatial distribution of phytoplankton production and chlorophyll *a* (chl *a*) biomass in the Hudson Bay Complex is investigated for the months of August and September between 2004 and 2006. Sampling was conducted at 6 stations along a longitudinal transect in the northern Hudson Bay (ca. 60°N) and at 4 to 6 stations in the Foxe Basin and Hudson Strait (FBHS). Samples from the euphotic zone were size-fractionated to determine the contribution of small (0.7-5 µm) and large cells (>5 µm) to total phytoplankton production and biomass. During the three sampling years, total production and chl *a* biomass were significantly higher in the FBHS area than in the Bay (243 to 3444 vs 54 to 929 mg C m<sup>-2</sup> d<sup>-1</sup> and 29 to 87 vs 6 to 51 mg chl *a* m<sup>-2</sup>, respectively). Primary production was generally dominated by small cells, except in the Hudson Strait in 2004. Chl *a* biomass, however, was dominated by large cells, except in the bay in 2005. Small cells generally account for a higher proportion of the production than their contribution to the chl *a* biomass. These results suggest that small phytoplankton cells were grazed intensively by microzooplankton whereas large cells accumulated within the euphotic zone. During this study, total production was inversely correlated with density stratification of the water column. This suggests that vertical mixing controls the phytoplankton production distribution, through its effect on nutrient supply. Future enhancement of the upper water column stratification by warming and freshwater input from precipitation may affect the phytoplankton production of the Hudson Bay complex.

## Poster S2.1-4744

### Effects of two different iron sources on the iron cycle in the subarctic North Pacific

Kazuhiro **Misumi**<sup>1</sup>, Daisuke Tsumune<sup>1</sup>, Takeshi Yoshimura<sup>1</sup>, Jun Nishioka<sup>2</sup>, Frank O. Bryan<sup>3</sup>, Keith Lindsay<sup>3</sup>, J. Keith Moore<sup>4</sup> and Scott C. Doney<sup>5</sup>

<sup>1</sup> Central Research Institute of Electric Power Industry, 1646 Abiko, Abiko, Chiba 270-1194, Japan. E-mail: misumi@criepi.denken.or.jp

<sup>2</sup> Institute of Low Temperature Science, Hokkaido University, North 19 West 8, Kita-ku, Sapporo, Hokkaido 060-0819, Japan.

<sup>3</sup> Climate and Global Dynamics Division, National Center for Atmospheric Research, Boulder, CO, USA.

<sup>4</sup> Department of Earth System Science, University of California at Irvine, Irvine, CA, USA.

<sup>5</sup> Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA, USA.

Dissolved iron concentrations in the subarctic North Pacific (SNP) are higher in the western region (WSNP) than in the eastern region (ESNP) at intermediate depths. The higher concentrations in the WSNP are considered to be due to 1) higher aeolian iron inputs in WSNP and/or 2) horizontal transport of iron from the continental shelf of the Sea of Okhotsk. By conducting numerical experiments, we examine which process more reasonably accounts for the iron distribution in the SNP. We used a Parallel Ocean Program combined with the Ocean Carbon Model Inter-comparison Project biotic carbon model which was modified by addition of a prognostic equation for productivity and inclusion of iron as a co-limiting nutrient. Three cases of experiments (CTL, DST and OKH) were conducted changing the way of iron input to the WSNP. In CTL, the model was forced with

aeolian iron input. In DST, the input fluxes in the WSNP were increased by factor of 10. In OKH, iron flux was considered to intermediate water of WSNP from the area of Kuril Islands. The additional flux in OKH was similar to the one in DST. The higher iron concentrations in intermediate water of WSNP are simulated in DST and OKH. In DST, however, the concentrations in surface water largely exceed those shown in observational data. The results suggest that the iron transport from the continental shelf of the Sea of Okhotsk is playing an important role in the iron cycle in SNP.

## Poster S2.1-4764

### Mechanisms underlying coastal waters CO<sub>2</sub> emissions

Ana Paula **Oliveira**, Graça Cabeçadas and Marta Nogueira

Instituto Nacional de Recursos Biológicos (INRB-IPIMAR), Avenida de Brasília, Lisboa 1449-006, Portugal. E-mail: aoliveira@ipimar.pt

In the CO<sub>2</sub> context, assessment of the role played by coastal waters adjacent to the Tagus and Sado estuaries (Portugal) was done based on data from May 2000, 2002 and 2003, periods representative of spring conditions. The estimated CO<sub>2</sub> fluxes reached, respectively, mean values of 6, 14 and 29 mmol CO<sub>2</sub> m<sup>-2</sup> d<sup>-1</sup>. In May 2000 the absence of upwelling and the moderate river flow (190 m<sup>3</sup> s<sup>-1</sup>) favoured the generation of a pronounced Tagus river plume enriched in nutrients, which induced significant phytoplankton growth (chlorophyll *a* up to 9.5 mg m<sup>-3</sup>), and the consequent uptake of CO<sub>2</sub>. Therefore, a decrease in surface water CO<sub>2</sub> partial pressure (*p*CO<sub>2</sub>) lowered the CO<sub>2</sub> emissions. In May 2002, a moderate upwelling event induced an increase of *p*CO<sub>2</sub>, and the development of phytoplanktonic *Coccolithus braarudii* species constituted an additional source of CO<sub>2</sub> to the water. Actually, the presence of such a phytoplanktonic bloom led to production of about 5 tons of calcite, which resulted in the release of 7.4 mmol CO<sub>2</sub> m<sup>-2</sup> d<sup>-1</sup>. During the more intense upwelling event, in May 2003, CO<sub>2</sub> emissions exhibited higher values, most likely, attributed to the upwelled waters enriched in dissolved inorganic carbon, and to the occurrence of a considerable river discharge (280 m<sup>3</sup> s<sup>-1</sup>). Despite the different conditions and processes responsible for the CO<sub>2</sub> emissions one may conclude that the respective coastal area functions as a source of CO<sub>2</sub> to the atmosphere, contributing to the global warming process.

## Poster S2.1-4781

### The Australian SAZ-SENSE study of the sensitivity of the Sub-Antarctic Zone to climate change: an introduction

Thomas W. **Trull**, A.R. Bowie, A. Davidson, F.B. Griffiths, P. Thomson, S.R. Rintoul, B. Tilbrook, S. Wright and the SAZ-SENSE team

Antarctic Climate and Ecosystems Cooperative Research Centre, University of Tasmania, Australian Antarctic Division and CSIRO Marine and Atmospheric Research, PB 80, Hobart, Tasmania 7001, Australia. E-mail: Tom.Trull@utas.edu.au

Sub-Antarctic Zone (SAZ) waters east of Tasmania (ET) exhibit higher levels of satellite chl *a* in than west of Tasmania (WT). The ET waters are affected by the input of sub-tropical waters from eddies of the East Australia Current, with some westward flow occurring south of Tasmania in summer. This flow forms part of the southern hemisphere super-gyre, which connects the Pacific and Indian oceans. That circulation contributes much of the variability in the total east-west transport between Australia and Antarctica, and is likely to be subject to climate changes such as southward movement and/or intensification of the westerly winds. The Tasman Sea to the east of Tasmania has experienced rapid warming over the past few decades. In summer 2007, the ACE CRC undertook an ET vs. WT comparison of biogeochemistry and microbial ecosystem function, with the overall objective to assess what changes might be expected in the circumpolar SAZ if it evolves from the cold low biomass WT to the warmer higher biomass ET state. Preliminary results suggest ET waters had a greater fraction of production from >20 μm phytoplankton, suggesting a more efficient transfer to higher trophic levels. Higher ET iron levels contributed to the enhanced production, but the pathways of iron delivery are not yet clear, nor are their possible responses to climate change. These results and previous work in the Southern Ocean suggest that ecosystem change may be driven by changes in iron supply from the ocean margins as much as it is from physico-chemical changes within the ocean.

### **Poster S2.1-4787**

#### **Uncertainties in the global carbon budget: the contribution of echinoderms to the shelf/neritic export at present**

Mario **Lebrato**, Darryl Green, Nadia Suárez-Bosche and M. Débora Iglesias-Rodríguez

National Oceanography Centre, University of Southampton, European Way, Southampton SO14 3ZH, UK. E-mail: ml1104@soton.ac.uk

The available estimates of carbon production, export, and accumulation in the neritic, shelf, and deep-sea areas are a limited representation of the global carbon budget. It has been assumed that the pelagic contribution of calcium carbonate is dominated by planktonic organisms yet the contribution of large calcium carbonate producing animals has been overlooked. Among these animals, echinoderms colonise environments ranging from the continental shelf down to the deep-sea. The reported values for neritic carbon export carry uncertainties of up to 100% in shelf and neritic environments. At present, the content of inorganic carbon carried by these organisms and that in the sediment remains an open question. We present the contribution of inorganic and organic carbon in a subset of ecologically relevant echinoderm species. We discuss the results in a biogeochemical context both in present-day and in future climate scenarios.

### **Poster S2.1-4811**

#### **Long-term nutrient changes in the southern Benguela: intensified upwelling due to global climate change?**

Jock C. **Currie**<sup>1</sup>, Mike I. Lucas<sup>1</sup>, Larry Hutchings<sup>2</sup> and Howard N. Waldron<sup>3</sup>

<sup>1</sup> Zoology Department, University of Cape Town, Private Bag X3, Rondebosch, Cape Town 7701, South Africa. E-mail: jockcurrie@gmail.com

<sup>2</sup> Marine and Coastal Management, Private Bag x2, Rogge Bay, Cape Town 8012, South Africa.

<sup>3</sup> Oceanography department, University of Cape Town, Private Bag X3, Rondebosch, Cape Town 7701, South Africa.

A predicted result of climate change on upwelling systems, is that an increasing thermal gradient between land and sea will result in greater equatorward winds driving greater upwelling intensity. Notable ecosystem changes have been documented in eastern boundary upwelling regions in recent decades, including the southern Benguela, where dominance shifts in pelagic fish and striking changes in zooplankton, demersal fish, linefish, squid, rock lobster and seabird abundances have been shown. Nutrient availability has undeniable bottom-up influences on upwelling systems, ultimately determining food web pathways by mediating phytoplankton competition and succession. We have compiled a long-term study of nutrient variability, including hydrographic data, for St Helena Bay in the southern Benguela upwelling region. Using subsurface measurements to avoid an uptake signal from phytoplankton and general linear models (GLMs) to remove seasonal effects, pronounced interannual variation was observed. Nitrate and phosphate concentrations both increased significantly between 1983 and 2004, by ~40% and ~50% respectively. Silicate shows no similar trend over this period. Oxygen concentrations showed a significant (~30%) downward trend between 1960 and 2004. Increased primary productivity is the most likely cause of elevated organic matter regeneration and oxygen utilisation. Neither complementary wind or chlorophyll data sets were obtainable for purpose of comparison with results. The increase in nutrients and decrease in oxygen have important implications for biogeochemical cycles, ecosystems and commercial fisheries. Due to its retention of upwelled water and organic material, St Helena Bay could provide an effective early warning system to detect and study changes in upwelling intensity and their consequences.

### **Poster S2.1-4844**

#### **Net metabolic balance in the eastern and central North Atlantic subtropical gyre in October-November 2006**

María **Aranguren-Gassis**<sup>1</sup> and the CARPOS team

<sup>1</sup> Universidad de Vigo, Departamento de Ecología y Biología Animal, Carretera Colegio Universitario s/n, 36310 Vigo, Pontevedra, Spain. E-mail: aranguren@uvigo.es

The contribution of the marine biota to oceanic carbon budgets remains a debated issue, partly because of the uncertainties in the net balance between the processes of production, export and oxidation of organic matter. These uncertainties make it difficult to elucidate the role of the ocean on climate change, and to anticipate the

effect of climate change on the marine biota. While the magnitude and variation of primary production (PP) in the ocean is relatively well known, the reason for this lack of knowledge is the paucity of measurements of respiration (R), which impede constraining net metabolic balance estimations. Such paucity is particularly important in the oligotrophic areas of the open ocean, representing 80% of the world ocean surface. We present here concurrent measurements of PP, R and net community metabolism in the photic layer made during a cruise that traversed from the eastern side to the centre of the North Atlantic subtropical gyre in October-November 2006. A zonal transect of 7 stations was initially sampled from 14°W-34°N to 26°W-36°N, with the aim of verifying the existence of a gradient in the net metabolism of the plankton communities from the periphery to the central region of the gyre. This sampling was followed by two lagrangian experiments, in the central, and NE marginal areas of the North Atlantic subtropical gyre. The results show the disparities on the net metabolic balance between different oligotrophic areas of the open ocean.

### Poster S2.1-4847

#### The dynamics of dimethylsulphide and dimethylsulphoniopropionate in a global prognostic model

Meike **Vogt**<sup>1</sup>, Sergio Vallina<sup>1</sup>, Laurent Bopp<sup>2</sup>, Erik T. Buitenhuis<sup>1</sup> and Corinne Le Quéré<sup>1,3</sup>

<sup>1</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK. E-mail: m.vogt@uea.ac.uk

<sup>2</sup> IPSL/LSCE, Orme des Merisiers, CE Saclay, Gif-sur-Yvette F- 91191, France.

<sup>3</sup> British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

Dimethylsulphide (DMS) is a climate relevant trace gas involved in cloud formation. DMS emission is also the most important pathway by which sulphur is recycled from the ocean to the land. DMS is produced from its marine precursor dimethylsulphoniopropionate (DMSP) in interactions within marine ecosystems. Here, we study the dynamics of DMS and DMSP using the global ocean biogeochemistry model PlankTOM5, which includes 3 phytoplankton and 2 zooplankton functional types. A fully prognostic DMS module describes intracellular particulate DMSP production, concentrations of dissolved DMSP and DMS production and consumption. The model produces annual mean DMS fields that compare reasonably well with observations, and predicts emissions of 23 TgS/yr for the present period. The interannual variability of DMS is low in temperate and tropical region and increases towards the high latitudes, where highest values for DMS are found. While the absolute values for the interannual variabilities of DMS and chlorophyll *a* are predicted to be similar by the model, their spatial distributions are different. The model can reproduce the summer paradox in parts of the low latitudes, but underpredicts DMS at the Bermuda Atlantic Time series station (BATS). We use the model to study the impact of ecosystem composition on DMS concentration patterns and fluxes. We find that while plankton distribution matters, bacterial parameters are also important for DMS concentration patterns. The introduction of strong light dependencies in the model improves the results for the summer paradox, but decreases the importance of ecosystem composition.

### Poster S2.1-4872

#### Testing potential impacts of changes in precipitation temporal patterns on biogeochemical properties of a coastal marine ecosystem

Cosimo Solidoro<sup>1</sup>, Gianpiero Cossarini<sup>1</sup>, Simone **Libralato**<sup>1</sup>, Stefano Salon<sup>1</sup> and Filippo Giorgi<sup>2</sup>

<sup>1</sup> Department of Oceanography, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Borgo Grotta Gigante, Brisciki 42/c, 34010 Sgonico, Zgonik (TS), Italy. E-mail: csolidoro@ogs.trieste.it

<sup>2</sup> International Centre for Theoretical Physics Abdus Salam ICTP, Strada Costiera, 34100, Trieste, Italy.

A downscaling approach has been used to assess potential effects of variations in nutrient loads induced by climate changes on the water quality of the Lagoon of Venice (Italy). The analysis is based on a hierarchy of dynamic and statistical models for linking climatic changes to effects on biogeochemical processes. The outputs of the regional climate model for present day scenario (1961-1990) are compared with local climatological observations as well as reanalyses of observations. Results showed a good agreement in terms of both monthly area averages and seasonal spatial distribution of precipitation data and mean frequency of rainy events is also satisfactorily reproduced. Moreover, outputs of regional climate model simulations for present day and future (A2 and B2 IPCC emission scenarios) conditions are used to force two statistical models that provide forcing and boundary

conditions for a 3D coupled transport biogeochemical model of the lagoon. Under both A2 and B2 IPCC scenarios we observe a strengthening of seasonal precipitation patterns (drier summer and rainier winter), which affect timing of nutrient inputs to the lagoon. In particular, results in terms of future spatio-temporal dynamics of biogeochemical properties evidenced that nutrient loads are, with respect to the reference scenario, higher in wintertime and lower in summertime. In winter nutrients are not used by phytoplankton, whose growth is limited by temperature, and are mainly exported from the system. Conversely, reduced nutrient inputs in summer strengthen their limiting effect for primary production. This causes a reduction of the planktonic productivity of the ecosystem.

## Poster S2.1-4875

### Interannual to decadal variability of the carbon cycle in the Pacific simulated in a 3-dimensional model

Akio **Ishida**<sup>1,2</sup>, Maki N. Aita<sup>1,2</sup> and Yasuhiro Yamanaka<sup>1,2,3</sup>

<sup>1</sup> Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3173-25, Showamachi, Kanazawa-ku, Yokohama 236-0001, Japan. E-mail: ishidaa@jamstec.go.jp

<sup>2</sup> Core Research for Evolutional Science and Technology (CREST), Japan Science and Technology Agency (JST), Kawaguchi 332-0012, Japan.

<sup>3</sup> Graduate School of Environmental Earth Science, Hokkaido University, N10W5, Kita-ku, Sapporo 060-0810, Japan.

To improve our understanding of physical and biological impact on the carbon cycle in the Pacific Ocean, interannual to decadal variability of the carbon cycle is diagnosed with a 3-dimensional physical-biogeochemical model. The simulations have been performed with two boundary conditions for atmospheric  $p\text{CO}_2$ : one using the historical increase in atmospheric  $p\text{CO}_2$  from year 1837 to 2002 (historical run), another with a constant pre-anthropogenic concentration of 278 ppmv (control run) in order to quantify the anthropogenic carbon cycle. The modelled surface ocean at the Hawaiian Ocean Time series (HOT) shows a long term shift in carbonate equilibrium to lower pH and lower saturation states of the carbonate mineral aragonite, which are consistent with the observation. The model simulates two dominant climate variations; Pacific Decadal Oscillation (PDO) and *El Niño*/Southern Oscillation (ENSO). In the central North Pacific, primary production and biomass increase after the climate shift during the mid-1970s, and  $\text{CO}_2$  flux also exhibits interannual-decadal variability. The variations of natural and anthropogenic  $\text{CO}_2$  flux are in phase, i.e. both increase and decreases in the central Pacific interannual to decadal scales. In contrast to the phase relation in the central Pacific, the variations of natural and anthropogenic  $\text{CO}_2$  flux are out of phase in the eastern Pacific, i.e. air-to-sea flux of anthropogenic  $\text{CO}_2$  decreases when natural  $\text{CO}_2$  flux increases and *vice versa*. This is explained with physical conditions such as upwelling and thermocline variability associated with *El Niño* and *La Niña*.

## Poster S2.1-4880

### Estimation of ocean carbon uptake with an Earth system model under $\text{CO}_2$ stabilisation scenario projection

Toru **Miyama** and Michio Kawamiya

Frontier Research Center for Global Change, JAMSTEC, 3173-25 Showamachi, Kanazawa-ku, Yokohama, Kanagawa, 236-0001, Japan. E-mail: tmiyama@jamstec.go.jp

For mitigation of global warming, the  $\text{CO}_2$  concentration must be stabilised at some level, and the amount of the permissible emission of  $\text{CO}_2$  for the stabilisation should be estimated. The  $\text{CO}_2$  stabilisation means that anthropogenic  $\text{CO}_2$  emission is balanced by nature uptake. Therefore, using an integrated Earth system model, we calculated the carbon fluxes in and out of the natural terrestrial and oceanic carbon cycle under prescribed  $\text{CO}_2$  stabilisation concentration scenarios from year 1850 to 2300. What we found is that the land carbon cycle would relatively quickly adjust to equilibrium within the 21st century under stabilising  $\text{CO}_2$  level. Furthermore, the global warming could change the terrestrial environment from a carbon sink to source by enhanced respiration. Thus the land would not be a reliable  $\text{CO}_2$  sink in the long term. On the other hand, the ocean would remain as sink beyond the year 2300 because the ocean needs a long time to equilibrate.  $\text{CO}_2$  uptake would gradually decrease during the adjustment to the stabilised  $\text{CO}_2$  concentration. Although the

feedback by climate change is relatively small compared with the land, the warmer sea temperature would reduce carbon uptake by the ocean. Under the 550 ppm stabilisation scenario, the ocean carbon uptake accumulated from the year 1850 to 2300 amounts to 600 PgC while the uptake reduction by climate change feedback is estimated as 108 PgC.

### Poster S2.1-4893

#### **A coupled approach data/model to infer the decadal changes of the surface carbon dioxide and related parameters in the Mediterranean Sea**

Ferial **Louanchi**<sup>1</sup>, M. Boudjakdji<sup>1</sup>, M. Belounis<sup>2</sup>, A. Taalba<sup>3</sup> and L. Nacef<sup>4</sup>

<sup>1</sup> Institute for Marine Sciences and Coastal Management, BP 19, Bois des cars, Dely-Brahim, Algiers 16320, Algeria.

E-mail: f\_louanchi@ismal.net

<sup>2</sup> University of Liège (Ulg), place du 20 août 9, Liège B-4000, Belgium.

<sup>3</sup> University of Perpignan, 52 Avenue Paul Alduy, Perpignan 66860, France.

<sup>4</sup> Office National de la Météorologie (ONM), Dar El Beida, Algiers, Algeria.

A coupled approach based on available data sets of temperature, salinity, oxygen, nutrients and chlorophyll (from Medatlas, 2002), and a model previously developed (Louanchi *et al.*, 1996) and modified for the present work, allows a reconstruction of dissolved inorganic carbon (DIC) and total alkalinity (TA) mixed-layer fields in the Mediterranean Sea. The modelled carbonate system parameters are validated using available data sets for this region. The errors do not exceed 10% of the modelled fields. From pre-anthropogenic conditions to the 1990s, the Mediterranean Sea has been a sink for atmospheric CO<sub>2</sub>, the amplitude of this sink being the weakest in the 1980s. Decadal variations of the carbonate system parameters are analysed considering the changes in physical and biological conditions over the decades. According to the model results, the atmospheric CO<sub>2</sub> increase since the pre-anthropogenic period is responsible for a DIC increase of about 70 μmol/kg, and a pH decrease of about 0.08 in surface waters. As a consequence, the carbonate saturation state has decreased by about 0.5 and 0.7 in aragonite and calcite, respectively. Future changes in pH and carbonate saturation are investigated according to several IPCC scenarios.

### Poster S2.1-4939

#### **Evaluation of DMS concentrations under global warming conditions by means of a mechanistic global ocean biogeochemistry model (PlankTOM5)**

Sergio **Vallina**<sup>1</sup>, Meike Vogt<sup>1,2</sup>, Erik T. Buitenhuis<sup>1</sup> and Corinne Le Quéré<sup>1,2</sup>

<sup>1</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK. E-mail: sergio.vallina@uea.ac.uk

<sup>2</sup> British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

Dimethylsulfide (DMS) emissions from the oceans and subsequent conversion to sulphate aerosols in the atmosphere is believed to affect the optical properties of low-height clouds through its influence on the number and density of cloud condensation nuclei (CCN). Higher number of CCN (e.g. from DMS oxidation to sulfates) imply more optically dense (whiter) and more persistent clouds, thus increasing albedo and therefore cooling the Earth's surface. This natural mechanism of increasing the Earth's albedo and reducing global temperature through the oceanic production and emission of DMS has been suggested to partially compensate human-driven global warming. In order to test the hypothesis that under global warming conditions oceanic DMS production will be enhanced (negative feedback) we have run a state-of-the-art global ocean biogeochemistry model (PlankTOM5) with atmospheric forcing(s) corresponding to a global warming IPCC scenario (SRES98-A2). PlankTOM5 comprises of 29 biogeochemical tracers and includes 3 phytoplankton (silicifiers, calcifiers and mixed phytoplankton) and 2 zooplankton (micro- and mesozooplankton) functional types as well as an explicit characterisation of DMS dynamics, a prognostic formulation for DMS and its oceanic precursors. PlankTOM5 is coupled to the General Circulation Model (NEMO2). Although still very preliminary, our results point towards a non-significant and spatially inhomogeneous change of global surface DMS concentrations under global warming conditions, that is probably not enough to offset the anthropogenically-driven temperature increase.

## S2.2 Ocean acidification and coral reef bleaching

21 May, 10:35 (S2.2-4800) Invited

### Ecosystem effects of ocean acidification in times of ocean warming: a physiologist's view

Hans O. **Pörtner**

Alfred-Wegener-Institute for Polar and Marine Research, Marine Animal Physiology, Bremerhaven D-27515, Germany.  
E-mail: hans.poertner@awi.de

Ocean warming and acidification occur at global scales and, in the case of temperature, have already caused shifts in marine ecosystem composition and functioning whereas, in the case of CO<sub>2</sub>, effects may still be so small that evidence for changes in the field is lacking. However, depending on ecosystem characteristics, future scenarios indicate a threatening of marine life forms through the specific or synergistic effects of both factors. This paper builds on the view that development of a cause and effect understanding is required beyond empirical observations, for a secure projection of ecosystem effects and for the development of quantitative scenarios. Identification of the mechanisms through which temperature and CO<sub>2</sub> related ocean physicochemistry affect organism fitness, survival and success, is crucial in this research strategy. From present evidence I suggest that the operation of unifying physiological principles, not only of temperature but also CO<sub>2</sub> effects, across animal groups and phyla. Thermal windows of optimised performance emerge as a basic character defining species success and survival, including their capacity to interact with other species. Through effects on performance at levels of reproduction, behaviour and growth, ocean acidification acts especially on lower marine invertebrates characterised by a low capacity to compensate for disturbances in extracellular ion and acid-base status. The key consequence is a narrowing of thermal tolerance windows, of the scope for performance at ecosystem level and of associated ranges of geographical distribution.

21 May, 11:00 (S2.2-4860) Invited

### Acidification of the Arctic Ocean

James C. **Orr**<sup>1</sup>, Sara Jutterström<sup>2</sup>, Laurent Bopp<sup>3</sup>, Leif G. Anderson<sup>2</sup>, Victoria J. Fabry<sup>4</sup>, Thomas Frölicher<sup>5</sup>, Peter Jones<sup>6</sup>, Fortunat Joos<sup>5</sup>, Ernst Maier-Reimer<sup>7</sup>, Joachim Segschneider<sup>7</sup>, Marco Steinacher<sup>5</sup> and Didier Swingedouw<sup>8</sup>

<sup>1</sup> Marine Environment Laboratory, IAEA, 4 Quai Antoine 1er, MC-98000, Monaco. E-mail: j.orr@iaea.org

<sup>2</sup> Department of Chemistry, Göteborg University, Göteborg S-412 96, Sweden.

<sup>3</sup> LSCE, UMR CEA-CNRS, CEA Saclay, Gif-sur-Yvette F-91191, France.

<sup>4</sup> Department of Biol. Sciences, Cal. State University San Marcos, San Marcos, CA 92096-0001, USA.

<sup>5</sup> Climate and Environmental Physics, University of Bern, Bern CH-3012, Switzerland.

<sup>6</sup> Bedford Institute of Oceanography, Dartmouth, NS, B2Y 4A2, Canada.

<sup>7</sup> Max Planck Institut für Meteorologie, Hamburg D-20146, Germany.

<sup>8</sup> Université Catholique de Louvain, Institut d'Astronomie et de Géophysique Georges Lemaître, Louvain-La-Neuve B-1348, Belgium.

Climate change in the Arctic will be amplified, leading to reduced sea-ice cover, warming and freshening of surface waters, and changes in vertical stratification. The Arctic Ocean will also undergo acidification. Previous modelling studies suggest that the coldest surface waters of the Southern Ocean will be the first to become undersaturated with respect to aragonite, the metastable form of calcium carbonate (CaCO<sub>3</sub>), i.e. within 50 years under the IS92a scenario. However, those studies did not discuss the potential for similarly dramatic changes in the Arctic Ocean, owing to a lack of gridded baseline data in the region. To assess CaCO<sub>3</sub> saturation in the Arctic Ocean, we used recent data along trans-Arctic sections as a baseline, to which we added 21st century perturbations in DIC, alkalinity, temperature, salinity, and nutrients from three coupled carbon-climate models forced under the SRES A2 scenario. In our projections by the year 2020, some Arctic Ocean surface waters become undersaturated with respect to aragonite and all surface waters succumb to these conditions by 2050. By 2100, all surface waters become undersaturated with respect to calcite, the stable form of CaCO<sub>3</sub>. At risk are pelagic and benthic marine calcifiers, including bivalve molluscs, a prominent species of the Arctic-shelf benthic community which serve as a major food source for walrus, grey whales, and spectacled eiders. Our findings indicate that owing to amplified Arctic climate change, which exacerbates effects from elevated CO<sub>2</sub>, undersaturated conditions detrimental to ecosystems will develop first in the Arctic Ocean, not in the Southern Ocean as suggested previously.

**21 May, 11:25 (S2.2-4786)**

### **Detecting climate change impacts in coral reef calcification**

Chris **Langdon**<sup>1</sup>, Sarah Cullison<sup>2</sup>, Michael DeGrandpre<sup>2</sup>, Wade McGillis<sup>3</sup>, David Kadko<sup>1</sup> and Jorge E. Corredor<sup>4</sup>

<sup>1</sup> University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149, USA.  
E-mail: clangdon@rsmas.miami.edu

<sup>2</sup> The University of Montana, Department of Chemistry, Missoula, MT 59812, USA.

<sup>3</sup> Columbia University, Lamont Doherty Earth Observatory, Palisades, NY 10964, USA.

<sup>4</sup> University of Puerto Rico Mayagüez, P.O. Box 908, Lajas 00667, Puerto Rico.

Ocean acidification can cause a significant reduction in coral reef calcification. Extrapolation of experimental results suggests that rates may fall below threshold levels required to offset erosive processes. Detecting climate change effects on coral reef calcification will require significant improvement of current measurement techniques to broaden the spatial scale of measurements so that whole reef systems are represented; not just lagoons or reef flats. Such new measurements must yield average rates over weeks to months rather than currently reported hourly rates and must be applied widely and long term. The key to detecting net climate change effects will be evidence that observed changes are globally distributed and varying temporarily in concert with observed climate parameters. To this end, four innovative methods are being tested at La Parguera, Puerto Rico. The first is based on locating current meters,  $p\text{CO}_2$ , pH and  $\text{O}_2$  sensors along the predominant axis of flow of a reef and measuring change in total alkalinity (TA) allowing Eulerian measurement of calcification from the change in water properties as water flows past sensors located 1.5 km apart. The second involves measuring spatial distribution of TA drawdown relative to offshore source water and using hydrodynamic circulation and model-derived water residence time to estimate effective drawdown across the whole reef system. The third, a profile flux technique, entails measuring vertical eddy diffusivity from highly resolved water velocity profiles and mean concentration gradients of oxygen and TA measured with sensors and/or discrete measurements. The fourth involves using a geochemical tracer  $^7\text{Be}$  to estimate water residence time.

**21 May, 11:40 (S2.2-4961)**

### **Potential effects of ocean acidification on deep-sea coral ecosystems**

John **Guinotte**, J.C. Orr, S. Cairns, A. Freiwald, L. Morgan and R. George

Marine Conservation Biology Institute, 2122 112th Avenue NE, Suite B-300, Bellevue, WA 98004, USA. E-mail: john@mcbi.org

Ocean pH and the calcium carbonate saturation state of the world's oceans are decreasing at an alarming rate due to an influx of anthropogenic  $\text{CO}_2$  to the atmosphere. Experimental evidence has shown declining carbonate saturation inhibits the ability of marine organisms to build calcium carbonate skeletons, shells, and tests. We put forward a hypothesis suggesting the global distribution of deep-sea scleractinian corals could be limited in part by the depth of the aragonite saturation horizon (ASH). Aragonite is the metastable form of calcium carbonate used by scleractinian corals to build their skeletons and the ASH is the limit between saturated and undersaturated water. The hypothesis is tested by reviewing the distribution of deep-sea, bioherm-forming scleractinian corals with respect to the depth of the ASH. Results indicate that > 95% of coral locations occurred in saturated waters during pre-industrial times. Projections indicate that approximately 70% of these locations will be in undersaturated waters by 2100. If this hypothesis is true, then decreasing carbonate saturation state will probably impact scleractinian cold water corals earlier than shallow water reef builders. Decreases in calcification rates could occur well before corals experience undersaturated conditions as aragonite saturation state decreases progressively over time. Indirect negative effects on fishes, including commercially important species and other deep-sea organisms which rely on deep-sea coral ecosystems for protection and nutritional requirements are possible. Manipulative  $\text{CO}_2$  experiments to determine cold water coral sensitivity and calcification response to decreasing carbonate saturation states should be a top priority for future research.

**21 May, 11:55 (S2.2-4834)**

### **More effective time grid reconstruction in the calibration of geochemical proxies from coral skeletons**

Simone **Russo**<sup>1</sup>, Paolo Montagna<sup>1</sup>, Malcolm McCulloch<sup>2</sup>, Sergio Silenzi<sup>1</sup>, Claudio Mazzoli<sup>3</sup>, Stefano Schiaparelli<sup>4</sup> and Rossella Baldacconi<sup>5</sup>

<sup>1</sup> Central Institute for Marine Research, Via Casalotti 300, Rome 00166, Italy. E-mail: s.russo@icram.org

<sup>2</sup> Research School of Earth Sciences, Australian National University, Mills Road, 0200 ACT, Canberra, Australia.

<sup>3</sup> Department of Geosciences, University of Padova, Via Giotto 1, Padova 35121, Italy.

<sup>4</sup> DIP.TE.RIS, University of Genova, C.so Europa 26, Genova 16132, Italy.

<sup>5</sup> Department of Zoology, University of Bari, Via Orabona 4, Bari 70125, Italy.

The extraction of paleoclimate signals from the aragonitic skeletons of scleractinian shallow-water corals and to a lesser extent deep-water corals using stable isotopes, trace and minor element compositions represents a significant scientific advance, although coral physiology (i.e. “vital effects”) plays an important role in modulating the environmental signals preserved within the growing carbonate skeleton. Typically, a geochemical proxy analysed along the coral growth axis is empirically calibrated against an environmental parameter (e.g. sea surface temperature) through the anchor-point method, considering common features in the two time series as fixed points and assuming a constant growth-rate between these points. This assumption is often at best a poor approximation since the growth rate can vary on a sub-annual (e.g. monthly) time scale. Here, we present an alternative method to obtain a growth-rate modulated time grid following a more rigorous approach, based on the spectral analysis. This method can reconstruct sub-annual variations in growth-rate and accretion stops, with the final aim being to derive better calibration functions to be used for paleoclimate reconstructions.

**21 May, 12:10 (S2.2-4794)**

### **Near-future levels of ocean acidification impair fertilisation and development in a sea urchin**

Jon **Havenhand**<sup>1</sup>, Fenina Buttler<sup>2</sup>, Michael C. Thorndyke<sup>3</sup> and Jane E. Williamson<sup>2</sup>

<sup>1</sup> Tjärno Marine Biological Laboratory, Göteborg University, Tjärno 45296, Sweden. E-mail: jon.havenhand@marecol.gu.se

<sup>2</sup> Marine Ecology Group, Biological Sciences, Macquarie University, NSW 2109, Australia.

<sup>3</sup> Kristineberg Marine Research Station, Göteborg University, 566 Kristineberg, Fiskebäckskil 45034, Sweden.

CO<sub>2</sub>-induced increases in the solubility of biogenic calcareous structures threaten the viability of keystone calcifying taxa such as corals, coccolithophores, and pelagic molluscs. Research to date has focussed on the adult stages of calcifying taxa, using gross pH changes relevant for the years 2200-2400. We investigated the consequences of exposure of the gametes and larvae of the sea urchin *Heliocidaris erythrogramma* to CO<sub>2</sub>-induced acidification by -0.4 pH units (the upper limits of predictions for the year 2100, IPCC AR4 2007). Unlike most urchin species, larvae of *H. erythrogramma* lack a calcareous skeleton. We found statistically significant reductions in sperm swimming performance, fertilisation success, and post-metamorphic juvenile morphology in acidified treatments. We discuss the implications of these findings for fertilisation success and development of the larvae of both non-calcified and calcified taxa, and for the population viability of marine invertebrates.

**21 May, 12:25 (S2.2-4570)**

### **Decadal changes in the carbonate system of the North Pacific Ocean**

Richard A. **Feely**, Christopher L. Sabine and Dana Greeley

Ocean Climate Research Division, NOAA/PMEL, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115-6349, USA. E-mail: Richard.A.Feely@noaa.gov

The addition of fossil fuel carbon dioxide to the atmosphere is rapidly changing seawater chemistry and the calcium carbonate saturation state of the world's oceans as a result of the acidifying effects of CO<sub>2</sub> on seawater. This acidification makes it more difficult for marine organisms (e.g. corals, plankton, calcareous algae, and mollusks) to build skeletons, tests, and shells of calcium carbonate. Impacts on these calcifying organisms will lead to cascading effects throughout marine ecosystems. Repeat hydrographic and coastal cruises in the North Pacific show direct

evidence of ocean acidification. The dissolved inorganic carbon increases, of about 10-15  $\mu\text{mol kg}^{-1}$  in surface and intermediate waters over the past 15 years, are consistent with corresponding pH decreases of approximately 0.025 units over large sections of the northeastern Pacific. These dramatic changes can be attributed, in most part, to anthropogenic  $\text{CO}_2$  uptake by the ocean over the past decade. These data verify earlier model projections that the oceans are undergoing ocean acidification as a result of the uptake of carbon dioxide released as a result of the burning of fossil fuels. From these results we have estimated an average upward migration of the aragonite saturation horizon of approximately 1-2  $\text{m yr}^{-1}$  in the North Pacific. Such shoaling is due to the effects of anthropogenic  $\text{CO}_2$ , ventilation and biological respiration processes in the surface and intermediate waters.

**21 May, 12:40 (S2.2-4671)**

### **Marine calcification in a high $\text{CO}_2$ world: changes in coccolithophore calcification since pre-industrial times**

M. Debora **Iglesias-Rodríguez**<sup>1</sup>, Paul R. Halloran<sup>2</sup>, Rosalind E.M. Rickaby<sup>2</sup>, Ian R. Hall<sup>3</sup>, Elena Colmenero-Hidalgo<sup>3</sup>, John R. Gittins<sup>1</sup>, Darryl R.H. Green<sup>1</sup>, Toby Tyrrell<sup>1</sup>, Samantha J. Gibbs<sup>1</sup>, Peter von Dassow<sup>4</sup>, Eric Rehm<sup>5</sup>, E. Virginia Armbrust<sup>5</sup> and Karin P. Boessenkool<sup>3</sup>

<sup>1</sup> National Oceanography Centre, University of Southampton, European Way, Southampton SO14 3ZH, UK. E-mail: dir@noc.soton.ac.uk

<sup>2</sup> Department of Earth Sciences, University of Oxford, Parks Road, Oxford OX1 3PR, UK.

<sup>3</sup> School of Earth, Ocean and Planetary Sciences, Cardiff University, Main Building, Park Place, Cardiff CF10 3YE, UK.

<sup>4</sup> Station Biologique de Roscoff, Place George Teissier, BP 74, 29682 Roscoff Cedex, France.

<sup>5</sup> School of Oceanography, Box 357940, University of Washington, Seattle, WA 98195, USA.

Ocean acidification occurs as a direct consequence of increasing carbon dioxide ( $\text{CO}_2$ ) partial pressure caused by the absorption of  $\text{CO}_2$  by the ocean, which lowers surface ocean carbonate, reduces surface water pH and the degree of supersaturation of calcium carbonate ( $\text{CaCO}_3$ ). It has been hypothesized that marine calcification is directly affected by the increasing  $\text{CO}_2$  partial pressure that drives a decrease in pH and the saturation state of  $\text{CaCO}_3$ . However, some of these studies have, at least in part, manipulated the carbonate system by the addition of acid or base to the growth medium. One problem with this approach is that it alters the total alkalinity, which is not the case when fossil fuel-derived  $\text{CO}_2$  dissolves in the ocean. Here we show that calcification and photosynthetic carbon fixation in the coccolithophore species *Emiliania huxleyi* are significantly increased by high  $\text{CO}_2$  and these calcification trends are consistent with those seen in the geological record. Our findings have significant implications for biogeochemical modelling of future oceans, and highlight acclimation and evolutionary adaptation of a major calcareous group to past and future ocean acidification.

**21 May, 12:55 (S2.2-4718)**

### **Effects of $\text{CO}_2$ induced acidification on diatom food quality and copepod reproduction**

Jörg **Dutz**

National Institute of Aquatic Resources, Department of Marine Ecology and Aquaculture, Technical University of Denmark, Kavalergården 6, Charlottenlund, DK-2920, Denmark. E-mail: jdu@difres.dk

Increasing dissolved  $\text{CO}_2$  concentrations and the associated decrease in ocean pH affect phytoplankton cell physiology, biochemical and elemental composition and community structure. Since the physiological condition and, particularly, the biochemical composition of phytoplankton can control zooplankton growth and reproduction, trophic transfer efficiency and secondary production might change in correspondence with the alteration of  $\text{CO}_2$  and/or pH. Experiments were conducted to test whether the reproductive success of copepods is related to the  $\text{CO}_2$  concentration and the pH of the growth medium of the diatom *Thalassiosira weissflogii*. The alga was grown in turbidostats under either ambient air or enhanced  $\text{CO}_2$  concentrations of 500 or 1000 ppm. In 6 day laboratory experiments, food uptake, egg production, hatching success and faeces production of the copepod *Temora longicornis* were determined, accompanied by measurements of carbon, nitrogen and lipid contents of the food. While no differences were observed in feeding, faeces production and egg hatching success, egg production was lower in copepods fed with diatoms grown at 500 and 1000 ppm than those fed with food grown at ambient conditions. Accordingly, the gross efficiency of egg production was reduced by ~10% at 500 and 1000 ppm. Because no direct effect of the increased  $\text{CO}_2$  and reduced pH on copepods was observed when the diatoms grown at ambient conditions were fed to copepods under 1000 ppm, the reduced efficiency in the utilisation of the ingested food for egg production is attributed to indirect changes in food quality.

21 May, 13:10 (S2.2-4779)

### Responses of phytoplankton assemblages and organic carbon dynamics to CO<sub>2</sub> increase

Takeshi **Yoshimura**<sup>1</sup>, Jun Nishioka<sup>2</sup>, Koji Suzuki<sup>3</sup>, Hiroshi Hattori<sup>4</sup>, Hiroshi Kiyosawa<sup>5</sup>, Daisuke Tsumune<sup>1</sup>, Kazuhiro Misumi<sup>1</sup> and Takeshi Nakatsuka<sup>2</sup>

<sup>1</sup> Central Research Institute of Electric Power Industry, 1646 Abiko, Abiko, Chiba, 270-1194, Japan. E-mail: ytakeshi@criepi.denken.or.jp

<sup>2</sup> Institute of Low Temperature Science, Hokkaido University, North 19 West 8, Kita-ku, Sapporo, Hokkaido 060-0819, Japan.

<sup>3</sup> Faculty of Environmental Earth Science, Hokkaido University, North 10 West 5, Kita-ku, Sapporo, Hokkaido 060-0810, Japan.

<sup>4</sup> Department of Marine Sciences and Technology, Hokkaido Tokai University, 5-1-1-1 Minamisawa, Minami-ku, Sapporo, Hokkaido, 005-8601, Japan.

<sup>5</sup> Marine Biological Research Institute of Japan, Shinagawa, Tokyo, 142-0042, Japan.

To investigate the responses of phytoplankton assemblages and organic carbon dynamics to CO<sub>2</sub> increase, a CO<sub>2</sub> manipulation experiment was conducted in the Sea of Okhotsk in summer 2006. Surface water with a natural phytoplankton assemblage was incubated in 8 L bottles with bubbling air containing different concentrations of CO<sub>2</sub> (180, 380, 750, and 1000 ppm). Temporal changes in phytoplankton pigments and particulate and dissolved organic carbon (POC and DOC) were observed for 14 days. The surface water of the sampling site was depleted in nutrients, so phytoplankton abundance in the bottles remained at a low biomass of 0.1-0.4 µg chlorophyll *a* L<sup>-1</sup> during the course of the experiment. If the values at the end of the experiment were compared in each treatment, the fucoxanthin/chlorophyll *a* ratios decreased with increasing CO<sub>2</sub>, indicating the relative abundance of fucoxanthin-containing phytoplankton such as diatoms would be sensitive to a change in CO<sub>2</sub>. This result may have been due to the higher efficiency of C-fixation by Rubisco in diatoms than other algal groups. Since no cells of coccolithophores were detected using a scanning electron microscope, we could not determine the response of coccolithophores to the CO<sub>2</sub> gradient. The amount of DOC accumulation decreased with increasing CO<sub>2</sub>, while no significant difference was observed for changes in POC between treatments. The continuing increase in atmospheric CO<sub>2</sub> is concluded to potentially affect the phytoplankton assemblage composition and organic carbon flow in the nutrient-depleted surface water in the subarctic regions.

21 May, 13:25 (S2.2-4547)

### The effect of ocean acidification and temperature on the fertilisation and development of the Sydney rock oyster, *Saccostrea glomerata* (Gould, 1850)

Laura M. **Parker**<sup>1</sup>, Pauline M. Ross<sup>1</sup> and Wayne A. O'Connor<sup>2</sup>

<sup>1</sup> University of Western Sydney, School of Natural Sciences, Hawkesbury H4, Locked Bag 1797, Penrith South DC, NSW 1797, Australia. E-mail: pm.ross@uws.edu.au

<sup>2</sup> Department of Primary Industries, Fisheries NSW, Australia.

There has been global concern regarding the elevation in atmospheric CO<sub>2</sub> and the subsequent impact of this on natural ecosystems. It is expected that by 2065, the atmospheric CO<sub>2</sub> may be double that of preindustrial levels. Such an increase in greenhouse gases may cause a substantial rise in sea temperature, increase the partial pressure of CO<sub>2</sub> (*p*CO<sub>2</sub>) in the surface ocean and subsequently have impacts on the fertilisation, development, survival and growth of marine organisms. While studies have investigated the effect of elevated *p*CO<sub>2</sub> on the calcification of marine organisms, less is known about the effect of elevated *p*CO<sub>2</sub> on the early stages of development. Furthermore, there has been limited investigation on the synergistic effects of elevated *p*CO<sub>2</sub> and temperature. Here, we examine the synergistic effects of elevated *p*CO<sub>2</sub> (375, 600, 750 and 1000 ppm) and temperature (18, 22, 26 and 30°C) on the fertilisation and embryonic development of the Sydney rock oyster *Saccostrea glomerata* (Gould, 1850). The results of this study showed that *p*CO<sub>2</sub> and temperature interacted significantly to affect the fertilisation and embryonic development of *S. glomerata*. There was reduced fertilisation, embryonic growth and development and increased abnormality at elevated *p*CO<sub>2</sub> and temperatures that were above and below 26°C. This study has found that in an acidifying and warming ocean, the fertilisation and embryonic development of the Sydney rock oyster, and potentially other estuarine molluscs will be significantly affected.

**21 May, 13:40 (S2.2-4698)**

**Increased CO<sub>2</sub> levels in the ecosphere may modify the structure of marine plankton**

Knut Yngve **Børsheim**

Oceanography and Climate Department, Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, NO-5817, Norway.  
E-mail: yngve.borsheim@imr.no

Stoichiometry of marine plankton vary only within limited ranges. Recently it has been showed that the average C:N ratio of phytoplankton may increase in a high CO<sub>2</sub> world. Increased availability of organic carbon may in principle stimulate heterotrophy, but heterotrophic prokaryotes are not only dependent on dissolved organic carbon (DOC) for their life support, they also compete with the primary producers for mineral nutrients. In our group based in Bergen, Norway, we have conducted several studies on the flow of carbon and nutrients in pelagic plankton, using both laboratory culture experiments and field work including mesocosm perturbation methodology. Although the concentration of labile marine DOC greatly exceeds the concentration of microbial biomass, bacteria do respond to increases in available organic carbon. Some of our results suggest that tipping points exists in the competition between heterotrophs and autotrophs, and that increased levels of CO<sub>2</sub> in the biosphere may induce the passage of such tipping points.

## S2.2

## Posters

### Poster S2.2-4541

#### Implications of the potential removal of a keystone sub-Antarctic species due to ocean acidification

Kim S. **Bernard**<sup>1,2</sup> and P. William Froneman<sup>2</sup>

<sup>1</sup> Elwandle Node, South African Environmental Observation Network, Private Bag 1015, Grahamstown 6140, South Africa.  
E-mail: kim@saeon.ac.za

<sup>2</sup> Southern Ocean Group, Zoology and Entomology Department, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa.

It has been predicted that by 2050 the acidity of the high latitude oceans will be so high that many shell-forming organisms, including euthecosome pteropods, will not be able to survive. Results of the present study suggest that the euthecosome pteropod, *Limacina retroversa*, can be considered a keystone species in the sub-Antarctic Polar Frontal Zone. The implications of the removal a keystone species are likely to be far reaching, but as yet, cannot be predicted due to a paucity of relevant data. Our findings suggest that *L. retroversa* generally exhibits relatively low abundances, contributing approximately 5.2% to total mesozooplankton numbers. Estimates of *L. retroversa* grazing rates, however, show that the pteropod plays a considerable role in the food web of the Polar Frontal Zone. *L. retroversa* exhibited ingestion rates of approximately 4137.6 ng (pigment) ind<sup>-1</sup> day<sup>-1</sup>, far exceeding those of any of the dominant copepods, as well as many of the larger grazers, including euphausiids. *L. retroversa* were responsible for removing up to 89.1% of the available phytoplankton biomass during the study, contributing to up to 84.4% of the total mesozooplankton grazing impact. This finding suggests that the species has the potential to reduce phytoplankton standing stocks and thus significantly contribute to the functioning of the Polar Frontal Zone ecosystem. It is clear that if *L. retroversa* disappears from the sub-Antarctic waters, the way in which the community functions at present will be greatly altered.

### Poster S2.2-4593

#### Ocean-atmosphere heat flux estimates over the Great Barrier Reef and Coral Sea: implications for recent mass coral bleaching events

Evan **Weller**<sup>1,2</sup>, Manuel Nunez<sup>1</sup> and Gary Meyers<sup>3</sup>

<sup>1</sup> School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia.  
E-mail: wellere@utas.edu.au

<sup>2</sup> CSIRO Marine and Atmospheric Research, Castray Esplanade, Hobart, Tasmania 7001, Australia.

<sup>3</sup> IMOS, University of Tasmania, Private Bag 110, Hobart, Tasmania 7001, Australia.

A regional scale estimate of the surface heat budget of the Great Barrier Reef (GBR) and Coral Sea (10°S-26°S, 142°E-155°E) has been developed for the period 1995-2005 in the hope of understanding the trends of sea surface temperatures (SST) and the surface heat balance. This study describes the methodology to acquire input parameters from satellite observations, the resultant individual components of the surface heat budget and their validation with existing data sets and surface measurements. These improved estimates allow a higher confidence in studies which examine recent SST trends and observed mass coral bleaching for the region. It is proposed that the greatest uptake of heat occurs over the spring/summer period in the central and southern regions of the Great Barrier Reef, agreeing well with areas where anomalously high sea surface temperatures are observed and where the most significant coral bleaching has occurred, and not in the most northern more tropical region as one may expect. The surface heat budget climatology was used to examine the mass bleaching episode that occurred in 2002. Results show that areas of maximum and minimum bleaching are better discriminated by the anomaly from mean seasonal values in  $Q_{NET \rightarrow}$ , with an accuracy of 86 and 79 percent, respectively, than by absolute  $Q_{NET \rightarrow}$ , absolute SST or SST anomaly. Influences of the net surface heat flux and oceanic processes have also been investigated with respect to the observed changes in SST and mixed layer depth temperatures, uncovering some interesting features of the GBR and Coral Sea such as seasonal upwelling and “geostrophic pumping”.

### Poster S2.2-4615

## CO<sub>2</sub>-driven acidification radically affects larval survival and development in marine organisms

Sam **Dupont**<sup>1</sup>, Jon Havenhand<sup>2</sup> and Michael C. Thorndyke<sup>1</sup>

<sup>1</sup> Kristineberg Marine Research Station, Göteborg University, 566 Kristineberg, Fiskebäckskil 45034, Sweden.  
E-mail: samuel.dupont@kmf.gu.se

<sup>2</sup> Tjärno Marine Biological Laboratory, Göteborg University, Tjärno 45296, Sweden.

The world's oceans are slowly becoming more acidic. In the last 150 years, the pH of the oceans has dropped by ~ 0.1 units. Estimates of future levels of atmospheric CO<sub>2</sub> vary, but modelling shows that the pH in the ocean is likely to fall by 0.2-0.4 pH units by the year 2100. These changes will have significant effects on marine organisms, especially those with calcareous skeletons such as echinoderms. Alarming little is known about the long term impact of predicted pH changes on marine invertebrate larval development. We used computerised monitoring and control of pH in natural sea water by controlled injection of CO<sub>2</sub>. This system permits the manipulation of pH to an accuracy of 0.04 units with dynamic stability. We will present results detailing the quantitative (survival, growth, etc.) and qualitative (skeleton formation, phenotype, etc.) impacts of acidification (pH range from 8.1 to 7.7) on the long term development of six key marine species from fertilisation to juvenile/adult stages: the pelagic copepod *Acartia tonsa*, the brittlestars *Amphiura filiformis* and *Ophiothrix fragilis*, the sea star *Asterias rubens* and the tunicates *Ciona intestinalis* and *Asciella aspersa*.

### Poster S2.2-4629

## Mass bleaching of a soft coral, *Sarcophyton* sp., in Thailand: is this related to climate change?

Suchana A. **Chavanich**<sup>1,2</sup>, Voranop Viyakarn<sup>1</sup> and Thepsuda Loyjiw<sup>1</sup>

<sup>1</sup> Department of Marine Science, Faculty of Science, Chulalongkorn University, Payathai Road, Bangkok, 10330, Thailand.  
E-mail: suchana.c@chula.ac.th

<sup>2</sup> National Center of Excellence for Environmental and Hazardous Waste Management, Chulalongkorn University, Bangkok 10330, Thailand.

During June to October 2006 and 2007, mass bleaching of a soft coral, *Sarcophyton* sp. was found in the upper Gulf of Thailand at the Royal Thai Marine Corps, Chonburi Province, eastern Thailand. Approximately 90% of the populations experienced extensive bleaching, and almost 95% of the colony was bleached. It was the first time that mass bleaching of *Sarcophyton* was observed in Thailand. The bleaching of soft corals was found between 1-2 metre depths below the mean seawater level. The results from the laboratory experiments showed that heat stress and low salinity were the main factors contributing to the bleaching of this soft coral species. During the months of the bleaching period, there were extremely low tides and unusually high rainfall, which had an effect on the salinity in the area. The field observations during 2006 and 2007 showed that one month after the phenomenon each year, fragmentation of *Sarcophyton* was observed. By the end of July, some colonies started recovering partially. At the beginning of October, 95% of the population of *Sarcophyton* recovered and survived the bleaching. Some hard coral species in the area such as *Favites halicora*, *Porites lutea*, *Hydnophora microconos*, *Goniastrea retiformis*, *Platygyra daedalea*, and *Turbinaria frondens* were also bleached, but only 10% of the populations were affected.

### Poster S2.2-4669

## Effect of changes in carbonate chemistry on larval development of echinoderms

Nadia **Suárez-Bosche**, Mario Lebrato, M. Débora Iglesias-Rodríguez and Darryl Green

National Oceanography Centre, University of Southampton, European Way, Southampton SO14 3ZH, UK. E-mail: nesubo@noc.soton.ac.uk

The increasing levels of CO<sub>2</sub>, as a result of anthropogenic activity cause a decrease in pH and the saturation of calcium carbonate. These changes from the industrial revolution are the highest reported for the last hundreds of thousands of years. There is an urgent need for a wider understanding of the effects that these changes will have on marine organisms, particularly calcium carbonate-producing organisms. Among these organisms, those with a free-swimming larval stage, may be particularly vulnerable to changes in carbonate chemistry. Echinoderm larvae are among the most susceptible to ocean acidification since calcification occurs at the very early developmental

stages. Additionally, agreement on experimental approaches to test the relationships between climate change and biotic responses are fundamental to make robust projections to the future. There are a few studies testing the impact of increasing carbon dioxide partial pressure on marine organisms, especially at the early stages of development. We tested this by using echinoderm larvae as a model organism representing ecologically important benthic calcified animals. We used present-day and future projections for CO<sub>2</sub> partial pressure to the years 2050 (~560 p.p.m.v. CO<sub>2</sub>) and 2100 (~700 p.p.m.v. CO<sub>2</sub>). Additionally, we tested the effect of saturation state of calcium carbonate by using artificial seawater simulating values of present-day and three projections for future climate scenarios. We report the effects of carbonate chemistry on larval physiology including calcification and discuss the results in an evolutionary context.

## Poster S2.2-4675

### Reconstructing past seawater pH from boron isotopes in carbonates

Carles **Pelejero**<sup>1</sup> and Eva Calvo<sup>2</sup>

<sup>1</sup> ICREA and Institut de Ciències del Mar, CSIC, Pg. Marítim de la Barceloneta, 37-49, Barcelona, Catalonia 08003, Spain.

E-mail: pelejero@icm.cat

<sup>2</sup> Institut de Ciències del Mar, CSIC, Pg. Marítim de la Barceloneta, 37-49, Barcelona, Catalonia 08003, Spain.

Marine absorption of CO<sub>2</sub> results in the progressive acidification of the oceans, which has detrimental and possibly devastating effects for marine organisms, particularly those that construct a skeleton of calcium carbonate (corals, mussels, clams, etc.). To better understand the magnitude of this environmental problem it is crucial to know how seawater pH has oscillated in the past. Because instrumental records of seawater pH exceeding a couple of decades are not yet available, past variations of pH need to be reconstructed using proxies in suitable archives. A very promising geochemical proxy is the isotopic composition of boron in fossil biogenic carbonates which, so far, is the only practical method to quantitatively determine seawater pH variations back through time. This proxy has provided some important reconstructions of pH using fossils of foraminifera found in deep sea sediments. More recently, the method has been proved to be successful by means of corals, and a first reconstruction from a massive *Porites* species coral from Flinders Reef, in the Coral Sea, has been produced. This reconstruction, that covers the last 300 years, displayed an interesting and surprising ~50 year cyclicity of ~0.3 units of change in marine pH. In this presentation, we will review the theoretical grounds of the boron isotope proxy, show the empirical calibrations performed so far, briefly comment on some aspects of the analysis of boron isotopes, and we will present and discuss some of the most relevant results on paleo-pH reconstructions published so far.

## Poster S2.2-4810

### A multi-temporal approach to tackle the ocean acidification problem: insights from coral cultures and instrumental time series of pH

Juancho **Movilla**<sup>1</sup>, Eva Calvo<sup>1</sup>, Carles Pelejero<sup>2</sup>, Marta Ribes<sup>1</sup> and Rafel Coma<sup>3</sup>

<sup>1</sup> Institut de Ciències del Mar, CSIC, Pg. Marítim de la Barceloneta 37-49, Barcelona, Catalonia 08003, Spain. E-mail: jmovilla@icm.csic.es

<sup>2</sup> Institució Catalana de Recerca i Estudis Avançats and Institut de Ciències del Mar, CSIC, Pg. Marítim de la Barceloneta, 37-49, Barcelona, Catalonia 08003, Spain.

<sup>3</sup> Centre d'Estudis Avançats de Blanes, Accés Cala Sant Francesc 14, Blanes, Girona, Catalonia 17300, Spain.

The increasing CO<sub>2</sub> levels in the atmosphere and their high uptake by the oceans are lowering the pH of the oceans. Predictions indicate decreases of approximately 0.3 to 0.5 pH units by year 2100 and of nearly 0.8 pH units by year 2300, a scenario for which there is no obvious precedent over the last hundreds of millions of years. Such pH reduction could have major effects on marine biota, especially on calcareous plankton and coral reef communities, which may be unable to calcify effectively under these conditions. In the specific case of the Mediterranean Sea, it is still not clear how rapidly it is absorbing anthropogenic CO<sub>2</sub> and thus lowering its pH but, owing to its smaller size, there is the possibility that the lowering of pH may be more severe and abrupt than in the world oceans. In the context of a recently started PhD, we aim to tackle this environmental issue from different perspectives: first, we plan to investigate the consequences of ocean acidification for marine organisms by means of manipulative experiments in aquaria, particularly targeting representative species of the Mediterranean coralligenous concretions such as the aragonitic corals *Leptosammia pruvoti* and *Cladocora caespitosa*. And second, we wish to characterise the modern temporal variability of pH in different environments by deploying a SAMI-pH that, using specific dyes and spectrophotometry, provides unattended measurements of pH at high precision (~0.0007 pH units). In this presentation we will outline the aims of this project and show the very first preliminary results.

**Poster S2.2-4972**

**Calcified marine invertebrates: latitudinal variation and ocean acidification**

Sue-Ann **Watson**<sup>1</sup>, Paul A. Tyler<sup>1</sup> and Lloyd S. Peck<sup>2</sup>

<sup>1</sup> School of Ocean and Earth Science, University of Southampton, National Oceanography Centre Southampton, European Way, Southampton SO14 3ZH, United Kingdom. E-mail: suwa@noc.soton.ac.uk

<sup>2</sup> British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

Heavily calcified marine animals such as molluscs, brachiopods and echinoderms have vital roles in ocean ecosystems and are major elements of Antarctic benthic communities. How will these heavily calcified animals cope in a changing world? Ocean acidification caused by anthropogenic CO<sub>2</sub> emissions will affect the ability of these calcareous organisms to build their shells and skeletons, particularly in the Southern Ocean where even modest CO<sub>2</sub> emission scenarios predict aragonite structures will enter a dissolution state by 2100. In order to assess the likely effects of ocean acidification in these calcareous invertebrates, we present data from polar, temperate and tropical latitudes on shell and skeleton size, CaCO<sub>3</sub> crystal form and elemental composition. Results show Antarctic invertebrates have thinner shells and less shell per unit body mass than closely related temperate and tropical species. In buccinid gastropods, shell accounts for only 35% of the total dry mass of the Antarctic snail, *Neobuccinum eatoni*, compared to 81% in the temperate snail, *Buccinum undatum*, and 90% in the tropical snails, *Cantharus fumosus* and *Phos senticosus*. The Antarctic sea urchin, *Sterechinus neumayeri*, has 15% less skeleton than the temperate urchin, *Psammechinus miliaris*. Scanning electron microscope imaging of crystal type shows the Antarctic brachiopod, *Liothyrella uva*, has a calcite shell whereas shells of Antarctic gastropods and bivalves are composed predominately of aragonite. Wavelength dispersive spectroscopy determined variation in shell chemical composition at different latitudes. Having a smaller, more soluble shell raises particular concern for these aragonite based animals from Antarctica.

## **S3.1** Natural hazards, sea level rise and coastal erosion

**22 May, 10:35 (S3.1-4964) Invited**

### **Coastal erosion under changing climates**

John G. **Rees**

British Geological Survey, Keyworth, Nottingham NG12 5GG, UK. E-mail: jgre@bgs.ac.uk

As a direct hazard to society, the problem of coastal erosion is seen as significantly smaller than that of coastal flooding - particularly in relation to increased sea level rise arising from global warming. However, we ignore the dynamics of erosion, and disconnect these from those of flooding at our peril. Recent decades have highlighted the importance of natural systems, which include mobile sediments and physical barriers, such as reefs, within soft coastal defence schemes. Such schemes are being seen as increasingly cost-effective under regimes of rapid environmental change, though the evolution and preservation of coastal barriers are themselves very vulnerable to erosion under high rates of climate change. Inherent uncertainties exist in the complex interrelationships between coastal management practices and natural systems; the linkage between these and societal impact needs to be understood on a wide range of scales. Future coastal zone management requires much greater interaction between scientists and decision-makers than in the past, and a shifting of research priorities. The focus of natural scientists should increasingly be on how coasts respond to storms – a subject that has been substantially neglected because of high observational costs and event infrequency. Similarly, social scientists need to address the valuation of coastal resources, ownership and population migration over short timescales – commonly somewhat subjective subjects with limited acceptance. The coastal erosion issues discussed will be illustrated using several examples that demonstrate also the extent of the challenges scientists and managers face in minimising societal costs of future coastal change.

**22 May, 11:00 (S3.1-4799) Invited**

### **Storm surges, perspectives and options**

Katja Woth<sup>1</sup> and Hans **von Storch**<sup>1,2</sup>

<sup>1</sup> Institute for Coastal Research, GKSS Research Center, Max-Planck-Str. 1, Geesthacht 215092, Germany.  
E-mail: hvonstorch@web.de

<sup>2</sup> KlimaCampus, Center for Marine and Atmospheric Sciences, Bundesstrasse 53, Hamburg 20146, Germany

This review paper attempts to summarise the scattered and fragmented knowledge about past and possible future changing storm surge statistics – with using the particularly well studied case of the North Sea as an example. For this region, a complete and robust analysis methodology has been developed in the past years. This methodology is based on dynamical and statistical models. Using the concept of dynamical downscaling, the development during the past decades, when sufficiently good and homogeneous weather data exist, has been “reconstructed”, and scenarios of possible future change are described. A “localisation” allows us to estimate changes at specific sites, e.g. harbours. Since local water level statistics do depend not only on climate variations but also on local modifications of the local bathymetry, new options for adaptation emerge. For the case of Hamburg, an option for such future adaptations are discussed.

**22 May, 11:25 (S3.1-4592)**

### **Improved ocean-warming estimates: implications for climate models and sea-level rise**

John A. **Church**<sup>1,2</sup>, C.M. Domingues<sup>1</sup>, N.J. White<sup>1,2</sup>, P.J. Gleckler<sup>3</sup>, S.E. Wijffels<sup>1</sup>, P.M. Barker<sup>1</sup> and J.R. Dunn<sup>1</sup>

<sup>1</sup> Centre for Australian Weather and Climate Research, CSIRO and the Australian Bureau of Meteorology, Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: John.Church@csiro.au

<sup>2</sup> Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania, Australia.

<sup>3</sup> Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Livermore, CA, USA.

Changes in the climate system’s energy budget are predominantly revealed in ocean temperatures and the associated thermal expansion contribution to sea-level rise. However, climate models do not reproduce the large decadal variability in globally-averaged ocean heat content inferred from the sparse hydrographic data set, even when

volcanic and other variable climate forcings are included. Also, the sum of the observed contributions to sea-level rise has not adequately explained the historical rise. Here, we report improved estimates of near-global ocean heat content and thermal expansion for the upper 700 m of the ocean for 1950 to 2003, using a reconstruction method that allows for sparse data coverage and applying recent corrections to reduce systematic errors in the most common ocean temperature observations. Our linear trend in ocean heat content (thermal expansion) corresponds to an air-sea flux of  $0.35 \pm 0.08 \text{ W m}^{-2}$  ( $0.52 \pm 0.10 \text{ mm yr}^{-1}$ ) for 1961 to 2003, and  $0.37 \pm 0.28 \text{ W m}^{-2}$  ( $0.80 \pm 0.39 \text{ mm yr}^{-1}$ ) for 1993 to 2003, over the ocean surface area considered ( $3.3 \times 10^{14} \text{ m}^2$ ). Compared to earlier estimates, our rates are about 50% larger for the historical period but about 40% smaller for the recent period, consistent with the recognition that previously estimated rates for the 1990s were biased high by instrumental errors. On average, the decadal variability of the climate models with volcanic forcing now agrees approximately with the observations but the multidecadal trends are smaller than observed. We add our observational estimates of upper ocean thermal expansion to other contributions to sea-level rise and find that the sum of contributions from 1961 to 2003 is about  $1.5 \pm 0.4 \text{ mm yr}^{-1}$ , in good agreement with our updated estimate of near-global mean sea level of  $1.6 \pm 0.2 \text{ mm yr}^{-1}$ .

**22 May, 11:40 (S3.1-4553)**

### **Two hundred years of sea-level rise reconstruction by combining instrumental and geological data from the southern Bay of Biscay**

Alejandro **Cearreta**<sup>1</sup>, Eduardo Leorri<sup>1</sup>, Roland Gehrels<sup>2</sup> and Benjamin Horton<sup>3</sup>

<sup>1</sup> Geología, Facultad de Ciencia y Tecnología, Universidad del País Vasco/EHU, Apartado 644, Bilbao 48080, Spain.  
E-mail: alejandro.cearreta@ehu.es.

<sup>2</sup> School of Geography, University of Plymouth, Plymouth PL4 8AA, UK.

<sup>3</sup> Department of Earth and Environmental Science, University of Pennsylvania, 240 South 33rd Street, Philadelphia, PA 19104-6316, USA.

Current concerns regarding global sea-level rise associated with anthropogenic warming of the atmosphere and oceans and its impact on coastal resources have increased the interest in past sea-level changes. The mean global rate of sea-level (RSL) rise has been estimated at  $\sim 1.8 \text{ mm/yr}$  for the last century, while satellite altimetry data provide new estimates of  $\sim 3 \text{ mm/yr}$ . Proxy records from salt marshes around the North Atlantic Ocean have provided indications that modern rates of sea-level rise (last  $\sim 100$  years) may be more rapid than the rate of rise in preceding centuries, and that the timing of this acceleration may be indicative of a link with human-induced climate change. So far, these high resolution sea-level reconstructions have only come from the northwestern North Atlantic. This contribution seeks to address this knowledge gap by combining tide-gauge and high-precision foraminifera-based transfer function reconstructions of RSL for the southern Bay of Biscay. We have produced three transfer functions with a precision of between 0.19-0.11 m. We placed the foraminifera-based prediction of palaeomorph elevation into a temporal framework through the  $^{137}\text{Cs}$ , Pb concentrations, and  $^{210}\text{Pb}$ -derived sediment accumulation rates. The resulting relative sea-level reconstructions imply a sea-level rise of  $22 \pm 4 \text{ cm}$  in this geographical area for the 20th century, which is in general agreement with the local tide-gauge records and the long-term regional gauge from Brest. In a region where sea-level data are very scarce even for the second half of the 20th century, this study offers an alternative method to reconstruct former sea levels.

**22 May, 11:55 (S3.1-4546)**

### **The VANIMEDAT project: decadal and interdecadal sea-level variability in the Mediterranean Sea and the northeastern sector of the Atlantic Ocean**

Damià **Gomis**<sup>1</sup>, Enrique Álvarez-Fanjul<sup>2</sup>, Michael N. Tsimplis<sup>3</sup>, Marta Marcos<sup>1</sup>, Ananda Pascual<sup>1</sup>, Simón Ruiz<sup>1</sup>, Sebastià Monserrat<sup>1</sup>, Francisco M. Calafat<sup>1</sup>, Gabriel Jordà<sup>1</sup>, Marcos G. Sotillo<sup>2</sup>, Begoña Pérez<sup>2</sup>, Immaculada Ferrer<sup>2</sup>, Roland Aznar<sup>4</sup>, Simon A. Josey<sup>3</sup>, Gilles Larnicol<sup>5</sup> and Samuel Somot<sup>6</sup>

<sup>1</sup> IMEDEA (Univ. Illes Balears-CSIC), C/ Miquel Marqués 21, Palma de Mallorca, Esporles 07190, Spain. E-mail: damia.gomis@uib.cat

<sup>2</sup> Puertos del Estado, Avda. del Partenón, 10, Campo de las Naciones, Madrid 28042, Spain.

<sup>3</sup> National Oceanography Centre, Waterfront Campus, European Way, Southampton SO14 3ZH, UK.

<sup>4</sup> Fac. de Física, Univ. Complutense de Madrid, Ciudad Universitaria, Madrid 28040, Spain.

<sup>5</sup> Collecte Localisation Satellites, 8-10, rue Hermès, Parc Technologique du Canal, Ramonville Saint-Agne 31520, France.

<sup>6</sup> Météo-France / Centre National de Recherches Météorologiques, 42 av. Gaspard Coriolis, Toulouse Cedex 31057, France.

We present a review of the results obtained in the framework of VANIMEDAT, a 3-year project funded by the Spanish Marine Science and Technology Programme. The main aim of the project is the study of the decadal and interdecadal sea-level variability of the Mediterranean Sea and the Atlantic sector surrounding the Iberian Peninsula. The results presented here will cover: 1) The consistency between the two major sea-level data sets:

tide gauge records and altimetry. A key issue has been to evaluate the differences between both data sets and to determine whether they are due to the different observational techniques, to actual differences between coastal and open-sea level or to both. As an application, we will present a reconstruction of Mediterranean sea level that covers the last decades of the 20th century. 2) Sea level trends, paying special attention to the quantification of the sea-level response to the different forcings (atmospheric pressure and wind, heat fluxes and the mass budget); in particular, we will show that the response to the atmospheric forcing, which has a zero-trend at a global scale, has been one of the major contributions to Mediterranean sea-level trends in the last decades of the 20th century. 3) The computation of sea level from baroclinic model runs; in particular we will focus on the evaluation of the steric component of sea-level variability from long-term regional hindcasts and from future climate scenarios.

**22 May, 12:10 (S3.1-4662)**

### **Recovery of sea level fields of the last decades from altimetry and tide gauge data**

Francisco M. **Calafat**, Damià Gomis, Ananda Pascual, Marta Marcos and Simón Ruiz

Natural Resources Department, Mediterranean Institute for Advanced Studies, C/Miquel Marquès 21, Palma de Mallorca 07190, Spain. E-mail: kiko.mir@uib.es

Sea-level observations spanning several decades (tide gauge series) only cover the shores, while sea-level observations covering the whole ocean extension (altimetry series) only span the last decade and a half. We have reconstructed the monthly distribution of sea-level in the Mediterranean Sea and the north-eastern sector of the Atlantic Ocean from altimetry and tide gauge data for the period between 1969 and 2000. To carry out the reconstruction two methodologies have been used, both of them based on a principal component analysis. The first methodology consists of a principal component regression of the amplitudes obtained from satellite altimetry and on the ones from tide gauges, while the second substitutes the leading amplitudes obtained from altimetry by the ones from tide gauges in its singular value decomposition. In order to characterise the goodness of the reconstruction and the sensitivity of the methodology we have used two parameters: correlation and relative root mean square error of the time series predicted by the reconstruction and the values actually observed. Results show that the reconstruction carried out by the second methodology gives better results, moreover it is less sensitive to the number of tide gauges used for the analysis. The reconstruction is accurate along the whole north coast of the Mediterranean Sea and along the Iberian Peninsula coast, with correlations higher than 0.8 and relative root mean square errors lower than 0.45. The lowest correlations were found in the Algerian Basin, the Atlantic coast of Morocco and the south-eastern region of the Mediterranean Sea, which is related to the fact that most tide gauges are located in the northern region of the Mediterranean Sea.

**22 May, 12:25 (S3.1-4559)**

### **Sea level change and extreme events in the Mediterranean Sea**

Marta **Marcos**<sup>1</sup> and Michael N. Tsimplis<sup>2</sup>

<sup>1</sup> IMEDEA (CSIC-UIB), Miquel Marqués 21, Mallorca, Esporles 07190, Spain. E-mail: marta.marcos@uib.es

<sup>2</sup> National Oceanography Centre, Southampton SO14 3ZH, UK.

Extreme sea levels pose significant threats to the coastal environment. The occurrence of extreme events results from the combination of various factors, primarily extreme storm events coupled with high tides and increased mean sea levels. Climate models are considered as reasonably capable to project global mean sea level changes from thermal expansion and circulation changes but neither them nor the atmospheric models, whether global or regional, are considered capable of assessing the modifications caused by climate change to the upper tail of the sea level or storm surge distribution with a reliably quantified uncertainty. Thus coupling the extreme distributions of sea level with the mean sea level changes under climate change scenarios provide a reasonable assessment of risk under climate change. In this work, we first present the results of the analysis of tide gauge stations around the Mediterranean Sea spanning several decades, in combination with the output of a barotropic model of the area forced by atmospheric pressure and wind, in order to investigate the temporal and spatial distribution as well as the forcing of sea level extremes. The anticipated changes in regional mean sea level under global warming scenarios are then added to the obtained return levels from observations to obtain return periods for sea level extremes around the basin. These climate change projections are based on the Atmosphere-Ocean General Circulation Models (AOGCMs) produced for the IPCC 4AR.

**22 May, 12:40 (S3.1-4573)**

### **Sea level trend in Gulf of Thailand using satellite altimetry data**

Sommart Niemnil<sup>1</sup>, Marc Naeiji<sup>2</sup> and Itthi Trisirisatayawong<sup>3</sup>

<sup>1</sup> Department of Hydrographic Engineering, Royal Thai Naval Academy, 204 Sukumvith Road, Paknam, Muang District, Samutprakan 10270, Thailand. E-mail: sniemnil@hotmail.com

<sup>2</sup> Department of Aerospace Engineering, Delft University of Technology, HS Delft 2629, Netherlands.

<sup>3</sup> Department of Survey Engineering, Chulalongkorn University, Bangkok 10330, Thailand.

Sea level change is an index of global change, especially global warming. Global sea level is rising at 1.8 mm/yr (IPCC, 2007), but few studies have been conducted regarding local sea level change and there is virtually no systematic study in the Gulf of Thailand. The objective of this research is to determine the rate of sea level change in the Gulf of Thailand using satellite altimetry data in proximity to three tide gauge stations of the Hydrographic Department, Royal Thai Navy, namely Sattahip station in Chonburi province, Ko Lak station in Prachubkhirkhun province and Ko Mattaphon station in Chumporn province and one station from the Port Authority of Thailand namely, Ko Sichang in Chonburi province. Analysis of satellite altimetry data yield the rising rate between 1.1 - 2.1 mm/yr which is higher than the rate calculated from tide gauge data (0.22 - 0.81 mm/yr). The results indicate the need for further investigation of local factors before actual rate of sea level change in the Gulf of Thailand can be determined.

**22 May, 12:55 (S3.1-4758)**

### **An analysis of Brazilian coastal erosion**

Ademilson Zamboni and João Luiz Nicolodi

Ministry of the Environment, Climate Changes and Environmental Quality Bureau, Environmental Quality Department, Coastal and Air Quality Management, Esplanada dos Ministérios, bloco B. Sala 833, Brasília, DF 70068-900, Brazil. E-mail: joão.nicolodi@mma.gov.br

Recognised as critical areas as regards climate change, beaches are some the planet's most complex and vulnerable environments. Currently, one of the most frequently observed phenomena is coastal erosion, whose magnitude and importance are further stressed by the increased occupation of the seashore and its inherent relation with the Earth's climate changes. Brazil's coast, which is about 8,500 kilometres long, is a permanent management challenge, due to the diversity of existing situations. Every policy aimed at managing the seashore must take into account the understanding that, when not rocky, the coastal area is subject to spatial changes in the short term, as this dynamic environment is directly influenced by waves and currents. This powerful dynamic is also related to anthropogenic processes which worsen erosion effects, giving the coast certain peculiarities which require permanent efforts to keep its dynamic balance. The Brazilian Ministry of the Environment has given special attention to this matter, and the first diagnostic results on the country's current situation were published in a book entitled *Erosão e Progradação do Litoral Brasileiro* (Erosion and Progradation of the Brazilian Coast), which identified risk areas (some 40% of the Brazilian shore) and aimed to create monitoring strategies and identify causes.

**22 May, 14:30 (S3.1-4588)**

### **Forecasting the seasonal to interannual variability of extreme sea levels**

Melisa Menéndez, Fernando J. Méndez and Inigo J. Losada

Environmental Hydraulics Institute "IH Cantabria", Universidad de Cantabria, E.T.S.I. Caminos Canales y Puertos, Avda de los Castros s/n, Santander 39005, Spain. E-mail: menendezm@unican.es

In this work, an emerging methodology for quantifying time variations on extreme sea levels is developed. The proposed statistical model is able to short-term predict the probability density function of extreme sea levels. The model uses a time-dependent generalised extreme value distribution (GEV) to fit monthly maxima series and is applied to different tide gauges in the Pacific and in the Atlantic Ocean, showing different behaviour in agreement with the different dynamics that affect every basin. The model allows the identification and estimation of the effects of several time scales - such as seasonality, interdecadal variability and secular trends - on the location, scale and shape parameters of the probability distribution of extreme sea levels. These factors are parameterised as functions of time (linear, quadratic, exponential and cosine functions) or covariates (for instance, the SOI or

NAO index), automatically obtaining the best model that explains the data variability sufficiently well. Significant influences with the nodal cycle, as well as with regional climate indices have been detected. Results show that the model is adequate to carry out a rigorous analysis of seasonal-to-interannual sea level extremes providing time-dependent quantiles and confidence intervals. The modelling of the different time scales helps to achieve a better understanding of recent secular trends for the extreme climate events and to predict in the short-term (for example in the next 12 months) the probability of a given sea level.

**22 May, 14:45 (S3.1-4895)**

### **Interannual variability and recent increase in the summertime significant wave heights in the western North Pacific**

Wataru **Sasaki**<sup>1</sup> and Toshiyuki Hibiya<sup>2</sup>

<sup>1</sup> Climate Variations Research Program, Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan. E-mail: [wsasaki@jamstec.go.jp](mailto:wsasaki@jamstec.go.jp)

<sup>2</sup> Department of Earth and Planetary Science, University of Tokyo, 1-15-1 Minamidai, Nakanoku, Tokyo 164-8639, Japan.

We investigate the relationship among the summer (June-August) mean of the monthly 90th percentile of significant wave heights (H90) in the western North Pacific (WNP), tropical cyclone activity and climate change in the tropical Pacific. The most prevailing interannual variability of H90 is identified by applying an Empirical Orthogonal Function analysis to H90 obtained from the ERA-40 wave reanalysis as well as from the optimally interpolated TOPEX/Poseidon (OITP) wave data. It is found that the increase of H90 is correlated with cyclonic surface wind anomalies in the WNP which links with warm SST anomalies in the Nino-3.4 region during the ENSO developing years. In particular, the first principal component (PC1) of H90 is found to be closely related to the zonal anomaly averaged over the region 5°N-15°N and 130°E-160°E (U10N). The positive U10N anomaly may be associated with an eastward extension of the monsoon trough off the east coast of the Philippines, which causes an eastward shift of TC occurrence. In fact, the mean position of TC occurrence during the typical seven high wave years shifts southeastward compared to that during the typical seven low wave years, so that TCs further develop while travelling longer distances until they encounter the continent or cool mid-latitude water. We also present a recent increase in the summertime significant wave heights in the WNP by using ERA-40 wave reanalysis as well as hindcast wave data obtained by driving a wave model with surface winds of the NCEP/NCAR reanalysis.

**22 May, 15:00 (S3.1-4557)**

### **Quantification of climate change impacts on hurricane flooding**

Jennifer L. **Irish**, Mir Emad Mousavi, Billy L. Edge, Francisco Olivera and Ashley E. Frey

Coastal and Ocean Engineering Division, Zachry Department of Civil Engineering, Texas A&M University, 3136 TAMU, College Station, TX 77843-3136, USA. E-mail: [jirish@civil.tamu.edu](mailto:jirish@civil.tamu.edu)

Reliable assessment of coastal flooding risk resulting from severe weather events, such as hurricanes, is essential when designing to protect communities and infrastructure against storm damage. However, the influence of climate change on flooding prediction is not well understood at present. Climate change may influence the risk of coastal flooding by changes in sea level and storm intensity. Historical trends in sea level are well documented, and indicate a sea level rise in many coastal communities worldwide, and many hypothesize that global warming will increase the intensity of tropical storms. Thus, it is prudent to consider the risk associated with such phenomena when assessing coastal flooding and damage risk. We conducted a case study for Corpus Christi, Texas, USA to demonstrate the impacts of climate change on coastal flooding. In our analysis, both sea level rise and hurricane intensification were considered. For this site, storm surge numerical simulations were carried out for three historical storms. Subsequent surge simulations due to future hurricane intensification were conducted by modifying the historical storms according to intensification predictions based on projected sea surface temperature rise. These simulations indicate that flood levels due to hurricane intensification increase linearly at a rate of 6 to 20 percent per degree of sea surface temperature rise, depending on geographic location. Our results present a means for quantifying the added flooding risk due to climate change and have the potential for wide-reaching impact on future community planning and engineering design to protect against climate change effects.

**22 May, 15:15 (S3.1-4825)**

### **Growing intensification of landfalling typhoon at higher latitude**

Il-Ju **Moon**<sup>1</sup>, Seok Jae Kwon<sup>2</sup> and S.K. Kang<sup>3</sup>

<sup>1</sup> College of Ocean Science, Cheju National University, Ara 1 Dong, Jejusi, Jeju, 690-756, Republic of Korea. E-mail: ijmoon@cheju.ac.kr

<sup>2</sup> Ocean Research Laboratory, National Oceanographic Research Institute, 1-17, 7Ga, HangDong, Incheon, 400-800, Republic of Korea.

<sup>3</sup> Korean Ocean Research & Development Institute, Ansan, 425-600, Republic of Korea.

Tropical cyclone (TC) best track data from the Joint Typhoon Warning Center (JTWC) and the Regional Specialized Meteorological Center (RSMC) during 1975-2005 have been analysed to investigate long-term intensity variation of typhoons making landfall over the East Asian countries. It is found that the intensity changes for landfalling TCs over 36 years are different according to country and latitude. At higher latitude, a larger intensification of TC is found during the 36 years. Korea is located at a mid latitude above 33°N and shows the most rapid intensification, while low-latitude countries in Asia show little intensification (in JTWC data) or even weakening (in RSMC). This demonstrates that higher-latitude countries in Asia are more influenced by the growing intensification of TC. Possible explanations will be suggested.

**22 May, 15:30 (S3.1-4829)**

### **Contribution of remote sensing data to ocean hazards monitoring and emergency system development**

Tetyana L. **Kuchma**

GIS Analyst Center, vul. Pyrogova 6a, Kiev 01030, Ukraine. E-mail: tanyakuchma@yahoo.com

One of the problems in creating an operational integrated space-based ocean hazards monitoring and emergency system is an absence of various pilot researches to develop methodological principles and unified algorithm of monitoring on an international level. To contribute to this need a pilot research on sea surface monitoring in the Black Seas was conducted. The objectives of the research were to: specify of the remote sensing needs for space-based monitoring of the sea surface and appropriate available satellite images for marine researches in the context of climate change monitoring. ENVISAT and ERS-2 Synthetic Aperture Radar (SAR) images with a resolution of 25-12 m were selected as a basis. SAR images do not depend on cloud coverage, season or daytime; which is important for operational use. Detecting the surface structure, SAR images can be useful for monitoring such ocean and marine phenomena, as atmospheric fronts, wind shadows, currents, calm zones, rain, topography, sewerage discharges, oil pollution, ice and internal waves. The same SAR images have crucial restrictions such as wind speed 2-14 m/s, and image operator experience. ENVISAT MERIS and AVHRR (NOAA) images together with SeaWiFS data were selected as reference data. That allowed us to study complex information, such as, temperature sea surface water, concentration of chlorophyll, marine flows and meteorological parameters. The strongest limitation of the specified data is a low spatial resolution. As a result, the recommendations for the monitoring system and Common Operative Picture development for the Ministry of Ukraine of Emergencies were conducted.

**22 May, 15:45 (S3.1-4554)**

### **The Ebro delta coastal response during 2001-2004: a proxy of the potential effects of an increase in storminess**

José A. **Jiménez**, Vicenç Gracia and Herminia I. Valdemoro

Laboratori d'Enginyeria Marítima, ETSECCPB, Universitat Politècnica de Catalunya, c/ Jordi Girona 1-3, Campus Nord ed. D1, Barcelona 08034, Spain. E-mail: jose.jimenez@upc.edu

One of the potential effects of climate change in our coasts is the increase in wave storminess. This should produce an increase in the frequency and intensity of erosive events in sensitive coastal zones. The Ebro delta coast (NE Spanish Mediterranean) provides an excellent "test case" to learn in an anticipated manner these consequences because it is composed of an unprotected and highly dynamic wave-dominated coastline. From analysis of storm-induced processes on the Ebro coast since 1990, it has been detected that most of the reported problems (affecting the hinterland by inundation and/or impulsive coastal erosion of a very large magnitude) were clustered, with most

events occurring from 2001 to 2004. From analysis of existing wave time series in the area, this period can be classified as “stormy” (storms’ frequency and intensity exceed those of “normal” years). To assess the importance of the contribution of this temporal increase in storminess to the long-term deltaic evolution, the coastal response during these three years has been characterised and compared with that calculated over a period of 4 decades. The two considered storm-induced processes are shoreline retreat and overwash transport. Results show that the magnitude of these processes during this period clearly exceeds long-term rates, with contributions in some areas up to the equivalent of 2 decades under normal conditions. With the results, the deltaic evolution under an increase in storminess scenario can be assessed and, especially sensitive areas could be easily identified in space and time.

**22 May, 16:00 (S3.1-4587)**

### **A methodology to evaluate the impacts of climate change in a coastal system**

Fernando J. Méndez, Inigo J. Losada, Raul Medina, Maitane Olabarrieta, Melisa Menéndez and Paula Camus

Environmental Hydraulics Institute “IH Cantabria”, Universidad de Cantabria, E.T.S.I. Caminos Canales y Puertos, Avda de los Castros s/n, Santander 39005, Spain. E-mail: mendezf@unican.es

In this work, a global frame for the determination of the impacts of climate change in a certain coastal area (beach, estuary, port, etc) is developed. Usually, relative sea level rise is the only variable that is considered to affect the coast. However, recent studies have shown that the complete ocean dynamics must be considered as well. Climate change can affect wave climate and, consequently, can modify the intensity and frequency of extreme events (wave height and storm surge) and can modify the direction of wave energy. All of these likely long-term variations in coastal dynamics can produce an important impact in the coastal area. The steps of the methodology consists of (a) calibration of reanalysis databases; (b) classification of sea states; (c) deep water-to-shallow water propagation of the most representative sea states; (d) propagation of the complete series of sea states using an interpolation scheme; (e) characterisation of shallow water wave climate in the objective area; (f) determination of long-term changes in usual wave climate parameters (such as the 50-year return period wave height, the annual mean wave height, the mean energy flux direction, etc); and (g) calculation of the impacts on beaches (e.g. shoreline retreat, erosion rates, flooding risk increase), ports (e.g. changes in the operability and reliability of maritime works), and estuaries (e.g. long-term modifications of tidal flats and tidal inlet geometry). In the presentation, several examples will show the ability and generalisation of this methodology.

**22 May, 16:15 (S3.1-4798)**

### **Potential impacts of climate change on NW Portuguese coastal zones**

Carlos Coelho<sup>1</sup>, Raquel Silva<sup>2</sup>, F. Veloso-Gomes<sup>2</sup> and F. Taveira-Pinto<sup>2</sup>

<sup>1</sup> Civil Engineering Department, University of Aveiro, 3810-193 Aveiro, Portugal.

<sup>2</sup> Hydraulics and Water Resources Institute, Faculty of Engineering, Porto University, Rua Dr. Roberto Frias, Porto, 4200-465, Portugal.  
E-mail: rcsilva@fe.up.pt

Coastal erosion is a common problem within Europe, which results from the dynamic nature of coastal zones, the anthropogenic influences, such as coastal interventions (defence and harbour structures), littoral occupation and river sediment supply reduction caused by dams, dredging and fluvial flow regularisation, and the effects of climate change. The present changes, which cause serious perturbations in the littoral drift system, are occurring at timescales that range from geological, like neotectonic events and sea level rise, to decadal. Climate change has possible effects on the wave climate (wave heights and directions) with direct implications for the potential alongshore transport. The likely increase of the occurrence of extreme events, the weakening of river sediment supply, and the generalised acceleration of sea level rise are also related to the coastal embayment’s infilling, acting as sinks of sand, tend to aggravate the coastal erosion phenomenon in a time horizon of decades. Coastal dynamics and erosion processes may cause serious damage, especially to people and assets in urban fronts, and they therefore merit special attention. To minimise these impacts, it is necessary to understand the various processes involved and assess different scenarios for coastal evolution prediction (medium to long term), and assess how numerical models may be of some help. Maps representing vulnerability and risk to energetic environmental actions (waves, tides, winds and currents) are thought to be of high importance for coastal planning and management, rationalising decision making. In this paper, a numerical model will be used to assess potential impacts of climate change in vulnerable coastal zones from the Portuguese northwest coast.

**22 May, 16:30 (S3.1-4902)**

**NW Iberian coastal current: a feature of extreme freshwater and wind conditions**

António Jorge **da Silva**<sup>1</sup>, Inês Martins<sup>1</sup>, Ana Santos<sup>1</sup> and Luísa Bastos<sup>2</sup>

<sup>1</sup> Instituto Hidrográfico, Rua das Trinas 49, Lisboa, 1249-093, Portugal. E-mail: [jorge.silva@hidrografico.pt](mailto:jorge.silva@hidrografico.pt)

<sup>2</sup> Centre for Marine and Environmental Research, Universidade do Porto, Rua dos Bragas 289, Porto, 4050-123, Portugal.

Buoyancy induced coastal currents are ubiquitous and recurrent, at least during part of the year, in areas where river runoff is significant. That is not the case of the western Iberian shelf where the average freshwater inflow in winter does not reach 1000 m<sup>3</sup>/s. However, interannual variability is important and extreme situations are frequent. To help disclose the buoyancy conditions that could induce a coastal current, hydrographic (CTD) surveys were designed to cover the whole shelf area from the Douro River mouth to Cape Finisterre, in different runoff and wind forcing conditions during winter 2006 and 2007. An ADCP moored over the inner shelf north of the Douro mouth monitored the current. Tracking of drifters deployed inside the Douro estuary allowed us to evaluate the spatial coherence of the current field. The presence of estuarine induced buoyancy was evident in the hydrographic structures, but their modifications responded mainly to the wind. At a runoff level of around 600 m<sup>3</sup>/s, a northward current was present only when southerlies blew, and buoyancy was too weak to counteract any wind reversal. Even at 1200 m<sup>3</sup>/s, it was unclear whether or not the associated winds were playing a decisive role in sustaining the current. Drift tracks were internally consistent and compatible with the current measurements, pointing to a rather coherent current field over the inner shelf. These results suggest that very high river flow is required to sustain a coastal current, confirming the intermittent character of the current and pointing to its dependence on wind forcing.

# S3.1

## Posters

### **Poster S3.1-4550**

#### **Moving of the Togo shoreline detected by remote sensing: an example of coastal vulnerability to sea level rise**

Pessiezoum D. **Adjoussi** and Adoté Blivi

CGILE/ University of Lomé, Rue 1335, Gbonvié, P.O. Box 93, Agbalépédogan, Lomé, Golfe 05, Togo. E-mail: adjoussi@hotmail.com

This study on the continuous coastal erosion of Togo, especially in the 25 km coastal drift cell that is not protected by construction works, relies on the use of new shoreline measuring techniques. The methods used are basically geomatic. Two Landsat TM imageries of January 1986 and of ETM+ in April 2001 have been acquired and the data treated according to the diachronic method. The results from these analyses have been reinforced by the positioning of the shoreline carried out in 2003 through GPS FX 312. The analysis has been supported by monthly follow-ups surveying the sector situated between the port and the village of Afiadégnigba, a distance of 15 km. The results show a major retreat of the shoreline from continuing erosion at an average speed of 6 to 8 m per year. The results of these survey follow-ups proved the intensification of the sedimentary crisis, due not only to the progressive blockage towards the east of the sediment transfer in the profile by the beach-rock but, above all, to the draining of the sub-current sands deposits of the continental shelf. The construction of a series of short ridges does not reduce the problem. On the other hand, a breakwater added to the beach-rock and/or the covering of the beach by a lot of gabions associated with the beach-rock will be appropriate for the stabilisation of the shoreline and the only solution for resolving the problem of erosion.

### **Poster S3.1-4578**

#### **Using GIS for vulnerability assessment to climate change: a case study National Park of Banc d'Arguin (Mauritania)**

Mohamed Ahmed **Sidi Cheikh** and Yelli Diawara

National Park of Banc d'Arguin, BP 5355, Avenue Gemal Abd-Nasseur, Nouakchott, Mauritania. E-mail: oulssidicheikh@yahoo.fr

The National Park of Banc d'Arguin (PNBA) is considered as one of the main areas of reproduction and is a nursery for the west African birds and fishes. This significant biodiversity results from an exceptional wealth of waters. It comes from a combination of the submarine and emergent meadows which hide the bottom of the Gulf and a plankton biomass produced by the permanent upwelling. The coastal ecosystem of the PNBA is extremely vulnerable to many hazards both natural and artificial. Any attack to its ecological integrity should provoke an impoverishment of resources of the entire regional ecosystem. However, there is currently a gradual acceleration of environmental and human change on the marine environment. Climate change could cause a sedimentary blockage or a destabilisation of the shoreline and Gulf bottoms. It could stifle or alter the mechanisms of primary production and consequently biodiversity and resources. These changes should reinforce the agitation of the sea and induce the erosion. Climate change may lead to adverse impacts on marine mammals and sea birds, including migratory bird populations which risk losing their habitat in the islands due to the elevation of the sea level. Remote sensing and GIS are indispensable tools for risk assessment and decision support. This work is a contribution to the study of the degradation of the coastal environment of the PNBA. Satellite images are used and coupled with bathymetric and topographic maps to delimit the zones of risks in order to minimise or reduce the negative impact of this phenomenon.

### **Poster S3.1-4614**

#### **Torrential rains: using satellite-retrieved sea surface temperature as a forecast input data**

Francisco Pastor, María J. Estrela, Javier Miró, Igor Gómez, Jose A. Valiente and Raquel **Niclòs**

Meteorology Department, Mediterranean Centre for Environmental Studies (CEAM), 14 Charles Darwin (Parc Tecnologic), Paterna 46980, Spain. E-mail: niclos@ceam.es

Sea surface temperature (SST) is a key factor in the development of torrential rains in the Spanish east coast and in the whole western Mediterranean Basin. It follows that information on the exact situation of SST fields can be useful in forecasting such torrential rain events. Currently, the only way to obtain an overall vision of the SST in the western Mediterranean Basin is by means of satellite images. We have thus used the longest available SST data series available obtained from satellite measurements, i.e. NOAA-AVHRR data ranging from 1985 to 2006. We have checked the CEAM climatic database for stations with daily rain values above 100 mm and then looked for the mean SST anomaly for the corresponding and previous months. In most cases, when rain measurements higher than 100 mm were recorded in at least one station in the Valencia region, the SST field showed positive anomalies with respect to the climate mean, pointing out a possible relation between the two variables.

### **Poster S3.1-4713**

#### **Toward future projections of wind and wave climate in the northwestern Pacific Ocean using three different regional climate models**

Wataru **Sasaki**<sup>1</sup>, Koji Dairaku<sup>2</sup> and Satoshi Iizuka<sup>2</sup>

<sup>1</sup> Climate Variations Research Program, Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan. E-mail: wsasaki@jamstec.go.jp

<sup>2</sup> Storm, Flood and Landslide Research Department, National Research Institute for Earth Science and Disaster Prevention, 3-1 Tennoudai, Tsukuba, Ibaraki, 305-0006, Japan.

Nearshore areas in east Asia are threatened by high waves caused by tropical cyclones in summer and extra-tropical cyclones in winter. Projection of nearshore winds and waves under global warming conditions is crucial for structural measures such as tide walls based on the estimated high-water levels and non-structural measures such as insurance or evacuation based on high surf warning. To predict regional ocean surface waves, sea surface wind fields are required to drive wave models with the proper horizontal resolution. However, outputs of global warming experiments prepared for the Intergovernmental Panel on Climate Change (IPCC) future climate scenarios have not been systematically down-scaled with respect to the northwestern Pacific Ocean, so there are few projections for nearshore winds and waves in the basin. In 2007, the Ministry of the Environment, Japan started a new research project on a multi-model ensemble dynamical downscaling with respect to East Asia. The purpose of the research project is to describe regional future climate scenarios in East Asia (particularly Japan) using 3 different regional climate models to provide improved guidance to the policy community beyond simple global climate models. We introduce preliminary results about the regional wind and wave fields under present climate conditions using outputs of the regional climate simulations with the lateral boundary conditions of the JRA25 (Japanese Reanalysis 25-year).

### **Poster S3.1-4789**

#### **Predicting of coastal flooding in Latium coast (central Italy)**

Saverio **Devoti**, Luca Parlagreco, Pasquale Di Pace and Sergio Silenzi

ICRAM, Central Institute for Marine Research, via Casalotti 300, Roma 00166, Italy. E-mail: s.devoti@icram.org

Sea level rise scenarios indicate for the next decades an increasing flooding risk for many of the low-lying coastal regions. In this study, the evaluation of the coastal vulnerability was assessed along the southern Latium coast, in central Italy. The approach was based on the amount of relative sea level rise that will occur by the year 2050 and on the potential impacts of a 50-year design storm. The relative sea level rise scenarios take into account both climatic components (global eustatic response and thermal expansion; IPCC, 2007) and the geological vertical displacements (local or regional). The rates of local tectonic uplift were calculated by comparing geomorphological field evidence with the predicted sea level rise curves obtained from the glacio-hydro-isostatic

model, developed by Lambeck and co-authors for Italian coastal regions. The occurrence of flooding events and the extension of the flooded area will be subsequently estimated considering the wave climate data and the geometry of the shoreface. A Digital Elevation Model will be used to evaluate which coastal sectors will remain at/or below the base level in relation to the occurrence of different scenarios. The results of the wave run-up and of relative sea-level rise scenarios will provide an estimation of their incidence on coastal vulnerability.

### **Poster S3.1-4828**

#### **Long-term variations of storm surge intensity along the Korean Coast and their connection with climate change**

Seok Jae **Kwon**<sup>1</sup>, Eunil Lee<sup>1</sup> and Il-Ju Moon<sup>2</sup>

<sup>1</sup> Ocean Research Lab., National Oceanographic Research Institute (NORI), 1-17, 7Ga, Hang-dong, Jung-Gu, Incheon, 400-800, Republic of Korea. E-mail: sj79kwon@momaf.go.kr

<sup>2</sup> College of Ocean Science, Cheju National University, Ara 1 Dong, Jejusi, Jeju-do 690-756, Republic of Korea.

There has been growing interest in how the storm surge intensity is changing due to typhoons associated with global warming. During the past 56 years, the number of typhoons affecting the Korean Peninsula (KP) was about 3.3 per year, and approximately one per year made landfalls over the KP. The intensity of the landfall typhoons over the KP is increasing continuously, which produces more severe damage in Korea. A recent typhoon leading to serious storm surge, resulted in 85 deaths and total property damage of about 5 billion US dollars. This study investigates the long-term variations of storm surge intensity along the Korean coast and their connections to climate change using the observed sea level data of the National Oceanographic Research Institute (NORI) over 50 years. The hourly surge data at the tidal stations constructed through the tide filtering and data corrections are used to investigate the long-term trend of extreme surge height. The results show that intensifying typhoons in Korea mainly contribute to increasing surge heights. The relation between storm surge trends and climate change will be discussed.

## **S3.2 Estuarine and wetland ecosystem functioning**

**23 May, 10:35 (S3.2-4756) Invited**

### **Assessing ecosystem properties and predicting responses of coastal lagoons to altered hydrology, nutrient cycling and direct anthropogenic pressures**

Pierluigi **Viaroli**

Department of Environmental Sciences, University of Parma, Viale G.P. Usberti 33A, Parma 43100, Italy. E-mail: pierluigi.viaroli@unipr.it

Due to their location between the continental and the marine domains, coastal lagoons present transitional conditions which could allow multiple alternate and stable states to coexist and persist. Such fragile equilibria can be altered by local anthropogenic pressures, e.g. aquaculture and tourism, associated with external organic and nutrient loadings. In turn, effects of local stressors can be amplified by climate-dependent factors, e.g. riverine discharge and sea level rise. In this contribution, the net ecosystem metabolism of a number of coastal lagoons in southern Europe is first presented, aiming at identifying the ratio of autotrophic to heterotrophic processes. Then, the recent evolution of primary producer communities is analysed considering nutrient loadings, hydrology and biogeochemical buffers. Local factors, namely aquaculture and tourism, are assessed in the light of their impacts on ecosystem processes and water quality. Impacts of aquaculture are then analysed in the Sacca di Goro lagoon, considering different riverine discharge scenarios, corresponding to wet, dry and normal conditions. Changes in river discharge are discussed as a critical factor in controlling nitrogen, phosphorus and reactive silica dynamics and inherent stoichiometry, as well as in determining the amplitude of the saline wedge. Increased perturbation intensity and abrupt changes in perturbations and stressors can induce wide variations of the transitional zone, which in turn could be responsible for the modification in biogeochemical processes and community structure.

**23 May, 11:00 (S3.2-4585) Invited**

### **Future climate and oxygen depletion in coastal oceans**

Robert J. **Diaz**

College of William and Mary, Virginia Institute of Marine Science, 1208 Greate Road, Gloucester Pt., VA 23062, USA. E-mail: diaz@vims.edu

How climate change will affect coastal dead zones will depend primarily on localised changes in freshwater runoff and nutrient loadings, which control stratification and support eutrophication, respectively. Increases in water temperatures will have direct effects on oxygen solubility, organism metabolism, and remineralisation rates, and indirect effects by enhancing stratification. Covarying with climate change will be increasing population and further changes in coastal landscapes. If in the next 50 years humans continue to modify and degrade coastal systems as they have in previous years, human population pressure will be the main driving factor in the spreading of coastal dead zones, and climate change factors will be secondary. Climate forcing, however, will tend to make systems more susceptible to the development of hypoxia through direct effects on solubility of oxygen, metabolism, and mineralisation rates. Climate change may be a principal factor in expansion of naturally occurring hypoxia associated with upwelling and oxygen minimum zones (OMZ) into shallower coastal waters. Expansion of oceanic oxygen depletion into shallow coastal system will negatively impact fisheries and energy flows in a similar manner as eutrophication-driven hypoxia. Areas at greatest risk currently are the western continental shelves of Mexico, Peru, Chile, Africa, Pakistan, and India where extensive OMZ and upwelling areas already exist. The development of new upwelling related dead zones along the western coast of other countries is highly likely if wind patterns shift. A recent example may be the development of a dead zone off the coast of Oregon.

**23 May, 11:25 (S3.2-4523)**

### **Challenges and issues in managing marine ecosystems in Sri Lanka**

Prabhath **Patabendi**

Centre for Environment Education and Research, NO, 858/6, New Kandy Road, Thalangama North, Malabe 10115, Sri Lanka.  
E-mail: ihdt@sltnet.lk

Sri Lanka is an island with a land area of 6,570,134 ha and a coastline of 1,600 km, which supports a highly productive marine ecosystem including fringing coral reefs and shallow beds of sea grasses. The island consists of a broad coastal plain and a central mountainous area rising to elevations of 2,500 m. Coastal ecosystems include a variety of tropical habitats including wetlands, lagoons, estuaries, mangroves, salt marshes, seagrass beds, coral reefs, coastal sand dunes, barrier beaches and spits. Sri Lanka has a very high biodiversity and is one of the 18 hot spots in the world. Sri Lanka derives nearly 20 percent of its gross domestic product from agriculture and fisheries. The coastal and marine ecosystems provide over 65 percent of the animal protein requirement of the country and accounts for nearly 80 percent of the fish production and 70 percent of industrial output. The eroding coastline especially threatens economic activity on the densely-populated western and southwestern coast. Between 200,000 and 300,000 square metres of beach are lost in a year to storms and high waves. This paper synthesizes the present challenges and issues in aquatic ecosystems in Sri Lanka as a small island country and gives recommendations for the policy makers for sustainable ecosystem management.

**23 May, 11:40 (S3.2-4877)**

### **Identification of important spatial and temporal scales of ecological variables: the relative contribution of climate variables on a soft bottom invertebrate assemblage**

Jonne **Kotta**, Ilmar Kotta and Helen Orav-Kotta

Estonian Marine Institute, University of Tartu, Mäealuse 10a, Tallinn 12618, Estonia. E-mail: jonne.kotta@sea.ee

Benthic communities have high structural variability at a multitude of scales and this variability is closely linked with physical setting. Identification of the important spatial and temporal scales helps us to unveil factors and processes generating these patterns. In this study we analysed (1) whether stability (Bray-Curtis dissimilarity) of invertebrate communities changed with geographical and temporal distance between communities, (2) whether the shape of such functional relationships varied among different invertebrate functional groups, and (3) what was the relative contribution of climate variables versus local abiotic and biotic forcing. In general the variability of invertebrate communities changed curvilinearly in space and the variability of invertebrate communities changed linearly in time. This indicates that the spatial patterns of invertebrate communities are primarily due to landscape-scale environmental variability and the temporal variability of invertebrate communities is mainly due to climate variables and eutrophication processes. This was also supported by strong links between landscape scale, eutrophication, climate and biotic variables.

**23 May, 11:55 (S3.2-4852)**

### **Changes in the benthic subtidal vegetation along the Basque coast (north Spain) and the probable relationship with climate change**

José M. **Gorostiaga**, Nahiara Mugarza, Stéfani Novoa, Alberto Santolaria, Antonio Secilla and Isabel Diez

Lab. Botánica, Dpto. Biología Vegetal y Ecología, Fac. Ciencia y Tecnología, Universidad del País Vasco / EHU, Apdo. 644 Bilbao 48080 Spain. E-mail: jm.gorostiaga@ehu.es

Due to recent concern about the effects of global warming and climate change, more scientific attention is being devoted to the prediction of biological changes in marine communities as well as to the evaluation of effects already attributed to climate change. The Basque coast could be especially vulnerable to the effects of climate change because of its unique biogeographical characteristics. The purpose of our work was to identify changes in the subtidal marine vegetation of a western stretch of the Basque coast during 1982-2007. A similar sampling survey carried out in 1982 was repeated in July 2007 but the increased to facilitate future comparisons. Seven transect lines (100 to 200 m long) were systematically distributed along 1.95 km of an exposed shoreline, from Pta. Kobaron to Pta. Muzkiz. Cover for main macrophytes (Braun-Blanquet scale) and biomass by means of a

stratified destructive sampling were estimated. Temporal and spatial differences in phyto-benthic assemblages were explored by applying ordination and classification techniques using the PRIMER software package. The results show significant changes in the subtidal marine vegetation in the studied area during the last 25 years. *Gelidium sesquipedale*, the dominant species in 1982, experienced a significant decrease in biomass and percentage coverage. Other significant changes in the floristic composition were also recorded. Of the several hypotheses considered, a combination of irradiance and seawater temperature increase since 1978 appears as the most plausible cause at this point, but further study is necessary.

**23 May, 12:10 (S3.2-4871)**

### **Effects of climate-driven changes on coastal food webs: the role of precipitation patterns**

Simone **Libralato** and Cosimo Solidoro

Dept. Oceanography, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Borgo Grotta Gigante, Brisciki 42/c, Sgonico, Zgonik, Trieste 34010, Italy. E-mail: slibralato@ogs.trieste.it

Climatic changes are expected to produce variations in the precipitation patterns that might substantially modify river runoff and nutrient loading to coastal areas. Modifications of the amount and timing of nutrient loads should affect biogeochemical processes and water quality with unknown effects on the coastal food webs. In this work, we analyse the potential cascading effects of changes in precipitation patterns on the higher trophic levels of the Venice Lagoon ecosystem (Italy) by using a hierarchy of linked models. An Ecopath with Ecosim model representing the estuarine food web was linked with a 3D transport-biogeochemical dynamic model (TDM) of the lagoon which, in turn, is forced with highly resolved meteorological outputs obtained from a Regional Climate model (RegCM). A scenario analysis is presented by comparing results for a reference situation (RF, 1961-1990) with results for two future IPCC scenarios (2071-2100), representing market oriented and local sustainability policies (scenarios A2 and B2, respectively). The local strengthening of seasonal dynamics and the decrease of summer precipitation in future scenarios are predicted to further affect biogeochemical properties. The effects of these changes on higher trophic levels are analysed by comparing the mean seasonal evolution of biomass for different trophic groups simulated under the different scenarios.

**23 May, 12:25 (S3.2-4751)**

### **Benthic diatom response to changing environmental conditions**

Tamara **Cibic**<sup>1</sup>, Oriana Blasutto<sup>2</sup>, Nicoletta Burba<sup>1</sup>, Andrea Bussani<sup>1</sup>, Cinzia Comici<sup>1</sup>, Claus Falconi<sup>1</sup> and Serena Fonda Umani<sup>3</sup>

<sup>1</sup> Biological Oceanography Department, National Institute of Oceanography and Experimental Geophysics, Via A. Piccard 54, Trieste 34014, Italy. E-mail: tcibic@ogs.trieste.it

<sup>2</sup> Regional Environmental Protection Agency - FVG, Via Cairoli 14, Palmanova, Udine 33057, Italy.

<sup>3</sup> Department of Biology, University of Trieste, Via A. Valerio, 28/A, Trieste 34127, Italy.

In the Gulf of Trieste (northern Adriatic Sea, Italy) the benthic diatom community dynamics were studied for seven years at two sublittoral stations and related to variations of temperature, salinity, freshwater inflow and nutrient concentrations. Bin-averaged temperature *versus* abundance of the main genera revealed that *Nitzschia* and *Navicula* increased with temperature (ca. 800 *Navicula* cells per °C and from 540 to 670 *Nitzschia* cells per °C), while *Paralia* and *Diploneis* decreased with increasing temperature. The more thermosensitive *Diploneis* seemed to be substituted by the more thermotolerant *Gyrosigma*. *Cylindrotheca* increased in correspondence with higher salinity. *Pleurosigma* revealed a positive and a negative relationship with salinity and temperature, respectively. With a further rise in temperature and salinity, following the increasing trend recorded during the last decades, the benthic diatom community is expected to shift. *Diploneis* could be replaced by *Gyrosigma*. *Navicula* and *Nitzschia* could markedly increase. In high salinity conditions a rise of *Pleurosigma* abundances is expected. Also the biodiversity of benthic diatoms is likely to decrease. The progressive lowering of the trophic state of the Gulf of Trieste will supposedly cause a decrease of all benthic diatom abundances. Because the Gulf of Trieste can be considered a natural megacosm due to its geomorphologic characteristics, the benthic diatom response to changing environmental conditions observed there could be extended beyond the geographic limits of this particular ecosystem. In the future, similar changes in the benthic diatom community are likely to occur in deeper basins.

**23 May, 12:40 (S3.2-4732)**

### **Conservation of the Goaso watersheds in Ghana, a participatory approach to sustainability**

Lambini Sakab **Kombat**

Ghana Youth Project, Saboba Chereponi Northern Region, Ghana. E-mail: sakablambini@yahoo.com

Watersheds provide the main source of livelihood for most rural communities in Ghana. As a result, this research was conducted with the aim of contributing to the knowledge on the status of the watersheds and to identify existing strategies, opportunities and constraints to sustainable management. It focused on the watersheds in the Goaso Forest District in collaboration with the key stakeholders. Data were obtained using various research methods such as questionnaires, focus group discussions, observations and desk studies. The findings of the team include the following: two main watersheds were identified in the forest district, namely, the Bia and Tano watersheds, the main human activities that take place are farming, fishing, logging and charcoal production, the quantity and size of fish had reduced, and the quantity of the Tano watershed has reduced and the quality (in terms of smell, taste and colour) of the Bia watershed has degraded as compared to some time past. Several watershed management strategies were identified in the district, with the main ones being the maintenance of buffer zones between farms and rivers, planting of trees around the water bodies and educational programmes for the sensitisation of the community on the need to protect the water bodies. Several recommendations including the following were proposed: education on management, strengthening of the collaborative management linkages and enactment of specific laws to protect the watersheds.

**23 May, 12:55 (S3.2-4604)**

### **Decadal change in soft-bottom community structure in high arctic fjord (Kongsfjorden, Svalbard)**

Monika **Kędra**, Maria Włodarska-Kowalczyk and Jan Marcin Węsławski

Department of Marine Ecology, Institute of Oceanology PAS, Powstańców Warszawy 55, Sopot 81-712, Poland. E-mail: kedra@iopan.gda.pl

In 1997 and 1998 soft-bottom fauna of an arctic glacial fjord Kongsfjorden was extensively sampled. Four major communities were identified along the fjord axis which should be related to the diminishing influence of the glacial activity. The sampling was repeated after 10 years, in 2006, in search for natural or climate driven community change. Spatial patterns in community structure and species diversity are significantly different in the central basin of Kongsfjorden while there is no change in the inner part of the fjord. In 1997-98 three faunal associations were distinguished in the inner and central part of the fjord, while in 2006 only two faunal associations were identified. After a decade there were no significant differences between two previously identified central basin faunal associations. Only the inner glacial association remained unchanged. The increased input of Atlantic water carried with an increasingly stronger West Spitsbergen Current can be the reason for unification of previous clear faunal division. Well separated from the central part of the fjord, with strong glacier influence, the faunal association in the inner glacial part of the fjord may be more isolated from the increased amount of warm Atlantic water. Therefore, no significant change was observed there.

**23 May, 14:30 (S3.2-4734)**

### **Temperature methanogenesis regulation in shallow temperate estuaries**

Sonia Moreno and F. Xavier **Niell**

Department of Ecology and Geology, Faculty of Sciences, Campus Universitario de Teatinos s/n, University of Málaga, Málaga 29071, Spain. E-mail: msonia@ma.es

The dynamics of methane production at different temperatures (15, 25, 30 and 35°C) and the main factors that control this process were investigated in fresh water and marine habitats (intertidal sediment and salt marsh) of a Mediterranean temperate estuary in southern Spain. The results indicated that methanogenesis is strongly influenced by temperature, observing activity above at 35°C. The fresh water site showed the highest rate of methanogenesis, being one order of magnitude higher than in intertidal sediment. The factors that regulate methanogenesis were different depending on the site. In the fresh water site, the available substrate *in situ* (acetate)

was the limiting factor of methanogenesis. The control factors were different in intertidal sediment and salt marsh. In the latter, the high sulphur load with the tidal movement is the most important methanogenesis control factor. Under this condition, sulphate-reducing bacteria activity is higher than methanogenesis, competing more efficiently for the same substrate. In the former, vascular plants and tidal oscillations have a key role in the sediment biogeochemical properties. Oxygenated sediment with positive oxido-reduction potential and acid pH are not a suitable environment for methanogenic bacteria activity.

**23 May, 14:45 (S3.2-4683)**

### **Changes in coastal upwelling conditions along the western coast of the Iberian Peninsula for the last 40 years**

Inés Álvarez<sup>1,2</sup>, Moncho Gómez-Gesteira<sup>1</sup>, Maite de Castro<sup>1</sup> and João Miguel Dias<sup>2</sup>

<sup>1</sup> Grupo de Física de la Atmosfera y del Océano, Universidad de Vigo, 32004 Ourense, Spain. E-mail: ialvarez@uvigo.es

<sup>2</sup> CESAM, Departamento de Física, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal.

The spatial and temporal variability of the upwelling regime along the western coast of the Iberian Peninsula (IP) has been analysed by means of two different, but complementary databases: QuikSCAT satellite database, available from mid-1999 with a high spatial resolution (0.25° x 0.25°); and the Pacific Fisheries Environmental Laboratory (PFEL) database, with a coarser spatial resolution (1° x 1°) extending back to 1967. Apart from the well known seasonality on the upwelling regime along the western IP, in which upwelling favourable conditions are observed during spring and summer, other features have been identified. (i) The coastal upwelling pattern is homogeneous along the entire western coast of the IP; (ii) Positive Ekman pumping has been observed near Capes Sao Vicente and Rocha during spring-summer and near Cape Finisterre all year; (iii) More favourable upwelling conditions have been observed in February and November during the last decade. This result is corroborated by sea level pressure composites, which show the existence of abnormally high pressures close to the IP during the last decade compared to historical records (1948-2006); (iv) A decadal analysis of upwelling index evolution from 1967 to 2006 showed that the upwelling conditions were highly variable during autumn-winter without a clear seasonal trend, while the variability was considerably lower during spring-summer; (v) Monthly upwelling trends indicate a weakening in upwelling intensity during most of the year with the exception of February, June and July.

**23 May, 15:00 (S3.2-4892)**

### **Response of structure and distribution pattern of benthic littoral communities to climatic variation and eutrophication**

Georg Martin

Estonian Marine Institute, University of Tartu, Mäealuse 10a, Tallinn 12618, Estonia. E-mail: georg.martin@ut.ee

Benthic littoral communities are widely used in assessment schemes for water quality in coastal ecosystems. These schemes are based on the assumption that different parameters of biological communities are able to react to changes in physical conditions, e.g. water turbidity, salinity, oxygen, etc. Widely used metrics for water quality are maximum depth penetration of aquatic vegetation, proportion of perennial and opportunistic species, and other parameters. In our study we analysed the pattern of different parameters of benthic littoral communities in relation to long-term variability in nutrient loading (eutrophication) to coastal ecosystem and variability of climatic conditions. Quantitative and qualitative data on the distribution of phytobenthic communities in the northern part of Gulf of Riga, northeastern Baltic Sea from three periods (1959-1961, 1986-1990 and 1995-2007) were analysed. Using different uni- and multivariate statistical methods, we were able to distinguish the effects of climatic variation from the signal related directly to eutrophication. Based on this information, corrections to the existing water quality classification scheme were proposed.

**23 May, 15:15 (S3.2-4555)**

### **Compositional changes in aquatic macrophytes propagate through detrital food webs**

Melanie J. **Bishop**<sup>1</sup> and Brendan P. Kelaher<sup>2</sup>

<sup>1</sup> Department of Environmental Sciences, University of Technology Sydney, PO Box 123, Broadway, NSW 2007, Australia.  
E-mail: Melanie.Bishop-1@uts.edu.au

<sup>2</sup> New South Wales Department of Environment and Climate Change, 2/107 Campbell Street, Narooma, NSW 2546, Australia.

The cumulative effects of climate change, catchment development and bioinvasion are causing worldwide changes to the diversity and abundance of estuarine primary producers. Among other important impacts, these changes are altering the quality and quantity of vegetative detritus entering benthic systems. We manipulated the availability of three detrital sources, *Avicennia marina* leaves, *Posidonia australis* blades and *Sargassum* sp. thalli, on an Australian mudflat to test hypotheses about how changes in the type and number of macrophytes contributing to detrital resources might impact benthic invertebrate assemblages of estuarine soft sediments. By controlling for changes in total detrital biomass and ensuring that each detrital source was present in two- and three-species mixes as well as monocultures, our experimental design was able to distinguish among effects of mixing, identity and biomass. Three months after detrital manipulation, macroinvertebrate abundance and species richness differed among treatments according to the biomass of detritus added and the non-additive effects of detrital species mixing. Whereas the mixing of two detrital species generally had an antagonistic effect on macroinvertebrate abundance and richness, faunal assemblages did not appreciably differ between three-species mixes and monocultures. Generally negative effects of two-species mixes on macroinvertebrates were opposed by positive effects on microphytobenthos. Non-additive effects on sediment communities were particularly apparent when *Sargassum* sp., the most labile of the three detrital sources considered, was included in two-species mixes. These results indicate that compositional changes to aquatic macrophyte communities, resulting from climate change and coastal development, will subsequently affect other components of the estuarine food web.

**23 May, 15:30 (S3.2-4707)**

### **Effects of land use, urbanisation, and climate change on coastal eutrophication in the Baltic Sea**

Candida **Savage**<sup>1</sup>, Peter R. Leavitt<sup>2</sup> and Ragnar Elmgren<sup>3</sup>

<sup>1</sup> Department of Marine Science, University of Otago, P.O. Box 56, Dunedin 9054, New Zealand. E-mail: candida.savage@stonebow.otago.ac.nz

<sup>2</sup> Limnology Laboratory, Department of Biology, University of Regina, Regina, SK, S4S 0A2, Canada.

<sup>3</sup> Department of Systems Ecology, Stockholm University, Stockholm SE-106 91, Sweden.

Coastal eutrophication is recognised as one of the foremost threats to ecosystem functioning. However, there is a lack of knowledge on the unique effects of point and diffuse sources of nutrients in degrading water quality and ecosystem function, or how these factors interact with climate variability to regulate coastal productivity. Sedimentary records of stable nitrogen and carbon isotope ratios and pigments were used to reconstruct the history of coastal eutrophication in Himmerfjärden, a mesohaline Baltic Sea bay in Sweden, and to evaluate the unique and interactive effects of land use, urbanisation and climate change on coastal eutrophication. Evidence indicates that changes in nutrient sources and cycling began in the 19th century, but eutrophication intensified only after the 1950s, coincident with increased population density and changes in land use. Specifically, sedimentary N and C content doubled,  $\delta^{13}\text{C}$  increased  $\sim 2\%$ , and concentrations of pigments indicative of total algal biomass ( $\beta$ -carotene, Chl *a*), diatoms (fucoxanthin, diatoxanthin), chlorophytes (lutein-zeaxanthin, Chl *b*) and cyanobacteria (canthaxanthin) increased fourfold after 1950. However, the most drastic changes in N sources occurred following initiation of treated wastewater discharge. Independent Variance Partitioning Analysis revealed that historical changes in both sediment geochemistry and algal communities were strongly related to changes in nutrient flux from land, specifically increased fertiliser use and wetlands drainage, and more recently also urban wastewater discharge. These results confirm that management strategies to restore degraded coastal habitats require cooperation between stakeholders at regional and national levels to both improve wastewater treatment and alter land use practices.

## S3.2

## Posters

### Poster S3.2-4577

#### **Anthropic and natural impacts upon the coastal lagoons in the SW of Spain (Doñana National Park)**

Arturo Sousa<sup>1</sup>, Pablo García-Murillo<sup>1</sup>, Julia Morales<sup>1</sup> and Leoncio García-Barrón<sup>2</sup>

<sup>1</sup> Department of Plant Biology and Ecology, University of Seville, Profesor García González 2, Seville E-41012, Spain.  
E-mail: asousa@us.es

<sup>2</sup> Department of Applied Physics II, University of Seville, Avda. Reina Mercedes s/n, Seville E-41012, Spain.

The Doñana peridunar lagoons, located in the SW of Spain (Doñana Biosphere Reserve), have been thoroughly studied from limnological and hydrogeological viewpoints because their conservation is of great interest. However, the impact exerted by human actions upon them and the most recent climatic changes in those lagoons are unknown. Our study reveals that anthropic activities have affected these lagoons for centuries in the form of fires. Besides, since 1965, they have also been affected by the drawing of underground water in connection with local coastal tourist resorts. A reconstruction of the evolution of these coastal lagoons reveals that, along with the anthropic impact, there is a natural impact due to the reactivation of mobile dunes that have cut and filled the initial lagoon complex. Thus, for the 1920-1987 period, this series of coastal lagoons has suffered a 70.7% reduction, although this process has lasted for centuries. The natural causes appear to be related to an advance of the active dune fronts in the coastal area. These fronts might be fed by the deposits of marine sand during the driest climatic phases of the Little Ice Age in Andalusia (Spain). Consequently, if the driest periods increase, as well as droughts as a whole, due to global warming in the SW of Europe, the drying up and disappearance of the lagoons under study could be prompted (as well as those of the lagoons in a similar situation located in the coastal strip of the south of Europe).

### Poster S3.2-4584

#### **Coastal hypoxia will be aggravated by climate change**

Nancy N. Rabalais

Louisiana Universities Marine Consortium, 8124 Hwy. 56, Chauvin, LA 70344, USA. E-mail: nrabalais@lumcon.edu

The occurrence of hypoxia in coastal areas is increasing, and the trend is consistent with the increase in human activities that result in increased fluxes of nutrients to coastal waters. More and more coastal systems, especially in areas of increased industrialisation and mechanised farming, where the physical conditions are appropriate and where nutrient loads are predicted to increase, will likely become eutrophic with accompanying hypoxia. The continued and accelerated export of nitrogen and phosphorus to the coastal ocean is the trajectory to be expected unless societal interventions are pursued. Increased production of biofuels will further amplify nutrient delivery from the land to the sea. Another source of future change in nutrient loadings leading to increased organic production and water column stratification is climate. Global climate changes within the range predicted to occur in the 21st century could have profound consequences to hypoxia in the northern Gulf of Mexico and globally. The annual discharge of several rivers would increase if the concentration of atmospheric CO<sub>2</sub> doubles, nutrient loads would increase, stratification would strengthen from increased freshwater inflow, and hypoxia would intensify and expand. Increases in surface water temperature would strengthen the summer pycnocline and perhaps worsen hypoxia. On the other hand, warmer Atlantic Ocean temperatures could also increase tropical storm activity and severity resulting in more mixing and reaeration events. Whichever occurs, the increase or decrease in flow, flux of nutrients and changes in water temperature are likely to have important, but as yet not clearly identifiable, influences on hypoxia.

### **Poster S3.2-4617**

#### **Changes in coastal wetland function with sea-level rise**

Robert R. Christian, Mark M. Brinson, David M. Kunz, Enrique Reyes and Christine M. Voss

Department of Biology, East Carolina University, Howell Science Complex, Biology Building S-105, Greenville, NC 27858, USA.  
E-mail: ChristianR@ecu.edu

Landscape alterations associated with sea-level rise and climate change are most obviously exemplified through changes in wetland class position and area. As change occurs in these aspects of wetlands, so does the extent of the various ecosystem functions. We have evaluated these relationships for the coastal wetlands of the southern Pamlico Sound, North Carolina, USA. The five major wetland classes within the system are freshwater riverine swamp forest; sea-level controlled swamp forest; irregularly flooded, oligohaline and meso-polyhaline marshes; and regularly flooded, tidal salt marshes. Attributes of each were estimated from decades of field work and were considered in assigning functions to each class and their vulnerabilities to disturbance and sea-level rise. Hydrologic and geomorphic, biogeochemical, and habitat functionality differed among wetland classes. For example biogeochemical functioning includes the manner and extent of organic matter accumulation and availability. The production of organic matter as wood or peat compared to readily recyclable leafy material changes across the landscape and wetland class. Similarly water storage and wildlife habitat features change across the landscape. Information about the attributes of the wetland classes was then associated with the results of a landscape model forecasting decades of effects of sea-level rise and disturbance. This exercise provides a qualitative view of how ecosystem functionality would be expected to change under different scenarios of sea level and geomorphic change.

### **Poster S3.2-4735**

#### **A series of data in water and sediment conditions (from 1980s to present) in a shallow temperate estuary (Palmones, Spain)**

Miriam Ruiz Nieto, Antonio Avilés and F. Xavier Niell

Department of Ecology, Faculty of Sciences, Campus Universitario de Teatinos s/n, University of Málaga, Málaga 29071, Spain.  
E-mail: miriamruiznieto@alu.uma.es

In this study the fluctuations suffered in the Palmones river estuary from the end of the 1980s to the present day have been analysed in water and sediment. Our aims are to continue the previous studies to determine if the estuary has been gradually eutrophicated and to identify the reasons for it. Phosphorous and nitrogen forms have been analysed as organic matter and C:N ratio determined. They have been related to rainfall pattern. Results show that the relation between the total inorganic phosphorous and the total organic phosphorous increased from the end of the 1980s to 2005, suggesting that inorganic processes dominated over biological processes. However, in the last two years there has been an increase in the organic fraction, so the biological control prevailed in this last period, as it was 15 years ago. Total phosphorous and organic matter values presented fluctuations, although the concentration increased in the sediment mainly related to drought periods. On the other hand, the C:N ratio kept constant with values between 12 and 15, which can be useful to identify the possible origin of the organic matter. The values of the different variables show that the eutrophication is progressive and mediated by a positive feedback of internal fertilisation (endofertilisation). The input of allochthonous organic matter coming from anthropogenic activities is mainly responsible of this effect.

### **Poster S3.2-4775**

#### **Influence of different North Atlantic Oscillation indices on climatic factors and water temperature in Basque estuaries (Gulf of Biscay)**

Guillermo Aravena<sup>1</sup>, Fernando Villate<sup>1</sup>, Arantza Iriarte<sup>1</sup>, Ibon Uriarte<sup>2</sup> and Berta Ibañez<sup>3</sup>

<sup>1</sup> Laboratory of Ecology, Department of Plant Biology and Ecology, Faculty of Science and Technology, University of the Basque Country, P.O. Box 644, Bilbao 48008, Spain. E-mail: arantza.iriarte@ehu.es

<sup>2</sup> Laboratory of Ecology, Department of Plant Biology and Ecology, Faculty of Pharmacy, University of the Basque Country, Paseo de la Universidad 7, Gasteiz 01006, Spain.

<sup>3</sup> Basque Foundation for Health Innovation and Research (BIOEF), Sondika, Bizkaia 48015, Spain.

The effect of the North Atlantic Oscillation (NAO) indices on climatic conditions and their subsequent influence on water temperature of two Basque estuaries (estuaries of Bilbao and Urdaibai) were assessed by transfer function (TF) models for the period 1997-2006. We observed that air temperature showed an immediate (lag

= 0) and significant negative response to the NAO but that neither rainfall nor the amount of cloudless hours were correlated with this climate index. This inverse relationship between surface air temperature and NAO is consistent with the response observed in northwest Africa and the Mediterranean region. TF models revealed that negative correlations between the NAO and air temperature seem to be stronger with seasonal NAO indices calculated taken Ponta Delgada (Azores) as the southern station of the dipole. Surface air temperature and water temperature were positively correlated. A cold summer registered in 2002 was strongly consistent with our TF results, where the positive phase of NAO was concurrent with a remarkable decrease of surface air temperature and water temperature. The effect of air temperature on water temperature had lags of 0 and 1.

### Poster S3.2-4896

#### **Prediction of variation in structure of benthic littoral communities on offshore hardbottom banks in the NE Baltic Sea related to changes in climatic conditions**

Liis **Rostin** and G. Martin

Estonian Marine Institute, University of Tartu, Mäealuse 10a, Tallinn 12618, Estonia. E-mail: liis.rostin@ut.ee

The study on possible effects of construction of an offshore windfarm on benthic littoral communities in the NE Baltic Sea was carried out during the vegetation season in 2007. The investigated area included offshore, hard substrate shallow with a surface area of approximately 20 km<sup>2</sup> surrounded by deep waters. The structure and distribution of the benthic littoral communities was studied in relation to the benthic morphology and topography. Distribution of most species was significantly related to the topographic features of the bottom as well as wind and wave exposure directions. Ice scarping and mechanical stress caused by wind induced wave action are supposed to be the main environmental factors structuring the benthic littoral communities in exposed offshore environments in the NE Baltic. It is also known from the previous studies in the same area that the structure of the pioneer community of the seasonal succession on exposed hard substrates is related to temperature and wave conditions. In the current study we have compared the different scenarios of environmental conditions including change in wind-driven wave activity as well as changes in ice scraping regimes on the quantitative and qualitative structure of benthic communities in the extremely exposed conditions of the NE Baltic Sea. The decrease of the ice cover period together with decreased thickness of ice cover may favour the development of perennial macroalgal communities in the shallow (up to 4 m) hard-substrate conditions, while increased wave activity may prevent algae with large thalli from establishing viable communities.

### Poster S3.2-4943

#### **Responses to thermal stress in the intertidal: utilisation of refuge by a predatory whelk**

Melissa K. **Langridge**, Craig E. Franklin and Greg A. Skilleter

School of Integrative Biology, University of Queensland, St Lucia Campus, Brisbane, QLD 4072, Australia. E-mail: mengl@bas.ac.uk

Rocky intertidal regions are model systems for examining the role of climate on communities as the ecology of intertidal organisms is closely linked to physical factors along vertical and horizontal gradients of the shore. We characterised the microclimates experienced by the predatory whelk, *Morula marginalba*, and used an integrated ecological and physiological approach to determine how their: (1) distribution and abundance, (2) utilisation of refuges (crevices and rock pools), and (3) thermal sensitivity (measured by metabolic response and tenacity) varies along gradients of thermal stress. In all microhabitats, substratum temperatures were more variable and maximal temperatures were greater higher on the shore than further down. Crevices and pools provided less thermally variable microhabitats to the whelks, and maximal temperatures were 5-10°C less within refuges than on exposed rock. Utilisation of refuges increased and abundance declined where thermal stress was greater higher on the shore and in locations sheltered from wave splash. Although whelks were able to lower their level of metabolism to cope with long-term increases in temperature, physiological function was severely compromised when body temperature exceeded 40°C. Refuges were thus essential to *M. marginalba* to avoid sublethal or lethal thermal stress where temperatures on exposed surfaces exceeded 50°C high on the shore. Refuges play an important role in the ecology and thermal physiology of organisms living on rocky shores and may act as buffers against climate-related stress as extremes in temperatures and storms become more frequent in the future.

**Poster S3.2-4950**

**Estimation of seaweed carbon uptake as a CO<sub>2</sub> removal mechanism**

Taehee Na<sup>1</sup>, Tongsup Lee<sup>1</sup>, Jung Hyun Oak<sup>1</sup>, Jaeyoung Lee<sup>2</sup> and Ik Kyo Chung<sup>1</sup>

<sup>1</sup> Division of Earth Environmental System, Pusan National University, Pusan, 609-735, Republic of Korea. E-mail: ocean95@pusan.ac.kr

<sup>2</sup> Ministry of Maritime Affairs and Fisheries, Seoul 110-793, Republic of Korea.

Aquatic primary production removes dissolved inorganic carbon (DIC, CO<sub>2</sub>+HCO<sub>3</sub><sup>-</sup>) which facilitates further dissolution of atmospheric CO<sub>2</sub>. Seaweeds, being immensely abundant in coastal waters, are considered by ocean-CO<sub>2</sub>-removal researchers to be model photosynthetic organisms. Measurements of seaweed production are difficult to predict by ordinary techniques (e.g. bottle incubation). Thus, an alternative, simple box model to estimate the net primary production of the brown seaweed *Sargassum horneri* was considered. The choices of states variables and model structure were made on the basis of experimental knowledge of the studied site. The primary production was calculated from the monthly variation of seaweed biomass and its carbon uptake over the period of the model simulation, and was compared with the former experimental results (i.e. for the <sup>13</sup>C method and the light/dark oxygen technique). The model simulation results confirmed the importance of considering the effect of increased temperature on seaweed production in order to account for their contribution on climate change. Our model-derived estimation of seaweed carbon uptake points to the need for additional research on the impact of global CO<sub>2</sub> removal by seaweeds.

## S4.1 Impacts on lower trophic levels

**22 May, 10:35 (S4.1-4576) Invited**

### **Temperature rules the oceans biota**

Ángel López-Urrutia

Centro Oceanográfico de Gijón, Instituto Español de Oceanografía, Avda. Príncipe de Asturias 70 bis, Gijón, Asturias E-33212, Spain.  
E-mail: alop@gi.ieo.es

Many ecological theories and rules try to explain the effects of temperature on the structure and functioning of populations and communities. Temperature sets the pace of many physiological processes, it therefore has direct effects on the rates at which marine organisms influence biogeochemical processes. The community structure and species diversity of marine communities is also related to temperature. Amongst others, these theories include the Metabolic Theory of Ecology, the temperature-size rule or macroecological explanations for the latitudinal diversity gradients. I will review some of these rules and the existing evidence from marine planktonic ecosystems to support them. I will also use these theories and empirical evidence to envision how possible scenarios of global warming would affect the structure and functioning of marine planktonic ecosystems and discuss the relative importance of these temperature driven changes within the complex changes envisioned in marine ecosystems with global climate change.

**22 May, 11:00 (S4.1-4624) Invited**

### **Anyway the wind blows... scenario from climate to the lower trophic levels in the western North Pacific**

Sanae Chiba

Frontier Research Center for Global Change, JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama 236-0001, Japan.  
E-mail: chibas@jamstec.go.jp

Retrospective studies have reported significant correlations between various climatic indices and variation of the lower trophic level marine ecosystems world wide. There is a global demand to understand the regionally specific processes linking climate-oceanography-ecosystems to provide a better scenario of on-going and future marine ecosystem changes. Information embedded in zooplankton specimens can be a useful clue to indicate the past changes in oceanographic condition and primary productivity. We started the project under as part of a collaboration between several research institutes and universities in 2003 on detailed analyses of the historical zooplankton samples of the Odate Collection, collected in the western North Pacific during 1960s-2000. This presentation summarises the major findings of the Odate Project. Quasi-monthly time series of copepods species composition, and copepodite stage composition and stable isotope ratio ( $\delta^{15}\text{N}$ ) of the dominant species (three *Neocalanus* spp. and *Eucalanus bungii*) were analysed together with climatic indices, seasonal hydrographic and Chl *a* data sets. We detected the two pathways of climatic influence on the lower trophic levels: 1) phenology controlled by decadal variation of wintertime wind stress, and 2) a biogeographical shift of the zooplankton community induced by dynamics of Kuroshio-Oyashio currents. The results suggested that the bottom-up control of the plankton productivity: phytoplankton phenology and subsequent match-mismatch were the plausible mechanisms of the zooplankton decline during the cool, windy 1980s and its recovery during the warm 1990s. Pan-Pacific to hemispheric comparison of mechanisms of long-term zooplankton variation will also be discussed.

**22 May, 11:25 (S4.1-4843)**

### **Effects of increasing UV radiation on arctic bacterioplankton community structure and activity**

Clara Ruiz-González, M. Galí, J.M. Gasol and R. Simó

Institut de Ciències del Mar. ICM-CSIC. E-08003 Barcelona. Spain. E-mail: clararg@cmima.csic.es

Environmental ultraviolet radiation (UVR) has been recognised for many years as a potential stressor of organisms in a variety of environments. Several studies have shown that marine bacterioplankton and phytoplankton are sensitive to solar radiation, especially to the shortest wavelength fraction of UVR. Ozone depletion and ice cover

reduction due to global warming might lead to increasing levels of UVR reaching the Arctic Ocean's surface, and therefore somehow affect planktonic communities. UV radiation causes damage to nucleic acids, proteins and lipids, and may lead to mutations, cell inactivation and death. It may also induce changes in dissolved organic matter composition and consequently modify the availability of nutrients for planktonic communities. As marine heterotrophic bacteria are considered to be too small to have developed efficient photoprotection systems, and as their genetic material involves a significant proportion of their cellular volume, it is thought that bacteria may be among the plankton groups more susceptible to sunlight damage. Our current work is focused on the study of potential changes in microbial diversity and biogeochemical activity when exposing samples to different light quality treatments. We used microautoradiography combined with fluorescence *in situ* hybridisation (MAR-FISH) in summer Arctic Ocean samples to test the effect of different irradiance spectrum conditions on heterotrophic bacterial community composition and activity at the single cell level. We show that UVR partially inhibited leucine and dimethylsulfoniopropionate (DMSP) assimilation by bacteria, so that light quality was affecting both carbon and sulfur cycling.

**22 May, 11:40 (S4.1-4524)**

### **Ocean's least productive waters are expanding**

Jeffrey J. Polovina, Evan A. Howell and Melanie Abecassis

Pacific Islands Fisheries Science Center, Honolulu Laboratory, National Marine Fisheries Service, NOAA, 2570 Dole Street, Honolulu, HI 96734, USA. E-mail: Jeffrey.Polovina@noaa.gov

A 9-year time series of SeaWiFS remotely-sensed ocean colour data is used to examine temporal trends in the ocean's most oligotrophic waters, those with surface chlorophyll not exceeding 0.07 mg chl/m<sup>3</sup>. In the North and South Pacific, North and South Atlantic, and South Indian Oceans, outside the equatorial zone, the areas of low surface chlorophyll waters have expanded at average annual rates from 0.79 to 4.40%/yr and replaced about 0.8 million km<sup>2</sup>/yr of higher surface chlorophyll habitat with low surface chlorophyll water. From 1998 through 2006 it is estimated that the low surface chlorophyll areas in these oceans combined have expanded by 6.6 million km<sup>2</sup> or by about 15.0%. In both hemispheres there is evidence of a more rapid expansion of the low surface chlorophyll waters during the winter. It is the North Atlantic with the smallest oligotrophic gyre that is expanding most rapidly both annually at 4.71%/yr and seasonally, in the first quarter at 6.96%/yr. The expansion of the low chlorophyll waters are consistent with global warming scenarios due to increased vertical stratification in the mid-latitudes but the rates of expansion we observe already greatly exceed recent model predictions.

**22 May, 11:55 (S4.1-4836)**

### **Role of microzooplankton grazing in the DMS cycle: laboratory and field studies**

Violeta Saló, Rafel Simó and Albert Calbet

ICM - Passeig Marítim de la Barceloneta, 37-49. E-08003 Barcelona, Spain. E-mail: vsalo@icm.csic.es

Dimethylsulphide (DMS) is a volatile molecule that is found all over the world's oceans. Its biochemical precursor dimethylsulphoniopropionate (DMSP) is produced by some phytoplankton taxa. Upon diffusion into the atmosphere DMS gets oxidized and can form cloud condensation nuclei. In 1987 the hypothesis was proposed that marine plankton play an important role in climate regulation through DMS emission. A few published studies have shown that microzooplankton grazing on DMSP-containing phytoplankton species leads to DMS production. Nonetheless, microzooplankton are thought also to assimilate part of the prey's DMSP and divert it from being transformed into DMS, although this assimilation has never been directly observed and measured. We carried out two different types of experiments: (a) A monthly series of dilution grazing experiments over a year in the coastal NW Mediterranean, where the microzooplankton grazing rates on both the whole phytoplankton community and the subcommunity of the DMSP producers were quantified along with DMS production. (b) A lab experiment where the heterotrophic dinoflagellate *Oxyrrhis marina* was fed with a monospecific culture of the diatom *Thalassiosira pseudonana*, which had been previously radiolabelled with <sup>35</sup>S-DMSP. One third of the ingested <sup>35</sup>S-DMSP was assimilated by the grazer. The results of these experiments confirm the important role of microzooplankton in controlling DMS production, and should be very useful in developing models of the DMS cycle.

**22 May, 12:10 (S4.1-4654)**

### **Shifts in phytoplankton ecosystem composition and large scale indices of climate variability**

Severine **Alvain**<sup>1,3</sup>, C. Le Quéré<sup>3</sup>, L. Bopp<sup>2</sup>, M.-F. Racault<sup>3</sup>, Y. Dandonneau<sup>4</sup> and C. Moulin<sup>2</sup>

<sup>1</sup> ELICO/MREN, CNRS-ULCO, 28 avenue Foch, BP 80, 62930 Wimereux, France. E-mail: s.alvain@wanadoo.fr

<sup>2</sup> LSCE/IPSL, CNRS-CEA-UVSQ, 91198 Gif sur Yvette, France.

<sup>3</sup> LGMAC, University of East Anglia, Norwich NR4 7TJ, UK.

Biogeochemistry of the ocean is strongly linked with ecosystem composition and more particularly with the phytoplankton. Proper knowledge and prediction of many essential biogeochemical cycles strongly depends on the nature of the phytoplankton ecosystem. It is thus of great importance to improve our knowledge about phytoplanktonic ecosystem composition responses due to climate variability at the large scale, especially in the context of global climate change. New remote sensing observations now give us the opportunity to acquire original information on this important topic. Thus, an algorithm has been developed to detect some dominant phytoplankton functional types (PFTs) from marine signal anomalies acquired by classic ocean colour satellites. Groups detected are diatoms, haptophytes, *Prochlorococcus*, cyanobacteria and *Phaeocystis*. This method, named PHYSAT, was applied to process daily global SeaWiFS data between 1997 and 2006. These original observations were used to study links between the distribution of dominant phytoplankton groups and some large scale indices of climate variability (respectively the NAO in the North Atlantic Ocean, the SOI in the Pacific Equatorial and the SAM in the Austral Ocean). A first comparison between temporal variability of those indices and the temporal and spatial variability of dominant phytoplankton groups has highlighted strong links between shifts in dominant phytoplankton groups and indices anomalies. These shifts are more particularly associated with an increase of surface wind speed during positive phase of the indices, especially at high latitudes.

**22 May, 12:25 (S4.1-4590)**

### **Propagation of an atmospheric climate signal to local phytoplankton in a small marine basin**

William K.W. **Li**

Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada. E-mail: LiB@mar.dfo-mpo.gc.ca

The long term response of phytoplankton to climate change needs to be recognised as a multiyear trend embedded in a strong repeating annual cycle. Seasonal forcing and response return approximately to their initial states at the beginning of each annual cycle, thus any long term signal must be discerned as departures from the annual average state. In the Bedford Basin (Canada), seasonal vertical stratification of the water column is determined primarily by temperature, but a multiyear change in the annual deseasonalised average stratification is induced by salinity which is linked to precipitation and river discharge. Stratification anomalies explain significant amounts of variability in the anomalies of nutrients and total phytoplankton biomass including that contributed by diatoms, but not the biomass of nanophytoplankton and picophytoplankton. Instead, the responses of the small phytoplankton groups seem more complex, apparently related to temperature and incident solar radiation but not mediated through vertical mixing. The adjustment of phytoplankton to environmental change over time appears consistent with patterns established from comparative analysis of widely-spaced ecosystems, but the proximal mechanisms have not been identified. Multiyear change is also evident in bacterioplankton and seston, indicating possible propagation of phytoplankton effects to other parts of the ecosystem. Observations from environmental monitoring provide a pragmatic evidential basis for prediction when both the climate driver and the ecological response undergo a coherent change away from their normal state.

**22 May, 12:40 (S4.1-4682)**

### **Ocean warming and phytoplankton size**

Xosé Anxelu G. Morán<sup>1</sup>, Ángel López-Urrutia<sup>1</sup>, Alejandra Calvo-Díaz<sup>1</sup> and William K.W. Li<sup>2</sup>

<sup>1</sup> Centro Oceanográfico de Xixón, Instituto Español de Oceanografía, Camín de L'Arbeyal, s/n, Xixón 33212, Spain.  
E-mail: xelu.moran@gi.ieo.es

<sup>2</sup> Research Division, Bedford Institute of Oceanography, Dept. of Fisheries and Oceans, Dartmouth, NS, B2Y 4A2, Canada.

Consistent associations between temperature and marine phytoplankton stocks have been recently documented. Although warming has been shown to result in a decline of total phytoplankton biomass, we lack a theoretical explanation for the unexpected parallel increase in absolute cell abundance, and we also lack knowledge of the specific effects of temperature on the picoplanktonic size fraction (<2 µm). Picophytoplankton (*Prochlorococcus* and *Synechococcus* cyanobacteria and small eukaryotic algae) are photosynthetic unicellular organisms found throughout the world's oceans that make a large contribution to global carbon fixation. We show that a combination of general ecological theories, namely the temperature-size rule and the allometric size-scaling of population abundance, yields the phytoplankton temperature-abundance relationship. Using this theoretical framework we predict that an increase in temperature will increase the importance of picophytoplankton in relation to the bulk of phytoplankton. To test this hypothesis we merged two time series data sets (n=154) obtained in the eastern and western temperate North Atlantic Ocean across a diverse range of environmental conditions, which show a remarkably consistent pattern of increasing picophytoplankton biomass over the -0.6 to 22°C temperature range. Furthermore, the relative contribution of small cells to total phytoplankton biomass displayed a strong positive temperature dependence. Temperature alone explained 73% of the variance of this contribution regardless of differences in trophic status or inorganic nutrient loading. Our analysis predicts a gradual shift towards smaller primary producers in a warmer ocean, providing a basis for assessing how phytoplankton communities might change in the future.

**22 May, 12:55 (S4.1-4856)**

### **Decadal changes in North Atlantic phytoplankton blooms**

Stephanie Henson, J.P. Dunne and J.L. Sarmiento

Atmospheric and Oceanic Sciences Program, Princeton University, Sayre Hall, 300 Forrester Road, Princeton, NJ 08544, USA.  
E-mail: shenson@princeton.edu

Changes in the timing, intensity and spatial distribution of seasonal phytoplankton blooms have consequences for biogeochemical cycling and ecosystem dynamics. The current ten year record of SeaWiFS ocean colour data allows interannual variability in bloom characteristics and spatial extent to be investigated for the North Atlantic. Four distinct biomes are identified, ranging latitudinally from early blooming sub-tropical conditions, to late starting, highly productive sub-polar regimes. The consequences of interannual variability in bloom timing and biome extent for subsequent bloom intensity are discussed. The same analyses are applied to output from a coupled biogeochemical model (MOM4-TOPAZ). The model reproduces the biomes and timing of the bloom well, allowing changes in phytoplankton phenology from 1959-2006 to be addressed. Understanding the changes in underlying physical processes that contribute to interannual to decadal variability will provide insight into the response of lower trophic levels to future climate change.

**22 May, 14:30 (S4.1-4685)**

### **The future of shelf seas: projections and observations of changes in the thermal structure and consequences for primary production and water quality**

Stephen Dye, Sonja Van Leeuwen, Naomi Greenwood and Liam Fernand

Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Pakefield Road, Lowestoft, NR33 0HT UK.  
E-mail: Liam.Fernand@cefas.co.uk

Phytoplankton are the base of the marine food web and in the temperate shelf seas, stratification is a key factor in controlling the timing, location and nature of the growth of phytoplankton. Our simulation suggests that in a few decades from now summer stratification in areas of the North and Celtic Seas could last up to 40 days longer. This presentation will present model simulations of the likely stratification under future climate scenarios (using

a 3D hydrodynamic model, POM), coupled to the ecological significance of such events for particularly sensitive areas. Observations taken in 2003 - which was very warm and potentially indicative of the future climate - show very low oxygen values in the bottom waters in the Oyster Grounds region of the North Sea. These data and more recent high frequency observations are presented along with model results (using a 1DV ecosystem model, POM-ERSEM). The implications of these processes are discussed with direct application to the North Sea but the issues of changing primary production and low oxygen are applicable to other shelf seas.

**22 May, 14:45 (S4.1-4857)**

### **A mechanistic perspective on ecosystem response to climate variability: the California Current Ecosystem LTER site**

Mark D. Ohman, Michael R. Landry, Ralf Goericke, Peter J.S. Franks, Karen S. Baker, and the CCE LTER participants

Scripps Institution of Oceanography, La Jolla, California, CA 92093, USA. E-mail: mohman@ucsd.edu

Building on nearly 6 decades of interdisciplinary ocean observations from the CalCOFI region, the NSF-supported California Current Ecosystem (CCE) Long-Term Ecological Research (LTER) site is addressing the mechanisms leading to ecosystem change in a coastal pelagic upwelling ecosystem. Previous work at the site has demonstrated 20th century ocean warming that was unprecedented in the previous 1400 years, illustrated nonlinear ecological responses to linear physical forcing, and identified low frequency changes in zooplankton assemblages related to the Pacific Decadal Oscillation or the North Pacific Gyre Oscillation. Here we explore the primary mechanisms underlying such low frequency ecosystem variations: (1) *in situ* changes in water column stratification and nutrient supply, (2) variations in along-shore or cross-shore advection, and (3) altered predation pressure. These mechanisms are being addressed with a research programme integrating *in situ* Lagrangian experiments; time series measurements including autonomous ocean gliders, satellite remote sensing, quarterly shipboard measurements, and high-frequency near-shore measurements; and a vigorous modelling programme that includes ROMs, allometrically-scaled, NPZD, and control volume property flux models. An innovative information management system (centred around DataZoo) is being developed that facilitates data access and communication among different programme elements. Results will illustrate advances in our coupled measurement/modelling programme.

**22 May, 15:00 (S4.1-4903)**

### **How does climate change impact the biodiversity of marine phytoplankton communities in the North Atlantic Ocean?**

Andrew D. Barton, M. Follows and S. Dutkiewicz

Massachusetts Institute of Technology, 77 Massachusetts Ave, 54-1511, Cambridge MA 02139, USA. E-mail: adbarton@mit.edu

The structure of marine phytoplankton communities plays an important role in regulating global biogeochemical cycles. How these communities respond to changing global climate is unclear. We are investigating the impact of environmental change associated with the North Atlantic Oscillation (NAO) and climate warming on phytoplankton community structure in a model of the North Atlantic Ocean. We employ the MIT ocean circulation model configured in an idealised basin of North Atlantic dimensions. The ocean model is forced with idealised wind stress and heat flux patterns consistent with negative and positive NAO phases and climate warming conditions. The physical model is overlain by a biogeochemistry model with four potentially limiting nutrients (nitrogen, phosphorus, iron, and silica) and an ecosystem model in which many tens of phytoplankton types are initialised with stochastically determined physiologies, drawn from reasonable ranges of traits. Ecosystem community structure “self-organises” according to the relative fitness of the initialised physiologies, and modelled community structure and biodiversity are emergent, rather than prescribed. Using this framework, we assess the climate-driven changes to phytoplankton community structure in the North Atlantic Ocean, focusing on the biodiversity of phytoplankton and the biogeography of key phytoplankton functional types. We analyse the biogeochemical impact of these ecological transitions by estimating the change in export of carbon from the euphotic zone in different climate states. Though idealised, the model suggests testable hypotheses for climate-induced structural shifts in marine ecosystems and their regional impact on biogeochemical cycles.

**22 May, 15:15 (S4.1-4649)**

### **Ecosystem consequences of decadal changes in energy and carbon flows due to climate-induced changes in Baltic zooplankton**

Christian **Möllumann**<sup>1</sup>, Janna Peters<sup>1</sup>, Rabea Diekmann<sup>2</sup> and Georgs Kornilovs<sup>3</sup>

<sup>1</sup> Institute for Hydrobiology and Fisheries Science, University of Hamburg, Grosse Elbstrasse 133, Hamburg D-22767, Germany.  
E-mail: christian.moellmann@uni-hamburg.de

<sup>2</sup> National Institute of Aquatic Resources at the Technical University of Denmark, Department of Marine Fisheries, Charlottenlund Castle, Charlottenlund DK-2920, Denmark.

<sup>3</sup> Latvian Fish Resources Agency, Daugavgrivas Street 8, Riga LV-1048, Latvia.

Climate-induced changes in hydrography, i.e. temperature and salinity, have significantly reorganised the central Baltic ecosystem. One of the most pronounced changes occurred in the zooplankton, namely a dominance change from *Pseudocalanus acuspes* to *Acartia* spp. and *Temora longicornis*. This climate-induced change in the zooplankton was a major driver for an ecosystem regime shift in the early 1990s. Along with the changes in ecosystem structure, trophic interactions in the food web and hence carbon and energy flows have potentially been significantly altered. These may have important consequences for the energy and matter transfer to higher trophic levels, mainly commercially important fish populations. Additionally the potential for carbon export out of the food web, i.e. for the efficacy of the biological pump may have changed. Here we combine analyses on long-term data on zooplankton and hydro-climatic variables with a network analysis of the Baltic food web. By this we first investigate long-term energy and carbon trends in Baltic copepod and cladoceran populations in relation to climate-induced changes in hydrography. Secondly, we construct mass-balance food web models for pre- and post regime shift periods to evaluate changes in ecosystem structure and function, as well as energy and carbon flows. Our study shows a significant change in the energy transport to higher trophic levels, especially affecting growth of the major planktivore, herring (*Clupea harengus*). We further demonstrate how the change in the zooplankton, especially the increase in *Acartia* spp., resulted in a major unused food resource and hence a potential export out of the system.

**22 May, 15:30 (S4.1-4533)**

### **Microplankton response to climatic variability in the English Channel and western Mediterranean Sea**

Fernando **Gómez**<sup>1</sup>, Sami Souissi<sup>2</sup>, Hervé Claustre<sup>3</sup> and Bernard Queguiner<sup>1</sup>

<sup>1</sup> Laboratoire d'Océanographie et de Biogéochimie, Centre d'Océanologie de Marseille, UMR 6535, CNRS - Université de la Méditerranée, 163 Avenue de Luminy, Case 901, 13288 Marseille, France. E-mail: fernando.gomez@fitoplancton.com

<sup>2</sup> Station Marine de Wimereux, Université des Sciences et Technologies de Lille-Lille1, FRE 2816 ELICO CNRS, 28 avenue Foch, BP 80, 62930 Wimereux, France.

<sup>3</sup> Laboratoire d'Océanographie de Villefranche-sur-Mer, CNRS UMR 7093, Quai de la Darse, BP 08, 06238 Villefranche-sur-Mer, France.

The composition of the micro-phytoplankton was investigated at a fixed station in the NW Mediterranean Sea (1998-1999) and two stations in the northeastern English Channel (1997-2005). A warming event in September 1999 was associated with the unusual presence of the dinoflagellate *Asterodinium* in the Tyrrhenian and Ligurian Seas. This was considered as a first phytoplankton indicator of warming in the Mediterranean Sea. In the NE English Channel, the extreme August 2003 heat-wave was associated with an exceptional peak of abundance of the dinoflagellates *Akashiwo sanguinea* and *Ceratium fusus*. Since 2003 and especially in 2005, the diatoms *Eucampia cornuta* and *Chaetoceros peruvianus* were detected for the first time, indicators of the northward spreading of subtropical species. The climatic conditions in 2005 were strongly anomalous. The spring bloom of the flagellate *Phaeocystis* was absent for the first time in recent decades. An unusual assemblage of large rhizosolenioid diatoms dominated in autumn. The meteorological events that favoured this unusual phytoplankton composition in 2005 and the influence on higher trophic levels are discussed.

**22 May, 15:45 (S4.1-4664)**

**Surface warming, decreasing upwelling intensity and plankton off Galicia (NW Spain)**

Antonio **Bode**<sup>1</sup>, Maria Teresa Alvarez-Ossorio<sup>1</sup>, Jose Manuel Cabanas<sup>2</sup>, Ana Miranda<sup>2</sup> and Manuel Varela<sup>1</sup>

<sup>1</sup> Instituto Español de Oceanografía, Centro Oceanográfico de A Coruña, Apdo. 130, A Coruña E-15080, Spain. E-mail: antonio.bode@co.ieo.es

<sup>2</sup> Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, Apdo. 1552, Vigo E-36200, Spain.

Plankton biomass and composition is expected to reflect changes in nutrient inputs and water column stratification. The mean intensity of the north-eastern Atlantic upwelling system at its northern limit (Galicia, NW Spain) decreased during the last 40 years while surface waters become warmer. In this regard, plankton biomass and species abundance data, both at regional and local scales were examined and related to upwelling intensity. Regional data were from the Continuous Plankton Recorder (since 1958) and local data came from the Spanish Atlantic Time series programme (since 1990). Phytoplankton biomass did not show significant trends but there was a significant decrease in diatom abundance at regional scales and also of large species at local scales. In contrast, zooplankton abundance (mainly copepods) significantly decreased offshore but increased near the coast, particularly due to the abundance of small-sized species (e.g. *Acartia*). *Temora stylifera*, a warm-water species became increasingly abundant at both regional and local scales in recent years. These results suggest that during the last 40 years local factors were able to modulate the effects of large scale environmental trends on the plankton.

**22 May, 16:00 (S4.1-4881)**

**The jellyfish joyride: can we stop oceans sliding down the slippery slope to slimy stingers?**

Anthony J. **Richardson**<sup>1,2</sup>, Andrew Bakun<sup>3</sup> and Mark J. Gibbons<sup>4</sup>

<sup>1</sup> Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, Cleveland, Queensland 4163, Australia.  
E-mail: anthony.richardson@csiro.au

<sup>2</sup> Department of Mathematics, University of Queensland, St Lucia, Queensland 4072, Australia.

<sup>3</sup> University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33131, USA.

<sup>4</sup> Department of Biodiversity and Conservation Biology, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa.

The most obvious human impacts on marine ecosystems have probably been on coral reefs, where our activities have precipitated a slide down a “slippery slope to slime”, with large hard corals being replaced by bacterial mats and seaweeds. Here we present evidence that pelagic ecosystems may also be on a trajectory that ends in noxious states, dominated by jellyfish. Rapid climate change may favour opportunistic rapidly-responding “generalist” species such as jellyfish over more “specialist” higher trophic level species that we have traditionally valued. Impacts of climate change act synergistically with eutrophication, overfishing, habitat modification and species translocation to flip pelagic ecosystems from being dominated by fish to a less desirable state dominated by jellyfish. Jellyfish possess a suite of highly successful attributes that reinforce outbreaks: they have no feeding satiation, when starved they shrink rather than die, under unfavourable conditions they undergo encystment from which they can re-emerge years later, and they have faster growth rates and lower energy requirements than almost any other metazoan. This alternate jellyfish stable state has dramatic and potentially lasting ecological, economic and social consequences. We must address the impacts of climate change in concert with other human stresses which act synergistically to alter ecosystem state. The battle plan needed to stop such changes requires both short-term coping strategies and longer-term strategic responses. Previous lessons teach us, however, that prevention is far easier than cure and more cost-effective, so directed and concerted early action is required to avert large-scale disruptions to pelagic ecosystems.

**22 May, 16:15 (S4.1-4653)**

### **Effects of North Atlantic climate variations on the Irish marine ecosystem**

Ilaria **Nardello**, Russell W. Poole, Heather Cannaby, Caroline Cusack, Ciar O'Toole, Chris Lynam, Sinan Y. Husrevoglu, Joe Silke, Guy Westbrook, Leonie Dransfeld, Ken Whelan and G. Nolan

Marine Climate Change Program, Marine Institute, Rinville (Oranmore), Co. Galway, Ireland. E-mail: [ilaria.nardello@marine.ie](mailto:ilaria.nardello@marine.ie)

Changes in the North Atlantic heat budgets may trigger consequences in global ocean circulation, with effects on regional climate systems and ecosystem dynamics. Ireland is in a geographically privileged position to monitor such changes, and has established a Marine Climate Change Research programme to investigate trends on decadal time series of both physical and biological 'essential ocean climate variables' (temperature, salinity, phytoplankton biomass), as well as other parameters (fish population dynamics). Subsurface temperature anomalies, monitored at a permanent observation station on the northern coast of Ireland, show a generally positive trend (+0.85°C) over the last 50 years, with repetitions of exceptionally warm years over the last decade. These regional results generally agree with basin-scale (North Atlantic) trends, and appear to be correlated to the main global temperature anomalies. From a biological perspective, considering twenty years of observations, the phytoplankton blooming season appears to have lengthened. Analyses of microalgal abundance and community structure are in progress, with the additional aim of identifying sentinel species for climate change. At higher trophic levels, the North Atlantic catch of salmon has decreased dramatically since the 1970s, in spite of severe exploitation regulation; sea-trout counts fell from 1000-3300 individuals (years 1970-1985) to consistently less than 500 after 1988. We hypothesize that climate variability and change in the North Atlantic affects the physical mechanisms controlling the dynamics of the lower trophic levels of the Irish Atlantic marine system, and question whether, and through which mechanisms, higher trophic-level dynamics correlate to these changes.

**22 May, 16:30 (S4.1-4848)**

### **Impacts of global warming on lower-trophic level ecosystems projected by a 3-D high-resolution ecosystem model**

Taketo **Hashioka**<sup>1,2</sup>, Takashi T. Sakamoto<sup>1</sup> and Yasuhiro Yamanaka<sup>1,2,3</sup>

<sup>1</sup> Frontier Research Center for Global Change (FRCGC) / Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3173-25, Showa-machi, Kanazawaku-ku, Yokohama, Japan. E-mail: [hashioka@jamstec.go.jp](mailto:hashioka@jamstec.go.jp)

<sup>2</sup> Core Research for Evolutional Science and Technology (CREST) / Japan Science and Technology Agency (JST), 4-1-8, Honcho, Kawaguchi-shi, Japan.

<sup>3</sup> Hokkaido University, Faculty of Environmental Earth Science, 060-0010, N10W5, Kita-ku, Sapporo, Japan.

In order to clarify the impact of global warming on marine ecosystems, we developed a 3-D high-resolution ecosystem model with an off-line calculation method which can directly use predicted results of climate models as a physical field of the ecosystem model. Our model, COCO-NEMURO which has a horizontal resolution of 1/4 by 1/6 degrees, consists of PICES NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) coupled with COCO (CCSR Ocean Component Model). We applied this model to the western North Pacific, and conducted a global warming experiment using predicted physical fields by a high-resolution climate model (the CCSR/NIES/FRCGC climate model which contributed to the IPCC-AR4). The experiment was conducted with an idealised scenario in which an atmospheric CO<sub>2</sub> concentration increases by 1% per year. Under the global warming condition, our model projected a significant decrease in the maximum phytoplankton biomass by 25% during the spring bloom in the subarctic-subtropical transition region. This result supports the projection of Hashioka and Yamanaka (2007) with a medium resolution version of COCO-NEMURO (1 by 1 degrees). However, it is interesting that the predicted maximum biomass in spring in the subarctic region increases by 20% in the new experiment with the high-resolution model, while there is a decrease in the annually averaged biomass. These results suggest that the impact of global warming would significantly appear in specific seasons and regions. We show the reason for these changes based on changes in the environmental factors associated with global warming (e.g. temperature, nutrient and light conditions).

**22 May, 16:45 (S4.1-4760)**

**SCOR WG125 “Global comparison of zooplankton time series”: a summary of results**

SCOR WG125 Members, Associate Members, Data Collaborators and David **Mackas**<sup>1</sup>

<sup>1</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada. E-mail: MackasD@pac.dfo-mpo.gc.ca

The short life span (weeks to a year) of mesozooplankton allows their population size to respond strongly and rapidly to interannual environmental change. This, plus the fact that there is no direct fishery mortality, makes long zooplankton time series a valuable resource for understanding ocean climate impacts on marine ecosystem structure and productivity. SCOR Working Group 125 recently compiled zooplankton time series from a number of regions worldwide, and converted them to intercomparable time series of annual anomalies. This report is a brief summary of what we learned (more detailed results reported in Workshop W1 presentations). Strong and ecologically important modes of low frequency zooplankton variability include changes of total biomass/biovolume/abundance (3-30x), changes of community composition (amount within individual species or species assemblages, 10-100x), changes of seasonal timing of within year maxima (weeks to months), and changes in size, condition, and chemical composition. All of the longer time series show very strong low frequency variability at multiple time scales ('ENSO', decadal regime, and overall trend). Decadal variability is spatially coherent within current systems (correlation length scale ~1000 km), but is usually weakly correlated or uncorrelated between hemispheres. Responses to ENSO events are ~synchronous but stronger in the Pacific than in the Atlantic. Log-scale anomalies of individual species and species assemblages are usually larger (by 2-3x) than the anomalies of total biomass, and show evidence of strong poleward displacement of zoogeographic boundaries in time intervals when temperature and stratification anomalies are positive.

# S4.1

## Posters

### Poster S4.1-4059

#### Effect of climate changes on the aquatic ecosystem of the Black Sea: from planktonic communities to fish recruitment

Yuriy N. Tokarev, Viktor V. Melnikov and Alexandra V. Temnykh

Department of Biophysical Ecology, Institute of Biology of the Southern Seas, NAS of Ukraine, Nakhimov Avenue 2, Sevastopol 99011, Ukraine. E-mail: atemnykh@rambler.ru

Dramatic changes which have occurred during the last three decades in the Black Sea are connected to a combination of two factors: anthropogenic influence and climate impact. Which factor is more important: anthropogenic forcing or climate impact has been debated in many recent papers. Opportunities to undertake retrospective analyses are provided after extensive studies by a number of large international projects in the Black Sea (such as NATO TU Black Sea) and new knowledge has been obtained about the reasons for long-term variability in the Black Sea ecosystem. Due to this, there are now opportunities for inter-ecosystem comparisons. In the present paper an empirical model is presented which shows that the changes of the European climate modify the long-term dynamics of the Black Sea ecosystem. The result of the present work is a schematic representation of the effect of climate impact on the cascade interactions of ecosystem levels due to the influence of natural and human factors: atmospheric circulation, water structure and circulation, anthropogenic influence, biodiversity, population changes, modification of planktonic and fish diet, outbreaks of alien species, food accessibility, fish recruitment and ecosystem balance.

### Poster S4.1-4534

#### Phytoplankton invasive species: comments on the validity of the non-indigenous dinoflagellates and diatoms in the European Seas

Fernando Gómez

Laboratoire d'Océanographie et de Biogéochimie, Centre d'Océanologie de Marseille, UMR 6535, CNRS - Université de la Méditerranée, 163 Avenue de Luminy, Case 901, Marseille, F-13288, France. E-mail: fernando.gomez@fitoplancton.com

Climate change is expected to alter the species composition of the local planktonic communities as well as their invasion by exotic species. The validity of categorising the diatoms and dinoflagellates reported in the literature as non-indigenous phytoplankton in the European Seas is investigated. Synonyms are often included as separate species (*Gessnerium mochimaensis* = *Alexandrium monilatum*, *Gymnodinium nagasakiense* = *Karenia mikimotoi*, *Pleurosigma simonsenii* = *P. planctonicum*). Other species names are synonyms of cosmopolitan taxa (*Prorocentrum redfieldii* = *P. triestinum*, *Pseliodinium vaubanii* = *Gyrodinium falcatum*, *Gonyaulax grindleyi* = *Protoceratium reticulatum*, *Asterionella japonica* = *Asterionellopsis glacialis*). Epithets of an exotic etymology (i.e. *japonica*, *sinensis*, *indica*) result in the consideration of cosmopolitan species as non-indigenous. Several taxa are even considered as non-indigenous in the type locality (*Alexandrium tamarense* and *A. pseudogoniaulax*). The records of *Alexandrium monilatum*, *A. leei* and *Corethron criophilum* are doubtful. Cold or warm-water species expand their geographical ranges or increase their abundances to detectable levels during cooling (*Coscinodiscus wailesii*, *Thalassiosira punctigera*) or warming periods (*Chaetoceros coarctatus*, *Proboscia indica*, *Pyrodinium bahamense*). These are examples of a marginal dispersal associated with climatic events instead of species introductions from remote areas. The number of non-indigenous phytoplankton species in European Seas has been greatly over-estimated.

#### Poster S4.1-4565

### The long-term dynamics of coccolithophorids in the Black Sea with respect to environmental trends

Alexander **Mikaelyan**<sup>1</sup>, Larisa Pautova<sup>1</sup> and Vladimir Silkin<sup>2</sup>

<sup>1</sup> P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Nahimovski prospect 36, Moscow 117997, Russia.

E-mail: mikael@ocean.ru

<sup>2</sup> Southern Branch of P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Golubaya Bukhta, Gelendjik-7, Krasnodar Territory 353470, Russia.

Coccolithophorids now are the subject of special interest due to their ability to produce a calcite cell wall which eventually increases deposition of carbon to bottom sediments. Satellite images show that blooms of these algae may occupy up to 20-60% of the total sea area in May-June. The goal of this study was to detect whether a long-term trend in coccolithophorid abundance exists or not? For this purpose the database on phytoplankton of the Black Sea was used. It includes data from 930 stations and 2600 samples collected from 1968 to 2007. Three evident time periods with different level of coccolithophorid abundance were revealed for May-June. Before the 1980s the role of coccolithophorids in the phytoplankton community was not substantial. Average wet biomass for the upper mixed layer was  $8 \mu\text{g l}^{-1}$  while their share of the total phytoplankton biomass was 3%. In the 1980s average biomass increased up to  $106 \mu\text{g l}^{-1}$ . From the 1990s to the present coccolithophorids dominate the structure of the phytoplankton community, with an average biomass of  $227 \mu\text{g l}^{-1}$  and percentage of the total phytoplankton biomass of 42%. They replaced dinoflagellates in the phytoplankton community. Forty years of coccolithophorid dynamics was compared with long-term trends of abiotic and biotic parameters. It was shown that during recent years the high concentrations of coccolithophorids were recorded after cold winters with subsequent relatively high phosphate concentration in the upper water layer and low nitrogen/phosphorus ratio. This pattern is in good concurrence with experimental results, which show an evident phosphate limitation of coccolithophorid growth in May-June.

#### Poster S4.1-4575

### Biological cycle of *Sphaeroma serratum* (Isopoda) in the Thau lagoon: impact of global change from 1972 to 2006

Damien Cazamea-Catalan<sup>2</sup>, Delphine **Bonnet**<sup>1</sup>, Guy Charmantier<sup>2</sup> and Mireille Charmantier-Daures<sup>2</sup>

<sup>1</sup> Equipe REMI, Laboratoire Ecosystèmes Lagunaires, Université Montpellier 2, UMR 5119 ECOLAG, CC093, Place Eugène Bataillon, Montpellier, Cedex 05, 34090, France. E-mail: delphine.bonnet@univ-montp2.fr

<sup>2</sup> Equipe AEO, UMR 5171 GPIA, CC 092, Université Montpellier II Sciences et Techniques, 34095 Montpellier Cedex 5, France.

In the context of global change, rising temperatures cause an evaporative increase in salinity, particularly in lagoons where responses to variations are faster than in the open sea. In the Thau lagoon, the impact of these changes has been investigated by studying the biological cycle of the isopod crustacean *Sphaeroma serratum*. The objective was to compare the resulting 2006-2007 data with those collected in 1972-1973 in the same lagoon. In 2006-2007, the average water temperature was  $17.9^\circ\text{C}$  versus  $15.4^\circ\text{C}$  in 1972-1973. The mean salinity also increased from 32‰ to 37.5‰. Important differences affecting the biological cycle were noted in 2006-2007 compared to 1972-1973. (i) Hatching occurred one month earlier, in May 2007 instead of June in 1973. (ii) Some females reproduced twice a year in 2006-2007 instead of once. The increase of temperature may thus improve the reproductive potential of females. (iii) In males, the 2006-2007 lifespan was shorter by 3 months compared to 1972-1973, maybe due to a decrease in osmoregulatory capacity of the pubescent adult males. The higher salinity resulting from increased temperatures may thus decrease the life duration of the male *S. serratum* perhaps by triggering an earlier senescence phase preceding death.

#### Poster S4.1-4608

### Hydrographic changes and their connection to the phytoplankton spring bloom in the German Bight

Karina **Stockmann**<sup>1</sup>, Ulrich Callies<sup>1</sup> and Karen H. Wiltshire<sup>2</sup>

<sup>1</sup> GKSS Research Centre, Max-Planck-Str. 1, Geesthacht 21502, Germany. E-mail: karina.stockmann@gkss.de

<sup>2</sup> Biologische Anstalt Helgoland, Alfred Wegener Institute for Polar and Marine Research, P.O. Box 180, 27483 Helgoland, Germany.

Algal counts from the Helgoland Roads time series (German Bight, North Sea) showed a step-like delay for the phytoplankton spring bloom starting in 1978. This may be evidence for a regime shift in the North Sea at the bottom of the food web. To investigate if a hydrographic regime shift could be responsible for the delay in the phytoplankton bloom, transport patterns in the German Bight were analysed and a sudden increase of the mean flushing rates was found in 1978 (by about 30%, from 31.000 m<sup>3</sup>/s to 42.000 m<sup>3</sup>/s). As the hydrodynamics control Secchi disk depth, salinity, temperature and nutrients, which influence phytoplankton, also these variables have been taken into account. For salinity and nutrient concentrations clear change points in 1978 and 1995 were found. Secchi disk depth and temperature change in about 1988. Regime shifts in the late 1970s, 1988 and the late 1990s are discussed in the literature. While the period 1978-1995 is clearly visible in the salinity data, nutrient concentrations and transport patterns of our study, it was not possible to identify any hydrodynamic shift in 1988. We conclude that such a shift in about 1988 most probably would have to be explained by factors other than the hydrodynamic flow patterns (e.g. temperature, Secchi disk depth).

#### Poster S4.1-4634

### To what extent do coastal zooplankton reflect Mediterranean climate variability?

Maria Grazia **Mazzocchi**

Stazione Zoologica A. Dohrn, Villa Comunale, Napoli 80121, Italy. E-mail: grazia@szn.it

Coastal areas are complex ecosystems characterised by high spatial and temporal variability of their physical and chemical factors, and by consequently remarkable variability in their pelagic populations. Moreover, the dynamics of coastal environments are continuously affected by anthropogenic activities, which tightly interplay with natural forcing and events. All these elements make it quite difficult to disentangle the various components of system variability and to clearly discern proximate from remote sources. At the same time, coastal areas are easily accessible and therefore the sites of the most numerous long-term studies are useful for monitoring the responses of the pelagic system to climate change. In coastal regions of the Mediterranean Sea, a semi-enclosed basin sensitive to climate variability, only a few investigations are regularly carried out to investigate zooplankton responses. A long-term time series is being conducted in the Gulf of Naples (western Mediterranean Sea) since 1984 to track the dynamics of the coastal mesozooplankton along with environmental variability. The samples are collected biweekly until 1990 and weekly since 1995, with a major interruption from 1991 to 1994. Various structural aspects of these pelagic communities are under investigation, from total dry biomass to species composition and abundance, with the aim of discerning recurrences and trends in different organisational levels and at different temporal scales. Some results are presented here that indicate how patterns that might be related to climate forcing can be better perceived in species rather than in bulk properties.

#### Poster S4.1-4650

### Coccolithophore response to abrupt and short-term climate changes in the Gulf of Lions (western Mediterranean) for the last 25,000 years

José-Abel **Flores**<sup>1</sup>, Francisco J. Sierro<sup>1</sup>, Elena Colmenero-Hidalgo<sup>1</sup>, José M. Gravalosa<sup>1</sup>, Miquel Canals<sup>2</sup>, Jaime Frigola<sup>2</sup>, Joan Grimalt<sup>3</sup>, Serge Berne<sup>4</sup> and Bernard Dennielou<sup>4</sup>

<sup>1</sup> University of Salamanca Facultad de Ciencias, Departamento de Geología, 37008 Salamanca, Spain. E-mail: flores@usal.es

<sup>2</sup> University of Barcelona, GRC Geociències Marines, 08028 Barcelona, Spain.

<sup>3</sup> Institute of Chemical and Environmental Research (CSIC), Department of Environmental Chemistry, 08034-Barcelona, Spain.

<sup>4</sup> IFREMER, Géosciences Marines, BP 70, 29280 Plouzané, France.

Cores PRGL-1 (310 m long) and MD99-2348 (21.5 m long) were recovered in the Gulf of Lions (42.690°N; 03.838°E) at 298.48 m water depth, during the PROMESS 1 campaign (SRV *Bavenit* drilling vessel) and IMAGES V (RV *Marion Dufresne*, Calypso piston core), respectively. The high sedimentation rates estimated by robust <sup>14</sup>C

dating have given us an excellent opportunity to perform high resolution analyses on these materials. In this study we present data from the last 25 kys. The retrieved sediments consist of silty-clay terrigenous material mixed with a small amount of calcareous microfossils. Quantitative analyses of coccolithophore assemblages allow us to identify significant changes in sea surface temperature in this period. Cold peaks are marked by increases in the proportion of *Gephyrocapsa muelleriae* and large morphotypes of *Emiliana huxleyi* ( $>5 \mu\text{m}$ ); some of the most significant can be correlated with Heinrich events. The high sedimentation rates observed during most of the interval studied also allow us to identify an overprinted multicentennial scale pattern related to Dansgaard-Oeschger cycles. The combined analyses of coccolithophores and planktonic foraminifers enables a sea surface temperature (SST) record to be made in which sharp fluctuations of around  $4^\circ\text{C}$  in amplitude have been detected. These abrupt changes in SST are also linked to changes in surface productivity and in the deep and intermediate water dynamics, probably related with variations in the atmospheric pattern (NAO-like oscillations).

PROMESS 1 is funded by the European Community (EVR1-T-40024).

#### Poster S4.1-4651

### Study of potential effects of climatic forcing on the ecosystems of the western Mediterranean Sea

Jordi Solé<sup>1</sup>, Simón **Ruiz**<sup>1</sup>, Ananda Pascual<sup>1</sup>, Bruno Buongiorno Nardelli<sup>2</sup>, Gianluca Volpe<sup>2</sup>, Rosalia Santoleri<sup>2</sup>, Alberto Alvarez<sup>1</sup>, Guillermo Vizoso<sup>1</sup> and Joaquín Tintoré<sup>1</sup>

<sup>1</sup> Instituto Mediterráneo de Estudios Avanzados, C./ Miquel Marqués, 21, Esporles 07190, Spain. E-mail: jordi.sole@uib.es

<sup>2</sup> Istituto di Scienze dell'Atmosfera e del Clima, Via del fosso del cavaliere 100, Roma 00133, Italy.

In this work we study the effect of climatic forcing on sea surface chlorophyll. We explore the relationships between atmospheric variables (wind stress and heat fluxes) and ocean colour images (SeaWiFS chlorophyll). The atmospheric data set was obtained in the framework of the HIPOCAS project through a dynamical downscaling ( $1/2^\circ \times 1/2^\circ$ ) from the NCEP/NCAR global reanalysis using the atmospheric limited area model REMO. The chlorophyll is estimated through the MedOC4 regional algorithm. SeaWiFS images are analysed using Data Interpolating Empirical Orthogonal Functions (DINEOF), providing both EOFs and the interpolated weekly time series, with a spatial resolution of  $1/16^\circ$ . We focus on the western Mediterranean by considering different subareas and we obtained the EOFs for all the selected variables. To relate the atmospheric variables with chlorophyll we used a genetic algorithm. The genetic algorithm gives the transfer function of each couple of variables and its functional dependencies. With this method we can assess and quantify the ecosystem response to the atmospheric forcing and to the climate change.

#### Poster S4.1-4656

### How will the ocean warming affect the planktonic diversity?

Luis Valdés, Gonzalo **González-Nuevo**, Maite Álvarez-Ossorio, Jesús Cabal and Enrique Nogueira

Centro Oceanográfico de Gijón, Instituto Español de Oceanografía, Avda. Príncipe de Asturias 70 Bis, Gijón 33212, Spain.

E-mail: Luis.Valdes@gi.ieo.es

Past oscillations in climate have been followed by abrupt changes in species diversity. Unfortunately the fossil record of planktonic organisms is restricted to a few groups with hard shells and skeletons (e.g. foraminifers and coccolithophorids), but they have been used in the study of biodiversity and extinction as far as the Cambrian (543 million years ago). In general, foraminifers increase in species richness and diversity when temperatures increase and *vice versa*. The same pattern seems to be valid by coccolithophorids. However, as they do not fossilize, little is known about the response of copepods (the most abundant class in the mesozooplankton) under past climate changes. In the present scenario of global warming, this lack of knowledge is being substituted by a subjective perception that the diversity of copepods is increasing, which is the opposite of that which is occurring with other invertebrates (e.g. insects, molluscs, echinoderms, etc.). In this paper we review data from published literature to compare the trends in copepod biodiversity at a global scale, in the biogeography domains and in some specific regional seas, during the last 50 years and we speculate about the expected trends if the warming is maintained in the next 100 years.

#### Poster S4.1-4672

### Impact of climate change on the marine pelagic ecosystems off Galicia (NW Spain). I: Water characteristics and plankton

M. **Varela**<sup>1</sup> and CLIGAL-Pelagic Working Group<sup>2</sup>

<sup>1</sup> Instituto Español de Oceanografía, Centro Oceanográfico de A Coruña, Apdo. 130, E15080 A Coruña, Spain.  
E-mail: manuel.varela@co.ieo.es

<sup>2</sup> CETMAR, C/ Eduardo Cabello s/n. E36208 Bouzas, Vigo, Spain.

Changes in atmospheric temperature and pressure fields at global and multidecadal scales have measurable effects on the characteristics of the upper ocean and, in turn on pelagic ecosystems. However, the direction of changes at these scales may be different at regional and local scales. To ascertain the significance of changes in relevant oceanographic and pelagic ecosystem variables in relation to climate change at the northern limit (Galicia, NW Spain) of the north-eastern Atlantic upwelling system, a multidisciplinary study was initiated in this region. The objectives were directed to determine patterns of change in: 1) marine climate and oceanographic properties, 2) diversity and composition of biological communities and 3) biological production, including fisheries and aquaculture. In this poster we highlight some of the results obtained for the two first objectives. Coastal surface waters in south Galicia warmed at a mean rate of  $0.27 \pm 0.03^\circ\text{C}$  every 10 years, but large variations were found at local scales. In addition, there was a measurable decrease in the mean intensity of the upwelling caused by a reduction in the duration and intensity of upwelling-favourable winds during the last 40 years. The impacts of such changes on plankton were difficult to assess because of the magnitude of high-frequency variability. However, zooplankton abundance in the last 40 years reduced offshore but increased near the coast. These results stress the importance of local factors modulating the impact of large scale environmental trends on the ecosystem.

#### Poster S4.1-4677

### The effect of the North Sea regime shift on the distribution of plankton functional groups and biomass

Marcos **Llope**<sup>1</sup> and Priscilla Licandro<sup>2</sup>

<sup>1</sup> Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Oslo, P.O. Box 1066, Blindern, Oslo, 0316, Norway. E-mail: marcos.llope@bio.uio.no

<sup>2</sup> Sir Alister Hardy Foundation for Ocean Science (SAHFOS), The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK.

One of the main concerns when trying to assess the effects of climate change on a given ecosystem is the occurrence of abrupt changes in the biological component in response to a gradual change in the environmental conditions. For instance, a gradual change in temperature might have little effect until a threshold is reached at which a large shift occurs. A regime shift in several biological compartments has been reported for the North Sea in the late 1980s and its causes and consequences have generated an extensive literature. In this study, we aim for better understanding of this phenomenon by using a new modelling approach to the CPR database. By using a modified non-parametric regression technique (threshold GAM) we investigate both when and where the plankton community experienced the most dramatic changes. To do this, we focus on broad biological descriptors (i.e. biomass of functional groups) while previous works were more focused on changes at a finer scale (i.e. species composition). Substantial changes were observed in the northern North Sea, not only during the late 1980s but also in other periods.

#### Poster S4.1-4679

### Unusual mucilage event along Italian coasts in the northern Adriatic Sea

Nunzio **Penna**<sup>1</sup>, Fabio Ricci<sup>2</sup> and Samuela Capellacci<sup>2</sup>

<sup>1</sup> Environmental Chemistry, University of Urbino, Loc. Crocicchia, Urbino (PU) 61029, Italy. E-mail: cebiam@uniurb.it

<sup>2</sup> Center of Environmental Biology, University of Urbino, V. le Trieste 296, Pesaro (PU) 61100, Italy.

The presence of mucilaginous masses in the Adriatic Sea has been known for a long time: the first records in Gulf of Trieste were noted in 1729. The phenomenon appeared along both the western Italian and eastern Slovenian-Croatian coastlines, causing serious problems for the tourism and fishing industries. The occurrence of mucilage masses is strongly related to the meteo-climatic and seawater conditions, calm sea, high temperatures, thermo-saline stratification of the water-column and nutrients. Mucilage masses usually appear during the summer, but they surprisingly occurred also in the winter of 2006/07 years. This anomalous event was probably linked to the climatic conditions, as both higher air and sea temperatures were observed.

#### Poster S4.1-4689

### Interannual variability in the size-abundance relationship of nano- and micro-phytoplankton in a coastal marine ecosystem

María **Huete-Ortega**<sup>1</sup>, Manuel Varela<sup>2</sup>, Antonio Bode<sup>2</sup> and Emilio Marañón<sup>1</sup>

<sup>1</sup> Departamento de Ecología y Biología Animal, Universidad de Vigo, Ctra/ Colexio Universitario s/n, Vigo, Pontevedra 36310, Spain.  
E-mail: mhuede@uvigo.es

<sup>2</sup> Instituto Español de Oceanografía, Paseo Marítimo Alcalde Francisco Vázquez, A Coruña 15001, Spain.

The size scaling theory has been shown to be a useful tool in modelling phytoplankton community structure. The aim of the present study was to determine the interannual variability in the relationship between abundance and cell size in nano- and micro-phytoplankton in a coastal marine ecosystem and to relate this variability to changes in climatological and hydrographical variables. Size-abundance spectra were determined monthly at 5 depths at a station located off A Coruña (NW Spain) during the period 1993-2002. The resulting slopes and the additional variables were studied using time-series analysis techniques. Despite the high productivity of the ecosystem studied and the variability observed over a variety of time-scales, we found that a significant, inverse relationship between abundance and cell size was persistent throughout the study. Also, over the time period analysed no trend was found in the size-abundance relationship, indicating that both larger and shorter species had the same relative importance. Finally, we evaluate the possible influence of different variables such as temperature, salinity, nutrients, upwelling and the North Atlantic Oscillation Index on the phytoplankton size structure.

#### Poster S4.1-4694

### Temporal variability of 10-year global SeaWiFS time series of phytoplankton chlorophyll *a* concentration

Vincent **Vantrepotte** and Frédéric Mélin

Joint Research Centre, European Commission, Global Environment Monitoring Unit, Institute for Environment and Sustainability, Via Fermi, TP 272, Ispra 21027, Italy. E-mail: vincent.vantrepotte@jrc.it

The SeaWiFS global data set now offers a 10-year time series of consistent, well calibrated, ocean colour record that is suitable for temporal analysis. First, the chlorophyll *a* (Chl *a*) signal is broken down into seasonal, irregular and trend components using an additive decomposition method and considering a linear description of the trend. This yields a classification of the biogeographic provinces of the ocean on the basis of their temporal variability. The variance associated with the seasonal signal represents about 90% of the total variance of Chl *a* monthly series for the mid-latitude regions, from the subtropical gyres to the subpolar waters. This seasonal contribution decreases for tropical and upwelling regions as well as for some marginal seas and coastal waters, where the component of irregular (interannual) variability can dominate. A general decline of Chl *a* is detected in the North Atlantic Drift province as well as in the gyres of northern and southern Pacific. Conversely, a significant increase of Chl *a* is observed, for instance, in the Arabian or Tasman Seas. For some provinces, this simple decomposition approach, assuming a fixed seasonal cycle and a linear trend, does not capture the essential temporal dynamics inherent to the system. A time series decomposition technique based on Census X-11 approach, that allows a varying seasonal amplitude, appears more suitable to describe systems exhibiting strong interannual variations such as the equatorial Pacific where the non-linear long-term evolution related, for instance, to ENSO explains 65% of the total variance.

#### Poster S4.1-4782

### Effects of iron on spatial and temporal phytoplankton distribution using a global 3-D ecosystem model (NEMURO)

Maki N. **Aita**<sup>1,2</sup>, S. Lan Smith<sup>1</sup>, Akio Ishida<sup>1,2</sup>, Michio J. Kishi<sup>1,3</sup> and Yasuhiro Yamanaka<sup>1,2,4</sup>

<sup>1</sup> Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25, Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan. E-mail: macky@jamstec.go.jp

<sup>2</sup> Core Research for Evolutional Science and Technology (CREST), Japan Science and Technology Agency (JST), Kawaguchi 332-0012, Japan.

<sup>3</sup> Faculty of Fisheries Science, Hokkaido University, N13 W8, Kita-ku, Sapporo, Hokkaido 060-0813, Japan.

<sup>4</sup> Faculty of Environmental Earth Science, Hokkaido University, N10 W5, Kita-ku, Sapporo, Hokkaido 060-0810, Japan.

Interannual to interdecadal scale oscillations in atmosphere-ocean systems affect marine ecosystems by altering nutrient supply across the thermocline and horizontal advection. Trace metals such as iron, supplied by atmospheric dust and other sources, are important for limiting primary production. To investigate effects of iron on marine

ecosystems, we used NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography); developed by the MODEL Task Team of PICES (North Pacific Marine Science Organization) embedded into a global three-dimensional physical-biogeochemical coupled model, '3D-NEMURO'. We simulated changes in the lower trophic level of the ecosystem caused by climate variability, using a monthly climatological average of the National Centers for Environmental Prediction (NCEP) 6-hourly data set as a surface forcing to drive the coupled model. The dust flux data used in the model is from the daily output of a global aerosol transport-radiation model, SPRINTARS (Spectral Radiation-Transport Model for Aerosol Species). We compare the standard version of NEMURO to our newly developed version including the iron cycle, focusing on the effect of iron on primary production and distribution of phytoplankton. We will also present preliminary results of decadal scale comparisons of historical simulations with each respective version.

#### Poster S4.1-4788

### Phytoplankton assemblages in the Gulf of Trieste (northern Adriatic Sea): are there signals of climate change? A twenty-year case study

Damiano Virgilio<sup>1</sup>, Nicoletta Burba<sup>1</sup>, Daniela Fornasaro<sup>1</sup>, Benedetta Guardiani<sup>1</sup>, Marina Cabrini<sup>1</sup> and Serena Fonda Umani<sup>2</sup>

<sup>1</sup> Department of Biological Oceanography, National Institute of Oceanography and Experimental Geophysics, via Auguste Piccard 54, Trieste 34014, Italy. E-mail: [dvirgilio@ogs.trieste.it](mailto:dvirgilio@ogs.trieste.it)

<sup>2</sup> Department of Biology, University of Trieste, via A. Valerio 28/1, Trieste 34127, Italy.

In the Gulf of Trieste (northern Adriatic Sea) at a coastal site (18 m depth) the microphytoplankton community has been studied since the early 1980s as part of larger projects on plankton dynamics and food web structure and efficiency. From March 1986 to September 2005, qualitative analyses of microphytoplankton species composition were performed on the basis of monthly or fortnightly sampling using Niskin bottles. To analyse the data set we have used a statistical approach based on clustering and degrees of membership, in order to identify phytoplankton assemblages during the two decades. The assemblages were identified using the Indicator Value and eight clusters were highlighted with specific species assemblages. Seven of these groups were represented by colonial diatoms, while only one was represented by autotrophic dinoflagellates. An annual pattern with different assemblages following one another during the seasons was observed. Within these general dynamics several changes were observed during the two decades; the analyses showed: 1) the disappearance of the late spring-summer assemblage (represented by autotrophic dinoflagellates) and of the early spring one (represented by the diatoms *Skeletonema costatum* and *Pseudo-nitzschia* spp.) towards the middle of 1990s; 2) the appearance of another late spring-summer assemblage (represented by the diatom *Cyclotella* spp. and the autotrophic dinoflagellate *Prorocentrum minimum*) towards the beginning of the 2000s. This evidence might suggest important modifications in the ecological niches probably due to both human impacts and climate change.

#### Poster S4.1-4790

### Seasonal and interannual variation of the marine ecosystem in the western subarctic Pacific simulated by a 3D marine ecosystem model

Naoki Yoshie<sup>1,2</sup>, Kosei Komatsu<sup>3</sup>, Shin-ichi Ito<sup>1</sup>, Tsuneo Ono<sup>4</sup>, Kazuaki Tadokoro<sup>1</sup>, Hiroaki Saito<sup>1</sup> and Yasuhiro Yamanaka<sup>5,6</sup>

<sup>1</sup> Tohoku National Fisheries Research Institute, Fisheries Research Agency, Shinhama-cho 3-27-5, Shiogama 985-0001, Japan. E-mail: [nyoshie@affrc.go.jp](mailto:nyoshie@affrc.go.jp)

<sup>2</sup> Japan Society for the Promotion of Science, 6 Ichibancho, Chiyoda-ku, Tokyo 102-8471, Japan.

<sup>3</sup> National Research Institute of Fisheries Science, Fisheries Research Agency, Fukuura 2-12-4, Kanazawa-ku, Yokohama 236-8648, Japan.

<sup>4</sup> Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro 085-0802, Japan.

<sup>5</sup> Graduate School of Environmental Science, Hokkaido University, N10W5, Kita-Ku, Sapporo 060-0810, Japan.

<sup>6</sup> Ecosystem Change Research Program, Frontier Research Center for Global Change, 3173-25 Showa-machi, Kanazawa-Ku, Yokohama 236-0001, Japan.

Spatiotemporal variations of the lower trophic level marine ecosystem in the western subarctic Pacific were investigated using a 3D marine ecosystem model, for understanding mechanisms of the variations and developing prediction of ecosystem responses to climate change. The marine ecosystem model was a plankton functional types model (e-NEMURO with 3N-4P-4Z-4D), which was coupled with an eddy-resolving physical model (C-HOPE,

grid size: 1/16°) assimilated to satellite altimetry (TOPEX/POSEIDON and Jason-1 data). The model was driven by atmospheric surface forcing (heat flux: NCEP/NCAR reanalysis data, wind stress: QuikSCAT data) for three years from 2003 to 2006. The model successfully reproduced the seasonal and interannual variations of plankton dynamics observed along a repeated monitoring line (A-line: from 42.8°N, 144.8°E to 38.0°N, 147.3°E, including the Oyashio (cold current) region and the Kuroshio (warm current)-Oyashio transition region). Especially the timing of the spring diatom bloom and the maximum chlorophyll *a* concentration of the bloom were quite similar to the observations. Both seasonal and interannual variations of the chlorophyll *a* concentration and zooplankton biomass in the Oyashio region were much larger than those in the Kuroshio-Oyashio transition region. The chlorophyll *a* concentrations in these regions were frequently influenced by the effects of mesoscale eddies, while the zooplankton biomass changed smoothly compared with the chlorophyll *a* concentrations.

#### Poster S4.1-4796

### A statistical analysis of climate variability and ecosystem response in the German Bight

Merja H. Schlueter<sup>1</sup>, Agostino Merico<sup>1</sup>, Karen H. Wiltshire<sup>2</sup> and Wulf Greve<sup>3</sup>

<sup>1</sup> Institute of Coastal Research, GKSS Research Center, Max-Planck-Str. 1, Geesthacht 21502, Germany. E-mail: merja.schlueter@gkss.de

<sup>2</sup> Biologische Anstalt Helgoland, Alfred Wegener Institute for Polar and Marine Research, P.O. Box 180, 27483 Helgoland, Germany.

<sup>3</sup> German Centre for Marine Biodiversity Research (Senckenberg Research Institute), Notkestr. 85, 22607 Hamburg, Germany.

We compiled homogeneous long-term time series of data with 39 variables representing the German Bight and for the period 1975-2004. A diverse set of variables was selected to cover multiple trophic levels and different environmental forcing. Previous studies have hypothesised the presence of regime shifts in observations extending over the entire North Sea. Focusing on a smaller spatial scale, and closer to the coast, we investigated the major modes of variability in the compiled time series using Principal Component Analysis. The results obtained confirm a previously identified regime shift in the North Sea in 1987/88 and suggest that the German Bight is dominantly characterised by long-term modes of variability. We conclude that the shift of 1987/88 was driven by climate forcing (through temperature, Gulf Stream Index, frost days and Secchi depth). Phosphate and ammonium showed highly negative correlations with the documented long-term mode of variability. Diatoms and *Calanus helgolandicus* did not show evidence of changes in relation to this mode. The results also underline the need for ecosystem modelling and the importance of maintaining long-term monitoring programmes.

#### Poster S4.1-4835

### The influence of northern hemisphere climate patterns on the Adriatic Sea pelagic ecosystem

Grbec Branka<sup>1</sup>, Mira Morović<sup>1</sup>, Juan Carlos Molinero<sup>2</sup>, Gordana Beg Paklar<sup>1</sup>, Frano Matić<sup>1</sup>, Ivona Marasović<sup>1</sup>, Jakov Dulčić<sup>1</sup> and Sanja Matić-Skoko<sup>1</sup>

<sup>1</sup> Institute of Oceanography and Fisheries, Šet I. Meštrovića 63, P.O.Box 500 21000 Split, Croatia. E-mail: grbec@izor.hr

<sup>2</sup> Leibniz-Institut für Meereswissenschaften, IFM-GEOMAR, FB3 - Marine 8 Ecology/Experimental Ecology, Düsternbrooker Weg 20, 24105 Kiel, Germany.

We investigated northern hemisphere climate effects on the long term variability of the marine ecosystem in the middle Adriatic Sea during the period 1961-2005. Air temperature, precipitation, evaporation, air-sea fluxes and the North Atlantic Oscillation index covary with the patterns observed in temperature and salinity data. The use of a sequential algorithm for regime shift detection (SARS) applied to the primary production and sardine/anchovy ratio revealed three periods with significantly different mean levels of productivity: 1961-1979, 1980-1996 and 1997-2002. Moreover, the years 1980 to 1996, with the highest primary production, showed contrasting periods of productivity. While the years 1980-1986 showed an increasing trend, the years 1987-1996 were characterised by an inverse pattern. Such opposite patterns appeared to be linked to modifications in thermohaline circulation related to the Eastern Mediterranean Transient (EMT) whose effects prevented warm and nutrient rich water mass intrusions into the Adriatic and reduced productivity. Weak ventilation in the Adriatic was also evident in the lower than normal sea temperature and oxygen concentrations below the thermocline. These results provide evidence on connections between shifts in primary production in the middle-Adriatic with the northern hemisphere climate system via changes in regional atmospheric conditions, and highlight the role atmospheric variability may play as a triggering factor for ecosystem-wide changes.

#### Poster S4.1-4838

### Impact of inorganic and organic nutrient inputs on bacterioplankton community composition along a latitudinal transect in the Atlantic Ocean

Eva **Teira**<sup>1</sup>, Sandra Martínez-García<sup>1</sup>, Alejandra Calvo-Díaz<sup>2</sup>, Xosé Anxelu G. Morán<sup>2</sup> and Emilio Fernández<sup>1</sup>

<sup>1</sup> Departamento Ecología y Biología Animal, Facultad de Ciencias, Universidad de Vigo. Campus Lagoas-Marcosende, 36310 Vigo, Spain.  
E-mail: teira@uvigo.es

<sup>2</sup> Instituto Español de Oceanografía, Centro Oceanográfico de Xixón, Camín de l'Árbeyal s/n, 33212 Xixón, Spain.

Oceans have a major role in the global carbon cycle, and consequently might influence and regulate climate change through feedback mechanisms. A predictable consequence of alterations in soil use and of hydrologic and global biogeochemical cycles is the modification of the amount and nature of continental and atmospheric matter inputs into the world's oceans, which in turn will likely affect microplanktonic structure and functioning. Bacterioplankton are responsible for a large fraction of the respiration and DOM remineralisation in the ocean; therefore, potential changes in their taxonomic composition due to changes in nutrient inputs may have important biogeochemical implications. We hypothesize the impact of nutrient loading depends on the type of input, the kind of the initial microbial community, and the interactions between microbial components. To test our hypothesis we conducted a set of microcosm experiments along a latitudinal transect in the Atlantic Ocean (26°N-29°S). We simulated changes in nutrient fluxes to surface waters by means of a series of addition treatments. We studied the effects of inorganic (nitrate, phosphate and silica) and organic (glucose and amino acids) inputs separately as well as their joint effect on the bacterioplankton community composition. Changes in the relative abundance of important bacterial groups (*Roseobacter*, SAR11, *Gammaproteobacteria*, *Bacteroidetes*) were followed using CARD-FISH (catalysed reporter deposition-fluorescence *in situ* hybridization). We observed that distinct groups responded differently to nutrient additions, and that the bacterial response varied depending on the initial microbial community composition. Our results further suggest that changes in bacterioplankton community structure are related to changes in bacterial carbon use.

#### Poster S4.1-4842

### Response of open ocean microbial communities to inorganic and organic inputs: a microcosm approach along a latitudinal transect in the Atlantic Ocean

Sandra **Martínez-García**<sup>1</sup>, Eva Teira<sup>1</sup>, Emilio Fernández<sup>1</sup> and Alejandra Calvo-Díaz<sup>2</sup>

<sup>1</sup> Departamento Ecología y Biología Animal, facultad de Ciencias, Universidad de Vigo. Campus Lagoas-Marcosende, 36310 Vigo, Spain.  
E-mail: sandra@uvigo.es

<sup>2</sup> Instituto Español de Oceanografía, Centro Oceanográfico de Xixón, Camín de l'Árbeyal s/n, 33212 Xixón, Spain.

The magnitude of the inputs of inorganic and organic matter into the open oceans as well as the ratio between these components are expected to change as a result of desertification processes and changes in wind stress related to climate change. Variations in frequency, strength and quality of these inputs will likely affect the structure and functioning of planktonic microbial communities in the world oceans. To test this hypothesis, we conducted a set of microcosm experiments along a latitudinal transect in the Atlantic Ocean (from 26°N to 29°S). In these experiments, we simulated quantitative and qualitative changes in nutrient fluxes to surface waters by means of a series of addition treatments. We studied the effects of inorganic (nitrate, phosphate and silica) and organic (glucose and amino acids) inputs separately as well as the joint effect of both components on microplankton community structure and metabolism, as determined from photosynthetic efficiency and rates of primary production, bacterial production and community respiration. The observed responses were highly variable and dependent on the initial communities sampled along the latitudinal transect. These results suggest that microplankton community structure should be considered in order to understand the effect of climate-driven changes in the inputs of matter into the oceans on the microbial ecology of the euphotic marine ecosystem.

#### Poster S4.1-4865

### Recent trends in the North Pacific chlorophyll and their controlling factor in relation to climatic forcing using satellite remote sensing

Kosei **Sasaoka**<sup>1</sup>, Sanae Chiba<sup>1</sup> and Toshiro Saino<sup>1,2</sup>

<sup>1</sup> Frontier Research Center for Global Change, JAMSTEC, 3173-25, Showa-machi, Kanazawa-ku, Yokohama 236-0001, Japan.  
E-mail: sasaoka@jamstec.go.jp

<sup>2</sup> Hydrospheric Atmospheric Research Center, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan.

The North Pacific is well known as one of the most biologically productive regions in the world ocean. High primary productivity and strong air-sea interactions characterise the carbon cycle of this region. Understanding the role of the biological pump in the ocean and monitoring variability of the chlorophyll *a* (chl *a*) and primary productivity is very important to clarify the geochemical cycles. Ocean colour remote sensing is a useful new tool for continuously monitoring the temporal and spatial variability of chl *a* concentration, and now over 10-year ocean colour remotely sensed data sets are available. In this study, we will describe seasonal and inter-annual variability of chl *a* concentrations and examine recent trends in chl *a* variability focused on the North Pacific using an ocean colour sensor (SeaWiFS) during 1997-2007. To clarify the factors controlling phytoplankton variability, we utilised a combination of satellite remote sensing data from AVHRR (sea surface temperature), SeaWiFS (photosynthetically active radiation, wind speed, as well as climatology data). Finally we will discuss the distribution patterns of chl *a* and their controlling factor in the North Pacific in relation to climatic forcing such as ENSO and/or monsoonal wind.

#### Poster S4.1-4868

### ICES Working Group on Zooplankton Ecology

Roger **Harris** and WGZE

Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK. E-mail: r.harris@pml.ac.uk

The ICES Working Group on Zooplankton Ecology (WGZE) was established as a Study Group by the ICES Council in 1990. In 1994, ICES changed the status of the group into a Working Group, giving it a more permanent position within the ICES structure. Since then the group has met annually to discuss research activities and technical issues on micro-, meso-, and macroplankton, as well as benthic meroplanktonic larvae and ichthyoplankton. The group is the only single disciplinary international group working on zooplankton in the world, giving it a special position within the community of marine researchers. The products of its work include Laboratory and Sea-going Workshops, Taxonomic Workshops, The Zooplankton Methodology Manual, The Annual Plankton Status Report, ICES Zooplankton Taxonomic ID Sheets and advice to other ICES expert groups. The products have wide use both within and outside the ICES community. The poster is intended to advertise some of the activities of WGZE, and to encourage participation and collaboration.

#### Poster S4.1-4869

### BASIN: Basin-scale Analysis, Synthesis, and Integration: resolving the impact of climatic processes on ecosystems of the North Atlantic basin and shelf seas

Roger **Harris** (on behalf of the BASIN Steering Group: Peter Wiebe, Cisco Werner, Brad DeYoung, Pierre Pepin and Mike St. John)

Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK. E-mail: r.harris@pml.ac.uk

BASIN is an initiative to develop a joint EU/North American research programme in the field of ocean ecosystems in support of the Global Earth Observation System of Systems (GEOSS) initiative. The focus of this initiative is the integration and synthesis of data sets for coupling with modelling studies at the basin-scale to elucidate the mechanisms underlying observed changes in physical and biological changes in the North Atlantic Ocean and to predict consequences of climate and environmental change. The first BASIN meeting took place in Iceland in March 2005 and provided the basis upon which further programme development has taken place (Wiebe *et al.* (Eds.). 2007. BASIN. Basin-scale Analysis, Synthesis, and INtegration. GLOBEC Report 23/US GLOBEC Report 20, 56pp.). Two subsequent science workshops have been held to identify

key issues and strategies for the development the BASIN programme. The first was held in Hamburg from 23-25 of January 2007 and the second was held in Chapel Hill, NC, from 1-3 of May 2007. These meetings identified and documented the state of the art of climate-related ecosystem research in the North Atlantic basin and associated shelf seas, and produced broad based objectives that are designed to foster the development of an understanding of the links between climate and the marine ecosystems of the North Atlantic Basin and the services these ecosystems provide including exploited marine resources. The key next step is to produce a science/implementation plan where by joint research initiatives involving the EU, USA, and Canada can be developed and funded.

#### **Poster S4.1-4870**

### **METAOCEANS: training in advanced meta-analysis and comparative analysis techniques applied to marine ecosystems**

Roger **Harris** and METAOCEANS students

Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK. E-mail: r.harris@pml.ac.uk

Major international programmes and parallel technological developments have resulted in large amounts of information on biogeochemistry, and the functioning and structure of marine ecosystems. The resulting data represents a key resource to explore patterns and carry out comparative ecosystem analyses. Many of these large data sets remain largely unexploited, as these data have been used in a local context and few attempts have yet been made to synthesize them, and to link them with others, to provide a global perspective. This is partially due to a gap in the training of marine scientists in meta- and comparative analyses. The METAOCEANS project, funded by the European Union, recognises this problem and provides an early stage training programme dedicated to train young scientists in advanced meta-analyses and comparative analyses techniques applied to marine ecosystems. The project combines the development of expertise on all relevant ecosystem functions, with emphasis on new approaches and analytical techniques. Twelve PhD students are currently working on subjects applying meta-analyses and comparative analyses techniques to the following topics: ecosystem metabolism, microbial food webs, planktonic processes, trophic links and human impacts. Research projects are carried out at six European institutes (AZTI, Spain; CNRS, France; CSIC, Spain; DIFRES, Denmark; PML, UK and UoB, Norway) with students spending time in other partner institutes as part of their training. The poster presents a synthesis of the current work accomplished within the METAOCEANS project.

#### **Poster S4.1-4874**

### **Effects of ice meltwater on Arctic bacterioplankton**

Maria M. **Sala**<sup>1</sup>, Jesús M. Arrieta<sup>2</sup>, Dolors Vaqué<sup>1</sup>, Julia Boras<sup>1</sup> and Carlos M. Duarte<sup>2</sup>

<sup>1</sup> Institut de Ciències del Mar (CSIC), Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain. E-mail: msala@icm.csic.es

<sup>2</sup> Institut Mediterrani d'Estudis Avançats (CSIC), Miquel Marqués 21, 07190 Esporles, Mallorca, Spain.

Climate change is causing a rapid melting of Arctic ice containing nutrients and contaminants accumulated during recent decades. We have evaluated the effects of ice meltwater on the bacterioplankton communities of the Arctic Ocean in two microcosm experiments. One-metre ice cores were sampled from two locations at the ice-edge in the Fram Strait (Arctic Ocean). Sections of the ice core were melted and 100 mL meltwater were added to 900 mL of < 0.8 µm filtered seawater. The bottles were incubated in the dark during 4 days. After the incubation, bacterial abundance, production and the activity of eight ectoenzymes and the utilization of 31 carbon sources were determined. Addition of meltwater resulted in an increase in bacterial abundance and production in all cases. Among the activities and carbon sources studied, meltwater generally caused an increase of chitinolytic and proteolytic activity and the utilisation of N-acetyl-glucosamine, all containing nitrogen. These results indicate that the addition of meltwater enhanced the use of organic nitrogen compounds which could be incorporated into the marine planktonic food web through their consumption by bacteria.

#### Poster S4.1-4876

### Interactions among climate, circulation, and plankton distribution in the Black Sea

Elena [Arashkevich](#), Alexander Timonin, Alexander Kazmin and Andrei Zatsepin

Shirshov Institute of Oceanology, RAS, 36 Nakhimovsky pr., Moscow 117997, Russia. E-mail: aelena@ocean.ru

Based on long-term investigations in the NE Black Sea, four main water circulation regimes and four corresponding types of cross- and long shore distribution of plankton have been distinguished. 1) The narrow fast Rim current flowing close to the continental slope causes the biomass increase over the slope and its dramatic decrease offshore. Intensification of long-shore transport and restriction of cross-shelf exchange favour the propagation of neritic species along the basin shelf and prevent their export offshore. 2) Vortical regime with nearshore eddy formation leads to a biomass increase over the shelf and at the frontal zones of the eddy. Revolute translational movement of eddies causes both cross- and along shelf transport of plankton. 3) Formation of long-lasting large eddies in the open sea causes the significant increase of plankton biomass in the eddy area especially at the periphery. Neritic species, benthic and fish larvae are trapped with the eddies and transported in the open sea. 4) Relaxation and meandering of the Rim current is accompanied with “smoothed” plankton distribution where the biomass and structure of the plankton community are similar nearshore and offshore. Substantial cross-shelf exchange causes “washout” of neritic species and larvae beyond the boundaries of their habitat. Every regime can exist at timescale up to seasonal. The interannual alterations of the prevailing circulation regime are related to the variable long-term thermohaline and wind forcings which, in turn, are affected by climate change. We show that the surface temperature and wind regime depend on the large scale atmospheric circulation and particularly on the North Atlantic Oscillation.

#### Poster S4.1-4914

### Comparing microphytoplankton seasonality after 50 years at a coastal site in the northwest Mediterranean

Renate [Scharek](#)<sup>1</sup>, Mikel Latasa<sup>2</sup>, Ramon Massana<sup>2</sup> and Vanessa Balagué<sup>2</sup>

<sup>1</sup> Centro Oceanográfico de Gijón (IEO). Av. Príncipe de Asturias, 70 Bis, Gijón E-33212, Spain.

<sup>2</sup> Institut de Ciències del Mar (CSIC). Passeig Marítim de la Barceloneta, 37-49, Barcelona E-08003, Spain. E-mail: rscharek@gi.ieo.es

We followed the temporal succession of the phytoplankton community at monthly intervals off the coastal town of Blanes (Catalunya, Spain). Microphytoplankton as well as some components of smaller size classes, reveal a marked seasonal variation. Diatom abundances peak in February/March and contribute the bulk biomass of the annual chlorophyll maximum. Assemblages change from year to year and resemble temperate spring bloom assemblages. Concentrations of the dinoflagellate genus *Ceratium* increase in late spring. Other microplanktonic dinoflagellates display a slight increase in summer. Microphytoplankton seasonality off Blanes is similar to other more eutrophic coastal systems with a spring bloom of diatoms and a summer biomass increase of microplanktonic dinoflagellates. Our observations reveal remarkable similarities to microphytoplankton annual dynamics observed off Blanes half a century earlier by Ramon Margalef during two time series carried out for 17 years. These concurrences indicate that microplanktonic population dynamics in Blanes probably have not changed significantly over many years.

#### Poster S4.1-4926

### Recent variability of coccolithophore blooms in the eastern Bering Sea shelf

Sei-Ichi [Saitoh](#)<sup>1</sup>, Takahiro Iida<sup>1</sup>, Kohei Mizobata<sup>2</sup> and Mitsuhiro Toratani<sup>3</sup>

<sup>1</sup> Laboratory of Marine Bioresource and Environment Sensing, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minatocho, Hakodate, Hokkaido 041-8611, Japan E-mail: ssaitoh@salmon.fish.hokudai.ac.jp

<sup>2</sup> International Arctic Research Center, University of Alaska Fairbanks, 11120 Glacier Highway, Juneau, AK 99801, USA.

<sup>3</sup> School of High-Technology for Human Welfare, Tokai University, Numazu 410-0395, Japan.

During the late-summer of 1997, for the first time ever recorded, most of the continental shelf of the eastern Bering Sea was covered by aquamarine waters, resulting from massive bloom of coccolithophores *Emiliania huxleyi*. Since then, coccolithophores blooms are not unusual but common in the eastern Bering Sea. Objectives of this study are, to examine recent temporal and spatial variability of coccolithophore blooms in eastern Bering Sea, and to evaluate the causes maintaining the blooms. Since 1997, coccolithophore blooms have been monitored using satellite ocean colour SeaWiFS and MODIS data and recently the peak of the bloom tended to occur in September.

#### Poster S4.1-4927

### COPEPOD: a climate studies resource for historical plankton data

Todd D. **O'Brien**

NOAA - National Marine Fisheries Service, 1315 East-West Hwy, Silver Spring, Maryland, USA. E-mail: Todd.O'Brien@noaa.gov.

The Coastal & Oceanic Plankton Ecology, Production & Observation Database (COPEPOD) is an online database of historical zooplankton and phytoplankton abundance, biomass, and composition data. COPEPOD offers easy, online searching and access to over one hundred thousand plankton tows from hundreds of cruises collected by a variety of monitoring programmes, surveys, and projects from around the world. Individual data sets can be downloaded in a variety of formats, or the user can select from an assortment of pre-made regional (e.g. "Antarctic", "North Atlantic") or taxonomic (e.g. "diatoms", "copepods") data compilations. COPEPOD also features an interactive map describing over forty zooplankton time series from around the world. Each mapped point provides a standardised content summary of the featured time series, as well as a contact person for the data. This poster summarises the COPEPOD interface and the content and data products available online now at: <http://www.st.nmfs.noaa.gov/plankton>

#### Poster S4.1-4931

### Seasonal and interannual variability of primary production in the scallop forming area in the Okhotsk Sea in relation to climate change

Muzzneena Ahmad Mustapha and Sei-Ichi **Saitoh**

Laboratory of Marine Bioresource and Environment Sensing, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato-cho, Hakodate, Hokkaido 041-8611, Japan. E-mail: ssaitoh@salmon.fish.hokudai.ac.jp

The Okhotsk Sea is one of the most biologically productive regions in the world, and it supports high fisheries production. It is well known as one of the southern most seasonal sea ice zones in the northern hemisphere. Seasonal change of sea ice in this area has large interannual variations and has been considered to play an important role in the high production at the ice edge. The coastal region of the Sea of Okhotsk, Hokkaido, is an ideal habitat for the Japanese scallop *Mizuhopecten yessoensis*, and has supported important fisheries for this species since the early 1900s. Understanding dynamics of ice formation and phytoplankton bloom development is important in management of this benthic community. The objectives of this study are to clarify the interannual variability of primary production in the scallop farming area in the Okhotsk Sea using satellite remote sensing and GIS. Prolonged high primary production after termination of the spring bloom is supported by the development of the frontal area along the Soya Warm Current in summer and of the East Sakhalin Current in autumn. Even at the weakening of one process, this area is sustained by other processes. Clarifying the effects of these physical processes is important to understand effects of future climate change and formulation of rational management plans in the scallop farming area.

#### Poster S4.1-4940

### Shifts in the Black Sea plankton communities: phenological response to climate forcing or nutrient alterations

Snejana P. **Moncheva**<sup>1</sup>, Valentina G. Doncheva<sup>1</sup>, Kremena B. Stefanova<sup>1</sup> and Lyudmila T. Kamburska<sup>1,2</sup>

<sup>1</sup> Institute of Oceanology, Bulgarian Academy of Sciences, P.O. Box 152, Varna, 9000, Bulgaria. E-mail: snejm@varna.techno-link.com

<sup>2</sup> EC, DG-JRC, Institute for Environment and Sustainability, TP 272, Ispra 21020, Italy.

Our study disclosed temporal patterns (seasonal, interannual, and decadal) of dominant phytoplankton and mesozooplankton species in the period 1960–2005 trying to disentangle the combined effect of rising temperatures and changing nutrient supply on the coastal ecosystem of the western Black Sea. For assessment of plankton community dominance we also discuss long-term dynamics of key taxonomic groups. We used seasonal decomposition techniques to reveal seasonality and trend of key plankton species. Statistical analyses were applied to disclose the extent of correlations between species and climate indices. Appearance/disappearance, replacement and numerical abundance of cold and warm-water species were used as an indication of shifts in the plankton communities (phenological response). At a species level we revealed temporal fluctuations of

*Emiliana huxleyi*, *Prorocentrum minimum*, *Skeletonema costatum* as the most typical bloom producing species. The copepods *Acartia clausi* and *Calanus euxinus* and the cladocerans *Penilia avirostris* and *Oikopleura dioica* (Appendicularia) were focused on. The results suggest reduced amplitude of seasonal oscillations and year to year variations, a decrease of phytoplankton blooms and their critical levels attained especially in summer, an increase in the dominance of diatoms, along with an elevated increased portion of taxa “other” than the habitual for the Black Sea basin species pool, chrysophytes, microflagellates and cryptophytes, and a shift of the seasonal succession of phyto and zooplankton species. The ecosystem shifted towards more harmonised seasonal dynamic-reduced amplitude of seasonal oscillations and year to year variations. The increased dominance of heterotrophic dinoflagellates and elevated presence of “other” concurrent species that alter the cross-phyllitic balance of the assemblages along with the reported deviations in the succession are signatures correlated to hydrometeorological, anthropogenic forcing and *Mnemiopsis* pressure in the Black Sea, an integrated phenological response to the altered environment. The decoupling of phenological relationships in the lower food chain might have important ramifications for trophic interactions, altering the energy flow and ecosystem-level changes.

#### Poster S4.1-4945

### Reaction of dominant copepods to climatic changes in the Barents Sea

E. Orlova<sup>1</sup>, V. Guzenko<sup>1</sup>, P. Dalpadado<sup>2</sup>, T. Knutsen<sup>2</sup>, V. Nesterova and O. Yurko<sup>1</sup>

<sup>1</sup> Polar Research Institute of Marine Fisheries and Oceanography, 6 Knipovich Street, 183763 Murmansk, Russia. E-mail: orlova@pinro.ru

<sup>2</sup> Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway.

Specific years typical of different climatic periods were taken as examples to show the peculiarities of the Barents Sea plankton community's structure and distribution in time and space. The dynamics of sea ice in summer was analysed as the major factor influencing the plankton's condition. The numbers, reproduction times and stage structures of *Calanus finmarchicus* and *C. glacialis* in the Arctic and mixed waters in August-September were studied. It was found that aggregations of the former are influenced by the rates of ice retreat, intensity of the local population's reproduction and transport of early stages from the southern spawning sites. Slow ice retreat causes the plankton to accumulate along the ice edge and rapid ice retreat in the areas with higher horizontal gradients of water temperature results in significant population increases (1987, 1989, 2002, and 2005). Also, in colder years distribution is limited by 77°N while in the warm years by 80-82°N. In 2004 when the ice edge in July was more dynamic, and also in 2006 when in August the Barents Sea was ice-free, the distribution area of *C. finmarchicus* was small and its number was low. The formation of *C. glacialis* aggregations mostly depends on the amount of ice and its melting which causes high numbers and broad distribution of this species (including early developmental stages) in some years (1989, 2004). In 2006 due to the absence of ice *C. glacialis* were very sparse in the north except for in the north-east where ice remained for the longest period. In the years under study in the northern areas in August-September reproduction of *C. finmarchicus* and *C. glacialis* was observed but in 2006 it was weak; also unlike other warm years where the populations of the both species had few early developmental stages.

## S4.2 Impacts on higher trophic levels

19 May, 11:20 (S4.2-4699) Invited

### Predicting impacts of climate change on fisheries production

Keith **Brander**

DTU Aqua, Charlottenlund Slot, Charlottenlund DK-2920, Denmark. E-mail: keith@ices.dk

Predictions of terrestrial crop and forestry production under climate change are made with medium confidence in the 2007 IPCC report, based on extensive experimental and comparative field studies of a small number of important species. Some relatively trivial predictions concerning fisheries are made with high confidence (distribution shifts; extinctions at the edges of ranges), but we have very low confidence in predictions of future fisheries production globally, regionally or for individual species. The reasons why we are less able to predict aquatic than terrestrial systems are fairly obvious and will be reviewed. We can improve our ability to predict future aquatic production by research and management which includes:

- Experiments and comparative field studies to investigate the effects of changes in temperature, oxygen, pH, ammonium, salinity etc. on individual species.
- Modelling of net primary production (all scales) with improved nutrient dynamics and temperature sensitivity.
- Regional and smaller scale models of coupled physical and biological systems which capture important local processes (e.g. declining salinity of the Baltic Sea).
- Analysis and models which aggregate and simplify fish community structure and production.
- Better understanding and representation of trophic dynamics.
- Management based on more active control of production systems.

These topics will be briefly introduced and some relevant research questions proposed.

A key limitation in our ability to predict future fisheries production arises because the response of marine ecosystems to changes in physical or biological forcing can be nonlinear, e.g. when a threshold value is exceeded and a major change in species composition, production, and dynamics takes place. Seasonal and extreme patterns of forcing variables must also be taken into account, since changes in mean values may fail to capture important processes. Aquatic food production is increasingly based on controlled systems (aquaculture, ranching etc.) and can be regarded as undergoing a transformation similar to that which has occurred in terrestrial food production and land use throughout human history. It may be time to acknowledge this trend and to review the basis of fisheries and marine ecosystem management from this perspective.

19 May, 11:45 (S4.2-4596) Invited

### What will happen on the stock of chum salmon, walleye pollack, and common squid in the Northern Pacific?

Michio J. **Kishi**<sup>1,2,3</sup>, Yasunori Sakurai<sup>2</sup> and Masahide Kaeriyama<sup>2</sup>

<sup>1</sup> Graduate School of Environmental Science, Hokkaido University, N10W5, Kita-ku, Sapporo, Hokkaido 060-0810, Japan.  
E-mail: mjkish@nifty.com

<sup>2</sup> Faculty of Fisheries Sciences, Hokkaido University Minatocho 3-1-1, Hakodate, Hokkaido 041-8611, Japan.

<sup>3</sup> Ecosystem Change Research Program, Frontier Research Center for Global Change, 3173-25, Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.

What will happen to the stocks of commercial fishes in the Northern Pacific under global warming? We forecast the future status of fish stocks based on the outputs from a global atmosphere–ocean–terrestrial coupled model with an A3 scenario. Hokkaido stock of chum salmon will disappear by 2100, although chum salmon in Bering Sea will remain. Honshu stock of walleye pollack will collapse in 2050 and Hokkaido stock will decrease dramatically by 2100. The spawning season of Japanese common squid will move 1-2 months ahead of the present season. Using NEMURO and NEMURO.FISH, developed by PICES MODEL Task Team, Hashioka *et al.* (2007) predicted the change of lower trophic biomasses in global warming case. A bio-energetic model of common squid in the Japan Sea shows a difference of growth as well as the possible change of its migration route under climate change. We will discuss the future possibility of NEMURO applications on the forecast of ecological states.

**19 May, 12:10 (S4.2-4719)**

### **Marine fish and fisheries in a changing climate**

Adriaan D. Rijnsdorp<sup>1</sup> and Christian Möllmann<sup>2</sup>

<sup>1</sup> Wageningen IMARES, Institute for Marine Resources and Ecosystem Studies, Haringkade 1, P.O. Box 68, IJmuiden 1970AB, The Netherlands. E-mail: Adriaan.Rijnsdorp@wur.nl

<sup>2</sup> Institute for Hydrobiology and Fisheries Science, University of Hamburg, Grosse Elbstrasse 133, Hamburg D-22767, Germany.

Based on first principles, we develop a framework for the integrated study of the response of fish populations to climate change. We summarise available literature on processes operating at the physiological, population and ecosystem level to interpret observed changes distribution and abundance in relation to changes in climate and predict possible changes in response to IPCC climate scenarios. Our study covered the eastern North Atlantic region between Iberian and Arctic waters. Major conclusions from this exercise are: (i) early life-history stages will be more sensitive to climate change due to their narrower temperature tolerance and lower body reserves, (ii) fish species of higher latitudes will be more sensitive due to their narrower tolerance range and the predicted larger increase in temperature, (iii) climate driven changes in spawning and nursery habitats are likely to be more important than changes in the adult habitat, (iv) the effect of climate on fish populations is local and will hence deviate from general predictions due to local differences in the availability of suitable habitat for successive life history stages and connectivity among these, (v) in temperate ecosystems fish stocks are likely affected by changes in their food base primary and secondary production in combination with bio-energetic and population dynamic processes, while in high latitude ecosystem processes, climate induced changes in predation will prevail, (vi) climate impact will interact with the effects of fishing and may change ecosystem control from top-down to bottom-up and *vice versa*.

**19 May, 12:25 (S4.2-4763)**

### **Impacts of climate shifts in the late 20th century on zooplankton and fishery resources in the Japan Sea**

Yury I. Zuenko, Elena I. Ustinova, Alexander N. Vdovin, Vladimir A. Nuzhdin and Natalia T. Dolganova

Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok 690950, Russia.

E-mail: zuenko@tinro.ru

The Japan Sea environments are determined by the monsoon regime, and in particular they depend on the strength of the Siberian High in winter and the Hawaiian High in summer. The winds from any direction cool the sea surface, although the summer monsoon supports a positive heat flux into the sea due to the strengthening of the warm northward currents. Indeed, weakening of the Siberian High caused winter warming in the Japan Sea surface waters since the late 1980s, and weakening of the Hawaiian High was the reason for the summer warming since the late 1990s. The winter sea surface temperature is an important factor in the intermediate water formation, so the temperature in the intermediate layer became higher in the late 1980s, but the sea surface temperature shift in the late 1990s had no significant effect on this layer. Large-sized cold-water copepods, became more abundant in the 1990s, because the warming favoured their maturation. Fluctuations of mass subtropic fishes and squids were coherent with the zooplankton abundance changes: jack mackerel, Pacific saury, and Japanese common squid bloomed in the highly-productive conditions of the 1990s. This appeared as increased catches of these species, with time-lags corresponding to their age at recruitment. The stocks of mass boreal fishes depend directly on thermal conditions or on both the environment and zooplankton abundance. Japanese sardine was a special case: its fluctuations depend directly on changes of neither abiotic nor biotic parameters, but they have an influence on zooplankton abundance. Cushing's match/mismatch hypothesis is discussed for this species.

**19 May, 12:40 (S4.2-4960)**

### **Effect of climate change on estuarine fish production in Queensland, Australia**

Jan-Olaf Meynecke

Centre for Aquatic Processes and Pollution, and School of Environmental and Applied Science, Gold Coast Campus Griffith University, PMB 50 GCMC, Queensland 4222, Australia. E-mail: j.meynecke@griffith.edu.au

The speculation that climate change may impact on sustainable fish production suggests a need to understand how these effects influence fish catch on a broad scale. Many commercially important fish species use estuarine habitats such as mangroves, tidal flats and seagrass beds as nurseries or breeding grounds and have lifecycles correlated to

rainfall and temperature patterns. Correlation of catches of mullet (e.g. *Mugil cephalus*) and barramundi (*Lates calcarifer*) with rainfall suggests that fisheries may be sensitive to effects of climate change. A conceptual model demonstrates ecological and biophysical links of estuarine habitats that influence capture fisheries production. The difficulty involved in explaining the effect of climate change on fisheries arising from the lack of ecological knowledge may be overcome by relating climate parameters with long-term fish catch data. Catch per unit effort, rainfall, the Southern Oscillation Index, temperature and catch time series for specific combinations of climate seasons and regions have been explored. The major fluctuations in Queensland's capture fisheries were contemporaneous with *El Niño* and *La Niña* events and reduced rainfall. Furthermore, results indicate that up to 30% of Queensland's total fish catch and up to 80% of the barramundi catch variation for specific regions can be explained by rainfall often with a lagged response to rainfall events. Monthly air temperature and monthly mullet, flathead (*Platycephalus fuscus*) and whiting (*Sillago* spp.) catch showed negative relationships in south-east Queensland and in the central east coast whereas barramundi catch was positive related to average air temperature in the central east coast. Our approach allows an evaluation of the economic consequences of climate parameters on estuarine fisheries, thus highlighting the need to develop forecast models and manage estuaries for future climate change impact by adjusting the quota for climate change sensitive species.

**19 May, 12:55 (S4.2-4897)**

### **Larval fish physiology and individual-based models: exploring climate impacts on early life stages of key species**

Myron A. **Peck**<sup>1</sup>, Ute Daewel<sup>1</sup> and Corinna Schrum<sup>2</sup>

<sup>1</sup> Center for Marine and Atmospheric Climate Research, University of Hamburg, Olbersweg 24, Hamburg 22767, Germany.

E-mail: myron.peck@uni-hamburg.de

<sup>2</sup> Bjerknes Center for Climate Research and Geophysical Institute, University of Bergen, Allégaten 70, Bergen 5007, Norway.

Individual-based models (IBMs) are popular tools used to investigate how abiotic and biotic factors influence the vital rates of early life stages of marine fishes. A variety of approaches have been used to represent the feeding and growth of marine fish larvae within IBM's, from simple/holistic descriptions with no prey fields to complex/mechanistic depictions using modelled prey fields. Here, we discuss aspects of larval physiology underpinning such models by reviewing the state of knowledge regarding how key environmental factors (e.g. temperature, prey availability) impact larval fish growth physiology. The review includes an analysis of laboratory data collected on a variety of species and aims to reveal both specific (within-species) and general (between-species) patterns. Since the choice of how to represent prey fields can be critical to IBM-based projections of larval fish growth and survival, we also comment on the utility and pitfalls associated with using model-derived prey fields. Next, we provide an example of results obtained from a coupled bio-physical IBM developed for sprat (*Sprattus sprattus*) and Atlantic cod (*Gadus morhua*). The coupled model system projected marked differences in the survival and growth of these species in the North Sea driven by species-specific differences in the spatial- and temporal extent of match/mismatch situations between first feeding larvae and their prey. Employing coupled models that utilise more generic fish early life stage IBMs seems warranted and would allow us to explore climate-driven processes (e.g. match/mis-match) in a wider variety of marine fish species.

**19 May, 14:30 (S4.2-4806)**

### **Temperature, light and food mediated growth for larval cod (*Gadus morhua*) at latitudinal extremes: a comparative study between the NW Atlantic and Norwegian Sea ecosystems**

Frode B. **Vikebø**<sup>1</sup>, T. Kristiansen<sup>2</sup>, F.E. Werner<sup>2</sup>, S. Sundby<sup>1</sup>, R.G. Lough<sup>3</sup> and E.G. Durbin<sup>4</sup>

<sup>1</sup> Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway. E-mail: frovik@imr.no

<sup>2</sup> University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3300, USA.

<sup>3</sup> NOAA, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA.

<sup>4</sup> University of Rhode Island, Kingston, Narragansett, RI 02881, USA.

Atlantic cod (*Gadus morhua*) is a widespread species distributed across the North Atlantic shelves of latitudinal range from Georges Bank (42°N) to Spitsbergen (80°N). Environmental constraints, such as temperature, light and prey availability, vary greatly both between and across the cod nursery grounds. These variations have strong impact on growth, feeding conditions, and survival for larval cod between years and habitats. We applied an individual based model for larval cod for environmental conditions at the latitudinal extremes of the Georges Bank (42°N) and Lofoten (68°N). The model contains modules for mechanistic feeding, ingestion, assimilation, gut content,

metabolism, and growth. It is forced with light, observed temperature profiles distributed across the respective habitats, and a range of prey concentrations for several years. The calculated growth rates quantify the requirements for food in order to grow at rates close to their size- and temperature-dependent capacity for the two habitats, both within and between years. These theoretical explorations combined with the observations on growth and abundance of year classes, open up our understanding of how larval fish may be affected by future climate changes. The observations of the ecological effects of the natural multidecadal climate oscillations of the 20th century give some indications. However, the projected amplitude of the temperature change by the mid 21st century exceeds by far the natural variability of the past century. Therefore, comparative studies covering the latitudinal extremes are one important way to improve our understanding of climate change beyond natural variation.

**19 May, 14:45 (S4.2-4646)**

### **Variability in environmental factors affecting the recruitment of fish species in the North East Atlantic**

Ralf van Hal<sup>1</sup>, Catherine L. Scott<sup>2</sup> and Christine Röckmann<sup>1</sup>

<sup>1</sup> Wageningen IMARES (Institute for Marine Resources and Ecosystem Studies), P.O. Box 68, 1970 AB IJmuiden, The Netherlands. E-mail: Ralf.vanhal@wur.nl

<sup>2</sup> School of Biological Sciences University of Liverpool, Crown Street, Liverpool L69 7ZB, UK.

Inter-annual variations in recruitment may be due to processes operating during specific life history stages: eggs and larvae, juveniles and adults. In order to better understand the recruitment mechanisms it is important to focus on the conditions that fish actually experience in the spawning area, nursery area and adult feeding grounds. Using spatially explicit data we analysed how potentially relevant environmental variables affected recruitment variation using additive modelling. The environmental data were a combination of measured, satellite and modelled sources. The analyses show that the recruitment of cod (*Gadus morhua*) in ICES area VIa is affected by the temperature in the spawning areas during the spawning period and the availability of important prey organisms. The recruitment of North Sea plaice (*Pleuronectes platessa* L.) is correlated with the NAO-winter index the year prior to spawning, and affected by the bottom temperature during the feeding period and the bottom temperature in the spawning period. The recruitment of North Sea autumn spawning herring (*Clupea harengus*) is affected by the spawning stock biomass and the salinity in the spawning area around the Orkney Islands. To assess if the above models could be used for predictions or management purposes they are compared to basic stock-recruitment relationships, such as Beverton-Holt (with or without including environmental factors), to determine if the inclusion of extrinsic environmental factors improves predictions of recruitment.

**19 May, 15:00 (S4.2-4920)**

### **Impact of climate variability on small pelagic fishes in the Atlantic and Pacific: a comparison**

Jürgen Alheit

Leibniz Institute for Baltic Sea Research, Seestr. 15, Warnemünde, 18119, Germany. E-mail: juergen.alheit@io-warnemuende.de

Populations of small pelagic fishes such as sardine, anchovy, sardinella, herring and sprat respond dramatically and quickly to changes in ocean climate because of their characteristic life history traits: short life spans, high fecundity and short, plankton-based food chains. Consequently, they are excellent indicators of the impact of climate variability and regime shifts in ecosystems as they exhibit drastic variations in population size during short periods. Numerous examples for the response (changes in abundance, distribution and phenology) to climate variability have been demonstrated for the rather small clupeoid populations in the NE Atlantic whereby the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) seem to be the external drivers. Interestingly, whereas open water populations of sardines and anchovies seem to react preferentially to the AMO, sprat and sardinellas in semi-enclosed basins respond primarily to the NAO. Although the large clupeoid populations in the eastern and western boundary currents of the Pacific have exhibited drastic fluctuations in abundance, their response to climate variability is not as clear-cut as in the Atlantic. The impact of the Pacific Decadal Oscillation (PDO) does not seem to be as overriding as the AMO and NAO in the Atlantic. Effects of different climate phenomena on small pelagic populations and the mechanisms by which they are brought about will be compared. Potentially climatically-induced teleconnection patterns will be investigated, including the Arctic Oscillation which affects both oceans.

19 May, 15:15 (S4.2-4626)

### Mechanisms of population dynamics of Japanese sardine and Japanese common squid in the Kuroshio/Oyashio current system, with a speculation on their future

Akihiko **Yatsu**<sup>1</sup>, Hiroshi Nishida<sup>2</sup>, Ken Mori<sup>1</sup>, Yasunori Sakurai<sup>3</sup> and Sanae Chiba<sup>4</sup>

<sup>1</sup> Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro 085-0802, Japan.

E-mail: yatsua@fra.affrc.go.jp

<sup>2</sup> National Research Institute of Fisheries Science, Fisheries Research Agency, Fukuura 2-12-4, Kanazawa-ku, Yokohama 236-8648, Japan.

<sup>3</sup> Graduate School of Fisheries Sciences, Hokkaido University, Minatomachi 3-1-1, Hakodate 041-8611, Japan.

<sup>4</sup> Ecosystem Change Research Program, JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama 236-0001, Japan.

In the Kuroshio/Oyashio current system, Japanese sardine *Sardinopus melanostictus* was the most dominant commercial pelagic fish during the 1980s. The Japanese common squid *Todarodes pacificus* is also a commercially important species whose catch increased during the 1990s, in contrast to the Japanese sardine. Based on the existing information, we constructed conceptual mechanistic models of the population dynamics of these two species including linkages to ocean/climate changes. Stronger Aleutian Low activities favour Japanese sardine through intensified Oyashio (spin-up), lower sea surface temperature (SST) in the Kuroshio Extension Current, and depression of the common squid population, one of the major predators. In turn, weaker Aleutian Low and *El Niño* (negative SOI) favour common squid through warming of SST in their spawning ground (the East China Sea) and shorter Kuroshio path (spin-down). Productivity of the Oyashio will be enhanced by a moderate SST rise, through more available light (stratification in surface layer), but will deteriorate with an extreme SST rise due to more stratification that reduces vertical supply of nutrients to sea surface during winter. Under global warming, the Aleutian Low will be intensified and thereby spin-up the Oyashio and Kuroshio. These conceptual models suggest effects of global warming on sardine and common squid are complex, because intensification of the Aleutian Low and SST rise have opposite effects on the population dynamics of these two species, and a SST rise in the Japan Sea will delay the spawning period of common squid, thus it may subsequently cause a mismatch with blooming of phytoplankton and subsequent availability of zooplankton.

19 May, 15:30 (S4.2-4612)

### Shifting warm-water to cold-water conditions and food web dynamics of juvenile Pacific salmon in the eastern Bering Sea ecosystem

Asit **Mazumder**<sup>1</sup>, Marc Trudel<sup>2,1</sup>, Ed Farley<sup>3</sup>, Jamal Moss<sup>3</sup>, Lisa Eisner<sup>3</sup> and Jim Murphy<sup>3</sup>

<sup>1</sup> Department of Biology, University of Victoria, P.O. Box 3020, Station CSC, Victoria, BC, V8W 3N5, Canada. E-mail: Mazumder@uvic.ca

<sup>2</sup> Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada.

<sup>3</sup> Auke Bay Laboratory, NOAA Ted Stevens Fisheries Science Center, Juneau, AK, USA.

The Eastern Bering Sea (EBS) ecosystem is an important feeding ground for juvenile Pacific salmon. Shifts in the relative strength of Pacific Decadal Oscillation and Arctic Oscillation, and associated shifts in thermal regimes in the EBS have been suggested to have major implications for energy flow along food web and trophic interactions among forage fish and juvenile salmon. The EBS shifted from a warm-water condition during 2002-2005 to a relatively cold-water condition during 2006-2007. This shift seems to be linked to dramatic shifts in the abundance of the major forage fish species, the most common diet of juvenile Pacific salmon species. We evaluate if the reversal of ocean thermal regimes cause significant shifts in food web dynamics and trophic interactions among the juveniles of salmon species, ontogenetic niche shifts as a function of size within species, and diet overlaps among species. To test our objectives, we used N and C stable isotope signatures of over 10,000 samples of juvenile salmon, forage fish and zooplankton collected during six years along north-south and east-west transects of the EBS. We present results showing how the change from warm to cold years are associated with significant contrasts in diet overlaps and trophic interactions among salmon species, and onshore-offshore variability in trophic shifts within Pacific salmon species as a function of body size, and discuss the implications of the observed variability for growth, survival and productivity of Pacific salmon.

19 May, 15:45 (S4.2-4551)

### Potential effect of rising temperature on growth performance and its influence on chum salmon

Kentaro **Morita** and Masa-aki Fukuwaka

Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, 116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan. E-mail: moritak@affrc.go.jp

The body sizes of animals often decrease with increasing temperature (Bergmann's rule). Therefore, global warming may reduce asymptotic size ( $L_{\infty}$ ). Empirical evidence suggests that ectotherms reared at higher temperatures grow to a smaller final size, the optimal temperature for the growth of ectotherms decreases with increasing body size, and larger fish prefer colder waters than smaller fish. Therefore, it has been hypothesized that the negative effects of rising temperature would be more severe for *large* fish. During 1973-2007, the sea surface temperature (SST) in the Bering Sea increased significantly. During the same period, the condition factor of large chum salmon decreased significantly, whereas that of small chum salmon did not. The condition factor of large chum salmon was negatively correlated with SST, indicating that global warming is already affecting the growth of large fish. To predict how chum salmon populations will respond to reducing the growth of large fish, we simulated the change in age and size at maturity, and spawning stock biomass (SSB) in response to decreasing  $L_{\infty}$  using a size-structured model with age- and size-specific maturation rates. This showed that a 5% decrease in  $L_{\infty}$  led to a 4% decrease in size at maturity, a 6% increase in age at maturity, and a 15% decrease in SSB.

19 May, 16:30 (S4.2-4625)

### Latitudinal gradients in growth and spawning of sea bass: effect of temperature and photoperiod

Catarina **Vinagre**, Telma Ferreira, Lélia Matos, Henrique N. Cabral and Maria José Costa

Instituto de Oceanografia, Faculdade de Ciências, Universidade de Lisboa, Lisbon 1749-016, Portugal. E-mail: cmvinagre@fc.ul.pt

0-group Sea bass, *Dicentrarchus labrax* (L.) were captured in four estuarine nursery areas along the Portuguese coast, during the spring and summer of 2005. This coast has a north-south orientation which means that these estuaries are located at approximately the same longitude but present a latitudinal orientation: the Ria de Aveiro at 40°34'N, the Mondego estuary at 40°06'N, the Tagus estuary at 38°45'N and the Mira estuary at 37°37'N. Growth and hatch dates were estimated through otolith daily increment analysis. A clear latitudinal gradient was detected in the growth rates, from north to south, sea bass from the Ria de Aveiro presented growth rates of 0.48 mm.d<sup>-1</sup>, while at the Mondego estuary it was 0.51 mm.d<sup>-1</sup>, in the Tagus estuary, 0.56 mm.d<sup>-1</sup> and at the Mira estuary, 0.61 mm.d<sup>-1</sup>. The estimated spawning periods also presented a north-south gradient with spawning starting earlier (December) in the Mira estuary and later (February) in the Ria de Aveiro. Analysis of SST data from the adjacent coastal waters shows that spawning is not solely triggered by an increase in temperature, like argued in other coastal areas. The important role of photoperiod is discussed. The impact of a future climate change scenario in the observed patterns is also discussed.

19 May, 16:45 (S4.2-4815)

### Fish population response to future climate drivers: a next step forward

Anne B. **Hollowed**<sup>1</sup>, Z. Teresa A'mar<sup>2</sup>, Richard Beamish<sup>3</sup>, Nicholas A. Bond<sup>4</sup>, James E. Overland<sup>5</sup>, Michael J. Schirripa<sup>6</sup> and Tom Wilderbuer<sup>1</sup>

<sup>1</sup> Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

<sup>2</sup> School of Fisheries and Aquatic Sciences, University of Washington, Seattle, WA 98195, USA.

<sup>3</sup> Department of Fisheries and Oceans, Nanaimo, Canada.

<sup>4</sup> Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Seattle, WA, USA.

<sup>5</sup> Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

<sup>6</sup> Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, USA.

The development of the analytical tools to implement forecasts of commercially exploited fish populations represents a critical first step towards integrated ecosystem assessment. We present an analytical approach to projecting climate change effects on groundfish and salmon in Alaskan waters. We use climate model simulations carried out for the Intergovernmental Panel on Climate Change Fourth Assessment Report and our

knowledge of processes underlying recruitment of managed fisheries to project the impacts of climate change on selected fish species. Climatologists screen models based on their ability to replicate the observed climate variability of the North Pacific in the hindcasts for the 20th century. The subset of better models provides a basis for projections through the first half of the 21st century. The ranges of realisations from an ensemble of forecasts provide measures of natural variability and uncertainties in the variables of interest. We will utilise these scenarios to predict the impact of climate change on ocean variables that influence recruitment success of our fish species. Time series of key oceanographic factors will be produced through analysis of the direct model output, and where necessary, through empirical downscaling. We demonstrate how time series of fish production can be estimated by incorporating the projected time trend in ocean variables to a stock recruit relationship to track population fluctuations under different harvest control rules and climate change scenarios. We report on an international effort to apply this approach to species throughout the Pacific Rim through the coordination of PICES and ICES.

**19 May, 17:00 (S4.2-4743)**

### **What drives tuna captures between 1525 and 1756 in southern Europe?**

Unai Ganzedo<sup>1</sup>, Eduardo Zorita<sup>2</sup>, Aldo Pier Solari<sup>3</sup>, Guillem **Chust**<sup>1</sup>, Angelo Santana Del Pino<sup>3</sup> and Juan José Castro<sup>3</sup>

<sup>1</sup> AZTI – Tecnalia, Marine Research Division, Herrera Kaia Portualdea z/g, 20110 Pasaia, Gipuzkoa, Spain. E-mail: uganzedo@pas.azti.es

<sup>2</sup> Institute for Coastal Research, GKSS-Research Centre, Geesthacht, Germany.

<sup>3</sup> Dept. Biología, Univ. Las Palmas de Gran Canaria, Edf. Ciencias Básicas (B-203), Campus de Tafira, 35017 Las Palmas de Gran Canaria, Spain.

The almadraba catch series on tuna species from 1525 to 1756 showed strong oscillations with a clear decreasing trend. The objective of this work is to test the potential influence of climatic factors in the bluefin tuna catches obtained between years 1525-1756 from Medina Sidonia almadraba. The spectrum analysis on the capture series showed the presence of short and medium term periodic cycles. The short-term periodicity (6-9 years) is probably associated with tuna density-dependent dynamics, and it is coincident with the highest cross-correlation coefficient between sea surface temperature and the captures (6 year lag). We used a generalised linear model to relate the tuna captures to climatic parameters. We carried out variance-partitioning analysis of tuna captures to assess the relative contribution of climate from temporal autocorrelation. The results indicated that climate accounts for 11.6% of the total variance, the temporal autocorrelation accounts for 12.9% of the total variance, and 35.1% of captures is accounted for by the joint effect of the two latter components. The temporal component indicates the role of population dynamics in tuna capture series. The significant variance accounted for by climate (specifically, greenhouse gases) suggests that the low temperatures during the Maunder minimum (the so called “The Little Ice Age”, years 1640-1715) may have reduced both recruitment and tuna abundance in the North Atlantic and Mediterranean Sea. Our findings suggest that both environmental and population dynamic components played an important role in the Medina Sidonia almadraba.

**19 May, 17:15 (S4.2-4739)**

### **Effects of ocean climate variation on production, maturation, and recruitment of snow crab (*Chionoecetes opilio*) on the Newfoundland-Labrador shelf**

Earl G. **Dawe**, Donald G. Parsons and Eugene B. Colbourne

Science Branch, Department of Fisheries and Oceans, P.O. Box 5667, St. John's, NL, A1C 5X1, Canada. E-mail: dawee@dfo-mpo.gc.ca

The snow crab (*Chionoecetes opilio*) is a highly stenothermal species. Males undergo their final molt across a broad size range such that some males fail to achieve the minimum legal size and recruit to the male-only fishery. This terminal molt is associated with sexual maturation in females, whereas in males (already sexually mature adolescents) it corresponds to achievement of adulthood, as reflected by the development of enlarged chelae. We found that size at maturity or adulthood was directly related to bottom water temperatures between 0 and 4°C. This suggests that in both sexes the terminal molt is delayed at high temperatures. Our study also showed that effects of ocean climate variation differ throughout the life cycle. Cold conditions in early life favour survival while in later life they promote early terminal molt, thereby reducing the proportion that will recruit to the fishery. Snow crab commercial catch rates are positively related to area of ice coverage and inversely related to bottom temperature, at lags of 6-10 years, suggesting that the positive effects on recruitment of cold conditions early in

the life history are stronger than the negative effects in later life. We find that the evidence for predator control of snow crab abundance is not convincing and we conclude that recruitment trends are more strongly associated with variability in the ocean climate and (by inference) production. This implies important consequences of future climate change to snow crab production and fisheries.

**19 May, 17:30 (S4.2-4605)**

### **The future of Baltic cod - modelling interactions between climate, food web dynamics and fisheries**

Martin O. **Lindegren** and Christian Möllmann

<sup>1</sup> Department of Marine Fisheries, Danish Institute for Fisheries Research, Charlottenlund Slot, Charlottenlund, Copenhagen 2920, Denmark.  
E-mail: mli@difres.dk

<sup>2</sup> Institute for Hydrobiology and Fisheries Science, University of Hamburg, Grosse Elbstrasse 133, Hamburg, D-22767, Germany.

Atlantic cod (*Gadus morhua*) is among the commercially most important fish species in the North Atlantic and has been subjected to excessive fishing pressure for many years. Additionally climate variability influence cod stocks, principally through effects on recruitment and growth. However, food web processes may additionally influence fish stock dynamics by producing feedback loops that determine the ultimate response of populations to climate change. Integrating these forces in models are therefore of great concern in developing a sustainable EBFM approach for Atlantic cod. By statistically fitting a generalised Lotka-Volterra food web model to time series data from the Baltic Sea, we developed a fishing and climate driven multi-species model that not only accurately recreates the past dynamics of Baltic cod but may also predict its future dynamics in the face of climate change. Based on the findings of the Assessment of climate change for the Baltic Sea Basin (BACC), we simulated plausible climate scenarios for the 21st century by generating a number of “red-shifted” climate time series. Using these scenarios as inputs, we forced our food web model bottom-up, exploring the impact of climate change on the future dynamics of Baltic cod. Further, by including management scenarios for all three species of the Baltic food web, we elaborated on the role of commercial fishing in developing a sustainable exploitation strategy. Replicated model runs show that only drastic decreases in fishing mortality and climate sensitive management actions will avoid future stock collapses and ensure the existence of Baltic cod for future generations to come.

**19 May, 17:45 (S4.2-4628)**

### **Climate-mediated changes in prey quality affect the production of wild Pacific salmon**

Marc **Trudel**<sup>1,2</sup>, David L. Mackas<sup>3</sup> and Asit Mazumder<sup>2</sup>

<sup>1</sup> Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada.  
E-mail: trudelm@pac.dfo-mpo.gc.ca

<sup>2</sup> Department of Biology, University of Victoria, .P.O. Box 3020, Station CSC, Victoria, BC, V8W 3N5, Canada.

<sup>3</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, P.O. Box 6000, 9860 West Saanich Road, Sidney, BC, V8L 4B2, Canada.

The marine survival of salmon has been observed to covary with climate and ocean conditions at small and large spatial scales. Several competing hypotheses have been proposed to explain these patterns. Although the specific mechanisms affecting the marine survival of salmon differ among these hypotheses, all generally agree that lower marine survival of Pacific salmon is associated with lower marine growth during their first year at sea. In this study, we examined the effects of ocean conditions on the growth and survival of Pacific salmon and developed forecasting models for the marine survival of Pacific salmon. Our work shows that, while plankton productivity and temperatures tend to be higher in the northern California Current Ecosystem, salmon are generally larger and fatter, and have higher growth in the Alaska Coastal Current Ecosystem. The poorer growth and condition of salmon in the northern California Currents Ecosystem appears to be related to a calorie-deficient diet rather than to lower rates of food consumption or to higher metabolic rates. This indicates that ocean conditions affect salmon production through changes in prey community composition and quality, which in turn are induced by the effects of climate on ocean circulation, and on the local success of different zooplankton life history strategies (year round activity vs seasonal dormancy and lipid accumulation).

**19 May, 18:00 (S4.2-4728)**

**The effect of environmental changes in the NE Atlantic sardine (*Sardina pilchardus*) fishery**

Carmela **Porteiro**, Jose M. Cabanas, M.B. Santos and G.J. Pierce

Instituto Español de Oceanografía, Subida a Radiofaro 50, Cabo Estay- Canido, P.O. Box 1552, Vigo 36280, Spain.  
E-mail: carmela.porteiro@vi.ieo.es

The Iberian sardine (*Sardina pilchardus*, Walb.) is distributed along the whole shelf of the Iberian Peninsula. Highest catches of the stock are taken from the southern part of the Galician waters (NW corner of the Iberian Peninsula) and northern Portugal. Landings comprised mainly young fish (0 and 1 yr old), which reflects the proximity of the main recruitment area of the stock to the fishing grounds. The fishery is dependant on the strength of the recruitment in this area and recruitment processes seem to be driven by oceanographic (local) and climatic (global) events. This study explored where the variability observed in the environmental variables at large (NAO-winter, Gulf Stream and AMO) and local scale (upwelling and poleward current) could explain the variability observed in the recruitment (and thus landings) in the area from 1940 to 2005. The fitted model matched quite well the predicted recruitment during the 1980s but when the whole time series was considered the performance of the model was poor. There appears to be a shift in the general trend of the environmental variables in 1995 which coincided with a consecutive series of poor recruitments at the end of the nineties.

## S4.2

## Posters

### Poster S4.2-4525

#### Cyclic climate changes and fish productivity in the past and at present

Leonid **KlyashTORIN**<sup>1</sup> and Alexey Lyubushin<sup>2</sup>

<sup>1</sup> Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17 V. Krasnoselskaya Street, Moscow 107140, Russia.  
E-mail: klyashTORIN@mtu-net.ru

<sup>2</sup> Institute of Physics of the Earth, Russian Academy of Science, Nakhimovskiy 36, Moscow 117997, Russia.

Long-term time series of various climatic indices and variation of commercial fish populations in the most productive areas of the Pacific and Atlantic are analysed. Comparison of climate index fluctuations and populations of a number commercial species for the last 1500 years indicates a coherent character of climate fluctuations and fish production dynamics. A simple stochastic model is suggested that makes it possible to predict trends of basic climatic indices and populations of some commercial fish species for several decades ahead. The approach based on the cyclic character of both climate and marine biota changes makes it possible to improve harvesting of commercial fish stocks depending on the phase (ascending or descending) of the long-term cycle of the fish population. In addition, this approach is helpful for making decisions on long-term investments in fishing fleet, enterprises, installations, etc. The results also elucidate the old discussion: which factor is more influential on the long-term fluctuations of major commercial stocks, climate or commercial fisheries.

### Poster S4.2-4595

#### Long-term changes in the abundance and population structure of yellowtail *Seriola quinqueradiata* in the Japanese waters and its relation to sea surface temperature over the last century

Yongjun **Tian**<sup>1</sup>, Hideo Sakaji<sup>2</sup>, Shingo Ino<sup>3</sup> and Masahiro Kuno<sup>4</sup>

<sup>1</sup> Japan Sea National Fisheries Research Institute, Fisheries Research Agency (FRA), 1-5939-22 Suido-cho, Niigata 951-8121, Japan.  
E-mail: yjtian@fra.affrc.go.jp

<sup>2</sup> National Research Institute of Fisheries Science, Research Agency (FRA), 2-12-4 Fukuura, Kanazawa, Yokohama 236-8468, Japan.

<sup>3</sup> Toyama Prefectural Fisheries Research Institute, 364 Takatsuka, Namerikawa, Toyama 936-8536, Japan.

<sup>4</sup> Mie Prefectural Science and Technology Promotion Center, 3564-3 Hamajima, Shima, Mie 517-0404, Japan.

The yellowtail *Seriola quinqueradiata* is one of the most important, large-predatory fishes in Japanese waters. It is traditionally caught by set-net traditionally and the catch is largely affected by oceanographic conditions. Using the historical catch data of yellowtail and a sea surface temperature (SST) data set for the waters around Japan over the last century, the long-term variability in the abundance of yellowtail and its relation with SST was examined. The total catch of yellowtail increased from 14,446 tons in 1894 to 77,462 tons in 2000 with an evident increasing trend over the last century. However, the trend is not linear but decadal with significant shifts occurring around in 1912, 1932, 1957, 1974 and 1990, strongly suggesting an effect of water temperature. Analysis between the catch by fisheries regions and SSTs showed that the catch trend was approximately in accordance with SSTs. In particular, the catch from the Japan Sea, where the yellowtail is mainly caught by set-net, was significantly and positively correlated with winter SST in the northern Japan Sea, indicated the increasing water temperature in the Tsushima Current region has a positive effect on the migration and recruitment of yellowtail to the Japan Sea. On the other hand, the catch from the set-net during the 1990s was lower than that in the 1950s, the lower catch since 1990 was a result of increasing fishing effort of purse seine on yellowtail. The total catch of large size adult yellowtail was still at a lower level compared with before 1950, suggesting that fishing may have an impact on the changing population structure.

### Poster S4.2-4613

## The influence of water temperature on abundance of walleye pollock and northeast arctic cod

Oleg A. **Bulatov**

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), Biological Resources Laboratory of Far East Seas, 17 V. Krasnoselskaya Street, Moscow 107140, Russia. E-mail: obulatov@vniro.ru

The solar activity, atmospheric circulation, seawater temperature, and chlorophyll *a* may be used as integrated factors affecting the existence conditions of biota in the ocean. The interannual variability of seawater temperature impacts essentially on success of fish reproduction, duration of early stages, food availability, and rate of metabolic processes. The analysis of relationship between the solar activity and concentrations of chlorophyll *a* in the southeastern Bering Sea in 1963-1994 showed a positive correlation ( $r=0.6$ ). The relationship between concentrations of chlorophyll *a* and sea surface temperature was direct also but the correlation coefficient was lower ( $r=0.4$ ). The correlation between the solar activity and sea surface temperature in the eastern Bering Sea during the 1970-1998 period was relatively weak ( $r=0.38$ ). To answer a question regarding the existence of statistically significant relationship between the year-class abundance of walleye pollock (*Theragra chalcogramma*) and that of Atlantic cod (*Gadus morhua*) a linear regression analysis was carried out. The results showed the absence of significant correlation between the year-class abundance of walleye pollock and near-surface water temperature ( $r=0.06$ ) and near-bottom water temperature ( $r= -0.23$ ). The highest correlation coefficients were obtained from the analysis of year-class abundance of pollock in the eastern Bering Sea at age of 1 and 5 years and the average seawater temperature in the 0-100 m layer a year ahead of spawning ( $r=0.77$  and  $r=0.72$ , respectively). When comparing chlorophyll *a* concentrations and walleye pollock abundance at age of 1 year for the 1970-1994 period, the correlation coefficient was low ( $r=0.11$ ). The relationship between the abundance of northeast Arctic cod (age 3+) and mean water temperature in the Barents Sea during 1977-2002 in the 0-100 m layer was statistically significant ( $r=0.68$ ).

### Poster S4.2-4621

## Pan-regional synthesis in the US GLOBEC programme

Dale Haidvogel<sup>1</sup>, Elizabeth J. Turner<sup>2</sup> and David **Mountain**<sup>3</sup>

<sup>1</sup> Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901-8521, USA.

<sup>2</sup> Center for Sponsored Coastal Ocean Research, National Oceanic and Atmospheric Administration (NOAA), Room 146, Gregg Hall, 35 Colovos Road, Durham, NH 03824, USA. E-mail: elizabeth.turner@noaa.gov

<sup>3</sup> 4072 E 22nd St, #225 Tucson, AZ 85711, USA.

The US GLOBEC programme is entering into its final phase of research with a pan-regional synthesis programme. Previous phases have included field and modelling programmes in the northwest Atlantic (Georges Bank), the northeast Pacific (northern California Current and coastal Gulf of Alaska), and the Southern Ocean (western Antarctic peninsula). The pan-regional phase seeks to make larger connections between these and other marine ecosystems. The overall synthesis and integration effort includes comparing the dynamics of closely related taxa in relation to common physical processes (e.g. stratification, upwelling and downwelling, or sea ice extent). Some examples are studies of calanoid copepods and gadoids on bank and shelf systems; copepods, euphausiids, and salmonids in the North Pacific; and euphausiids, calanoid copepods, and upper trophic level predators (e.g. seabirds, penguins, seals and cetaceans) in continental shelf waters of the Southern Ocean. Modelling of all kinds – conceptual, mathematical, numerical, and statistical – will be a major focus of the GLOBEC Pan-Regional Synthesis, having already played a central role in the regional studies. Pan-regional synthesis will examine processes controlling the population dynamics and recruitment of the target organisms as a function of system type, to ascertain how these processes would be affected by a changing climate. It will further understanding of ecosystem response to climate change, particularly in connection with other, anthropogenic forcing. Ultimately, pan-regional synthesis will provide guidance on how to assess ecosystem-level questions within the GLOBEC context, and identify implications for the management of marine resources in a changing climate.

#### Poster S4.2-4655

### Relationship between ocean warming and catches of Atlantic salmon (*Salmo salar*) at the southern boundary of the European geographical distribution

Jesús **Cabal**<sup>1,2</sup>, Gonzalo González-Nuevo<sup>1</sup>, Jerónimo de la Hoz<sup>3</sup>, Enrique Nogueira<sup>1</sup> and Luis Valdés<sup>1</sup>

<sup>1</sup> Centro Oceanográfico de Gijón, Instituto Español de Oceanografía, Avda. Príncipe de Asturias 70 Bis, Gijón 33212, Spain. E-mail: cabal@gi.ieo.es

<sup>2</sup> EUIT Forestales, Universidad de Oviedo, Campus Mieres, C/Gonzalo Gutierrez-Quirós s/n, Mieres 33600, Spain.

<sup>3</sup> Sección de Pesca fluvial (Medio Ambiente), C/ Coronel Aranda s/n, EASMU, Oviedo 33005, Spain.

The northern part of the Iberian Peninsula is a transitional area between boreal and subtropical fauna and flora. This boundary may displace northward due to global warming and, under this scenario, abundance of boreal species in this area will decrease. One of these species is *Salmo salar*, an anadromous fish, whose populations in the northern Iberian rivers are the southernmost Atlantic salmon populations in their European geographical distribution. These populations are expected to be particularly vulnerable to global warming. Time series analysis of captures of *Salmo salar* from 1950 to 2006 in rivers localised in the north Iberian Peninsula show that the spatial distribution of salmon populations have progressively become more restricted to rivers localised in the central Cantabrian thus narrowing their spatial distribution range. Besides, the number of adults captured has declined significantly in the last 25 years. In this communication we discuss the plausible relationship between the compression of the distribution area and the decreasing trend of abundance of *S. salar* in the north Iberian Peninsula with trends of various environmental variables related to the effect of global warming in the North Atlantic.

#### Poster S4.2-4665

### Impact of climate change on the marine pelagic ecosystems off Galicia (NW Spain). II: Living resources

A. **Bode**<sup>1</sup> and CLIGAL-Pelagic Working Group<sup>2</sup>

<sup>1</sup> Instituto Español de Oceanografía, Centro Oceanográfico de A Coruña, Apdo. 130, E15080 A Coruña, Spain. E-mail: antonio.bode@co.ieo.es

<sup>2</sup> CETMAR, C/ Eduardo Cabello s/n. E36208 Bouzas, Vigo, Spain.

Trends in biological production, including fisheries and aquaculture, were analysed as part of a multidisciplinary study directed to ascertain the significance of changes in relevant oceanographic and pelagic ecosystem variables in relation to climate change off Galicia (NW Spain). Marine productivity was largely determined by the seasonal upwelling as this region is at the northern limit of the northeast Atlantic upwelling system. In this way, the decrease in upwelling intensity and warming of surface waters during the last decades may have potential impacts on productivity and selected resources. For instance, warm-water fish species became more frequent in recent years and a decreasing trend in the yields of some fisheries (e.g. sardine and octopus) was found. Long-term changes in the size and distribution of clams and in the quality of cultured mussels were also related to changes in local and regional oceanography. The patterns of change in the exploited populations, however, must be interpreted in the framework of their low frequency variability (including multidecadal oscillations), which in most cases is still poorly described.

#### Poster S4.2-4674

### Impacts of climate variability on spatial distribution of 0-group fish in the Barents Sea

Elena **Eriksen**, Geir Odd Johansen, Randi Ingvaldsen and Jan Erik Stiansen

Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway. E-mail: elena.eriksen@imr.no

Capelin (*Mallotus villosus* Müller, 1776), juvenile herring (*Clupea harengus* L.), cod (*Gadus morhua* L.), and haddock (*Melanogrammus aeglefinus* L.) are commercially and ecologically important fish species in the Barents Sea, representing different biogeographic groups. All these stocks have nursing areas in the Barents Sea. However, the response of the spatial distribution of the fish larvae from climate variability is not well known. For more than 20 years spatial data on fish larvae have been collected in August-September in the Barents Sea, together with hydrographic data. These spatial data span a period with a strong increasing temperature trend, from the cold 1960s-1970s to the very warm 1990s-2000s. The presented data are from the period 1980-1996. Climatic variation is represented by time series of spatial temperature fields based on observations, observed mean temperatures in

Atlantic water masses, and modelled inflow of Atlantic water masses into the area. Fish larva are presented as 0-group fish (age 0, about half year old). Geographic distributions of the 0-group are based on field observations from designated 0-group surveys. Results from the spatial analysis of variation in fish larvae distribution as affected by climatic variation are presented. Further, a study of temperature limits for the distribution areas is shown. Finally, the results are discussed with respect to expected future climate changes in the Barents Sea.

#### **Poster S4.2-4696**

### **Impact of climate change and variability on coastal water and fisheries resources of Bangladesh**

Kawser Ahmed<sup>1</sup> and Shamima Sultana<sup>2</sup>

<sup>1</sup> Ecology, Environment and Climate Change Lab., Department of Fisheries, University of Dhaka, Curzol Hall Campus, Dhaka-1000, Bangladesh. E-mail: kawser@univdhaka.edu; kawser\_du@yahoo.com

<sup>2</sup> Ecological and Environmental Economics Group, Department of Economics, Bangladesh University of Business and Technology, Dhaka-1216, Bangladesh.

By 2050, flooding and droughts will increase in Bangladesh and the probability of an extreme wet year will increase seven fold and dry years will increase by 4.4 times. A 1 m rise in sea level over the next 100 years will lead to the permanent inundation of nearly 20% of the country affecting approximately 25% of the population. Many of the freshwater fish species in Bangladesh are already under great threat. Climate change will aggravate the situation further. Production of inland capture is likely to decline due to 10% loss of area. Production from floodplains, the largest contributor to inland capture fishery is likely to decline. Contributions from estuarine zones are likely to increase due to the expansion of their area and as they are biologically the most productive. Increased ocean temperature may alter coastal ocean currents. These in turn influence the residence time of water in nearshore environments, which may have negative consequences on the growth and survival of many aquatic animals. The carrying capacity of the Bay of Bengal is likely to be changed due to an increase in total chlorophyll leading to a considerable change in the distribution, migration and fishing grounds of the various pelagic fishes. Offshore fisheries may be the least affected by future climate change and sea level rise. However, there will be a profound change in the near-shore marine fisheries. The greatest impact may be on fish species which are dependent on the estuaries and creeks of the coastal zone for breeding or spawning.

#### **Poster S4.2-4741**

### **Impact of climate variability on the California Current ecosystem and Pacific salmon survival: linkages, ocean condition indicators, forecasting, and management perspectives**

Edmundo Casillas<sup>1</sup> and W.T. Peterson<sup>2</sup>

<sup>1</sup> NOAA-Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd E, Seattle, WA 98112, USA. E-mail: edmundoc.casillas@noaa.gov

<sup>2</sup> NOAA-Fisheries, Northwest Fisheries Science Center, Newport, OR 97365, USA.

Recently, the northeast Pacific has experienced high-frequency variability in the PDO pattern: cool phase from 1999-2002; warm phase from late 2002-2006; cool from 2006 to present. We have used this 'natural' experiment to determine how quickly marine organisms respond to strong climate variability focusing our studies on an iconic species in the North Pacific, the Pacific salmon. We use our 12 year time series of hydrography and zooplankton collected off Newport OR and our 10 year time series of hydrography, zooplankton and pelagic fish collected off Washington and Oregon to investigate the response of the pelagic marine ecosystem to recent changes in the state of the North Pacific. Ecosystem indicators have been developed from these time series as metrics to describe interannual variability in ocean conditions, and to forecast recruitment variability of salmon in Pacific northwest waters. We communicate our results through a web site; the site includes information on the status of the northern California Current ecosystem on a seasonal basis, and provides a one-year lead forecast of returns of coho salmon and a two-year lead forecast of Chinook returns, based on the "stoplight" approach. Our ability to manage fishery resources in the future will depend in part on our ability to forecast the impact of changing ocean conditions as a result of global climate change. We suggest that use of comprehensive ecosystem observations, from physics to fish, will become a requirement if we are to understand how variations in physical climate will affect fisheries and marine ecosystem productivity.

#### Poster S4.2-4748

### Sedimentary fish abundance records over the last 1500 yrs from the western North Pacific: basin-scale link of sardine and anchovy abundance

Michinobu **Kuwae**<sup>1</sup>, Hidetaka Takeoka<sup>1</sup>, Koji Omori<sup>1</sup>, Narumi K. Tsugeki<sup>2</sup> and Takashige Sugimoto<sup>3</sup>

<sup>1</sup> Center for Marine Environmental Studies, Ehime University, Bunkyo-cho 2-5, Matsuyama, Ehime 790-8577, Japan.  
E-mail: mkuwae@sci.ehime-u.ac.jp

<sup>2</sup> Ecology and Evolutionary Biology, Graduate School of Life Sciences, Tohoku University, Sendai, Miyagi 980-8578, Japan.

<sup>3</sup> Institute of Oceanic Research and Development, Tokai University, Shizuoka 424-8610, Japan.

In the latter half of the twentieth century, catch records of sardine and anchovy revealed multidecadal-scale variations, showing synchronous and asynchronous patterns between remote regions off Japan, California, Peru, and Chile; a basin-wide link of variations in pelagic fish abundance was detected. Sedimentary reconstruction of fish abundance over the past millennia revealed centennial-scale or millennial-scale variability of anchovy and sardine abundance in the California Current system, and variability of sockeye salmon in the Gulf of Alaska. However, no sedimentary record exists for the western Pacific. Therefore, the existence of a centennial-scale and millennial-scale link between abundances of remote pelagic fish populations in the Pacific remains unclear. We first discovered sedimentary anchovy and sardine scales in a seasonally anoxic basin, Beppu Bay, of the western Seto Inland Sea of Japan. The sedimentary scale records are anticipated to be a potential source to elucidate not only long-term variations in anchovy and sardine populations in the western Pacific but also a basin-wide link of variations in pelagic fish abundance on centennial to millennial timescales. In the presentation, we will deliver the 1500-yr fish abundance records from Beppu Bay and discuss the basin-scale link of fish abundances among sardine and anchovy in the western and eastern North Pacific and Pacific salmon.

#### Poster S4.2-4765

### Is a changing North Sea environment making sustainable exploitation of herring more difficult?

Mark R. **Payne**<sup>1</sup>, Emma M.C. Hatfield<sup>2</sup>, Mark Dickey-Collas<sup>3</sup>, Tone Falkenhaus<sup>4</sup>, Alejandro Gallego<sup>2</sup>, Joachim Gröger<sup>5</sup>, Priscilla Licandro<sup>6</sup>, Marcos Llope<sup>7</sup>, Peter Munk<sup>1</sup>, Christine Röckmann<sup>3</sup>, Jörn O. Schmidt<sup>8</sup> and Richard D.M. Nash<sup>9</sup>

<sup>1</sup> National Institute of Aquatic Resources (DTU-Aqua), Technical University of Denmark, Charlottenlund 2920, Denmark.  
E-mail: mpa@difres.dk

<sup>2</sup> FRS Marine Laboratory, 375 Victoria Road, Aberdeen, AB11 9DB, UK.

<sup>3</sup> Wageningen IMARES, 1970 AB IJmuiden, The Netherlands.

<sup>4</sup> Institute of Marine Research Flødevigen, 4817 His, Norway.

<sup>5</sup> Institute for Sea Fisheries, Federal Research Institute for Rural Areas, Forestry and Fisheries, Palmallee 9, Hamburg D-22767, Germany.

<sup>6</sup> Sir Alister Hardy Foundation for Ocean Science (SAHFOS), The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK.

<sup>7</sup> Centre for Ecological and Evolutionary Synthesis (CEES), Universitetet i Oslo, Oslo 0316, Norway.

<sup>8</sup> Leibniz Institute of Marine Sciences (IFM-GEOMAR), Düsterbrookweg 20, Kiel 24105, Germany.

<sup>9</sup> Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway.

Environmental change can affect the productivity of fish stocks. In the North Sea herring (*Clupea harengus* L.) stock, environmentally induced change is impacting sustainable exploitation. Despite simultaneously having a large stock size, relatively low exploitation and Marine Stewardship Council accreditation (implying sustainability), an unprecedented five sequential years of poor production (recruitment) have occurred. Analysis shows that over-fishing does not appear to be playing a role in this sequence of recruitment failures, as it has in the past (e.g. during the mid-1970s); instead, survey data show that recent year-class-strength is determined during the larval over-wintering period. Changes in the North Sea environment appear to be the most-probable ultimate-cause of these failures. Recent warming of the North Sea has caused numerous shifts in this ecosystem, and changes in the herring stock may have been initiated by the lately reported 2000 “regime-shift” in the plankton community. It is therefore possible that we are observing the first consequences of this change for the higher trophic levels. It is not possible to say when or whether the sequence of poor recruitment will abate: there is no indication of a recovery in recruitment in the short term. Unless fishing mortality is rapidly reduced to sustainable levels, another collapse of this stock is possible. Stock managers must recognise that in dynamic ecosystems and environments, the past does not necessarily provide a reliable indication of future productivity.

## **Poster S4.2-4773**

### **Evidence of north-east Atlantic tropicalisation**

Ángela M. **Caballero-Alfonso** and José J. Castro-Hernández

Campus Universitario de Tafira, Edif. Ciencias Básicas, Facultad de Ciencias del Mar, sn. Dto. Biología, Lab. B-203, Las Palmas de Gran Canaria University, CP-35017, Spain. E-mail: angela.caballero102@doctorandos.ulpgc.es

There is a scientific and social preoccupation due to the so called “climate change”, even when the Earth’s climate has always been changing between cold and warm periods, but this last is occurring faster than the previous historical ones. Environmental variations affect terrestrial and marine ecosystems, and the changes observed in the fish fauna distribution along the north-eastern Atlantic Ocean could be other evidence of this climatic process. To quantify the variations observed in fish fauna composition during the last sixty years, and analyse the tropicalisation process, we have considered the geographic area between 28°N and 60°N, that involve the FAO fishing area 27 and the north part of 34, according to the number of sites, oceanographical characteristic of this region and thermal faunistic limits. According to the last, we identified two sub-areas, the southern one extended from the Canary Islands to the NW Spain and the northern one from the Gulf of Biscay to the North Sea. We have checked the literature in order to review the number of reference of “rare/uncommon” fishes species reported by areas each year, and the number of fisheries that collapsed or declined in the lasts decades, with the objective to relate this records with changes in the environment (warming or overfishing). Our preliminary results show a relation between temperature changes and the northward fish movements, which indicate the existence of a process of tropicalisation of the northeast Atlantic. However, more exhaustive analysis should be done.

## **Poster S4.2-4780**

### **Comparing Pacific and Atlantic leatherback turtle movements and oceanography using state-space modelling**

Helen **Bailey**<sup>1</sup>, George Shillinger<sup>2</sup>, Daniel Palacios<sup>1,3</sup>, Steven J. Bograd<sup>1</sup>, James Spotila<sup>4</sup>, Frank Paladino<sup>5</sup>, Scott Eckert<sup>6</sup>, Graeme Hays<sup>7</sup> and Barbara Block<sup>2</sup>

<sup>1</sup> NOAA/NMFS/SWFSC/Environmental Research Division, 1352 Lighthouse Avenue, Pacific Grove, CA 93950, USA.  
E-mail: Helen.bailey@noaa.gov

<sup>2</sup> Stanford University, Hopkins Marine Station, 120 Oceanview Boulevard, Pacific Grove, CA 93950, USA.

<sup>3</sup> Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa, 1000 Pope Road, Marine Science Building 312, Honolulu, HI 96822, USA.

<sup>4</sup> Drexel University, Department of Bioscience and Biotechnology, 3141 Chestnut Street, Philadelphia, Pennsylvania 19104, USA.

<sup>5</sup> Department of Biology, Indiana-Purdue University, Fort Wayne, IN 46805, USA.

<sup>6</sup> Wider Caribbean Sea Turtle Conservation Network, Duke University Marine Laboratory, 135 Duke Marine Lab Drive, Beaufort, NC 28516, USA.

<sup>7</sup> Institute of Environmental Sustainability, University of Wales Swansea, Singleton Park, Swansea SA2 8PP, UK.

Leatherback turtles are currently critically endangered and could be on the verge of extinction within the Pacific Ocean. They are the largest species of marine turtle and conduct long pan-oceanic migrations between their nesting and foraging grounds. Over the last decade, developments in satellite telemetry have revolutionised our understanding of their movements and distribution, but satellite location data suffer from having non-Gaussian estimation errors and being recorded irregularly in time. Estimation errors are also generally large for marine animals that spend little time at the surface. State space models (SSM) provide a valuable tool for modelling movement data by simultaneously accounting for measurement error and variability in the movement dynamics. A two-mode switching SSM also enables the behavioural mode to be estimated for each location, providing an objective method for defining phases of movement. This model was applied to the satellite tracks of leatherback turtles in the Pacific Ocean, where there have been rapid population declines, and in the Atlantic Ocean, where numbers have been increasing. Comparison of their migration movements and the oceanographic conditions in the two ocean basins provides a valuable insight into their responses to environmental variability and the potential impacts of climate change. The difference between the two oceans in the time spent in the two behavioural modes, migrating versus foraging, is also assessed. The more prolonged and widely dispersed foraging phase in the Pacific suggests that food patches are less predictable and may explain the longer period between nesting seasons for these females.

**Poster S4.2-4826**

**Associating a fish kill event with seawater temperature in the Philippines**

Ulysses Madrid Montejo, Norvida Cruz Gatdula, Mirriam Formeloza Cayme and Valeriano Meneses Borja

Marine Fisheries Resources and Environment Research Division, National Fisheries Research and Development Institute, Kayumanggi Press Building, 940 Quezon Avenue, Quezon City, Metro Manila 1103, Philippines. E-mail: umontojo@pacific.net.ph

On June 11, 2007 a massive fish kill occurred in Caquiputan Strait, northwestern Philippines (16°18'N, 119°55'E) that affected milkfish, *Chanos chanos* mariculture farms in the area. Results of the study we conducted indicate that the incident was primarily due to pollution from aquaculture activities which was triggered by the physical condition of the area. However data obtained also showed relatively high values for seawater temperature which could also be associated with the fish kill event. A review of the five-year hydrological data of Caquiputan Strait revealed that highest recorded average seawater temperature was observed during the 2007 fish kill.

**Poster S4.2-4830**

**Impact of climate change in the 20th century on benthos communities in Peter the Great Bay (Japan Sea)**

Victor A. Nadtochy, Yury I. Zuenko and Galina V. Moiseychenko

Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok 690950, Russia. E-mail: emmajessica@mail.ru

Water temperature changes at the standard oceanographic section in the northwestern Japan Sea are traced for 1927-2007 and compared with the changes in benthos communities of Peter the Great Bay between three surveys: in 1925, 1972-1973, and 2003. Large-scale changes of water temperature in the subsurface layer corresponded generally to the winter SST changes and were caused by winter monsoon fluctuations. The subsurface temperature followed the fluctuations of the Siberian High activity in winter and had a negative trend in 1920-1930s, positive trend in 1940-1950s, slight negative trend in 1970-1980s, and was rising fast (0.3 deg./decade) in the 1990s and the next decade. Against a background of these large-scale tendencies measured by fractions of a degree C, stronger quasi-decadal fluctuations develop with the range of about 1°C, and local effects of deep sea-shelf exchange and vertical mixing are important for the coastal zone. In spite of the high variability of environmental conditions on the shelf, the composition of the benthos communities in Peter the Great Bay was rather stable, with cold-water species dominating. However, the large-scale changes in the thermal regime had consequences in quantitative parameters of the communities. The community of sea cucumbers, being dominant permanently in the central part of the Bay (60-120 m depth), became both more diverse and more abundant in 2003 as compared with the “cold” 1970s, and the warming was particularly favourable for the dominant species *Pentamera calcigera*. The mean spatial density of the benthos biomass over the bay was also higher in 2003 (395 g/m<sup>2</sup>) than in 1972-1973 (209 g/m<sup>2</sup>). Obviously, recent “warming” at the bottom in the northwestern Japan Sea shelf causes an increase in benthos biodiversity (by appearance of low-abundance subtropical species) but is still favourable for the abundant boreal species.

**Poster S4.2-4833**

**The effect of the environmental variability on the early life stage of flounder *Platichthys flesus* in the Baltic Sea**

Didzis Ustups, Baerbel Karulis-Muller, Andrei Makarchouk and Maris Pliksh

Faculty of Biology, University of Latvia, Kronvalda Blvd 4, Riga, LV 1048, Latvia. E-mail: didzis.ustups@lzra.gov.lv

Flounder (*Platichthys flesus*) is a temperate marine fish that is well adapted to the brackish waters of the semi-enclosed Baltic Sea. Conditions for life in the deeper waters of the Baltic Sea are strongly influenced by inflows of highly saline and oxygenated water from the North Sea. These events, termed major Baltic inflows, have an episodic character and are the only mechanisms by which the central Baltic deep water is renewed. In the absence of such inflows, stagnation occurs and the oxygen and salinity concentrations below the halocline progressively decreased. It is generally agreed that recruitment variation in flatfish stocks is dominated by density independent factors operating at a local scale on the eggs and larvae meaning that climate and hydrodynamic circulation are key factors in these species distribution and abundance. The aim of the present investigation is to examine whether

variations in the hydrological regime can explain the fluctuations in early life stage of flounder that have occurred over the past 35 years. We evaluate the hypothesis that the spatial heterogeneity of the available reproduction area is defined as bottom area with dissolved oxygen > 1 ml/l and salinity > 10.6 psu affects the survival of flounder eggs and larvae and determines recruitment success

#### Poster S4.2-4851

### Toward a better understanding of climate forcing on decadal changes in the Adriatic Sea ecosystem

Mira **Morović**<sup>1</sup>, Branka Grbec<sup>1</sup>, Juan Carlos Molinero<sup>2</sup>, Gordana Beg Paklar<sup>1</sup>, Jakov Dulčić<sup>1</sup>, Mario Bone<sup>1</sup>, Frano Matić<sup>1</sup> and Živana Ninčević<sup>1</sup>

<sup>1</sup> Institute of Oceanography and Fisheries, Šet I.Meštrovića 63, P.O. Box 500, Split 21000, Croatia. E-mail: morovic@izor.hr

<sup>2</sup> Leibniz-Institut für Meereswissenschaften, IFM-GEOMAR, FB3 - Marine 8 Ecology/Experimental Ecology, Düsternbrooker Weg 20, Kiel 24105, Germany.

We analysed information gathered from multidisciplinary oceanographic monitoring since 1950 in the Adriatic Sea, in the light of changes of dominant climate indices in the northern hemisphere (e.g. NAOI, AOI, MOI). Together with the oceanographic parameters, which included temperature, salinity, and water transparency, we assessed the patterns of variability of regional atmospheric variables (i.e. zonal and meridional wind components, sea level pressure, temperature, solar radiation) and biological indicators of the ecosystem functioning like primary production, fish and other species landings. The potential link between ecosystem and climate variables with global factors like sunspots was also investigated. Fourier and sliding-correlation analyse were used to identify high and low frequency variability of the investigated time series, and the evolving relationships between them. These results provide new concepts for an integrated management of the pelagic ecosystem of the Adriatic Sea.

#### 19 May, 18:00 (S4.2-4901)

### Distribution dynamics of three hake species along the NW African coast: is climate variability a key factor?

Cesar Meiners<sup>1,2</sup>, Lourdes Fernandez<sup>1</sup> and Ana **Ramos**<sup>1</sup>

<sup>1</sup> Instituto Español de Oceanografía, Centro Oceanográfico Málaga, Puerto pesquero s/n 29640 Fuengirola (Málaga), Spain. E-mail: c\_meiners@yahoo.com

<sup>2</sup> Centro de Ecología y Pesquerías, Universidad Veracruzana, Calle Hidalgo No.617, Col. Río Jamapa 94290, 94290 Boca del Río, Veracruz, Mexico

The NW African coast supports important demersal fisheries, some of them based on three different hake species: European hake (*Merluccius merluccius*) and two black hake species (*M. senegalensis* and *M. polli*). This area is the southern distribution limit for European hake, and the black hakes are truly Africans, but along the Saharan Bank the three species overlap their distribution. According to observations and fishery data, we know about marked changes in the relative contribution to the total hake catches, suggesting different response to certain “factors”. We know about strong dependence of European hake abundance with climate-environment variability in NW Africa forced by the North Atlantic Oscillation (NAO), affecting the early life stages of this species. In order to contribute to building the multi-species approach of fisheries dynamics of hakes in NW Africa, the aim of this work was performing a comparative approach using the same environmental descriptor (NAO) over the abundance of the three hake species during the last two decades. The catch-based time series was correlated with the annual NAO index lagged by time, as a proxy of climate-environment variability. There was a an opposite response between European hake ( $r= 0.77$ ;  $p<0.0005$ ) and black hake ( $r= -0.69$ ;  $p<0.0001$ ) abundance vs NAO. Results suggest that during less intense upwelling years, the black hake could extend their range due to an increase in suitable conditions but it was detrimental to European hake as their northward distribution contracted. On the other hand, during highly intense upwelling years, European hake increases their distribution area because of the prevalence of the cold-season oceanographic period. This situation shows a highly dynamic structure into the same eastern boundary upwelling system.

#### Poster S4.2-4905

### Biophysical modelling of climate impacts on larval fish: testing parameterisations at the individual level

Myron A. **Peck**<sup>1</sup>, Helena Hauss<sup>2</sup> and Laura Würzberg<sup>1</sup>

<sup>1</sup> Center for Marine and Atmospheric Climate Research, University of Hamburg, Olbersweg 24, Hamburg 22767, Germany.  
E-mail: myron.peck@uni-hamburg.de

<sup>2</sup> Leibniz-Institute of Marine Sciences at Kiel University (IFM-GEOMAR) Düsternbrooker Weg 20, Kiel 24105, Germany.

Coupled bio-physical individual-based models (IBMs) are frequently used to assess climate impacts on early life stages of marine fish larvae. During the last two decades, however, advances in the physics have greatly outpaced those in larval physiology. Here we present the results of laboratory experiments that were designed to test parameter estimates currently used within the IBM subroutine for larval fish foraging and growth. Measured and modelled growth rates were compared for Atlantic herring (*Clupea harengus*) larvae feeding on different size classes of copepod prey at 7 and 13°C. Model estimates of growth potential were based upon functions of prey encounter rate, prey capture success, assimilation efficiency and metabolic costs developed for herring in previous laboratory studies. The model performed well with unfed fish where modelled and predicted rates of weight loss agreed closely at both temperatures. However, the model estimates of growth in fed fish were much higher than mean values of growth observed in fed treatment groups. However, rates of growth (biochemically-based), food consumption (both prey items in guts and feeding strike frequency) and activity (pause duration, pause frequency) were quite variable among individuals. After taking into account this high inter-individual variability, modelled and observed growth agreed well. A list of recommended IBM parameter values for larval clupeid physiology is provided. Although not a direct test of “climate impacts” *per se*, such laboratory experiments are critical if we hope to produce models providing robust estimates of the influence of climate-driven processes on early life stages of key fish species.

#### Poster S4.2-4933

### Influence of physical and biological oceanography on population fluctuations of the yellow croaker (*Larimichthys polyactis*) in the Yellow Sea/East China Sea

Yeonghye **Kim**, Sukgeun Jung, Jinkoo Kim and Young-Shil Kang

National Fisheries Research and Development Institute, Busan 619-902, Republic of Korea. E-mail: yhkim@nfrdi.re.kr

Yellow croaker, *Larimichthys polyactis*, is a commercially important demersal fish in the Yellow and East China Sea. It migrates vertically and horizontally with certain rhythm. Croakers descend to the sea bottom during the daytime and ascend toward the surface at night, probably following the diurnal vertical migration of their zooplankton prey such as Euphausiids, copepoda and other crustaceans. They ontogenetically migrate from spawning to nursery, and then to their over-wintering grounds. The Yellow Sea stock migrates to spawn in the Korean western sea during the April to June period. This stock arrives earlier in the southern compared with the northern Yellow Sea. Spatially, catch levels are higher in shallow, coastal areas than offshore areas. This species migrates to the waters near Chilsan and Wi Islands in April-May, and then moves northward to the waters near Yeonpyeong Islands in June-August. Young croakers (< 2-year old individuals) dominate Korean commercial catches, which are mostly landed at Chuja and Heuksan Islands from October to the next March. We will identify physical and biological factors influencing stock fluctuation of yellow croaker to predict stock fluctuation of yellow croaker based on the age-specific catch levels and ontogenetic migration.

#### Poster S4.2-4944

### Climate change and prospects of fisheries in the Barents Sea and adjacent Arctic seas

Oleg **Titov**, Boris Prishepa, Yuri. Lepesevich, Nikolay Tarasov and Andrey Pedchenko

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, 183038 Murmansk, Russia.  
E-mail: titov@pinro.ru

The last decade is in general characterised by the stable increase of the air temperature over the area of the Barents Sea and adjacent seas. Similar processes were observed in the hydrosphere. The warming of the “ocean-atmosphere” system caused the decrease of the ice cover area in the sea. The present-day changes of climate have

already had an impact on the biological resources of the Barents Sea and adjacent areas. The most noticeable changes take place in the geographical redistribution of the fishing over the sea and of new fish species traditionally dwelling in warm Atlantic waters. A consequence of changing climate in the last decade is the fact that the boundaries between the Arctic and Atlantic oceanic systems have become weaker, and the frontal zones in the Barents Sea became correspondingly fuzzier. In connection with this one can assume that the climate warming could have a certain negative impact on the abundance of such important commercial species as cod and capelin, the habitats of which are densely connected with frontal zones. Thus, even now it is necessary to switch the task of studying of implications of the climate change from theory to practice. In our opinion one of the first steps in investigating implications of global warming for fishing bioresources should be a programme studying fishing bioresources in the Kara Sea.

#### **Poster S4.2-4956**

### **Influence of a change in climate on the development of molluscs in marine farming (for Possyet Bay, Sea of Japan)**

Larissa A. **Gayko**

Far East Branch Russian Academy of Sciences, of V.I. Il'ichev Pacific Oceanological Institute, Baltiyskaya St. 43, Vladivostok 690041, Russia. E-mail: [gayko@yandex.ru](mailto:gayko@yandex.ru)

The tendencies of climate change, namely global warming, are of great interest. The research in climatic changes in separate regions is especially interesting for estimation of their possible aftermaths and impact on the environment and economy. To develop scientific methods of long-term prediction of mollusk productivity, it is necessary to study the effects of hydrological parameters on Japanese scallop and the technology of its cultivation. The information used in this study was scallop observations from a sea farm at Possyet (1970-2005), a multiyear series of mean diurnal data from the Hydrometeorological Station Possyet, and the State Network of Hydrometeoservice situated in Possyet Bay. This paper sets forth the results of statistical analysis of thermohalinic characteristics of four periods of the annual developmental cycle of the Japanese scallop. The departures from the mean values of the duration of biological periods and their thermohaline characteristics were calculated. The results show that all parameters undergo considerable interannual variability. Comparing the duration of the development of Japanese scallop for the periods 1970-1990 and 1999-2005, the mean duration itself was not changed but the maximum and minimum duration decreased. Good-harvest and low-harvest years are identified on the basis of an analysis of the distribution of harvest deviations from the trend.

#### **Poster S4.2-4966**

### **Is there evidence of climate change impacts on Portuguese coastal fish assemblages?**

Henrique N. **Cabral**<sup>1</sup>, J.L. Costa<sup>1</sup>, C. Vinagre<sup>1</sup>, J. Loff<sup>1</sup>, J.J. Jacinto<sup>1</sup>, N. Lopes<sup>2</sup>, C. Freitas<sup>2</sup> and M.J. Costa<sup>1</sup>

<sup>1</sup> Universidade de Lisboa, Faculdade de Ciências, Centro de Oceanografia, Campo Grande, 1749-016 Lisboa, Portugal.  
E-mail: [hcabral@fc.ul.pt](mailto:hcabral@fc.ul.pt)

<sup>2</sup> Câmara Municipal de Almada, Departamento de Planeamento e Gestão Ambiental Sustentável, Casa Municipal de Ambiente, Rua Bernardo Francisco da Costa 42, 2800-029 Almada, Portugal.

The Portuguese coast is located in a biogeographical transition area. Due to this particular situation, fish characteristic of the Mediterranean and warm temperate regions can be found in sympatry with others typical from cool temperate and boreal latitudes. Hence, this is a good geographical area to evaluate changes in fish communities due to climate change. Although time series data on fish assemblage composition and structure is extremely scarce and fragmented, an effort was made in the present study to compile the available data, both from historical records and more recent surveys, including some collections conducted in 2007 in the Almada Atlantic front (central coast of Portugal), as a result of a joint project between Almada City Council and the Oceanographic Institute. For some coastal areas, fish assemblage composition and structure (based on functional guilds) was compared throughout the last decades, and its relationship with climatic change evaluated, especially with regard to sea surface temperature. The implications of an increase in sea surface temperature on coastal fish assemblages in this geographical area are discussed and its possible impacts foreseen.

### Poster S4.2-4973

#### Could warmer years mean good years for cod? A pan-Atlantic meta-analytic perspective

Irene **Mantzouni** and Brian R. MacKenzie

National Institute of Aquatic Resources, DTU Aqua, Dept. of Marine Ecology and Aquaculture, Kavalergården 6, 2920 Charlottenlund, Denmark. E-mail: ima@difres.dk

This study aims to identify the effect of temperature on cod (*Gadus morhua*) population dynamics by meta-analysing data across the species distributional range in the North Atlantic. Our objective is to evaluate how extreme temperature conditions in each region affects recruitment and conversely the temperature conditions experienced in years when extremely high or low recruitment is produced. For this purpose, we first compiled an extensive database consisting of updated available time series of recruitment, spawning stock and total biomass, plus time series of upper layer (0-100 m) temperature during the cod spawning season (spring), for all populations. We then applied parametric and non-parametric meta-analytical methods using standard and novel effect size metrics (e.g. response ratio between strong and weak year-classes) to evaluate potential associations between years having exceptional temperature conditions and exceptional recruitment. Stock-specific metrics were combined through random and mixed effects meta-analytic methods in order to identify patterns in effects and produce overall results regarding cod response to ocean warming, allowing for the influence of other ecosystem characteristics specific to each stock. The methods employed include hierarchical Bayesian meta-analysis, which allow us to integrate various levels of uncertainty in addition to scientific knowledge. We find that there are geographic patterns in cod response to temperature, with stocks inhabiting the colder range being favoured by warmer years. On the other hand weak year-classes are associated with the extreme high temperature for the warmer range stocks. The critical temperature appears to be *ca.* 7°C, above which negative effects prevail.

### Poster S4.2-4980

#### Anchovy as indicator of climatic regime shifts?

Kristina **Raab**, Mark Dickey-Collas and Adriaan D. Rijnsdorp

Wageningen IMARES (Institute for Marine Resources and Ecosystem Studies), P.O. Box 68, 1970 AB IJmuiden, The Netherlands. E-mail: Kristina.raab@wur.nl

Small pelagic fish have been proposed as candidate indicator species for predicting climatic regime shifts. The relative availability of information (through fishing or surveys), relatively low time-lags in responses to environmental change (because of close linkage to primary and secondary production) and the wide geographical distribution of small pelagic fish are three characteristics making them potentially useful indicator species. Conspicuous recent changes in the North Sea zooplankton and fish communities indicate that a regime shift has occurred and in this context we use a small pelagic fish to test the above expectation. Anchovy (*Engraulis encrasicolus*) increases observed in the North Sea over the past half decade were examined to reveal whether a clear response of anchovy populations to climate via direct (temperature related) and indirect (food web related) mechanisms could be detected. The analysis is carried out in time and space and we assess whether anchovy populations could be useful predictors of climatic change in temperate waters.

## **S5.1 Scenarios for polar, mid-latitude, sub-tropical, and tropical environments and ecosystems**

**21 May, 10:35 (S5.1-4770) Invited**

### **Impacts of climate change on Antarctic marine ecosystems**

Graham W. **Hosie**

Australian Antarctic Division, Department of the Environment, Water, Heritage and the Arts, 203 Channel Highway, Kingston, Tasmania 7050, Australia. E-mail: graham.hosie@aad.gov.au

Antarctic waters are expected to be particularly sensitive and vulnerable to climate change. Global warming will affect sea ice patterns and the survival of Antarctic krill and cold water plankton. Increased UV levels will also affect them. Ocean acidification has been predicted to be a more immediate threat to the plankton of the region causing the demise of species with calcium carbonate shells, e.g. pteropods. These events need to be considered together due to possible synergistic effects. Changes in plankton composition have been observed in the North Sea, Atlantic and North Pacific with flow on effects through the food web and linked to declines in fish stocks. A decline in krill abundance since the 1970s and associated increase in salps has been associated with the decrease in sea ice extent. The Southern Ocean Continuous Plankton Recorder Survey has also identified major changes in zooplankton composition in the sea ice zone (SIZ) around the year 2000 with smaller zooplankton now dominating instead of krill. Large blooms of *Emiliania huxleyi* are now extending southward well into the SIZ possibly due to ocean warming. In 2004/05 in waters north of the SIZ, pelagic foraminiferans exceeded 50% numerical abundance instead of the 2% long term average, replacing *Oithona* as the dominant species. The causes of the changes are still being investigated. However, such changes in food composition at the base of the food web and a shift downwards in the size of zooplankton prey could have a major impact on the survival of higher predators.

**21 May, 11:00 (S5.1-4778) Invited**

### **A scenario approach to forecast potential impacts of climate change on red king crabs in the eastern Bering Sea**

Gordon H. **Kruse**<sup>1</sup>, Jie Zheng<sup>2</sup> and James E. Overland<sup>3</sup>

<sup>1</sup> School of Fisheries and Ocean Sciences, Juneau Center, University of Alaska Fairbanks, 11120 Glacier Highway, Juneau, AK 99801, USA. E-mail: Gordon.Kruse@uaf.edu

<sup>2</sup> Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box 25526, Juneau, AK, 99802-5526, USA.

<sup>3</sup> Pacific Marine Environmental Laboratory/NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

We developed scenario-based forecasts of potential impacts of climate change on three stocks (Bristol Bay, Pribilof Islands and Norton Sound) of red king crabs (*Paralithodes camtschaticus*) in the eastern Bering Sea (Alaska). Seven mechanisms responsible for crab population dynamics were identified: larval prey type, larval prey timing, larval advection, juvenile predation and competition, benthic energy flow, ocean acidification, and commercial fisheries. Based on reasoned expert professional judgment, scenarios of the impacts of climate change on the biomass and commercial harvests for the years 2030 and 2050 were developed, driven by forecasts of anthropogenic and environmental conditions. Forecasts were developed largely from projections of key atmospheric and oceanographic variables from the Fourth Assessment Review by the Intergovernmental Panel on Climate Change. For each crab stock, three estimates of red king crab biomass – central, low, and high – were derived for each scenario year. Although results vary by area, global warming is generally expected to result in declines in all three stocks of red king crabs in the Bering Sea. Mechanisms operating to favour crab productivity include benefits of stock rebuilding plans and potential improved timing of red king crab larvae and their prey. These positive effects are likely to be overwhelmed by deleterious mechanisms including larval advection to unsuitable nursery habitats (Bristol Bay only), increased predation and food competition by expanding groundfish populations, and reduced energy flow to the benthic invertebrate prey species. Effects of ocean acidification on the growth and survival of king crab larvae are not likely by 2050.

**21 May, 11:25 (S5.1-4631)**

### **Predicting the effects of climatic change on the biodiversity of intertidal sessile fauna on coral reefs**

Simon J. **Walker**, Greg A. Skilleter and Bernie M. Degnan

School of Integrative Biology, University of Queensland, Brisbane, QLD 4072, Australia. E-mail: s355626@student.uq.edu.au

On coral reefs, sessile taxa occupying intertidal rubble habitats contribute significantly to the overall biodiversity and ecosystem function of coral reef ecosystems. The existing strong physical gradients in these intertidal habitats will be exacerbated under predicted climatic change, but it is unclear how communities will respond to these changes. We examined how biodiversity in these assemblages would be affected by one aspect of climatic change – increased storm intensity – through experimental manipulations of the disturbance regime on One Tree Reef in the southern Great Barrier Reef. We monitored colonisation of undisturbed (secured) and disturbed (unsecured), natural (coral) rubble plates over nine months. At the exposed sites disturbance resulted in 71% loss of species richness and 88% loss in total coverage low on the shore. Even at the sheltered location, there was significantly more species present when disturbance was removed. Some species that were absent on natural (unsecured) plates successfully colonised the undisturbed plates, indicating that disturbance was restricting their distribution. As physical disturbance regimes increase due to more intense storms and wave action associated with global warming, we can expect to see a corresponding decrease in the diversity of these cryptic sessile assemblages. This could have implications for the future health and productivity of coral reef ecosystems, given the ecosystem services these organisms provide.

**21 May, 11:40 (S5.1-4632)**

### **Possible change in seaweed distribution in East Asia under a particular scenario of global warming**

Teruhisa Komatsu<sup>1</sup>, Atsuko Mikami<sup>1</sup>, Etienne **Boisnier**<sup>1</sup>, Tatsuyuki Sagawa<sup>1</sup>, Hideaki Tanoue<sup>1</sup>, Tetsuro Ajisaka<sup>2</sup> and Yoshihiko Sakanishi<sup>3</sup>

<sup>1</sup> Ocean Research Institute, the University of Tokyo, 1-15-1 Minamidai, Nakanoku, Tokyo 164-8639, Japan.  
E-mail: komatsu@ori.u-tokyo.ac.jp

<sup>2</sup> Graduate School of Global Environmental Studies, Kyoto University, Kitashirakawa-Oiwakecho, Sakyo-ku, Kyoto 606-8502, Japan.

<sup>3</sup> Hokkaido National Fisheries Research Institute, 116 Katsurakoi, Kushiro, Hokkaido, 085-0802, Japan.

Global warming effects on coastal marine ecosystems are already perceptible. Seaweed beds constitute highly valuable spawning, nursery and feeding grounds for numerous organisms in coastal waters. Hence, fisheries resources as well as biological diversity are dependent on the presence of these beds. Geographical distributions of seaweeds greatly depend on water temperatures in summer and winter because they are very sensitive to maximum and minimum water temperatures. As a result, it is expected that a water temperature increase will drastically influence the current distribution. In order to test this hypothesis, we referred to a scenario of global warming (A2) developed by Center for Climate System Research of the University of Tokyo. This simulation enables the prediction of water temperature in the Pacific Ocean and adjacent seas by 1 degree. Using simulated surface water temperatures in February and August in 2050 and 2099, we examined changes in the spatial distribution of a specific seaweed species: *Sargassum horneri*. This species was selected because it is an important species forming seaweed beds and has a wide thermal tolerance. Results show that the southern limit of *S. horneri* distribution is expected to keep moving northward such that it may broadly disappear from Honshu Island, the Chinese coast and the Korean Peninsula by 2099. Since *S. horneri* forms drifting seaweeds in the East China Sea and that these floating habitats constitute a key nursery ground for yellowtail and jack mackerel spawning, *S. horneri* disappearance is expected to significantly damage not only fishes related to the plants but also pelagic ones.

**21 May, 11:55 (S5.1-4959)**

**North Pacific Research Board and National Science Foundation partner to study biological processes on eastern Bering Sea shelf ecosystem and impacts of climate change**

Clarence **Pautzke**<sup>1</sup>, W. Wiseman<sup>2</sup> and F. Wiese<sup>1</sup>

<sup>1</sup> North Pacific Research Board, 1007 West 3rd Avenue, Suite 100, Anchorage, AK, 99501, USA. E-mail: cpautzke@nprb.org

<sup>2</sup> National Science Foundation, 4201 Wilson Blvd., Suite 755, Arlington, VA 22230, USA.

The North Pacific Research Board (NPRB) and National Science Foundation (NSF) are partnering in a massive \$50 million study of the eastern Bering Sea shelf ecosystem and how it may respond to climate change and loss of sea ice. It will include three field seasons in 2008-2010 and two years for analysis and reporting. Over 70 federal, state, and university scientists will be involved, hailing from Alaska, Washington, Oregon, British Columbia, and elsewhere in North America. NSF will study atmosphere and ocean physics and lower trophic levels, including physical and biological sampling near sea ice and the ocean floor, primary production, nutrients and stratification, and energy transfer through zooplankton. NPRB will emphasise forage fish, commercial fish species such as pollock, Pacific cod, and arrowtooth flounder; northern fur seals, walrus and whales; and common murrelets and blacklegged kittiwakes. Foraging patterns of birds and mammals will be studied within large prey aggregations near the Pribilof, Bogoslof, and St. Lawrence Islands. Federal matching funds from the National Oceanic and Atmospheric Administration, US Geological Survey, and US Fish and Wildlife Service will support trawl surveys, seabird telemetry, and studies of fur seal pups and persistence of foraging hotspots. Local and traditional knowledge will provide additional views on how the ecosystem functions. This study is certain to improve our understanding of biological processes that underpin the robust Bering Sea fisheries and our predictive capacity of those fish stocks as a result of an innovative, bio-physical ecosystem model that will tie programme components together.

**21 May, 12:10 (S5.1-4819)**

**Getting hot and bothered about climate change impacts in Australian waters**

Alistair J. **Hobday**<sup>1,2</sup>, Elvira S. Poloczanska<sup>1</sup>, Thomas J. Kunz<sup>1</sup>, Tom A. Okey<sup>1</sup> and Anthony J. Richardson<sup>3,4</sup>

<sup>1</sup> Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, P.O. Box 1538, Hobart, Tasmania 7001, Australia. E-mail: alistair.hobday@csiro.au

<sup>2</sup> University of Tasmania, School of Zoology, Private Bag 5, Hobart, Tasmania 7001, Australia.

<sup>3</sup> Department of Mathematics, University of Queensland, St Lucia, Queensland, 4072, Australia.

<sup>4</sup> Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, P.O. Box 120, Cleveland, Queensland, 4163, Australia.

Marine ecosystems are extremely important economically and ecologically to Australia in terms of tourism, coastal defence, harvestable resources, and ecosystem services. Australian waters harbour a number of unique ecosystems which may be particularly vulnerable to climate change. We present findings of comprehensive reviews of observed and potential climate change impacts on Australian marine life, fisheries and aquaculture. Ocean acidification, alteration of storm regimes and warmer temperatures are expected to have the greatest impacts on tropical fauna increasing the frequency of coral reef bleaching and altering recruitment strength of important commercial species such as prawns. A strengthening of the East Australian Current is projected to drive intense warming of the Tasman Sea, challenging the persistence of cool-temperate fauna and flora. Climate change will impact the biological, economic and social aspects of many of Australia's valuable fisheries. Aquaculture industries have considerable adaptation potential via selective breeding, regulating the environment, and new species opportunities. Wild fisheries will see increased opportunity where tropical species move polewards, while for southern fisheries, reconciling non-climate threats with increasing temperature will require proactive management. Climate change impacts are already being recorded in Australian waters and future changes are likely to be dramatic and have considerable socio-economic and ecological consequences, especially in 'hot spots' of climate change such as the Tasman Sea and the Great Barrier Reef. The reviews indicate that while we have a general understanding of the likely mechanisms of climate change impacts on a few species, we have limited knowledge at an ecosystem level.

21 May, 12:25 (S5.1-4841)

### Long term changes in North Sea physics and phytoplankton from NORWECOM

Solfrid Sætre [Hjollo](#), Morten Skogen and Einar Svendsen

Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway. E-mail: Solfrid.Hjollo@imr.no

We explore the North Sea long term changes in circulation, hydrographic conditions and phytoplankton conditions in the period 1985-2007 from a simulation by the numerical model NORWECOM. The model is shown to reproduce the observed hydrographic conditions, inflows, heat content and phytoplankton distribution. A bipolar North Sea flow pattern is identified, with the northernmost pattern being regulated by large scale atmospheric forcing. For the last decade, mean annual heat content has been above the long term mean, and accumulated heat corresponds to an average temperature increase of roughly 0.5°C. The heat flow through the North Sea boundaries is explored and the seasonally variable main sources of heat identified. The model confirms a clear trend towards lower levels in the southern North Sea nutrients as a result of reduced anthropogenic loads. The interannual variability in primary production is controlled by the physics, and these mechanisms are investigated.

21 May, 12:40 (S5.1-4864)

### Long-term environmental changes and the responses of the ecosystem in the northern South China Sea during 1976-2004

Xiuren [Ning](#)<sup>1,2,3</sup>, Chuanlan Lin<sup>3</sup>, Qiang Hao<sup>2,3</sup>, Chenggang Liu<sup>1,2,3</sup> and Fengfeng Le<sup>2,3</sup>

<sup>1</sup> State Key Lab of Satellite Ocean Environment Dynamics, PR China. E-mail: ning\_xr@126.com

<sup>2</sup> SOA Key Lab of Marine Ecosystems and Biogeochemistry, PR China.

<sup>3</sup> Second Institute of Oceanography (SIO), State Oceanic Administration (SOA), Hangzhou, Zhejiang, 310012, PR China.

Physical and chemical oceanographic data were obtained by seasonal monitoring along transect N, in the northern South China Sea (nSCS) during 1976-2004. The fluctuations of DIN (dissolved inorganic nitrogen), seawater temperature (SST and  $T_{av}$  - average temperature of the water column), N:P ratio and salinity ( $S_{av}$  and  $S_{200}$ —salinity at 200 m layer) exhibited an increasing trend, while those of  $T_{200}$ , DO, P, Si, Si:N and SSS exhibited a decreasing trend. The annual rates of DIN, DO, T and S revealed pronounced changes, and the climate trend coefficients  $R_{xt}$ , which was defined as the correlation coefficient between the time series of an environmental parameter and the nature number, were 0.38 to 0.89 and significant ( $p \leq 0.01$  to 0.05). The results also show that marine ecosystems of the nSCS have obviously been influenced by the positive trends of both SST and DIN, and negative trends of both DO and P, e.g. before 1997 DIN concentration was very low and N:P ratios less than half of the Redfield ratio (16), indicating potential N limitation; while since 1998 all  $Si:P > 22$  and the  $N_{av}:P_{av}$  close to the Redfield ratio, indicating potential limitation of P and the limitation of N has mitigated. Ecological investigation shows that there were some improved responses of ecosystems to the long-term environmental changes, chlorophyll *a* concentration, primary production, phytoplankton abundance, benthic biomass, cephalopod catch and demersal trawl catch have increased. But phosphorus depletion in the upper water resulted in a succession of phytoplankton communities, i.e. the dominant species shifted from diatoms to dinoflagellates and cyanophytes. The signs of ecosystem response resulted from environmental changes, induced not only by climate changes, i.e. global climatic events, like ENSO, but also anthropogenic activities, which are discussed.

21 May, 12:55 (S5.1-4919)

### Predicting climate warming impact on marine fish communities from biogeography: example from tropical, subtropical and temperate case studies

Fabian [Blanchard](#)<sup>1</sup>, Jean-Charles Poulard<sup>2</sup>, Hicham Masski<sup>3</sup> and Claude Roy<sup>4</sup>

<sup>1</sup> Ifremer, BP 477, Cayenne Cedex, 97331, French Guyana. E-mail: Fabian.Blanchard@ifremer.fr

<sup>2</sup> Ifremer, BP 21105, Nantes Cedex 03, 44311, France.

<sup>3</sup> INRH, 2 rue Tiznit, Casablanca, 20000, Morocco.

<sup>4</sup> IRD, Plouzané, 29280, France.

Species have adapted to the mean conditions encountered within their distribution area, including temperatures. Hence the temperature characteristics observed within the distribution area may indicate the thermal affinity and tolerance of the species. In a given ecosystem, the species adapted to warm waters should be favoured (increase of their biomass) by an increase of the sea temperatures, while the species adapted to cold waters should be unfavoured. However

ecosystem responses to the common, large scale climatic forcing could vary in respective latitudinal regions due to regionally-specific environmental/ecological characteristics. These hypotheses were tested comparing the changes observed during the last decades in three fish communities of continental shelves regarding the temporal trend of sea surface temperatures of the three ecosystems, the biogeographic origin and the corresponding thermal affinity of the species from the communities. The three ecosystems chosen were a mid-latitude area, the Bay of Biscay (France), a sub-tropical up-welling area (South Morocco), and a tropical one, the Guyana shelf. Biomass data from scientific trawl surveys carried out in the three systems were used to assess the community changes. The results are discussed according to the diversity-stability hypotheses and the fishing pressure in these ecosystems as confounding factor.

**21 May, 13:10 (S5.1-4952)**

### **The ecosystem response of the Barents and Norwegian seas to future climate change with emphasis on the higher trophic levels**

Kenneth F. Drinkwater, Harald **Loeng** and S. Sundby

Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway. E-mail: ken.drinkwater@imr.no

Under future climate change, the Arctic is expected to undergo the largest changes in temperature. In the Barents Sea, ocean temperatures are predicted to increase between 2-8°C while farther south in the Norwegian Sea it is expected to be 1-3°C due to atmospheric warming and increased Atlantic Water inflow. In this presentation we use past observations and statistical relationships between ecological variables and climate along with the predicted future climate changes to develop future ecological scenarios. With the increased thermal heating, sea ice will disappear from the Barents Sea. Where this happens, the increase in light levels will lead to increased annual phytoplankton production. Arctic zooplankton biomass is expected to decrease and Atlantic zooplankton to increase as the Atlantic Water influence increases. In the Norwegian Sea plankton changes will be much reduced. At the higher trophic levels, higher recruitment levels and faster growth of species such as Atlantic cod, herring and capelin are expected in both seas, leading to increases in overall production and biomass. Distribution will spread northward including spawning sites for some species. Pelagic production will increase especially within the Norwegian Sea. Species such as blue whiting and mackerel will likely spread northward as well as into the Barents Sea. The effects of both fishing and species competition on the future changes in the major commercial species will be discussed. With an expected increase in the overall fish production increases in the abundance of marine mammals and seabirds are expected.

**21 May, 13:25 (S5.1-4515)**

### **Climate changes and tourism: southeastern Anatolia region and southeastern Anatolia Project (GAP) in Turkey as a case study**

Bulent **Acma**

Anadolu University, Department of Economics, Unit of Southeastern Anatolia Project (GAP) 26470, Eskisehir, Turkey.  
E-mail: bacma@anadolu.edu.tr

The Republic of Turkey has a special place in the Mediterranean Region from the respects of both its social-economic structure and its geo-politic and geo-strategic importance. It is also a model for the Middle East Countries by combining the traditional and modern life styles. The Southeastern Anatolia Project (Turkish: Güneydoğu Anadolu Projesi, GAP) is a multi-sector integrated regional development project based on the concept of sustainable development for the 9 million people living in the Southeastern Anatolia region of Turkey. GAP's basic aim is to eliminate regional development disparities by raising people's income level and living standards; and to contribute to such national development targets as social stability and economic growth by enhancing the productive and employment generating capacity of the rural sector. Climatic changes were observed in the region after the creation of artificial lakes for irrigation. The modified climate has started to cause changes in rural tourism in the region. It has also allowed for new types of flora to become established and created an environment for alternative types of tourism. In recent years, remarkable developments have been observed in eco-tourism and agro-tourism in the region and a general increase in the flow of tourists to the region has been observed. The main purpose of this study is to analyse the effects of climatic changes in the region. A brief introduction to the region and to the GAP Project will be given followed by an examination of the climatic structure of the region. Both the climatic features and tourism structure before and after the GAP Project will be included. In the third section, the results of climatic changes and new tourism alternatives will be analysed. Again, in this section, the existing tourism potential will be determined. This study will present a series of policies and strategies for differential tourism and tourism development after the climatic changes in this region

# S5.1

## Posters

21 May, 12:55 (S5.1-4548)

### Resilience of mangroves to indirect effects of climate change

Jared O. **Bosire**

Kenya Marine and Fisheries Research Institute (KMFRI), P.O. Box 81651, Mombasa, Kenya. E-mail: jbosire@kmfri.co.ke

Climate change threatens the very survival of species and the integrity of ecosystems world-wide on which humans and generally all life on earth depends. Wetlands will suffer the most being a transitional ecotone between land and water bodies. Emerging scientific information indicates that the 1997/8 and last year's heavy rains in Kenya previously thought to have been caused by *El Niño* were a consequence of global climate change due to a phenomenon referred to as the Indian Ocean Dipole. During this event in 1997/8, there was elevation of sea surface temperature by 1°C which led to 50-80% coral reef death along the Kenyan coast due to bleaching. The impact of this phenomenon on mangroves, which are an important coastal resource has not been assessed. But preliminary data from Mwache Creek, Kenya indicates that there was extensive mangrove dieback in some areas due to massive sedimentation following severe erosion upstream. Land-use practices seem to be exacerbating soil erosion and sedimentation in this area. Such land-use practices observed include: shifting cultivation, overgrazing and poor tillage of land without any soil and water conservation measures whatsoever. As a result there is continuous loss of the top soil rich with nutrients leading to poor productivity which has significantly compromised the food security of the local people. Recovery of the impacted mangroves is limited and opportunistic species e.g. salt tolerant grasses and *Sueda maritime* are colonising the impacted sites, which has consequences on the livelihoods of the local people depending on the mangrove ecosystem for wood products, fisheries and even shoreline protection. Human intervention to restore the impacted mangroves and an integrated management of these mangroves with the contiguous terrestrial ecosystems will be necessary to mitigate the effects of climate change and safeguard the livelihoods of dependant communities.

### Poster S5.1-4845

#### Influence of climatic changes on density dynamics of boreal and subtropical bivalves larvae in plankton of Minonosok Bight (Possyet Bay, Japan/East Sea)

Anna V. **Radovets**<sup>1</sup> and Nadezhda K. Khristoforova<sup>2</sup>

<sup>1</sup> Pacific Research Fisheries Centre (TINRO-Centre), 4 Shevchenko Alley, Vladivostok 690950, Russia. E-mail: radovets@list.ru

<sup>2</sup> Far Eastern State University, 8 Sukhanova Street, Vladivostok 690600, Russia.

The study was carried out in connection with global temperature changes, registered in the 20th century. The work was conducted in summer-autumn 2002-2004 in Minonosok Bight of the Possyet Bay, Japan/East Sea, 10-15 years after the last corresponding investigations. The influence of water temperature and salinity changes on the density dynamics of bivalve larvae in the plankton was studied. Features of the temporary distribution and dimensional structure of commercial bivalve larvae in the plankton of the Minonosok Bight in early 2000s were determined. Significant changes in terms of the pelagic period of larvae were revealed for *Mizuhopecten yessoensis*, *Mytilus trossulus*, *Chlamys farreri nipponensis* and *Crassostrea gigas* in comparison with available data obtained in the period from the mid-1970s to the early 1990s. These changes are explained by water temperature rise. It was established, that the degree of mollusk's reaction to a water temperature rise is connected with the thermopathy determined by biogeographic characteristics and ecological plasticity. A tendency towards an increase in the number of larvae of subtropical bivalves – *C. f. nipponensis* and *C. gigas* was marked.

**Poster S5.1-4922**

**Effect of *El Niño* Southern Oscillation events on the distribution and abundance of phytoplankton in the northern South China Sea**

Fengfeng **Le**<sup>1</sup> and Xiuren Ning<sup>1,2</sup>

<sup>1</sup> SOA Key Lab of Marine Ecosystems and Biogeochemistry, Second Institute of Oceanography (SIO), State Oceanic Administration (SOA), Hangzhou, Zhejiang 310012, PR China. E-mail: Le\_ff@126.com

<sup>2</sup> State Key Lab of Satellite Ocean Environment Dynamics, SIO, SOA, Hangzhou, Zhejiang 310012, PR China.

The distribution of physical and chemical parameters and their impact on phytoplankton abundance and primary production in the northern South China Sea were compared in two opposing situations: the *El Niño* Southern Oscillation (ENSO) event of 1998 and the non-ENSO period of 2004. During *El Niño* conditions (June-July 1998), lower cell abundance was recorded in the region of 18-22°N, 110-117°E. In August 2004, under the non-ENSO conditions, a well-established coastal upwelling produced an increase in the surface layer nutrient supply. This in turn caused an increase in phytoplankton populations at the surface layer, with chlorophyll concentrations  $>1.5 \text{ mg} \cdot \text{m}^{-3}$  and microalgae populations  $>300 \times 10^3 \text{ cell} \cdot \text{dm}^{-3}$  respectively. Integrated over 150 m, chlorophyll *a* concentrations were 4.2 times larger in 2004 than in 1998. A strong subsurface Chl *a* maximum which was dominated by photosynthetic picoplankton was found to contribute significantly to phytoplankton stocks and production year round, especially in shelf and open seas. The analysis of the spatial distribution of phytoplankton species shows how the community structure is related to the gradient of the nutrients from coastal region to the open sea.

## **S5.2 Adaptation and mitigation of impacts on the marine environment and ecosystems**

**23 May, 10:35 (S5.2-4949) Invited**

### **How can fisheries adapt to a changing ocean climate: beyond ecosystem-based fishery management**

Andrew A. **Rosenberg**

Institute for the Study of Earth Oceans and Space, Morse Hall 142, University of New Hampshire, Durham, NH 03824, USA.  
E-mail: andy.rosenberg@unh.edu

Fishermen are masters of adaptation, but fishery management is not. In many cases, the policy and management strategies and tactics applied in developed fisheries around the world lag the changes in those fisheries by years. Fishermen adapt to changing conditions at sea on very short time-scales, changing regulations on an annual or multi-annual timeframe, and to market and business conditions on many different scales. But can fishermen and managers adapt to fundamental changes in ocean conditions, and do so without undermining sustainability of changing ocean ecosystems? This paper explores the adaptation strategies from a manager's perspective including changing the incentive structure in fisheries to support sustainability, altering the responsiveness of fishery management strategies as climate changes, and changing the perspective of fishery management working in isolation from other sectors of human activities in the marine environment. Taking an ecosystem-based approach to management across sectors of human activity is key to adaptation, but that ecosystem approach must be framed by the environmental changes that are driven by climate change.

**23 May, 11:00 (S5.2-4710) Invited**

### **Ecological and rapid evolutionary responses to climate change: implications for marine management**

Marissa L. **Baskett**

National Center for Ecological Analysis and Synthesis, Santa Barbara, CA 93101, USA. E-mail: mbaskett@nceas.ucsb.edu

An understanding of ecological and rapid evolutionary responses to climate change is critical to effective management and conservation of marine ecosystems given future change. Potential ecological and evolutionary responses to climate change include movement, acclimation, and genetic adaptation in phenology, life history traits, and physiological tolerance. Adaptive responses are particularly relevant to species which exist at environmental extremes and the limits of their physiological tolerances, such as coral reefs and polar species. Theoretical explorations of ecological and evolutionary responses to climate change can inform conservation management prioritisation such as which types of locations to protect in marine reserves. To illustrate this potential, I will provide an overview of the general theory of rapid evolutionary responses to environmental change, which indicates the rate of change to which a species may adapt and the characteristics (e.g. genetic variance, selection strength) which influence that adaptive rate. Then I will apply this theory to case studies, such as the potential for coral reef ecological and evolutionary responses to the increase in thermal stress expected with climate change. Overall, theoretical predictions indicate the need to account for uncertainty and protect diversity in order to conserve marine ecosystems and their services in a changing climate.

**23 May, 11:25 (S5.2-4924)**

### **A global map of human impact on marine ecosystems**

Benjamin S. Halpern<sup>1</sup>, Shaun Walbridge<sup>1</sup>, Kimberly A. Selkoe<sup>1,2</sup>, Carrie V. Kappel<sup>1</sup>, Fiorenza Micheli<sup>3</sup>, Caterina D'Agrosa<sup>4,5</sup>, John F. Bruno<sup>6</sup>, Kenneth S. Casey<sup>7</sup>, Colin Ebert<sup>1</sup>, Helen E. Fox<sup>8</sup>, Rod Fujita<sup>9</sup>, Dennis **Heinemann**<sup>10</sup>, Hunter S. Lenihan<sup>11</sup>, Elizabeth M.P. Madin<sup>12</sup>, Matthew T. Perry<sup>1</sup>, Elizabeth R. Selig<sup>6,13</sup>, Mark Spalding<sup>14</sup>, Robert Steneck<sup>15</sup> and Reg Watson<sup>16</sup>

<sup>1</sup> National Center for Ecological Analysis and Synthesis, 735 State Street, Santa Barbara, CA 93101, USA.

<sup>2</sup> Hawai'i Institute of Marine Biology, P.O. Box 1346, Kane'ohe, HI 96744, USA.

<sup>3</sup> Hopkins Marine Station, Stanford University, Oceanview Boulevard, Pacific Grove, CA 93950-3094, USA.

<sup>4</sup> Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460, USA.

<sup>5</sup> current address: School of Life Sciences, Arizona State University, Tempe, AZ 85287-4501 USA.

<sup>6</sup> Department of Marine Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3300, USA.

<sup>7</sup> NOAA National Oceanographic Data Center, 1315 East-West Highway, Silver Spring, MD 20910 USA.

<sup>8</sup> Conservation Science Program, World Wildlife Fund - US, 1250 24th Street, NW, Washington, DC 20037 USA.

<sup>9</sup> Environmental Defense, 5655 College Avenue, Suite 304, Oakland, CA 94618 USA.

<sup>10</sup> Ocean Conservancy, 1300 19th Street NW, 8th Floor, Washington, DC 20006 USA. E-mail: dheinemann@oceanconservancy.org

<sup>11</sup> Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106, USA.

<sup>12</sup> Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, CA 93106, USA.

<sup>13</sup> Curriculum in Ecology, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3275, USA.

<sup>14</sup> Conservation Strategies Division, The Nature Conservancy, 93 Centre Drive, Newmarket, CB8 8AW, UK.

<sup>15</sup> School of Marine Sciences, University of Maine, Darling Marine Center, Walpole, ME 04353, USA.

<sup>16</sup> Fisheries Center, 2202 Main Mall, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

The management and conservation of the world's oceans require synthesis of spatial data on the distribution and intensity of human activities and their overlap on marine ecosystems. We developed an ecosystem-specific, multi-scale spatial model to synthesize 17 global data sets of anthropogenic drivers of ecological change, including climate change, for 20 marine ecosystems, including coral reefs, seagrass beds, continental shelves, and the deep ocean. This approach stands out from past studies, which have focused largely on single activities or single ecosystems in isolation, and rarely at the global scale. Analyses indicate that no area is unaffected by human influence and that a large fraction is strongly affected by multiple drivers. The most heavily affected ocean regions include large areas of the North Sea, South and East China Seas, Caribbean Sea, east coast of North America, Mediterranean Sea, Red Sea, Persian Gulf, Bering Sea, and several regions in the western Pacific. Large areas of relatively little human impact remain, particularly near the poles, but as global warming melts polar ice these ecosystems may also become severely disrupted. Not surprisingly, anthropogenic drivers associated with global climate change are distributed widely and are an important component of global cumulative impacts, particularly for offshore ecosystems. This study provides critical information for evaluating where certain activities can continue with relatively little effect on the oceans, where other activities might need to be stopped or moved to less sensitive areas, and where the resilience of marine ecosystems to climate change impacts is likely to be weakest.

**23 May, 11:40 (S5.2-4921)**

### **Response and adaptation of salmon of the Pacific Northwest and the Columbia River region of the United States (Washington and Oregon) to climate change**

William T. **Peterson**<sup>1</sup>, Edmundo Casillas<sup>2</sup>, Cheryl Morgan<sup>3</sup>, Hongsheng Bi<sup>3</sup> and Hui Liu<sup>3</sup>

<sup>1</sup> NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport OR, USA. E-mail: bill.peterson@noaa.gov

<sup>2</sup> NOAA-Fisheries, Northwest Fisheries Science Center, 2525 Montlake Blvd, Seattle WA, USA.

<sup>3</sup> Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, Newport OR, USA.

To determine how different life history types of salmon may respond to climate change, one needs descriptions of the present status of their freshwater and marine habitats as well as projections of the future status of these habitats. Basic information required includes: when and where salmon spawn in freshwater environments, when individuals migrate to the sea, where they live in the ocean, and when they return to their spawning habitats. IPCC AR4 climate models suggest that winter precipitation in the mountains on the west coast of North America will fall in the form of rainfall rather than snow. Highest river flows will be in winter (fed by rainfall) rather than in spring (if fed by snowmelt), thus spring-run salmon life history types which depend upon high river flows in spring may be selected against, whereas fall/winter runs may be positively selected. Significant changes may occur in the ocean habitats, especially in highly-productive coastal upwelling regions,

however existing climate models have not resolved potential changes in marine productivity and marine ecosystem structure. Thus using first principles, we will develop a set of hypotheses of how salmon-specific marine habitats and ecosystems may change, focusing on effects of changes in the Pacific Decadal Oscillation, coastal upwelling, length of the upwelling season, source waters which feed the California Current, and marine food chain structure.

**23 May, 11:55 (S5.2-4529)**

### **Fishery management responses to climate change in the North Pacific**

Diana L. **Stram** and Chris Oliver

North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK 99501, USA. E-mail: diana.stram@noaa.gov

In the North Pacific, warming trends, coupled with lack of sea ice, raise concerns about the population level and ecosystem impacts of climate change. However, scientists are only beginning to understand the potential feedback mechanisms that will affect everything from plankton populations to major fish species distributions. Fishery managers need to be in a position to prepare for and respond to changing fishing patterns and potential ecosystem impacts as better information unfolds. The North Pacific Fishery Management Council has jurisdiction over the Exclusive Economic Zone off Alaska, with primary responsibility for managing groundfish (e.g. pollock, cod, flatfish, etc.) harvested mainly by trawlers, hook and line, and pot fishermen, and shared management with the State of Alaska for crab and scallop fisheries. The Council is taking management actions in light of uncertainty about the ecosystem impacts of warming trends (and loss of sea ice) and potential expansion of fishing activities in the North Pacific. Extensive trawl area closures have been established to protect vulnerable crab habitats and to slow the northern expansion of the trawl fleet into newly ice free waters. Efforts are underway to close the Arctic Ocean to all commercial fishing until further research into its unique characteristics can be evaluated. A pilot Fishery Ecosystem Plan for the Aleutian Islands evaluates the region's physical, biological and cultural interactions with a view to informing management decisions. The Council is also developing additional measures to respond to varying distributions of fish and shellfish due to changing climate in the North Pacific.

**23 May, 12:10 (S5.2-4853)**

### **Building local solutions to manage the effects of global climate change on a marine ecosystem: a process guide for place-based resource managers**

Kelley D. **Higgason**<sup>1</sup> and Maria Brown<sup>2</sup>

<sup>1</sup> Environmental Management Graduate Program, University of San Francisco, 2130 Fulton St., San Francisco, CA 94117, USA.  
E-mail: kelley.higgason@noaa.gov

<sup>2</sup> NOAA/NOS/ONMS, Gulf of the Farallones National Marine Sanctuary, 991 Marine Dr., The Presidio, San Francisco, CA 94129, USA.

The marine environment plays an important role in the amount of carbon dioxide (CO<sub>2</sub>) that remains within the Earth's atmosphere, but has not received as much attention as the terrestrial environment when it comes to climate change discussions, programmes, and action plans. It is now apparent that the oceans have begun to reach a state of saturation, no longer maintaining the "steady-state" carbon cycle that existed prior to the industrial revolution. The increasing amount of CO<sub>2</sub> present within the oceans and the atmosphere has a cascading effect on the marine environment. Potential physical effects of climate change within the marine environment, including ocean acidification, changes in upwelling and wind regimes, increasing global sea surface temperatures, and sea level rise, can lead to dramatic changes within marine and coastal ecosystems. Too often, resource managers feel overwhelmed by the addition of a new programme area of this magnitude. They may not feel they have the time, funding, or staff to take on a challenge as large as climate change and continue to not act as a result. This paper addresses three main areas of concern for marine resource managers: the potential effects of climate change on temperate marine environments, public perception of climate change, and the challenge of facilitating behavioural change. Using NOAA's Gulf of the Farallones National Marine Sanctuary as a case study, an easy-to-use process guide is provided, enabling resource managers to effectively incorporate climate change mitigation and adaptation strategies into their current operations.

**23 May, 12:25 (S5.2-4594)**

### **Managing local human impacts in marine systems under global climate change**

Bayden D. Russell, Jo-Anne Thompson and Sean D. Connell

Southern Seas Ecology Laboratories, School of Earth and Environmental Sciences DX 650 418, University of Adelaide, Adelaide 5005, South Australia. E-mail: bayden.russell@adelaide.edu.au

Elevated nutrients can have devastating and long lasting negative effects in marine systems. Current management of these impacts is based on contemporary environmental conditions, with no thought of future conditions that may be caused by climate change. However, forecasted changes, such as ocean acidification, are likely to combine with current impacts to enhance conditions where “weedy” species will dominate algal communities. For example, it is likely that the currently observed switches of reefs dominated by long lived species of algae to annual, weedy species will increase under climate change scenarios. We investigated the combined effects of elevated CO<sub>2</sub> and nutrient concentrations on coralline algae (perennial species which cover up to 80% of rocky reefs in southern Australia) and turf-forming algae (annual, weedy species). Both elevated CO<sub>2</sub> and nutrient concentrations had rapid negative effects on the photosynthetic activity and biomass of coralline algae, but a positive effect on turf-forming species. Importantly, the negative effects of CO<sub>2</sub> on coralline algae outweighed those of elevated nutrients. This result illustrates the importance of considering future environmental conditions in management of contemporary local impacts (e.g. nutrient discharge into coastal waters), as these global impacts may have large effects at local scales.

**23 May, 12:40 (S5.2-4818)**

### **Marine ecosystems: under resourced, overlooked and under threat?**

Elvira S. Poloczanska<sup>1</sup> and Anthony J. Richardson<sup>2,3</sup>

<sup>1</sup> Climate Adaptation National Research Flagship, CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: elvira.poloczanska@csiro.au

<sup>2</sup> University of Queensland, Department of Mathematics, St Lucia, Queensland 4072, Australia.

<sup>3</sup> Climate Adaptation National Research Flagship, CSIRO Marine and Atmospheric Research, PO Box 120, Cleveland, Queensland 4163, Australia.

The IPCC 4th Assessment Report identified 28,586 significant biological changes consistent with recent climate change in terrestrial systems, but only 85 from marine and freshwater systems (<0.3%). We believe the dearth of documented biological changes in marine environments does not mean our oceans are immune to climate change, but rather is a misleading and dangerous artefact reflecting the distribution of global science funding, biases within the IPCC process, and historical realities in marine science research. We cannot use our more extensive knowledge of terrestrial biological climate impacts to fill our knowledge gap for marine environments because of fundamental differences in threats and responses between these systems. Historical realities in marine science and in the current IPCC process have also stymied inclusion of much of the marine climate impacts work. For example, the longest marine time series are generally from commercial fisheries and are a relatively untapped resource, although these suffer from aliasing with heavy exploitation. The marine science community has also contributed to the problem through inadequate reporting of climate impacts. Emerging evidence suggests marine ecosystem responses to climate change may be faster than in terrestrial systems, despite slower ocean warming. A coherent vision is needed to focus marine biological climate impacts research, lobby for greater resources, and ensure broad uptake within the IPCC process. We describe focused research priorities that will help fill our current knowledge gap. This fundamental information is critical for developing integrated and adaptive management strategies to protect marine environments in the future.

**23 May, 12:55 (S5.2-4549)**

### **Adaptation of fishing communities in the Philippines to natural risks**

Maria Rebecca A. Campos

Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 10996 Campos Compound, Faculty Village, College, Laguna 4031, Philippines. E-mail: cmaribec@yahoo.com

More than half a million small fishers in the Philippines have been availing of loans from Quedancor, the credit arm of the Department of Agriculture. The financing scheme has been quite successful with the repayment rate at 95%. However, the occurrence of natural calamities such as typhoons; as well as pests and diseases has affected the productivity of fisheries, thus, hindering fishers from paying and renewing their loans. Failure to access credit

could disable them to continue venturing on fishing activities and could eventually jeopardise the welfare of their entire household. The inability of creditors to pay their loans and meet their obligations also impairs, to a large extent, the financial operation and viability of the lending institutions. This study analyses the natural risks and adaptation practices of these fishers. It recommends mitigation mechanisms to minimise the impact of natural calamities. Moreover, it suggests a bridge financing scheme that can be an effective and efficient instrument to enable fishers to carry on their livelihood activities and support their families' basic needs and slowly recover from their losses.

**23 May, 14:30 (S5.2-4636)**

### **Implications of changing sea surface temperature in the Bay of Bengal: livelihoods of coastal fisherfolks in jeopardy**

Ahsan U. **Ahmed**<sup>1</sup> and S. Neelormi<sup>2</sup>

<sup>1</sup> Centre for Global Change, 12-Ka/A/1 Shaymoli Second Lane, Dhaka 1207, Bangladesh. E-mail: ahsan.ua@gmail.com

<sup>2</sup> Associate Professor, Department of Economics, Jahangirnagar University, Savar 1342, Bangladesh.

The sea surface temperature (SST) has been exhibiting a general increasing trend of about 0.45°C during the past four decades. Increases in SST during the monsoon period have been particularly high. Climate change has been believed to be predominantly responsible for such increases in SST. The marked increase in SST in 2007 caused a large accumulation of heat energy, forcing the formation of 12 'low pressures' to 'deep depressions', with a much higher frequency than normal. Consequently, the tidal activity on the surface becomes rough and turbulent. The coastal fisherfolk communities in Bangladesh represent the poorest of the poor, who can hardly earn a living from traditional fishing practices. A fishing trip generally lasts for about 15 days, including time for travelling to and from the fishing grounds in the Bay of Bengal. If the sea surface becomes rough, fishermen cannot continue fishing. The time intervals between two subsequent 'rough sea events' in 2007 were often short, which either forced coastal fishermen to stay out of action in anticipation of complete loss of investment or forced them to abandon incomplete fishing trips – the latter being economically draining. Because of too many incomplete fishing trips and scanty return from subsequent investments, coastal fisherfolk's livelihoods have been devastated. The increasing intensity of sea roughness along the Bay of Bengal and the loss of livelihoods of fisherfolks is attributed to a climate change induced increase in SST. The nation needs to devise plans to enhance resilience of these fisherfolks and facilitate towards reducing their overall vulnerability through planned adaptation.

**23 May, 14:45 (S5.2-4530)**

### **Marine Protected Areas as a tool for long-term monitoring of marine biota: separating climate from anthropogenic influences**

Albrecht **Götz**, Russell Chalmers, Rhett Bennett, Sven Kerwath and Paul Cowley

Elwandle Node, South African Environmental Observation Network (SAEON), 18 Somerset Street, Grahamstown, Eastern Cape 6140, South Africa. E-mail: albrecht@saeon.ac.za

Randomly stratified underwater visual censuses and controlled angling were used to investigate the ichthyofauna at protected and exploited sites in and around the Goukamma Marine Protected Area (MPA). Roman (*Chrysoblephus laticeps*), the principal reef fish species targeted by the fishery, showed significantly higher densities within the protected parts of the study area (cpue: 4.3 fish per angler hour) as compared to the exploited area (cpue: 3.4 fish per angler hour). Furthermore, fishing pressure reduced age-at-maturity and sex change but increased the condition of roman. Sonar tagging experiments revealed a small home range of roman (1,000 m<sup>2</sup>), however, females extended their home range during the spawning season (10,000 m<sup>2</sup>). Using movement and life-history information, an individual based model showed the potential of roman populations to enhance adjacent fisheries through spill-over. A shore-based cpue assessment over eight years revealed high levels of natural variability of the reef fish community in a large MPA. Experiments during boat-based cpue and diving surveys identified the most suitable established and new survey methods for monitoring and a standardised sampling protocol to reduce bias and variability in the data. An overview of current long-term MPA monitoring projects in South Africa is presented.

**23 May, 15:00 (S5.2-4754)**

### **Functional indicators monitoring ecological status and vulnerability of marine macroalgae to climate change**

Felix L. **Figueroa**, N. Korbee and M. Segovia

Department of Ecology, University of Málaga, Campus Univ. de Teatinos s/n 29071 Málaga, Spain. E-mail: Felix\_lopez@uma.es

Macroalgae are used as biological indicators of the ecological status as an expression of the quality of the structure and functioning of coastal ecosystems. They are good indicators because their sedentary condition integrates the effects of long term exposure of nutrient or climate variations. The biological indicators are usually based on composition, abundance and biomass of macrophytes. In this paper, an ecophysiological approach to determine both ecological status and vulnerability and adaptation capacity of marine macroalgae to climate change is presented. We discuss the usefulness of functional indicators as maximal quantum yield as *in vivo* Chl *a* fluorescence associated to Photosystem II as an indicator of physiological status, and stress indicators: heat shock proteins, proteases and reactive oxidative species (ROS). The interactive effects of factors of climate change (increased temperature) with increased UV-B radiation (due to ozone depletion) and nutrient availability (increased inorganic nitrogen) in macroalgae from southern Spain is presented. The integration of ecological and ecophysiological approaches will give the basis for the evaluation of ecological status and the prediction of the variations of the structure-function of aquatic ecosystems.

**23 May, 15:15 (S5.2-4934)**

### **Evaluation of climate change impacts and adaptation responses for marine activities: the CLIMAR project**

Dries **Van den Eynde**<sup>1</sup>, Renaat De Sutter<sup>2</sup>, José Ozer<sup>1</sup>, Stéphanie Ponsar<sup>1</sup>, Katrien Van der Biest<sup>3</sup>, Els Vanderperren<sup>4</sup>, Toon Verwaest<sup>3</sup> and Annemie Volckaert<sup>2</sup>

<sup>1</sup> Management Unit of the North Sea Mathematical Models, Royal Belgian Institute for Natural Sciences, Gulledele 100, B-1200 Brussels, Belgium. E-mail: D.VandenEynde@mumm.ac.be

<sup>2</sup> Arcadis - Ecolas NV, Kortrijksesteenweg 302, B-9000 Gent, Belgium.

<sup>3</sup> Flanders Hydraulics Research, Berchemlei 115, B-2140 Antwerpen, Belgium.

<sup>4</sup> Institute for Agricultural and Fisheries Research, Section Fisheries, Ankerstraat 1, B-8400 Oostende, Belgium.

Based on the recommendations of the IPCC, Kyoto-Protocol and relevant strategic documents, scientific research is needed to assess the impact of climate change, specifically on the vulnerable marine ecosystem and its users. While preventive source measures such as reducing greenhouse gas emissions are necessary to tackle the problem over the long term, adaptive measures are necessary to cope with the primary and secondary impacts of climate change in the North Sea. Furthermore, instruments are needed that can evaluate the adaptation measures on their sustainability, their impact on marine activities and their relationship with preventive measures and sectoral policies. In the project CLIMAR, the elaboration of an evaluation framework for adaptation scenarios/measures as a response to climate induced impacts for the total North Sea environment is established. Results are presented from the research and modelling activities, that are being carried out to differentiate the primary impacts of climate change from the natural evolution at the North Sea scale. These primary impacts include sea level rise, increased storminess, possible increased rainfall, erosion, temperature changes, salinity, etc. Further, first results are presented on the assessment of the secondary impacts of climate change, both on the ecological system of the North Sea as well as on social-economic activities (fisheries, transport and harbour, dredging, risk of flooding, wind energy, etc.). Two extensive case-studies (coastal flooding, fisheries sector) have high extrapolation potential towards the global North Sea environment. Adaptive measures are being formulated both for the ecosystem as well as for the other marine activities.

**23 May, 15:30 (S5.2-4057)**

**Hicacos peninsula, face to future changes**

Barbaro V. Moya<sup>1</sup>, Alfredo Cabrera<sup>2</sup>, Lorenzo Castillo<sup>3</sup> and Jose Rojo<sup>4</sup>

<sup>1</sup> Meteorological Centre of Matanzas, Cuba. E-mail: barbaromoya@yahoo.com

<sup>2</sup> Varadero Beach Integrated Management Center, Cuba.

<sup>3</sup> Environment Unit of Matanzas, Matanzas, Cuba.

<sup>4</sup> Institute for Physical Planning, Matanzas, Cuba.

Varadero beach is located in the Hicacos Peninsula on the north coast of Matanzas province in Cuba. Varadero is one of the most important touristic places in Caribbean. It is approximately 20 km in length and 1-2 km in width and its height is between 5-10 m above sea level. The physio-geographic conditions in Varadero make it a place that is vulnerable to environmental change. Its geographic position, exposure to sea-level rise, floods, drought, changes in temperature, sunshine, winds, and hydrology, as well as its fragile ecosystems, are all aspects of its natural vulnerability to climate change. For the past decade, we have been studying the vulnerability of Varadero Beach to climate change, and evaluating future climate change scenarios, to determine the vulnerability and impacts. This work, involving physiographic and socio-economic diagnostics, focuses on climate variability, future climate change scenarios, vulnerabilities and impacts on tourism. We use these analyses to develop measures that will permit adaptation and future sustainability of this important region.

## **W1 Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels**

**18 May, 09:40 (W1-4768)**

### **The SCOR WG125 toolkit: issues and methods for analysing zooplankton time series**

Todd D. O'Brien<sup>1</sup>, David L. Mackas<sup>2</sup>, Mark D. Ohman<sup>3</sup>, Ángel López-Urrutia<sup>4</sup> and SCOR WG125 Contributors

<sup>1</sup> National Marine Fisheries Service, 1315 East-West Hwy, Silver Spring, MD 21044, USA. E-mail: Todd.O'Brien@noaa.gov

<sup>2</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada.

<sup>3</sup> Scripps Institution of Oceanography, La Jolla, CA 92093-0218, USA.

<sup>4</sup> Instituto Español de Oceanografía, Avda Príncipe de Asturias 70, Gijón 33212, Spain.

The SCOR Working Group on Global Comparison of Zooplankton Time series (WG125) was formed to promote between-region comparisons of longer zooplankton time series from around the globe. With data contributions and participation from 12 countries, over twenty long-term regional zooplankton time series have been identified, and their data have been collated and prepared for numerical analysis. Zooplankton biomass and community composition vary strongly at a range of time scales (e.g. decadal, interannual, seasonal, and diel), and also at a range of spatial scales. Detection and interpretation of variability at one time scale typically requires data transformation, averaging and filtering to reduce aliasing from other scales. A variety of methods were applied to the WG125 zooplankton time series. In this paper, we illustrate how choice of method can influence the output time series, and introduce the SCOR WG125 toolkit of numerical choices and methods.

**18 May, 10:00 (W1-4767)**

### **SCOR WG125: global comparison of zooplankton biomass time series**

Todd D. O'Brien<sup>1</sup>, David Mackas<sup>2</sup>, Hans M. Verheye<sup>3</sup> and SCOR WG125 Contributors

<sup>1</sup> National Marine Fisheries Service, 1315 East-West Hwy, Silver Spring, Maryland, USA. E-mail: Todd.O'Brien@noaa.gov

<sup>2</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada.

<sup>3</sup> Research Aquarium, Beach Road, Sea Point, Cape Town, South Africa.

The SCOR Working Group on Global Comparison of Zooplankton Time series (WG125) has compiled a global assortment of longer zooplankton time series, with the goal of identifying dominant modes of zooplankton variability, their amplitudes and time scales, and the degree of correlation/synchrony among regions, zooplankton variables, and climate indices. Although the level of taxonomic resolution varies widely among our data sets, each provides indices of total mesozooplankton biomass or biovolume, which have been processed to give time series of anomalies relative to local average seasonal cycles. Strong low frequency fluctuations and trends were evident in most regions. In general, boundary current upwelling regions tend to have the largest amplitude of variation, followed by high-latitude continental margins. Sustained trends in response to global warming, where detected, include examples of both increases and decreases. Evidence of temporal synchrony and/or large-scale spatial teleconnection among zooplankton time series, or with climate indices, varied from site to site, with trends found in one site being completely absent from an immediately adjacent site. Changes and synchrony appeared to be influenced by local environmental conditions (e.g. upwelling regions versus continental shelf versus sheltered bays), as well as corresponding changes in species composition (discussed in other papers in this workshop).

**18 May, 10:20 (W1-4930)**

### **Temporal variations in the zooplankton community: a 20 year time-series analysis at station L4 in the English Channel**

Damien **Eloire**<sup>1,2</sup>, Delphine Bonnet<sup>2</sup> and Roger Harris<sup>1</sup>

<sup>1</sup> Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH, United Kingdom. E-mail: dmelo@pml.ac.uk

<sup>2</sup> Université Montpellier II – CNRS (UMR 5119), Case 093, Place Eugène Bataillon, 34095 Montpellier, France.

Since 1988, the composition of the zooplankton community has been monitored weekly at station L4 located 20 miles off Plymouth in the western English Channel. Samples are collected vertically from the seafloor to the surface using a WP2 net (200 µm mesh size). An original approach, consisting in identifying the most abundant groups and species for each year (altogether contributing to approximately 80% of the total zooplankton abundance) is being exploited to explore the temporal pattern and structure of the zooplankton community. Temporal analysis and statistical techniques are being used to investigate seasonality, the long-term trend, and any relationships within the community and with environmental parameters and climate indices. The results show that 80% of the total zooplankton abundance can be explained by only 12 of the 60 groups and species identified at L4 every year. Copepods contributing to this fraction are the most abundant species representing 63.4% of the total zooplankton abundance for the entire time-series. Moreover, it seems that these dominant groups and species do not show any long-term correlation neither with the sea surface temperature nor with climate indices such as the NAO index, but for some of them their interannual variations are significantly correlated (e.g. *Acartia* spp. and *Paracalanus* spp. or *Oithona* spp. and *Temora* spp.).

**18 May, 10:40 (W1-4761)**

### **Climate-associated latitudinal shifts of zooplankton species and species assemblages**

David L. **Mackas**<sup>1</sup>, Anthony J. Richardson<sup>2</sup>, Hans M. Verheye<sup>3</sup>, William Peterson<sup>4</sup>, Sanae Chiba<sup>5</sup>, Gregory Beaugrand<sup>6</sup>, Bertha Lavaniegos<sup>7</sup> and SCOR WG125 Contributors

<sup>1</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada. E-mail: mackasd@pac.dfo-mpo.gc.ca

<sup>2</sup> CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia.

<sup>3</sup> Marine and Coastal Management, DEAT, Cape Town, South Africa.

<sup>4</sup> Hatfield Marine Science Center, NOAA-Fisheries, Newport, OR, USA.

<sup>5</sup> Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.

<sup>6</sup> CNRS, Université des Sciences et Technologies de Lille1, BP 80 62930, Wimereux, France.

<sup>7</sup> CICESE, Ensenada, Baja California, Mexico.

Taxonomically-resolved zooplankton time series from individual ocean regions reveal low frequency fluctuations and trends in zooplankton community composition that are correlated with indices of ocean climate. Species-level variations are often 3-10 fold more intense than accompanying responses of total zooplankton biomass. One common mode of zooplankton community change is decreased abundance/biomass of historically endemic taxa, accompanied by increased abundance of taxa previously found in adjoining equatorward (or sometimes seaward) ocean regions. Spatial comparisons among regions and large-scale CPR surveys show that local changes reflect larger-scale shifts of zoogeographic distributions, equivalent to about 10° poleward displacement in both the NE Atlantic and NE Pacific Oceans. Patterns are qualitatively similar for both abundance of dominant taxa and rate of occurrence of rare “indicator” taxa. The proximate causes for the shifts in distribution are less clear, but almost certainly involve both initial changes in advective supply-loss rates associated with changing current patterns, and subsequent altered environmental conditions related to changing temperature, stratification, and prey/predator communities. The zooplankton distribution shifts tend to be step-like, associated with relatively short-term (1-2 year) advection and warming events, but time-lagged (by weeks to months) and more persistent (by months to years) than the physical anomalies.

**18 May, 11:30 (W1-4946)**

### **Long-term changes in zooplankton community size structure: a global comparison**

Hans M. **Verheye**<sup>1</sup>, Dave Checkley<sup>2</sup>, Sanae Chiba<sup>3</sup>, Young-Shil Kang<sup>4</sup>, Webjørn Melle<sup>5</sup>, Mark D. Ohman<sup>6</sup>, Anthony J. Richardson<sup>7</sup> and SCOR WG125 Contributors

<sup>1</sup> Marine and Coastal Management, DEAT, Private Bag X2, Rogge Bay 8012, Cape Town, South Africa. E-mail: hverheye@deat.gov.za

<sup>2</sup> Scripps Institution of Oceanography, UCSD, 2220 Sverdrup Hall, 8615 Discovery Way, La Jolla, CA 92037, USA.

<sup>3</sup> Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.

<sup>4</sup> National Fisheries Research and Development Institute, 408-1 Sirang-ri, Gijang-eup, Gijang-kun, Busan 619-705, Republic of Korea.

<sup>5</sup> Research Group Plankton, Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway.

<sup>6</sup> Scripps Institution of Oceanography, La Jolla, CA 92093-0218, USA.

<sup>7</sup> CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia.

The distribution of body size can be an important characteristic of a zooplankton community. Body size is a major determinant of various production rate processes, with growth rate generally decreasing with increasing body size. Size also strongly influences predator-prey relationships, with pelagic organisms tending to feed on others smaller in size. Here we examine and compare long-term changes in the size composition of zooplankton communities from different regions globally. This is the largest comparative analysis of copepod size to date in the world's oceans. The focus is on copepods, which are generally the most abundant members in most zooplankton communities and provide the dominant trophic link between primary producers and fish. Unlike most other taxonomic groups, copepods are usually identified to species level and there is generally good knowledge of their body size. Tracking changes through time of mean size of copepod communities enables detection of major changes in the community structure as a consequence of shifts in environmental conditions. Moreover, average zooplankton community size can be considered as an indicator of food for fish and fluctuations in fish recruitment have been attributed to changes in zooplankton community structure. We conclude that because warm-water copepods are often smaller than their cold-water counterparts, a shift to a smaller average size is indicative of warming of the system and has a fundamental effect on community rate processes.

**18 May, 11:50 (W1-4704)**

### **Changing seasonal timing of zooplankton populations, and their link to ocean climate**

David **Mackas**<sup>1</sup>, Wulf Greve<sup>2</sup>, Martin Edwards<sup>3</sup>, Sanae Chiba<sup>4</sup>, Gregory Beaugrand<sup>5</sup>, Elena Arashkevich<sup>6</sup> and SCOR WG125 Contributors

<sup>1</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada. E-mail: mackasd@pac.dfo-mpo.gc.ca

<sup>2</sup> Senckenberg Research Institute, D-22607 Hamburg, Germany.

<sup>3</sup> Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK.

<sup>4</sup> Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan.

<sup>5</sup> CNRS, Université des Sciences et Technologies de Lille 1, BP 80 62930, Wimereux, France.

<sup>6</sup> Shirshov Institute of Oceanology RAS, 36 Nakhimovsky pr. 117997 Moscow, Russia.

The short life span (weeks to a year) of most mesozooplankton allows their population size to respond rapidly to interannual environmental changes, and also leads to large seasonal cycles producing 3-10 fold (or more) variation of abundance, biomass, species composition, and age structure within species. Although the zooplankton seasonal response is somewhat predictable and repetitive, recent analyses have found that the detailed phasing is highly sensitive to interannual differences in environmental conditions: there can be year-to-year differences of one to several months in the timing of the 1-2-month wide annual peak of abundance and biomass. The resulting potential for timing match-mismatch between prey and predators makes this an important and interesting signal, which can be tracked by either population size or age-stage structure. Within species, the usual trend is a shift to earlier development in years when temperatures are higher and stratification stronger. However, temperature-timing regressions frequently differ among species and functional groups, leading to different amounts of timing offset for a given temperature perturbation. Climate warming can also drive changes in community composition that favour summer-dominant over spring-dominant taxa.

18 May, 12:10 (W1-4968)

### Long-term changes in zooplankton phenology at Helgoland Roads

Merja H. **Schlueter**<sup>1</sup>, Agostino Merico<sup>1</sup>, Karen H. Wiltshire<sup>2</sup> and Wulf Greve<sup>3</sup>

<sup>1</sup> GKSS Research Center, Institute of Coastal Research, Max-Planck-Str. 1, D-21502 Geesthacht, Germany. E-mail: merja.schlueter@gkss.de

<sup>2</sup> Biologische Anstalt Helgoland, Alfred Wegener Institute for Polar and Marine Research, P.O. Box 180, 27483 Helgoland, Germany.

<sup>3</sup> Senckenberg Research Institute, Notkestr.85, D-22607 Hamburg, Germany.

An in-depth analysis of biotic and abiotic long-term time series suggested a climatic regime shift in the German Bight in 1987/88, confirming earlier investigations that extended across the entire North Sea. The main outcome of this study was that temperature plays an important role in the regime dynamics of the German Bight ecosystem. A principal component analysis on this multiple time series data set also suggested that the variability of a number of zooplankton species contributes only marginally to the regime shift. However, here we report that further investigations, which are focused specifically on the long-term (1975-2005) changes of zooplankton phenology, do suggest drastic shifts. Recent analyses based on Bayesian inference show that the annual peaks in zooplankton abundance appear earlier in the year after the regime shift of 1987/88 compared to before the regime shift when seasonal abundance peaks generally occurred later in the year. We also observe that the periods of high abundance have a longer duration since the regime shift. Interestingly, five small calanoid copepods, typical of the German Bight assemblage, do not appear to be affected by these changes.

18 May, 12:30 (W1-4633)

### Pan-North Pacific synthesis of long-term variation of *Neocalanus* spp. based on stable isotope analysis (SCOR WG125 contribution)

Sanae **Chiba**<sup>1</sup>, H. Sugisaki<sup>2</sup>, K. Tadokoro<sup>3</sup>, A. Kuwata<sup>3</sup>, T. Kobari<sup>4</sup>, A. Yamaguchi<sup>5</sup> and D.L. Mackas<sup>6</sup>

<sup>1</sup> Frontier Research Center for Global Change, JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama 236-0001, Japan.  
E-mail: chibas@jamstec.go.jp

<sup>2</sup> National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-ku, Yokohama 236-8648, Japan.

<sup>3</sup> Tohoku National Fisheries Research Institute, 3-27-5 Shinhamma, Shiogama, Miyagi 985-0001, Japan.

<sup>4</sup> Aquatic Resource Division, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan.

<sup>5</sup> Graduate School of Fisheries Science, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido 041-8611, Japan.

<sup>6</sup> Institute of Ocean Science, Fisheries and Oceans Canada, Sidney, BC, V8L 4B2, Canada.

Previous detailed retrospective analyses of historical collections of zooplankton have revealed phenological and biogeographical shifts of zooplankton species on both sides of the North Pacific after the 1970s. It was suggested that these shifts were influenced by variability of the coastal currents induced by the Aleutian Low dynamics and/or by recent warming. However, the regionally specific food web processes which link climate to zooplankton variation are less clear partly because (in contrast to zooplankton) there are no detailed time series data available for phytoplankton. Nitrogen stable isotope ratio ( $\delta^{15}\text{N}$ ) of zooplankton is indicative of the abundance of phytoplankton in the zooplankton diet, and can provide a useful clue to understanding the bottom-up control of lower trophic level productivity. In this study, we investigated regional differences in ecosystem responses to the common climatic forcing in the North Pacific based on  $\delta^{15}\text{N}$  of *Neocalanus* species, which were widely distributed and dominant in the subarctic North Pacific. Time series of  $\delta^{15}\text{N}$  of *Neocalanus cristatus*, *N. plumchrus* and *N. flemingeri* collected in the western, central and eastern North Pacific were compared. Within each region, interannual variation of  $\delta^{15}\text{N}$  was similar among the three species, indicating shared patterns of bottom-up control. In all three regions,  $\delta^{15}\text{N}$  declined by ca. 0.3% in the late 1980s and increased in the late 1990s. This suggests favourable conditions of phytoplankton availability for *Neocalanus* during the late 1980s to late 1990s, although interspecific and regional differences in the extent and timing of the change were noted. Causes of the suggested changes in phytoplankton availability will be discussed for each region.

**18 May, 12:50 (W1-4882)**

### **Are pelagic systems bottom-up or top-down controlled?**

Anthony J. **Richardson**, Patricia Ayon and SCOR WG125 Members

<sup>1</sup> CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia. E-mail: anthony.richardson@csiro.au

<sup>2</sup> Area de Evaluación de Producción Secundaria, Unidad de Oceanografía Biológica, Dirección de Investigaciones Oceanográficas, Instituto del Mar del Perú, Apartado 22 Callao, Perú.

An appealing conceptual framework for investigating mechanisms controlling ecosystem dynamics is the potential importance of “bottom-up” (resource limitation) and “top-down” (predation pressure) forcing across successive trophic levels. In pelagic ecosystems, climate change might be expected to have substantial impacts if signals propagate up the food web (bottom-up control), whereas overfishing might be more influential if signals cascade down the food web (top-down control). Unfortunately, many studies of this nature have been limited in terms of spatial scale (mesocosms, bays, seas), temporal scale (months to a few years), taxonomic resolution (populations of selected species), or have no replication and thus no generality. Further, top-down control has generally only been found in enclosed lakes or seas, although some recent evidence suggests oceanic pelagic ecosystems may also operate in this manner. Here we use assembled time series of phytoplankton, zooplankton, planktivorous fish, and piscivorous fish from eastern boundary upwelling zones, shelf regions, and the open ocean to assess the relative importance of top-down and bottom-up control. We use a meta-analytic approach to provide a robust synthesis of global relationships between successive trophic levels. We find strong evidence for bottom-up control between phytoplankton and zooplankton in many regions, but weaker relationships between zooplankton and planktivores, and between planktivores and piscivores. We conclude that bottom-up control operates over the broad temporal and spatial scales of our analyses, but there is little support for top-down control. This finding suggests that impacts of climate change on plankton are likely to propagate upwards to higher trophic levels.

**18 May, 14:30 (W1-4975)**

### **Comparison of early stages of *Mnemiopsis leidyi* invasion into the Black, Caspian and Baltic Seas**

Juha **Flinkman**<sup>1</sup>, E. Arashkevich<sup>2</sup>, M. Lehtiniemi<sup>1</sup> and S. Viitasalo<sup>1</sup>

<sup>1</sup> Finnish Institute of Marine Research, P.O. Box 2, FI-00561 Helsinki, Finland. E-mail: Juha.flinkman@fmr.fi

<sup>2</sup> Shirshov Institute of Oceanology RAS, 36 Nakhimovsky pr., Moscow 117997, Russia.

We compare the early stages of comb jelly *Mnemiopsis leidyi* invasion into the Black and Caspian Seas (starting 1982 and 1999, respectively), and recently into the Baltic Sea (from 2006). There are differences in all aspects of invasions: rapidity of dispersion, growth rate, feeding and reproductive behaviour, and vertical and seasonal distribution in the water column in relation to hydrography. So far, maximum *Mnemiopsis* abundances (January 2008) in the Baltic Sea have been 50% and 24% of the maximum abundances in the Black and Caspian Seas (1988), respectively. However, expressed as biomass, the current high values in the Baltic are only 0.2% and 0.4% of those observed in Black and Caspian Seas. This implies that the specimens are much smaller in the Baltic than in the Black and Caspian Seas. Vertical distributions are also dissimilar. In the Black and Caspian Seas, *Mnemiopsis* occupies the upper mixed layer during late spring-summer-autumn period. In winter, single individuals are also found in the upper 30 m layer. In the Baltic Sea, only larval stages are in the upper water column, whereas all the larger individuals are concentrated around the halocline at 60-80 m depth, where conditions are very stable all year. In the Baltic, the abundances as well as maximum size of individuals were higher in December-January than in August-September, when zooplankton abundances are highest. This indicates a steady population increase, as well as independence of food sources confined to the surface layer. We discuss the differences in dispersion, growth and reproduction rates, and food utilisation in relation to differences in hydrography between the Baltic, Black and Caspian Seas, as well as observed and possible impacts on the ecosystems of these brackish water inland seas.

**18 May, 14:50 (W1-4784)**

**Retrospective analysis of zooplankton decadal time series in the western Mediterranean Sea using an automated imaging system**

Maria Grazia **Mazzocchi**<sup>1</sup>, Lars Stemmann<sup>2,3</sup>, Carmen Garcia Comas<sup>1,2,3</sup>, Maurizio Ribera d'Alcala<sup>1</sup>, Gregory Beaugrand<sup>4</sup>, Stéphane Gasparini<sup>2,3</sup>, Frederic Ibañez<sup>2,3</sup>, Stéphane Pesant<sup>2,3</sup>, Marc Picheral<sup>2,3</sup> and Gabriel Gorsky<sup>2,3</sup>

<sup>1</sup> Stazione Zoologica 'A. Dohrn', Villa Comunale, 80121 Napoli, Italy. E-mail: grazia@szn.it

<sup>2</sup> Université Pierre et Marie Curie-Paris 6, UMR 7093, Villefranche sur Mer, F-06234 France.

<sup>3</sup> Laboratoire d'Océanographie de Villefranche (LOV), Observatoire Océanologique, BP 28, 06234 Villefranche sur mer Cedex, France.

<sup>4</sup> CNRS, Université de Lille 1, 28 avenue Foch, BP 80, 62930 Wimereux, France.

The Mediterranean Sea is a semi-enclosed basin that in the past decade has shown significant variability related to climate change. Plankton communities have been monitored at a few locations in the Mediterranean for which long-term time series of variable duration exist. We present two ongoing time series conducted in the coastal zone of the Ligurian and Tyrrhenian seas, showing mesozooplankton abundances and size spectra derived from image analysis of historical samples collected over the last 40 and 20 years respectively. The initial results are compared with available environmental and climatic data at different temporal and spatial scales. To our knowledge, this is the first comparative study based on retrospective analysis of plankton samples using an automatic imaging system. We discuss the use of rapid imaging technology to build homogeneous data sets for comparative study of plankton time series. Our work is still in progress and this contribution is mainly intended as an opportunity for open discussion of issues and perspectives when comparing zooplankton time series.

**18 May, 15:10 (W1-4906)**

**Zooplankton time series related to North Atlantic climate changes in waters of the Balearic Sea: a case of boundary area in the central western Mediterranean**

Maria Luz **Fernandez de Puellas**<sup>1</sup>, Juan Carlos Molinero<sup>2</sup>, Laura Vicente<sup>1</sup>, Ana Morillas<sup>1</sup> and Javier Jansá<sup>1</sup>

<sup>1</sup> Centro Oceanográfico de Baleares, Instituto Español de Oceanografía, P.O. Box 291, Palma de Mallorca, Spain.

E-mail: mluz.fernandez@ba.ieo.es

<sup>2</sup> Leibniz-Institut für Meereswissenschaften, IFM-GEOMAR, FB3, Marine Ökologie, Düsterbrookweg 20, 24105 Kiel, Germany.

Temporal distribution patterns of major zooplankton groups are presented in relation to the regional hydrography at a monitoring station in the Balearic Sea (western Mediterranean) over an 11-year period. The study is based on samples collected every 10 days from 1994 to 2004 and results are related to the North Atlantic climate variability. Strong but different relationships are apparent between the abundance of major zooplankton groups and the influence of local surface water masses as the main drivers of their biological variability. Dominant species of major zooplankton groups were identified and related to patterns of phytoplankton biomass (chlorophyll) and the principal physico-chemical variables characterising the area. The hydrological regime of the boundary Balearic waters showed manifested interannual changes characterised by a clear increase in the long-term trend of salinity, whereas temperature, does not show a significant trend. Chlorophyll pigment concentration and the abundance of smaller zooplankton increased, but average size, biomass and abundance of total mesozooplankton declined. The synchronous variability of major zooplankton groups and hydrography indicates the rapid response of this community to the influx of cold northern and warm southern Atlantic water masses into the study area. We suggest that changes in the hydrography of the Balearic Sea are linked to large-scale changes likely occurring on a basin scale, which is reflected in mesoscale hydrographic changes in the western Mediterranean. The relationship between the zooplankton and changes in the hydrological regime in the context of the North Atlantic climate is discussed.

**18 May, 15:30 (W1-4666)**

### **The Gulf of Trieste, 1970-2005: a changing ecosystem**

Alessandra **Conversi**<sup>1</sup>, T. Peluso<sup>1</sup> and S. Fonda-Umani<sup>2</sup>

<sup>1</sup> CNR - Consiglio Nazionale delle Ricerche, ISMAR - La Spezia, Forte S. Teresa, Loc. Pozzuolo, 19032 Lerici (SP), Italy.  
E-mail: a.conversi@ismar.cnr.it

<sup>2</sup> Department of Biology, University of Trieste, V.A. Valerio, 28/A, 34127 Trieste, Italy.

The Gulf of Trieste, in the North Adriatic Sea, hosts one of the longest (since 1970) mesozooplankton time series in the Mediterranean Sea. In this study we investigate interannual variability of copepod abundance over 36 years, with particular attention to species trends and phenology. Two periods are identified, 1970-1987 and 1988-2005, which are characterised by ecosystem-wide changes. These changes include: the arrival of new species (*Diaixis pygmoea*), establishment of previously rare species (*Oithona similis* and *Oithona nana*), the rise (*Oncaea* spp. and *Euterpina acutifrons*) or decline (*Pseudocalanus elongatus*, *Clausocalanus* spp.) of several species, and changes in the phenology in the majority (65%) of species, with predominantly forward shifts in the timing of the seasonal peak. While *Acartia clausi* remains the dominant species, there is a general trend toward dominance by smaller species in the second period. We hypothesize that the changes in copepod abundance patterns in the Gulf of Trieste are related to the general warming (SST), and associated northerly displacements within the system (the climate envelope hypothesis), and to the changes in the Mediterranean surface circulation that started at the end of the 1980s and affected the whole basin in the following years.

**18 May, 16:20 (W1-4727)**

### **Large-scale geographic variations in diversity of marine zooplankton: theories, environmental controls, and functioning of pelagic ecosystems**

Isabelle **Rombouts**<sup>1</sup>, G. Beaugrand<sup>2</sup>, F. Ibañez<sup>1</sup> and L. Legendre<sup>1</sup>

<sup>1</sup> Université Paris VI Laboratoire d'Océanographie de Villefranche-sur-mer, UMR CNRS 7093 (LOV) B.P. 28, 06234 Villefranche-sur-mer cedex, France. E-mail: isabelle.rombouts@etu.upmc.fr

<sup>2</sup> Université des Sciences et Technologies de Lille - Lille 1, Laboratoire d'Océanologie et de Géosciences, UMR CNRS 8187 (LOG), 28 avenue Foch, 62930 Wimereux, France.

One of the most consistent patterns in biogeography is the tendency for an increase in species diversity from the poles to the equator. For several decades, extensive research has been carried out to provide ecological explanations for these large-scale spatial patterns in biodiversity. Hydro-climatic forcing on pelagic marine diversity has been investigated at the ocean basin scale using zooplankton species composition time series. However, an examination of environmental controls on the temporal and spatial variation of zooplankton diversity on a global scale has not yet been attempted. This macro-ecological approach can elucidate the future effects of a changing climate on the diversity of copepods and functioning of pelagic ecosystems on a large geographical scale. In a first stage, this study will try to identify the most important physico-chemical factors that control the variability in diversity of copepods in different biomes and examine the covariance between environmental variability and zooplankton diversity along a latitudinal gradient. Understanding the causes of variation in zooplankton diversity enables the development of a model to predict copepod diversity as a function of its most important environmental descriptors and forecast responses in ecosystem structure to environmental changes.

**18 May, 16:50 (W1-4883)**

### **Are there teleconnections among zooplankton time series within and between ocean basins?**

Chris Reason<sup>1</sup>, Anthony J. **Richardson**<sup>2</sup> and SCOR WG125 Contributors

<sup>1</sup> University of Cape Town, Private Bag X3, Rondebosch, Cape Town 7701, South Africa.

<sup>2</sup> CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia.

Much of the impact of climate change on zooplankton is likely to act through existing modes of variability in the Earth's climate system. Such climate modes are expressed as differences in synoptic atmospheric pressure fields. They alter regional wind fields, current strengths, nutrient dynamics and water temperatures. Here we use a global data set of zooplankton time series to re-analyse and update several published relationships between zooplankton

and large-scale climate indices. We then examine the evidence for teleconnections among zooplankton time series both within and between ocean basins. Such relationships between plankton composition or abundance and integrative climate indices provide insight into how climate change may affect the world's oceans in the future, as climate models project changes in many important climate indices.

**18 May, 17:10 (W1-4859)**

**Global zooplankton time series comparisons: where is the synchrony?**

Harold **Batchelder**<sup>1</sup>, David Mackas<sup>2</sup>, Todd D. O'Brien<sup>3</sup> and SCOR WG125 Contributors

<sup>1</sup> Oregon State University, College of Oceanic & Atmospheric Sciences, Corvallis, OR 97331-5503, USA.  
E-mail: hbatchelder@coas.oregonstate.edu

<sup>2</sup> Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2, Canada.

<sup>3</sup> Marine Ecosystems Division, NOAA-Fisheries, 1315 East-West Highway, Silver Spring, MD 20910-3282, USA.

A global analysis of zooplankton time series data from multiple geographic locations might provide new insights and scientific stimulation similar to that resulting from a similar analysis of small pelagic fish populations in the early 1980s. Zooplankton time series have both advantages and disadvantages when compared to time series of fish stocks: they are not impacted by “harvesting” but they are few in number. SCOR-WG125 has been “identifying and consolidating a globally representative set of long zooplankton time series”. To be considered for this analysis a data set must be nearly continuous and extend 10+ years. Very few time series extend the 50+ years necessary to examine multiple transitions of climate forcing (e.g. PDO, NPI, AO, NAO) at hemispheric or global scales. Examination of synchrony demands that zooplankton data sets overlap in time. Time series may start, stop, and be intermittent or irregular due to funding issues or changing scientific interest. To examine synchrony, we consider the zooplankton time series that have nearly complete (i.e. uninterrupted) records and that overlap 15+ years for inter-basin or inter-hemisphere comparisons, and overlap 10+ years for regional to within-basin comparisons. We compare standardized anomalies to eliminate issues regarding order of magnitude and measurement unit. Our analysis provides evidence of within-basin synchrony at regime and ENSO time scales for geographic separations extending to a few thousand kilometres. Evidence for “global” synchrony of zooplankton populations is weak or perhaps present but not discernable due to the short (<50 years) period of observations available.

**W2/3**

**Linking global climate model output to a) trends in commercial species productivity and b) changes in broader biological communities in the world's oceans**

**18 May, 11:00 (W2/3-4622)**

**A method for using IPCC model simulations to project changes in marine ecosystems**

Nicholas A. **Bond**<sup>1</sup>, James E. Overland<sup>2</sup> and Muyin Wang<sup>1</sup>

<sup>1</sup> Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, 7600 Sand Point Way NE, NOAA/PMEL, P.O. Box 354925, Seattle, WA 98195-4925, USA. E-mail: nicholas.bond@noaa.gov

<sup>2</sup> Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

In preparation for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, an international group of modelling centres carried out sets of global climate simulations. A total of 23 different coupled atmosphere-ocean general circulation models were employed under common emission scenarios. The objective of this paper is to describe a protocol for using these simulations towards the projection of the future states of marine ecosystems, drawing on examples from the North Pacific and Bering Sea. Our method relies on critical evaluation of the models' 20th century hindcasts of variables pertaining to the ecosystems of interest. Experience indicates that typically about one-half of the models are able to replicate the spatial pattern, temporal scale and magnitude of variance in the basin-scale climate forcing observed in the 20th century. Different models tend to have different strengths; a model's capability to hindcast an individual parameter such as sea ice does not guarantee it performs equally well for other parameters such as precipitation. Therefore, the subset of models used for projections into the 21st century should be tailored to the specific application. At the same time, it is desirable to retain as many independent simulations for the 21st century as possible (at least 5) in that an ensemble of simulations is required to ascertain the probable ranges of future extremes in the climate forcing, and the uncertainties in the projections in general.

**18 May, 11:30 (W2/3-4974)**

**Climate change, oceanic response and possible effects on fish stocks in New Zealand waters**

Mary E. **Livingston**

Ministry of Fisheries, Science Group, P.O. Box 1020, Wellington, New Zealand. E-mail: mary.livingston@fish.govt.nz

A relatively isolated island nation ~2000 km from the nearest continental land mass, climate-change related trends in New Zealand waters have been equivocal over the past 50 years compared with some other parts of the world. Bathymetric topography in the region constrains the location of the subtropical front relative to our more productive fishing grounds, and although sea temperatures have been rising over the last decade, mean temperatures are little higher than those of the 1950s. New information suggests that this is about to change. New Zealand prides itself in its approach to fisheries management through the Quota Management System introduced in the mid-1980s. However, we are significantly stretched when it comes to planning fisheries management within the context of climate variability or change. Short time series make it difficult to draw definitive conclusions about the interactions between climate variables, ocean productivity and fish abundance. This paper provides an overview of results from recent studies and how we plan to integrate investigation of climate change with current fisheries research planning.

**18 May, 11:45 (W2/3-4935)**

**Forecasting climate change impacts on the distribution and abundance of jack mackerel around Korean waters**

Jae Bong **Lee**<sup>1</sup>, Anne B. Hollowed<sup>2</sup>, Nicholas A. Bond<sup>3</sup>, James E. Overland<sup>4</sup>, Chang Ik Zhang<sup>5</sup> and Dong Woo Lee<sup>1</sup>

<sup>1</sup> National Fisheries Research & Development Institute, Busan 619-905, Republic of Korea. E-mail: leejb@nfrdi.re.kr

<sup>2</sup> Alaska Fisheries Science Center, NOAA, Seattle, WA 98115, USA.

<sup>3</sup> Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, Seattle, WA 98195, USA.

<sup>4</sup> Pacific Marine Environmental Laboratory, NOAA, Seattle, WA 98115, USA.

<sup>5</sup> Pukyong University, Dayeon3-dong, Nam-gu, Busan 608-737, Republic of Korea.

We used the existing knowledge of the functional relationships between climate and fish production and distribution to forecast climate change impacts on Korean fisheries. The surface current drifted westward during the 1980s and moved eastward to the western area of Kyushu of Japan during the 1990s. The role of transport to nursery grounds as a factor contributing to survivorship of jack mackerel was evaluated by comparing of the amount of variance explained by a Ricker spawner-recruitment relationship with and without transport indices. Climate change impacts were projected for the 21st century using output from a large number of coupled Atmosphere-Ocean General Circulation Models made available through the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. We provided individual model realisations of future SST, ocean drift and other oceanographic variables which are factors that influence year-class success of jack mackerel around Korean waters. These variables will be incorporated into a stock projection model to forecast future production scenarios. We incorporated environmental forcing into a stock projection model by modifying the spawner-recruitment relationship.

**18 May, 12:00 (W2/3-4925)**

**Techniques for forecasting climate-induced variation in the distribution and abundance of mackerels in the northwestern Pacific**

Sukyung **Kang**<sup>1</sup>, Jae Bong Lee<sup>1</sup>, Anne B. Hollowed<sup>2</sup>, Nicholas A. Bond<sup>3</sup> and Suam Kim<sup>4</sup>

<sup>1</sup> National Fisheries Research & Development Institute, Busan 619-902, Republic of Korea.

<sup>2</sup> Alaska Fisheries Science Center, NOAA, Seattle, WA, USA.

<sup>3</sup> Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, Seattle, WA, USA.

<sup>4</sup> Pukyong University, Dayeon3-dong, Nam-gu, Busan 608-737, Republic of Korea.

Scientists have compared temporal trends in interannual variability in oceanographic, climatic, and fishery data with temporal trends in the production or distribution of marine fish to evaluate the potential impact of climate variability on fisheries resources. In this investigation we examine time series of mackerel production in relation to ocean conditions in the marginal seas of the northwestern Pacific Ocean. SST in the Yellow Sea, the East China Sea (ECS) and the East/Japan Sea were compared to the national landings of mackerels in China, Japan and Korea. Data sets included time series of landings from Korean and Japanese fisheries from 1950 to the present. Analysis of temporal trends in SST revealed a decadal signal in SST that was negatively correlated to the PDO before and after 1981. Analysis of the spatial pattern of SST revealed an inverse phase relationship in SST anomalies between the eastern (130°E) and western (123°E) ECS. We hypothesize that mackerel production is positively influenced by warm ocean conditions in the ECS through its influence on the volume of suitable spawning habitat. We forecast the impact of climate change on mackerel production by embedding temporal trends in the volume of spawning habitat into a stock projection model. We downscale time forecasts of atmospheric/ocean conditions from the Intergovernmental Panel on Climate Change models to extract trends for local ocean conditions in the ECS. These trends are incorporated into stock projection models by adding terms governing density dependent competition for spawning habitat.

**18 May, 12:15 (W2/3-4720)**

**Effects of climate change on sole and plaice: timing of spawning, length of the growth period and rate of growth**

Adriaan D. **Rijnsdorp**<sup>1</sup>, Joep J. de Leeuw<sup>1</sup>, Lorna R. Teal<sup>1</sup> and Henk W. van der Veer<sup>2</sup>

<sup>1</sup> Wageningen IMARES, Institute for Marine Resources and Ecosystem Studies, P.O. Box 68, 1970 AB IJmuiden, The Netherlands. E-mail: Adriaan.rijnsdorp@wur.nl

<sup>2</sup> Royal Netherlands Institute for Sea Research, NIOZ, P.O.Box 59, 1790 AB, Den Burg, The Netherlands.

The effect of the rising sea water temperature on the timing of spawning, the duration of the growth period and the growth rate of 0-group sole and plaice in the southeastern North Sea was investigated for the period 1970-2004. Increasing water temperature in winter significantly advanced the timing of spawning and increased the growth period of sole, a warm-water species that spawns in spring, but not of plaice, a temperate species that spawns in winter. Growth rate increased with higher summer temperatures in sole and to a lesser degree in plaice. Compared with experimental growth rates at ambient temperatures and unlimited food, observed growth rates were close to experimental values until mid June, but were much lower in July-September, suggesting food limitation in summer. The higher temperatures observed since 1989 positively affected the quality of the shallow coastal waters as a nursery area for sole but not for plaice. However, a further increase in summer may negatively affect the nursery quality if the production rate of benthic food cannot meet the increase in energy requirements of 0-group flatfish and/or exceed the temperature tolerance range.

**18 May, 12:30 (W2/3-4540)**

**The impact on management performance of including indicators of environmental variability in management strategies for the Gulf of Alaska walleye pollock fishery**

Z. Teresa **A'mar**<sup>1</sup>, André E. Punt<sup>2</sup> and Martin W. Dorn<sup>3</sup>

<sup>1</sup> University of Washington, Quantitative Ecology and Resource Management, Box 352182, Seattle, WA 98195-2182, USA. E-mail: zta@u.washington.edu

<sup>2</sup> University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195-5020, USA.

<sup>3</sup> Alaska Fisheries Science Center, NOAA Fisheries, 7600 Sand Point Way NE, Bin C15700, Seattle, WA 98115-0070, USA.

Management strategy evaluation (MSE) is the process of using simulation testing with feedback to examine the robustness of candidate management strategies to error and uncertainty. The MSE framework includes an operating model of 'true' population dynamics, from which data are generated and used in the estimation model; an estimation model which provides derived measures of population metrics (e.g. spawning biomass, fishing mortality, etc.) to assess the stock relative to target and limit reference points; and a decision rule which determines management action based on the stock status. The latter two steps constitute the management strategy. The structure of the management strategy can be selected to attempt to satisfy desired (but conflicting) management goals and objectives. Performance measures are used to quantify the effectiveness of the management strategy relative to the management objectives of avoiding low stock size and achieving high, stable catches given error and uncertainty in biological processes and data collection. MSE is used in this paper to assess the performance of the current management strategy for the fishery for walleye pollock, *Theragra chalcogramma*, in the Gulf of Alaska when subject to the effects of regime shifts and environmental variability. These effects are of particular interest in this fishery, where such changes can modify stock production. The results indicate that management strategies more responsive to fluctuations in productivity due to environmental influences demonstrate the best performance.

**18 May, 12:45 (W2/3-4862)**

**Simulation testing two methods of including environmental data in stock assessments**

Michael J. **Schirripa**<sup>1</sup>, Richard D. Methot<sup>2</sup> and C. Phillip Goodyear<sup>3</sup>

<sup>1</sup> NOAA Fisheries, Northwest Fisheries Science Center, 2032 SE OSU Drive, Newport, OR 97365, USA. E-mail: Michael.Schirripa@noaa.gov

<sup>2</sup> NOAA Fisheries, Office of Science and Technology, 2725 Montlake Blvd., Seattle, WA 98112, USA.

<sup>3</sup> 1214 N Lakeshore Drive, Niceville, FL 32578, USA.

The North Pacific Marine Science Organization (PICES) Working Group 16 report on the impacts of climate and climate change concluded that climate is a major factor affecting the productivity of virtually all key commercial species. However, almost none of the stock assessments conducted on these species explicitly include climate effects

in the assessment model. The objective of this investigation is to evaluate two methods of including environmental variability directly into the assessment and its effect on the estimation of recruitment parameters, stock status, and the conservation benchmarks used to manage a stock. Two methods of incorporating environmental effects will be tested using the stock assessment model Stock Synthesis II. The first method models annual deviations in the stock-recruitment curve assuming no observation error in the environmental data by recalculating the expected value of recruitment according to anomalies in the environmental time series for a given year. The second method allows for observation error in the environmental time series and uses this data as an index to tune the vector of estimates of annual recruitment deviations. Both methods are tested against simulated data sets in an effort to determine which method produces the most accurate results and are suitable for future use. Response variables to the two methods include estimates of key benchmarks such as virgin recruitment and biomass, stock-recruitment steepness parameter, maximum sustainable yield and depletion.

**18 May, 13:00 (W2/3-4846)**

### **Climate change and changing fisher behaviour in the Bering Sea pollock fishery**

Alan Haynie

NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: Alan.Haynie@noaa.gov

One component of the recently initiated Bering Sea Integrated Ecosystem Research Project (BSIERP) is a spatial economic model that predicts changes in fishing activity in the Bering Sea pollock fishery that may result from climate change. Random utility models such as the model employed here have been used in the Bering Sea and elsewhere to model how fishers make decisions about where to fish. Commercial fishers choose different areas to fish based on a myriad of observable and unobservable characteristics of the area and the fisher. We commonly model location choice as a function of the expected catch (or revenue) in an area, fuel and fish prices, distance to an area, vessel characteristics, and to a more limited degree, institutional and environmental conditions. In the Bering Sea pollock fishery, climate variables affect many aspects of the fishing decision. Key among these impacts is the role that climate has on fish location and abundance and the impact that weather plays in daily participation choices for smaller vessels. In this paper, we expand a robust spatial economic model to include climate data (e.g. ice cover, SST, wind). Including this information in the model will allow us to determine the relative impact of observable contemporaneous environmental conditions on location choices. We also develop a framework to include predictions of changing pollock abundance in the model, which will allow us to estimate fisher response to scenarios developed by oceanographic and ecosystem modellers involved in the BSIERP project.

**18 May, 13:15 (W2/3-4572)**

### **Large scale circulation over the west Indian Ocean and the south west monsoon**

U.K. Singh and P.S. Salvekar

Indian Institute of Tropical Meteorology, Pune-08, India. E-mail: umesh@tropmet.res.in

The focus of this study is to document the role of the west Indian Ocean over the Indian monsoon during the last decade (1998-2007). Understanding the interannual variability of the southwest monsoon is an important and challenging factor. To date the relationship of the Mascarian high and the southwest monsoon has been well documented in the literature. However, the temporal variation of meteorological parameters, over the region east of Madagascar to the west coast of India, are not yet examined in detail. In the present study extensive analyses of daily outgoing longwave radiation (OLR), zonal wind ( $u$ ) at 850 and 200 hpa and Global Precipitation Climatology Project (GPCP) rainfall over the region 50-80°E and 30°S-30°N from April to September for all 10 years was carried out. In all cases, a 5-day running mean smoother was applied to the data to reduce the large day-to-day oscillations. We have prepared time-latitudinal plots averaged over longitude 50-80°E. Northward movement of large scale circulation and the core of maximum winds are clearly depicted and are found to be closely related with the GPCP rainfall region. The study was very useful for understanding monsoon performance in the last decade. It is suggested that large scale circulation over the west Indian Ocean may be the dominating factor in the overall performance of the southwest monsoon over India.

**18 May, 15:00 (W2/3-4757)**

### **Modelling the response of ocean biology to climate warming using an empirical approach**

Jorge L. **Sarmiento**, Patrick Schultz, Michael Hiscock and Stephanie Henson

Princeton University, Atmospheric and Oceanic Sciences Program, 300 Forrester Road, Sayre Hall, Princeton, NJ 08544, USA.  
E-mail: jls@princeton.edu

We previously used sea ice extent, upwelling velocity, and wintertime mixed layer depth to define six physically based biomes and how these respond to climate warming as predicted by coupled climate models. Here, we discuss results of a new study using statistical approaches to identify patterns in satellite observations of chlorophyll and biomass, and then use these to define an alternative set of biomes. We next analyse the results for correlations between the biomes and physical processes that we can use to estimate how the boundaries of the biomes might shift in response to climate warming. We suggest that such an empirical modelling approach offers a useful alternative to the traditional NPZ type ecosystem modelling usually used to predict ecosystem responses to climate warming.

**18 May, 15:15 (W2/3-4793)**

### **Future ecosystem changes projected by a 3-D high-resolution ecosystem model**

Taketo **Hashioka**<sup>1,2</sup>, Takashi T. Sakamoto<sup>1</sup>, Takeshi Okunishi<sup>3</sup> and Yasuhiro Yamanaka<sup>1,2,4</sup>

<sup>1</sup> Frontier Research Center for Global Change (FRCGC) / Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3173-25, Showa-machi, Kanazawaku-ku, Yokohama, Japan. E-mail: hashioka@jamstec.go.jp

<sup>2</sup> Core Research for Evolutional Science and Technology (CREST) / Japan Science and Technology Agency (JST), 4-1-8, Honcho, Kawaguchi-shi, Japan.

<sup>3</sup> Tohoku National Fisheries Research Institute, Fisheries Research Agency (FRA), 3-27-5, Shinhamacho, Shioyama, Miyagi 985-0001, Japan.

<sup>4</sup> Hokkaido University, Faculty of Environmental Earth Science, 060-0010, N10W5, Kita-ku, Sapporo, Japan.

In recent years, several studies have tried predicting future impacts of global warming on marine ecosystems using results obtained from climate models. As an approach to modelling responses to global warming, we developed a 3-D high-resolution ecosystem model (COCO-NEMURO; which has a horizontal resolution of 1/4 by 1/6 degrees) with an off-line calculation method that can directly use predicted results of climate models as a physical field of the ecosystem model. COCO-NEMURO consists of PICES NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) coupled with COCO (CCSR Ocean Component Model). As a first step, we applied this model to the western North Pacific, and conducted a global warming experiment using physical fields predicted by a high-resolution climate model (the CCSR/NIES/FRCGC climate model, which contributed to the IPCC-AR4). We conducted the global warming experiment following an idealised scenario in which atmospheric CO<sub>2</sub> concentration increases by 1% per year. Under the global warming condition, our model predicted significant changes in the maximum phytoplankton biomass during the spring bloom period (i.e. 20% increase in the subarctic region and 25% decrease in the subarctic-subtropical transition region). Since these changes would affect the higher-trophic level ecosystem, we have been also developing an integrated marine ecosystem model explicitly representing linkages between the lower-trophic level ecosystem and major pelagic fishes based on COCO-NEMURO. In this workshop, we present our approach to the projection of future ecosystem changes.

**18 May, 15:30 (W2/3-4803)**

### **Dynamic bioclimate envelope model to predict climate-induced changes in distribution of marine fishes and invertebrates**

William W.L. **Cheung**, Vicky W.Y. Lam and Daniel Pauly

Sea Around Us Project, Fisheries Centre, Aquatic Ecosystems Research Laboratory, 2202 Main Mall, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. E-mail: w.cheung@fisheries.ubc.ca

Global climate change is recognised as an important determining factor for the future distributions of marine organisms, notably fishes and invertebrates. Shifting of distribution ranges may affect the structure and function of marine ecosystems and global marine fisheries. In this study, we develop a dynamic bioclimate envelope model to predict the effect of climate change on the distributions of marine species with an emphasis on commercially

exploited fishes and invertebrates. Firstly, the model infers, for various species, bioclimate envelopes based on their current distribution. Bioclimate envelopes are defined by sea water temperature, bathymetry, habitats, salinity and distance from sea ice. Secondly, the model predicts the shifting of the bioclimate envelopes induced by changes in climate variables. Simultaneously, following the shifting of the bioclimate envelopes, the model simulates movement of relative abundance through changes in population growth, mortality, larval dispersal and adult movement. We test the model with several commercially exploited fish species with widely different biogeography. The model provides reasonable and robust predictions of future distribution ranges of the four species under different scenarios of sea water warming. Moreover, the predictions are robust to major model assumptions and parameter uncertainty. Using realistic climate change predictions from the global circulation models, our model can predict the possible shifts in distribution of marine species under different climate change scenarios. Such predictions can be incorporated into ecosystem simulation models to assess the synergistic effects of trophic interaction, climate change and anthropogenic impacts, such as fishing, on marine biological communities and fisheries.

**18 May, 15:45 (W2/3-4805)**

### **Informing location choices for ecosystem model development using a vulnerability index**

Alistair J. **Hobday**<sup>1,2</sup>, Thomas J. Kunz<sup>1</sup>, Thomas A. Okey<sup>3,4,5</sup>, Elvira S. Poloczanska<sup>1</sup> and Anthony J. Richardson<sup>3,6</sup>

<sup>1</sup> Climate Adaptations Flagship, CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia.  
E-mail: Alistair.Hobday@csiro.au

<sup>2</sup> School of Zoology, University of Tasmania, Private Bag 5, Hobart, Tasmania 7001, Australia.

<sup>3</sup> Climate Adaptations Flagship, CSIRO Marine and Atmospheric Research, PO Box 120, Cleveland, Qld 4163, Australia.

<sup>4</sup> Bamfield Marine Sciences Centre, PO Box 100, Bamfield, BC, V0R 1B0, Canada.

<sup>5</sup> University of Victoria School of Environmental Studies, PO Box 1700 STN CSC, Victoria BC, V8W 2Y2, Canada.

<sup>6</sup> Department of Mathematics, University of Queensland, St Lucia, Queensland 4072, Australia.

Vulnerability assessments can provide information on potential climate impacts and underpin strategic prioritisation for allocation of scientific and management resources. One way such a vulnerability assessment can underpin research strategy is to provide quantitative frameworks for identifying ecosystems, habitats, biological components, or human values at greatest risk. This can then guide locations where ecosystem models should be developed, and what drivers are likely to be critical for model inclusion. To illustrate this, we describe a novel approach for assessing vulnerability of marine life to climate change using a bioregional approach for Australia. We score the vulnerability for each of seven large marine domains based on 22 quantitative indicators categorised into three dimensions of vulnerability. These dimensions represent the different aspects of stress that impact marine life and the different characteristics that mediate stressors: one dimension measures exposure to climate change, one measures sensitivity in each region, and one measures adaptive capacity. Four to eight indicators were scored for each dimension. Indicators of climate change (difference between projections for the 2070s from the 1990s) were obtained from the CSIRO Mk 3.5 model, and non-climate indicators from existing Australian data sets. Our approach identified the principal stressors for each domain. In each region, policies can be targeted toward major non-climate stressors that could mitigate future impacts of climate change. What is then needed is to consider impacts on a finer scale in the most vulnerable habitats using downscaled climate models to force ecosystem models in these regions at greatest risk.

**18 May, 16:30 (W2/3-4913)**

### **Towards the integration of biogeochemical and food web models for a comprehensive description of marine ecosystem dynamics**

Simone **Libralato**<sup>1</sup>, Cosimo Solidoro<sup>1</sup> and Villy Christensen<sup>2</sup>

<sup>1</sup> Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Dept. Oceanography, Borgo Grotta Gigante - Brisciki 42/c - 34010 Sgonico - Zgonik (TS) Italy. E-mail: slibralato@ogs.trieste.it

<sup>2</sup> Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada.

A truly comprehensive perspective on the effects of climatic changes on marine ecosystems requires a contemporaneous accounting of both biogeochemical/physical processes and food web dynamics in an end-to-end modelling description of the ecosystem. The development of end-to-end models (e.g. from viruses to fishes,

from nutrients to fisheries, including climatic changes) can be performed in different ways, depending on the peculiarity of the starting models, the methods used for their integration, the variables used as linkage and forcing, and the ultimate goal of the analysis. For this workshop, we will summarise the main outcomes of the November 2007 workshop held in Trieste (Italy) on “Biogeochemical processes and fish dynamics in food web models for end-to-end conceptualisation of marine ecosystems: theory and use of Ecopath with Ecosim”. The workshop was attended by 56 participants from 25 different countries and was intended to explore the capabilities of the Ecopath with Ecosim package for building End-to-End models of marine ecosystems. Contributions to the workshop presented possibilities for including external forcings into food web dynamics as well as for linking and coupling biogeochemical and food web models. This work is intended to give a summary of the main challenges identified, of the ideas and future prospects, and of the preliminary applications presented during the workshop.

**18 May, 16:45 (W2/3-4822)**

### **Which forcing factors fit? Using ecosystem models to investigate the relative influence of fishing and primary productivity on the dynamics of marine ecosystems**

Steven **Mackinson**<sup>1</sup>, G. Daskalov, S.J.J. Heymans, S. Neira, H. Arancibia, M. Zetina-Rejón, D. Lecari, J. Hong, C. Hequin, M. Coll, F. Arreguin-Sanchez, L. Shannon and K. Lees

<sup>1</sup> Cefas, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK. E-mail: [steve.mackinson@cefas.co.uk](mailto:steve.mackinson@cefas.co.uk)

Estimates of fishing mortalities and primary production (or proxies for primary production) were used to drive the past dynamics of fish assemblages in 10 contrasting trophodynamic models of marine ecosystems. Historical trends in fish abundance were reconstructed by fitting model predictions to observations from stock assessments and fisheries independent survey data. We measured how much better or worse were model predictions when changes in primary production were combined with forcing by fishing. Searching for cross system patterns, the relative contribution of fishing and changes in primary production are evaluated for the ecosystem as a whole and for selected similar species in different ecosystems. The analysis enables us to provide a simple qualitative way to explain which forcing factors have the most influence on modelled dynamics. However, because past relationships of the role of fishing and changes in primary production on ecosystems cannot be used reliably to predict future responses to climate change, integration of biogeochemical models with higher trophic level models will be required. Such work has already been initiated; the principles behind which are discussed here.

**18 May, 17:00 (W2/3-4831)**

### **The effects of climate change on the northern Benguela ecosystem**

Sheila J.J. **Heymans**

Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Dunbeg, PA37 1QA, Argyll, UK.  
E-mail: [sheilaheyman@yahoo.com](mailto:sheilaheyman@yahoo.com)

The Benguela upwelling system is one of the most productive ecosystems in the world. It is driven mainly by the prevailing southwesterly winds off the coast of southern Africa. These winds cause perennial upwelling off Lüderitz and seven other smaller cells up and down the Namibian coast. The upwelled water reduces sea surface temperature and increase the nutrient content of the coastal waters. There is evidence that hake (one of the most important commercial species in the system) recruitment is dependent on low surface temperatures and nutrients. In contrast, anchovy catches are often favoured by the breakdown of the Lüderitz upwelling cell, which acts as a barrier to the import of recruits from the south. The changes in the northern Benguela ecosystem (from 1956-2000) was shown to be correlated to sea surface temperature and wind stress in the system. In this study the effect of global warming on the northern Benguela system was simulated by using the 1956 Ecopath with Ecosim model fitted to 2000 and imposing possible increased sea surface temperature regimes over the next 50 years. The effects of this possible increase in temperature were then compared in terms of changes in ecosystem function and commercial gain possible from the ecosystem.

## **W4** Prospects for multidisciplinary long-term ocean observations

**21 May, 14:30 (W4-4967)**

### **Ocean variability and trends, and the sustained Global Ocean Observing System**

D.E. **Harrison**

NOAA/PMEL/OCRD, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: [harrison@pmel.noaa.gov](mailto:harrison@pmel.noaa.gov)

While there is much interest at present in how climate change will be expressed in the ocean in coming decades (and longer), recent analyses of the frustratingly incomplete historical ocean temperature data set clearly show that the better sampled areas of the ocean have basin-scale variability on a wide range of time scales. Regional multi-decadal cooling and warming can be substantially greater than longer-term regional trends. Estimating long term trends is quite challenging in many areas, even over the post-World War II period, given the amplitude of oceanic variability. The need for sustained sampling of the ocean on relevant space and times scales is critical for climate assessment, climate research and climate forecasting as well as ecosystem management, carbon budget estimates and other non-physical variable objectives. A plan for an initial sustained global ocean observing system has been agreed and implementation (see GCOS-92) called for by the GEO, UNFCCC and other international groups. Significant progress in implementation has been achieved, with open access to the data collected and to many of the ocean analysis products now being routinely generated by groups participating in the Global Ocean Data Assimilation Experiment (high spatial resolution, near-real-time) and the ocean reanalysis activity led by CLIVAR's Global Synthesis and Observations Panel. It is important to extend the range of variables observed globally and systematically as rapidly as technology permits. An international symposium, OceanObs09, is planned to provide a forum for the ocean observing community to celebrate the accomplishments of the past decade, to demonstrate the utility to society of the information gained and to agree on the plan for the coming decade. A major objective is to provide an opportunity for the biogeochemical and ecosystem communities to present consensus plans for sustained observing activities for feasible variables.

**21 May, 14:50 (W4-4977)**

### **High-resolution ocean and atmosphere $p\text{CO}_2$ time series measurements from open ocean and coastal moorings**

Christopher L. **Sabine**, Richard A. Feely, Stacy Maenner and Christian Meinig

Pacific Marine Environmental Laboratory, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: [Chris.Sabine@noaa.gov](mailto:Chris.Sabine@noaa.gov)

Ocean carbon measurements have shown significant biogeochemical variability over a wide range of timescales from sub-diurnal to decadal periods. *In situ* measurements are also providing a growing body of evidence that episodic phenomena are extremely important causes of variability in  $\text{CO}_2$  and related biogeochemical properties. Year-to-year variations in ocean physics, bulk biological production, and ecological shifts can drive significant changes in surface water  $\text{CO}_2$ , and thus air-sea flux. Time series records are essential for characterising the natural variability and secular trends in the ocean carbon cycle and for determining the physical and biological mechanisms controlling the system. The biological and chemical responses to natural perturbations (e.g. ENSO, dust deposition events) are particularly important with regard to evaluating potential responses to anthropogenic forcing and for evaluating the prognostic models used in climate projections. Ship-based time series are impractical for routinely measuring variability over intervals from a week to a month, they cannot be made during storms or high-sea conditions, and they are too expensive for remote locations. Instrumental advances over the past 15 years have led to autonomous moorings capable of sampling properties of chemical, biological, and physical interest with duty cycles of a year or more. Although these new technologies are still under-utilised, they have been identified as a critical component of the global ocean observing system for climate. We will discuss the latest developments in autonomous carbon sensors and how they are helping to improve our understanding of the ocean carbon system.

**21 May, 15:10 (W4-4971)**

**Prospects for using profiling floats and gliders for biogeochemical sustained observations?**

Martin **Visbeck**<sup>1</sup>, Johannes Karstensen<sup>1</sup>, Arne Körtzinger<sup>1</sup> and Nicolas Gruber<sup>2</sup>

<sup>1</sup> IFM-GEOMAR Leibniz-Institut für Meereswissenschaften, Düsternbrooker Weg 20, 24105 Kiel, Germany.

E-mail: mvisbeck@ifm-geomar.de

<sup>2</sup> ETH Zürich, CHN E21.1, Universitätstr. 16, 8092 Zurich, Switzerland.

Over the last decade the physical oceanographic community has made tremendous advances in the exploitation of relatively inexpensive autonomous profiling platforms. Today about 3000 profiling floats observe the upper 2 km of all ice-free ocean roughly every 10 days as part of the Argo project. In regions with strong flows or near the coasts the freely drifting profiling floats are increasingly augmented by a more elaborate and capable platform called a glider. At the moment there are three groups who have developed operational gliders: 1) the Seaglider by APL-University of Washington (shallow and deep versions); 2) the Slocum by Webb Research Corp (shallow, deep and thermal versions) and 3) the Spray by Scripps Institution of Oceanography. Although the designs are different they have many features in common. They all have a small size (1.5 m long, 30 cm diameter, 1.5 m wingspan with a mass of about 50 kg in air and +/-200g in water), their horizontal speeds are ~20-40 cm/s with descent/ascent rates of ~10-20cm/s. For a maximum dive to 1 km depth a typical glider will move 2-6 km horizontally between surfacing. For most applications measurements are carried out during the descent using a variety of sensors including temperature, salinity, and most recently dissolved oxygen. Depending on battery type, sensor load, speed of travel and depth of sampling the typical glider endurance is about 1-3 months (proven average value at the moment) and the glider can travel around 1000-3000 km before planned recovery and maintenance. Several of the gliders and a subset of the profiling floats already have been equipped with dissolved oxygen sensors and LED based fluorometers. As sensor technology keeps advancing the prospects for some global biogeochemical measurements hosted by robotic autonomous platforms become increasingly realistic.

**21 May, 15:30 (W4-4970)**

**Decadal CO<sub>2</sub> uptake by the ocean deduced from the CLIVAR/CO<sub>2</sub> Repeat Hydrography Program**

Richard A. **Feely**<sup>1</sup>, Christopher L. Sabine<sup>1</sup> and Rik Wanninkhof<sup>2</sup>

<sup>1</sup> Ocean Climate Research Division, NOAA/PMEL, 7600 Sand Point Way NE, Seattle, WA 98115, USA. E-mail: Richard.A.Feely@noaa.gov

<sup>2</sup> Ocean Chemistry Division, NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149, USA.

In 2003, the US CLIVAR/CO<sub>2</sub> Repeat Hydrography Program began re-occupying a subset of the WOCE/JGOFS lines in an effort to evaluate the decadal changes in ocean carbon inventories. The programme has identified 19 hydrographic sections distributed around the global ocean that will be re-occupied approximately every 10 years. This work is being conducted in collaboration with other nations that have similar repeat hydrography programmes in the Atlantic Pacific, Indian and Southern Oceans. Preliminary estimates of anthropogenic CO<sub>2</sub> accumulation along representative north-south cruises indicate that the North Atlantic shows the largest anthropogenic increase, illustrating the importance of North Atlantic Deep Water formation as a mechanism for transporting anthropogenic CO<sub>2</sub> into the ocean interior. The formation of mode and intermediate waters in the southern hemisphere also contributes to the substantial DIC increases in the South Atlantic and South Pacific. The North Pacific shows a relatively modest increase because of the lack of deep-water formation and restricted intermediate water formation in that region. Preliminary estimates of the accumulation of anthropogenic CO<sub>2</sub> in the Indian Ocean between the 1995 WOCE/JGOFS cruises and the 2007 repeat hydrography cruise indicates a similar pattern of accumulation as shown by the earlier work of Sabine *et al.* (1999). These latest results show conclusively that anthropogenic CO<sub>2</sub> is continuing to accumulate in the Atlantic, Pacific and Indian Oceans. In general, they agree with the long-term storage patterns of Sabine *et al.* (2004) that the largest inventories are associated with the regions where water masses are being formed and moving into the ocean interior. However, when studied in detail, the results from the Pacific and Atlantic Oceans have shown that regional circulation changes can have a significant impact on carbon inventories on decadal timescales. In some cases these changes may enhance the storage of carbon and, in other cases, they may decrease the uptake resulting from rising atmospheric CO<sub>2</sub>. Because circulation and biological changes can vary on seasonal to decadal scales, it is critical to continue to monitor the changes in ocean carbon inventories and how they interact with the secular increases in anthropogenic CO<sub>2</sub>. As additional cruises are completed the full picture of the decadal storage will be developed.

**21 May, 15:50 (W4-4969)**

## **The role of fixed-point deep ocean observatories in a global observing system**

Richard S. Lampitt, K.E. Larkin, S.E. Hartman and M. Pagnani

National Oceanography Centre, European Way, Southampton SO14 3ZH, UK. E-mail: R.Lampitt@noc.soton.ac.uk

At a time of increasing concern about global climate change and environmental degradation, long-term time series observations of the oceans can offer some of the most important insights into the structure and function of this environment and the ways our oceans are changing. Whilst data from research cruises have provided much of our current understanding, these only provide “snapshots” of the oceans and there is an increasing realisation that crucially important processes occur on time scales that can not be observed by such cruises. Furthermore, many of these important processes are outside the reach of satellite sensors. In order to understand the complexity of the oceans, sustained *in situ* observations are required providing high quality data on climatically and ecologically relevant variables at a few key locations. Fixed-point deep ocean observatories are therefore an integral part of the diverse monitoring systems now developing. Historically, fixed-point deep ocean observatories have been developed independently with national funding. As a consequence, observatories have developed in a rather fragmented way. OceanSITES has become the international coordinated framework for fixed point observatories and has been pivotal in creating a philosophy of data management and sharing. The OceanSITES network advocates shared efforts in operations, technical expertise and science exploitation to form an international collaborative network of ocean observatories that are multidisciplinary, open to development with real-time data telemetry and an open data policy. EuroSITES, a 3 year (3.5 Million Euro) FP7 European project, forms an integrated network of the 9 existing deep ocean observatories around Europe. Beginning in spring 2008 and coordinated by the National Oceanography Centre, Southampton, EuroSITES will form the European component of OceanSITES and aims to progress European ocean observation technology beyond the current state-of-the-art. This will be achieved through enhancement and standardisation of existing *in situ* infrastructure through best practice and common data management linking sites both geographically across Europe and through the water column to the seafloor and subseafloor. EuroSITES will also support research and development into novel sensors to measure climatically and ecologically relevant variables that are currently not possible. Close interaction between all relevant international projects and initiatives is essential to develop a unified approach to ocean observation. Only then can the global observational community form an integrated, collaborative network and contribute effectively to GEO tasks and to the greater vision of GEOSS.

# W4

## Posters

### **Poster W4-4536**

#### **Long term monitoring of oceans around Southern Africa**

Juliet C. **Hermes**, Angus Paterson and Johan Pauw

South African Environmental Observation Network (SAEON), Private Bag X2, Roggebaai 8012, South Africa. E-mail: Juliet@saeon.ac.za

The South African Environmental Observation Network (SAEON) aims to provide a comprehensive, sustained, co-ordinated and responsive South African Earth observation network that delivers long-term reliable data for scientific research and informs decision making for a knowledge society and improved quality of life. SAEON addresses the environmental observation and information needs of future generations, reaching far and wide, nationally, regionally and globally, and its success as a platform for environmental observations depends on delivery of reliable environmental data and products for science, policy and management. Education-Outreach, based on the environmental sciences, has a specific focus on science educators, learners and research students. The marine offshore node of SAEON aims to fill the gaps in long-term ocean monitoring, helping to understand the impact of climate change on oceans and their resources surrounding South Africa, as well as improving our knowledge of the ocean's influence on climate change. It is vital that we better understand these oceans as they have been shown to play a major role in the weather and climate patterns over southern Africa. Thus the impact of climate change through factors such as increases in temperature and sea level rise, which are already evident, are likely to have devastating effects on the lives of millions of impoverished people.

## **W6 Storm surges and flooding in the Baltic Sea**

### **I. Observations and analyses of sea level data (Chair: K. Klevanny)**

**18 May, 09:50 (W6-4678)**

#### **Extreme sea level statistics along the Estonian coast**

Aleksander Toompuu<sup>1</sup>, Evgueni A. Kulikov<sup>2</sup> and Germo **Vali**<sup>1</sup>

<sup>1</sup> Marine Systems Institute, Tallinn University of Technology, Akadeemia tee 21, 12618 Tallinn, Estonia. E-mail: alex@phys.sea.ee

<sup>2</sup> Shirshov Institute of Oceanology, Russian Academy of Sciences, Nakhimovskiy 36, Moscow 117997, Russia.

The distributions of daily, weekly and monthly sea level maxima of twenty sea level records along part of the Latvian coast of the Gulf of Riga and along the Estonian coast have been analysed. The five-year (1978 to 1982) sea level data consist of either hourly or bench-stick (two or four times per day) mareograph readings. The estimated maximum sea level histograms were approximated by three extreme-value model distributions of the Gumbel, Frechet and Weibull type. There is a general tendency of westward decrease in the location and scale parameter values of the fitted Gumbel distribution in the Gulf of Finland, where the sea level stations are situated nearly in the east-west direction. A similar trend is also observed for the Gulf of Riga, where the distribution location and scale parameter values are larger for the stations located along the eastern coast of the Gulf. This observed regular trend is most likely related to (a) the bottom topography, which affects water flow in and out of the deep western basins of the gulf, (b) the relatively shallow eastern part of the gulf, and (c) the prevailing forcing by westerly winds in the area, governed by their respective water dynamics. The eastern coasts of these two areas are therefore more at risk from flooding by extreme sea levels than the coasts in the western Gulf of Riga.

**18 May, 10:20 (W6-4630)**

#### **Calculation of extreme water level rises along the western part of the Gulf of Finland**

Alexander S. **Averkiev**<sup>1</sup> and Konstantin A. Klevanny<sup>2</sup>

<sup>1</sup> Russian State Hydrometeorological University, Malookhtinskii Pr., 98, 195196 St. Petersburg, Russia. E-mail: asav@rshu.ru

<sup>2</sup> St.Petersburg Center for Hydrometeorology and Environmental Monitoring, 23 Linija VO, 2a, 199106 St. Petersburg, Russia.

Because of the recent climate change, floods along the Gulf of Finland coasts are expected to become more frequent and more serious phenomena in the future. In the previous works, the most dangerous cyclone trajectories and extreme possible water level rises were studied with the CARDINAL modelling system for the St. Petersburg, Kronshtadt and Leningrad NPS (nuclear power station) locations in the eastern Gulf of Finland. Simulations were done for an idealised round cyclone with extreme parameters (pressure in the cyclone centre of 960 gPa and maximum wind speed of 30-35 m/s at a distance of 200 km from the centre and behind the cold front). In this paper, similar simulations were done for locations in the western Gulf of Finland (Hanko, Helsinki, NPS in Loviisa and Kotka, and also for Pärnu in the Gulf of Riga) and the same parameters were estimated. In particular for Helsinki, Loviisa and Kotka, it was found that the maximum water levels occur when the cyclone centre moves 150-200 km north from these locations. In some cases and locations, the water level time histories have one peak, while there are usually two peaks when the cyclone moves towards the north-east or to the east. In both cases, the following maximum water level values were obtained relative to the zero-mean sea level: 210 cm in Kotka, 200 cm in Loviisa and 165 cm in Helsinki. As the coastline in these places is very irregular, these results are likely to be amended when using a more refined model of the Baltic Sea.

**18 May, 10:50 (W6-4733)**

## **Sea level trends along the coast of the Gulf of Finland of the Baltic Sea**

Oleg P. Nikitin<sup>1</sup> and Andrey O. Koch<sup>2</sup>

<sup>1</sup> State Oceanographic Institute, Kropotkinsky per., 6, Moscow 119034, Russia. E-mail: opnikitin@mail.ru

<sup>2</sup> Russian State Hydrometeorological University, 195196, St.Petersburg, Malookhtinsky Pr., 98, Russia.

Historical time series of monthly mean values of sea level were compiled and analysed for trends for all stations in the Gulf of Finland for time periods starting from the beginning of sea level observations at each station and until the station closed, or the year 2005 for Russian, 2004 for Finnish and 1991 for Estonian stations. It was found that along the northern coast of the Gulf of Finland, the sea level trends change from minus 3-4 mm/year along the western part of this coast (at Turku and Hanko) to plus 0.7 mm/year along the eastern part of the coast (at Lisiy Nos). Along the southern coast of the Gulf of Finland, the sea level trends change from west to east (from station to station) and not as regularly as along the northern coast. However, trend values along the southern coast are considerably less than along the northern coast. It was therefore concluded that within the limits of errors of trend calculations, the sea level trends along the southern coast also change from negative values in the west (minus 0.3 mm/year at Poosaspea) to plus 1.2 mm/year in the east (at Lomonosov). At the head of the Gulf (at Port of Nevskaya), the positive trend was the largest: 3.2 mm/year. Relative to the global sea level rise (about 2 mm/year during the last century) trend values are negative in all points except Saint Petersburg. Their spatial distribution is consistent with the map of post-glacial uplift in Fennoscandia.

**18 May, 11:30 (W6-4885)**

## **On diurnal tidal resonance in the Baltic Sea and Gulf of Finland**

Alexander B. Rabinovich and Evgueni A. Kulikov

P.P. Shirshov Institute of Oceanology, RAS, Moscow 117997, Russia. E-mail: abr@iki.rssi.ru

Tides in the Baltic Sea are quite small; maximum tidal amplitudes are less than 10 cm. Nevertheless, they significantly influence the water masses in the sea and interact with other dynamical processes, including storm surges and seiche (eigen) oscillations in the Baltic Sea as a whole and in large Baltic Sea gulfs, in particular, in the Gulf of Finland. The specific mechanism of tidal generation in the Baltic Sea is quite interesting. The semidiurnal tides are *free* (co-oscillating), as they are driven by the tidal waves arriving from the North Sea. In contrast, the diurnal tides are *forced*, generated directly in the Baltic Sea due to proximity of the diurnal period to the resonant period of the fundamental Baltic Sea mode (~27.7 hrs). Long-term hourly sea level data from a number of tide gauges were used to investigate the tidal motions in this basin. Tidal harmonic analysis of yearly time series by the least squares method was used to estimate 11 tidal constituents, including annual ( $S_a$ ), semiannual ( $S_{sa}$ ), five diurnal ( $K_1$ ,  $O_1$ ,  $P_1$ ,  $Q_1$  and  $S_1$ ) and four semidiurnal ( $M_2$ ,  $S_2$ ,  $N_2$  and  $K_2$ ) harmonics. To increase the accuracy, the computed complex amplitudes for individual years were averaged over the observational period at each station. The tidal amplitudes were normalised by their theoretical tidal potential values and then used to estimate tidal admittance characteristics of the Baltic Sea, which clearly shows the resonance of diurnal tides. This effect is especially pronounced in the Gulf of Finland, where diurnal tides have a character of the Helmholtz mode, in good agreement with the results of numerical modelling. Additional interesting effect was found at some stations in this gulf, exhibiting distinct "radiational" (solar) harmonics:  $S_1$ ,  $S_2$ ,  $S_3$ ,  $S_4$ , and  $S_5$ . These are likely associated with coastal sea breeze winds.

**18 May, 12:00 (W6-4681)**

## **Spectral analysis of sea level in the Gulf of Finland**

Evgueni A. Kulikov<sup>1</sup>, Oleg P. Nikitin<sup>2</sup> and Aleksander Toompuu<sup>3</sup>

<sup>1</sup> Shirshov Institute of Oceanology, RAS, Moscow 117997, Russia. E-mail: kulikove@cnt.ru

<sup>2</sup> State Oceanographic Institute, Kropotkinsky per., 6, Moscow, Russia.

<sup>3</sup> Marine Systems Institute, Tallinn University of Technology, Akadeemia tee 21, Tallinn 12618, Estonia.

Following an earlier study of the stochastic properties of the Baltic Sea level variability, we present results from spectral analysis of sea level data at several of the Gulf of Finland tidal stations located on the Estonian and Russian coasts. Spectral analysis was performed on hourly data sets, with 5 to 20-year duration, and on corresponding

atmospheric data from NCEP/NCAR reanalysis. The spectral analysis reveals marked differences between the sea level spectra for different stations. There is a significant rise of energy toward the head of the Gulf of Finland in the frequency band of 0.5-1 cpd, which is likely related to the natural seiche mode for the Baltic Sea which has a period of about 27 hours. For the most part, the analysis of coherence and phase functions showed that sea level oscillations in the Gulf of Finland can be characterised as standing waves. Cross-spectral analysis between the atmospheric parameters (pressure and winds) and sea level gave insight to the forcing mechanisms of the Baltic Sea level variability. We found that sea level response to the atmospheric pressure changes does not follow the law of the inverted barometer. Actually, the modified relationship between the barometric pressure and sea level is determined by the limitation of the Baltic Sea area, which is a nearly closed basin. The frequency response of sea level to wind forcing in the Gulf of Finland has a resonant character over periods of 27-30 hours. The zonal wind was found to be a more important factor than the meridional wind.

**18 May, 12:30 (W6-4923)**

### **Sea level variability and trends from satellite altimetry and tide gauges in the eastern Baltic Sea**

Josef Y. Cherniawsky<sup>1</sup>, Evgueni A. Kulikov<sup>2</sup> and Oleg P. Nikitin<sup>3</sup>

<sup>1</sup> Fisheries & Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada. E-mail: cherniawskyj@dfm-mpo.gc.ca

<sup>2</sup> Shirshov Institute of Oceanology of the RAS, Moscow, Russia.

<sup>3</sup> State Oceanographic Institute, Moscow, Russia.

Sea level data from coastal tide gauges show strong variability over synoptic and longer time scales in the eastern Baltic Sea, where intense winter storms produce annual flooding in its coastal cities. Water transport through the Danish Straits affects the mean sea level, while some of the shorter-period variability is attributed to the excitation of characteristic wave modes in the Baltic Sea. We analyse data from satellite altimeters and tide gauge observations from several coastal stations in order to calculate and map monthly and annual statistics, power spectra and sea level trends over the past ~15 years. The implications of these calculations and the potential utility of near-real-time satellite altimeter data in the shallow seas for analyses and predictions of coastal flooding will also be discussed.

## **II. Modelling and forecasting of water level (Chair: E. Kulikov)**

**18 May, 14:30**

### **Prof. Alexei Vsevolodovich Nekrasov (1933-2008)**

K. Klevanny and A. Rabinovich

**18 May, 14:50 (W6-4602)**

### **Influence of cyclone parameters upon the characteristics of storm surges in St. Petersburg**

Alexey V. Nekrasov and Stanislav D. Martyanov

Russian State Hydrometeorological University, 195196, Malookhtinsky Pr. 98, St. Petersburg, Russia. E-mail: martyanov-sd@rambler.ru

Formation of a storm surge by a cyclone moving to the east along the Gulf of Finland, which typically produces the most dangerous sea level oscillations in St. Petersburg, Russia, can be explained using a combination of a few individual *progressive waves*, arising, according to the concept of Lamb, at both sides of a cyclone and travelling in opposite directions in an idealised uniform channel. The resulting superposition of *forced* and *free* waves in the channel is also being taken into consideration. The character of these individual waves is determined (besides the cyclone dimensions and intensity) by: (a) cyclone propagation speed relative to the long wave speed and (b) displacement of the cyclone centre from the channel axis. The latter determines the position of a prevailing maximum of the effective external forcing and is closely related to the type of the initial disturbance, depending

on whether it is produced mainly by wind stress, by pressure depression, or by both. A number of numerical experiments with this simplified conceptual model show that the obtained results are mostly consistent, at least qualitatively, with our primary assumptions. These results help to understand certain elements of the formation of storm surges in the Gulf of Finland and will hopefully assist in improving the flood forecasting system for St. Petersburg.

**18 May, 15:20 (W6-4887)**

### **Numerical study of wind-driven circulation in the Gulf of Finland with the Regional Ocean Modelling System (ROMS)**

Andrey O. **Koch**<sup>1</sup> and Natalia A. Tikhonova<sup>2</sup>

<sup>1</sup> Department of Mathematics, Russian State Hydrometeorological University, Malookhtinsky pr. 98, St. Petersburg, 195196, Russia.  
E-mail: andrey\_koch@mail.ru

<sup>2</sup> State Oceanographic Institute, Saint-Petersburg Branch, V.O., 23rd line 2A, St. Petersburg 199026, Russia.

A model of circulation in the Gulf of Finland, based on the Regional Oceanic Modelling System (ROMS), has been implemented with 1 km horizontal resolution to study the variability of sea level and currents over different time scales. This study was carried out for the years 1994 and 1999, when several inundations at locations in the eastern Gulf of Finland were observed during the fall, including the 6th largest inundation (in 1999) over more than 300 years of recorded history. The model reproduces accurately the wind-driven dynamics in the Gulf of Finland, verified through comparison with current velocities from moorings and SSH observations from coastal gauges and along-track satellite altimetry. The model also describes satisfactorily seasonal-scale variability in sea level and its modulation by intensified atmospheric activity in the autumn. For those dates when storm surges resulted in extremely high sea level rise at the mouth of Neva River and at some other locations, the model showed a similar pattern to the observed sea level and current velocity changes, thus encouraging the use and development of the ROMS “community code” for investigations of the Baltic Sea dynamics.

**18 May, 16:00 (W6-4659)**

### **Numerical modelling of the Baltic sea-level variability**

Evgueni A. **Kulikov**<sup>1</sup> and Isaac I. Fine<sup>2</sup>

<sup>1</sup> P.P. Shirshov Institute of Oceanology, RAS, Moscow 117997, Russia. E-mail: kulikove@cnt.ru

<sup>2</sup> Heat and Mass Transfer Institute, NANB, 15, P. Brovka Str., Minsk 220072, Belarus.

This study aims to develop an effective numerical model of the Baltic Sea that can be used for multi-year simulations of wind-driven sea level variations in the Gulf of Finland. We present results from analyses of the observed and simulated statistical characteristics of sea-surface variability. The main purpose of the numerical experiments was to study the resonant sea-level response that is related to characteristic seiche modes in the Baltic Sea. A wind-driven 2D version of the Princeton Ocean Model (POM) has been developed and carefully tested for the Baltic Sea. Six-hourly data from NCEP/NCAR Reanalysis (surface wind and pressure) were used for forcing the model from 1990 to 2006. The computed spectra of simulated sea level variations show a prominent peak with a period of 27-29 hours, a well-known period of the natural seiche mode for the Baltic Sea. Cross-spectral analysis of the observed and simulated sea level records was carried out for Narva and Tallinn. A good agreement was found in the low frequency range of 0-1.5 cpd between the observed and simulated phase values. Phase lags between the stations along the coast of the Gulf of Finland were attributed to dissipative processes in the shallow areas of the gulf. We can, therefore, conclude that the dissipation parameters specified in the model are appropriate for simulations of the wind-driven circulation in the basin. The coherence between along-gulf sea level variations is frequency-dependent and its properties appear to be similar for the observed and model-simulated data. In particular, the frequency of zero coherence is the same for both data sets. The minimum coherence is at the frequency supporting a uninodal standing wave in the Gulf of Finland, with its nodal line located near Tallinn. It was found that for stations inside the Gulf of Finland, the sea level response for the “resonant” mode is stronger for the meridional winds.

**18 May, 16:30 (W6-4976)**

### **Model development for flood forecast improvement in the Netherlands**

Martin Verlaan and Herman Gerritsen

Deltares/Delft Hydraulics, Delft, The Netherlands. E-mail: martin.verlaan@deltares.nl

In the Netherlands, the Storm Surge Warning Service (SVSD) is responsible for warning the coastal authorities in situations of high water threats. The time between warning for dangerous high water and the actual occurrence of high water is an important parameter in the planning of the response, e.g. decisions on closure of the storm surge barriers, dike watch and potentially even an activation of an evacuation scenario (remember Katrina!). In view of this, SVSD aims to extend the time horizon of the water level forecasts in the near future, and make these forecasts for a dense distribution of locations ("stations") along the Dutch coast, instead of just the current five main stations (Vlissingen, Hoek van Holland, Den Helder, Harlingen and Delfzijl), which up to now are taken as representative for a specific coastal section. The present water level forecast model is not adequate for the above and needs to be replaced. A further SVSD objective is to forecast the wave conditions in parallel to the water level forecasts, for the same densely distributed coastal stations. The relevant parameters are the water level, the significant wave height, wave period and angle of wave attack on the coast. In the near future, SVSD will then be able to make predictions of the hydraulic loads on the local stretches of water defences that are under threat, to advise on focused response actions. The present paper discusses the new water level model grid and the approach to model calibration for tidal motion and storm surges. Varying grid size, domain decomposition and parallel computing are key features. A generic data assimilation environment with optimisation methods such as DUD, Powell and Simpson is used for parameter estimation and objective assessment of results. It is shown how the parameter estimation process can be structured effectively by some simple physically based assumptions. The proposed wave modelling consists of an outer model for calculating the deep water processes until roughly the 20 m depth contour, from which a wave model with full physics will calculate the wave processes from there towards the sea defences. In the near shore area, wave-induced currents are significant for the water level and flow forecasts, while in turn, water level and current variations are key inputs for the wave modelling. The same data assimilation environment has been used to assist the parameter estimation, analysing the effects of constraints, determining confidence bands, etc. Finally, some suggestions for intertwined flow and wave forecasting are discussed.

**18 May, 17:00 (W6-4581)**

### **Recent improvements in automated flood forecasting system for St. Petersburg**

Konstantin A. Klevanny and Suleiman-Mohammad W. Mostamandi

St.Petersburg Center of Hydrometeorology and Environmental Monitoring, 23 Linija VO, 2a, 199106, St. Petersburg, Russia.  
E-mail: klevanny@x-users.ru

Storm surges from the Baltic Sea inundate St. Petersburg, which is located in the shallow end of the eastern Gulf of Finland, on average once per year. In the past, successful forecasts were directly related to proper understanding of the meteorological conditions and to correct forecasts of the western component of the wind over the Gulf of Finland. In the early 1960s, a one-dimensional model of the Baltic Sea was developed and used until 1997 as an additional tool in forecasting the threat of floods. In December 1999, a new and up-to-date automated forecasting system was installed at the North-West Hydrometeorological Service of Russia in St. Petersburg, as a result of two joint Netherlands-Russia projects that are headed by Dr. H. Gerritsen of WL/Delft Hydraulics. The new system is based on a two-dimensional model of the Baltic Sea developed with the CARDINAL modelling system and on weather forecasts provided by the HIRLAM atmospheric model of the SMHI. Forecasts of water flow through the Danish Straits, which can change the mean water level in the Baltic Sea by up to 1 m, are provided by BSH in Hamburg. The advance time of this system is 48 hours. The system is constantly being updated. Recent improvements include: a) a more refined model of the Baltic Sea with double horizontal resolution and b) twice as frequent access to the SMHI weather forecasts. While the first improvement had little effect, the second one resulted in a noticeable increase in the quality of the forecasts.

## List of participants

### **Algeria**

---

#### **Ferial Louanchi**

Laboratoire d'Environnement Marin  
Institut des Sciences de la Mer et de l'Aménagement  
du Littoral  
Bois des Cars, BP 19  
Dely - Brahim  
Algiers 16320  
Algeria  
E-mail: f\_louanchi@ismal.net

### **Australia**

---

#### **Gael Alory**

Marine and Atmospheric Research  
Commonwealth Scientific and Industrial Research  
Organisation (CSIRO)  
P.O. Box 1538  
Hobart, Tasmania 7001  
Australia  
E-mail: gael.alory@legos.obs-mip.fr

#### **Nathan L. Bindoff**

ACE CRC, IASOS and CSIRO MAR  
University of Tasmania and CSIRO  
Private Bag 80  
Hobart, Tasmania 7000  
Australia  
E-mail: n.bindoff@utas.edu.au

#### **Melanie J. Bishop**

Climate Risk CoRE  
Department of Biological Sciences  
Macquarie University, NSW 2109  
Australia  
E-mail: mbishop@bio.mq.edu.au

#### **Christopher J. Brown**

The Ecology Centre  
Goddard Building  
University of Queensland  
St Lucia, Queensland 4072  
Australia  
E-mail: christo.j.brown@gmail.com

#### **John A. Church**

Centre for Australian Weather and Climate Research  
CSIRO Marine and Atmospheric Research  
GPO Box 1538  
Hobart, Tasmania 7001  
Australia  
E-mail: john.church@csiro.au

#### **Matthew H. England**

Climate Change Research Centre  
University of New South Wales  
Sydney, NSW 2052  
Australia  
E-mail: M.England@unsw.edu.au

#### **Ming Feng**

CSIRO Marine and Atmospheric Research  
Underwood Avenue  
Floreat, WA 6014  
Australia  
E-mail: ming.feng@csiro.au

#### **Sian Grigg**

Department of Physical Geography  
Macquarie University  
Herring Road  
North Ryde, Sydney, NSW 2109  
Australia  
E-mail: siangrigg@hotmail.com

#### **Alistair Hobday**

CSIRO - Australia  
Castray Esplanade  
Hobart, Tasmania 7001  
Australia  
E-mail: alistair.hobday@csiro.au

#### **Ove Hoegh-Guldberg**

Centre for Marine Studies  
The University of Queensland  
Gehrmann Building, Level 7  
St Lucia, Queensland 4072  
Australia  
E-mail: oveh@uq.edu.au

#### **Graham W. Hosie**

SCAR Southern Ocean CPR Survey  
Australian Antarctic Division  
203 Channel Highway  
Kingston, Tasmania 7050  
Australia  
E-mail: graham.hosie@aad.gov.au

#### **Melissa K. Langridge**

School of Integrative Biology  
St Lucia Campus  
University of Queensland  
Brisbane, Queensland 4520  
Australia  
E-mail: mklangridge@hotmail.com

**Jan-Olaf Meynecke**

Australian Rivers Institute (ARI)/Griffith University  
Gold Coast Campus  
Queensland 4222  
Australia  
E-mail: j.meynecke@griffith.edu.au

**Sue Murray-Jones**

SA Dept Environment and Heritage  
P.O. Box 1047  
Adelaide, South Australia 5022  
Australia  
E-mail: murray-jones.sue@saugov.sa.gov.au

**Laura M. Parker**

School of Natural Sciences  
University of Western Sydney  
Bourke Street  
Richmond, NSW 2753  
Australia  
E-mail: lauraparker\_83@hotmail.com

**Elvira S. Poloczanska**

CSIRO Marine and Atmospheric Research  
P.O. Box 1538  
Hobart, Tasmania 7001  
Australia  
E-mail: elvira.poloczanska@csiro.au

**Anthony J. Richardson**

Department of Mathematics  
University of Queensland  
St Lucia, Queensland, 4072  
Australia  
E-mail: Anthony.Richardson@csiro.au

**Bayden Russell**

Earth and Environmental Sciences, DX 650 418  
University of Adelaide  
Adelaide, South Australia 5005  
Australia  
E-mail: bayden.russell@adelaide.edu.au

**Irina V. Sakova**

CSIRO Marine and Atmospheric Research  
CSIRO  
Castray Esplanade, GPO Box 1538  
Hobart, Tasmania 7001  
Australia  
E-mail: Irina.Sakova@csiro.au

**Alexander Sen Gupta**

Centre for Climate Change Research  
University of New South Wales  
School of Mathematics  
Sydney, NSW 2052  
Australia  
E-mail: a.sengupta@unsw.edu.au

**Lauren Thorburn**

FRC Environmental  
185 Main Road  
Wellington Point  
Brisbane, Queensland 4160  
Australia  
E-mail: lthorburn@frcenv.com.au

**Thomas W. Trull**

Antarctic Climate and Ecosystems Cooperative  
Research Centre  
University of Tasmania/CSIRO Marine and  
Atmospheric Research  
Private Bag 80  
Hobart, Tasmania 7007  
Australia

**Simon James Walker**

School of Integrative Biology  
University of Queensland  
Goddard Building  
Brisbane, Queensland 4072  
Australia  
E-mail: swalker@sib.uq.edu.au

**Evan J. Weller**

Geography and Environmental Studies  
University of Tasmania/CSIRO Marine and  
Atmospheric Research  
Private Bag 78  
Hobart, Tasmania 7001  
Australia  
E-mail: wellere@utas.edu.au

---

---

**Bangladesh**

**Ahsan U. Ahmed**

Centre for Global Change  
12-Ka/A/1 Shaymoli Second Lane  
Dhaka 1207  
Bangladesh  
E-mail: ahsan.ua@gmail.com

**Md. Kawser Ahmed**

Department of Fisheries  
University of Dhaka  
Curzol Hall Campus  
Dhaka 1000  
Bangladesh  
E-mail: kawser\_du@yahoo.com

---

---

**Belgium**

**Yosief Hiabu Berhane**

Ecological Marine Management  
Vrije Universiteit Brussel  
VUB Room 13  
Plenlaan 2, Brussels B-1050  
Belgium  
E-mail: yberhane@vub.ac.be

### **Miguel Nuevo Alarcon**

DG Research, Environment Directorate  
European Commission  
Rue du Champ de Mars 21  
Brussels B-1049  
Belgium  
E-mail: Miguel.Nuevo-Alarcon@ec.europa.eu

### **Dries Van den Eynde**

Management Unit of the North Sea Mathematical  
Models  
Royal Belgian Institute for Natural Sciences  
Gulledelle 100, Brussels 1200  
Belgium  
E-mail: D.Vandeneynde@mumm.ac.be

## **Brazil**

---

### **Patrick Degret Montezuma**

Oceanographic Institute of São Paulo University  
Rua Alagoas 133 AP14  
Higienópolis  
São Paulo, SP 01242-001  
Brazil  
E-mail: montezuma@io.usp.br

### **João Luiz Nicolodi**

Coastal Management Program  
Ministry of Environment of Brazil  
Esplanada dos Ministérios  
Bloco B. Sala 833  
Brasilia, Distrito Federal 70068-900  
Brazil  
E-mail: joao.nicolodi@mma.gov.br

### **Paulo Nobre**

Centro de Previsão de Tempo e Estudos Climáticos  
Instituto Nacional de Pesquisas Espaciais  
Rodovia Presidente Dutra, Km 40  
Cachoeira Paulista, SP 12630-000  
Brazil  
E-mail: pnobre@cptec.inpe.br

### **Rodrigo Kerr Duarte Pereira**

Department of Physics  
Fundação Universidade Federal de Rio Grande  
Av. Itália Km 8  
Rio Grande do Sul 96201-900  
Brazil  
E-mail: pgofkerr@furg.br

## **Bulgaria**

---

### **Daniela Petrova Georgieva-klisarova**

Institute of Fisheries and Aquaculture  
Boulevard Primorski 4  
P.O. Box 72  
Varna 9000  
Bulgaria  
E-mail: danibelbg@yahoo.com

### **Snejana Petrova Moncheva**

Institute of Oceanology - BAS  
1 May Str. No.40  
Varna 9000  
Bulgaria  
E-mail: snejanam@abv.bg

## **Canada**

---

### **Eddy C. Carmack**

Fisheries and Oceans Canada  
Institute of Ocean Sciences  
P.O. Box 6000  
Sidney, BC V8L 4B2  
Canada  
E-mail: CarmackE@dfo-mpo.gc.ca

### **Josef Cherniawsky**

Fisheries and Oceans Canada  
Institute of Ocean Sciences  
P.O. Box 6000  
Sidney, BC V8L 4B2  
Canada  
E-mail: CherniawskyJ@pac.dfo-mpo.gc.ca

### **William Cheung**

Fisheries Centre  
University of British Columbia  
2202 Main Mall  
Aquatic Ecosystems Research Laboratory  
Vancouver, BC V6T 1Z4  
Canada  
E-mail: w.cheung@fisheries.ubc.ca

### **Eugene Barry Colbourne**

Fisheries and Oceans Canada  
80 East White Hills Road  
St. John's, NL A1C 5X1  
Canada  
E-mail: colbourn@dfo-mpo.gc.ca

### **Earl G. Dawe**

Fisheries and Oceans Canada  
Science Branch  
80 White Hills Road  
St. John's, NL A1C 5X1  
Canada  
E-mail: dawee@dfo-mpo.gc.ca

**Joannie Ferland**

Institut des Sciences de la Mer  
University of Quebec at Rimouski  
67a rue St-Joseph E  
Rimouski, QC G5L 2A9  
Canada  
E-mail: joannie.ferland@uqar.qc.ca

**Michael G. Foreman**

Fisheries and Oceans Canada  
Institute of Ocean Sciences  
P.O. Box 6000  
Sidney, BC V8L 4B2  
Canada  
E-mail: ForemanM@pac.dfo-mpo.gc.ca

**John Curtis Fyfe**

Canadian Centre for Climate Modelling and Analysis  
Environment Canada  
University of Victoria  
P.O. Box 1700 STN CSC  
Victoria, BC V8W 2Y2  
Canada  
E-mail: John.Fyfe@ec.gc.ca

**William K.W. Li**

Ecosystem Research Division  
Bedford Institute of Oceanography  
1 Challenger Drive  
Dartmouth, NS B2Y4A2  
Canada  
E-mail: LiB@mar.dfo-mpo.gc.ca

**David L. Mackas**

Fisheries and Oceans Canada  
Institute of Ocean Sciences  
P.O. Box 6000  
Sidney, BC V8L 4B2  
Canada  
E-mail: MackasD@pac.dfo-mpo.gc.ca

**Asit Mazumder**

Department of Biology  
University of Victoria  
3800 Finnerty Road  
Victoria, BC V8W3N5  
Canada  
E-mail: mazumder@uvic.ca

**Skip McKinnell**

PICES Secretariat  
P.O. Box 6000  
Sidney, BC V8L 4B2  
Canada  
E-mail: mckinnell@pices.int

**Tom Okey**

Pew Fellow / UVic / Bamfield Marine Station  
P.O. Box 100  
Bamfield, BC V0R 1B0  
Canada  
E-mail: Thomas.Okey@gmail.com

**Richard B. Rivkin**

Ocean Sciences Centre  
Memorial University of Newfoundland  
Elizabeth Avenue  
St. John's, NF A1C 5S7  
Canada  
E-mail: rrivkin@mun.ca

**Richard E. Thomson**

Fisheries and Oceans Canada  
Institute of Ocean Sciences  
9860 West Saanich Road  
Sidney, BC V8L 4B2  
Canada  
E-mail: Richard.Thomson@dfo-mpo.gc.ca

**Marc Trudel**

Fisheries and Oceans Canada  
Pacific Biological Station  
3190 Hammond Bay Road  
Nanaimo, BC V9T 6N7  
Canada  
E-mail: trudelm@pac.dfo-mpo.gc.ca

---

**Chile**

---

**Oscar Pizarro**

Department of Geophysics  
University of Concepcion  
Cabina 7, Barrio Universitario s/n  
Concepcion, 4070386  
Chile  
E-mail: orpa@profc.udec.cl

---

**Congo, Democratic Republic of**

---

**Benjamin Mpidi Lukoki**

Fondation des Oeuvres pour la Solidarité et le Bien  
Etre Social  
Fosbes Ong 25 By-Pass  
Q/Masanga-Mbila  
C/Mong-Ngafula  
Kinshasa/D  
Kinshasa, 411 Kin 1  
Democratic Republic of Congo  
E-mail: minis\_dev@yahoo.fr

**Tony Frachaha Ndefru**

Research and Development  
Fosbes Ong 25 By-Pass  
Q/Masanga-Mbila  
C/Mong-Ngafula  
Kinshasa/D  
Kinshasa, 411 Kin 1  
Democratic Republic of Congo  
E-mail: tonyndefru@yahoo.fr

---

---

**Croatia**

**Branka Grbec**

Laboratory for Physical Oceanography  
Institute of Oceanography and Fisheries  
Set. Ivana Mestrovica 63  
Split, 21000  
Croatia  
E-mail: grbec@izor.hr

**Mira Morović**

Physical Oceanography  
Institute of Oceanography and Fisheries  
Šet. I. Meštrovića 63  
P.O. Box 500  
Split, 21000  
Croatia  
E-mail: morovic@izor.hr

---

---

**Cuba**

**Barbaro V. Moya**

Meteorological Center of Matanzas  
Milanes 27  
Matanzas, Matanzas 40100  
Cuba  
E-mail: barbaromoya@yahoo.com

---

---

**Denmark**

**Keith Brander**

DTU-Aqua  
Charlottenlund Slot  
Charlottenlund, DK-2920  
Denmark  
E-mail: keith@ices.dk

**Jörg Dutz**

Danish Institute for Fisheries Research  
Kavalergården 6  
Charlottenlund, DK-2920  
Denmark  
E-mail: jdu@difres.dk

**Adolf Karl Kellermann**

International Council for the Exploration of the Sea  
H.C. Andersens Boulevard 44-46  
Copenhagen V, DK-1553  
Denmark  
E-mail: adi@ices.dk

**Martin O. Lindegren**

Department of Marine Fisheries  
Danish Institute for Fisheries Research  
Charlottenlund Slot  
Charlottenlund (Copenhagen), 2920  
Denmark  
E-mail: mli@difres.dk

**Irene Mantzouni**

Department of Marine Ecology and Aquaculture  
DTU Aqua  
Kavalergården 6  
Charlottenlund, 2920  
Denmark  
E-mail: ima@aqua.dtu.dk

**Mark R. Payne**

National Institute of Aquatic Resources (DTU-Aqua)  
Technical University of Denmark  
Charlottenlund Slot  
Charlottenlund, 2920  
Denmark  
E-mail: mpa@difres.dk

---

---

**Egypt**

**Nayrah Abd Elnabi Ali Shaltout**

Department of Marine Chemistry  
National Institute of Oceanography and Fisheries  
1 Adeeb Mouakad Street  
Borg Aleman, Alsiouf Shamaa  
Alexandria, 4020  
Egypt  
E-mail: nayrahshaltout@yahoo.com

---

---

**Estonia**

**Jonne Kotta**

Department of Marine Biology  
Estonian Marine Institute  
Mäealuse 10a  
Tallinn, 12618  
Estonia  
E-mail: jonnekotta@gmail.com

**Georg Martin**

Department of Marine Biology  
Estonian Marine Institute  
Mäealuse 10a  
Tallinn, 12617  
Estonia  
E-mail: georg.martin@ut.ee

**Liis Rostin**

Estonian Marine Institute  
University of Tartu  
10a Mäealuse Street  
Tallinn, 12618  
Estonia  
E-mail: liis.rostin@ut.ee

**Aleksander Toompuu**

Marine Systems Institute  
Tallinn University of Technology  
Akadeemia tee 21  
Tallinn, 12618  
Estonia  
E-mail: alex@phys.sea.ee

**Germo Väli**

Department of Marine Physics  
Marine Systems Institute at Tallinn University of  
Technology (MSI)  
Akadeemia tee 21  
Tallinn, 12618  
Estonia

**Finland**

---

**Juha Matti Flinkman**

Finnish Institute of Marine Research  
FIMR, Erik Palménin aukio 1,  
P.O. Box 2  
Helsinki, FIN-00560  
Finland  
E-mail: juha.flinkman@fimr.fi

**France**

---

**Delphine Bonnet**

Laboratoire Ecosystèmes Lagunaires  
Université Montpellier 2  
UMR 5119, CC093, Place Eugène Bataillon  
Montpellier, 34095  
France  
E-mail: delphine.bonnet@univ-montp2.fr

**Fernando Gomez**

Laboratoire d'Océanographie et de Biogéochimie  
Centre d'Océanologie de Marseille, UMR 6535, CNRS  
Université de la Méditerranée  
163 Avenue de Luminy, Case 901  
Marseille, 13288  
France  
E-mail: fernando.gomez@fitoplancton.com

**Patrick Lehodey**

Spatial Oceanography Division  
CLS  
8-10 rue Hermes  
Ramonville, 31520  
France  
E-mail: PLehodey@cls.fr

**Andrew Lenton**

LOCEAN/IPSL  
Université Pierre et Marie Curie  
Case 100, 4 Place Jussieu  
Paris, Ile de France 75005  
France  
E-mail: andrew.lenton@locean-ipsl.upmc.fr

**Claire Lo Monaco**

LOCEAN-IPSL  
Université Pierre et Marie Curie  
Case 100, 4 place Jussieu  
Paris, 75252 Cedex 05  
France  
E-mail: claire.lomonaco@locean-ipsl.upmc.fr

**Nicolas Metzl**

LOCEAN/IPSL CNRS  
Université P. et M. Curie  
Case 100, 4 Place Jussieu  
Paris, 75252 Cedex 05  
France  
E-mail: metzl@ccr.jussieu.fr

**Isabelle Rombouts**

Laboratoire d'Océanographie de Villefranche-sur-mer,  
UMR CNRS 7093 (LOV)  
B.P. 28  
Villefranche-sur-mer, 06234  
France  
E-mail: isabelle.rombouts@etu.upmc.fr

**Nicholas Stephens**

Laboratoire des Sciences de l'Environnement Marin  
Institut Universitaire Européen de la Mer  
Place Nicolas Copernic  
Technopôle Brest Iroise  
Plouzané, 29280  
France  
E-mail: nicholas.stephens@univ-brest.fr

**Didier Swingedouw**

GlobC  
CERFACS  
42 Avenue Gaspard Coriolis  
Toulouse, 31057  
France  
E-mail: swingedo@cerfacs.fr

## **French Guiana**

---

### **Fabian Blanchard**

Mediterranean and Tropical Fisheries Department  
IFREMER  
B.P. 477, Domaine Suzini  
Cayenne, 97300  
French Guiana  
E-mail: Fabian.Blanchard@ifremer.fr

## **Gambia**

---

### **Pa Malick Secka**

Sabscoms Multimedia  
18 Lancaster Street  
Banjul, 00220  
Gambia  
E-mail: seckamalick@yahoo.com

## **Germany**

---

### **Juergen Alheit**

Leibniz Institute for Baltic Sea Research  
Seestr. 15  
Rostock, 18119  
Germany  
E-mail: juergen.alheit@io-warnemuende.de

### **Claus W. Boening**

Ocean Circulation and Climate Dynamics  
Leibniz-Institute of Marine Sciences (IFM-GEOMAR)  
Duesternbrooker Weg 20  
Kiel, D-24105  
Germany  
E-mail: cboening@ifm-geomar.de

### **Andreas Irmisch**

Forschungszentrum Jülich GmbH  
Seestraße 15  
Rostock, 18119  
Germany  
E-mail: a.irmisch@fz-juelich.de

### **Holger Klein**

Bundesamt für Seeschifffahrt & Hydrographie  
Bernhard-Nocht-Str. 78  
Hamburg, 20359  
Germany  
E-mail: holger.klein@bsh.de

### **Wolfgang Koeve**

Leibniz Institute of Marine Sciences (IFM-GEOMAR)  
West Campus, Düsternbrooker Weg 20  
Kiel, 24145  
Germany  
E-mail: wkoeve@ifm-geomar.de

### **Wilhelm Kuttler**

University of Duisburg-Essen  
Universitätsstr. 5  
Essen, NRW 45141  
Germany  
E-mail: wilhelm.kuttler@uni-due.de

### **Christian Moellmann**

Institute for Hydrobiology and Fisheries Science  
University of Hamburg  
Grosse Elbstrasse 133  
Hamburg, D-22767  
Germany  
E-mail: christian.moellmann@uni-hamburg.de

### **Myron A. Peck**

Center for Marine and Climate Research  
University of Hamburg  
Olbersweg 24  
Hamburg, 22767  
Germany  
E-mail: myron.peck@uni-hamburg.de

### **Hans O. Pörtner**

Alfred-Wegener-Institute  
Am Handelshafen 12  
Bremerhaven, 27578  
Germany  
E-mail: hpoertner@awi-bremerhaven.de

### **Maya Lea Robert**

Alfred-Wegener-Institute for Polar and Marine  
Research (AWI)  
Am Handelshafen 12  
Bremerhaven, 27570  
Germany  
E-mail: Maya.Robert@awi.de

### **Merja H. Schlueter**

GKSS-Forschungszentrum, Institute for Coastal  
Research  
Max-Planck-Str. 1  
Geesthacht, 21502  
Germany  
E-mail: merja.schlueter@gkss.de

### **Jörn Oliver Schmidt**

Leibniz Institute of Marine Sciences (IFM-GEOMAR)  
Office Bldg. West, Düsternbrooker Weg 20  
Kiel, 24105  
Germany  
E-mail: jschmidt@ifm-geomar.de

### **Karina Stockmann**

GKSS Research Centre  
Max-Planck-Str. 1  
Geesthacht, 21502  
Germany  
E-mail: karina.stockmann@gkss.de

**Martin Visbeck**

IFM-GEOMAR  
Duesternbrooker Weg 20  
Kiel, 24105  
Germany  
E-mail: [mvisbeck@ifm-geomar.de](mailto:mvisbeck@ifm-geomar.de)

**Hans von Storch**

Institute for Coastal Research  
GKSS Research Center  
Max-Planck-Str. 1  
Geesthacht, 21502  
Germany  
E-mail: [hvonstorch@web.de](mailto:hvonstorch@web.de)

**Julia Wohlers**

Leibniz Institute of Marine Sciences IFM-GEOMAR  
Duesternbrooker Weg 20  
Kiel, 24105  
Germany  
E-mail: [jwohlers@ifm-geomar.de](mailto:jwohlers@ifm-geomar.de)

---

**Ghana**

---

**Lambini Sakab Kombat**

Youth Environmental Project  
NYEP  
Doris Seidu, Parliament House  
Accra, 0233  
Ghana  
E-mail: [sakablambini@yahoo.com](mailto:sakablambini@yahoo.com)

---

**Greece**

---

**Evgenia Lefkaditou**

Hellenic Centre for Marine Resources  
Institute of Marine Biological Resources  
Ag. Kosmas, Helliniko  
Athens, 16777  
Greece  
E-mail: [teuthis@ath.hcmr.gr](mailto:teuthis@ath.hcmr.gr)

---

**India**

---

**Chikka Kalyani Devasena**

Centre for Mathematical Modeling and Computer  
Simulation (C-MMACS)  
Belur Campus Wind Tunnel Road  
Bangalore, Karnataka 560037  
India  
E-mail: [kalyani@cmmacs.ernet.in](mailto:kalyani@cmmacs.ernet.in)

**Naveen Gandhi**

Planetary and Geosciences Division  
Physical Research Laboratory  
Navrangpura  
Amedabad, Gujrat 380 009  
India  
E-mail: [naveen@prl.res.in](mailto:naveen@prl.res.in)

**Edward JK Patterson**

Suganthi Devadason Marine Research Institute  
44-Beach Road  
Tuticorin, Tamil Nadu 628 001  
India  
E-mail: [jkpatty@hotmail.com](mailto:jkpatty@hotmail.com)

**Santosh Kumar Sarkar**

Department of Marine Science  
University Of Calcutta  
35 Ballygunge Circular Road  
Calcutta 700019  
India  
E-mail: [sarkar.santosh@gmail.com](mailto:sarkar.santosh@gmail.com)

**Umesh Kumar Dineshwar Singh**

Indian Institute of Tropical Meteorology  
Dr. Homi Bhabha Road  
Near NCL Post, Pashan  
Pune, Maharashtra 411008  
India  
E-mail: [umesh@tropmet.res.in](mailto:umesh@tropmet.res.in)

---

**Indonesia**

---

**Denny Wijaya Ksuma**

Indonesia Ministry of Marine Affairs and Fisheries  
Institution for Marine Research and Observation  
Br. Dangin Berawah, Desa Perancak  
Negara, Bali 82251  
Indonesia  
E-mail: [denny@dkp.go.id](mailto:denny@dkp.go.id)

---

**Ireland**

---

**Heather Cannaby**

Marine Climate Change  
Marine Institute  
Rinville, Oranmore, Eire  
Ireland  
E-mail: [heather.cannaby@marine.ie](mailto:heather.cannaby@marine.ie)

**Caroline Cusack**

Marine Institute  
Rinville, Oranmore, Co Galway  
Ireland  
E-mail: [caroline.cusack@marine.ie](mailto:caroline.cusack@marine.ie)

**Y. Sinan Husrevoglu**

Marine Institute  
Rinville, Oranmore, Co. Galway  
Ireland  
E-mail: [sinan.husrevoglu@marine.ie](mailto:sinan.husrevoglu@marine.ie)

**Christopher Lynam**

Marine Institute  
Rinville, Oranmore, Co. Galway  
Ireland  
E-mail: [Chris.Lynam@marine.ie](mailto:Chris.Lynam@marine.ie)

**Ilaria Nardello**

Marine Institute  
Rinville, Oranmore, Co. Galway  
Ireland  
E-mail: [ilaria.nardello@marine.ie](mailto:ilaria.nardello@marine.ie)

**Glenn Nolan**

Marine Institute  
Rinville, Oranmore, Co. Galway  
Ireland  
E-mail: [glenn.nolan@marine.ie](mailto:glenn.nolan@marine.ie)

**Ciar O'Toole**

Marine Institute  
Furnace, Newport, Co. Mayo  
Ireland  
E-mail: [ciar.otoole@marine.ie](mailto:ciar.otoole@marine.ie)

**Italy**

---

---

**Daniele Bevacqua**

Scienze Ambientali  
Univerità degli Studi di Parma  
via Usberti 11/A  
Parma, 43100  
Italy  
E-mail: [daniele.bevacqua@poste.it](mailto:daniele.bevacqua@poste.it)

**Stefano Ciavatta**

EuroMediterranean Centre for Climate Change  
(CMCC)  
Via della Libertà 12  
Venice, 30175  
Italy  
E-mail: [ciavatta@unive.it](mailto:ciavatta@unive.it)

**Tamara Cibic**

National Institute of Oceanography and Experimental  
Geophysics  
Via A. Piccard 54  
Trieste, 34014  
Italy

**Alessandra Conversi**

ISMAR - La Spezia  
C.N.R. - National Research Council  
Forte S. Teresa, Loc. Pozzuolo  
Lerici, (SP) 19032  
Italy  
E-mail: [a.conversi@ismar.cnr.it](mailto:a.conversi@ismar.cnr.it)

**Saverio Devoti**

ICRAM, Central Institute for Marine Research  
Via di Casalotti 300  
Roma, 00166  
Italy  
E-mail: [s.devoti@icram.org](mailto:s.devoti@icram.org)

**Lyudmila Kamburska**

GEM Unit, Institute for Environment and  
Sustainability  
European Commission-DG JRC  
TP 272, Via E. Fermi 1  
Ispra, Varese 21020  
Italy  
E-mail: [lyudmila.kamburska@jrc.it](mailto:lyudmila.kamburska@jrc.it)

**Simone Libralato**

Department of Oceanography  
OGS  
Borgo Grotta Gigante  
Brisciki 42/c  
Sgonico, Trieste 34010  
Italy  
E-mail: [slibralato@ogs.trieste.it](mailto:slibralato@ogs.trieste.it)

**Serena Massolo**

Department of Chemistry and Industrial Chemistry  
University of Genova  
via Dodecaneso 31  
Genoa, 16146  
Italy  
E-mail: [massolo@chimica.unige.it](mailto:massolo@chimica.unige.it)

**Maria Grazia Mazzocchi**

Laboratory of Biological Oceanography  
Stazione Zoologica Anton Dohrn  
Villa Comunale  
Napoli, 80121  
Italy  
E-mail: [grazia@szn.it](mailto:grazia@szn.it)

**Paolo Montagna**

ICRAM  
Via Casalotti 300  
Rome, 00166  
Italy  
E-mail: [paolomontagna@hotmail.com](mailto:paolomontagna@hotmail.com)

**Tiziana Peluso**

Istituto di Scienze Marine (ISMar)  
CNR  
Forte Santa Teresa  
Pozzuolo di Lerici  
La Spezia 19036  
Italy  
E-mail: [tiziana.peluso@uniparthenope.it](mailto:tiziana.peluso@uniparthenope.it)

**Nunzio Penna**

Environmental Chemistry Department  
University of Urbino  
Loc. Crocicchia  
Urbino, Pesaro-Urbino 61029  
Italy  
E-mail: [cebiam@uniurb.it](mailto:cebiam@uniurb.it)

**Giovanni Rusciadelli**

Scienze della Terra  
Università G. d'Annunzio di Chieti  
Via dei Vestini, 33  
Chieti, 66013  
Italy  
E-mail: grusciadelli@unich.it

**Simone Russo**

ICRAM  
Via di Casalotti 300  
Rome 00166  
Italy  
E-mail: s.russo@icram.org

**Vincent Vantrepotte**

Global Environment Monitoring Unit  
Institute for Environment and Sustainability  
Joint Research Centre, European Commission  
Via Fermi, TP 272  
Ispra, 21027  
Italy  
E-mail: vincent.vantrepotte@jrc.it

**Pierluigi Viaroli**

Department of Environmental Science  
University of Parma  
Viale G.P. Usberti 33/A  
Parma, 43100  
Italy  
E-mail: pierluigi.viaroli@unipr.it

**Damiano Virgilio**

Department of Biological Oceanography  
National Institute of Oceanography and Experimental  
Geophysics  
via Auguste Piccard 54  
Trieste, 34014  
Italy

**Japan**

---

**Maki Noguchi Aita**

Ecosystem Change Research Program  
Frontier Research Center for Global Change,  
JAMSTEC  
3173-25 Showa-machi, Kanazawa-ku  
Yokohama, Kanagawa 236-0001  
Japan  
E-mail: macky@jamstec.go.jp

**Michio Aoyama**

Geochemical Research Department  
Meteorological Research Institute  
1-1 Nagamine  
Tsukuba, Ibaraki 305-0052  
Japan  
E-mail: maoyama@mri-jma.go.jp

**Etienne Boisnier**

1-15-1 Minamidai  
Nakano-ku  
Tokyo 164-8639  
Japan  
E-mail: etienne@nenv.k.u-tokyo.ac.jp

**Sanae Chiba**

Ecosystem Change Research Program  
Frontier Research Center for Global Change,  
JAMSTEC  
3173-25 Showa-machi, Kanazawa-ku  
Yokohama, Kanagawa 236-0001  
Japan  
E-mail: chibas@jamstec.go.jp

**Seita Emori**

Center for Global Environmental Research  
National Institute for Environmental Studies  
16-2 Onogawa  
Tsukuba, Ibaraki 305-8506  
Japan  
E-mail: emori@nies.go.jp

**Masahiko Fujii**

Sustainability Governance Project, Creative Research  
Initiative  
Hokkaido University  
N9W8, Kita-ku  
Sapporo, Hokkaido 060-0809  
Japan

**Taketo Hashioka**

Ecosystem Change Research Program  
Frontier Research Center for Global Change,  
JAMSTEC  
3173-25 Showa-machi, Kanazawa-ku  
Yokohama, 236-0001  
Japan  
E-mail: hashioka@jamstec.go.jp

**Akio Ishida**

Frontier Research Center for Global Change  
Japan Agency for Marine-Earth Science and  
Technology (JAMSTEC)  
3173-25 Showa-machi, Kanazawa-ku  
Yokohama, 236-0001  
Japan

**Michio J. Kishi**

Graduate School of Environmental Science  
Hokkaido University  
N10W5, Kita-ku  
Sapporo, Hokkaido 060-0810  
Japan  
E-mail: mjkish@nifty.com

**Michinobu Kuwae**

Center for Marine Environmental Studies  
Ehime University  
Bunkyo-cho 2-5  
Matsuyama, Ehime 790-8577  
Japan  
E-mail: mkuwae@sci.ehime-u.ac.jp

**Kazuhiro Misumi**

Environmental Science Research Laboratory  
Central Research Institute of Electric Power Industry  
1646 Abiko  
Abiko-shi, Chiba-ken 270-1194  
Japan  
E-mail: misumi@criepi.denken.or.jp

**Toru Miyama**

Frontier Research Center for Global Change  
JAMSTEC  
3173-25 Showa-machi, Kanazawa-ku  
Yokohama, 236-0001  
Japan  
E-mail: tmiyama@jamstec.go.jp

**Kentaro Morita**

Fisheries Research Agency  
Hokkaido National Fisheries Research Institute  
116 Katsurakoi  
Kushiro, Hokkaido 085-0802  
Japan  
E-mail: moritak@affrc.go.jp

**Toshiro Saino**

Hydrospheric Atmospheric Research Center (HyARC)  
Nagoya University  
Furo-cho, Chikusa-ku  
Nagoya, Aichi 464-8601  
Japan  
E-mail: tsaino@hyarc.nagoya-u.ac.jp

**Sei-Ichi Saitoh**

Graduate School of Fisheries Sciences  
Hokkaido University  
3-1-1 Minato-cho  
Hakodate, Hokkaido 041-8611  
Japan  
E-mail: ssaitoh@salmon.fish.hokudai.ac.jp

**Wataru Sasaki**

Frontier Research Center for Global Change  
Japan Agency for Marine-Earth Science and Technology  
3173-25 Showa-machi,  
Kanazawa-ku, Yokohama  
Kanagawa 236-0001  
Japan  
E-mail: wsasaki@jamstec.go.jp

**Kosei Sasaoka**

Frontier Research Center for Global Change  
JAMSTEC  
3173-25, Showa-machi, Kanazawa-ku  
Yokohama, 236-0001  
Japan  
E-mail: sasaoka@jamstec.go.jp

**Shusaku Sugimoto**

Department of Geophysics  
Graduate School of Science, Tohoku University  
6-3 Aramaki-aza-Aoba, Aoba-ku  
Sendai, 980-8578  
Japan  
E-mail: sugi@pol.geophys.tohoku.ac.jp

**Takashige Sugimoto**

School of Marine Science and Technology  
Tokai University  
3-20-1 Orido, Shimizu-ku  
Shizuoka, Shizuoka Prefecture 424-8610  
Japan  
E-mail: sugimoto@scc.u-tokai.ac.jp

**Kazuaki Tadokoro**

Stock Productivity Section  
Tohoku National Fisheries Research Institute, FRA  
3-27-5 Shinhama-cho  
Shiogama, Miyagi 985-0001  
Japan  
E-mail: den@affrc.go.jp

**Kazutaka Takahashi**

Tohoku National Fisheries Research Institute, FRA  
3-27-5 Shinhama-cho  
Shiogama, Miyagi 985-0001  
Japan  
E-mail: issey@affrc.go.jp

**Yongjun Tian**

Japan Sea Fisheries Resources Division  
Japan Sea National Fisheries Research Institute, FRA  
1-5939-22 Suido-cho, Chuo-ku  
Niigata, 951-8121  
Japan  
E-mail: yjtian@fra.affrc.go.jp

**Akihiko Yatsu**

Seikai National Fisheries Research Institute, FRA  
1551-8, Taira-machi  
Nagasaki, 851-2213  
Japan  
E-mail: yatsua@fra.affrc.go.jp

**Naoki Yoshie**

Biological Oceanography Section  
Tohoku National Fisheries Research Institute, FRA  
3-27-5 Shinhama-cho  
Shiogama, Miyagi 985-0001  
Japan  
E-mail: nyoshie@affrc.go.jp

### **Takeshi Yoshimura**

Environmental Science Research Laboratory  
Central Research Institute of Electric Power Industry  
1646 Abiko  
Abiko, Chiba 270-1194  
Japan  
E-mail: ytakeshi@criepi.denken.or.jp

### **Jordan**

---

#### **Mohammad Badran**

Marine Science Station  
University of Jordan  
P.O. Box 195  
South Beach Aqaba  
Aqaba, 7722  
Jordan  
E-mail: abaadam@hotmail.com

### **Kenya**

---

#### **Jared O. Bosire**

Kenya Marine and Fisheries Research Institute  
(KMFRI)  
P.O. Box 81651  
Mombasa, 81651  
Kenya  
E-mail: jbosire@kmfri.co.ke

### **Latvia**

---

#### **Georgs Kornilovs**

Latvian Fish Resources Agency  
Daugavgrivas str. 8  
Riga, LV-1048  
Latvia  
E-mail: Georgs.Kornilovs@lzra.gov.lv

#### **Didzis Ustups**

Faculty of Biology  
University of Latvia  
Kronvalda Blvd 4  
Riga, LV 1048  
Latvia  
E-mail: didzis.ustups@lzra.gov.lv

### **Libya**

---

#### **Hussein B. Ghanoush**

Libyan Petroleum Institute LPI  
P.O. Box 6431  
Gergarash Street  
Tripoli  
Libya  
E-mail: ganoush@hotmail.com

### **Mauritania**

---

#### **Mohamed Ahmed Sidi Cheikh**

Observatoire  
National Park of Banc d'Arguin  
BP 5355, Avenue Gemal Abd-Nasseur  
Nouakchott, 5355  
Mauritania  
E-mail: oulidsidicheikh@yahoo.fr

### **Monaco**

---

#### **James C. Orr**

Marine Environment Laboratories  
IAEA  
4 Quai Antoine 1er  
Monaco, MC-98000  
Monaco  
E-mail: james.orr1@gmail.com

### **Morocco**

---

#### **Hassan El Ouizgani**

Faculté des Sciences  
BP 8106  
Agadir, Souss 80000  
Morocco  
E-mail: h.elouizgani@menara.ma

### **Namibia**

---

#### **Jock C. Currie**

Department of Zoology  
University of Cape Town  
12 Mowen street  
Swakopmund  
Namibia  
E-mail: jockcurrie@gmail.com

### **Nepal**

---

#### **Hari Kumar Thapa**

Economic and Social Development Council- Nepal  
Ka-587 Tinkune 35 Koteshwor  
Kathmandu, GPO Box 23581  
Nepal  
E-mail: info@esdc.org.np

### **Netherlands Antilles**

---

#### **Herman Gerritsen**

Deltares/Delft Hydraulics  
P.O. Box 177  
Delft, 2600 MH  
Netherlands Antilles  
E-mail: herman.gerritsen@deltares.nl

## **New Zealand**

---

### **Keith Andrew Hunter**

Chemistry Department  
University of Otago  
Union Place  
PO Box 51  
Dunedin, Otago 9054  
New Zealand  
E-mail: khunter@chemistry.otago.ac.nz

### **Mary Elizabeth Livingston**

Ministry of Fisheries  
101-103 The Terrace  
Wellington, P.O. Box 1020  
New Zealand  
E-mail: mary.livingston@fish.govt.nz

### **Candida Savage**

University of Otago  
310 Castle Street  
Dunedin, 9016  
New Zealand  
E-mail: candida.savage@stonebow.otago.ac.nz

## **Nigeria**

---

### **Archibong O. Ediang**

Marine Division  
Nigerian Meteorological Agency  
PMB 1215, Oshodi  
Lagos, 23401  
Nigeria  
E-mail: ediang2000@yahoo.com

### **Hyacinth Cyprain Nnamchi**

Department of Geography  
University of Nigeria  
Nsukka, Enugu State 410001  
Nigeria  
E-mail: nnamchy@yahoo.co.uk

### **Micheal Olukayode Olaniyan**

Nigeria Merchant Navy Officers Association  
24 Palace Road  
Olodi Apapa  
Lagos 2341  
Nigeria  
E-mail: nigeriamerchantnavy\_1@yahoo.com

### **Olanrewaju Oyewole**

Lagos State University  
P.O. Box 2185  
Ikeja, Lagos 100001  
Nigeria  
E-mail: lanreoyewole@gmail.com

## **Norway**

---

### **Knut Yngve Børsheim**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: yngve.borsheim@imr.no

### **Elena Eriksen**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: elena.eriksen@imr.no

### **Solfrid Sætre Hjøllo**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: Solfrid.Hjollo@imr.no

### **Randi Ingvaldsen**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: randi@imr.no

### **Tore Jakobsen**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: tore.jakobsen@imr.no

### **Geir Odd Johansen**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: geir.odd.johansen@imr.no

### **Marcos Llope**

Centre for Ecological and Evolutionary Synthesis,  
Department of Biology  
University of Oslo  
P.O. Box 1066 Blindern  
N-0316 Oslo  
Norway  
E-mail: marcos.llope@bio.uio.no

### **Harald Loeng**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: harald.loeng@imr.no

### **Torbjørn Lorentzen**

Bjerknes Centre for Climate Research  
Allegaten 55  
N-5007 Bergen  
Norway  
E-mail: torbjorn.lorentzen@bjerknes.uib.no

### **Jan Erik Stiansen**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: jan.erik.stiansen@imr.no

### **Frode Vikebo**

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5817 Bergen  
Norway  
E-mail: frovik@imr.no

## **People's Republic of China**

---

### **Fengfeng Le**

SIO, SOA  
36 Baochubei Road  
Hangzhou, 310012  
People's Republic of China  
E-mail: le\_ff@126.com

### **Xiuren Ning**

Marine Ecosystem and Biogeochemistry  
Second Institute of Oceanography, SOA  
36 Baochu Bei Road  
Hangzhou, Zhejiang 310012  
People's Republic of China  
E-mail: ning\_xr@126.com

### **Huaming Yu**

College of Physical and Environmental Oceanography  
Ocean University of China  
238 Songling Road  
Qingdao, Shan Dong 266100  
People's Republic of China  
E-mail: huamingyu@gmail.com

### **Xia Zhang**

Room 218, Yingxue Building  
Xiamen University  
Xiamen City, Fujian Province 361005  
People's Republic of China  
E-mail: tyouxia@gmail.com

## **Peru**

---

### **Enrique E. Aguirre**

University of San Marcos  
Alfonso Ugarte 408, San Cayetano  
Lima 10  
Peru  
E-mail: enrique.huaringa@gmail.com

## **Philippines**

---

### **Maria Rebecca Alviar Campos**

Southeast Asian Regional Center for Graduate Studies  
and Research in Agriculture  
10996 Campos Compound  
Faculty Village College  
Laguna 4031  
Philippines  
E-mail: cmaribec@yahoo.com

### **Ulysses Madrid Montojo**

Marine Fisheries and Environmental Research  
National Fisheries Research and Development Institute  
Kayumanggi Press Building  
940 Quezon Avenue  
Quezon City  
Metro Manila 1103  
Philippines  
E-mail: umontojo@pacific.net.ph

## **Poland**

---

### **Monika Kędra**

Department of Marine Ecology  
Institute of Oceanology PAS  
Powstańców Warszawy 55  
Sopot, 81-712  
Poland  
E-mail: kedra@iopan.gda.pl

## **Portugal**

---

### **Henrique Nogueira Cabral**

Instituto de Oceanografia  
Faculdade de Ciências da Universidade de Lisboa  
Campo Grande  
1749-016 Lisboa  
Portugal  
E-mail: hcabral@fc.ul.pt

### **Maria Alexandra Chicharo**

Centro de Ciências do Mar, FCMA  
University of Algarve  
Campus de Gambelas  
Faro, 8005-137  
Portugal  
E-mail: mchichar@ualg.pt

**Maria José Costa**

Faculdade de Ciências da Universidade de Lisboa  
Instituto de Oceanografia  
Campo Grande  
Lisboa, 1749-016  
Portugal  
E-mail: andre.sequeira@sa.fc.ul.pt

**António Jorge da Silva**

Instituto Hidrográfico  
Rua das Trinas 49  
Lisboa, 1249-093  
Portugal  
E-mail: jorge.silva@hidrografico.pt

**Ana Paula Oliveira**

Aquatic Environment and Biodiversity Unit  
Instituto Nacional de Recursos Biológicos (INRB-  
IPIMAR)  
Avenida Brasília  
Lisbon, 1449-006  
Portugal  
E-mail: aoliveira@ipimar.pt

**Raquel Silva**

IHRH/FEUP  
Rua Dr. Roberto Frias  
Porto, 4200-465  
Portugal  
E-mail: resilva@fe.up.pt

**Catarina Vinagre**

Instituto de Oceanografia, Faculdade de Ciências  
Universidade de Lisboa  
Campo Grande  
Lisbon, 1749-016  
Portugal  
E-mail: cmvinagre@fc.ul.pt

---

---

**Puerto Rico**

**Jorge E. Corredor**

Department of Marine Sciences  
University of Puerto Rico  
Road 304 End  
Magueyes Island  
Lajas, PR 00667  
Puerto Rico  
E-mail: quimocea@caribe.net

**Julio Manuel Morell**

Department of Marine Sciences  
University of Puerto Rico  
Road 304 End  
Magueyes Island  
Lajas, PR 00667  
Puerto Rico  
E-mail: jmorell@uprm.edu

---

---

**Republic of Korea**

**Sukyung Kang**

Yeongdong Inland Fisheries Research Institute  
National Fisheries Research and Development Institute  
424-1, Songhyun-ri, Songang-Myeon  
Yangyang-Gun, Gangwon-do 215-821  
Republic of Korea  
E-mail: kangsk@momaf.go.kr

**Yeonghye Kim**

National Fisheries Research and Development Institute  
408-1 Shirang-ri, Gijang-up, Gijang-gun  
Busan, 619-902  
Republic of Korea

**Seok Jae Kwon**

National Oceanographic Research Institute  
1-17, 7Ga, Hang-dong, Jung-Gu  
Incheon, 400-800  
Republic of Korea  
E-mail: sj79kwon@momaf.go.kr

**Jae-Bong Lee**

National Fisheries Research and Development Institute  
408-1 Shirang-ri, Kijang-up, Kijang-gun  
Busan, 619-905  
Republic of Korea  
E-mail: leejb@nfrdi.re.kr

**Il-Ju Moon**

College of Ocean Science  
Cheju National University  
Ara 1 Dong  
Jejusi, Jejudo 690-756  
Republic of Korea  
E-mail: ijmoon@cheju.ac.kr

**Taehee Na**

Pusan National University  
Chemical Oceanography Lab.  
Busan, 609-735  
Republic of Korea  
E-mail: ocean95@pusan.ac.kr

---

---

**Russia**

**Elena Arashkevich**

P.P. Shirshov Institute of Oceanology  
36 Nakhimovsky Prospect  
Moscow, 117997  
Russia  
E-mail: aelena@ocean.ru

**Alexander Sergeevich Averkiev**

Russian State Hydrometeorological University  
Maloochtinsky, 98  
Saint-Petersburg, 195196  
Russia  
E-mail: asav@rshu.ru

**Oleg A. Bulatov**

Russian Federal Research Institute of Fisheries and  
Oceanography (VNIRO)  
17 V. Krasnoselskaya Street  
Moscow, 107140  
Russia  
E-mail: obulatov@vniro.ru

**Alexander N. Demidov**

Department of Oceanography  
Moscow State University  
GZ MGU, Lininskie Gory  
Moscow, 119992  
Russia  
E-mail: alik1@mail.ru

**Anastasia S. Falina**

P.P. Shirshov Institute of Oceanology, RAS  
Nakhimovskiy prospekt 36  
Moscow, 117997  
Russia  
E-mail: falina\_a@mail.ru

**Sergey Gulev**

SAIL  
P.P. Shirshov Institute of Oceanology  
36 Nakhimovskiy Prospekt  
Moscow, 117997  
Russia  
E-mail: gul@sail.msk.ru

**Talgat R. Kilmatov**

Department of Physical Oceanography  
V.I. Il'ichev Pacific Oceanological Institute (POI)  
FEB RAS  
43 Baltiyskaya Street  
Vladivostok, Primorsky 690041  
Russia  
E-mail: talgat\_k@mail.ru

**Konstantin Alexeevich KLevanny**

St.Petersburg Center for Hydrometeorology  
23 liniya V.O. 2a  
St.Petersburg, 199106  
Russia  
E-mail: klevanny@x-users.ru

**Evgueni Kulikov**

Tsunami Lab  
P. P. Shirshov Institute of Oceanology  
36 Nakhimovskiy Prospekt  
Moscow, 117997  
Russia  
E-mail: kulikove@cnt.ru

**Stanislav Martyanov**

Russian State Hydrometeorological University  
Malookhtinsky Prospekt 98  
Saint-Petersburg, 195196  
Russia  
E-mail: martyanov-sd@rambler.ru

**Suleiman Mostamandy**

Weather Forecast  
Russian State Hydrometeorological University  
Malaokhtenskaya 98  
St. Petersburg, 195196  
Russia  
E-mail: suleiman@meteo.nw.ru

**Galina V. Moyseychenko**

Laboratory of Applied Ecology and Toxicology  
Pacific Research Institute of Fisheries and  
Oceanography (TINRO-Center)  
4 Shevchenko Alley  
Vladivostok, 690950  
Russia  
E-mail: emmajessica@mail.ru

**Vadim V. Navrotsky**

V.I. Il'ichev Pacific Oceanological Institute, FEB RAS  
43 Baltiyskaya Street  
Vladivostok, Primorsky 690041  
Russia  
E-mail: navrotskyv@poi.dvo.ru

**Oleg Petrovich Nikitin**

State Oceanographic Institute  
Kropotkinsky per., 6  
Moscow, 119034  
Russia  
E-mail: opnikitin@mail.ru

**E. Orlova**

Polar Research Institute of Marine Fisheries and  
Oceanography (PINRO)  
6 Knipovich Street  
Murmansk, 183763  
Russia  
E-mail: inter@pinro.murmansk.ru

**Alexander B. Rabinovich**

Russian Academy of Sciences  
P.P. Shirshov Institute of Oceanology  
36 Nakhimovskiy Prospekt  
Moscow, 117997  
Russia  
E-mail: abr@iki.rssi.ru

**Artem A Sarafanov**

P.P. Shirshov Institute of Oceanology  
36 Nakhimovskiy Prospekt  
Moscow, 117997  
Russia  
E-mail: sarafanov@mail.ru

**Roman Tarakanov**

P.P. Shirshov Institute of Oceanology  
36 Nakhimovskiy Prospekt  
Moscow, 117997  
Russia  
E-mail: rtarakanov@gmail.com

**Oleg Titov**

Polar Research Institute of Marine Fisheries and  
Oceanography (PINRO)  
6 Knipovich Street  
Murmansk, 183038  
Russia  
E-mail: titov@pinro.ru

**Igor A. Zhabin**

V.I. Il'ichev Pacific Oceanological Institute, FEB RAS  
43 Baltiyskaya Street  
Vladivostok, Primorsky 690041  
Russia  
E-mail: zhabin@poi.dvo.ru

**Yury I. Zuenko**

Pacific Research Institute of Fisheries and  
Oceanography (TINRO-Center)  
4 Shevchenko Alley  
Vladivostok, Primorsky 690950  
Russia  
E-mail: zuenko@tinro.ru

**Saudi Arabia**

---

**Khaled A Al Abdulkader**

Environmental Protection Department  
Saudi Aramco  
P.O. Box 06348  
Dhahran, Eastern 31311  
Saudi Arabia  
E-mail: khaled.abdulkader@aramco.com

**Sénégal**

---

**Alhaji Sanfa Mansaray**

Masianday Foundation  
Rue 22X27 BP.28249  
Medina, Dakar  
Senegal 22182  
West Africa

**Somalia**

---

**Iman Ali Abdi**

Ministry of Environment  
Makah Al Mukarama Street in Mogadishu  
Mogadishu  
Banadir 2525  
Somalia  
E-mail: iimaancali@hotmail.com

**South Africa**

---

**Daniel Baird**

University of Stellenbosch  
Merriman Avenue  
Stellenbosch, Western Cape 7602  
South Africa  
E-mail: danbaird@sun.ac.za

**Albrecht Götz**

SAEON  
18 Somerset Street  
Grahamstown, Eastern Cape 6140  
South Africa  
E-mail: albrecht@saeon.ac.za

**Juliet Clair Hermes**

Marine Offshore Node  
South African Environmental Observation Network  
Private Bag X2, Roggebaai  
Cape Town, 8012  
South Africa  
E-mail: juliet@saeon.ac.za

**Angus William Paterson**

SAEON  
18 Somerset Street  
Private Bag 1015  
Grahamstown, Eastern Cape 6140  
South Africa  
E-mail: angus@saeon.ac.za

**Chris Reason**

Department of Oceanography  
University of Cape Town  
Private Bag X3  
Rondebosch, 7701  
South Africa  
E-mail: Chris.Reason@uct.ac.za

**Amanuel Afewerki Syoum**

Johannesburg  
Maakel 49751  
South Africa  
E-mail: moreah71@yahoo.com

**Sakhile Vincent Tsotsobe**

DEAT/MCM  
Marine Research Aquarium  
Beach Road  
Sea Point  
Cape Town, Western Cape 8005  
South Africa  
E-mail: stsobs@deat.gov.za

**Hans Maxime Verheye**

Marine and Coastal Management  
Marine Research Aquarium  
Beach Road  
Sea Point  
Cape Town, Western Cape 8001  
South Africa  
E-mail: hverheye@deat.gov.za

**Spain**

---

**Miguel Alcaraz**

Institut de Ciències del Mar, CSIC  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, Catalunya 08003  
Spain  
E-mail: miguel@icm.csic.es

**Ganix Esnaola Aldanondo**

AZTI-Tecnalia, Marine Research Division  
Herrera kaia portualdea z/g  
Pasaia, 20110  
Spain  
E-mail: gesnaola@pas.azti.es

**Ines Alvarez**

Física Aplicada  
Universidad de Vigo  
Facultad de Ciencias de Ourense  
Edificio de Física  
Ourense, 32004  
Spain  
E-mail: ialvarez@uvigo.es

**Marta Alvarez**

Department of Biogeochemistry  
IMEDEA  
C/ Miquel Marqués 21  
Esporles, Mallorca 07190  
Spain  
E-mail: marta.alvarez@uib.es

**Francisco Alvarez-Garcia**

Department of Physics  
University of Alcalá  
Ctra. Madrid-Barcelona, km. 33.6  
Alcalá de Henares, 28871  
Spain  
E-mail: franciscoj.alvarez@uah.es

**Ricardo Anadón**

Biología de Organismos y Sistemas  
Universidad de Oviedo  
Valentin Andres Alvarez s/n  
Oviedo, Asturias 33071  
Spain  
E-mail: ranadon@uniovi.es

**María Aranguren-Gassis**

Ecología y Biología Animal  
Universidad de Vigo  
Facultad Cc. del Mar, ctra. Colegio Universitario s/n  
Vigo, Pontevedra 36310  
Spain  
E-mail: aranguren@uvigo.es

**Josep Baeza**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: josepinbm@hotmail.com

**Verónica M. Benítez Barrios**

Facultad de Ciencias del Mar  
Universidad de Las Palmas de Gran Canaria  
Sancho Panza 33  
Puerto del Rosario, Fuerteventura  
Las Palmas de Gran Canaria 35600  
Spain  
E-mail: veronica.benitez102@doctorandos.ulpgc.es

**Antonio Bode**

Centro Oceanográfico de A Coruña  
Instituto Español de Oceanografía  
Apdo. 130  
A Coruña, E-15080  
Spain  
E-mail: antonio.bode@co.ieo.es

**Julia Anna Boras**

Department of the Marine Biology and Oceanography  
Institut de Ciències del Mar CMIMA - CSIC  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, Catalunya 08003  
Spain  
E-mail: boras@icm.csic.es

**Roberta Boscolo**

CLIVAR IPO  
c/o IIM-CSIC  
Eduardo Cabello 6  
Vigo, 36208  
Spain  
E-mail: rbos@iim.csic.es

**Eva Bosom**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: ebosom@gmail.com

**Jesus Cabal**

Centro Oceanografico de Gijón  
Instituto Español de Oceanografía  
Avda. Principe de Asturias 70 Bis  
Gijón, Asturias, 33212  
Spain  
E-mail: jcabal@gi.ieo.es

**Albert Caballero**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: caballero.albert@gmail.com

**Ángela M. Caballero-Alfonso**

Department of Biology  
Las Palmas de Gran Canaria University  
Campus Universitario de Tafira, sn. Edif. Ciencias Básicas  
Las Palmas de Gran Canaria  
Las Palmas 35017  
Spain  
E-mail: angela.caballero102@doctorandos.ulpgc.es

**Jose M. Cabanas**

Department of Oceanography  
Instituto Español de Oceanografía  
Subida a Radiofaro 50, Cabo Estay- Canido  
P.O. Box 155  
Vigo, 36211  
Spain  
E-mail: jmanuel.cabanas@vi.ieo.es

**Francisco M. Calafat**

Mediterranean Institute for Advanced Studies  
C/ Miquel Marquès 21  
Palma de Mallorca, Balears 07190  
Spain  
E-mail: kiko.mir@uib.es

**Albert Calbet**

Institut de Ciències del Mar, CSIC  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, Catalunya 08003  
Spain  
E-mail: acalbet@icm.csic.es

**Eva Calvo**

Institut de Ciències del Mar, CSIC  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, Catalunya 08003  
Spain  
E-mail: ecalvo@icm.cat

**Alejandra Calvo-Díaz**

Centro Oceanográfico de Xixón/Gijón  
Instituto Español de Oceanografía  
Camín de L' Arbeyal s/n  
Xixón/Gijón, Asturias 33212  
Spain  
E-mail: a.calvodiaz@gi.ieo.es

**Alejandro Cearreta**

Estratigrafía y Paleontología  
Universidad del País Vasco/EHU  
Facultad de Ciencia y Tecnología, Apartado 644  
Bilbao, 48080  
Spain  
E-mail: alejandro.cearreta@ehu.es

**Guillem Chust**

AZTI - Tecnalia/Marine Research Division  
Txatxarramendi ugarte a z/g 48395 Sukarrieta (Bizkaia)  
Sukarrieta  
Basque country 48395  
Spain  
E-mail: gchust@suk.azti.es

**David Costalago**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: costalago@cmima.csic.es

**Maria Jesus De Pablo**

Autonomous University  
Condesa de Venadito, 6 - 11D  
Madrid, 28027  
Spain  
E-mail: mariajesus.depablo@gmail.com

**M<sup>a</sup>Luz Gemma Fernandez de Puelles**

Spanish Institute of Oceanography  
Muelle de Poniente s/n P.O. Box 291  
Palma de Mallorca, Balears 07015  
Spain  
E-mail: mluz.fernandez@ba.ieo.es

**Lourdes Fernández-Peralta**

CECAF Fisheries  
Instituto Español de Oceanografía  
Centro Oceanográfico de Málaga  
Puerto Pesquero s/n  
Fuengirola, Málaga 29640  
Spain  
E-mail: lourdes.fernandez@ma.ieo.es

**Felix Lopez Figueroa**

University of Malaga  
Facultad de Ciencias, Campus Universitario de  
Teatinos  
Malaga E-29071  
Spain  
E-mail: Felix\_lopez@uma.es

**José-Abel Flores**

Departamento de Geología  
Universidad de Salamanca  
Facultad de Ciencias  
Salamanca, 37008  
Spain  
E-mail: flores@usal.es

**Martí Galí**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, Catalonia 08028  
Spain  
E-mail: itramgali@gmail.com

**Damià Gomis**

Recursos Naturals  
IMEDEA (Univ. Illes Balears-CSIC)  
Dep. de Física, Ed. Mateu Orfila  
Campus UIB, C/ Miquel  
Palma de Mallorca, Illes Balears 07120  
Spain  
E-mail: damia.gomis@uib.cat

**Fernando González**

Área de Ecología, Dpto Biología de Organismos y  
Sistemas  
Universidad de Oviedo  
C/ Catedrático Rodrigo Uría s/n  
Oviedo, Asturias ES33071  
Spain  
E-mail: fgtaoada@gmail.com

**Manuel González**

AZTI-Tecnalia  
Muelle de Herrera, s/n, Zona Portuaria d  
Gipuzkoa, 20110-Pasaia  
Spain  
E-mail: mgonzalez@pas.azti.es

**Ricardo González Gil**

Universidad de Oviedo  
Catedrático Rodrigo Uría s/n  
Oviedo, Asturias 33071  
Spain  
E-mail: rgonzalezgil@gmail.com

**Gonzalo González-Nuevo**

Instituto Español de Oceanografía  
Avda. Príncipe de Asturias 70 bis  
Gijón, Asturias 33213  
Spain  
E-mail: gonzalez\_nuevo@gi.ieo.es

**Cesar M. Gonzalez-Pola**

Physical Oceanography  
Spanish Institute of Oceanography  
c/ Príncipe de Asturias 70 Bis.  
Gijón, Asturias CP 33212  
Spain  
E-mail: cesar.pola@gi.ieo.es

**José María Gorostiaga**

University of Basque Country  
Lab. Botánica, Dep. Biología Vegetal y Ecología  
Fac. C  
Bilbao, Bizkaia 48080  
Spain  
E-mail: jm.gorostiaga@ehu.es

**Juan Höfer**

Universidad de Oviedo  
Catedrático Rodrigo Uría s/n  
Oviedo, Asturias E33071  
Spain  
E-mail: juanhofer@gmail.com

**Maria Huete Ortega**

Facultad de Ciencias del Mar. Universidad de Vigo  
Ctra/ Colexio Universitario s/n  
Vigo, Pontevedra 36310  
Spain  
E-mail: mhuete@uvigo.es

**Arantza Iriarte**

University of the Basque Country  
Barrio Sarriena, s/n  
Leioa, Bizkaia 48940  
Spain  
E-mail: arantza.iriarte@ehu.es

**Eduardo Fernandez Jimenez**

Universidad de Cadiz  
Residencia Universitaria "Brisas del Mar"  
C/Estuario S/  
Puerto Real, Cadiz 11510  
Spain  
E-mail: eduardo.jimenezfernandez@alum.uca.es

**José A. Jiménez**

Universitat Politècnica de Catalunya  
c/ Jordi Girona 1-3  
Campus Nord ed D1  
Barcelona, 08034  
Spain  
E-mail: jose.jimenez@upc.edu

**Cristina Lamela**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: sos.relinda@gmail.com

**Aránzazu Lana**

Institut de Ciències del Mar  
CMIMA-CSIC  
Passeig Marítim de la Barceloneta, 37-49  
Barcelona, 08003  
Spain  
E-mail: lana@cmima.csic.es

**Mikel Latasa**

Centro Oceanográfico Xixón-Gijón  
Instituto Español de Oceanografía  
Avda. Príncipe de Asturias 70 bis  
Gijón, Asturias E-33213  
Spain  
E-mail: latasa@gi.ieo.es

**Irene Leoni**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: merengina@libero.it

**Nerea Lezama**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: nereota@hotmail.com

**Angel Lopez-Urrutia**

Centro Oceanografico de Gijón  
Instituto Español de Oceanografía  
Avda. Principe de Asturias 70 Bis  
Gijón, Asturias 33212  
Spain  
E-mail: alop@gi.ieo.es

**Maria Nieves Lorenzo**

University of Vigo  
Facultad de Ciencias, As Lagoas  
Ourense, E-32004  
Spain  
E-mail: nlorenzo@uvigo.es

**Inigo Javier Losada**

Environmental Hydraulics Institute  
Universidad de Cantabria  
E.T.S.I. Caminos, Canales y Puertos.  
Avda. de los Cast  
Santander, Cantabria 39005  
Spain  
E-mail: losadai@unican.es

**Jose luis Madrazo**

Full & Cas SI  
Verde 5, Galizano  
Santander  
Cantabria 39160  
Spain  
E-mail: josemadrazo@hotmail.com

**Marta Marcos**

IMEDEA  
Miquel Marqués 21  
Mallorca, Esporles 07190  
Spain  
E-mail: marta.marcos@uib.es

**Cristina Mari**

University of Barcelona  
Avda. Diagonal, 645  
Barcelona, 08028  
Spain  
E-mail: cristinamaritur@gmail.com

**Sandra Martínez-García**

Universidad de Vigo  
Campus Lagoas-Marcosende  
Vigo, Pontevedra 36310  
Spain  
E-mail: sandra@uvigo.es

**Gema Martínez-Méndez**

Institut de Ciència i Tecnologia Ambientals  
Universitat Autònoma de Barcelona  
Facultat de Ciències Edifici Cn  
Campus Bellaterra  
Cerdanyola, Barcelona E-08193  
Spain  
E-mail: gema.martinez@uab.cat

**Fernando J. Méndez**

Universidad de Cantabria  
Environmental Hydraulics Institute "IH Cantabria"  
E.T.S.I. Caminos Canales y Puertos  
Avda. de los Castro  
Santander, Cantabria 39005  
Spain  
E-mail: mendezf@unican.es

**Melisa Menendez**

Environmental Hydraulics Institute  
Universidad de Cantabria  
E.T.S.I. Caminos Canales y Puertos  
Avda. de los Castro  
Santander, Cantabria 39005  
Spain  
E-mail: menendezm@unican.es

**Jesús M. Mercado**

Centro Oceanográfico de Málaga  
Instituto Español de Oceanografía  
Puerto Pesquero s/n Apdo. 285  
Fuengirola, 29640  
Spain  
E-mail: jesus.mercado@ma.ieo.es

**Enrique Monton Chiva**

Climate Laboratory  
Universitat Jaume I  
Avda. Sos Baynat, s/n  
Castellon, Castellon 12071  
Spain  
E-mail: montone@his.uji.es

**Marisa Montoya**

Dpto. Astrofísica y Ciencias de la Atmosfera  
Universidad Complutense de Madrid  
Ciudad Universitaria s/n  
Madrid, 28040  
Spain  
E-mail: mmontoya@fis.ucm.es

**Xosé Anxelu G. Morán**

Centro Oceanográfico de Xixón  
Instituto Español de Oceanografía  
Camín de L'Arbeyal, s/n  
Xixón, Asturias 33212  
Spain  
E-mail: xelu.moran@gi.ieo.es

**Sonia Moreno**

Faculty of Sciences  
University of Málaga  
Campus Universitario de Teatinos s/n  
Málaga, 29071  
Spain  
E-mail: msonia@uma.es

**Juancho Movilla**

CSIC  
Pg. Marítim de la Barceloneta 37-49  
Barcelona, Catalonia 08003  
Spain  
E-mail: jmovilla@icm.csic.es

**Javier Pereiro Muñoz**

Instituto Español de Oceanografía  
Apartado 1552  
Vigo, Pontevedra 36200  
Spain  
E-mail: javier.pereiro@vi.ieo.es

**Irene Navarro**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: ins20@hotmail.com

**Laura Navarro**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: laura.nav@hotmail.com

**Raquel Niclos**

Mediterranean Centre for Environmental Studies,  
CEAM  
14 Charles Darwin (Parc Tecnologic)  
Paterna, 46980  
Spain  
E-mail: Raquel.Niclos@uv.es

**F. Xavier Niell**

Faculty of Sciences  
University of Málaga  
Campus de Teatinos s/n  
Málaga, 29071  
Spain  
E-mail: fxn@uma.es

**Miriam Ruiz Nieto**

Faculty of Sciences  
University of Málaga  
Campus de Teatinos s/n  
Málaga 29071  
Spain  
E-mail: miriamruiznieto@alu.uma.es

**Pablo Ortega**

Dpto. Astrofísica y Ciencias de la Atmósfera  
Universidad Complutense de Madrid  
Facultad de Ciencias Físicas, Ciudad Universitaria s/n  
Madrid 28040  
Spain  
E-mail: portegam@fis.ucm.es

**Carles Pelejero**

Departament de Biologia Marina i Oceanografia  
ICREA and Institut de Ciències del Mar, CSIC  
Pg. Marítim de la Barceloneta, 37-49  
Barcelona, Catalonia 08003  
Spain  
E-mail: pelejero@icm.cat

**Mari Carmen Pineda**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: maykka17@gmail.com

**Irene Polo**

Universidad Complutense de Madrid  
Av. Complutense s/n  
Madrid, 28040  
Spain  
E-mail: ipolo@fis.ucm.es

**Carmela Porteiro**

Instituto Español de Oceanografía  
Cabo Estay- Canido  
Vigo, 36280  
Spain  
E-mail: carmela.porteiro@vi.ieo.es

**Ana Ramos**

Instituto Español de Oceanografía  
Punta del Apio  
San Miguel de Oia  
Vigo, Pontevedra 36200  
Spain  
E-mail: ana.ramos@vi.ieo.es

**José María Rodríguez**

Centro Oceanográfico de Gijón  
Instituto Español de Oceanografía  
Avda. Príncipe de Asturias 70 Bis  
Gijón, Asturias 33212  
Spain  
E-mail: j.m.rodriguez@gi.ieo.es

**Simon Ruiz**

Natural Resources Department  
IMEDEA (CSIC-UIB)  
C/Miquel Marqués, 21  
Esporles, Islas Baleares 07190  
Spain  
E-mail: simon.ruiz@uib.es

**Clara Ruiz-González**

Department of Marine Biology and Oceanography  
Institut de Ciències del Mar (ICM-CSIC)  
Paseo Marítim De La Barceloneta 37-49  
Barcelona 08003  
Spain  
E-mail: clararg@icm.csic.es

**Enric Saiz**

Department of Marine Biology and Oceanography  
Institut de Ciències del Mar (ICM-CSIC)  
Paseo Marítim De La Barceloneta 37-49  
Barcelona 08003  
Spain  
E-mail: enric@icm.csic.es

**Sofía Sal**

C/Trinidad Nº10 4  
Gijón, 33201  
Spain  
E-mail: softysb@hotmail.com

**Maria M. Sala**

Institut de Ciències del Mar (CSIC)  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, 08003  
Spain  
E-mail: msala@icm.csic.es

**Renate Scharek**

Centro Oceanográfico de Gijón  
Instituto Español de Oceanografía  
Avda. Príncipe de Asturias, 70 Bis  
Gijón, Asturias 33212  
Spain  
E-mail: rscharek@gi.ieo.es

**Rafel Simó**

Institut de Ciències del Mar (CSIC)  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, 08003  
Spain  
E-mail: rsimo@icm.csic.es

**Arturo Sousa**

Department of Plant Biology and Ecology  
University of Seville  
Profesor García González 2  
Seville, E-41012  
Spain  
E-mail: asousa@us.es

**Eva Teira**

Universidade de Vigo  
Facultade de Ciencias do Mar  
Vigo, 36310  
Spain  
E-mail: teira@uvigo.es

**Benedicte Thienpont**

Universidad de Barcelona  
Avda Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: benedicte.thienpont@yahoo.com

**Luis Valdés**

Centro Oceanográfico de Gijón  
Instituto Español de Oceanografía  
Avda. Príncipe de Asturias 70  
Gijón, Asturias 33213  
Spain  
luis.valdes@gi.ieo.es

**Ingrid Vallory**

University of Barcelona  
Avda. Diagonal 645  
Barcelona, 08028  
Spain  
E-mail: i\_vallory@yahoo.es

**Dolors Vaqué**

Institut de Ciències del Mar (CSIC)  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, 08003  
Spain  
E-mail: dolors@icm.csic.es

**Manuel Antonio Varela**

Medio Marino  
Instituto Español de Oceanografía  
Paseo Marítim Alcalde Francisco Vázquez nº 10  
A Coruña, 15001  
Spain  
E-mail: manuel.varela@co.ieo.es

**Montserrat Vidal**

University of Barcelona  
Avda. Diagonal, 645  
Barcelona, 08028  
Spain  
E-mail: montsevidal@ub.edu

**Enrique Vidal-Vijande**

GOIFIS  
IMEDEA (Instituto Mediterraneo de Estudios  
Avanzados)  
C./ Miquel Marqués, 21  
Esporles, Baleares 07190  
Spain  
E-mail: enrique.vidal@uib.es

**Lidia Yebra Mora**

Institut de Ciències del Mar (CSIC)  
Passeig Marítim de la Barceloneta 37-49  
Barcelona, 08003  
Spain  
E-mail: lyebra@icm.csic.es

**Sri Lanka**

---

**Prabhath De Silva Patabendi**

Institute of Human Development  
858/6, New Kandy Road,  
Thalangama North  
Malabe, Western 10115  
Sri Lanka  
E-mail: ihdt@sltnet.lk

**Sweden**

---

**Sam Dupont**

Göteborg University  
Kristineberg Marine Research Station  
Kristineberg 566  
Fiskebackskil, 45034  
Sweden  
E-mail: dupont@bani.ucl.ac.be

**Jon Havenhand**

University of Gothenburg  
Tjärnö Marine Biological Laboratory  
Strömstad, 45296  
Sweden  
E-mail: jon.havenhand@marecol.gu.se

**Michael Charles Thorndyke**

Kristineberg Marine Research Station  
Royal Swedish Academy of Sciences  
Kristineberg  
Fiskebackskil, 450 34  
Sweden  
E-mail: mike.thorndyke@kmf.gu.se

**Switzerland**

---

**Damilola Sunday Olawuyi**

Environmental LawUnitar  
United Nations  
11-13 Chemin des Anemones, CH-1219  
Chatelaine  
Geneva, CH1211  
Switzerland  
E-mail: dsolawuyi@yahoo.com

**Jill A. Peloquin**

ETH Zurich  
Universitätstrasse 16  
Zurich, 8092  
Switzerland  
E-mail: jill.peloquin@env.ethz.ch

**Thailand**

---

**Suchana A. Chavanich**

Department of Marine Science  
Chulalongkorn University  
Payathai Road  
Bangkok, 10330  
Thailand  
E-mail: suchana.c@chula.ac.th

**Sommart Niemnil**

Department of Hydrographic Engineering  
Royal Thai Naval Academy  
204 Sukumvith Road  
Paknam, Muang District  
Samutprakan, 10270  
Thailand  
E-mail: sniemnil@hotmail.com

**The Netherlands**

---

**Ralf van Hal**

Department of Ecology  
Wageningen IMARES  
Haringkade 1  
IJmuiden, Noord-Holland 1973 RR  
The Netherlands  
E-mail: ralf.vanhal@wur.nl

**Kristina E Raab**

Wageningen IMARES  
P.O. Box 68  
IJmuiden, 1970 AB  
The Netherlands  
E-mail: kristina.raab@wur.nl

**Adriaan D. Rijnsdorp**

Department of Fisheries  
Wageningen IMARES  
Haringkade 1, P.O. Box 68  
Ijmuiden, 1970 AB  
The Netherlands  
E-mail: adriaan.rijnsdorp@wur.nl

**Togo**

---

**Pessiezoum D. Adjoussi**

CGILE/Université de Lome  
Rue 1335, Gbonvié  
P.O. Box 93, Agbalépédogan  
Lome, Golfe 05  
Togo  
E-mail: adjoussi@hotmail.com

## **Turkey**

---

### **Bulent Acma**

Department of Economics and Environment  
Anadolu University  
Yunusemre Campus  
Eskisehir, 26470  
Turkey  
E-mail: [bacma@anadolu.edu.tr](mailto:bacma@anadolu.edu.tr)

### **Gonul Icemer**

Department of Environmental Engineering  
Akdeniz University  
Dumlupinar Bulvari, Campus  
Antalya, 07058  
Turkey  
E-mail: [gicemer@akdeniz.edu.tr](mailto:gicemer@akdeniz.edu.tr)

## **USA**

---

### **Teresa A'mar**

Quantitative Ecology and Resource Management  
University of Washington  
P.O. Box 355020, SAFS  
Seattle, WA 98195-5020  
USA  
E-mail: [zta@u.washington.edu](mailto:zta@u.washington.edu)

### **Helen Bailey**

Environmental Research Division  
NOAA/NMFS/SWFSC  
1352 Lighthouse Avenue  
Pacific Grove, CA 93950  
USA  
E-mail: [helen.bailey@noaa.gov](mailto:helen.bailey@noaa.gov)

### **Andrew D. Barton**

Earth Atmospheres and Planetary Science  
Massachusetts Institute of Technology  
77 Massachusetts Avenue 54-1511  
Cambridge, MA 02139  
USA  
E-mail: [adbarton@mit.edu](mailto:adbarton@mit.edu)

### **Marissa L Baskett**

National Center for Ecological Analysis and Synthesis  
735 State St., Ste. 300  
Santa Barbara, CA 93101  
USA  
E-mail: [mbaskett@nceas.ucsb.edu](mailto:mbaskett@nceas.ucsb.edu)

### **Hal P. Batchelder**

College of Oceanic and Atmospheric Sciences  
Oregon State University  
104 COAS Admin. Bldg.  
Corvallis, OR 97331-5503  
USA  
E-mail: [hbatchelder@coas.oregonstate.edu](mailto:hbatchelder@coas.oregonstate.edu)

### **Nicholas A. Bond**

Joint Institute for the Study of Atmosphere and Ocean  
University of Washington  
7600 Sand Point Way NE, NOAA/PMEL  
Seattle, WA 98195-4925  
USA  
E-mail: [nicholas.bond@noaa.gov](mailto:nicholas.bond@noaa.gov)

### **Edmundo Casillas**

Northwest Fisheries Science Center, NMFS, NOAA  
2725 Montlake Blvd E  
Seattle, WA 98112  
USA  
E-mail: [edmundo.casillas@noaa.gov](mailto:edmundo.casillas@noaa.gov)

### **Robert R. Christian**

Department of Biology  
East Carolina University  
Howell Science Complex, Biology Building S-105  
Greenville, NC 27858  
USA  
E-mail: [christianr@ecu.edu](mailto:christianr@ecu.edu)

### **Ruth Curry**

Department of Physical Oceanography  
Woods Hole Oceanographic Institution  
MS #21, 354 Clark Lab  
Woods Hole, MA 02543  
USA  
E-mail: [rcurry@whoi.edu](mailto:rcurry@whoi.edu)

### **Michael J. Dagg**

Louisiana Universities Marine Consortium  
8124 Hwy 56  
Chauvin, LA 70344  
USA  
E-mail: [mdagg@lumcon.edu](mailto:mdagg@lumcon.edu)

### **Robert J. Diaz**

Virginia Institute of Marine Science  
1208 Greate Road  
Gloucester Pt., VA 23062  
USA  
E-mail: [diaz@vims.edu](mailto:diaz@vims.edu)

### **Richard A. Feely**

Ocean Climate Research Division, NOAA/PMEL  
Alaska Fisheries Science Center  
7600 Sand Point Way NE  
Seattle, WA 98115-6349  
USA  
E-mail: [Richard.A.Feely@noaa.gov](mailto:Richard.A.Feely@noaa.gov)

### **Joaquim I. Goes**

Biological Oceanography Department  
Bigelow Laboratory for Ocean Sciences  
P.O. Box 475, McKown Point Road  
West Boothbay Harbor, Maine 04575  
USA  
E-mail: [jgoes@bigelow.org](mailto:jgoes@bigelow.org)

**John Guinotte**

Marine Conservation Biology Institute  
2122 112th Avenue NE, Suite B-300  
Bellevue, WA 98004  
USA  
E-mail: john@mcbi.org

**Marah J. Hardt**

Blue Ocean Institute  
School of Marine and Atmospheric Science  
Stony Brook University  
Stony Brook, NY 11794-5000  
USA  
E-mail: mhardt@blueocean.org

**D.E. Harrison**

Pacific Marine Environmental Laboratory NOAA  
7600 Sand Point Way NE  
Seattle, WA 98115  
USA  
E-mail: D.E.Harrison@noaa.gov

**Alan C. Haynie**

Alaska Fisheries Science Center  
NOAA Fisheries  
7600 Sand Point Way NE, Bldg 4  
Seattle, WA 98115  
USA  
E-mail: Alan.Haynie@noaa.gov

**Dennis Heinemann**

Ocean Conservancy  
1300 19th Street NW  
8th Floor  
Washington, DC 20036  
USA  
E-mail: dheinemann@oceanconservancy.org

**Stephanie Henson**

Atmospheric and Oceanic Sciences Program  
Princeton University  
Sayre Hall, 300 Forrester Road  
Princeton, NJ 08544  
USA  
E-mail: shenson@princeton.edu

**Julian Herndon**

Romberg Tiburon Center for Environmental Studies  
San Francisco State University  
3192 Paradise Dr.  
Tiburon, CA 94920  
USA  
E-mail: jherndon@sfsu.edu

**Alice Hiciburundi**

Division for Ocean Affairs and the Law of the Sea/  
Office of Legal Affairs  
United Nations  
2 United Nations Plaza  
Room DC2-0422  
New York, NY 10017  
USA  
E-mail: hiciburundi@un.org

**Kelley Higgason**

Environmental Management Graduate Program  
University of San Francisco  
539 B 5th Ave.  
San Francisco, CA 94118  
USA  
E-mail: khiggason@hotmail.com

**Anne B. Hollowed**

Alaska Fisheries Science Center, NMFS, NOAA  
7600 Sand Point Way NE  
Seattle, WA 98115-6349  
USA  
E-mail: Anne.Hollowed@noaa.gov

**Jennifer L. Irish**

Coastal and Ocean Engineering Division  
Zachry Department of Civil Engineering  
Texas A&M University  
3136 TAMU  
College Station, TX 77843-3136  
USA  
E-mail: jirish@civil.tamu.edu

**Andrey Olegovich Kokh**

College of Oceanic and Atmospheric Sciences  
Oregon State University  
2900 NW Polk Ave. Apt. 206  
Corvallis, OR 97330  
USA  
E-mail: andrey\_koch@mail.ru

**Gordon H. Kruse**

Juneau Center, School of Fisheries and Ocean Sciences  
University of Alaska Fairbanks  
11120 Glacier Highway  
Juneau, AK 99801-8677  
USA  
E-mail: Gordon.Kruse@uaf.edu

**Chris Langdon**

Rosensteil School of Marine and Atmospheric Science  
University of Miami  
4600 Rickenbacker Causeway  
Miami, FL 33149  
USA  
E-mail: clangdon@rsmas.miami.edu

**Jane Lubchenco**

Department of Zoology  
Oregon State University  
3029 Cordley Hall  
Corvallis, OR 97331  
USA  
E-mail: lubchenco@oregonstate.edu

**Clyde MacKenzie**

74 Magruder Road  
Highlands, 07732  
USA  
E-mail: clyde.mackenzie@noaa.gov

**Douglas G. Martinson**

Lamont-Doherty Earth Observatory  
Columbia University  
61 Route 9W  
Palisades, NY 10964  
USA  
E-mail: dgm@ldeo.columbia.edu

**Galen A. McKinley**

Atmospheric and Oceanic Sciences  
University of Wisconsin - Madison  
1225 West Dayton Street  
Madison, WI 53706  
USA  
E-mail: galen@alum.mit.edu

**Martin A. Montes-Hugo**

Marine Sciences-Coastal Ocean Observation Lab  
Rutgers University-Institute of Marine and Coastal  
Sciences  
71 Dudley Road  
New Brunswick, NJ 08901  
USA  
E-mail: montes@marine.rutgers.edu

**David Mountain**

4072 E 22nd St, #225  
Tucson, AZ 85711  
USA  
E-mail: dmountain@capecod.net

**Todd D. O'Brien**

COPEPOD - Marine Ecosystems Division  
NMFS, NOAA  
1315 East-West Hwy, F/ST7, Rm #12503  
Silver Spring, MD 20910  
USA  
E-mail: Todd.O'Brien@noaa.gov

**Mark D. Ohman**

Scripps Institution of Oceanography, UCSD  
9500 Gilman Drive  
La Jolla, CA 92093-0218  
USA  
E-mail: mohman@ucsd.edu

**Francisco Olivera**

Department of Civil Engineering  
Texas A&M University  
3136 TAMU  
College Station, Texas 77843  
USA  
E-mail: folivera@civil.tamu.edu

**Clarence Pautzke**

Executive Director  
North Pacific Research Board (NPRB)  
1007 West 3rd Avenue, Suite 100  
Anchorage, AK 99501  
USA  
E-mail: cpautzke@nprb.org

**William T. Peterson**

NOAA-Fisheries, Hatfield Marine Science Center  
Oregon State University  
2030 SE Marine Science Dr.  
Newport, OR 97365  
USA  
E-mail: Bill.Peterson@noaa.gov

**Emily Pidgeon**

Conservation International  
2011 Crystal Dr, Suite 500  
Arlington, VA 22202  
USA  
E-mail: e.pidgeon@conservation.org

**Jeffrey J. Polovina**

Honolulu Laboratory  
Pacific Islands Fisheries Science Center, NMFS,  
NOAA  
2570 Dole Street  
Honolulu, HI 96734  
USA  
E-mail: Jeffrey.Polovina@noaa.gov

**Bo Qiu**

Department of Oceanography  
University of Hawaii at Manoa  
1000 Pope Road  
Honolulu, HI 96822  
USA  
E-mail: bo@soest.hawaii.edu

**Nancy N. Rabalais**

Louisiana Universities Marine Consortium  
8124 Hwy. 56  
Chauvin, LA 70344  
USA  
E-mail: nrabalais@lumcon.edu

**Keith B. Rodgers**

AOS Program  
Princeton University  
300 Forrestal Road, Sayre Hall  
Princeton, NJ 08544-0710  
USA  
E-mail: krodgers@princeton.edu

**Andrew A. Rosenberg**

Institute for the Study of Earth, Oceans and Space  
University of New Hampshire  
Morse Hall 142  
Durham, NH 03824  
USA  
E-mail: andy.rosenberg@unh.edu

**Christopher L. Sabine**

Pacific Marine Environmental Laboratory  
National Oceanic and Atmospheric Administration  
7600 Sand Point Way NE  
Seattle, WA 98115-6349  
USA  
E-mail: chris.sabine@noaa.gov

**Jorge L. Sarmiento**

AOS Program  
Princeton University  
300 Forrestal Road, Sayre Hall  
Princeton, NJ 08544  
USA  
E-mail: jls@princeton.edu

**Michael J. Schirripa**

Fishery Resource Analysis and Monitoring Division  
Northwest Fisheries Science Center, NMFS, NOAA,  
Hatfield Marine Science Center  
2032 SE Osu Dr.  
Newport, OR 97365  
USA  
E-mail: Michael.Schirripa@noaa.gov

**Ronald J. Stouffer**

GFDL/NOAA  
Geophysical Fluid Dynamics Laboratory  
Princeton, NJ 08542  
USA  
E-mail: ronald.stouffer@noaa.gov

**Diana Lynn Stram**

North Pacific Fishery Management Council  
605 West 4th Ave., Suite 306  
Anchorage, AK 99501  
USA  
E-mail: diana.stram@noaa.gov

**Lynne D. Talley**

Scripps Institution of Oceanography  
University of California San Diego  
9500 Gilman Drive  
La Jolla, CA 92093-0230  
USA  
E-mail: ltalley@ucsd.edu

**Nathan G. Taylor**

School of Aquatic and Fishery Sciences  
University of Washington  
P.O. Box 355020  
Seattle, WA 98195-5020  
USA  
E-mail: ngtaylor@u.washington.edu

**Ukraine**

---

**Valeriy N. Khokhlov**

Hydrometeorological Institute  
Odessa State Environmental University  
Lvovskaya Street 15  
Odessa, 65016  
Ukraine  
E-mail: vkhokhlov@ukr.net

**Tetyana L. Kuchma**

GIS Analyst Center  
Vul. Purogova 6a  
Kiev, 01030  
Ukraine  
E-mail: tanyakuchma@yahoo.com

**Alexandra V. Temnykh**

Department of Biophysical Ecology  
Institute of Biology of the Southern Seas  
Nakhimov Avenue 2  
Sevastopol, 99011  
Ukraine  
E-mail: atemnykh@rambler.ru

**Vladislav E. Tymofeiev**

Climate Research and Long-Range Weather Forecast  
Ukrainian Research Hydrometeorological Institute  
Prospekt Nauki 37  
Kiev, 03028  
Ukraine  
E-mail: tvvlad@mail.ru

**United Kingdom**

---

**Thamer Badi Alrashidi**

National Oceanography Centre, Southampton  
University of Southampton  
European Way, Dock 4  
Southampton, SO14 3ZH  
United Kingdom  
E-mail: thamer22@noc.soton.ac.uk

**Severine Alvain**

School of Environmental Sciences  
University of East Anglia  
Norwich, NR4 7TJ  
United Kingdom  
E-mail: s.alvain@wanadoo.fr

**Paul Jonathon Buckley**

Cefas  
Pakefield Road  
Lowestoft, Suffolk NR33 0HT  
United Kingdom  
E-mail: paul.buckley@cefas.co.uk

**Damien Eloire**

Plymouth Marine Laboratory  
Prospect Place  
Plymouth, Devon PL1 3DH  
United Kingdom  
E-mail: dmelo@pml.ac.uk

**Liam J. Fernand**

CEFAS  
Pakefield Road  
Lowestoft, Suffolk NR330HT  
United Kingdom  
E-mail: Liam.fernand@cefas.co.uk

**Roger Harris**

Plymouth Marine Laboratory  
Prospect Place  
Plymouth, Devon PL1 3DH  
United Kingdom  
E-mail: r.harris@pml.ac.uk

**Sheila Johanna Jacomina Heymans**

Scottish Association for Marine Science  
Dunstaffnage Marine Laboratory  
Dunbeg, Argyll PA371QA  
United Kingdom  
E-mail: sheilaheyman@yahoo.com

**N. Penny Holliday**

National Oceanography Centre, Southampton  
University of Southampton  
Waterfront Campus, European Way  
Southampton, SO14 3ZH  
United Kingdom  
E-mail: nph@noc.soton.ac.uk

**Jason Holt**

Proudman Oceanographic Laboratory  
6 Brownlow Street  
Liverpool, L3 5DA  
United Kingdom  
E-mail: jholt@pol.ac.uk

**Kevin Horsburgh**

Proudman Oceanographic Laboratory  
6 Brownlow Street  
Liverpool, L3 5DA  
United Kingdom  
kevinh@pol.ac.uk

**Sarah L. Hughes**

Fisheries Research Services  
Victoria Road  
Aberdeen, AB11 9DB  
United Kingdom  
E-mail: s.hughes@marlab.ac.uk

**Maria Débora Iglesias-Rodríguez**

National Oceanography Centre, Southampton/  
University of Southampton  
European Way  
Southampton, SO14 3ZH  
United Kingdom  
E-mail: dir@noc.soton.ac.uk

**Simon A. Josey**

National Oceanography Centre, Southampton  
European Way  
Southampton, SO14 3ZH  
United Kingdom  
E-mail: Simon.A.Josey@noc.soton.ac.uk

**Kate Elisabeth Larkin**

National Oceanography Centre, Southampton  
European Way  
Southampton, Hampshire SO14 3ZH  
United Kingdom  
E-mail: kell@noc.soton.ac.uk

**Corinne Le Quere**

British Antarctic Survey  
High Cross  
Madingley Road  
Cambridge, C3B0ET  
United Kingdom  
E-mail: c.lequere@uea.ac.uk

**Mario Lebrato**

National Oceanography Centre, Southampton/  
University of Southampton  
European Way  
Southampton, SO15 2 FR  
United Kingdom  
E-mail: ml1104@soton.ac.uk

**Jason A. Lowe**

Hadley Centre  
Met Office  
FitzRoy Road  
Exeter, Devon EX1 3PB  
United Kingdom  
E-mail: jason.lowe@metoffice.gov.uk

**Steven Mackinson**

Cefas  
Pakefield Road  
Lowestoft, Suffolk NR34 0LH  
United Kingdom  
E-mail: steve.mackinson@cefas.co.uk

**Robert Marsh**

School of Ocean and Earth Science  
University of Southampton  
National Oceanography Centre, Southampton  
European Way  
Southampton, SO14 3ZH  
United Kingdom  
E-mail: rma@noc.soton.ac.uk

**Roisin Moriarty**

British Antarctic Survey  
High Cross  
Madingley Road  
Cambridge, Cambridgeshire CB3 0ET  
United Kingdom  
E-mail: roim@bas.ac.uk

**Marie-Fanny Racault**

School of Environmental Sciences  
University of East Anglia  
Norwich, Norfolk NR4 7TJ  
United Kingdom  
E-mail: m.racault@uea.ac.uk

**John Gareth Rees**

British Geological Survey  
Keyworth  
Nottingham, NG12 5GG  
United Kingdom  
E-mail: jgre@bgs.ac.uk

**Philip C. Reid**

Sir Alister Hardy Foundation for Ocean Science  
The Laboratory, Citadel Hill  
Plymouth, Devon PL1 2PB  
United Kingdom  
E-mail: pcre@sahfos.ac.uk

**Patrik Stromberg**

Plymouth Marine Laboratory  
Prospect Place  
Plymouth, PL1 3DH  
United Kingdom  
E-mail: psto@pml.ac.uk

**Nadia Elisa Suarez-Bosche**

National Oceanography Centre, Southampton/  
University of Southampton  
European Way  
Southampton, Hampshire SO14 3ZH  
United Kingdom  
E-mail: nesubo@noc.soton.ac.uk

**Andrew Sugden**

Editorial Department  
AAAS Science International  
82-88 Hills Road  
Cambridge, CB2 1LQ  
United Kingdom  
E-mail: asugden@science-int.co.uk

**Ian J. Totterdell**

Met Office Hadley Centre for Climate Change  
FitzRoy Road  
Exeter, EX1 3PB  
United Kingdom  
E-mail: ian.totterdell@metoffice.gov.uk

**William Turrell**

FRS Marine Laboratory  
PO Box 101  
Victoria Road  
Aberdeen, Aberdeenshire AB11 9DB  
United Kingdom  
E-mail: b.lawrence@marlab.ac.uk

**Sergio Vallina**

School of Environmental Sciences  
University of East Anglia  
Norwich, Norfolk NR4 7TJ  
United Kingdom  
E-mail: sergio.vallina@uea.ac.uk

**Meike Vogt**

School of Environmental Sciences  
University of East Anglia  
Norwich, Norfolk NR4 7TJ  
United Kingdom  
E-mail: m.vogt@uea.ac.uk

**Andrew J. Watson**

School of Environmental Sciences  
University of East Anglia  
Norwich, NR4 7TJ  
United Kingdom  
E-mail: a.watson@uea.ac.uk

**Sue-Ann Watson**

School of Ocean and Earth Sciences  
University of Southampton  
European Way  
Southampton, Hampshire SO14 3ZH  
United Kingdom  
E-mail: suwa@noc.soton.ac.uk

## Author index

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