PICES XIII S8-2015 Oral
Increases in calcium and total alkalinity in the Bering and Chukchi Seas

Andrey G. **Andreev**[1], C.-T. A. Chen[2] and Nataliya Sereda[1]

[1] Pacific Oceanological Institute, Baltiyskaya Str., Vladivostok, 690041, Russia. E-mail: andreev@poi.dvo.ru
[2] Institute of Marine Geology and Chemistry, National Sun Yat- Sen University, Kaohsiung, 804, Taiwan, China Taipei

Increases in the surface air temperature and the arctic river discharge over the past century are likely to have an impact on the carbonate parameters of the seawater in the Arctic Ocean. The calcium (Ca) and total alkalinity (TA) distributions in the Arctic marginals seas are particularly interesting because this area receives much land runoff and is thus expected to undergo the greatest variations as a consequence of global climatic change. Data collected in August-September 2002 during the cruise of the R/V "*Professor Khromov*" and the historical data are used to demonstrate a significant increase of TA and Ca in the shelf areas of the northwestern Bering Sea (Anadyr Bay) and the western Chukchi Sea. Processes that may lead to the observed changes, such as the increased riverine flux of the calcium and carbonates, the salinification due to enhanced brine production related with ice grow in winter, as well as shoaling of the calcite and aragonite saturation horizons are discussed.

PICES XIII S8-2124 Poster
Interannual variability of dissolved oxygen and inorganic carbon in the Kuril Basin of the Okhotsk Sea

Andrey G. **Andreev** and Viktoria Baturina

Pacific Oceanological Institute, Baltiyskaya Str., Vladivostok, 690041, Russia. E-mail: andreev@poi.dvo.ru

Data collected between 1993 and 2003 are used to find the correlation between the temporal and spatial variations of the dissolved oxygen (DO) and inorganic carbon in the Kuril Basin of the Okhotsk Sea. Using a 60-year data set we have investigated the seasonal and interannual variability of the DO on isopycnals in the intermediate waters and its relationships with the temperature, the isopycnal depth and the upper-ocean salinity and stratification.

Our analyses revealed that the decadal oscillations and trends in the DO and temperature on isopycnals in the intermediate layer of the Kuril Basin can be explained by the increase/decrease of the supply of the Alaska Stream Current waters to the Okhotsk Sea. We find that the interannual variations in the upper-ocean salinity and density, Amur River discharge and excess precipitation over evaporation, and temperature and DO of the intermediate waters in the Okhotsk Sea are well correlated with the spatially averaged winter atmospheric pressure in the North Pacific (North Pacific Index).

The most likely scenario explaining these correlations is variability in the wintertime wind and ocean circulation regime which in turn are linked to atmospheric forcing (NPI).

PICES XIII S8-2146 Oral
Modeling decadal variability of carbon cycle in the Pacific Ocean

Fei **Chai**[1], Lei Shi[1], Mingshun Jiang[2], Tsung-Hung Peng[3] and Yi Chao[4]

[1] School of Marine Science, 5471 Libby Hall, University of Maine, Orono, ME, 04469-5741, U.S.A. E-mail: fchai@maine.edu
[2] ECOS Department, University of Massachusetts Boston, 100 Morrissey Blvd., Boston, MA, 02125, U.S.A.
[3] NOAA Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Causeway, Miami, FL, 33149-1026, U.S.A.
[4] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109, U.S.A.

To improve our understanding of physical variability and the carbon cycle response in the Pacific Ocean, especially on seasonal to decadal time scales, we have developed a physical-biogeochemical model for the Pacific Ocean. The lower trophic level ecosystem processes are linked with upper ocean carbon chemistry and embedded into a three-dimensional circulation model that is forced with observed the air-sea fluxes between 1952 and 2002. The improved physical-biogeochemical model produces a 50-year (1952-2002) retrospective analysis for the Pacific Ocean. The physical-biogeochemical model is capable of reproducing many observed features and their variability in

the Pacific Ocean. Analyses of the modeled results are focused on the North Pacific, a sink region for both natural and anthropogenic carbon. The abrupt shift in the North Pacific climate system that occurred during the mid 1970s, the modeled air-sea flux of CO_2 and the response of the upper ocean carbon cycle to this climate shift are discussed. Using the physical-biogeochemical model, we estimate how much anthropogenic CO_2 has entered into the North Pacific Ocean during the past several decades. The model estimated anthropogenic CO_2 uptake rate for various regions compare favorably with observational and other modeling estimates.

PICES XIII S8-2055 Oral
Carbonate Chemistry of the South China Sea

Chen-Tung Arthur **Chen**[1], Shu-Lun Wang[2], Wen-Chen Chou[1] and David D. Sheu[1]

[1] Institute of Marine Geology and Chemistry, National Sun Yat-Sen University, Kaohsiung, 804, Taiwan, China Taipei
E-mail: ctchen@mail.nsysu.edu.tw
[2] Department of Marine Environment Engineering, National Kaohsiung Marine University, Kaohsiung 811, Taiwan, China Taipei

In order to study the dissolved carbonate system in the South China Sea (SCS) and to understand the water mass exchange between the SCS and the West Philippine Sea (WPS), pH, total alkalinity and total CO_2 were measured aboard R/V *Ocean Researcher 1*. Because of the sill separating these two seas in the Luzon Strait with a maximum depth of 2200 m, the SCS Deep Water has the characteristics similar to the water at about 2200 m in the WPS. The minimum in pH and the maxima in normalized alkalinity and total CO_2 commonly found in the open oceans at mid-depth are also prominent in the WPS but are very weak in the SCS. Rivers, inflows of the Kuroshio Surface Water and Kuroshio Deep Water through the Luzon Strait as well as inflows through the Mindoro Strait transport carbon to the SCS year-round. On the other hand, the out-flowing Taiwan Strait water, as well as the SCS Surface and Intermediate Waters in the Luzon Strait transport carbon out of the SCS year-round. Carbon is transported into the SCS through the Sunda Shelf in the wet season but is transported out of the SCS in the dry season.

fCO_2 data and mass balance calculations indicate that the SCS is a weak CO_2 source in the wet season but an even weaker CO_2 sink in the dry season. Taken together, the SCS is a very weak CO_2 source. The anthropogenic CO_2 penetrates to about 1500 m deep in the SCS and the entire SCS contains $0.60 \pm 0.15 \times 10^{15}$ g excess carbon. Typical profiles of pH as well as the degrees of saturation of calcite and aragonite in 1850, 1990 and 2050 AD are presented. The maximum decrease in pH is estimated to be 0.16 pH unit in the surface layer with a doubling of CO_2. Aragonite in the upper continental slope may start to dissolve, thus neutralizing excess CO_2 around 2050 AD.

PICES XIII S8-2180 Poster
Spatial-temporal variations of pCO_2 and their driving forces in the western Arctic Ocean

Liqi **Chen**[1,4], Zhongyong Gao[1,2], Liyang Zhang[1,3] and Suqing Xu[1,3]

[1] Key Laboratory of Global Change and Marine-Atmospheric Chemistry, SOA, Xiamen, 361005, People's Republic of China
E-mail: Lqchen@soa.gov.cn
[2] Third Institute of Oceanography, SOA, Xiamen, 361005, People's Republic of China
[3] Department of Oceanography, Xiamen University, Xiamen, 361005, People's Republic of China
[4] Chinese Arctic and Antarctic Administration, Beijing, 100860, People's Republic of China

The 1st and 2nd Chinese National Arctic Research Expeditions were conducted in 1999 and 2003, respectively, in summer time to survey the Bering Sea and the western Arctic Ocean. The partial pressure of CO_2 in surface water (pCO_2) was continually measured using a Li-Cor 6262 CO_2/H_2O infrared analyzer onboard the icebreaker *Xuelong*. Distributions of pCO_2 show obvious geographic differences with lower values in continental shelf regions, increasing values in the slope regions and higher values in abyssal plains such as in the Canadian Basin. Major driving forces were analyzed and attributed to biological or physical processes. The Chukchi Sea appears to be a significant region for atmospheric CO_2 absorption through its characterized processes in summer time such as rapid sea ice melting, high primary production on the continental shelf and marginal ice zone (MIZ), and transformed water from the Bering Sea, *etc*. Analyzing spatial-temporal variations of pCO_2, this paper tried to distinguish different effects of driving forces to help understand the carbon cycle in the Arctic Ocean. Concentrations of pCO_2 show sharp fluctuations in the Chukchi continental shelf, which could be traced to inflows from the Bering Abyssal Plain and the Alaska coast current which bring higher pCO_2 water to the shelf. pCO_2 in the melted sea ice water zone is more stable and decreases towards the

ice edge, which is related to changes of temperature and salinity as well with the sea ice's melted state. Decreases can be found to reach the lowest in the ice edge then increase to more stable values in the pack ice zone. The temperature and salinity in surface sea water (SST and SSS) are almost steady in the pack ice zone. Therefore, biological production would play a major driving force for pCO_2 changes except for a gyre impact. For example, an abnormal increase of pCO_2 at 72.5°N along 169°W was observed where the Bering Sea water flows through. The temporal distribution of pCO_2 in the Chukchi Sea shows effects from sea ice melting, biological production and water masses transports. In the area adjacent to the Bering Strait (66-69°N), pCO_2 in mid-August is much lower than that in the end of July due to blooming of alga. In 68.5~69°N on 169°W, the pCO_2 and SST in August are much higher than in July, which could be attributed to a water mass transport from the Alaska coast current (ACC). In August in MIZ, pCO_2 and SST increased a little because SST is playing a major driving force during the sea ice melting, making the Pack ice zone recede.

PICES XIII S8-2008 Oral

Drivers of the seasonality in surface water pCO_2 in contrasting regimes in the subarctic North Pacific

Melissa **Chierici**, A. Fransson and Y. Nojiri

National Institute for Environmental Studies, c/o Climate Change Research Project, 16-2 Onogawa, Tsukuba, Ibaraki, 305-8506, Japan
E-mail: melissa.chierici@nies.go.jp

We evaluated the role of temperature, biological processes, air-sea exchange and the contribution from vertical mixing on the seasonality of surface water pCO_2 in the subarctic North Pacific during 2000. In addition to atmospheric pCO_2 and sea surface data of pCO_2 and nitrate, we used subsurface nitrate data and mixed layer depths from a new climatology and wind speed from the NCEP/NCAR Reanalysis for the evaluation. Data was divided into six domains extending from the Oyashio Current system (OY) to the Vancouver Island upwelling system including the Western subarctic Gyre (WSG) and the Alaska Gyre (AG). The magnitude of these processes showed large regional and temporal variability. In all areas, the major drivers for the monthly pCO_2 change were temperature and biological processes. The effect from air-sea exchange and vertical mixing played a minor role on the annual net pCO_2 change. However, our results also imply a difference between the controls of the pCO_2 in the WSG and the AG where vertical mixing in the WSG contributed to a pCO_2 change twice of the magnitude of the AG and showed less effect from temperature. This suggests that a change in the marine conditions (*e.g.* temperature and mixed layer depth) would have different consequences for the CO_2 system and the air-sea CO_2 flux in the AG and the WSG.

PICES XIII S8-2005 Oral

Modelling the impact of climate change on the carbon cycle: Redfield and non-Redfield models

James **Christian**

Fisheries and Oceans Canada, Canadian Centre for Climate Modelling and Analysis, University of Victoria, PO Box 1700 STN CSC, Victoria, BC, V8W 2Y2, Canada. E-mail: jim.christian@ec.gc.ca

The biogeochemical cycles of carbon, nitrogen, phosphorus, and iron are tightly coupled in the upper ocean, and coupling of carbon cycle to other elemental cycles affects the net air-sea exchange of CO_2, "burial" of carbon in the meso- and bathypelagic ocean, and the relative importance of biotic and abiotic terms in the carbon cycle. While the Redfield Ratio remains one of the most robust and significant generalizations of ocean biogeochemistry, the assumption of fixed stoichiometry in biogeochemical ocean models is increasingly untenable. Model simulations at Station ALOHA (22˚45'N, 158˚W) show an enhancement of ocean carbon uptake in models where C/N/P ratios are permitted to vary. Several critical components of the biological pump, including primary production of organic matter and partitioning of export between dissolved and particulate organic carbon, are shown to be particularly sensitive to the variation of C/N/P ratios. In future climates, evolution of the phytoplankton community in response to climate variability may affect carbon fluxes in a number of ways that are unlikely to be adequately simulated by fixed-ratio models.

PICES XIII S8-1834 Oral
Attributing the causes of North Pacific oxygen changes

Curtis **Deutsch**, Steven Emerson and Luanne Thompson

Department of Oceanography, University of Washington, Seattle, WA, 98115, U.S.A. E-mail: cdeutsch@ocean.washington.edu

We investigate the variability of dissolved oxygen in the upper water column of the North Pacific using a hind cast model simulation. The model applies the biogeochemical framework of the Ocean Carbon Model Intercomparison Project (OCMIP) to an isopycnal General Circulation Model (GCM) whose circulation is forced at the surface by historical atmospheric conditions. The resulting O_2 changes are similar in pattern and magnitude to those observed along repeat transects through the subtropical and subpolar gyres (Emerson *et al.* 2004). We perform a set of additional simulations designed to separate the contributions of changes in biology, ventilation, and circulation to O_2 variability. We find that the direct effect of circulation change is the dominant cause of O_2 changes over most of the North Pacific, and that model O_2 changes between the 1980's and 1990's are a transient response to circulation changes initiated in the 1970's. Variations in thermocline ventilation lead to significant O_2 decreases in the Subarctic Northwest Pacific, and changes in biological oxygen consumption are significant only in the upper thermocline.

PICES XIII S8-2151 Oral
Processes controlling air-sea exchange of carbon dioxide, Kaneohe Bay, Oahu, Hawaii

Kathryn E. **Fagan**, Fred T. Mackenzie, Daniel W. Sadler and Justin Dilg

School of Ocean and Earth Science and Technology, University of Hawaii, 1000 Pope Road, Honolulu, HI, 96822, U.S.A.
E-mail: kfagan@hawaii.edu

In contrast to the open ocean, the coastal zone air-sea CO_2 exchange remains questionable because of the lack of data, particularly time series data. Kaneohe Bay, located on the windward side of Oahu, is a complex coastal region with a large barrier coral reef, numerous patch reefs, and several riverine inputs. Since September 2003 surface water has been collected bimonthly throughout the bay for total alkalinity (TA) and dissolved inorganic carbon (DIC) analysis. The partial pressure of carbon dioxide (pCO_2) is calculated using TA, DIC, and constants from Mehrbach et al. (1973), refit by Dickson and Millero (1987). For all data collected before December 2003, pCO_2^{sw} were above the atmospheric level (~375 μatm) for all sites (~400 – 1300 μatm). The highest values occurred at sites within Kaneohe Stream. The lowest values, still above atmospheric, occurred at sites outside the barrier reef, indicating that high surface water pCO_2^{sw} extend beyond the boundaries of the bay. A large storm occurred at the end of November 2003 that dramatically reduced pCO_2^{sw} to at or below the atmospheric partial pressure throughout the entire bay. This appears to be the result of increased river runoff adding additional nutrients to the bay that enhanced photosynthesis throughout the bay thereby drawing down surface water CO_2. Despite the significant effect of the storm, average pCO_2^{sw} for September 2003 through February 2004 are above the atmospheric level and indicate that Kaneohe Bay probably behaves as a net source of CO_2 throughout the year because of calcification and perhaps heterotrophy.

PICES XIII S8-1985 Oral
Decadal changes of CO_2 in the North Pacific Ocean

Richard A. **Feely**[1], C. L. Sabine[1], R. Wanninkhof[2], A. Murata[3], R. Key[4], C. Winn[5], M. F. Lamb[1] and D. Greeley[1]

[1] Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA, 98115, U.S.A. E-mail: Richard.A.Feely@noaa.gov
[2] Atlantic Oceanographic and Meteorological Laboratory, National Oceanic and Atmospheric Administration, 4301 Rickenbacker Causeway, Miami, FL, 33149, U.S.A.
[3] Japan Marine Science and Technology Center, 2-15 Natsushimi–cho, Yokosuka, Kanagawa, 237-0061, Japan
[4] Atmosphere and Ocean Sciences, Princeton University, Princeton, NJ, 08533, U.S.A.
[5] Hawaii Pacific University, 1164 Bishop Street, Honolulu, HI, 96813, U.S.A.

The North Pacific Ocean plays an important role in controlling the long-term fate of CO_2 on Earth. Much of our understanding of the distribution of anthropogenic CO_2 in the North Pacific stems from intensive work conducted during the last two decades. Discrete high-quality dissolved inorganic carbon and total alkalinity data were acquired

as part of the WOCE/JGOFS Global CO_2 survey in the Pacific Ocean between 1991 and 1999 followed by repeat surveys in 2001 and 2004 as part of the Sub-arctic Gyre Experiment (SAGE) and Repeat Hydrography Program, respectively. The results of these research studies suggest an annual CO_2 uptake of 1.0-1.3 μmol kg^{-1} yr^{-1} in the mixed layer, based on direct observations and multiple linear regression approaches. Water column integrated uptake rates ranged from 0.25 to 1.3 mol m^{-2} yr^{-1}, depending on location and/or approach used. Deep ventilation within the Kuroshio Extension and the subsequent circulation in the subtropical gyre generates a strong east-west gradient in the anthropogenic CO_2 penetration depth. The combined effect of the tilted density surfaces and the younger waters with higher anthropogenic CO_2 concentrations leads to higher total column inventories in the western North Pacific. The gyre circulation and mixing works to smear out this anthropogenic signal. The integrated amount of anthropogenic CO_2 in the North Pacific is estimated to be 16.5 Pg C through 1994 north of the equator but not including the marginal seas. This estimate is approximately 16% of the amount of anthropogenic CO_2 taken by the global oceans.

PICES XIII S8-1817 Oral

Oxygen and Apparent Oxygen Utilization content variability in the upper North Pacific Ocean (1955 to 1998)

Hernan E. **Garcia**, Tim Boyer, Syd Levitus, Ricardo Locarnini and John Antonov

NOAA/NODC Ocean Climate Laboratory, SSMC III, E/OC5, 1315 East-West Highway, Silver Spring, MD, 20910, U.S.A.
E-mail: Hernan.Garcia@noaa.gov

Because of strong linkages, seasonal variations of oxygen, carbon, and nutrients can be used to estimate seasonal new production. However, over the past few decades a net decrease has occurred in the amount of atmospheric O_2/N_2 and oceanic O_2. In the ocean, these changes in oxygen concentration are generally larger than can be accounted for by thermal changes alone, suggesting that they are produced by biologically mediated O_2 production (marine production), vertical thermal stratification, or circulation variability. Here we use in situ data from CalCOFI, BATS, and the World Ocean Database to examine inter-annual to decadal variability in the inventories of dissolved oxygen, apparent oxygen utilization, and heat in the upper 1500 meters of the world ocean with emphasis on the North Pacific for the 1955 to 1998 time period. The water column inventories are generally characterized by relatively small linear trends superimposed on large decadal variability. Relatively lowest anomalies in the 1950s were followed by high anomalies in the mid 1980s and by low anomalies in the mid-1990s. Variability in the trends of these parameters is sensitive to the starting and ending time periods chosen to estimate any long-term trends. About half of the O_2 content variability can be explained based on gas solubility variability due to heat (temperature) content anomaly changes over the same time period. This suggests the interplay of additional forcing processes other than changes in O_2 solubility alone due to transient surface warming or cooling. The results suggest that the inventory of O_2 in the ocean is not in steady state as previously assumed.

PICES XIII S8-2031 Invited

Interannual to decadal variability in the carbon cycle and biogeochemistry of the North Pacific– Highlights from the NOAA/GCP/PICES synthesis and modeling workshop

Nicolas **Gruber**[1], Christopher L. Sabine[2], Richard A. Feely[2], Scott C. Doney[3], Robert M. Key[4], Jorge L. Sarmiento[4], Alexander Kozyr[5] and the workshop participants[6]

[1] IGPP and Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, Los Angeles, CA, 90095, U.S.A.
E-mail: ngruber@igpp.ucla.edu)
[2] NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA, 98115, U.S.A.
[3] Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, U.S.A.
[4] Princeton University, AOS Program, Forrestal Campus/Sayre Hall, Princeton, NJ, 08533, U.S.A.
[5] Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN, 37831, U.S.A.
[6] we thank all participants for their contributions

Evidence is accumulating that the cycling of carbon and of related biogeochemical elements varies significantly on time-scales from years to decades throughout the North Pacific (*e.g. Emerson et al.,* 2004). However, most of these studies were limited in time, space or number of parameters. What is lacking is a synthesis of North Pacific variability that may help us to understand better the possible mechanisms controlling the observed spatiotemporal patterns. We

will report results of a workshop convened this June that brought together experts to work toward eliminating this gap. The workshop focused on three central questions: How are air-sea CO_2 fluxes in the North Pacific affected by different modes of variability? How and why are the distribution of carbon, nutrients and oxygen in the water column changing with time? What are the requirements for detecting a climate change signal in the oceanic carbon cycle? Preliminary highlights that emerged from the workshop are: i) The occurence of substantial changes in the rate of surface ocean accumulation of CO_2 in the early to mid-1990s over the southern and central portions of the North Pacific, likely associated with a re-organization of the North Pacific climate state, ii) a changed perception of the observed interior ocean biogeochemical changes as reflecting decadal time variability rather than continuous linear trends, and iii) the emergence of the conclusion that most of the water column trends in oxygen are caused by physical rather than biological processes. Further analyses are under way, and we will report a more complete synthesis and a number of identified research needs at the meeting. (http://www.pmel.noaa.gov/co2/NP/)

PICES XIII S8-2147 Oral
Modelled carbon fluxes in the NE Pacific SERIES iron fertilization experiment

Debby **Ianson**[1], Christoph Voelker[2] and Ken Denman[3]

[1] OSAP, Institute of Ocean Sciences, PO Box 6000, Sidney, BC, V8L 4B2, Canada. E-mail: iansond@pac.dfo-mpo.gc.ca
[2] Alfred Wegener Institute, Bremerhaven, Germany
[3] Canadian Centre for Climate and Modelling Analysis, Victoria, Canada

The SERIES iron fertilization patch has been modelled as a physically homogeneous patch that expands and contracts in both the horizontal and the vertical entraining and losing fluid as prescribed by observations. Within the patch an ecological model, that follows carbon, nitrogen and silica independently, has been coupled to a mechanistic iron model. Chemical observations during the SERIES experiment are used to constrain the ecological/iron model. We use the model parameterization to experiment with the effect of nitrogen and silicic acid availability on carbon fluxes, focusing on carbon export.

PICES XIII S8-1876 Oral
Variations and distributions of pCO_2^{sw} in the western North Pacific during 1990 to 2003

Hisayuki Y. **Inoue**[1], Masao Ishii[2], Takashi Midorikawa[3], Akihiko Murata[4] and Kazuhiro Nemoto[3]

[1] Graduate School of Environmental Earth Sciences, Hokkaido University, N10W5, Kita-ku, Sapporo, 060-0810, Japan
E-mail: hyoshika@ees.hokudai.ac.jp
[2] Geochemical Research Department, Meteorological Research Institute, Nagamine 1-1, Tsukuba, Ibaraki, 305-0052, Japan
[3] Climate and Marine Department, Japan Meteorological Agency, Otemachi 1-3-4, Chiyoda-ku, Tokyo, 100-8122, Japan
[4] Ocean Observation and Research Department, JAMSTEC, Natsushima 2-15, Yokosuka, Kanagawa, 237-0061, Japan

Measurements of the partial pressure of CO_2 (pCO_2^{sw}) have been made at least once a year in the western North Pacific (3-34˚N along 137˚E, Nemoto *et al.*, 2004) every winter since 1981. Over the 1990s, measurements of pCO_2^{sw} have been made frequently and extensively in the western North Pacific, which allow us to evaluate the seasonal, inter-annual, and long-term trends of pCO_2^{sw} in the subtropics of the western North Pacific. In order to evaluate temporal variations in pCO_2^{sw}, the curve fitting technique of Thoning *et al.* (1989) was applied to the observed data. This gave an average feature of seasonal variation in pCO_2^{sw}. During the winter season, the pCO_2^{sw} was low compared to the air (pCO_2^{air}) in latitudes slightly south of the Kuroshio ($\Delta pCO_2 = pCO_2^{sw} - pCO_2^{air} = -60\mu atm$), and it tended to increase toward south reaching levels slightly lower than pCO_2^{air} in the equatorial Pacific ($\Delta pCO_2 = -10\mu atm$). During the summer season the pCO_2^{sw} south of the Kuroshio increased to levels ($\Delta CO_2 = 20\text{-}30\mu atm$) higher than pCO_2^{air} in lower latitudes. In the area of the present work (3-35°N, 137°E), the pCO_2^{sw} showed an average growth rate of 1.6 µatm/yr (nearly equal to that of pCO_2^{air}) with large variability (±8.9 µatm/yr). Large growth rate of pCO_2^{sw} occurred in early 1998, which was probably associated with the 1997/98 ENSO phenomena. At the meeting, we will report variations in pCO_2^{sw} on time scale of months to years.

PICES XIII S8-1915 Poster

Decadal trend of the oceanic CO_2 in the western equatorial Pacific warm pool

Masao **Ishii**[1], Shu Saito[1], Takeshi Kawano[2], Kazuhiko Matsumoto[2], Kazuhiro Nemoto[3], Hitomi Kamiya[3], Takashi Midorikawa[3] and Hisayuki Y. Inoue[4]

[1] Geochemical Research Department, Meteorological Research Institute, Nagamine 1-1, Tsukuba, 305-0052, Japan
E-mail: mishii@mri-jma.go.jp
[2] Ocean Observation and Research Department, Japan Marine Science and Technology Center, Natsushima 2-15, Yokosuka, 237-0061, Japan
[3] Climate and Marine Department, Japan Meteorological Agency, Otemachi 1-3-4, Chiyoda-ku, Tokyo, 100-8122, Japan
[4] Graduate School of Environmental Earth Science, Hokkaido University, N10W5, Kita-ku, Sapporo, 060-0810, Japan

Decadal trends of CO_2 concentration (xCO_2) and total inorganic carbon (TCO_2) in the surface layer of the western equatorial Pacific were analyzed using data collected during 46 cruises conducted between 1990 and 2003. At 160°E (5°S–5°N), the apparent rate of CO_2 concentration increase in surface water (xCO_2^{sea}) was +5.0 ± 1.2 ppm yr^{-1} while the atmospheric (xCO_2^{air}) increase was +1.6 ppm yr^{-1}. Such a faster increase of xCO_2^{sea} relative to xCO_2^{air} is mainly ascribed to the tendency that the ENSO warm phase prevailed in the early 1990s. During the warm phase the warm pool, with lower xCO_2^{sea}, extended over the western Equatorial Pacific. In contrast, the ENSO cold phase, occurred in the period 1998-2001 when the western Equatorial Pacific was under the influence of equatorial divergence with high xCO_2^{sea}. We also analyzed the intrinsic trends of xCO_2^{sea} and TCO_2 in the warm pool observed between 150°E and 160°W by comparing the data with $21.5 < \sigma_t < 21.8$ to eliminate the influence of equatorial divergence and the influence of N_2 fixation that was often seen in a shallow mixed layer above a developed barrier layer. The increasing rate of xCO_2^{sea} in the warm pool was +1.2 ± 0.7 ppm yr^{-1} between 1992 and 2003, which is similar to the increasing rate of xCO_2^{air}. It is also consistent with the increasing rate of salinity-normalized TCO_2 of +1.0 ± 0.4 μmol kg^{-1} yr^{-1} in the warm pool during the same period.

PICES XIII S8-1918 Poster

Change in total inorganic carbon and dissolved oxygen along the 137°E meridian between 1994 and 2003

Shu Saito[1], Masao **Ishii**[1], Hidekazu Matsueda[1], Keizo Shutta[2], Masahiko Fujimura[2], Ikuo Kaneko[3] and Takashi Midorikawa[3]

[1] Meteorological Research Institute, Japan Meteorological Agency, 1-1, Nagamine, Tsukuba, Ibaraki, 305-0052, Japan
E-mail: ssaito@mri-jma.go.jp
[2] Oceanographical Division, Kobe Marine Observatory, Japan Meteorological Agency, 1-4-3, Wkihamakaigan-dori, Chuou-ku, Kobe, Hyogo, 651-0073, Japan
[3] Marine Division, Marine and Climate Department, Japan Meteorological Agency, 1-3-4, Otemachi, Chiyoda-ku, Tokyo, 100-8122, Japan

Japan Meteorological Agency (JMA) has been making repeat observations including hydrography and partial pressure of CO_2 (pCO_2) measurements along the 137°E meridian (3°N - 34°N) in the western North Pacific. We made measurements of total inorganic carbon (TCO_2) as well as dissolved oxygen and nutrients in the water column along this line in July 1994 (WHP P9) and in November 2003, and determined the changes in these chemical parameters over the 9 years. On isopycnal surfaces sigma-theta = 25.1 - 25.4 kg/m^3, we found that salinity-normalized TCO_2 ($NTCO_2$) increased by 20.8 μmol/kg on average, which is about twice as large as that expected from the increase in pCO_2 in surface seawater, while AOU and nitrate increased by 5.1 μmol/kg and +0.98 μmol/kg, respectively. On the other hand, changes in $NTCO_2$, AOU and nitrate were +11.4 μmol/kg, +2.8 μmol/kg and +0.21 μmol/kg on sigma-theta 26.0 - 26.7 kg/m^3, and +3.1 μmol/kg, -5.7 μmol/kg and -0.99 μmol/kg on sigma-theta 26.7 - 27.0 kg/m^3 (all data are still preliminary). Data in January 1997 and in June 2000 are also to be presented and discussed.

PICES XIII S8-2047 Invited
Microbial biogeochemical Processes in the North Pacific Subtropical Gyre

David M. **Karl**

University of Hawaii, 1000 Pope Rd. MSB 629, Honolulu, HI, 96822, U.S.A. E-mail: dkarl@hawaii.edu

In October 1988, two transdisciplinary time-series stations were established in the open sea; one in the North Atlantic near Bermuda (BATS) and the other in the North Pacific near Hawaii (HOT). These two programs emerged from common planning to become open ocean twins with similar scientific objectives, research approaches, sampling frequencies, and methods of ecosystem interrogation. The primary objective is to observe and interpret time-dependent variations in microbial community structure and function, and the coupled changes in C-N-P cycling and energy flow through the microbial-based food web. Ideally, these repeat observations of key microbial and biogeochemical parameters would provide the data sets necessary for calibration and validation of existing ocean carbon cycle models – and, if necessary, to improve them. The repeat time-series would also provide data – largely for the first time – to define a mean state, or climatology, of oceanic microbes and processes from which a quantitative anomaly field could be derived. When our program began 15 years ago, we anticipated observing a time- and space-independent "climax" community of well known microbes. What we are finding is a complex, time-variable microbial assemblage, one that is phylogenetically diverse and metabolically versatile. For example, we have documented major shifts in community structure, induction of novel substrate processing pathways, and niche specialization/separation among otherwise closely related microorganisms, and much more. The causal mechanisms are not well understood, but appear to be consistent with ocean basin-scale climate variability. This sea of change keeps marine microbes in motion, and provides enormous opportunity for future research.

PICES XIII S8-2080 Oral
What controls the uptake of atmospheric CO_2 by the well-ventilated East/Japan Sea?

Geun-Ha Park[1], Kitack **Lee**[1], Kyung-Ryul Kim[2] and Dong-Jin Kang[2]

[1] School of Environmental Science and Engineering, Pohang University of Science and Technology, Pohang, 790-784, Republic of Korea
E-mail : ktl@postech.ac.kr

[2] Research Institute of Oceanography, School of Earth & Environmental Sciences, Seoul National University, Seoul, 151-742, Republic of Korea

Coastal and marginal seas account for only 7% of the surface of the world ocean. Nonetheless, they play an important role in the global carbon cycle by linking atmospheric, terrestrial, and oceanic carbon reservoirs. In particular, the East/Japan Sea could sequester a significant amount of CO_2 because it has a deep convection system, which vigorously brings surface water charged with anthropogenic CO_2 to the interior of the basin. During the period 1999-2000, a multi-national effort (USA, Russia, and Korea) led to a creation of comprehensive inorganic carbon and water mass tracer database for the East/Japan Sea. This paper presents comprehensive analysis of the basin-wide inventory of the anthropogenic CO_2 in the East/Japan Sea using high-quality inorganic carbon, alkalinity, nutrients, and chlorofluorocarbon, collected from the 1999-2000 survey. Anthropogenic CO_2 was separated from the large pool of dissolved inorganic carbon using an extended version of the ΔC^* method originally developed by Gruber et al. (1996). The extension of the method includes the use of an optimum multi-parameter analysis to determine the relative contributions from various source water types to the sample on an isopycnal surface. We attempt to find key mechanisms controlling the transfer CO_2 from the atmosphere to East/Japan Sea estimated anthropogenic CO_2 concentrations.

PICES XIII S8-2102 Oral
Age and AOU increases at the North Pacific subtropical-subpolar gyre boundary

Sabine **Mecking**[1], Mark J. Warner[2] and John L. Bullister[3]

[1] Woods Hole Oceanographic Institution, 360 Woods Hole Road, Woods Hole, MA, 02543, U.S.A.
E-mail: smecking@whoi.edu
[2] School of Oceanography, University of Washington, P.O. Box 355351, Seattle, WA, 98195-5351, U.S.A.
[3] Pacific Marine Environmental Laboratory/NOAA, 7600 Sandpoint Way NE, Seattle, WA, 98115, U.S.A.

Changes in CFC-derived ventilation ages (pCFC-12 ages) and apparent oxygen utilization (AOU) are investigated in the eastern North Pacific, where a portion of a 1991 World Ocean Circulation Experiment (WOCE) cruise along 152ºW was repeated in 1997 and a portion of a 1985 WOCE cruise along 24ºN was repeated in 2000. Between 1991 and 1997, a large increase in pCFC-12 ages and AOU is observed at the subtropical-subpolar gyre boundary at 152ºW. pCFC-12 ages (including a correction for mixing biases) and AOU increased by as much as 4 years and 40 μmol kg^{-1}, respectively, which corresponds to an increase of 33-40%. These results are in agreement with previous studies suggesting a reduction of ventilation in the subpolar gyre. A proposed mechanism for this is a reduction or cessation of the outcropping of the core isopycnal of the age and AOU changes (σ_0 = 26.65 kg m^{-3}). Since mixing-bias corrected pCFC-12 ages and AOU at 152ºW changed in approximately equal proportions, oxygen utilization rates (OUR = AOU/age) remained roughly constant from 1991 to 1997. Hence, there is no evidence that changes in biology may be causing the differences in AOU observed at 152ºW. In contrast, OURs appear to have decreased off the coast of California in the 24ºN sections from 1985 to 2000 indicating that export production may have decreased in the fresh subpolar waters that form the eastern limb of the subtropical gyre. It is recognized, however, that the estimation of OURs is sensitive to assumptions about outcrop saturations.

PICES XIII S8-1895 Poster
Long-term trend and interannual variations of winter oceanic pCO_2 and air-sea CO_2 flux in the western North Pacific

Kazuhiro Nemoto[1], Takashi **Midorikawa**[1], Hitomi Kamiya[1], Masao Ishii[2], Hidekazu Matsueda[2] and Hisayuki Y. Inoue[3]

[1] Climate and Marine Department, Japan Meteorological Agency, Otemachi 1-3-4, Chiyoda-ku, Tokyo, 100-8122, Japan
E-mail: t-midorikawa@met.kishou.go.jp
[2] Geochemical Research Department, Meteorological Research Institute, Nagamine 1-1, Tsukuba, 305-0052, Japan
[3] Graduate School of Environmental Earth Science, Hokkaido University, N10W5, Kita-ku, Sapporo, 060-0810, Japan

The Japan Meteorological Agency and Meteorological Research Institute have been conducting observations of CO_2 partial pressure in surface waters (pCO_2^{sea}) and overlying air (pCO_2^{air}) onboard the R/V *Ryofu Maru* from 3°N to 34°N along 137°E in the western North Pacific during nearly the same periods from late January to early February every winter, since 1981. We report the long-term trend and interannual variations of winter pCO_2^{sea} and air-sea CO_2 flux in the extensive area from subtropical to equatorial along 137°E based on two-decades of records. In the long term, the pCO_2^{sea} has increased at a similar growth rate (1.7-1.8 μatm yr^{-1}) to that of pCO_2^{air} (1.5-1.6 μatm yr^{-1}) over the whole region from 3°N to 34°N. These increases depend primarily on the increases in DIC concentration derived from the oceanic uptake of anthropogenic CO_2 from the atmosphere. The pCO_2^{sea} showed relatively large interannual variations (a standard deviation of yearly anomalies, Δ_{pCO_2}, 3.8-7.6 μatm), compared with pCO_2^{air} (Δ_{pCO_2}, 0.03-0.04 μatm). The air-sea CO_2 flux for January to February was estimated to be in the ranges from -0.64 ± 0.09 mol C m^{-2} at 25-28°N to 0.04 ± 0.05 mol C m^{-2} at 3-6°N and showed the insignificant secular trend with the confidence limit of 95% over the whole latitude ranges. These results suggest that the western subtropical North Pacific has acted persistently as a strong sink. The factors resulting in different interannual variations of winter pCO_2^{sea} and air-sea CO_2 flux at different latitudes will be discussed.

PICES XIII S8-2140 Oral

Interannual to decadal variability in Equatorial Pacific pCO_2 and surface CO_2 fluxes: An intermodel comparison

Keith B. **Rodgers**[1], Richard A. Feely[2], Olivier Aumont[1], James Orr[3], Gurvan Madec[1], Nicolas Metzl[4], Raghu Murtugudde[5], Patrick Wetzel[6], Ernst Maier-Reimer[6], Corinne Le Quere[7], Eric Buitenhuis[8], Fei Chai[9], Galen McKinley[10], Yasuhiro Yamanaka[11], Holger Brix[12], Nicolas Gruber[12], Taro Takahashi[13], Rik Wanninkhof[2], Hisayuki Y. Inoue[14] and Masao Ishii[15]

[1] LODYC, T 45-55, 4E, Paris, 75252, France. E-mail: rodgers@lodyc.jussieu.fr
[2] NOAA-PMEL, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, U.S.A
[3] LSCE, Saclay
[4] LBCM, Case 134, 4 Place Jussieu, Paris, 75252, France
[5] University of Maryland, ESSIC/UMD, College Park, MD, 20742, U.S.A.
[6] MPIM, Hamburg
[7] UEA/BAS and MPI-BGC, Jena
[8] MPI-BGC, P.O. Box 100164, Jena, D07701, Germany
[9] University of Maine, 5741 Libby Hall, Orono, ME, 04469-5741, U.S.A.
[10] University of Wisconsin
[11] FRCGC, 3173-25, Showa-machi, Yokohama, 236-0001, Japan
[12] IGPP & Department of Atmospheric and Oceanic Sciences, UCLA, 5853 Slichter Hall, Los Angeles, CA, 90095, U.S.A.
[13] LDEO
[14] Hokkaido University, Japan
[15] Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052, Japan

An intermodel comparison of simulated sea surface pCO_2 and air-sea CO_2 fluxes for the Equatorial Pacific is presented. The models in this study include those from the University of Maine (NCOM), University of Wisconsin (MIT), MPI-Hamburg (MPI OM1-MAMMOC5), LODYC (ORCA2-PISCES), MPI Jena (ORCA2-PISCES-T), University of Maryland (ESSIC-BGCM), the Frontier Research Center for Global Change (COCO-NEMURO), and UCLA (UOM-FGM). Although the models differ in their resolution as well as their representation of the oceanic carbon cycle, they have all been forced with NCEP reanalysis fluxes over the period 1948-2002.

Model validation is performed against a wide range of oceanic CO_2 measurements spanning the last several decades. The models are first compared with the Takahashi *et al.* (surface delta-pCO_2 data product corresponding to 1995, as this provides a basin-scale dianostic of the surface delta-pCO_2 found in the models. The long-term trend as a function of latitude and longitude is also considered over the period 1960-1995 to identify the extent to which sea surface pCO_2 in the Equatorial Pacific is "tracking" the increase in atmospheric CO_2 associated with the anthropogenic transient (Feely *et al*., 1999).

We then consider variability on seasonal, interannual, and decadal timescales. The eastern, central, and western Equatorial Pacific regions are considered separately, as the processes responsible for variability in these regions are thought to be different. For the western and central Pacific, the analysis focuses on repeat cruises along 137ºE and 165ºE, as well as repeat measurements along on the equator. For the eastern equatorial Pacific, the analysis includes comparison with time series of sea surface pCO_2 constructed for 150ºW and 110ºW. Particular attention is paid to the changes associated with the transition between the mean El-Niño-like conditions which prevailed throughout the early- and mid-1990s, to the persistent La Nina conditions which followed the 1997/98 El Niño event.

PICES XIII S8-1988 Poster

The oceanic sink for anthropogenic CO_2

Christopher L. **Sabine**[1], Richard A. Feely[1], Nicolas Gruber[2], Robert M. Key[3], Kitack Lee[4], John L. Bullister[1], Rik Wanninkhof[5], C.S. Wong[6], Douglas W.R. Wallace[7], Bronte Tilbrook[8], Frank J. Millero[9], Tsung-Hung Peng[5], Alexander Kozyr[10], Tsueno Ono[11] and Aida F. Rios[12]

[1] NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA, 98115, U.S.A. E-mail: chris.sabine@noaa.gov
[2] University of California Los Angeles, IGPP & Department of Atmospheric and Oceanic Sciences, Los Angeles, CA, 90095, U.S.A.
[3] Princeton University, AOS Program, Forrestal Campus/Sayre Hall, Princeton, NJ, 08533, U.S.A.
[4] Pohang University of Science and Technology, San 31, Nam-gu, Hyoja-dong, Pohang, 790-784, Republic of Korea
[5] NOAA Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Cswy., Miami, FL, 33149, U.S.A.
[6] Institute of Ocean Sciences, Climate Chemistry Laboratory, PO Box 6000, Sidney, BC, V8L 4B2, Canada

[7] Universitat Kiel, Institut fuer Meereskunde, Duesternbrooker Weg 20, D-24105 Kiel, Germany
[8] CSIRO Marine Research and Antarctic Climate and Ecosystem CRC, Hobart 7001, Australia
[9] University of Miami, RSMAS-Div. of Marine and Atm. Sciences, 4600 Rickenbacker Causeway, Miami, FL, 33149, U.S.A.
[10] CDIAC, Oak Ridge National Laboratory, U.S. Department of Energy, Mail Stop 6335, Oak Ridge, TN, 37831-6335, U.S.A.
[11] FRSGC/IGCR, Sumitomo Hamamatsu-cho, bldg. 4F, 1-18-16 Hamamatsutyo, Minato-ku, 105-0013, Japan
[12] Instituto de Investigaciones Marinas.CSIC, c/Eduardo Cabello, 6, 36208 Vigo, Spain

Using inorganic carbon measurements from an international survey effort in the 1990s consisting of 9618 hydrographic stations collected on 95 cruises and a tracer based separation technique (ΔC*), we estimate a global oceanic anthropogenic CO_2 sink for the period from 1800 to 1994 of 118±19 PgC. Variations in surface concentrations of anthropogenic CO_2 are related to the length of time that the waters have been exposed to the atmosphere and to the buffer capacity, or Revelle Factor, for seawater. Currently, approximately 30% of the anthropogenic CO_2 is found shallower than 200 m and nearly 50% above 400 m depth. The global average depth of the 5 μmol kg^{-1} contour is 1000 m. About 60% of the inventory is found in the Southern Hemisphere. The oceanic sink accounts for ~48% of the total fossil fuel and cement manufacturing emissions between 1800 and 1994, implying that the terrestrial biosphere was a net source of CO_2 to the atmosphere of about 39±28 Pg C for the period. By contrast, over the last 20 years the net terrestrial biosphere is thought to be a sink for anthropogenic CO_2 of about 15±9 Pg C. Over the last 20 years, the percentage of anthropogenic emissions taken up by the oceans appears to be smaller than over the last 200 years. The current fraction of total anthropogenic CO_2 emissions stored in the ocean appears to be about one third of the long term potential.

PICES XIII S8-2069 Poster
CO_2 is HOT: Fifteen years quantifying carbon dioxide in the subtropical Pacific Ocean

Daniel W. **Sadler**

School of Ocean and Earth Science and Technology, University of Hawaii, 1000 Pope Road, Honolulu, HI, 96822, U.S.A.
E-mail: sadler@hawaii.edu

The Hawaii Ocean Time-series (HOT) program has continuously measured the oceanic carbon dioxide system for 15 years at Station ALOHA in the subtropical North Pacific Ocean near Hawaii. Samples are collected approximately monthly using a rosette system fitted with a SeaBird CTD. Dissolved inorganic carbon (DIC) and total alkalinity (TA) samples are returned to our shore-based laboratory and analyzed using semi-automated coulometry and open-cell titration techniques, respectively, following methods recommended by the Department of Energy (DOE). pH is determined spectrophotometrically at-sea also following DOE guidelines. The accuracy of these measurements is maintained using certified seawater reference materials. Precision for measurement of DIC is better than 1 μmol/kg and for TA it is better than 2 μmol/kg. Precision of pH measurements is 0.001 pH units with an estimated accuracy of 0.004 pH units. We are in the process of procuring a new underway pCO_2 system. HOT program data are accessible online using HOT-DOGS - the Hawaii Ocean Time-series Data Organization & Graphical System located at: http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html. A list of publications based on the HOT CO_2 time-series is accessible at: http://hahana.soest.hawaii.edu/hot/hotpub.html. Key findings include: The distributions of DIC, TA and pH are controlled by both physical and biogeochemical processes. A seasonal cycle of DIC in the surface water reveals the waters around Hawaii are a net sink for CO_2. An inventory shows the surface ocean accumulating DIC consistent with increasing atmospheric CO_2. The strength of the CO_2 sink is strongly influenced by regional changes in precipitation and evaporation due to climatic variability.

PICES XIII S8-1893 Oral
Seasonal change in surface pCO_2 distribution in the East China Sea

Jeong Hee **Shim**[1], Young Chul Kang[2], Dong Seon Kim[2], Jae Hak Lee[1] and Chul Ho Kim[1]

[1] Ocean Climate and Environment Research Division, KORDI, P.O. Box 29, Ansan, 425-600, Republic of Korea. E-mail: jhshim@kordi.re.kr
[2] Polar Research Institute, KORDI, P.O. Box 29, Ansan, 425-600, Republic of Korea

Surface pCO_2, temperature, salinity, nutrients, and chlorophyll *a* were measured in the East China Sea (31~34 °N, 124~128 °E) from August 26 to September 2, 2003, and from April 28 to May 7, 2004. The high-salinity Tsushima Warm Current was observed in the eastern portion of the survey area in both years. Consequently, temperature and

salinity showed similar distributions in the summer of 2003 and the spring of 2004. By contrast, the surface pCO_2 changed dramatically from summer to spring across the shelf front, where the Tsushima Warm Current meets Yellow Sea water. High pCO_2 (> 380 μatm) in the east, and low pCO_2 (< 280 μatm) in the west, off China, were observed in the summer of 2003, and the pattern was reversed in the spring of 2004. Surface pCO_2 was positively correlated with temperature in the eastern portion of the shelf front in both summer and spring (r=0.82 and 0.74, respectively). Therefore, east of the front, temperature is thought to primarily control surface pCO_2, while west of the front it is controlled by many factors, such as fresh water discharge from Yangtze River in summer, water stability, primary productivity, and organic decomposition. The highly elevated pCO_2 west of the front in spring despite the low temperature and high chlorophyll concentration might be the result of surface water mixing with CO_2-rich bottom waters in spring or massive fresh water discharge from the Yangtze River in summer.

PICES XIII S8-1917 Poster
Variability in the degree of saturation for CFCs in the North Pacific Central Mode Water

Takayuki **Tokieda** and Masao Ishii

Geochemical Research Department, Meteorological Research Institute, Nagamine 1-1, Tsukuba, Ibaraki, 305-0052, Japan
E-mail: ttokieda@mri-jma.go.jp

We made observations of chlorofluorocarbons (CFCs) in seawater along 165°E in the western North Pacific in spring. In the North Pacific Central Mode Water (NPCMW), as defined by the lower potential vorticity below the seasonal thermocline that is formed between the Kuroshio Bifurcation Front and Kuroshio Extension Front, CFC-12 have been significantly under-saturated (~96%) with respect to the atmospheric CFC-12, and the degree of under-saturation has changed year by year. Since the mode water is formed through deep vertical convection in the surface layer in winter and is considered not greatly influenced by mixing with ambient waters during the subsequent advection into the interior of the ocean, these results suggest that CFCs in the mixed layer in winter were already under-saturated with respect to the atmospheric CFCs. It is also found that the density of NPCMW is changing year by year, which suggests that the mixing ratio of subtropical water and subarctic water to form NPCMW is changing year by year. On the basis of these results, the relationship between the density and degree of CFCs under-saturation is also to be presented.

PICES XIII S8-2134 Poster
Temporal and spatial variation of dissolved inorganic carbon in the western North Pacific in recent years

Nobuo **Tsurushima**[1], Yutaka W. Watanabe[2], Yukihiro Nojiri[3] and Koh Harada[1]

[1] National Institute of Advanced Industrial Science and Technology, Onogawa 16-1, Tsukuba, 305-8569, Japan. E-mail: tsurushima-n@aist.go.jp
[2] Graduate school of Environmental Earth Science, Hokkaido University, N10W5, Sapporo, 060-0810, Japan
[3] National Institute for Environmental Studies, Onogawa 16-2, Tsukuba, 305-8506, Japan

Temporal and spatial variations of dissolved inorganic carbon (DIC) in the western North Pacific were reassessed using the recent time-series data and cross-sectional data sets since the 1990s. DIC in the surface seawater have been determined by the Japanese ocean time series program at station KNOT (155°E, 44°N) from 1998 to 2004. The seasonal amplitude of DIC was more than 100 μmol/kg, which is larger than those of existing pelagic ocean time series sites. This large variation is mainly due to the biological production in spring to fall and strong vertical mixing in winter. Applying the equation of the Fourier sine expansion (Tanaka et al., 2003: GRL, 10.1029/2003GL018503), we estimated the increase rate of DIC in surface seawater at 1.0 μmol/kg/year. This value closely approximated the expected value under the equilibration between air and sea at KNOT. On the other hand, the increase rates of DIC were more variable in the intermediate and deep sea waters. We estimated the increase rates of DIC using the isopycnal data in 1992 and 2000 along the 165°E north-south transect. Increase rates of DIC were several times larger than the predicted values estimated only from the influence of anthropogenic carbon, especially in mid to high latitude areas. The distribution of DIC increase rates in the transect showed similar patterns with that of AOU. This suggests the possibility that the change of water circulation significantly influences the carbon cycle in the ocean.

PICES XIII S8-2174 Oral

Initial results of Russian-American Long-term Census of the Arctic (RUSALCA) Expedition: 2004

Terry E. **Whitledge**[1], Kathleen Crane[2], Vladimir Smolin[3], Kevin R. Wood[2] and Mikhail Zhdanov[4]

[1] School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, PO Box 757220, Fairbanks, AK, 99775-7220, U.S.A.
E-mail: terry@ims.uaf.edu
[2] Arctic Research Office, NOAA, 1315 East West Highway, Silver Spring, MD, 20910, U.S.A.
[3] Far Eastern Hydrometeorological Research Center, 24 Fontannaya St., Vladivostok, 690600, Russia
[4] Group Alliance, 13 M. Kozikhinsky Prospect, Moscow, 123001, Russia

In 2003, NOAA and the Russian Academy of Sciences signed a Memorandum of Understanding for World Ocean and Polar Regions Studies. The first project mentioned in the Memorandum, is a collaborative U.S – Russian Federation oceanographic expedition to the Arctic seas regions shared by both countries: the Bering and Chukchi Seas. In 2003, Russia and the United States requested proposals for sampling in U.S. and Russian territorial waters. The expedition during the summer of 2004 is the first activity under the Russian-American Long-term Census of the Arctic (RUSALCA), a joint project of NOAA and the Russian Academy of Science. The cruise objectives are to support the U.S. interagency Study of Environmental Arctic Change (SEARCH) Program [http://psc.apl.washington.edu/search/] and the NOAA Ocean Exploration Program.

These seas and the life within are thought to be particularly sensitive to global climate change because they are centers where steep thermohaline and nutrient gradients in the ocean coincide with steep thermal gradients in the atmosphere. Monitoring the flux of fresh and salt water passing through Bering Strait as well as establishing benchmark information about the distribution and migration patterns of the life in these seas are critical pieces of information needed prior to the emplacement of a climate-monitoring network in this region. During the expedition a mooring was deployed in western Bering Strait, more than 100 hydrographic stations, daily productivity measurements, microbial activity, zooplankton biomass, larval and adult fish abundance, benthic epifauna/infauna and rates of sediment processes were used to study the possible ramifications of climate change in this critical region where Pacific waters are transported into the Arctic.

PICES XIII S8-1882 Oral

Carbon change during SERIES (Sub-arctic Ecosystem Response Iron Enhancement Study)

C. S. **Wong**[1], Shau-King Emmy Wong[1] and Yukihiro Nojiri[2]

[1] Climate Chemistry Laboratory, Institute of Ocean Sciences, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada
E-mail: WongCS@pac.dfo-mpo.gc.ca
[2] National Institute for Environmental Studies, Tsukuba, 15-2, Onogawa, Ibaraki, 305-8506, Japan

An iron enrichment, SERIES, was conducted July 9 to August 4, 2002 within an area of 50 km^2 near Ocean Station P (50ºN, 145ºW) in the sub-arctic Alaskan Gyre. The objective was to assess the CO_2 drawdown due to addition of iron as ferrous sulphate. Changes in CO_2 chemistry and inorganic and organic carbon budget and fluxes were observed inside the iron-enriched patch using hydrocasts and free-drifting sediment traps. Haptophytes, mainly the coccolithophorid of *Emiliania hyxleyi,* increased in the first 12 days with a maximum flux for day 11 and day 12, causing a change in pCO_2 due to the formation of biogenic calcium carbonate shell. There was another larger calcium carbonate flux from day 15 to day 19 with flux reaching the 125 m sediment trap. Diatom, which increased during the period of day 4 to day 13, remained high till day 19 after iron addition. pCO_2 drawdown was significantly large with a sudden increase in opal flux towards the end of the observational period, for day 21 to day 24, followed by high organic carbon flux in day 23. The study indicated different phases of biogenic fluxes of opal, calcium carbonate and organic carbon.