

Results from BEST, BSIERP, and other IPY-relevant research in the northern Bering Sea

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Dalian P.R. China



Video clip courtesy of BBC Planet Earth team on Healy 04-02

Acknowledgments

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- ³North Carolina State University, Raleigh
- ⁴University of Wyoming, Laramie
- ⁵University of Tennessee
- ⁶Alaska Science Center, U.S. Geological Survey

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U.S. National Oceanic and Atmospheric Administration

Integrated U.S. Ecosystem Research in the Bering Sea

Bering Ecosystem Study (BEST)
U.S. National Science Foundation

<http://www.nsf.gov>



Bering Integrated Ecosystem Research Program (BSIERP)
North Pacific Research Board

**(government chartered independent research foundation
with oversight through U.S. Department of Commerce)**

www.nprb.org



UNDERSTANDING ECOSYSTEM PROCESSES IN THE

Bering Sea



AN HISTORIC PARTNERSHIP BETWEEN THE NORTH PACIFIC RESEARCH BOARD AND THE NATIONAL SCIENCE FOUNDATION

AT A GLANCE

General Program
Information

Meet the Scientists

Study Region Map

Photo Gallery

NEWS + UPDATES

In the News

Scientific Cruises

Media

Teachers + Students

OUR FOCUS

An Ecosystem
Approach

Human Communities

Ecosystem Modeling

Animal Stories

FOUNDATIONS

History

Bering Sea Ecosystem Research:
An unprecedented scientific effort
between NPRB and NSF

SIX YEARS
93 SCIENTISTS
MILLIONS
OF CREATURES
ONE STORMY SEA



PROGRAM UPDATES

SAB Election Results

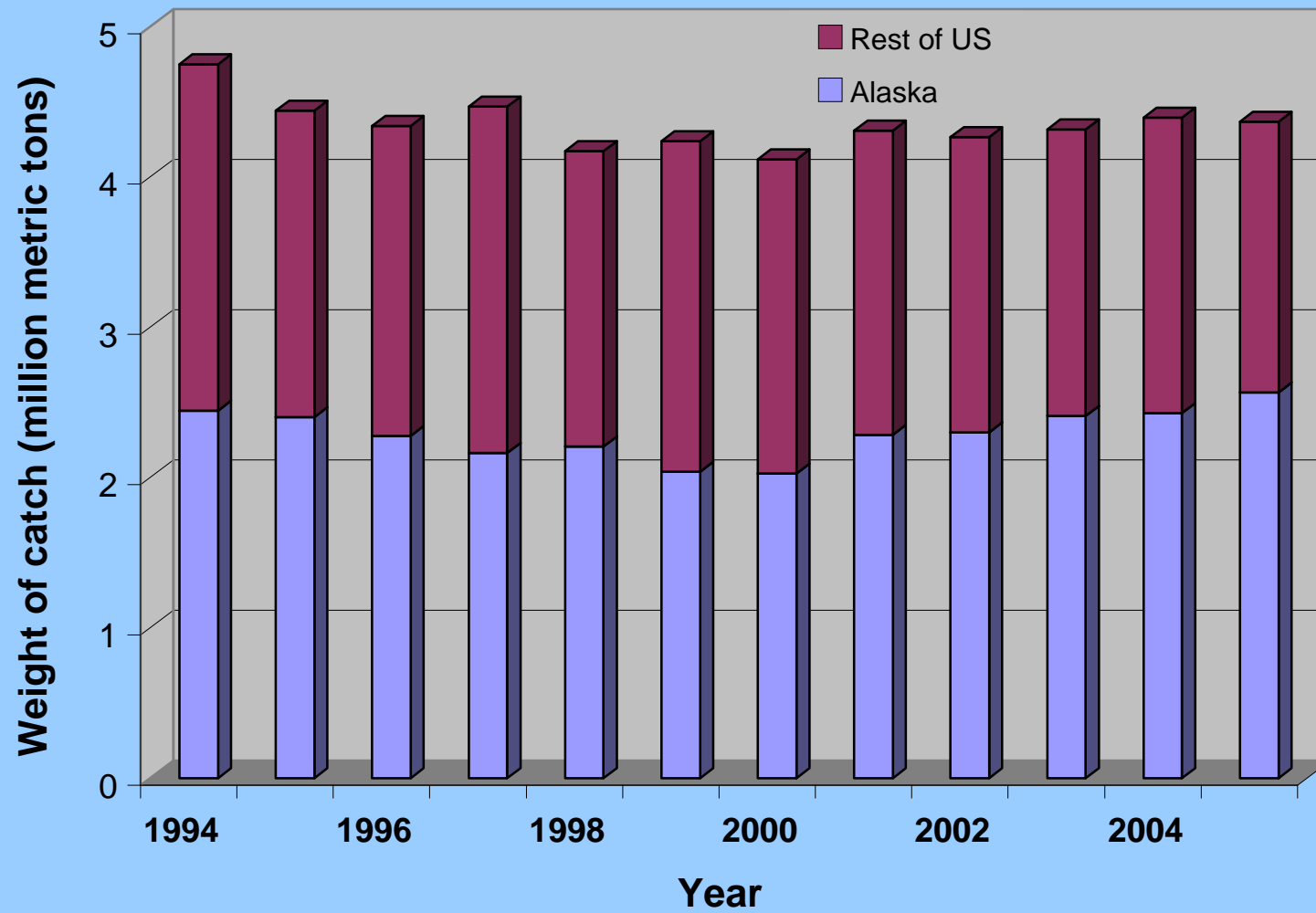
The votes for the **Scientific Advisory Board** have been tallied. Terms were randomly determined per the Program Management Plan. Congratulations to:

- Kerim Aydin, Rolf Gradinger, Phyllis Stabeno (1-year term)
- Carin Ashjian, Rodger Harvey, Mike Sigler (2-year term)

JOB OPPORTUNITY

OSU College of Oceanic +
Atmospheric Sciences Research
Associate (Postdoctoral)
Study the distribution and

US Domestic Commercial Fisheries



Change in the nation's "fish basket"

Rising temperatures are transforming Alaska's Bering Sea, the source of half of America's seafood and the mainstay of Seattle's fishing industry. Crab, flatfish, walrus and seal populations are suffering while pollock and cod are on the rise.

A FROZEN WORLD

Ice provides habitat for mammals and birds and nurtures a food chain that favors bottom-feeding species like crab, flatfish and gray whales; it also creates a deep pool of near-freezing water that crab prefer and pollock avoid.

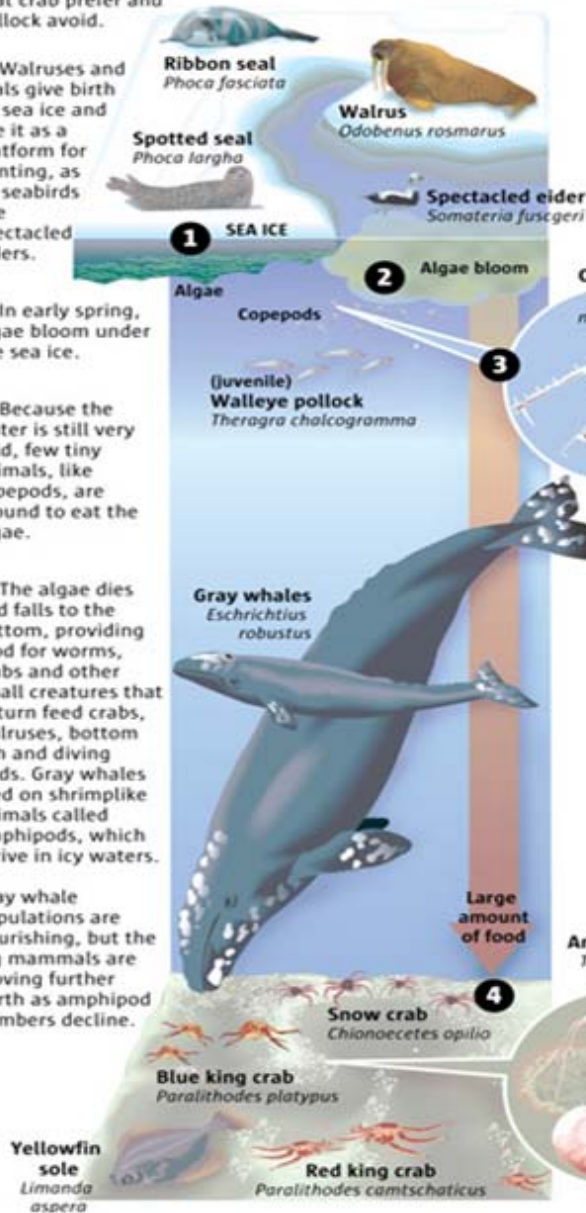
1. Walruses and seals give birth on sea ice and use it as a platform for hunting, as do seabirds like spectacled eiders.

2. In early spring, algae bloom under the sea ice.

3. Because the water is still very cold, few tiny animals, like copepods, are around to eat the algae.

4. The algae dies and falls to the bottom, providing food for worms, crabs and other small creatures that in turn feed crabs, walruses, bottom fish and diving birds. Gray whales feed on shrimplike animals called amphipods, which thrive in icy waters.

Gray whale populations are flourishing, but the big mammals are moving further north as amphipod numbers decline.



THAWING OUT

An ice-free sea favors species that live and feed in the water column, like pollock, cod and orcas.

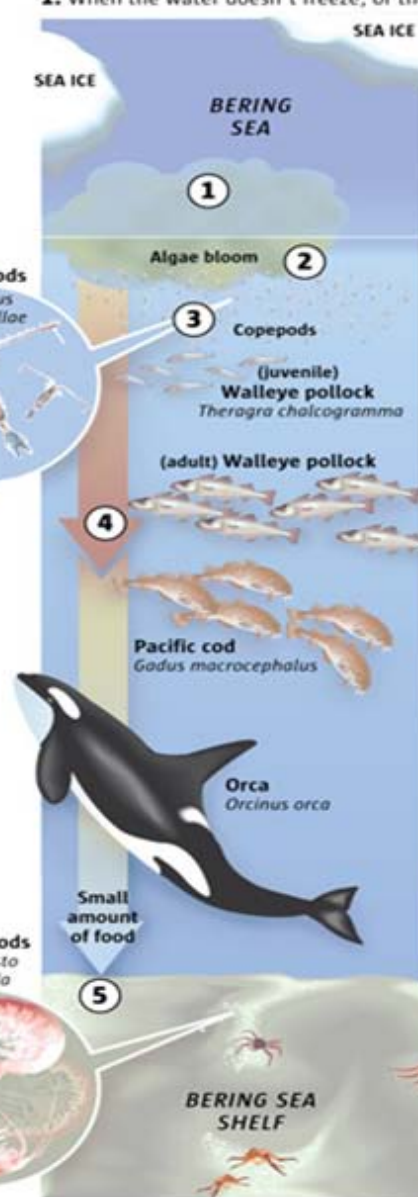
1. When the water doesn't freeze, or the ice melts early, walruses and seals have fewer places to give birth. Forced into deeper waters further north where ice remains, walruses can't reach the bottom to forage for clams.

2. Without ice to provide a substrate, algae don't bloom until later in the spring.

3. In the warmer waters, zooplankton, including copepods, flourish, consuming the algae.

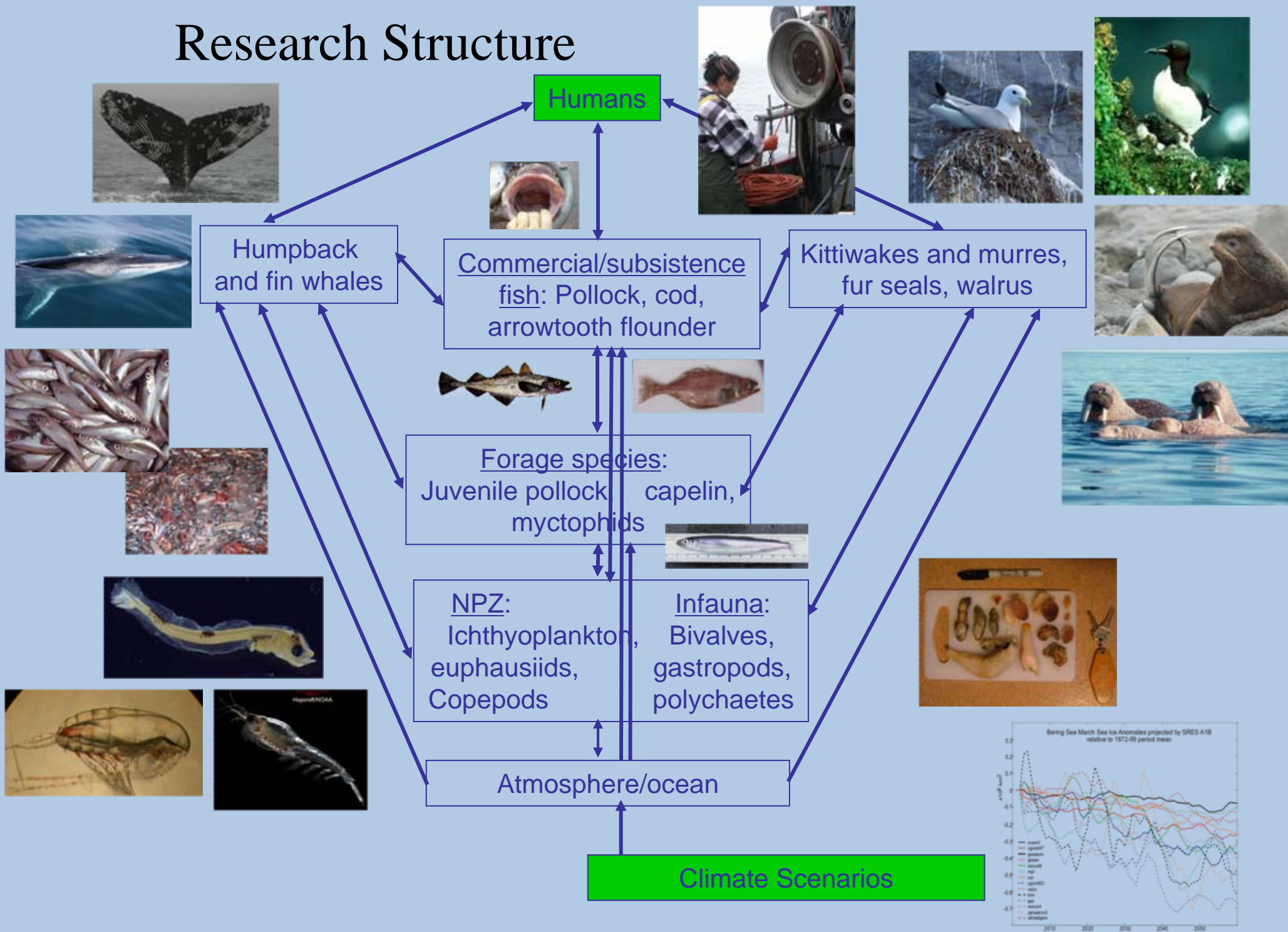
4. The zooplankton provide food for small fish, including juvenile pollock and cod, which also spread north as the pool of cold water shrinks; orca feed on the adult pollock and cod.

5. Less food reaches the bottom for crab and other bottom-feeders.

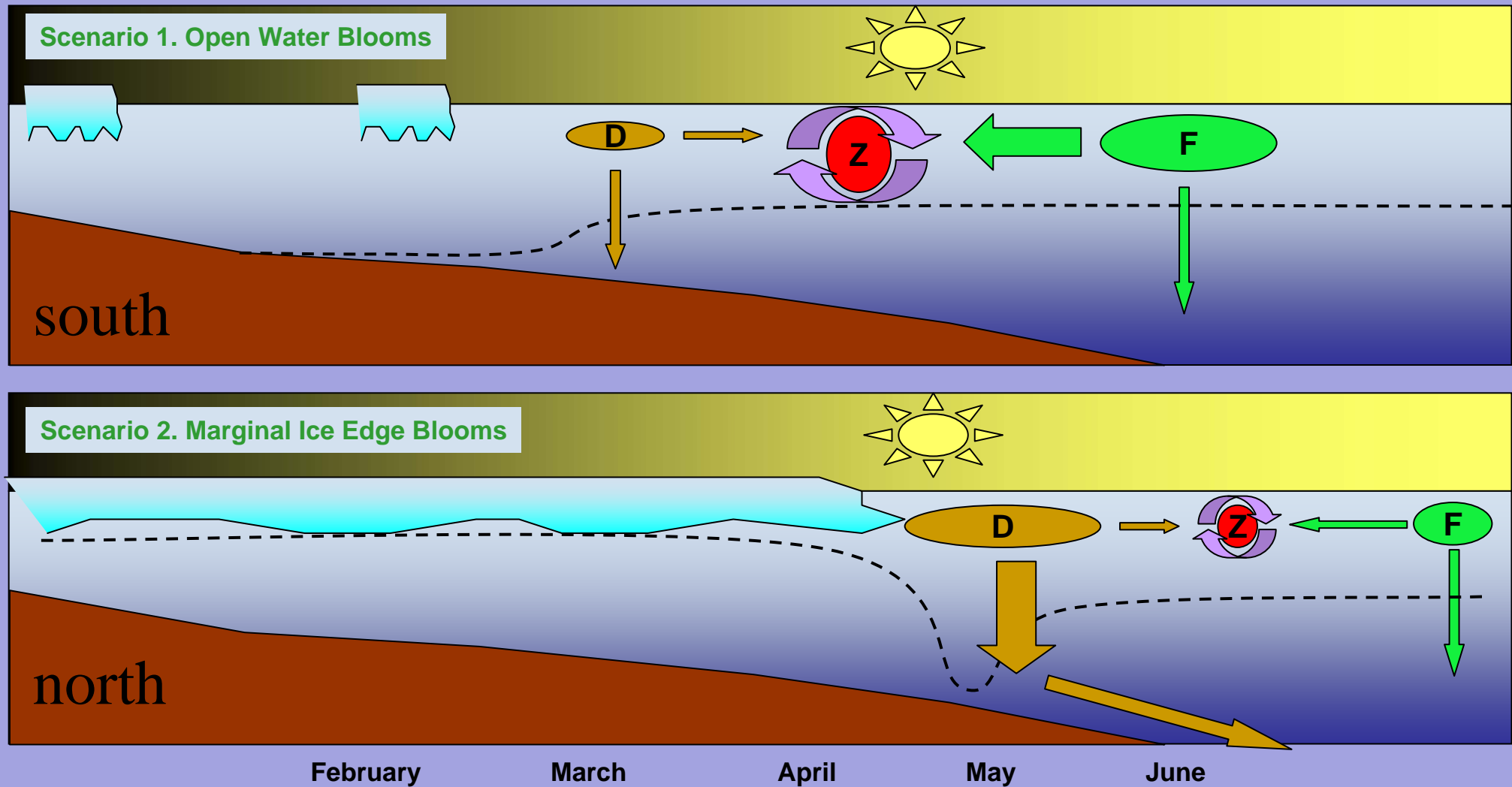


Sources: "A Major Ecosystem Shift in the Northern Bering Sea," Science, vol. 311, March 10, 2006; "BEST, Bering Ecosystem Study Science Plan," Arctic Research Consortium of the United States (ARCUS), 2004

BSIERP – BEST Field Research Structure

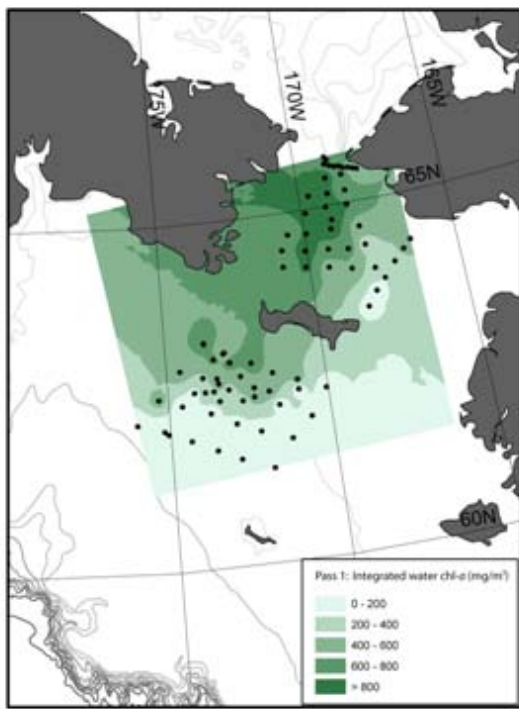


South to north pelagic to benthic ecosystem transition

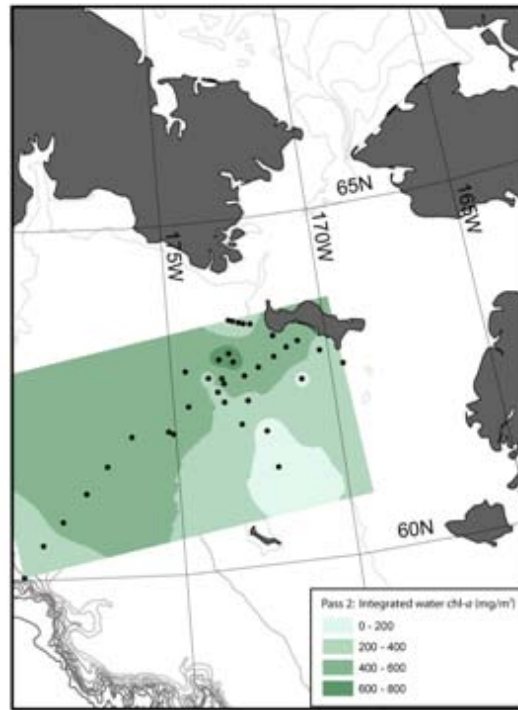


Graphic courtesy of Brad Moran and Mike Lomas

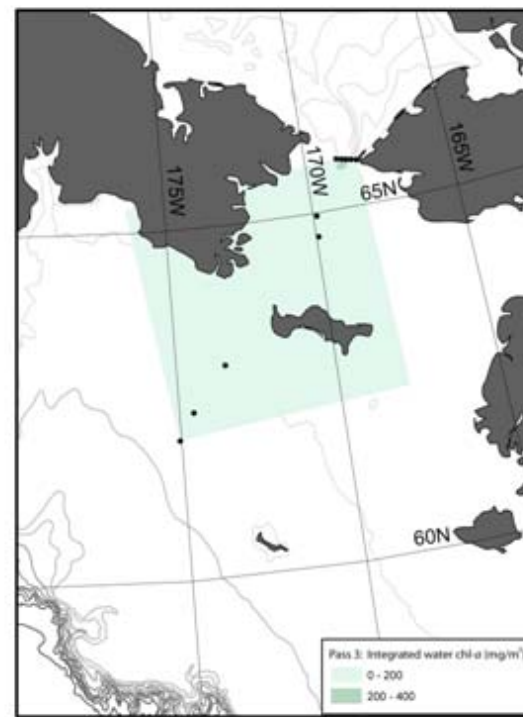
Key - Diatoms, Zooplankton, Flagellates



9-27 May 2006



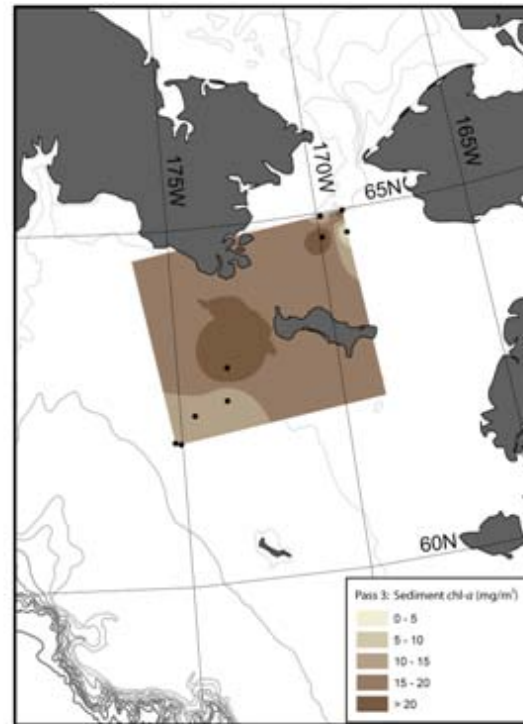
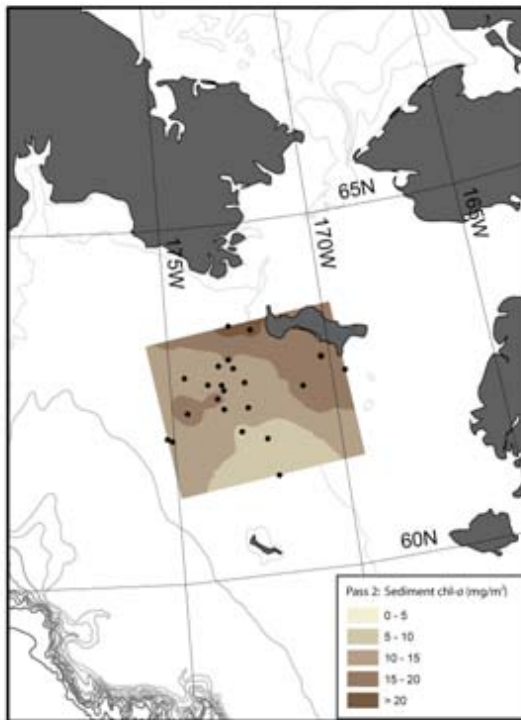
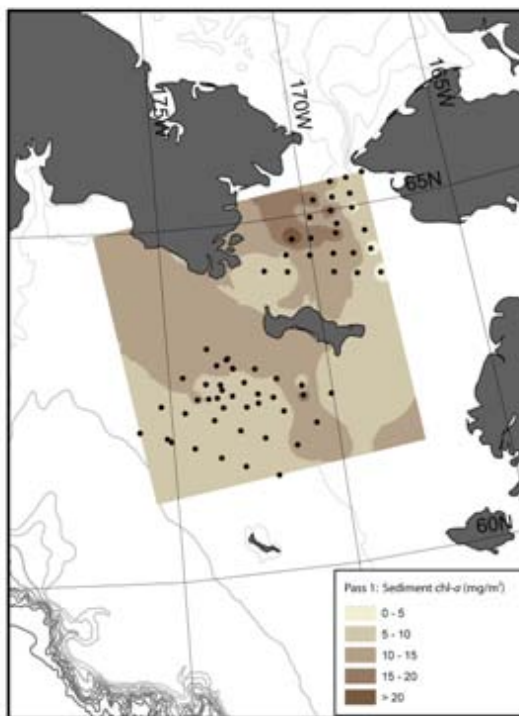
27 May-3 June 2006



12-15 July 2006

Integrated
water
column
chlorophyll

11-1053 mg
m⁻²



Mean
chlorophyll
in surface
sediments

<1 to 40 mg
m⁻²

Surface Seawater Temperature (5 m)

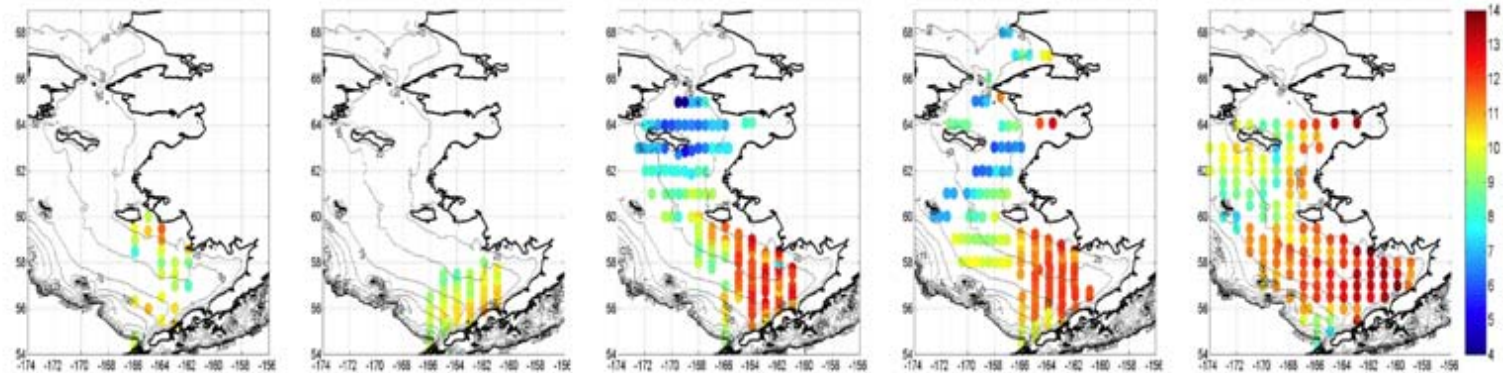
2000

2001

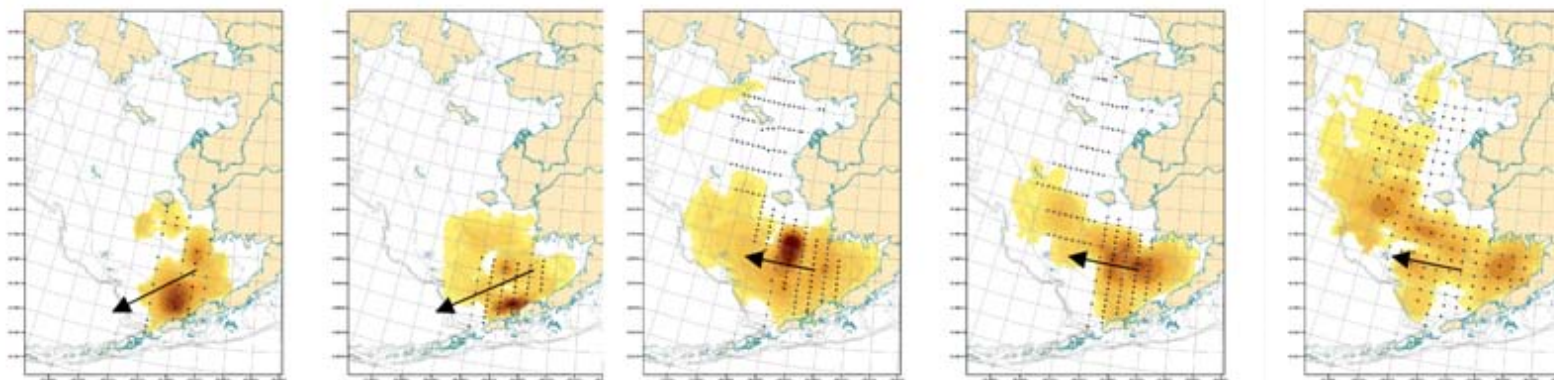
2002

2003

2004



Juvenile Sockeye Salmon Distribution and Seaward Migration Pathway change in Bristol Bay sockeye salmon distribution and seaward migration pathways in relation to warming sea surface temperatures

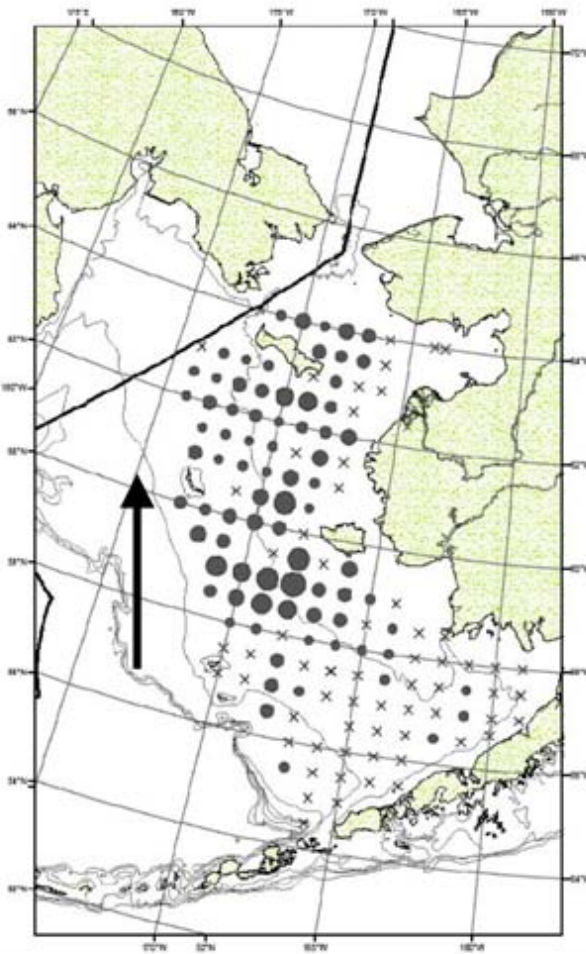
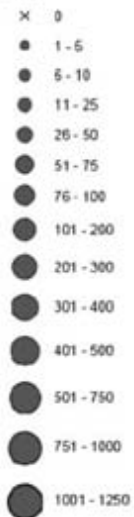


Low Survival

High Survival [courtesy Ed Farley/NOAA]

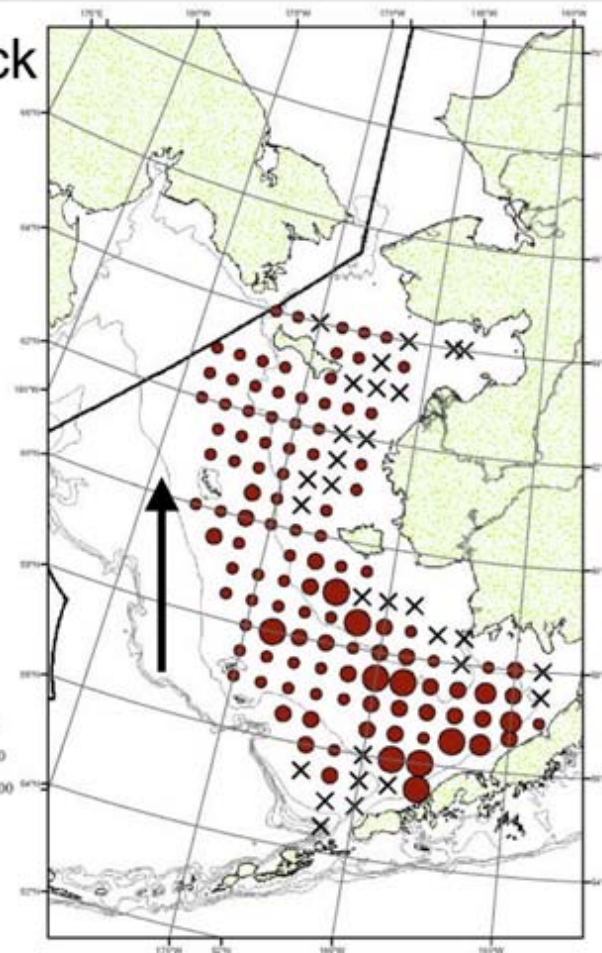
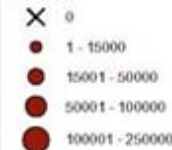
Pink salmon

Pink



Pollock

pollock

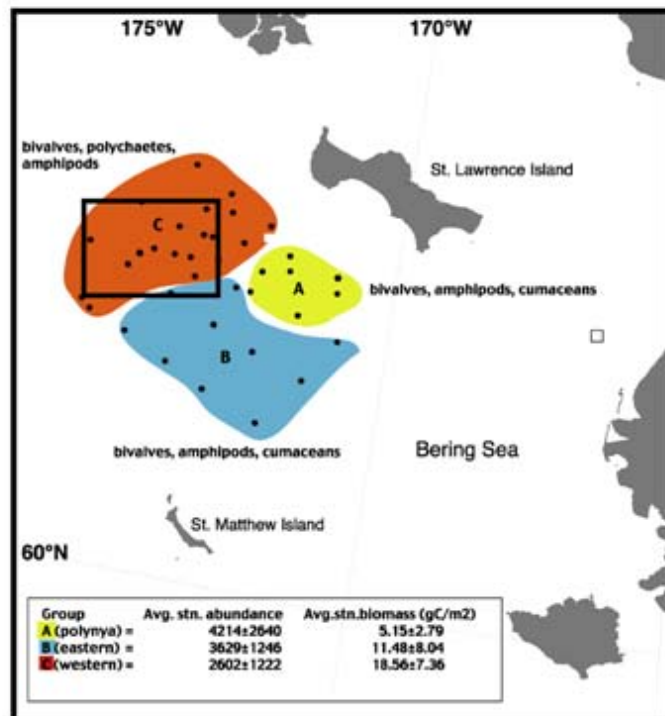


10 Million new Salmon in the N. Bering Sea in 2004; coincident with increased northward movement of pollock
[courtesy Jack Helle/NOAA]

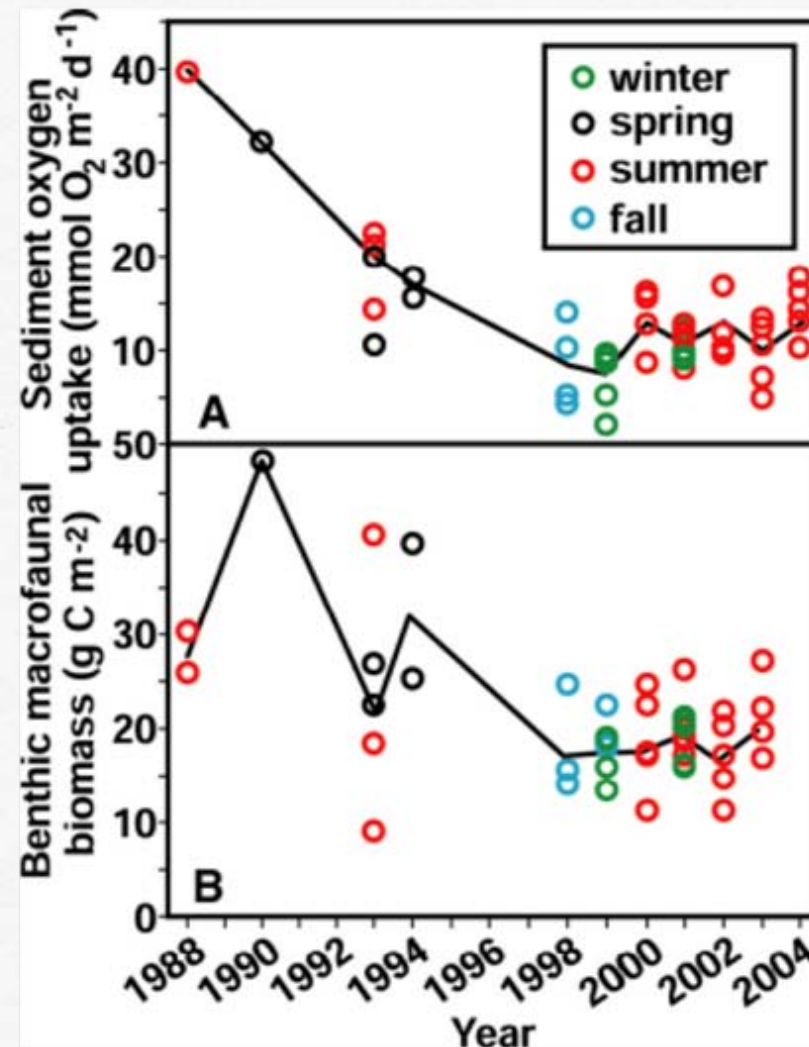
Change in sediment oxygen uptake (indicator of carbon supply to benthos) and benthic macrofaunal biomass SW of St. Lawrence Island

(trend lines through station means)

BSEO-S sites embedded in Group C. orange



[Simpkins et al., 2003, Polar Biology 26]



[Grebmeier et al., 2006, Science 311]

Significantly changing taxa



Ampeliscidae



Haustoriidae

1.0 mm



©2003 MBARI

Leuconidae



Orbiniidae

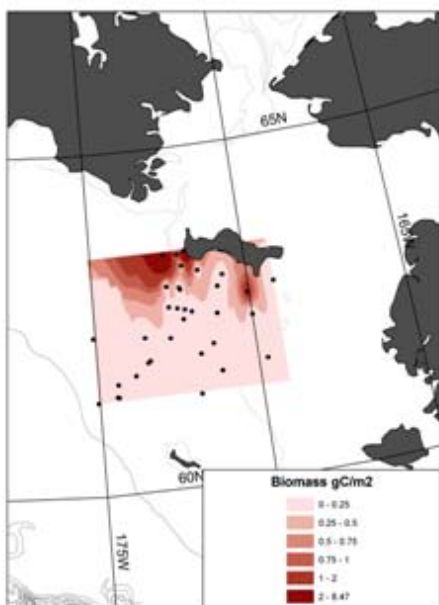
Significantly changing taxa



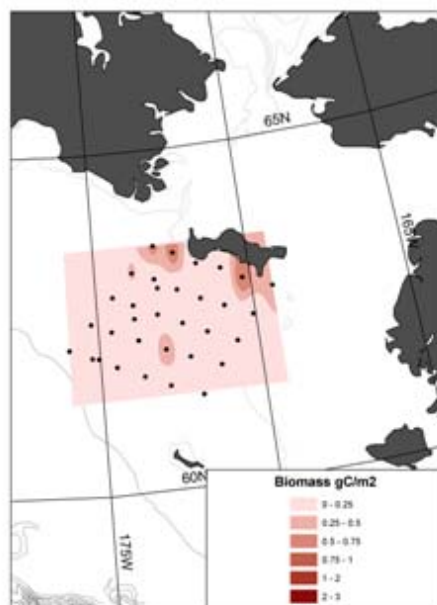
—
0.5 mm



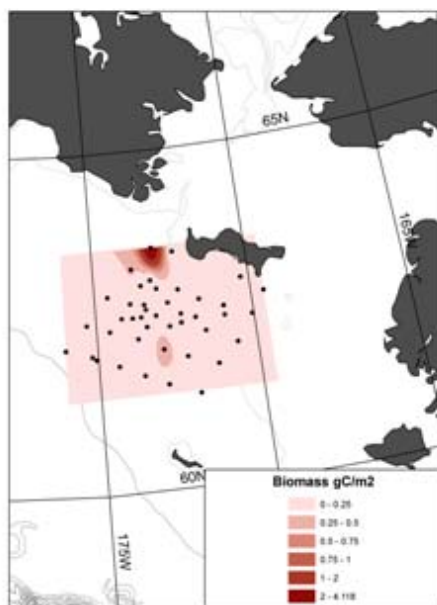
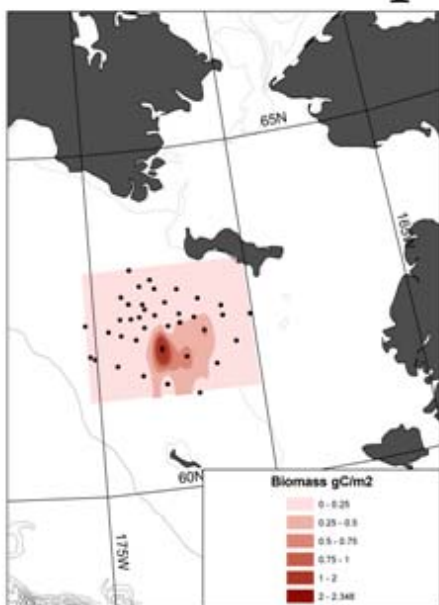
Stoker (1970-74)



HX171 (1993)



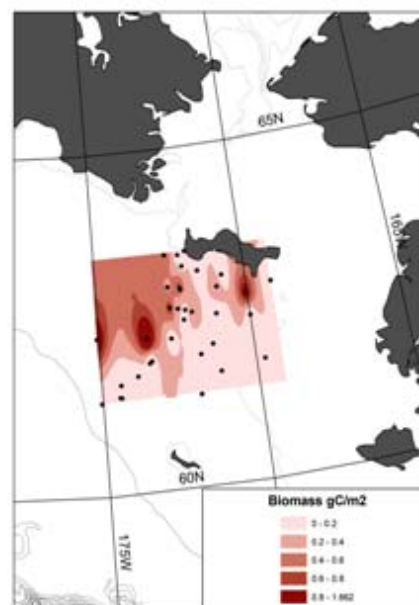
Ampeliscidae



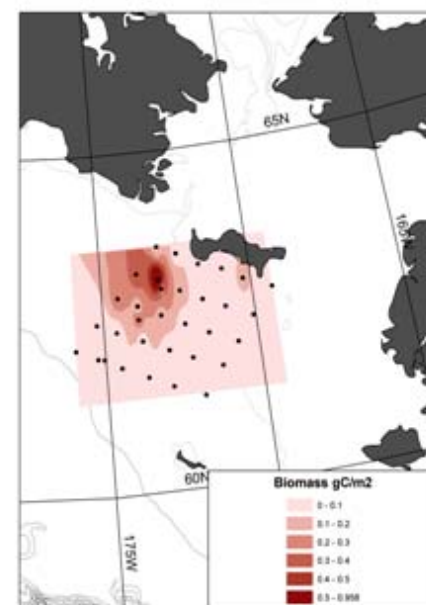
SLIPP01 (2001)

HLY0601 (2006)

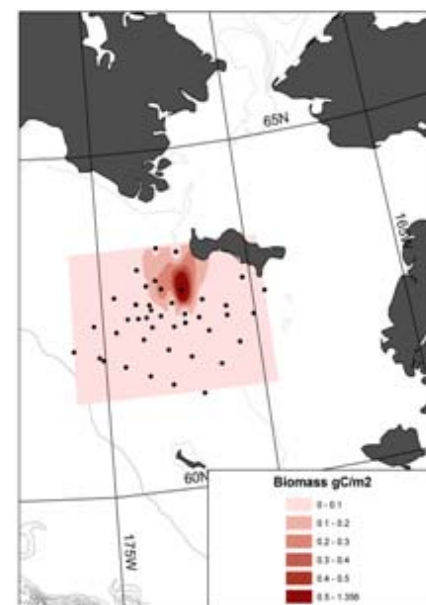
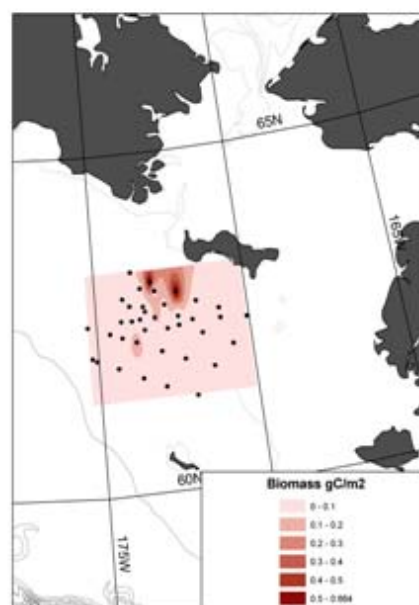
Stoker (1970-74)



HX171 (1993)



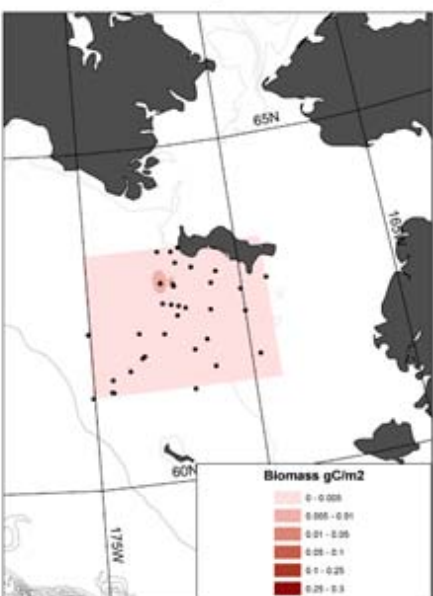
Haustoriidae



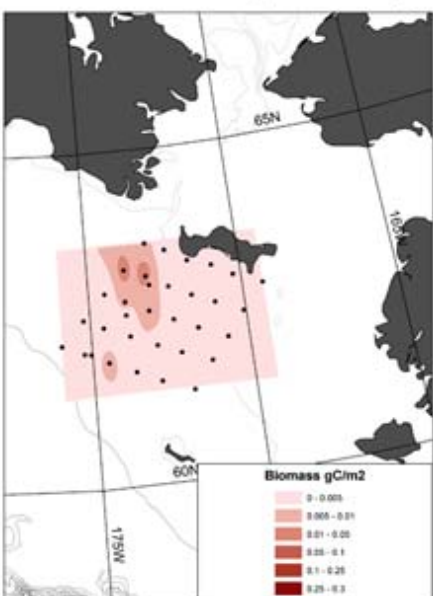
SLIPP01 (2001)

HLY0601 (2006)

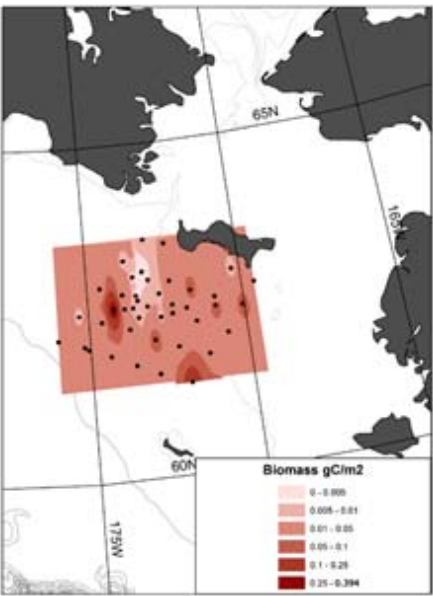
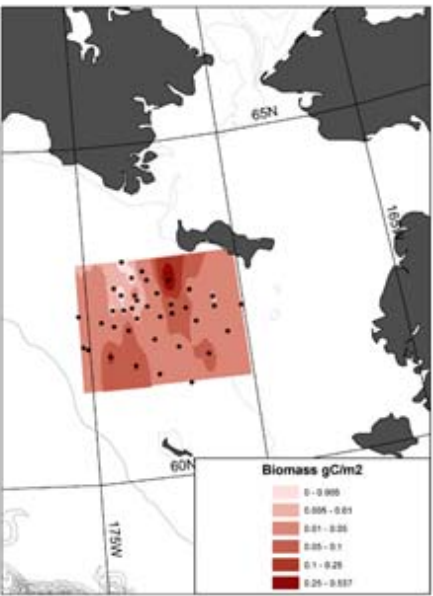
Stoker (1970-74)



HX171 (1993)



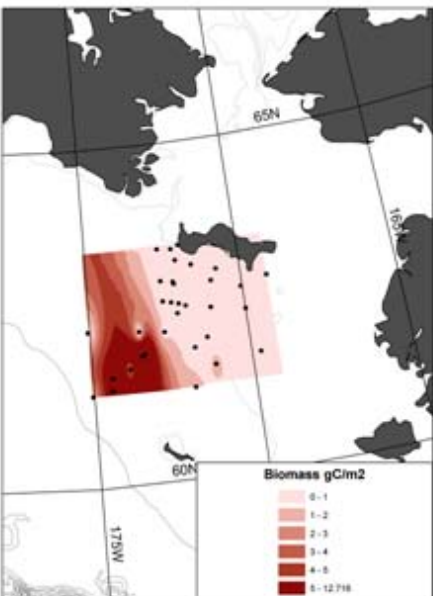
Leuconidae



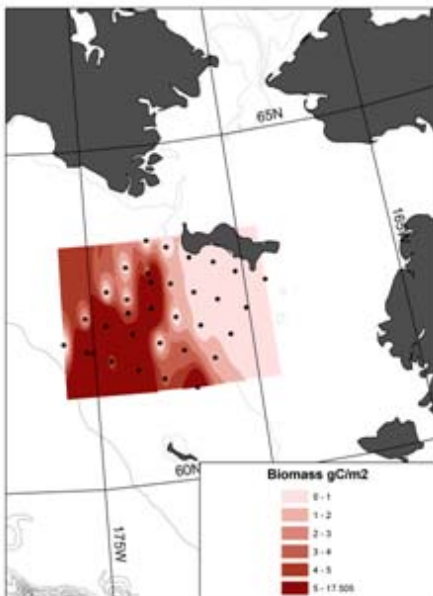
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HLY0601 (2006)

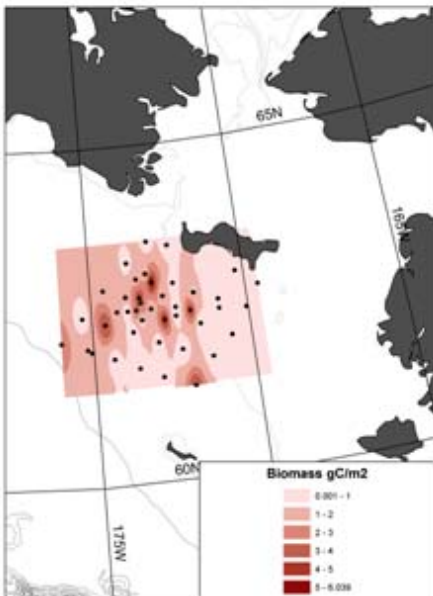
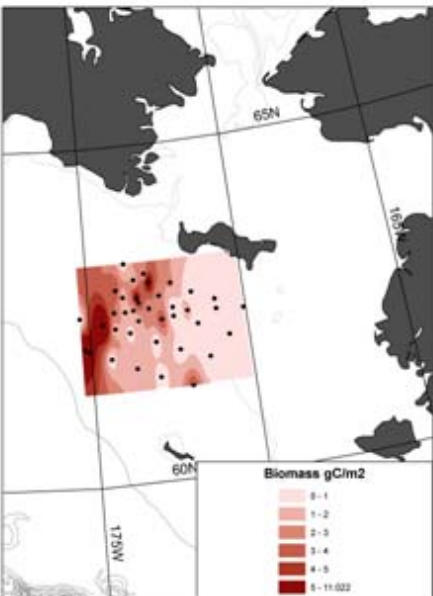
Stoker (1970-74)



HX171 (1993)



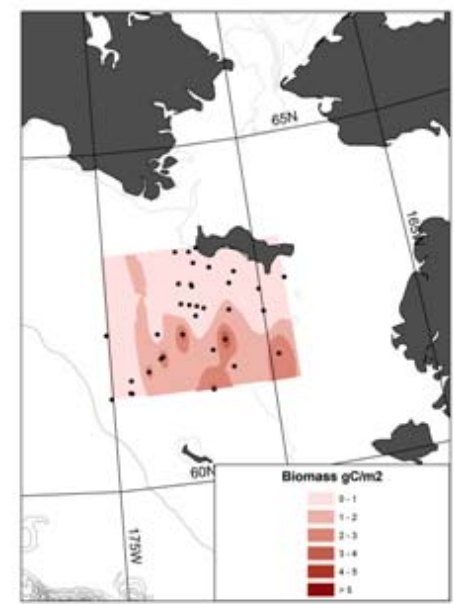
Nuculanidae



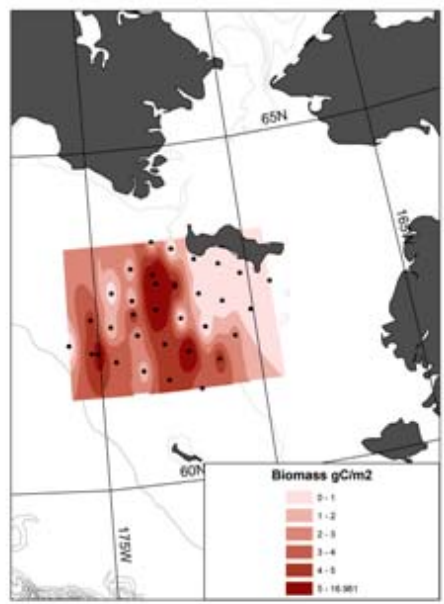
SLIPP01 (2001)

HLY0601 (2006)

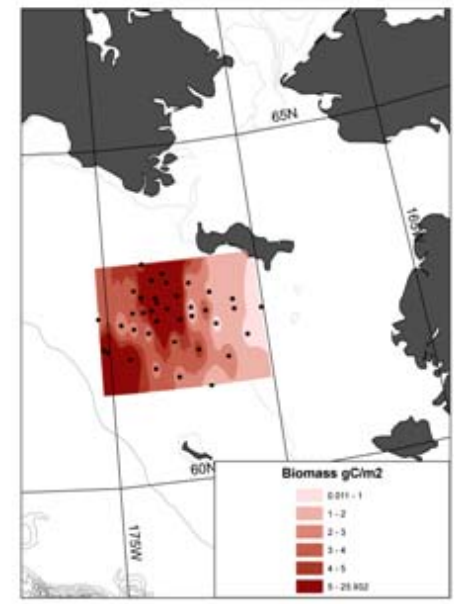
Stoker (1970-74)



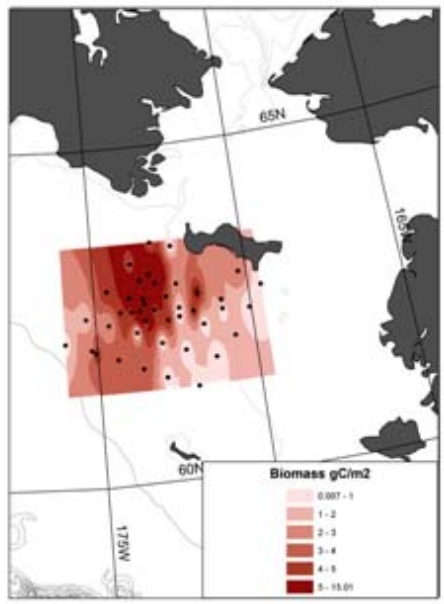
HX171 (1993)



Nuculidae

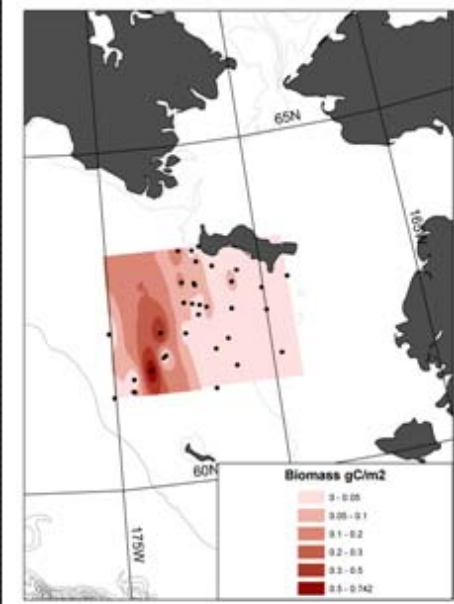


SLIPP01 (2001)

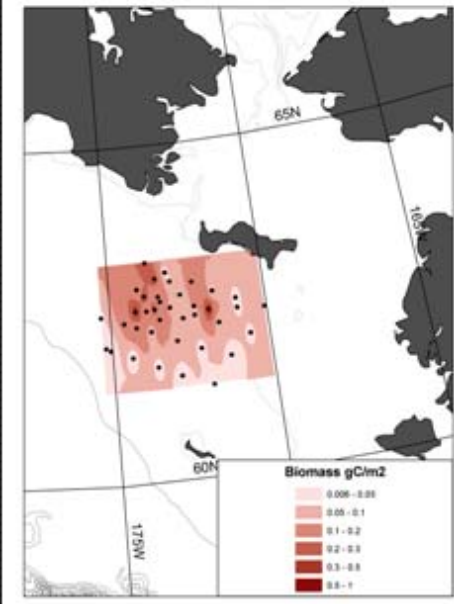


HLY0601 (2006)

Stoker (1970-74)

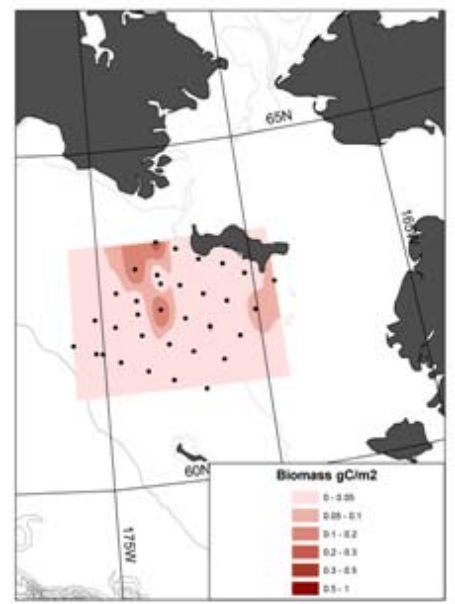


Orbiniidae



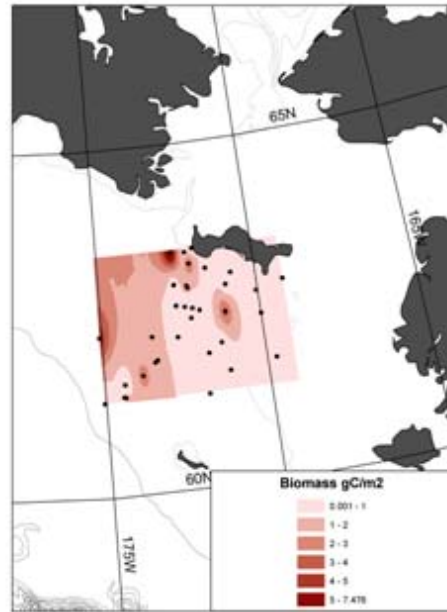
SLIPP01 (2001)

HX171 (1993)

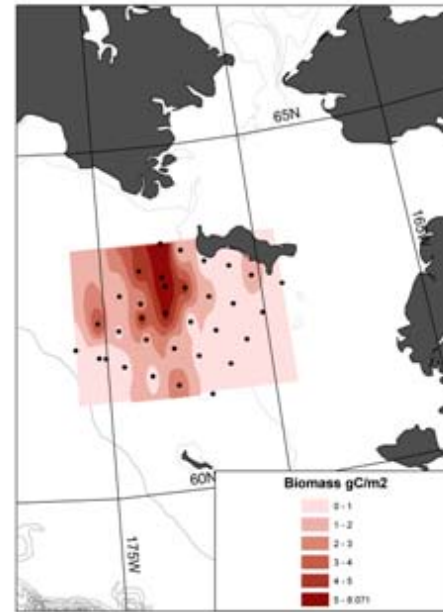


HLY0601 (2006)

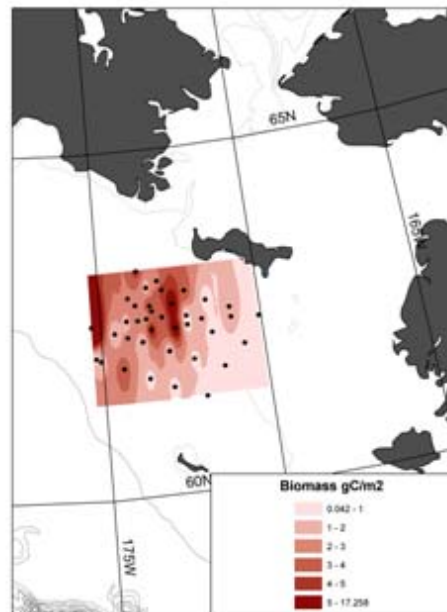
Stoker (1970-74)



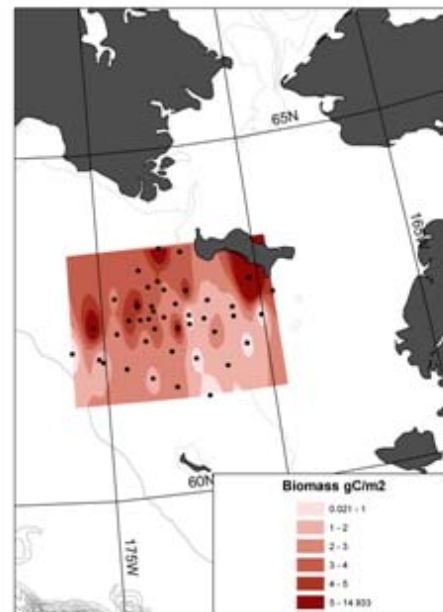
HX171 (1993)



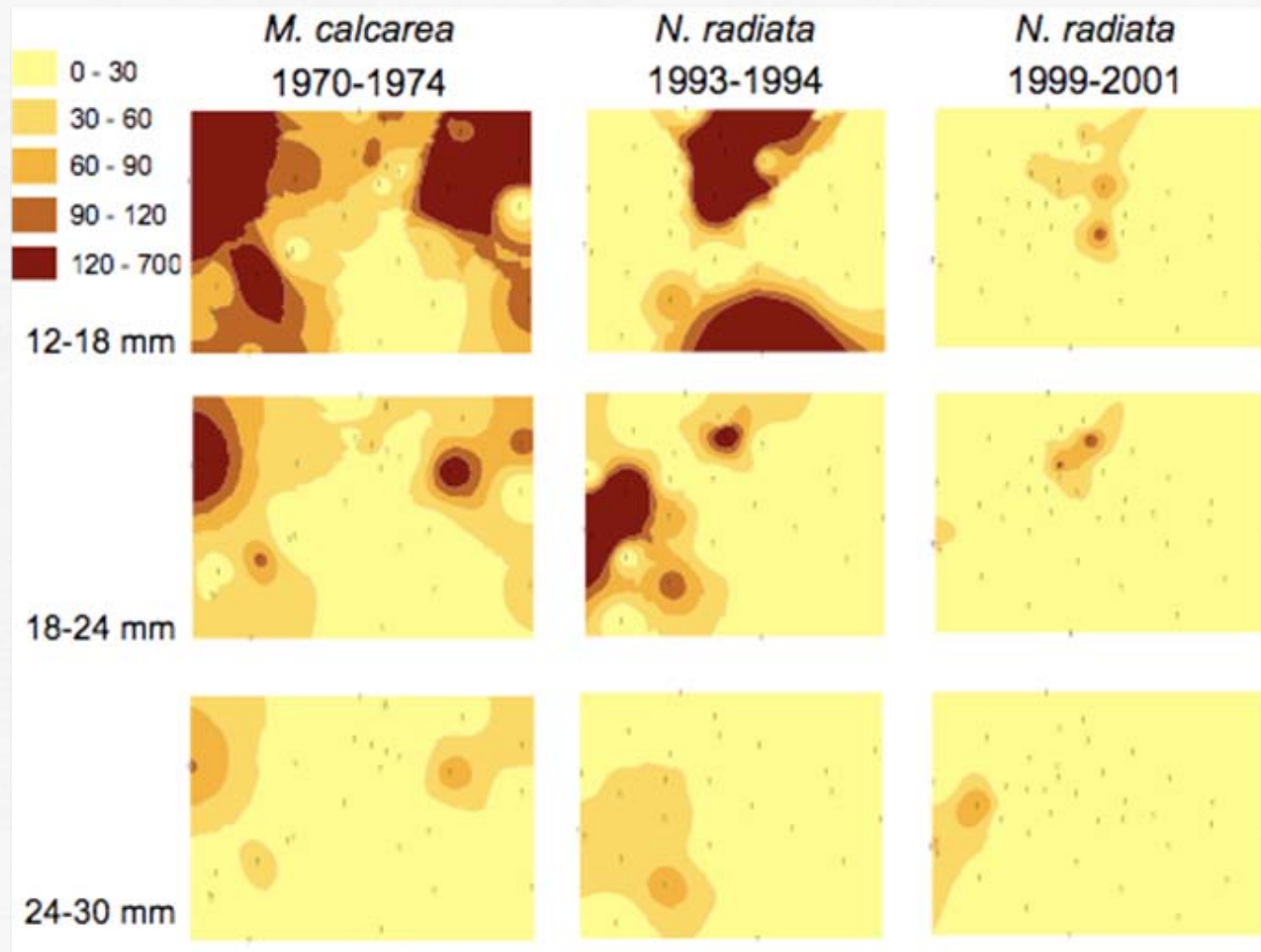
Tellinidae



SLIPP01 (2001)



HLY0601 (2006)



Lovvorn et al. manuscript submitted

Fish/prey photos:
Xuehua Cui



Shorthorn sculpin: 352mm, 599g

Live ampharetid worm

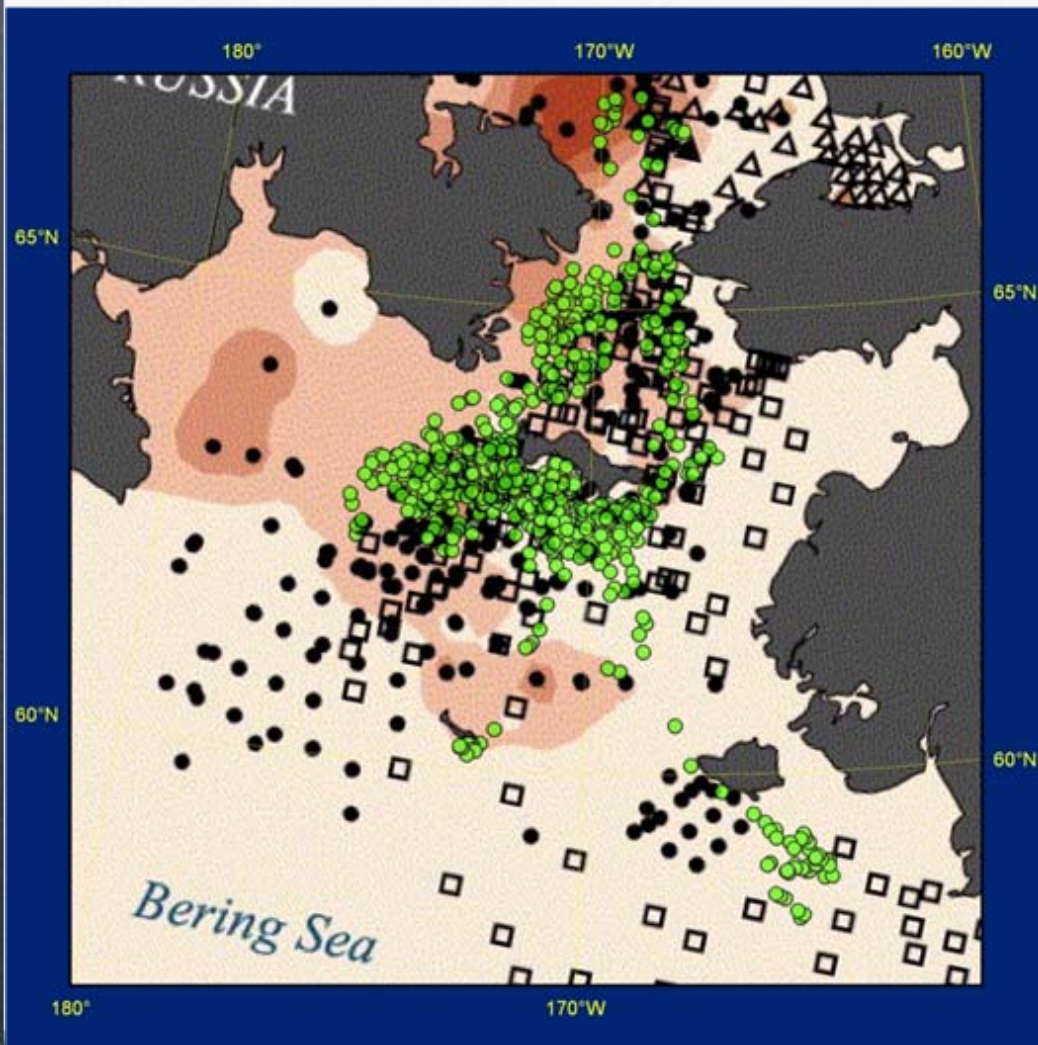


Photo: Art Howard/
PolarPalooza



Ecological impacts

Most biologically productive sector of the Arctic marine system is the Bering and Chukchi Seas



- bivalve prey for walrus



[courtesy Gay Sheffield, ADFG]

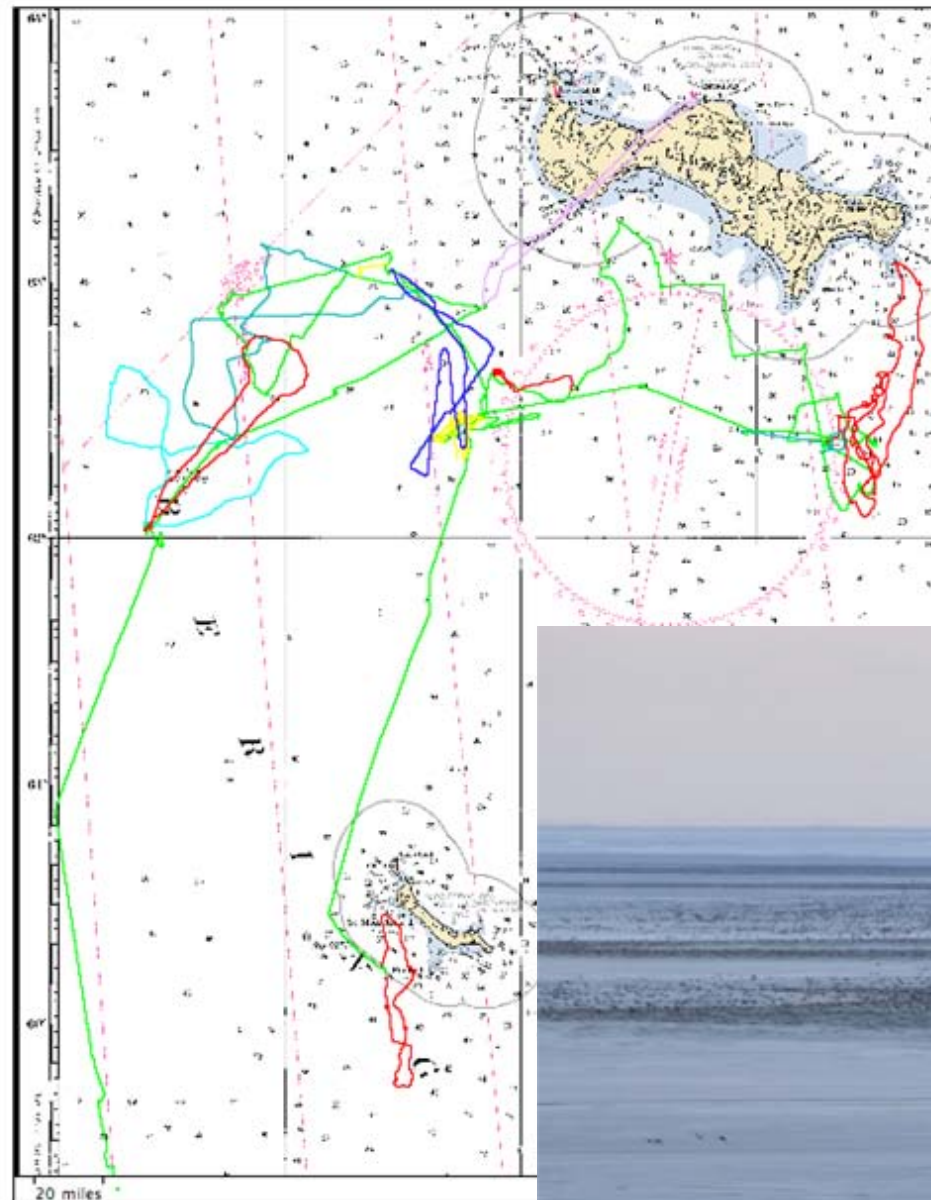
- 2006 tagged walrus locations (green dots, courtesy of Chad Jay, USGC) overlain on ~35 year composite of benthic infaunal biomass (Grebmeier et al. 2006)*
- different black symbols differentiate different collectors (Grebmeier et al. 2006)*
- note general location walrus in regions of high benthic prey biomass

*Progress in Oceanography 71: 331-361

Walrus tagging



clip courtesy of
Tony
Fischbach,
Alaska Science
Center, USGS



Helicopter tracks
flown as part of
walrus and spectacled
eider surveys

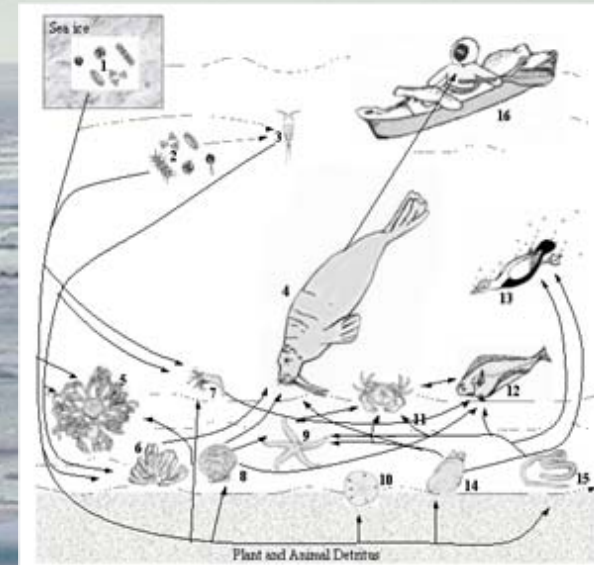


“Walrus-prey” Patch Dynamics Study (BSIERP and BEST)

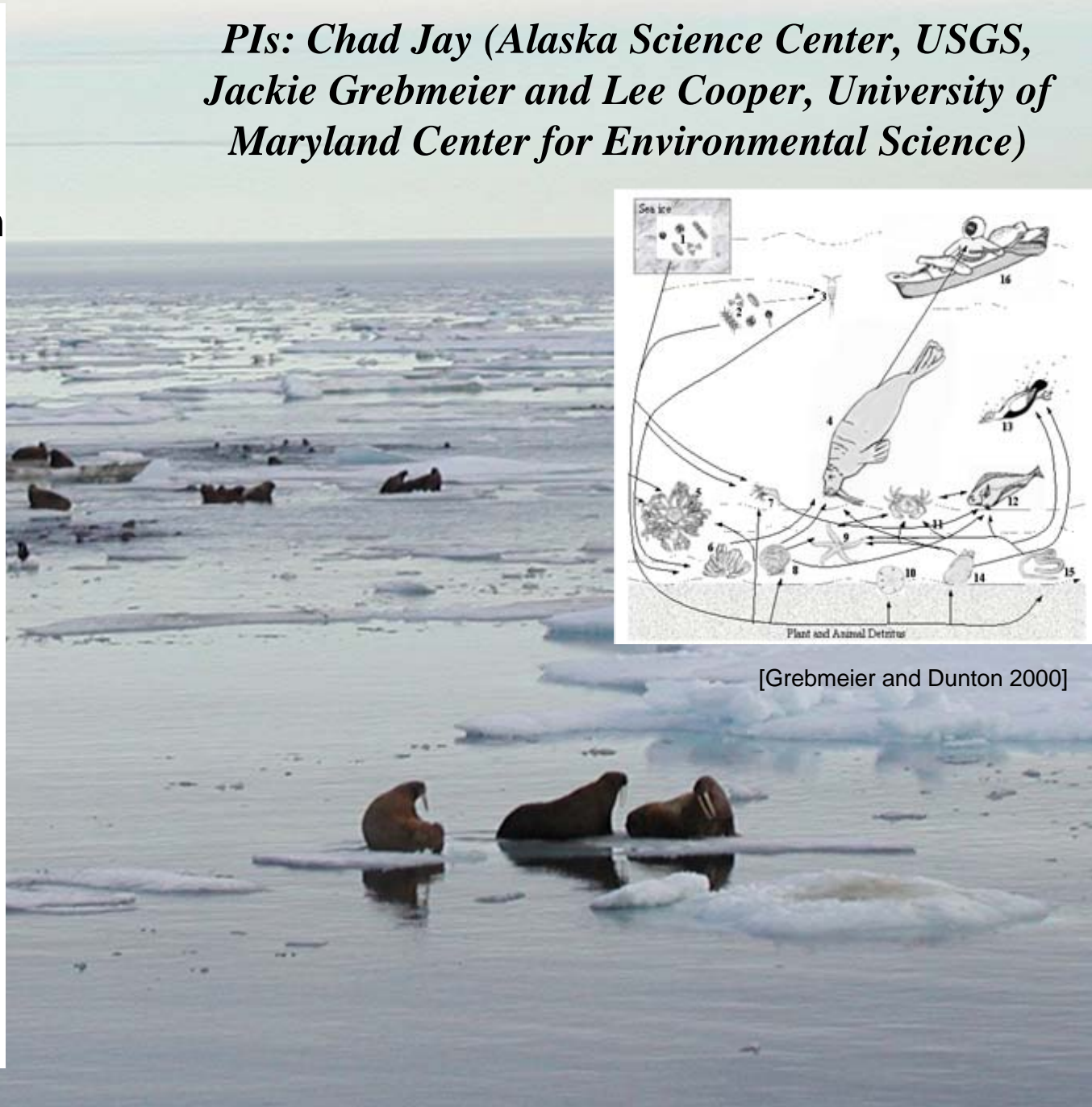
Objectives

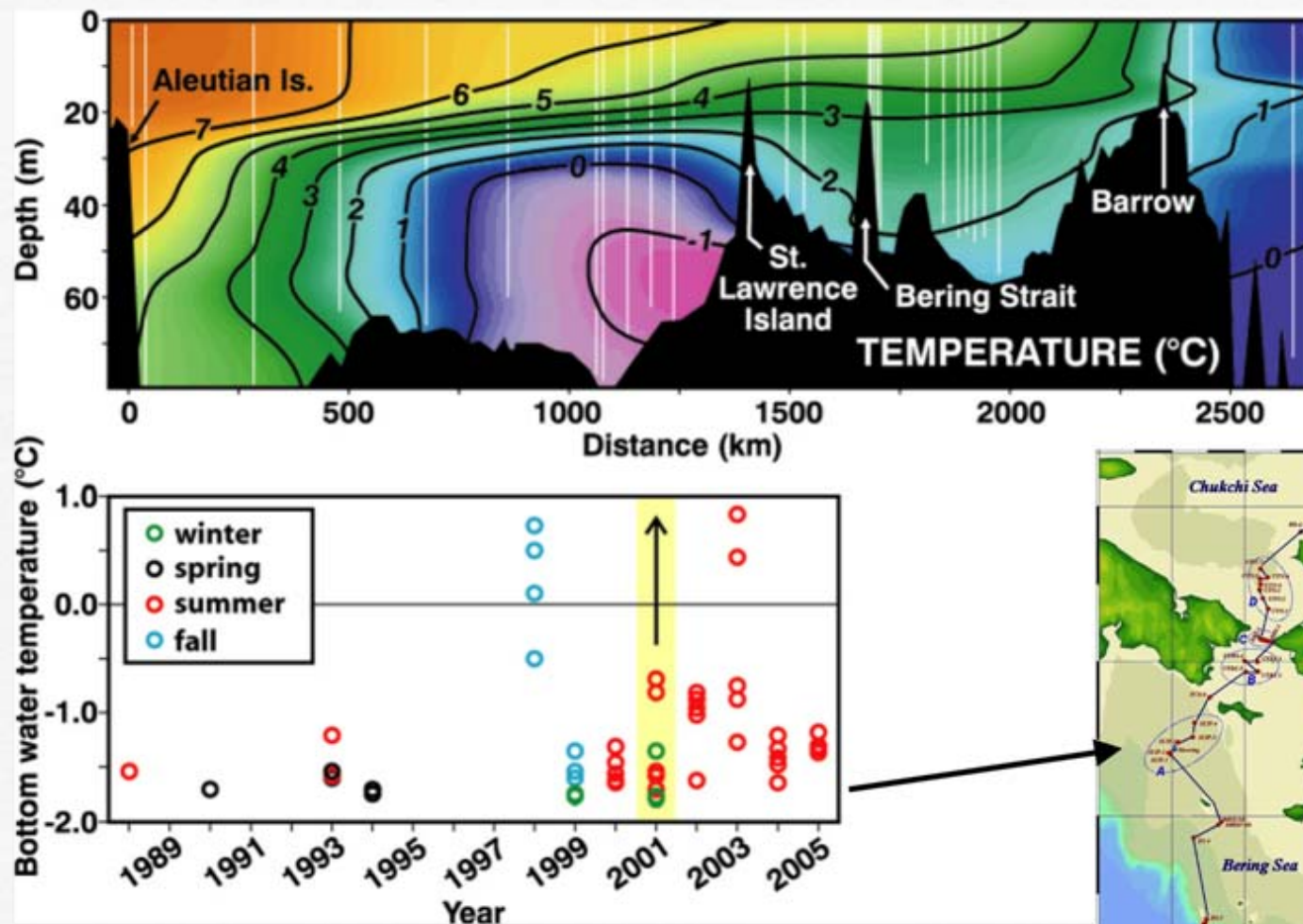
- field/retrospective evaluation of benthic infauna, sediments, and oceanographic conditions in context of walrus feeding sites, both historical and tagged
- grid of benthic infauna in walrus feeding area at various spatial scales (<5-20 nautical miles) to evaluate variable prey patches and food quality; videographic evaluation of epifauna
- helo survey and tagging of walruses
- predator/prey caloric content, stable isotopes, and pilot predator/prey DNA studies

PIs: Chad Jay (Alaska Science Center, USGS, Jackie Grebmeier and Lee Cooper, University of Maryland Center for Environmental Science)

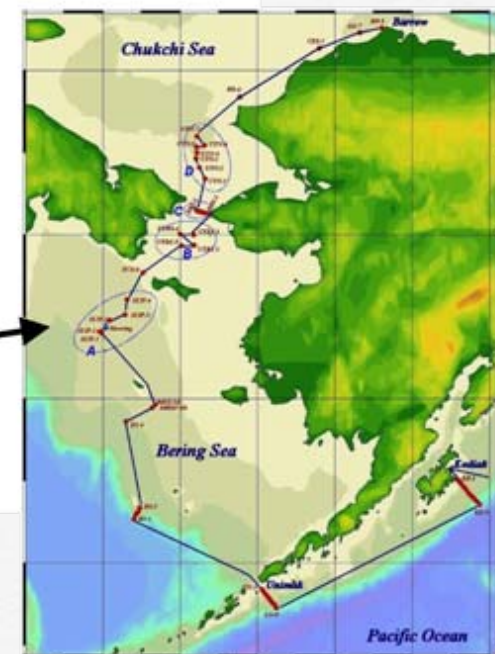


[Grebmeier and Dunton 2000]





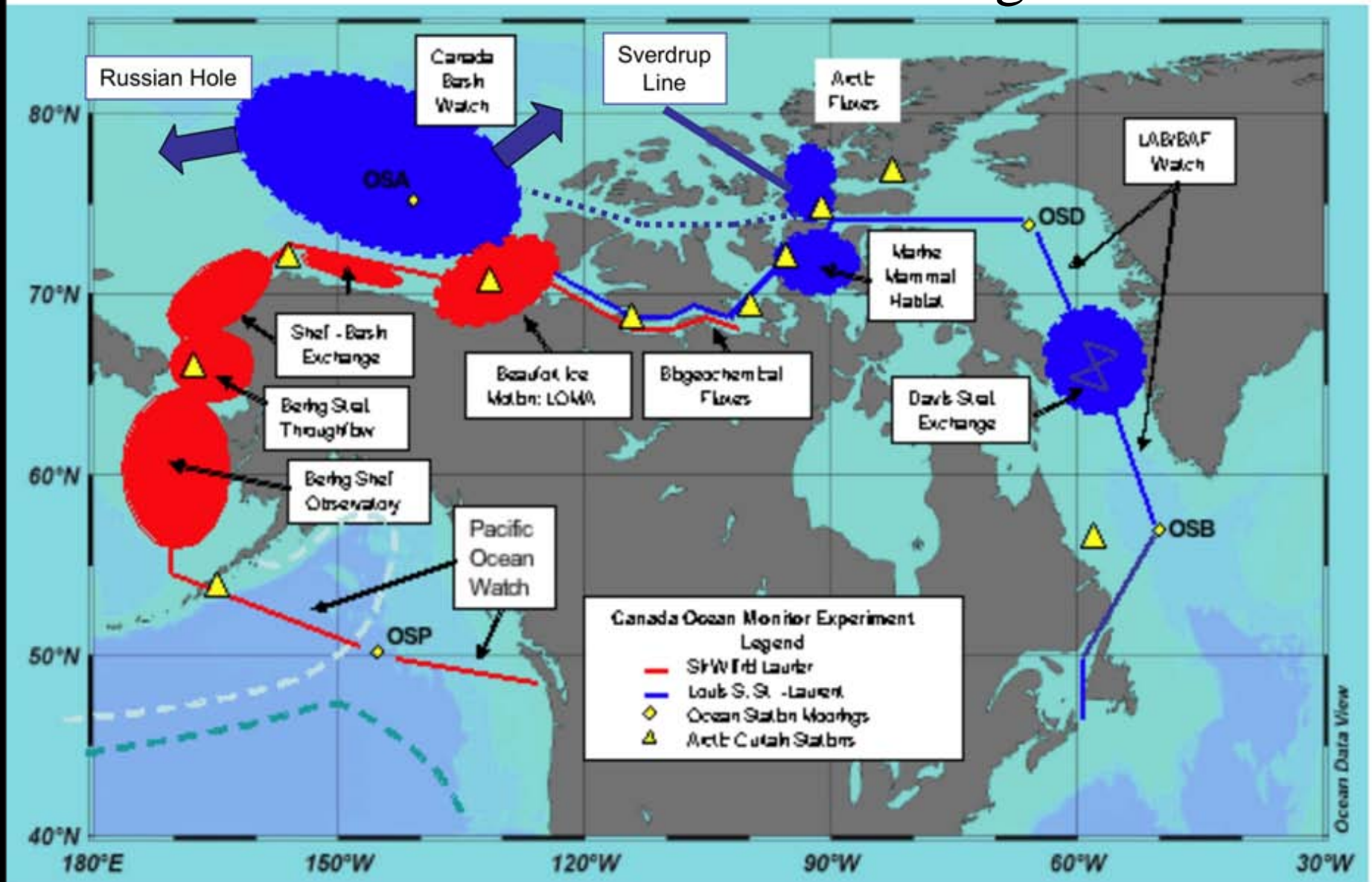
Seawater temperature extending from the Aleutian Islands, Alaska (top left) to Barrow, Alaska (top right) in July 2001 from the CCGS *Sir Wilfrid Laurier*. Bottom panel is time series of bottom water temperatures (<0°C) in cold pool SW of St. Lawrence Island.



Annual July cruises on CCGS *Sir Wilfrid Laurier*

[Grebmeier et al., 2006, Science 311]

Canada's Three Oceans Program



Canadian work planned in Bering Sea through 2050

International participation BEST-
BSIERP cruise March 2008



Boris Sirenko,
Zoological Institute,
Saint Petersburg

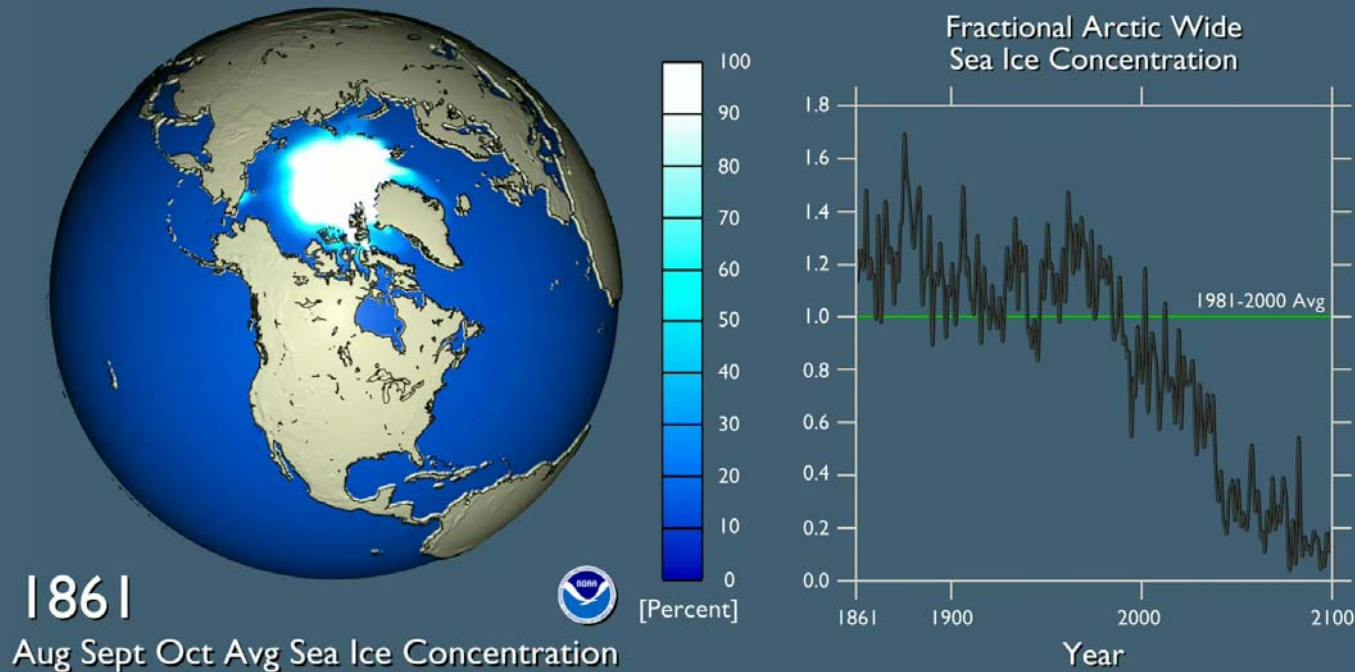


Christian Morel photos

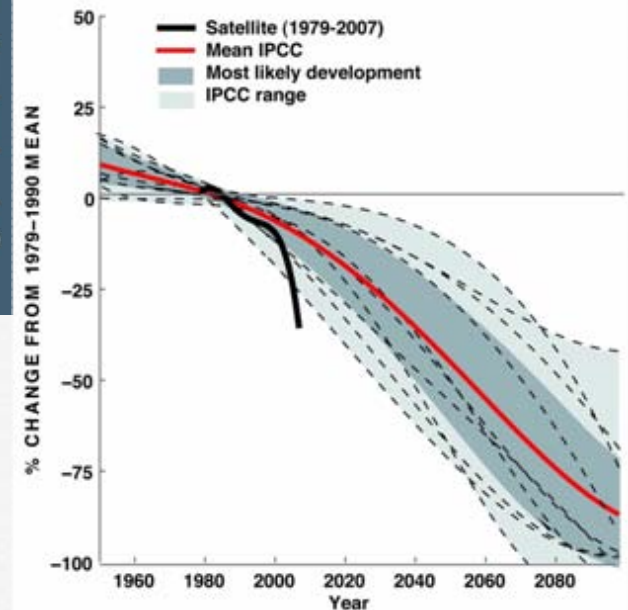


Jinping Zhao and
Yutian Jiao, Ocean
University of China

NOAA GFDL CM2.1 Model Simulation: SRES A1B Scenario

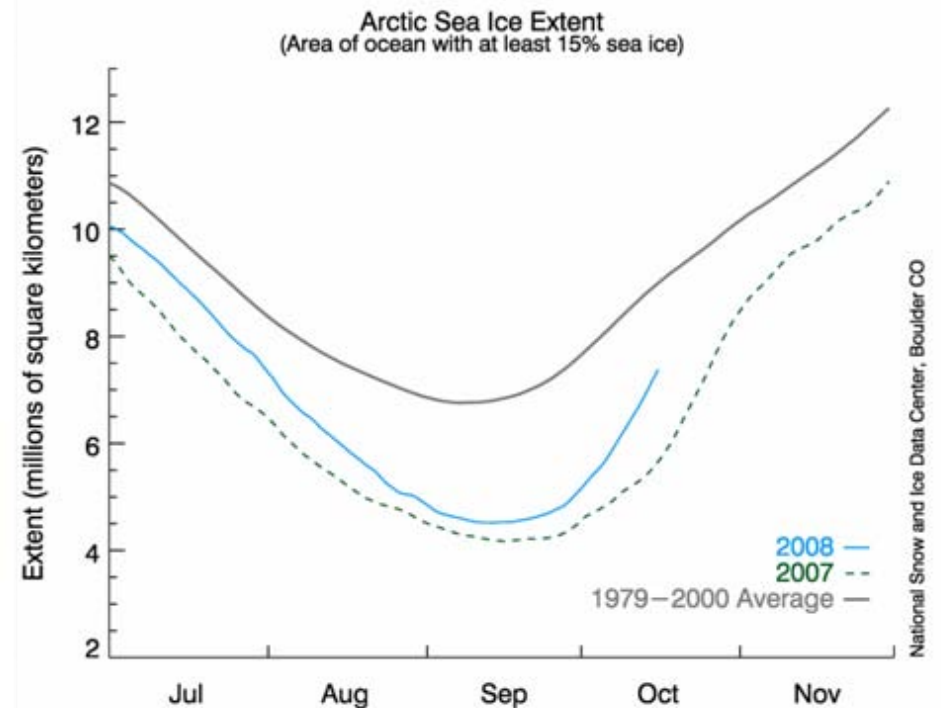
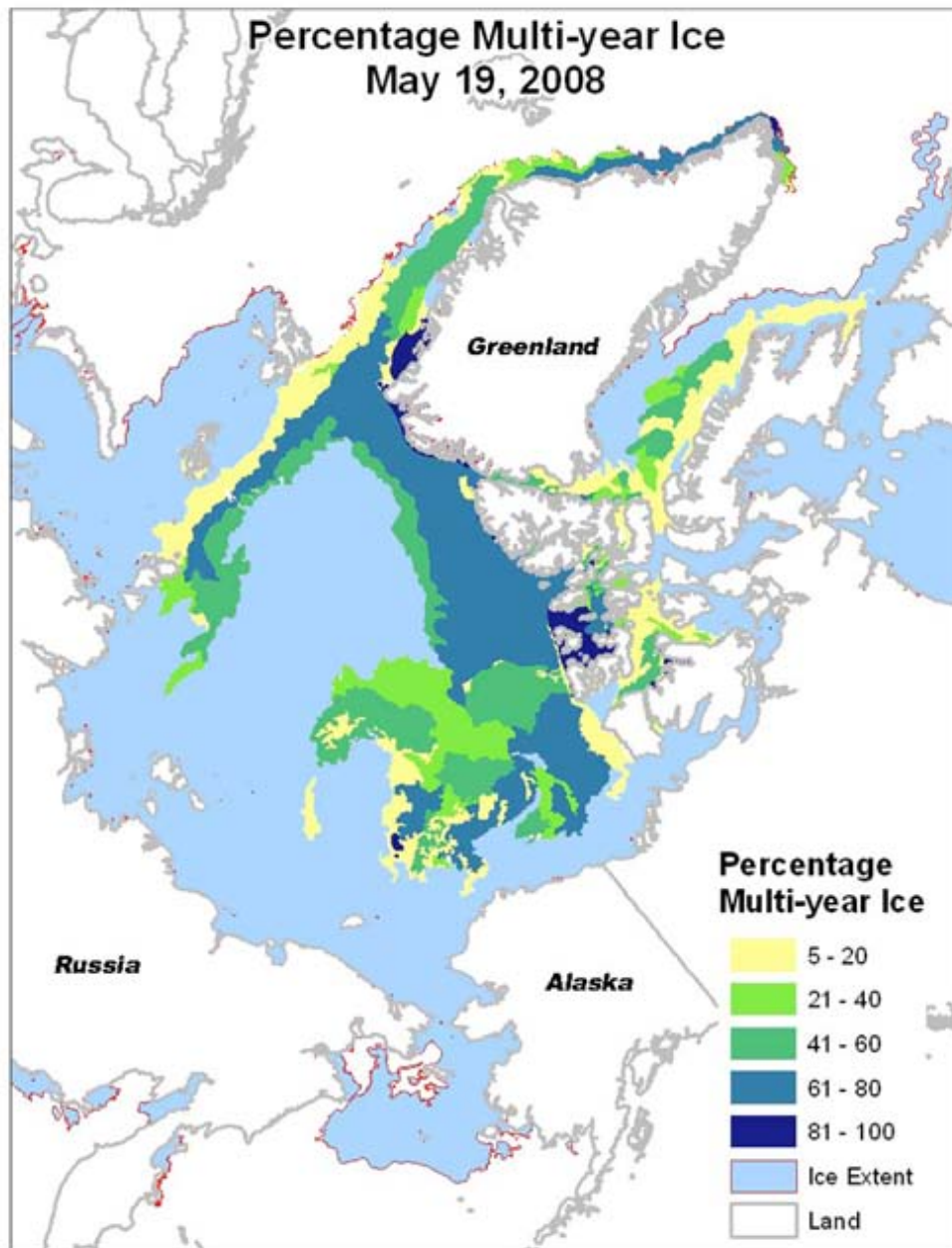


Mis-match of models vs.
seasonal sea ice retreat 2007-
2008



Arctic sea ice loss compared to IPCC models

Arctic ice extent loss to September 2007 compared to IPCC modelled changes using the SRES A2 CO₂ scenario (IPCC high CO₂ scenario). September loss data from satellite observations. Data smoothed with a 4th order polynomial to smooth out the year-to-year variability. Chart courtesy Dr Asgeir Sorteberg, Bjerknes Centre for Climate Research and University Center at Svalbard, Norway. Date: 23 September 2007 www.carbonequity.info/images/seaice07.jpg



Source: U.S. National Snow and Ice Data Center

"I think we're going to beat last year's record melt, though I'd love to be wrong."

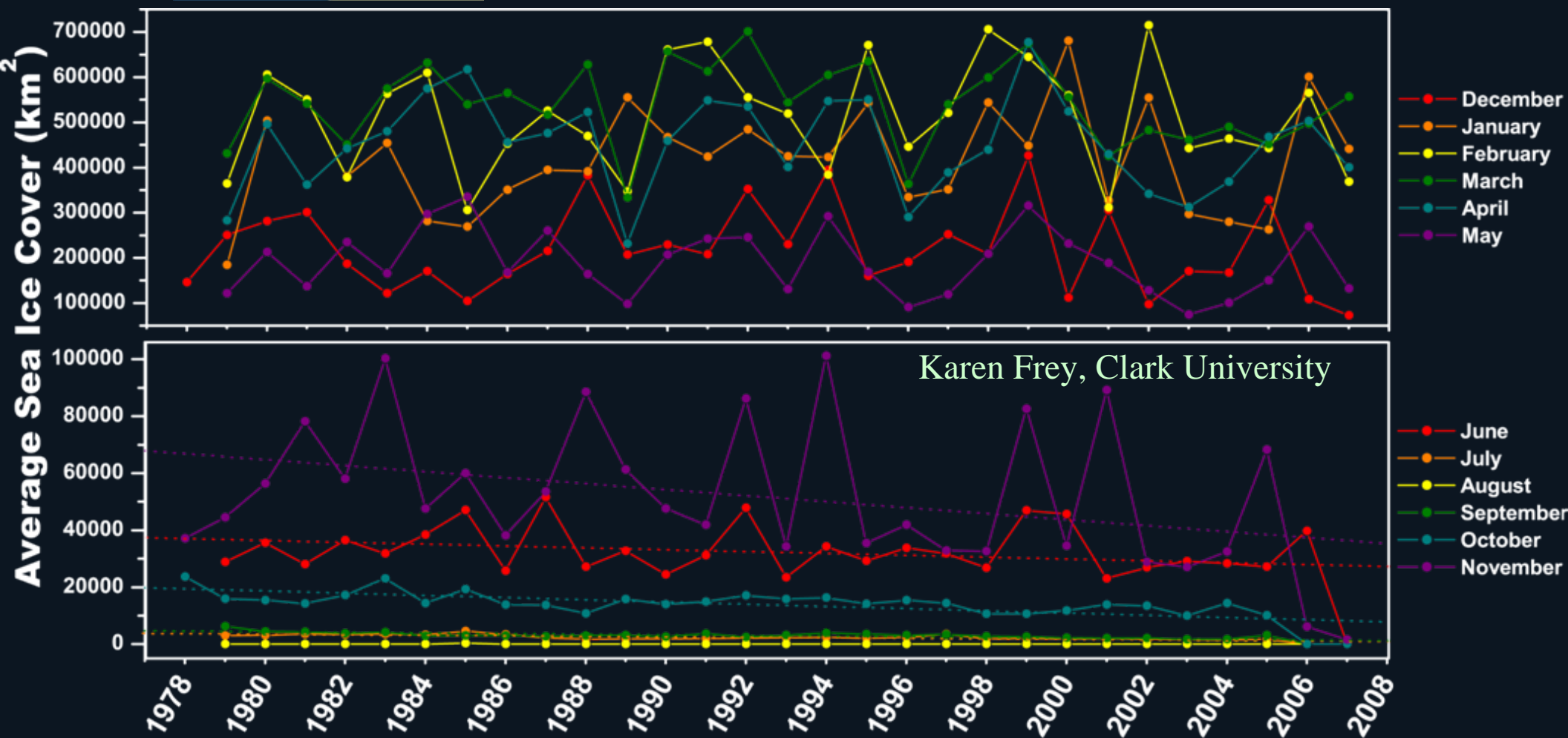
"If we do, then I don't think 2013 is far off any more. If what we think is going to happen does happen, then it'll be within a decade anyway."

Julienne Stroeve, NSIDC, quoted by BBC, 18 June 2008

Bering Sea Ice Trends (1978–2007)



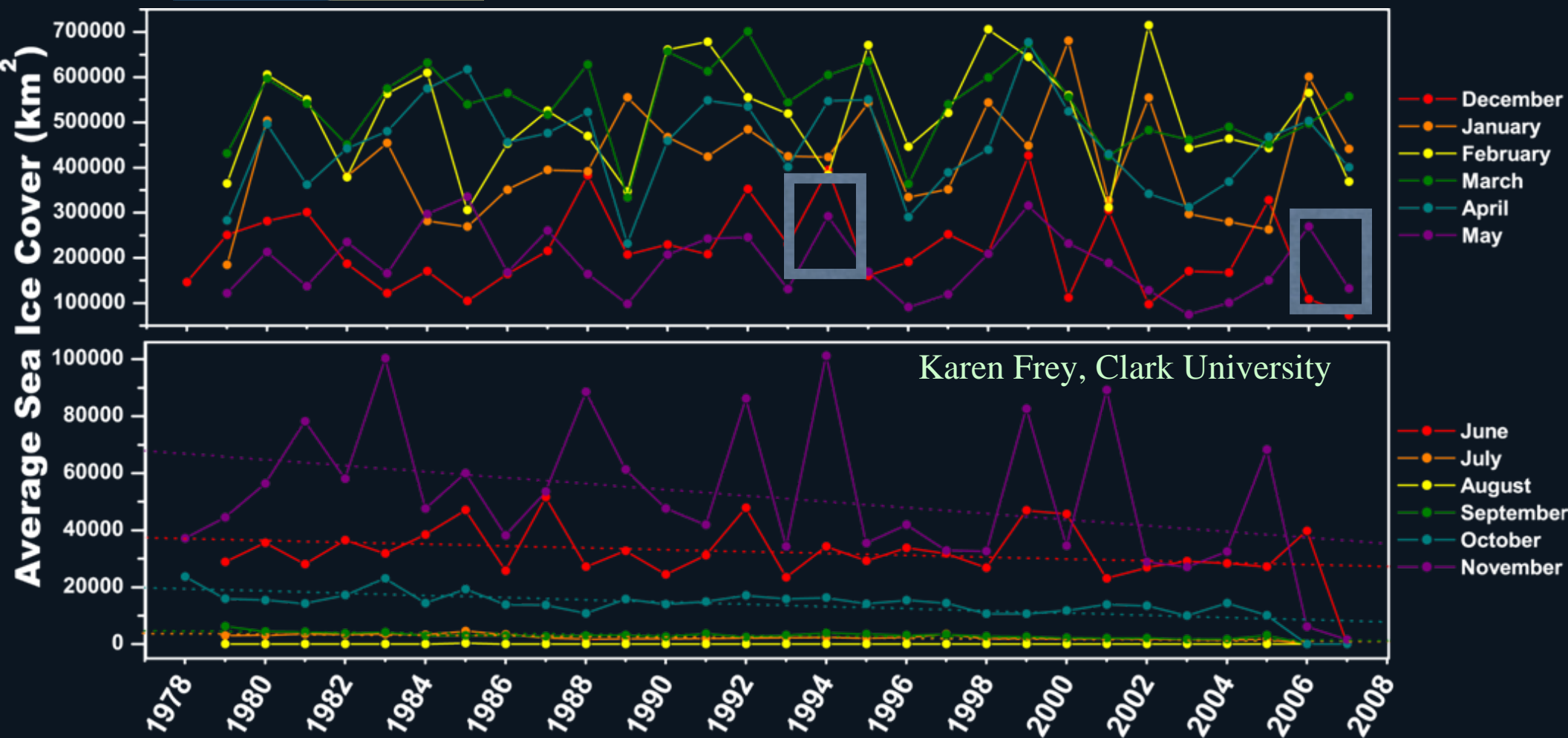
SMMR and SSM/I Satellite Passive
Microwave Sea Ice Concentrations



Bering Sea Ice Trends (1978–2007)



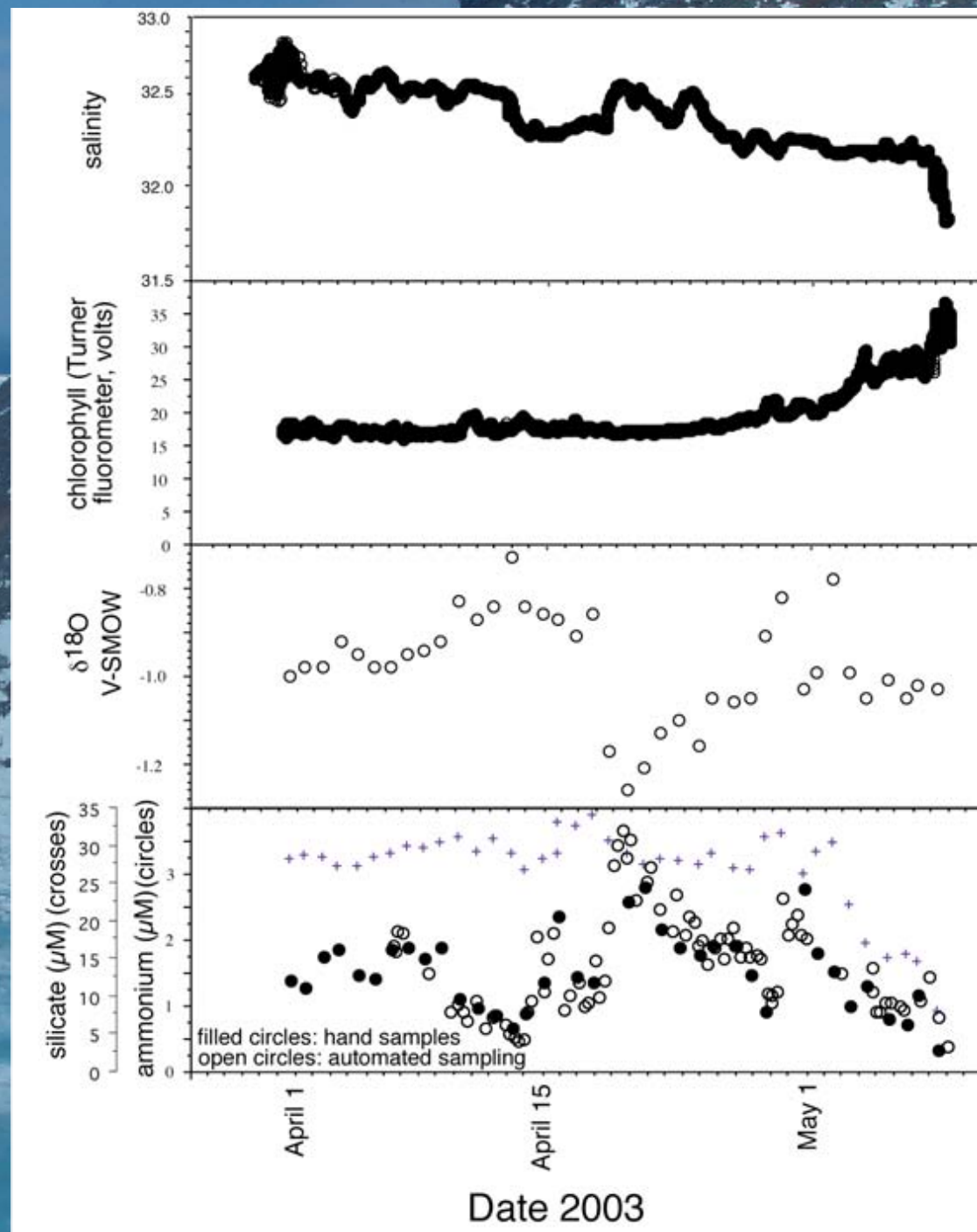
SMMR and SSM/I Satellite Passive
Microwave Sea Ice Concentrations

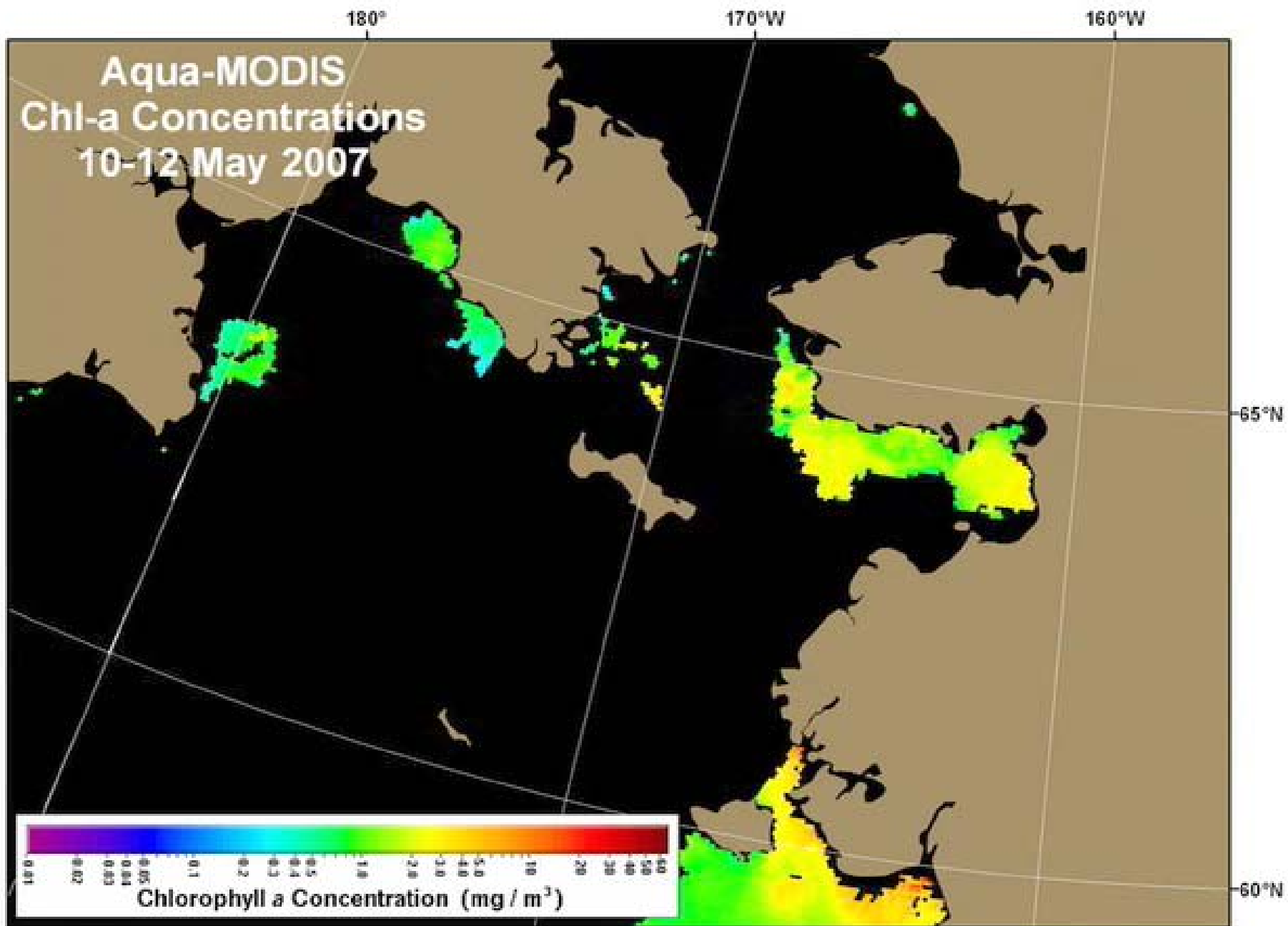


Water pumped ashore
over ice for analysis

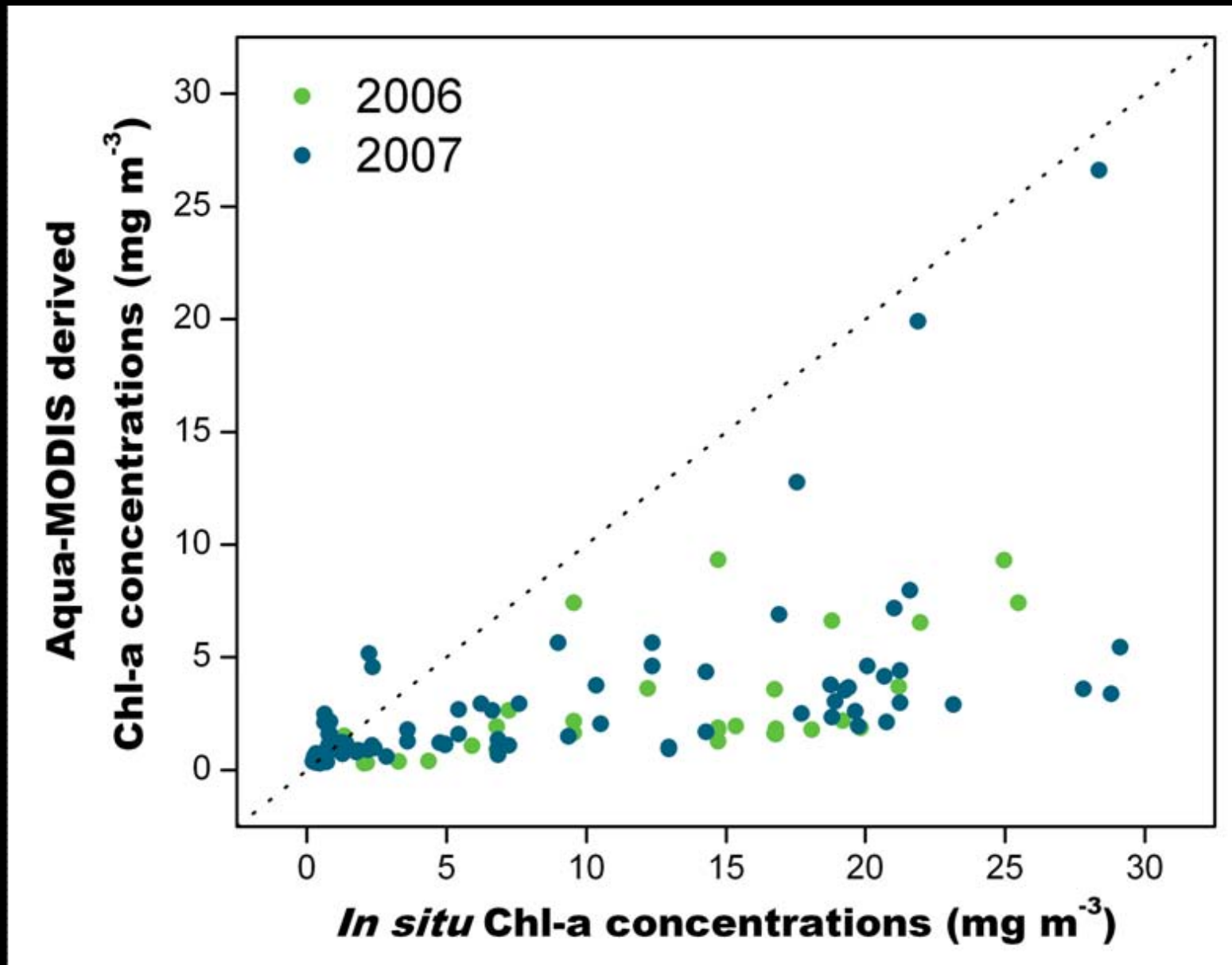


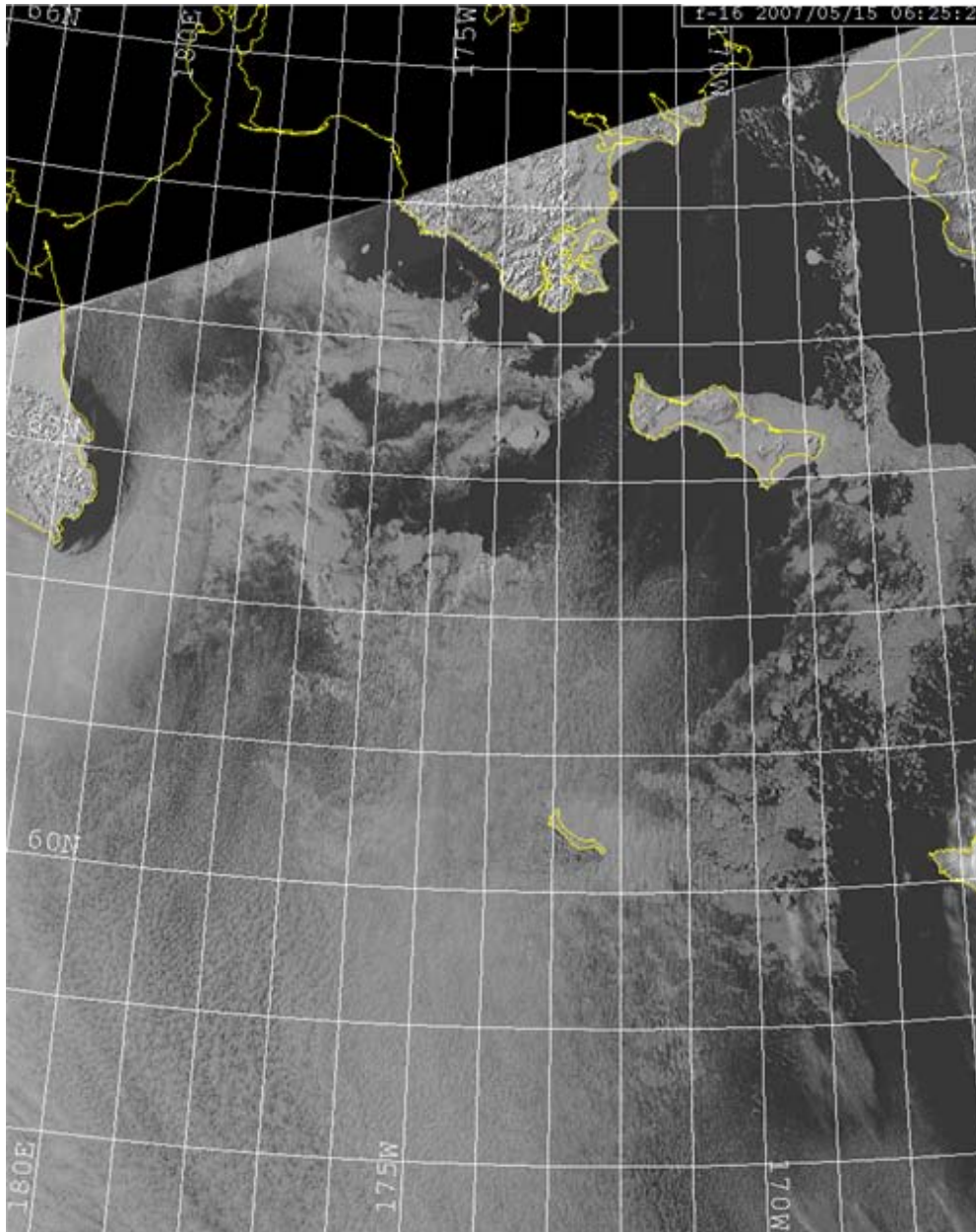
Data from *Arctic 59*: 129-
141, 2006



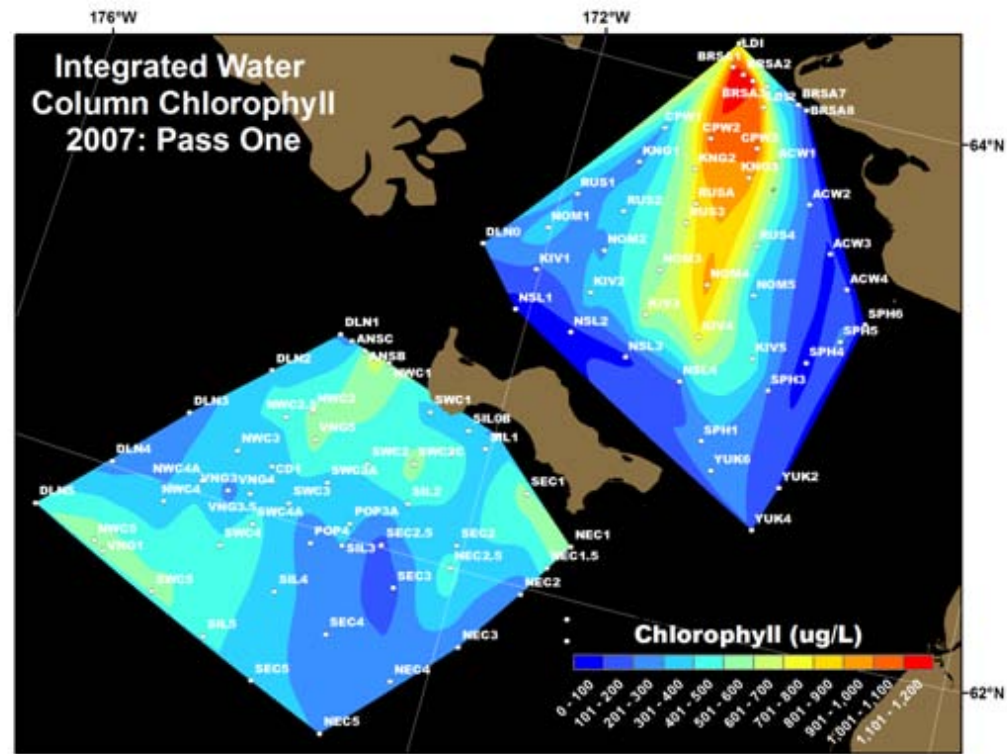


Satellite vs. *In Situ* Chl-*a* Concentrations

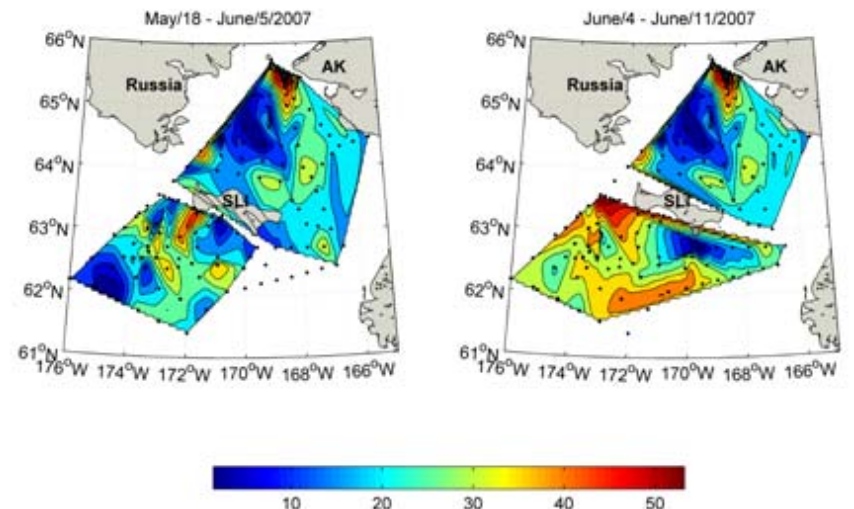




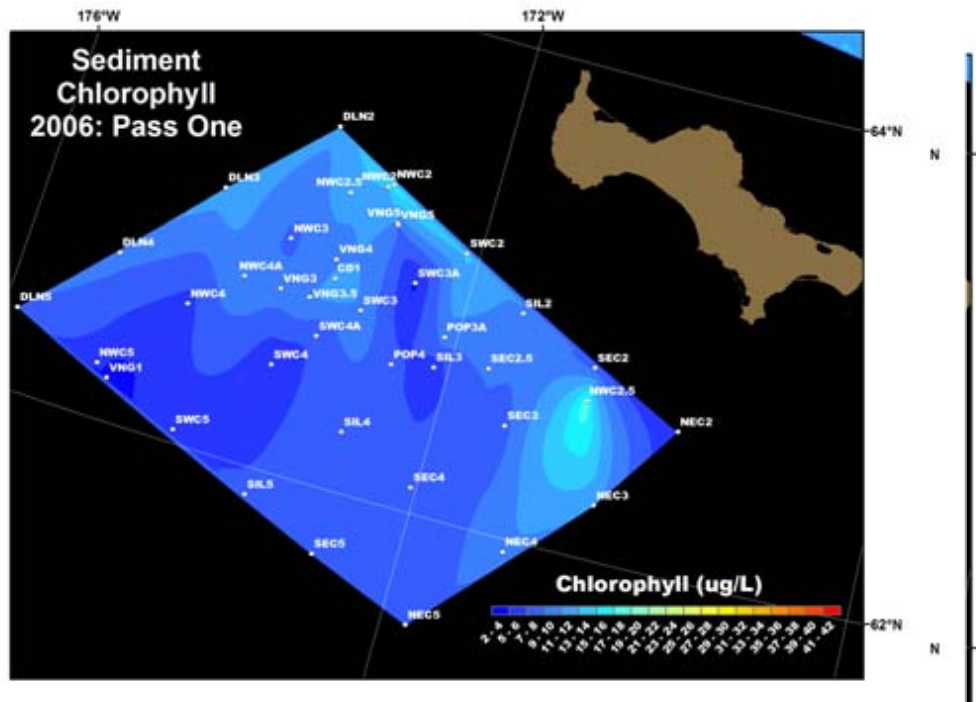
16 May 2007



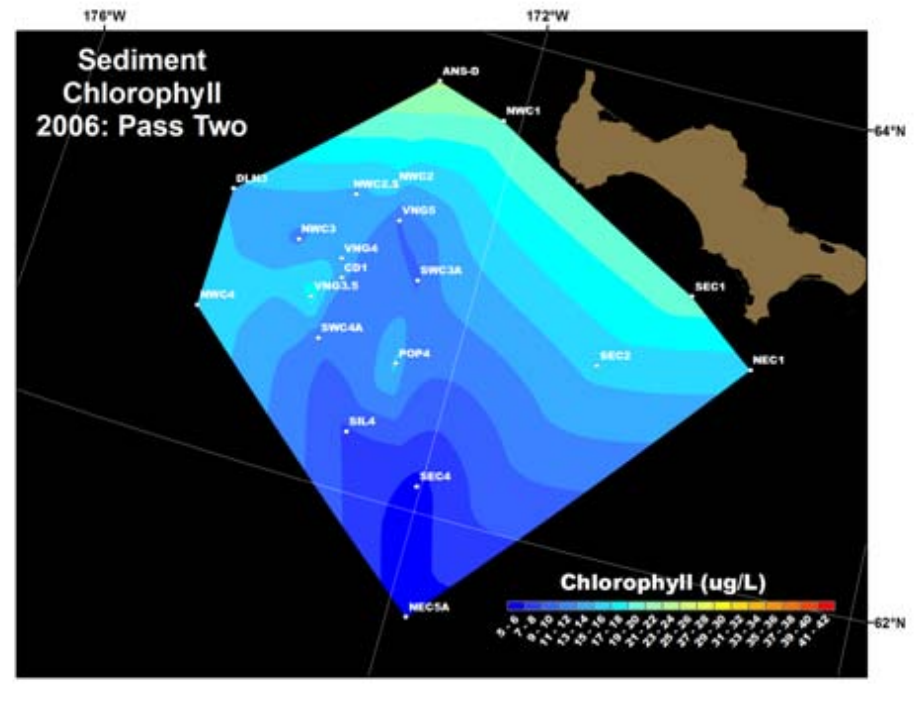
18 May - 4 June 2007



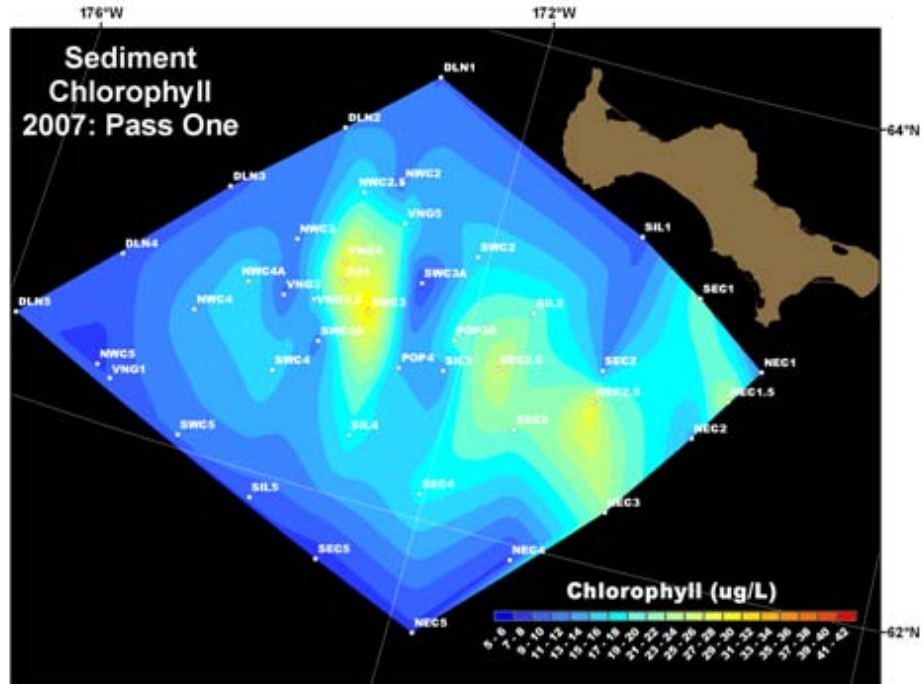
Depth of chlorophyll maximum



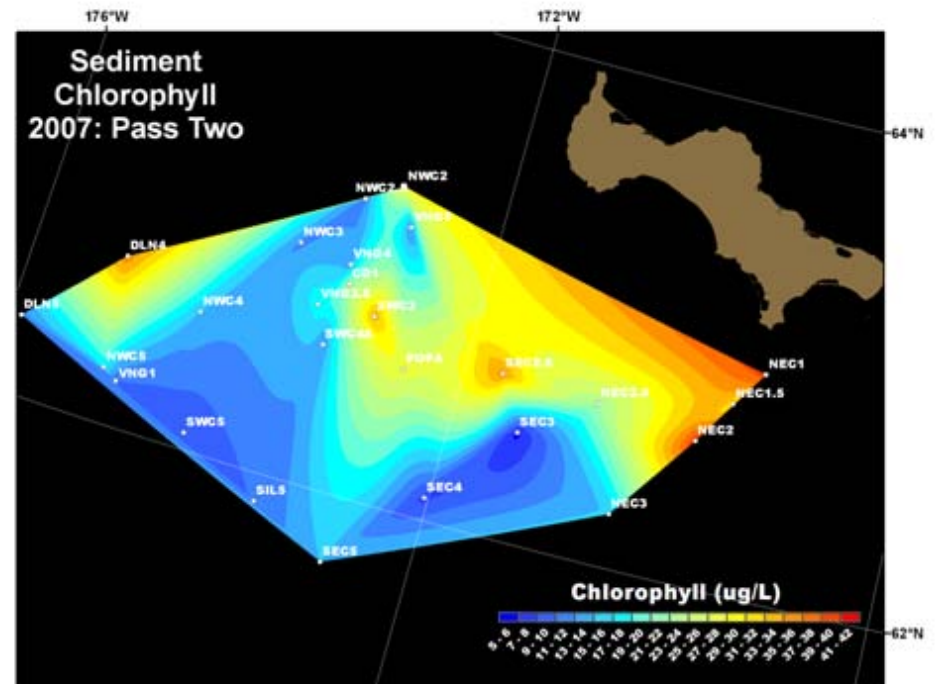
May 9-19, 2006 (Pass One)



May 27-June 1, 2006 (Pass Two)



May 18-29, 2007 (Pass One)

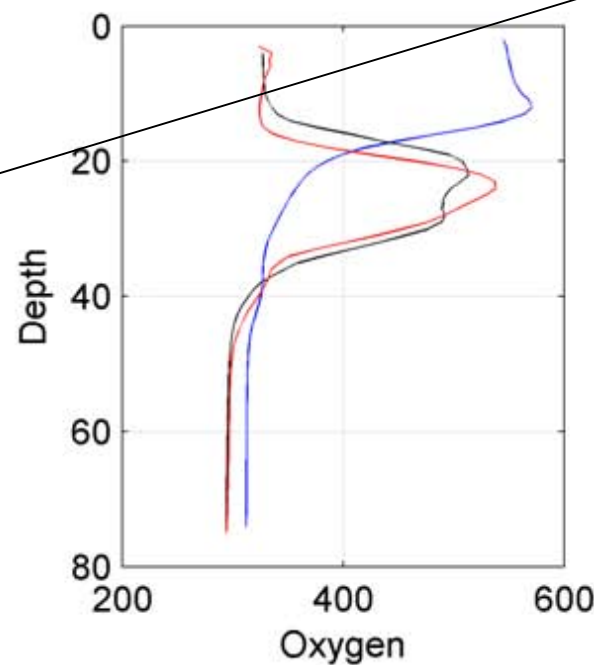
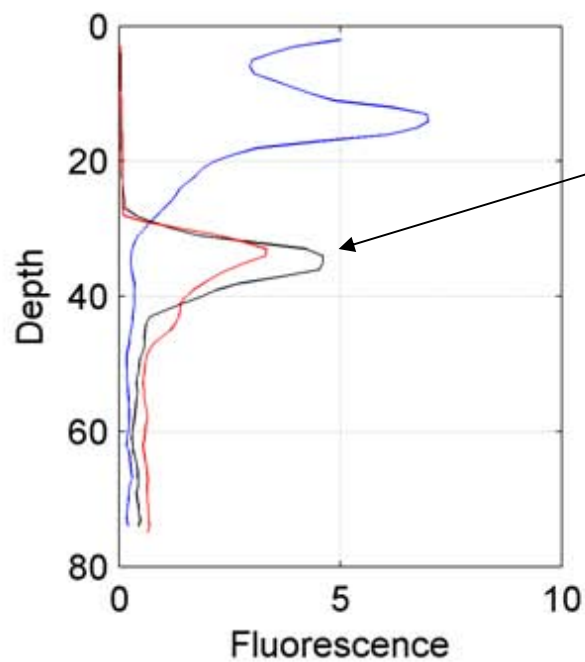
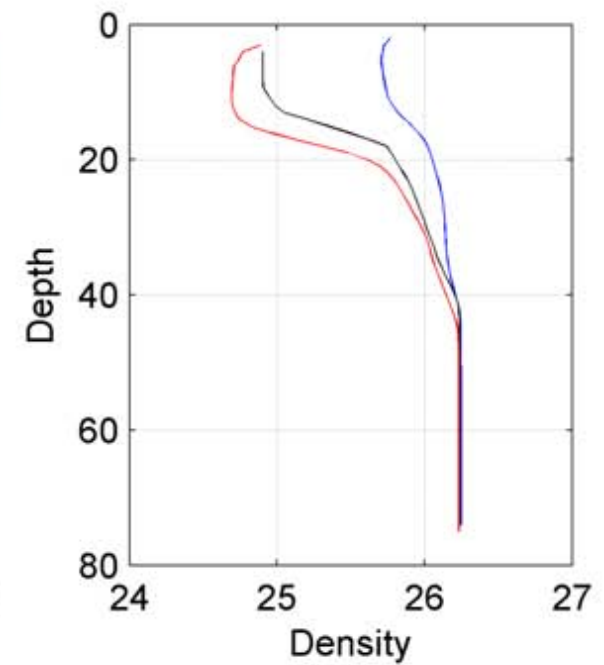
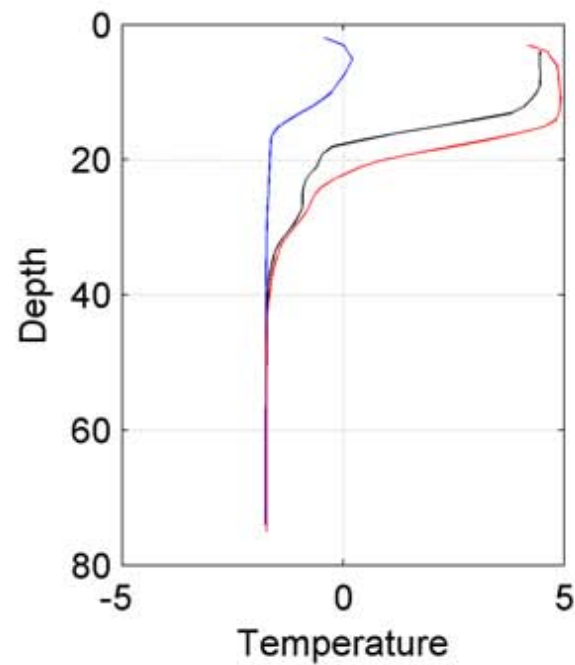
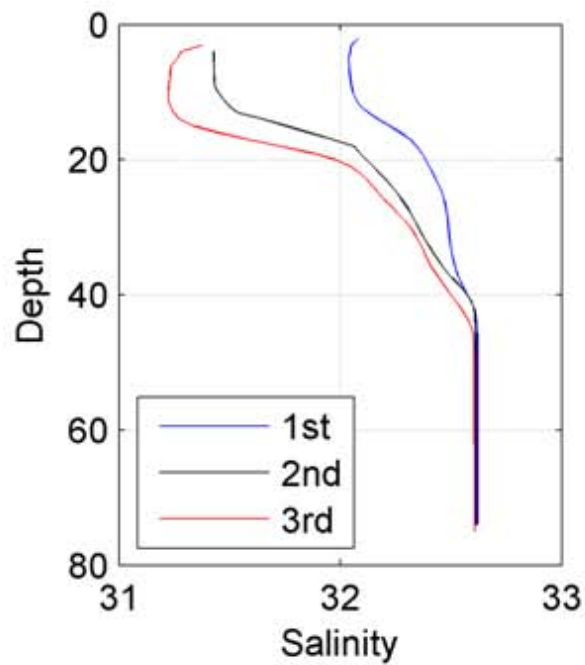


June 5-15, 2007 (Pass One)

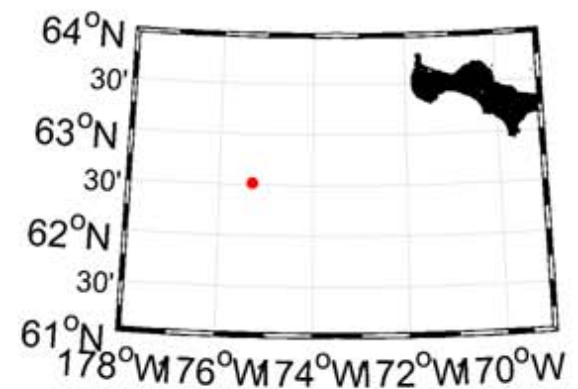
HLY0702- DLN4

StationNumber: 8

day2007: 141 164 166

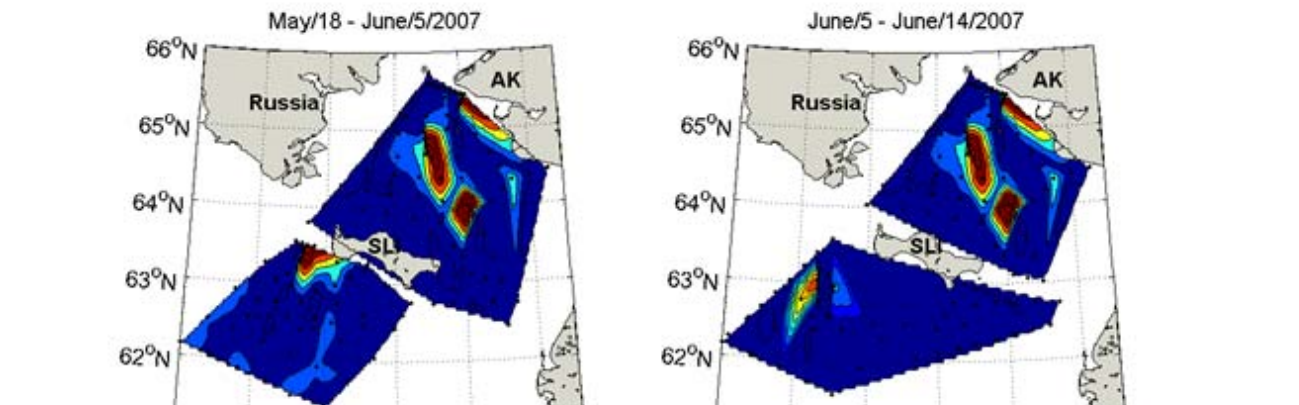


Nitrate+nitrite~14 μ M at 35m
throughout sampling



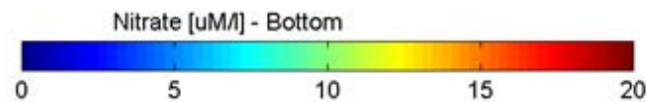
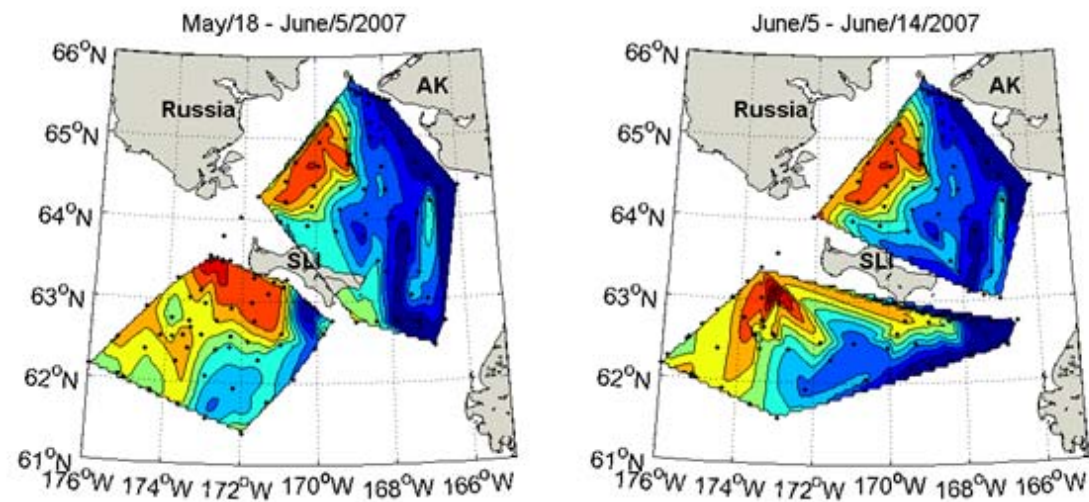
May 21 (blue), June 13 (black), June
15, 2007 (red)

Nitrate (μM) surface (top panel) and bottom water (lower panel)

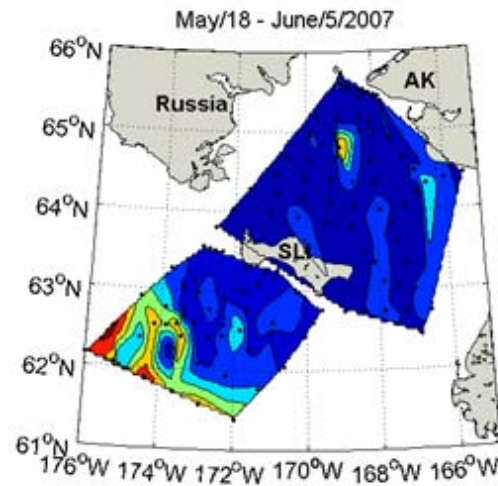


Pass 1

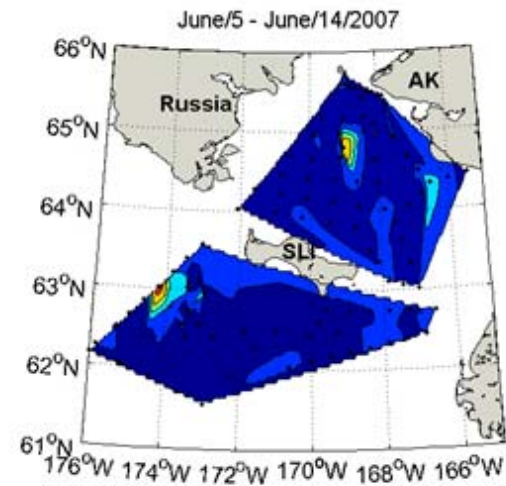
Pass 2



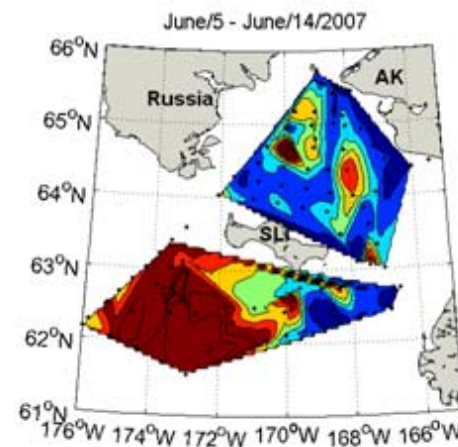
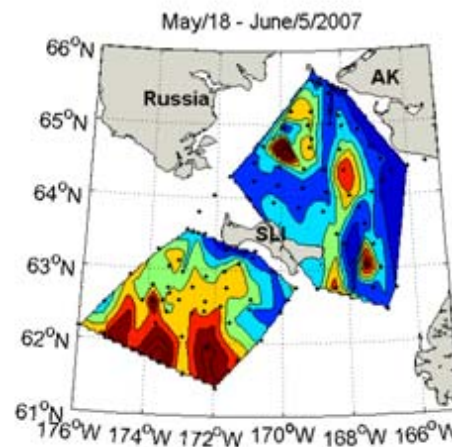
Ammonium (μM) surface (top panel) and bottom water (lower panel)



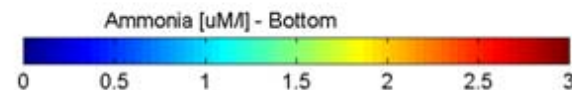
Pass 1



Pass 2

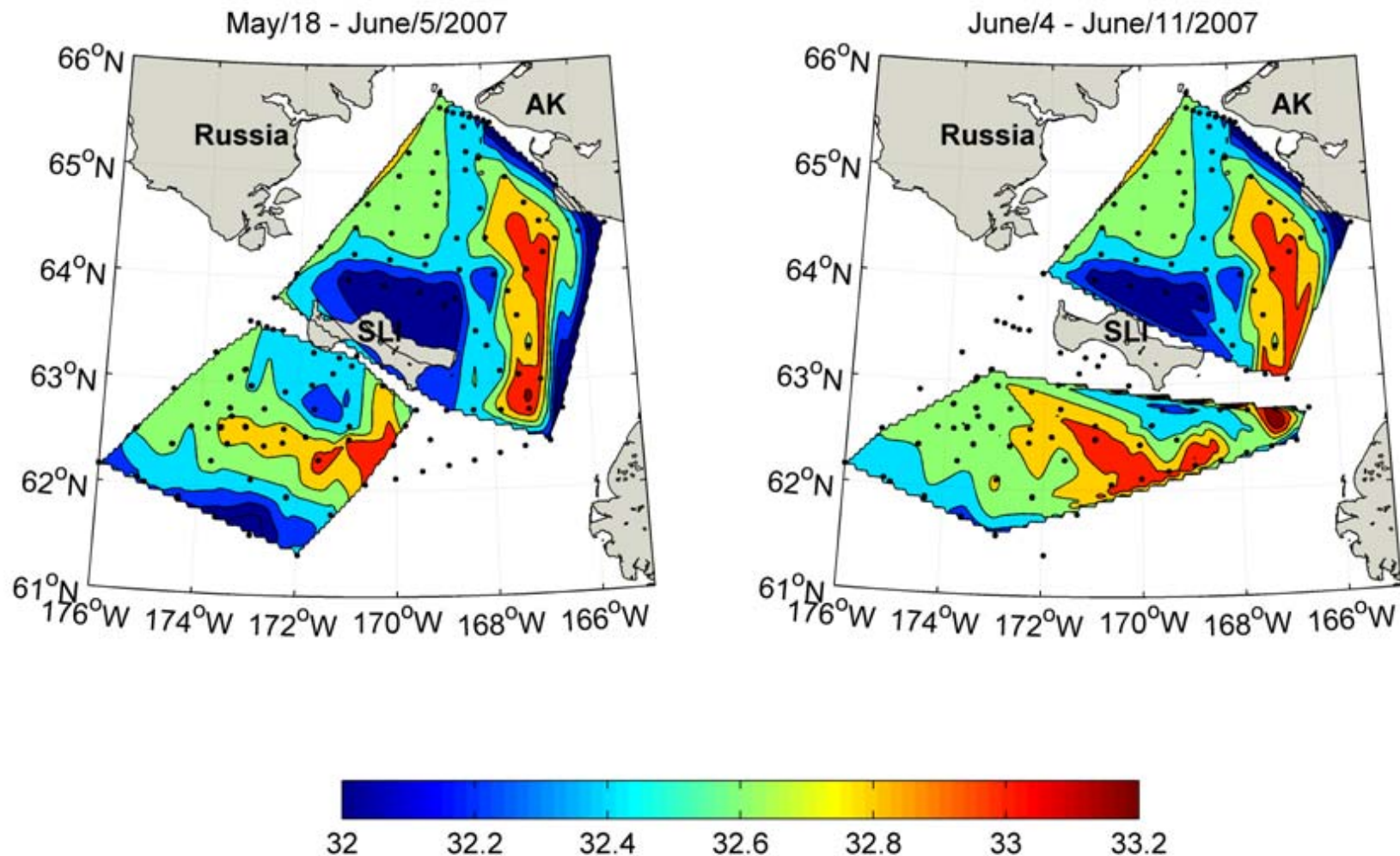


-shows
interactions
with benthos



High salinity (>33) water observed in 2007 (but not in 2006) from April brine injection events

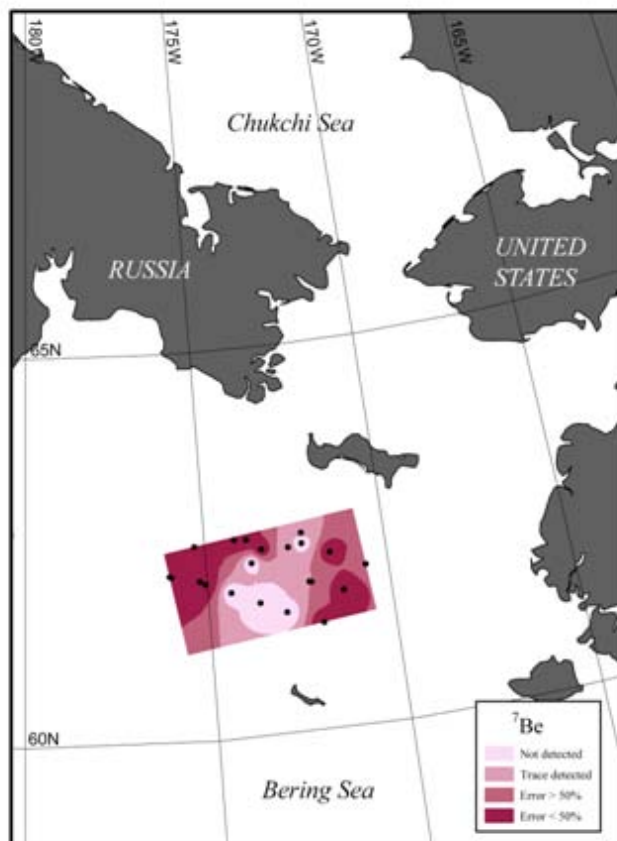
Results: better water column ventilation, possibly more intense spring bloom development than in 2006



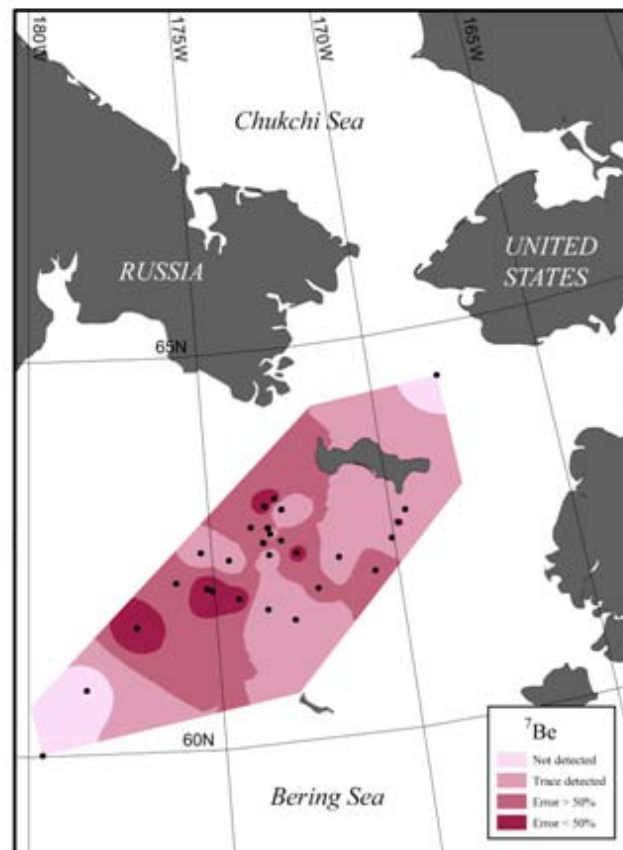
Short-term particle accumulation tracer

Beryllium-7 (53 d half-life) distributions on surface (0-1 cm) sediments

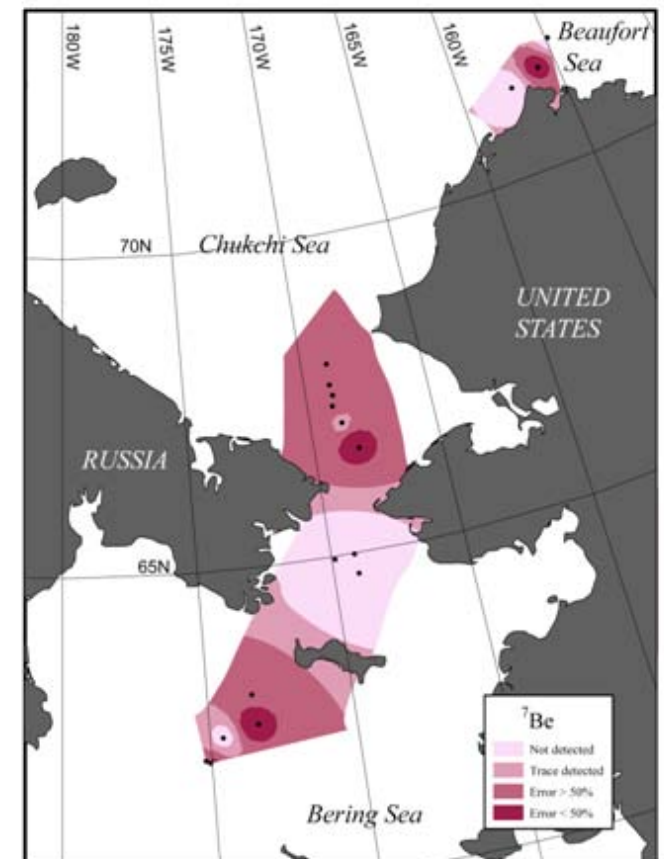
18-29 May 2007



6-15 June 2007



13 -20 July 2007



Sampling Dates <i>Alpha Helix</i> 1994 <i>Healy</i> 2006 <i>Healy</i> 2007	Mean Integrated chlorophyll (mg m ⁻² ±SE)	Mean bottom water nitrate (μM ± SE)	Significant paired t-test differences (<0.05)
26 May-6 June 1994	556.6±52.5	10.7 ±1.0	n=30
11-19 May 2006	246.0±50.0	6.4 ±0.8	n=30
28 May-2 June 2006	395.2±61.8	8.3 ±1.0	Pass 2 (11 stations)
19-27 May 2007	400.4±21.3	12.0 ±0.6	n=30
6-13 June 2007	256.1±74.3	12.3±1.4	Pass 2 (13 stations)

Conclusions

- Opportunities for International Collaborations during BSIERP- BEST Programs
- Significant benthic biomass and community structure changes since 1970
- Chlorophyll biomass significantly different in each of three years during ice-melt (1994, 2006, 2007) that had similar ice retreat timing but significantly different oceanographic conditions
- Repeat sampling shows that even within-season variation is large and blooms highly localized
- Water mass and nutrient variation, wind-mixing and late winter brine formation are potentially important variables that will also impact spring productivity in addition to the timing of ice retreat