Modeling Ice-Ocean-Ecosystem in the Bering-Chukchi-Beaufort Seas:

Using IPY (2007-2008), RUSALCA 2004 and 2009 measurements

Jia Wang

NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan USA

Haoguo Hu, Xuezhi Bai

University of Michigan

Ann Arbor

And RUSALCA Pis:

Pickart, Whitledge, Hopcroft

Woodgate

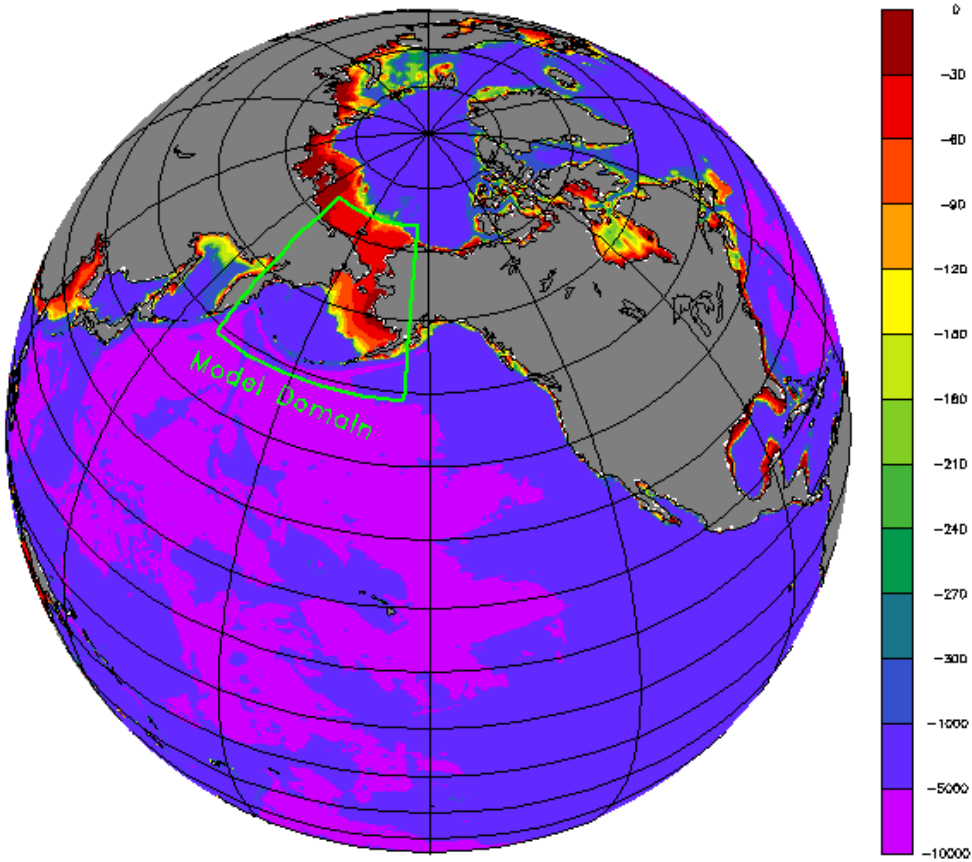
RUSALCA PIs Meeting, February 20-22, 2014, Honolulu

Modeling Bering-Chukchi Sea Marine Ecosystem

- CIOM with fully dynamics and thermodynamics, multiple category ice thickness (ridging)
- 3.8km and 21 level
- 6-hourly or daily forcing
- 3 configurations:

Bering Sea only (7-12km), Chukchi only (3.8km), Bering-Chukchi Sea (3.8-12km)

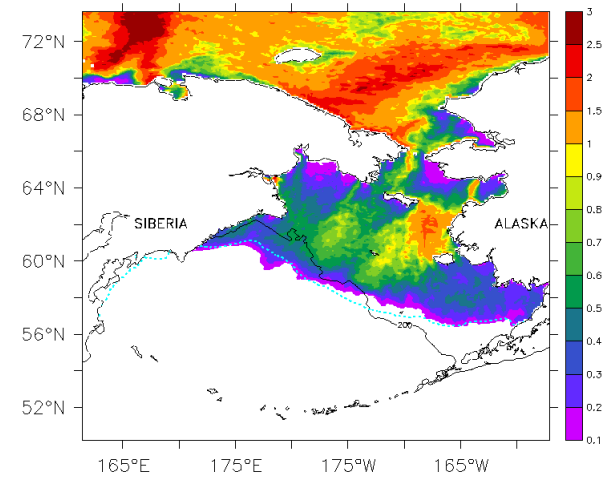
- Hypotheses test/RUSALCA synthesis
- Realistic simulation

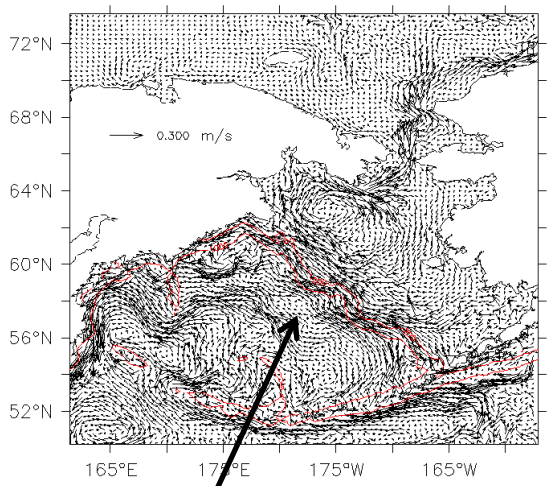


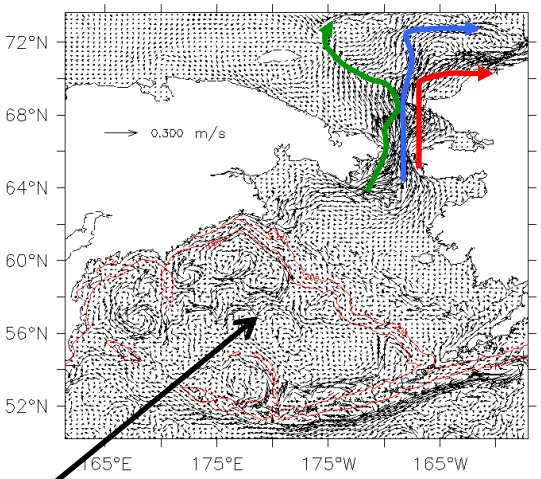
View From Space

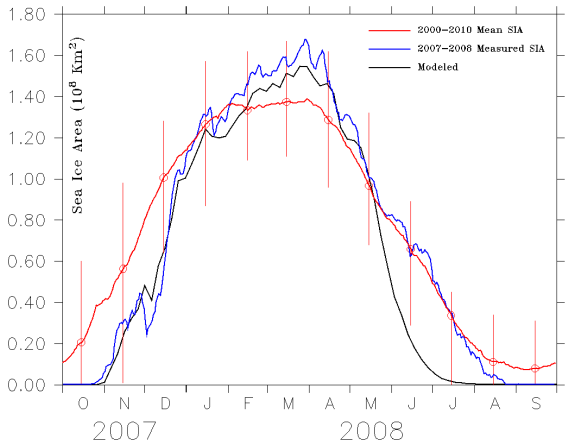
Coupled Ice-Ocean-Ecosystem Model in the Bering-Beaufort-Chukchi Seas (IPY)

Modeled ice thickness (3/08) surface current (3/08) surface current (7/08)



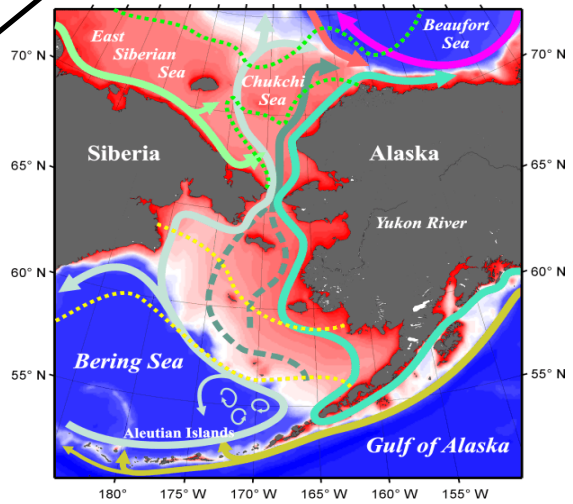


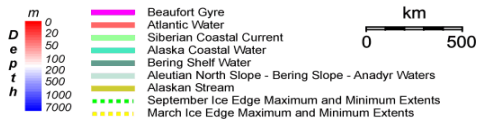




Few eddies

More eddies

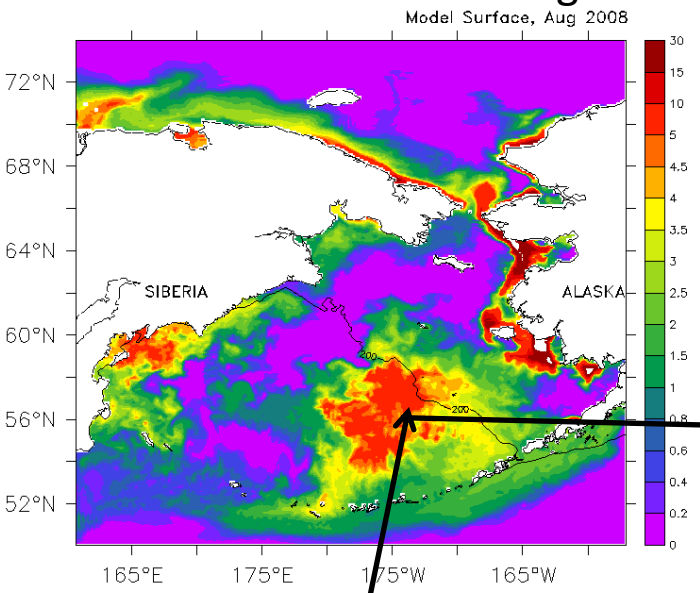




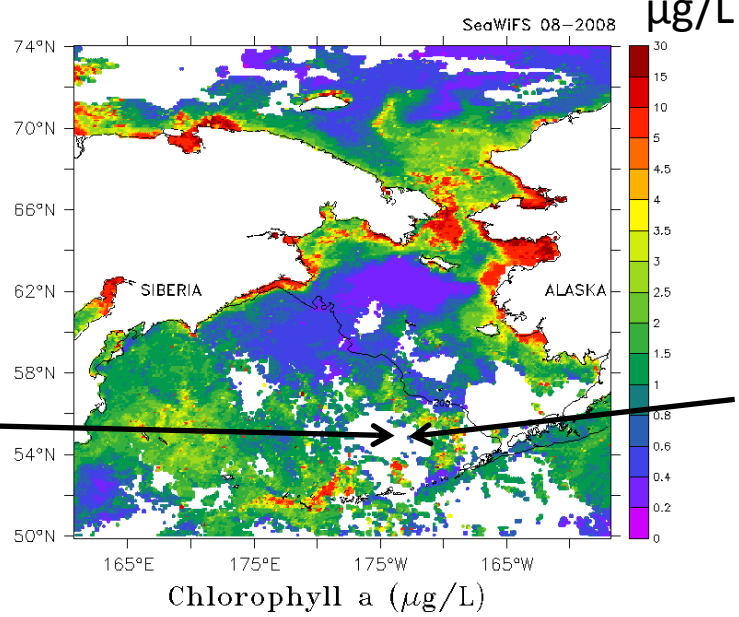
Simulated sea ice area (black line) and satellite-measured sea ice area (blue) over the entire Bering and Chukchi Seas for 2007-2008. The red line denotes the 11-year average area and the red vertical bars denote the maximum and minimum ice areas during 2000-2011. (Wang et al. 2013, JGR)

Coupled Ice-Ocean-Ecosystem Model in the Bering-Beaufort-Chukchi Seas (IPY)

Modeled August 2008

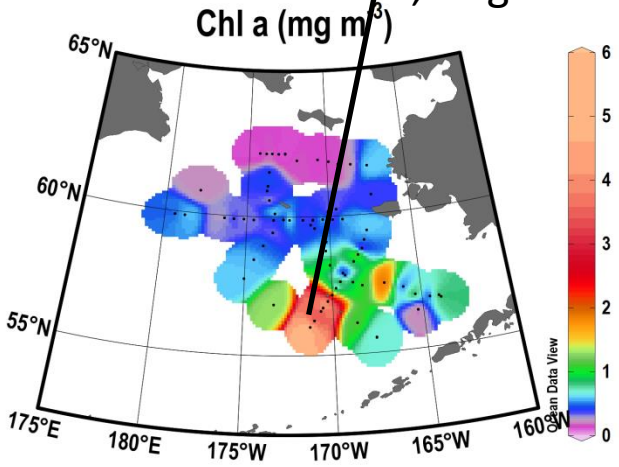


Satellite

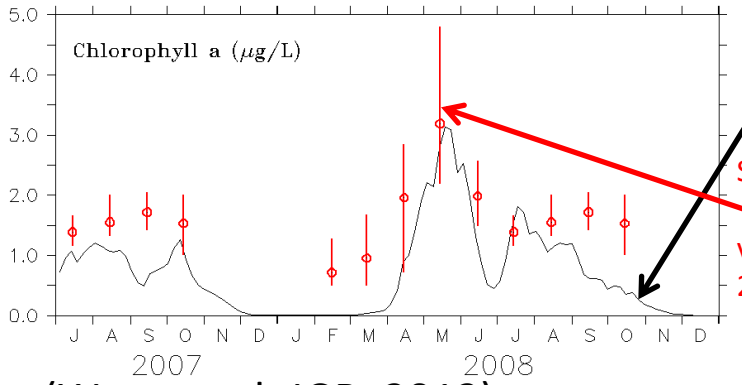


Cloud cover

In situ measurement, August 2008



Seasonal variation 2007-2008

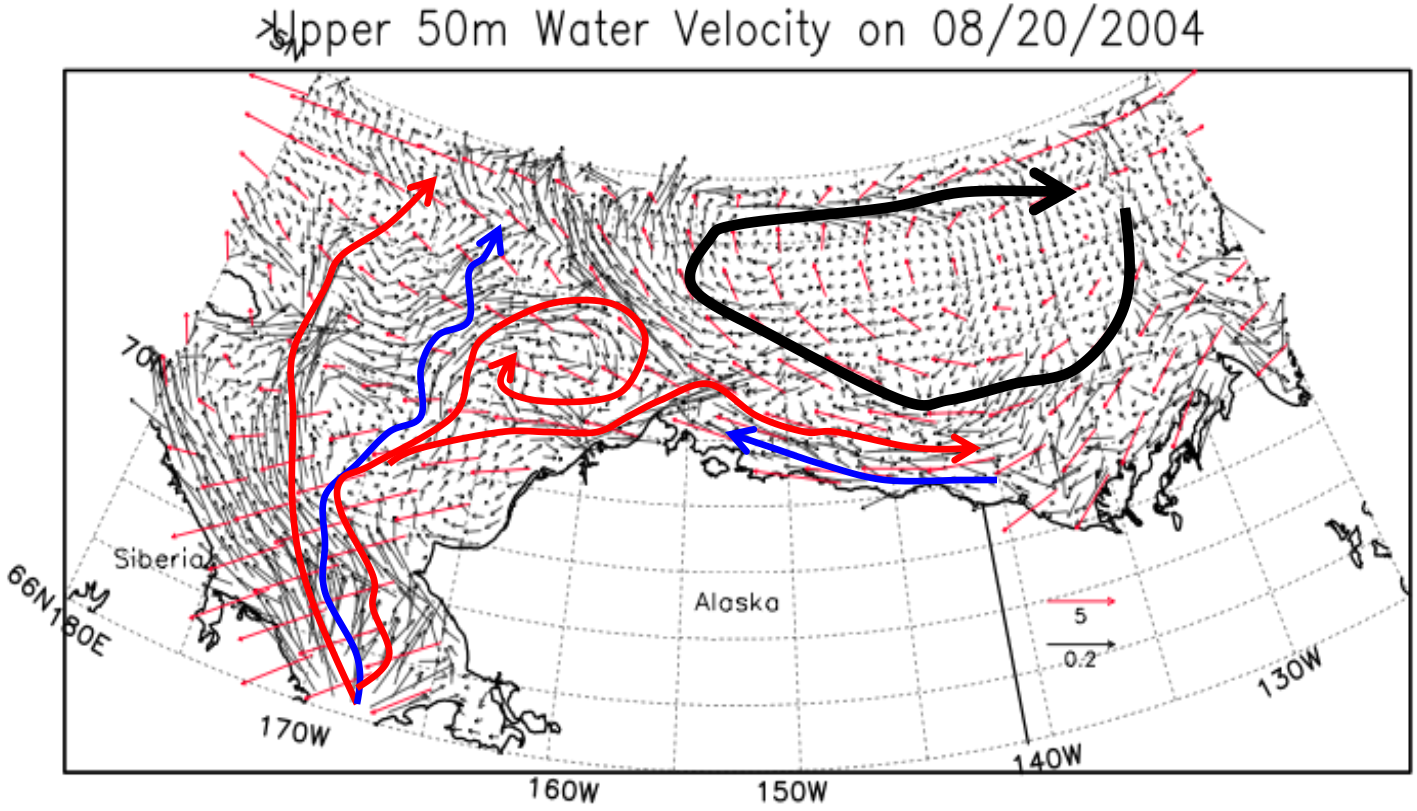


Modeled

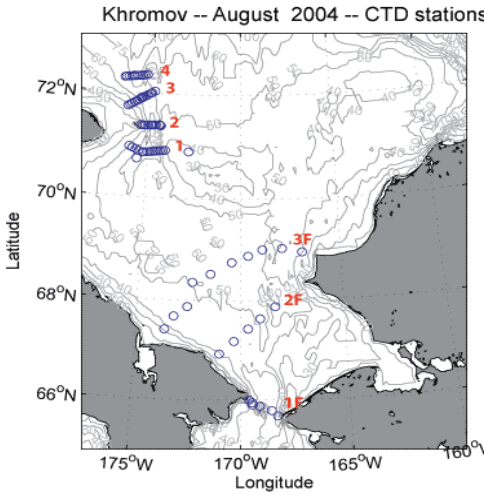
Satellite-measured with max-min values during 2000-2010

(Wang et al. JGR, 2013)

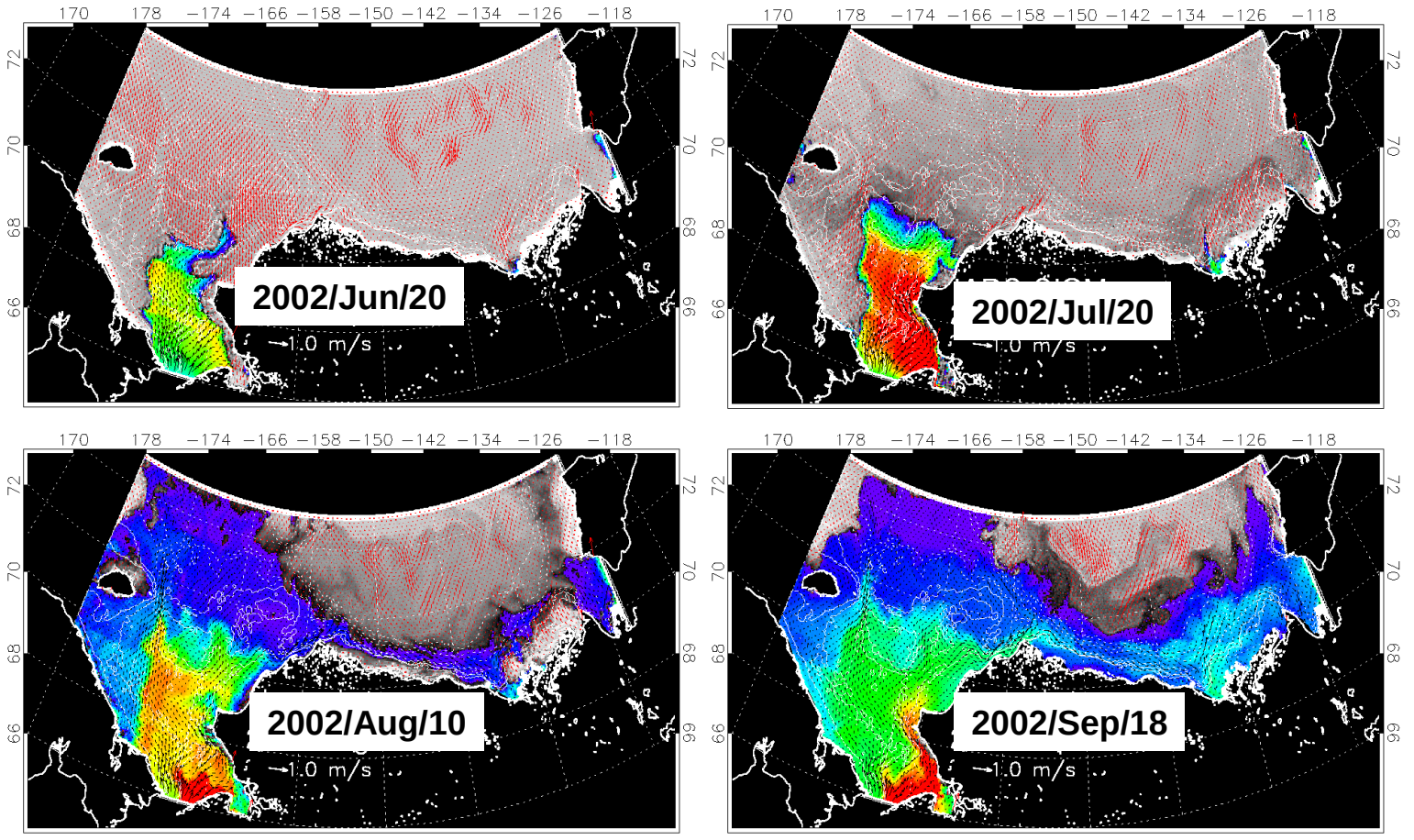
Verification of CIOM using 2004 RUSALCA Data (T) in the Bering-Beaufort-Chukchi Seas (work in progress)



RUSALCA
Aug 2004

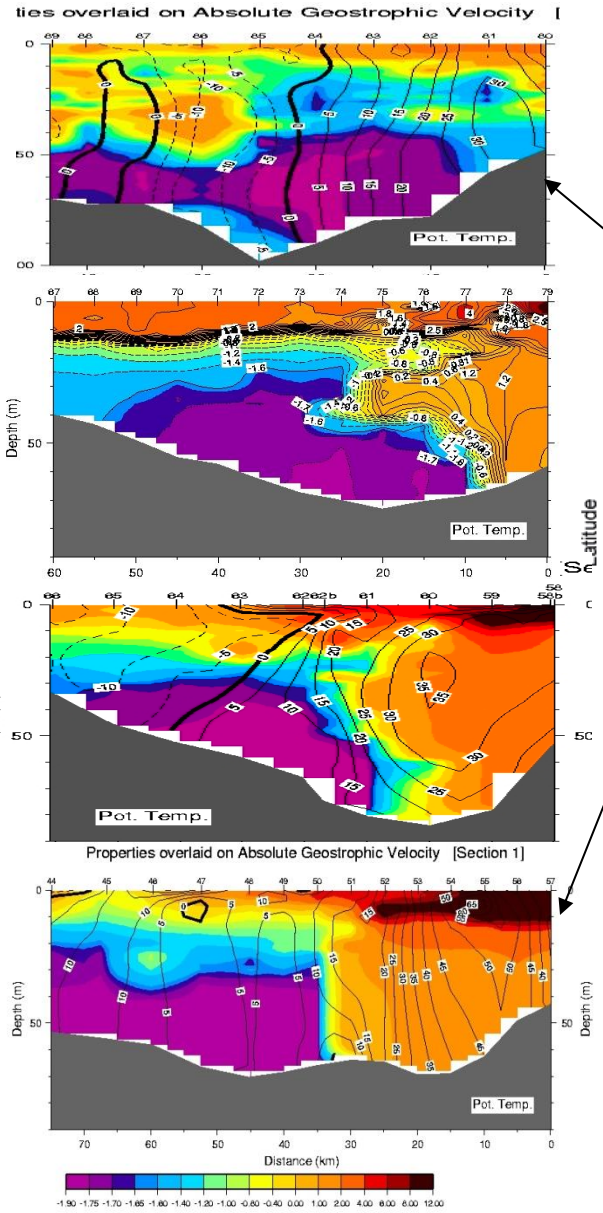


CIOM-simulated ice-ocean system

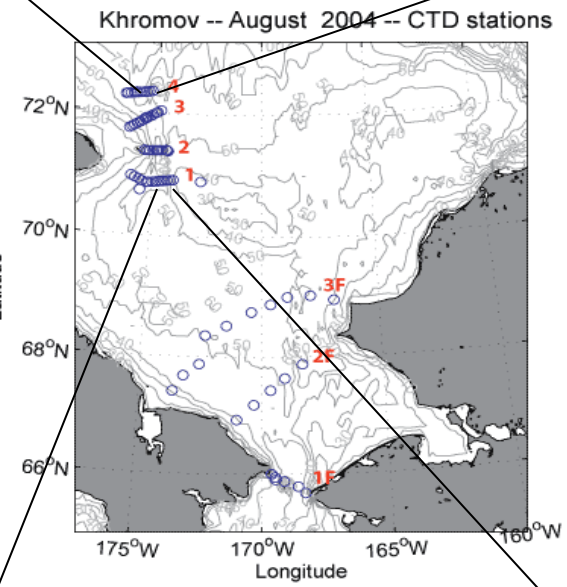


Verification of CIOM using 2004 RUSALCA Data (T&V) in the Bering-Beaufort-Chukchi Seas

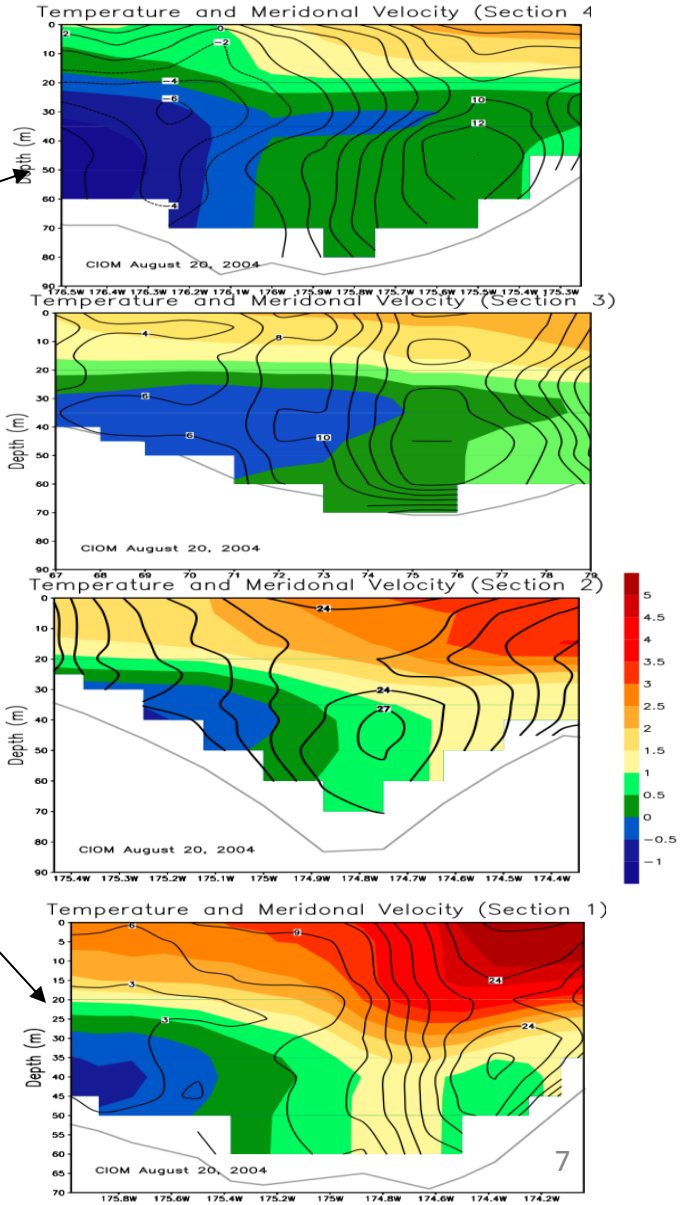
Observed (Pickart)



Aug 2004

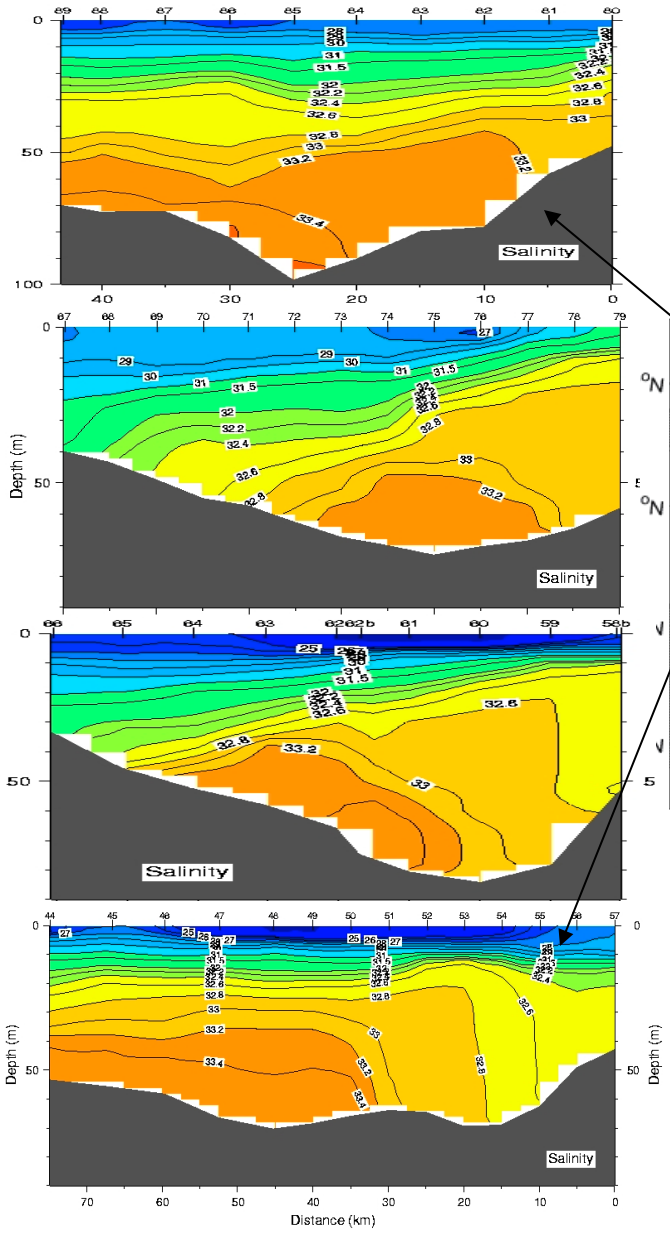


CIOM-simulated (GLERL)

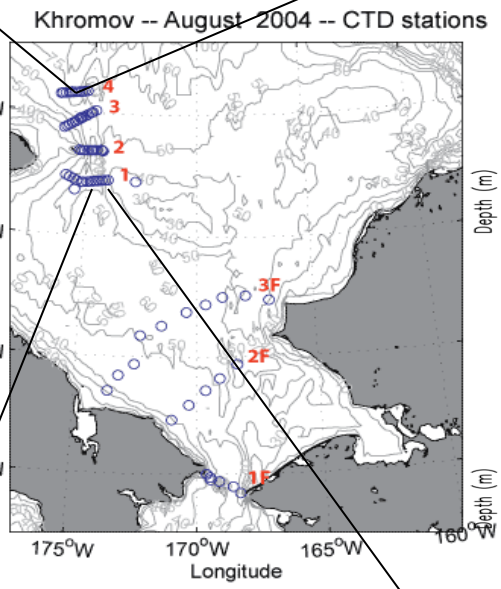


Verification of CIOM using 2004 RUSALCA Data (S) in the Bering-Beaufort-Chukchi Seas

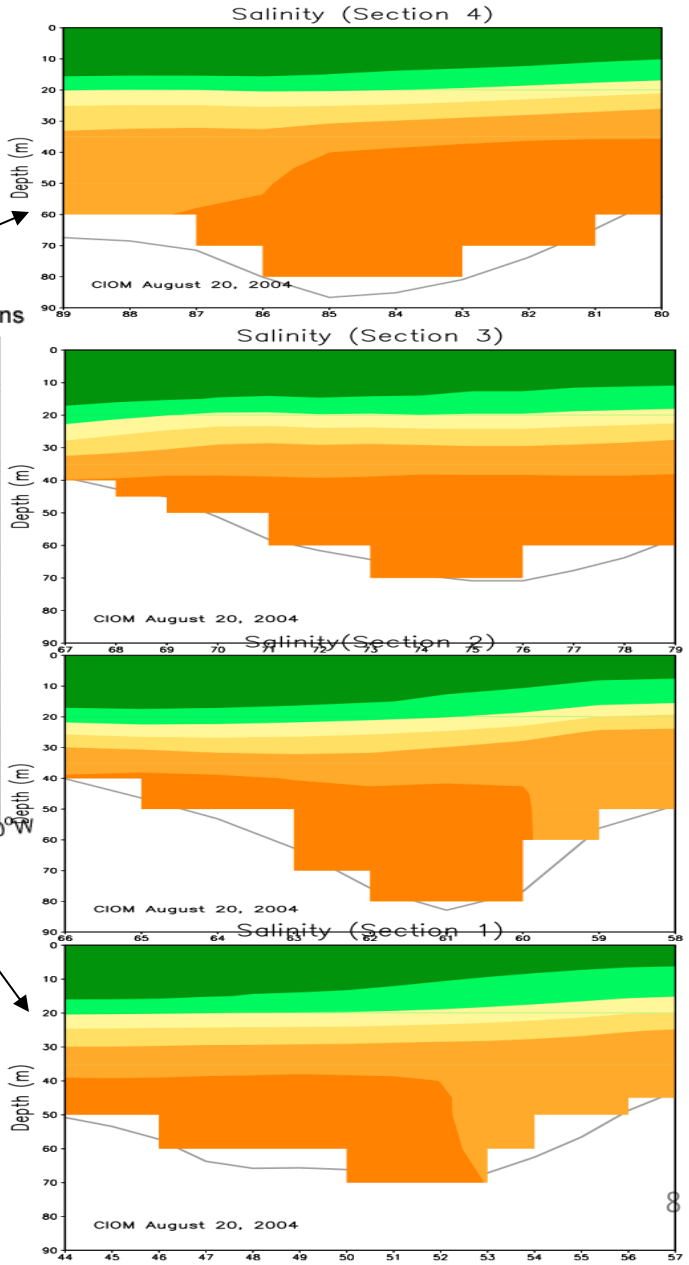
Observed (Pickart)



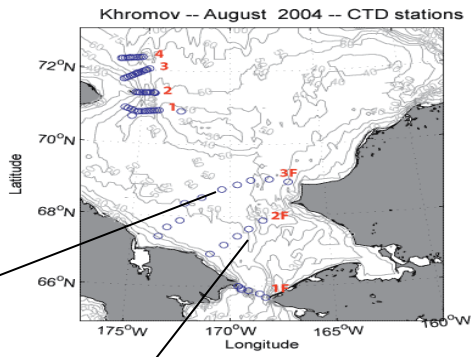
Aug 2004
(need tidal forcing)

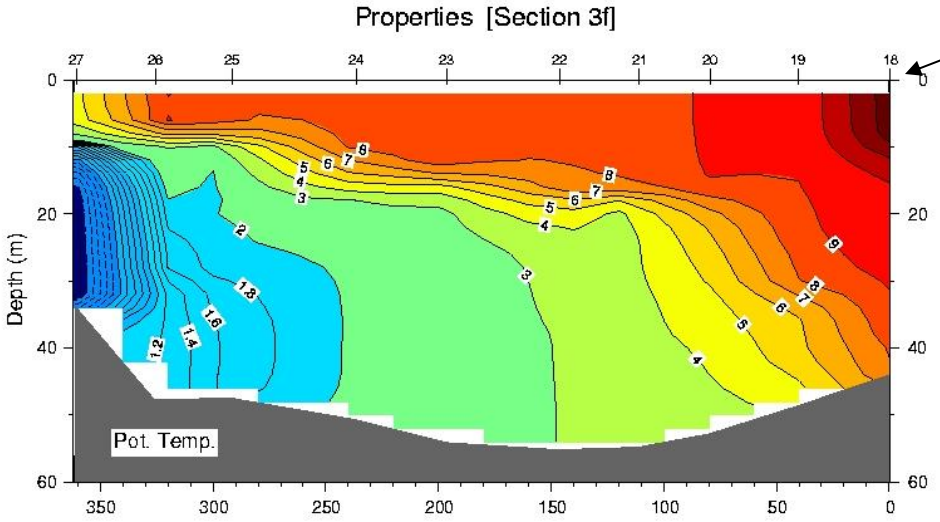


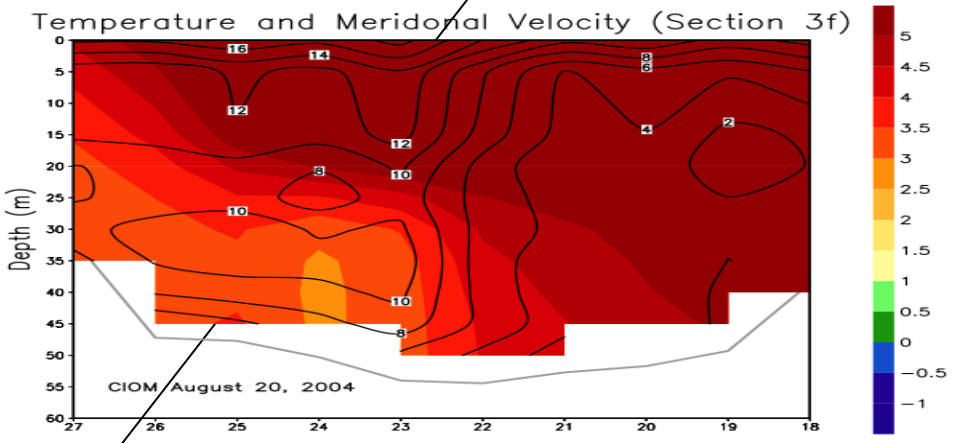
CIOM-simulated (GLERL)

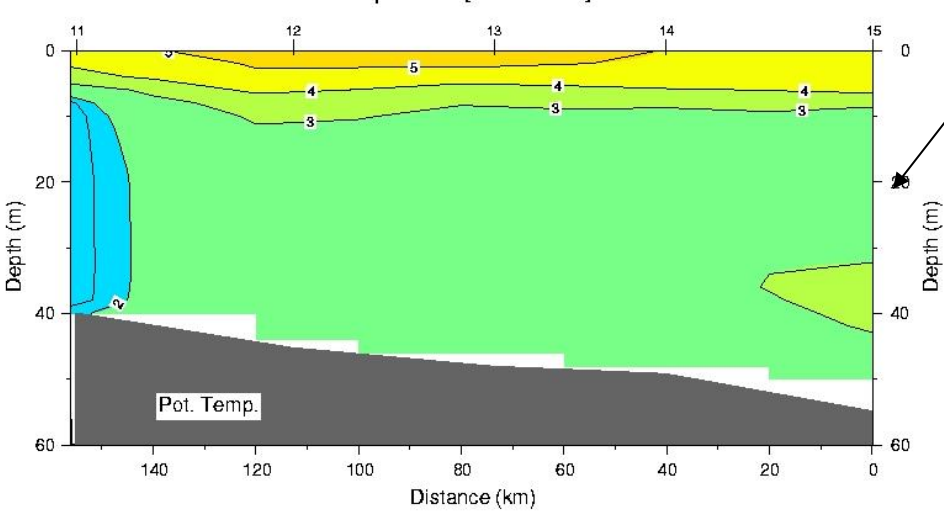


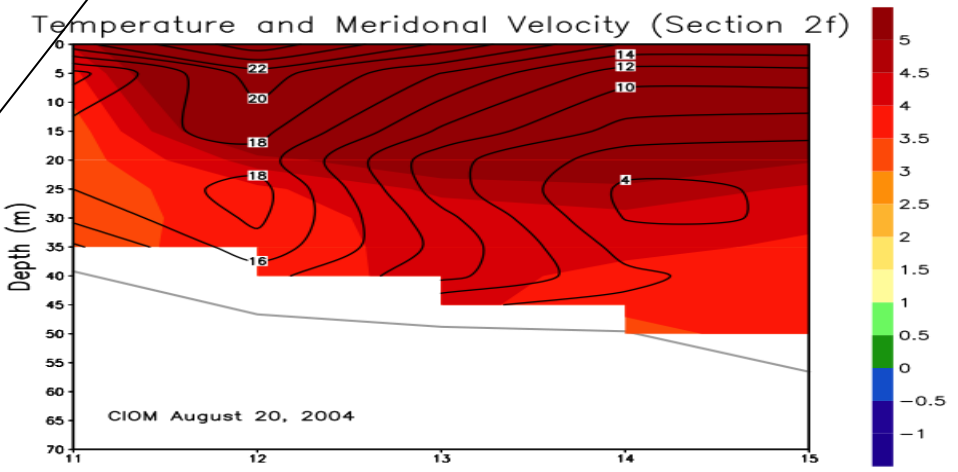
Southern Chukchi Sea



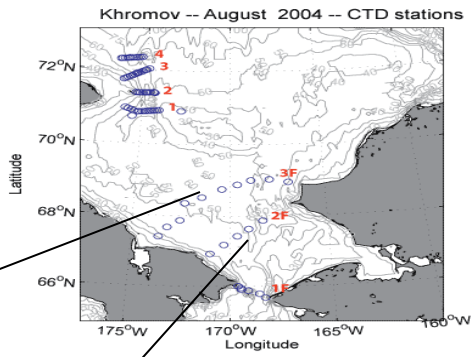


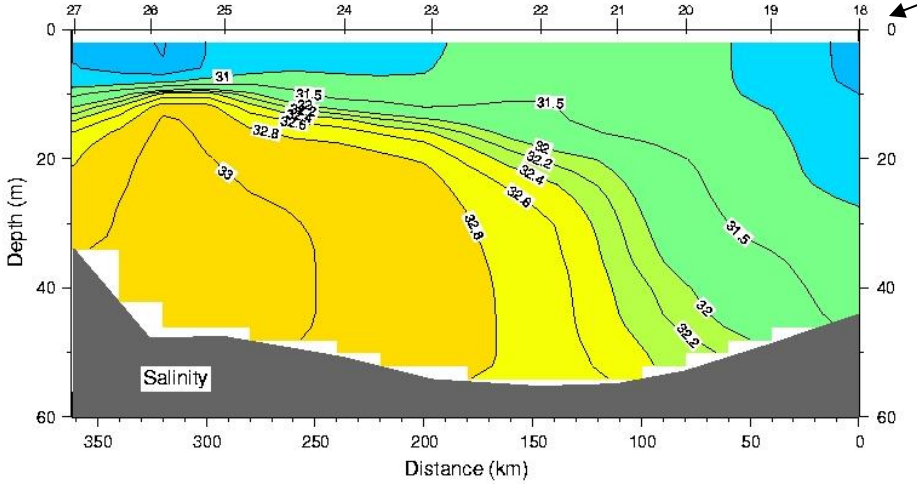


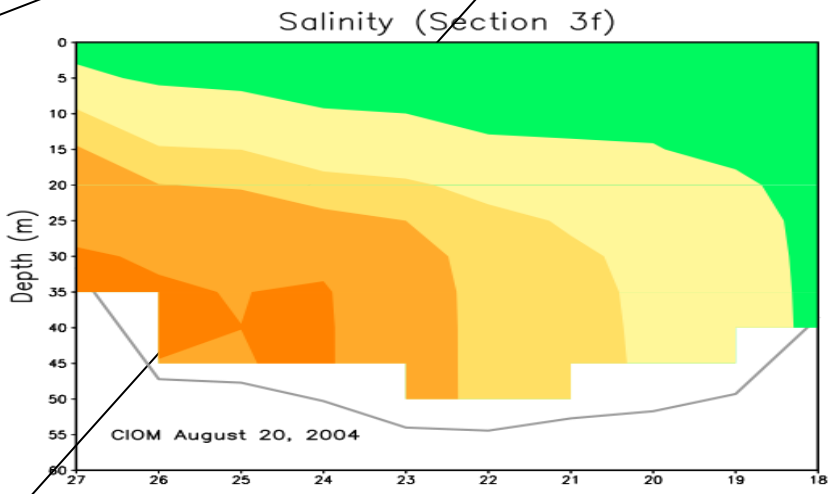


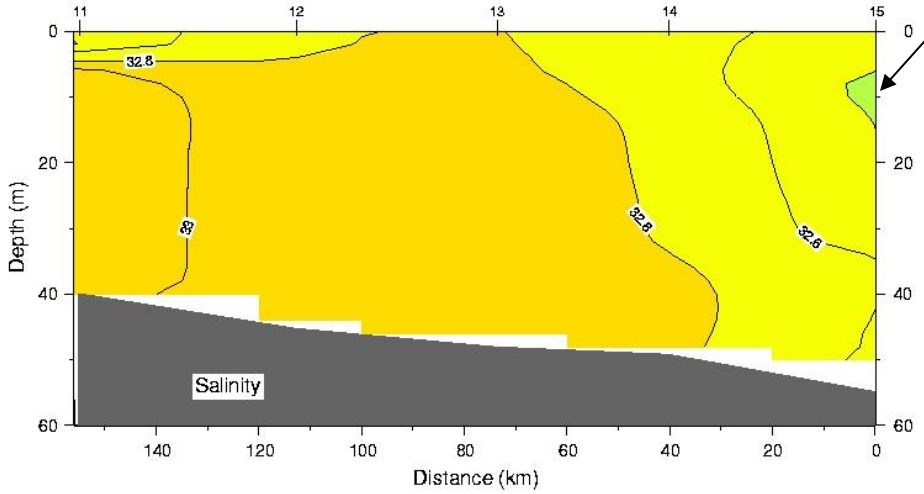


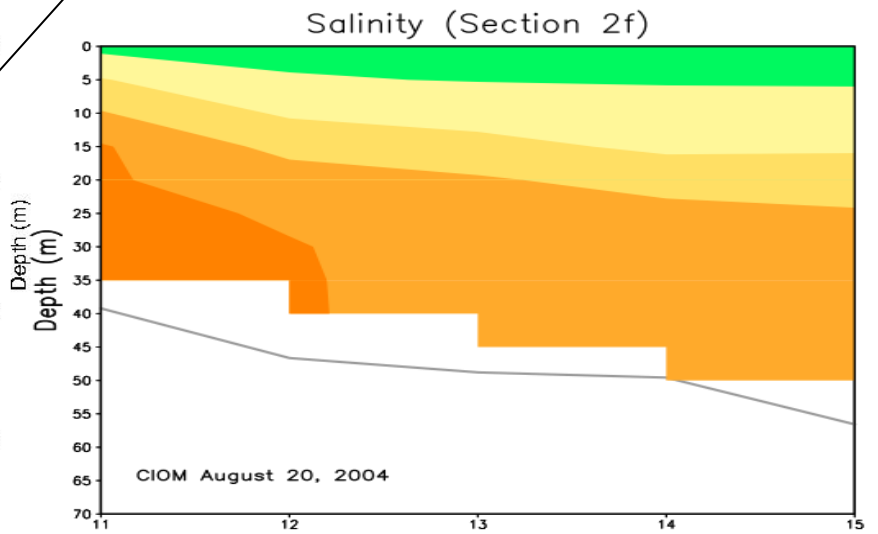
Southern Chukchi Sea: S





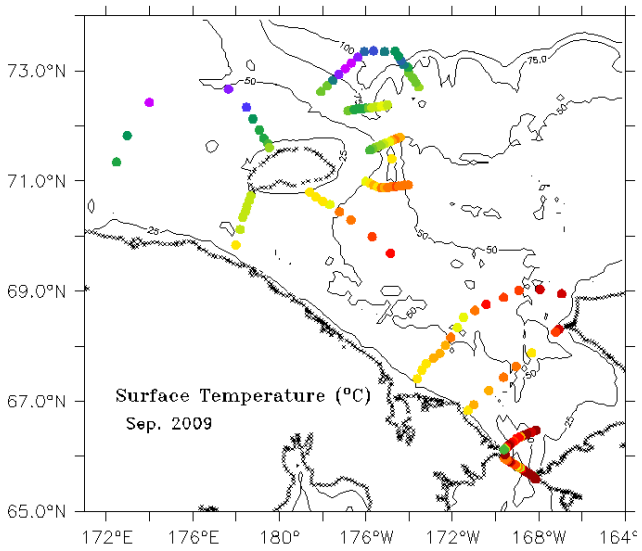




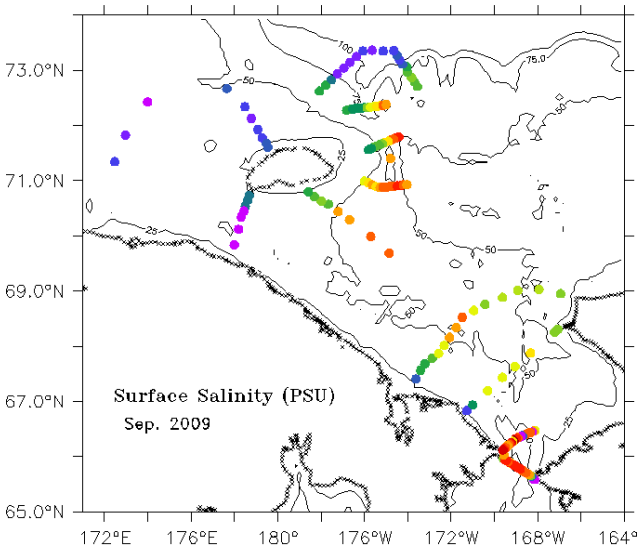


Verification of CIOM using 2009 RUSALCA Data in the Bering-Beaufort-Chukchi Seas (work in progress)

Measured Sep 2009

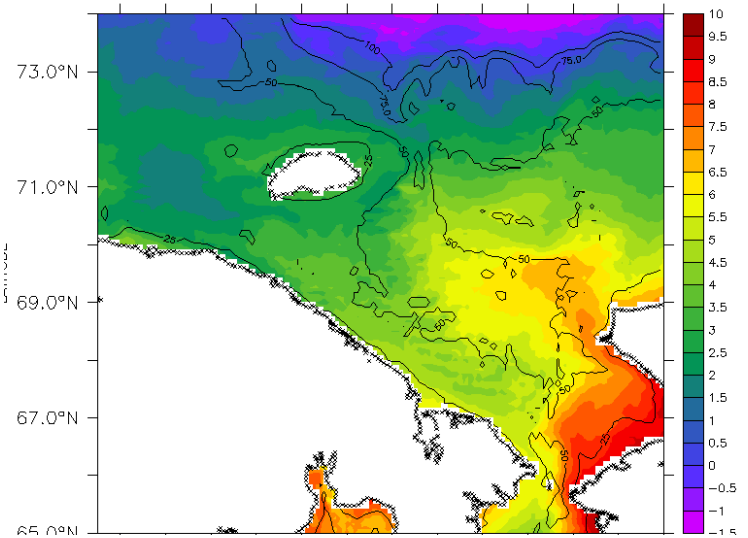


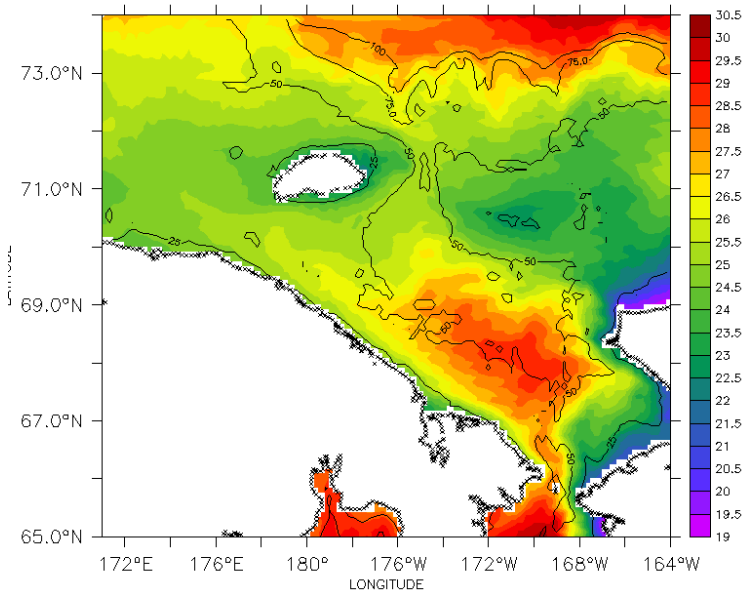
SST

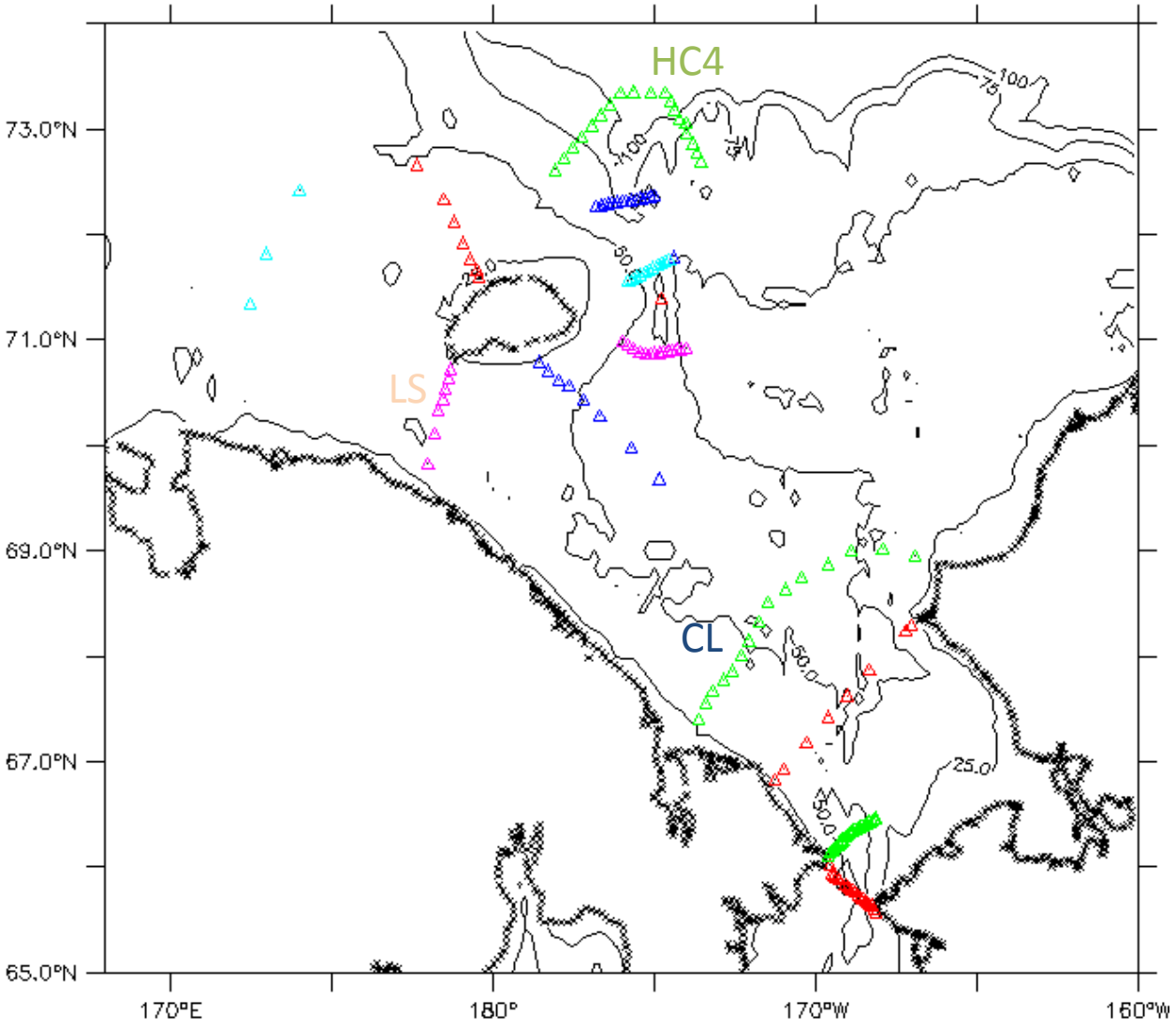


SSS

Modeled

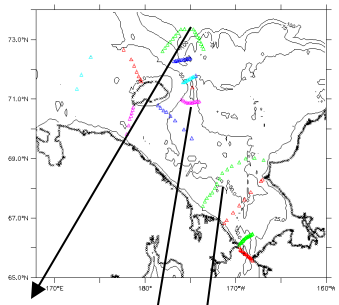






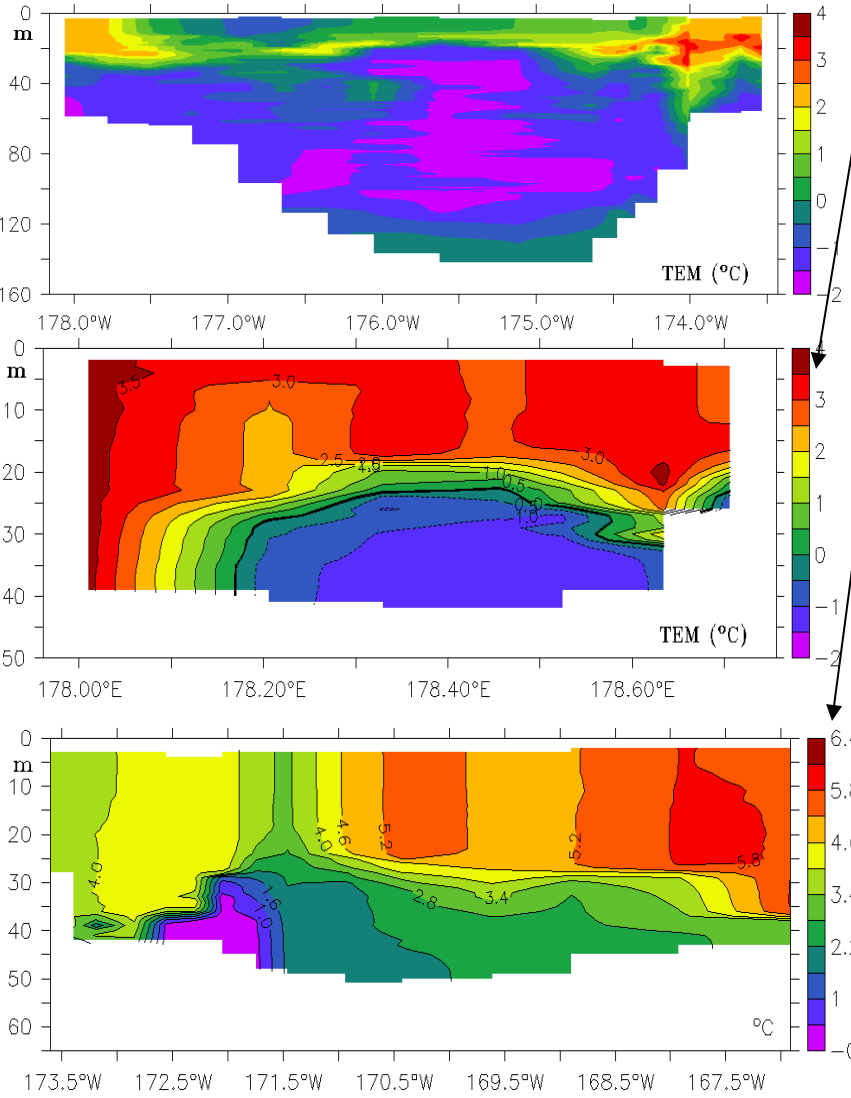
Cruise stations, Sep 3-29, 2009

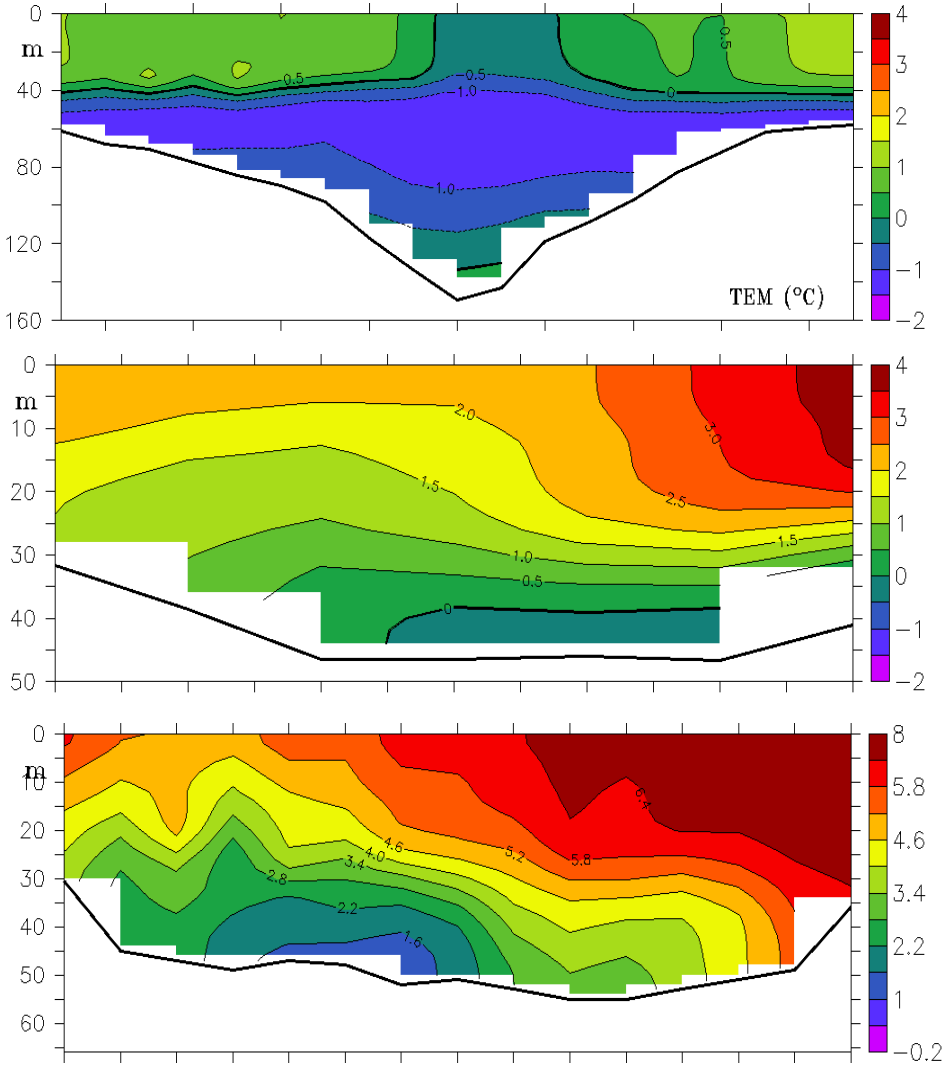
Verification of CIOM using 2009 RUSALCA Data (T) in the Beaufort-Chukchi Seas

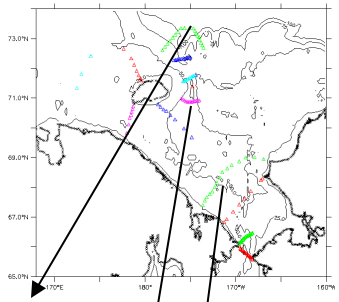


RUSALCA-observed temperature (Pickard and others)

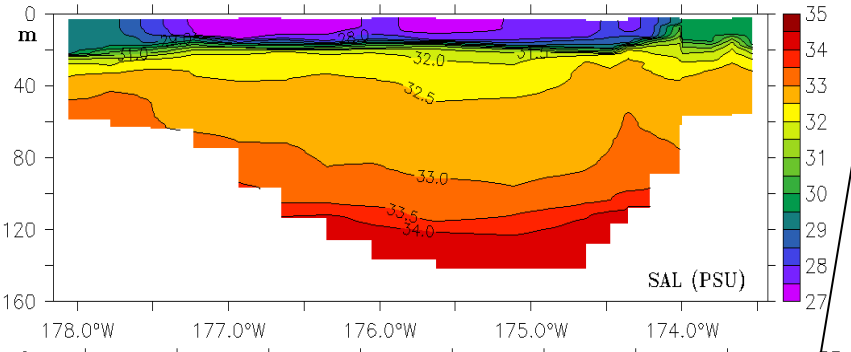
CIOM-simulated temperature (GLERL)

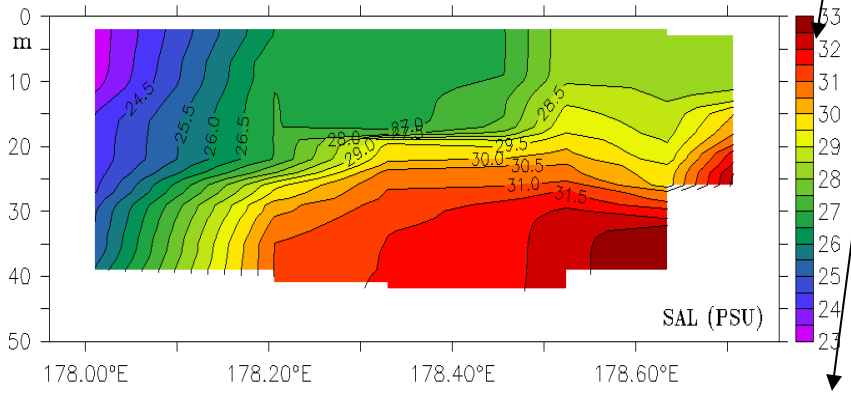


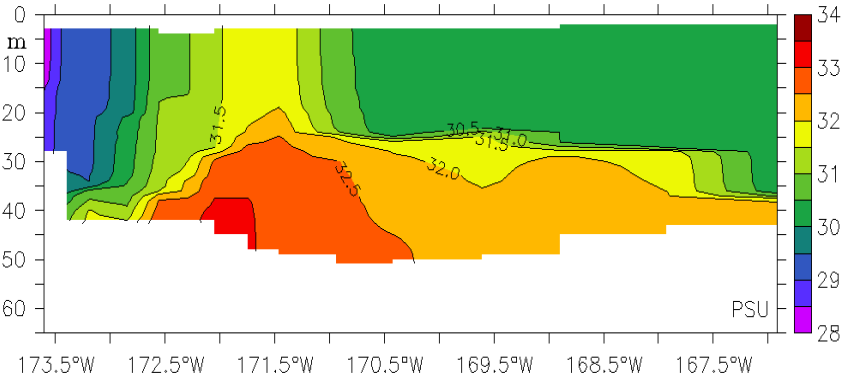




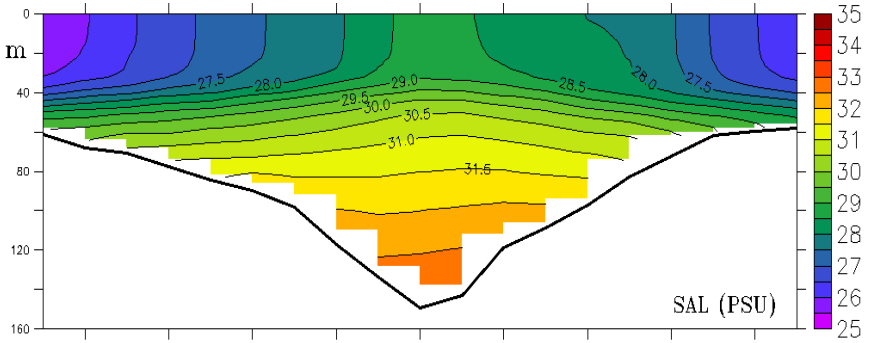
Observed salinity

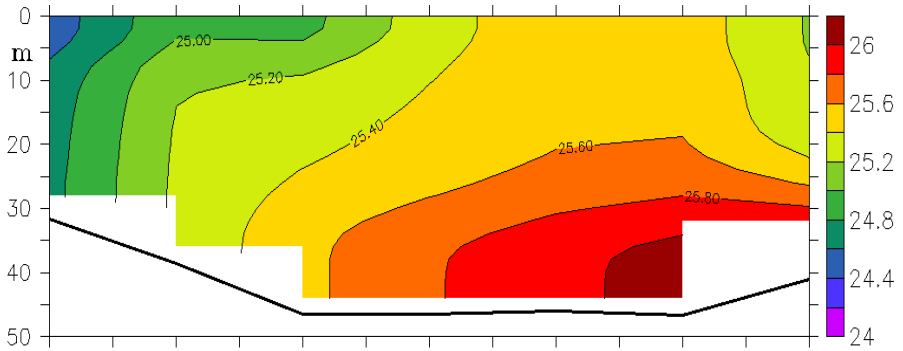


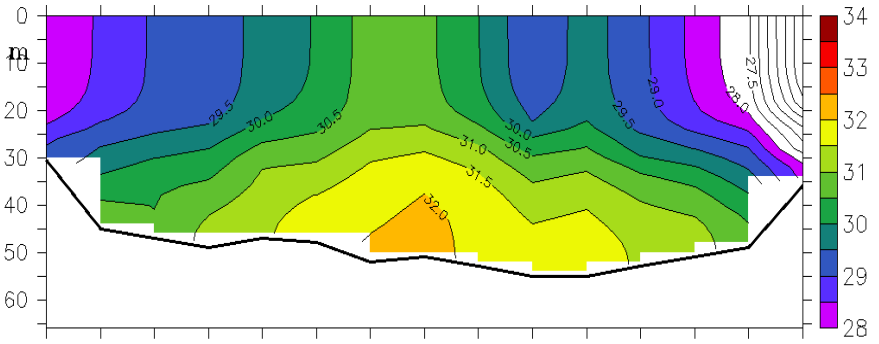




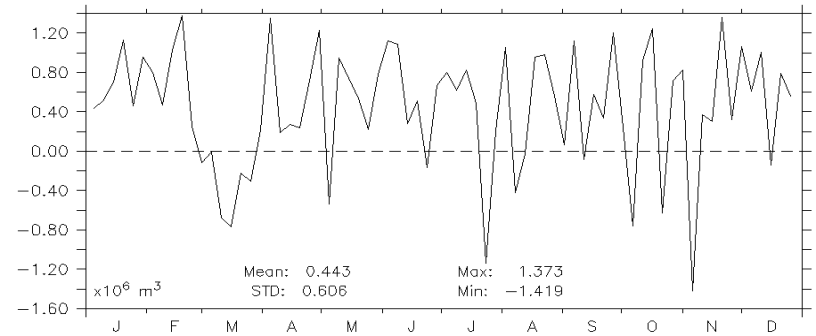
Simulated salinity

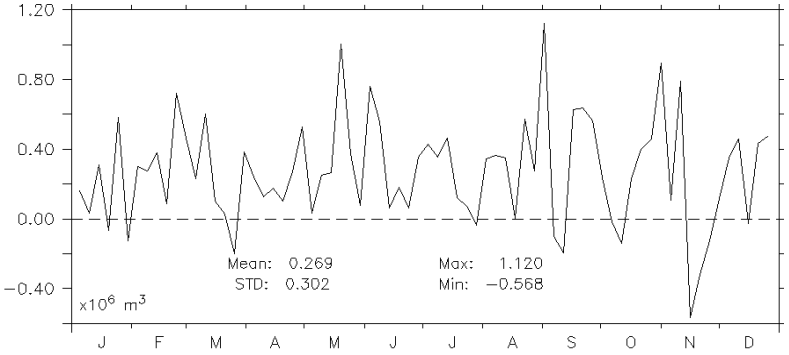


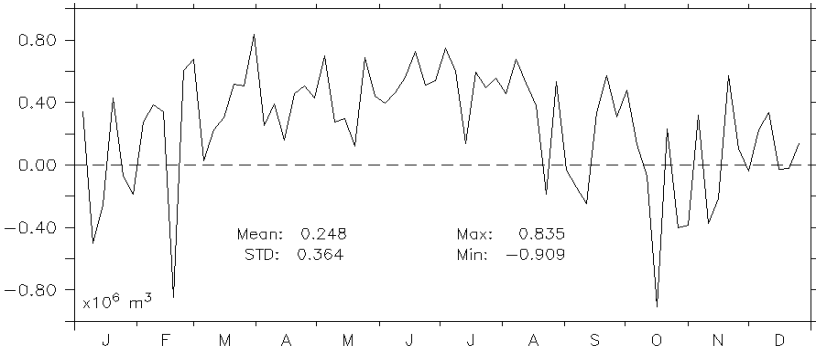


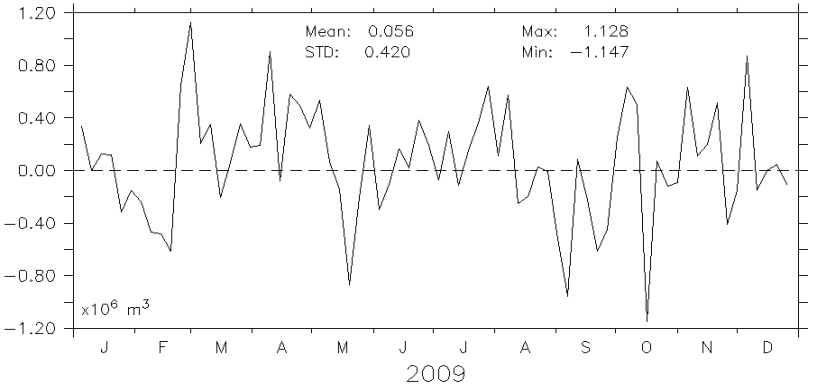


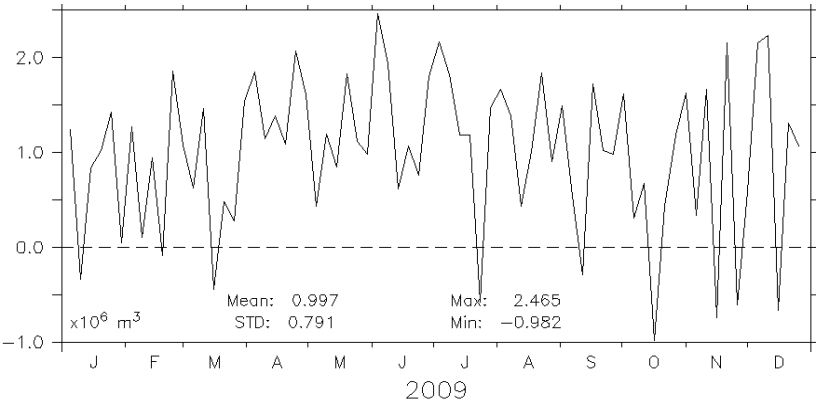
Volume Transport through Five Straits











2009 Transport through

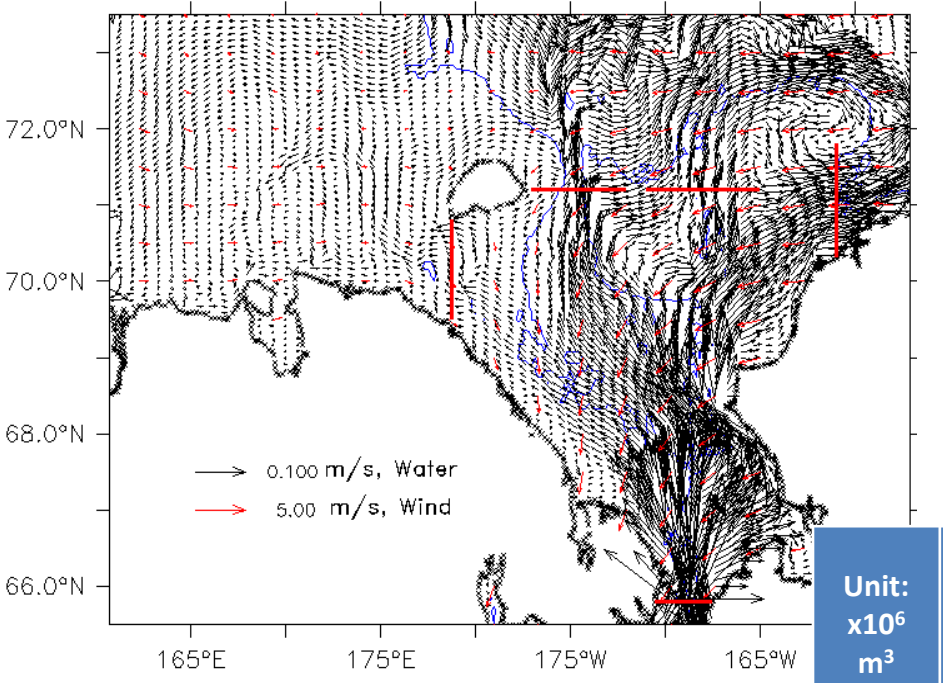
Barrow Canyon

Central Channel

Herald Valley

Long Island Strait

Bering Strait.



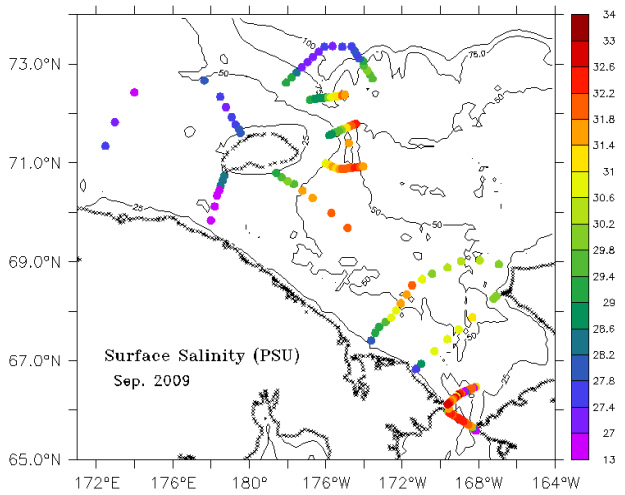
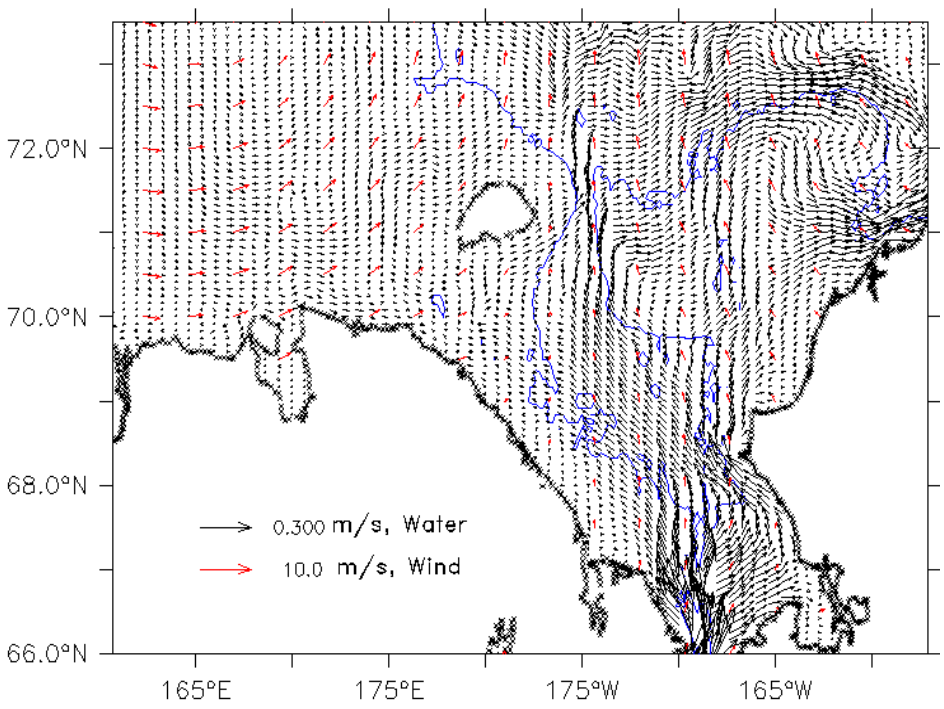
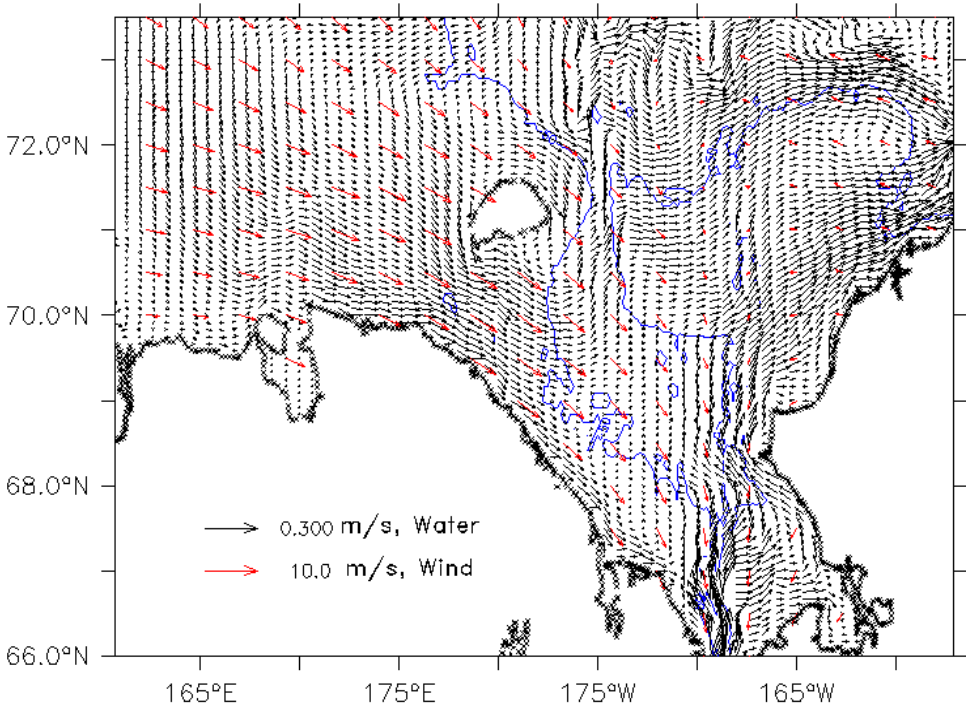


Table: Water transports in the Chukchi Sea in 2009, positive and negative values denote flowing into and out of Chukchi Sea, respectively.

Unit: $x10^6$ m^3	Mean	STD	Max	Min	Observations
Barrow Canyon	0.443	0.606	1.373	-1.419 (westward)	0.45 (itoh et al 2013)
Central Valley	0.269	0.302	1.120	-0.568 (southward)	0.2 ± 0.1 (Weingartner et al. 2005)
Herald Valley	0.248	0.364	0.835	-0.909 (southward)	0.1~0.3 (Woodgate et al 2004)
Long Strait	0.056	0.420	1.128	-1.147 (eastward)	??
Bering Strait	0.997	0.791	2.465	-0.982 (southward)	0.8 ± 0.2 (Woodgate et al. 2004)



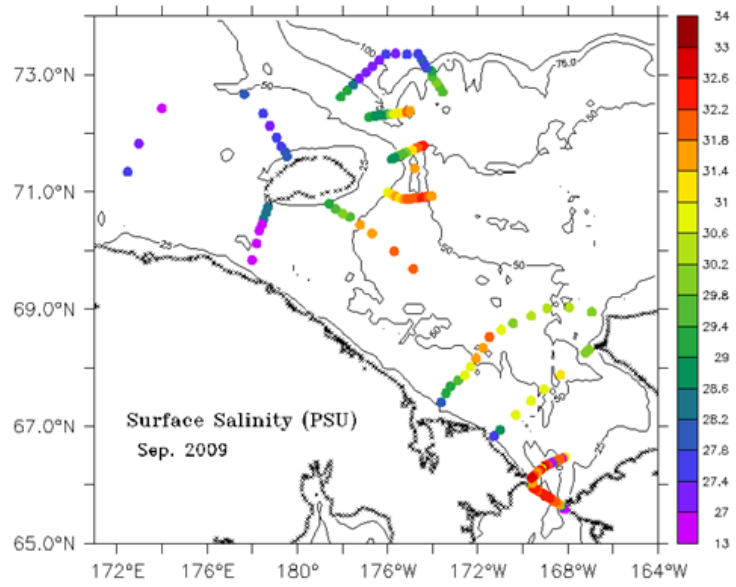
August

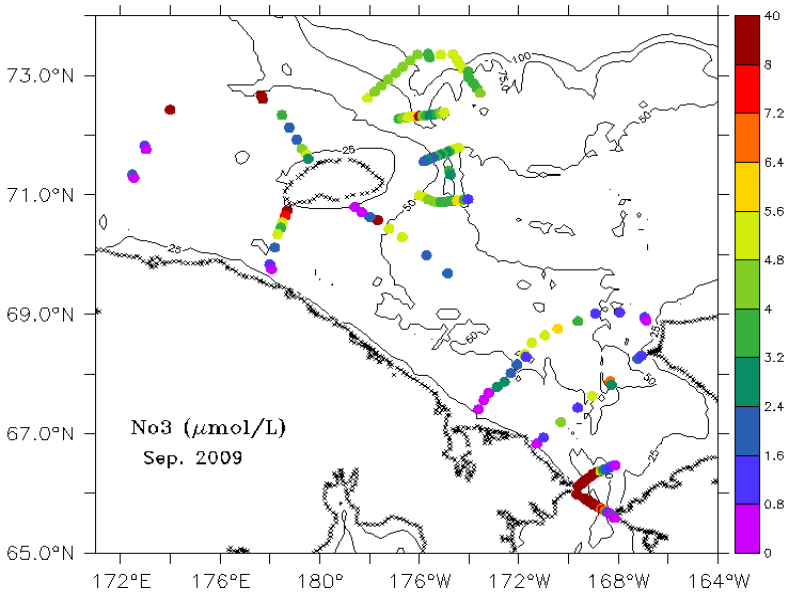


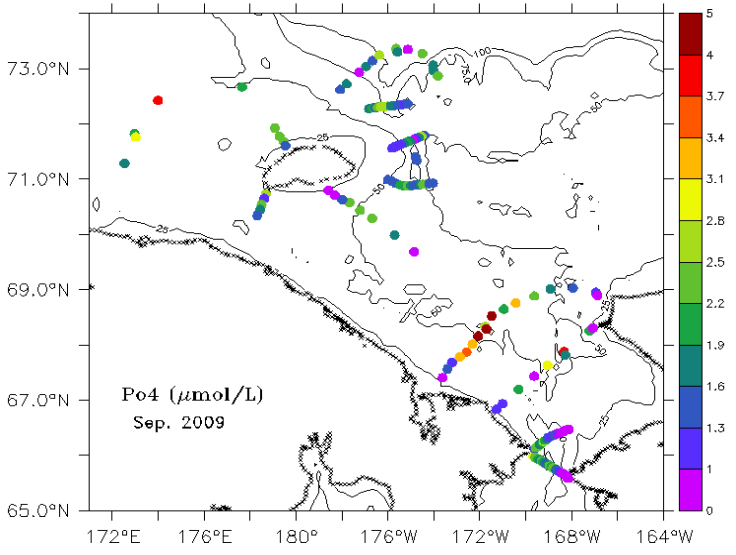
September

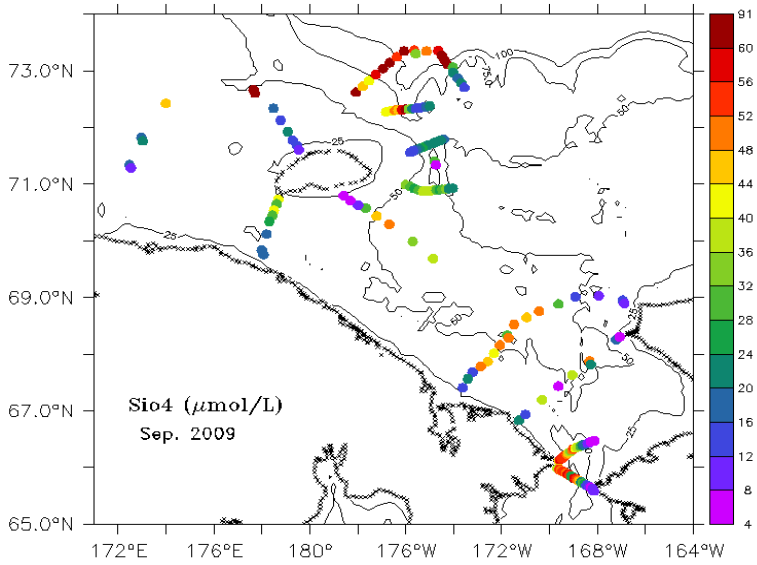
Depth-averaged currents in the Chukchi Sea 2009

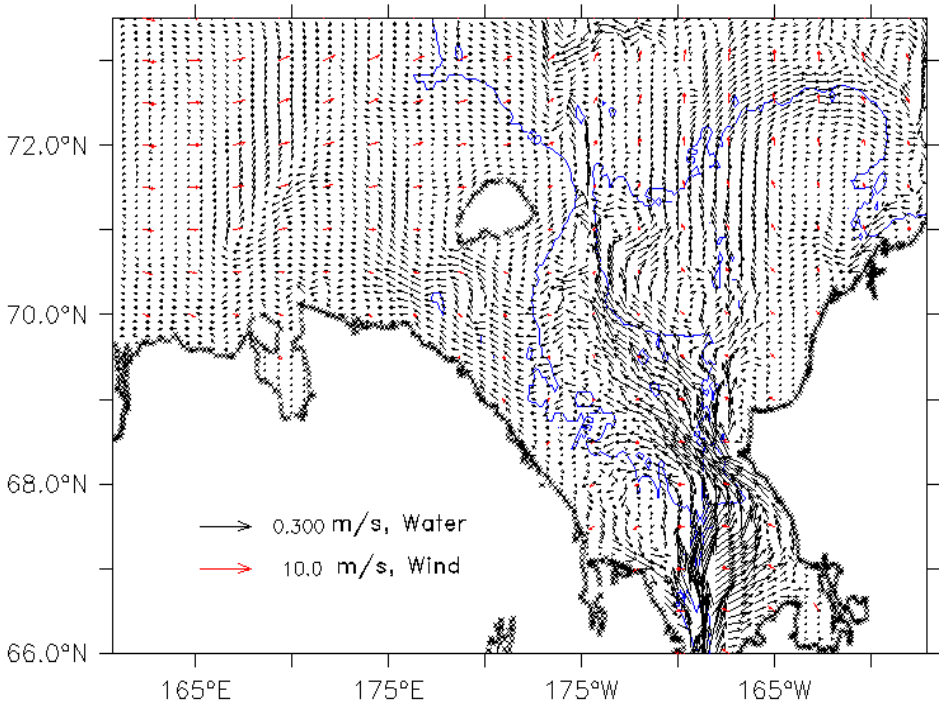
RUSALCA Measurements in 2009



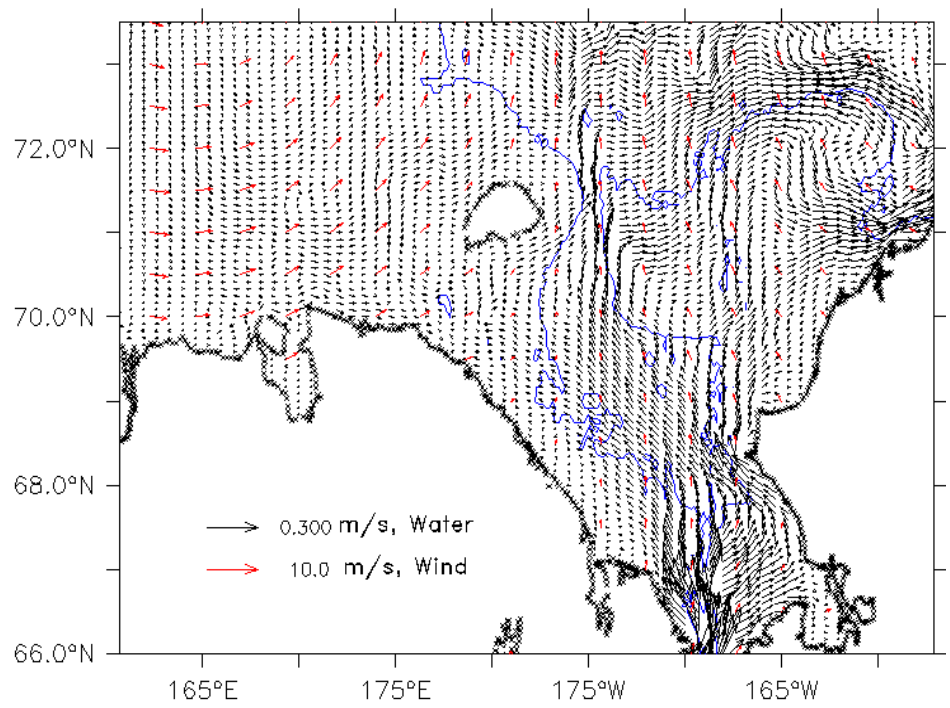








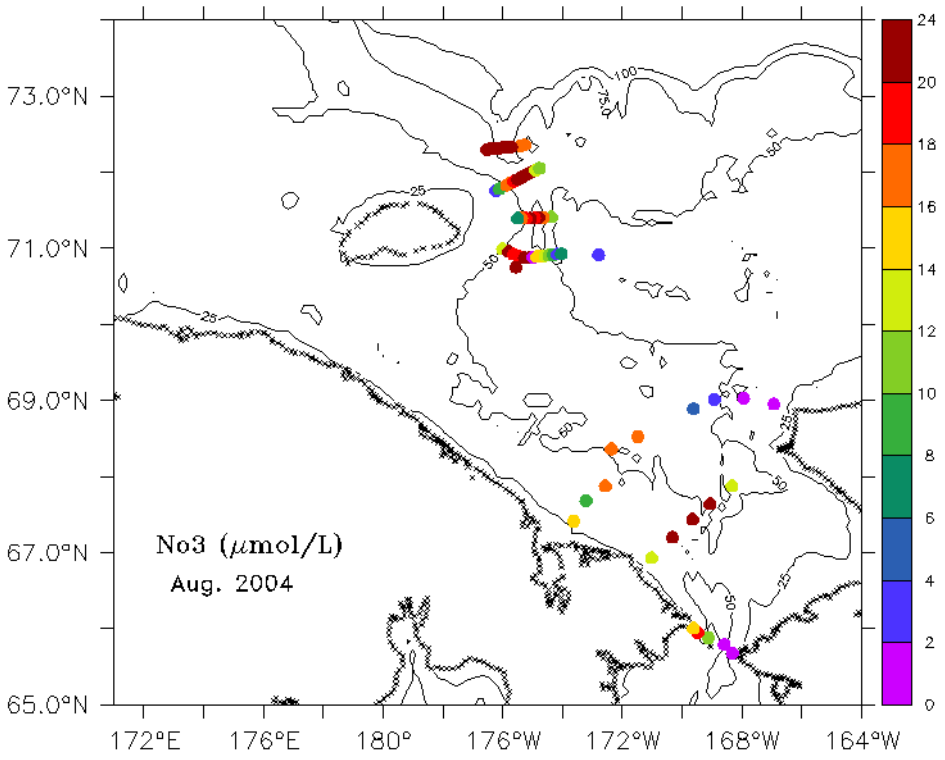
2004

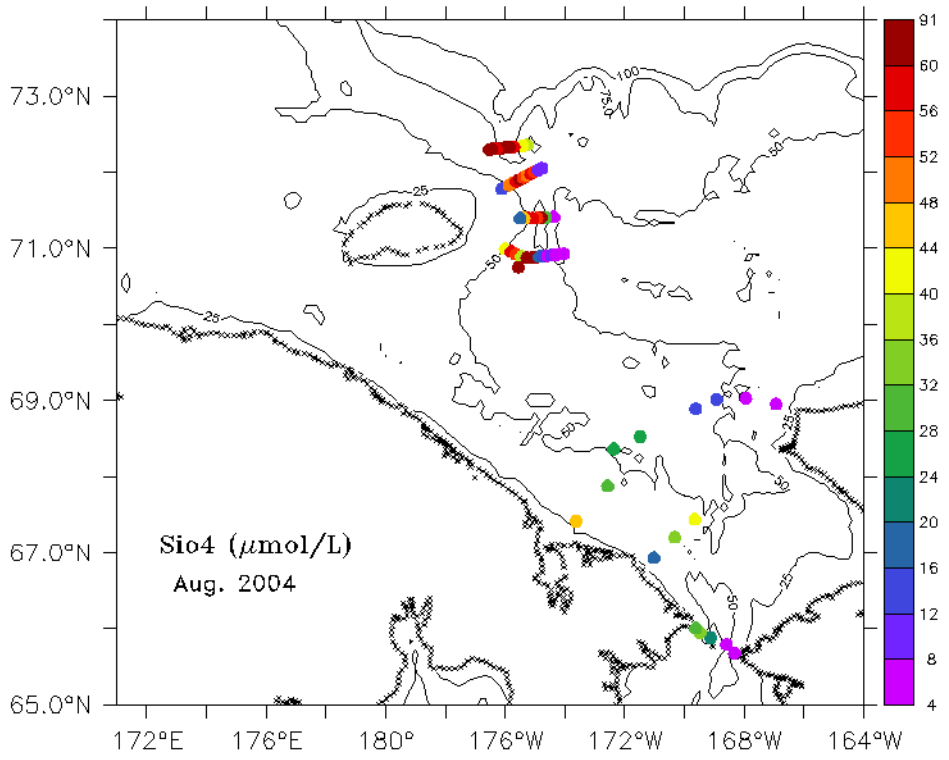


2009

August depth-averaged currents in the Chukchi Sea

RUSALCA Measurements in 2004

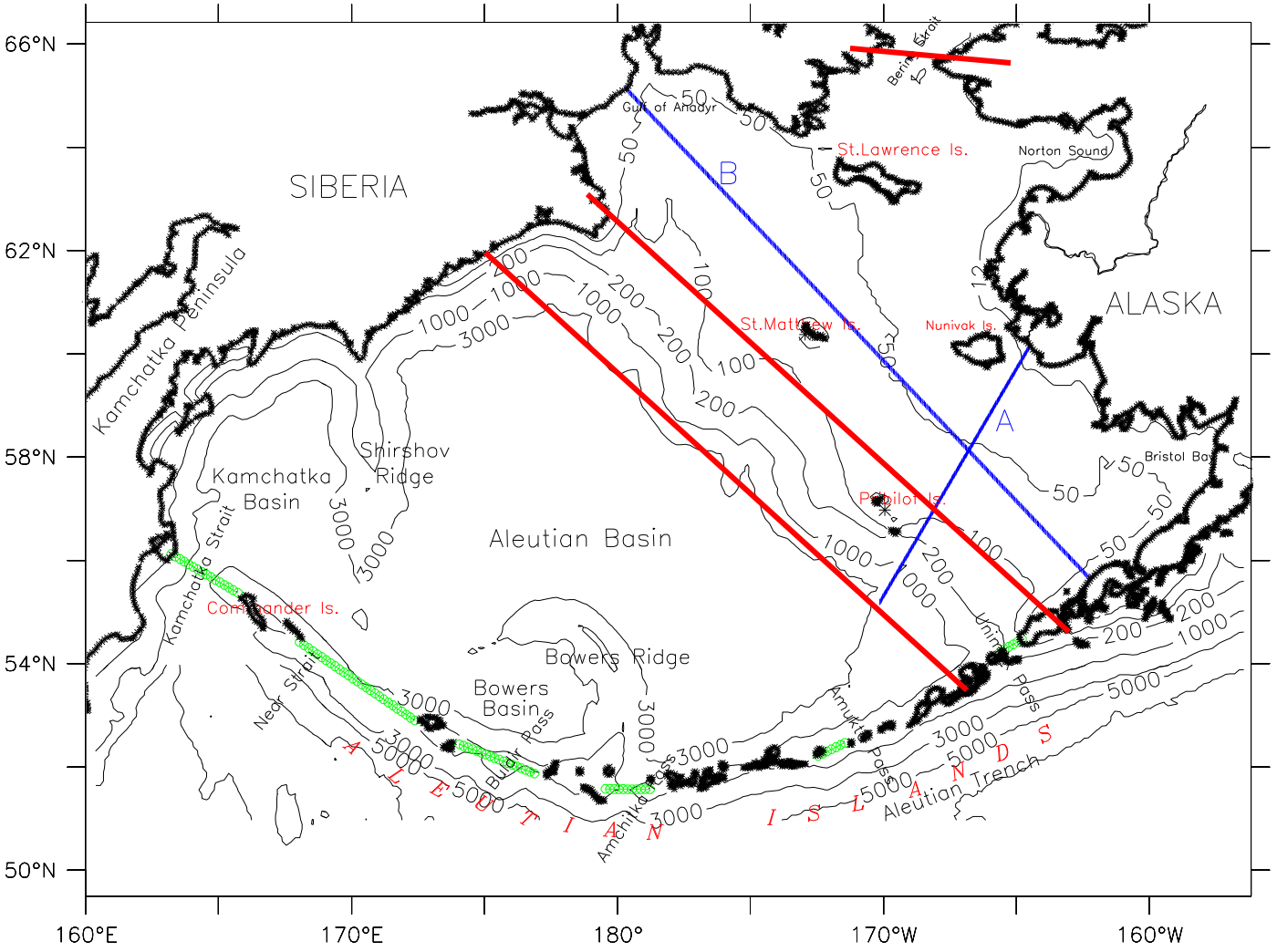


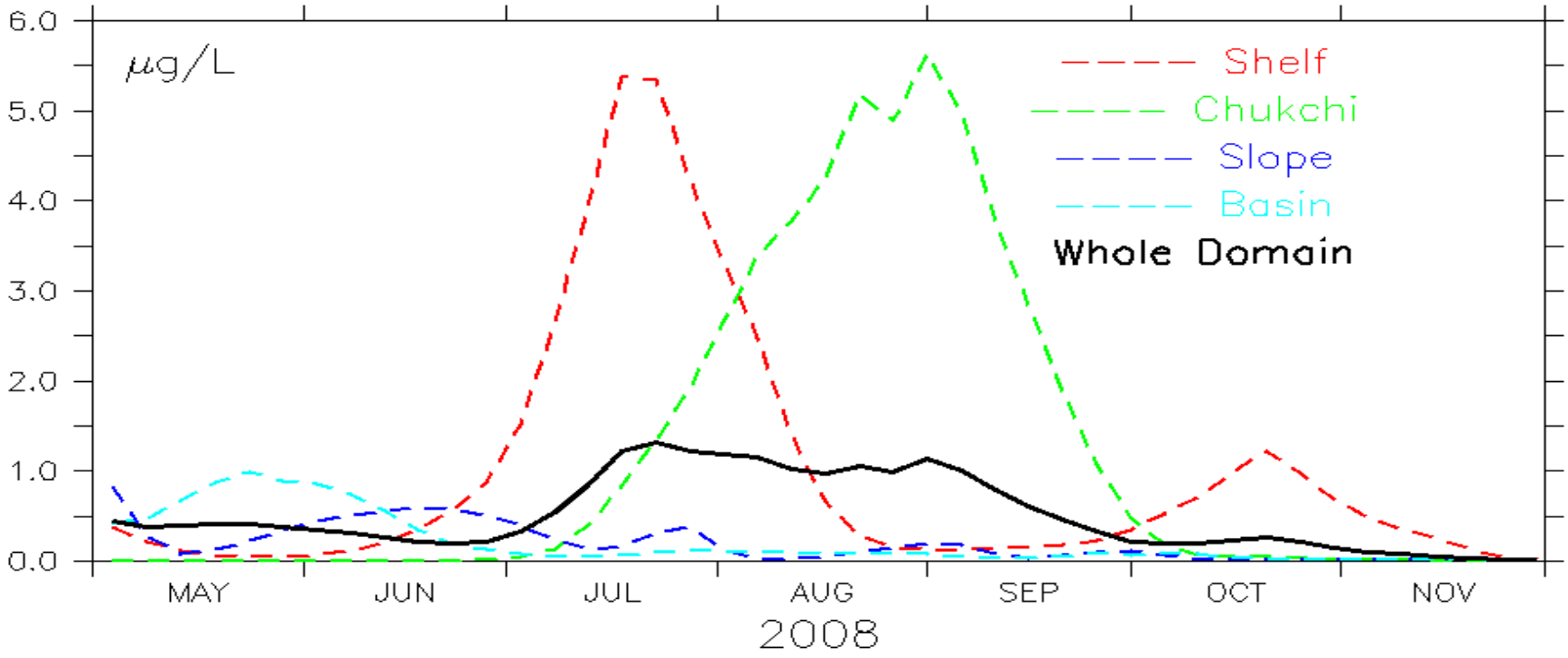


NO3 SiO4

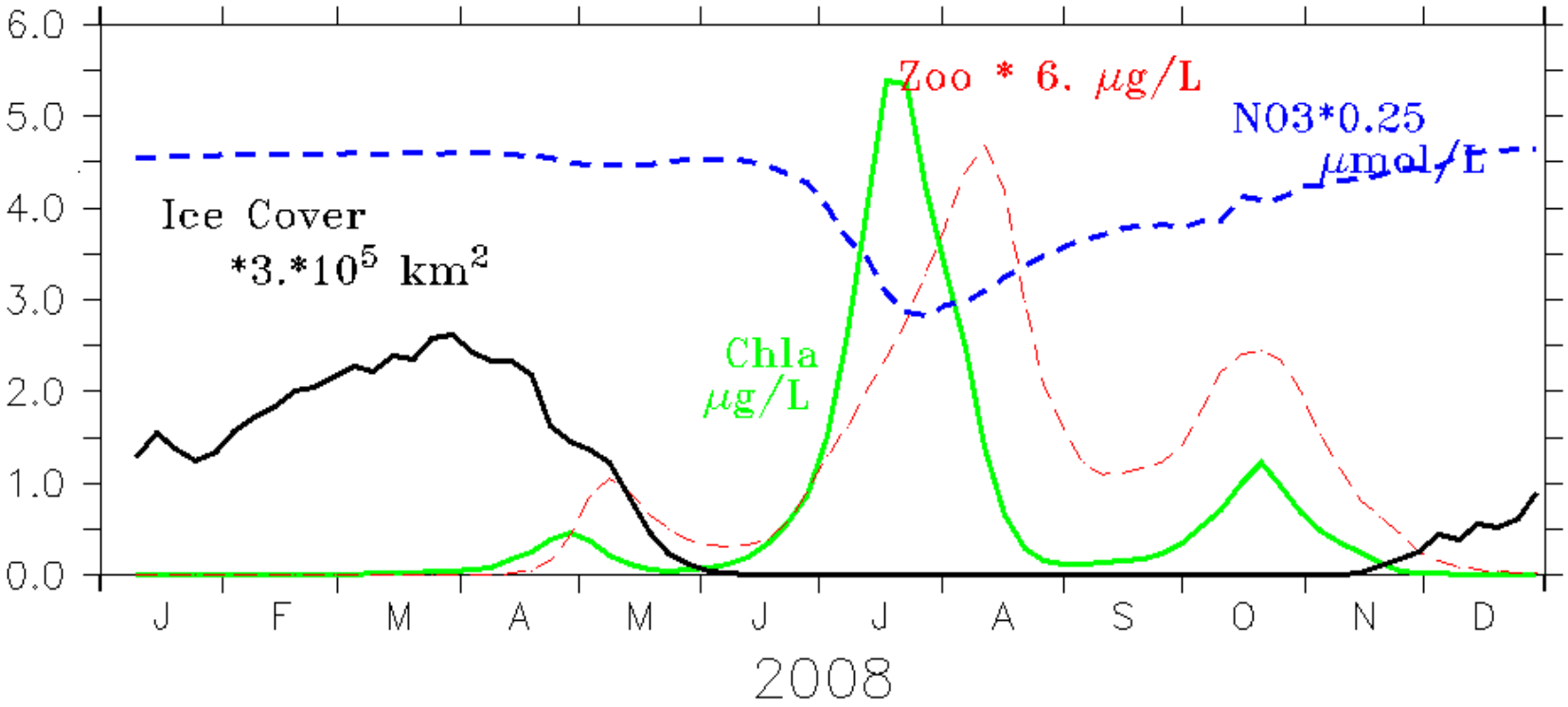
Measurement of August 2004 in the Chukchi Sea

Regional Average





Simulated seasonal variation of phytoplankton (Chl a) for the subregions and the whole domain.



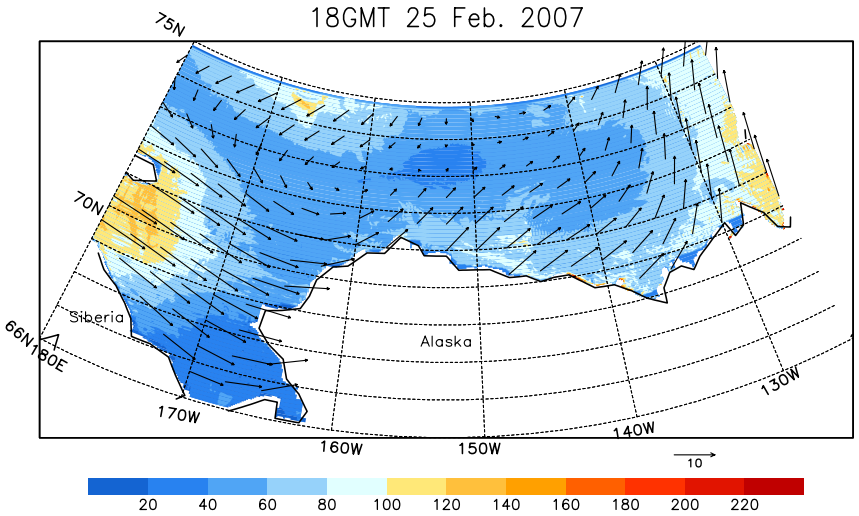
Modeled seasonal variations of sea ice cover (black line), nitrate (blue dashed), chlorophyll a (green), and zooplankton (red dashed) over the Bering Shelf . The units and factors are given.

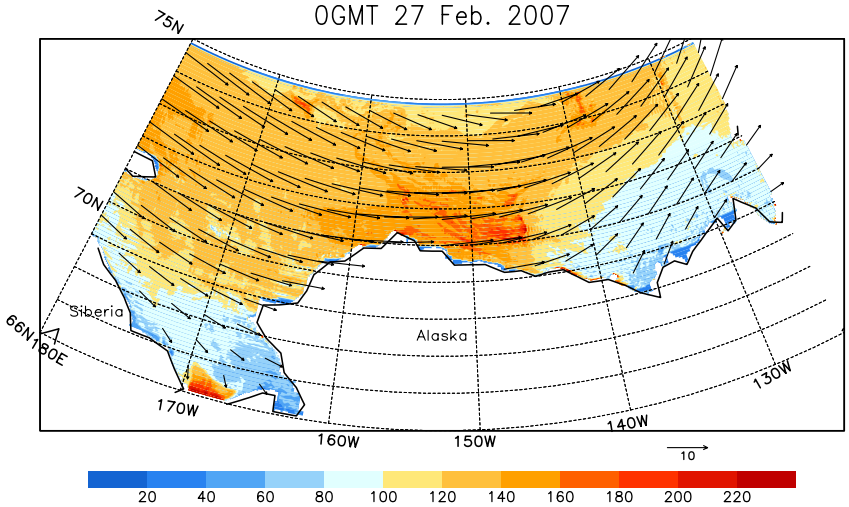
Table 1. Subdomain- and time- (May-November) average chl-a comparison between the control run (second column) and sensitivity experiments of 1) an increase of solar radiation by 10% (third column), 2) an increase of nutrients from open boundaries (OB) by 20% (fourth column), and 3) an increase of air temperature by 2 oC (fifth column). Numbers in parentheses are the relative increase rate.

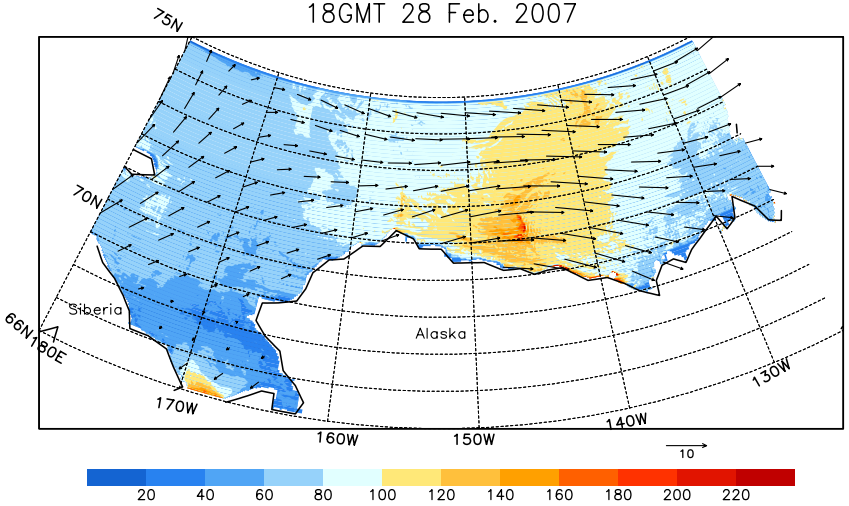
Chl-a (μg/L)	Standard	Solar +by 10%	Nutrients +by 20%	SAT +by 2 oC
Basin	0.204	0.003 (1.47%)	0.050 (24.5%)	-0.035 (-17.15%)
Slope	0.186	0.008 (4.30%)	0.096 (51.6%)	0.041 (22.04%)
Shelf	0.987	0.005 (0.51%)	0.051 (5.10%)	0.135 (13.66%)
Chukchi	1.160	0.002 (0.17%)	0.016 (1.30%)	0.220 (18.97%)
Whole	0.507	0.004 (0.78%)	0.035 (6.90%)	0.054 (10.65%)

Table 3. Bering shelf domain- and time (May-November) average comparison between the control run (second column) and sensitivity experiments of 1) an increase of solar radiation by 10% (third column), 2) an increase of nutrients from open boundaries (OB) by 20% (fourth column), and 3) an increase of air temperature by 2 oC (fifth column). Numbers in parentheses are the relative increase rate.

Variables	Standard	Solar +by 10%	Nutrients +by 20%	SAT +by 2 oC
Ice Cover (km2)	2.20×105	-2.97×10^3 (-1.35%)		-2.32×10^4 (-10.56%)
Chl-a (μg/L)	0.987	0.005 (0.51%)	0.051 (5.10%)	0.135 (13.66%)
Zoopl. (μg/L)	0.272	-0.012 (-4.42%)	0.016 (5.89%)	0.055 (20.08%)
NO3 (μmol/L)	15.71	0.194 (1.23%)	1.612 (10.3%)	5.053 (32.16%)

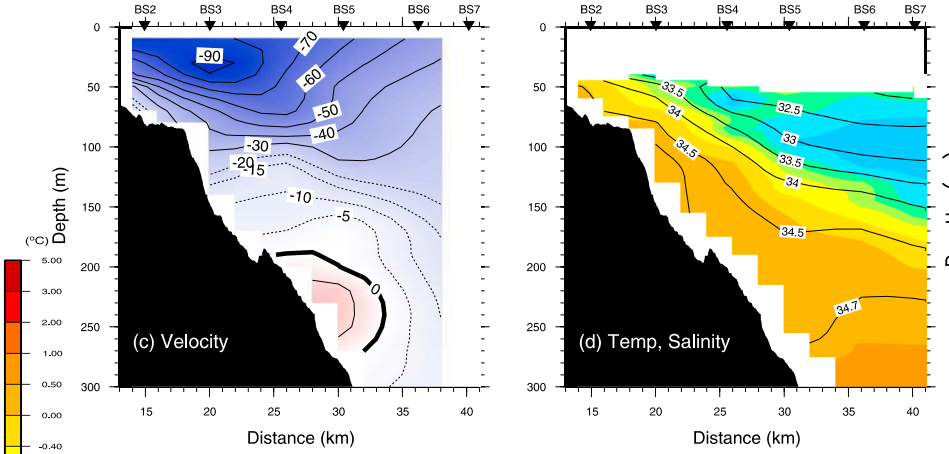




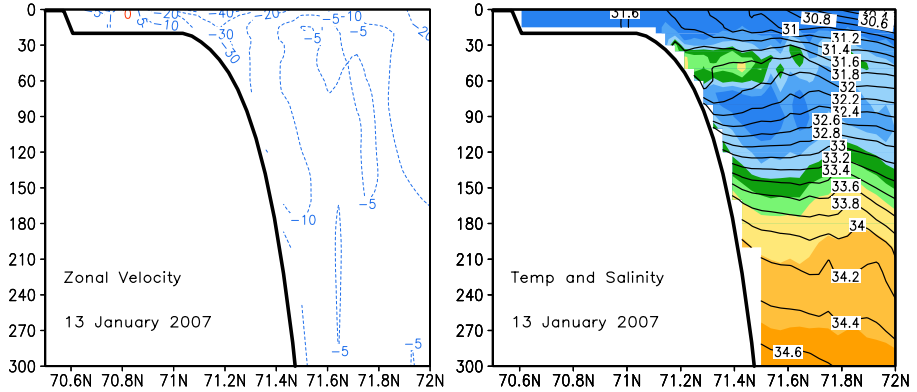


Calculated net surface heat flux (W/m^2, positive upward) with wind vectors overlain during the passage of the cyclone on 25-27 February 2007.

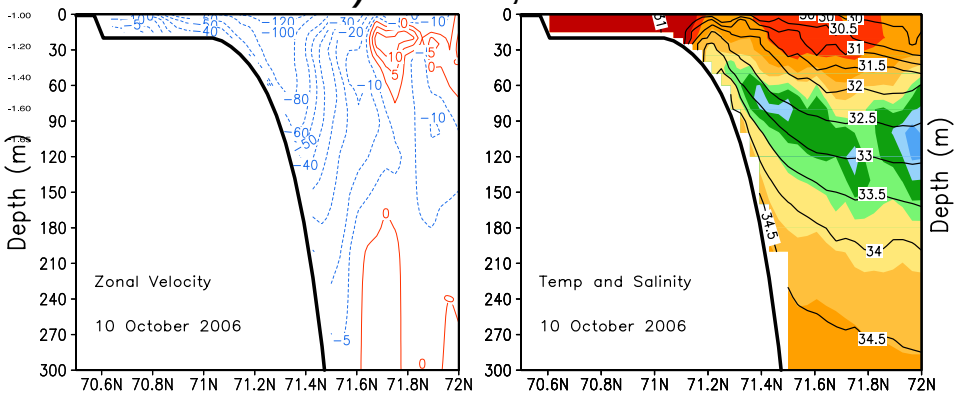
a) Observed (Pickard)



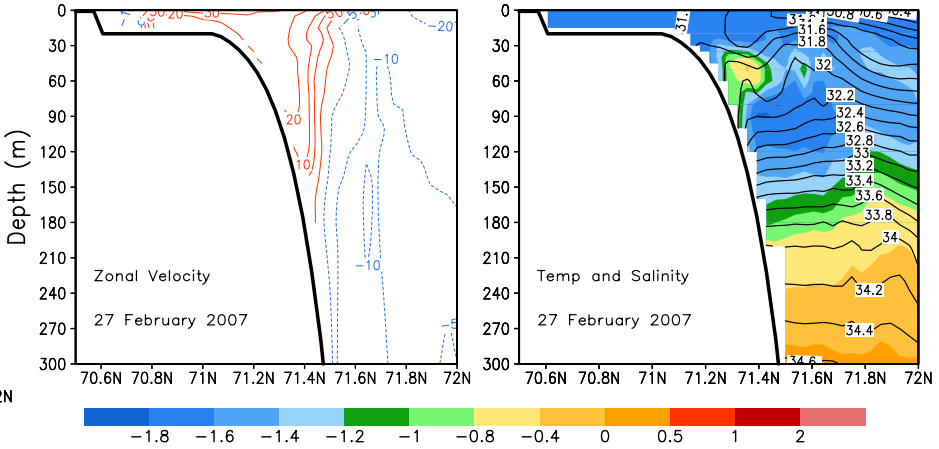
c) Jan. 17, 2007 (Storm: Jan 13)

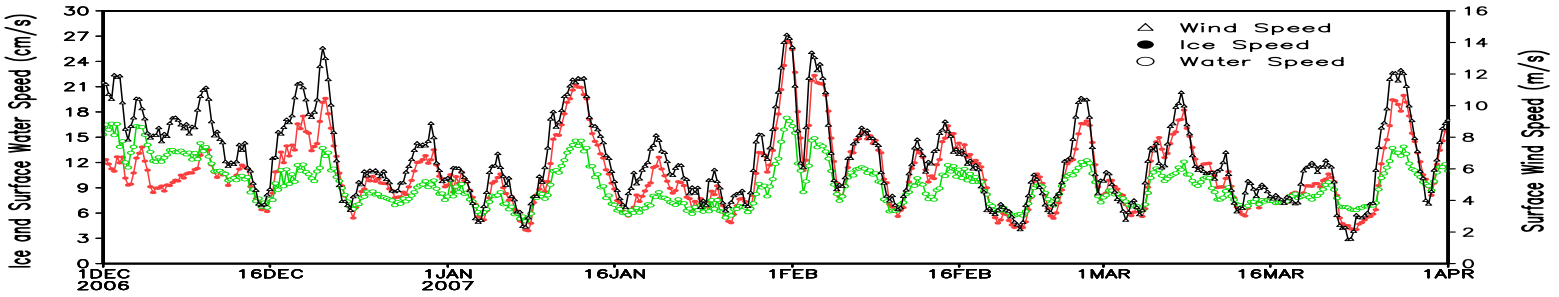


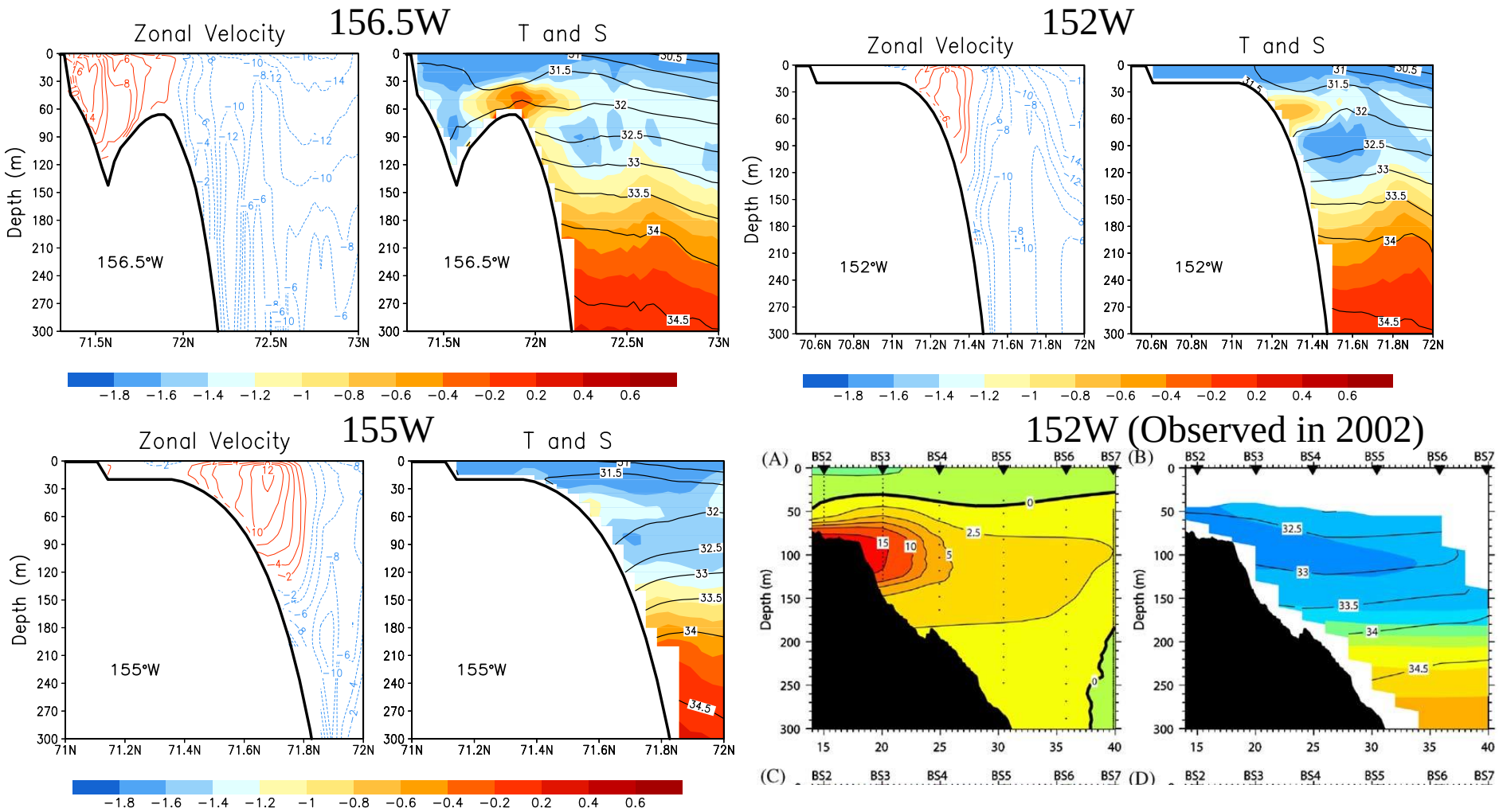
b) Oct. 6, 2006



d) Feb 27, 2007 (Storm: Feb 1)







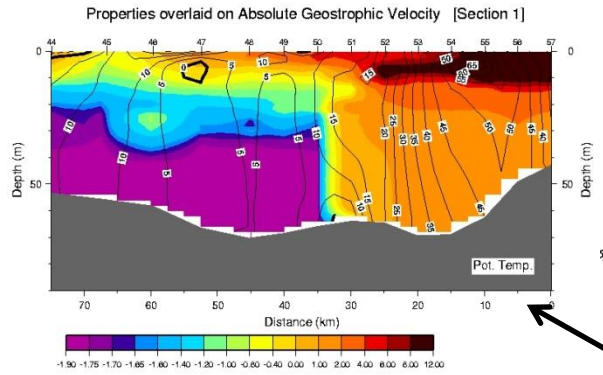
Simulated vertical sections of winter mean zonal velocity (contour, unit: cm/s) and temperature (shaded) and salinity (black line) along 156.5W, 155W and 152W.
(e) Observed winter mean vertical section of along stream velocity (cm/s) from the 152W mooring array in 2002 (from Nikolopoulos et al. 2009). (f) Same as (e) but for potential temperature (color shaded, ° C) and salinity (contours).

Future Plan

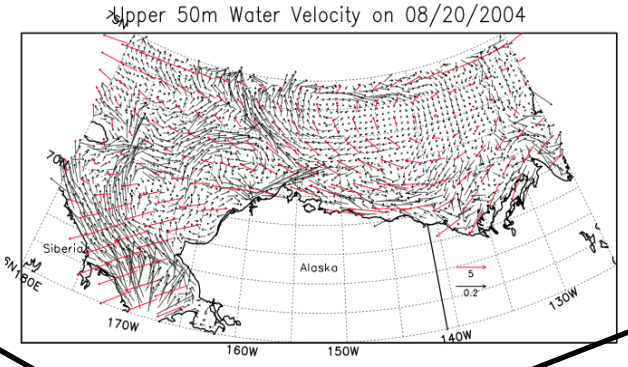
- Writing up papers of 2004, 2009 on physical characteristics of volume transport
- Simulate nutrient transport through these straits and channels, validated by RUSALCA measurements (Hopcroft, Asjian)
- Synthesis work on physical dynamics (Pickard, Woodgate, UAF PIs)
- Synthesis work on lower trophic level dynamics in 2009, 2012 (Hopcroft, Whitledge)

Verification of CIOM using 2004 RUSALCA Data (T) in the Bering-Beaufort-Chukchi Seas (GLERL)

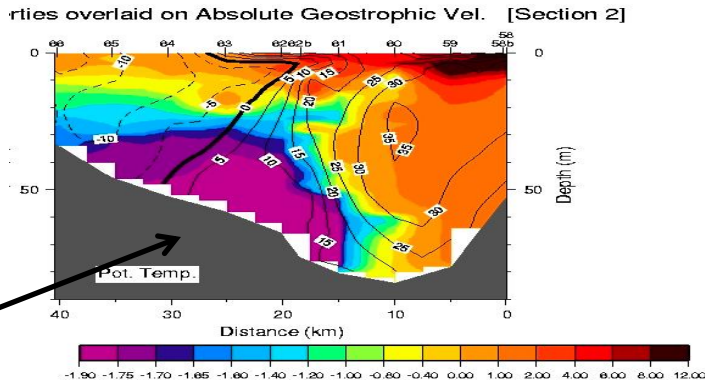
Transect 1



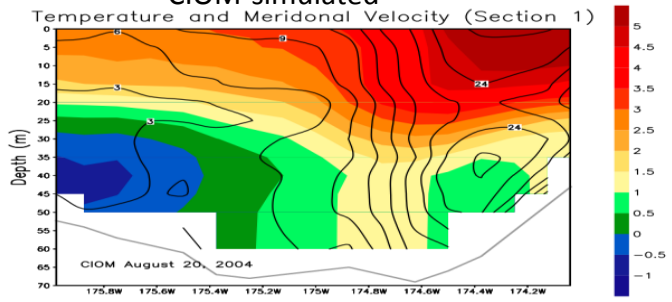
Aug 2004

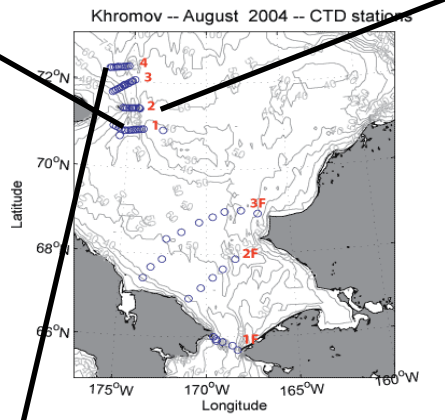


Transect 2

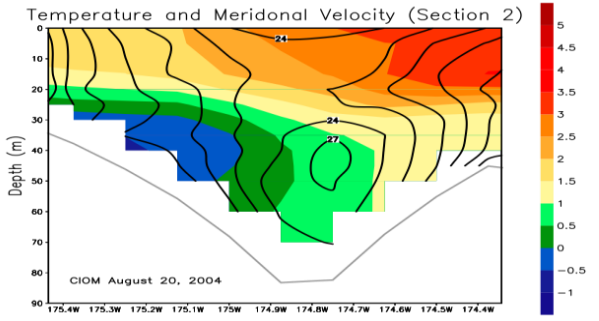


CIOM-simulated

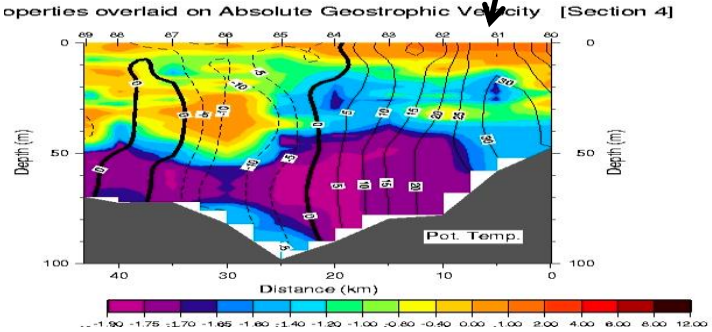




CIOM-simulated



Transect 4



CIOM-simulated