High Resolution CESM: A 40-year CORE Forced Global Coupled 0.1° Ocean/Sea-Ice Simulation

Julie McClean, Caroline Papadopoulos and Elena Yulaeva
Scripps Institution of Oceanography

David Bailey
National Center for Atmospheric Science

CESM Workshop 2013
Breckenridge, Colorado
June 2013

Computer Resources: NERSC and CSL Yellowstone allocation.

Funding: Office of Science (BER) Department of Energy

Ultra High Resolution Global Climate Simulation to Explore and Quantify Predictive Skill for Climate Means, Variability and Extremes

Kate Evans (ORNL), Mat Maltrud (LANL), Julie McClean (SIO), Caroline Papadopoulos (SIO), Milena Veneziani (LANL), Marcia Branstetter (ORNL), Elena Yulaeva (SIO)

James Hack (ORNL), Phil Jones (LANL), Mark Taylor (SNL)
Bill Collins (LBNL), Dave Bader(LLNL)

Project Goals

1. Perform a multi-decadal (1970-2009) global coupled 0.1° ocean/sea-ice simulation using POP and CICE in the CESM framework forced with CORE2 IAF (interannually varying atmospheric reanalysis fluxes).

2. Examine the depiction and veracity of ice-ocean processes in this eddying ocean simulation.

Global 0.1° POP/CICE

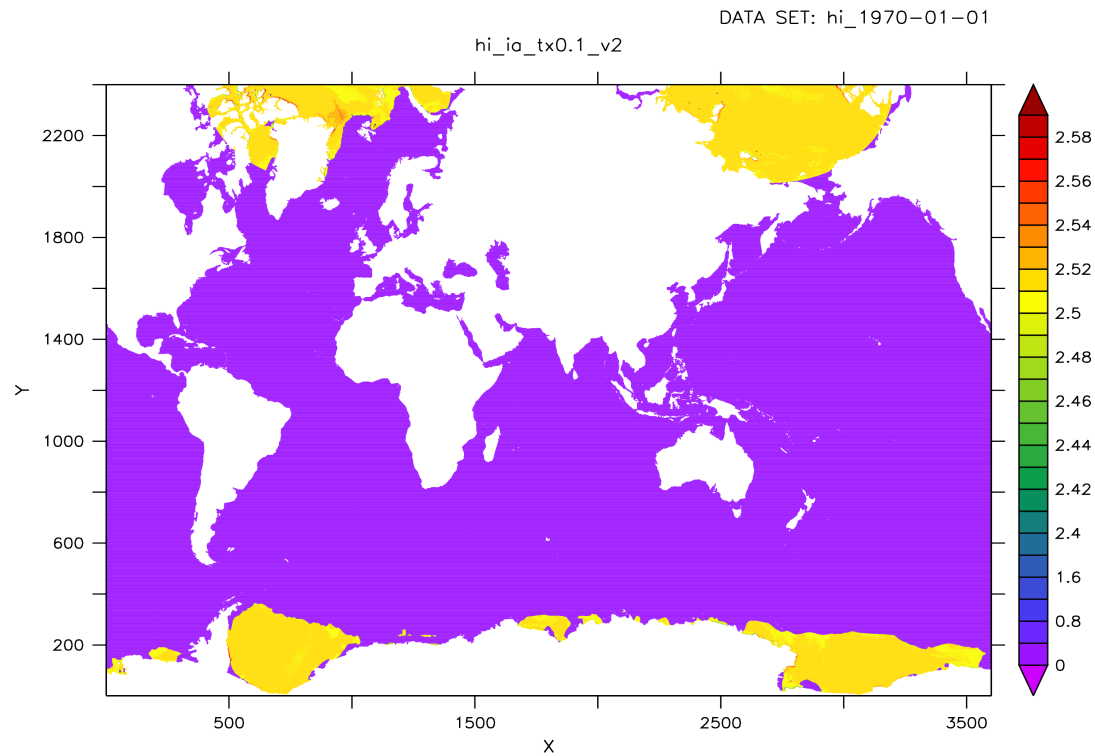
- **CESM framework:** (1.03/1.04) on Hopper at NERSC (1970-1990) and then 1.05 on Yellowstone (1989-2009).
- **Grid:** 0.1°, 42 levels on tripole grid for both POP and CICE with PBCs.
- **Forcing**: CORE2 interannually varying fluxes (CORE2 IAF) : NCEP reanalysis only for the near surface vector wind, air temperature, specific humidity and density. Also a variety of satellite based radiation, sea surface temperature, sea-ice concentration and precipitation products (Large and Yeager, 2009).
- **Ice sensitivities** investigated using both 0.1° and 1° POP/CICE.
- **Initialization**: 17-day spun-up ocean using stand-alone POP and "tailored" ice.
- **Sea-ice/snow solar radiation transfer parameterization** was CCSM3 default for 1970-1979. Switched to D-Edd (dt_mlt_in = 1, and rsnw_mlt_in = 1000) at the end of 1979. This delays the melt until -1°C and the snow grains grow to a maximum of 1mm in size. Also adjustments to Arctic LWDN and solar radiation in CORE2.

Initial Ice Condition

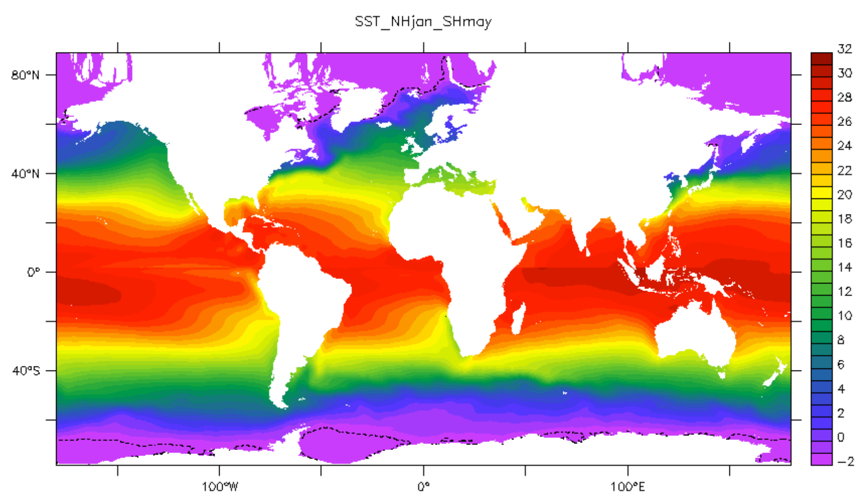
- Created from observed SST (Reynolds et al., 2007).

- May SST in the SH and January SST in the NH.

- Chosen to produce an ice edge that is consistent with location of January (climatological) SSM/I 15% ice concentration contour.



grid cell mean ice thickness (m)



Arctic Sea Ice Concentration (%)

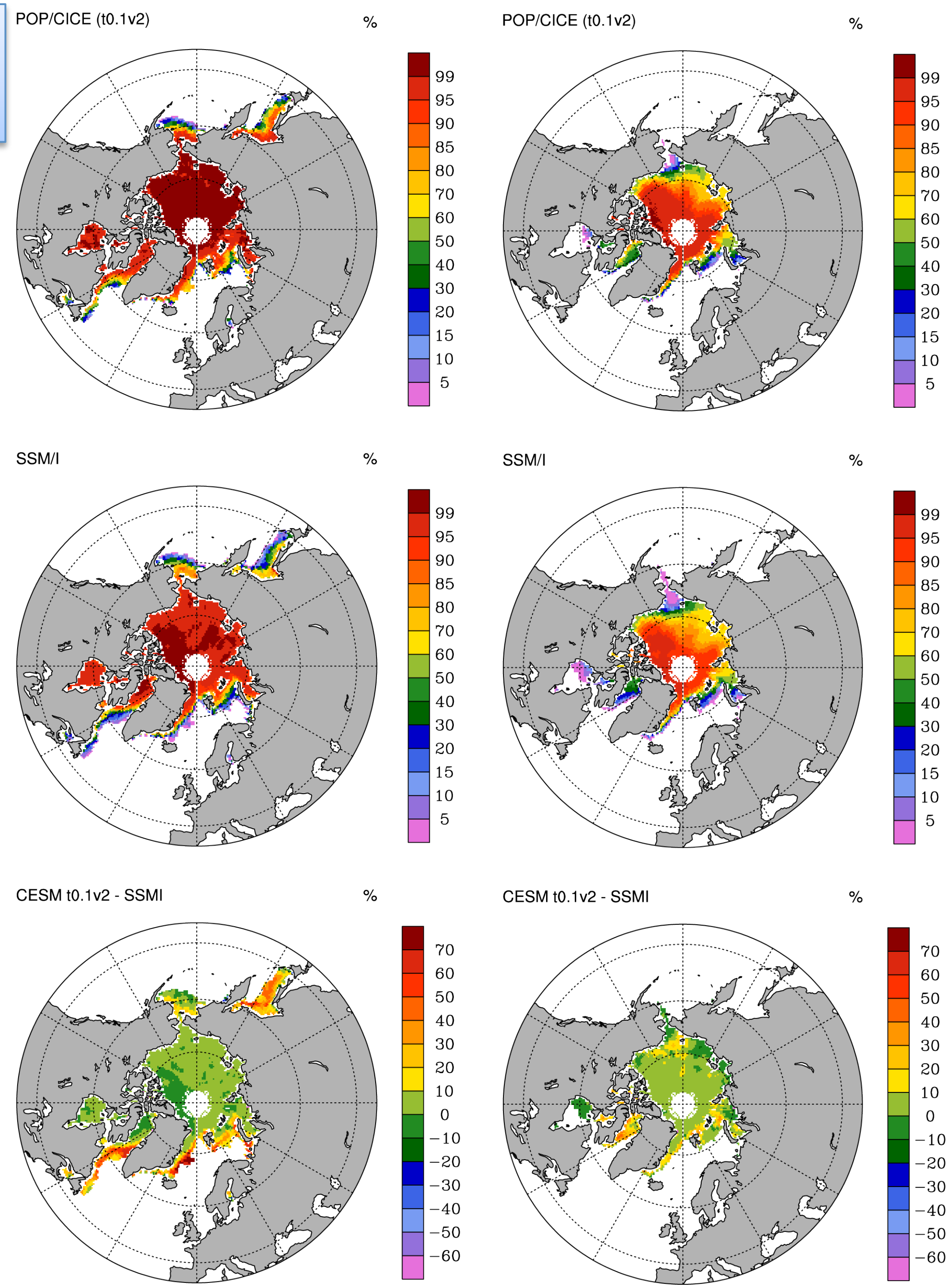
Feb-March
2004-2008

Oct-Nov
2003-2007

0.1° POP/CICE

SSM/I

POP/CICE - Obs



Arctic Sea Ice Thickness (m)

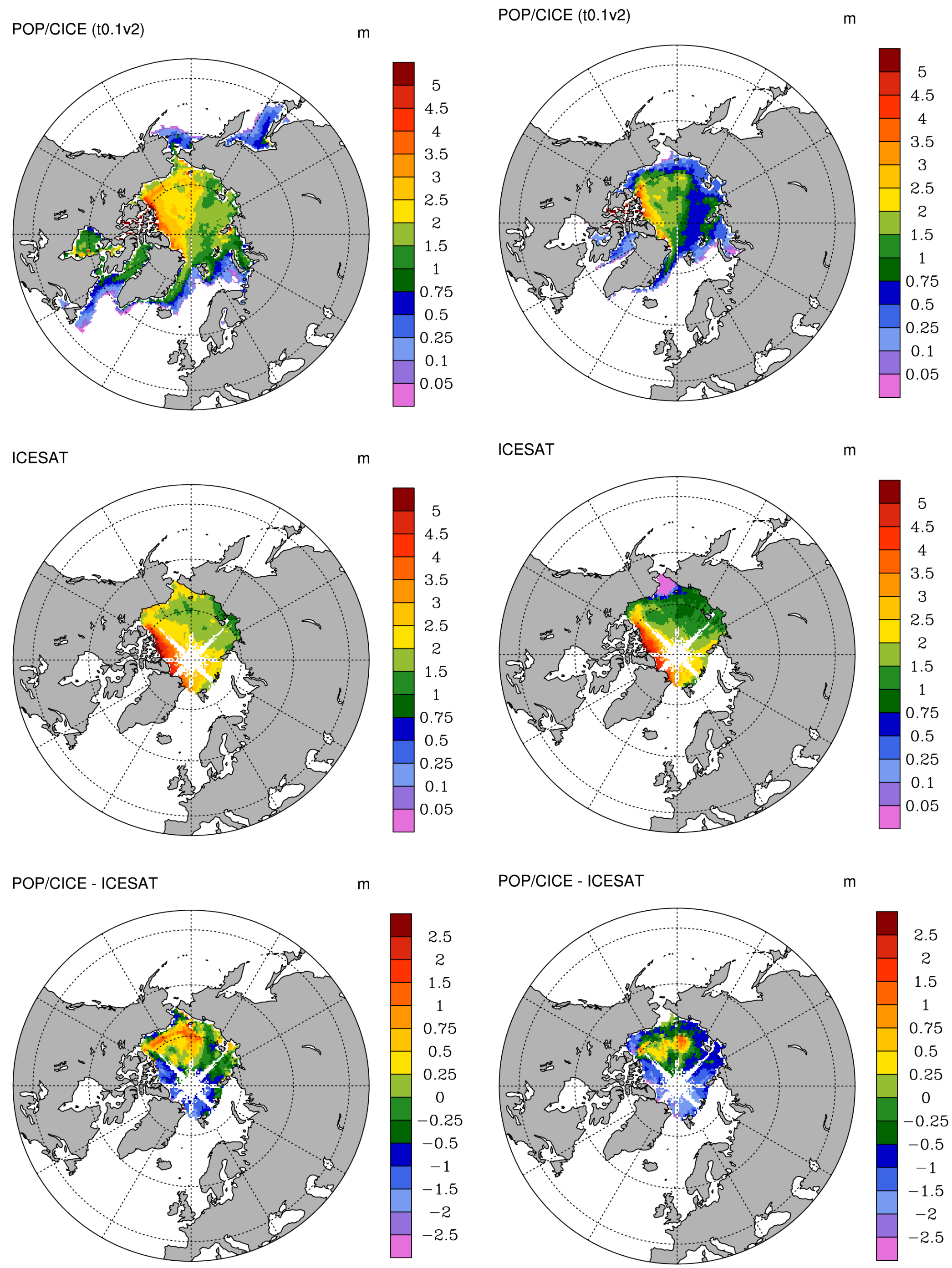
Feb-Mar
2004-2008

Oct-Nov
2003-2007

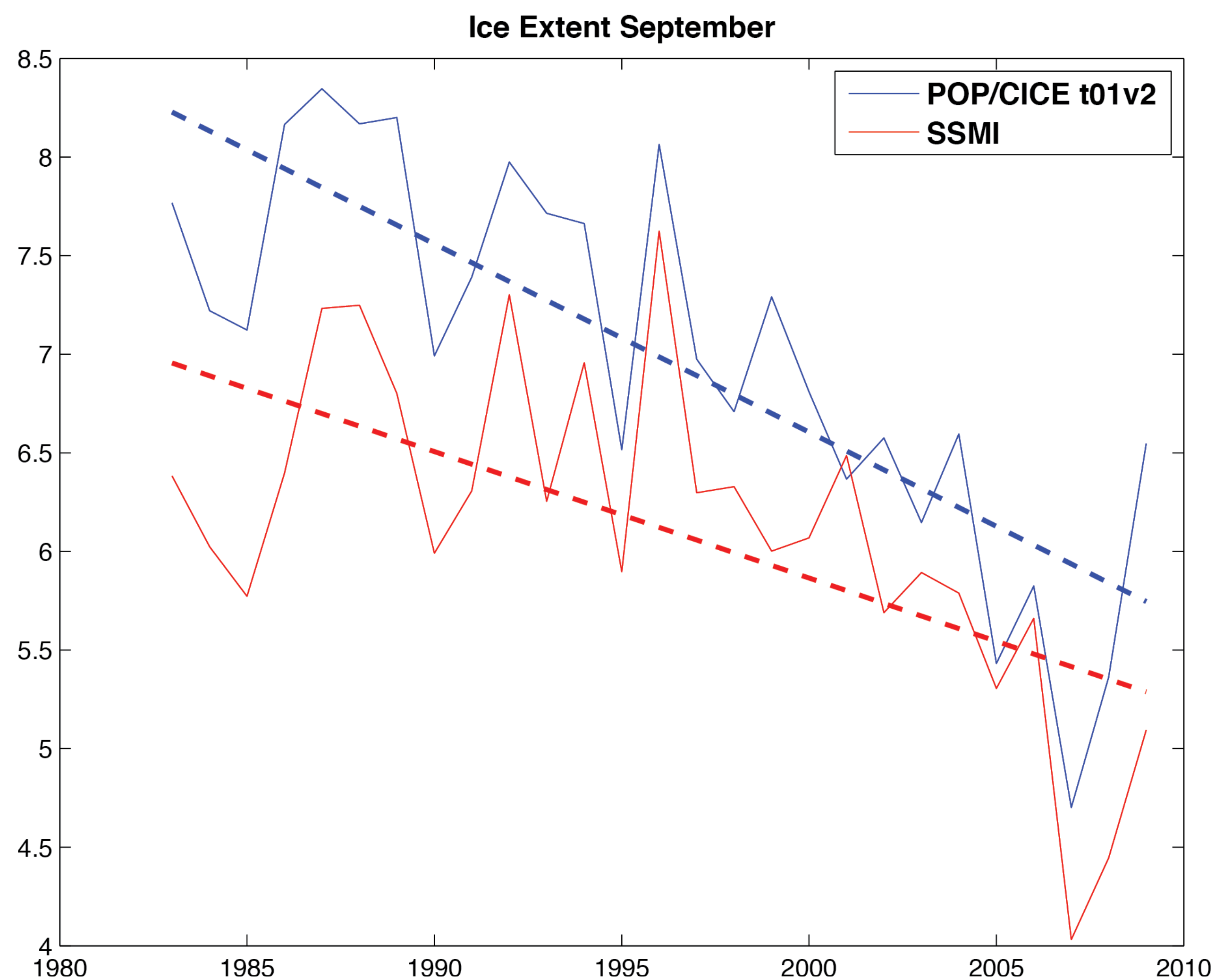
0.1° POP/CICE

IceSAT

POP/CICE - Obs



September Arctic sea ice extent (10^6 km^2) from 0.1° POP/CICE (blue) and SSM/I (red)

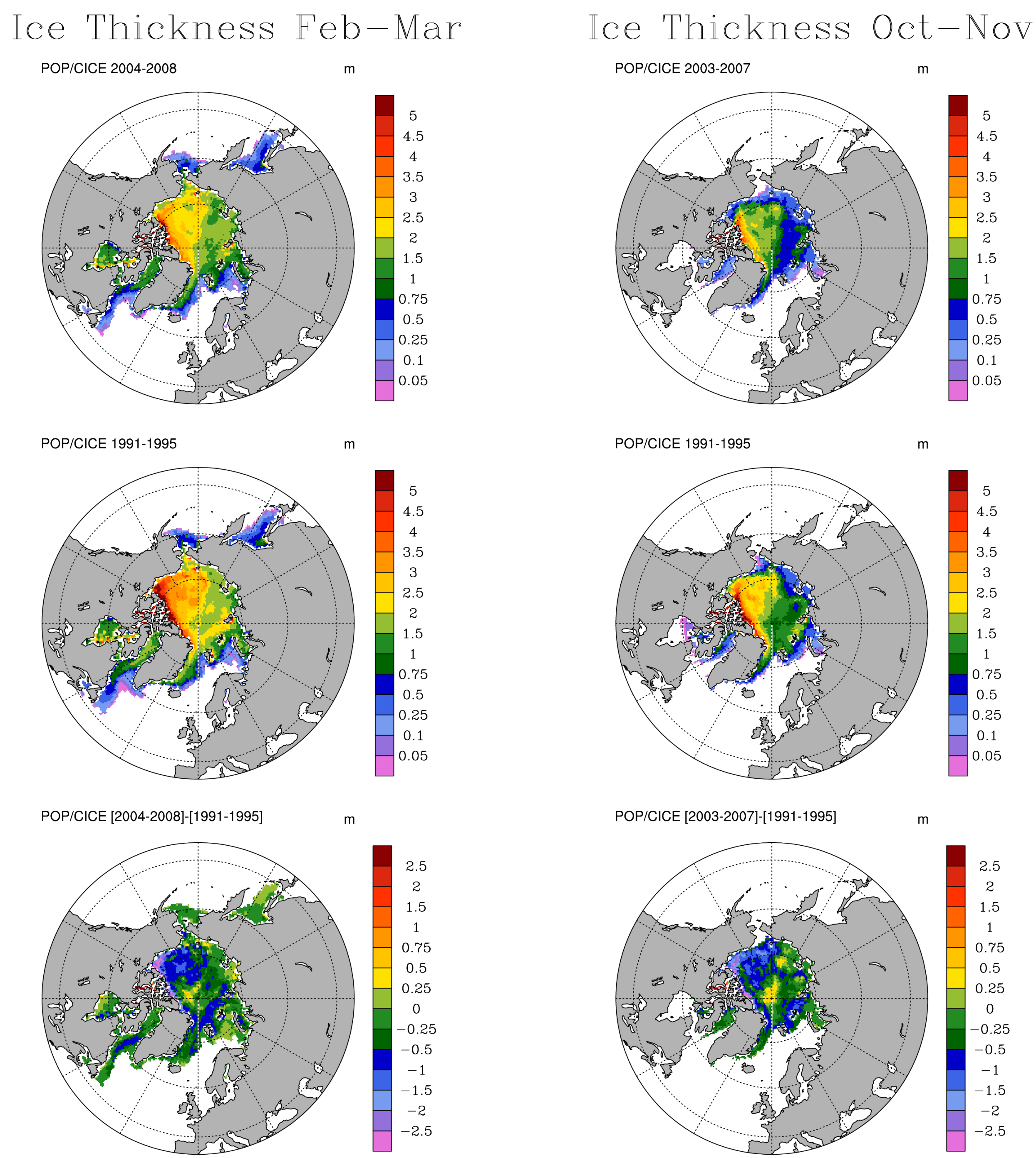


Ice Thickness Changes (m)

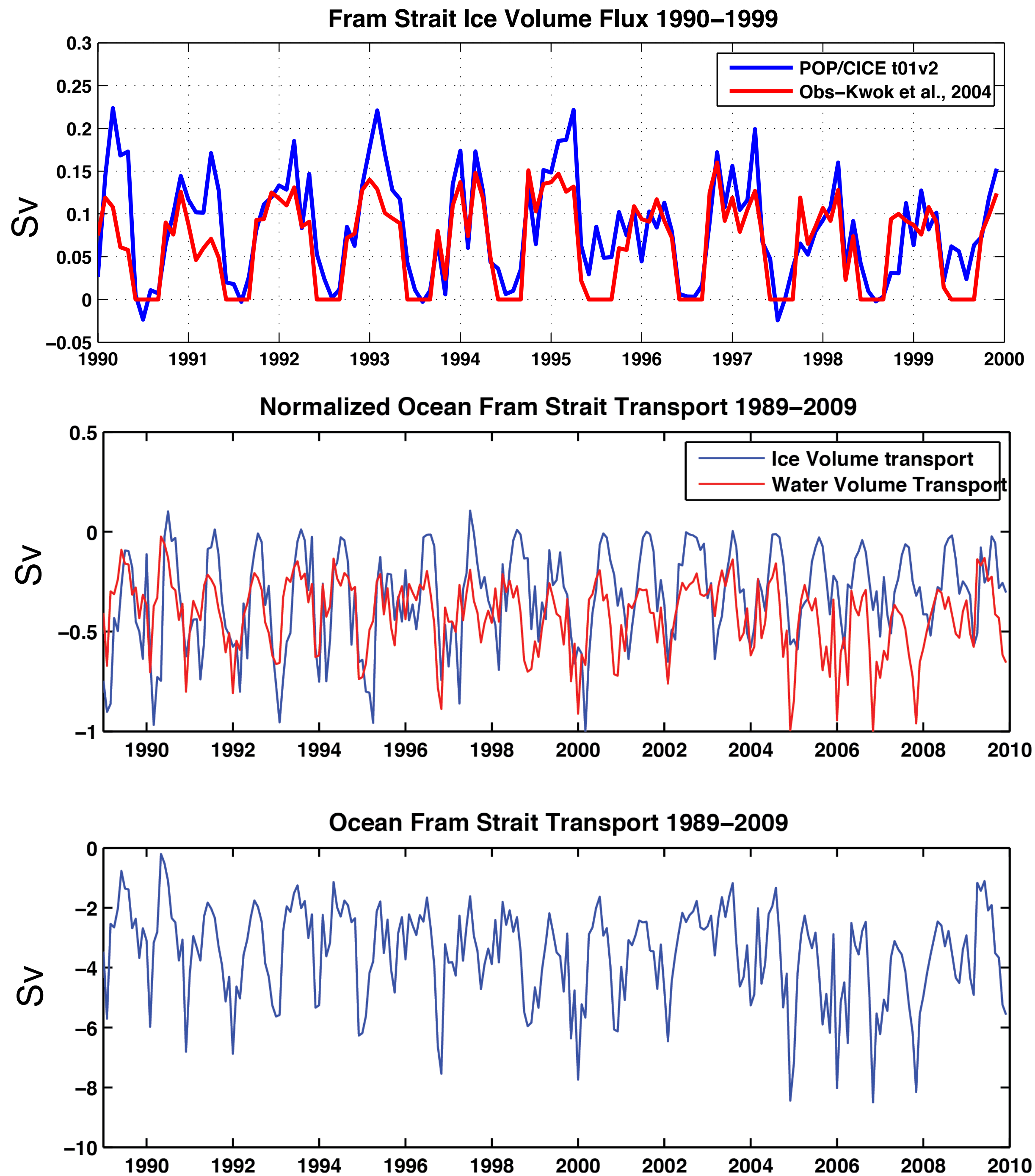
0.1° POP/CICE: 2004-2008 (LHS) and 2003-2007 (RHS)

0.1° POP/CICE: 1991-1995

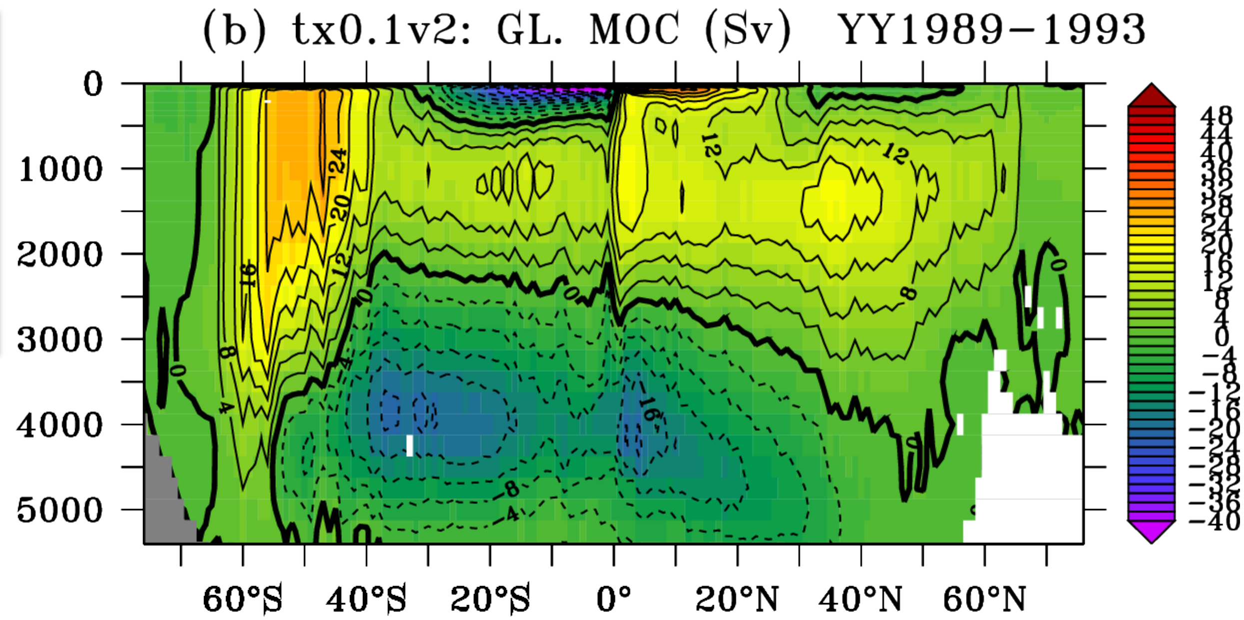
0.1° POP/CICE: (2004-2008) – (1991-1995)

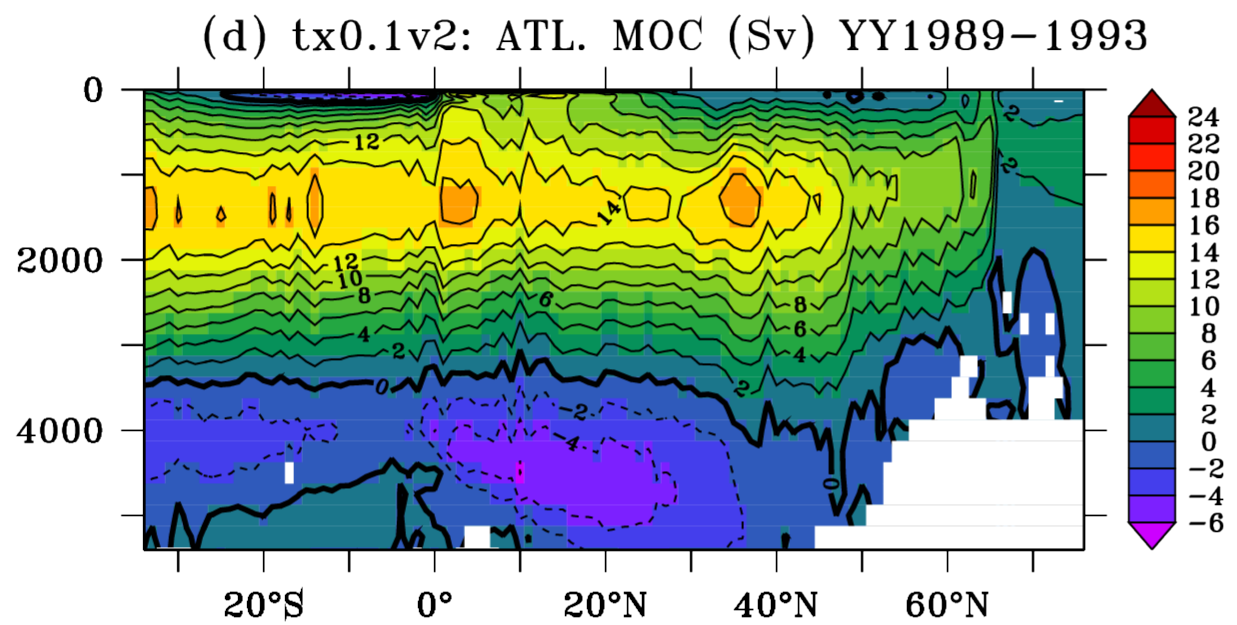


0.1°POP/CICE FRAM STRAIT: Solid and Liquid Volume Transports (Sv)

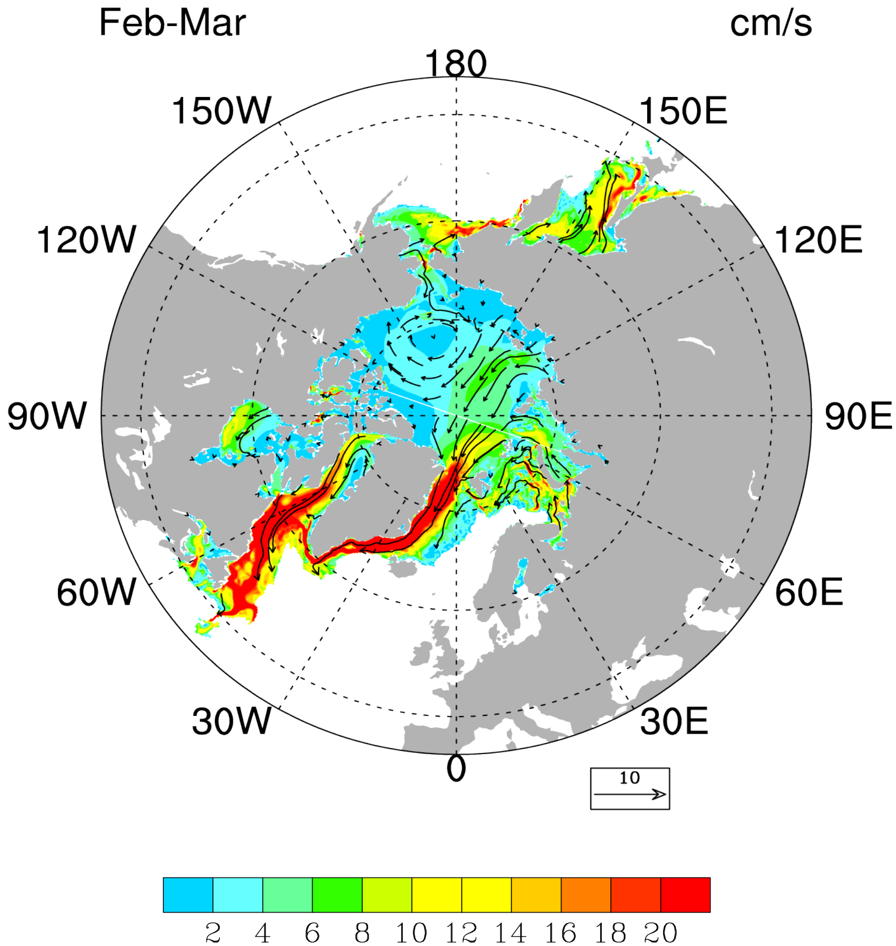


0.1° POP/CICE Meridional Overturning Circulation (Sv): 1989-1993

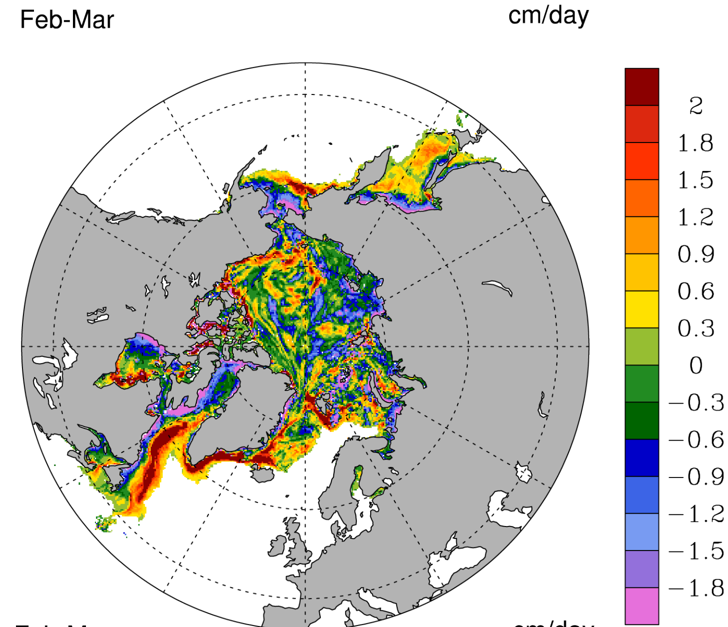


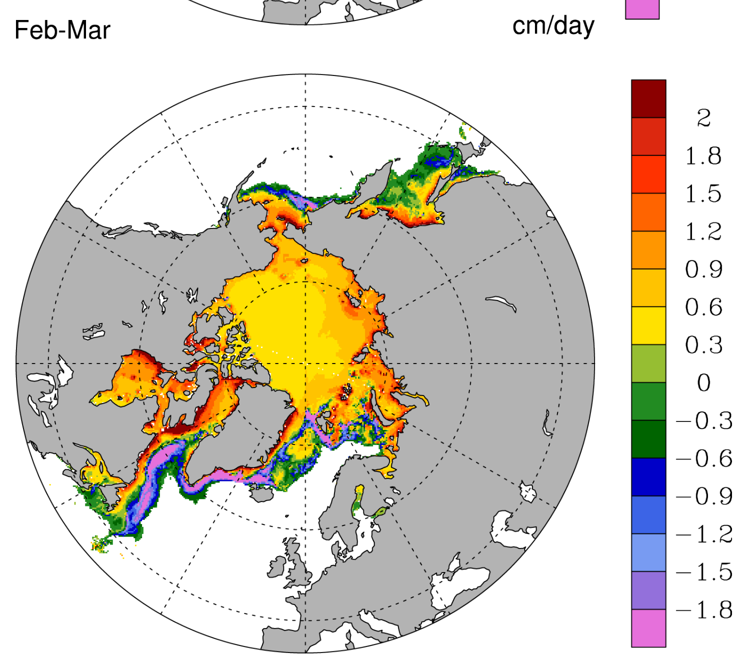


Ice Drift (LHS) and Volume Dynamic (upper) and Thermodynamic (lower) Ice Tendencies for Feb-Mar 1989-1993 from 0.1° POP/CICE.



Magnitude of ice vectors (cm/sec)





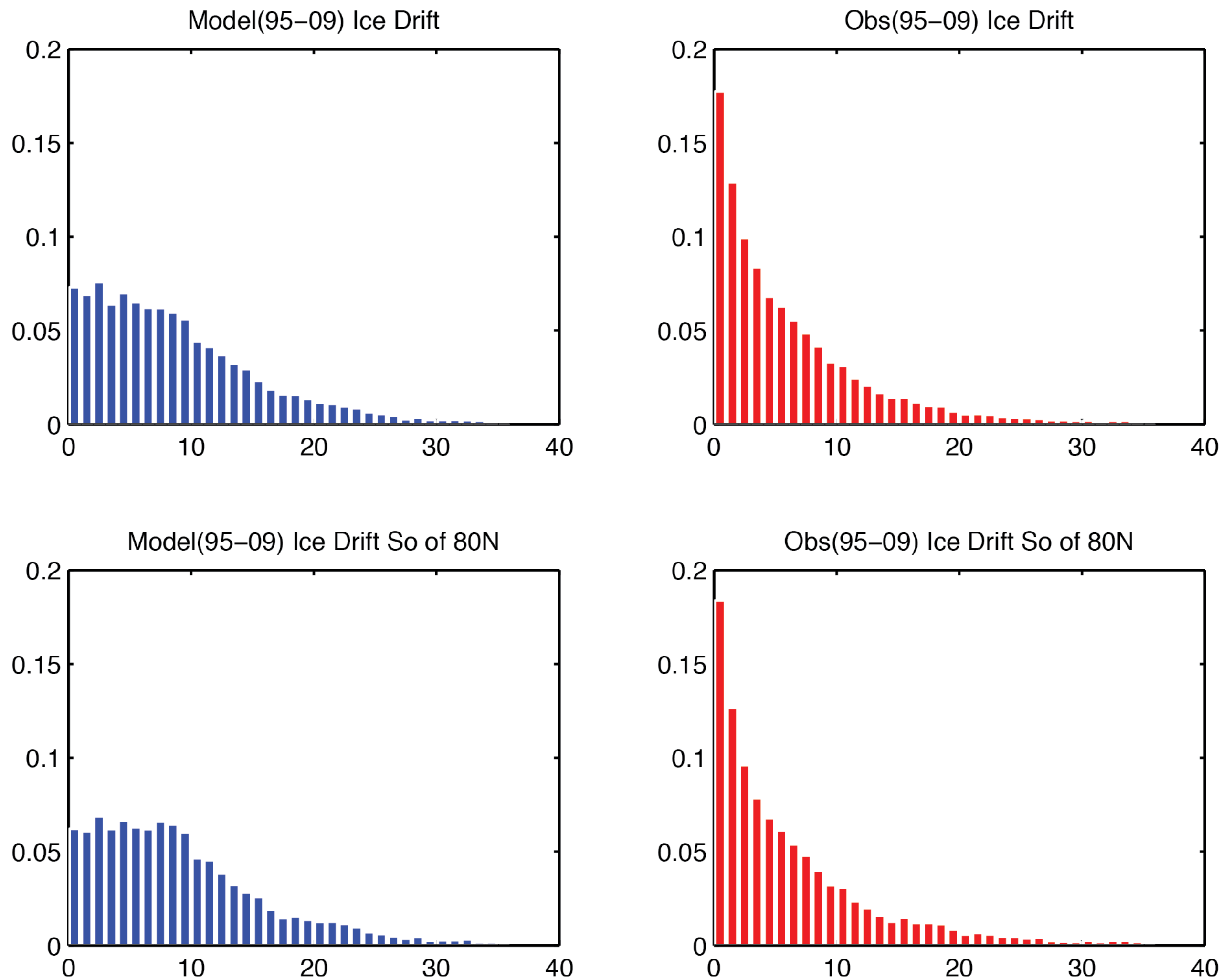
Probability Density Functions

North. Hem. 0.1° POP/ CICE Ice Drifts 1995-2009

North. Hem. Ice Drift Buoy Data 1995-2009

Co-located/ coincident with buoy data

NH: <80°N

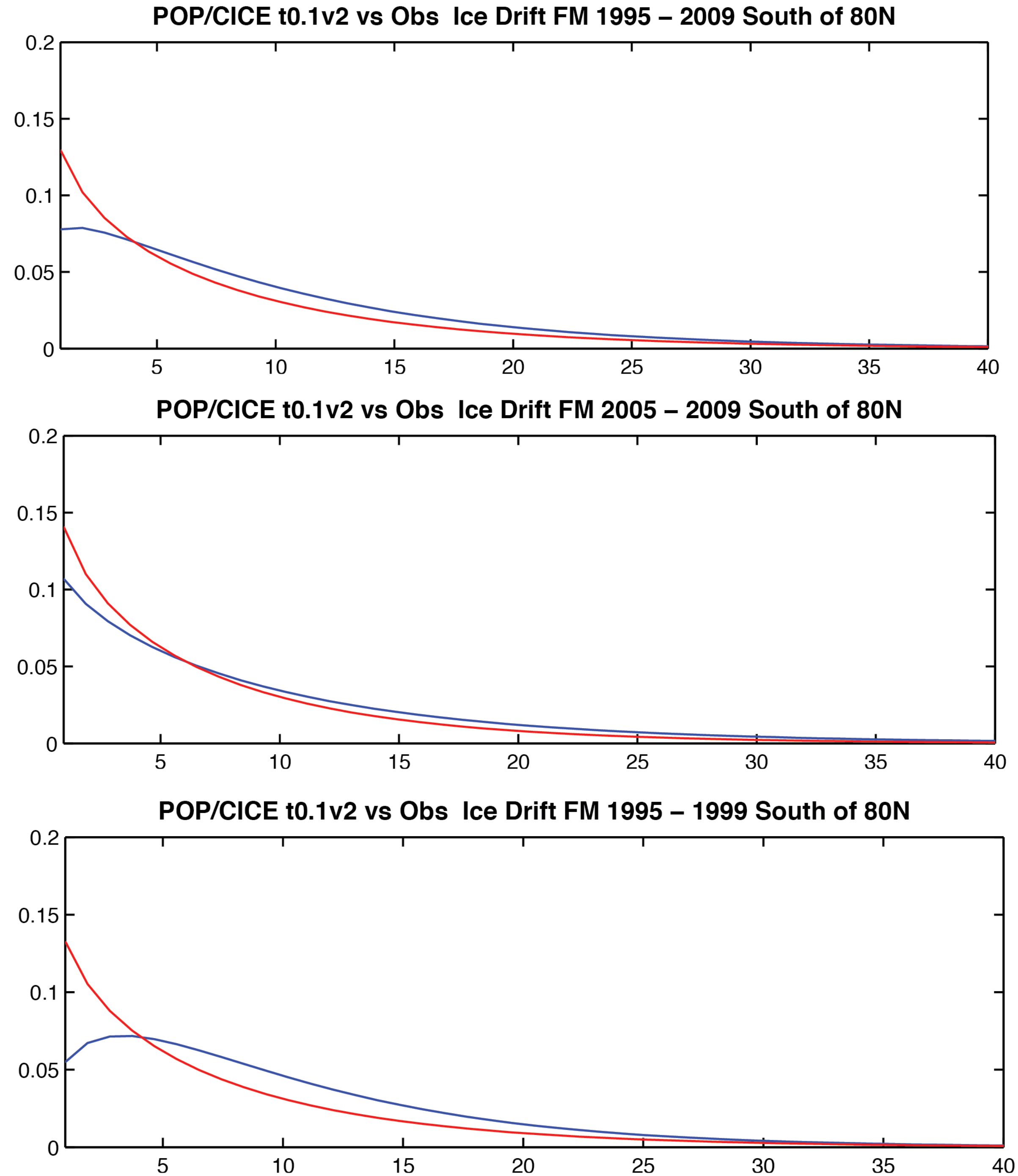


IABP: International Arctic Buoy Programme

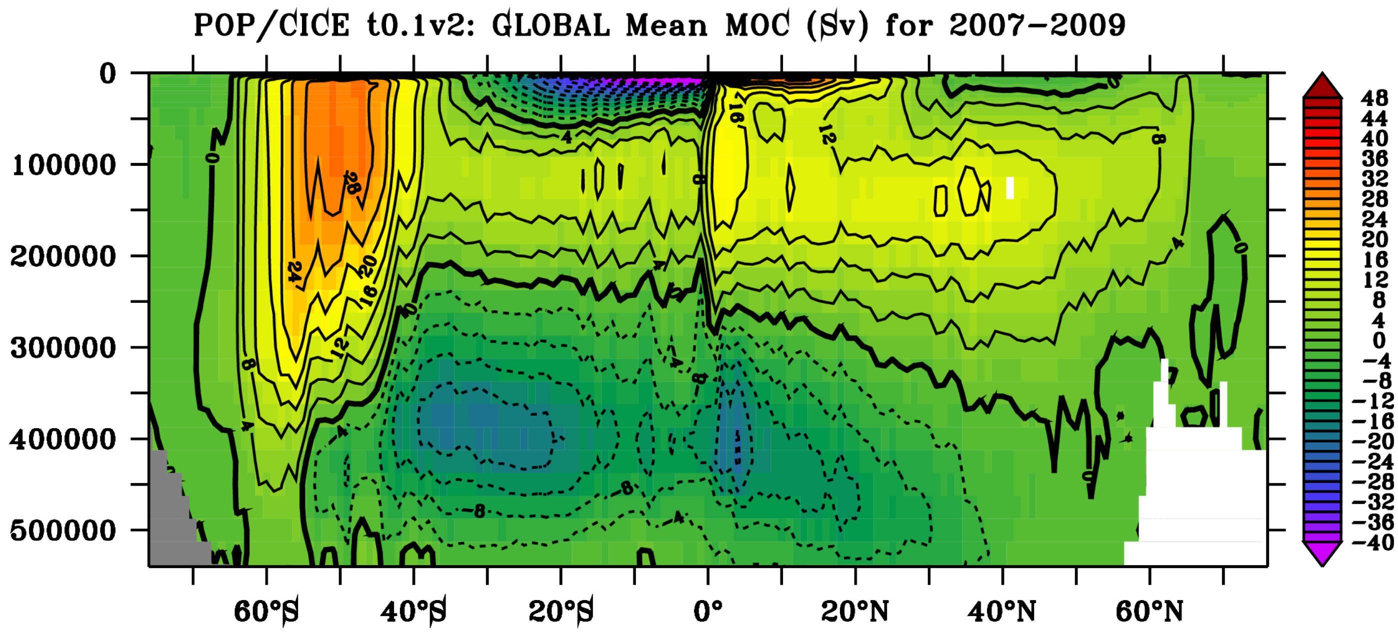
Probability Density Functions

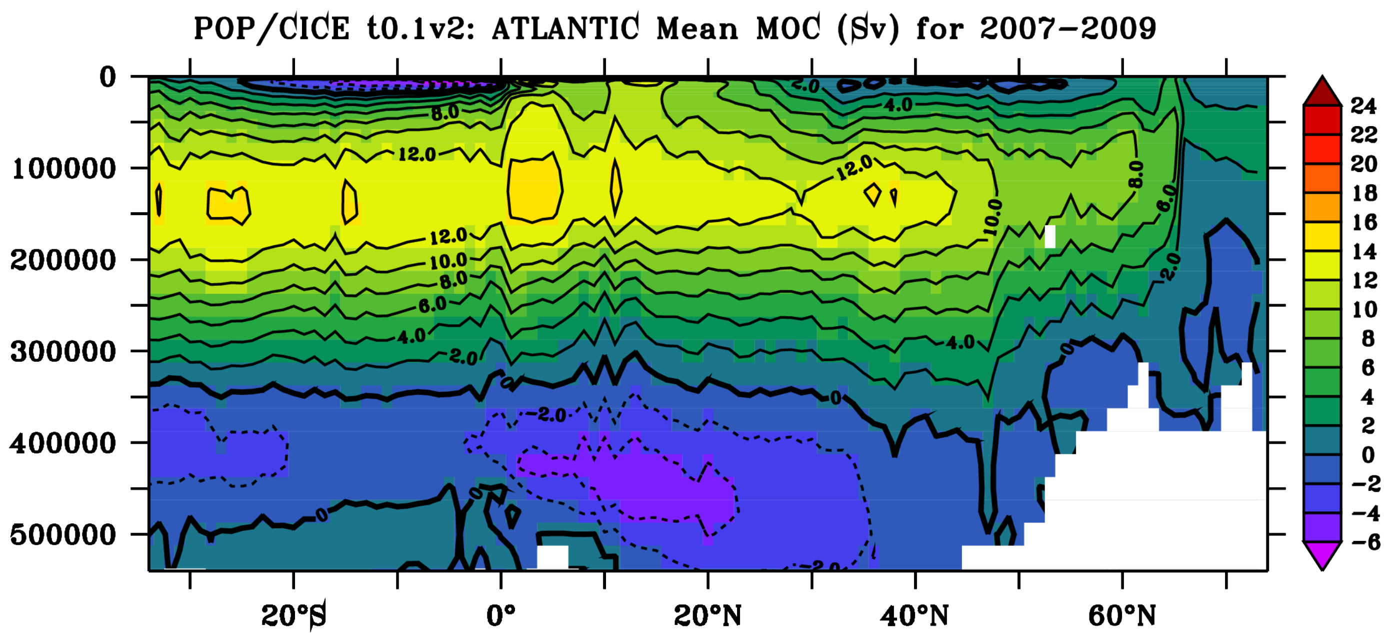
Co-located/ coincident with buoy data

NH: <80°N



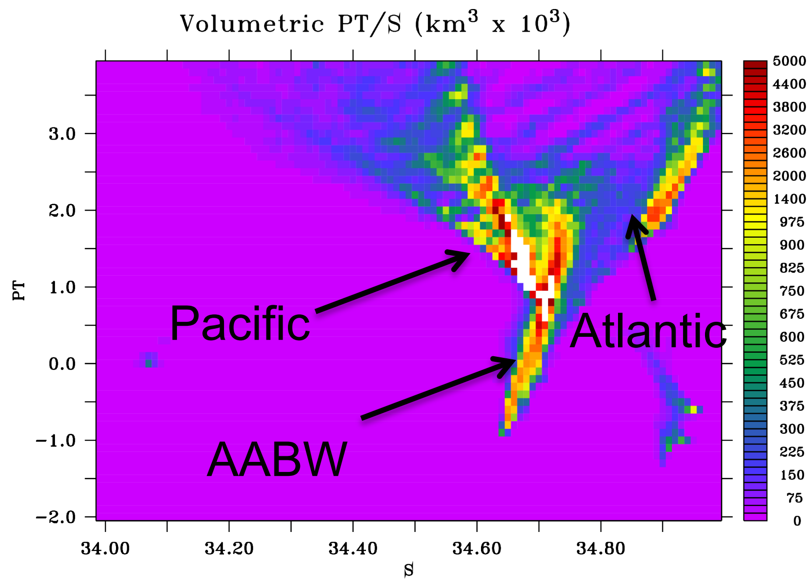
0.1° POP/CICE: Meridional Overturning Circulation (Sv): 2007-2009



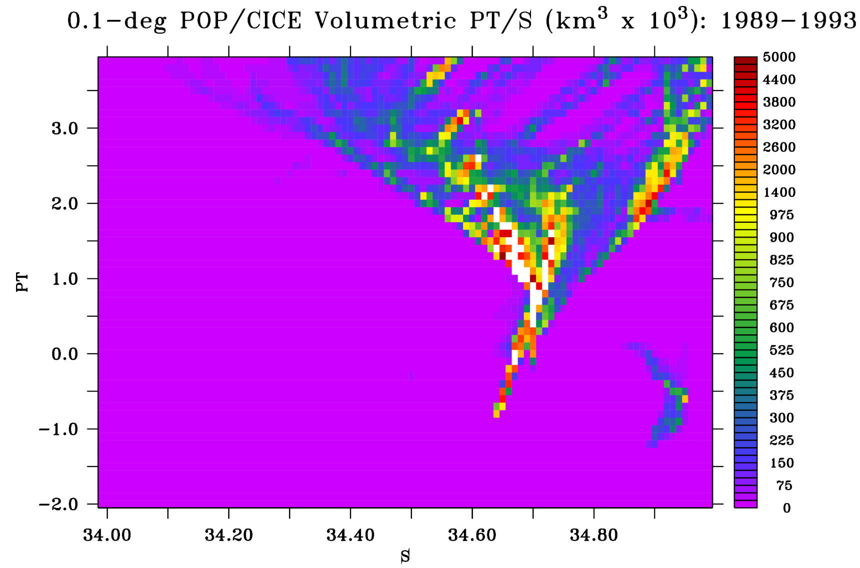


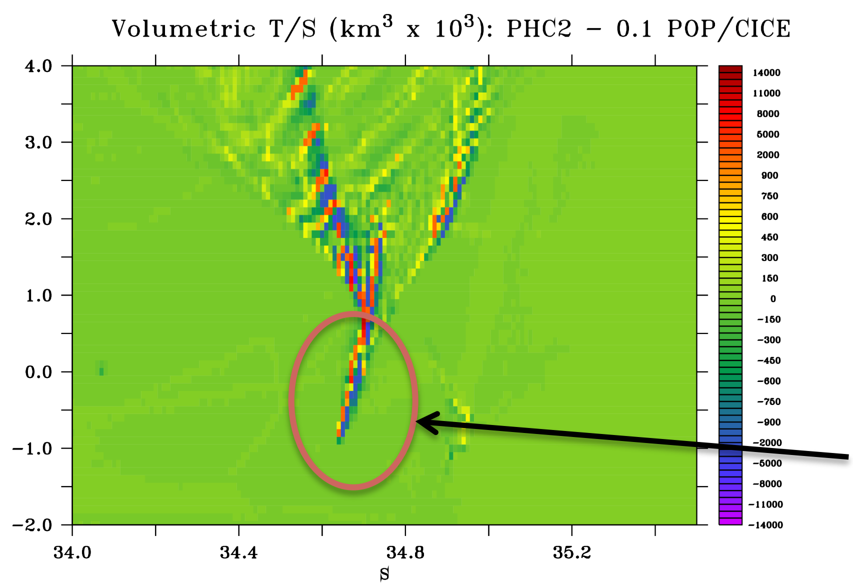
Worthington Volumetric Temperature-Salinity Census

PHC2



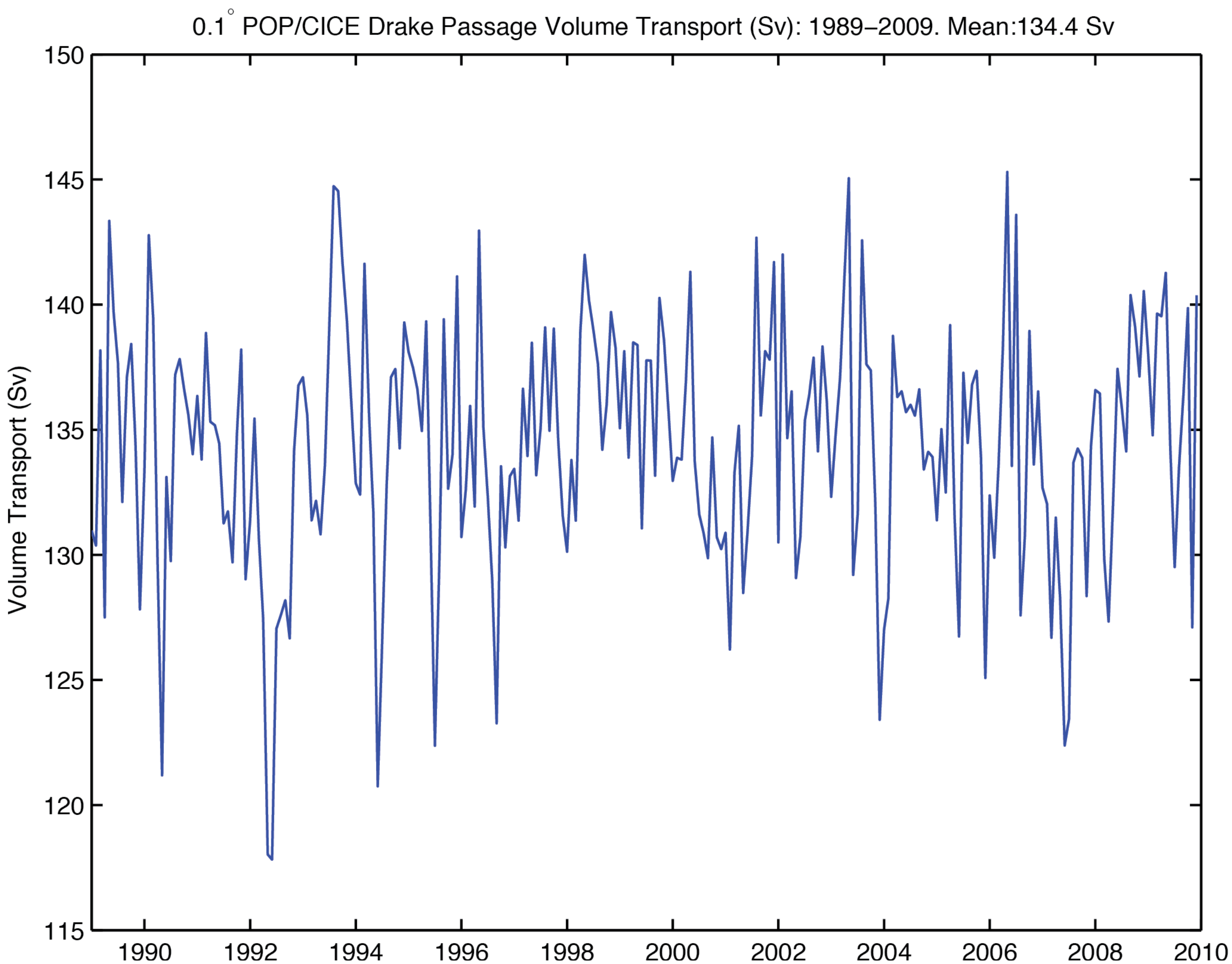
0.1° POP-CICE





Slightly higher salinity Antarctic Bottom Water

0.1° POP/CICE Drake Passage Volume Transport (Sv); Mean = 134.4 Sv



Bering Sea: Sea Ice/Ocean/Atmosphere Interactions in the 1980s: Seasonal Cycle and Interannual anomalies.

Linghan Li (SIO, Ph.D. dissertation in prep.)

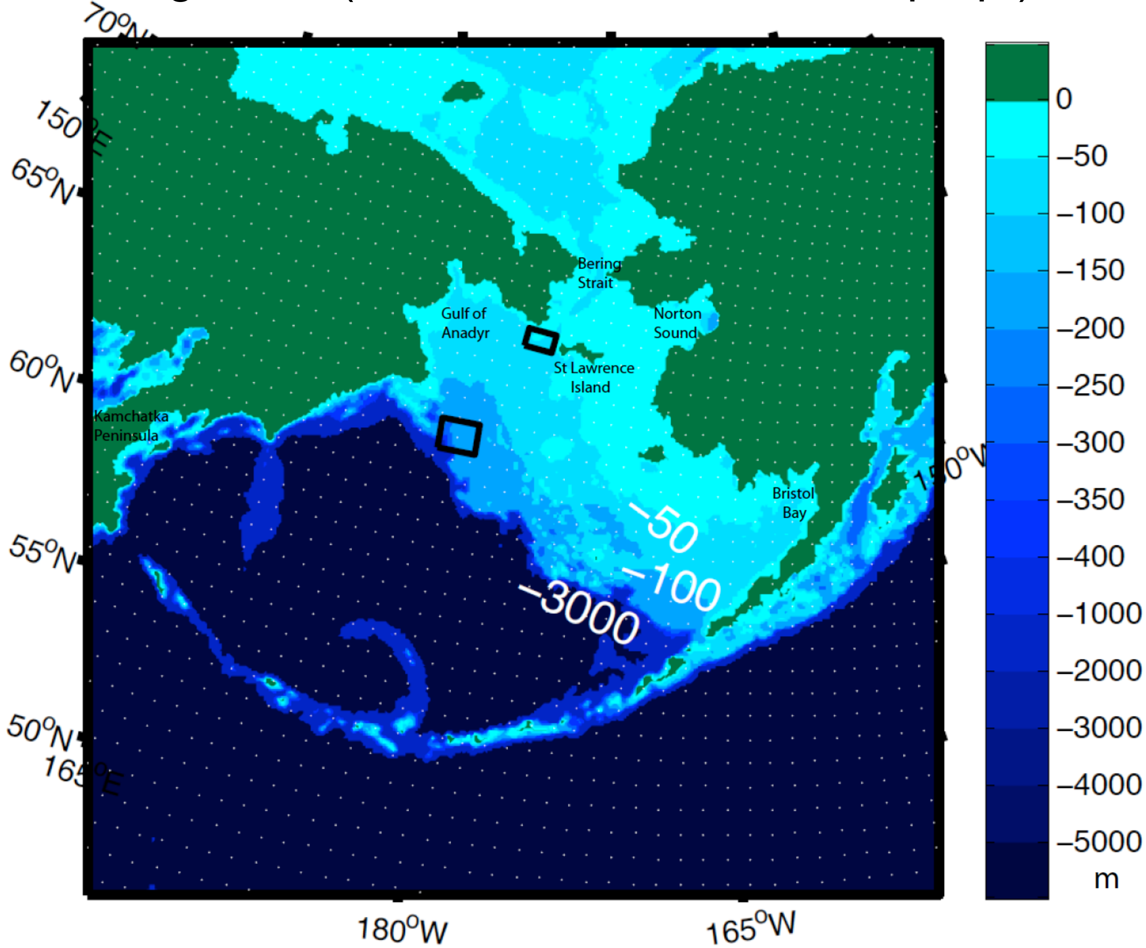
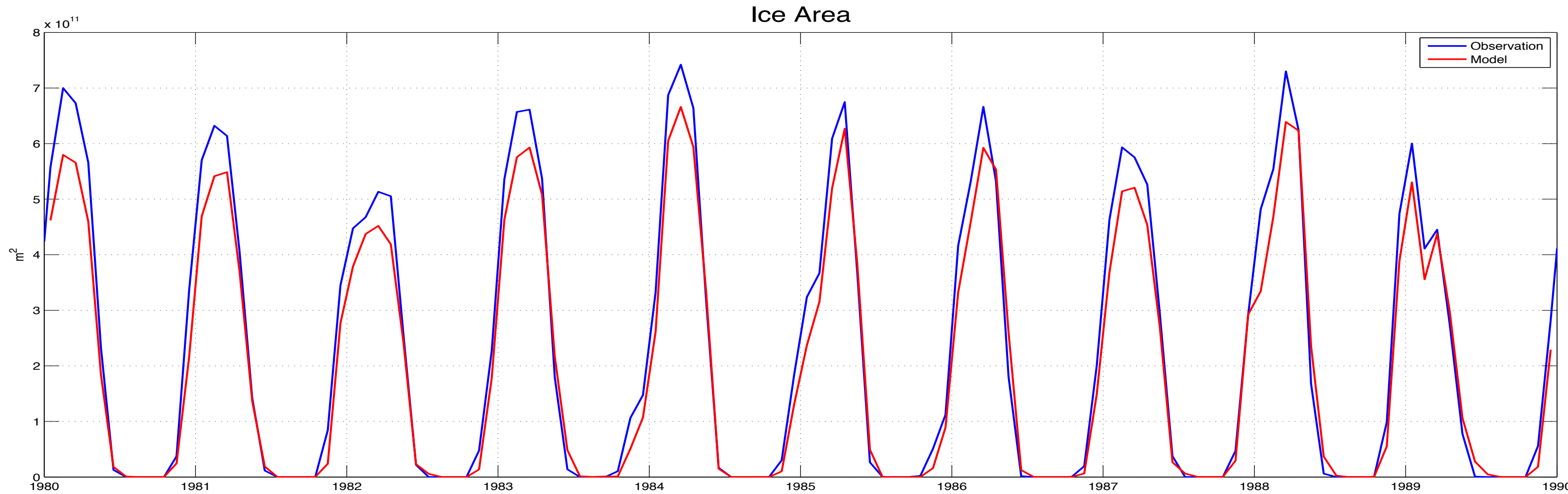


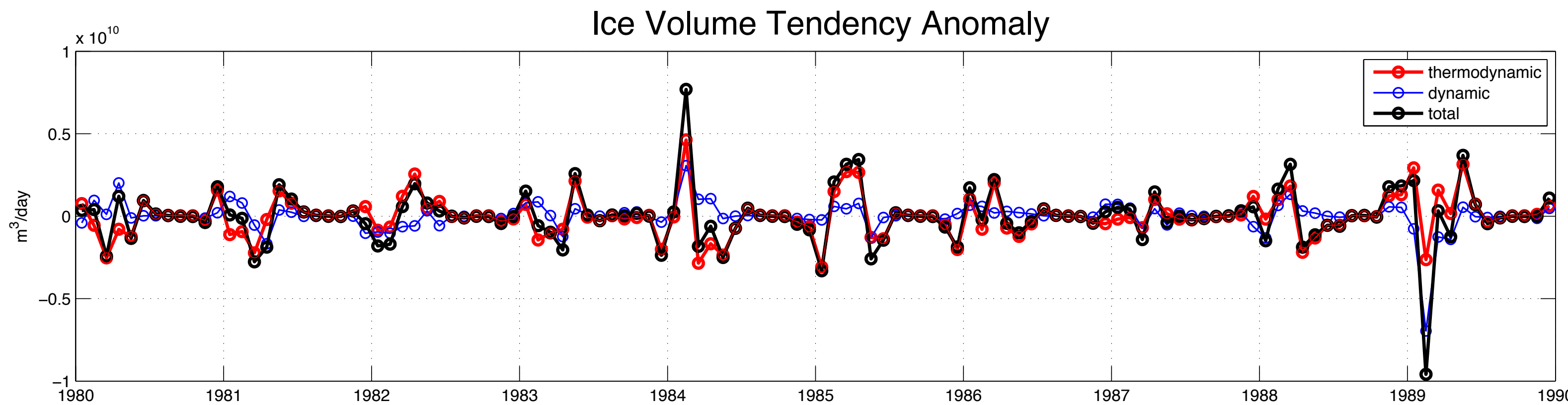
Figure 1 Bathymetry of the Bering Sea (contours) and the model T-grid points (white dots) subsampled every 10 points. The bathymetry is from POP-CICE model output of ocean depth at T-grid points. 2 black boxes shows 2 study areas for Figure 8.

Bering Sea

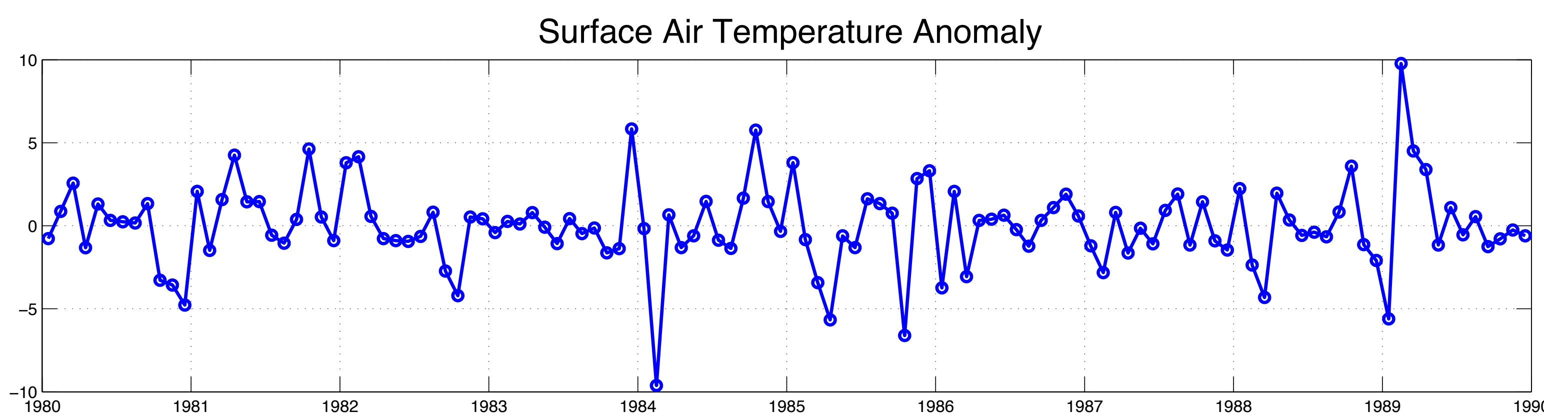
Ice Area



Seasonal cycle removed

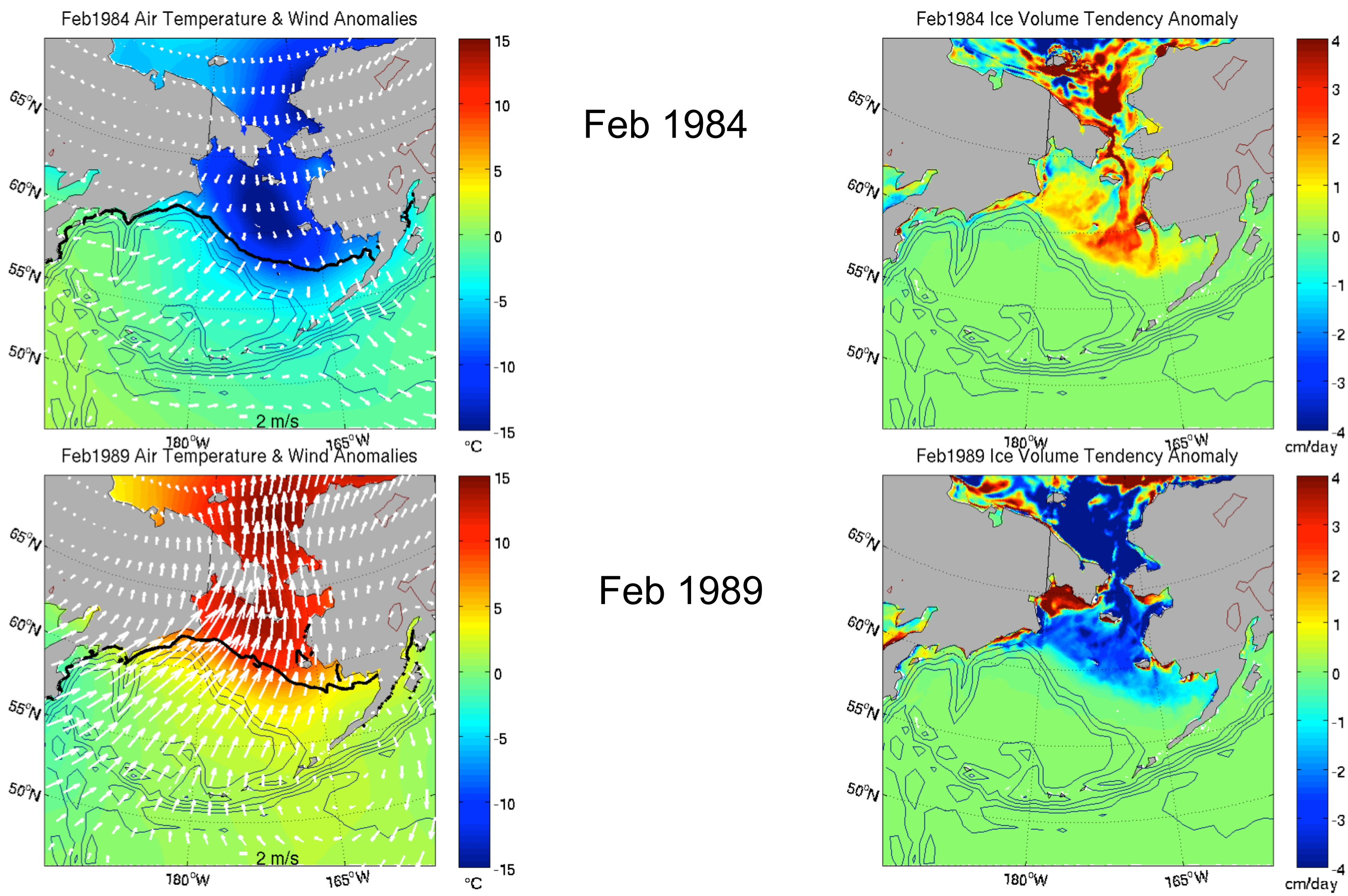


°C



Linghan Li (SIO) Ph.D. Dissertation (in prep.)

Bering Sea: Anomalous February 1984 and 1989 events are due to position of the Aleutian Low during "warm" and "cold" winters as described by Rodionov et al (2007) using NCEP/NCAR Reanalysis.



Linghan Li (SIO) Ph.D. Dissertation (in prep.)

Conclusions

- The 40-year global forced 0.1° POP/CICE simulation shows realistic behavior in both hemispheres giving us confidence to examine regional ice/ocean processes.

- In the Arctic for 1995-2009, 0.1° POP/CICE has fewer occurrences of very slow ice drifts and somewhat more occurrences of stronger drifts relative to International Arctic Buoy Program observations.

- Erroneous export of sea ice via the East Greenland and Labrador Current will result in erroneous freshwater export to the North Atlantic; this may explain the low AMOC maximum.

- Anomalous behavior of sea-ice in the Bering Sea in February 1984 and 1989 can be related via air temperature to "warm" and "cold" winters arising from the positioning of the Aleutian Low.