Collaborative Research: Toward reanalysis of the Arctic Climate System—sea ice and ocean reconstruction with data assimilation

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Motivation and goals

- An Integrative Data Assimilation for the Arctic System (IDAAS) has been recommended for development by SEARCH in 2005. While existing operational reanalyses assimilate only atmospheric measurements, an IDAAS activity would include non-atmospheric components: sea ice, oceanic, terrestrial geophysical and biogeochemical parameters and human dimensions data.

- Atmospheric reanalysis products play a major role in the arctic system studies and are used to force sea ice, ocean and terrestrial models, and to analyze the climate system's variability and to explain and understand the interrelationships of the system's components and the causes of their change.

- Motivated by this success and the major goals and recommendations of SEARCH, we work to develop an integrated set of assimilation procedures for the ice–ocean system that is able to provide gridded data sets that are physically consistent and constrained to the observations of sea ice and ocean parameters.

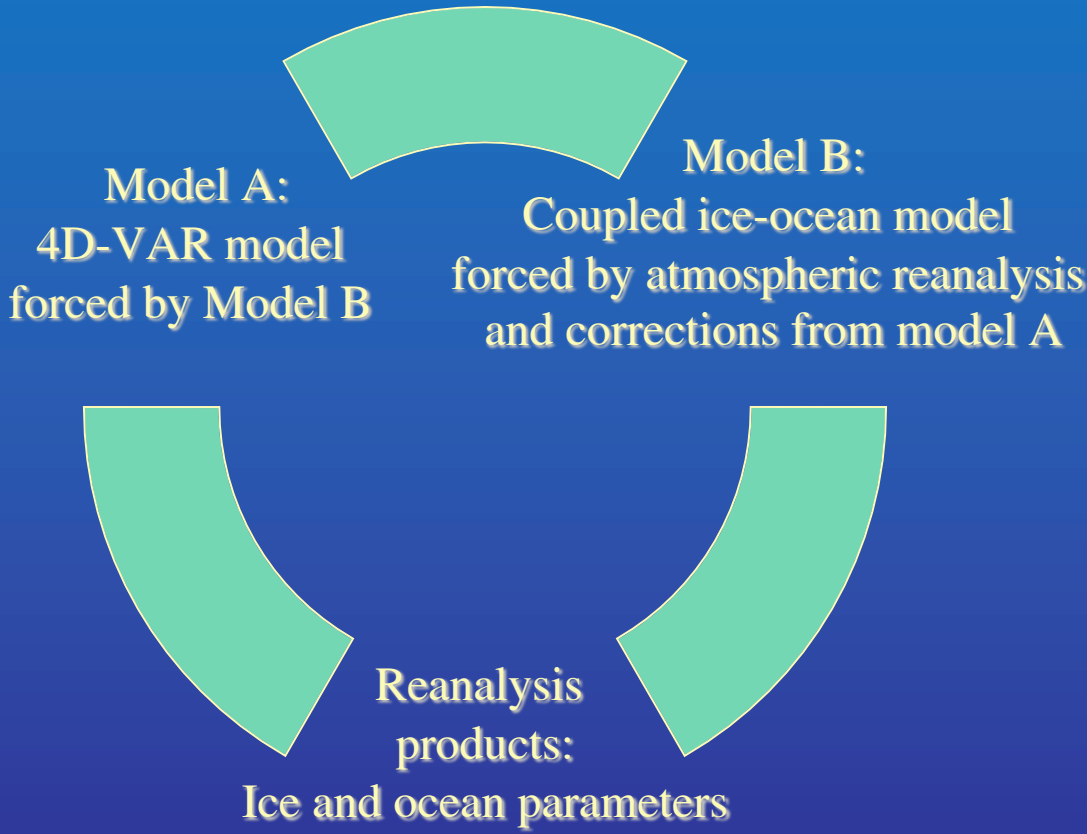
Project objectives are to:

- **Develop an integrated set of assimilation procedures for the ice–ocean system**
- **Validate the system performance, assess the quality of the major system products, and provide the community with gridded sea ice and ocean parameters**
- **Investigate arctic system variability and the processes important for causing the observed changes based on the reanalysis products.**

Approach

Existing conventional methods of oceanic modeling with data assimilation do not have algorithms for the coupled ice-ocean systems.

In order to reach project goals we have developed an approach based on employing of two models. Model “A” uses a conventional Four Dimensional Variational (4D-VAR) technique. It does not have sea ice but uses all needed information from model “B” which is a regional coupled ice-ocean model. The B model is forced by atmospheric reanalysis fields and corrects its forcing based on data obtained from model “A”.

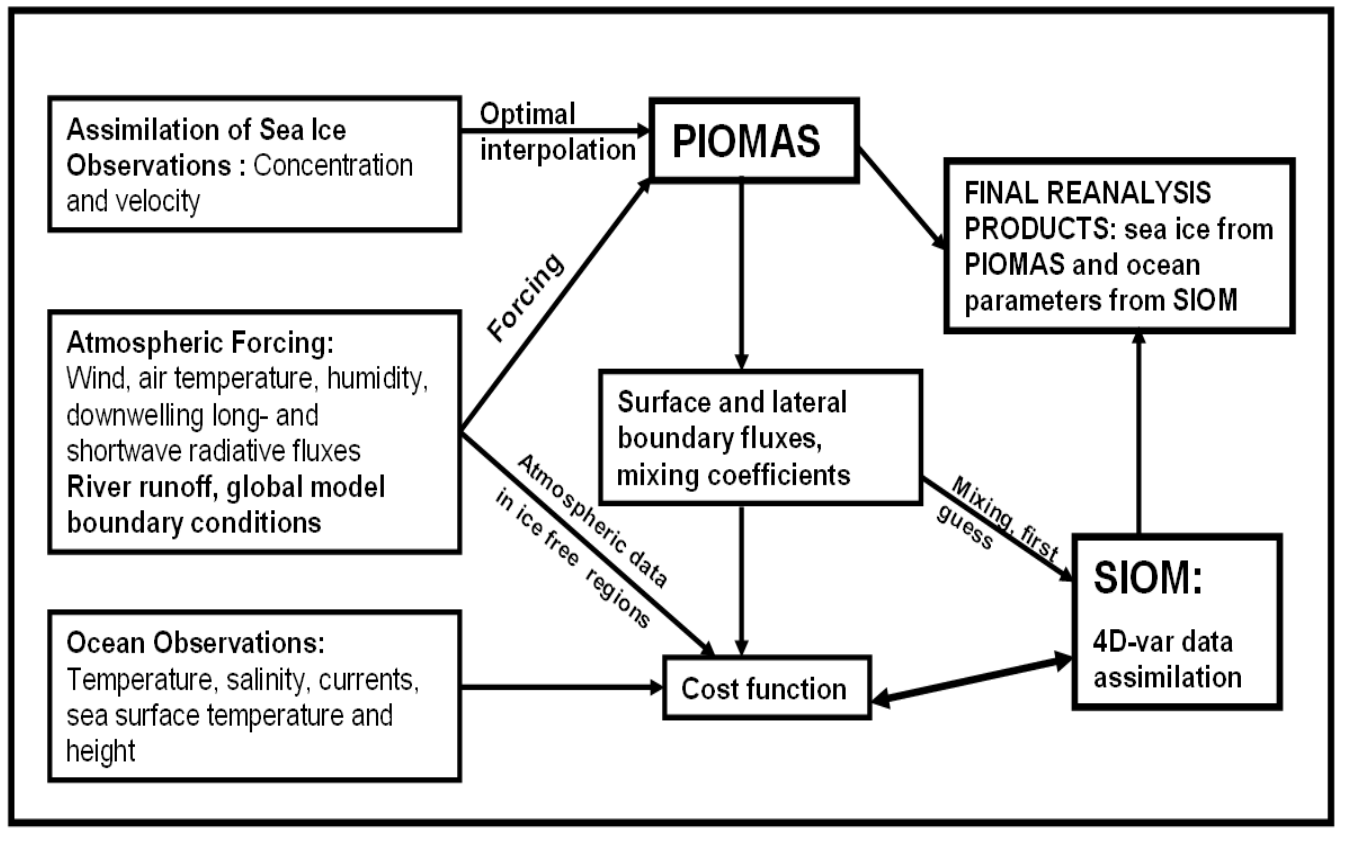


Models

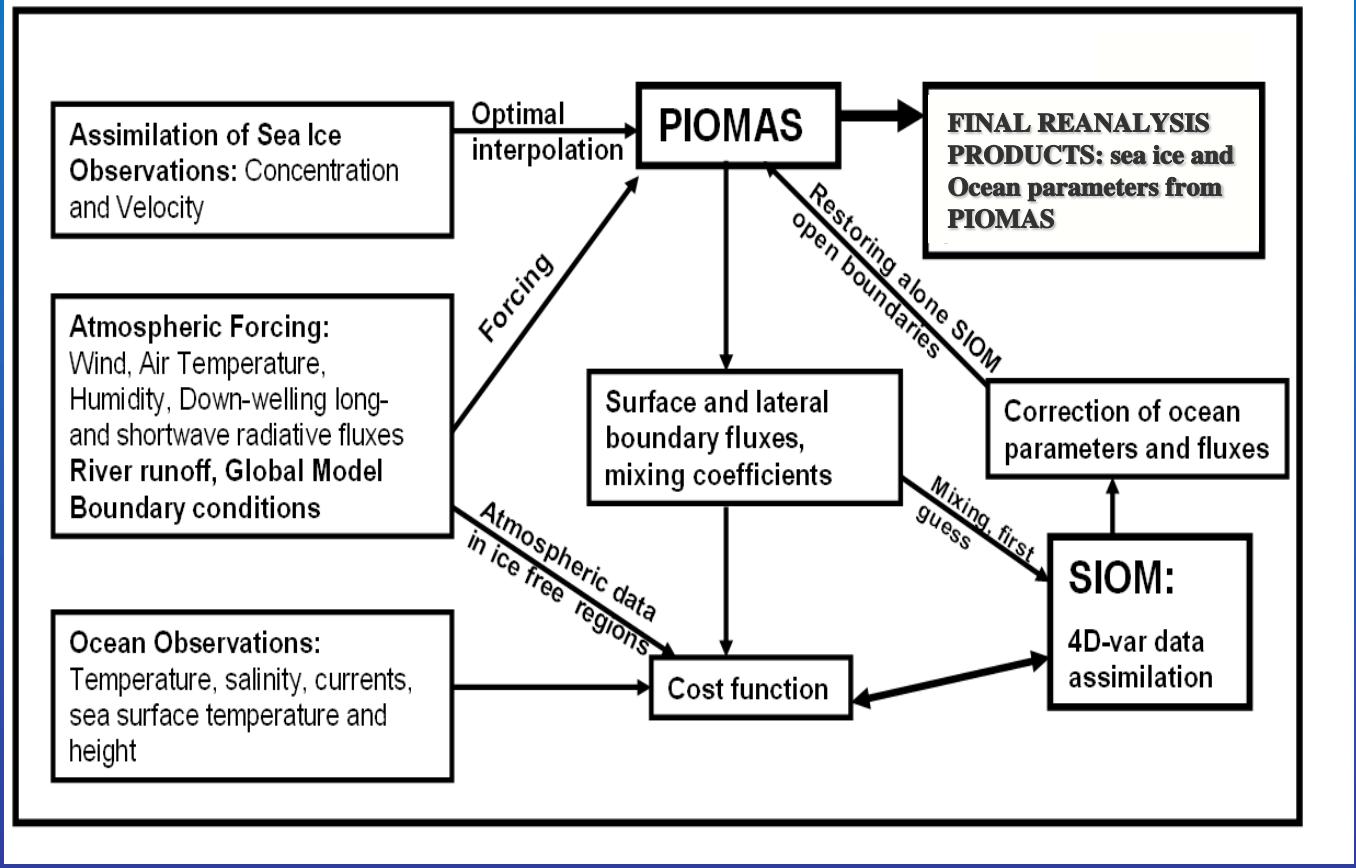
- ***Semi-Implicit Ocean Model (SIOM)*** was designed specifically for the implementation of 4D-Var methods into regional models controlled by currents at the open boundaries and by surface fluxes and is a modification of the Madec *et al.*, [1999] model. The SIOM 4D-Var data assimilation system has been implemented successfully for the reconstruction of the summer circulation in the Barents, Bering and Kara seas (Panteleev *et al.*, 2006a,b,c), and for the variational hindcast of the circulation in the Tsushima Strait (Nechaev *et al.*, 2005).

- ***Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS)*** was developed at the Polar Science Center, University of Washington. This is a coupled parallel ocean and sea ice model capable of assimilating sea ice concentration and velocity data. PIOMAS is configured to cover the region north of 43°N. The model grid is based on a generalized orthogonal curvilinear coordinate system with the northern grid pole displaced into Greenland. This allows the model to have good resolution in the connections between the Arctic Ocean and the Atlantic Ocean. The model is one-way nested to a Global Ice-Ocean Modeling and Assimilation System which consists of similar sea ice and ocean models. Output from this model will be specified along the southern boundaries of POIMAS (43°N) as open boundary conditions.

Data flow chart for the data assimilation procedure “a”.

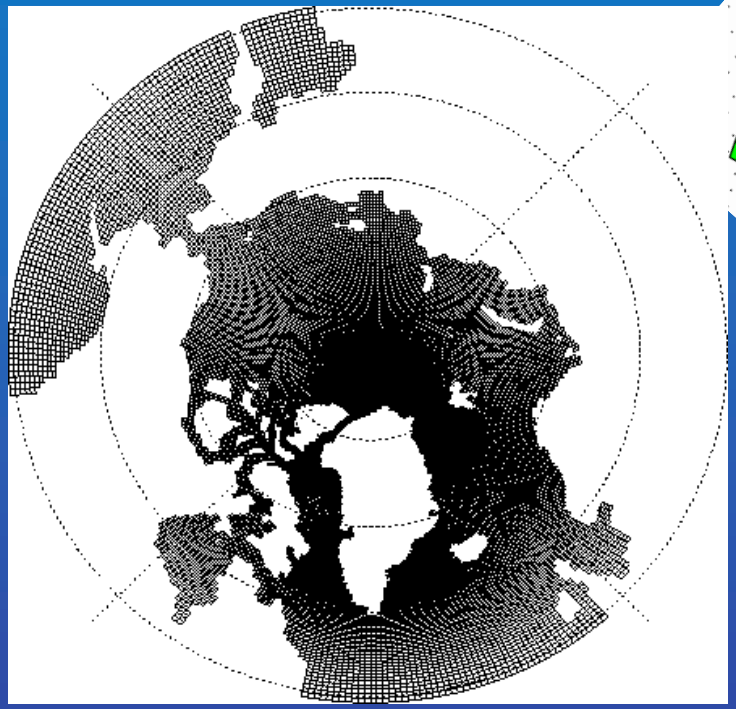


Data flow chart for the data assimilation procedure "b" employing an incremental data assimilation method.

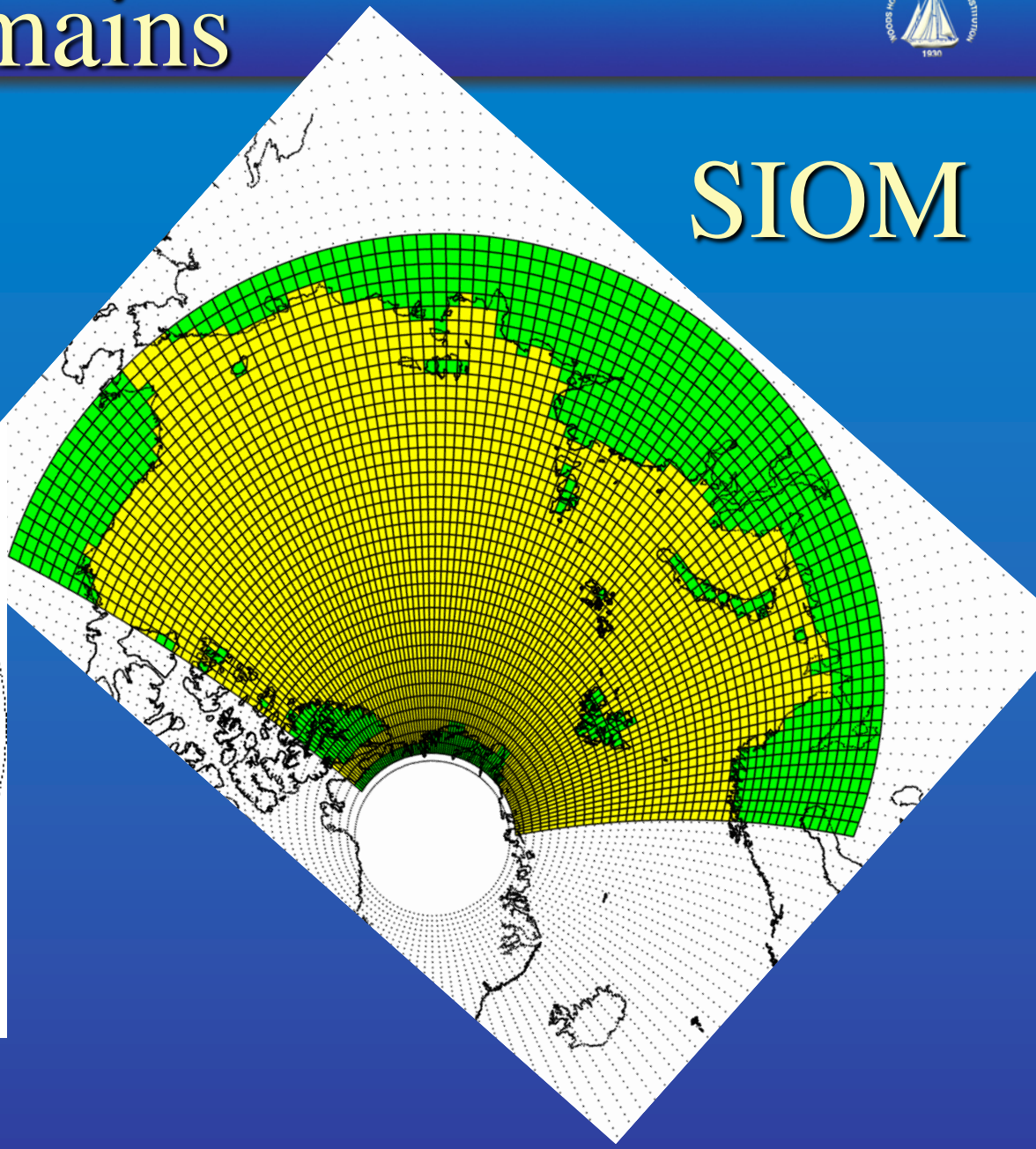


Model Domains

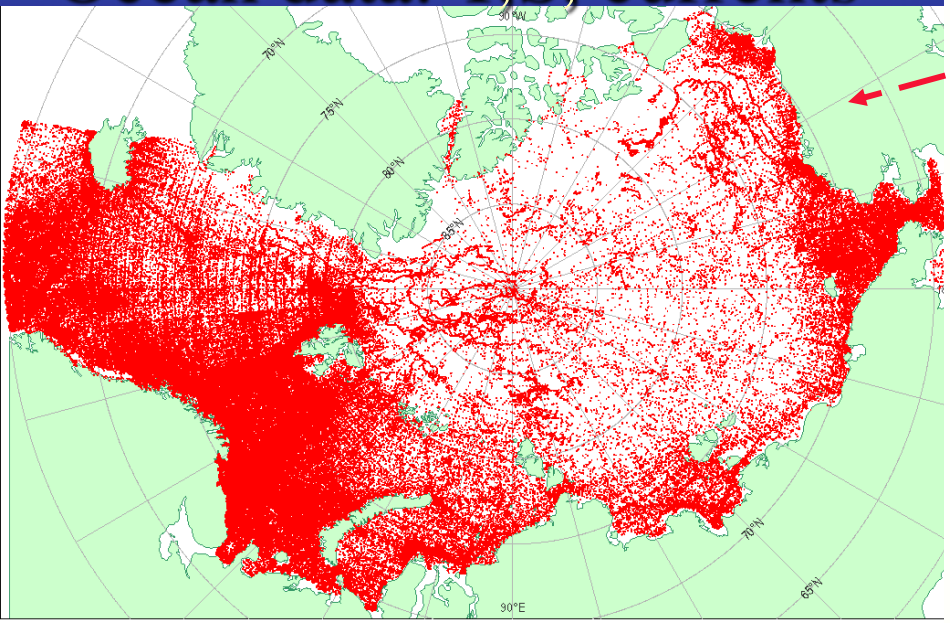
PIOMAS

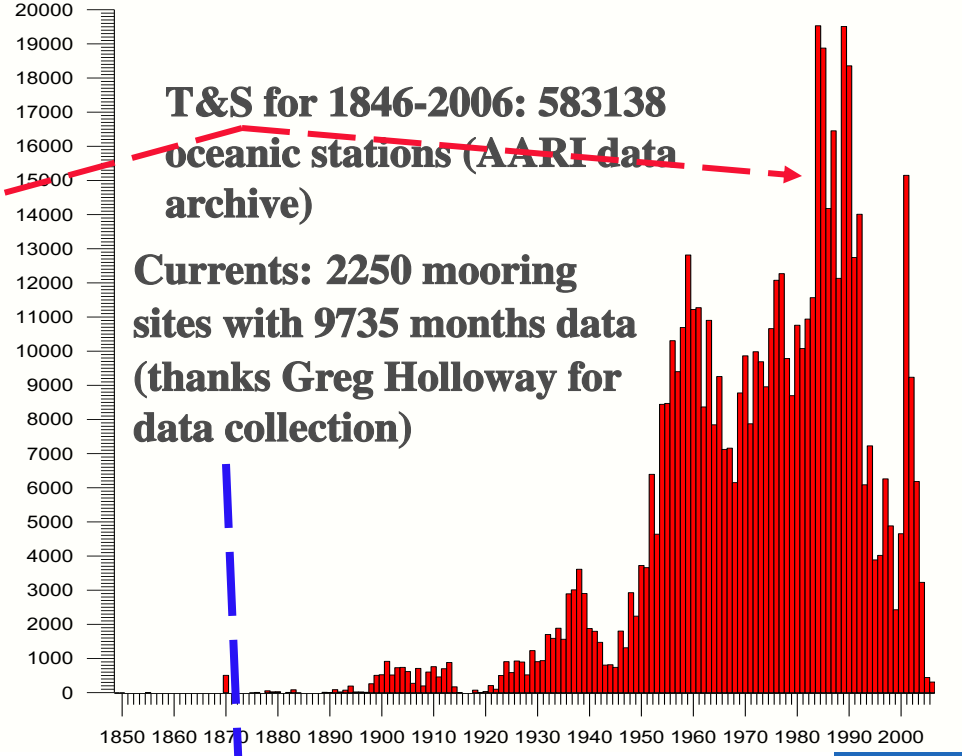


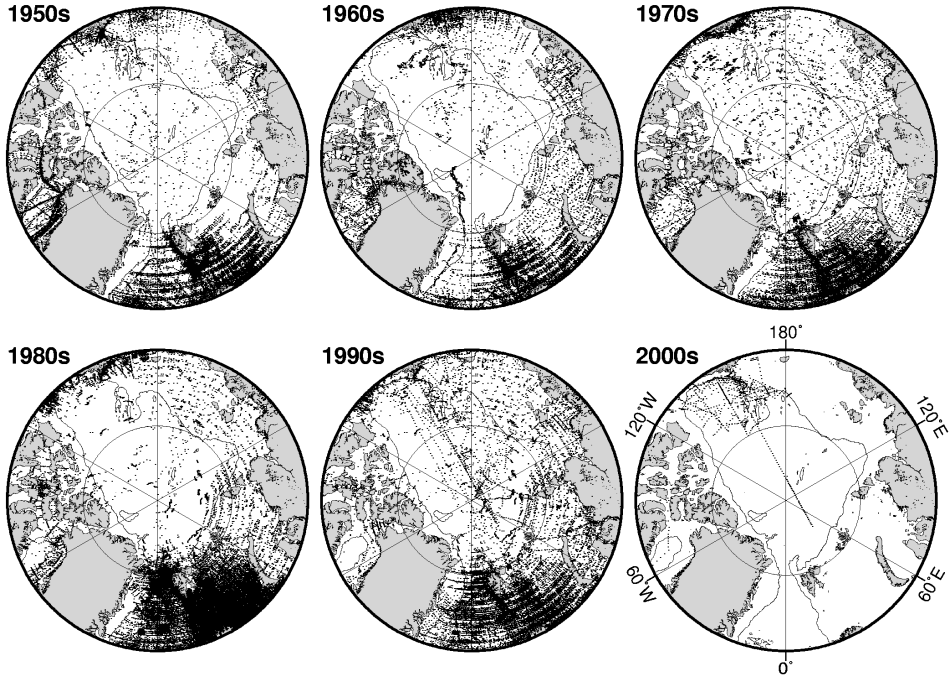
SIOM

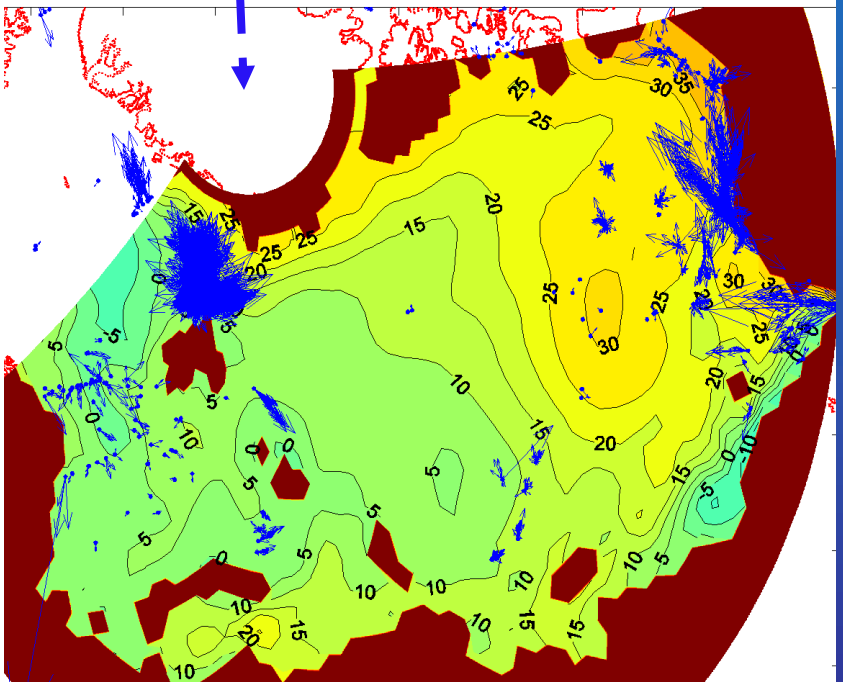


Ocean data: T,S, currents









Atmospheric and ice data

- The atmospheric data (10-m wind, 2-m air temperature and humidity, sea level pressure, and the downwelling long- and shortwave radiative fluxes) will be taken from the ERA-40 Reanalysis through 2001 and the ECMWF operational analysis after that.

- The ice concentration data will be obtained from the ERA-40/ECMWF data sets as well. This approach will guarantee consistency of all data fields (e.g. wind, air temperature, ice concentration and, and SST).

- These fields are originated from: 1) the monthly mean HadISST data set from the UKMO Hadley Centre for 1956-1981; and 2) the weekly NCEP 2D-VAR data for 1982-present (Reynolds *et al.*, 2002). Both data sets are based on satellite and conventional SST/IC observations.

- The most recent ECMWF SST fields are from new daily analyses made at NCEP. The ice velocity is taken from the optimally interpolated ice velocity fields produced by Chuck Fowler and archived as a Polar Pathfinder dataset at NSIDC. They are derived from buoy, AVHRR, and passive microwave estimates of the ice velocity.

Expected Products

- Because this is a first attempt at constructing a 4D-Var reanalysis of the Arctic Ocean system we plan to reconstruct sea ice and ocean monthly fields for three distinct periods, each representing a different state of the arctic climate.

- The first period is 1972-1978 (7 years) when the Arctic was relatively cold and there is a large quantity of hydrographic data available

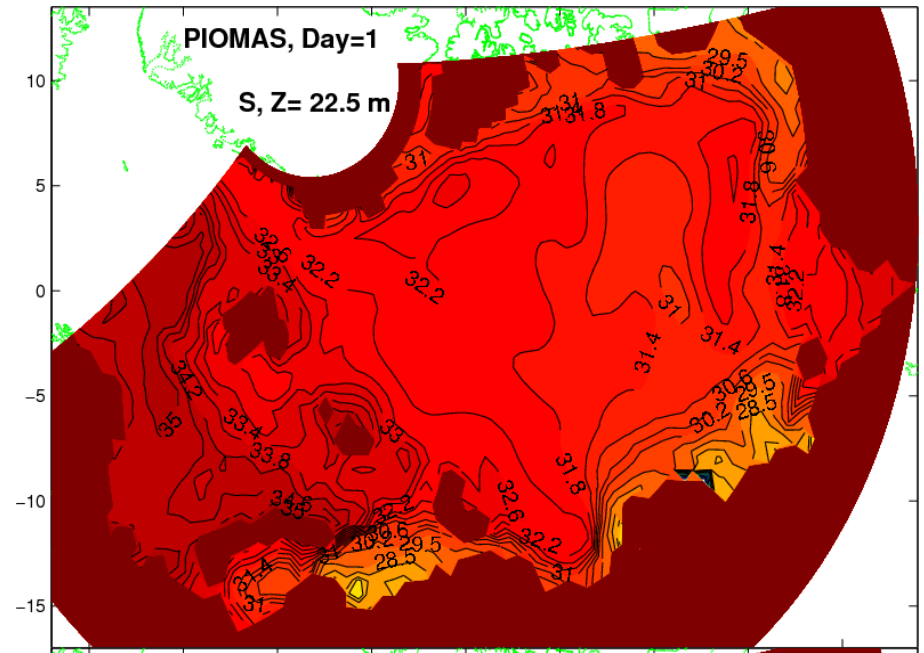
- The second is 1989-1996 (7 years) when large changes begin in the Arctic Ocean circulation, in its hydrographic structure and in sea ice conditions

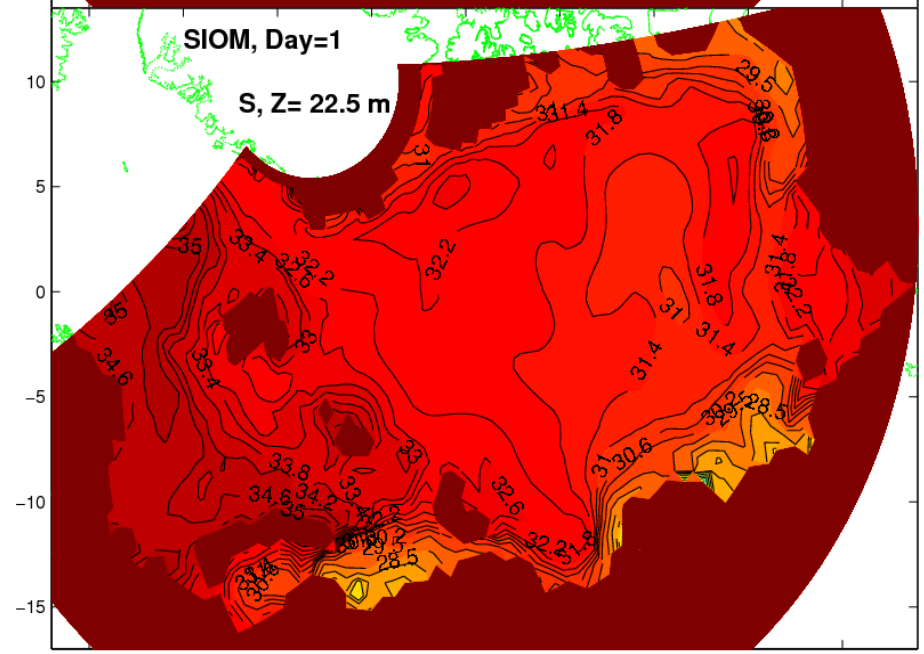
- The third is 2001-present when substantial amounts of open water begin to appear in the late summer.

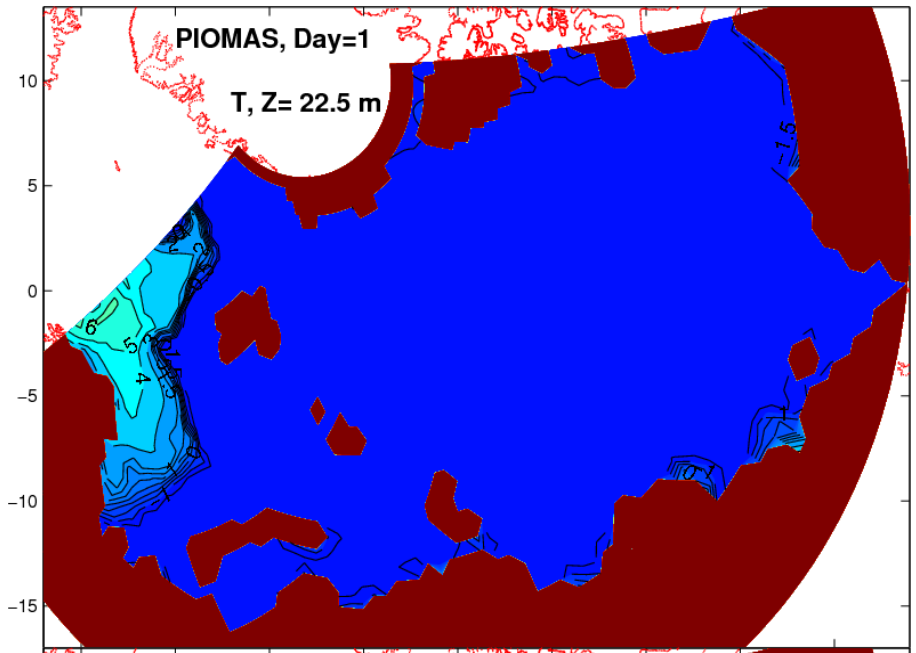
Completed tasks

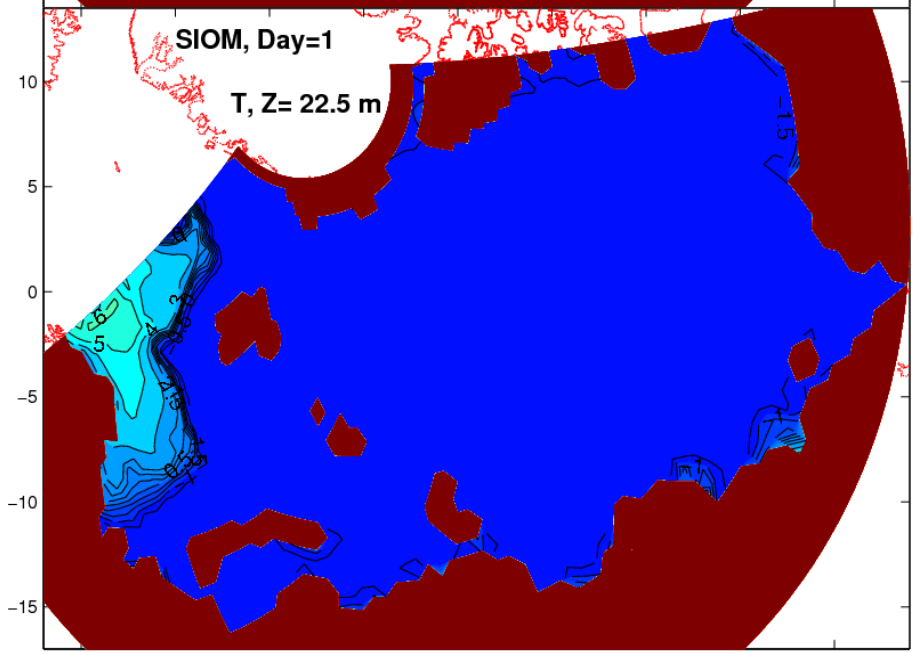
- Our research during the first year has focused on the preprocessing of different kinds of data, linking PIOMAS and SIOM, and carrying out preliminary experiments testing the system and analyzing results.

S (left) and T (right) at 22.5 m ocean depth









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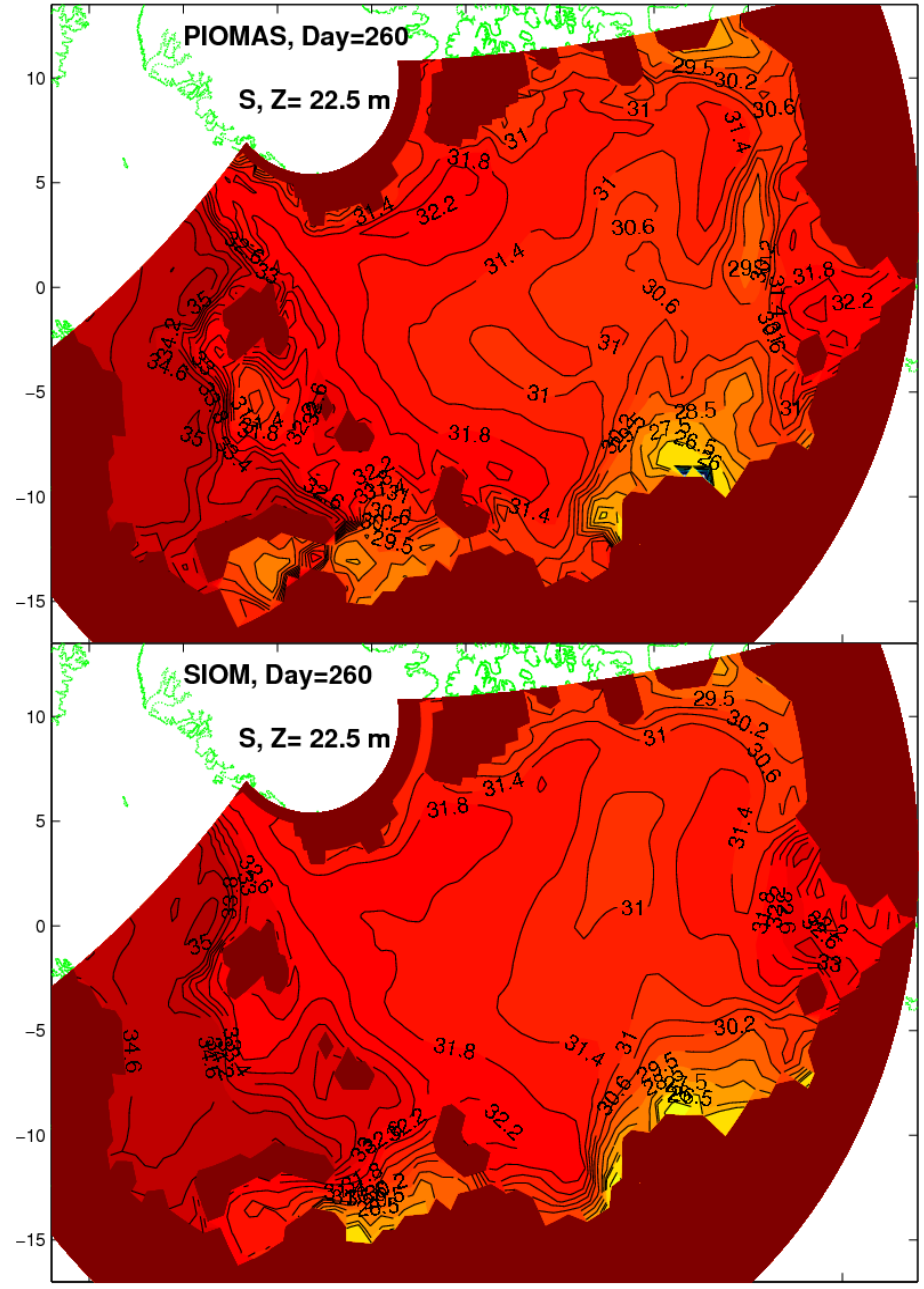
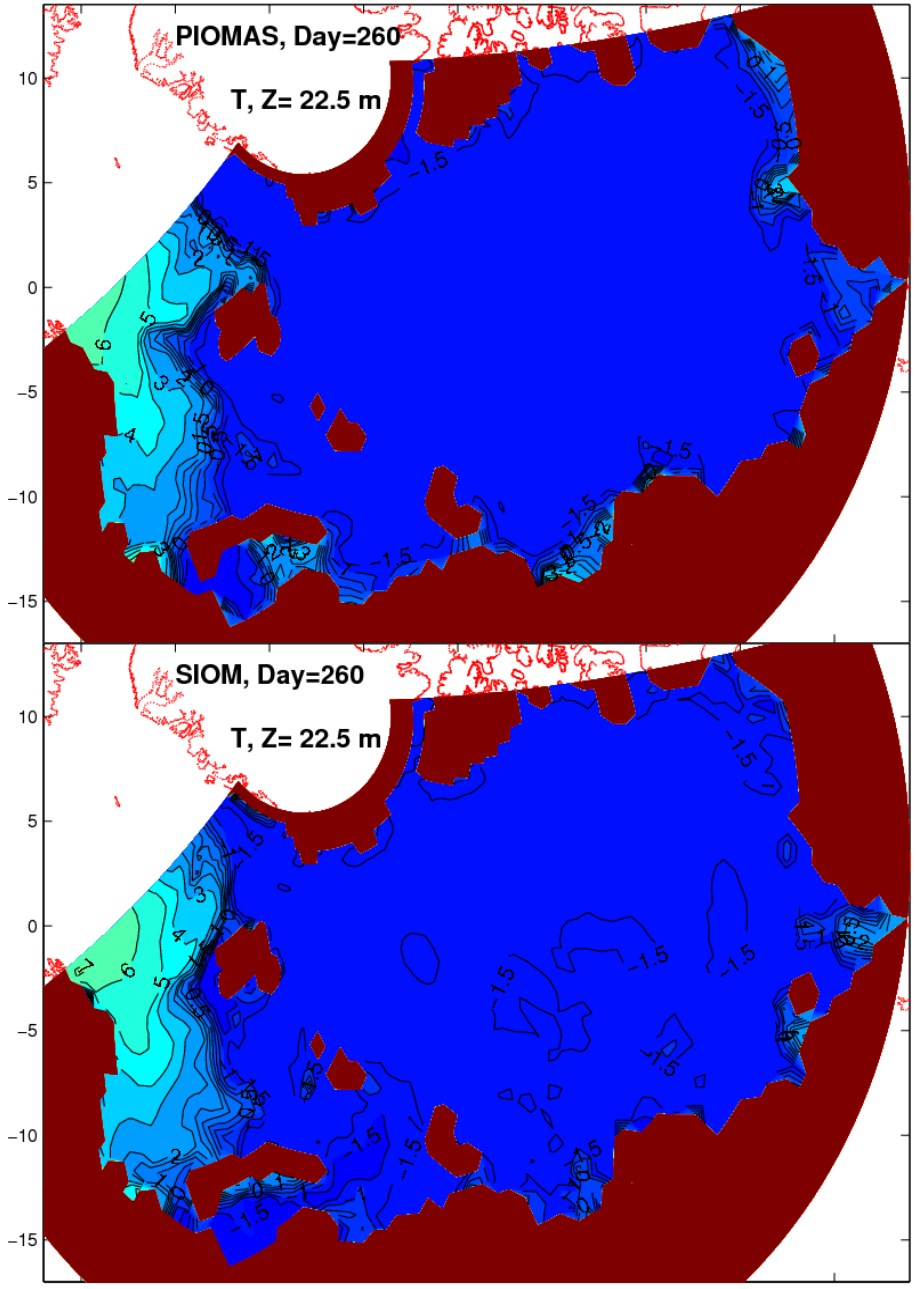
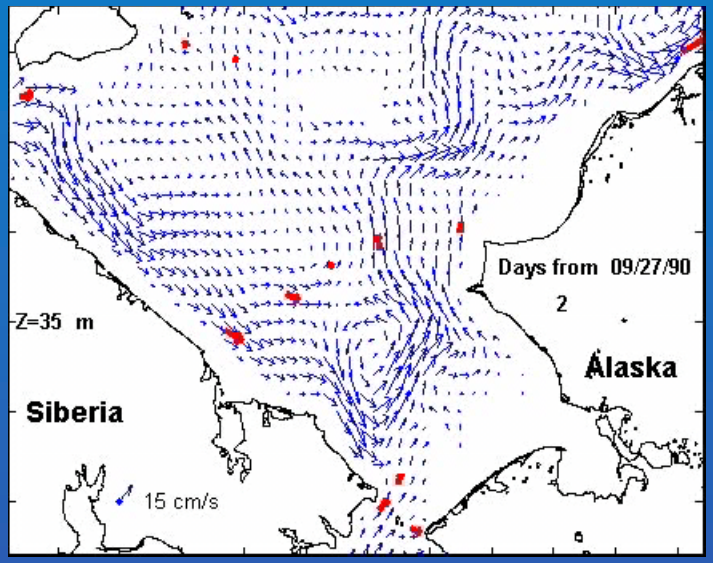




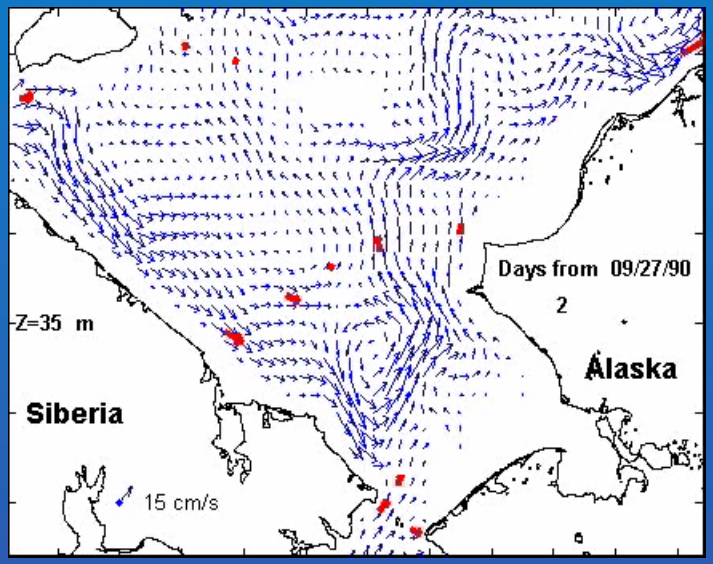
Circulation in the Chukchi Sea (1990)

SIOM and NCEP/NCAR



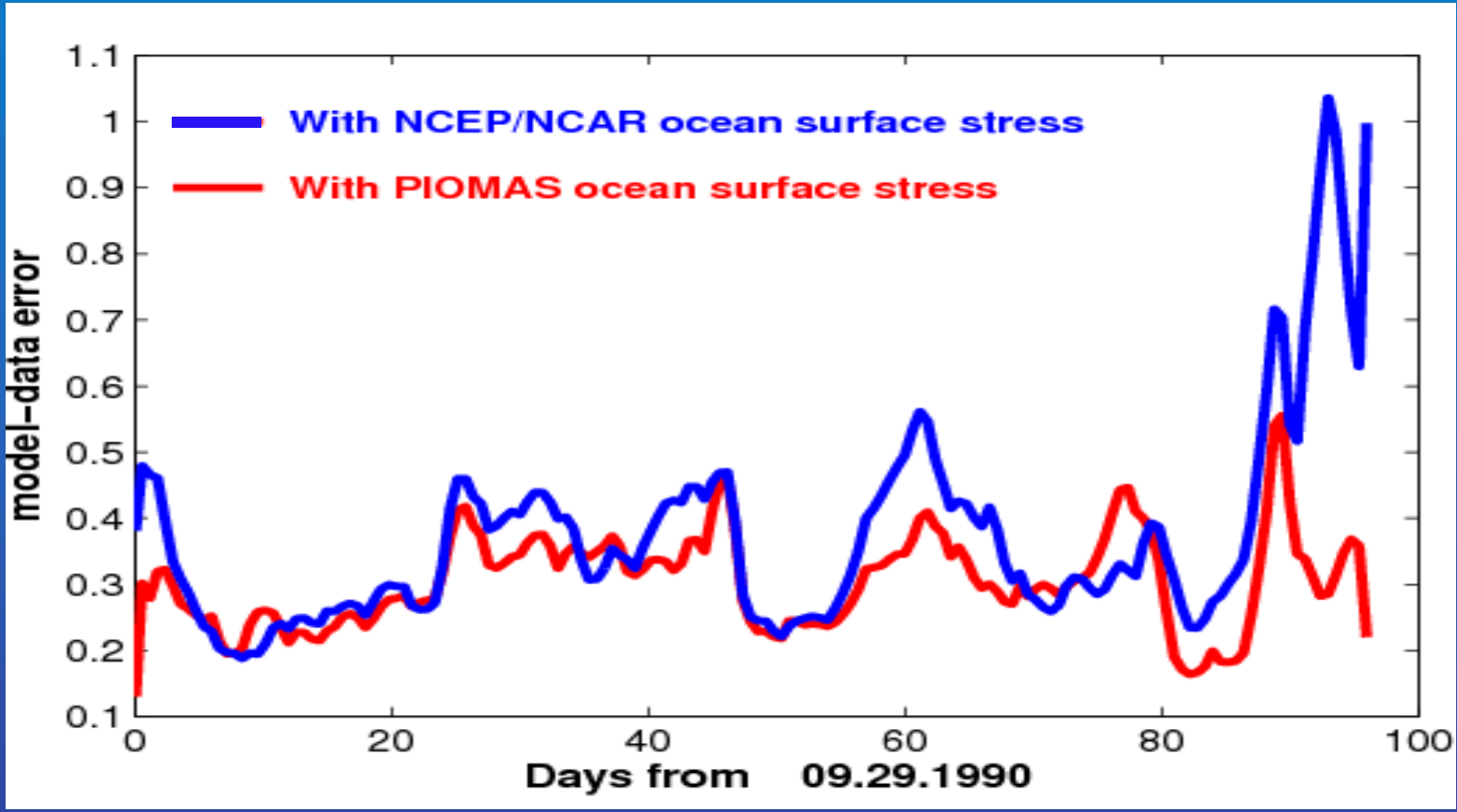
Model-mooring error: 0.37

SIOM and PIOMAS



Model-mooring error: 0.3

Model errors (based on mooring data)



Potential linkages and integration