Reanalysis of the Arctic Ocean circulation and adjoint sensitivity analysis of the velocity observations

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AOMIP, October 19-22, 2010

2010 Ocean Sciences Meeting. Oregon

26 February *2010*

8:45 AM - 9:00 AM

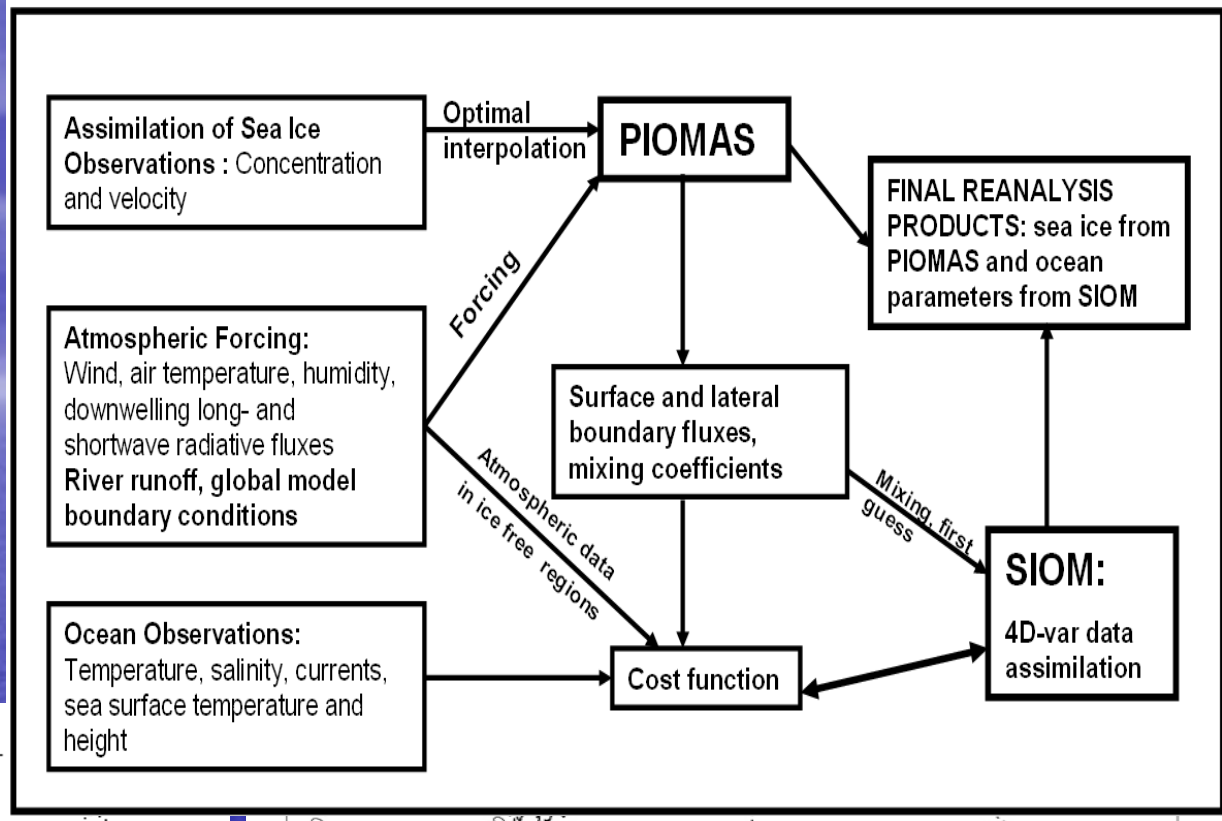
Models

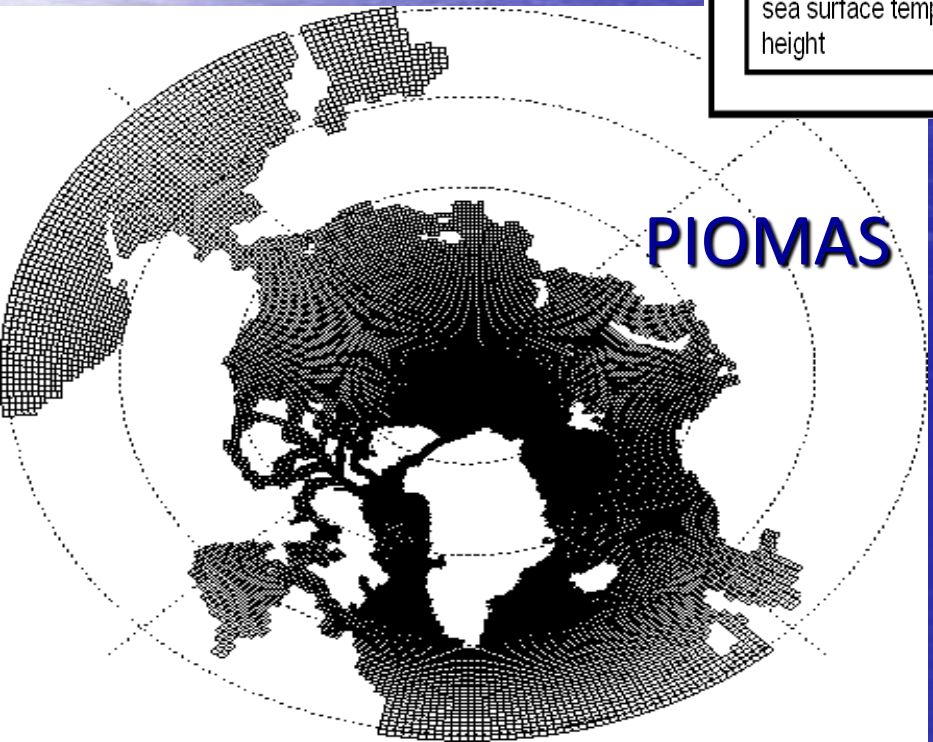
- ***Semi-Implicit Ocean Model (SIOM)*** **was designed specifically for the implementation of 4D-Var methods into regional models controlled by currents at the open boundaries and by surface fluxes and is a modification of the Madec *et al.*, [1999] model. The SIOM 4D-Var data assimilation system has 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 is specified along the southern boundaries of POIMAS (43°N) as open boundary conditions.**

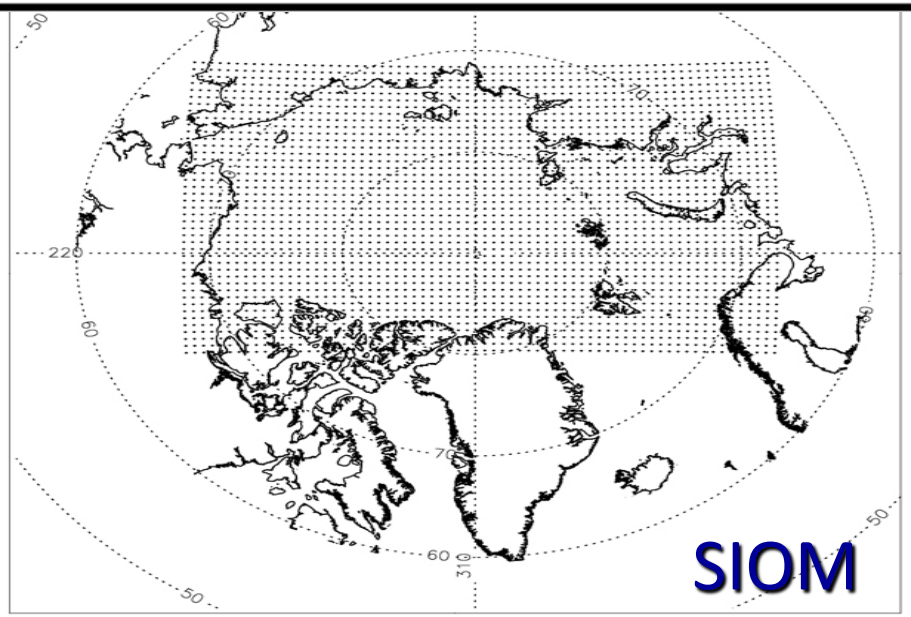
Data flow chart for the data assimilation

and models configurations



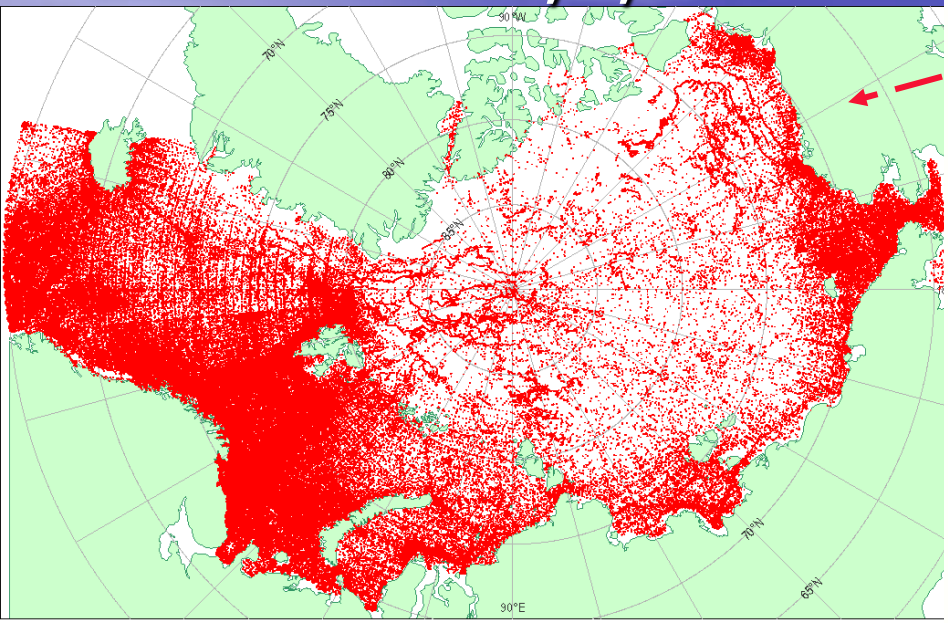


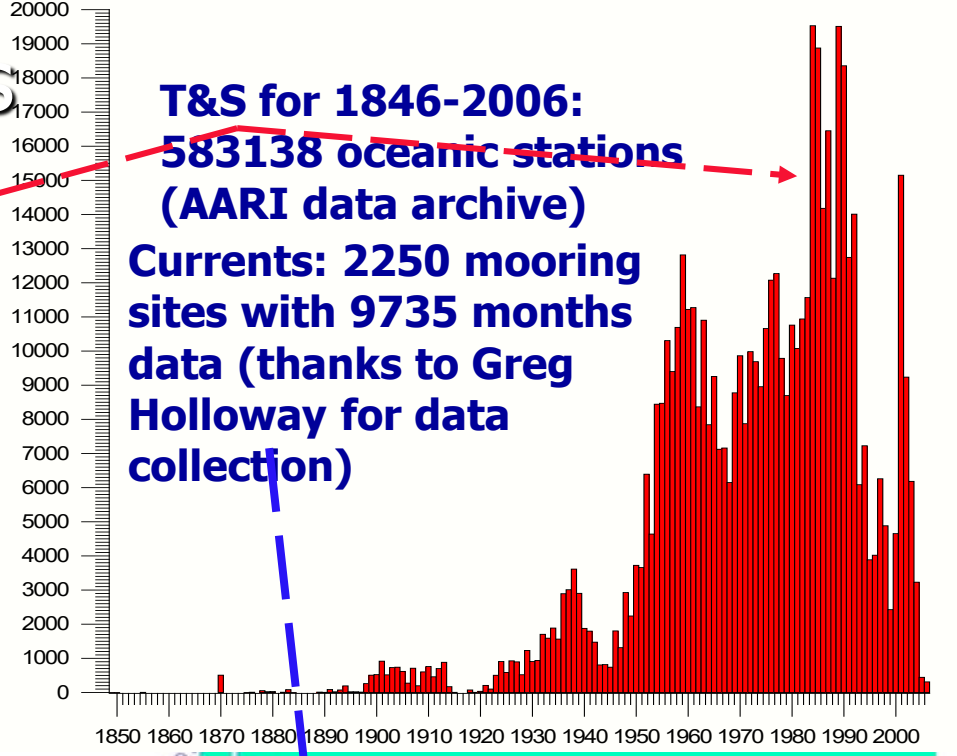
PIOMAS



SIOM

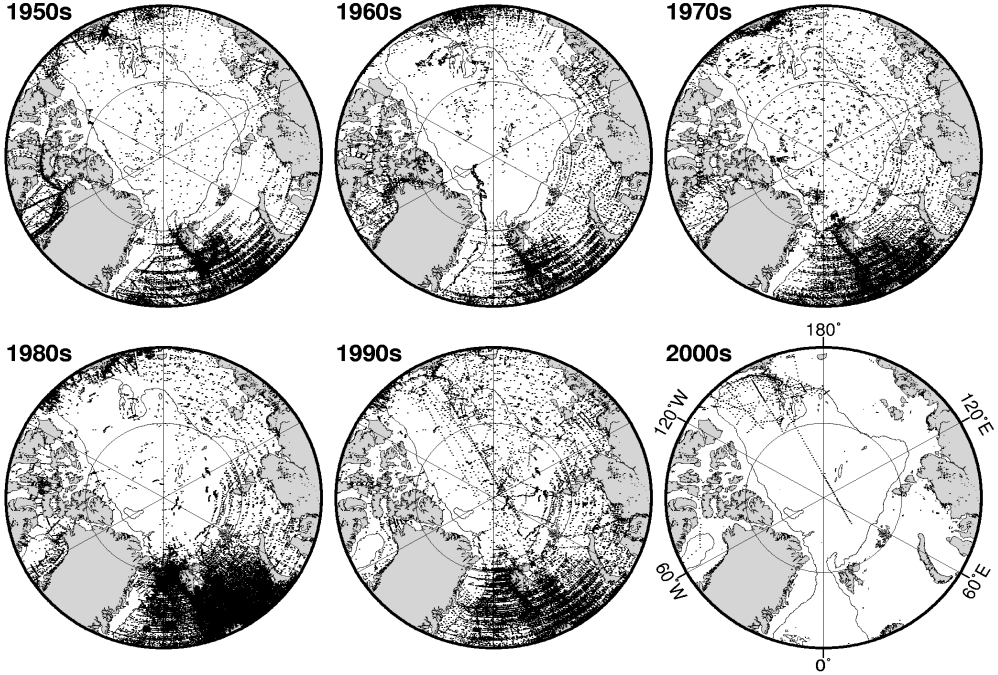
Ocean data: T,S, currents

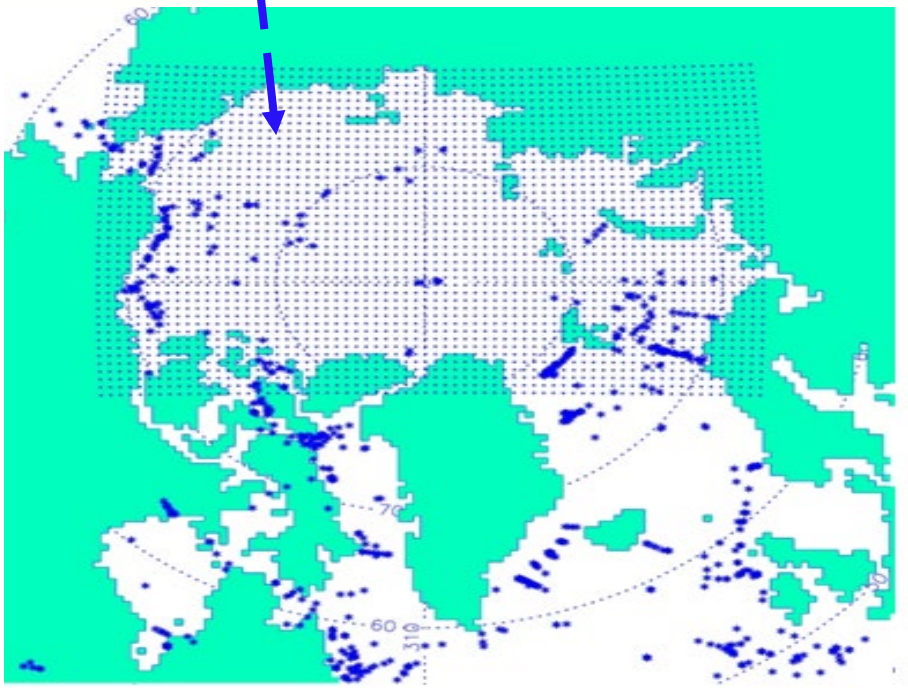




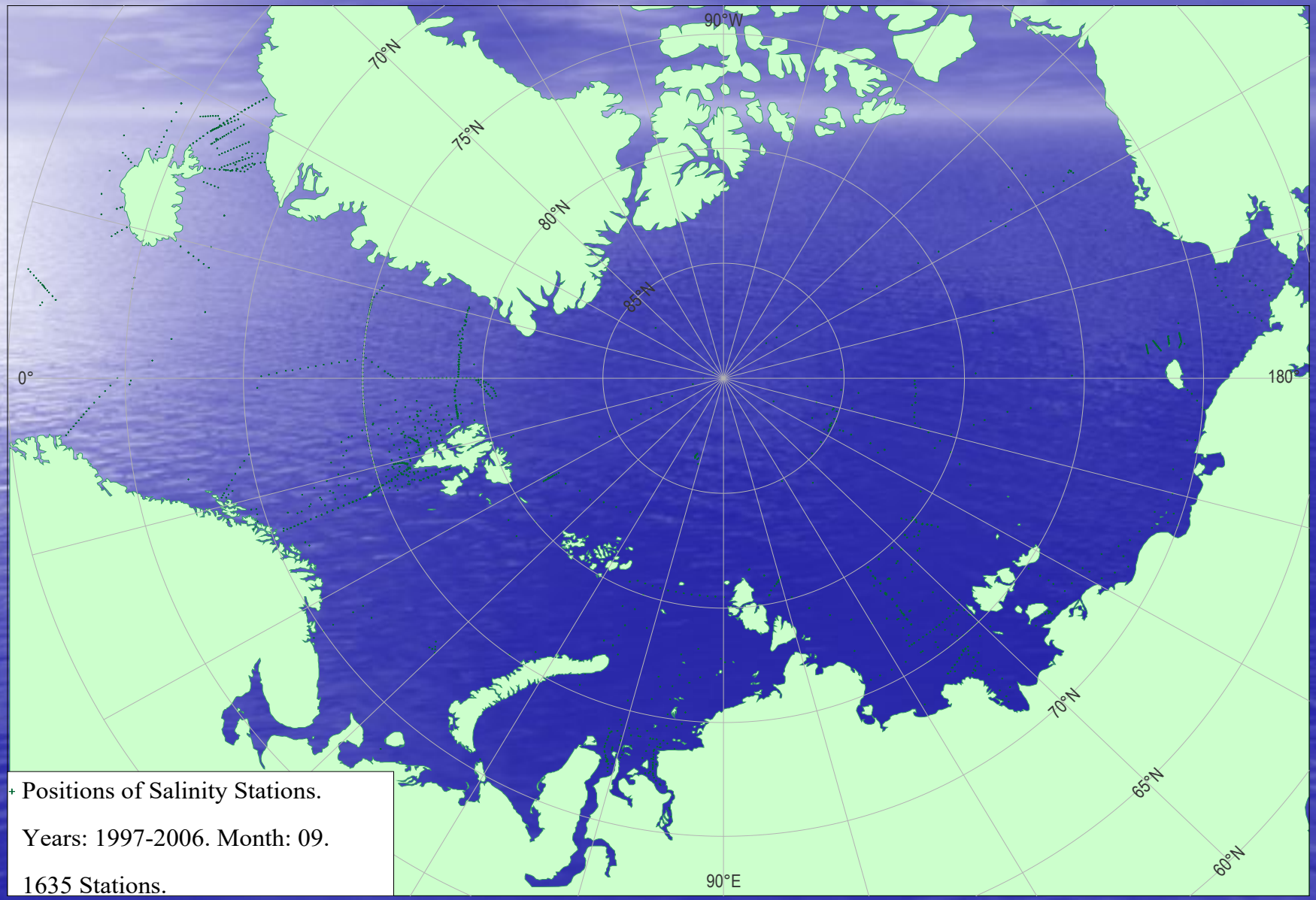
T&S for 1846-2006: 583138 oceanic stations (AARI data archive)

Currents: 2250 mooring sites with 9735 months data (thanks to Greg Holloway for data collection)





All ocean T,S data for a period 1997-2006



Results:

www.whoi.edu/science/PO/arcticgroup/projects/andrey_project2/resultsAP.html

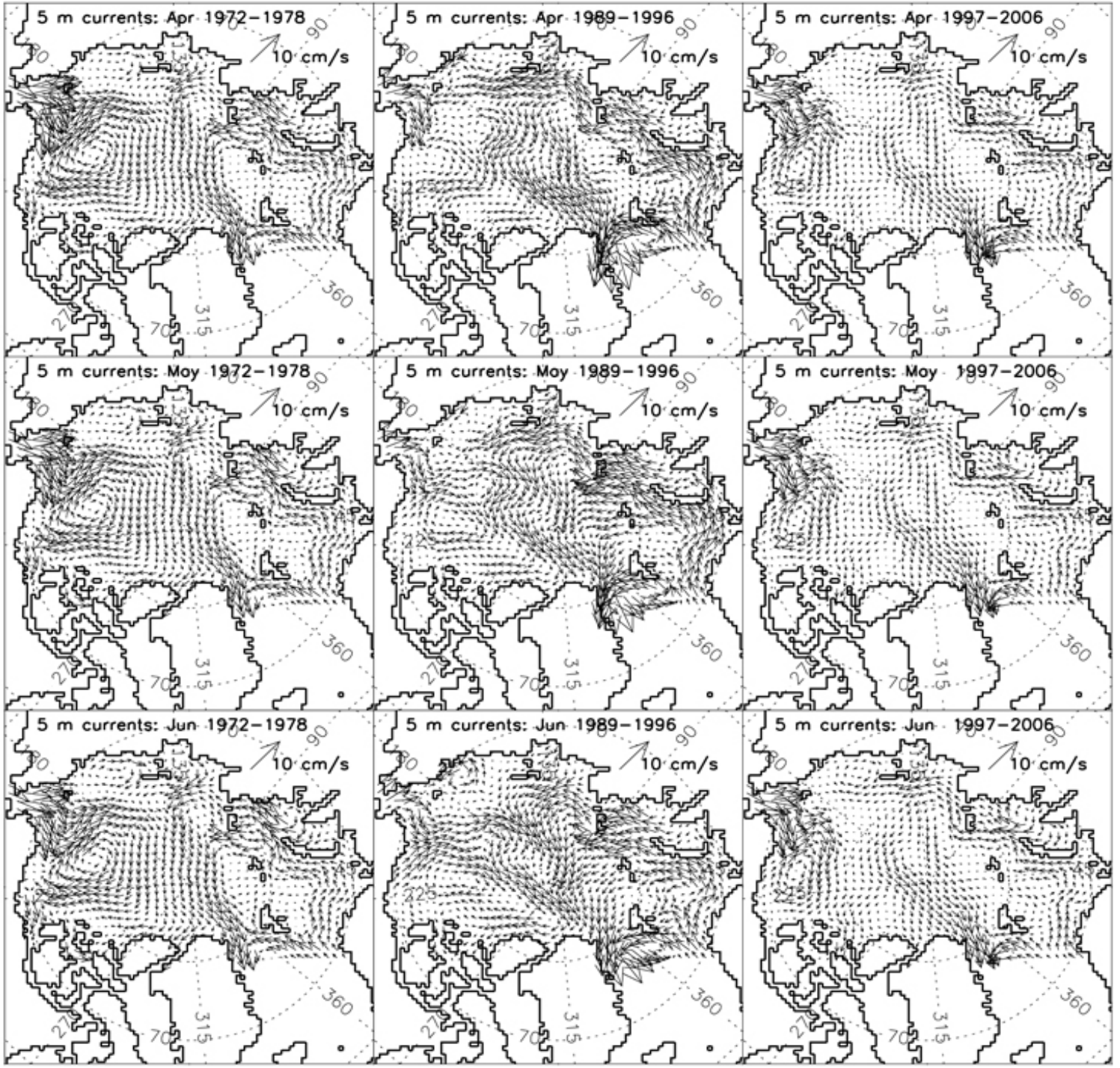
- **Water circulation, temperature and salinity of the Chukchi Sea were reconstructed for 1990-1991. This test allowed us to investigate our algorithms and employed technologies. See:** Panteleev, G., D. A. Nechaev, A. Proshutinsky, R. Woodgate, and J. Zhang (2010), Reconstruction and analysis of the Chukchi Sea circulation in 1990-1991, J. Geophys. Res., doi:10.1029/2009JC005453
- **Reanalysis of the Arctic Ocean climatic conditions: 1947-2006**
- **Reanalysis of the Arctic Ocean climatic conditions for three periods: 1972-1978, 1989-1996 and 1997-2006 was completed.**

State 1947-2006 was used as a first guess.

- **Reanalysis of the Arctic Ocean climatic conditions for every year: 1972-1978, 1989-1996 and 1997-2006 was completed.**

States 1972-1978, 1989-1996 and 1997-2006 were used as a first guesses.

- **Decadal changes of the reconstructed fields were analyzed.**
- **Adjoint sensitivity analysis of the mooring observations in the Chukchi Sea and in Arctic Ocean.**


5 m currents: Apr 1972–1978
10 cm/s
5 m currents: Apr 1989–1996
10 cm/s
5 m currents: Apr 1997–2006
10 cm/s
5 m currents: May 1972–1978
10 cm/s
5 m currents: May 1989–1996
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5 m currents: May 1997–2006
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5 m currents: Jun 1972–1978
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5 m currents: Jun 1989–1996
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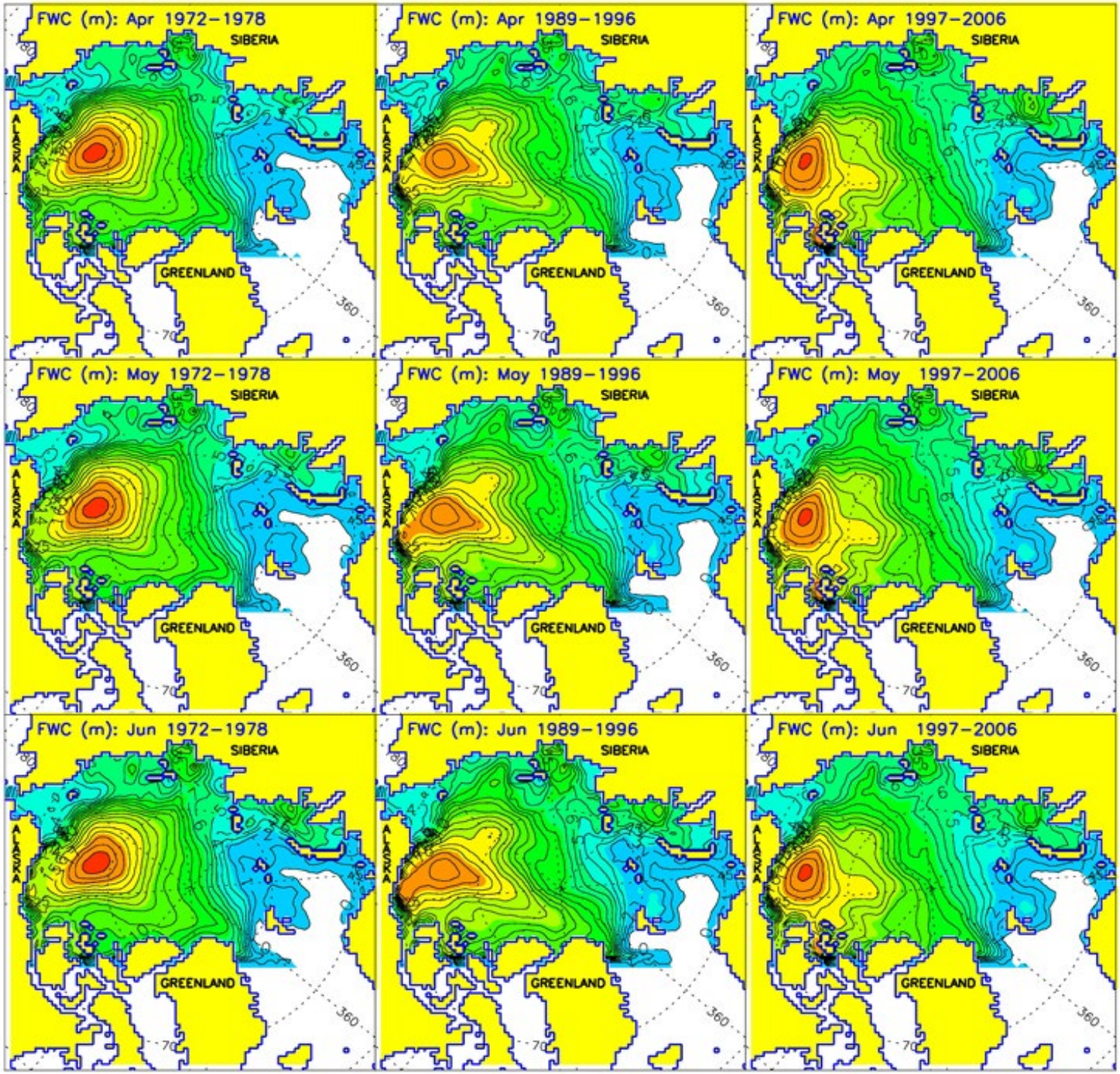
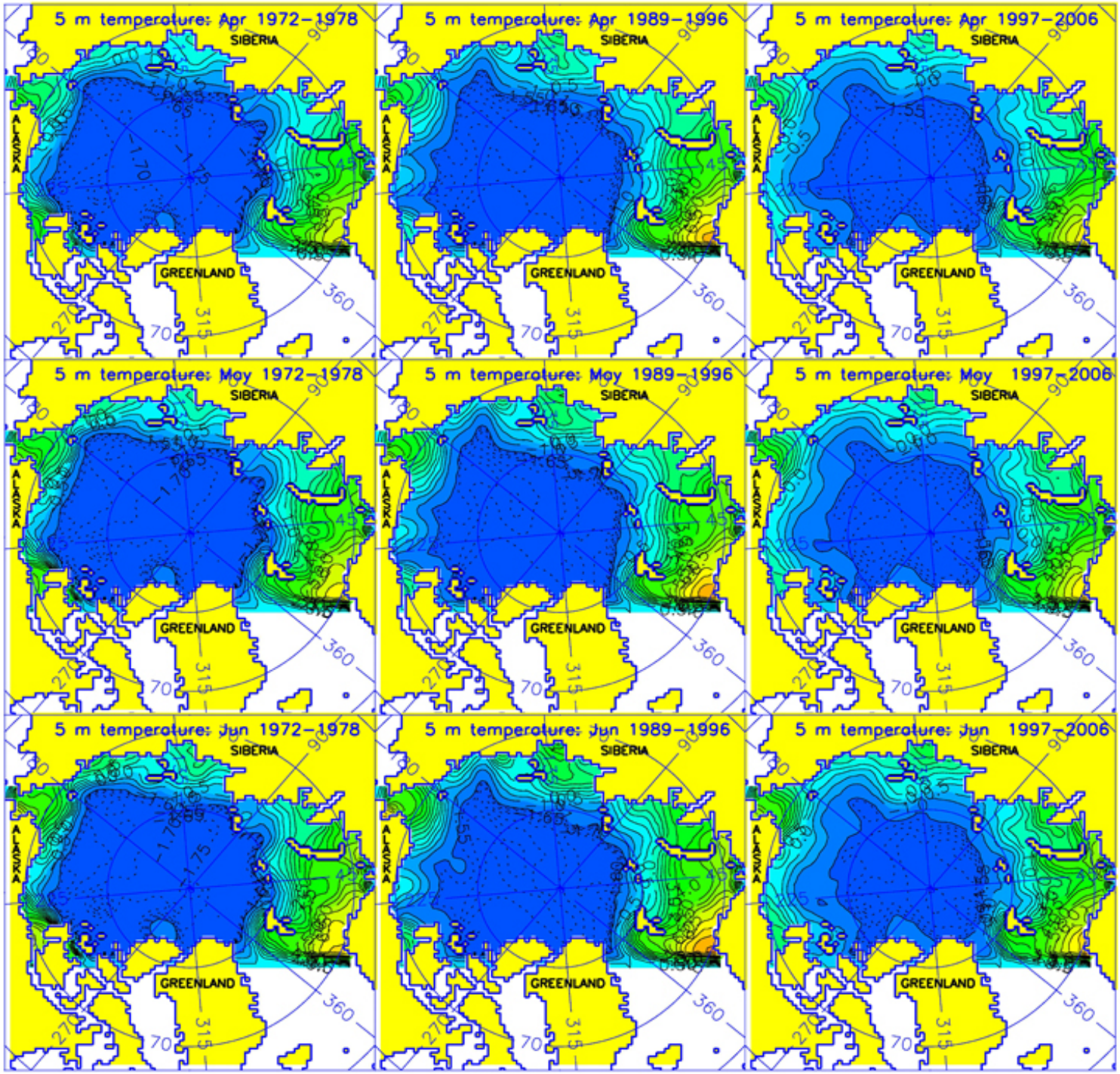
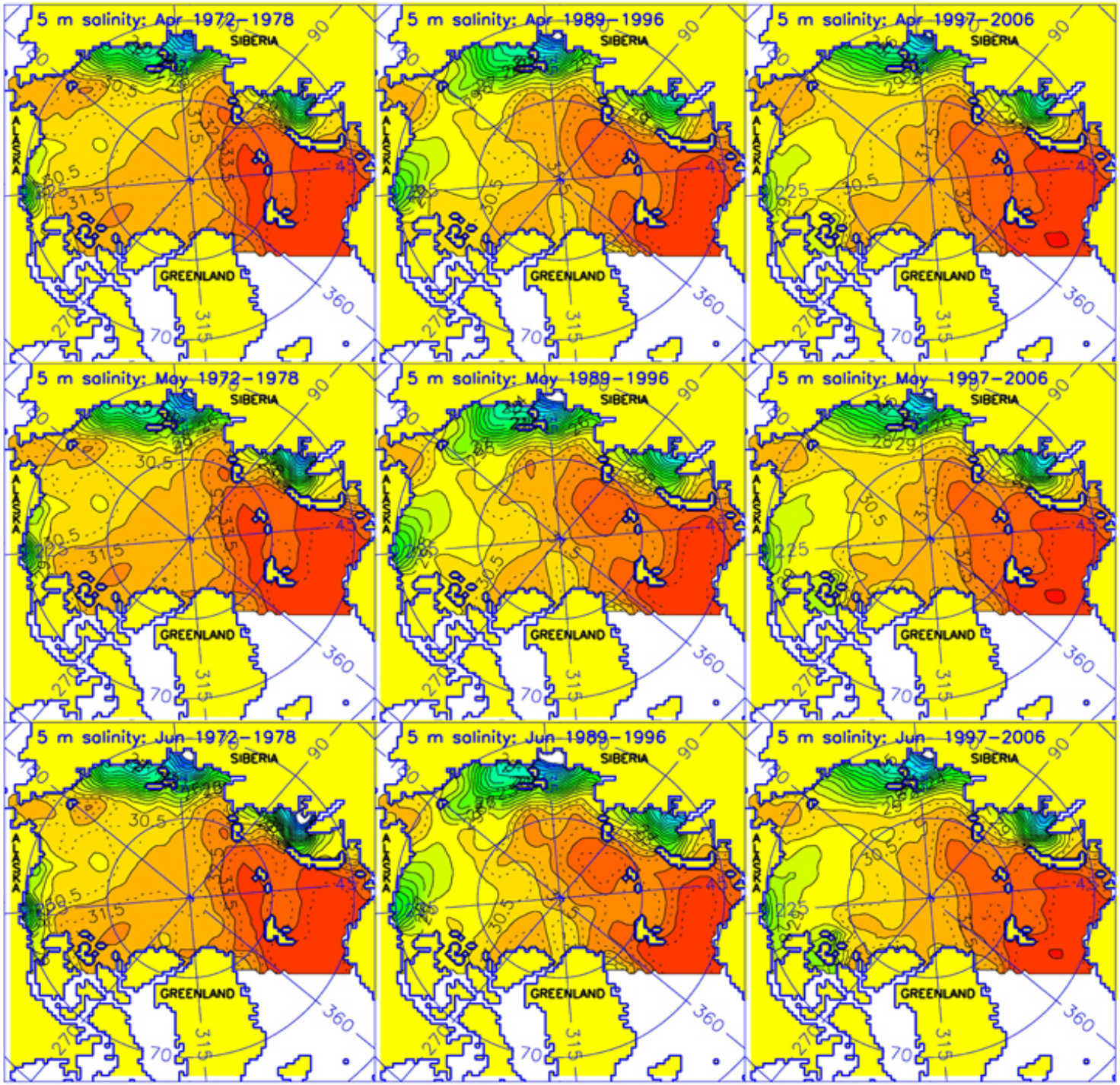
5 m currents: Jun 1997–2006
10 cm/s


FWC (m): Apr 1972–1978
FWC (m): Apr 1989–1996
FWC (m): Apr 1997–2006
FWC (m): May 1972–1978
FWC (m): May 1989–1996
FWC (m): May 1997–2006
FWC (m): Jun 1972–1978
FWC (m): Jun 1989–1996
FWC (m): Jun 1997–2006
SIBERIA
ALASKA
GREENLAND


5 m temperature: Apr 1972–1978
5 m temperature: Apr 1989–1996
5 m temperature: Apr 1997–2006
5 m temperature: May 1972–1978
5 m temperature: May 1989–1996
5 m temperature: May 1997–2006
5 m temperature: Jun 1972–1978
5 m temperature: Jun 1989–1996
5 m temperature: Jun 1997–2006
SIBERIA
ALASKA
GREENLAND


5 m salinity: Apr 1972–1978
5 m salinity: Apr 1989–1996
5 m salinity: Apr 1997–2006
5 m salinity: May 1972–1978
5 m salinity: May 1989–1996
5 m salinity: May 1997–2006
5 m salinity: Jun 1972–1978
5 m salinity: Jun 1989–1996
5 m salinity: Jun 1997–2006
SIBERIA
ALASKA
GREENLAND

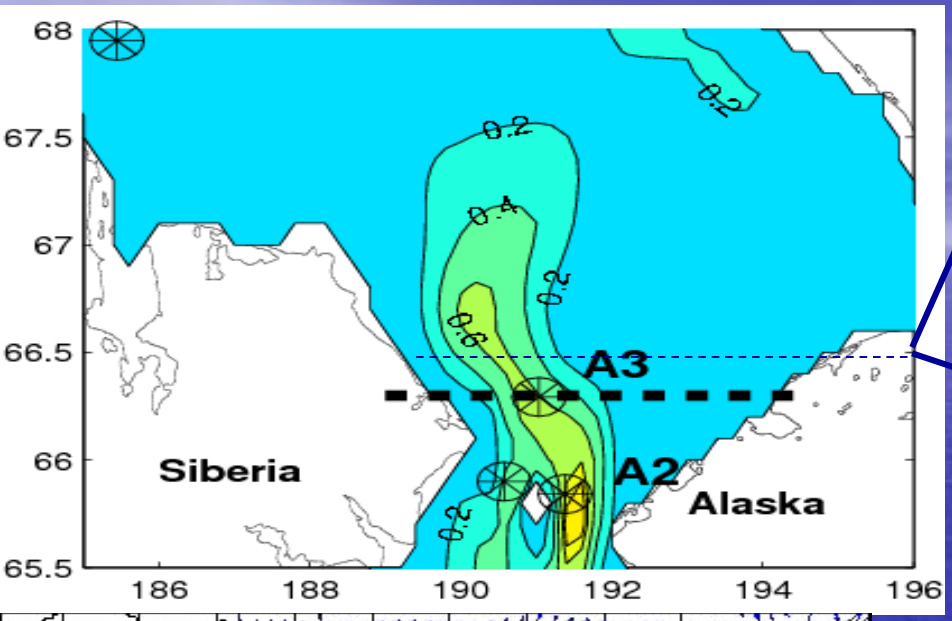
Approaches: adjoint sensitivity analysis

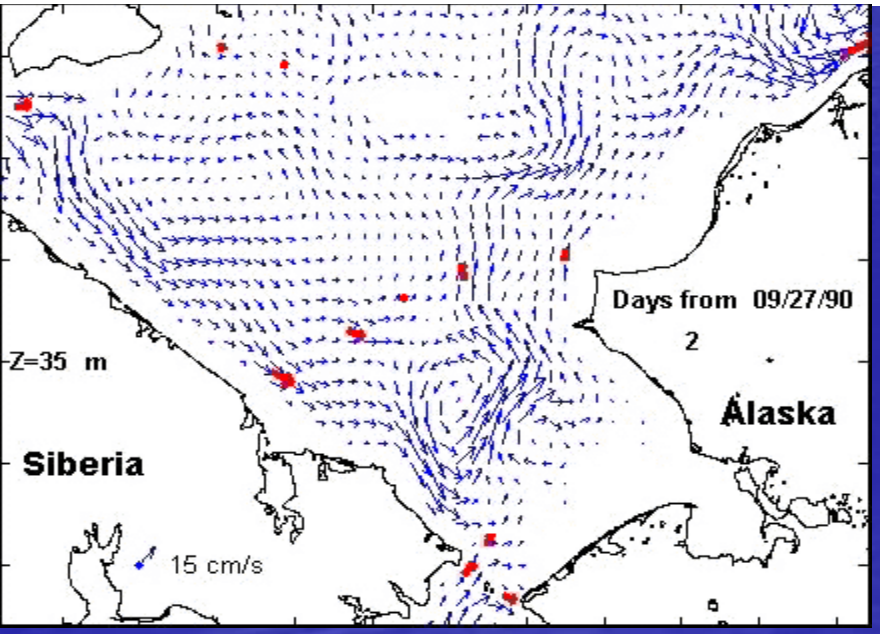
1) The 4dVar data assimilation procedure transforms *a priori* probability distribution for the data by injecting dynamical information, and establishes the dynamically-constrained correlations between any functions $\mathbf{L}(y)$ of the ocean state variables y described by the model operator **M**.

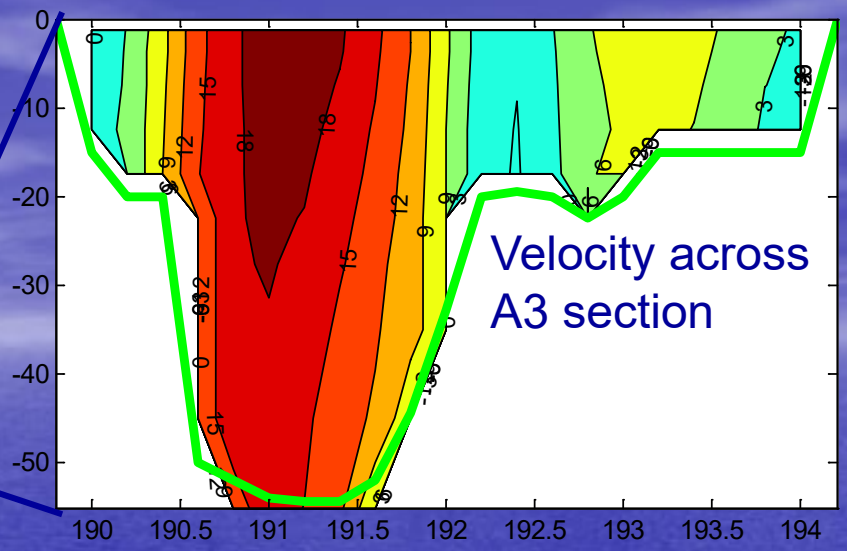
2) In the framework of Gaussian statistics, *a posteriori* probability density is described by the inverse covariance $\mathbf{H}=\partial^2 J/\partial c^2$. Therefore, covariance between two quantities q_1, q_2, expressed in terms of the control variables c as $q_1 = \mathbf{L}_1 y = \mathbf{L}_1\mathbf{M}c$, $q_2 = \mathbf{L}_2 X = \mathbf{L}_2\mathbf{M}c$, is $\mathrm{cov}(q_1, q_2) = \mathbf{L}_1\mathbf{M}\mathbf{H}^{-1}\mathbf{M}^{\mathrm{T}}\mathbf{L}_2^{\mathrm{T}}$.

3) The magnitude S of $\mathrm{cov}(q_1, q_2)$ can be used to estimate sensitivity of a target quantity (say, q_2) to an observation of q_1 in the presence of other data and dynamical constraints, which define the structure of **H**. We investigate sensitivity of the optimized value of q_2 to observations of q_1 (i.e. the derivative $[\delta q_2/\delta q_1]$) under the assumption that the prior error variances σ of the control variables are much smaller than the combined observational and model error variances: $S=|\delta q_2/\delta q_1| = |\mathbf{W}\mathbf{L}_1^{\mathrm{T}}\mathbf{M}\mathbf{V}\mathbf{M}^{\mathrm{T}}\mathbf{L}_2^{\mathrm{T}}|$.

Adjoint Sensitivity: d(BSTr)/dV(x,y)







From 1990-1991 observations:
Correlation (V_{A3},BST) = 0.88
Correlation (V_{A2},BST) = 0.94

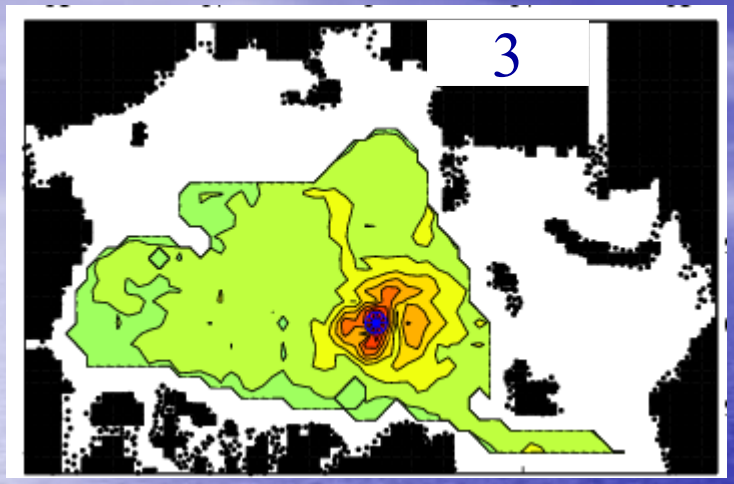
Adjoint sensitivity analysis:

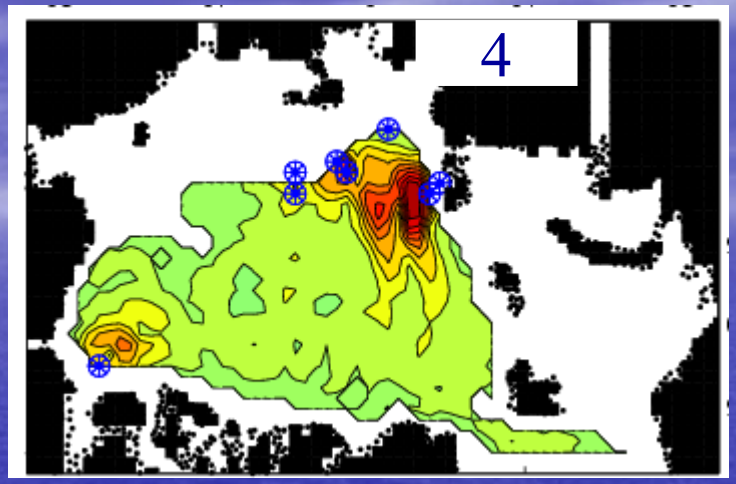
Where is the best location to estimate Bering Strait transport from one mooring?

Reconstructed velocity for 1990-1991 was used for the analysis

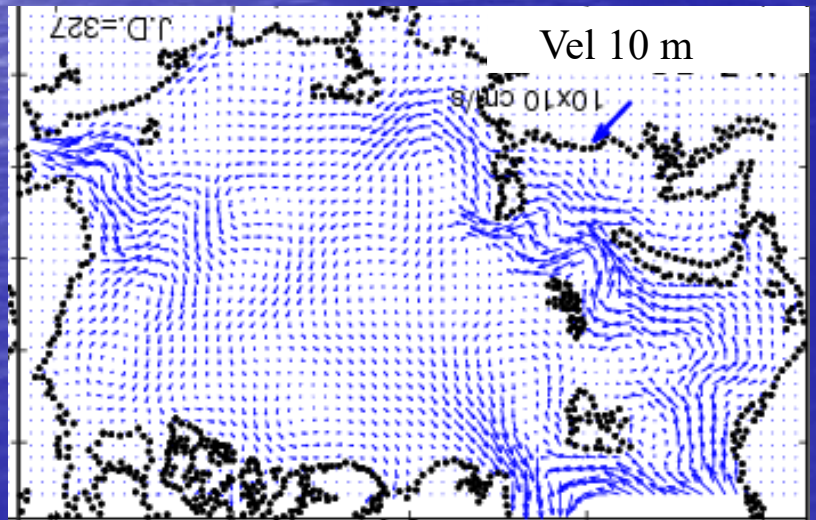
Arctic Ocean Reanalysis 1997-2006

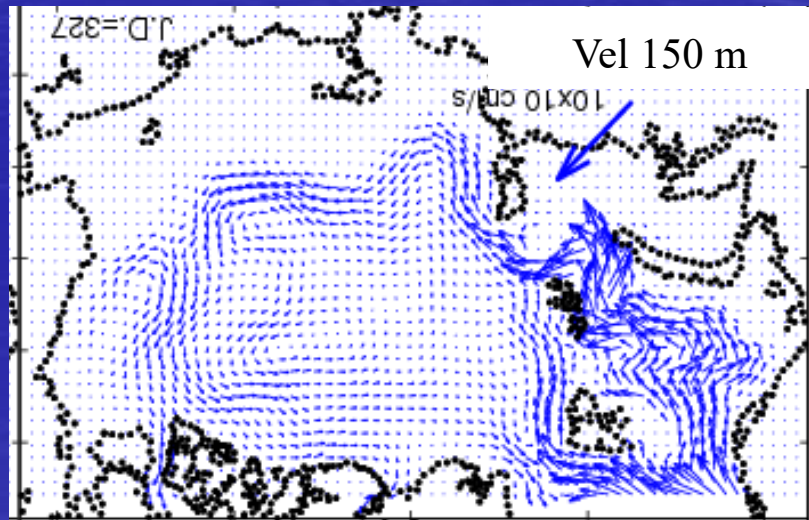
Adjoint sensitivity analysis of the mooring observations in Arctic Ocean





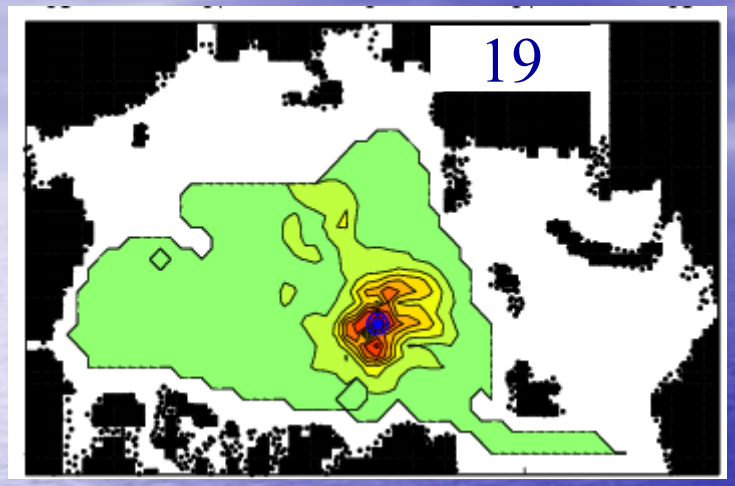
Response of the tangent linear model in the upper layer 0-300m to perturbation of the transport observations in 0-100m after data assimilation.

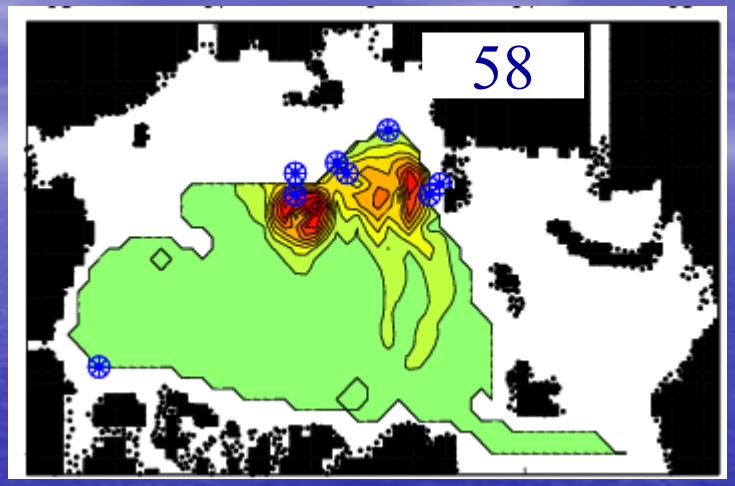


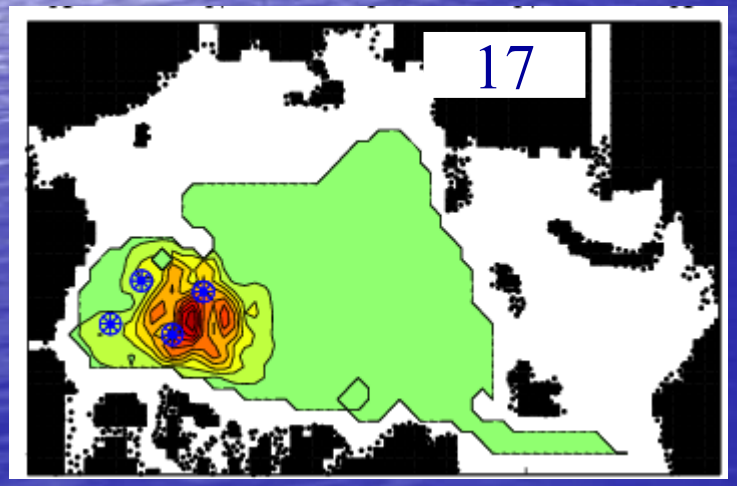


Arctic Ocean Reanalysys 1997-2006

Adjoint sensitivity analysis of the mooring observations in Arctic Ocean





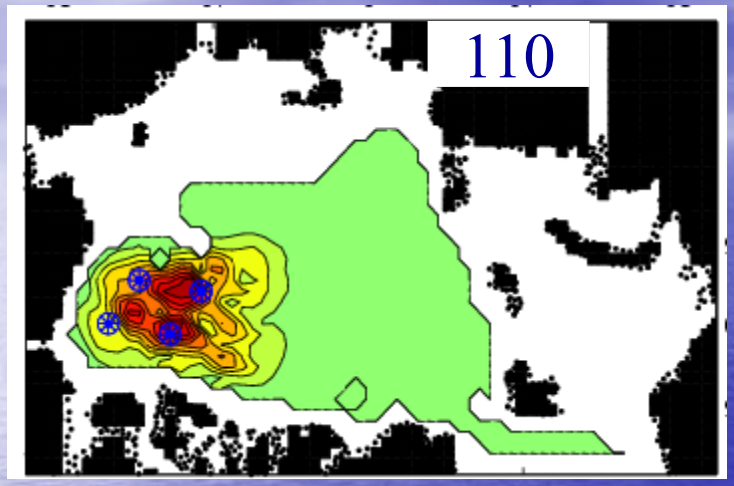


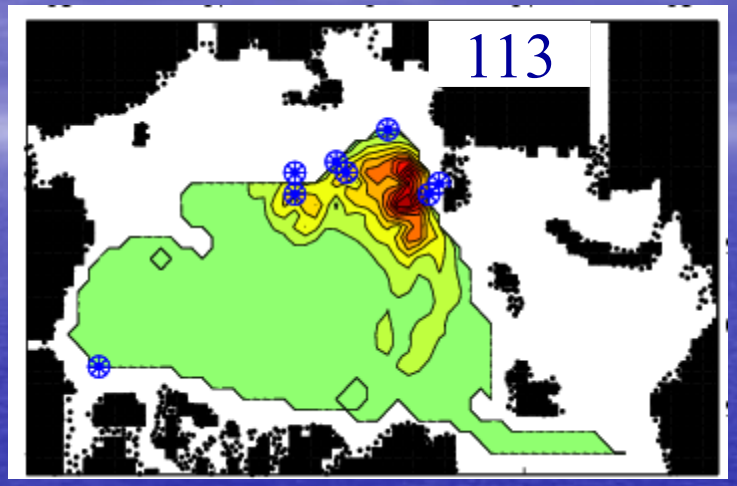
Response of the tangent linear model in the upper layer 0-300m to perturbation of the transport observations in 0-1000m after data assimilation.

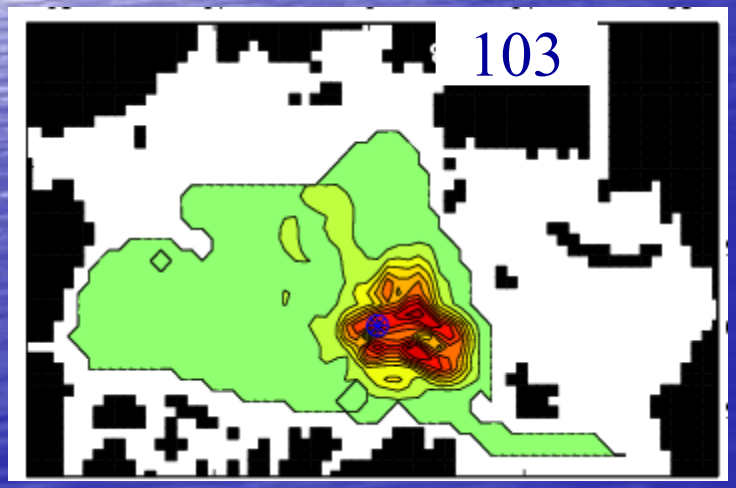
The numbers shows the integral relative sensitivity of the circulation in 0-300m.

Arctic Ocean Reanalysis 1997-2006

Adjoint sensitivity analysis of the mooring observations in Arctic Ocean







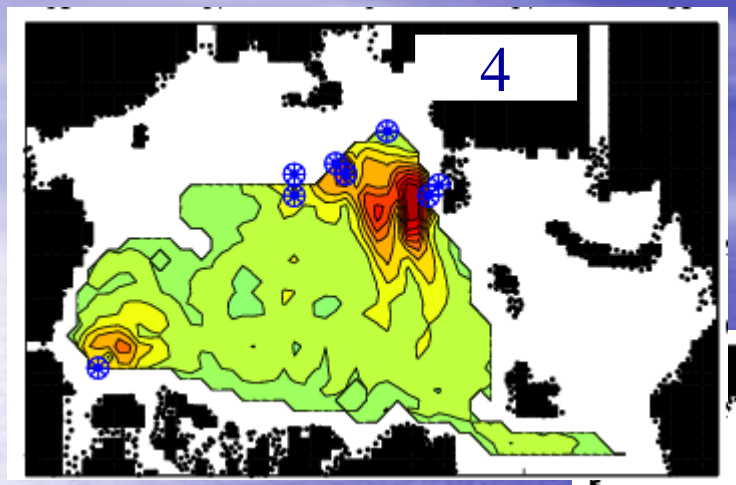
Response of the tangent linear model in the upper layer 0-300m to perturbation of the transport observations in 0-bottom after data assimilation.

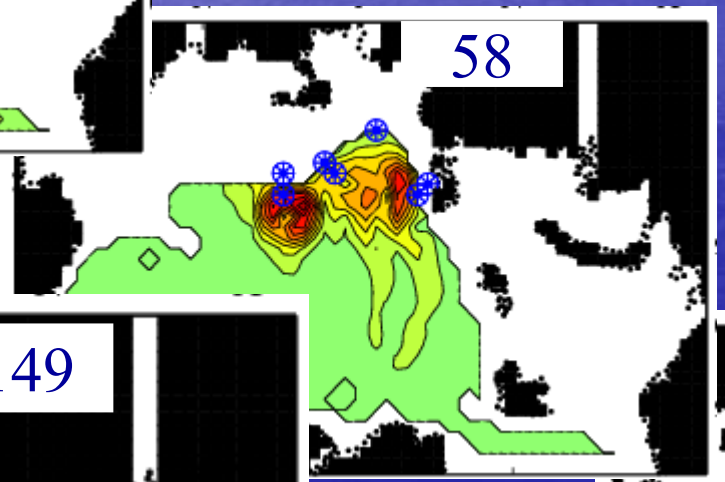
The numbers shows the integral relative sensitivity of the circulation in 0-300m.

Response of the tangent linear model in the upper layer 0-300m to perturbation of the transport observations in 0-100, 0-1000, 0-bottom after data assimilation.

The numbers shows the integral relative sensitivity of the circulation in 0-300m.

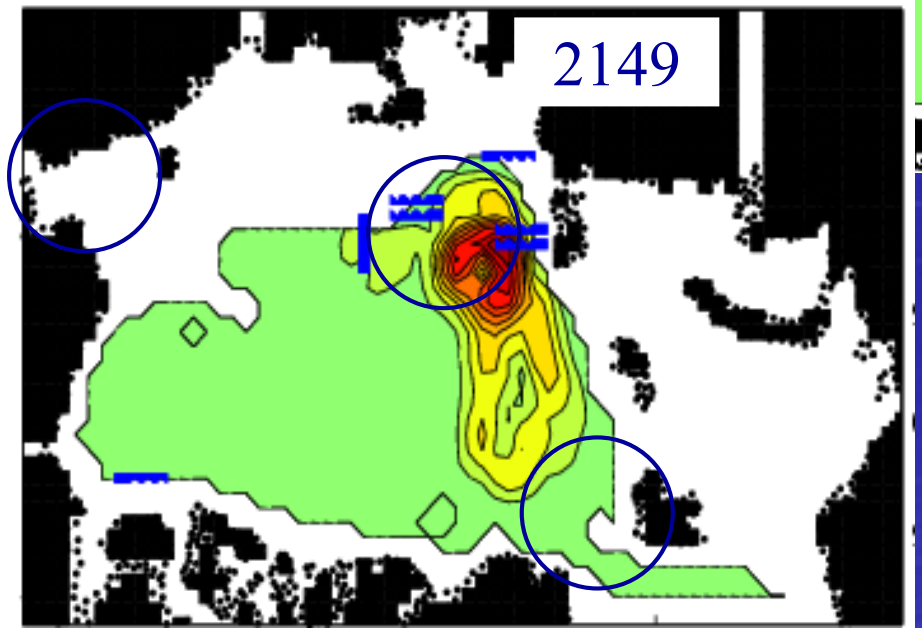
0-100m

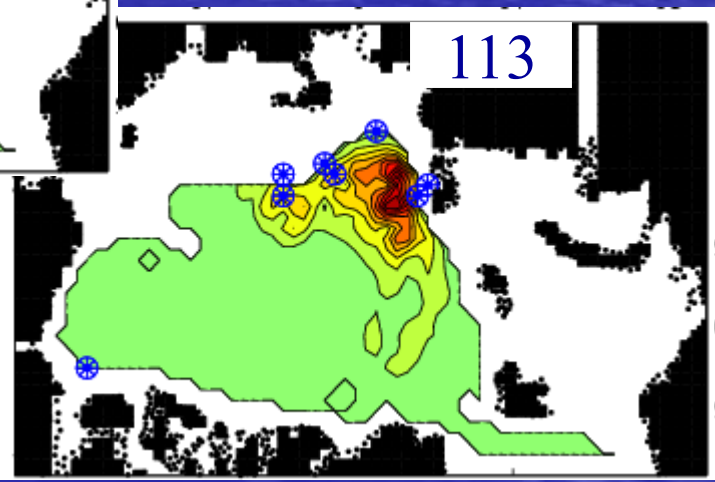




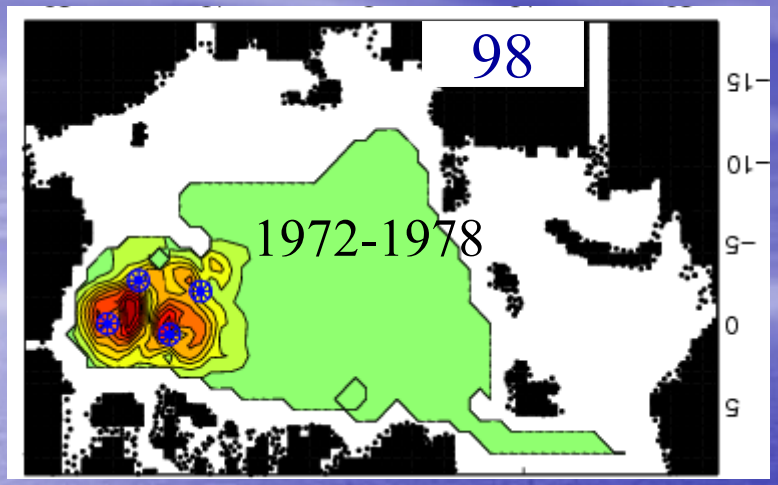
0-1000m

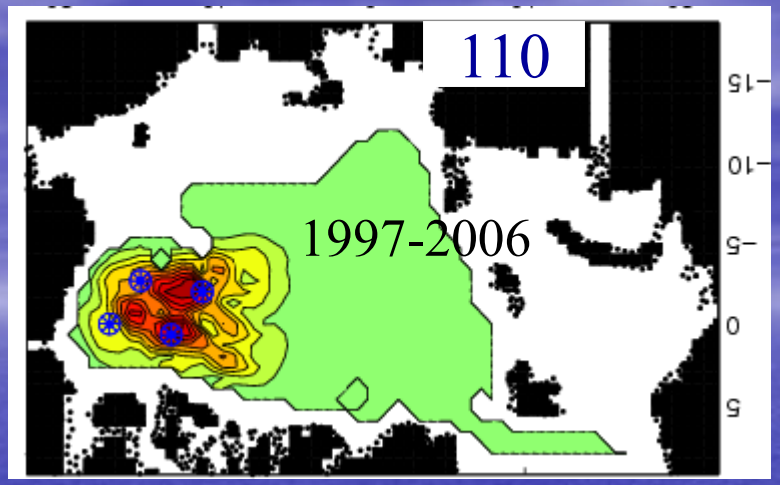
0-bottom



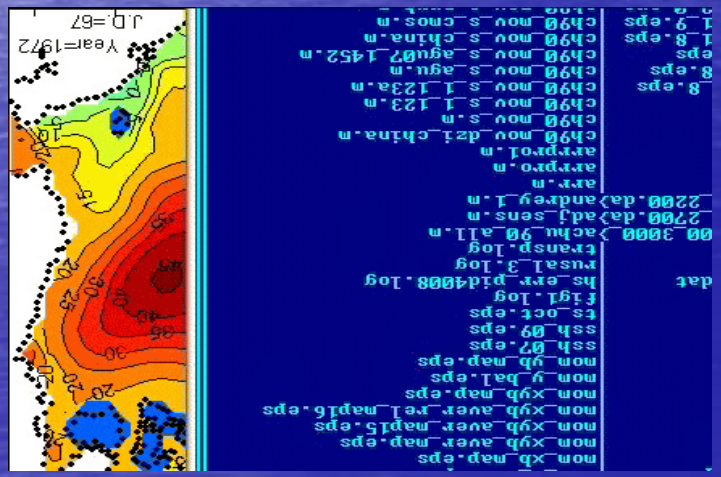


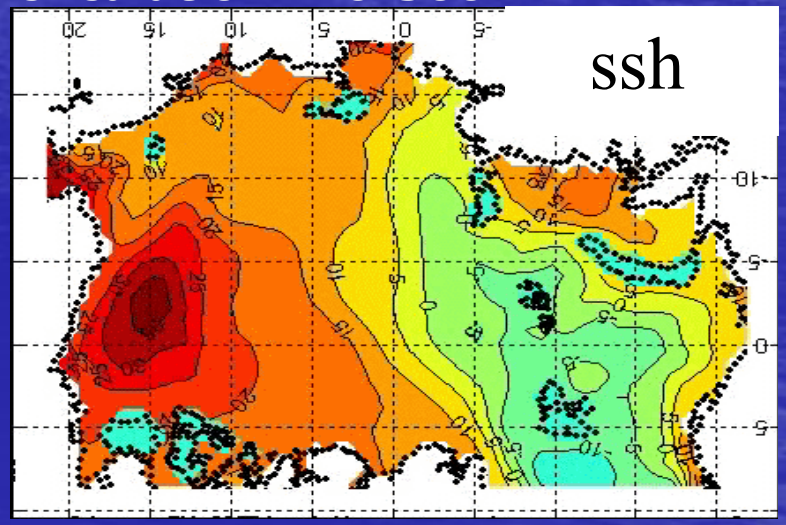
Should we measure along the transects?



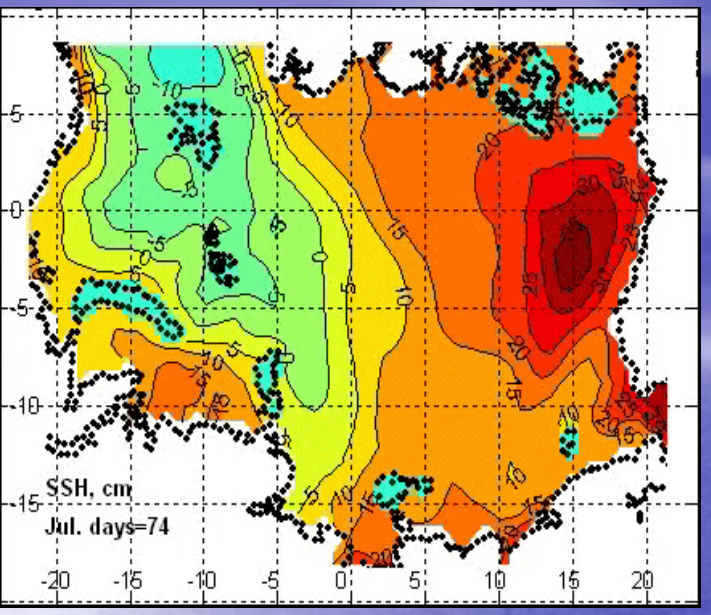


Response of the tangent linear model in the upper layer 0-300m to perturbation of the transport observations in 0-bottom after data assimilation.The numbers shows the integral relative sensitivity of the circulation in 0-300m.





Operational (real time) adaptive adjoint sensitivity analysis is needed!



http://oregon.iarc.uaf.edu

Figure 1. Reconstructed (optimized) circul
In order to get adjoint sensitivity results
(e-mail) and mooring coordinates in the
ATTENTION: The adjoint sensitivity sys
Because of that the current vercion of th
the region with the depth > 1000m.

Your Name: Ded Mozai

Your Email Address: @boloto.ru

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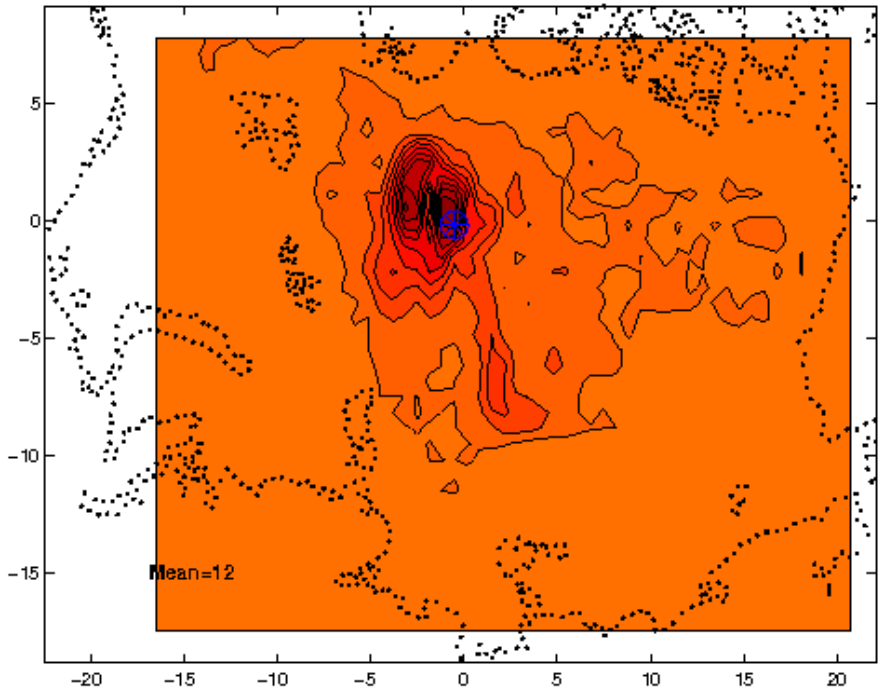

Conclusions

1. The optimized circulation can be used for optimization of the moorings

2. Adjoint sensitivity analysis of the optimized AO circulation allows the following conclusions:

- **Current observational systems (BG, NABOS, NP) do not correlate**
- **It is important to measure the total transport. Observations in upper layer are less valuable.**
- **Transport observations along transects provide larger impact to the reconstruction of the circulation than observations in isolated moorings**
- **According to the circulation in 1990-1991 the best location to estimate the Bering Strait transport is the mooring located in the US region of the Bering Strait**
- **Real time, adaptive (in real time) sensitivity is needed.**

3. Optimization of one mooring is straightforward, but
how to find optimal position for 10 moorings?
how to optimized positions for ARGO or other drifters?
how to optimize the CTD survey?