ECCO Update

GODAE OceanView Meeting, Paris, Nov., 14-18 2011

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Main partners: JPL, MIT, AER, SIO, Univ. Hamburg

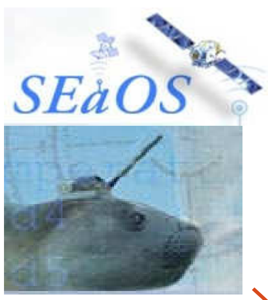
National Oceanographic Partnership Program

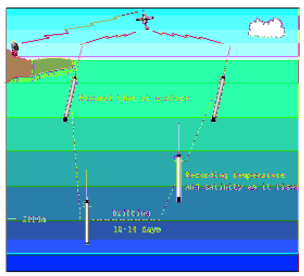
ECCO Global Ocean-Sea Ice Synthesis

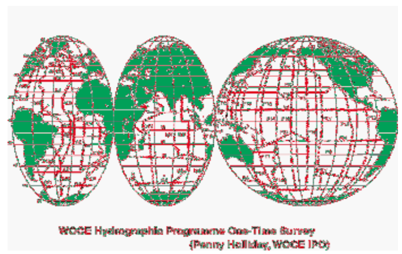
- Assimilate a diverse sets of satellite and in-situ observations using inverse methods.
- Ocean state estimation products from 1992 onward, extended routinely (1950-2001 for G-ECCO)
- Mainly gear towards climate & biogeochemistry applications

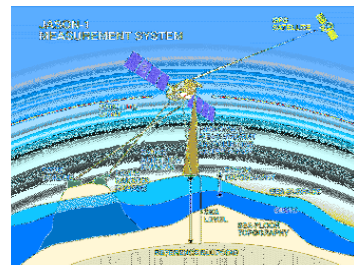
In-situ observations

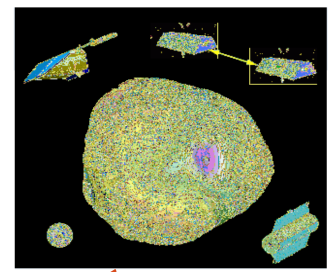
Satellite data

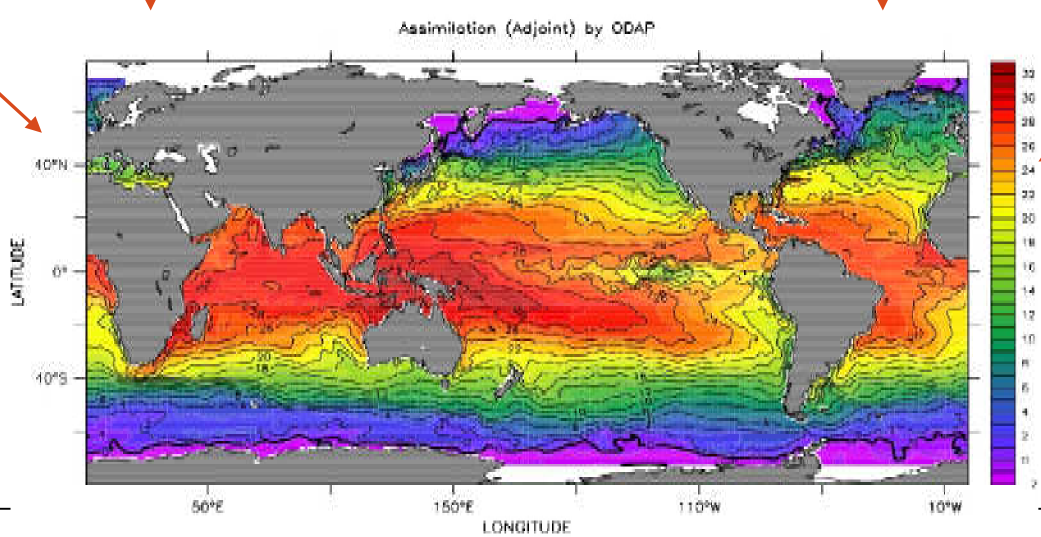






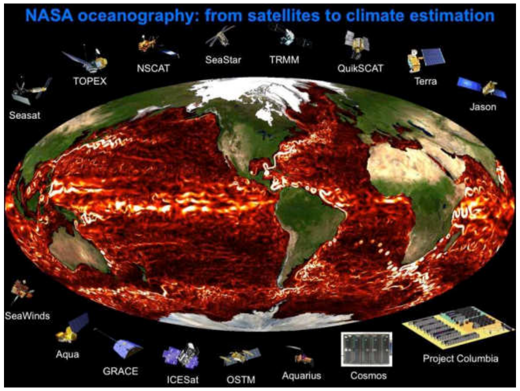






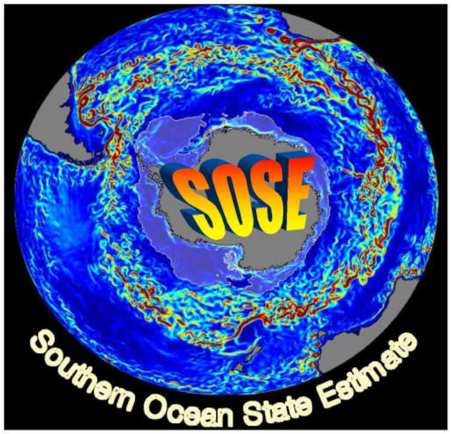
From Global to Regional Estimation

Global: (1° to 18 km, 23 to 50 levels)



- Core effort: ECCO Central Solution – a.k.a. ECCO-CLIVAR (adjoint)
- ECCO-JPL near realtime estimation (Kalman filter & smoother)
- ECCO2/3 eddy-permitting estimation (Green's function, adjoint)
- G-ECCO (adjoint, five decades)

Regional (downscaling):



- Southern Ocean
- Tropical Pacific
- Gulf of Mexico
- California Current System

ECCO Central Solution: observations (Table 1) & Key Attributes (Table 2)

Table 1

Variable	Source (Duration) / Reference (Year)
Sea level	TOPEX/Poseidon, Jason-1 & -2 (1992-2010), Geosat-Follow-On (2001-2005), ERS-1/2 (1992-2001), ENVISAT (2002-2008), tide gauges (1992-2010)
climatology (T&S)	Gouretski and Koltermann (2004)
Temperature	CTDs (1992-2010), XBTs (1992-2010), Argo floats (1997-2010), TOGA/TAO+PIRATA moorings (1992-2010), Southern Elephant seals as Oceanographic Samplers (SEaOS; 2006-2008), RAPID moorings (2004-2010)
Salinity	CTDs (1992-2010), Argo floats (1997-2010), SEaOS (2006-2008)
SST	AVHRR (1992-2010), TMI (1998-2010), AMSR-E (2002-2010)
Sea surface salinity	thermosalinographs (Etudes Climatiques de l'Ocean Pacifique,1992-1999)
Key transports	Florida Strait transport (1992-2010)
Sea ice concentration	SSM/I (1992-2010)
Time-mean SSH	GRACE (2002-2010), altimetry (1992-present)
Ocean bott. press.	GRACE (2002-2010)
Wind stress	NSCAT (1996-1997), QuikSCAT (1999-2008), ERS-1/2 (1992-2001)

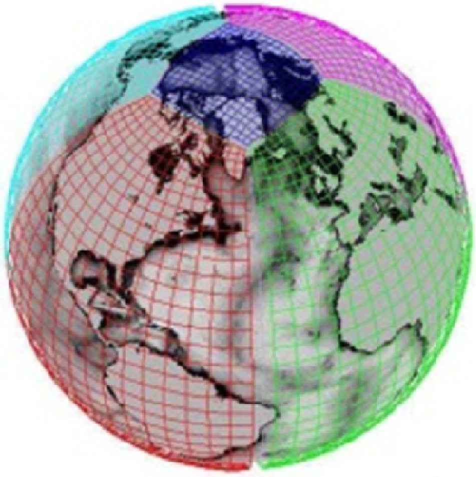
Table 2

	In data server	In production	Upcoming	
Attribute	**V2**	**V3**	**V4**	**NRT**
Synthesis method	adjoint	adjoint	adjoint	RTS smoother
Period	1992-2004	1992-2010	1992-present	1992-present
Observations	Table 1	Table 1	Table 1	sea level & T profiles
Model domain (horiz. Resolution/vert. levels/extent)	1°/23/80°S~80°N	1°/23/80°S~80°N	1°/23/90°S~90°N	0.3°~1°/46/80°S~79°N
Sea-ice model	diagnostic	prognostic	prognostic & adjoint	diagnostic
Forcing	fluxes	bulk formula	bulk formula	fluxes
Controls	initial condition, air-sea fluxes	initial condition, atmospheric state	initial condition, atmospheric state model parameters	initial condition, wind stress

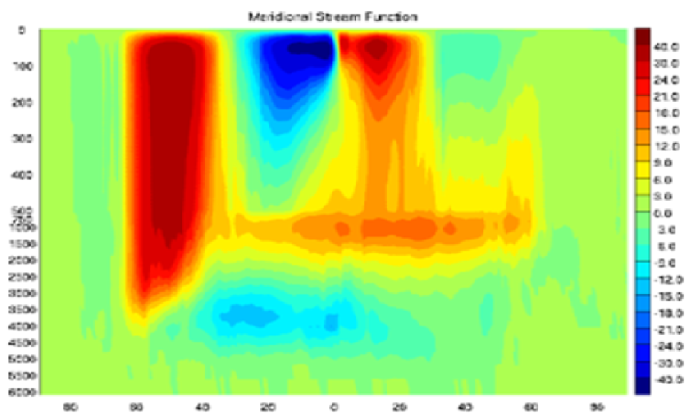
Version 4 of ECCO Central Solution

- Inclusion of the Arctic Ocean
- Prognostic sea ice model & its adjoint
- Inclusion of mixing parameters as control

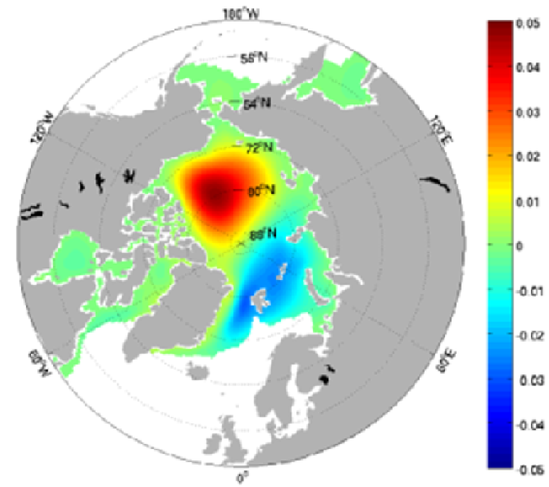
Global grid



Estimated time-mean global MOC

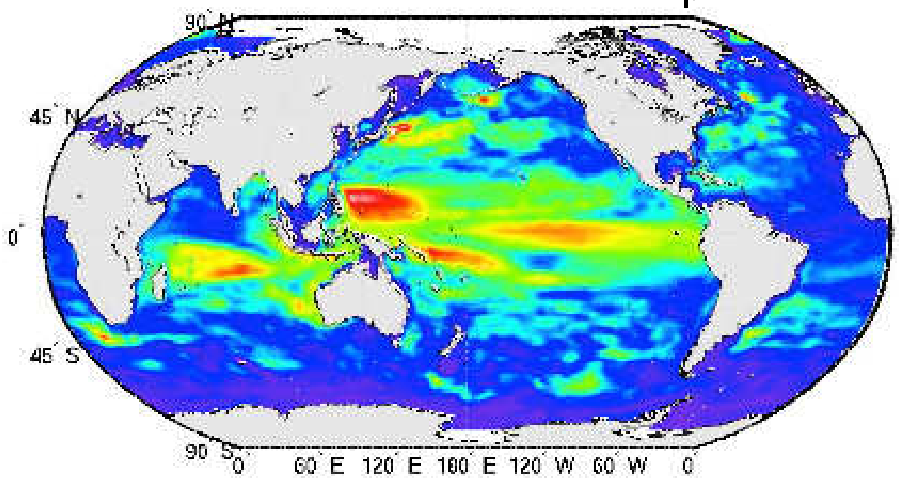


Estimated sea ice circulation



Understanding sea level budget: wind-forced variability

Total Variability ζ_ρ^W

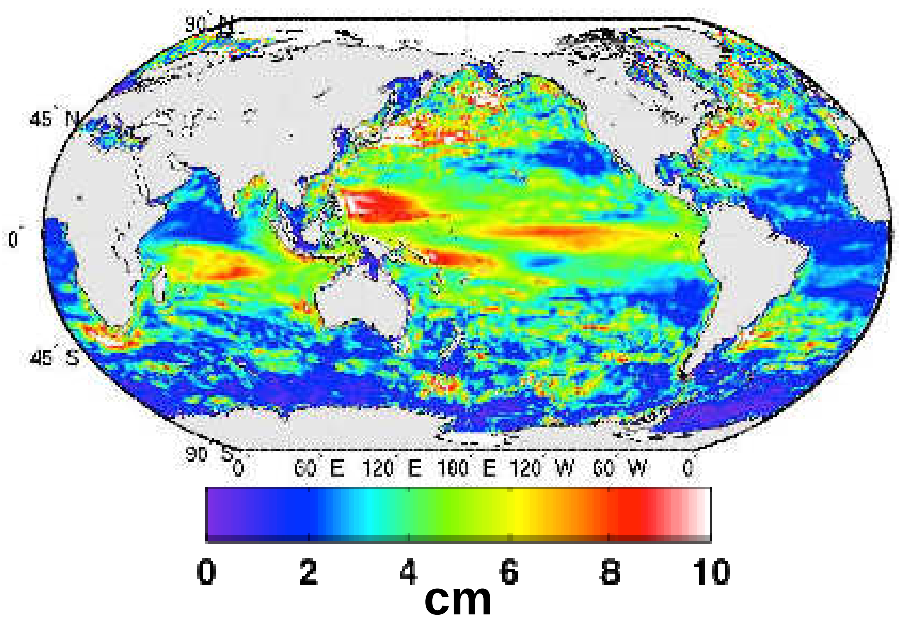


Steric height budget:

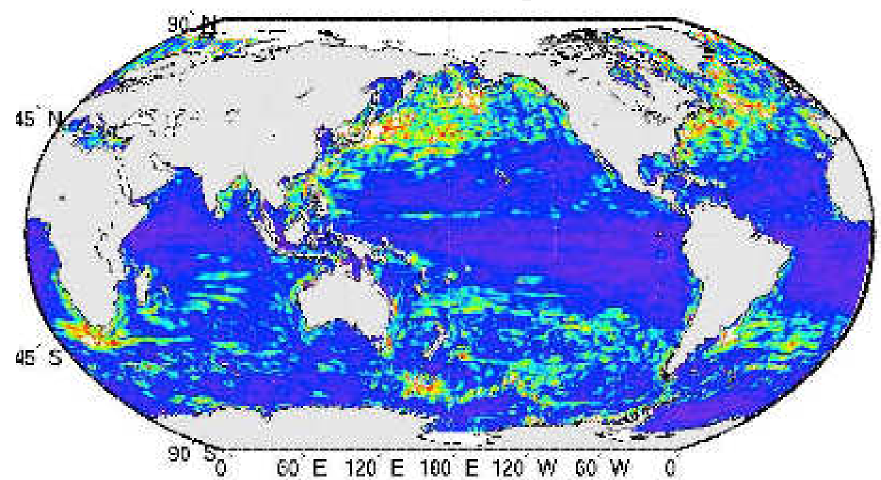
$$\zeta_\rho = A + M + F$$

Piecuch & Ponte (2011) GRL **38**

Advective Transport A^W

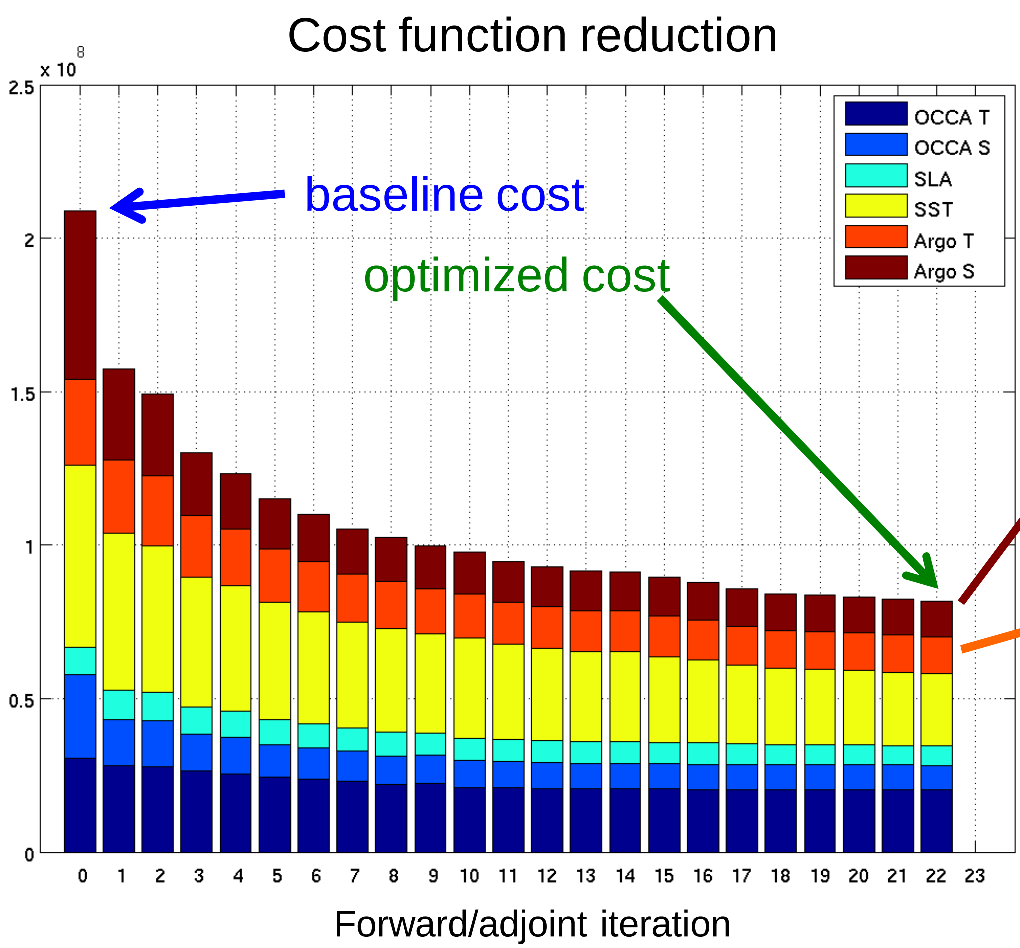


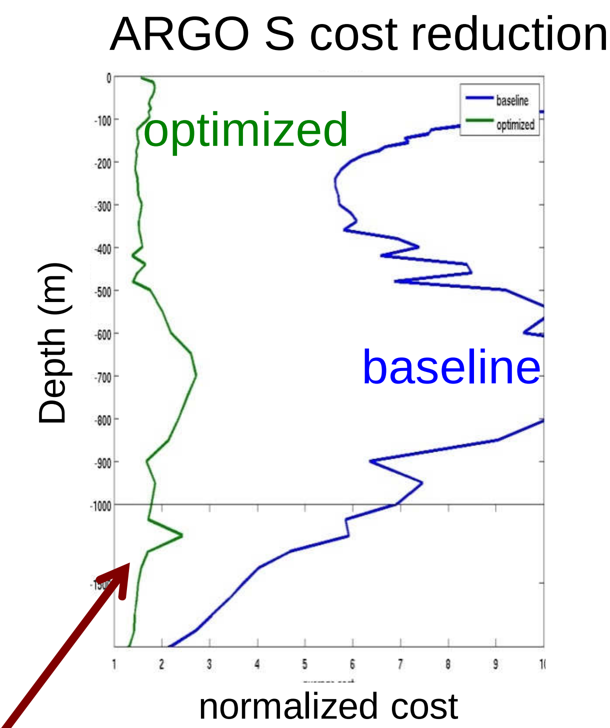
Diffusive Transport M^W

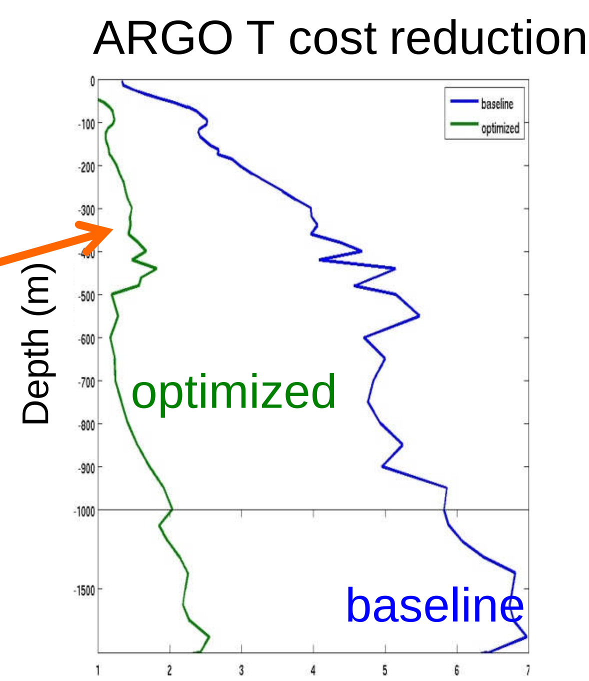


ECCO2 adjoint-based optimization of an eddying global-ocean & sea ice MITgcm configuration

- Data constraints currently include JASON SLA, AMSR-E SST, ARGO T/S profiles, and OCCA T/S climatology.
- Control variables are initial T/S and atmospheric boundary conditions (wind, precipitation, air temperature and humidity, incoming radiation)

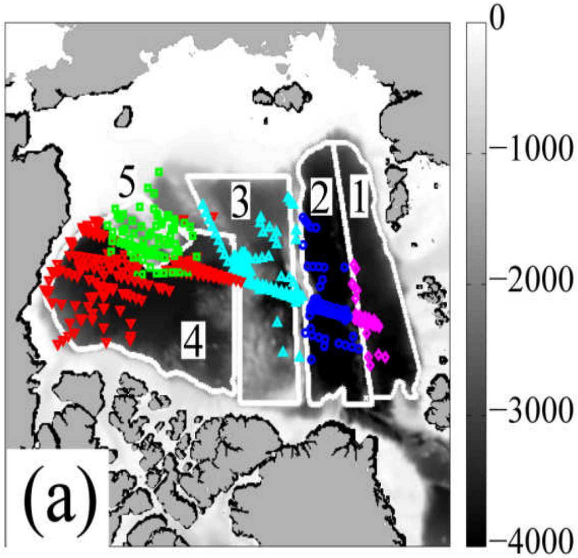




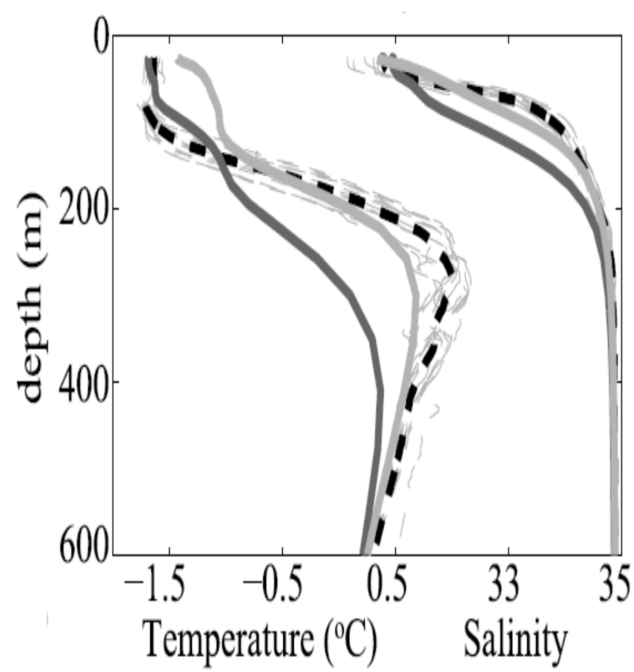


Salt-plume parameterization in ECCO2 improves representation of the Arctic halocline

Arctic hydrographic stations



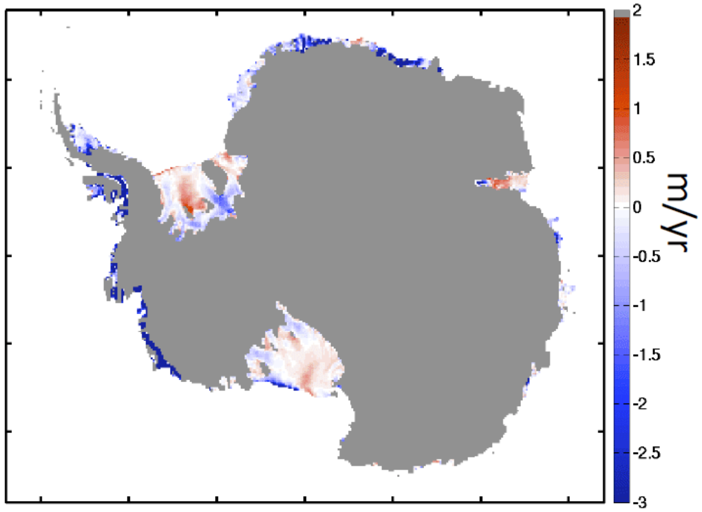
Observations
Baseline simulation
With plume parameterization



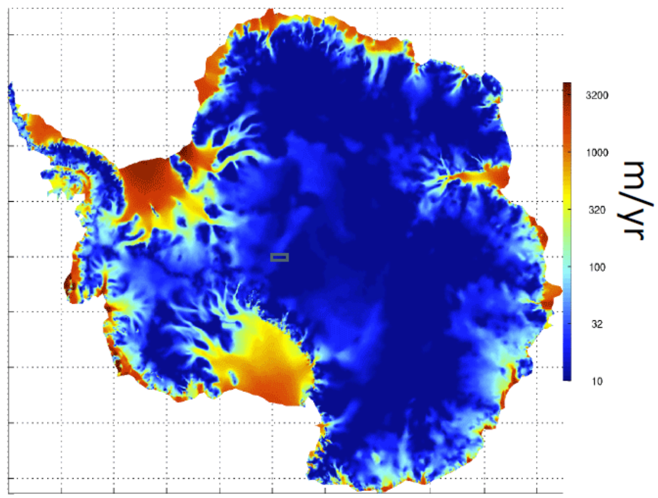
(Nguyen, Menemenlis, and Kwok, 2009)

Toward coupled ocean, land ice simulations

a) ECCO2 ice shelf cavity melt rate



b) ISSM land ice surface velocity



- The interaction between ocean and ice sheets on rather small scales, that is, in sub-ice shelf cavities around Antarctica and in narrow fjords around Greenland, may provide a key link between observed accelerated glacier flow and large scale oceanic variability and circulation changes.

- Critical processes on the oceanic side include topographic steering, eddy variability, tidal mixing, and brine rejection by sea ice.

- For ice sheets, critical processes include grounding line migration and higher-order stress coupling.

- Faithful representation of these ocean/ice-sheet interactions thus emerges as a new frontier for Earth System Models and it may well be the key ingredient in any coupled modeling effort that attempts to quantify and reduce uncertainties in sea level rise projections for the next century.

Adjoint sensitivities of sub-ice shelf melt rates to ocean circulation under Pine Island Ice Shelf, West Antarctica

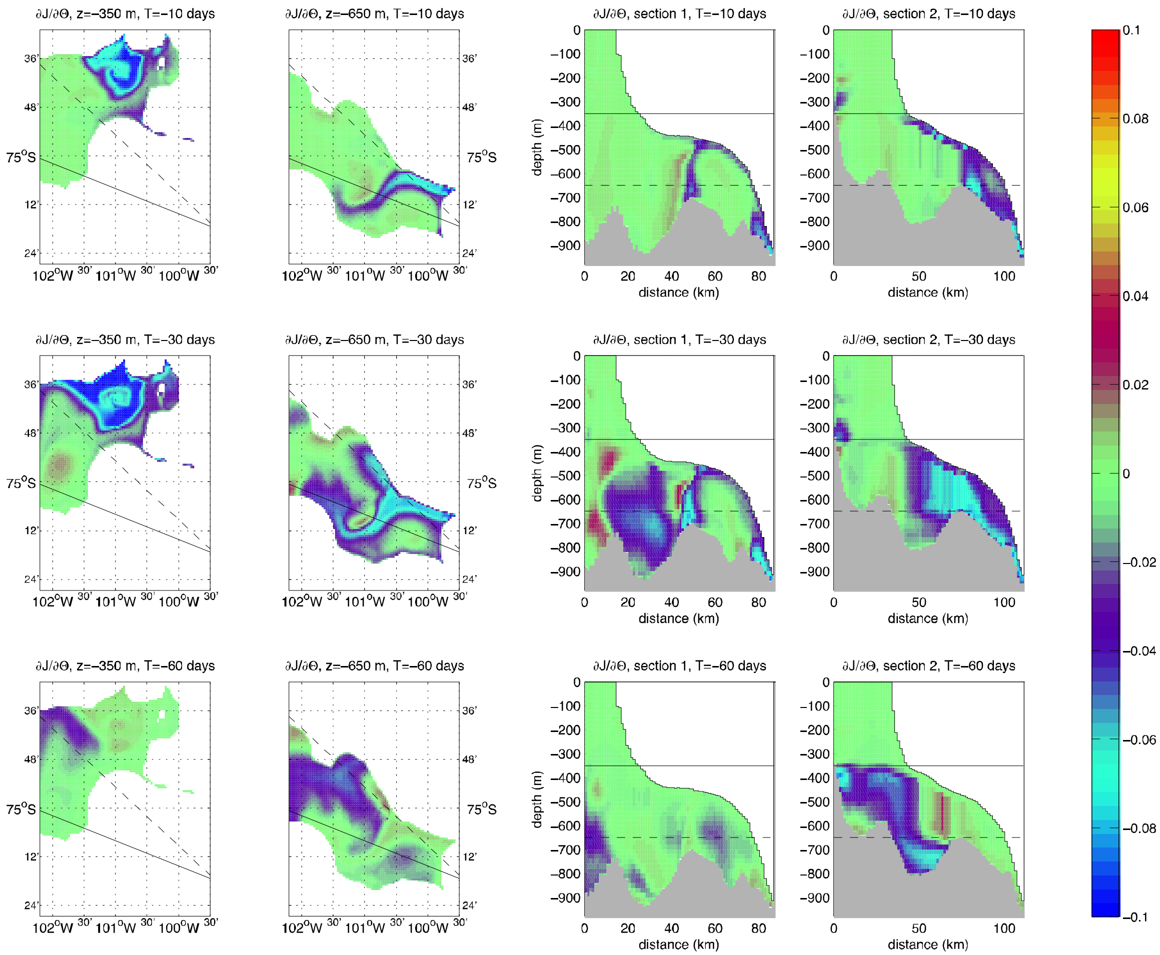


Fig. 4. Adjoint sensitivities $\delta^* T = (\partial J \partial T)^T$ at $t = \tau_f - 10$ days, -30 days, and -60 days. Horizontal slices at $z = -350$ m and $z = -650$ m on the left hand side, vertical sections on the right hand side. The solid lines in the horizontal slice plots indicate section 1 (right-center), and the dashed lines section 2 (far right). The solid and dashed lines in the vertical section plots indicate the positions of the horizontal slices. Units are in $\mathrm{m^3\,s^{-1}\,K^{-1}}$, $0.1\ \mathrm{m^3\,s^{-1}\,K^{-1}} \approx 3\ \mathrm{Mt\,a^{-1}\,K^{-1}} \approx 3\ \mathrm{mm\,a^{-1}\,K^{-1}}$.

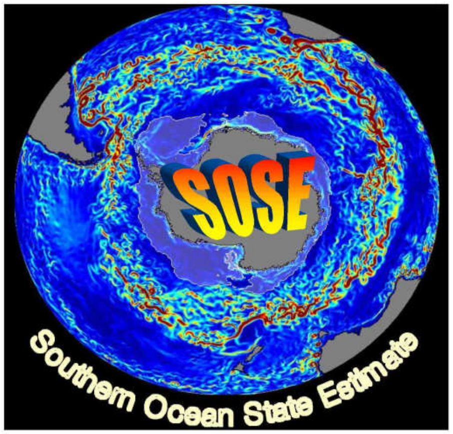
Heimbach and Losch have developed an adjoint model for the MITgcm ice shelf cavity model.

As a first demonstration of this new capability, they investigated the sensitivity of sub-ice shelf melt rates to changes in the oceanic state.

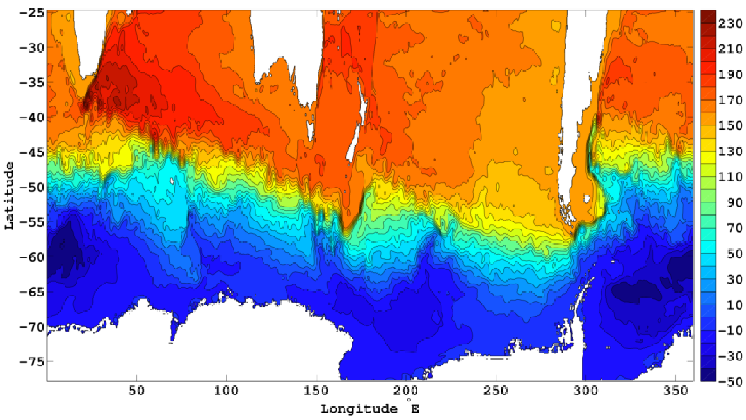
The inferred sensitivities reveal a dominant time scale of roughly 60 days over which the shelf exit is connected to the deep interior.

To the extent that these transient patterns are robust they carry important information for decision-making in observation deployment and monitoring.

(Heimbach and Losch, submitted)

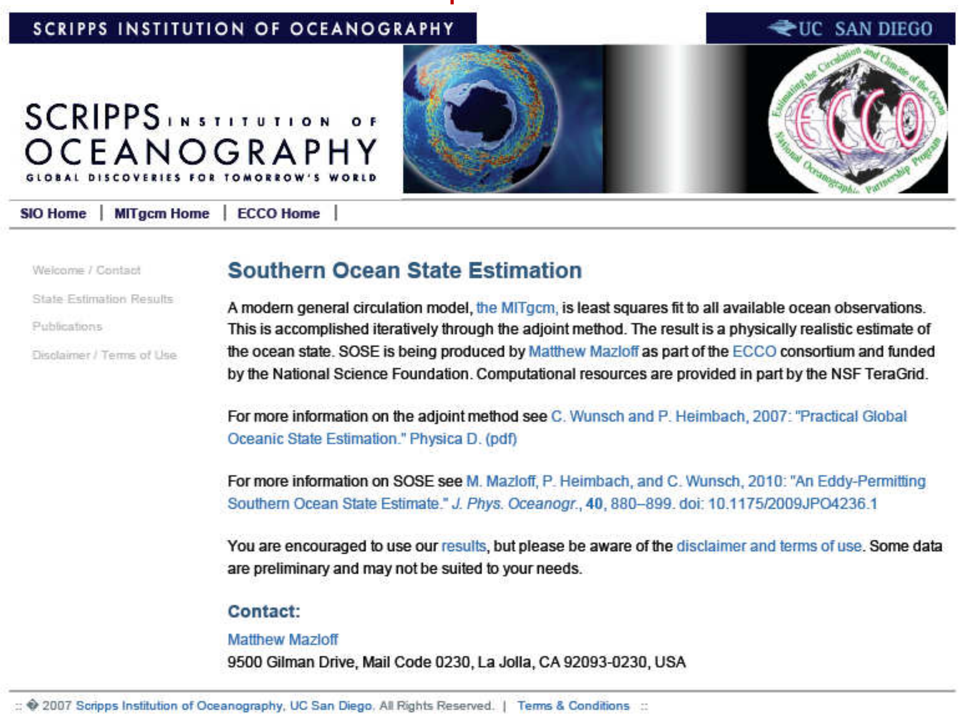


- Domain: 78° South to 24.7° South
- 1/6°, 42 depth levels (partial cells)
- Initial and northern boundary conditions derived from and constrained to G. Forget's (2010) 1° resolution global state estimate (OCCA).
- Full (and adjointable) coupled sea-ice model



Vertically integrated (barotropic) transport streamfunction [Sv] (2005-2006 average)

SOSE solutions available at http://sose.ucsd.edu/DATA/



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Southern Ocean State Estimation

A modern general circulation model, the MITgcm, is least squares fit to all available ocean observations. This is accomplished iteratively through the adjoint method. The result is a physically realistic estimate of the ocean state. SOSE is being produced by Matthew Mazloff as part of the ECCO consortium and funded by the National Science Foundation. Computational resources are provided in part by the NSF TeraGrid.

For more information on the adjoint method see C. Wunsch and P. Heimbach, 2007: "Practical Global Oceanic State Estimation." Physica D. (pdf)

For more information on SOSE see M. Mazloff, P. Heimbach, and C. Wunsch, 2010: "An Eddy-Permitting Southern Ocean State Estimate." *J. Phys. Oceanogr.*, **40**, 880–899. doi: 10.1175/2009JPO4236.1

You are encouraged to use our results, but please be aware of the disclaimer and terms of use. Some data are preliminary and may not be suited to your needs.

Contact:
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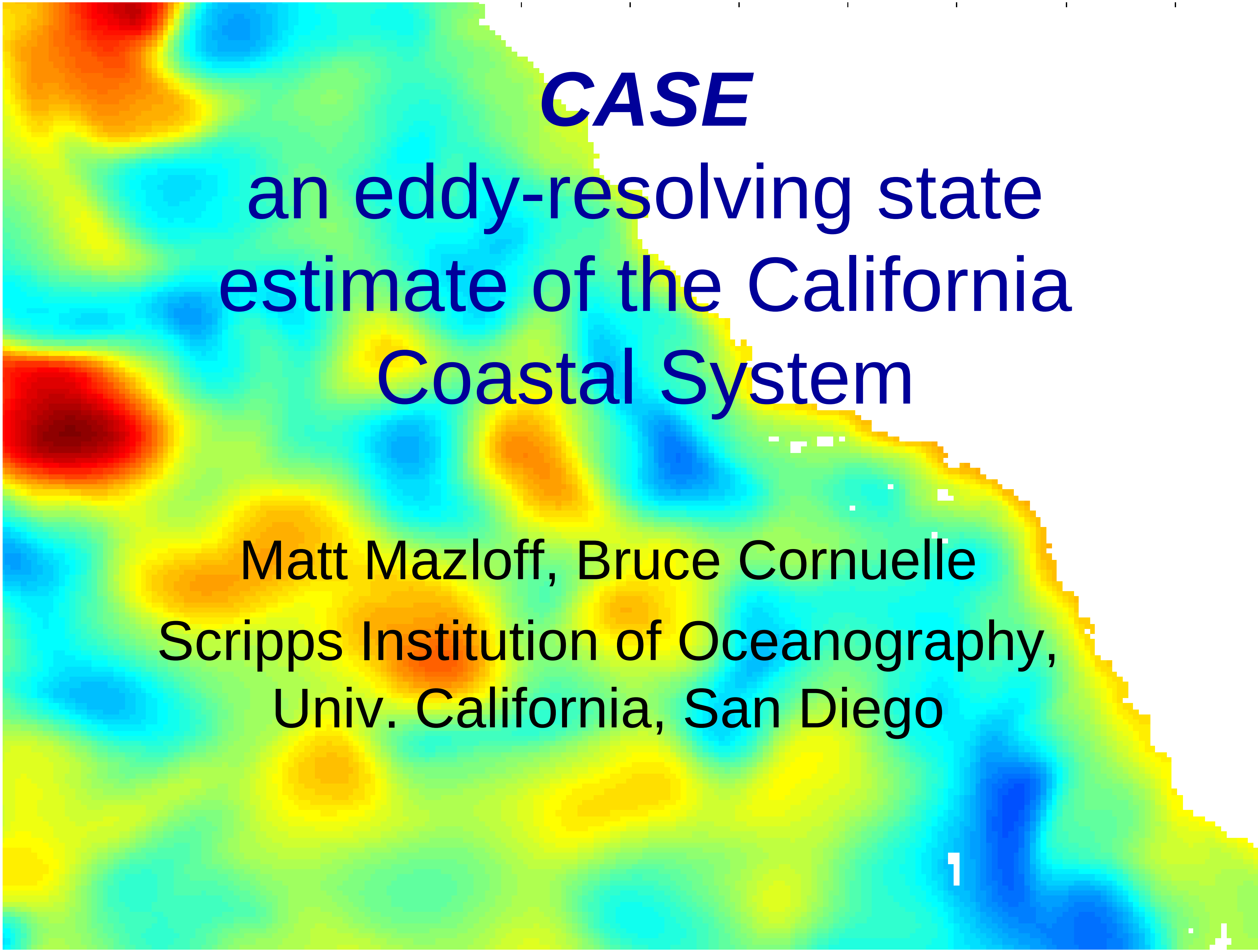
9500 Gilman Drive, Mail Code 0230, La Jolla, CA 92093-0230, USA



CASE
an eddy-resolving state estimate of the California Coastal System

Matt Mazloff, Bruce Cornuelle

Scripps Institution of Oceanography,
Univ. California, San Diego

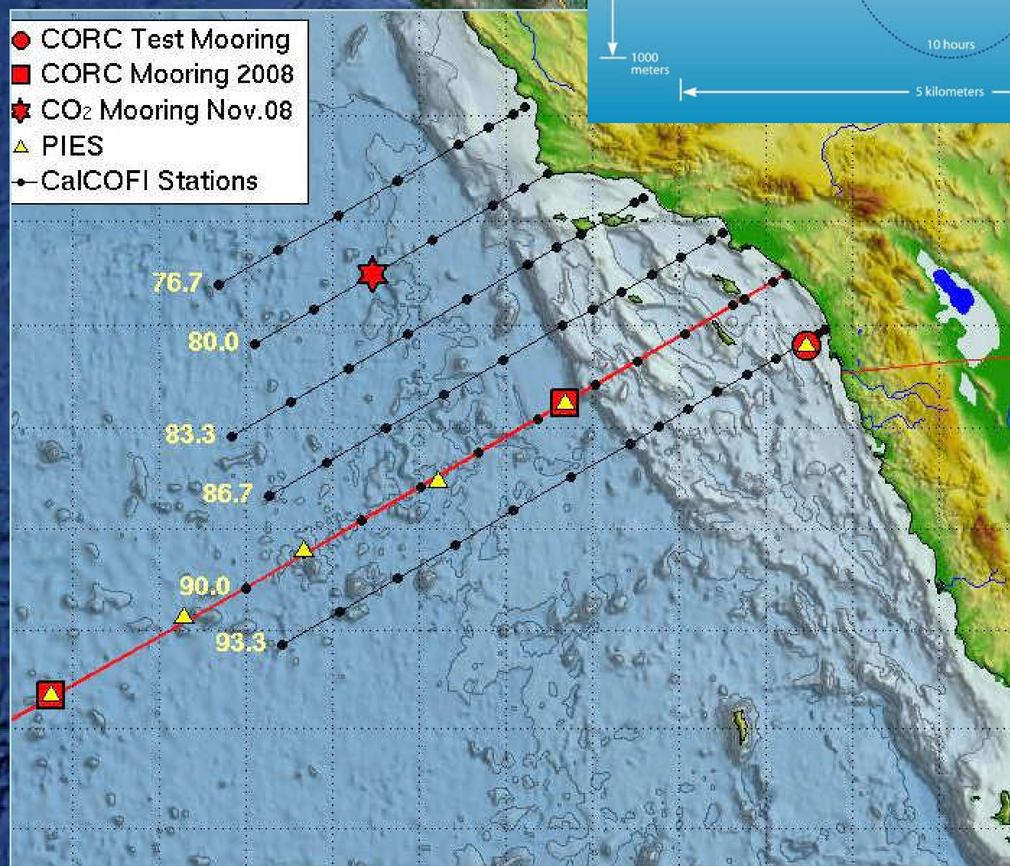
CASE: 1/16° with 72 levels

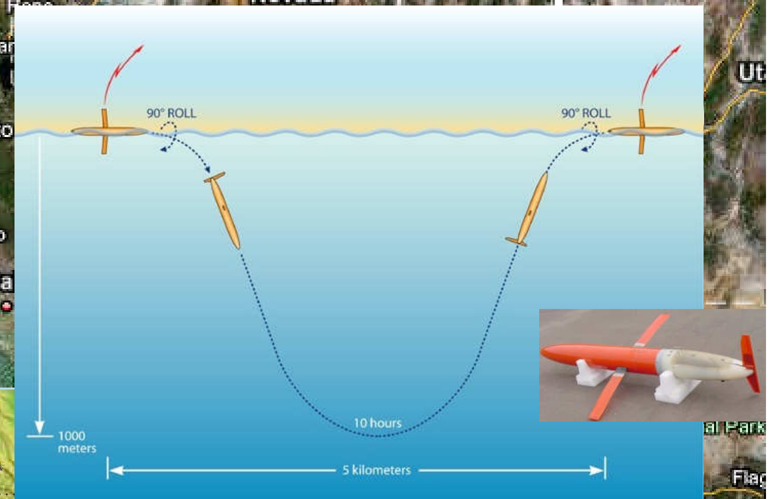
27.2°N – 40°N,

230°E – coast

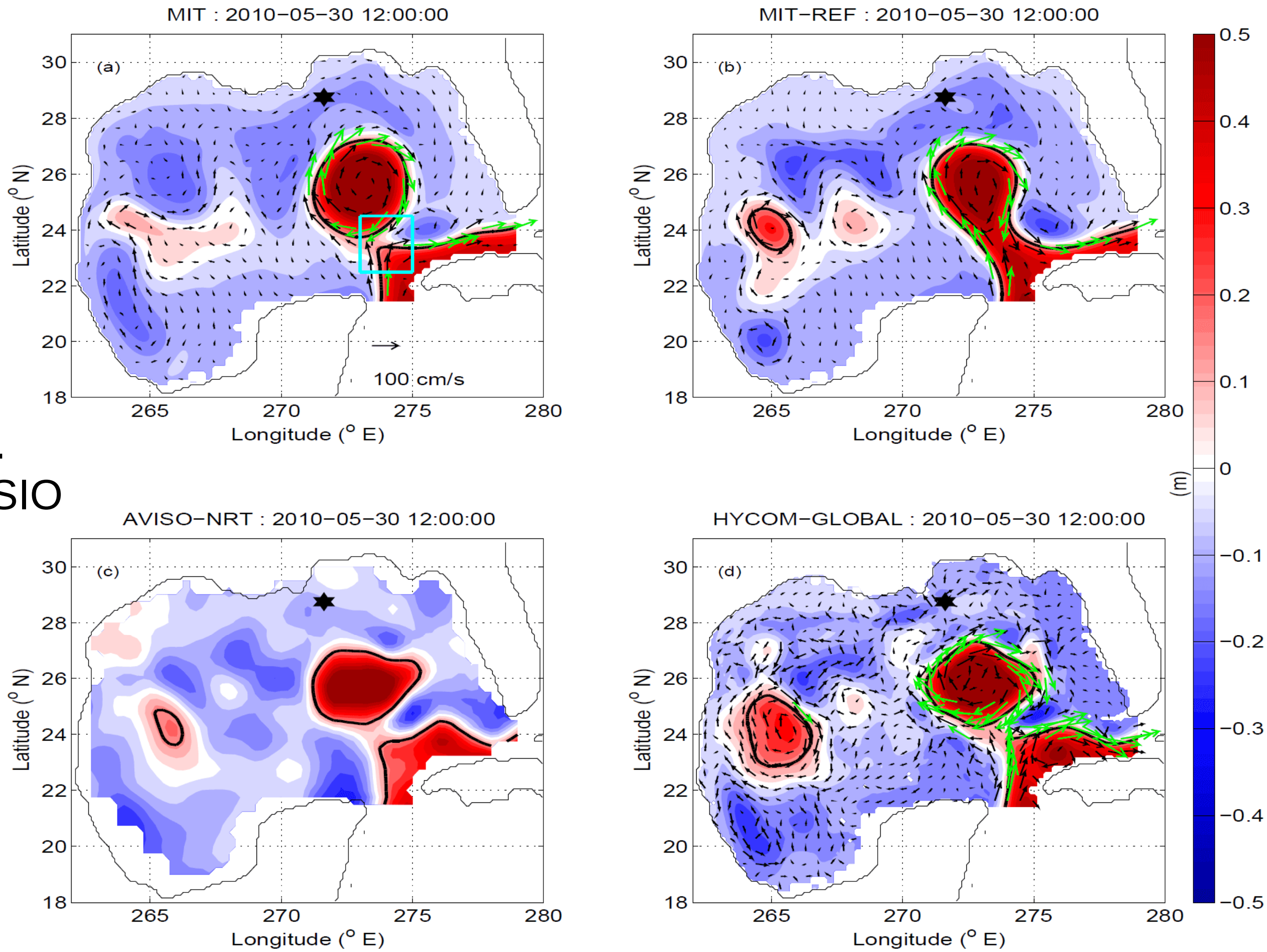
currently Jan 2007 through July 2009

A well observed ocean region (gliders, moorings, PIES, etc.)





Gulf of Mexico Analysis and Forecast



Courtesy B. Cornuelle, SIO

SSH anomaly on May 30 2010: (a) MITgcm one-month forecast; (b) MITgcm REF Run; (c) AVISO analysis, (d) HYCOM global analysis.

Summary

- ECCO Central Solution evolving from version 2 to version 4, with major improvements to handle the Arctic Ocean data assimilation.

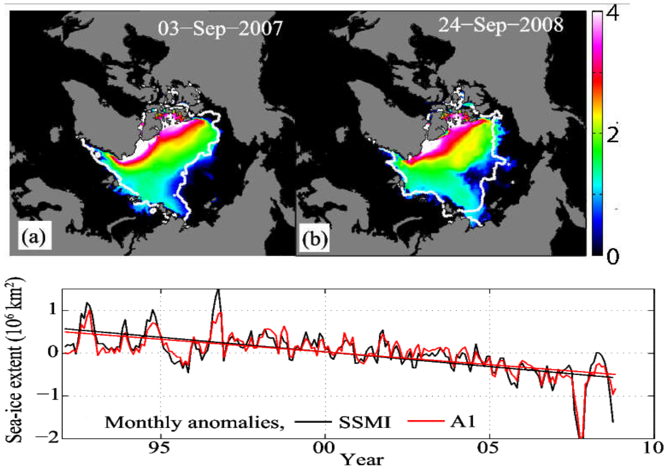
- ECCO-2 evolves towards ECCO-3, with heavy emphasis on ocean-ice shelf interaction and carbon flux studies.

- Various regional high-resolution estimation and ocean forecasting systems.

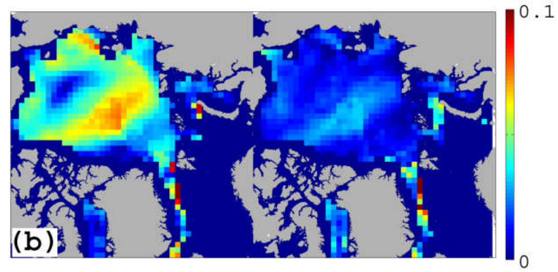
Backup

An optimized, property-conserving Arctic Ocean simulation

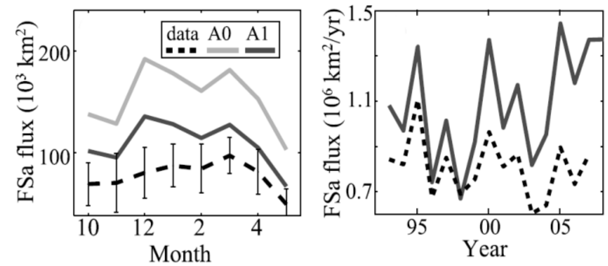
Sea ice extent



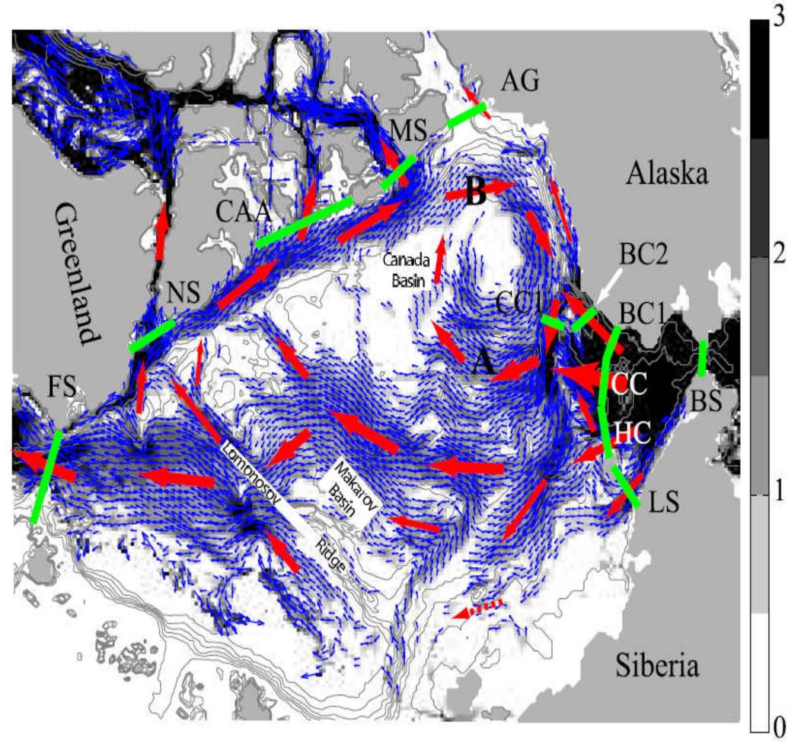
Sea ice velocity



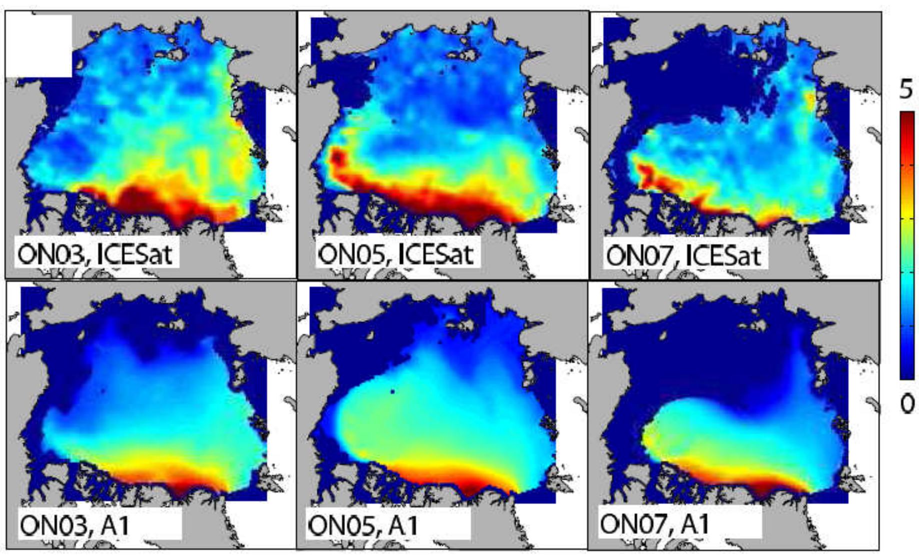
Sea ice flux



Pacific water circulation, upper 200 m (1994-2004)



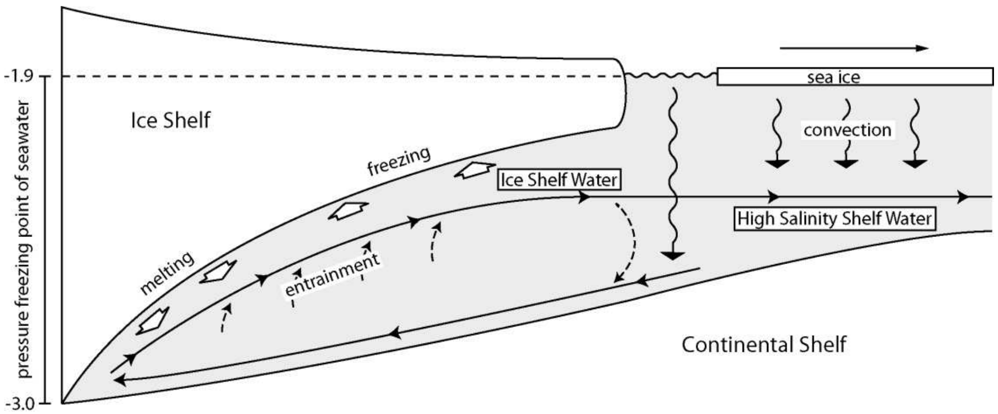
Sea ice thickness

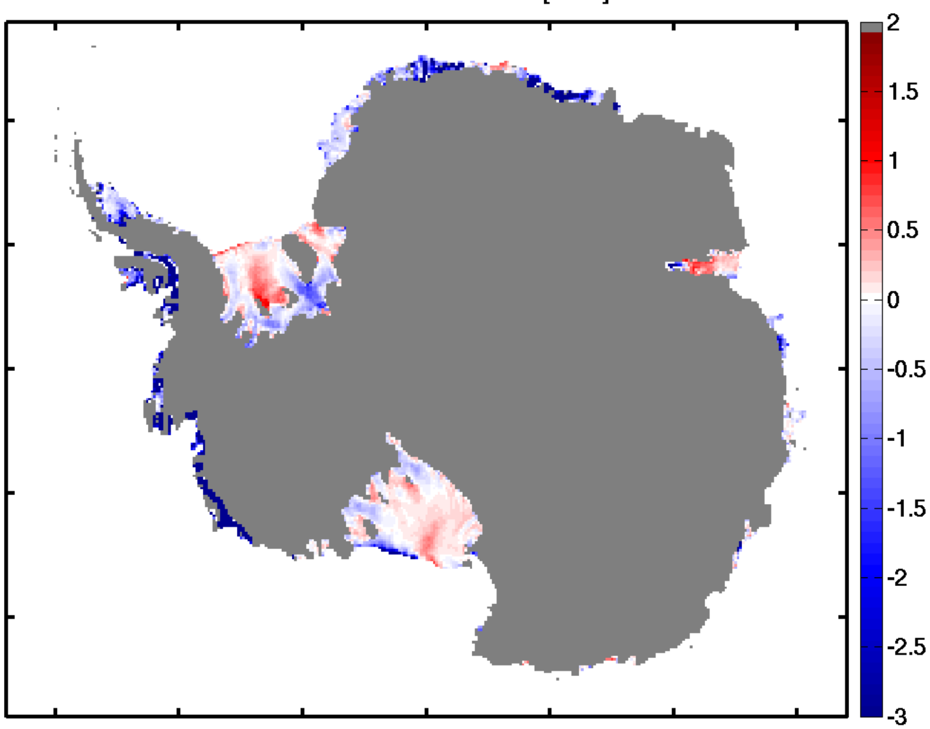


(Nguyen, Menemenlis, and Kwok, 2011)

Modeling ice shelf-ocean interactions

Courtesy of Michael Schodlok





ECCO2 estimates of basal melting
Freshwater flux (59 mSv or 1600 Gt/a) is double previous (BRIOS) estimates, more consistent with mass loss derived from ICESat/GLAS data (55 mSv), comparable in size with iceberg calving (2000 Gt/a).

Antarctic Bottom Water formation
Freshwater input from basal melt decreases High Salinity Shelf Water production, which affects Antarctic Bottom Water production and meridional overturning.

Coupling with ISSM
Experimental coupling with JPL/UCI ISSM is underway for improved estimates of ice shelf-ocean boundary conditions.