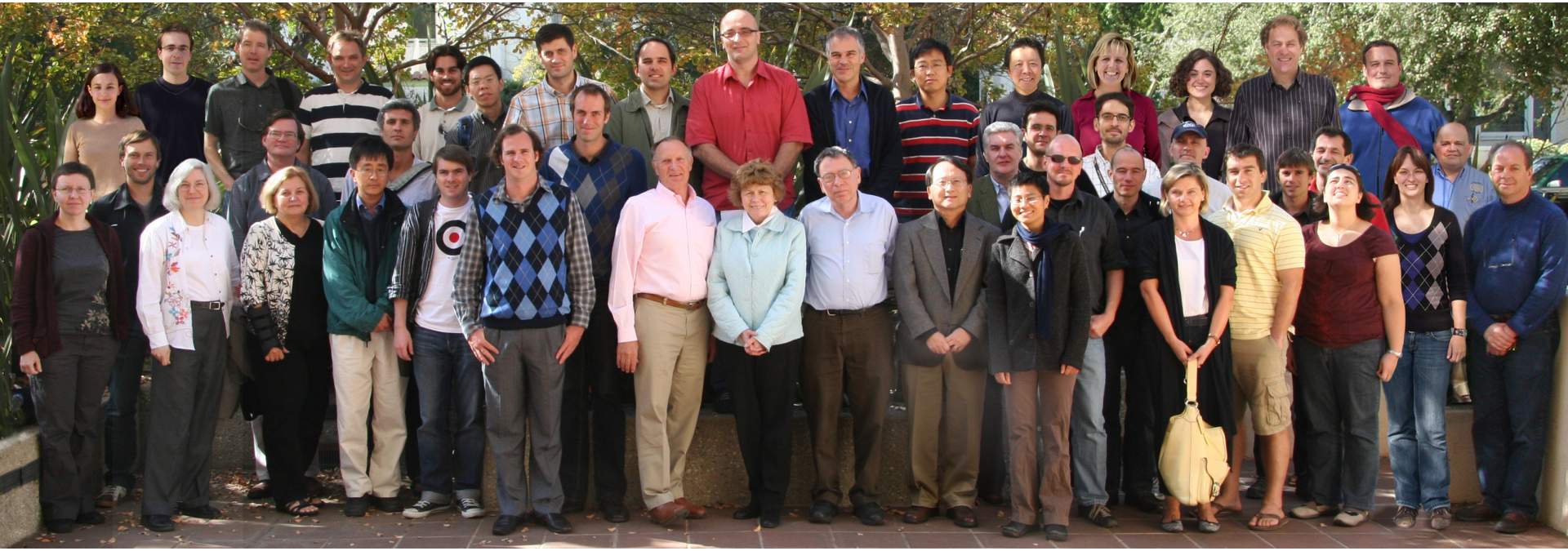
ECCO2 meeting highlights

California Institute of Technology, Pasadena, 9-10 November 2009



A healthy mix of science applications for the high-res solutions is developing, with particular emphasis on eddy processes, polar regions, and ecosystem dynamics.

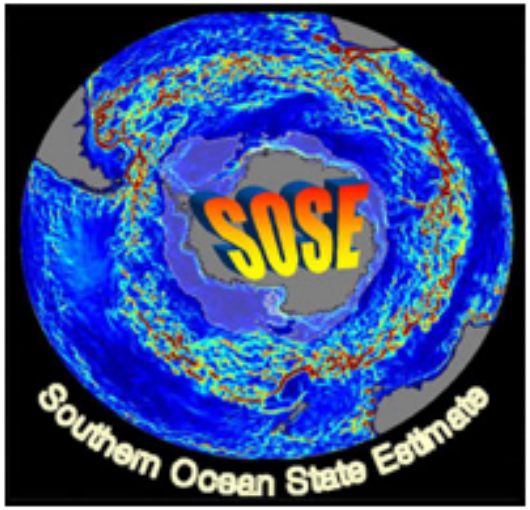
Forward and adjoint model development is progressing at a good pace and the utilization of these tools is spreading to other groups.

The first-ever adjoint-method optimization of a global, eddying, ocean and sea ice model is underway. This optimization is the technical centerpiece of ECCO2.

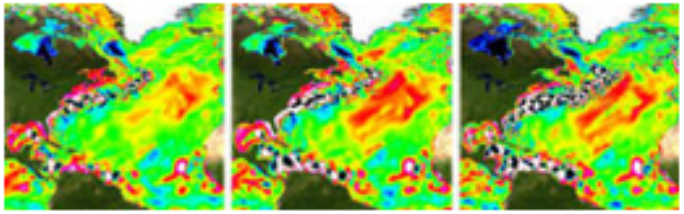
Meeting agenda and presentations at **http://ecco2.jpl.nasa.gov/meetings/2009/ECCO2**

Science applications of the hi-res solutions

- Global cubed-sphere (CS510)



- Southern Ocean State Estimate

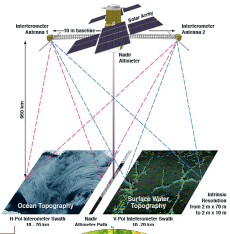


- Isotropic 80S-80N latitude-longitude

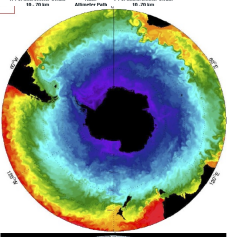
R. Glazman & Y. Golubev, 2005: Variability of the ocean-induced magnetic field predicted at sea surface and at satellite altitudes. *J. Geophys. Res.*, **110**, C12011.
R. Kwok, G. Cunningham, H. Zwally, and D. Yi, 2006: ICESat over Arctic sea ice: Interpretation of altimetric and reflectivity profiles. *J. Geophys. Res.*, **111**, C06006.
G. Forget and C. Wunsch, 2007: Global hydrographic variability and the data weights in oceanic state estimates. *J. Phys. Oceanogr.*, **37**, 1997.
R. Ponte, C. Wunsch, and D. Stammer, 2007: Spatial mapping of time-variable errors in Jason-1 and TOPEX/POSEIDON sea surface height measurements. *J. Atmos. Ocean. Technol.*, **24**, 1078.
X. Davis, 2008: Numerical and theoretical investigations of North Pacific Subtropical Mode Water with implications to Pacific climate variability. Ph.D. thesis, University of Rhode Island, Kingston.
B. Fox-Kemper and D. Menemenlis, 2008: Can Large Eddy Simulation Techniques Improve Mesoscale Rich Ocean Models? *Ocean Modeling in an Eddying Regime*, AGU, 319-338.
R. Kwok, E. Hunke, W. Maslowski, D. Menemenlis, and J. Zhang, 2008: Variability of sea ice simulations assessed with RGPS kinematics. *J. Geophys. Res.*, **131**, C11012.
M. Mazloff, 2008: The Southern Ocean meridional overturning circulation as diagnosed from an eddy permitting state estimate. Ph.D. thesis, MIT/WHOI, Cambridge, MA.
D. Volkov and L. Fu, 2008: The role of vorticity fluxes in the dynamics of the Zapiola Anticyclone. *J. Geophys. Res.*, **113**, C11015.
D. Volkov, T. Lee, and L. Fu, 2008: Eddy-induced meridional heat transport in the ocean. *Geophys. Res. Lett.*, **35**, L20601.
A. Condron, P. Winsor, C. Hill, and D. Menemenlis, 2009: Response of the Arctic freshwater budget to extreme NAO forcing. *J. Climate*, **22**, 2422.
M. Manizza, et al., 2009: Modeling transport and fate of riverine dissolved organic carbon in the Arctic Ocean. *Global Biogeochem. Cycles.*, **23**, GB4006.
A. Nguyen, D. Menemenlis, and R. Kwok, 2009: Improved modeling of the Arctic halocline with a sub-grid-scale brine rejection parameterization. *J. Geophys. Res.*, **114**, C11014.
L.-L. Fu, 2009: Pattern and velocity propagation of the global ocean eddy variability. *J. Geophys. Res.*, **114**, C11017.
R. Abernathey, J. Marshall, M. Mazloff, and E. Shuckburgh, in press: Enhancement of mesoscale eddy stirring at steering levels in the Southern Ocean. *J. Phys. Oceanogr.*
I. Hoteit, B. Cornuelle, and P. Heimbach, in press: An eddy-permitting, dynamically consistent adjoint-based assimilation system for the Tropical Pacific. *J. Geophys. Res.*
M. Mazloff, P. Heimbach, and C. Wunsch, in press: An eddy-permitting Southern Ocean State Estimate. *J. Phys. Oceanogr.*
L. Zanna, P. Heimbach, A. Moore, and E. Tziperman, in press. Optimal growth of Atlantic SST anomalies in an idealized ocean GCM. *J. Phys. Oceanogr.*

Reprints and a more complete list of ECCO2 and ECCO-GODAE publications are available at http://ecco2.org/manuscripts

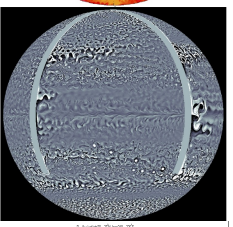
Ongoing ECCO2 applications pertaining to eddy processes



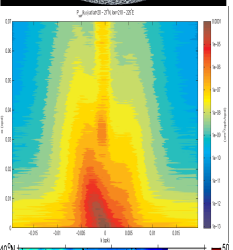
E. Rodriguez & L.-L. Fu
SWOT mission design



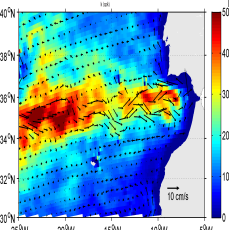
R. Abernathey et al.
Estimating effective diffusivities



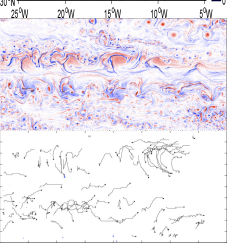
J. Marshall et al.
GFD studies on CS510 grid



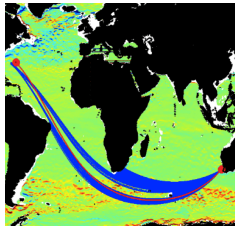
C. Wunsch et al.
Eddy field in model and data



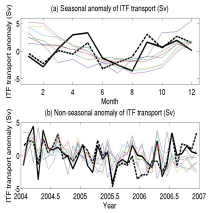
D. Volkov & L.-L. Fu
Variability of Azores current



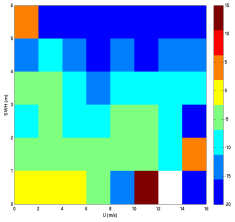
C. Ubelmann
Vortices in Tropical Pacific



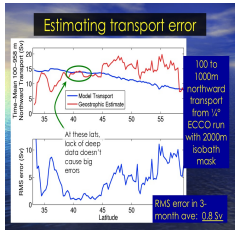
B. Dushaw
Sound speed propagation



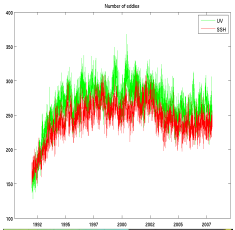
T. Lee & M. Schodlok
Indonesian-throughflow



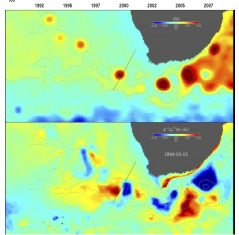
J. Hausman & V. Zlotnicki
Sea state bias



J. Willis
Estimating transport errors

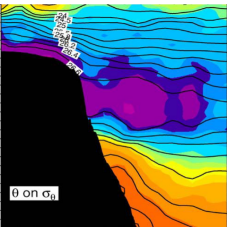


H. Brix
SST, eddies & pattern recognition

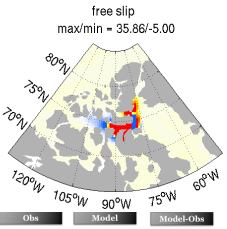


C. Hill, O. Jahn & S. Yeboah
Agulhas retroflection

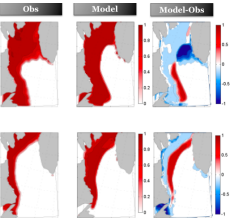
Ongoing ECCO2 applications pertaining to polar processes



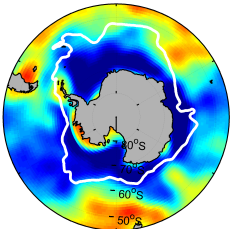
A. Nguyen
Formation of Arctic upper halocline



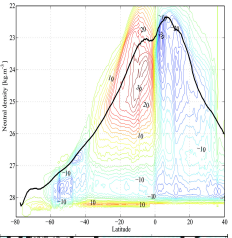
P. Heimbach et al.
Canadian Arctic Archipelago and
Fram Strait ice export sensitivities



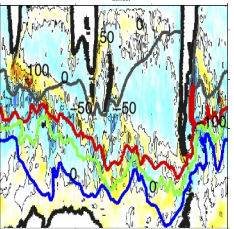
I. Fenty & P. Heimbach
Sea ice in Labrador Sea



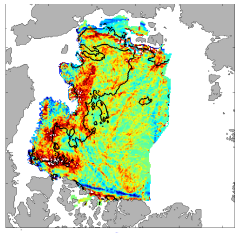
C. Boening & V. Zlotnicki
GRACE & Southern Ocean



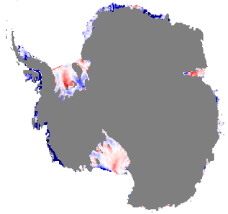
A. Fetter & V. Zlotnicki
Antarctic Intermediate Water



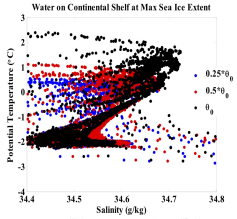
I. Cerovecki, L. Talley & M. Mazloff
Southern Ocean air-sea fluxes



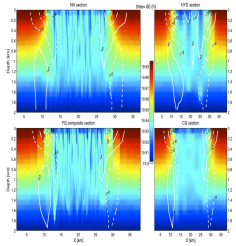
G. Spreen et al.
Arctic sea ice kinematics



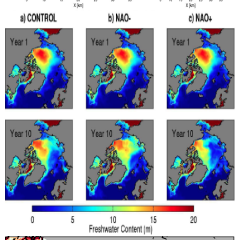
M. Schodlok
Ocean, ice-shelf interactions



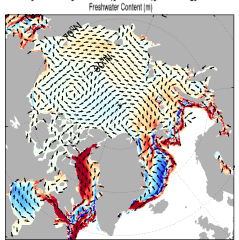
M. Miller et al.
Ocean cooling and ice sheets



J.-M. Campin
Modeling of deep convection

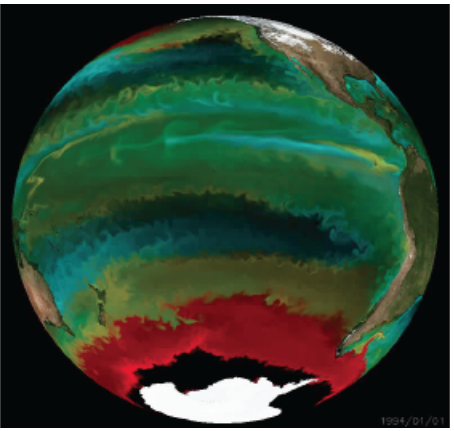


C. Hill, J. Utke & P. Heimbach
Freshwater impact on N. Atlantic

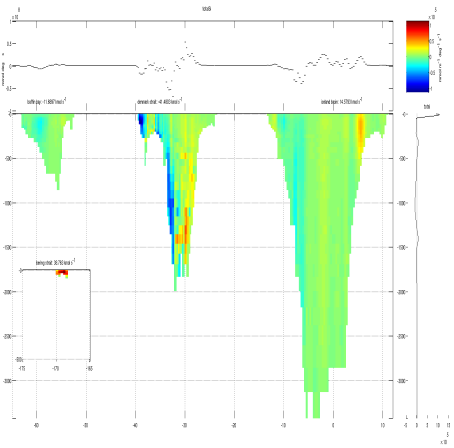


M. Losch et al.
Sensitivity of sea ice dynamics

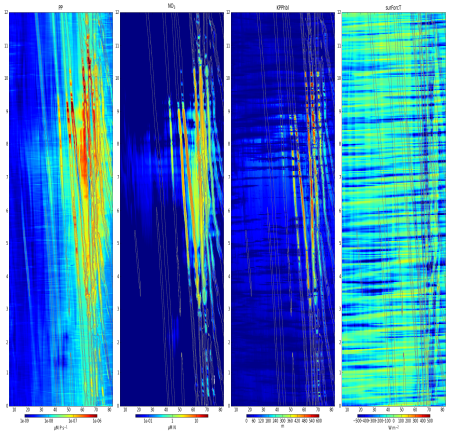
Ongoing ECCO2 applications pertaining to ecosystem dynamics



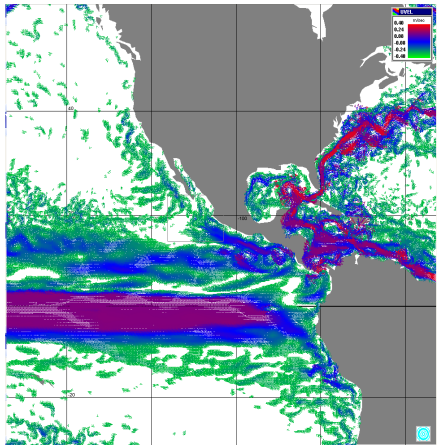
C. Hill, O. Jahn, S. Dutkiewicz & M. Follows
Biogeochemistry and ecosystem dynamics



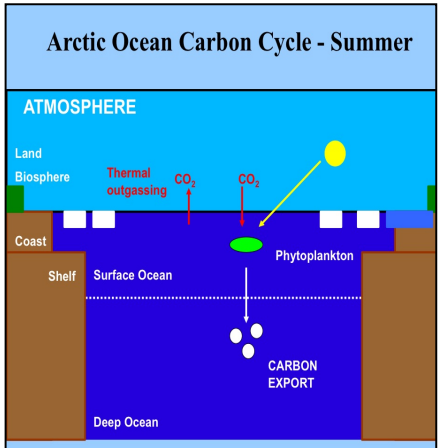
C. Hill, O. Jahn, S. Dutkiewicz & M. Follows
Arctic nutrient streams



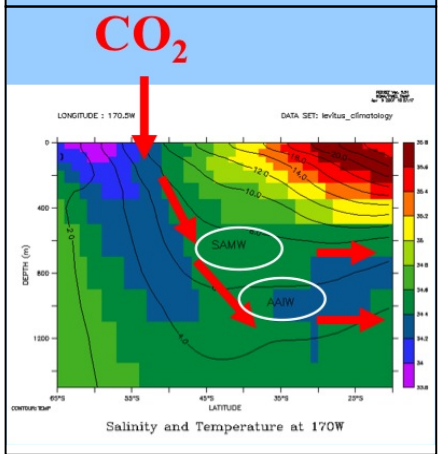
C. Hill, O. Jahn & S. Yeboah
Biology interaction with eddies



D. Kiefer et al.
Pelagic habitat analysis module

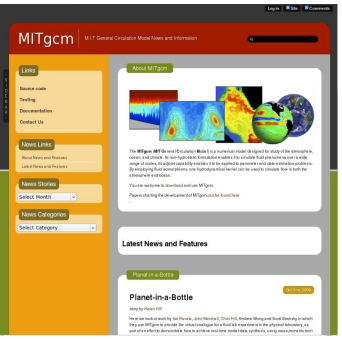


M. Manizza
Arctic Ocean carbon cycle

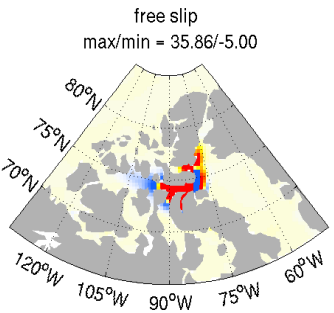


M. Manizza
Southern Ocean CO2 uptake

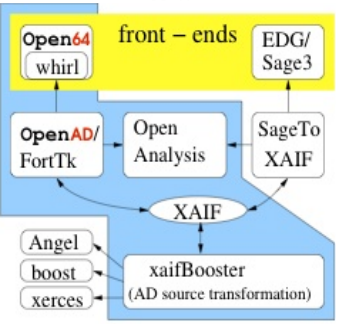
Enabling technologies for ocean/ice modeling and state estimation



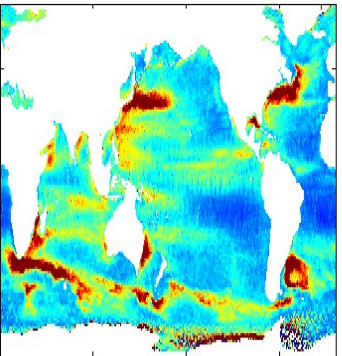
J.-M. Campin et al.
MITgcm forward model



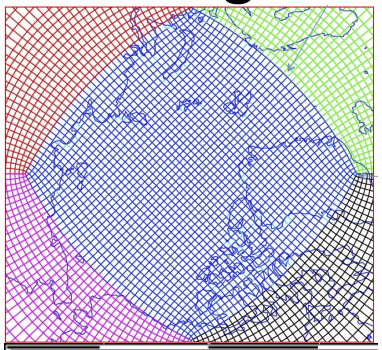
P. Heimbach et al.
MITgcm adjoint model



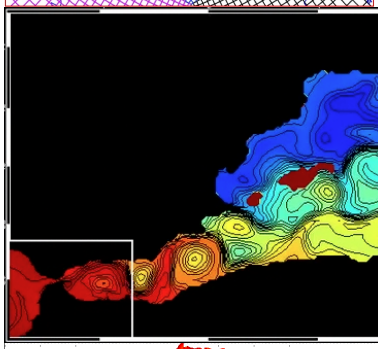
J. Utke et al.
OpenAD development



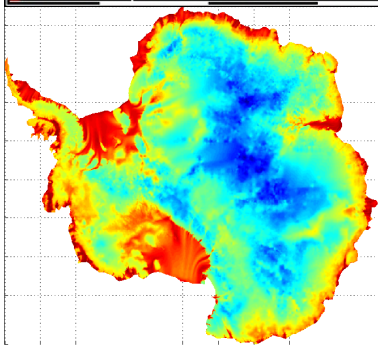
G. Forget
Observational constraints



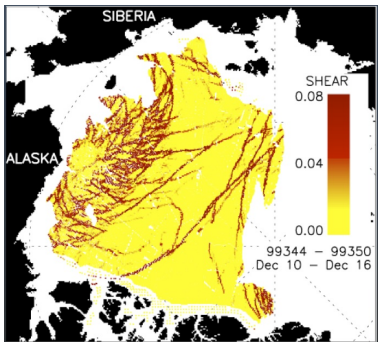
C. Hill
High resolution gridding



G. Sannino et al.
High-resolution nesting
in Strait of Gibraltar

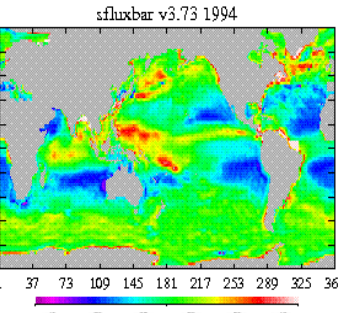


H. Seroussi, M. Morlighem,
E. Rignot & E. Larour
Ice sheet system model



D. Sulsky
Material point method
for sea ice mechanics

Exchange of expertise and technology with other projects



P. Heimbach & I. Fukumori
ECCO-CLIVAR

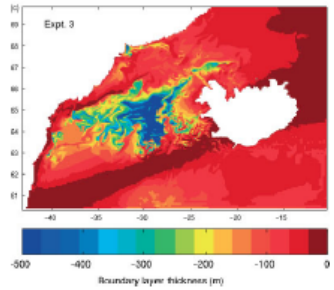
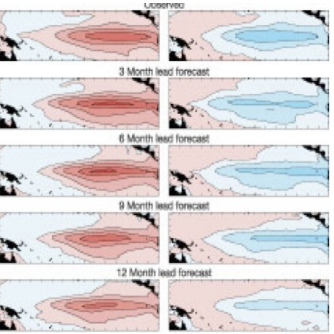
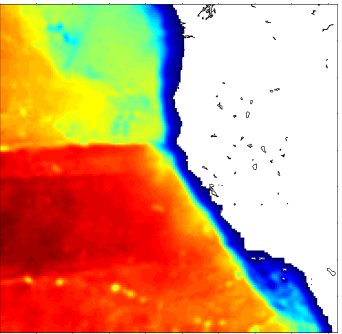


Figure 6. Oceanic boundary-layer thickness (m) at 0300 UTC on 9 March 2007: (a) Expt. 1, (b) Expt. 2, and (c) Expt 3.

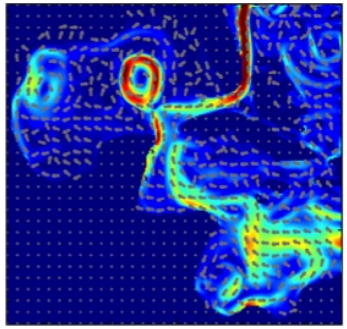
T. Haine
High resolution ocean and sea ice simulation/estimation



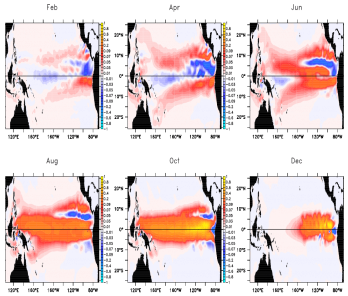
J. Gebbie et al.
Adjoint activities at Harvard



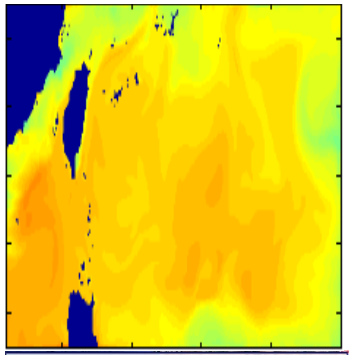
A. Moore et al.
ROMS 4D-var applications



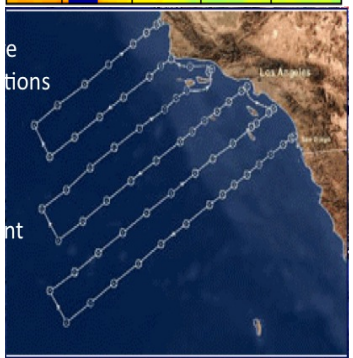
B. Cornuelle et al.
Gulf of Mexico estimation



X. Zhang et al.
Tropical Pacific estimation

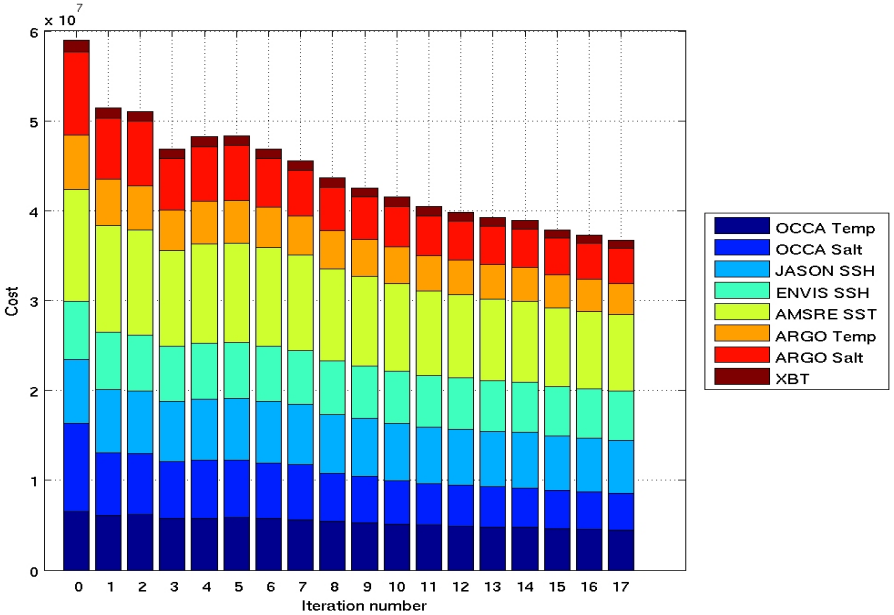


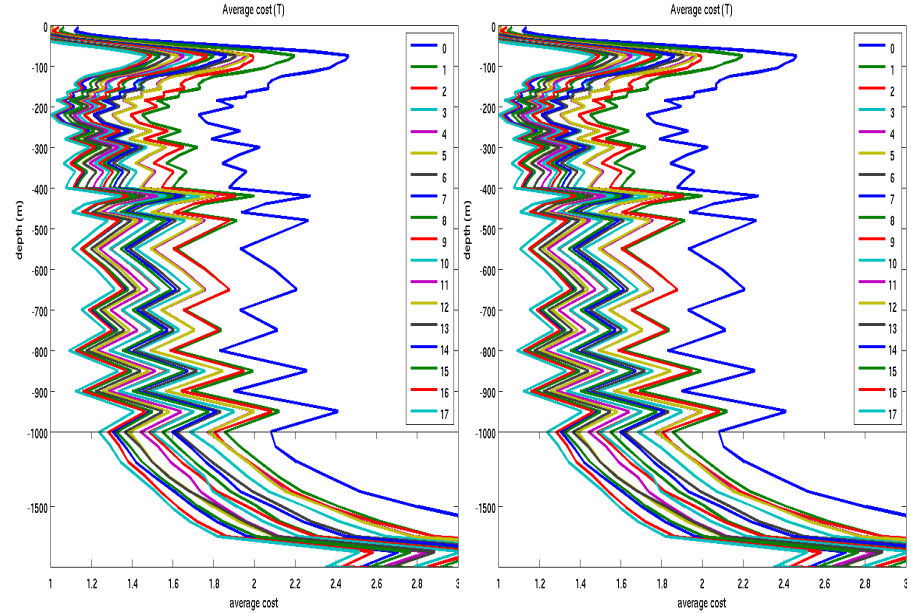
G. Gopalakrishnan et al.
Taiwan region estimation

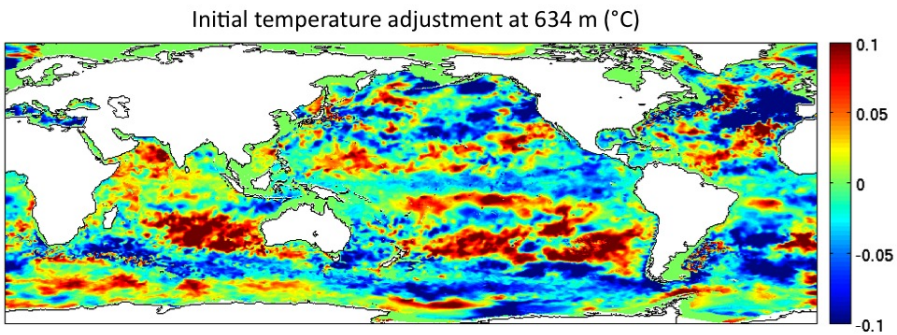


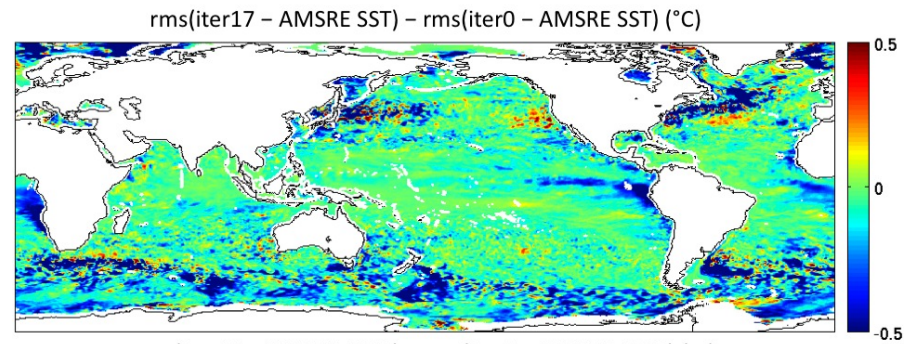
M. Mazloff et al.
California coastal system estimation

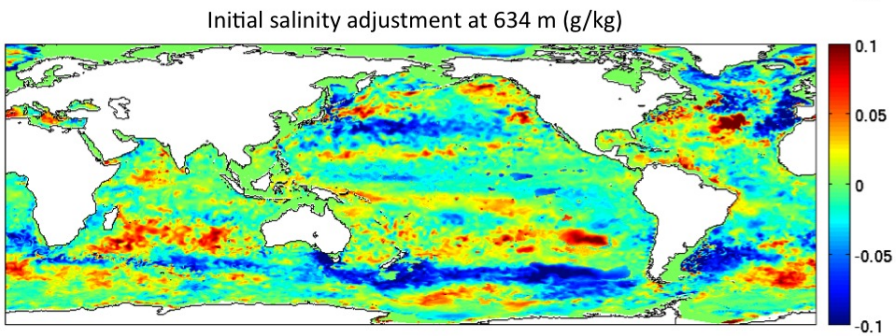
Global, eddying ocean and sea ice state estimation

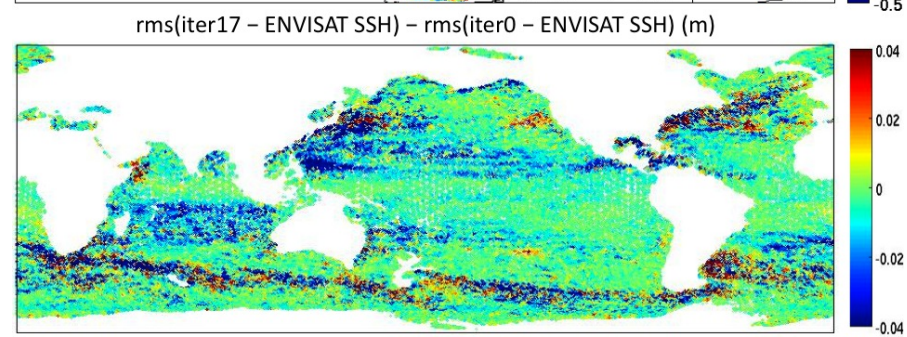












Some proposed future work

- R. Gross: Oceanic angular momentum for earth rotation studies
- D. Moroni: Improved wind stress parameterization and constraints
- P. Heimbach: Northern Ocean State Estimation (NOSE)
- C. Hill: Petascale Arctic, Atlantic, Antarctic Virtual Experiment (PAVE)

Tuesday afternoon round table discussion

CS510 adjoint

- analysis of existing solution: need to demonstrate noticeable beneficial impact
- additional data constraints: MDT, GRACE, sea ice, QuikSCAT
- additional controls: spatially varying GM and cross isopycnal mixing
- improved minimization algorithm: parallelization, smoothing, and L-BFGS
- after Ocean Sciences longer optimization period and entrain early science users

Forward model solutions

- merge optimized Arctic and Antarctic (including ice shelf cavities) in the global solution
- more (budget terms, SBO) and higher frequency diagnostics for science applications
- improved parameterizations (bottom BL, submeso, Winton, tides, surface fluxes)
- experiment with JRA25 and ERA-interim surface boundary conditions
- higher resolution (vertical, horizontal, Arctic, Atlantic, Antarctic, and global)

2009 ECCO2 meeting summary and future focus areas

Meeting summary:

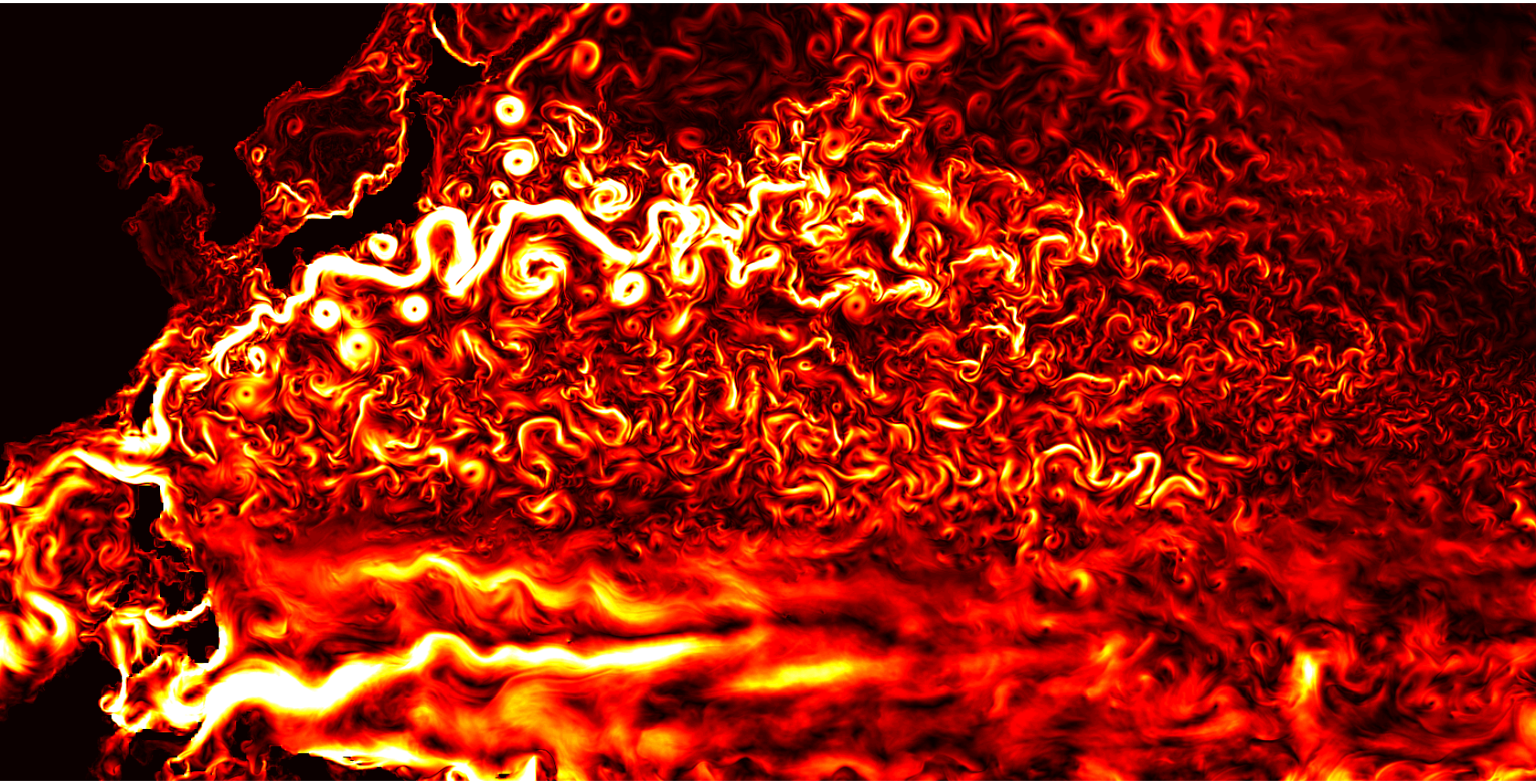
- Healthy mix of science applications (eddy processes, polar regions & ecosystem dynamics)
- Vigorous forward and adjoint model development (shared with community)
- First-ever adjoint-method optimization of global, eddying, ocean and sea ice model

ECCO2 project is on track to demonstrate practicality and scientific usefulness of global, eddying, ocean and sea ice state estimation.

Suggested future focus areas:

(i)Additional **data constraints** (e.g., scatterometer, gravity, surface salinity & sea ice data) and **control parameters** (e.g., along and cross-isopycnal mixing)
(ii)Quantitative description of model-data differences, attribution to **model and data errors**, and development of empirical and physical models for these differences
(iii)Improved representation of **polar and subpolar processes** (e.g., sea ice dynamics, ice-shelf ocean interactions & deep and intermediate water mass formation mechanisms)
(iv)Increased horizontal and vertical **resolution** (regionally and globally)
(v)Support rich set of **science applications** (e.g., sea level change, hydrological cycle, polar oceans, sea ice, land ice & atmosphere interactions, evaluation of IPCC solutions predictability and prediction, formal uncertainty quantification, ecosystem dynamics, ocean biogeochemistry studies & the ocean carbon cycle)

ECCO2 and SWOT



Is the real ocean behaving like this? A question to be answered by SWOT.

Will use the 1/16° simulation to study the sampling capability of SWOT for:

- observing the evolution of the field and
- estimating the 3-dimensional circulation of the ocean and transports.