Estimating the Circulation and Climate of the Ocean (ECCO)

1. Ocean/Ice synthesis in ECCO

   Several posters…..

2. Looking ahead

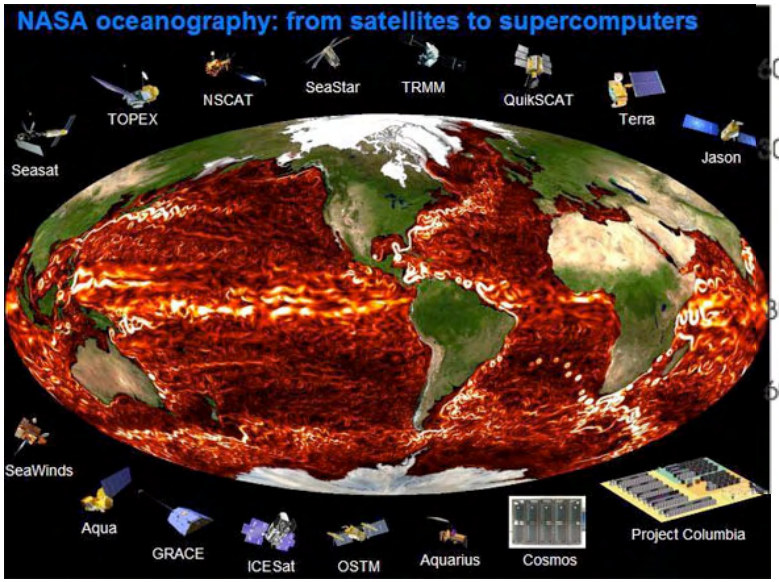
   Thinking about the coupled problem:
   prototype ocean decadal predictability systems

3. Conclusions

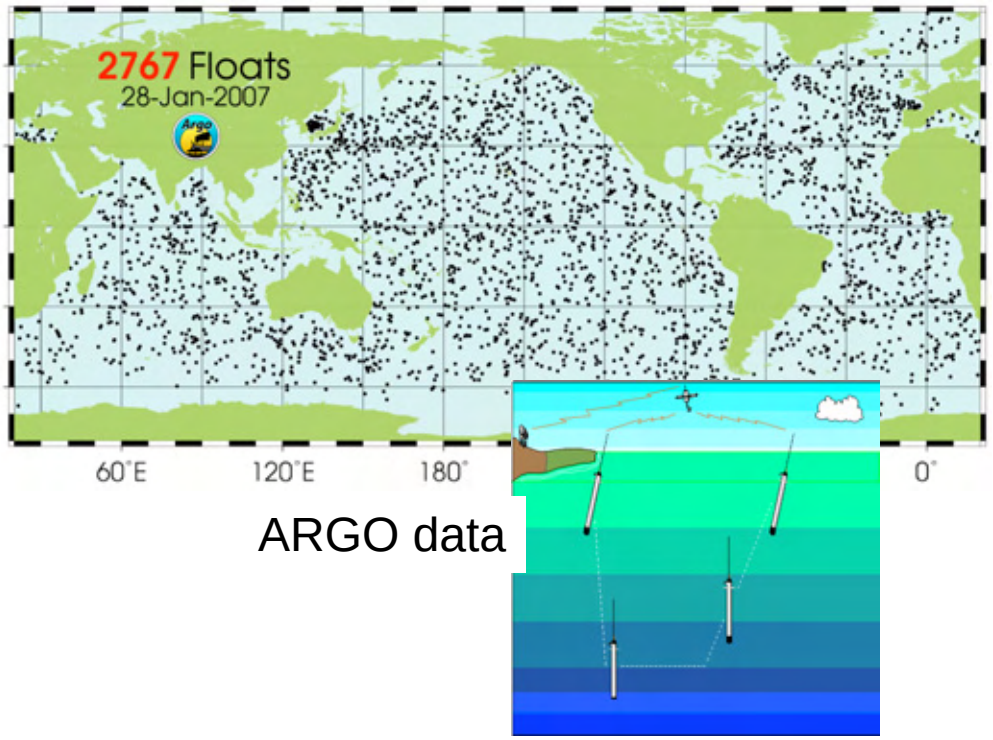
1. Ocean synthesis: ECCO project

Aims to ***describe and understand ocean circulation*** by combining all extant observations with a state-of-the-art ocean model using advanced data assimilation methods.

Remotely sensed observations



In-situ observations



ARGO data

Model

ECCO

– developed technology of ocean state estimation:
Engine is the MITgcm and its adjoint

Being used to solve massive least-squares problems

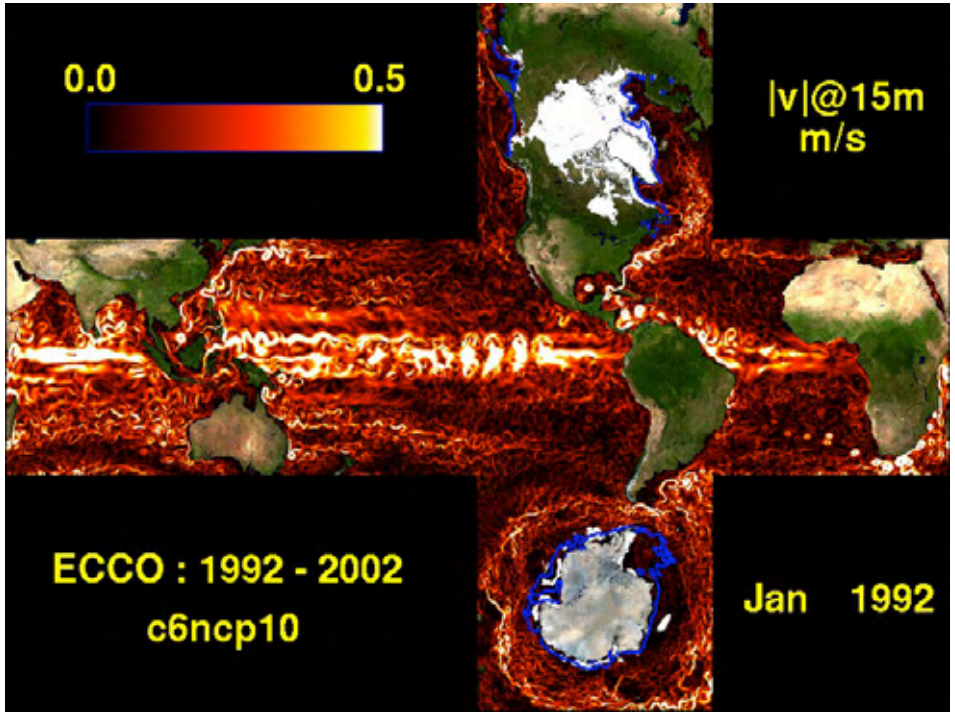
– yielded estimates of evolving state of ocean
– improving all the time

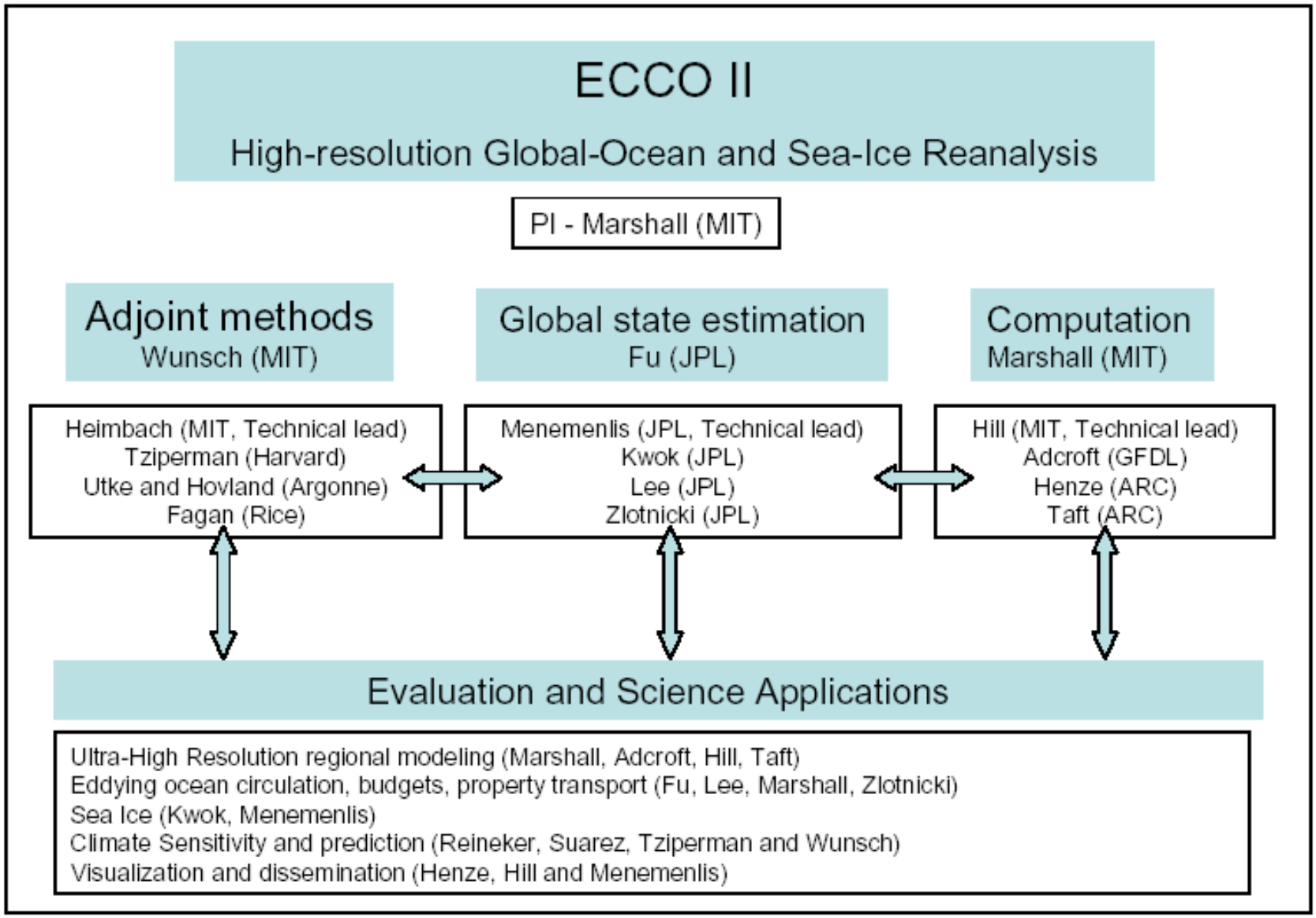
ECCO II

Focus is high spatial resolution and polar processes

Ocean eddies
and Sea Ice

Weather and Climate
dichotomy!

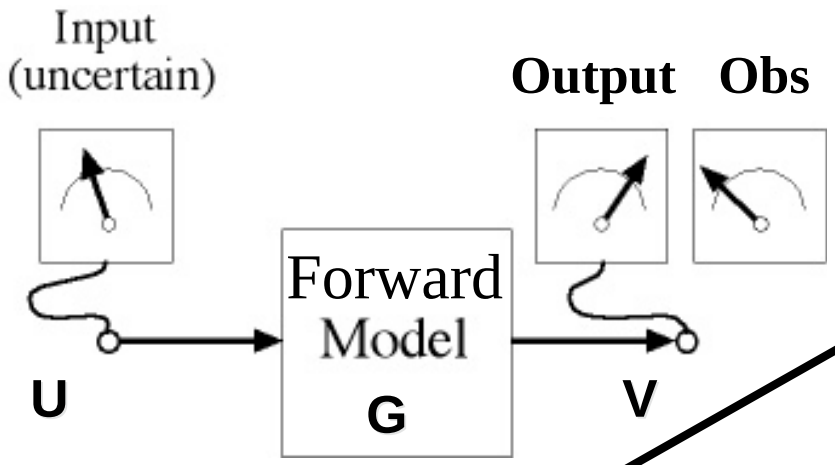




Reviewed progress after 1 year at Pasadena meeting in January, 2007

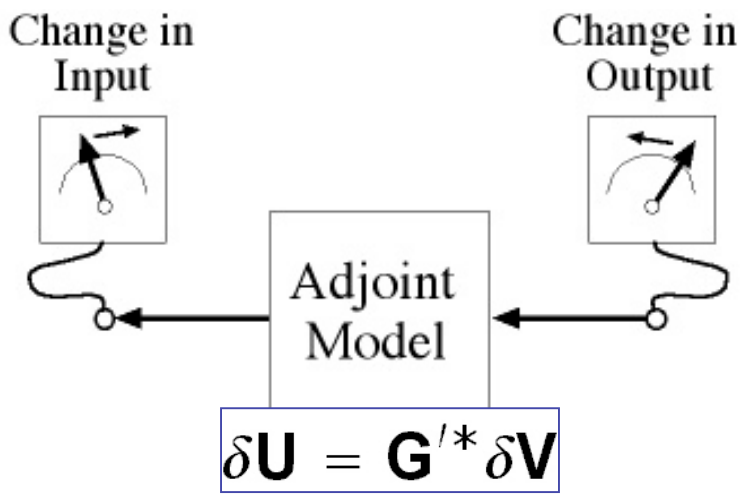
Control theory

Forward



$$\delta \mathbf{V} = \mathbf{G}' \delta \mathbf{U}$$

Backward



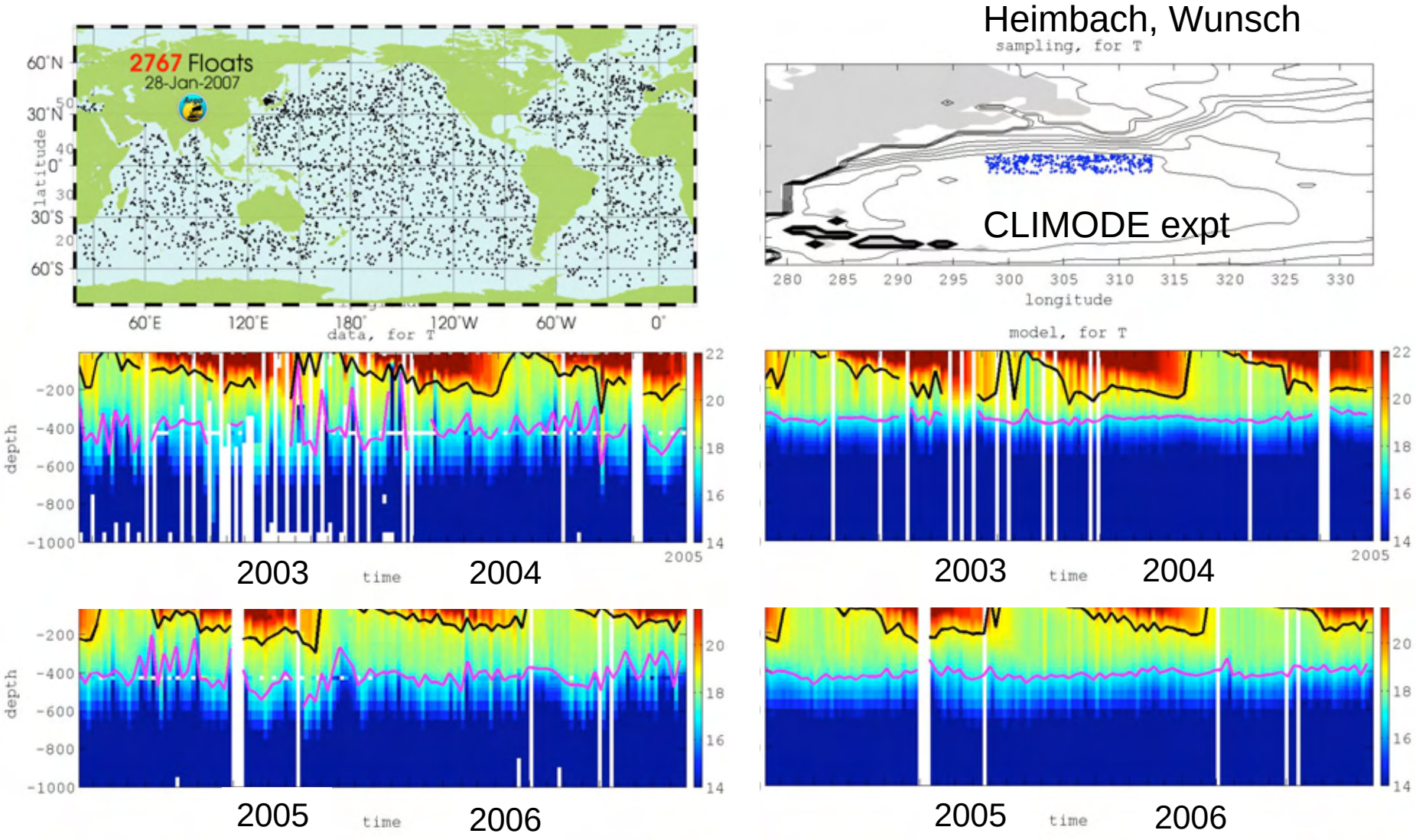
$$\delta \mathbf{U} = \mathbf{G}'^{*} \delta \mathbf{V}$$

System can be used in a number of different ways:

- Forward model
- Sensitivity analysis
- Minimize a ‘cost function’
  e.g misfit to observations,
  maximize entropy production

Examples……

Evolving state of global ocean during 1992-present



Meridional overturning circulation

Strength of Atlantic MOC at 25N from ocean analysis

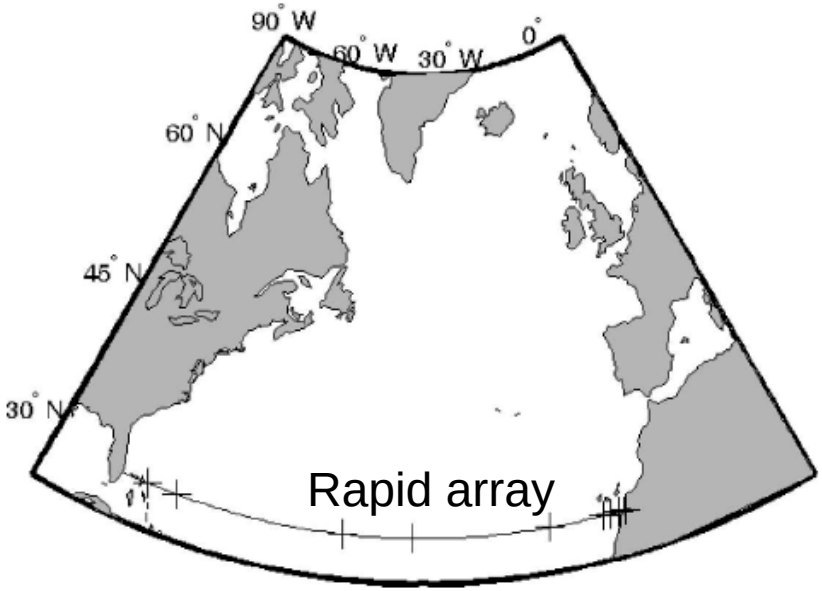


FIG. 1. Line at 26°N across which fluxes are discussed. The plus signs denote positions of U.K. RAPID moorings in the North Atlantic.

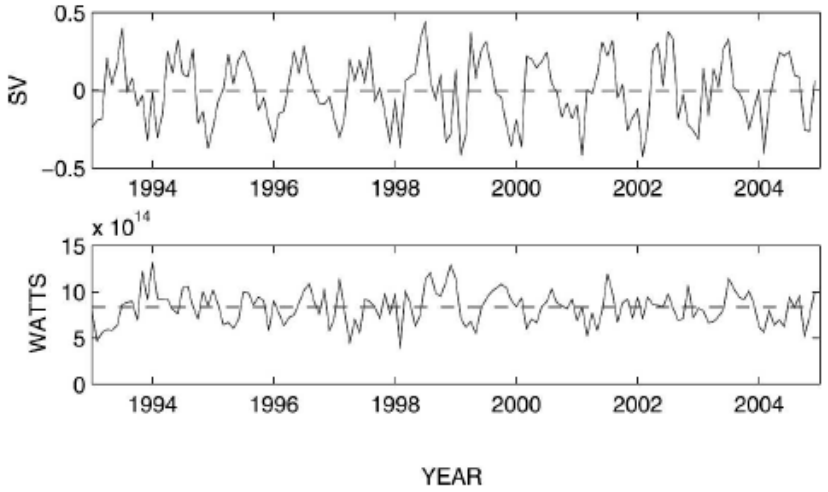
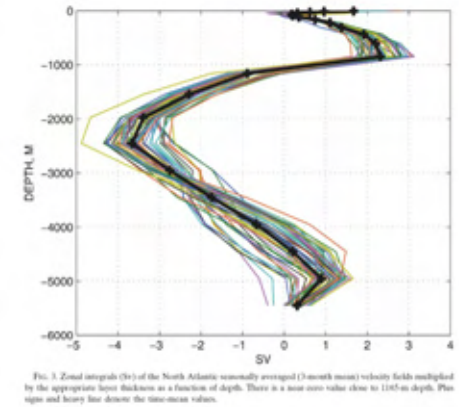
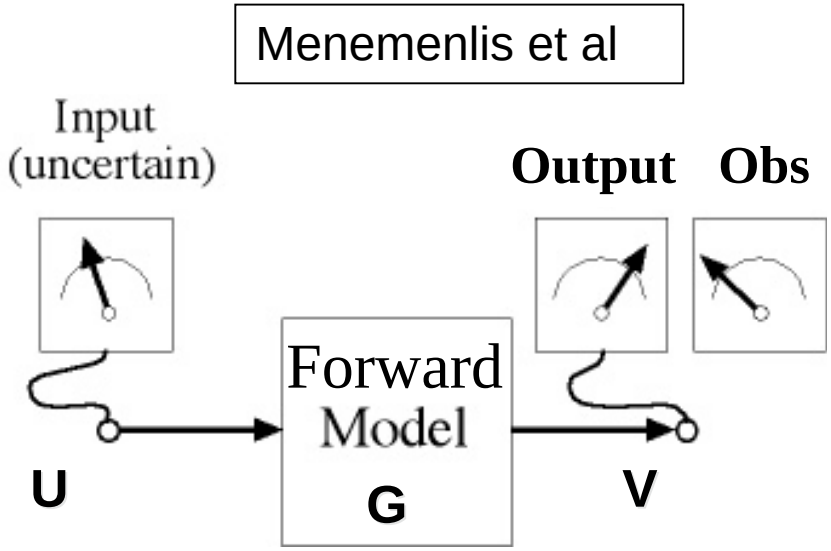


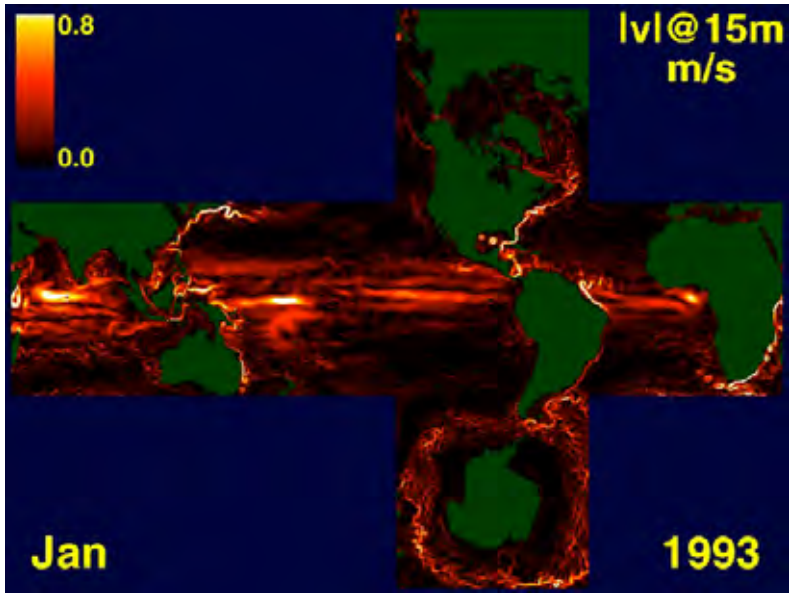
FIG. 2. (top) Net (top to bottom integral) volume transport at monthly intervals across 26°N in the North Atlantic as a function of time from the optimized ECCO-GODAE model (solution V2.177). Values represent primarily fluctuations in seasonal mass storage. (bottom) The monthly mean net heat flux (W). Ticks denote the beginning of the year.



Wunsch and Heimbach, 2006

Forward integrations in a Green Function optimization





Repeated forward integrations using perturbed parameters

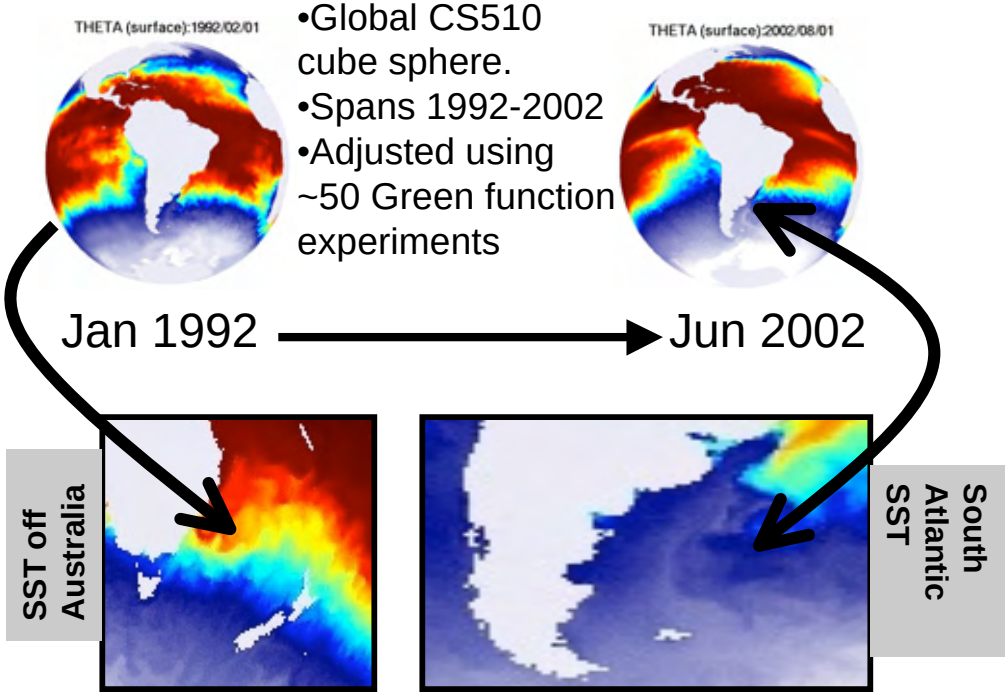
$$\mathbf{V}_1 = \mathbf{G}\mathbf{U}_1$$
$$\mathbf{V}_2 = \mathbf{G}\mathbf{U}_2$$
$$\vdots$$
$$\mathbf{V}_n = \mathbf{G}\mathbf{U}_n$$

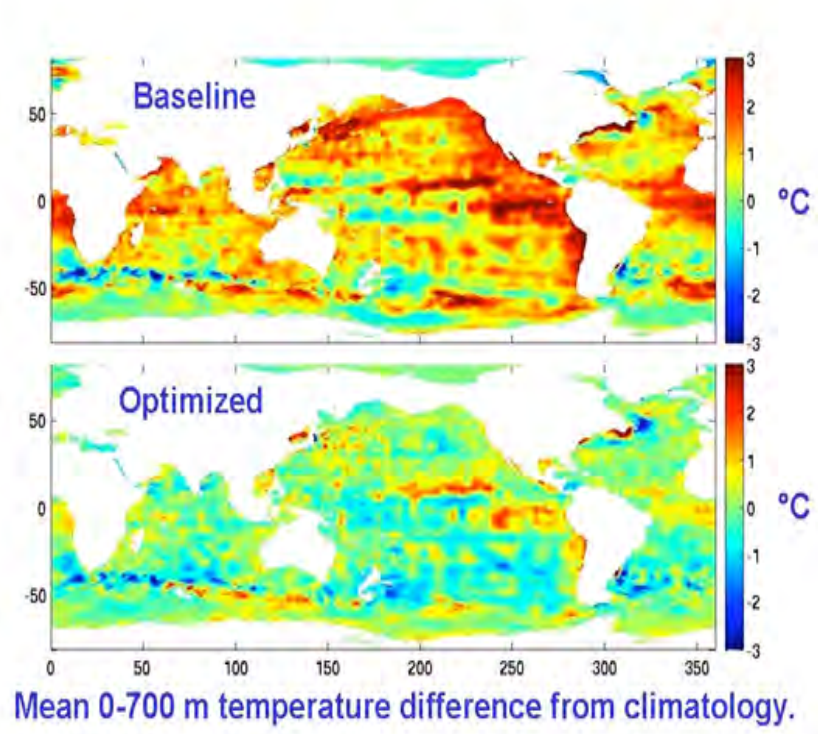
n is about 50

Construct a linear combination of V's that minimizes model-data misfit – guides adjustment of U's.

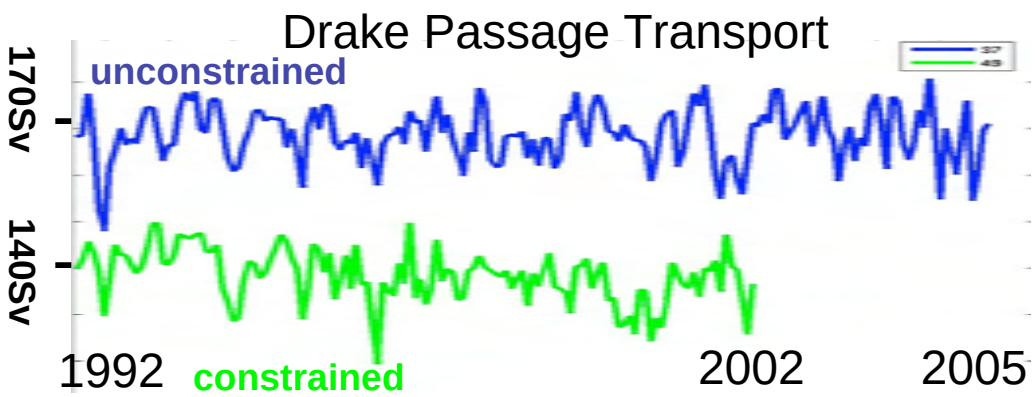
Perturbed parameters

horizontal viscosity
vertical viscosity
vertical diffusivity
albedo
critical Richardson number
sea-ice model parameters
initial conditions of T/S
surface forcing
SSS relaxation timescale
etc etc…..



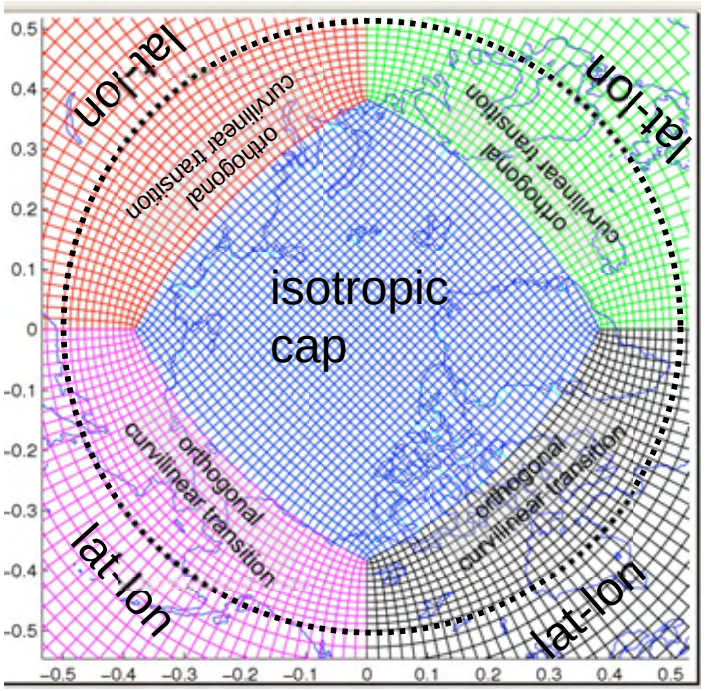


Mean 0-700 m temperature difference from climatology.



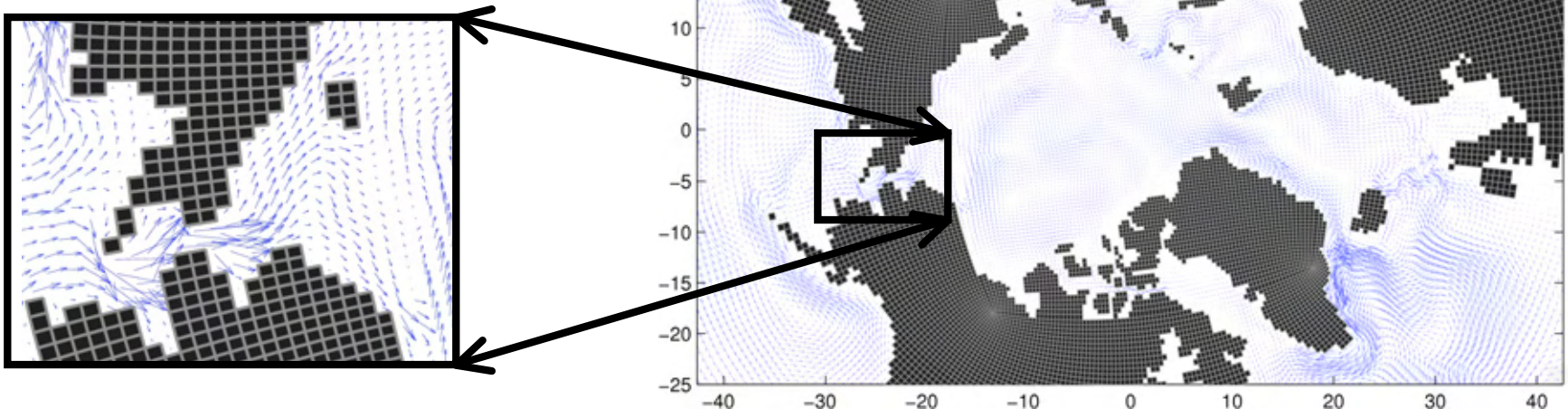
Top panel: temperature difference in the top 680 m between the WOCE Global Hydrographic climatology (WGCH) and a 1992-2002 baseline integration driven by NCEP surface atmospheric boundary conditions. Bottom panel: temperature difference from WGCH for an integration whose initial conditions, surface boundary conditions, and internal model parameters following preliminary calibration using Green function experiments.

Model development: variants on the cubed sphere



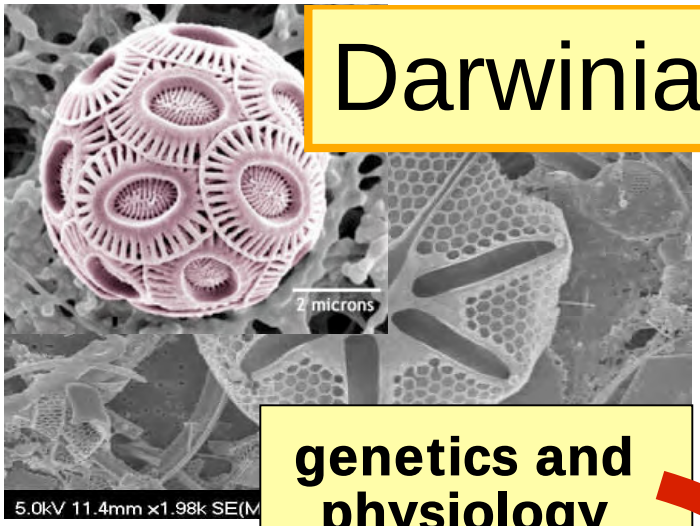
Hill, Hill and Heimbach

Numerically-generated “patch” grids
Lat-lon elsewhere

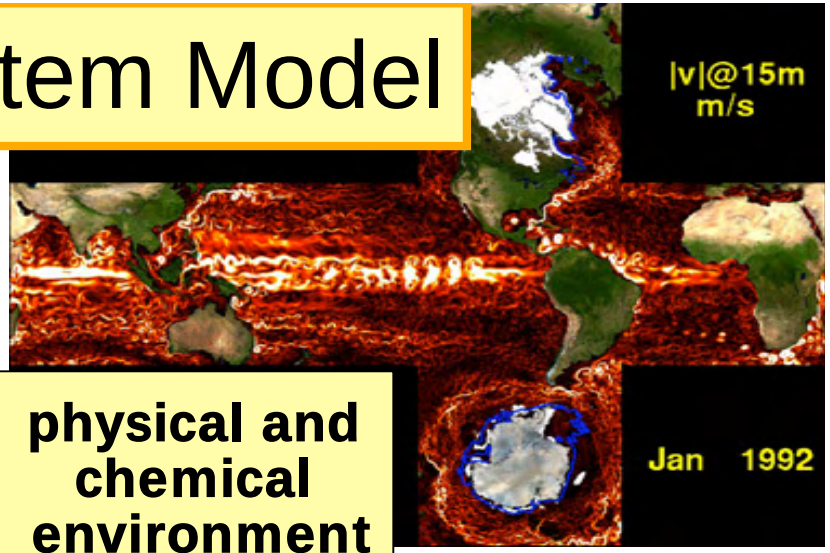


Uniform resolution of ~ 40km

Darwinian Ecosystem Model



Mick Follows



genetics and physiology

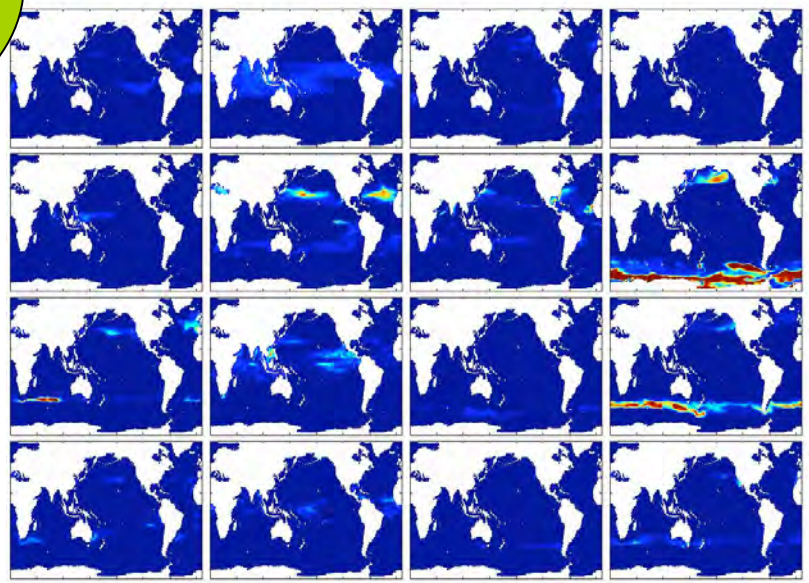
physical and chemical environment

competition predation selection

Emergent ecosystem structure and function

Variants on a generic phytoplankton

- Initialize hundreds of potentially viable phytoplankton types
- Explicit selection for fittest organisms



16 most abundant types of photoplankton

Summary of ECCO status

Lots to do, but elements are in place to:

assess the current state of the ocean, the status of the MOC, ice extent, sea-level etc etc

But note:

Oceanographic community remains suspicious

State estimates need to be evaluated scientifically

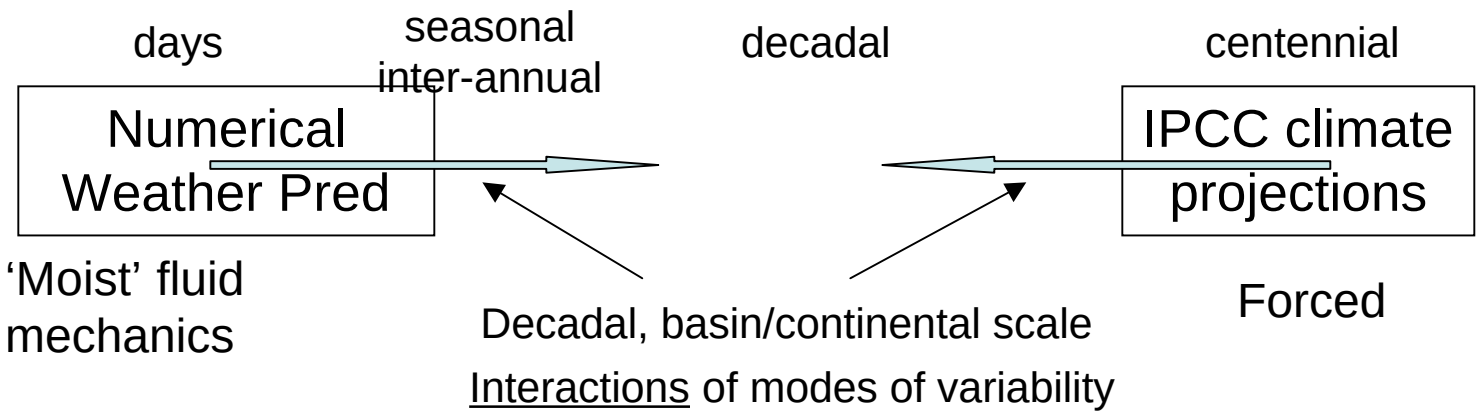
Looking ahead

Next big push must be to address the coupled problem

Decadal predictability of the ocean

2. Looking ahead

Predictability ‘end-members’



Much effort has been placed in setting up prediction systems pushing out from NWP

It would be highly productive to attempt to ‘push down’ from IPCC-class coupled models

Information content in projections depends on predictability of ‘slow’ components of the climate system

Pre-requisite for predictability of the coupled system is ability to ‘nowcast’ and ‘project’ the state of the ocean (and ice).

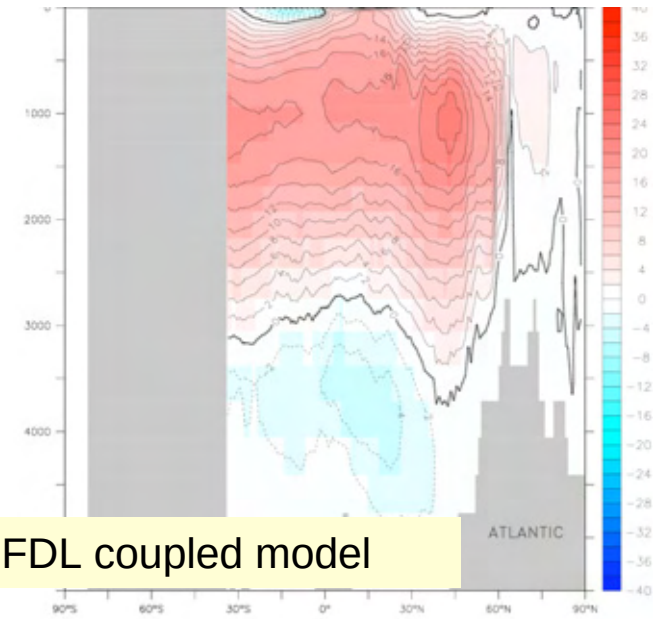
ECCO

Ocean state estimation

Priority for the decadal challenge is ocean/ice data assimilation (not atmospheric)

ECCO project needs to couple with meteorology both intellectually and with models

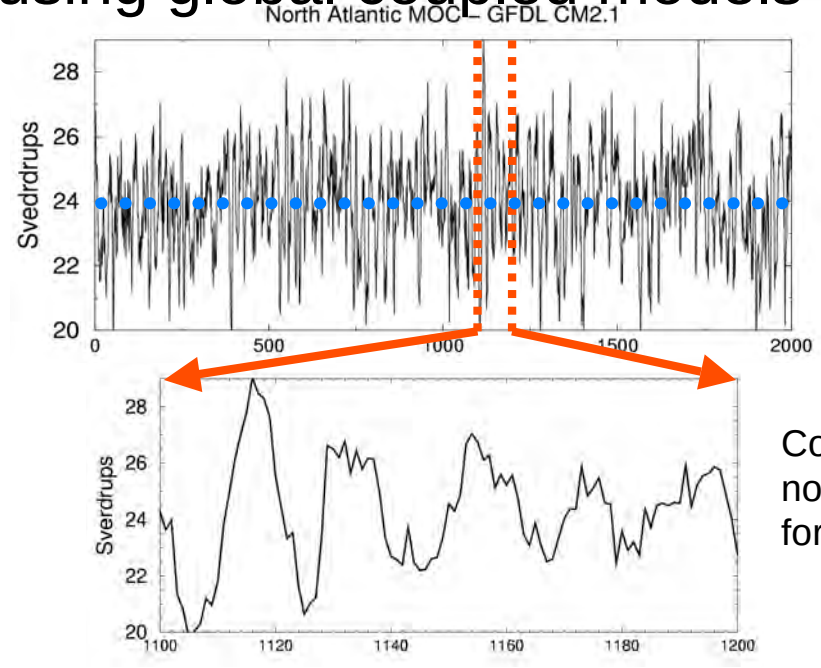
Decadal predictability studies using global coupled models



GFDL coupled model

Atlantic MOC – GFDL CM2.1 Model

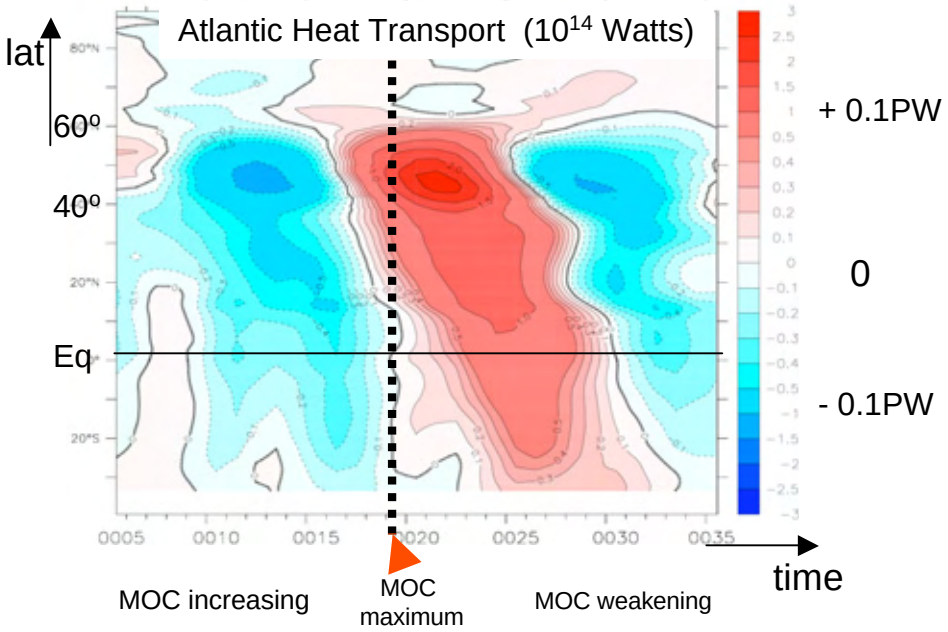
GFDL



Control: no anthro forcing

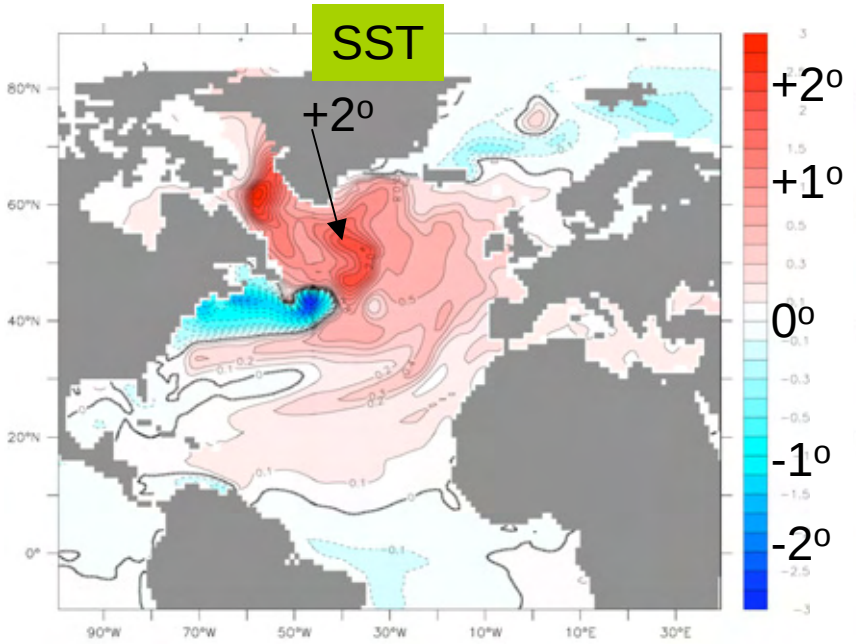
Workshops on Atlantic decadal predictability
GFDL, June 06; AOML, January, 07

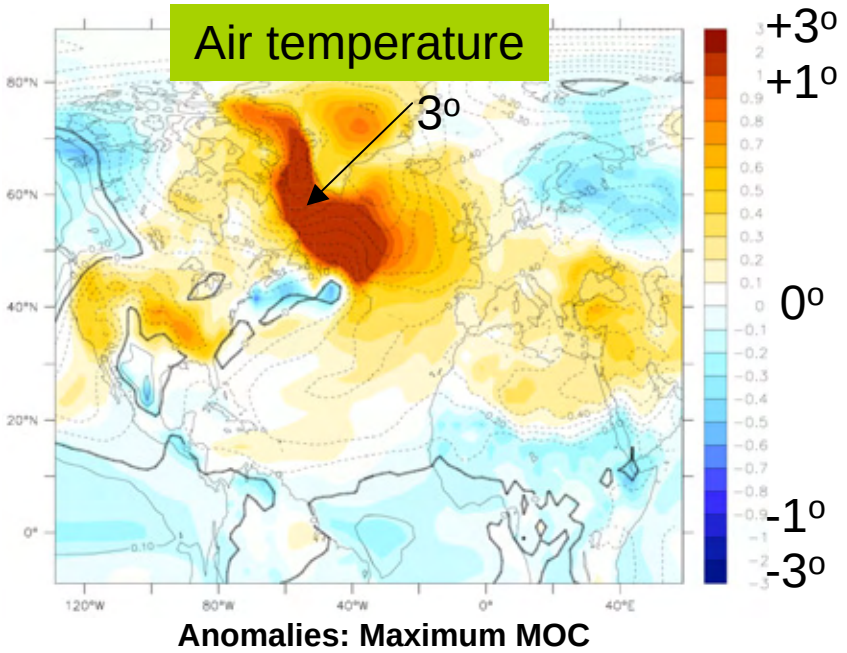
Workshop focused on Atlantic, but models are global.



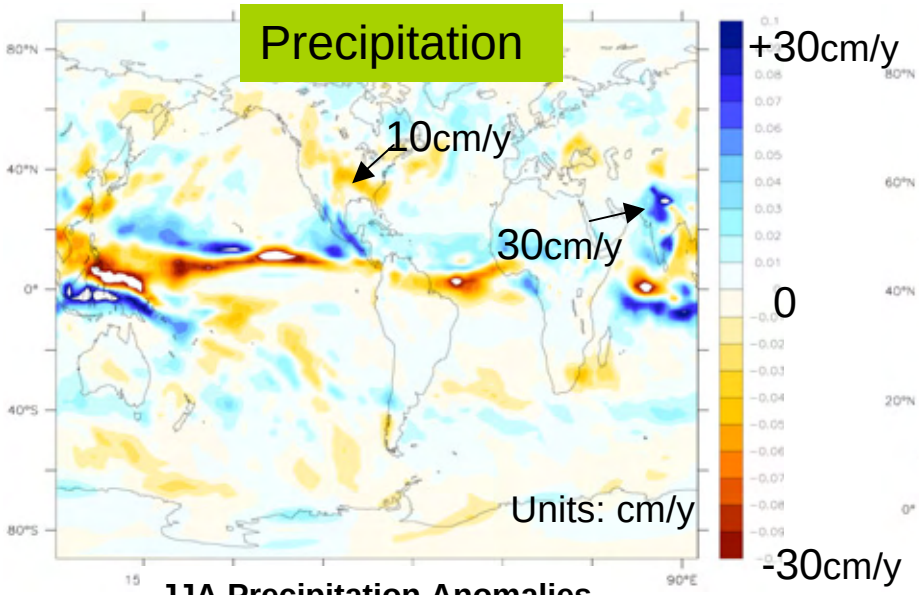
Courtesy of Tom Delworth

Anomalies associated with interdecadal MOC fluctuations

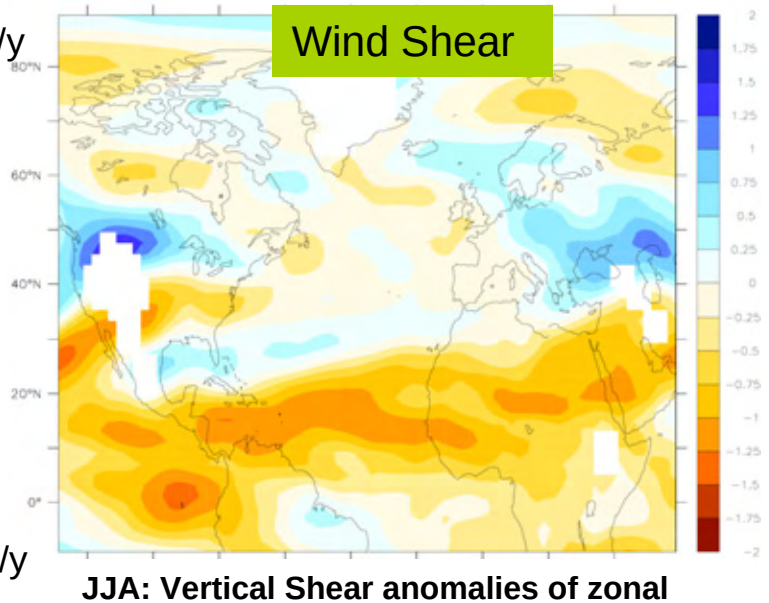




Anomalies: Maximum MOC



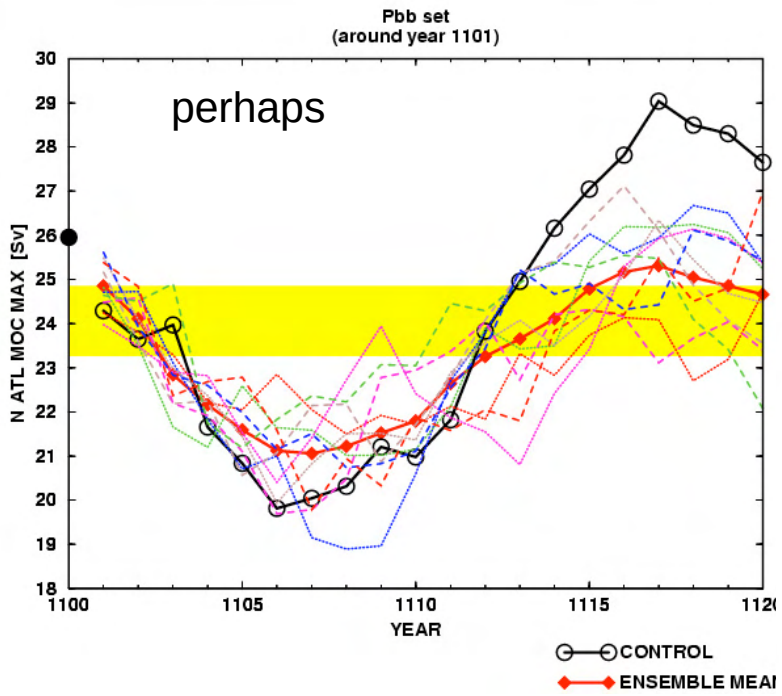
JJA Precipitation Anomalies
Maximum MOC

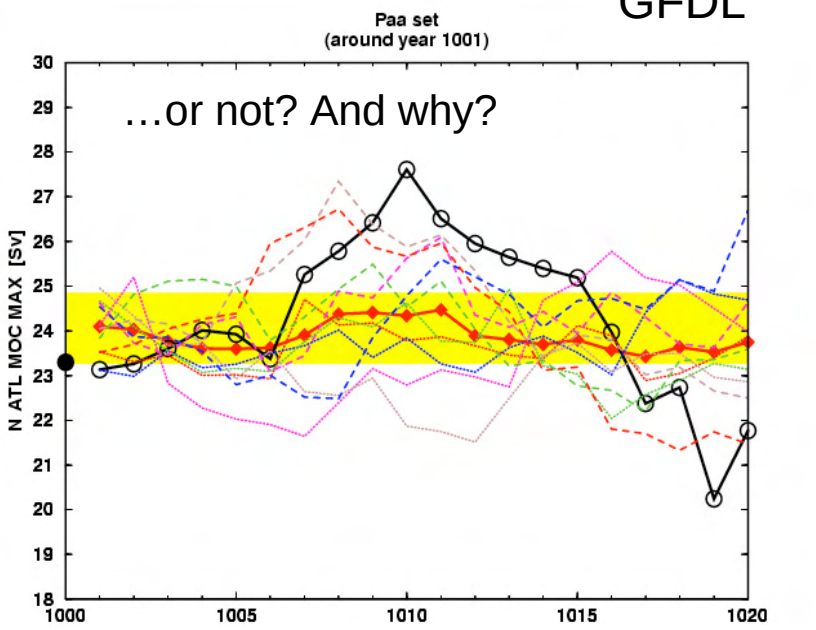


JJA: Vertical Shear anomalies of zonal wind (850mb-300mb) Maximum MOC

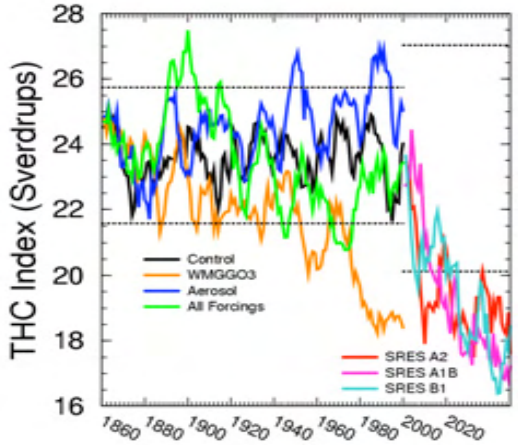
Does, e.g., the MOC have any predictability?

Keith Dixon
GFDL





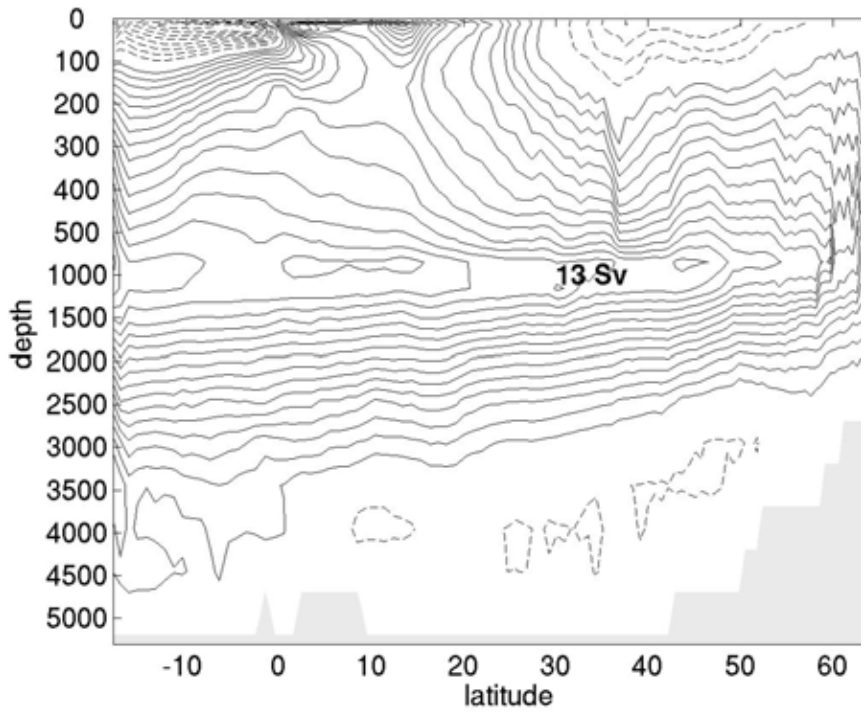
Workshop report:
Leetmaa and Marshall, 2006



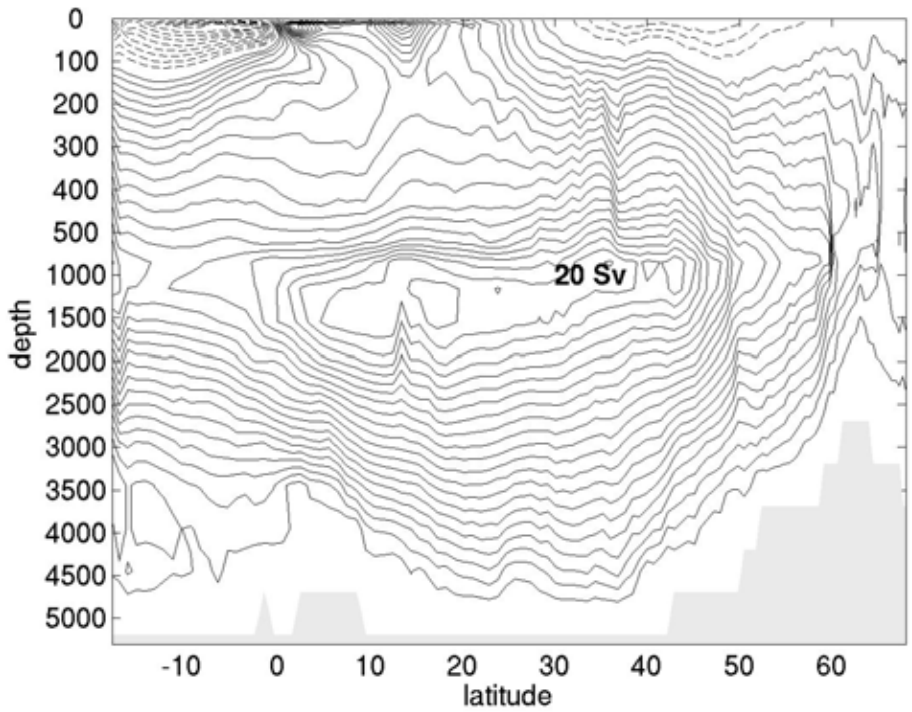
Early warning system for abrupt MOC changes?

ECCO has shown that

Assimilation of ARGO profiles dramatically improves the ability of the model to simulate the MOC and its heat transport.



before assimilation

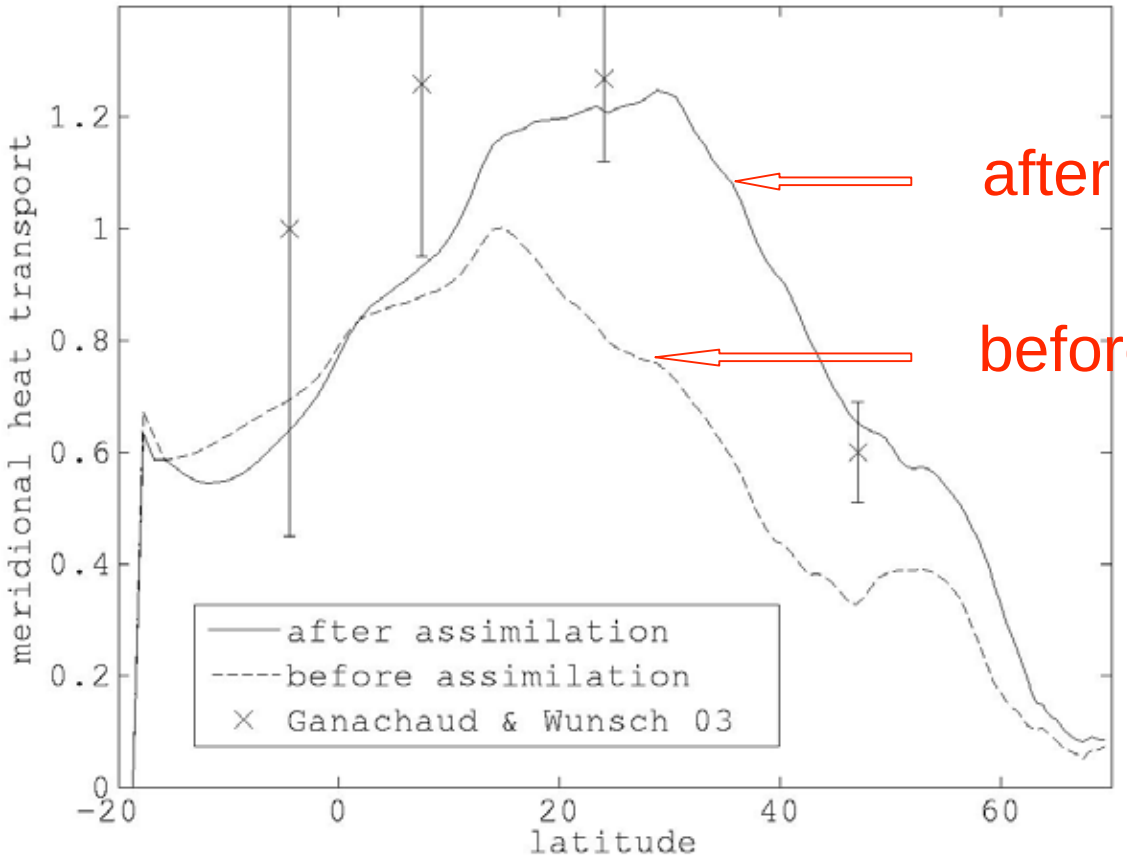


after assimilation

Forget et al (2007), to appear

Meridional heat transport

PW



after assimilation

before assimilation

Assimilation of ARGO profiles, May 2002-Apr 2003

(+climatology south of 30N & below 2000m)

Forget et al (2007), to appear

3. Conclusions

Lots to do, but elements are in place to:

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State estimates need to be evaluated scientifically

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Decadal predictability of the ocean

Coupling of ECCO with GEOS 5 has begun