

THE WORLD OCEAN CIRCULATION EXPERIMENT (WOCE)
AND
THE JOINT GLOBAL OCEAN FLUX STUDY (JGOFS)

Origins, linkages, future

Washington DC 5 May 2003

WOCE was conceived in late-1970s
not so easy to re-capture thinking of the time:

- Era of the new process studies built on newly available technologies: upwelling regions (CUEA), mesoscale eddies (MODE, POLYMODE), internal waves (IWEX), Florida Current and Drake Passage transports (ISOS), Pacific surface temperature anomalies (NORPAX),...
- Models were either global and 'sticky' or regional barely showing mesoscale eddies in a simplified geometry
- Long sections seemed a relic of an earlier era.
- No one paid attention to global scales

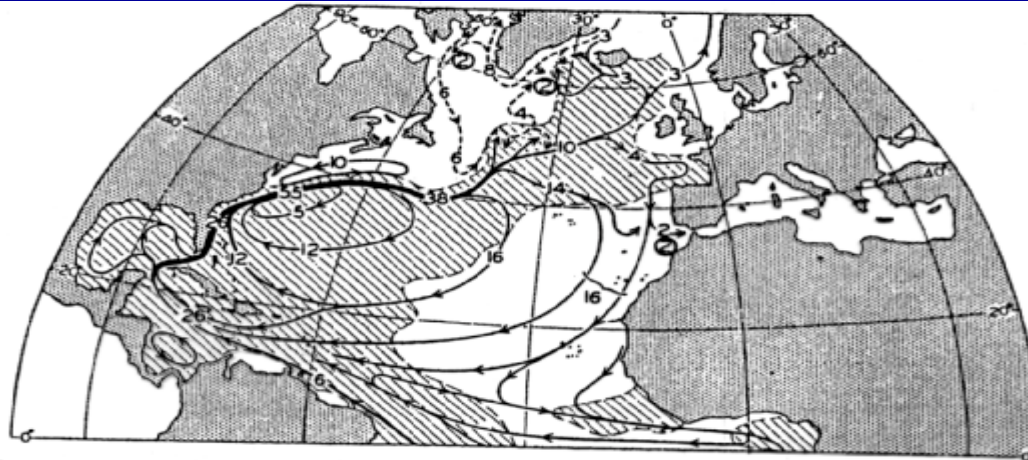


Fig. 187. Transport of Central Water and Subarctic Water in the Atlantic Ocean. The lines with arrows indicate the direction of the transport, and the inserted numbers indicate the transported volumes in millions of cubic meters per second. Full-drawn lines show warm currents, dashed lines show cold currents. Areas of positive temperature anomaly are shaded.

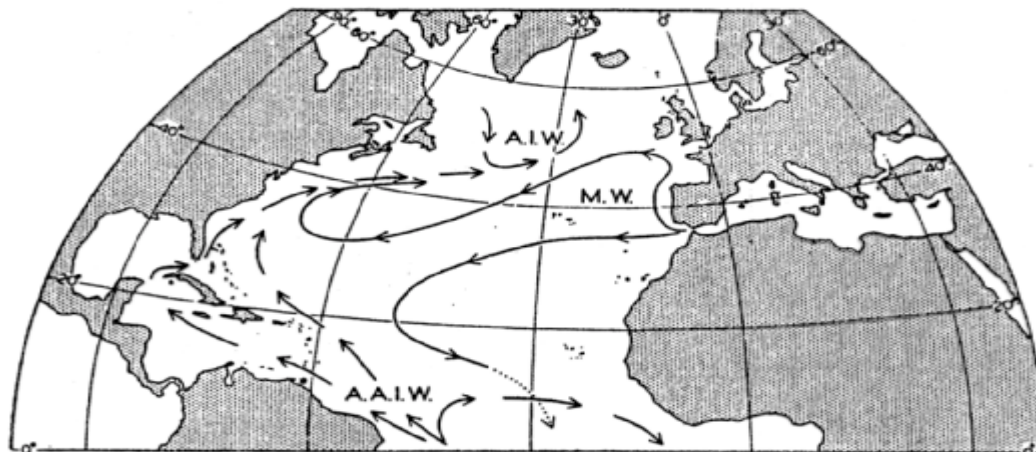
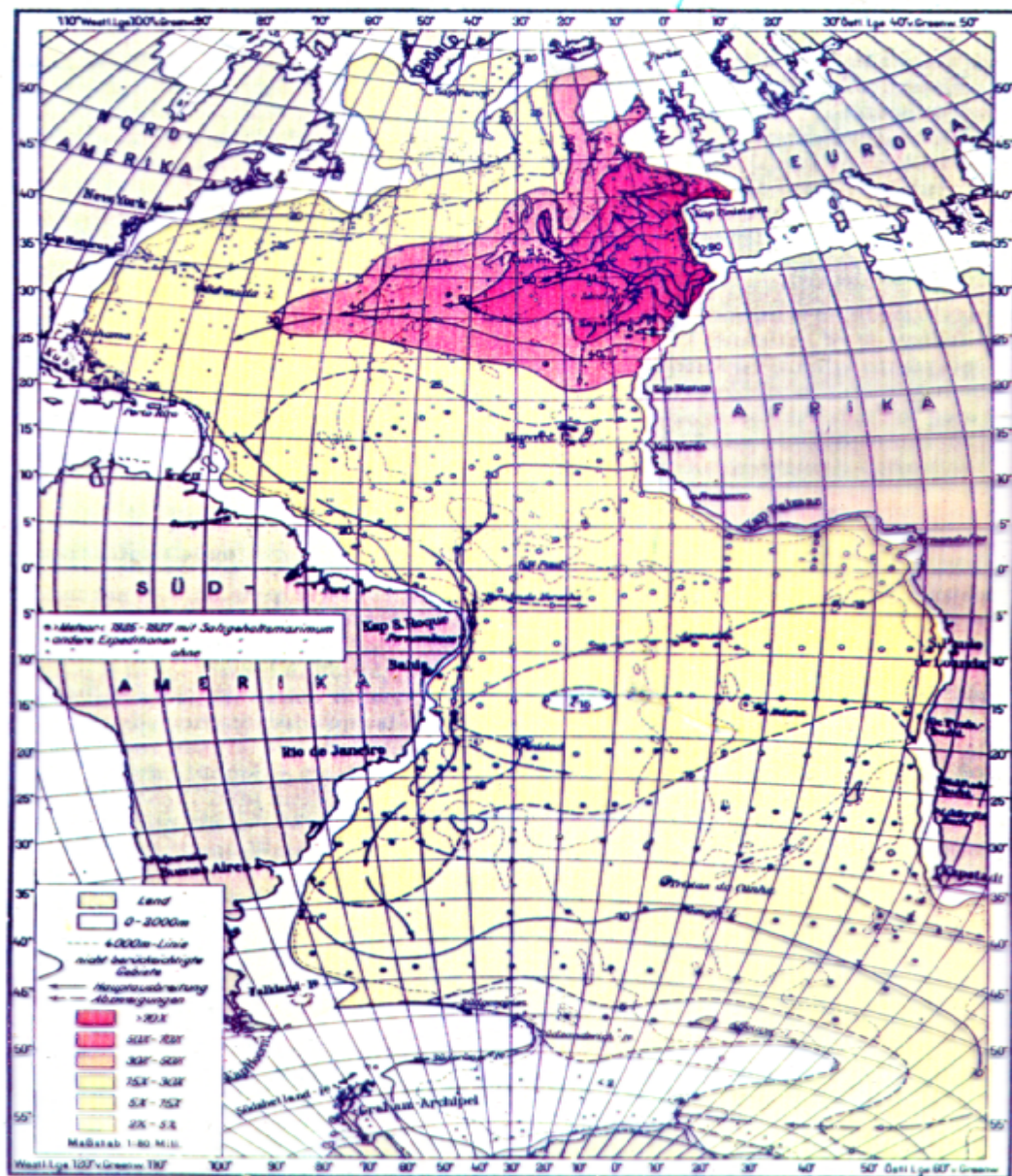


Fig. 188. Approximate directions of flow of the intermediate water masses of the North Atlantic. A.I.W., Arctic Intermediate Water; M.W., Mediterranean Water; A.A.I.W., Antarctic Intermediate Water.



Spreading of the Upper North Atlantic Deep Water in the core layer (intermediate salinity maximum), represented by the percentage of the Mediterranean component M.

Ruddiman, 2001

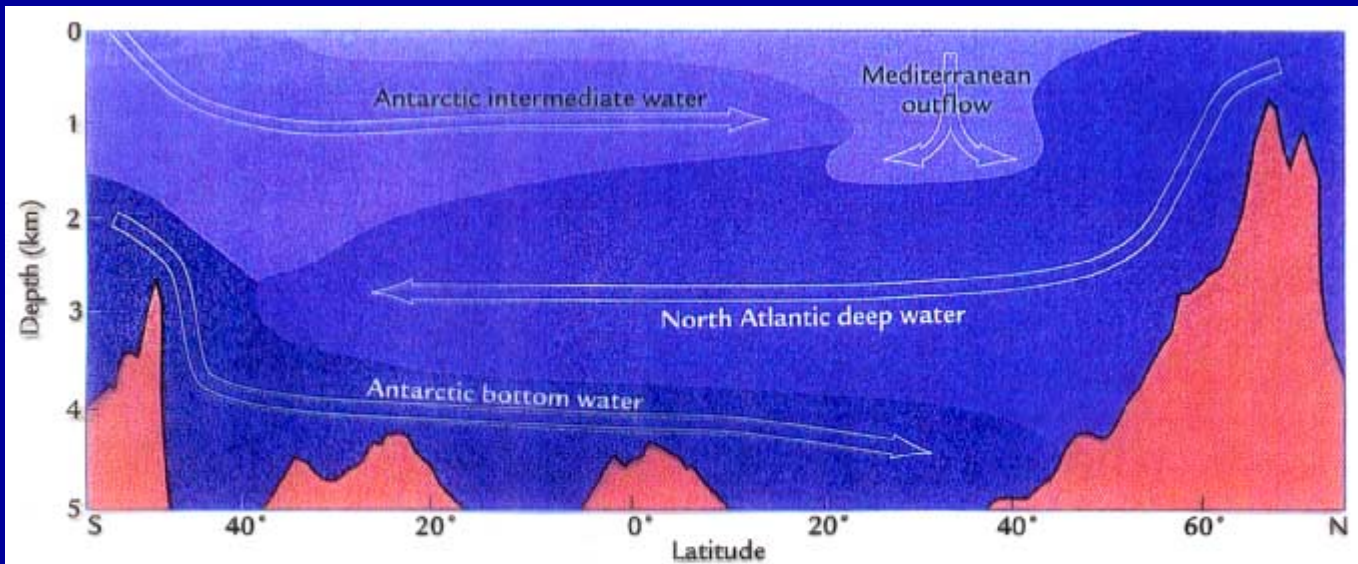
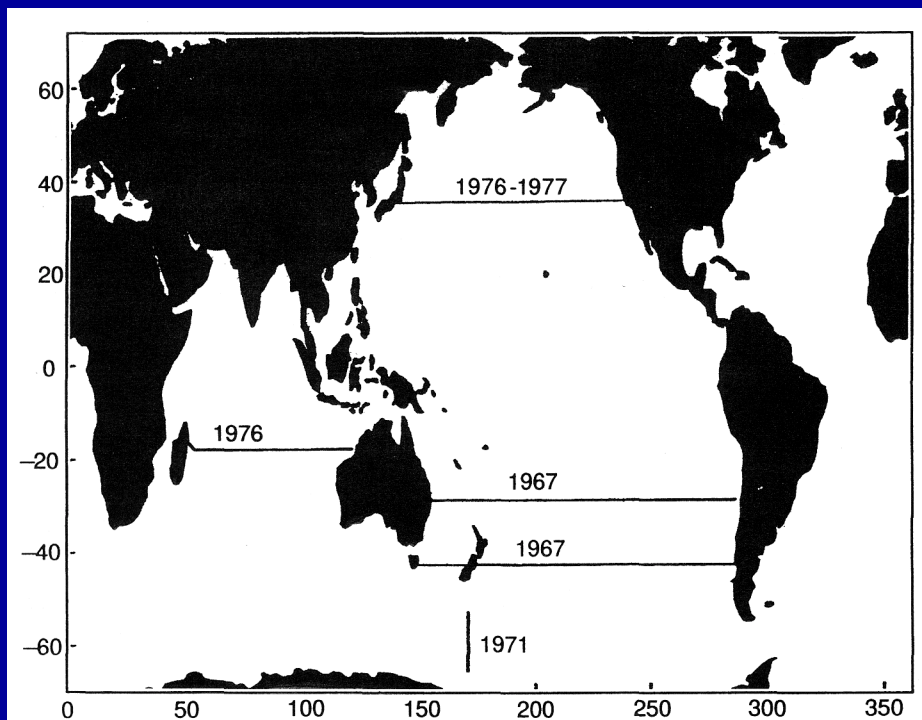
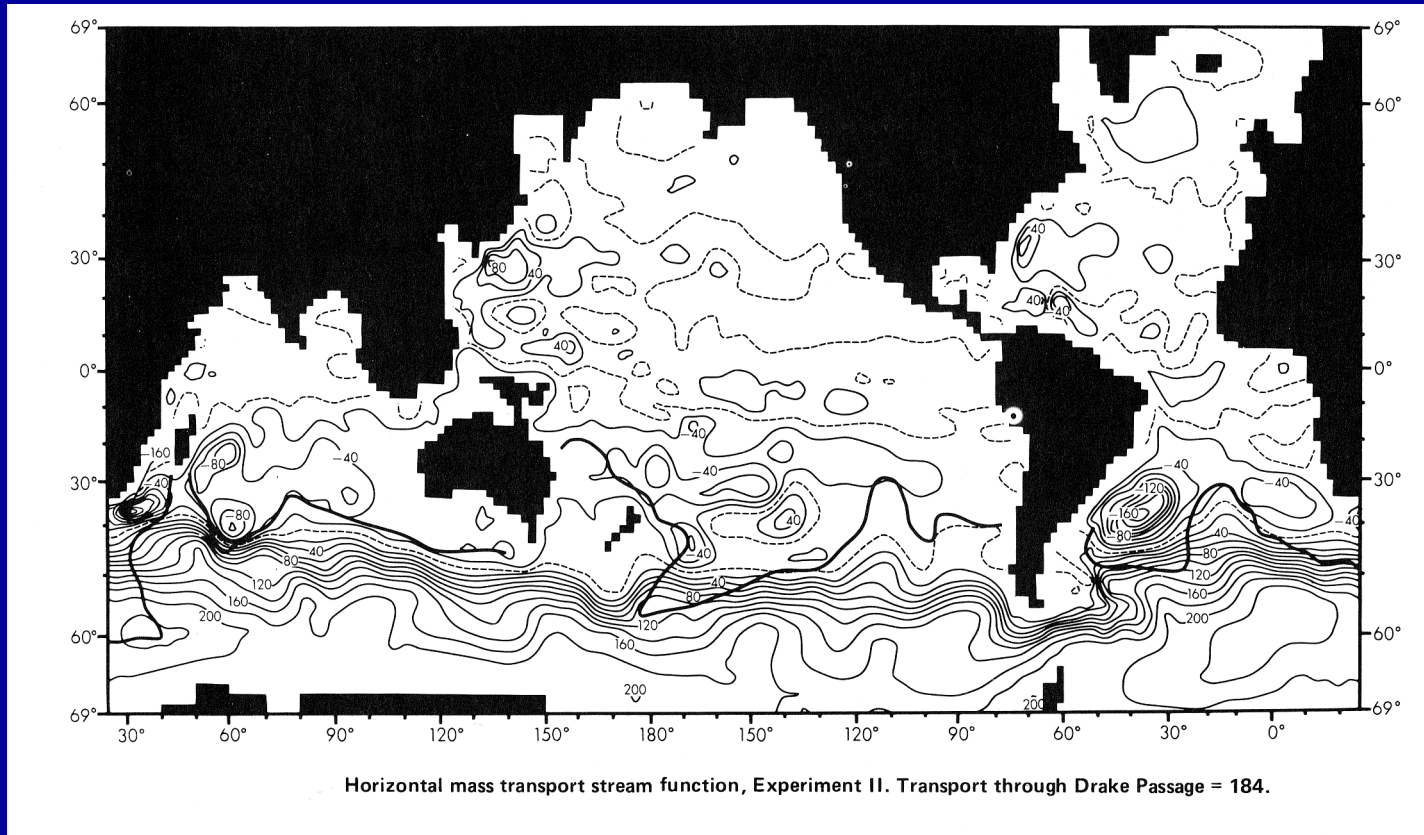


FIGURE 2-26 Deep Atlantic circulation Water filling the North Atlantic basin comes from sources in the high-latitude North Atlantic, the Southern Ocean near Antarctica, and (at shallower depths) the Mediterranean Sea. (Adapted from E. Berner and R. Berner, *Global Environment* [Englewood Cliffs, N.J.: Prentice-Hall, 1996].)



From Michael Cox. Steady winds, steady flow.




What became WOCE and what became JGOFS were originally the responsibility of a single steering committee.

A major goal was to understand the oceanic carbon uptake.
(R. Revelle was conspicuous in calling attention to this problem.)

Fairly quickly became clear that the physical oceanographers had their hands full with defining the oceanic physical state; technical issues of carbon measurement and interpretation required greater expertise.

Some consensus was achieved that to understand the biogeochemical processes, one had to eliminate the major uncertainties arising from the purely physical part.

SEP - 7 1988



August 30, 1988


Dr. Carl Wunsch
Dept. of Earth, Atmospheric, and Planetary Sciences
Massachusetts Institute of Technology
Cambridge, MA 02139

Dear Carl,

I am glad to be reassured that WOCE will take global circulation models and tracers very seriously. My concern is not that this won't be done but rather that the program is too much driven by satellite topography, rapid hydrographic sections and inverse modeling. In my view this approach is basically a dead end. The great hope of the future is atmospheric driven models. After all only with such models can we make any sort of prediction as to how the atmosphere will respond to greenhouse forcing.

I agree that atmospheric driven ocean models must fit the temperature and salinity field (and that to some extent they currently fail this test). However, one does not need a WOCE program to generate an observed temperature and salinity distribution. We have a perfectly adequate one for this purpose.

Tracers are important because they add a time dimension to the verification of atmospheric driven models. We do not have an adequate picture of the evolution of the tracer fields. In preparing a plan for WOCE tracer sampling, use should be made of tracer evolution scenarios generated by the Princeton model. While far from perfect this approach is certainly a great improvement over the seat of the pants approach to planning we have taken thus far.



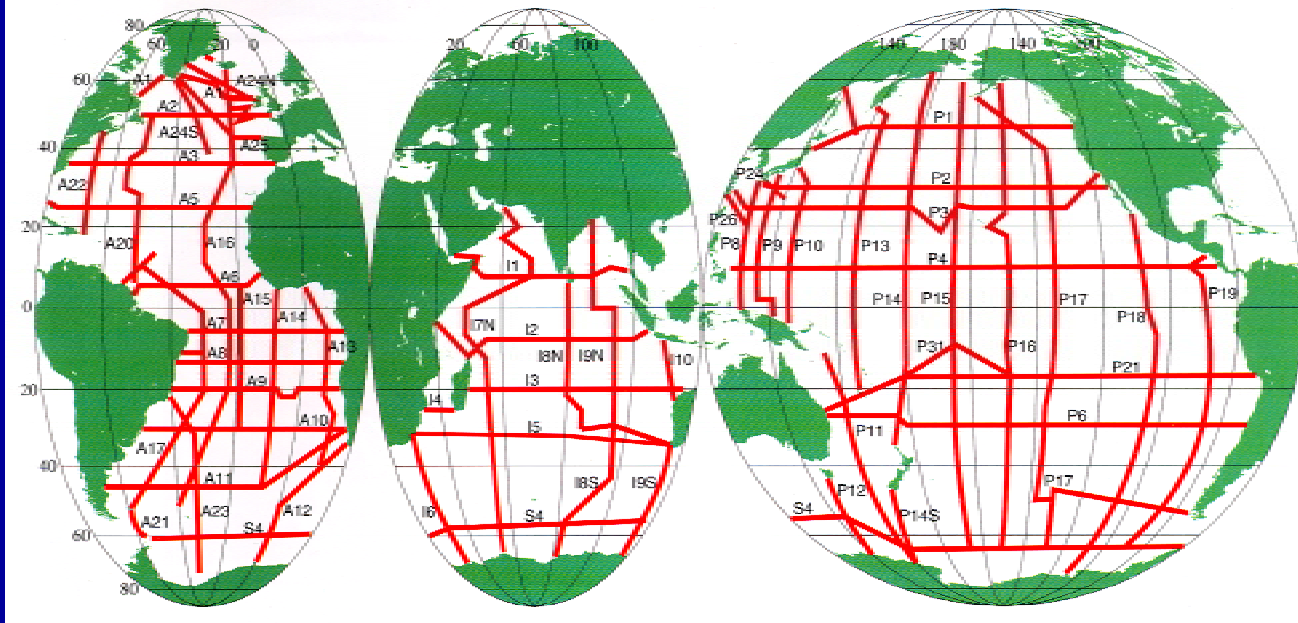
An amicable separation was agreed upon.

An agreement for joint custody of the global ocean CO₂ Survey was put in place.

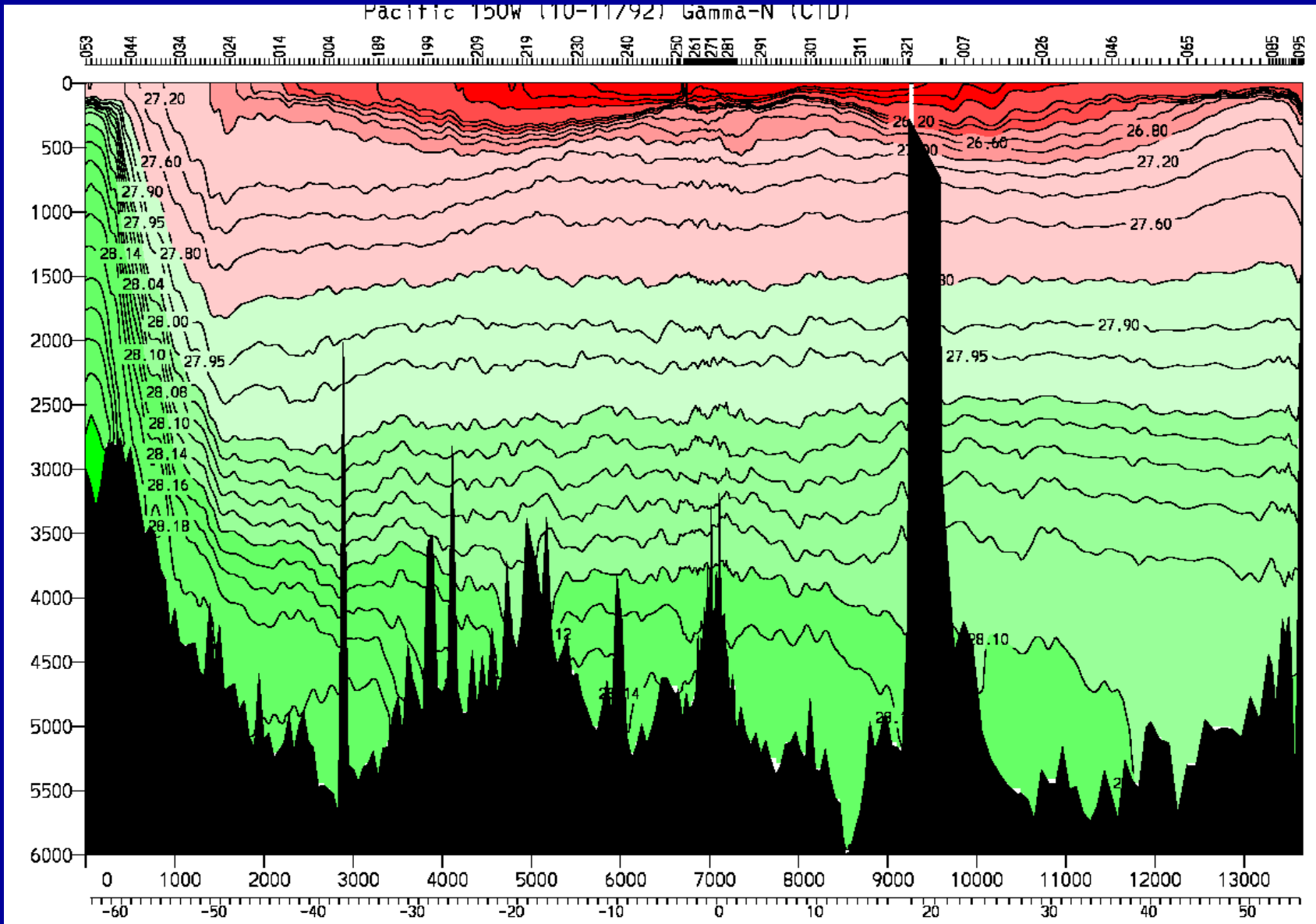
A major struggle took place within the WOCE planning committees over the relative emphasis on global observations (descriptions) and regional process studies which to some were more “scientific.”

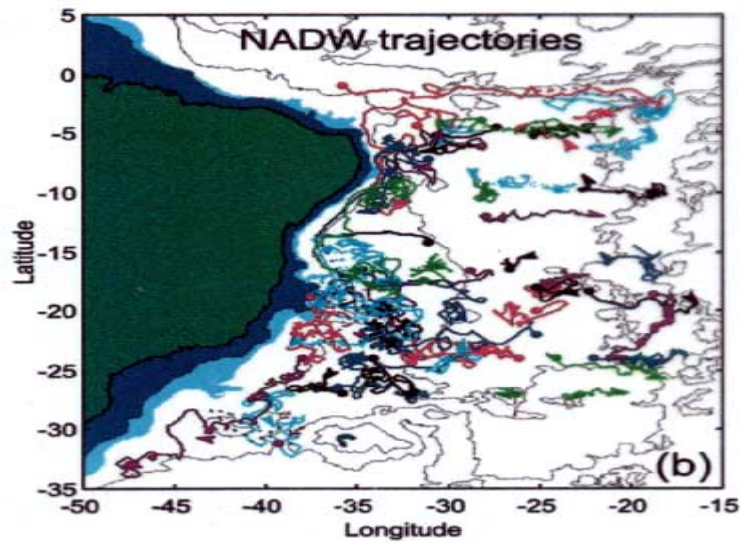
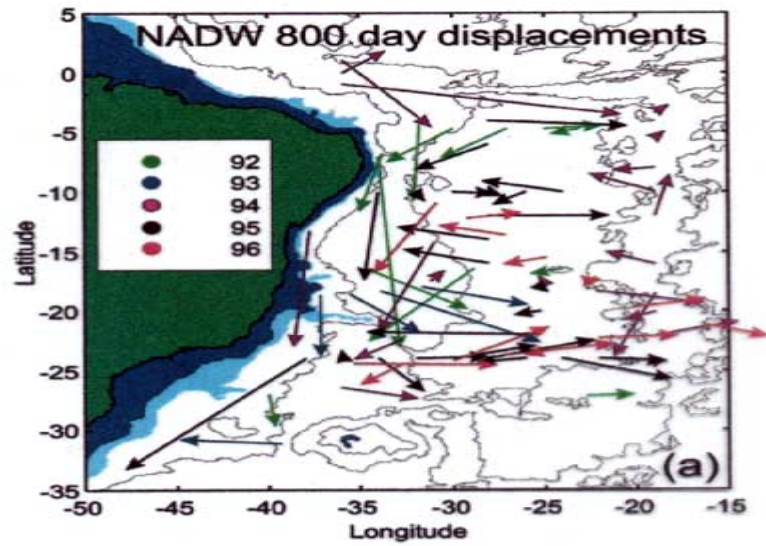
In the end a reasonable balance was achieved.

WOCE Hydrographic Program One-Time Survey

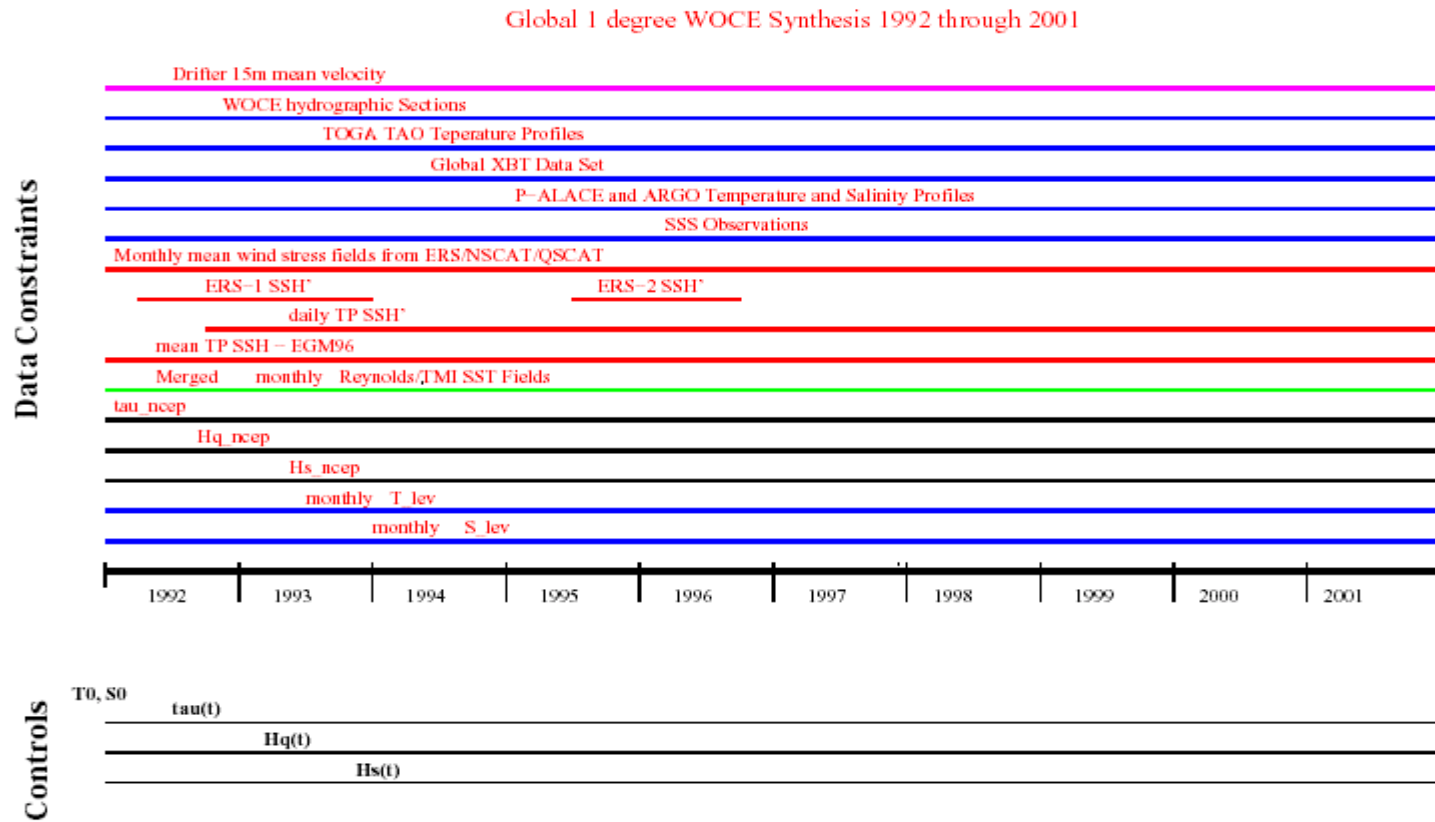


For the first time hydrography was adequately sampled spatially
(horizontal derivatives can be computed quantitatively)



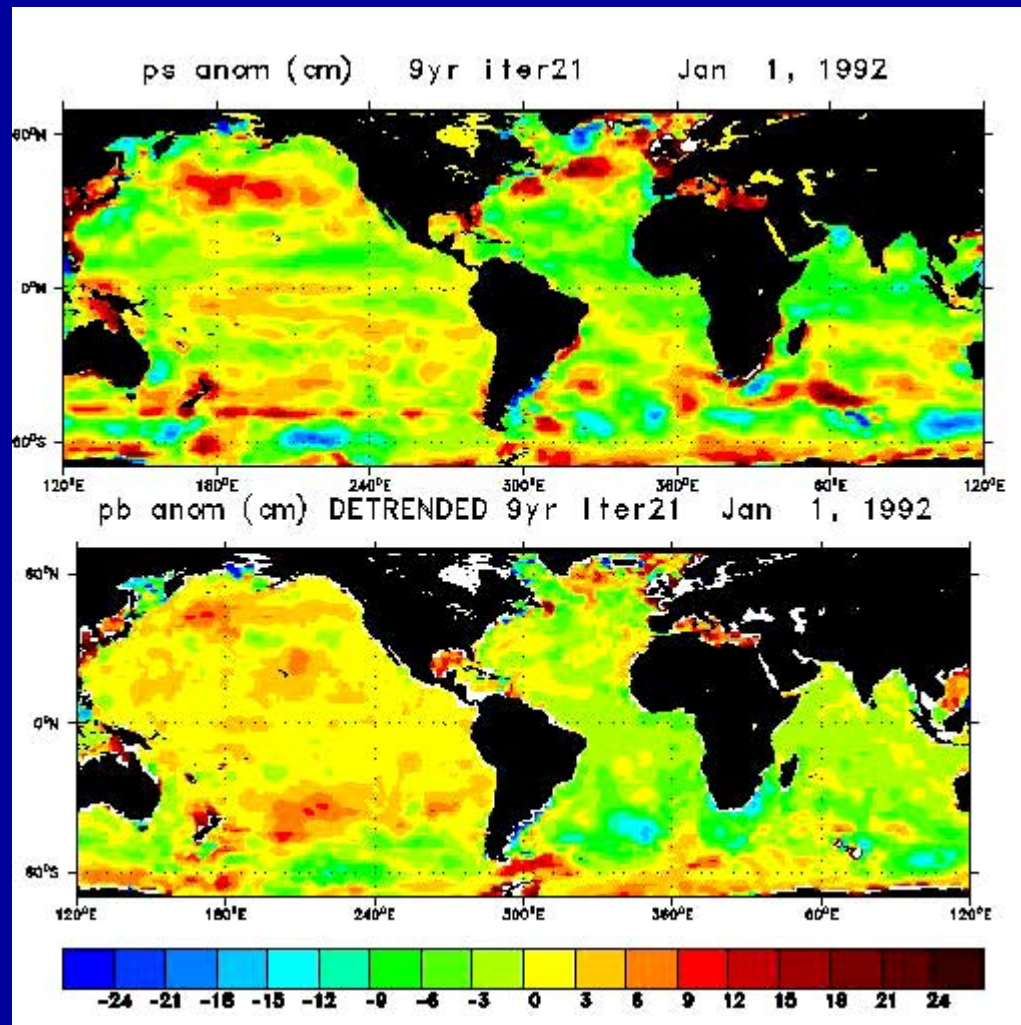


ECCO Consortium WOCE Synthesis. GCM at 1° lateral resolution. 22 layers.

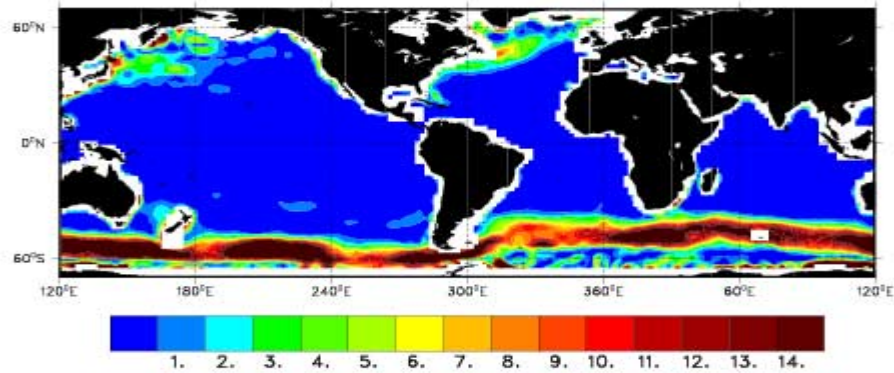


ECCO Consortium: Estimating the Circulation and Climate of the Oceans.

(MIT/SIO/JPL) 1cm elevation/pressure $\approx 7 \times 10^6 \text{m}^3/\text{s}$. For model output: <http://www.ecco-group.org>. National Ocean Partnership Program (NOPP) supported.

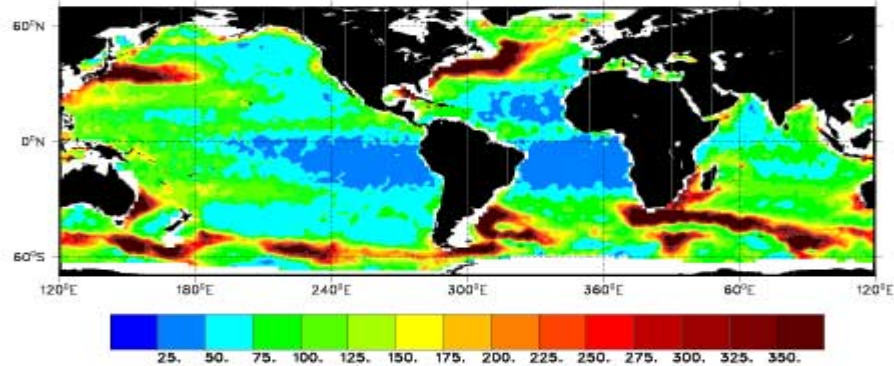


a)



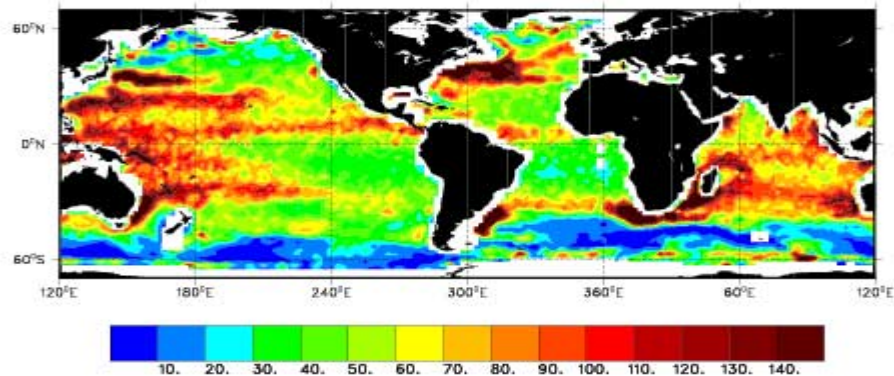
Mean KE

b)



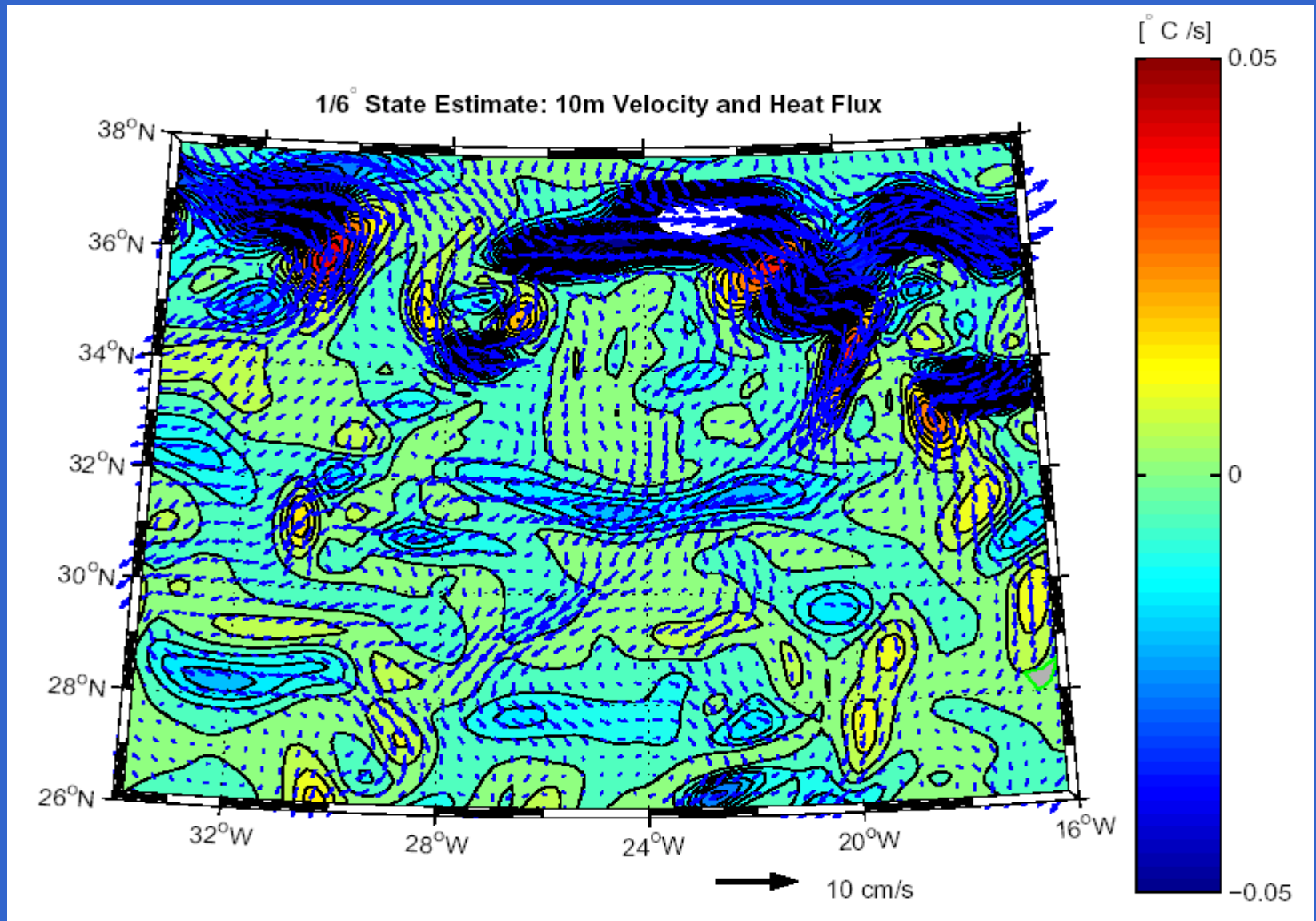
Eddy KE

c)



Ratio:
Eddy KE/Mean KE

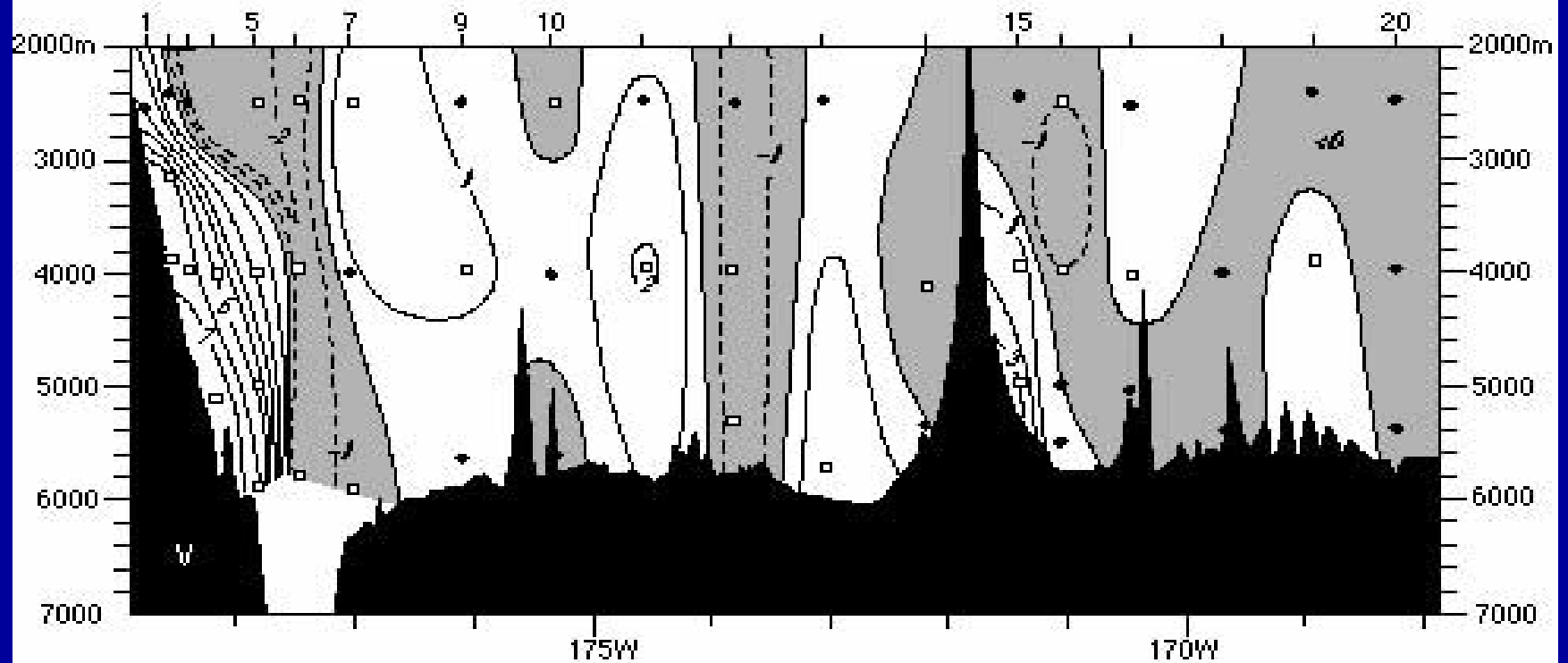
G. Gebbie, 2003 Resolved eddy field, open boundaries, constrained.



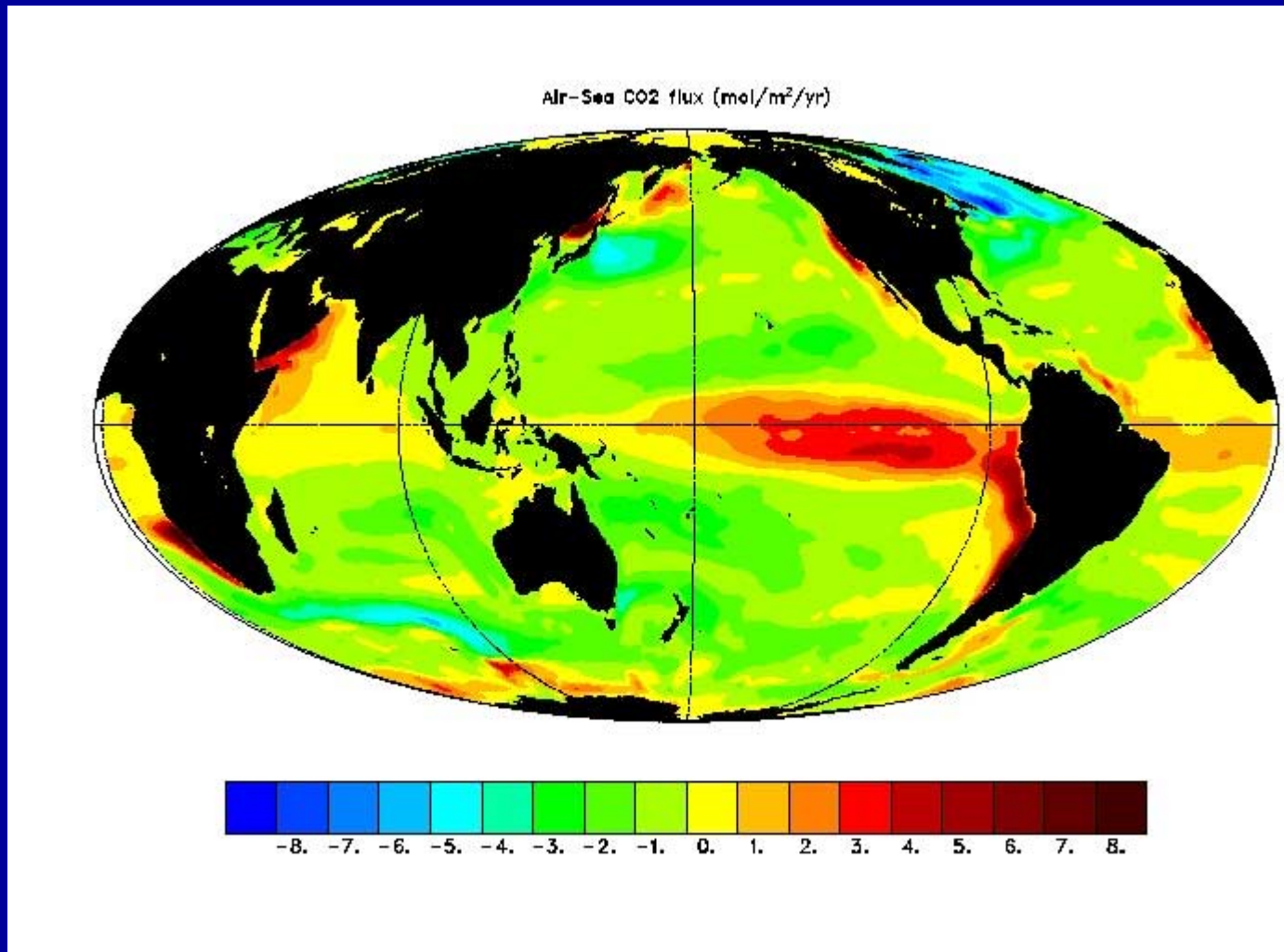
Snapshot 1 June 1993

Whitworth, Warren, Nowlin, Rutz,
Pillsbury and Moore (1999)

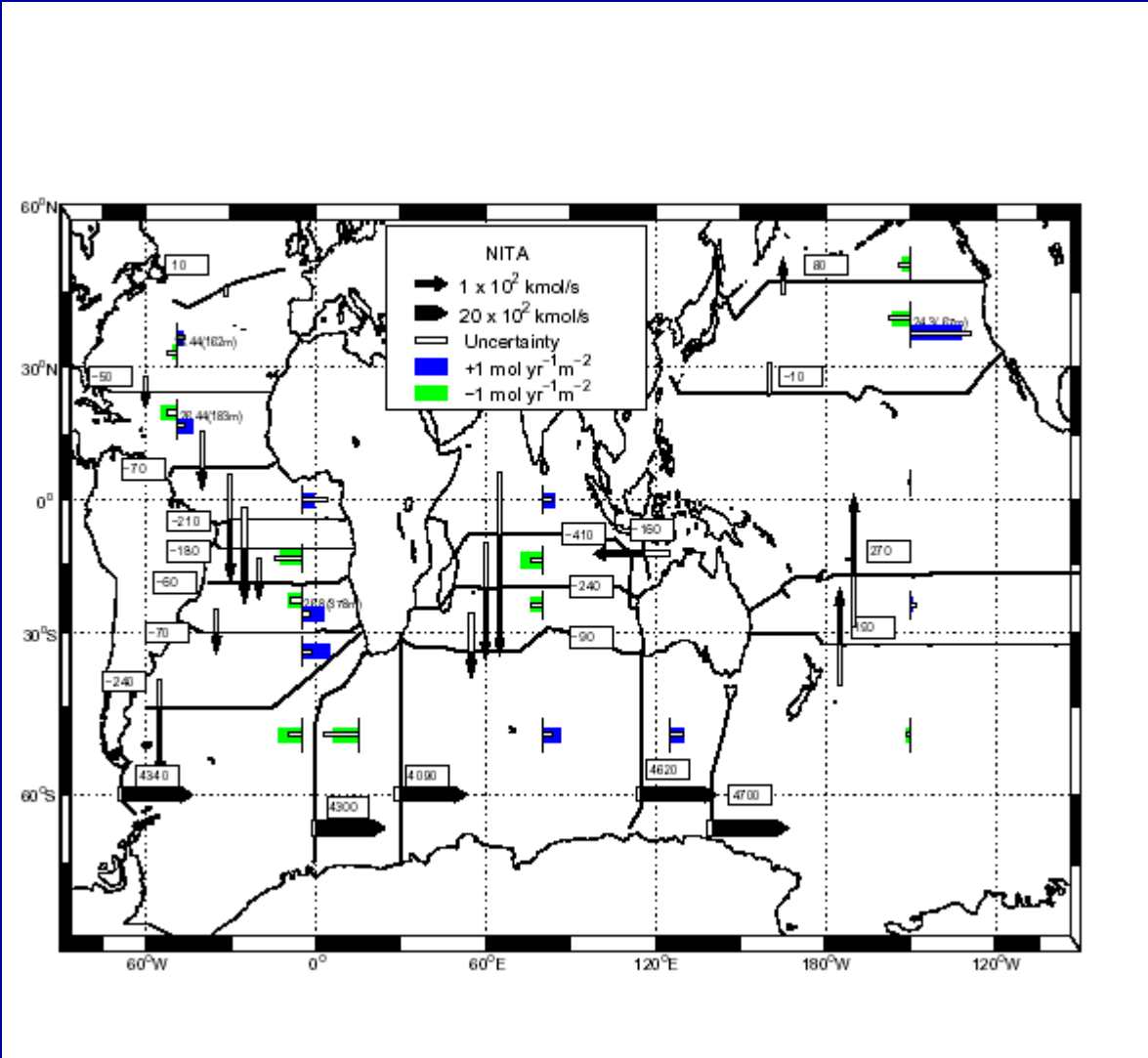
Time-Averaged Northward Velocity PCM9 Array



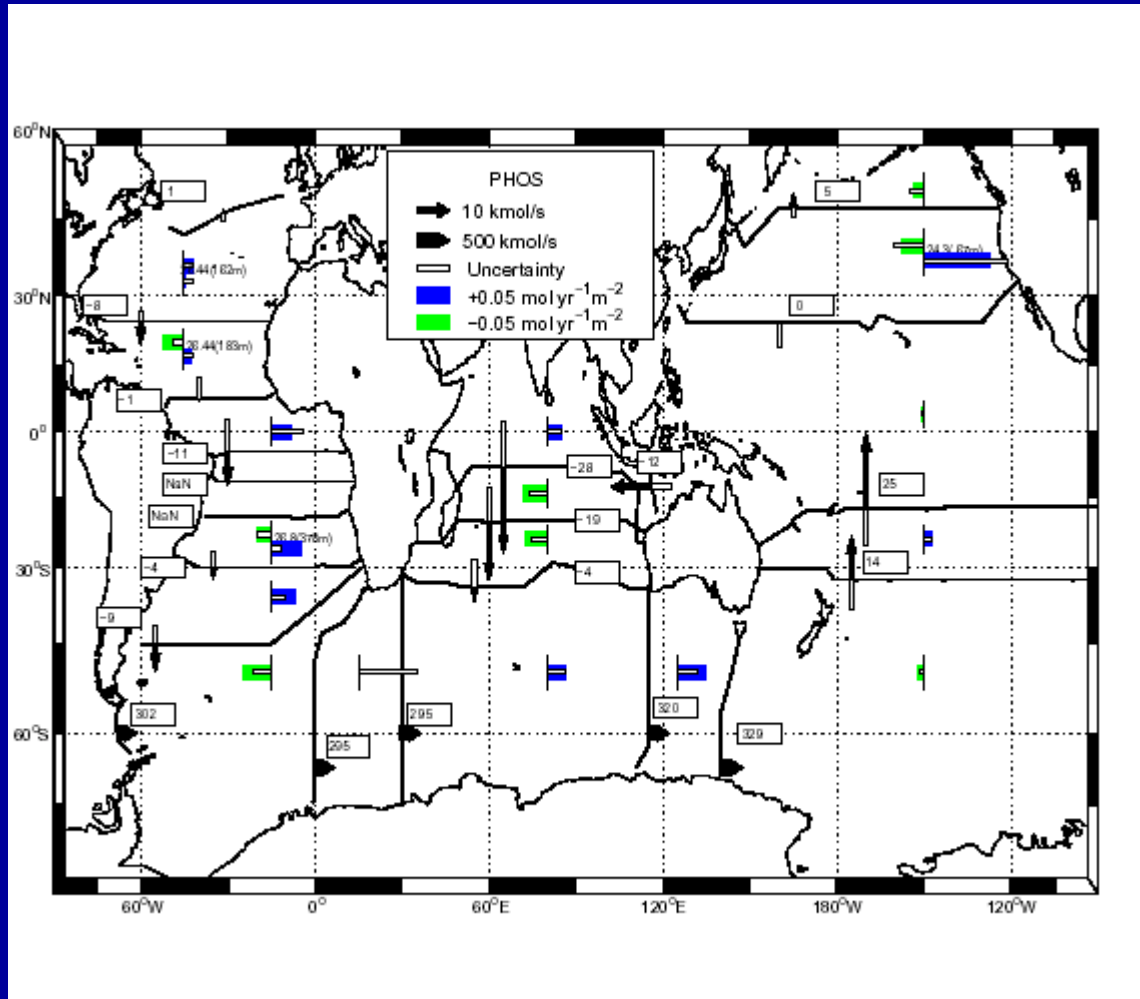
G. Mckinley, 2002

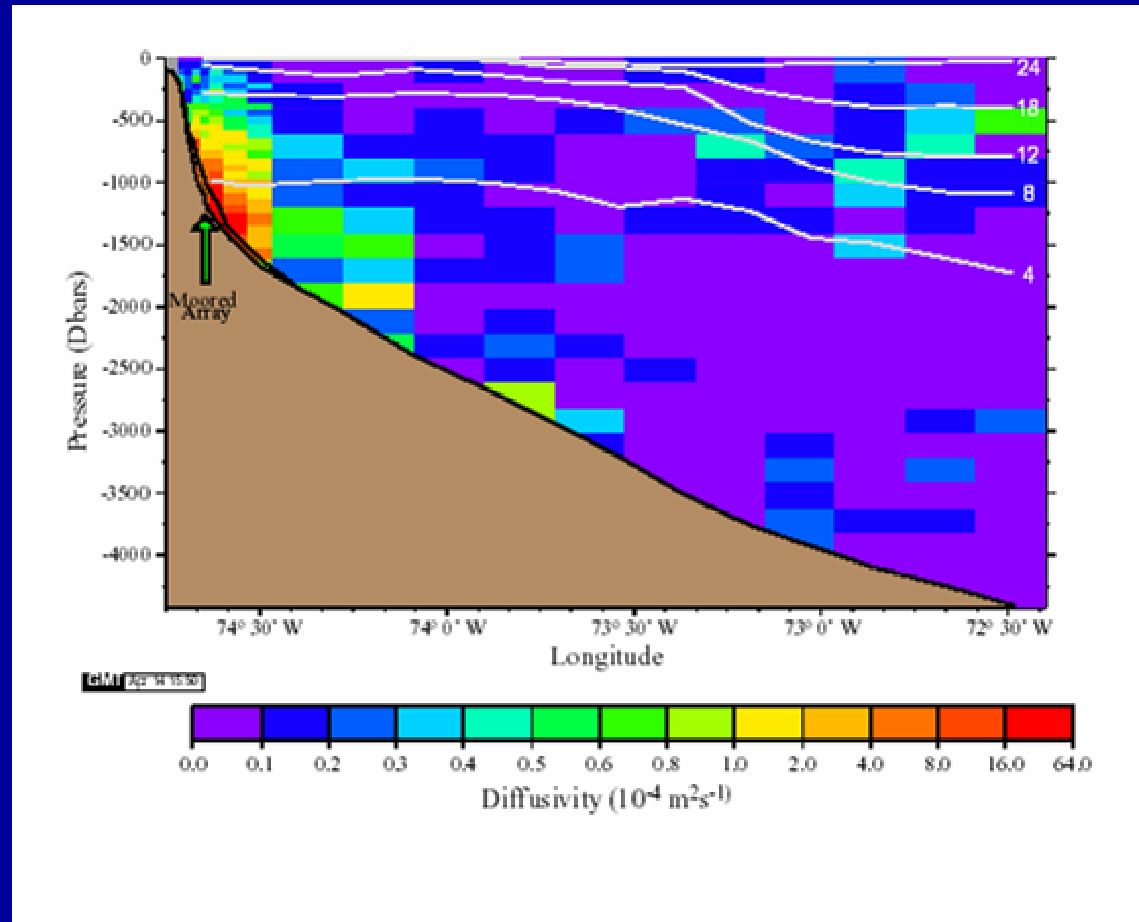


A. Ganachaud, 2002



A. Ganachaud, 2002





What was accomplished?

The ocean circulation was observed on all scales from millimeters to 10,000km+, thus ending the era of pure exploration of the physical ocean that began in the 18th Century

Combined global observing systems and the new generation of general circulation models now permit day-to-day three-dimensional time-dependent estimates of the ocean circulation. This is the real revolution! (Many inaccuracies still present, but no reason to doubt continuing improvements.)

Where do we go from here?

A zero-order description of the full ocean circulation has finally been achieved. There are no time/space scales that have not been measured at all. That the ocean is a very dynamic place rather than a static, almost geological flow, is gradually becoming accepted. *(Need to re-write the textbooks, however.)*

Have a reasonable baseline for measuring future large-scale change.

Estimates will continue to improve if we can sustain the global observing system that WOCE put in place temporarily.

For those interested in biogeochemical cycles, it now becomes possible to focus primarily (but not wholly!) on the biogeochemical processes without being distracted by the possibility of zero-order ignorance of the ocean circulation.

The two communities can be expected to overlap much more in the future---as confidence in the biogeochemistry leads to questions about estimates of the fluid flow/mixing.

Acknowledgements.

The World Ocean Circulation Experiment was a temporary coalition of individual scientists, program managers, private and governmental organizations, and international governmental and non-governmental bodies. Thousands of people contributed.

Challenge for the future is to sustain it in some form so that we continue to observe and improve understanding of the oceans.