Abyssal Circulation & Deep Western Boundary Currents

Glenn Sterenborg

07/12/05

- definition of abyssal circulation

- importance of abyssal circulation

- theory of abyssal circulation

- observations

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Definition of Abyssal Circulation

- A circulation of mass. This circulation also carries heat, salt, oxygen, and other properties.
- Mostly wind related, but tidal mixing is also important. Wind is a factor because it cools the surface and evaporates water;this determines where deep convection occurs. It also produces turbulence in the deep ocean which mixes cold water upward
- Circulation is driven or 'pulled' by upwelling; *not* by sinking of dense water

Importance of Abyssal Circulation

- Cold deep water/warm surface waters contrast determines stratification of the oceans which impacts ocean dynamics.
- The volume of deep water >> volume of surface water
- Abyssal circulation influences Earth's heat budget and climate. Variation from decades to centuries to millennia.
- Cold water can absorb CO_2 from the atmosphere

Theory of Abyssal Circulation

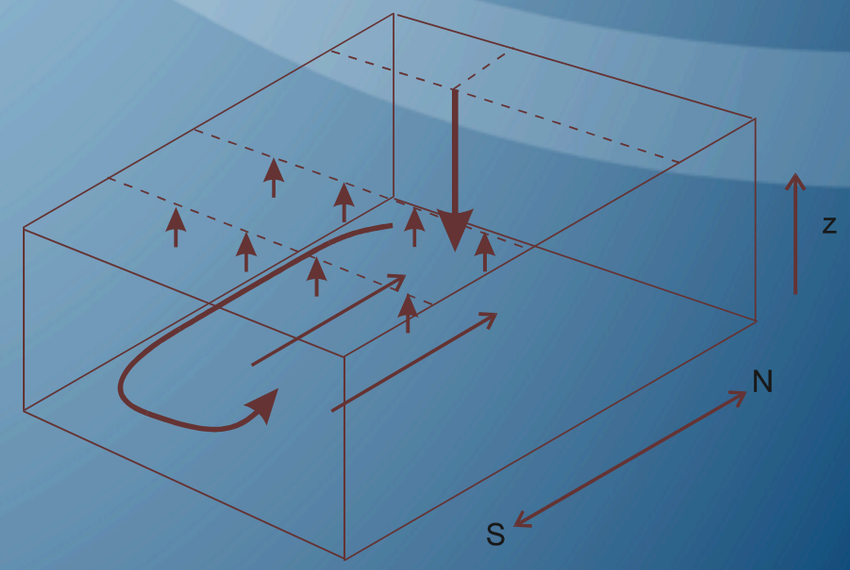
- 2 layer ocean (top/bottom)
- localized sources of cold deep water at high latitudes supplied by deep convection
- upwelling throughout basin determines circulation
- flat bottom
- included Coriolis variation with latitude

Theory of Abyssal Circulation

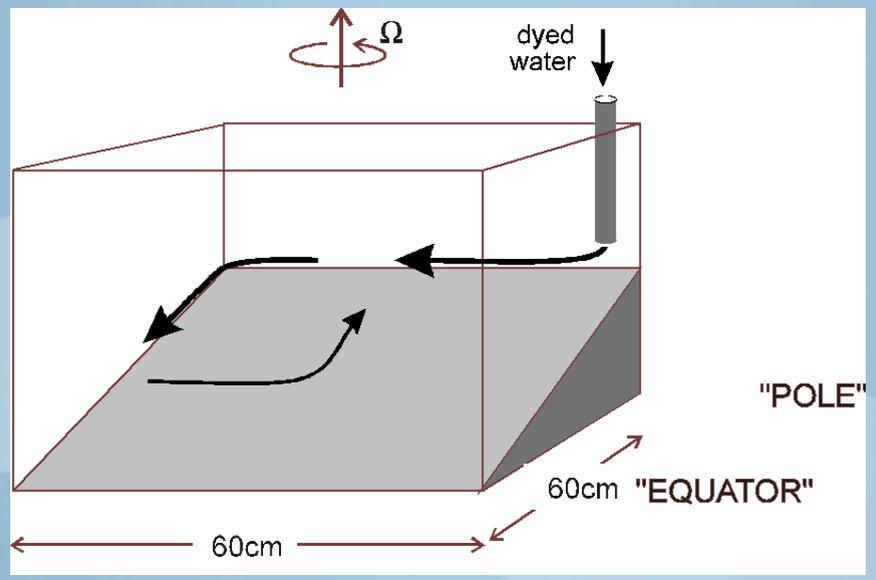
- Result of balance is poleward flow due to vortex stretching by the upwelling

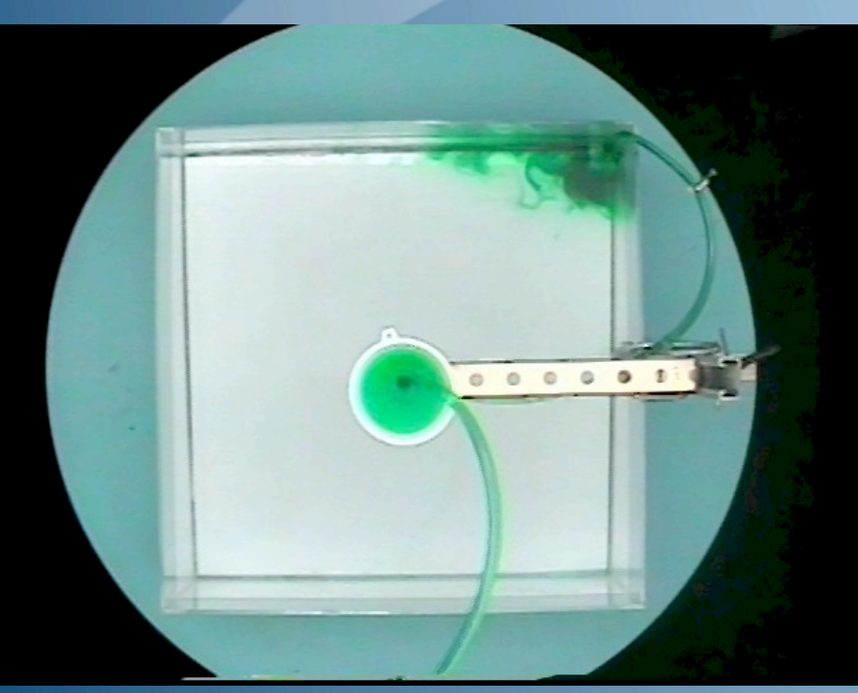
- *It runs towards the deepwater source!!*

- Thus need flow away from source to close the circulation: Deep Western Boundary Current



Theory of Abyssal Circulation





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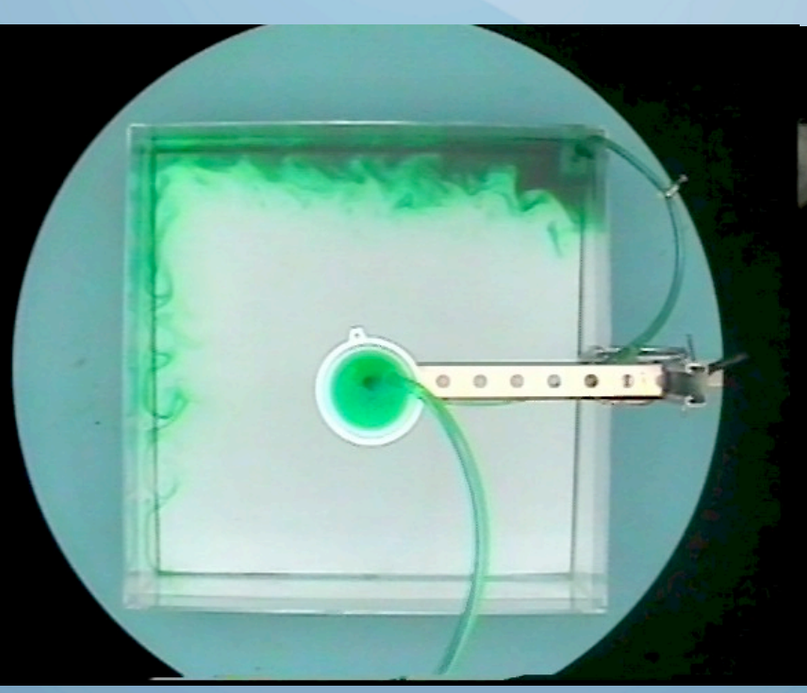

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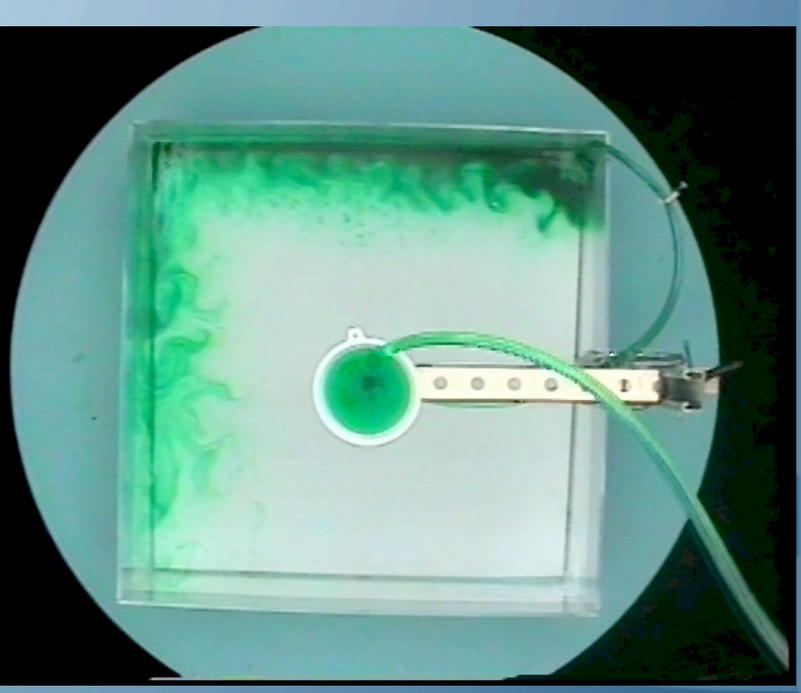

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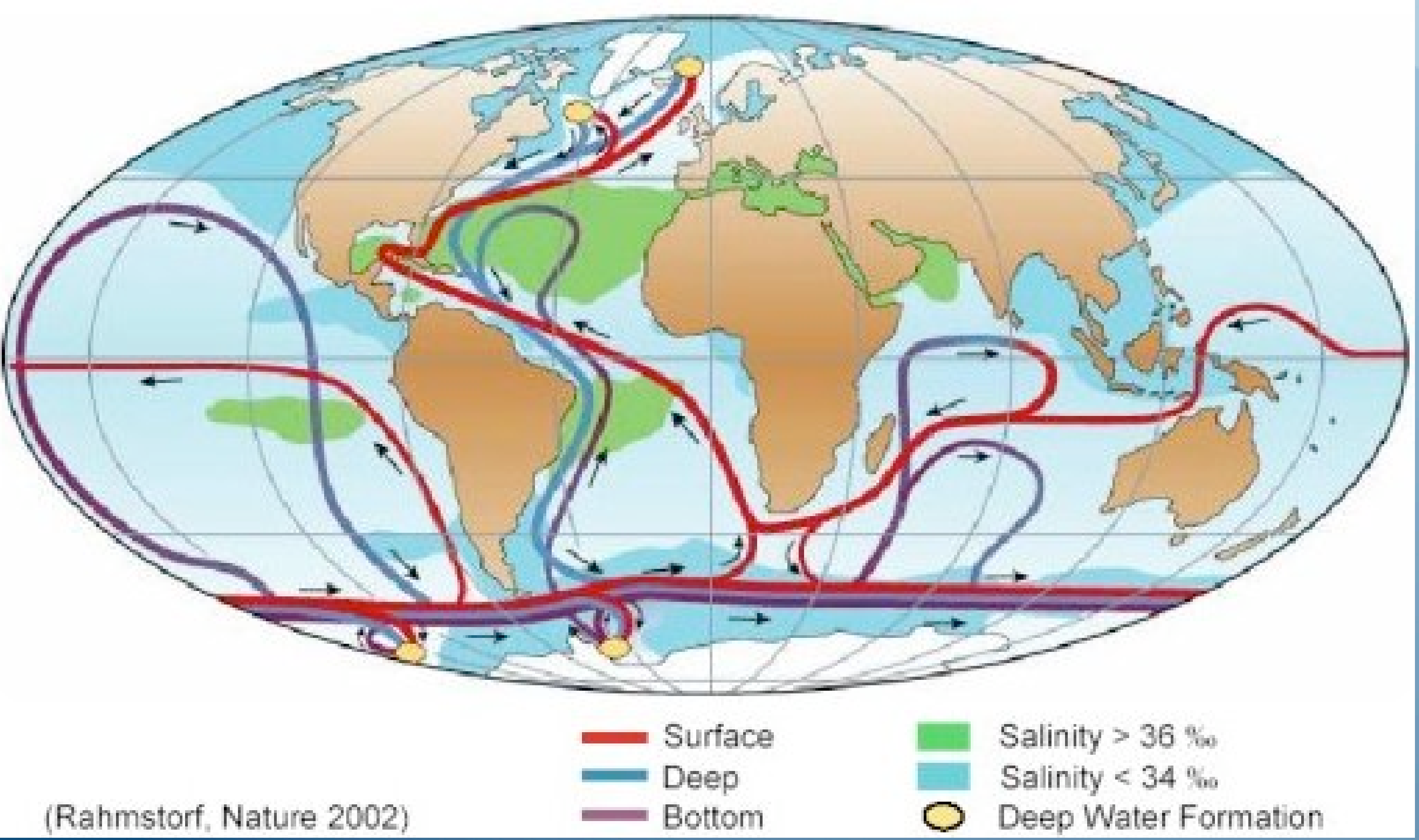
Theory of Abyssal Circulation

- No abyssal topography
- More ‘sources’ exist than predicted

Abyssal circulation:

- part of the THC
- balance between local 'sources' and widespread upwelling on basin scales - 'sink'
- again: abyssal circulation is 'pulled' by mixing or upwelling and not 'pushed' by dense water sinking
- transport: ~ 15 - 20 Sv
- speed: O(mm/s)
- long time scales: O(1000 yrs)



(Rahmstorf, Nature 2002)

Deep Western Boundary Currents:

- up to 30 cm/s
- ~40 km wide
- very high density water
- flow away from source occurs in DWBC *only*
- cross-equatorial flow occurs *only* in DWBC

- South Atlantic: DWBC now a buoyant anomaly compared with ambient waters at same latitude.

Observations

- Given that mean flow ~ 1 mm/s, direct measurement of abyssal circulation is not possible.
- Measured distribution of temperature, salinity, oxygen, silicate, CFC and other tracers used to infer knowledge.
- DWBC is strong enough to be identified

Deep water sinking at Labrador Sea, 56 N

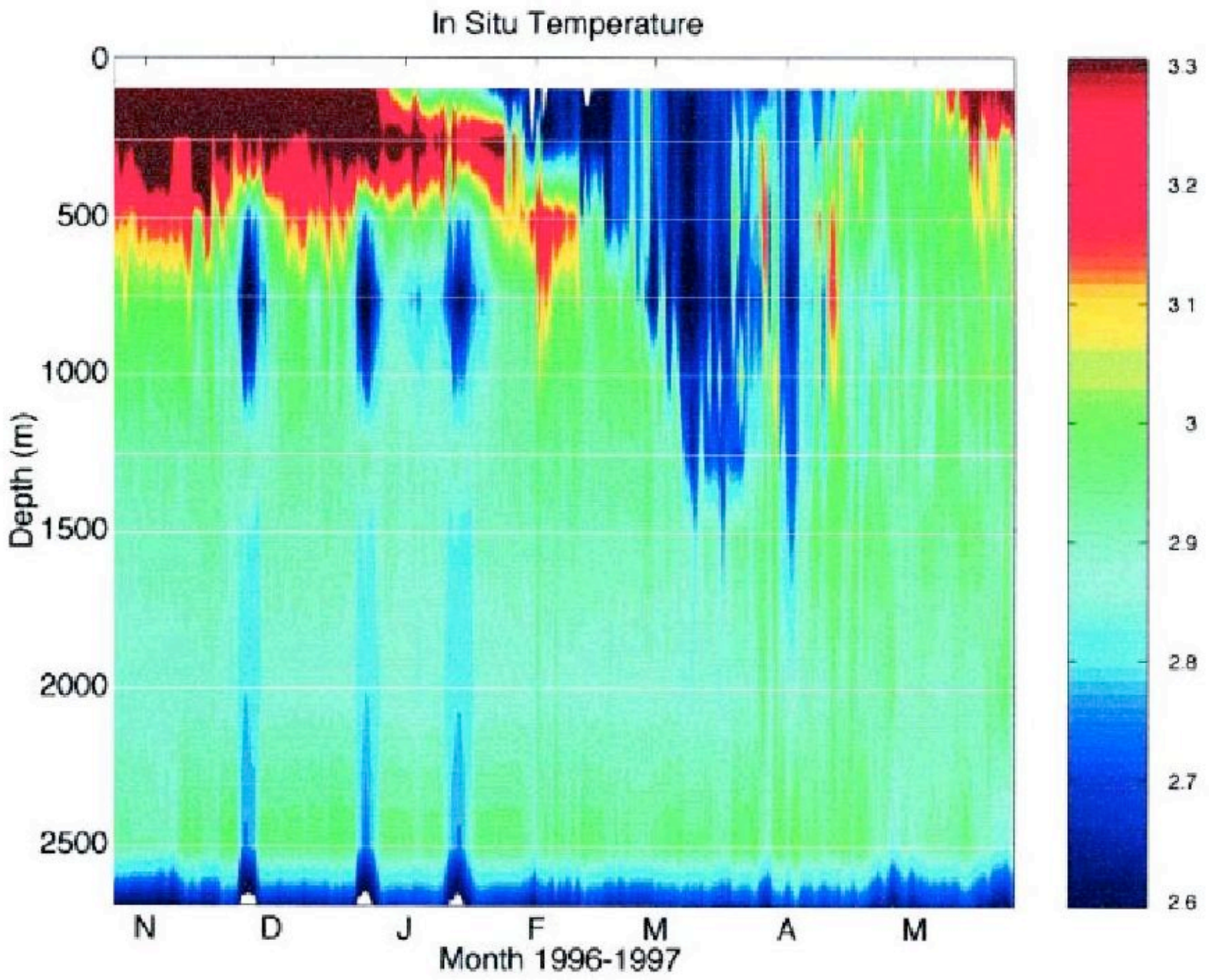
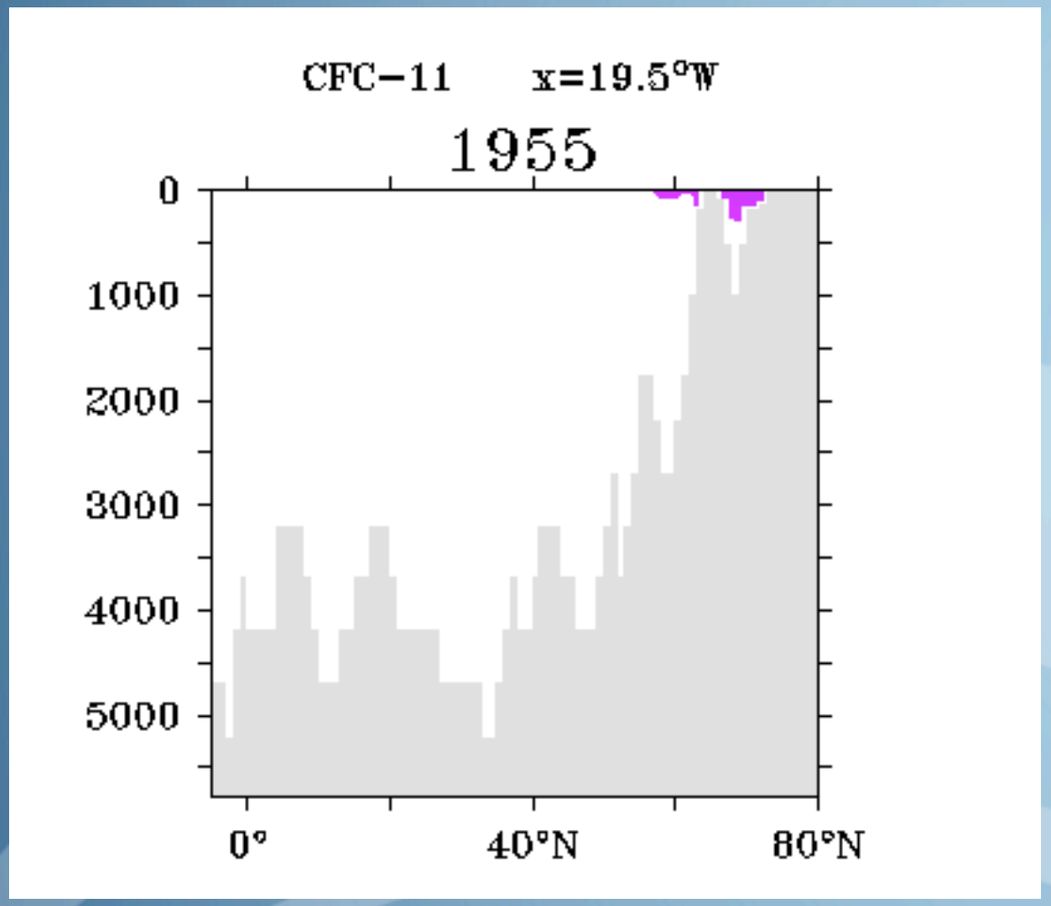
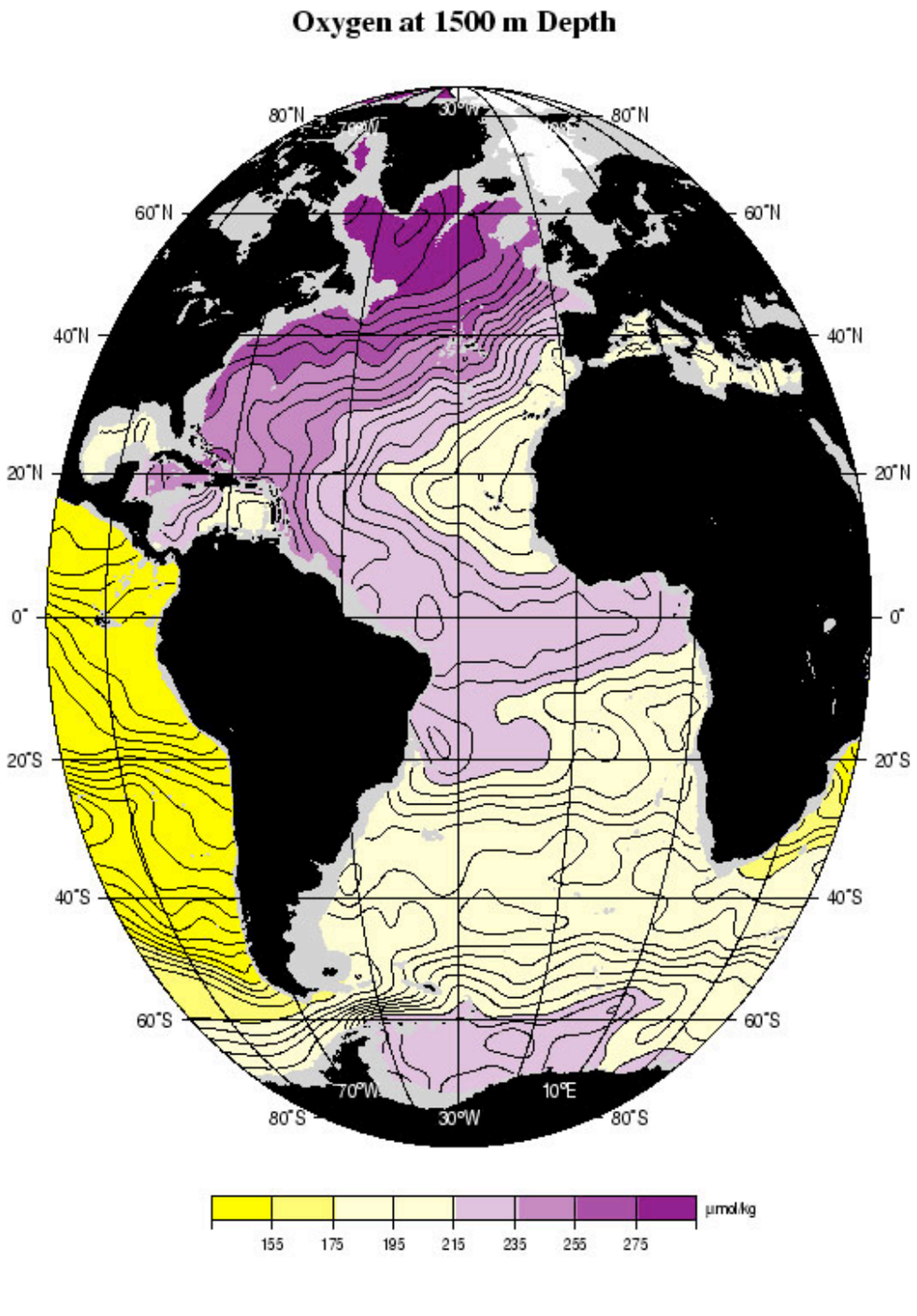


FIG. 23. The potential temperature (°C) field for October 1996–May 1997 at the Bravo mooring (see Fig. 9) showing the build up of warm (and saline) buoyant fluid until January, the subsequent deepening in excess of 1500 m, and then restratification in May (courtesy of P. Rhines).



- http://puddle.mit.edu/~mick/cfcsec.html

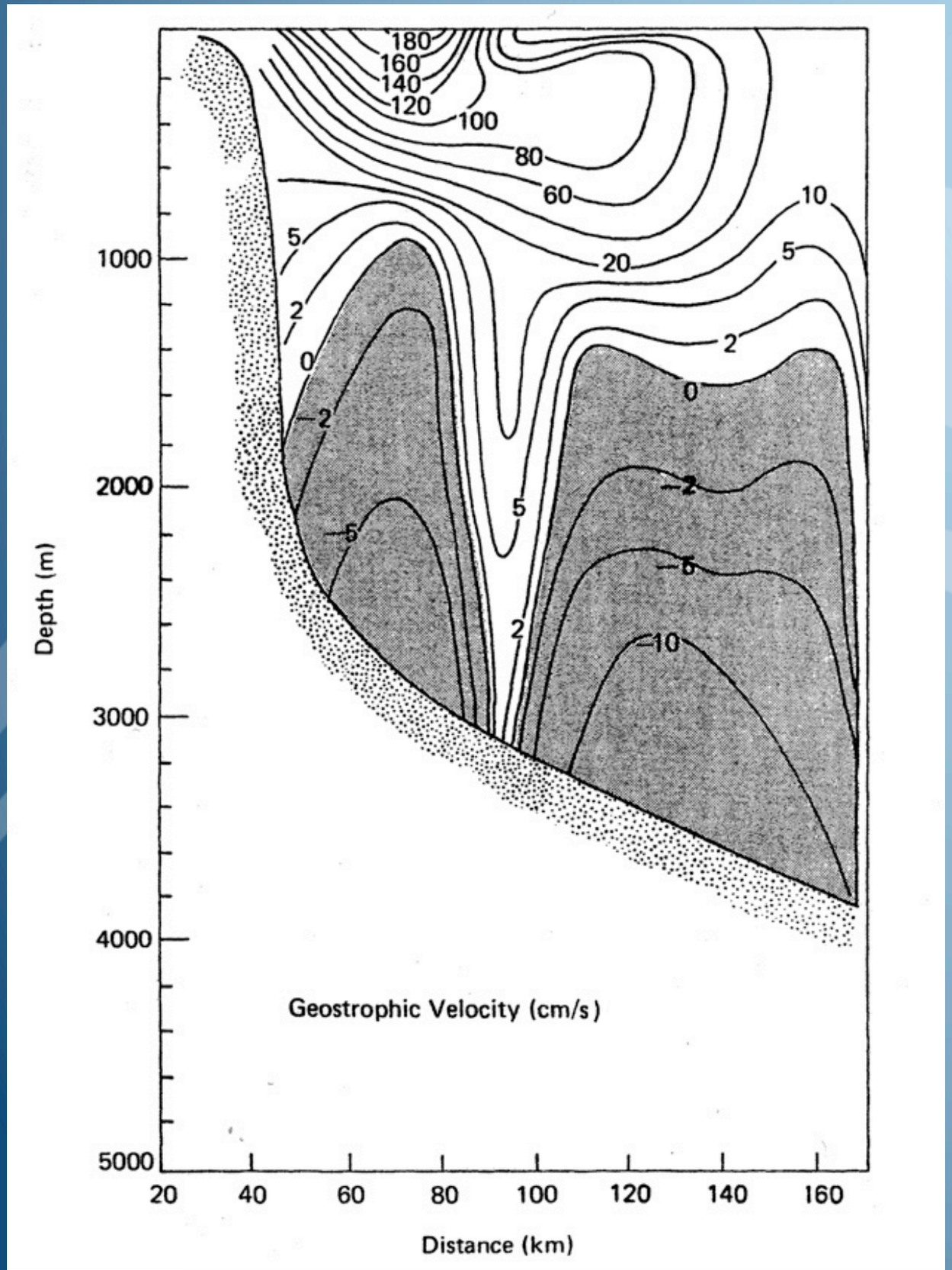
Dissolved oxygen at 1500 m depth:



Surface waters are near saturation in oxygen content. As water leaves the surface , its oxygen content is slowly used up by bio-activity.

Thus, oxygen concentration acts as clock. The lower the content, the older the water.

Typical Gulf Stream cross section



Notice how in the upper layer there exists a northward flow - whereas in the bottom layer there is a southward flow

Questions

References:

- http://www-paoc.mit.edu/labweb/lab14/gfdxiv.htm
- http://www-pord.ucsd.edu/~ltalley/sio210/pickard_emery/chapter_8.htm
- http://www.pik-potsdam.de/~stefan/thc_fact_sheet.html
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- Stommel/Arons 1960 Deep Sea Research
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