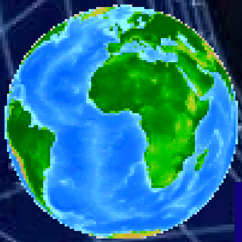
Sea surface salinity as a key to the global ocean conveyor

Bernd J. Haupt & Dan Seidov



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Global Ocean Conveyor

- Present-day ocean thermohaline circulation is driven by the deepwater sources in the Northern and Southern Hemisphere.
- During the geologic past and in the foreseeable future the balance of the deepwater sources can change, causing climate to differ dramatically from its present-day state.
- The climate leaves behind an impact on the lithosphere’s sediment cover. What type of physical climate signal can be seen in the sediment cover?

Glacial Earth

Global Ocean Conveyor

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Glacial Earth

Stommel-Arons Ocean circulation (1958)

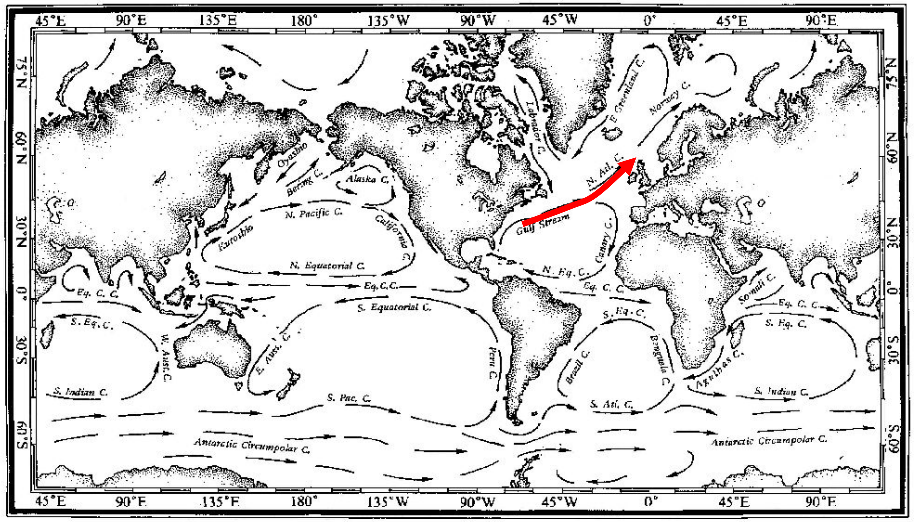


Fig. 2.17 The general surface circulation of the ocean in schematic form. The dominant features are the large, anticyclonic subtropical gyres in each ocean basin, the equatorial current systems, and the Antarctic Circumpolar Current.

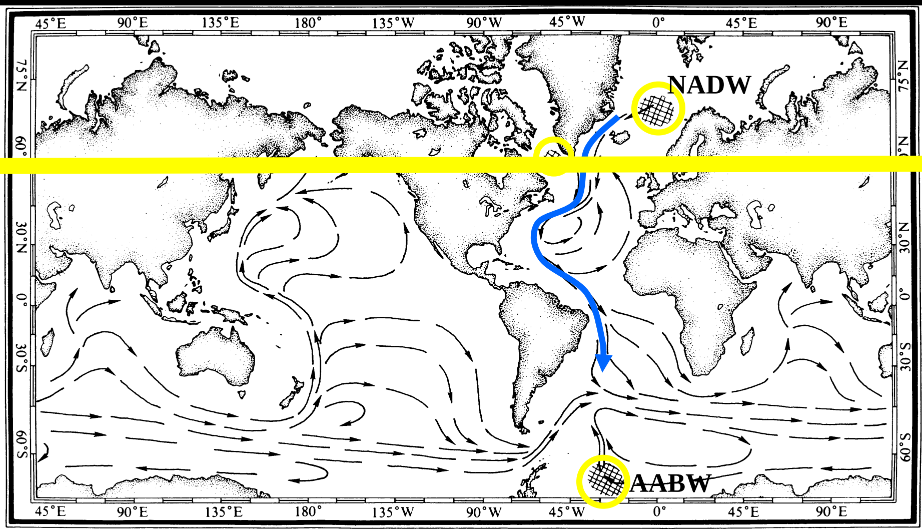
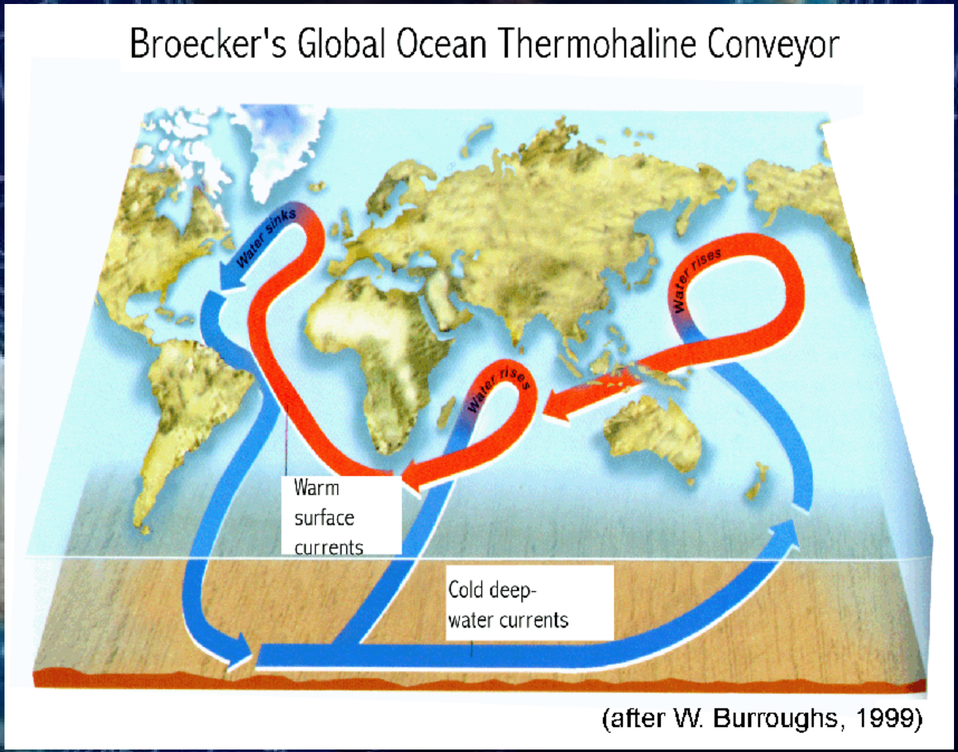


Fig. 2.23 Schematic flow lines for abyssal circulation. The cross-hatched areas indicate regions of production of bottom water. [Adapted from Stommel, H., *Deep Sea Research* (1958).]

- Meridional ocean circulation is responsible for poleward heat transport.
- Present-day ocean circulation is driven by deep-water sources in high latitudes.
- Geological past shows substantial differences in ocean circulation during warm and cold climates.
- Geological past shows that an imbalance between high latitudinal deep-water sources has dramatically altered the climate.

Global Ocean (Salinity) Conveyor Belt

- The concept of the global conveyor has been put forward by W. Broecker in 1991 and has proven to be one of the most fruitful ideas in paleoceanography.
- This salinity conveyor belt is a truly global system of currents inter-connecting very distant regions of the word ocean



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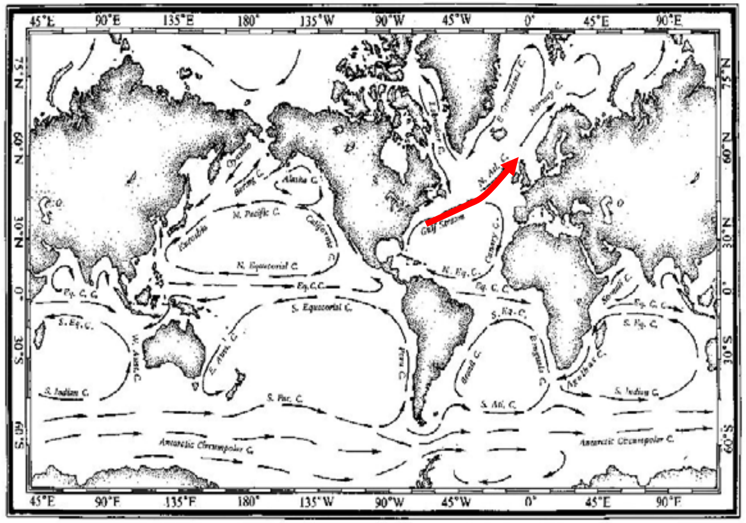

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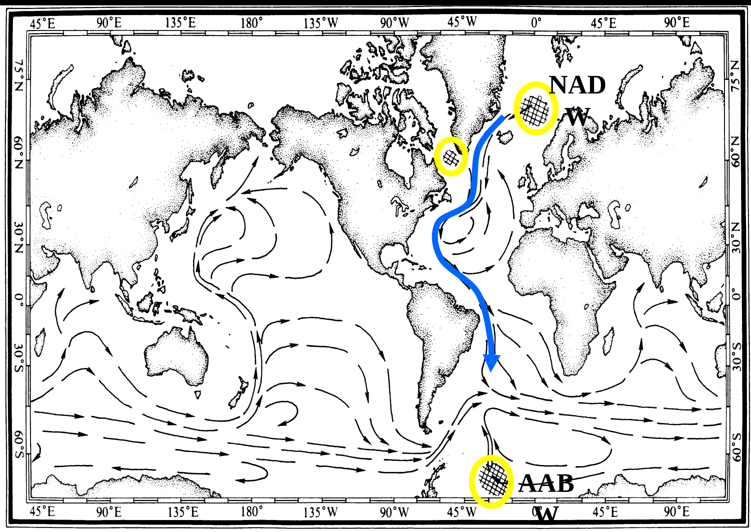

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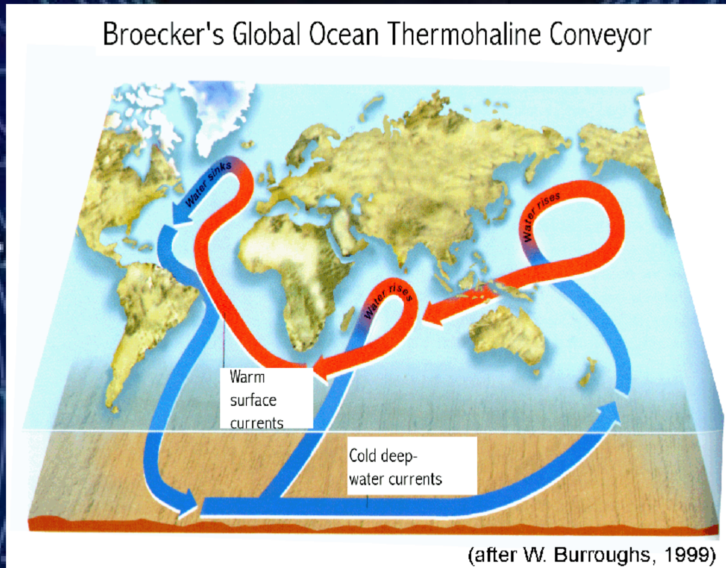
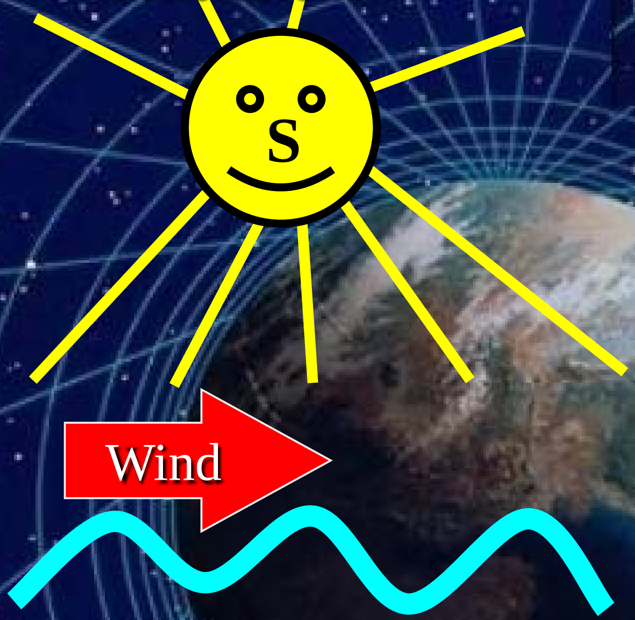
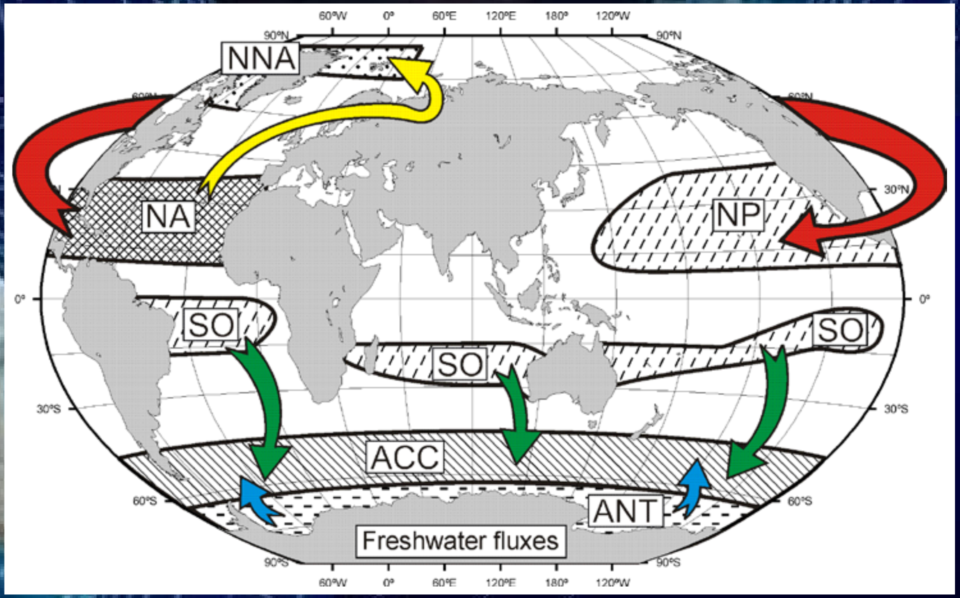


Structure of presentation

- Problem
  - What is the key to the large-scale ocean circulation?
  - Can the climate variability be clearly seen in the ocean sediment?
  - Are the linkages between climate, ocean, and sedimentary processes well enough understood?
- Overview about the model and experiments using simplified sea surface boundary conditions
- Conclusions





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Citation from IAMG'02 abstract submitted in beginning of 2002:

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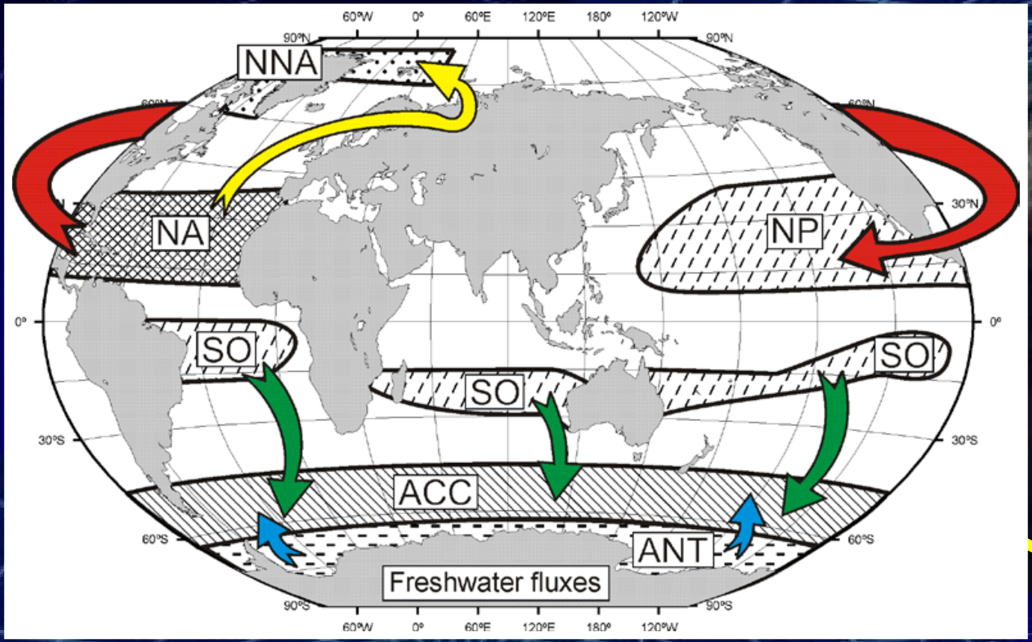
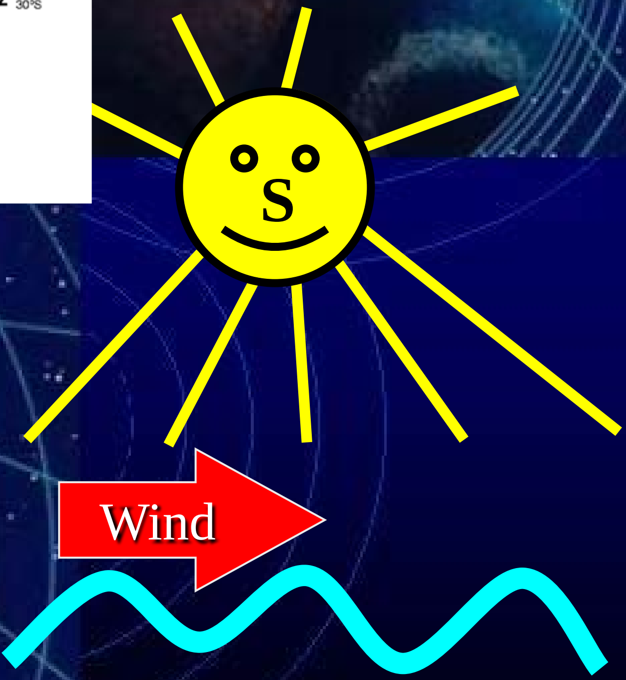
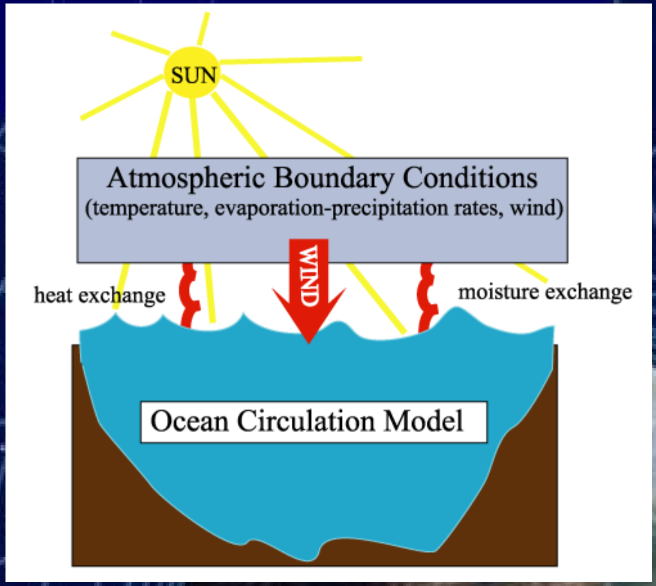
What is the key to the large-scale ocean circulation?

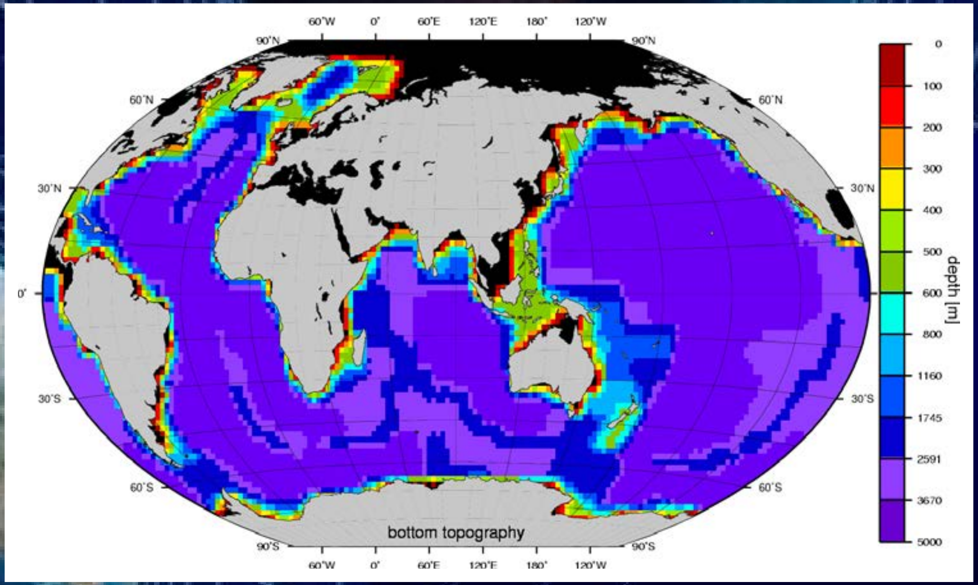




Global ocean circulation model

- MOM 2 (Modular ocean model version 2.2) from GFDL (Geophysical Fluid Dynamics Laboratory)
- Grid resolution: - horizontal: 6 x 4° (62 x 45 grid points)
  - vertical: 12 unevenly spaced layers

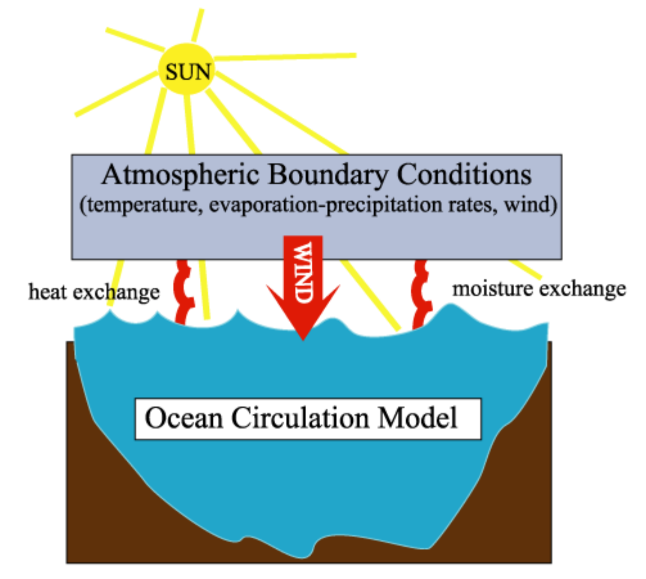


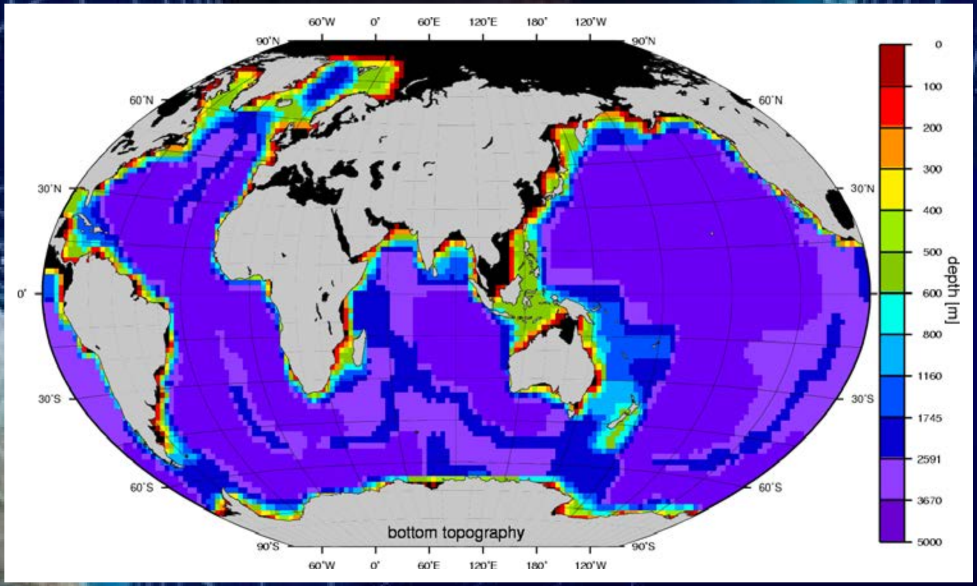


Bottom topography (ETOPO 5)

Global ocean circulation model

The numerical model MOM 2 (Modular ocean model version 2.2) developed at GFDL (Geophysical Fluid Dynamics Laboratory) has been used at Penn State to address past and possible future changes in the ocean global conveyor. The model equations are solved with different boundary conditions representing glacial, interglacial, and possible global warming scenarios.





Bottom topography (ETOPO 5)

Grid resolution:

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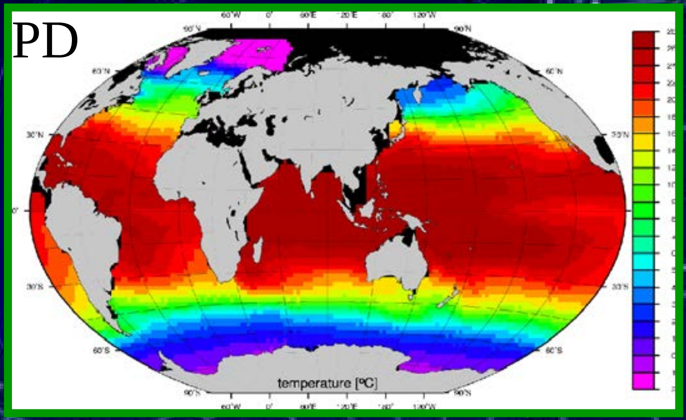
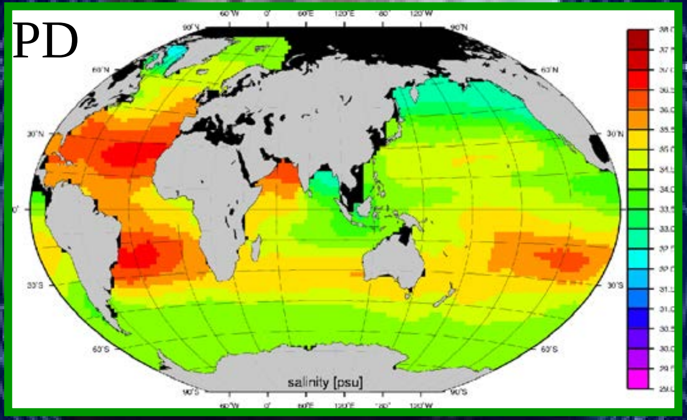
Present-day control experiment

Sea surface boundary conditions (effective freshwater flux)

SST [Levitus and Boyer, 1994]

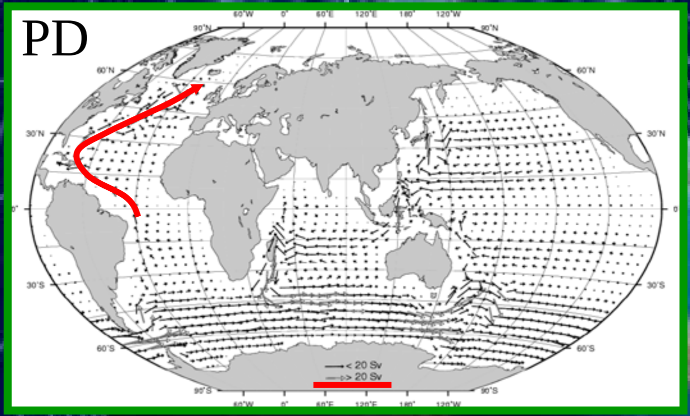


SSS [Levitus et al., 1994]

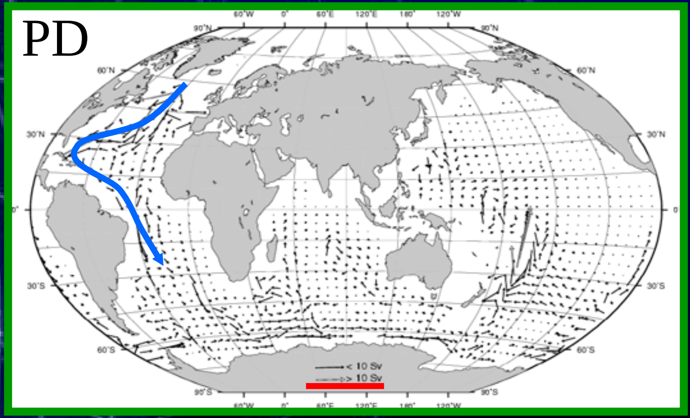


Vertical integrated water mass transport in Sverdrup

above 1500 m



below 1500 m



1 Sverdrup (Sv) = 10^6 $m^3 s^{-1}$

Atlantic water masses

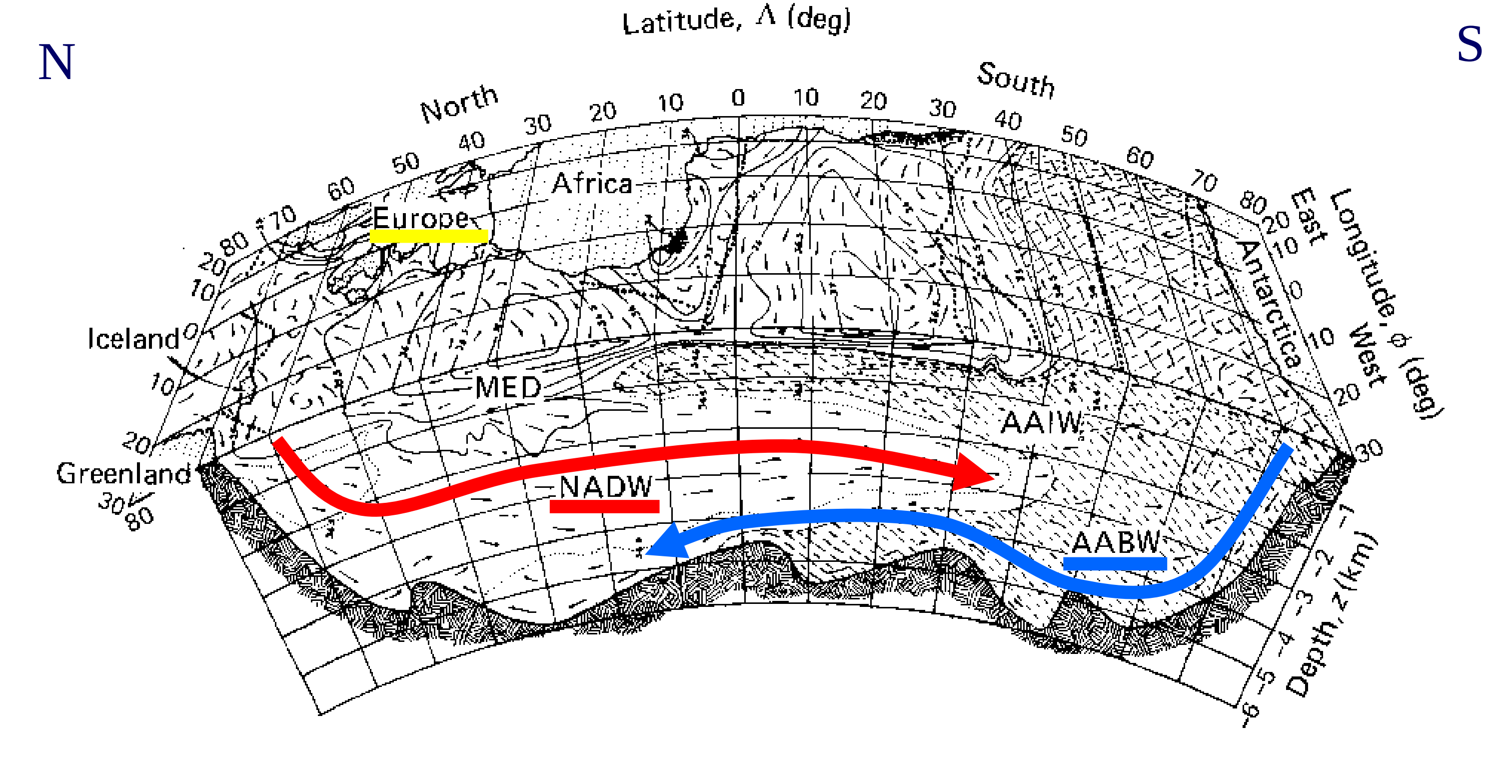
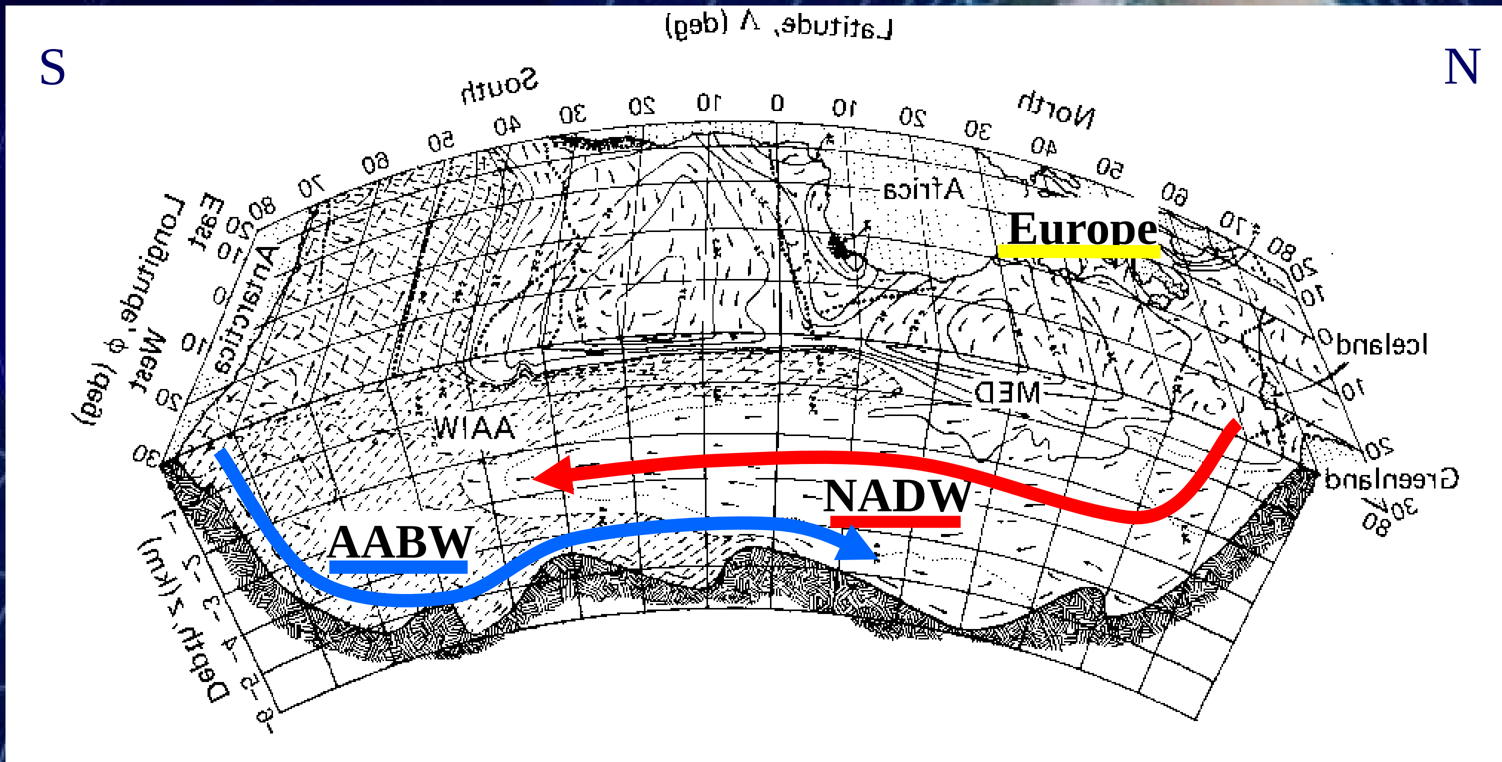


Fig. 2.22 Schematic cross section of surface and subsurface currents in the North and South Atlantic. [Adapted from Wüst, G., *Kieler Meeresforschungen* (1950).]

- NADW = North Atlantic Deep Water
- AABW = Antarctic Bottom Water

Atlantic water masses (mirror image)



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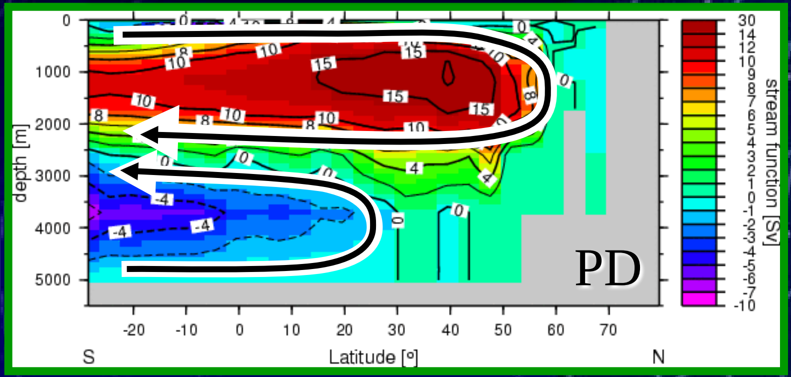
Characteristics of the present-day Atlantic Ocean

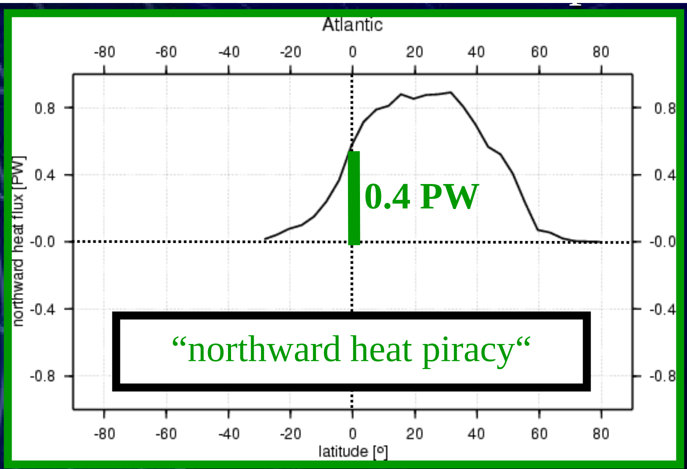
Meridional overturning in Sv



present-day forward conveyor

The positive values depict clock-wise motion while negative values depict counterclockwise motion. The Atlantic's overturning is valid only within this ocean's geographical boundary (with meridional walls at both sides; therefore, the area south of 30°S is not shown).

North Atlantic Ocean heat transport in PW



1 Sverdrup (Sv) = 10^6 m^3s^{-1}

1 PW = 10^{15}W

Experiments with freshwater fluxes

Exp.	Freshwater flux from central NA into NP [Sv]	Freshwater flux from central NA into NNA [Sv]	Freshwater flux from SO into Antarctica [Sv]	Freshwater flux from SO into ACC-region [Sv]
1	-	-	-	-
2	-	-	-	-
3	0.0345	-	-	-
4	0.15	0.015	-	-
5	0.1	-	-	0.08
6	0.075	0.015	-	0.06
7	0.05	0.0075	-	0.04
8	0.03	0.0075	0.015	0.025

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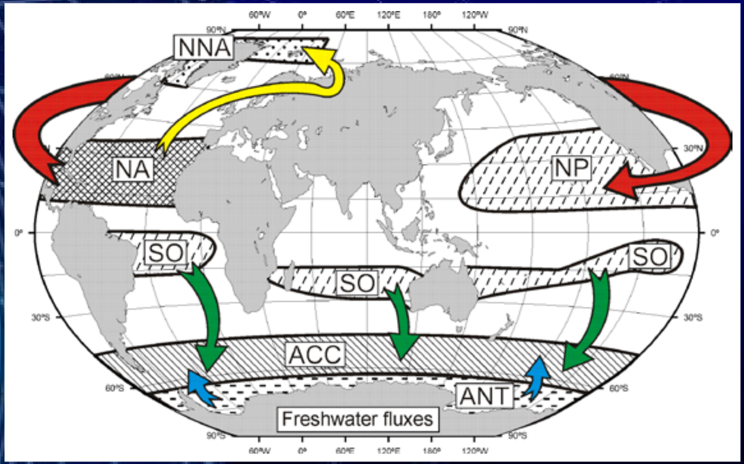
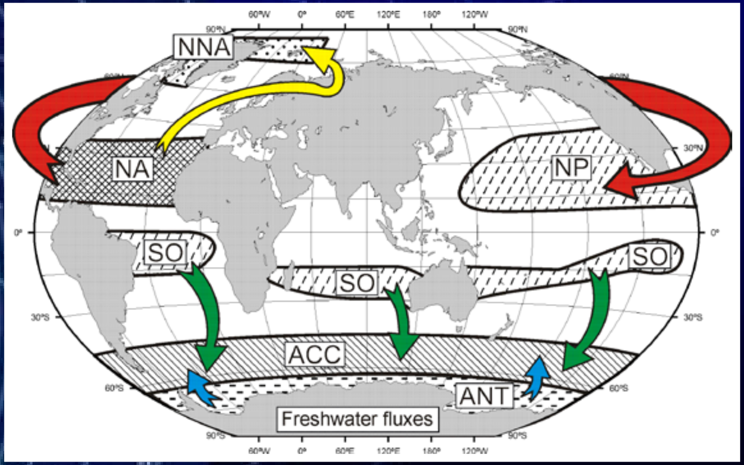


Experiments with freshwater fluxes

Exp.	Freshwater flux from central NA into NP [Sv]	Freshwater flux from central NA into NNA [Sv]	Freshwater flux from SO into Antarctica [Sv]	Freshwater flux from SO into ACC-region [Sv]	Max. northward oceanic heat flux in the NA [PW]	Maximum meridional overturning in the NP [Sv]
1	-	-	-	-	0.85	-5
2	-	-	-	-	0.7	15
3	0.0345	-	-	-	0.8	10
4	0.15	0.015	-	-	1.5	-5
5	0.1	-	-	0.08	1.45	0
6	0.075	0.015	-	0.06	1.07	-5
7	0.05	0.0075	-	0.04	1.25	0
8	0.03	0.0075	0.015	0.025	1.16	0



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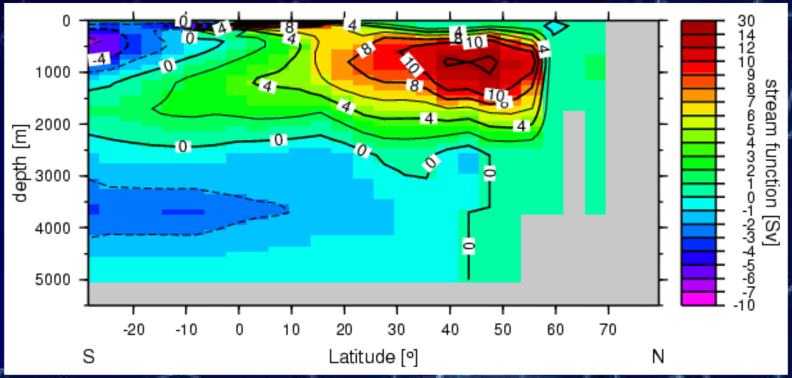
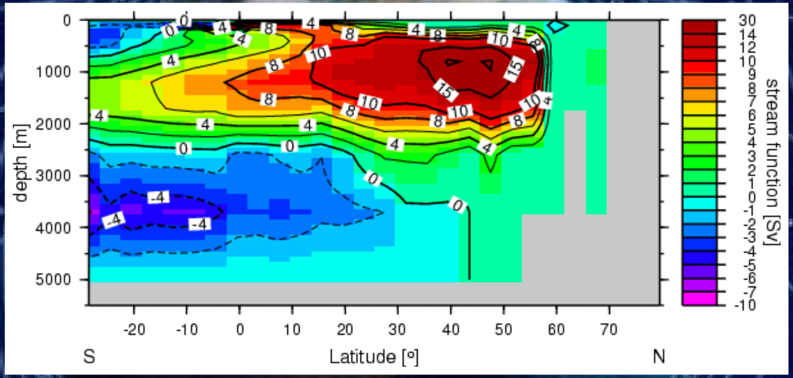
Meridional overturning in the North Atlantic (Sv)

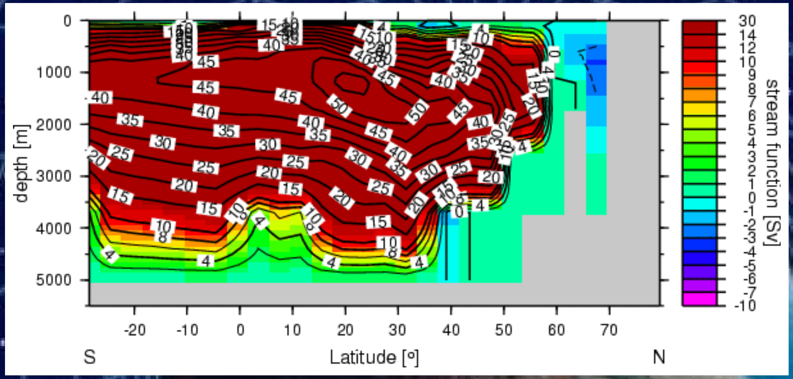
Experiment 2



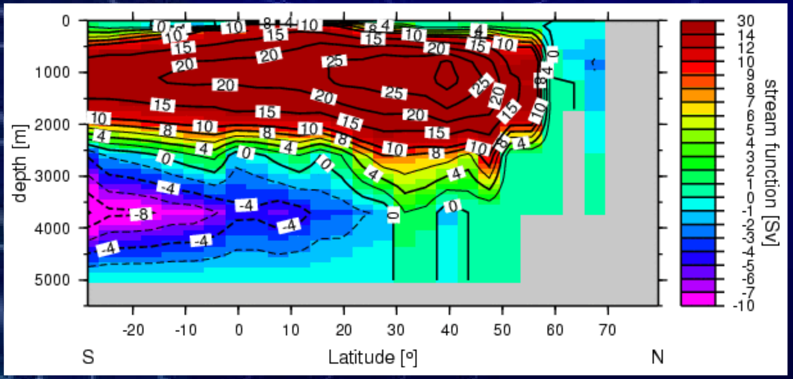
Experiment 3



Experiment 4



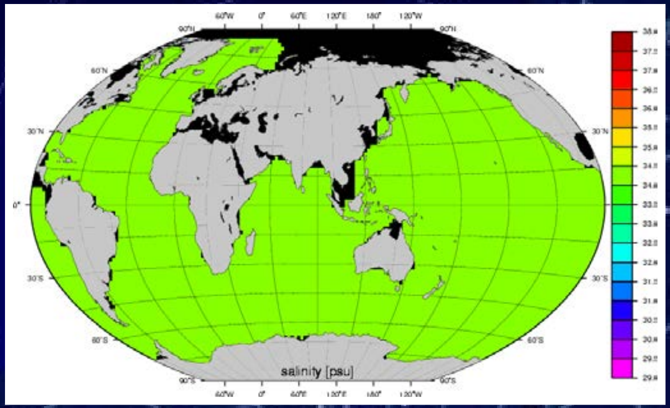
Experiment 8



(1 Sv = $10^6\ m^3 s^{-1}$)

Sea surface salinity in psu

Experiment 2



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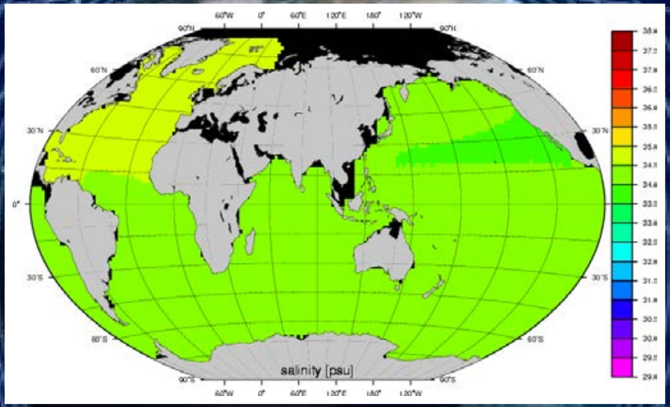

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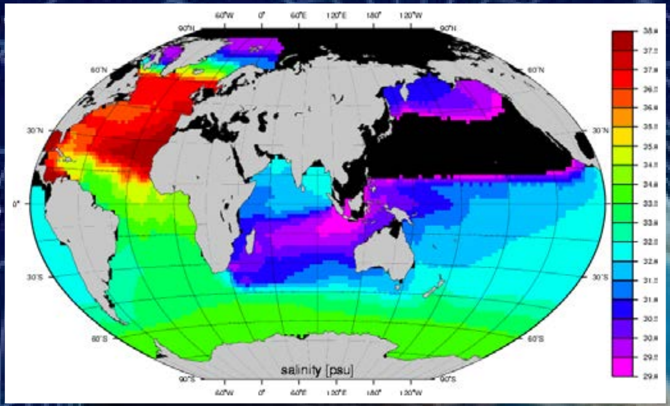

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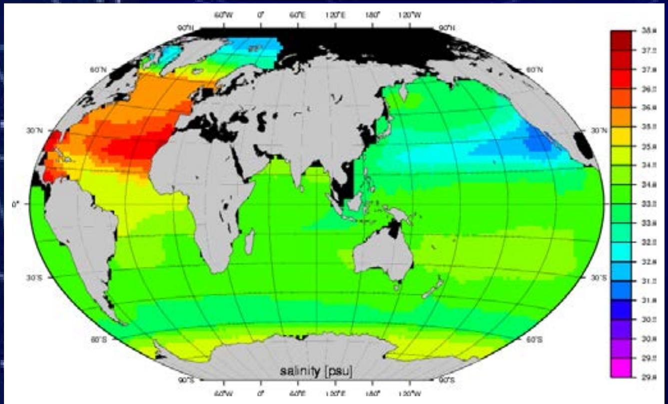

North Atlantic Ocean heat transport in PW

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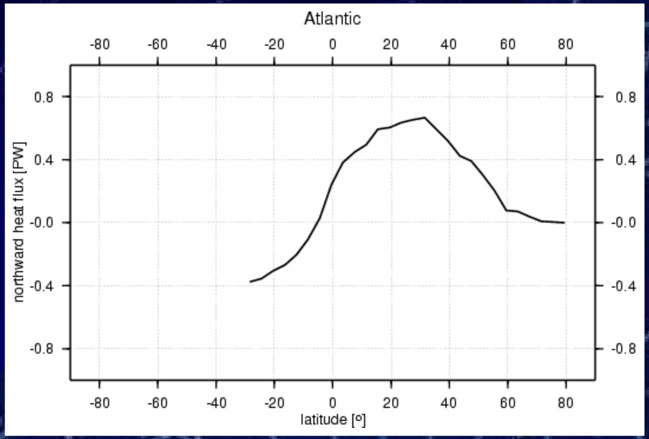

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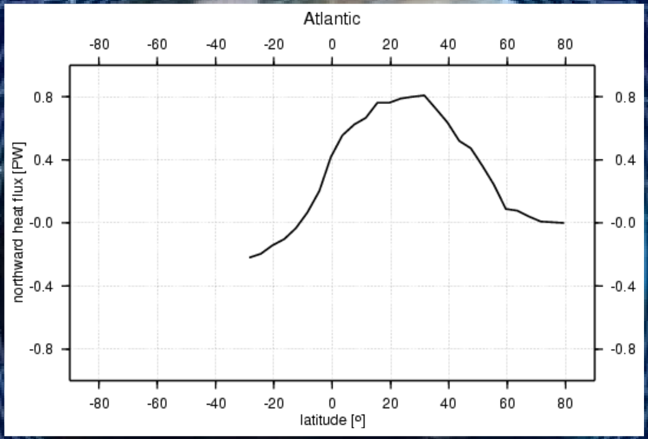

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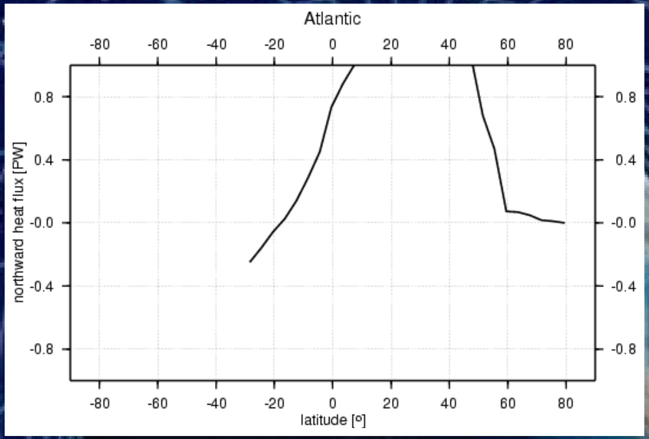

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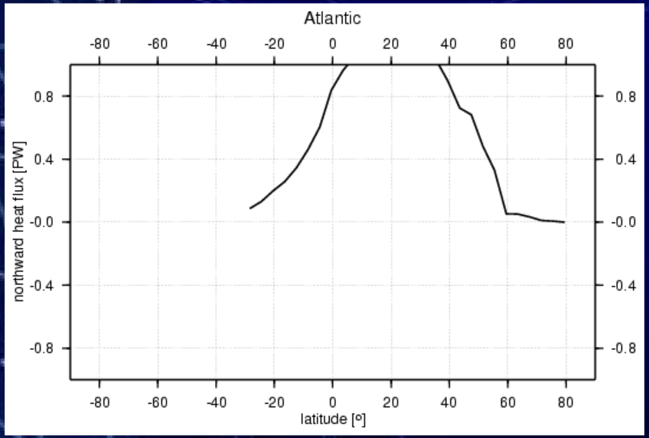
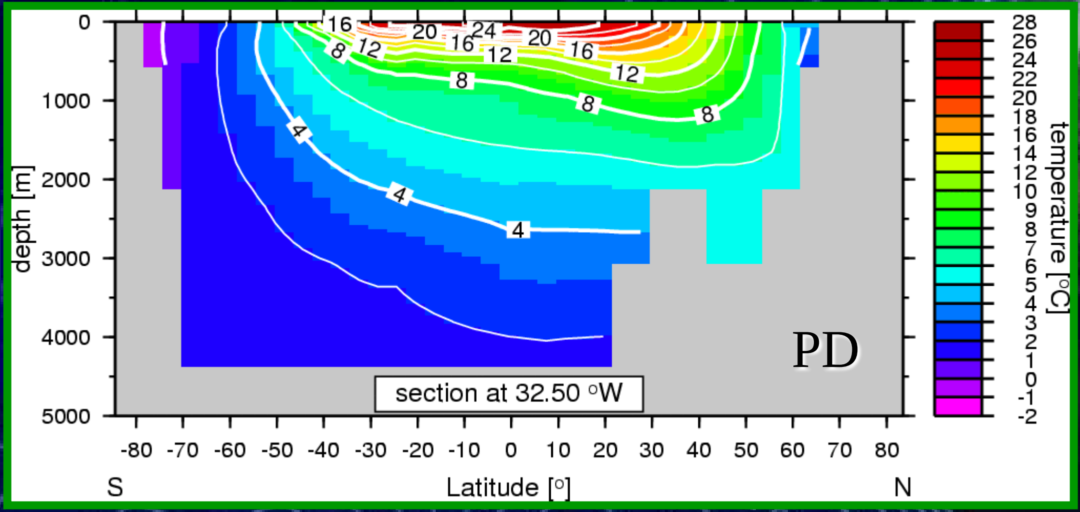
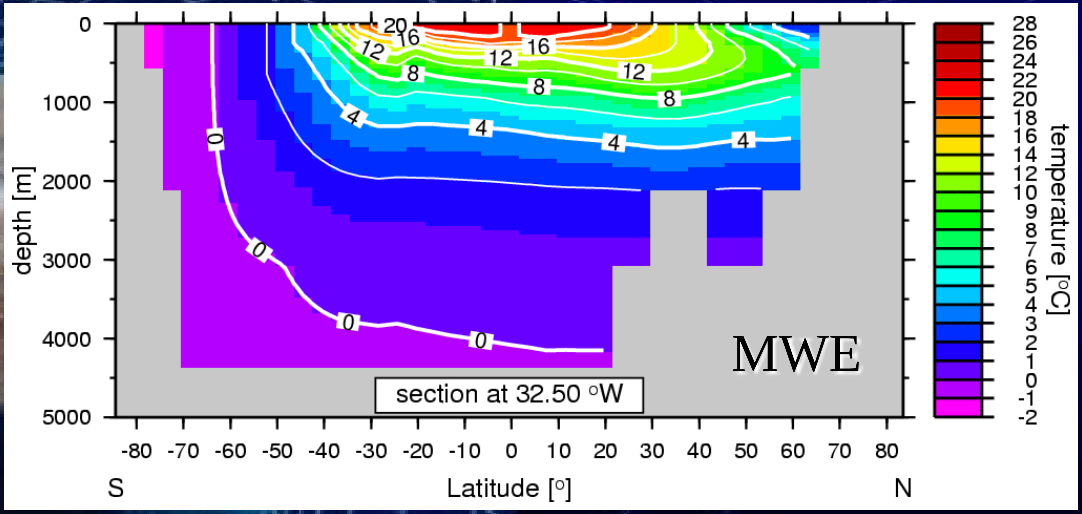


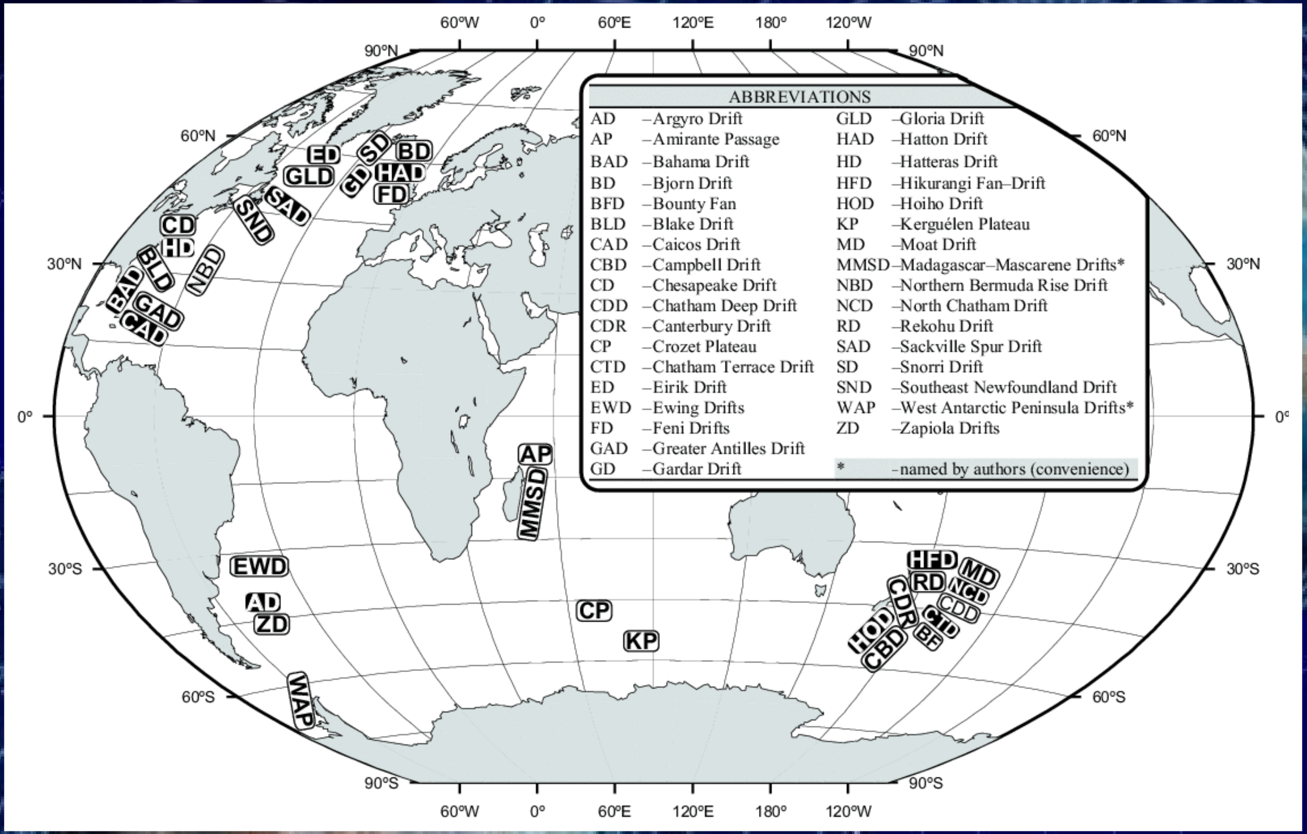
1 PW = 10^{15}W

Meridional temperature section in the North Atlantic



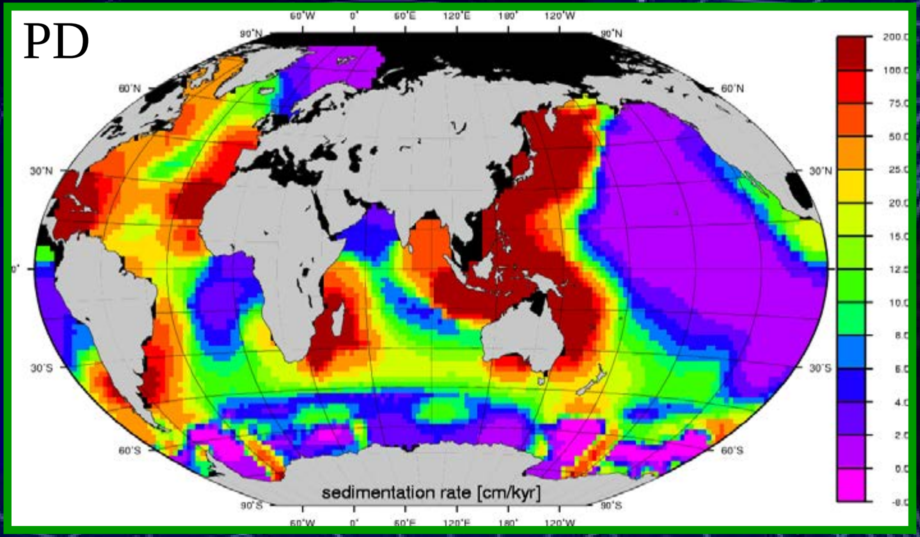


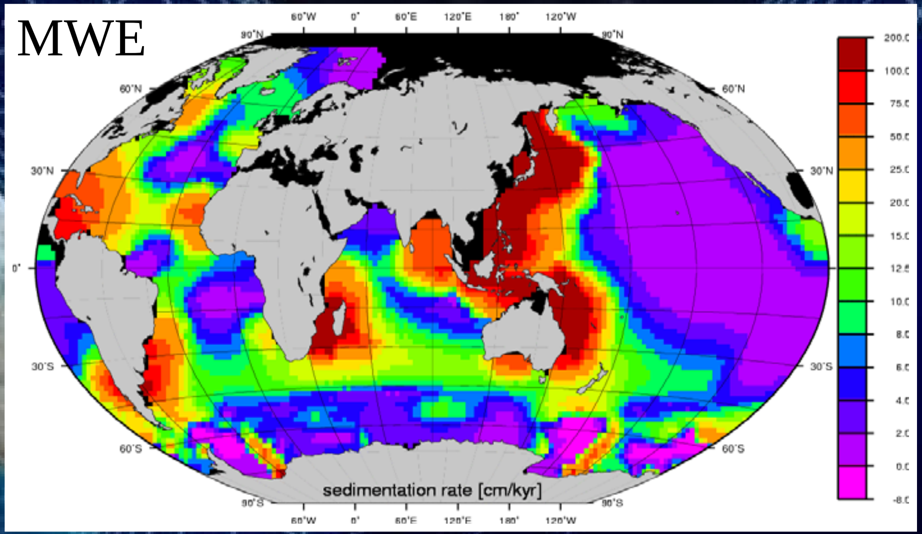
Known sediment drifts



- Sediment drifts reflect development times from tens to hundreds of thousands of years.
- Drifts are formed along the deep western boundary currents.
- Drifts reflect a long–term response to environmental conditions rather than a short-term response to discrete events [Flood and Shor, 1988].

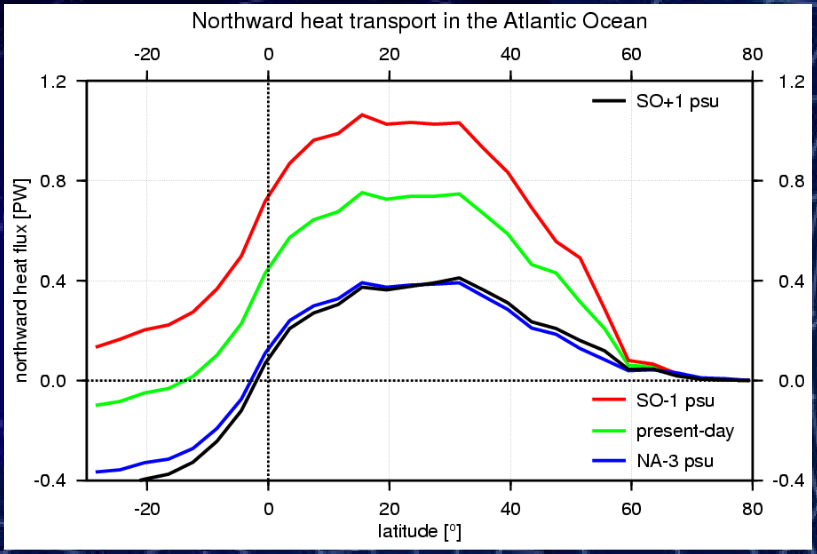
Modeled sediment drifts





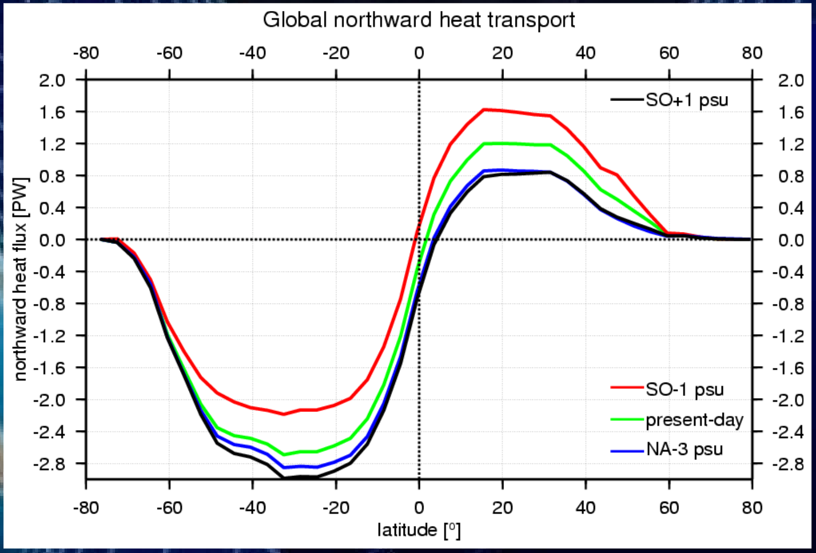
Meridional northward ocean heat transport (PW)

(1 PW = 10^{15} W)



- Southern meltwater events accelerate the global conveyor and increase the northward ocean heat transport.

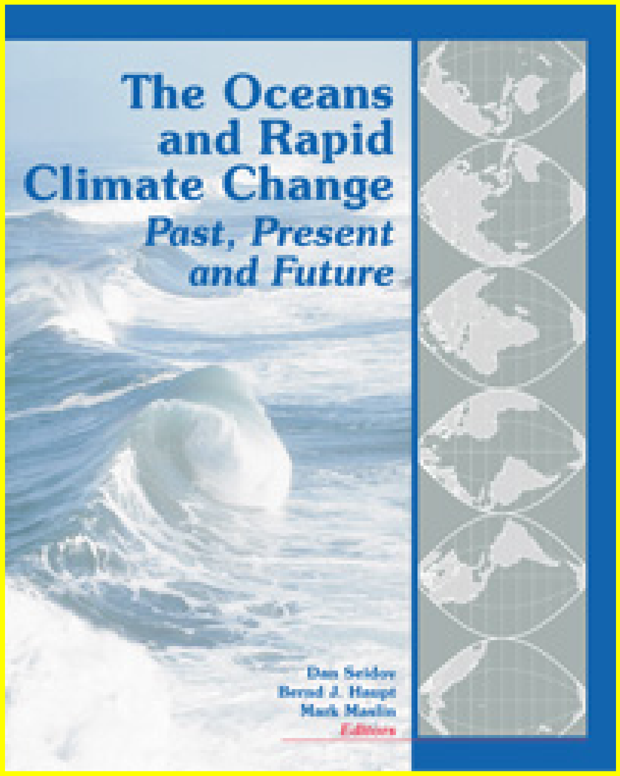
- Northern meltwater events slow down the global conveyor and decrease the northward oceanic heat transport.



Conclusions

- The key for global thermohaline circulation lies in the high latitudes of both hemispheres. The global conveyor reacts sensitively to southern freshwater changes.
- Despite the fact that our chosen freshwater fluxes are small and not very realistic, depicting only the most prominent features of real-world hydrological cycle, it has been possible to mimic a THC very close to those in the control run, provided both NA-NP **and** the southern “freshwater bridges” have been effected.
- The NA-NP “freshwater bridge“ accelerates the global conveyor and increases the northward oceanic heat transport.
- Freezing of ice (brine water rejection) around Antarctica slows down the global conveyor and decreases the northward oceanic heat transport.

Thank you!



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