Improvements of the HYCOM-CICE coupled model during the CORE-II project

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Outline

- The CORE project
- HYCOM results in CORE-II
- Improvements to the HYCOM-CICE global 0.72º configuration
    - Addition of a new Bulk Formulation (Large and Yeager [2004])
    - Modification of the method to coupled ocean and ice
    - Addition of a spatially varying SSS relaxation option
    - Change in the calculation of the thermobaric corrections
- Comparison between the new CORE-II simulation and the old one
- On-going work

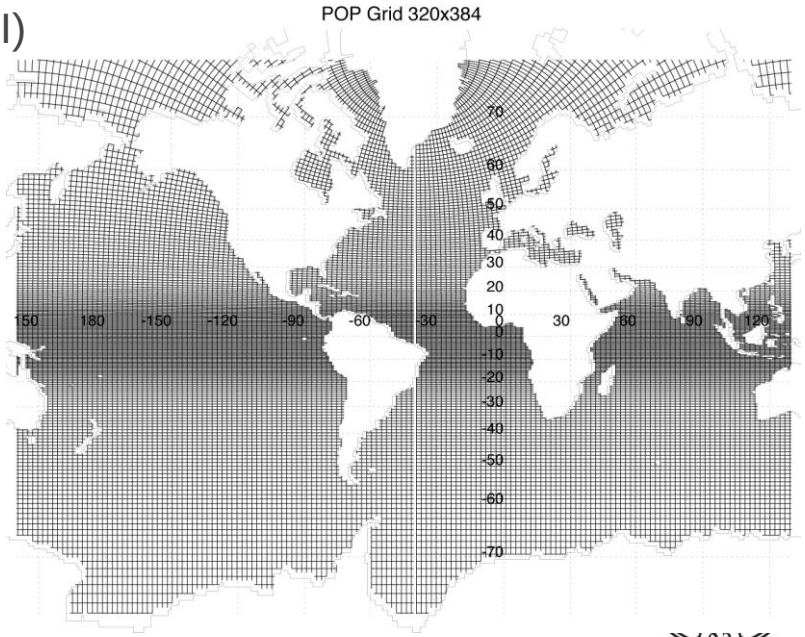
The CORE project

- The CORE project provides a framework to compare the behavior of different coupled Ocean-Ice models forced with the same atmospheric fields.
- Same protocol:
  - Same 300 years atmospheric forcing (CORE-I (climatology) or CORE-II (interannual 1948-2007))
  - Preferably with the same bulk formulation (Large and Yeager 2004)
  - Normalization of the salt flux at the surface to guarantee a constant global salinity
  - Surface Salinity relaxation of 4years over 50m.
- Publications :
  - CORE-I
    - Griffies et al. (2009) Ocean Modelling
  - CORE-II (Ocean Modelling)
    - Danabasoglu, G. et al. (2014) published (AMOC mean state)
    - Griffies et al. (2014) published (Sea Level)
    - Downes et al. (2015) accepted (Southern Ocean water mass)

HYCOM in the CORE project

CCSM3-HYCOM's EXPERIMENT:

- HYCOM version 2.2.*18*
- CSIM as active ice component
- POP Bipolar gx1v3 (~1º) global grid
- Bathymetry from 2 min gridded relief data of National Geophysical Data Center
- Large and Yeager (2004) through the coupler
- Advection of rho and S => non conservation of heat
- Normalization of the salt flux at the surface (CORE-II)
- SSS-relaxation: 20 days/30m (CORE-II)



CORE-I experiment performed by Jianjun Yin

CORE-II experiment performed by Jianhua Lu

HYCOM in CORE-II

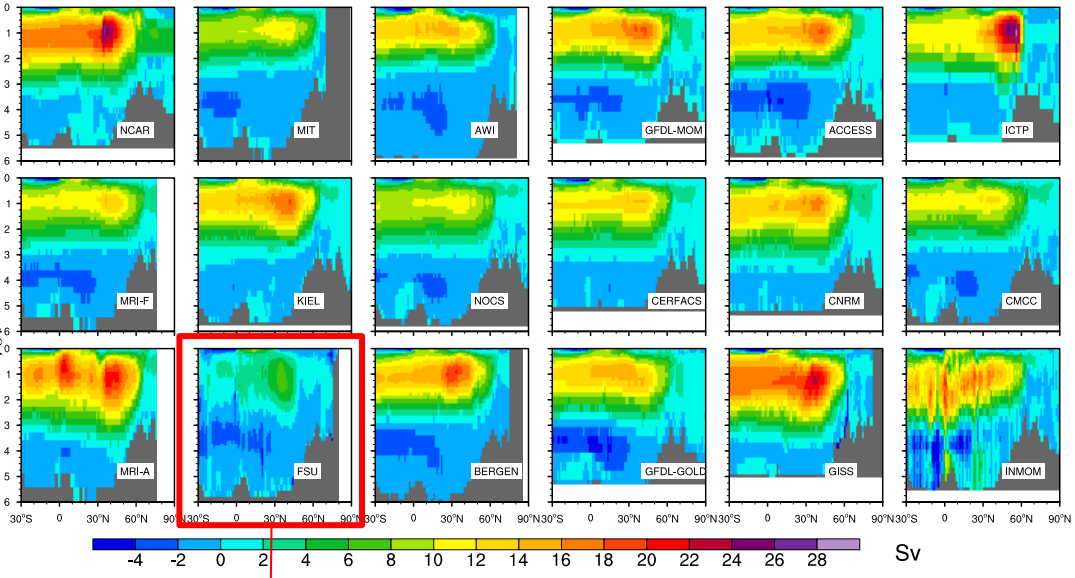


Figure 3: Time-mean AMOC plotted in depth (km) and latitude space. The positive and negative contours indicate clockwise and counter-clockwise circulations, respectively. In MIT, AWI, MRI-F, MRI-A, FSU, BERGEN, and GISS, the AMOC distributions do not include the high latitude North Atlantic and / or Arctic Oceans, and hence are masked. Unless otherwise noted, the time-mean refers to the 20-year means for years 1988-2007, corresponding to simulation years 281-300, in all the figures.

Collapse of the AMOC after 1st cycle

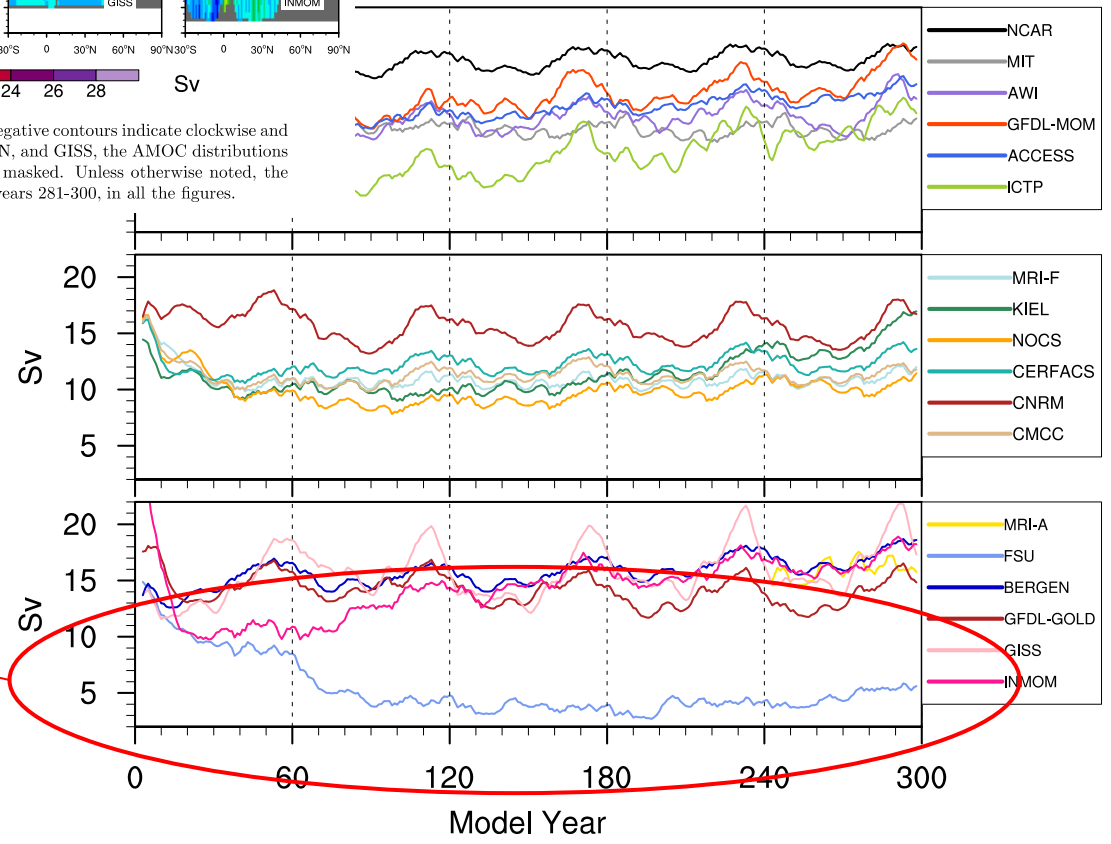
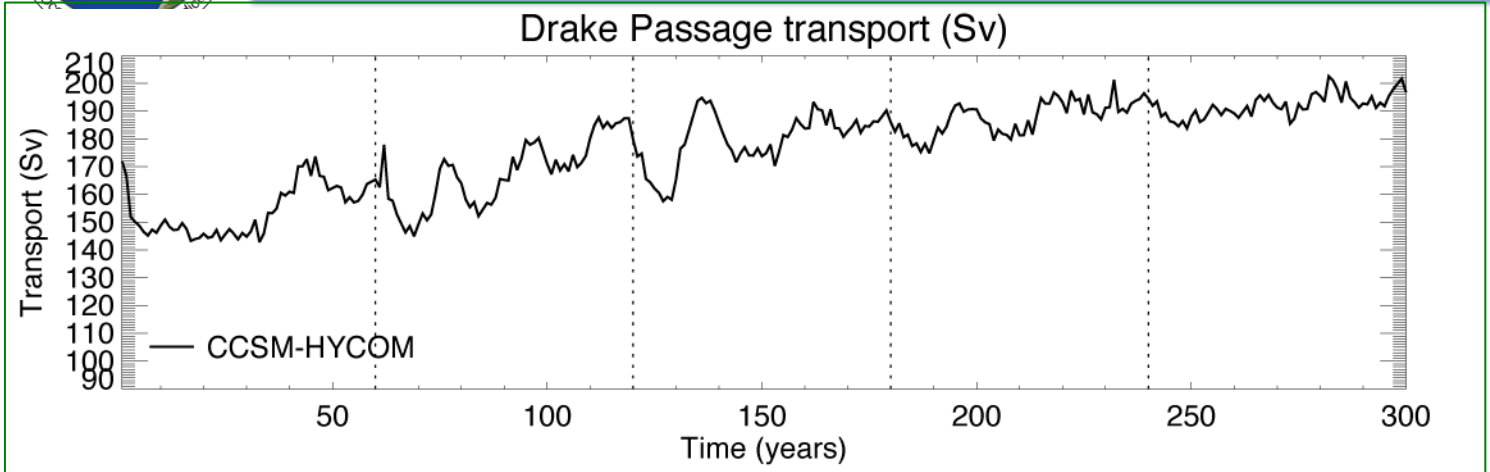


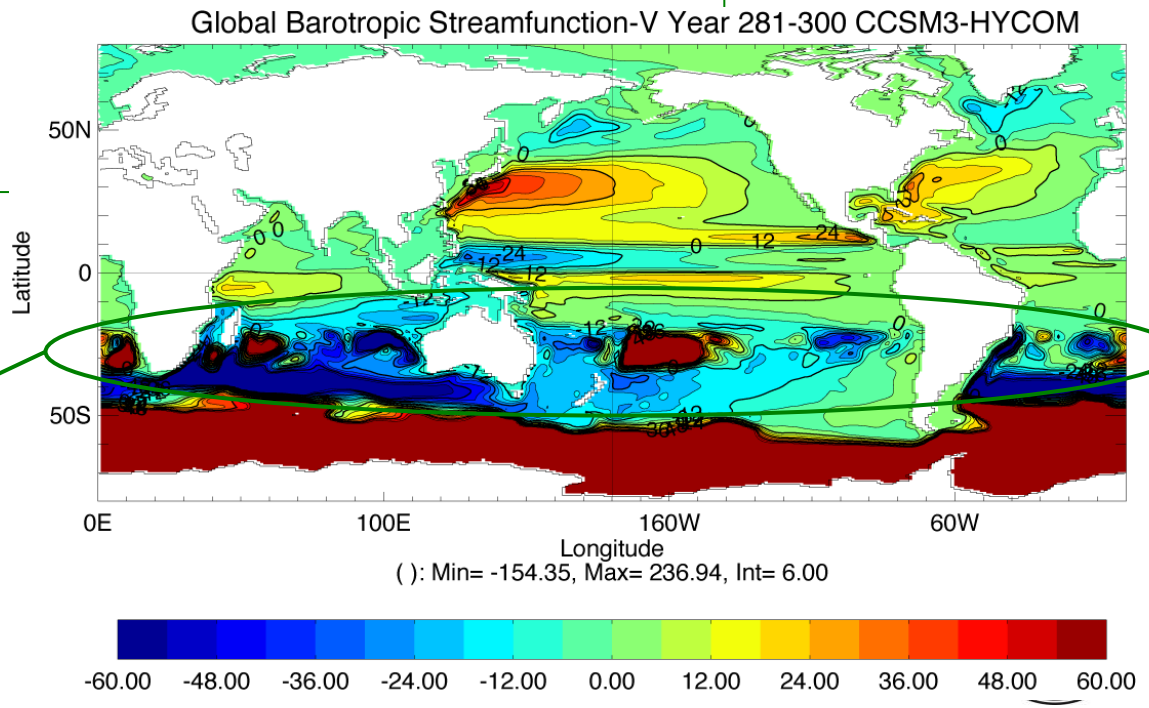
Figure 1: AMOC annual-mean maximum transport time series at 26.5°N for the entire 300-year integration length. The time series are smoothed using a five-point box car filter. The repeating 60-year forcing cycle, corresponding to calendar years 1948-2007, is indicated by the dashed lines in each panel.

Danabasoglu et al. 2014

HYCOM in CORE-II (cont.)



- Drake passage transport not stabilized
- Evolution of transport not the same between cycles

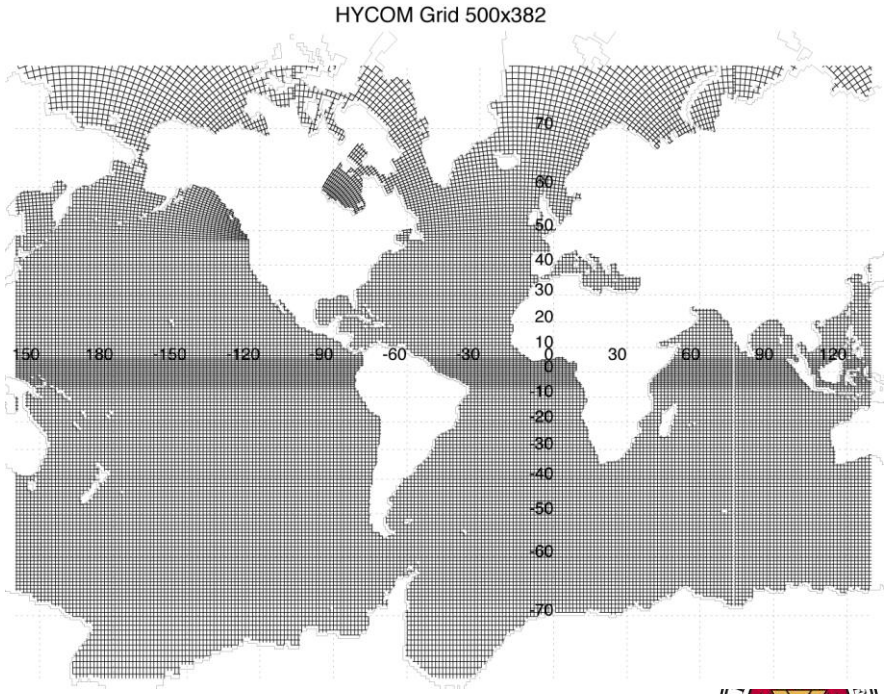


Spurious barotropic velocities appearing in the southern hemisphere
=> Thermobaric instabilities

Standard HYCOM-CICE configuration

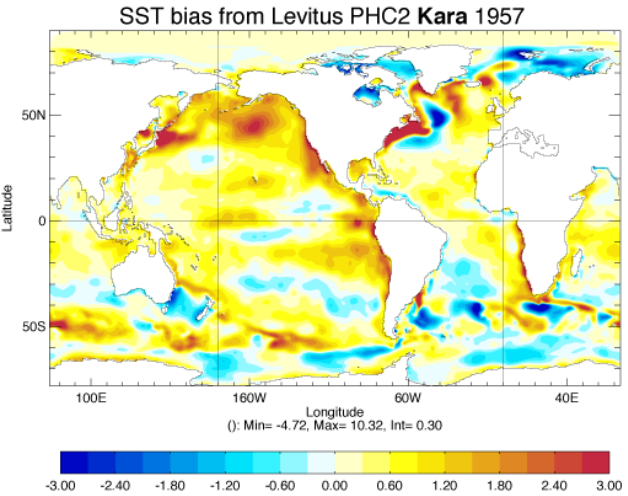
HYCOM-CICE EXPERIMENT:

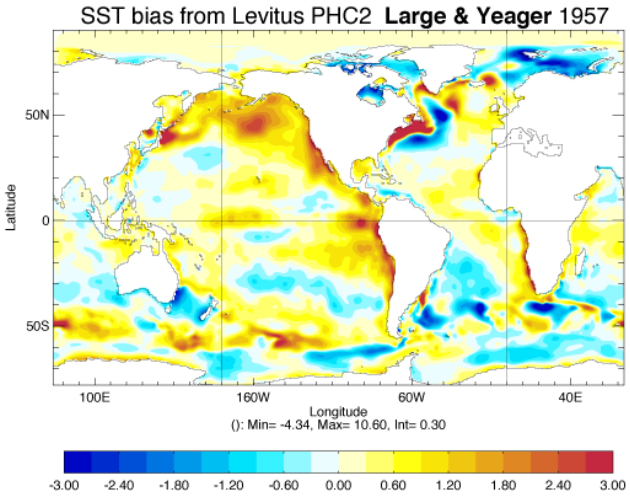
- HYCOM version 2.2.74
- CICE v4.0 as active ice component
- Partial coupling between Ocean and Ice (only ice cover, ice velocities are used and ice flux are re-calculated by the energy loan model)
- Tripolar HYCOM Standard 0.72º global grid
- Bathymetry from 2-minute NAVO/NRL DBDB2
- Advection of T and S => conservation of heat
- Kara (2004) bulk formulation
- SSS-relaxation: 30 days (default)
- CORE-II atmospheric forcing interpolated in time to get a 6-hour frequency

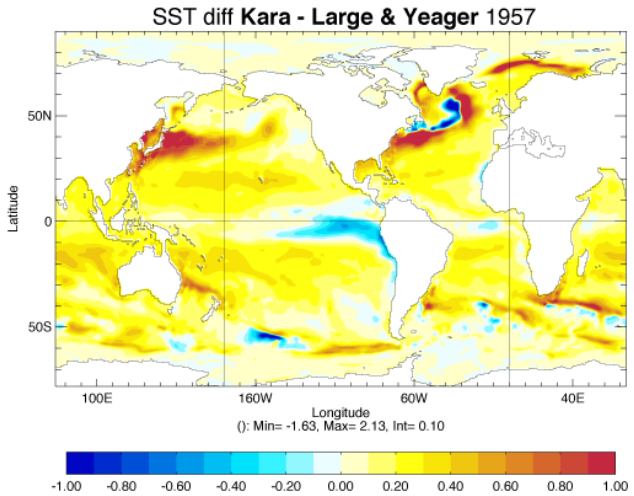


The Large and Yeager bulk formulation vs. the Kara bulk formulation

⇒ 2 experiment of 10 years with CORE-II (1948-1957)

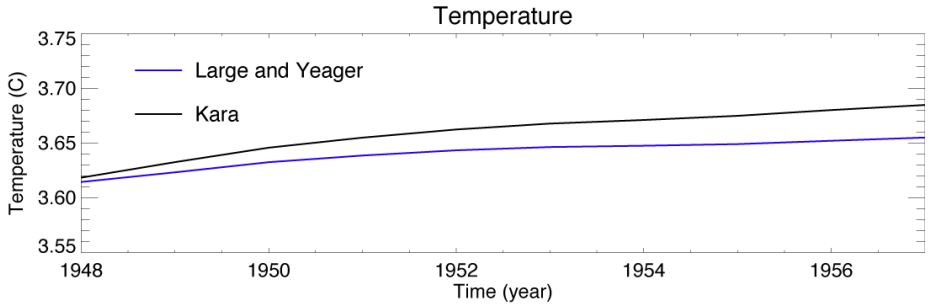


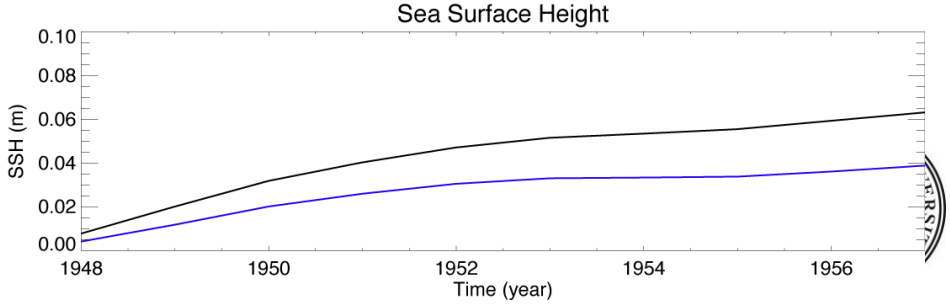




In 10 years, difference of :

- ~0.20ºC in SST
- 0.03ºC in global Temperature
- 2cm in SSH

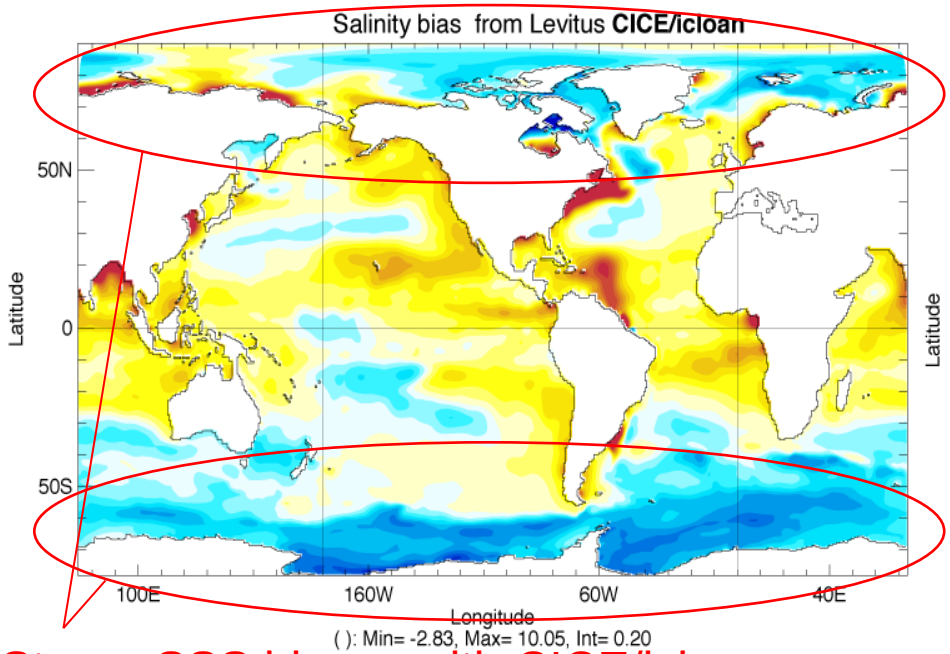




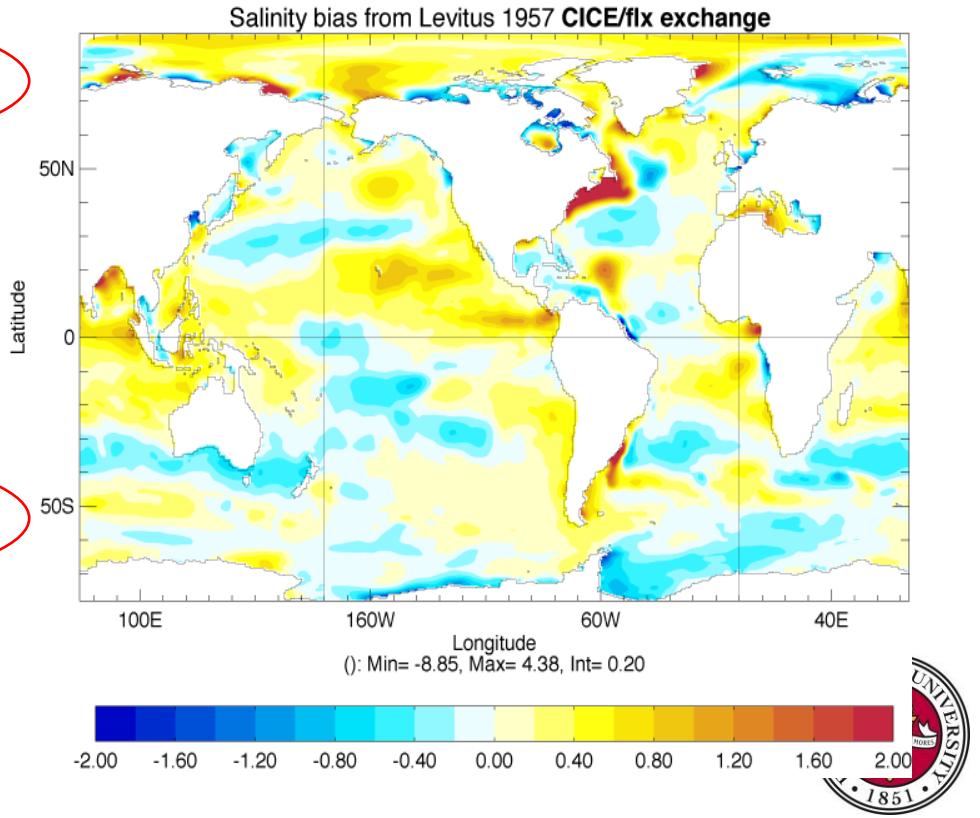
HYCOM-CICE coupling

⇒ 2 experiment of 10 years with CORE-II (1948-1957) with SSS relaxation of 4 years/50 m:

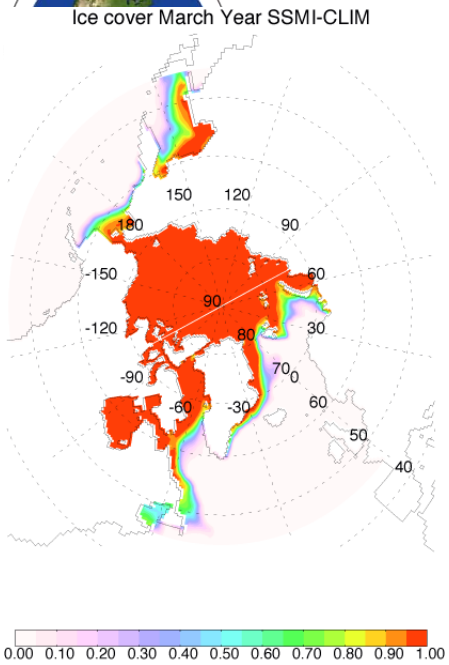
- Standard configuration: partial coupling between Ocean and Ice (only ice cover, ice velocities are used and ice flux are re-calculated by the energy loan model)
- Full flux exchange: using the heat and salt ice fluxes from **CICE**

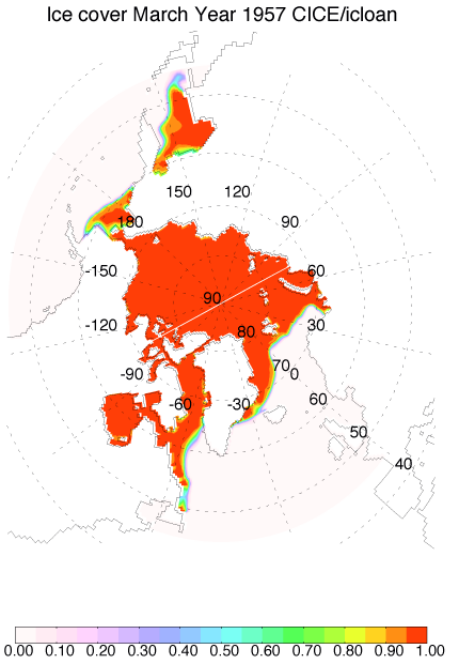


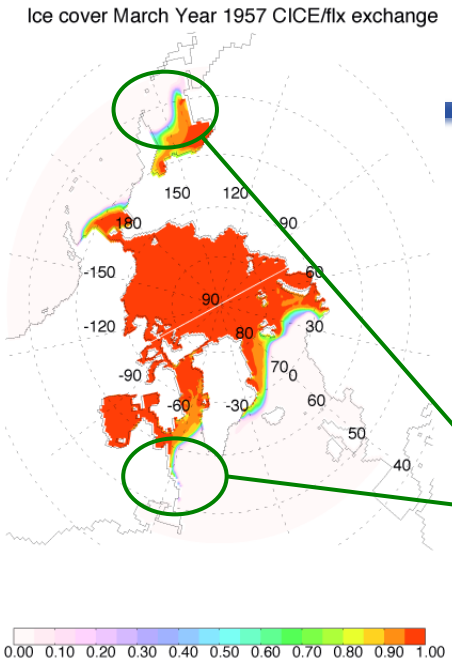
Strong SSS biases with CICE/icloan



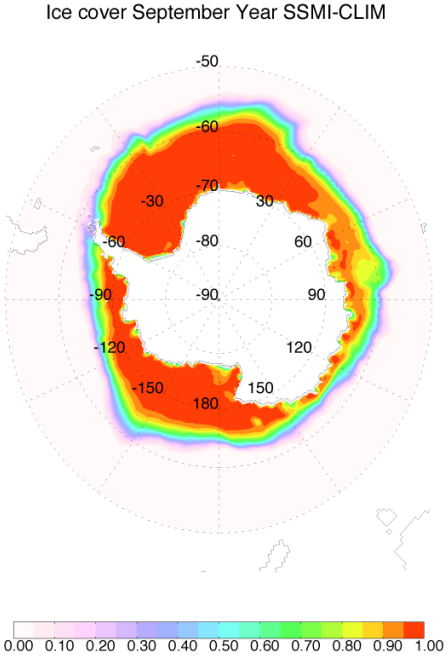
HYCOM-CICE coupling (cont.)

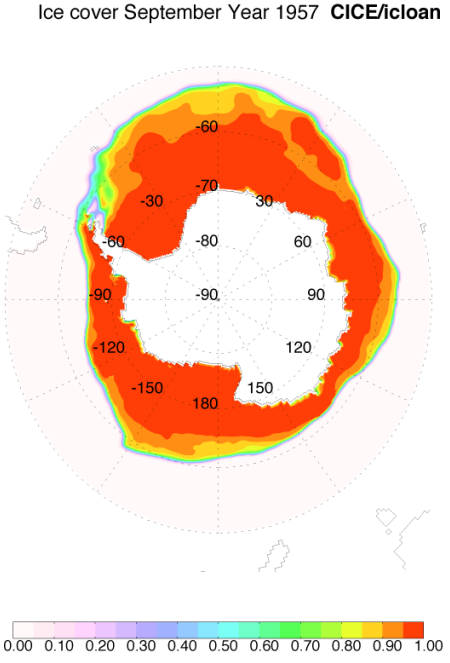


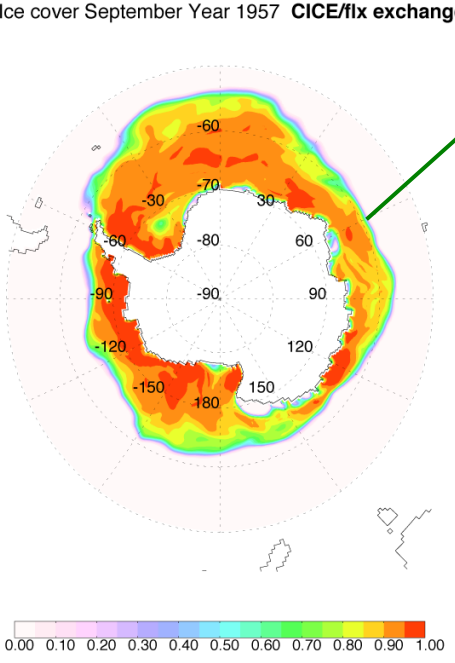




- Reduced ice cover with flux exchange

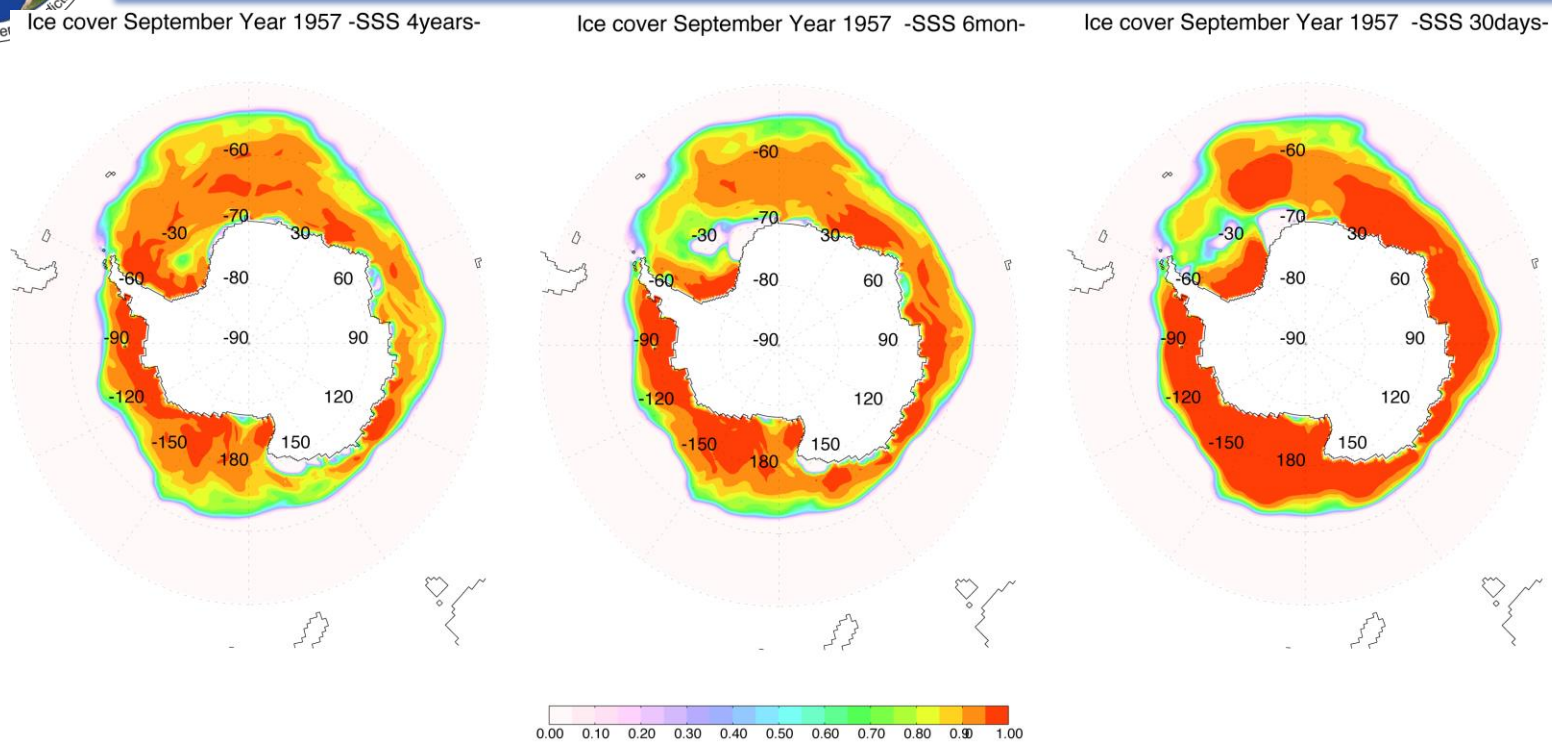






- Reduced ice concentration especially over the South Pole

Sensitivity of the Southern ice cover/concentration to SSS relaxation



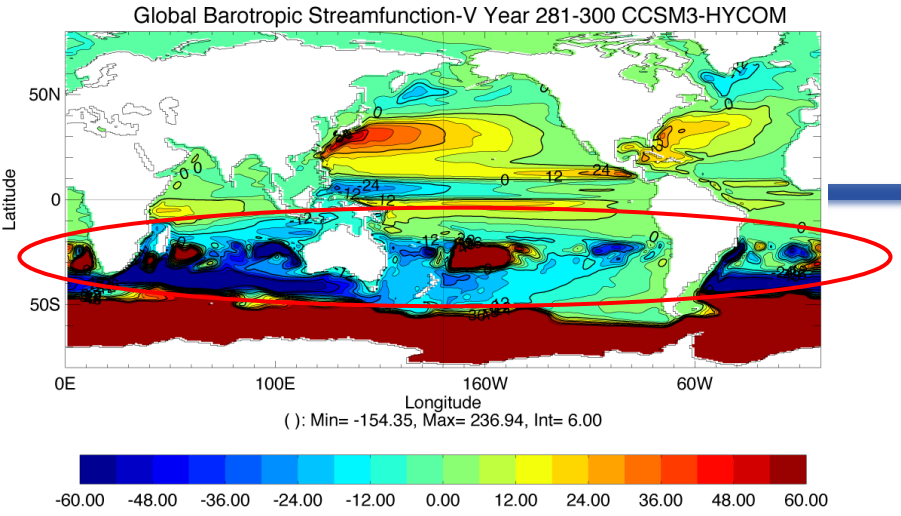
3 experiment of 10 years with CORE-II (1948-1957)

- SSS relaxation of 4y/50m, 6months/50m and 30days/50m

⇒ Strong difference between 30 days and 6months.
⇒ Loss of the ice cover with 4 years eventually (not shown)
⇒ 6 months still reasonable

⇒ Spatially varying SSS relaxation for CORE-II : 4years/50m everywhere except 6months/50m over the Antarctic Region

Thermobaric corrections

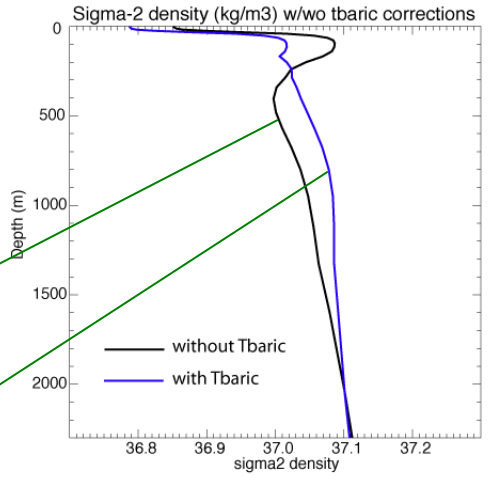


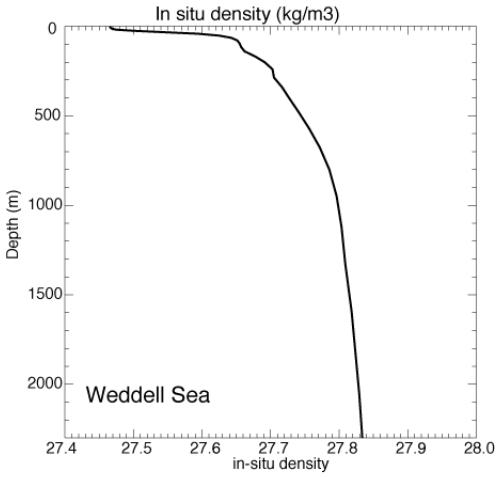
(Sun et al. 1999)

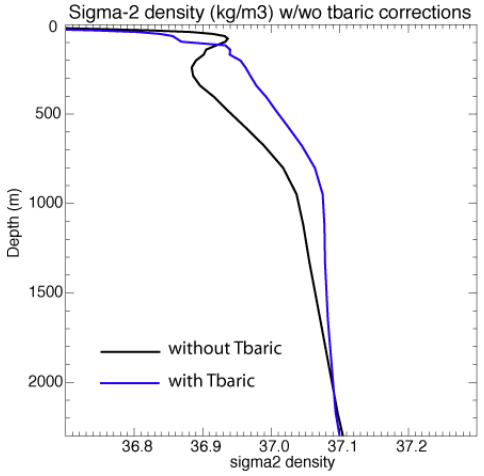
Incompressibility assumption:
Potential density ≈ In-Situ Density

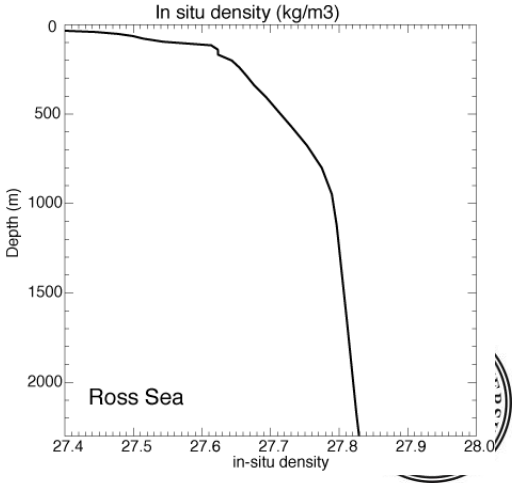
⇒ Density inversion for sigma-2

⇒ Use of thermobaric corrections on the density profile for the calculation of the pressure gradient force.



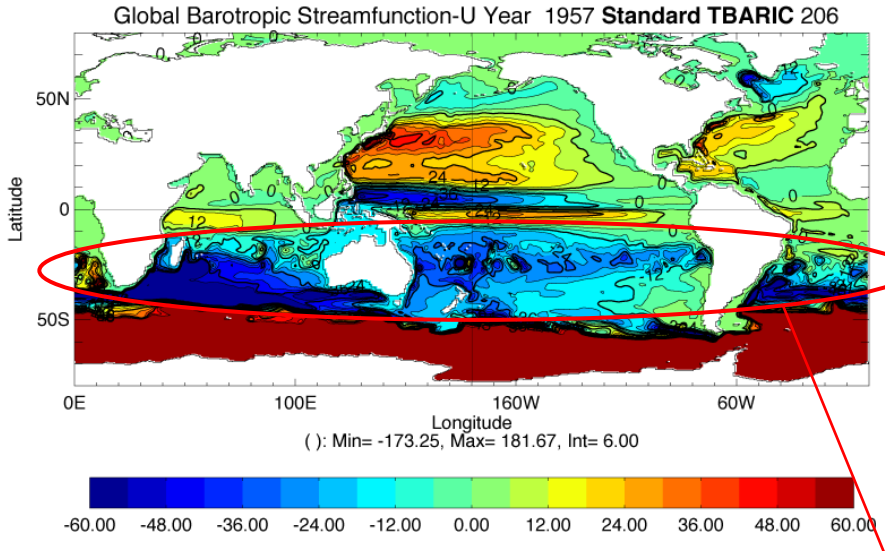


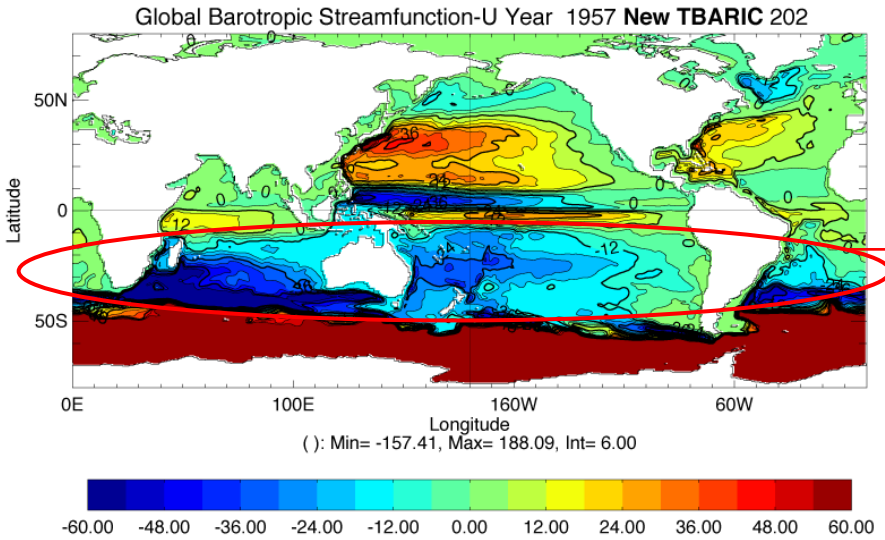




Thermobaric corrections are not the same between low/mid-latitudes and high-latitudes leading to instabilities in the transition zone

Thermobaric corrections





(Sun et al. 1999)

In terms of specific volume (1/ρ):

$$\underbrace{\alpha(\vartheta,S,p)}_{\text{In-situ spec. vol.}} = \underbrace{\alpha_r(\vartheta,S)}_{\text{“Potential” spec. vol.}} \underbrace{\exp\int_{p}^{p_r}\kappa(\vartheta,S,p')\,dp'}_{\text{Compressibility term approx. by a **least square polynomial**}}$$

Standard Method: p at the interface

New Method: p in the middle of the layer

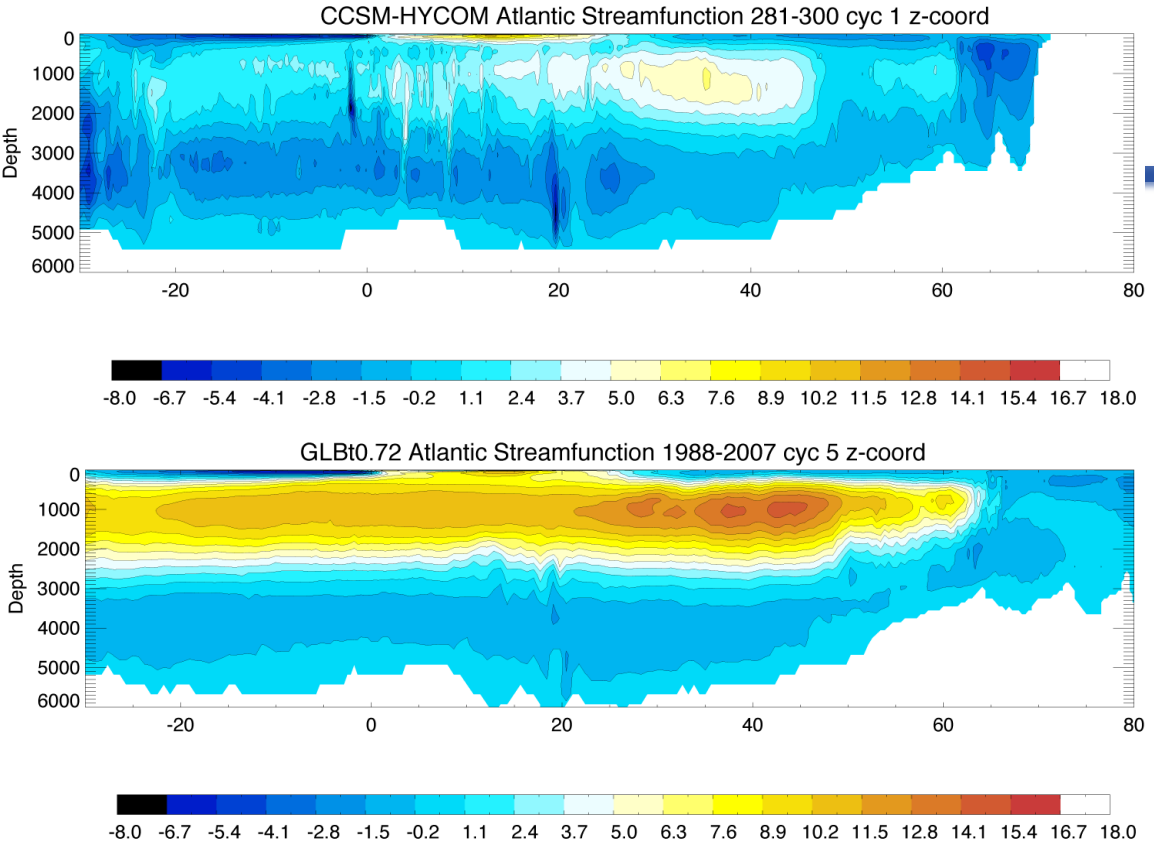
(Hallberg et al. 2005)

New HYCOM-CICE set-up

HYCOM-CICE EXPERIMENT:

- HYCOM version 2.2.74
- CICE v4.0 as active ice component
- **Full coupling between Ocean and Ice**
- Tripolar HYCOM Standard 0.72º global grid
- Bathymetry from 2-minute NAVO/NRL DBDB2
- **Large and Yeager bulk formulation**
- **Spatially varying SSS-relaxation: 4years/50m everywhere except 6months/50m in Antarctic region**
- Normalization of the salt flux at the surface
- **New thermobaric formulation**
- 5 cycles of 1948-2007 CORE-II atmospheric forcing
- Levitus PHC2.1 initial conditions
- **Advection of T and S**

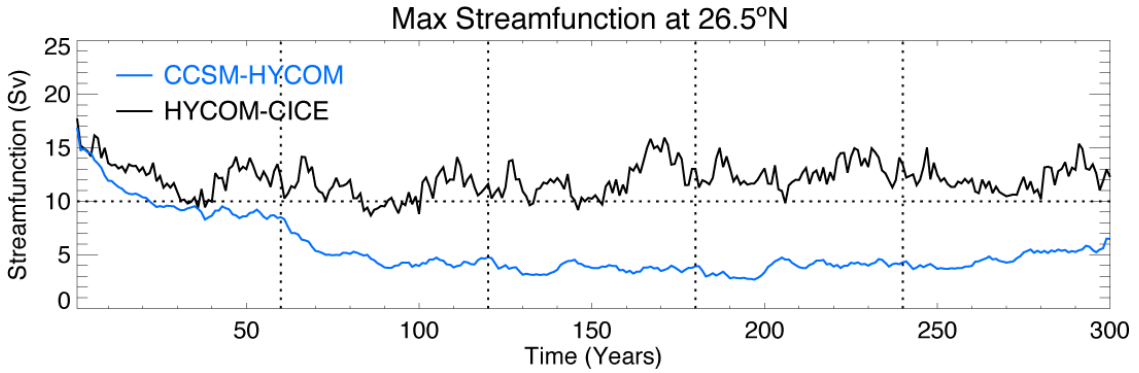
Atlantic MOC



Vertical Atlantic Streamfunction

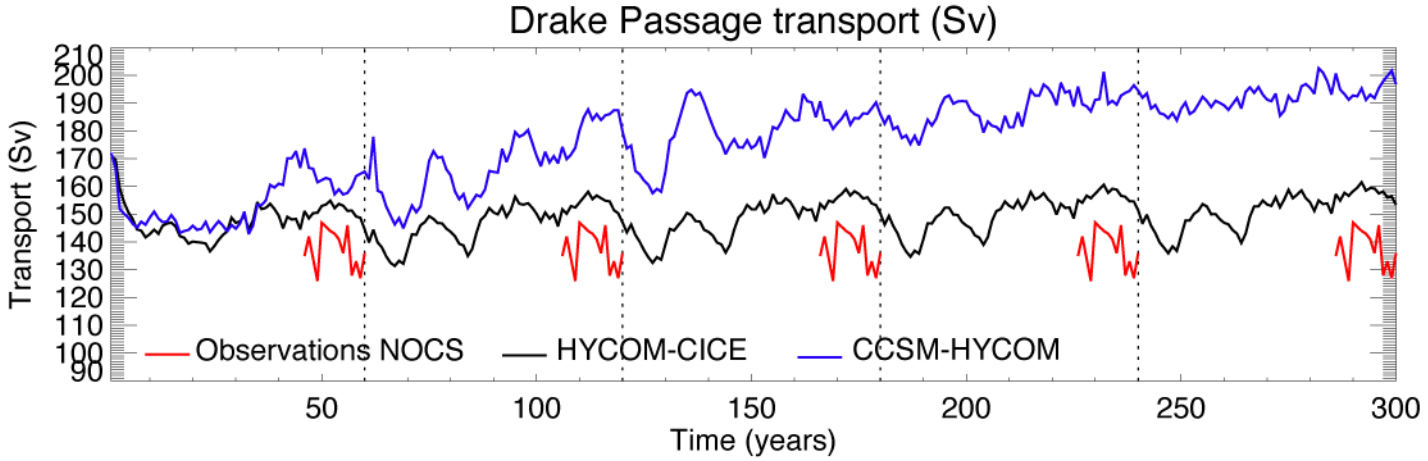
Max AMOC at 26.5ºN in the last 20 years:

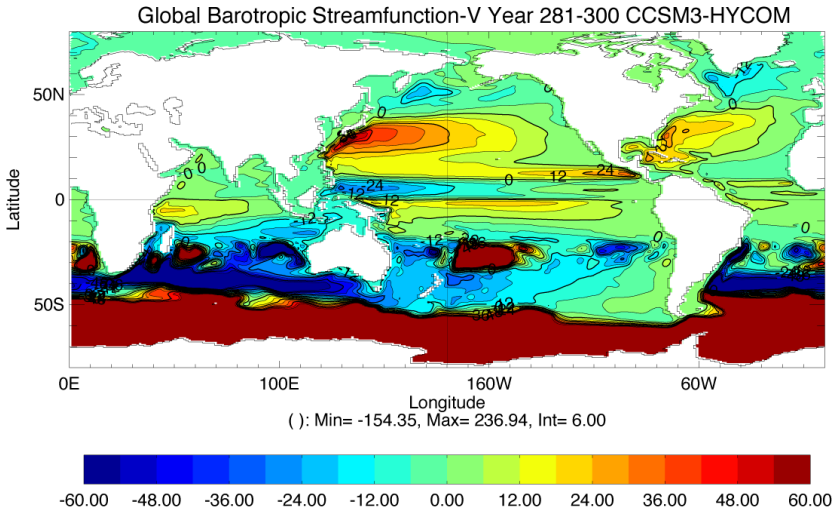
- CCSM-HYCOM = 5.4Sv
- HYCOM-CICE = 12.6Sv

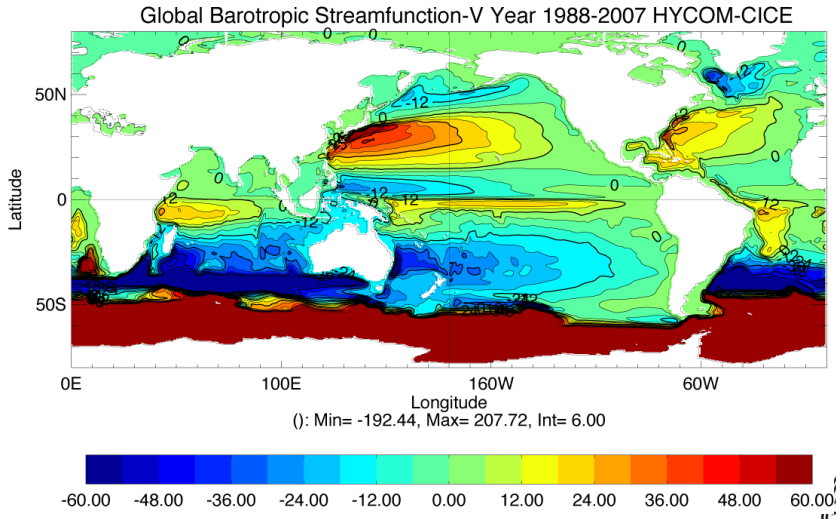


=> Other results on AMOC in Danabasoglu et al. 2015, submitted

Drake Passage transport and BSF







Other diagnostics

Other results will be found in CORE-II special issue of Ocean Modelling:

⇒ For the CCSM3-HYCOM simulation:

⇒ in Wang et al. (2015) submitted, on the Arctic Ocean sea-ice and freshwater

⇒ For the HYCOM-CICE simulation:

⇒ in Danabasoglu et al. (2015), submitted, on the AMOC variability

⇒ in Farneti et al. (2015), submitted, on the Southern Ocean circulation

⇒ in Tseng et al. (2015), submitted, on the Pacific Ocean

⇒ in Ilicak et al. (2015), submitted, on the Arctic Ocean hydrography

On-going Work

- HYCOM as an alternative ocean component to POP in CESM:
  - Bipolar gx1v6 global grid and 2 min NGDC bathymetry
  - Active Ocean-Ice (G-compset) working (CORE-I atmospheric forcing)
  - Active Ocean-Ice-Atmosphere (B-compset) working

⇒ Evaluations are done in comparison with HYCOM-CICE and CESM-POP for the active Ocean-Ice case and with CESM-POP for the active Ocean-Ice-Atmosphere case

⇒ Comparison with HYCOM-CICE-NAVGEM for different resolutions (*0.72º,0.36º,0.08º*) on the *seasonal, annual, decadal* time-scale.

- Comparison of HYCOM behavior between 3 different grids and bathymetry:
  - HYCOM GLBt0.72 tripolar grid and DBDB2 bathymetry
  - POP gx1v6 bipolar grid and NGDC bathymetry
  - NEMO ORCA0.5 tripolar grid and ETOPO2 Bathymetry