Ocean Climate Simulations with Uncoupled HYCOM and Fully Coupled CCSM3/HYCOM

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Outline

- Simulations with Uncoupled HYCOM under CORE forcing
  - Brief review about the CORE
  - Description of HYCOM and POP and salinity forcing
  - The simulation of the Atlantic Meridional Overturning Circulation and closely related fields.
- Simulations with Fully Coupled CCSM3/HYCOM
  - Default simulations
  - Parameter tuning and sensitivity experiments
- Conclusion

The Coordinated Ocean-ice Reference Experiment (CORE)

- Protocol to examine the simulations of ocean-ice models with a consistent forcing (Griffies et al., 2009)
- The atmospheric state is prescribed

  Climatology of Large and Yeager (2004)

  short-wave radiation, long-wave radiation, wind stress, wind speed, surface air temperature, relative humidity, precipitation, runoff
- CCSM bulk formula

Salinity Forcing

(1) P-E+R

(2) P-E+R + weak restoring $V_{piston} = 50m/4year$

(3) P-E+R + strong restoring $V_{piston} = 50m/360day$

$$\boxed{\begin{aligned} &F(x,y,t) = V_{piston}\left[SSS^{data}(x,y,t') - SSS^{model}(x,y,t)\right] - \langle F \rangle(t) \\ &t' = 1,2,\ldots 12month \end{aligned}}$$

HYCOM: $\langle F \rangle = 0$ global mean restoring flux is not compensated

POP: $\langle F \rangle \neq 0$; additional restoring under sea ice
(Bill Large, personal communication)

So one should be cautious when comparing the salinity restoring cases

HYCOM and POP

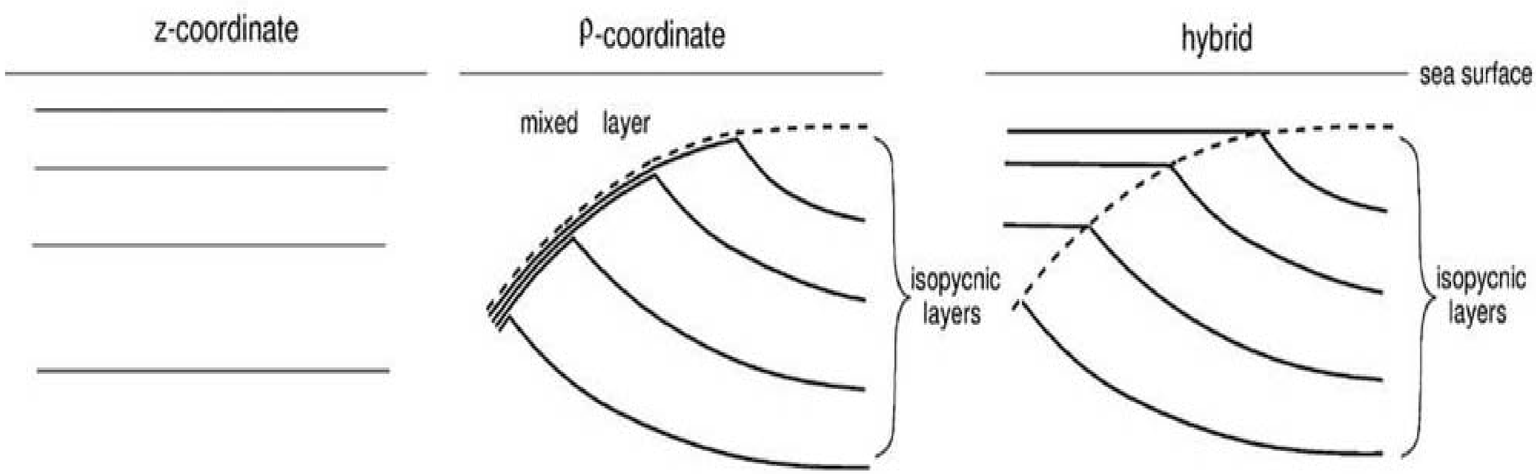
Grid: NCAR's gx1v3 grid; HYCOM: Arakawa-C; POP: Arakawa-B

Vertical resolution: HYCOM: 32 hybrid layers; POP: 40 levels

Initialization: January of the Poles Hydrographic Climatology, resting

Duration: 150 years for three salinity boundary conditions

POP



HYCOM

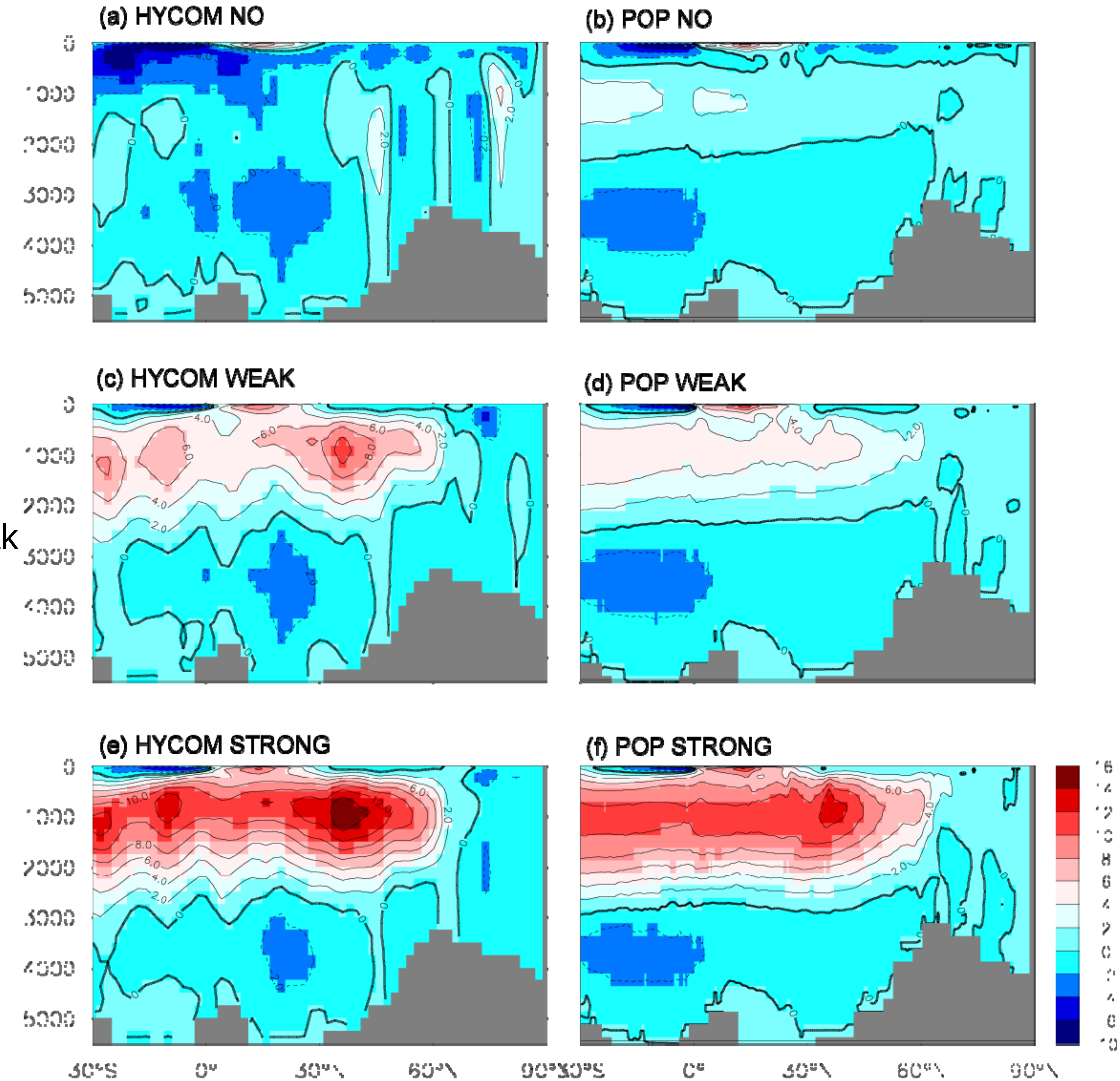
MOC

Collapses

Active but weak

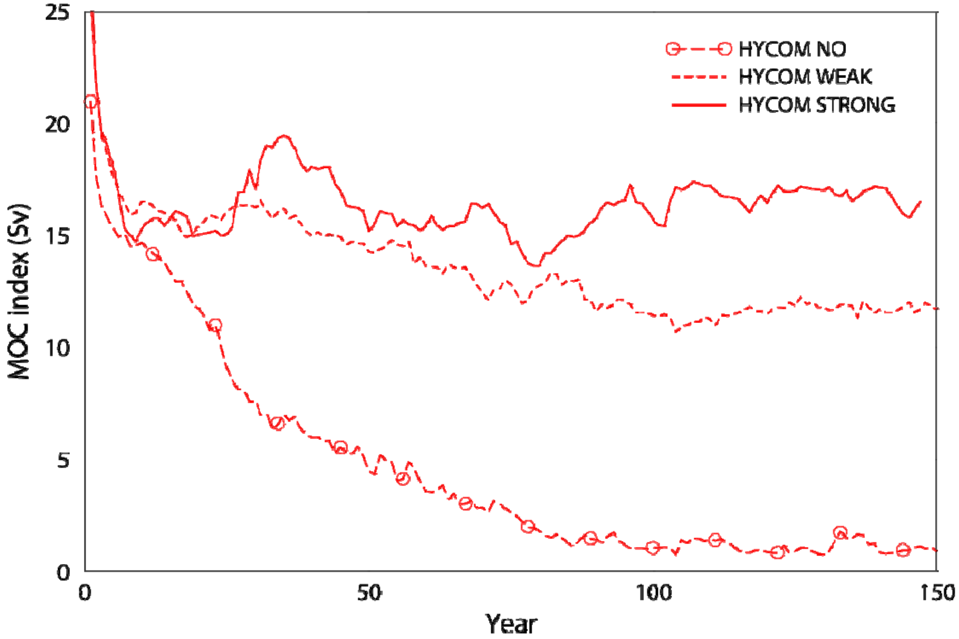
Vigorous

Unit: Sv

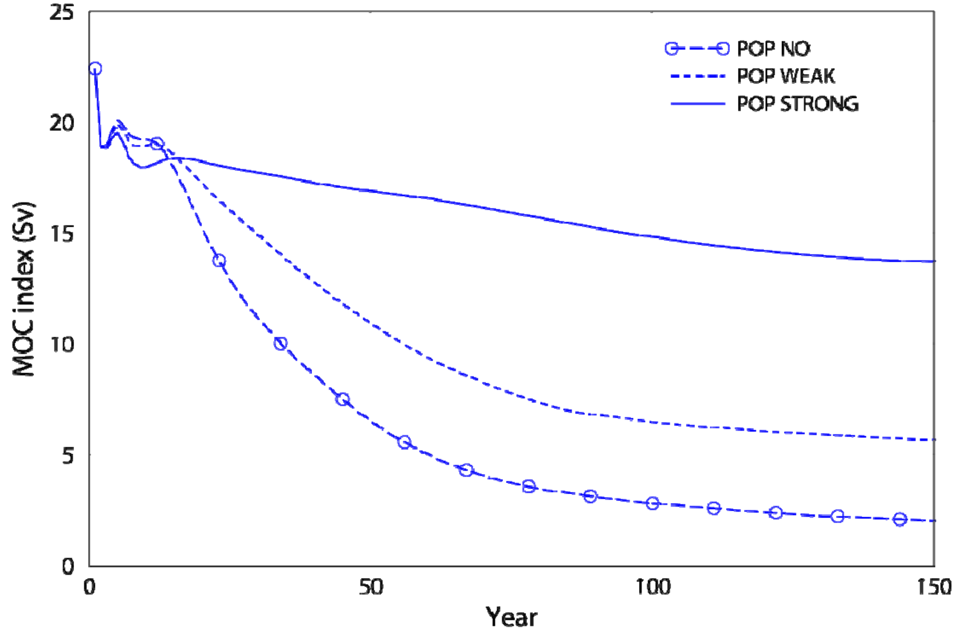


Time Evolution

HYCOM



POP



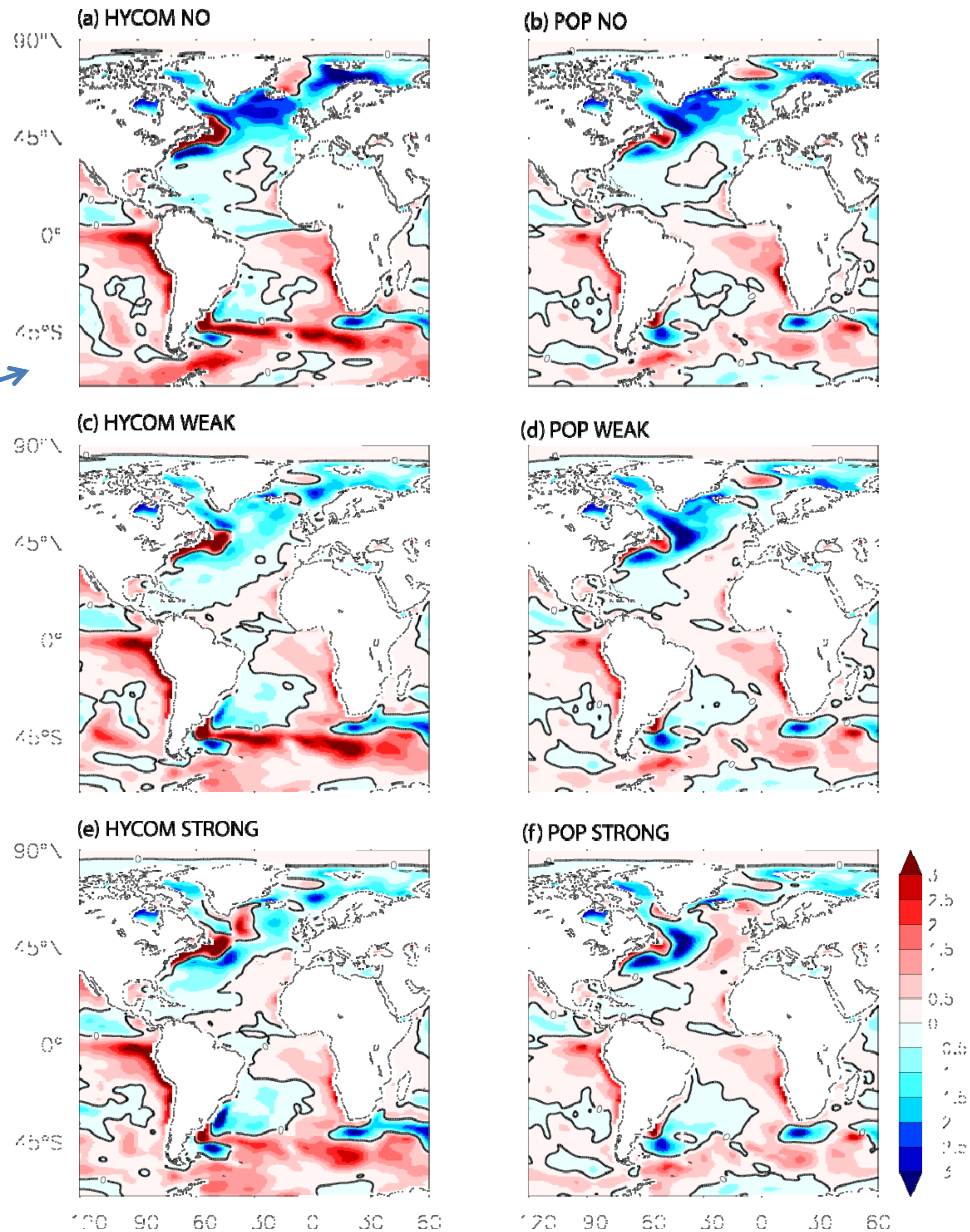
The MOC index is defined as the maximum streamfunction value at 45^{o}N

A notable difference is the variability of the MOC

SST Biases

Cooling at high-latitude NA

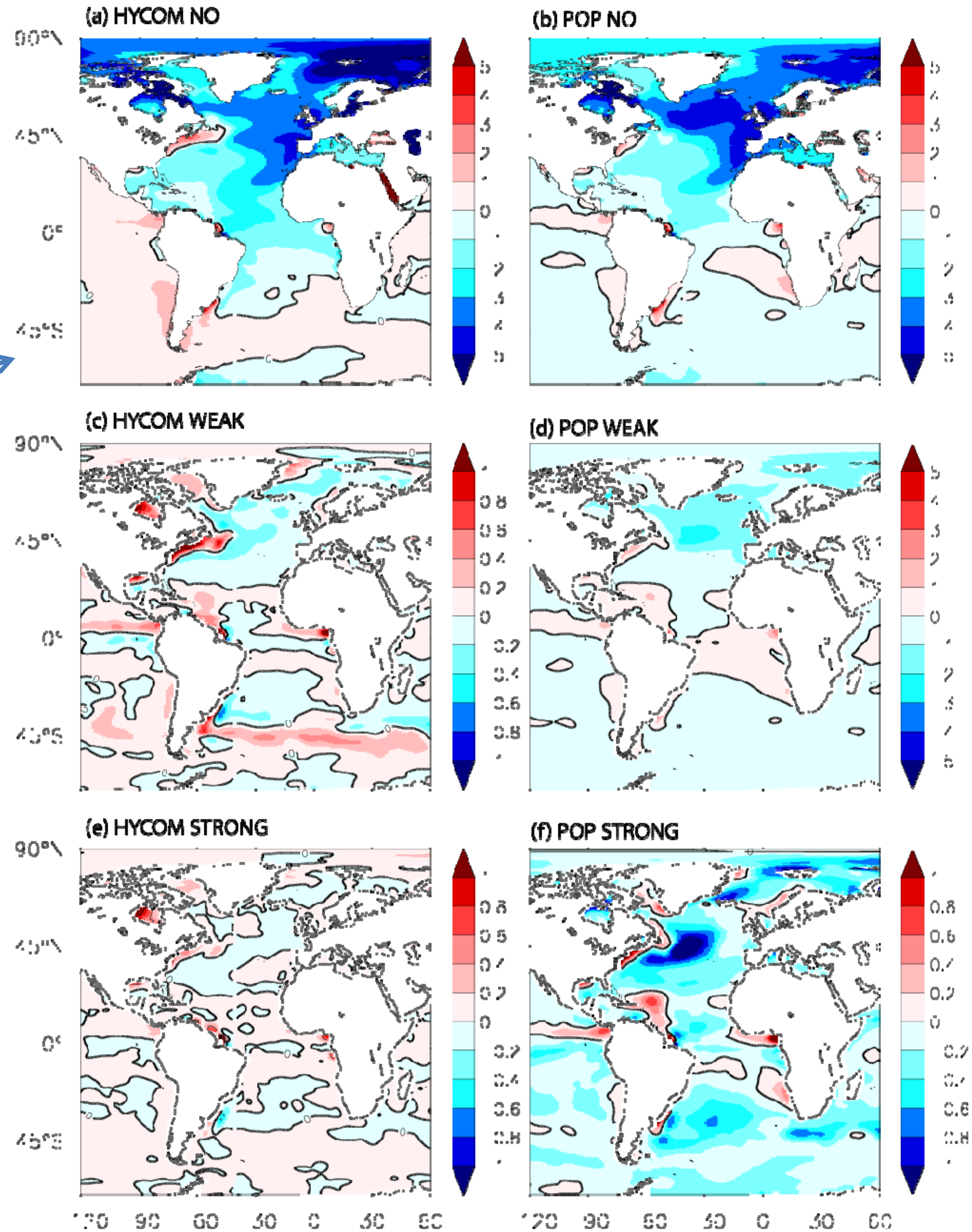
Reduces



SSS Biases

Large freshening at high-latitude NA

Reduces

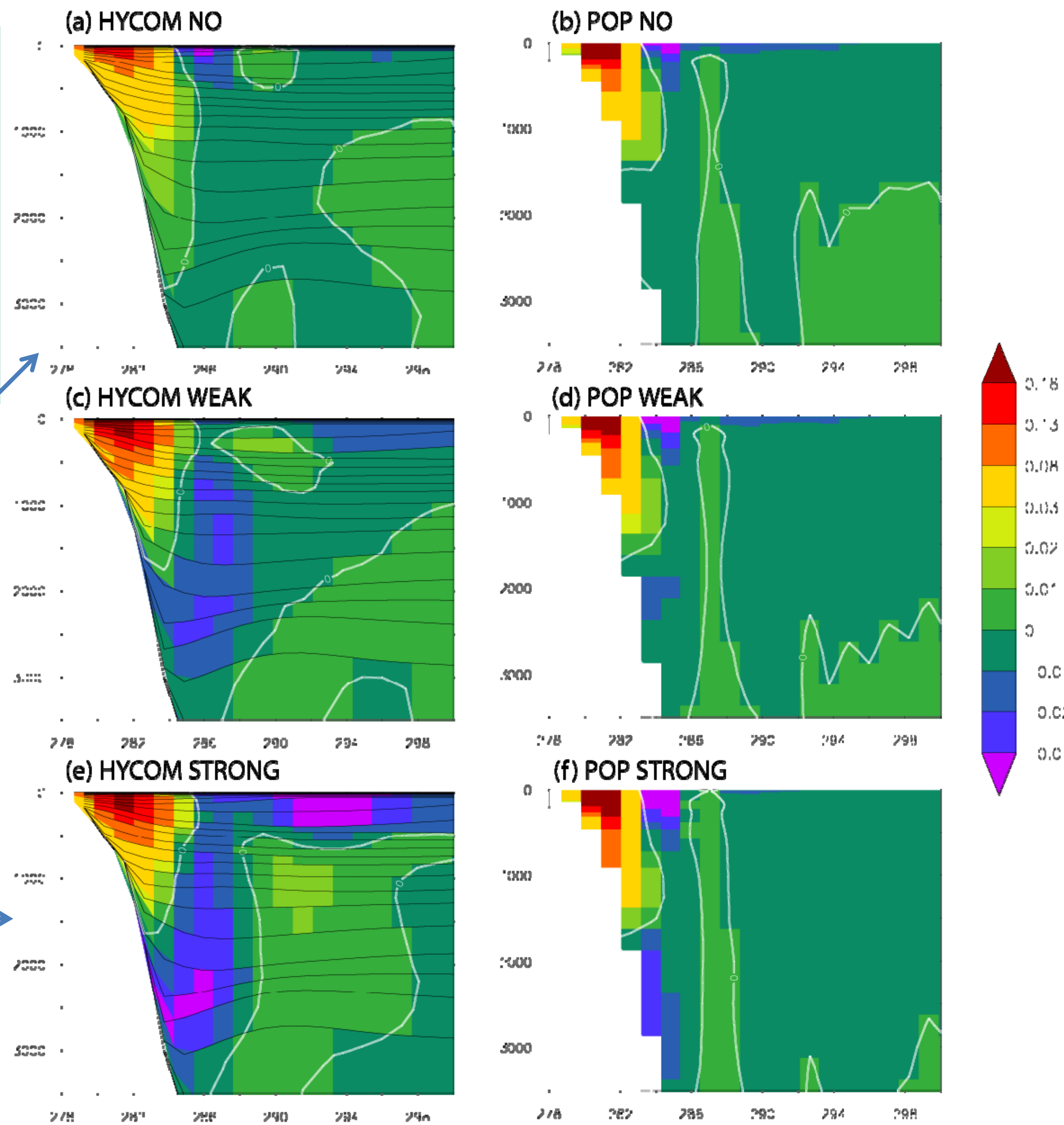


Meridional Velocity at 30ºN

No deep western boundary current

Strong deep current

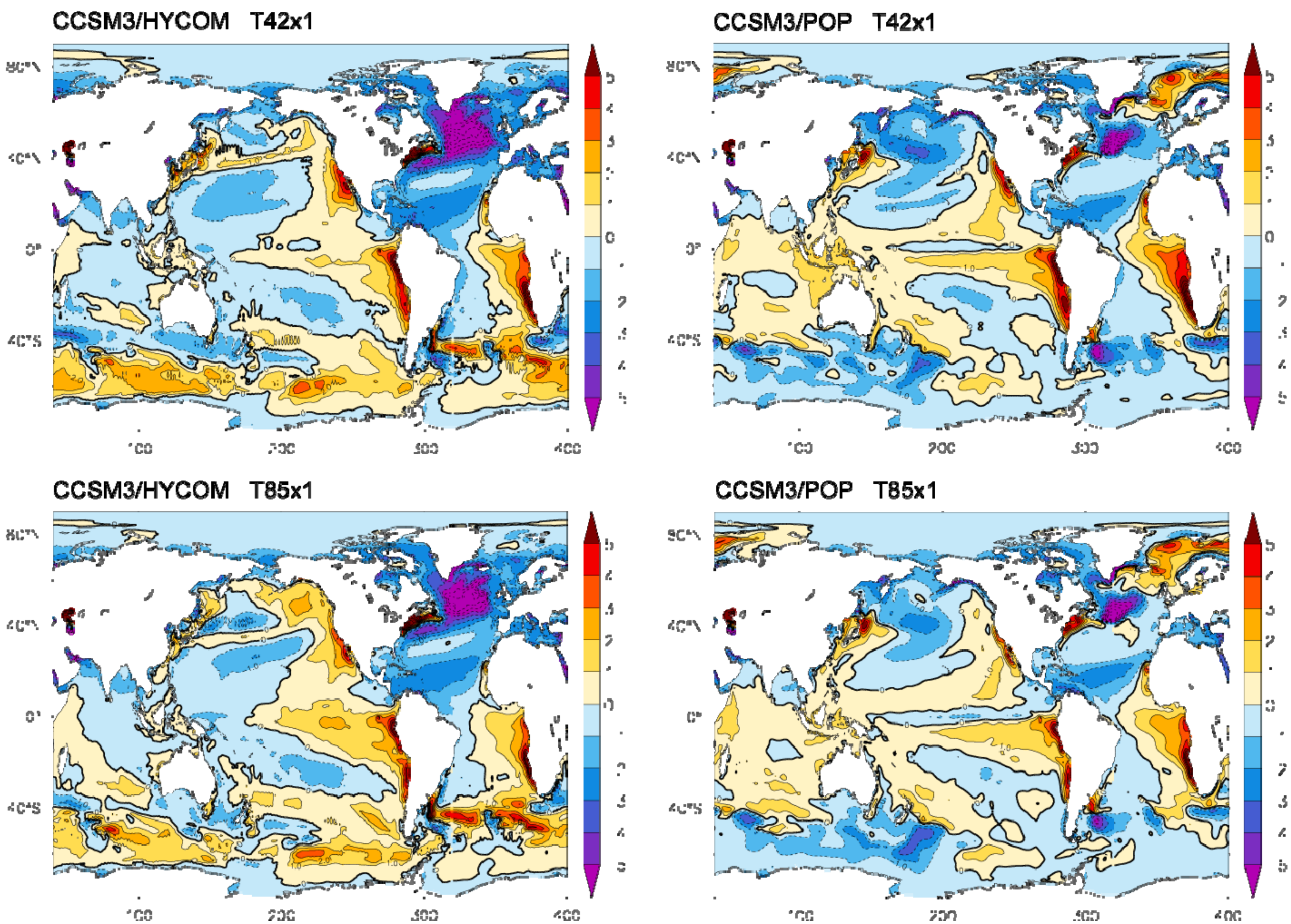
Unit: m/s



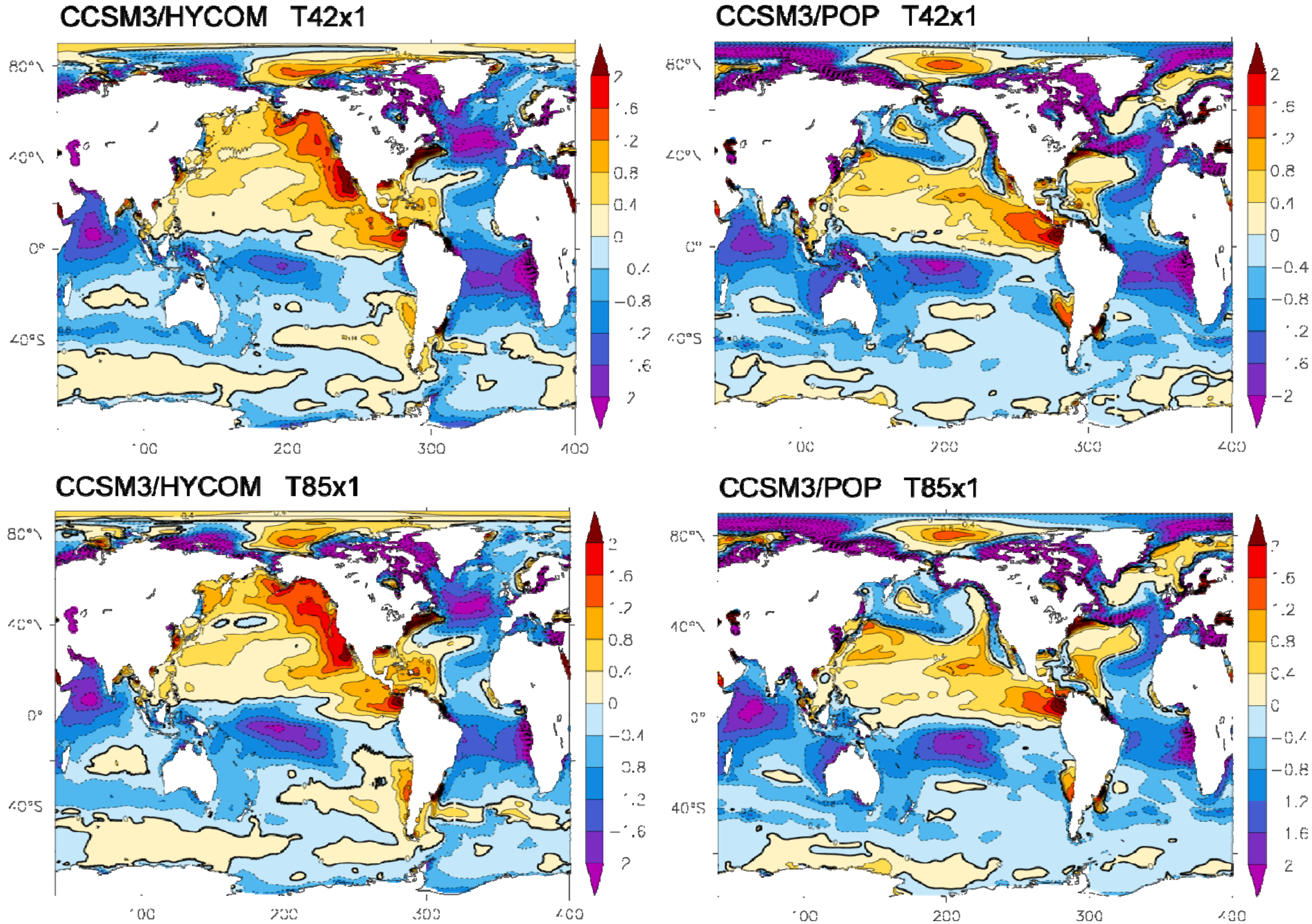
Fully Coupled CCSM3/HYCOM Simulations

- Two versions of fully coupled CCSM3/HYCOM have been configured: 1 degree HYCOM coupled to T42 and T85 CAM.
- Long-term integrations have been obtained with both versions. The simulation results have been compared to observations and those from CCSM3/POP.

SST Biases (^oC) with the Default Setting - years 91-100



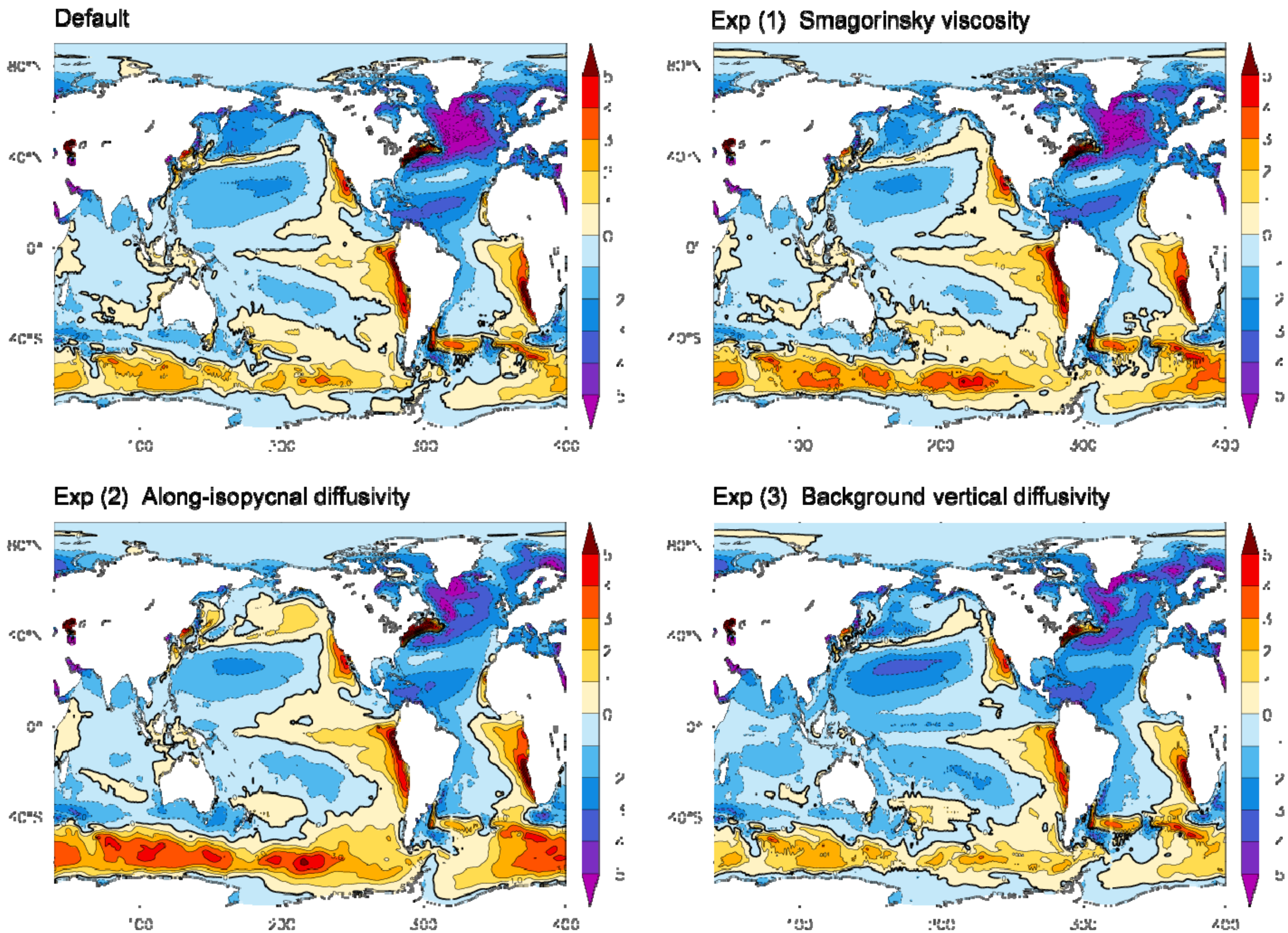
SSS Biases (*psu*) with the Default Setting - years 91-100



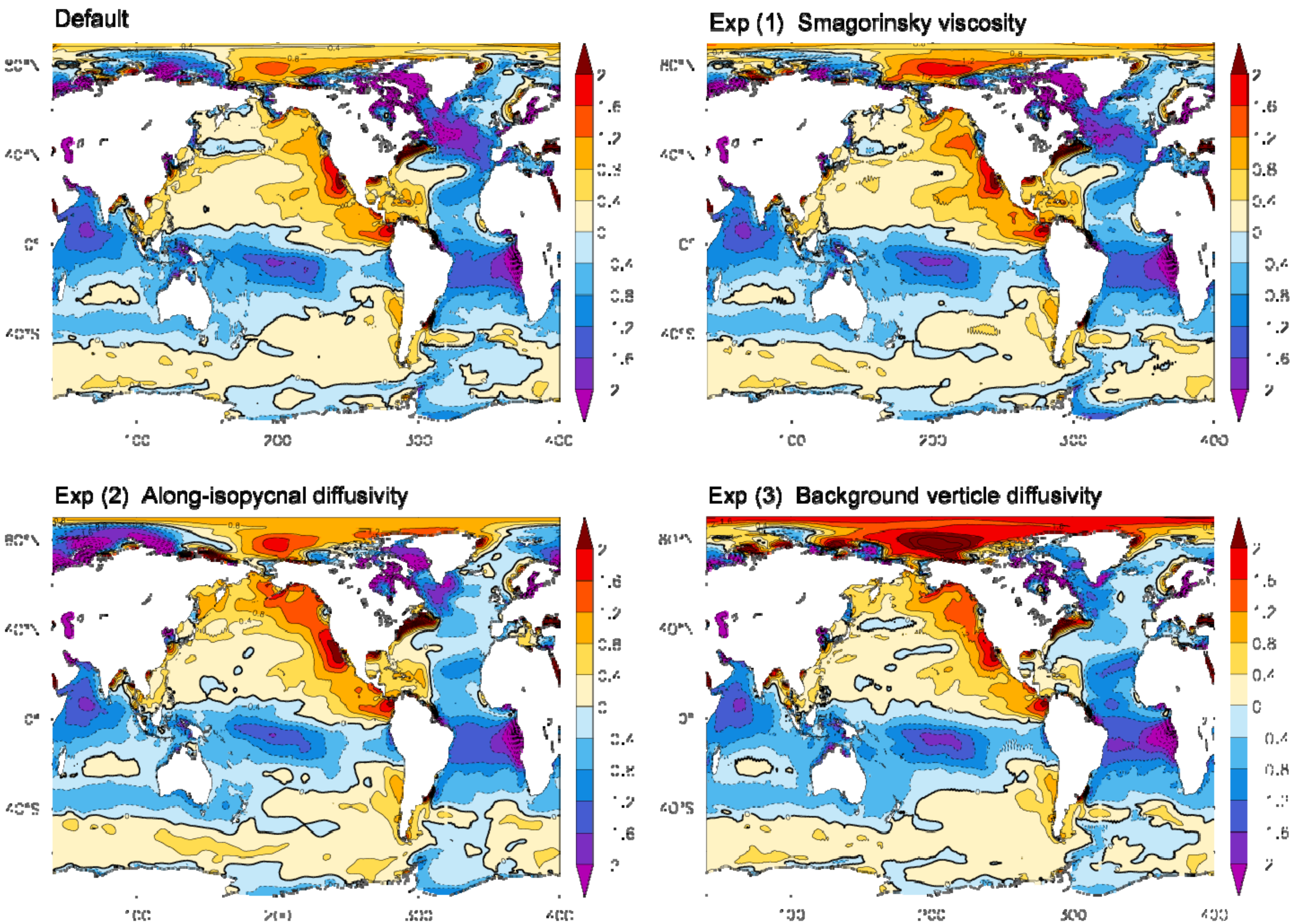
Parameter Tuning and Sensitivity Experiments

	Smagorinsky viscosity parameter	Along-isopycnal diffusivity parameter	Background vertical diffusivity parameter
Default	0.2	0.005	10^{-5}
Exp (1)	0.1	0.005	10^{-5}
Exp (2)	0.2	0.03	10^{-5}
Exp (3)	0.2	0.005	5×10^{-5}

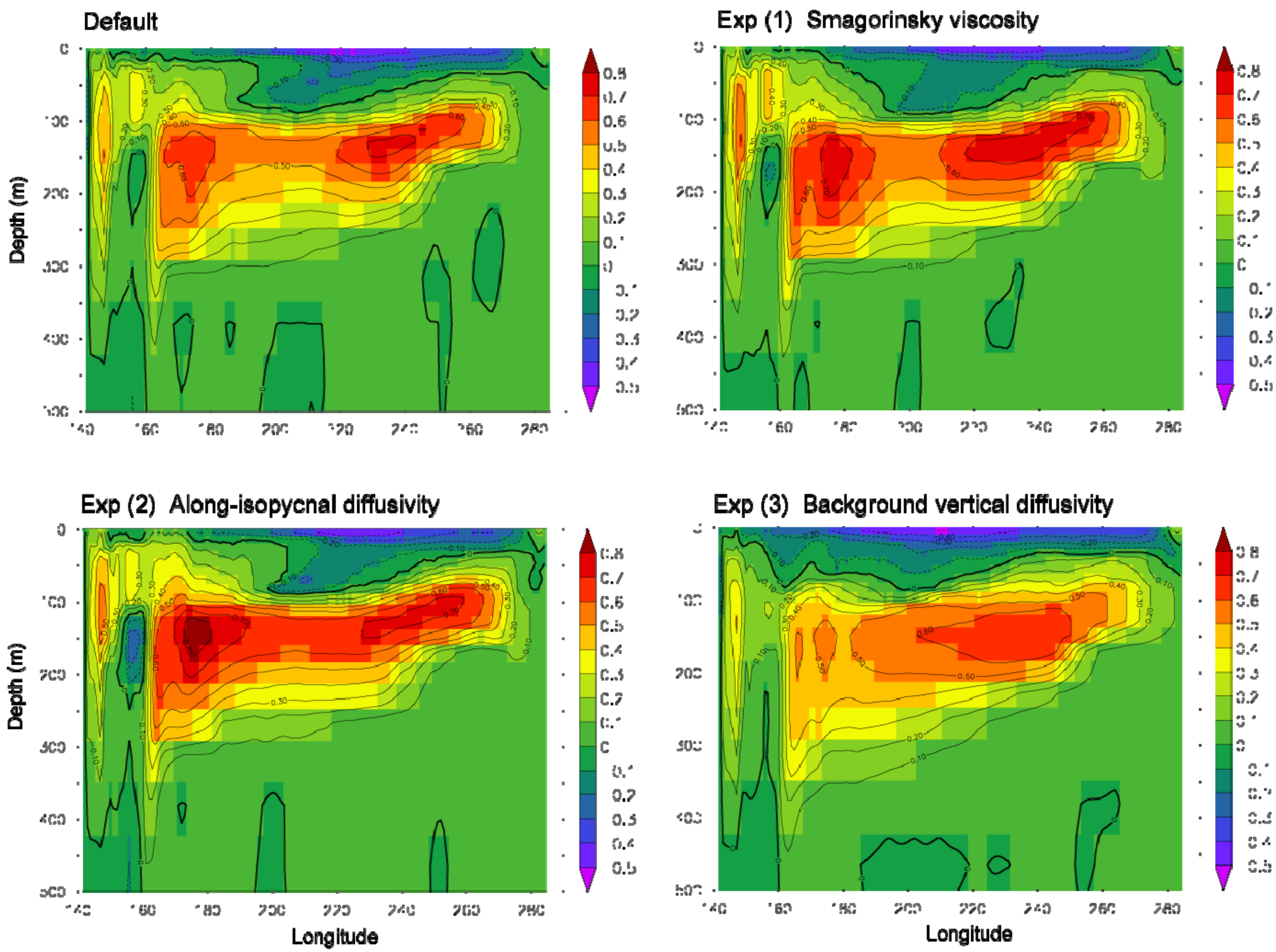
SST Biases (°C) years 26-30



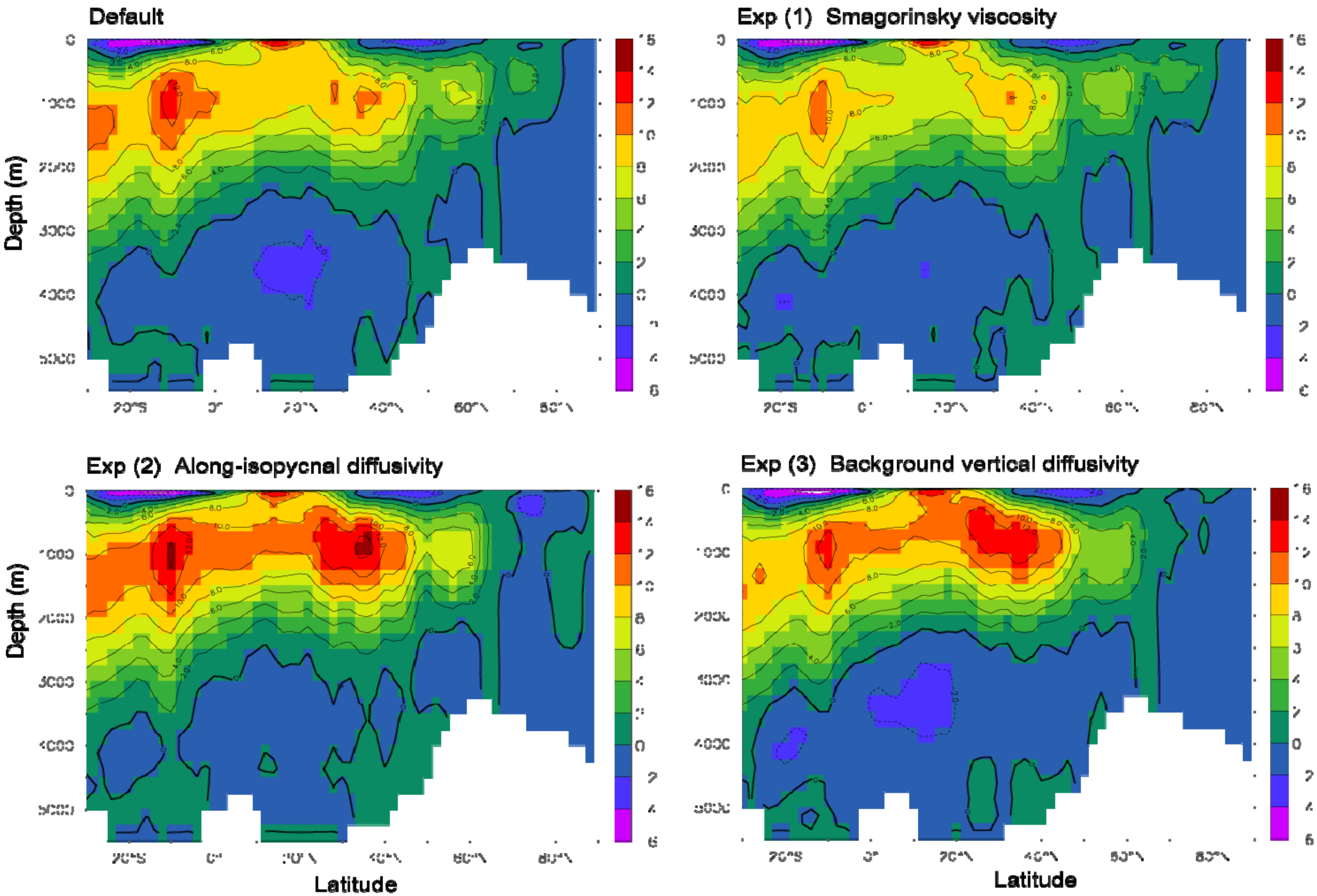
SSS Biases (*psu*) years 26-30



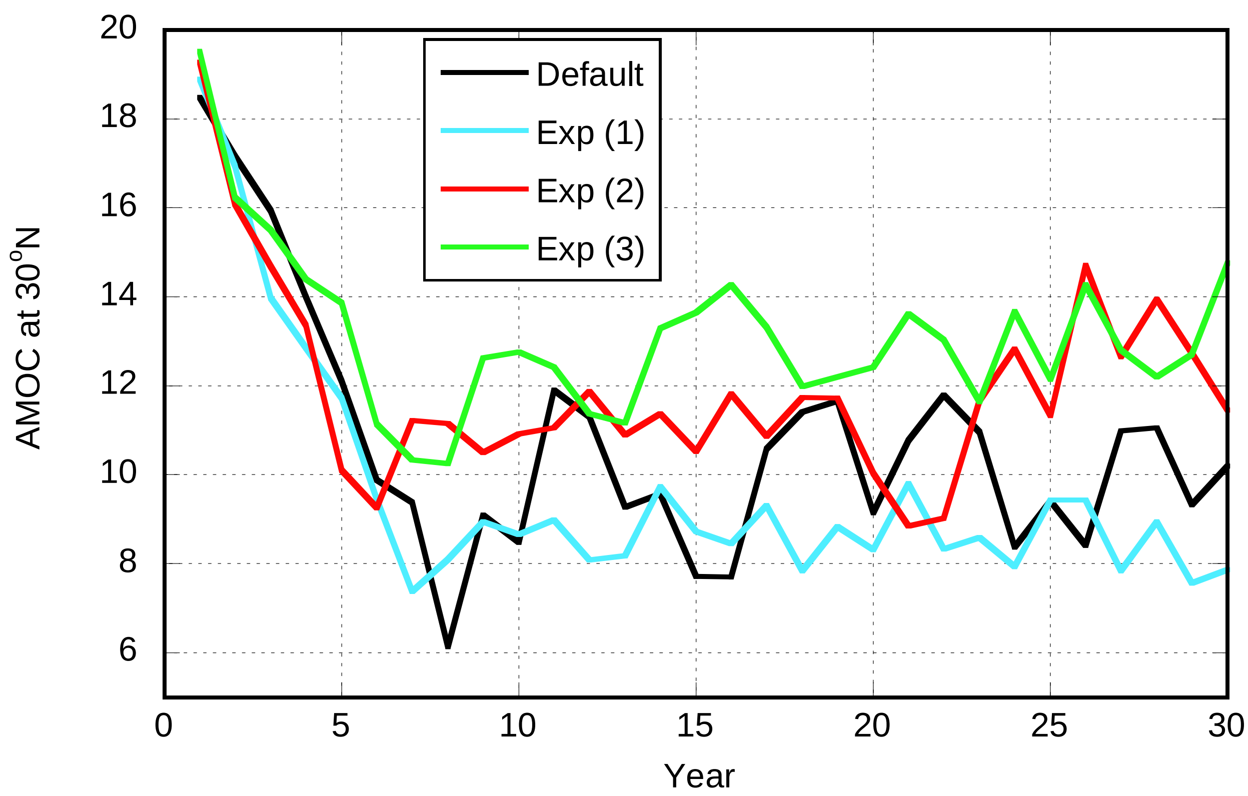
Pacific Equatorial Undercurrent (m/s) years 26-30



Atlantic Meridional Overturning Circulation (Sv)



Atlantic Meridional Overturning Circulation (Sv)



The AMOC index is the maximum overturning streamfunction in 500-3000 m at 30ºN.

Conclusions and Future Work

- Both uncoupled HYCOM and POP cannot simulates an active AMOC under CORE forcing without the application of salinity restoring.
- Once salinity restoring is applied, the AMOC is active in both models. The stronger the restoring, the more vigorous of the AMOC.
- The AMOC shows differences in HYCOM and POP such as its variability. Not clear why this is the case.
- The fully coupled CCSM3/HYCOM shows a cold bias in the northern North Atlantic. This cold bias is can be reduced by varying the Smagorinsky coefficient, along-isopycnal diffusivity and background vertical diffusivity.
- Future studies: Impact of the coordinate distribution, GM mixing and different atmosphere (CAM 4.0)