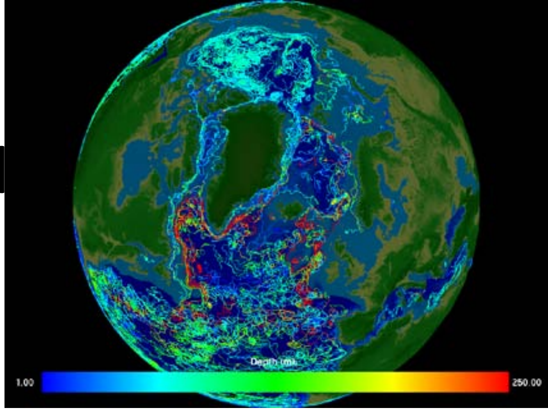
Ultra-High-Resolution Coupled Climate Simulations



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14th Annual CCSM Workshop, Breckenridge CO

15-18 June December 2009

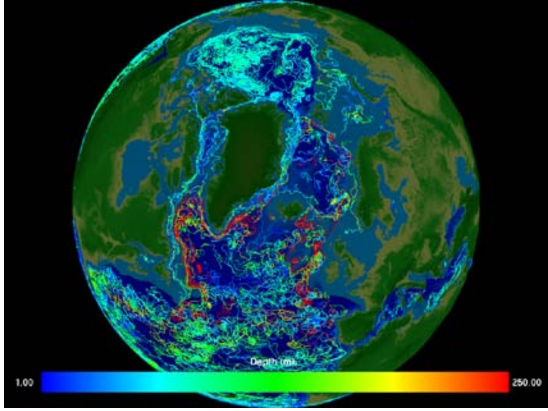
Acknowledgements

Funding: Climate Change Prediction Program/Department of Energy, LLNL Strategic Mission Support.

High Performance Computing Resources: Computer time on Lawrence Livermore National Laboratory's Atlas machine was provided under LLNL's Multiprogramatic and Institutional Computing Initiative.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Project Goals



- Execute a fully coupled global simulation with atmospheric and ocean-sea ice components having ~ 5 and 10 X the horizontal resolution of standard climate component models, respectively.
- Simulate fully-coupled system at these scales for sufficiently long periods to obtain a statistically significant description of climate across a range of spatial scales from local to global to enable probabilistic prediction of future climate.
- Such global coupled simulations have not been conducted before in the U.S.

Outline

- Description of high-resolution CCSM set-up
- Overview of fidelity of ocean and ice components.
- Biases in atmosphere model.
- Typhoons
- Agulhas eddy pathway characteristics

High Resolution CCSM

CCSM4 (ccsm4_0_alpha31) Components:

- Community Atmosphere Model version 3.5 (CAM) with finite volume dynamical core
- Community Land Model version 3.0 (CLM3)
- Parallel Ocean Program version 2.0 (POP)
- Los Alamos Sea Ice Model version 4.0 (CICE)
- Coupler version 7.0

Configurations:

- 0.50° ATM,LND + 0.1° OCN, ICE: FRANKLIN at NERSC
  - 2 years (GC008 at LLNL)
  - ~15 years (Bhr21)
- 0.25° ATM,LND + 0.1° OCN,ICE : ATLAS at LLNL
  - ~18 years (T4031qtA,T4031qtB)

CCSM4: Grids, Decompositions and Time Steps

Atmosphere

- 0.23x0.31x26L lat-lon-vertical grid
- Dynamics uses 128x8 lat-vertical decomposition
- Physics time step = 15 minutes
- Dynamics time step = 0.75 minutes

Ocean

- 0.1° tripole grid with 42 levels
  - Ocean uses 72x60 block sizes
  - Ocean time step = 4.8 minutes

Ice

- 0.1° tripole grid
- Ice uses 2x2400 block sizes
- Ice time step = 15 minutes
- Ice dynamics time step = 5 minutes

Coupling

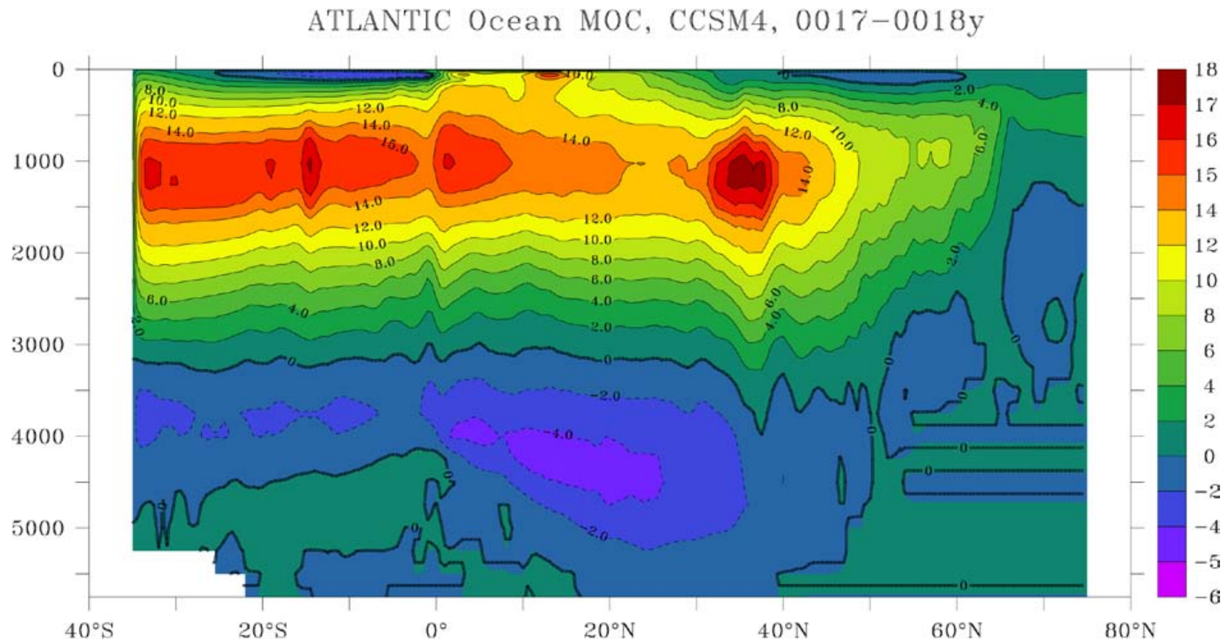
- CAM, CLM, CICE: Coupling time = 15 minutes
- POP couples every 6 hours

CCSM4 Initial Conditions

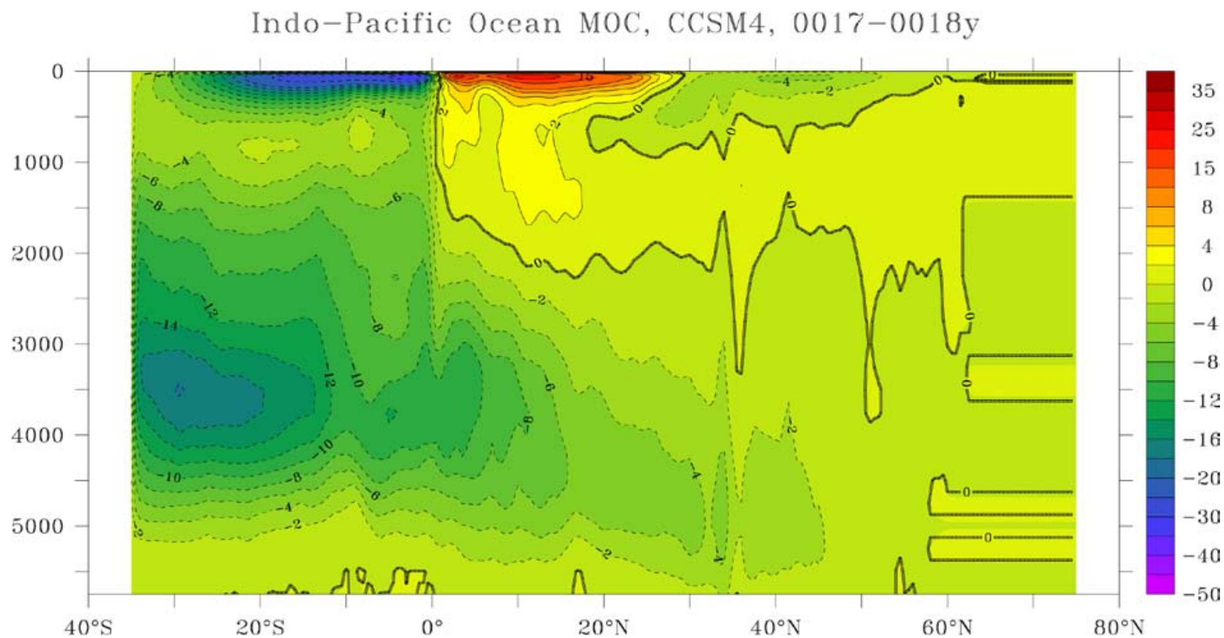
- CAM and CLM started from rest.
- GC008 POP was initialized using θ and S from WOCE climatology.
- T4031qt POP used a 2 year restart from GC008.
- Ice cover initialization is latitude and SST dependent with equatorward ice extent limits at 70°N and 60°S and a nonlinear ice thickness distribution.
- 1990’s GHG forcing

Meridional Overturning Streamfunction (Sv)

Max of 18 Sv at 40°N; Stand-alone POP was 23 Sv Maltrud and McClean, 2005)

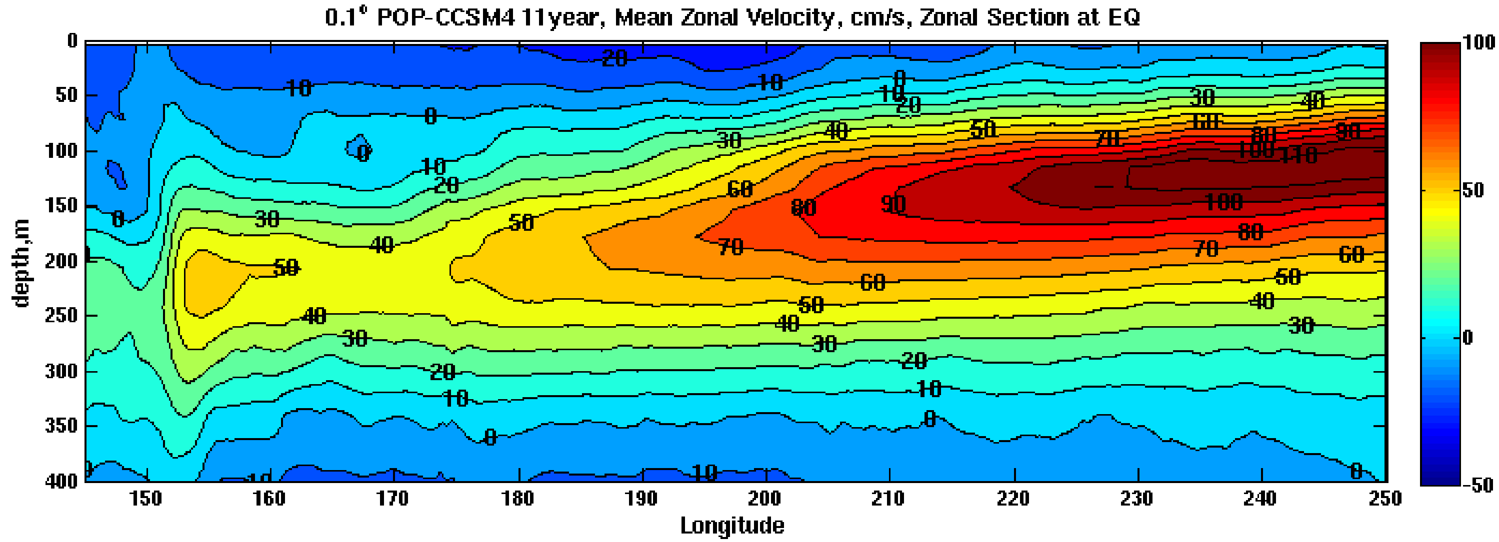


Robust bottom water: 17 Sv Stand-alone POP was 14 Sv (M&M, 2005)



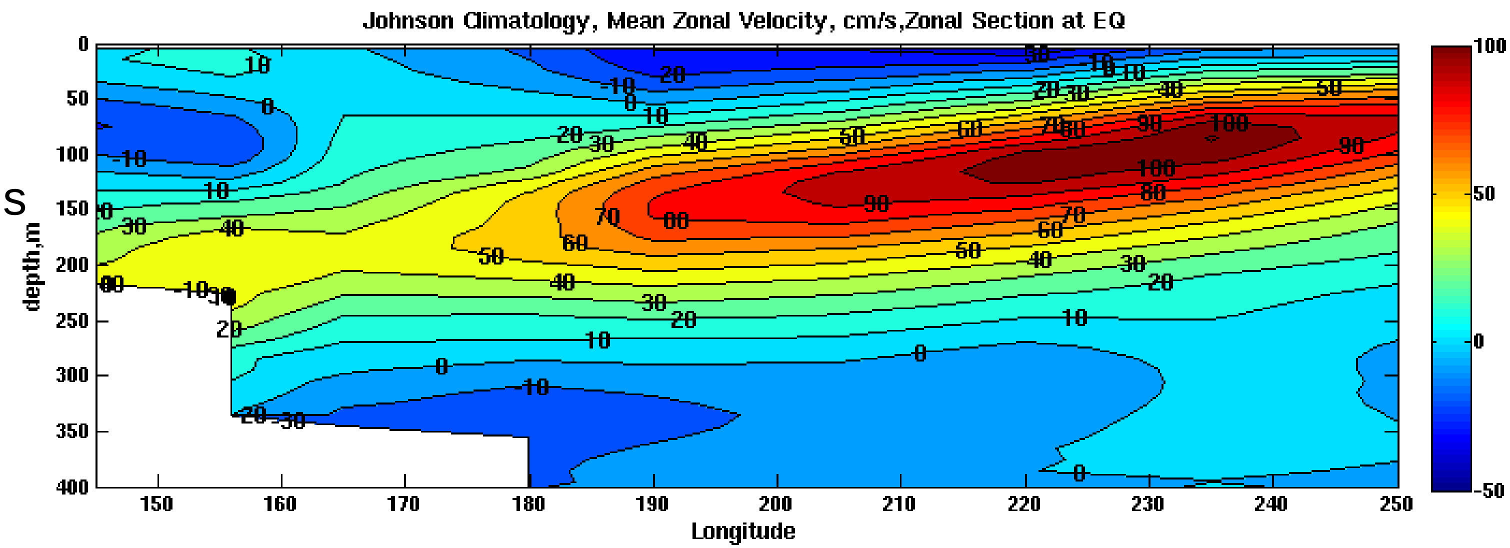
Annual Mean Zonal Velocity (cm/s) at the Equator

CCSM4



Observations

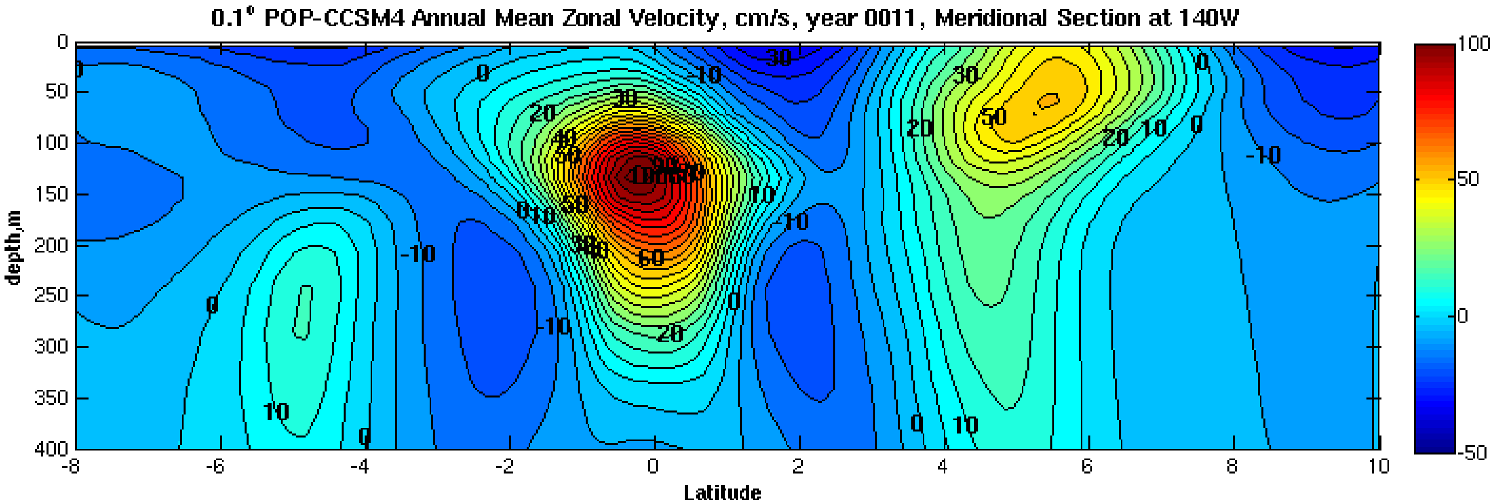
Johnson et al. (2002)



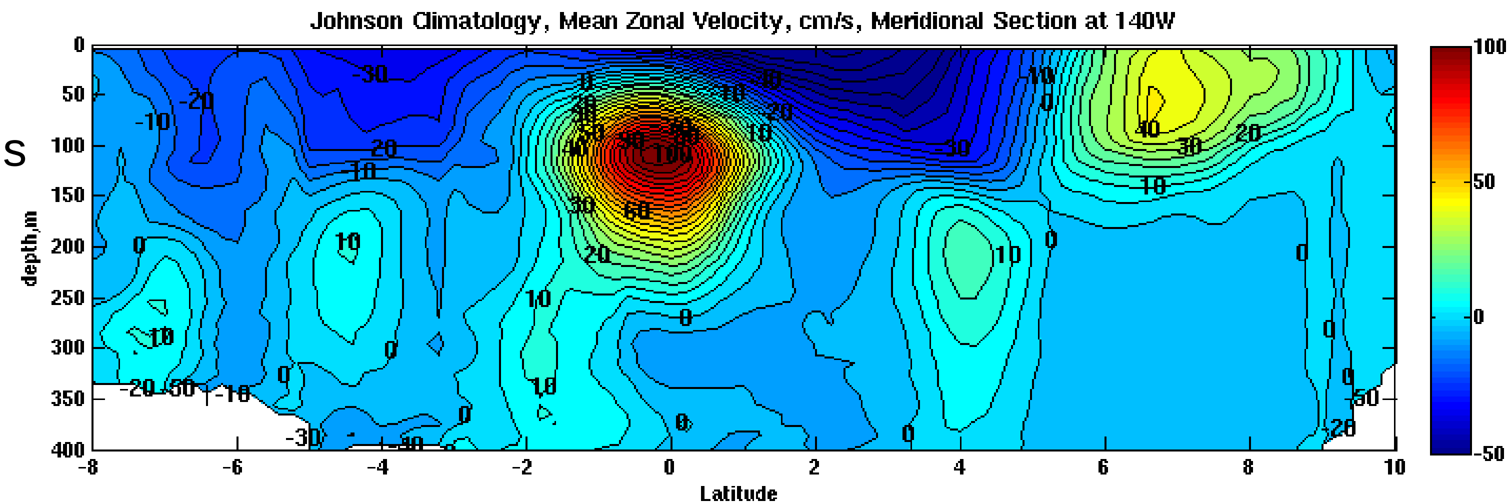
EUC core ~10 cm/s stronger than in reality in the east. At 140°W simulated core is ~ the same magnitude as observed but lies some 20m deeper in the water column.

Annual Mean Zonal Velocity (cm/s): Meridional section at 140° W

CCSM4

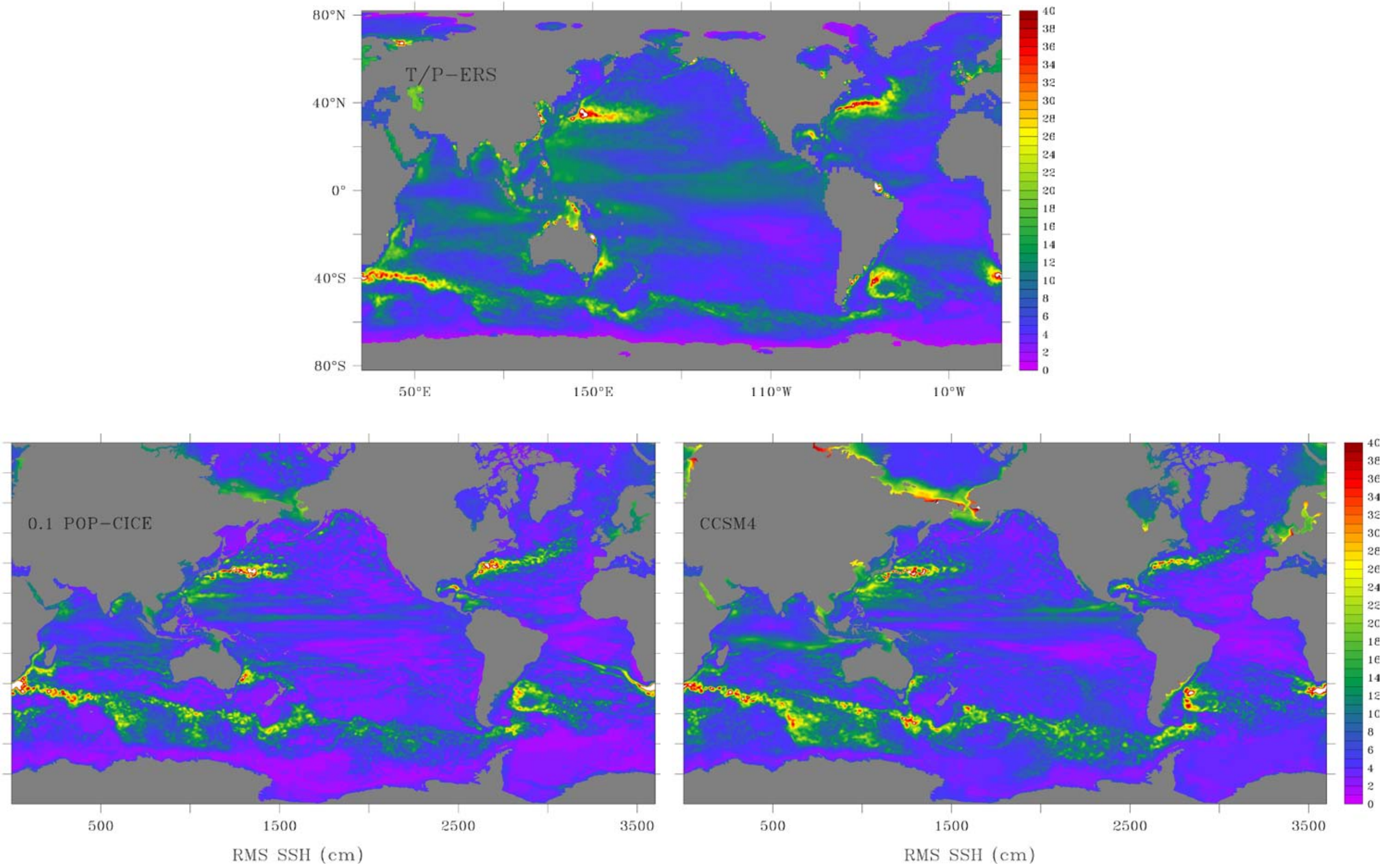


Observations

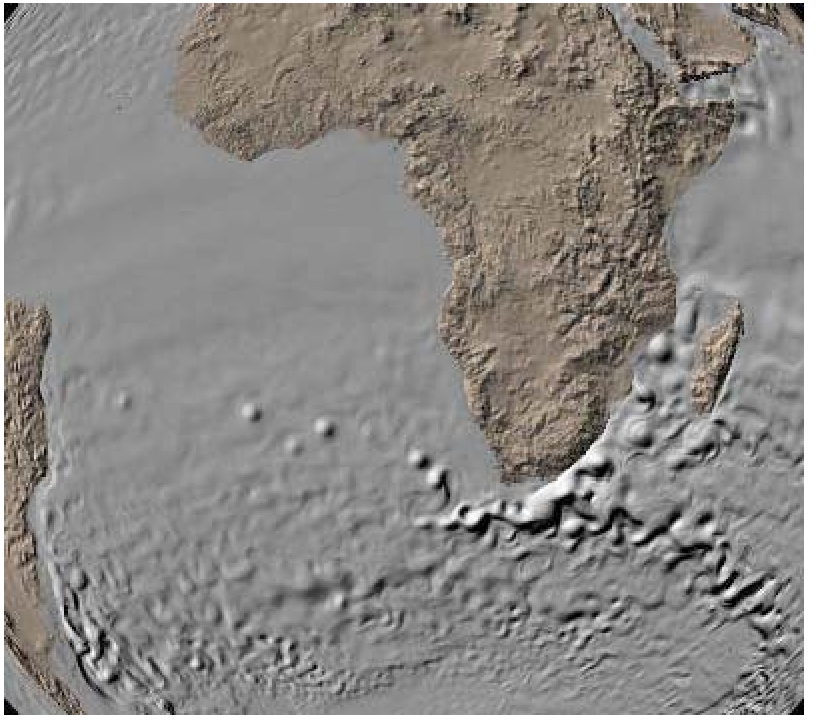


The simulated NECC core is located ~1° equatorward of the observed core.

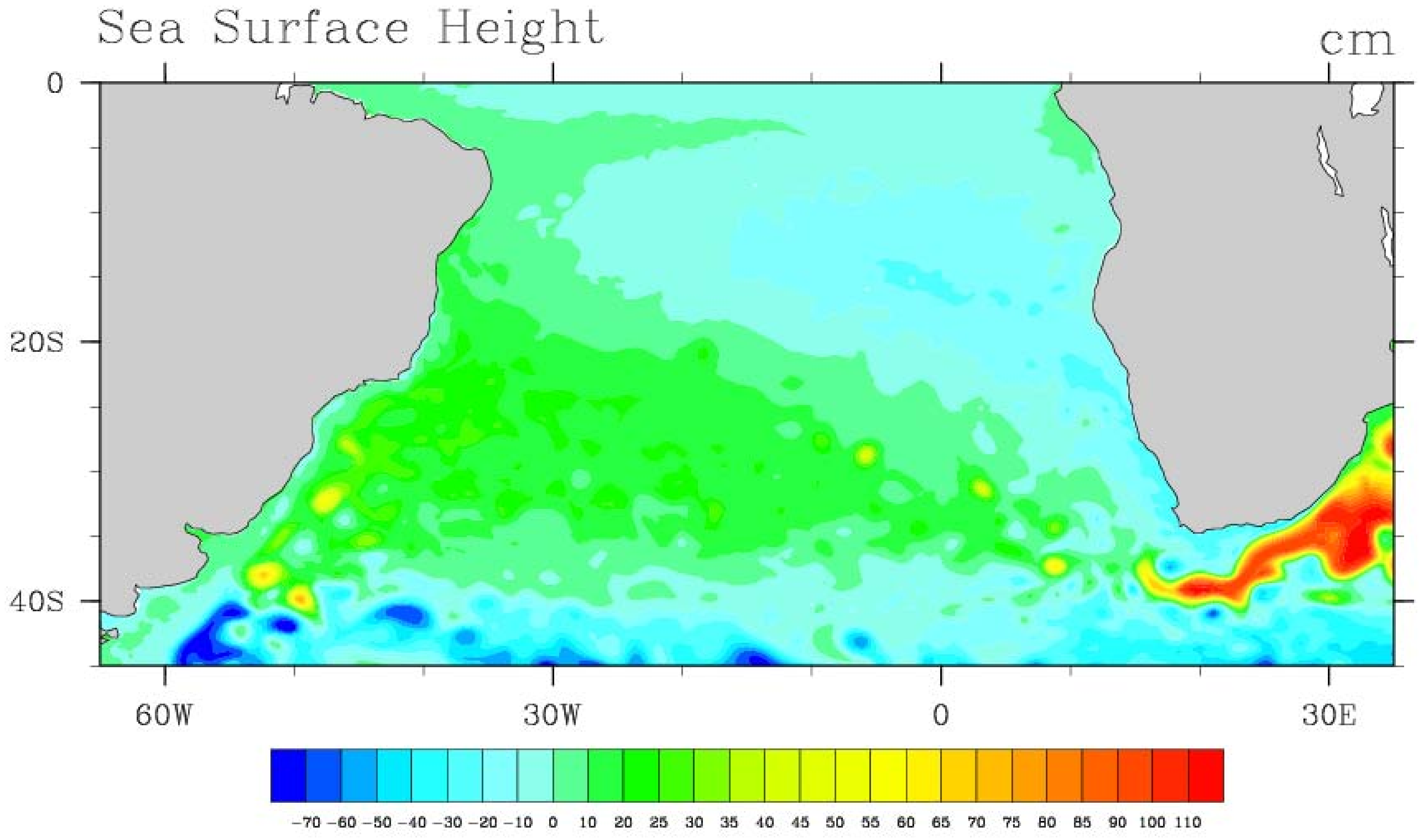
RMS SSHA (cm) from Altimetry (top), 0.1° POP-CICE (lower left) and CCSM4 (lower right)



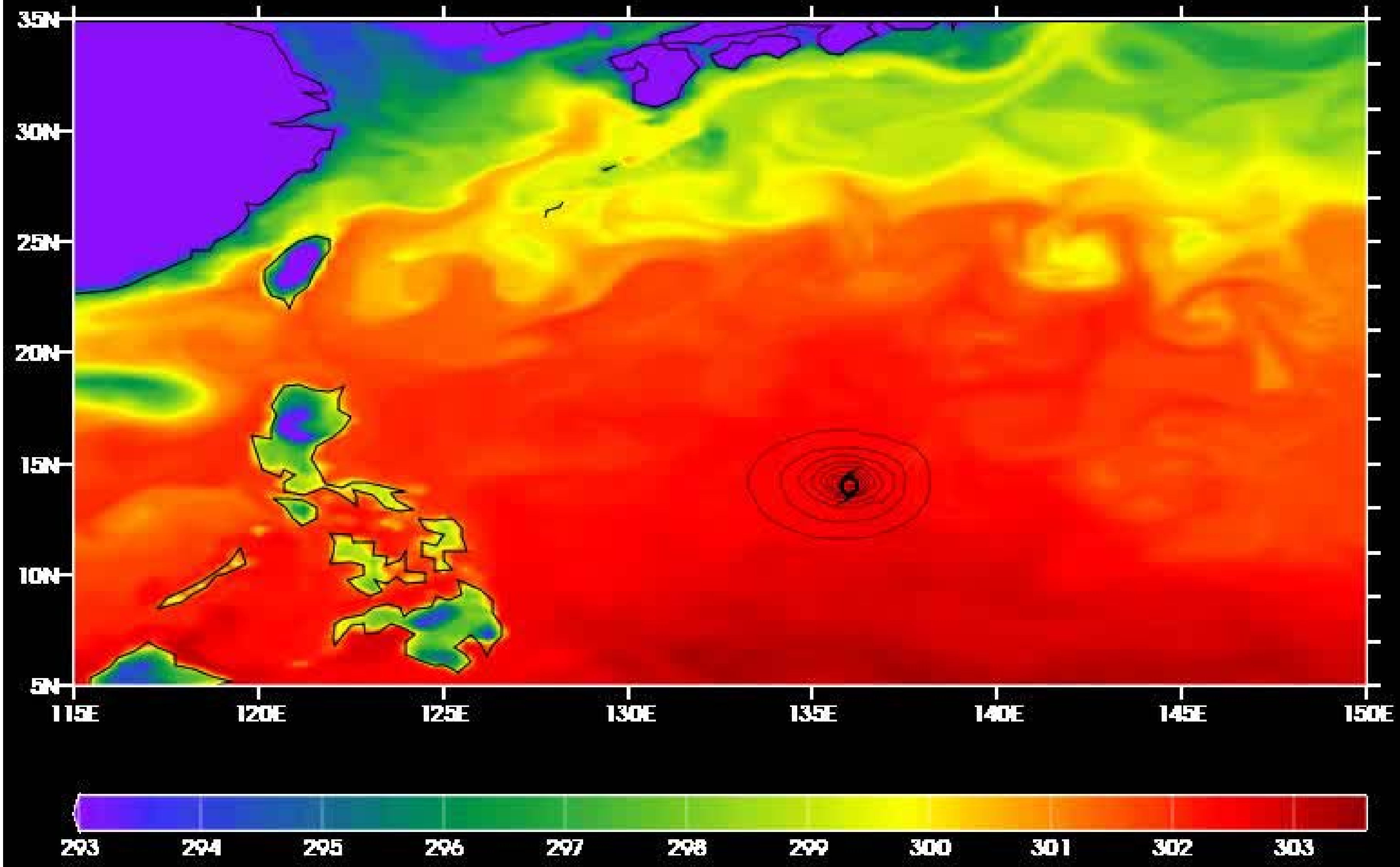
Sea Surface Height (cm) from stand-alone 0.1° POP
Maltrud and McClean (2005)

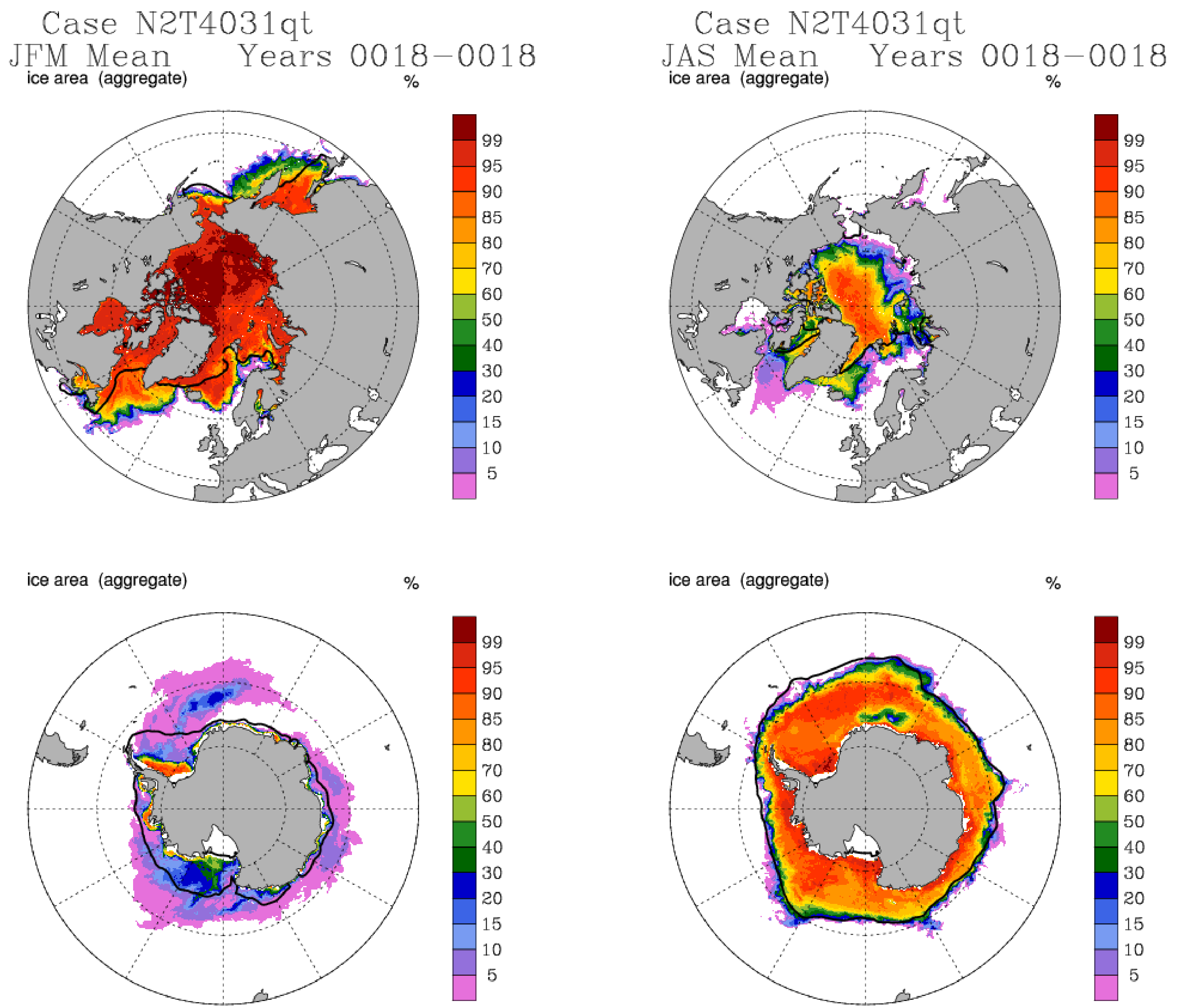


CCSM4


Sea Surface Height
cm
0
20S
40S
60W
30W
0
30E
−70 −60 −50 −40 −30 −20 −10 0 10 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 100 110

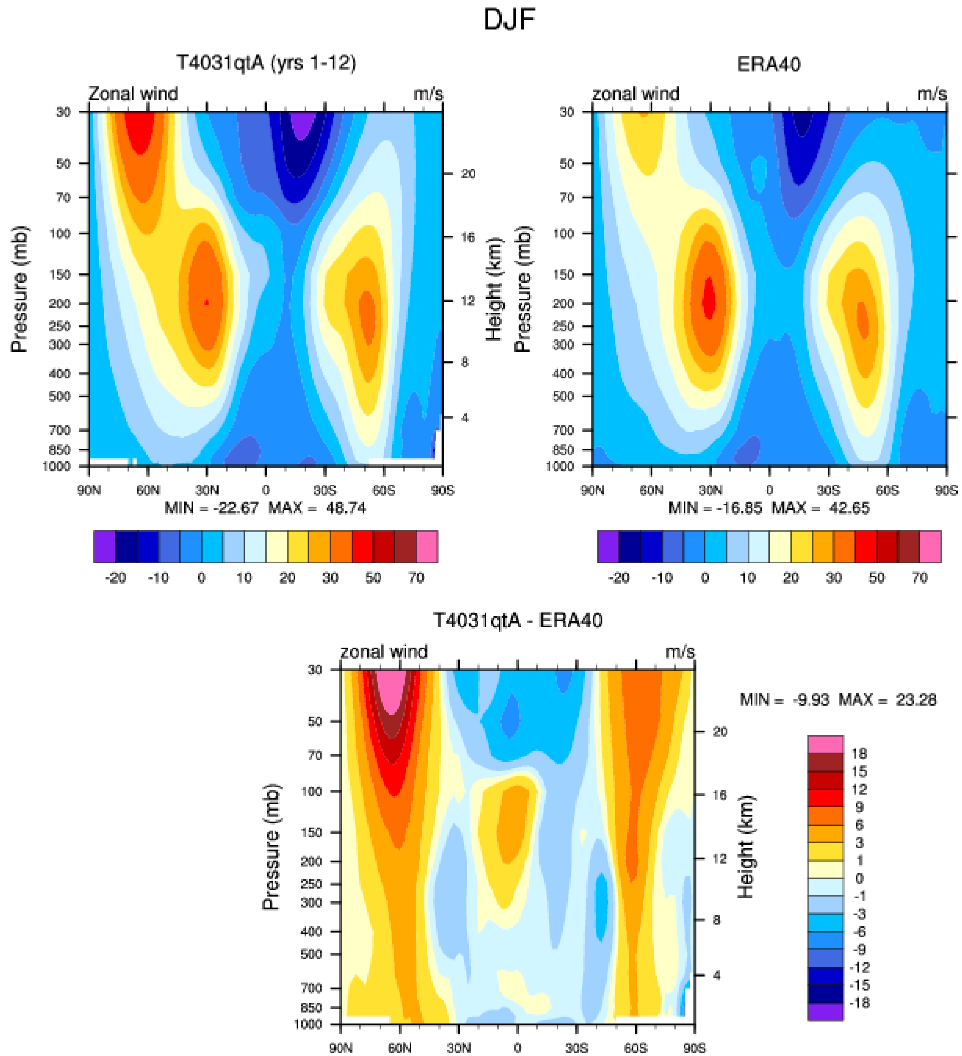
Category 4 Typhoon: Colors show sea-surface temperature and the contour lines display surface pressure

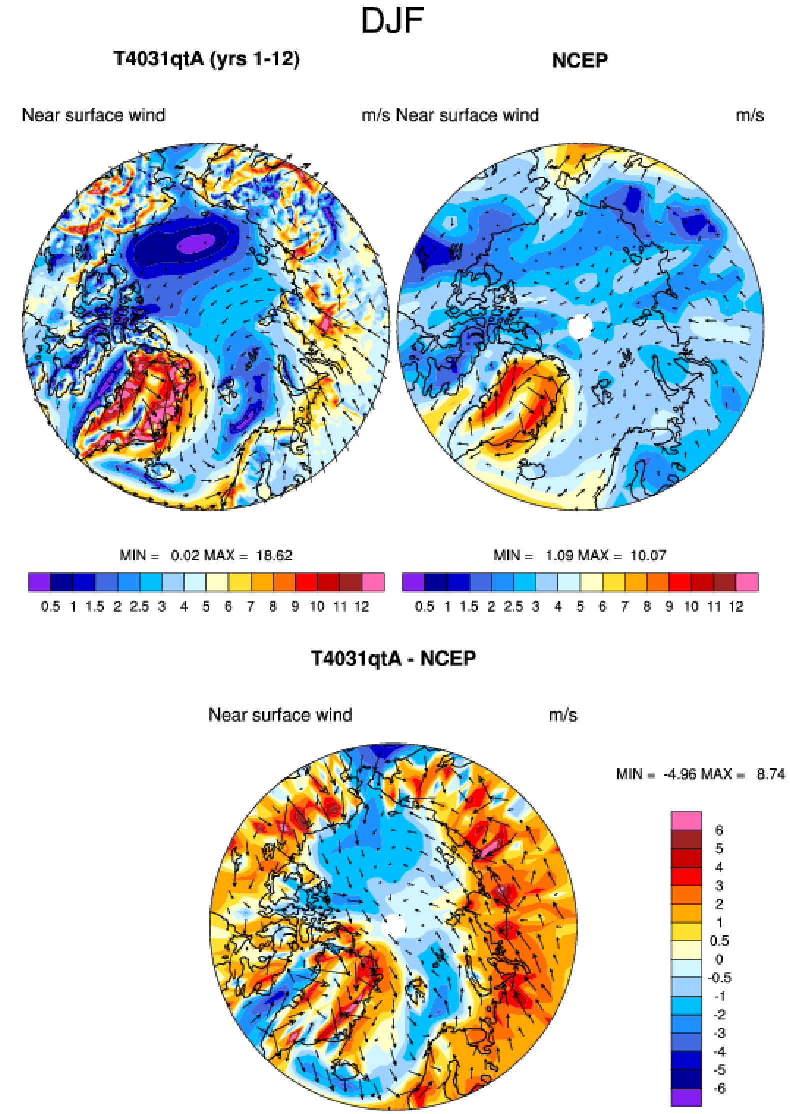




Case N2T4031qt
JFM Mean Years 0018–0018
ice area (aggregate)
%
99
95
90
85
80
70
60
50
40
30
20
15
10
5
Case N2T4031qt
JAS Mean Years 0018–0018
ice area (aggregate)
%
ice area (aggregate)
%
ice area (aggregate)
%

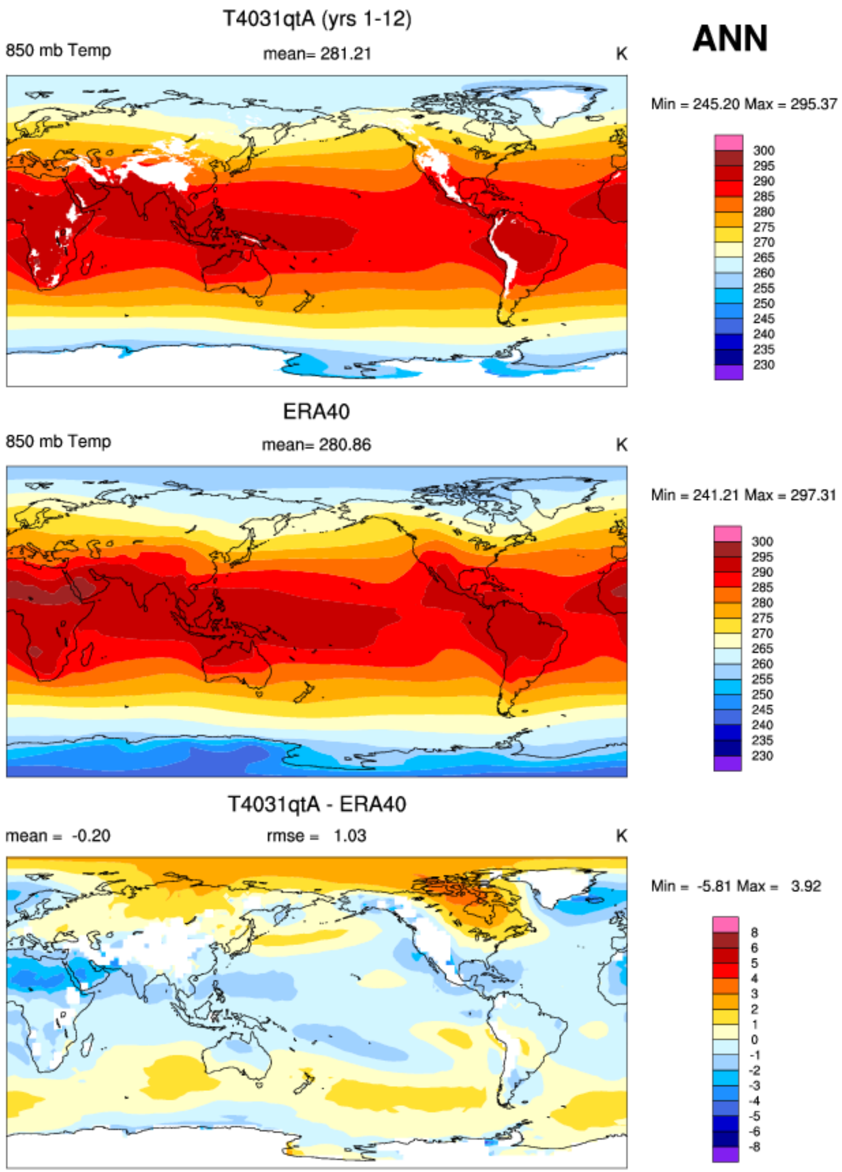
Polar Circulation Problems





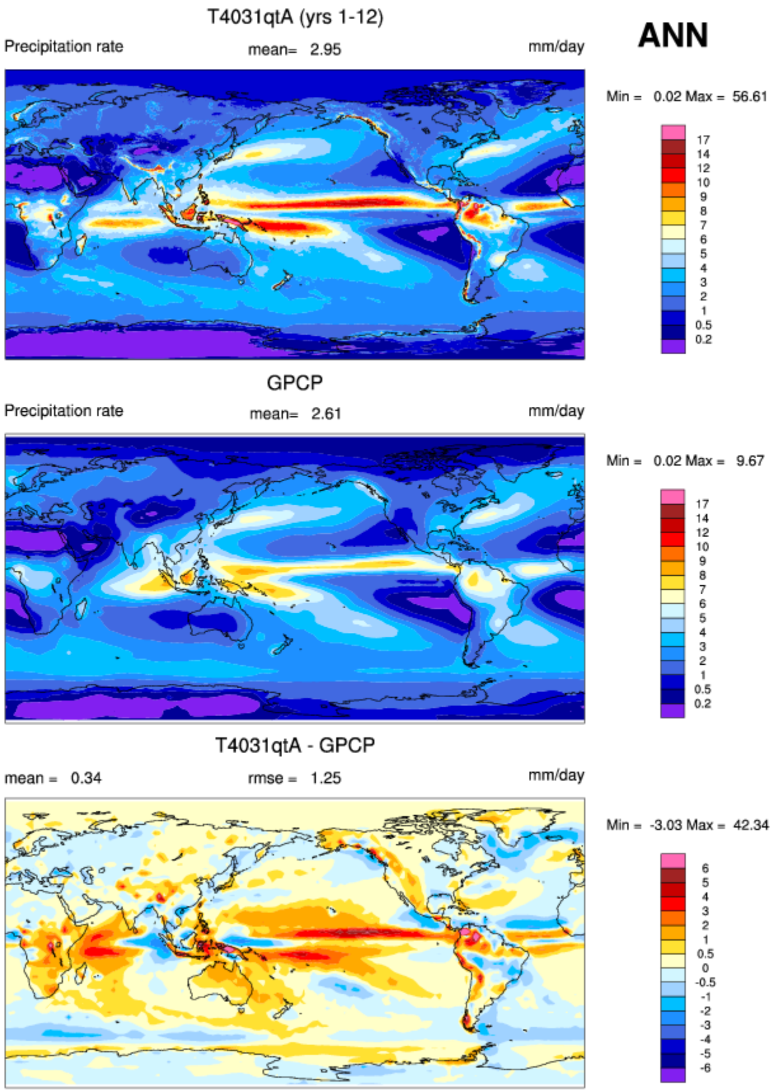
The left figure depicts the overestimation of the zonal wind towards the poles. This is severe at upper levels but also extends to surface. The right figure shows the overly strong and shifted Icelandic Low.

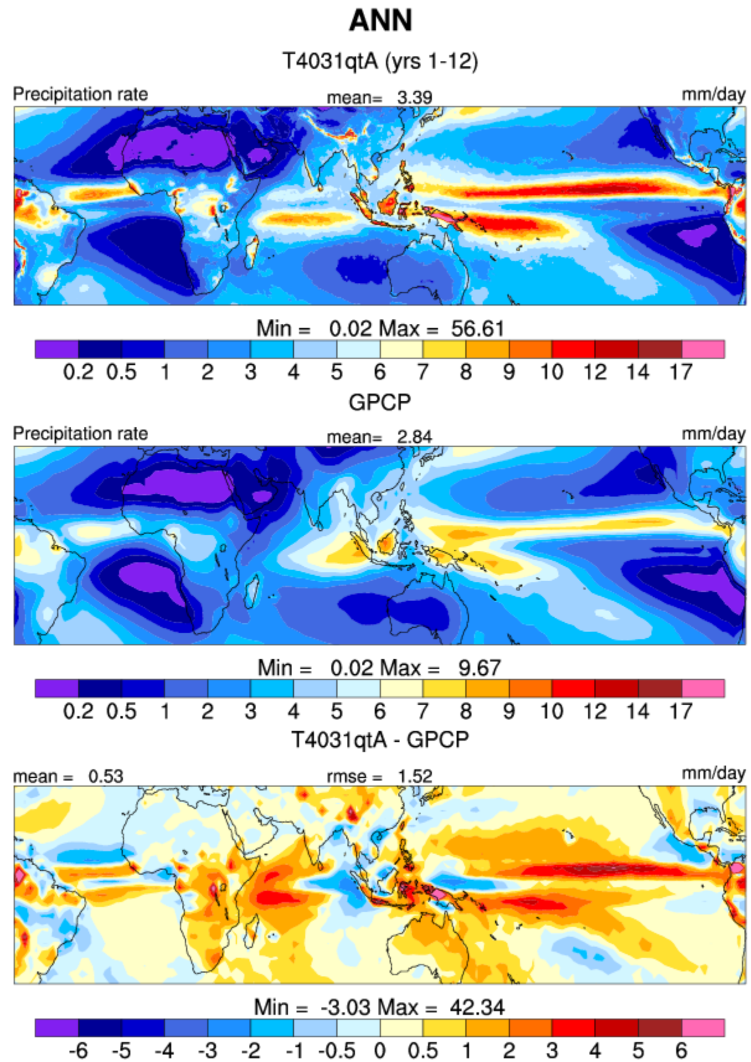
Comparison of 850 hPa Temperature from the model and ERA40



The 850 hPa model temperature field shows remarkable fidelity, with some significant errors areas in the Boreal polar region.

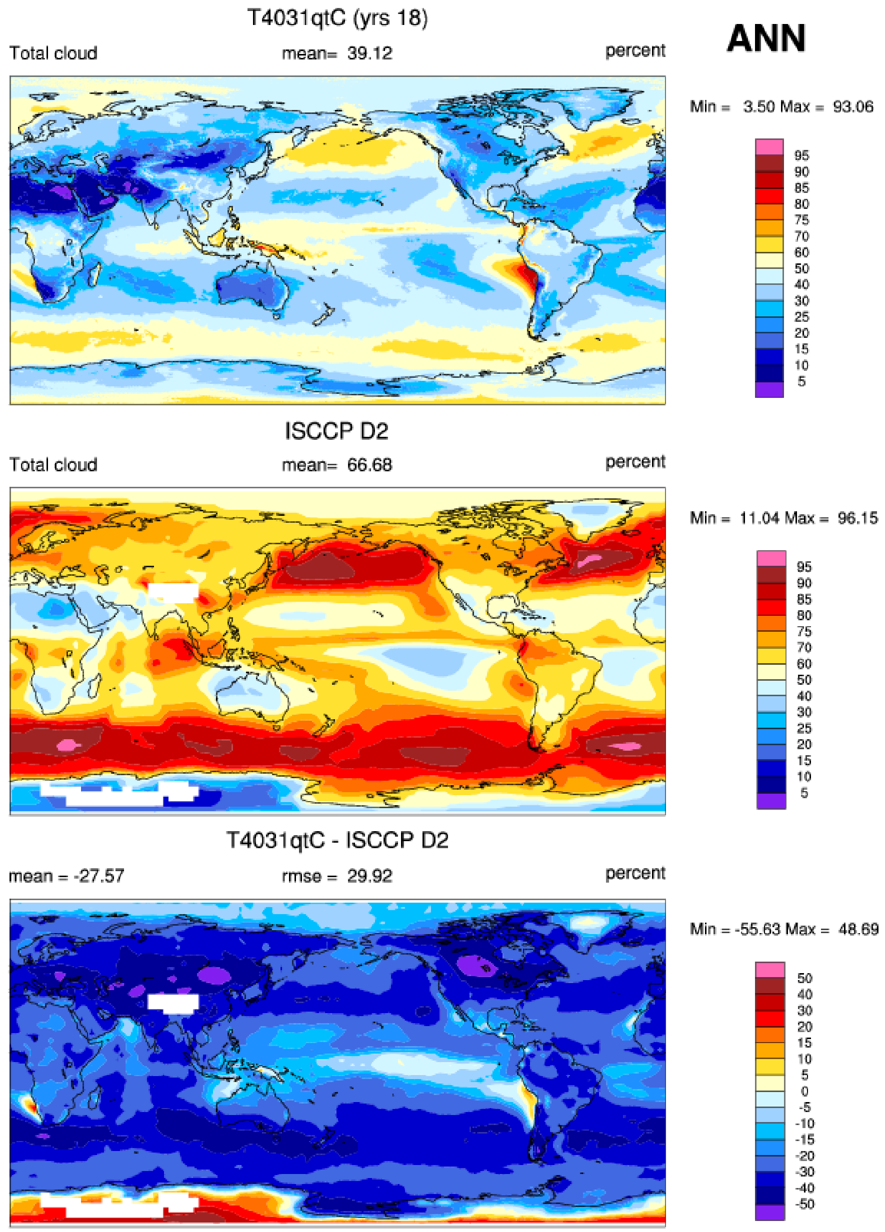
RAINFALL





Comparison of the annual mean rainfall of the model and GPCP observations. The model overestimates precipitation in the Tropics.

CLOUD AMOUNT



Low bias in cloud amounts in mid-latitudes results in excess in surface shortwave flux.

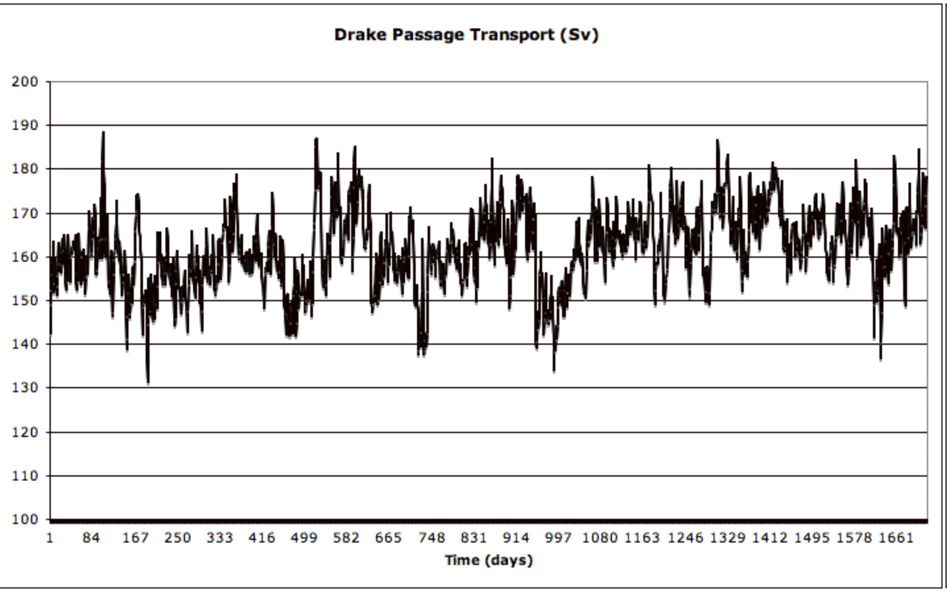
Conclusions

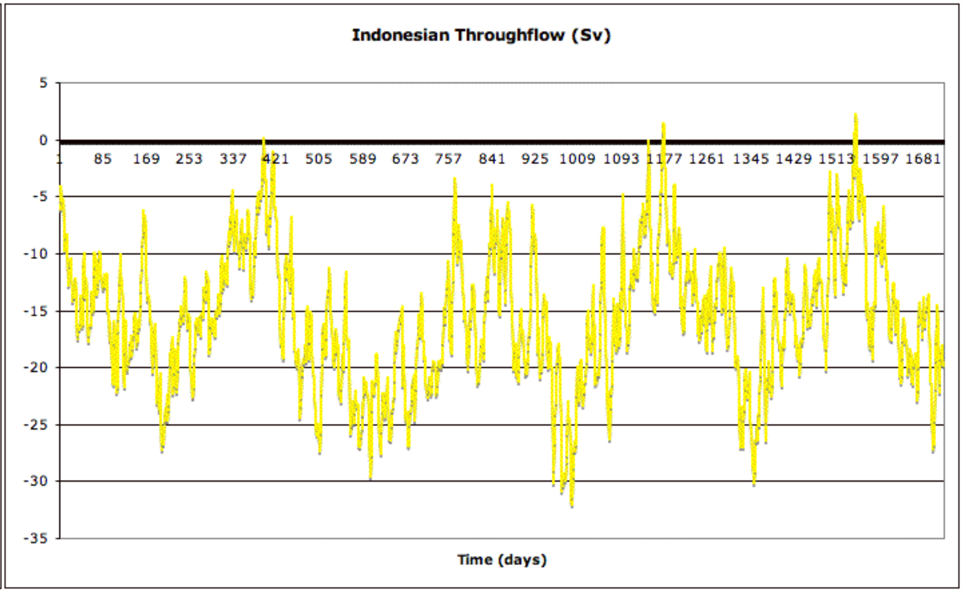
The simulation’s climate is very reasonable considering that no tuning has been done to correct biases.

It demonstrates the feasibility and highlights the potential of future very high resolution long coupled climate runs.

Because of the large biases, the simulation will be halted after 20 years and the results of 5-10 year climatologies examined to design future experiments.

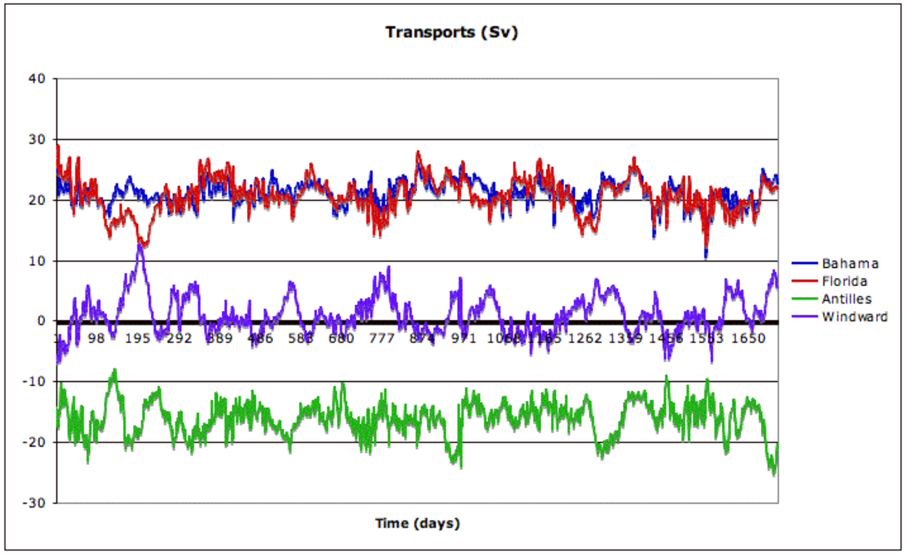
Volume Transports (Sv): Year 11

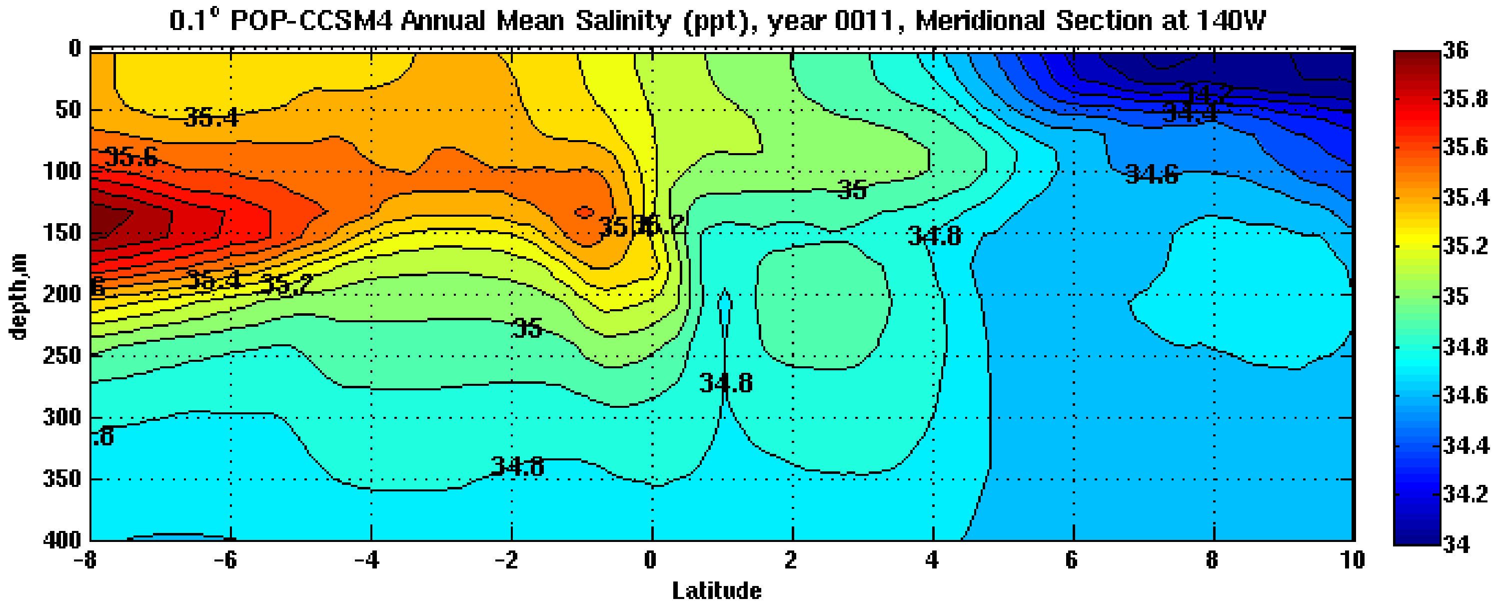




<u>Observational Estimates:</u>

- Drake Passage : ~135 Sv (Cunningham et al. 2003)
- Indonesian Throughflow: ~10 Sv (Gordon, 2005)
- Bahama- FL : ~32 Sv (Larsen, 1992)




0.1° POP-CCSM4 Annual Mean Salinity (ppt), year 0011, Meridional Section at 140W
depth,m
Latitude
0
50
100
150
200
250
300
350
400
-8
-6
-4
-2
0
2
4
6
8
10
36
35.8
35.6
35.4
35.2
35
34.8
34.6
34.4
34.2
34
35.4
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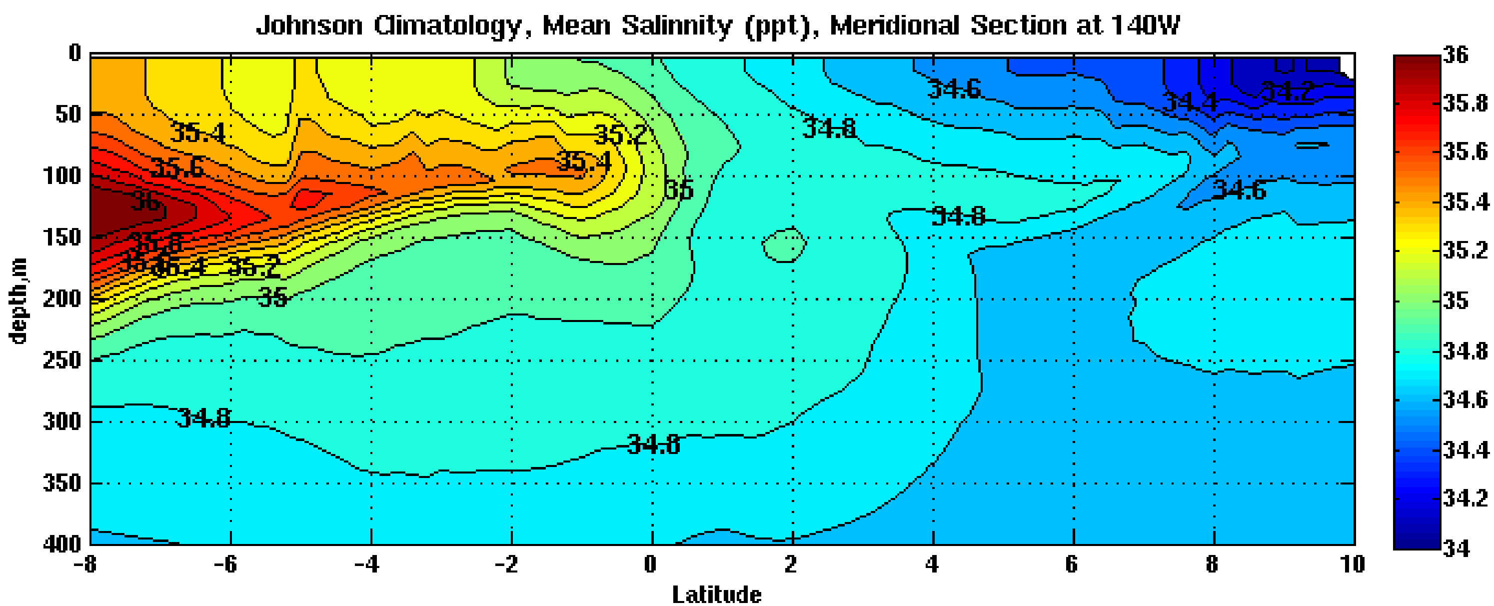
35.2
35
35
35.2
34.8
34.8
34.8
34.6
34.4
34.2


Johnson Climatology, Mean Salinnity (ppt), Meridional Section at 140W
depth,m
Latitude
0
50
100
150
200
250
300
350
400
-8
-6
-4
-2
0
2
4
6
8
10
36
35.8
35.6
35.4
35.2
35
34.8
34.6
34.4
34.2
34
35.4
35.6
36
35.8
35.4
35.2
35
35.2
35.4
35
34.8
34.6
34.8
34.4
34.2
34.6
34.8
34.8