

# **Incorporation of the HYbrid Coordinate Ocean Model (HYCOM) into the Community Climate System Model (CCSM): Evaluation and Climate Applications**

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# Overview

## Goals:

- To assess the impact of the primarily isopycnic versus depth coordinates in ocean and climate modeling;
- To use CCSM with the layered ocean model HYCOM as a research tool for climate studies.

## Status

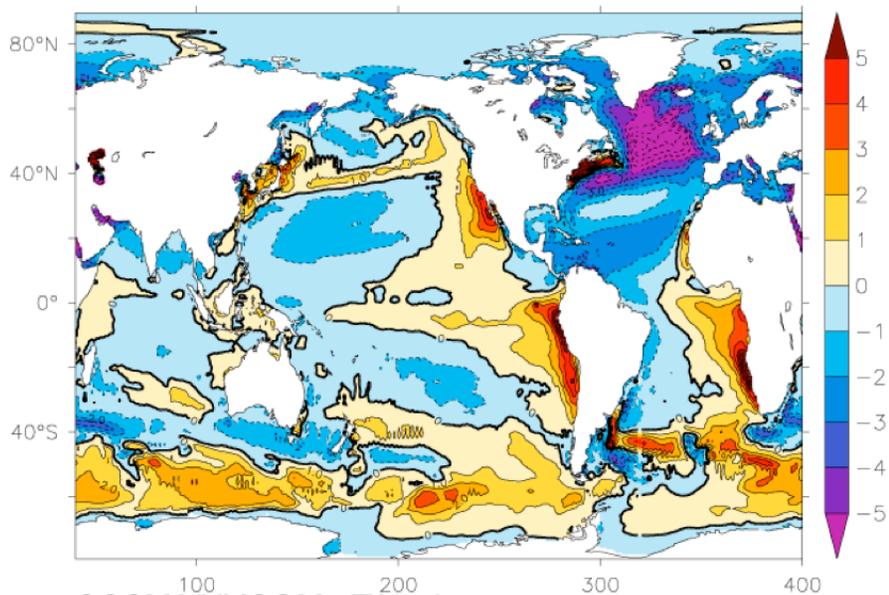
- Long-term coupled CCSM3/HYCOM (400 years for T42x1 and 300 years T85x1) simulations have been performed and a systematic study on the sensitivity of the simulation results to critical model parameters (viscosity, isopycnal and diapycnal diffusivity) have been carried out. Nearly 50 TB data have been archived and are under diagnosis.
- Study on internal climate variability in the coupled model is being performed.

# Part (I) Comparison of the mean ocean climate in CCSM3.0/HYCOM2.0 with CCSM3.0/POP and Observations

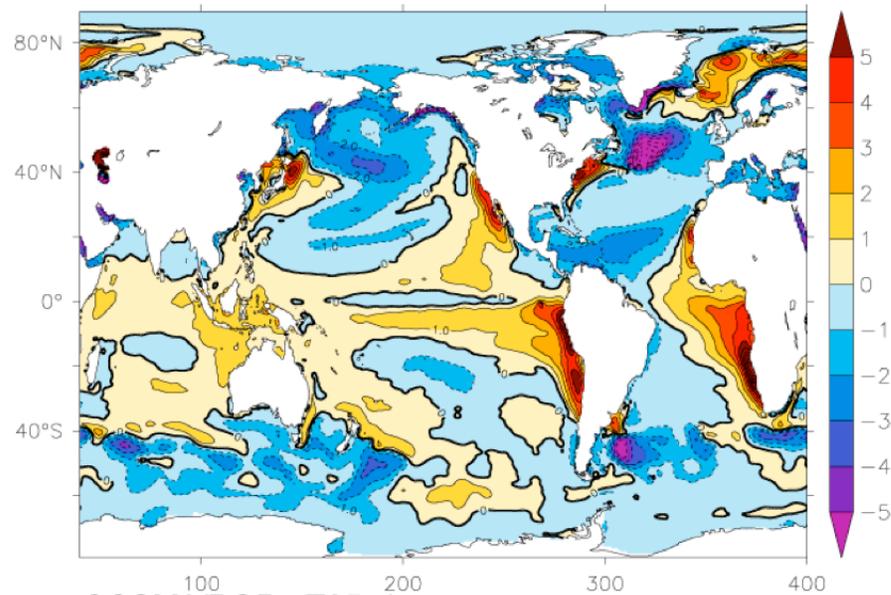
Forcing: used in standard CMIP3 present-day control experiments

# SST Biases ( $^{\circ}\text{C}$ ) (years 91-100)

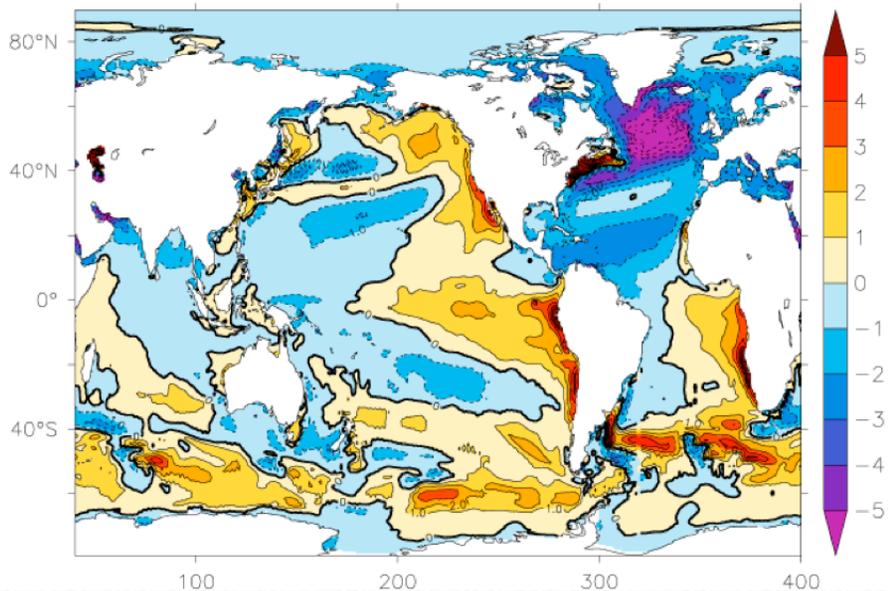
CCSM3/HYCOM T42x1



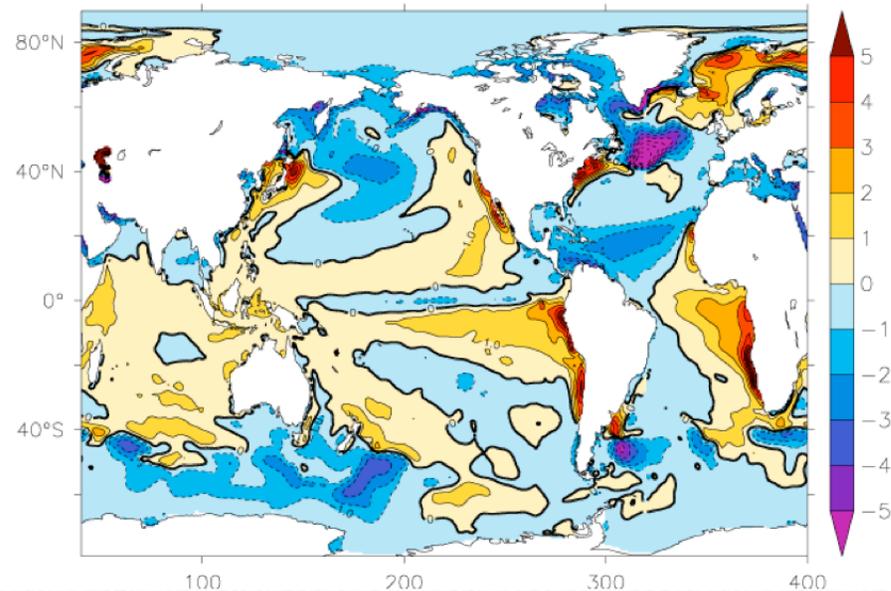
CCSM3/POP T42x1



CCSM3/HYCOM T85x1

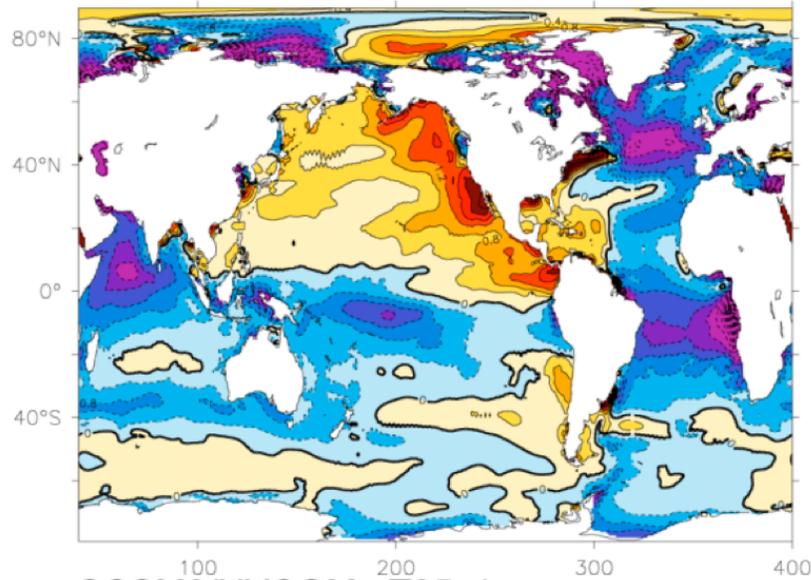


CCSM3/POP T85x1

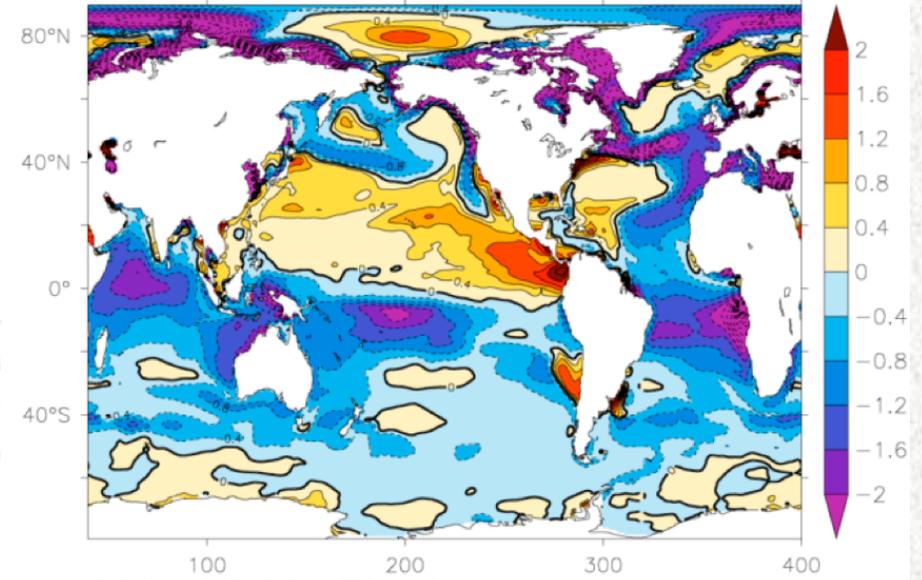


# SSS Biases (psu) (years 91-100)

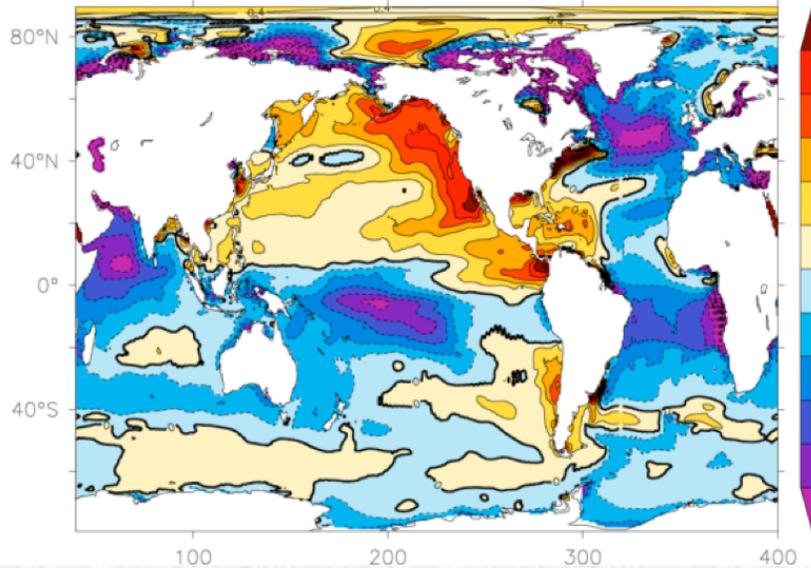
CCSM3/HYCOM T42x1



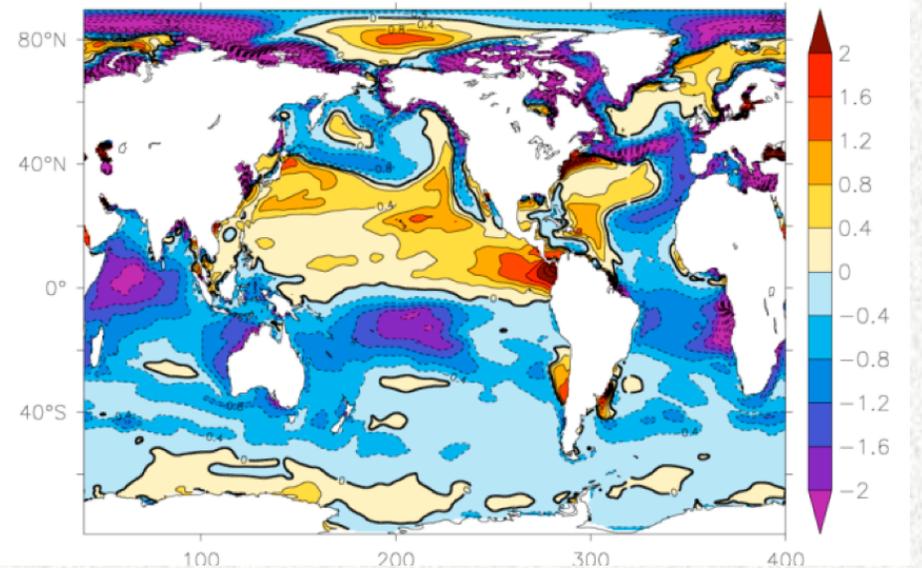
CCSM3/POP T42x1



CCSM3/HYCOM T85x1



CCSM3/POP T85x1



## About the source of Biases

Part of the similar biases appeared in both HYCOM and POP may be due to the resolution of atmospheric model as suggested by Gent et al. (2009);

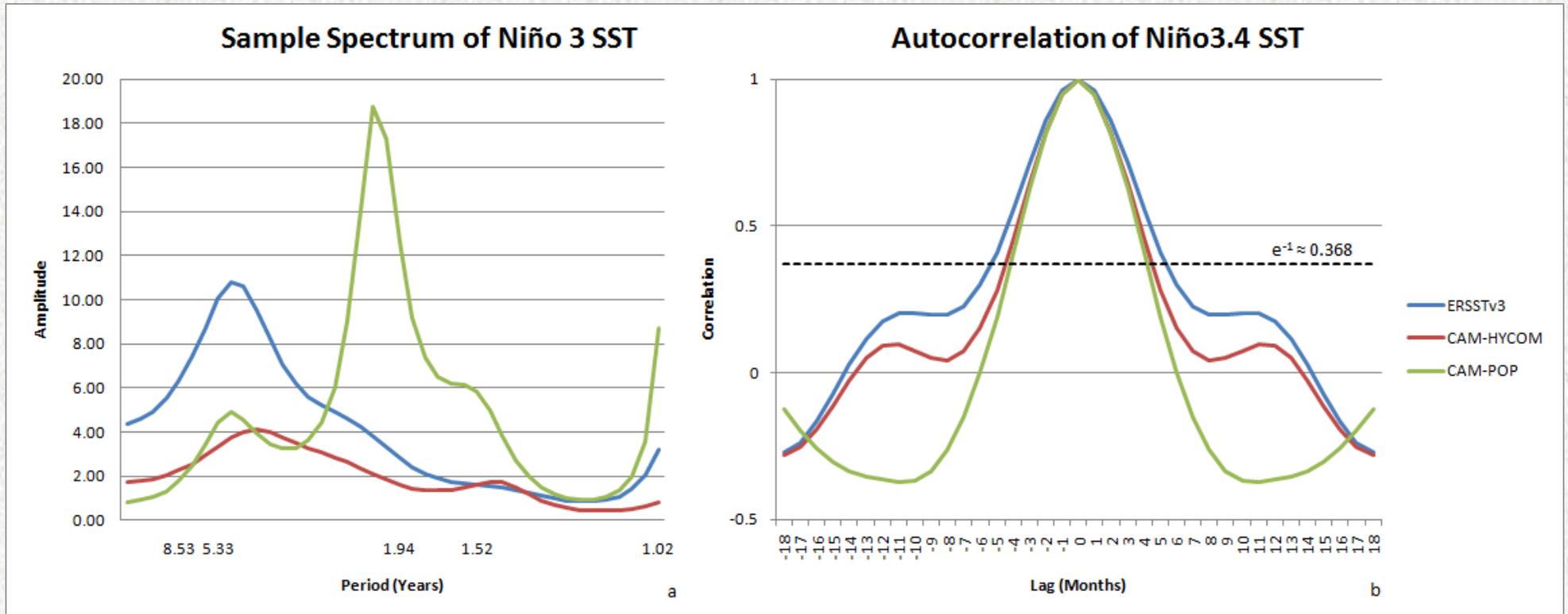
The different vertical coordinate and oceanic physical parameterizations cause the different biases in the two models, but the processes responsible for the differences are not clear yet.

# Part (II) Comparison of the main climate modes in CCSM3.0/HYCOM2.0 with CCSM3.0/POP and Observations

(1) Compare the possible differences in the internal variability;

(2) Use the climate-mode diagnosis as a tool in model development to understand the source of model biases and further improve model configuration.

# No biennial peak for the ENSO simulation in CCSM3.0/ HYCOM2.2

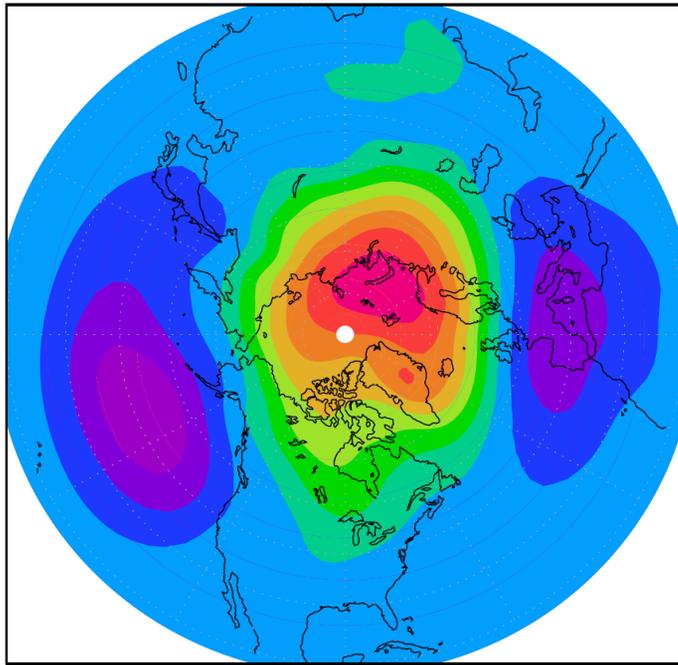


Courtesy of J.P. Michael; Michael *et al.* (2011) to be submitted

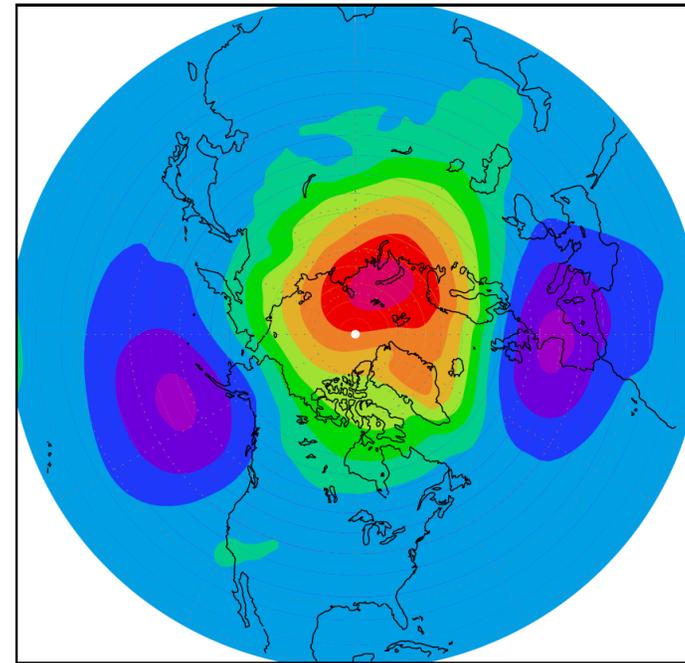
The change in ocean component alone in the CCSM3 may make the biennial peak disappeared.

# Northern Annular Mode (NAM)

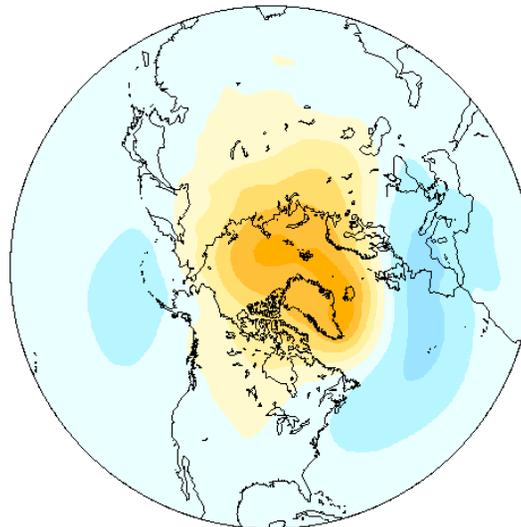
NAM (CCSM3.0/HYCOM2.2)



NAM (CCSM3.0/POP)



Northern Annular Mode

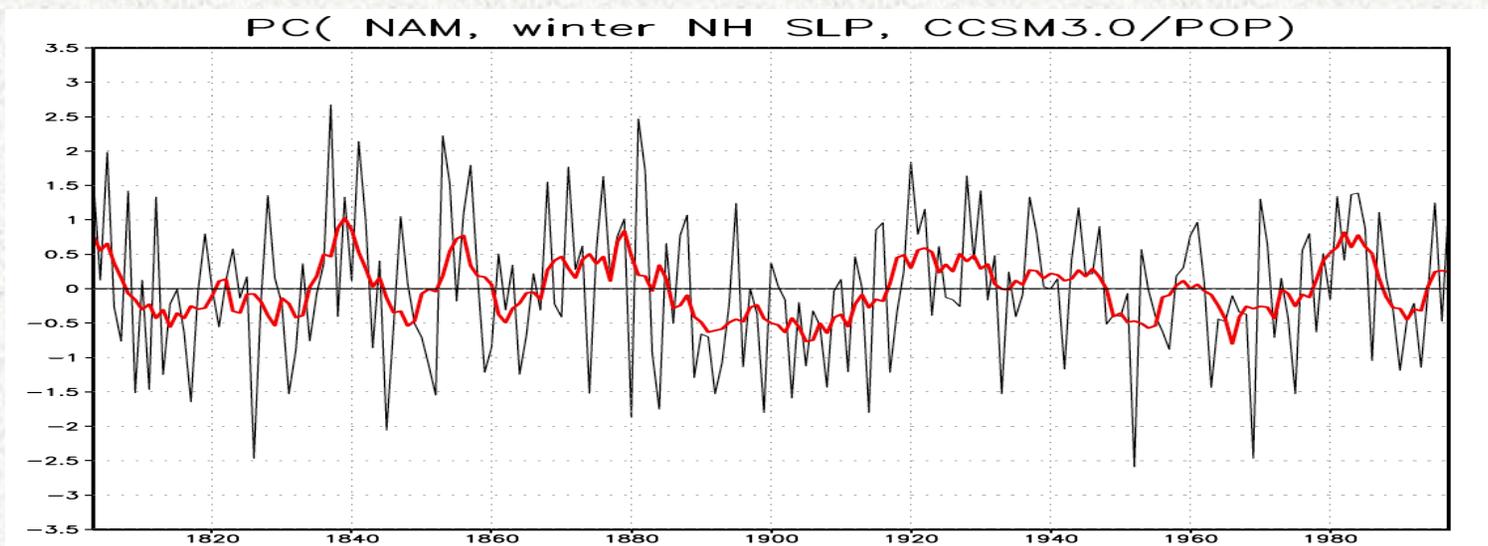
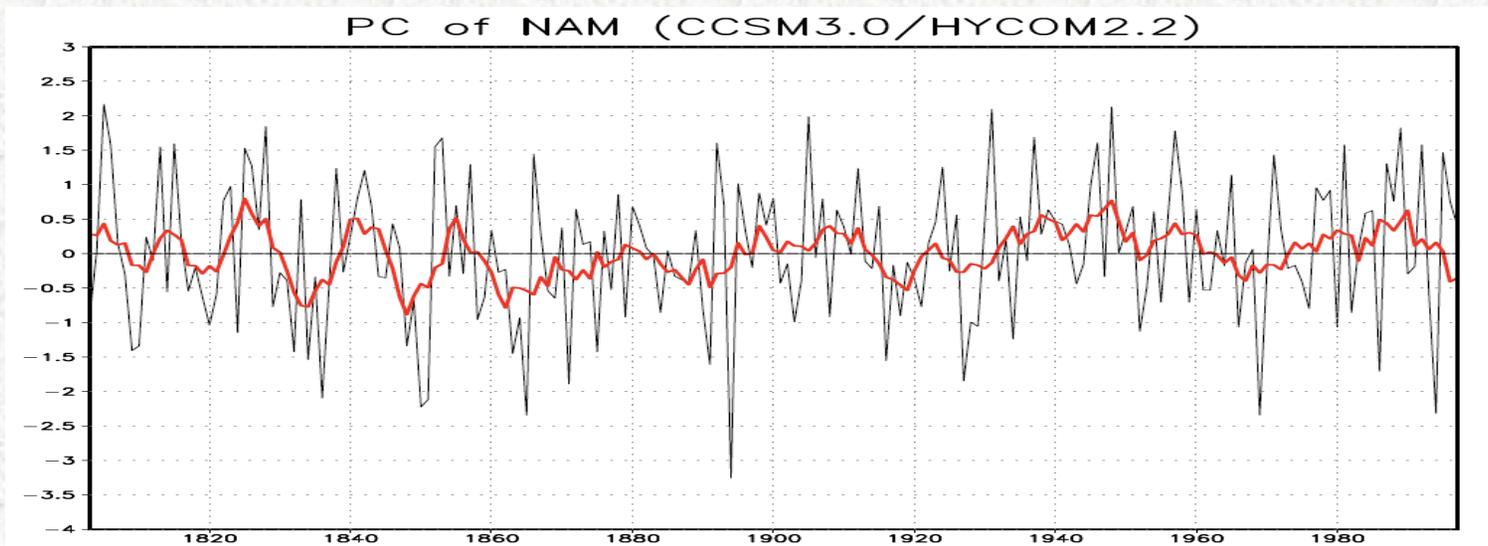


The Pacific component of the NAM in both models is stronger than in observation

The biases in the spatial pattern of NAM may be important to the bias in SST and SSS biases in N. Pacific and N. Atlantic

<http://jisao.washington.edu/analyses0302/nam.gif>

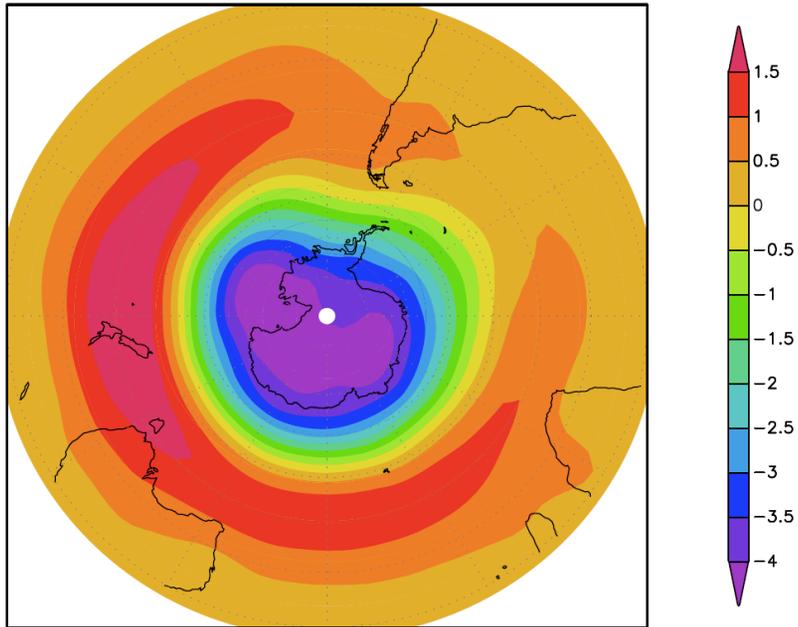
# Time Series of NAM in models



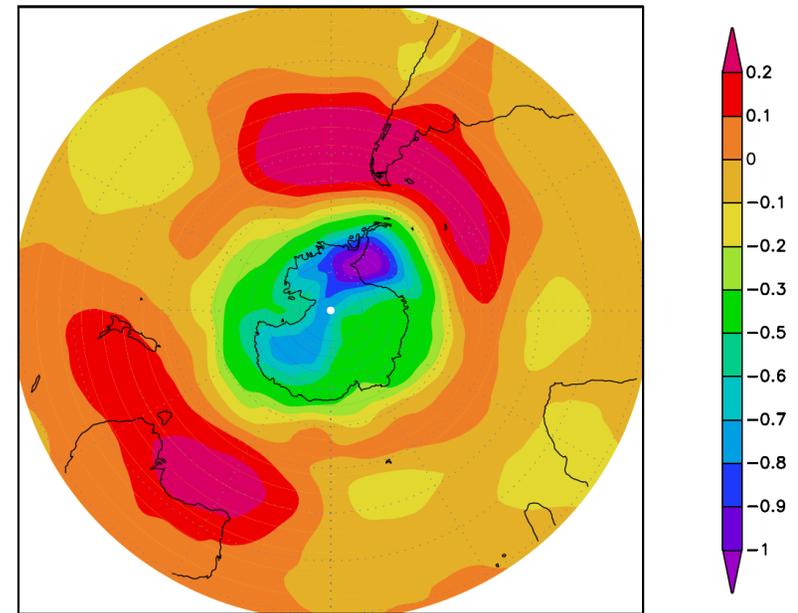
Note: Years ( X- axis) are “virtual” numbers for the 200 simulation- years , not actual 1801-1999.

# Southern Annular Mode (SAM)

SAM (CCSM3.0/HYCOM2.2)

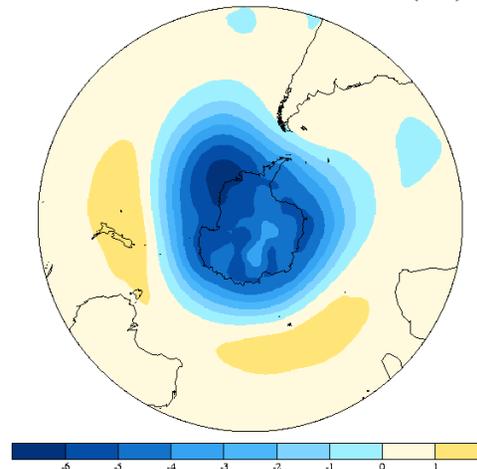


SAM (CCSM3.0/POP)



The strength and spatial structure of SAM in CCSM3.0/HYCOM2.2 are closer to the observation than that in CCSM3.0/POP.

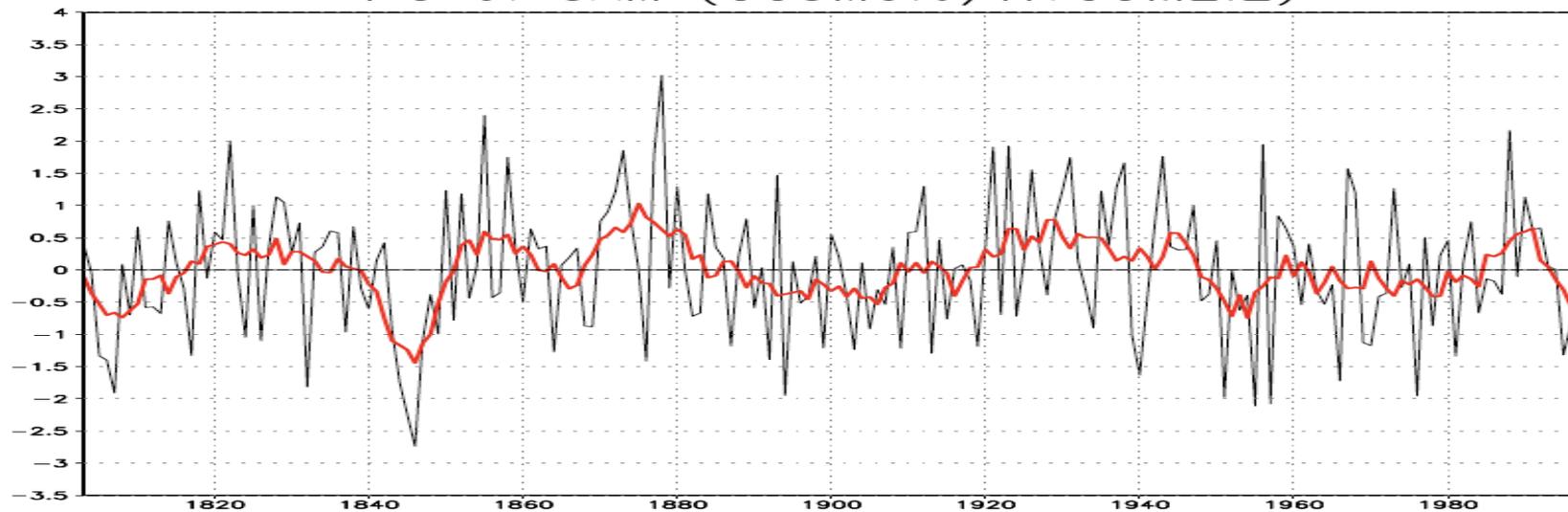
SLP-based Antarctic Oscillation (mb)



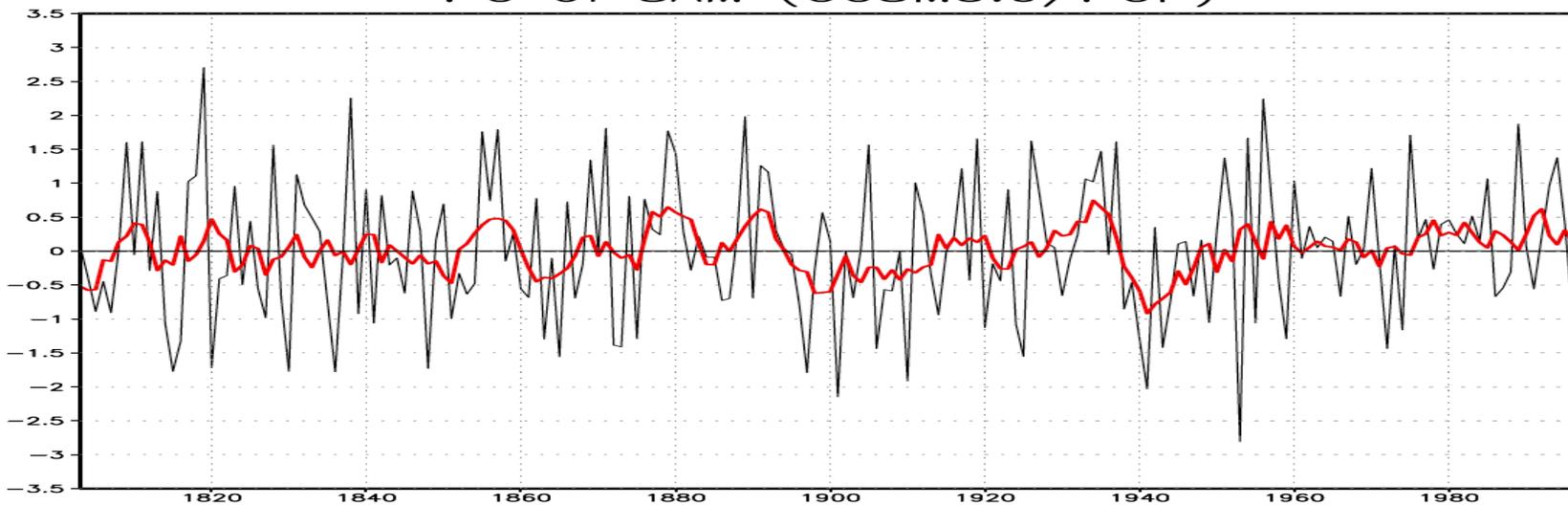
Note the location of the main centers of SAM in CCSM3/POP

# Time Series of SAM in models

PC of SAM (CCSM3.0/HYCOM2.2)



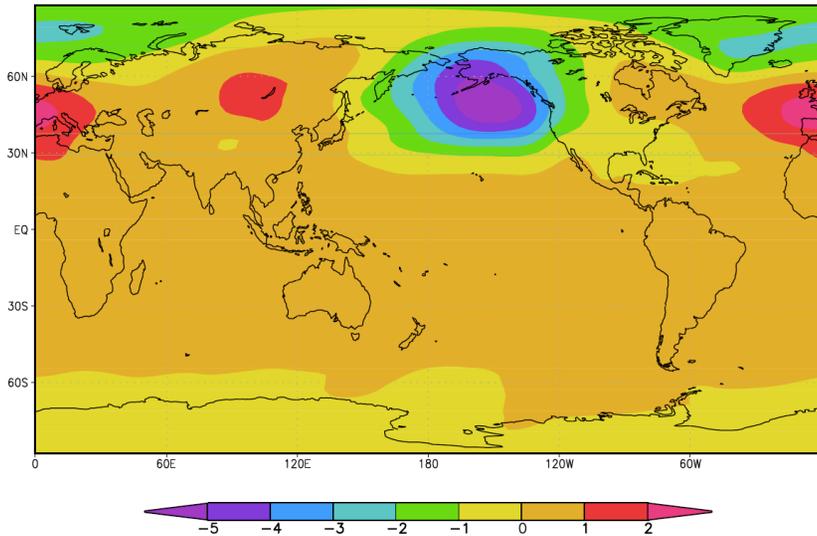
PC of SAM (CCSM3.0/POP)



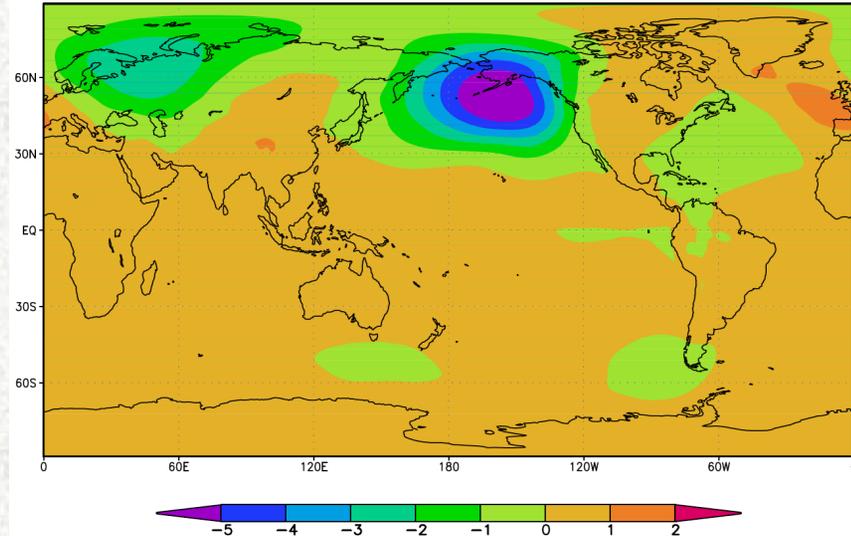
Longer period in CCSM3.0/HYCOM2.2 for inter-decadal variability of SAM

# PNA in N.H. Sea Level Pressure (SLP)

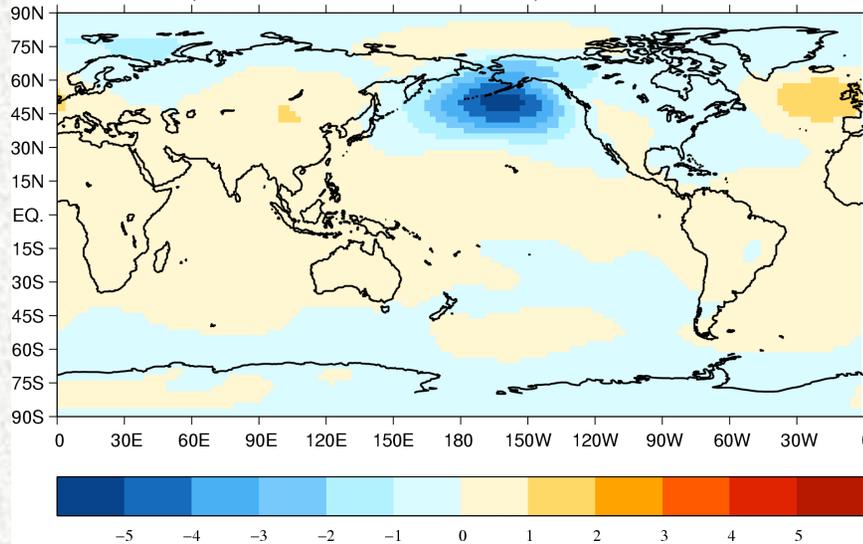
PNA (EOF2 NH-SLP, CCSM3.0/HYCOM2.2)



PNA (EOF2, NH-SLP, CCSM3.0/POP)



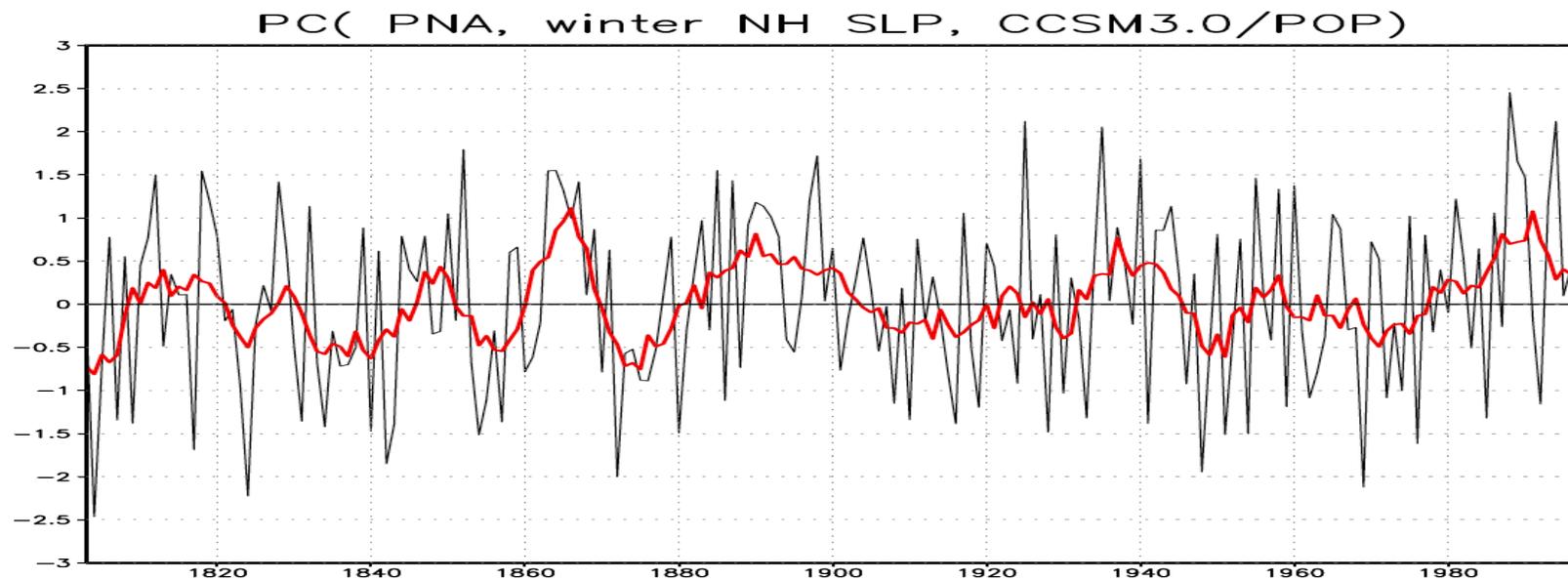
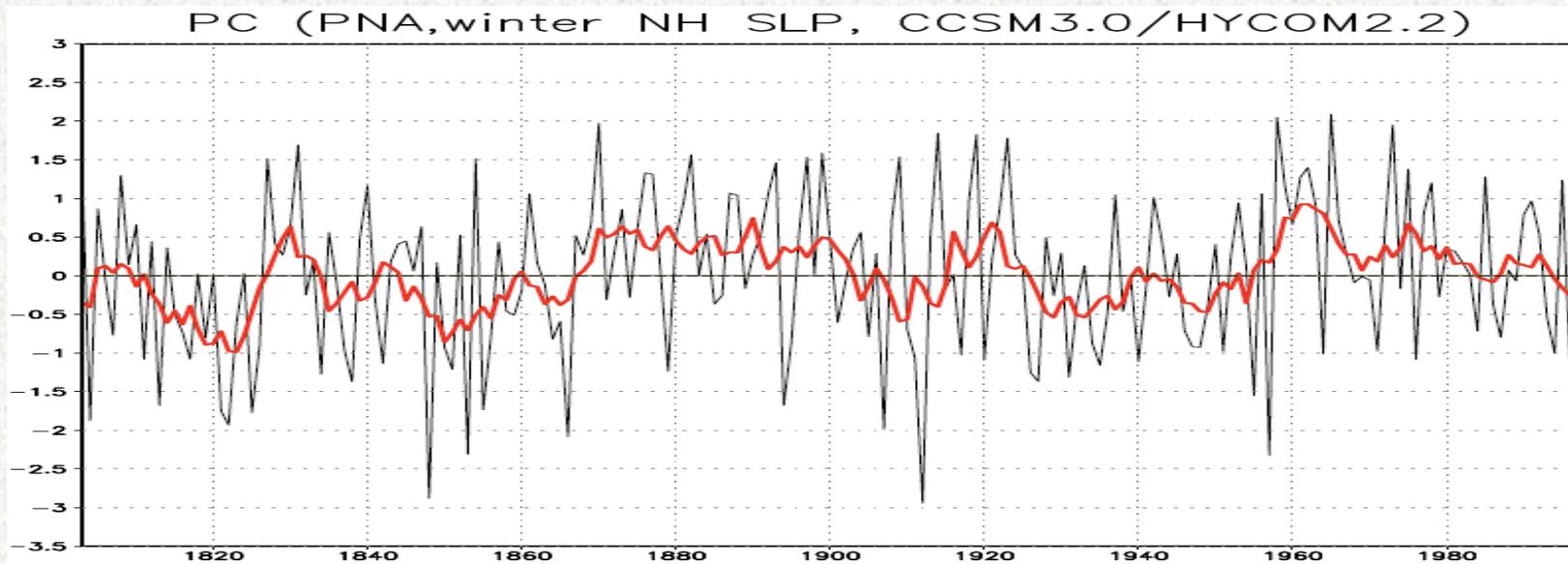
PNA (EOF2 NH SLP anomalies) 1948 – March 2010



10.3% of the variance.  
Plotted as regression coefficients, with units of mb.

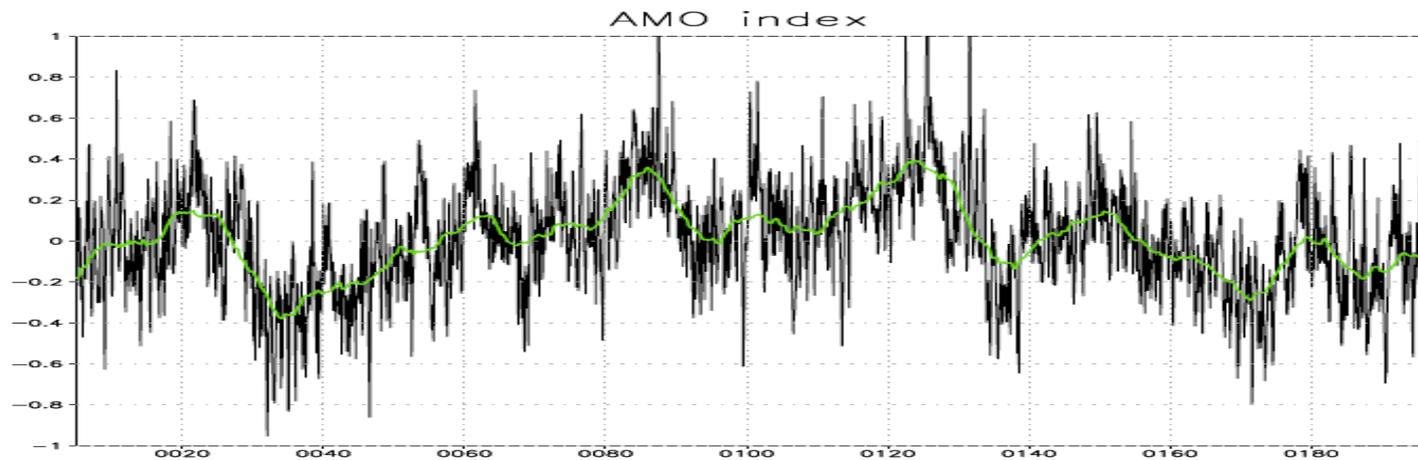
The North Pacific center of the PNA pattern similar in both models, but the North America and Atlantic part in CCSM3.0/HYCOM2.2 closer to the observation.

# Time Series of PNA in models



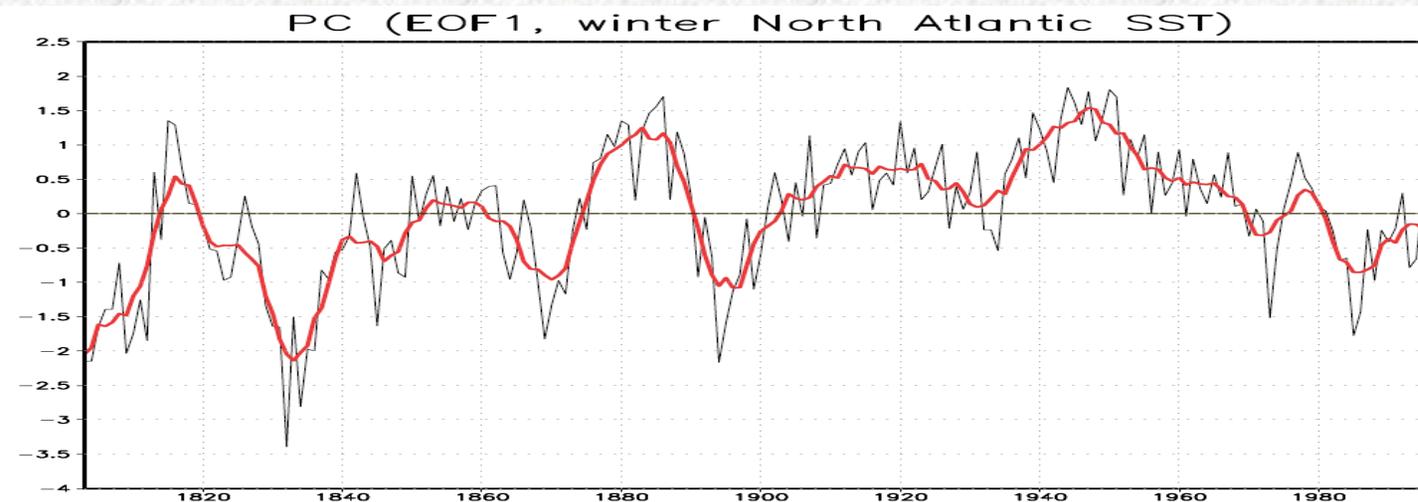
Slightly longer period in CCSM3.0/HYCOM2.2 for inter-decadal variability of PNA

# Variability of N. Atl. SST in CCSM3/HYCOM2.2

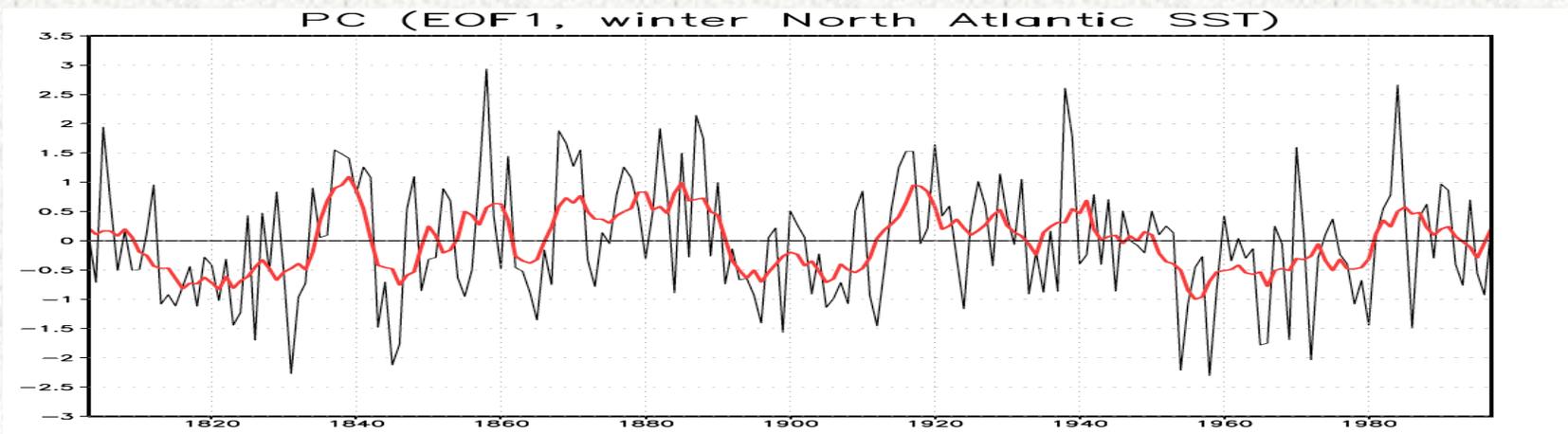
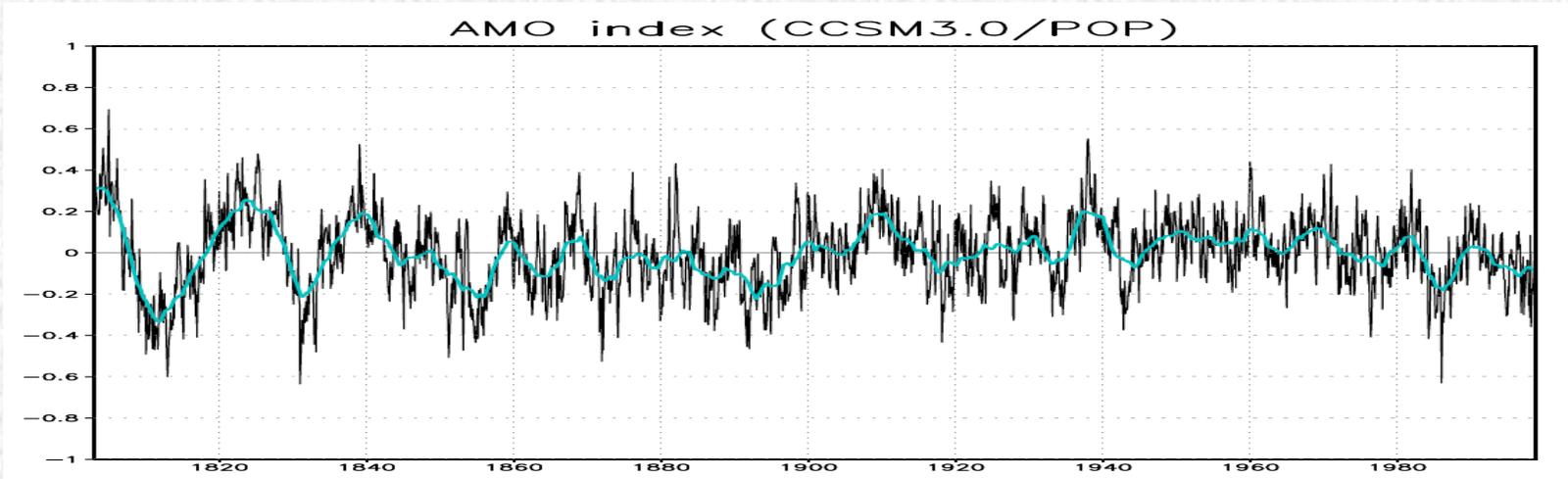


Larger interdecadal variability for AMO and North Atlantic SST in CCSM3.0/HYCOM2.0;

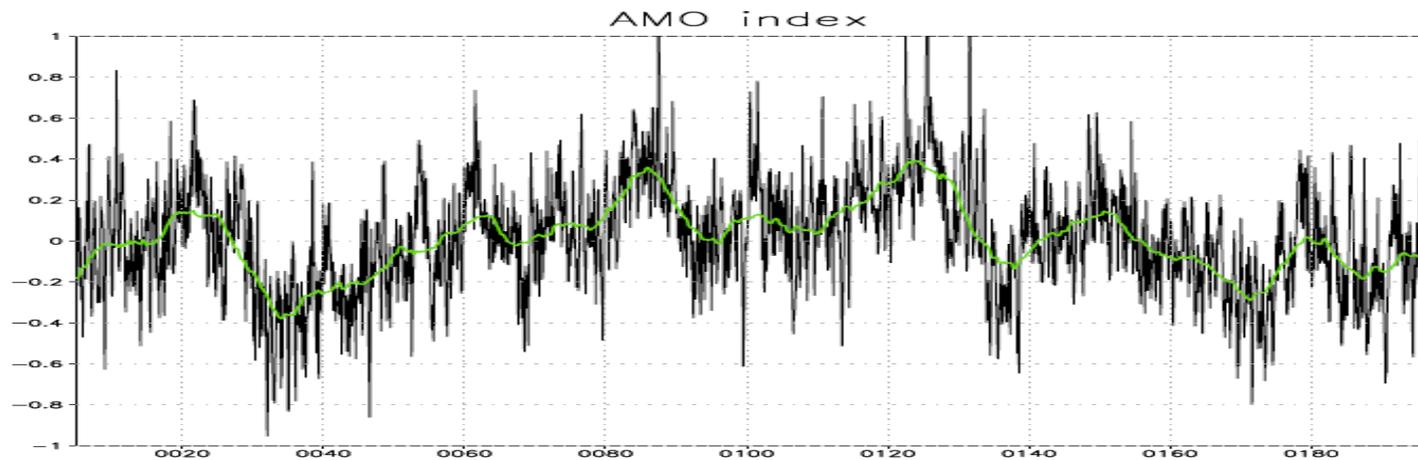
Similar time-scale for interdecadal variability.



# Variability of N. Atl. SST in CCSM3/POP

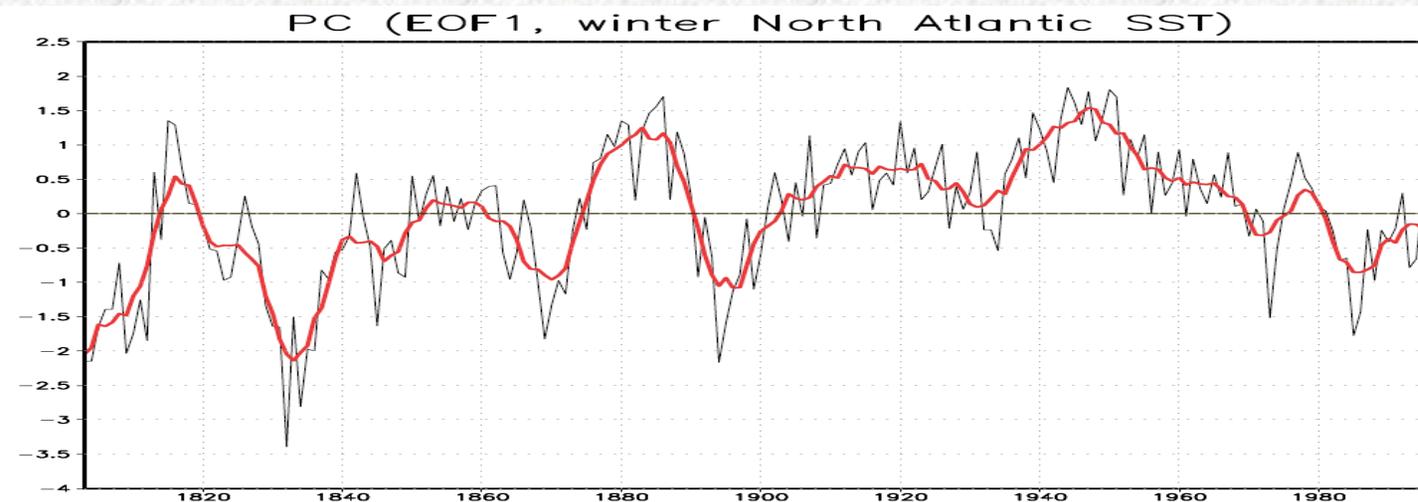


# Variability of N. Atl. SST in CCSM3/HYCOM2.2



Larger interdecadal variability for AMO and North Atlantic SST in CCSM3.0/HYCOM2.0;

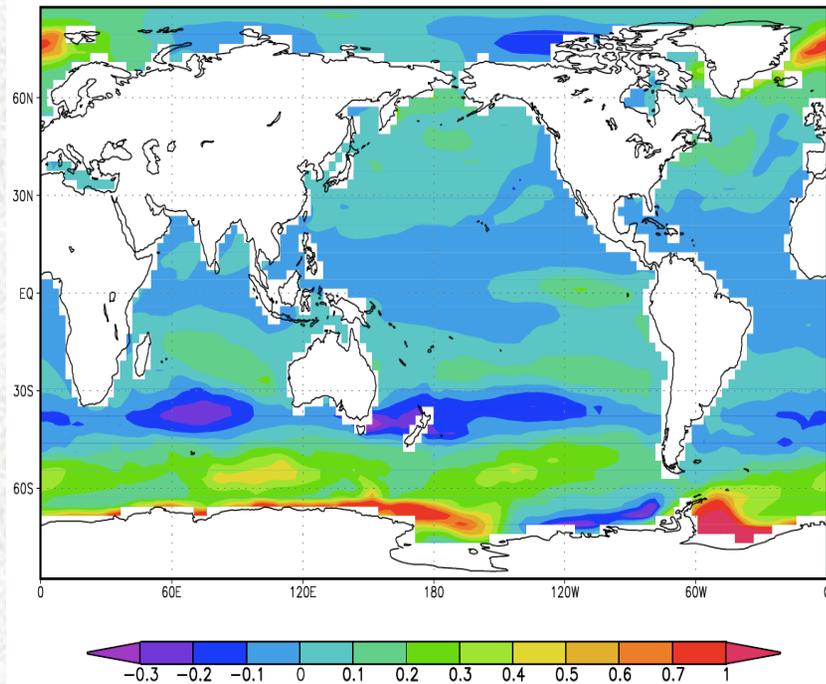
Similar time-scale for interdecadal variability.



# EOF1 of the Southern Ocean SST

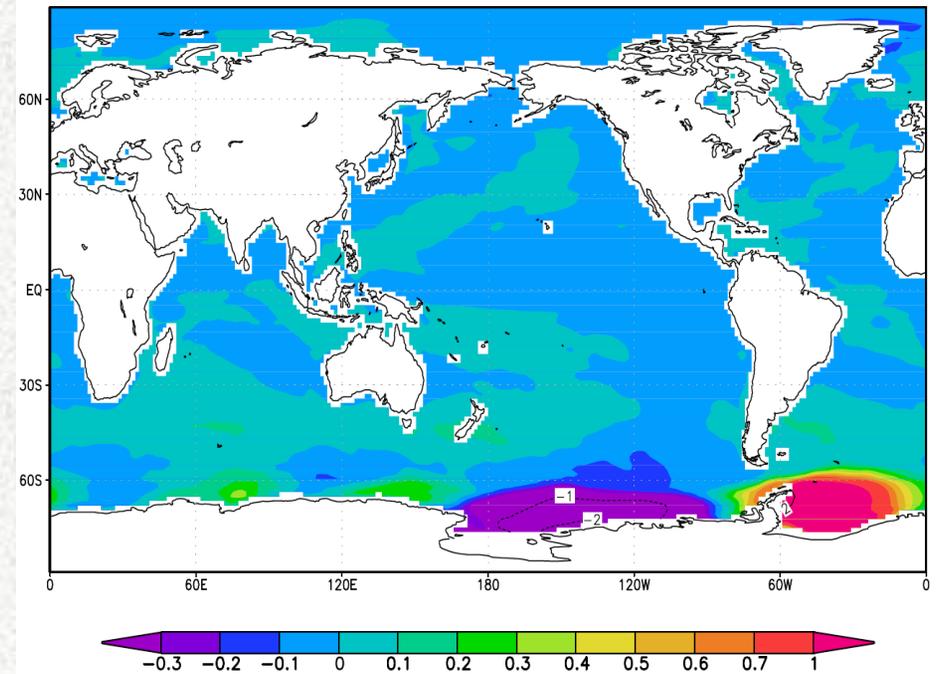
CCSM3.0/HYCOM2.2

EOF1 of monthly Southern Ocean SST



CCSM3.0/POP

EOF1 (Monthly Southern Ocean SST, CCSM3.0/POP)

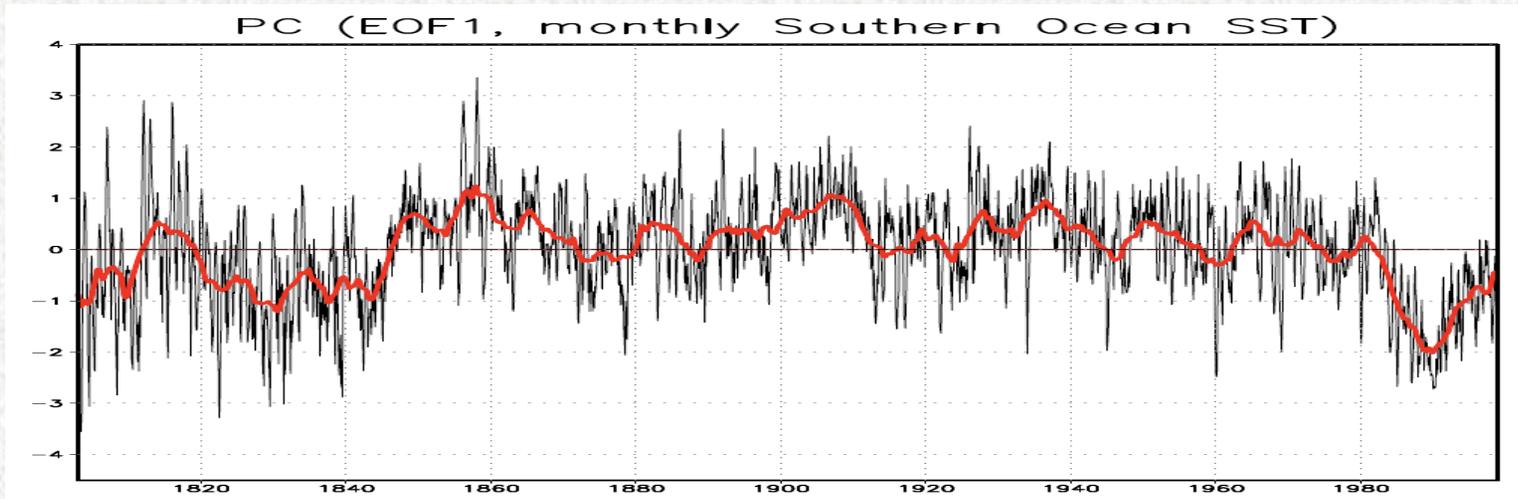


More annular component;  
Meridional seesaw between mid-latitude SST and high-latitude SST

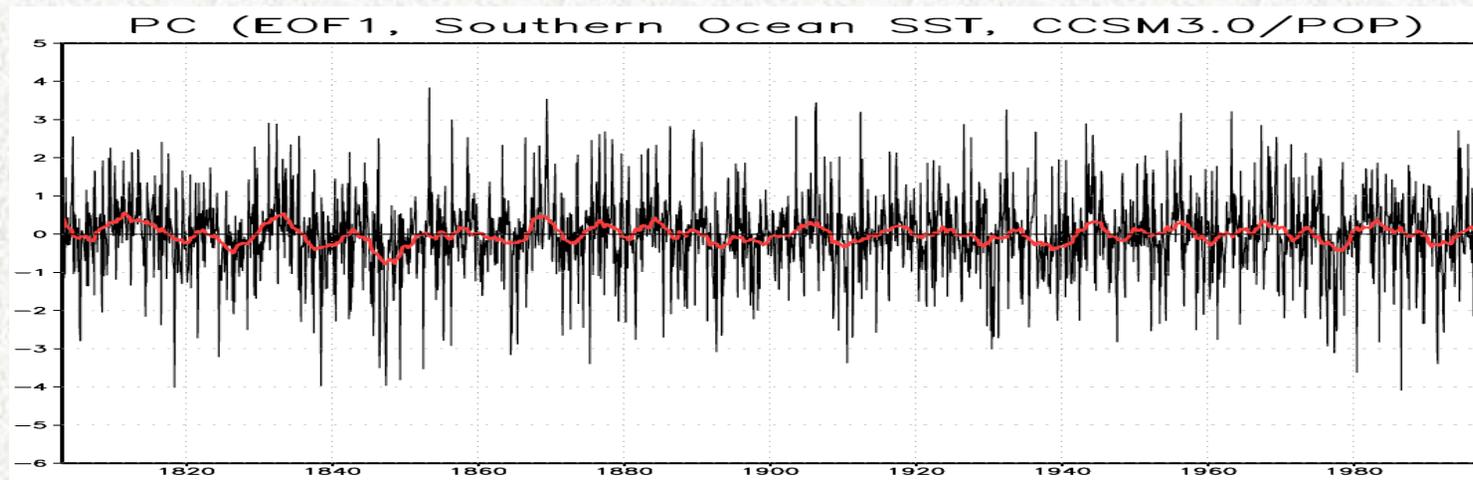
Zonal seesaw between SSTs in Ross Sea and Weddell Sea

# Time Series of EOF1 of the Southern Ocean SST in CCSM3/HYCOM2.2 and CCSM3/POP

CCSM3.0/HYCOM2.2



interdecadal variability more salient in CCSM3.0/HYCOM than in CCSM3.0/POP



CCSM3.0/POP

## Summaries for Part (II): CCSM3/HYCOM vs CCSM3/POP: Climate Variability

With the same configurations for atmospheric, land, sea-ice models, the simulations with CCSM3/HYCOM and CCSM3/POP show important differences in main internal climate modes and their variability:

- (1) the biennial peak disappeared for the ENSO simulation in CCSM3/HYCOM;*
- (2) longer period for the interdecadal variability of NAM and PNA in CCSM3/HYCOM;*
- (3) Stronger and a pattern closer to the observation for SAM in CCSM3/HYCOM;*
- (4) larger interdecadal variability in AMO and the North Atlantic SST in CCSM3/HYCOM;*
- (5) different structures in the Southern Ocean SST variability in two ocean components in a same coupled climate model configuration.*

The inclusion of a different ocean component in a same CESM framework may help to reduce the uncertainties in decadal climate prediction.

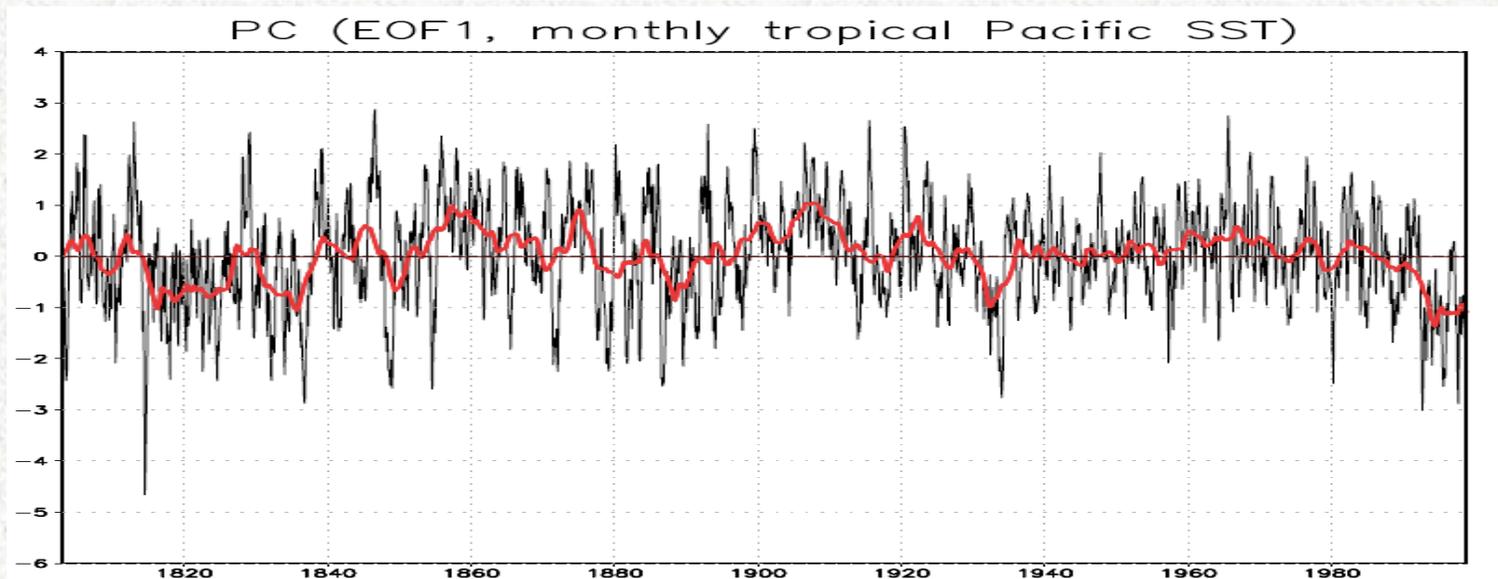
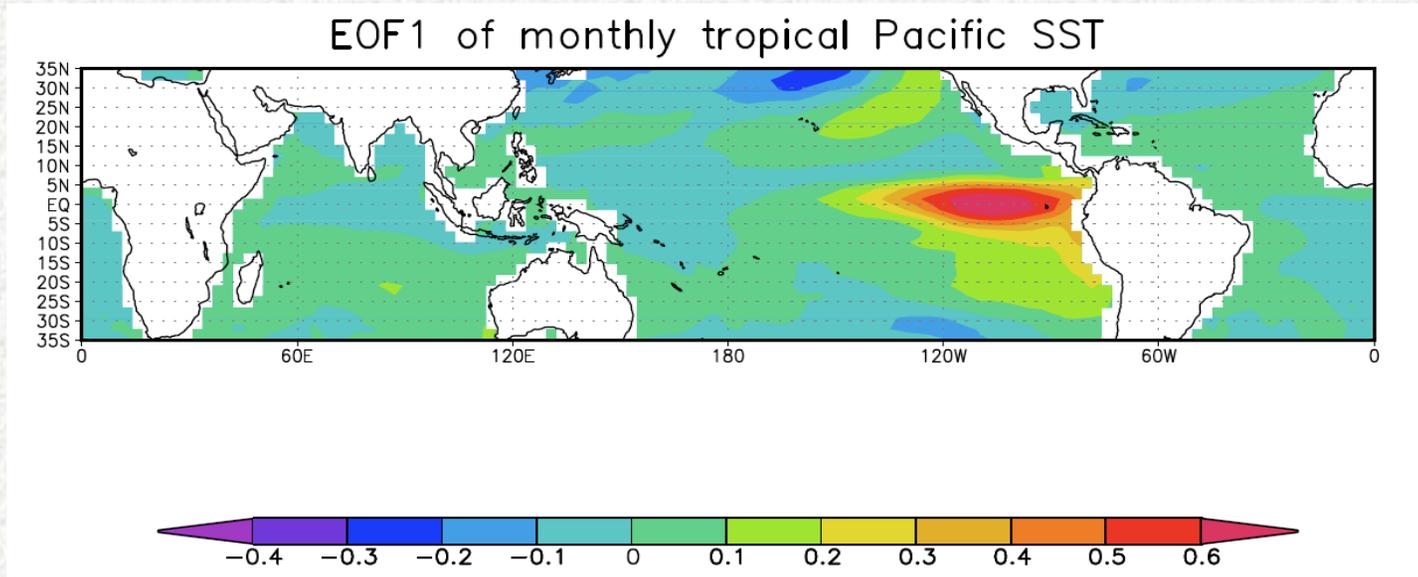
# Summaries (*cont.*)

(2) The climate-mode diagnosis as a tool in model development is useful to (1) understand the source for model biases and further improve model configuration; (2) provide a possible two-way linkage among the theoretical understanding (eddy-mean flow interaction, tele-connections, etc.), model algorithm and parameterizations, and the diagnosis of model output, and therefore help to develop a model hierarchy.

# Acknowledgements

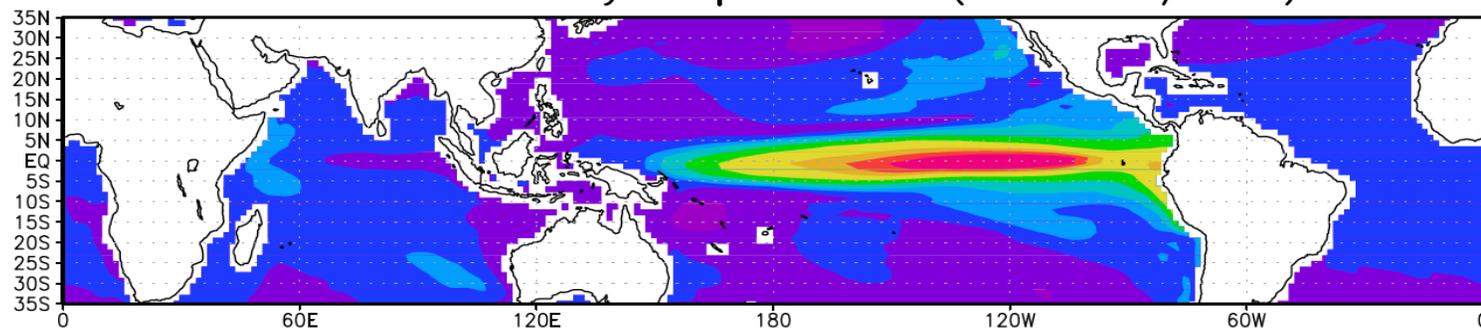
- DOE Grant DE-FG02-07ER64470 “Incorporation of the HYbrid Coordinate Ocean Model (HYCOM) into the Community Climate System Model (CCSM): Evaluation and Climate Applications”;
- NCAR’s ocean working group.

# EOF1 of tropical SST (CCSM3.0/HYCOM2.2)

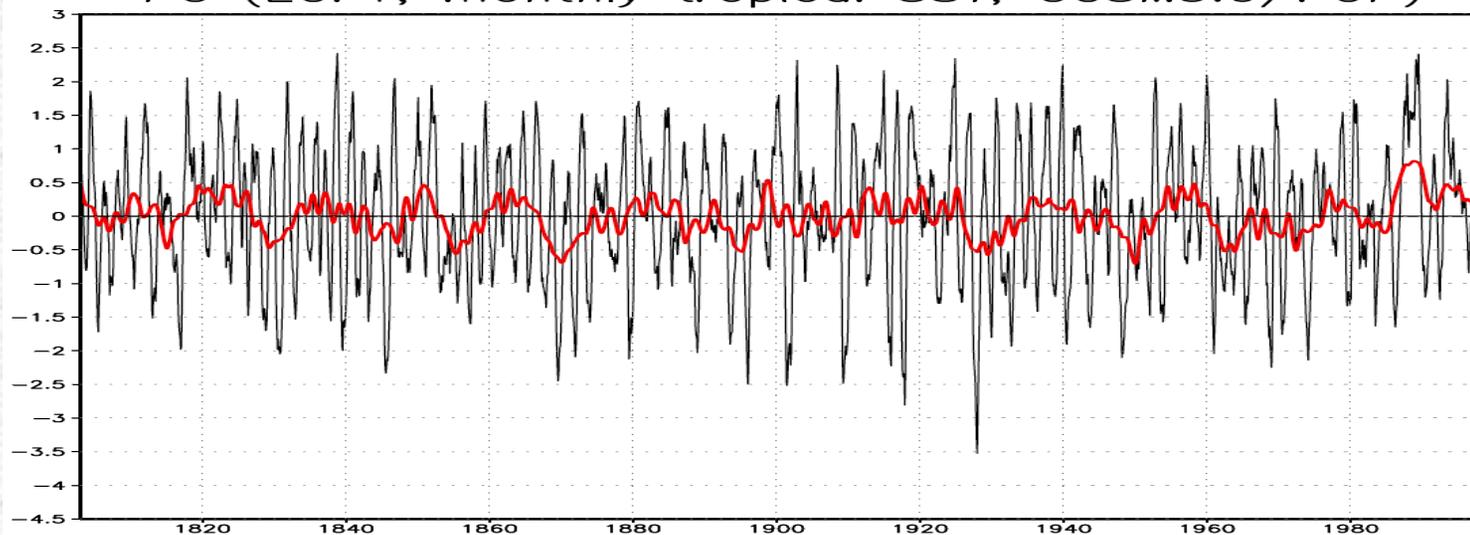


# EOF1 of tropical SST (CCSM3.0/POP)

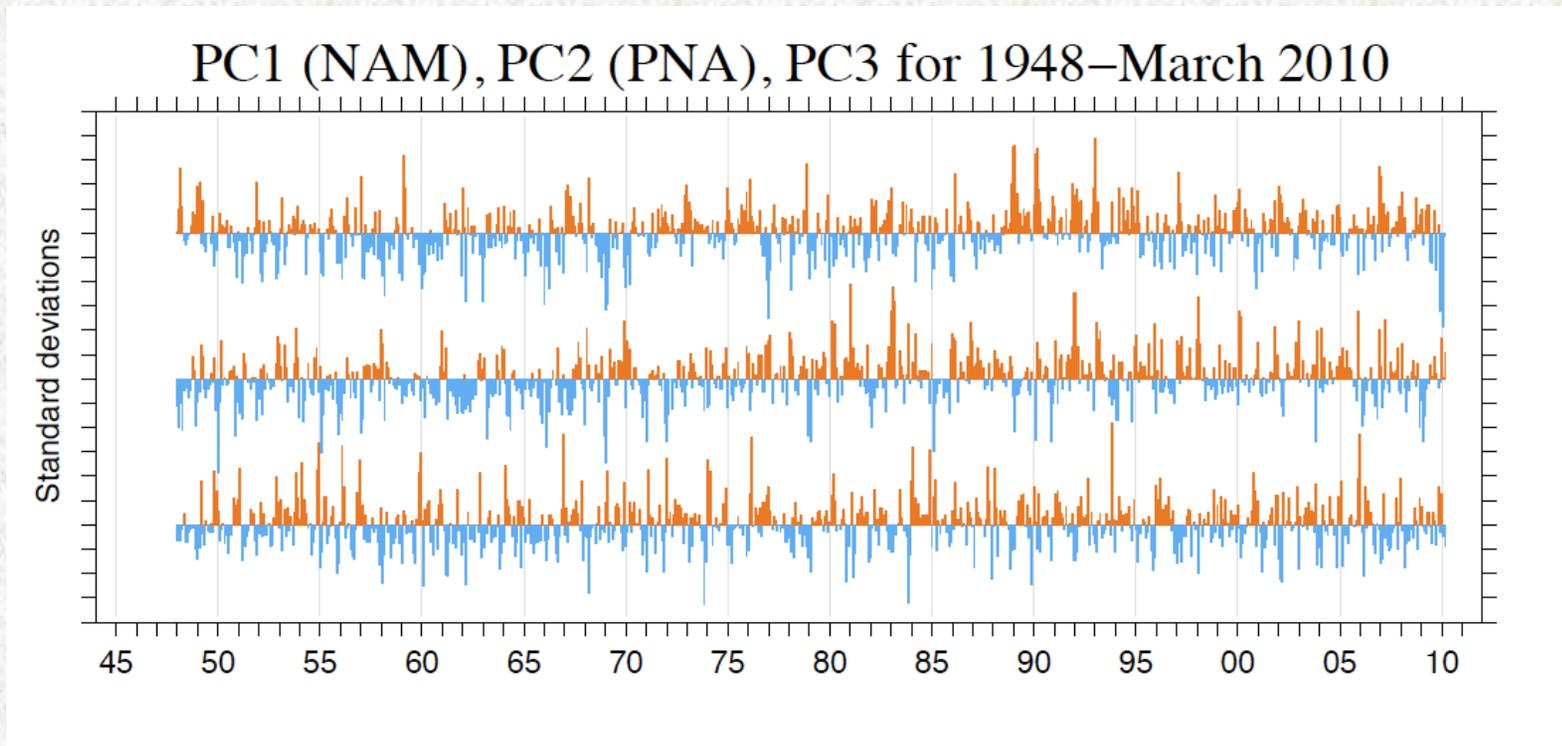
EOF1 of monthly tropical SST (CCSM3.0/POP)



PC (EOF1, monthly tropical SST, CCSM3.0/POP)



# Time Series of NAM, PNA, SAM in observations



<http://jisao.washington.edu/analyses0302/slpanompc.pdf>