Evaluation of the Short-Term Climate Variability in GEOS-5 AOGCM Simulations

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1. Introduction

The GEOS-5 Atmosphere-Ocean General Circulation Model (AOGCM) has been developed for subseasonal-to-decadal climate prediction studies. Its main components are the GEOS-5 atmospheric model, the catchment land surface model, and MOM4, the ocean model developed by the Geophysical Fluid Dynamics Laboratory. The ocean and atmosphere exchange fluxes of momentum, heat and fresh water through a "skin layer" interface that includes parameterization of the diurnal cycle and a sea ice model, LANL CICE (fig. 1). All components are coupled together using the Earth System Modeling Framework (ESMF). The model has been tested in coupled simulations and data assimilation mode and is able to produce a stable, realistic mean climate and inter-annual climate variability. An evaluation of the model performance in climate simulations is presented below.

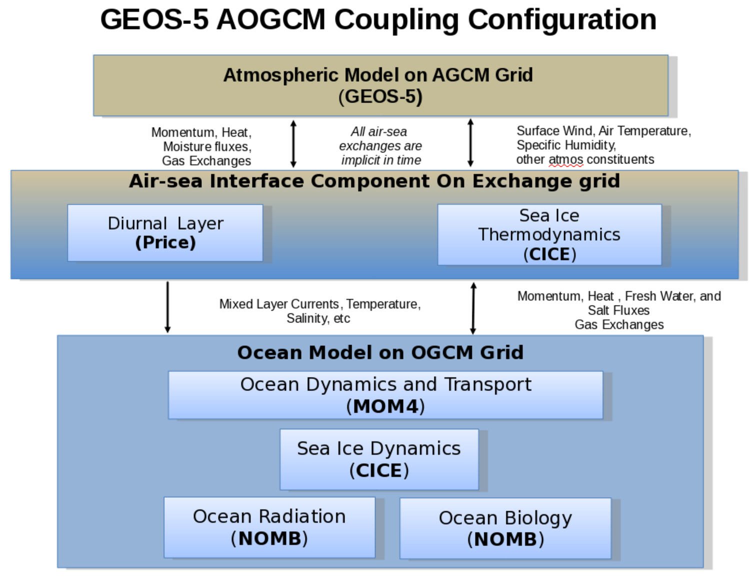

Figure 1: *GEOS-5 AOGCM coupling configuration.*

2. Experiment design

To assess the performance of the GEOS-5 AOGCM, a coupled simulation of 90 years' duration was analyzed. The configuration of the validation simulation is as follows:

- AGCM 2.5^0 horizontal resolution with 72 vertical levels up to 0.01hPa;
- OGCM 1^0 horizontal resolution, with meridional refinement to $1/3^0$ in the equatorial region, and with 50 vertical levels;
- AGCM component is initialized from an AMIP run;
- OGCM initial conditions are taken from a test run initialized with observed temperature and salinity, and spun up for 50 years;
- perpetual 1950 boundary conditions.

3. Mean climate

3.1 Comparison with AMIP simulations

The atmospheric climate performance in the coupled model is compared with that from AMIP simulations to isolate coupling issues. Both are compared with GMAO's atmospheric reanalysis for the satellite era - the Modern-Era Retrospective analysis for Research and Applications (MERRA)

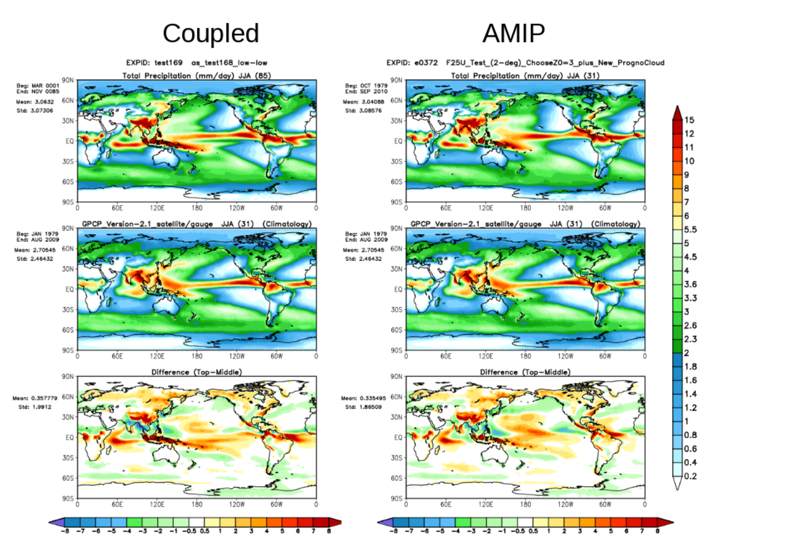

Figure 2: *JJA precipitation from coupled (left column) and AMIP (right column) simulations. The top row shows the GEOS-5 simulation, the middle row shows the climatology from MERRA, and the bottom row shows the difference between the top and middle plots.*

The mean atmospheric climate simulated by the AOGCM is similar to that simulated by the GEOS-5 AGCM forced by the observed SST. As an example, figure 2 shows comparison of the JJA precipitation climatology in coupled and AMIP simulations.

3.2 Surface climatology

The surface climate reaches equilibrium in several decades. Figure 3 shows the model SST and SSS, along with the difference from observations. The dominant errors shown in figure 3 are typical for current climate models.

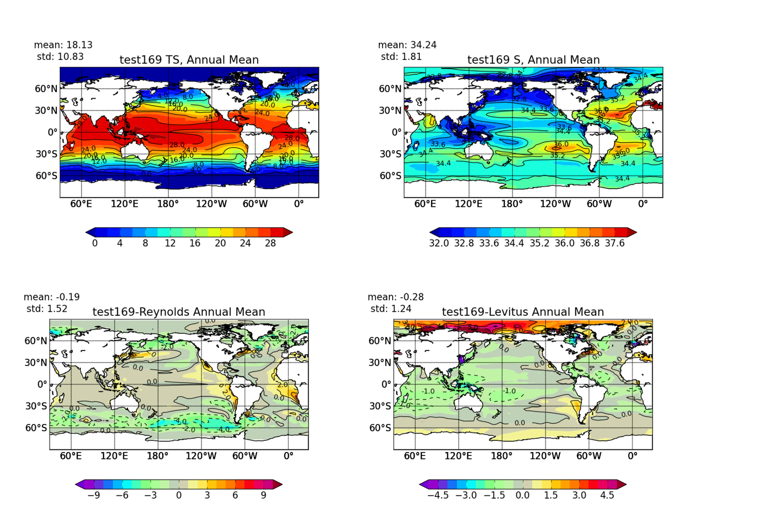

Figure 3: *SST (top-left) and SSS (top-right) from the GEOS-5 AOGCM, and the difference from Reynolds SST (bottom-left) and Levitus SSS (bottom-right) climatologies.*

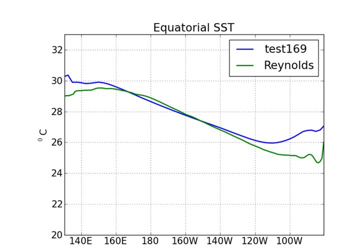

Figure 4: *Annual Mean Equatorial SST from GEOS-5 and Reynolds.*

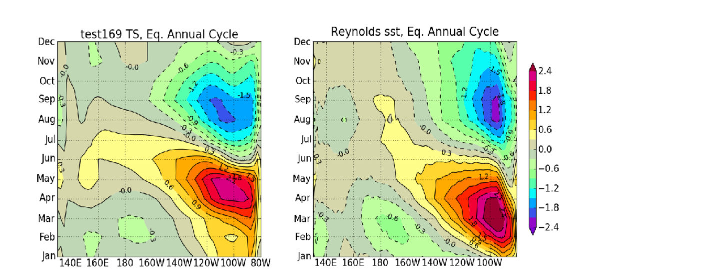

Figure 5: *Equatorial annual cycle of SST from the GEOS-5 AOGCM (left) and Reynolds (right) with the annual mean removed.*

Figures 4 and 5 show the Pacific equatorial profiles of SST from the validation run and Reynolds. The warm bias in the eastern equatorial Pacific and phase shift in the annual cycle of equatorial SST are typical for current coupled models.

4. Climate variability

To assess the ability of the GEOS-5 AOGCM to predict climate on seasonal and decadal time scales, short term variability in validation run was analyzed. In addition to observed climatologies, a comparison is made with MERRA.

4.1 El-Niño Southern Oscillation

ENSO variability is examined using the leading EOF mode of the global SST.

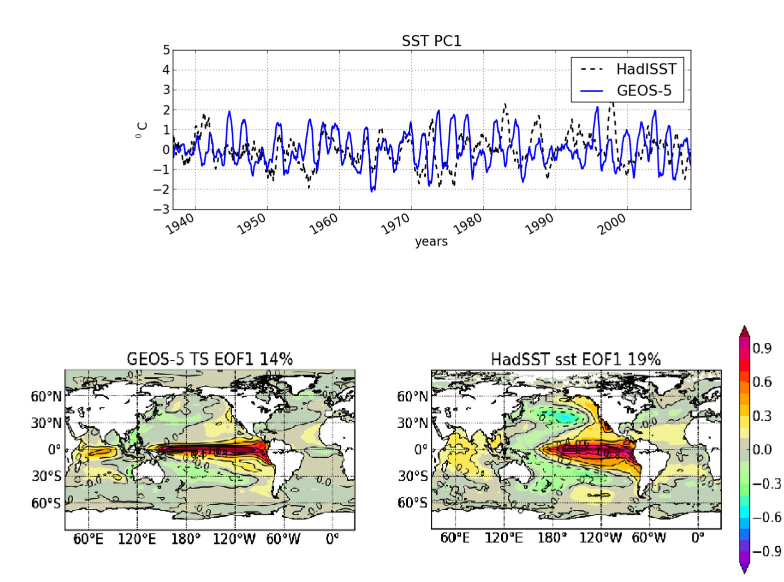

Figure 6: *Top: the leading principal components of the global SST from GEOS-5 and the Hadley Centre data set. Bottom: the leading EOF patterns for GEOS-5 SST (left) and HadSST (right).*

The model produces a prominent ENSO signal with higher frequency and narrower pattern extended further into the western Pacific compared to observed ENSO (fig. 6).

4.2 Pacific North American teleconnection

The PNA index is defined as Z500(20^0N,160^0W)-Z500(45^0N,165^0W)+ Z500(55^0N,115^0W)- Z500(30^0N,-85^0W), where Z500 is 500mbar geopotential height anomaly.

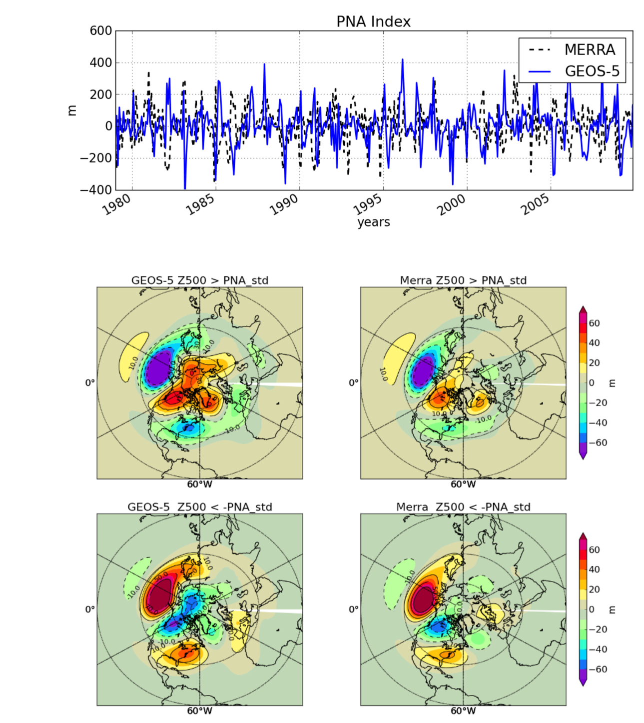

Figure 7: *Top: the PNA indexes from GEOS-5 and MERRA. Middle and bottom: composites of the GEOS-5 (left) and MERRA (right) 500mbar geopotential height anomaly based on the PNA indexes.*

The model produces a realistic PNA signal with variability on sub-seasonal to interannual time scales. The PNA pattern has positive centers in the vicinity of Hawaii and over the intermountain region of North America, and negative centers located south of the Aleutian Islands and over the southeastern United States during the positive phase (fig. 7).

4.3 North Atlantic Oscillation

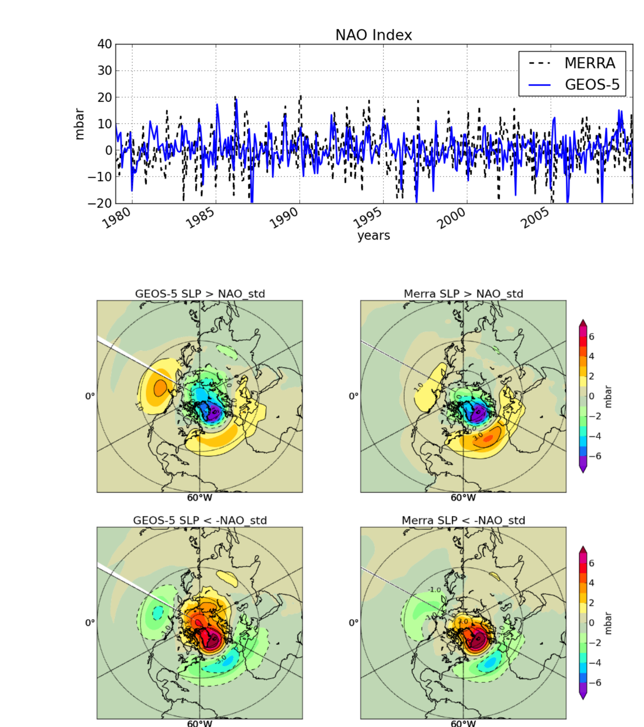

Figure 8: *Top: the NAO indexes from GEOS-5 and MERRA. Middle and bottom: composites of the GEOS-5 (left) and MERRA (right) SLP anomaly based on the NAO indexes.*

The NAO index is defined as difference of SLP anomaly at (27^0W,34^0N) and (32^0W,60^0N). The model NAO has realistic dipole pattern with the negative center over Greenland and positive center over the Atlantic ocean between 35^0N and 40^0N during the positive phase (fig. 8).

4.4 Pacific Decadal Oscillation

The PDO index is defined as the leading principal component of the North Pacific SST between (120^0E,100^0W) and (20^0N,60^0N).

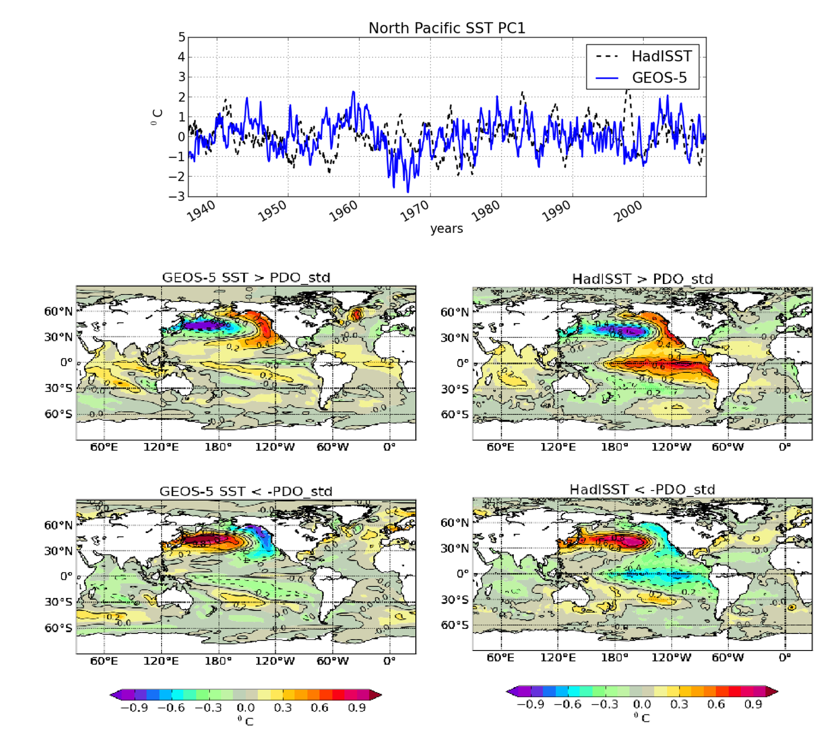

Figure 9: *Top: the leading principal components of the North Pacific SST from GEOS-5 and the Hadley Centre data set. Middle and bottom: composites of the GEOS-5 (left) and Hadley (right) SST anomaly based on the indexes from the top panel.*

The PDO signal is a combination of interannual and decadal modes. The model PDO has a realistic pattern in the extra-tropics, but does not have a tropical imprint as in the observed PDO (fig. 9).

5. Summary

The GEOS-5 AOGCM produces a stable, realistic mean climate and realistic representations of the major modes of short term climate variability. Some biases are currently being diagnosed, including a significant drift of the Atlantic Meridional Overturning Circulation (AMOC), which is accompanied by cooling of the North Atlantic ocean and expansion of winter sea ice margin. The model is used by GMAO for ocean data assimilation and seasonal forecasts. An ensemble of decadal prediction runs have been recently undertaken by the GMAO following the experimental suite specified for the Coupled Model Intercomparison Project phase 5 (CMIP5).

References

www.geos5.org