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The GEOS-5 AOGCM

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1. Introduction

The GEOS-5 Atmosphere-Ocean General Circulation Model (AOGCM) is a state-of-the art coupled climate model developed at the Global Modeling and Assimilation Office (GMAO). In this presentation, an overview of the model design is given, and model performance is evaluated in terms of simulating the mean climate and inter-annual climate variability.

The GEOS-5 AOGCM is designed to simulate climate variability on a wide range of time scales, from synoptic time scales to multi-century climate change, and have been tested in coupled simulations and data assimilation mode.

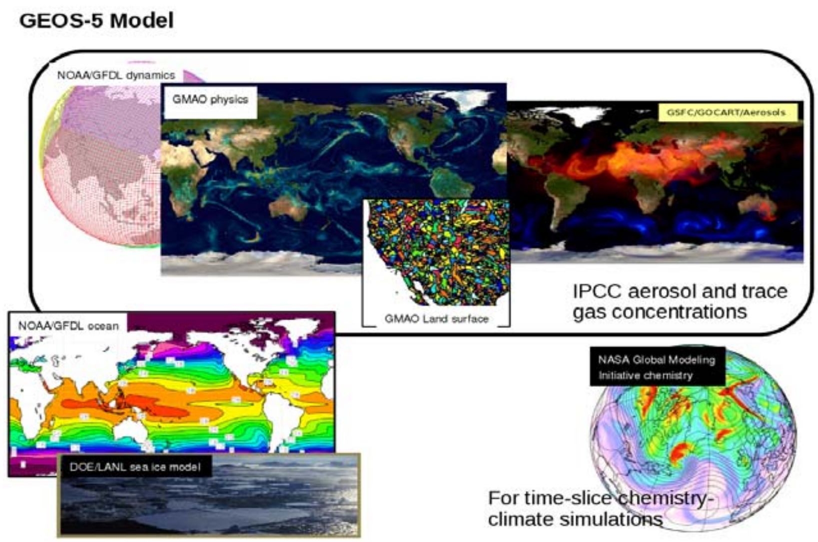

Fig. 1 Components of the GEOS-5 AOGCM. Components in the black frame are used in a production of AGCM data assimilation system. Other components are tested in coupled and data assimilation modes.

The main components of the GEOS-5 AOGCM (Fig. 1) are the atmospheric model, the catchment land surface model, both developed by the GMAO (GEOS-5 AGCM, Rienecker *et al.* 2008), and MOM4, the ocean model developed by the Geophysical Fluid Dynamics Laboratory (Griffies *et al.* 2005). These two components exchange fluxes of momentum, heat and fresh water through a "skin layer" interface. The skin layer includes parameterization of the diurnal cycle and a sea ice model (LANL CICE, Hunke and Lipscomb 2008). All components are coupled together using the Earth System Modeling Framework (ESMF) interface.

2. Experiment design

A 150-year validation experiment has been conducted to test the current performance of the GEOS-5 AOGCM. The resolution of the atmospheric component in this experiment is 2.5º longitude × 2º latitude with 72 vertical levels up to 0.01hPa. The ocean resolution is 1º longitude and latitude, with meridional equatorial refinement to 1/3º, and 50 vertical levels. A coupled model configuration with a 1.5º×1º atmospheric grid, and 0.5º ocean grid is also being tested. Initial conditions for the atmospheric component are taken from an uncoupled experiment forced by the observed sea surface temperature. The ocean is initialized with a steady state, with temperature and salinity from the Levitus and Boyer climatology. The atmospheric state in the coupled experiment is compared to the results from an uncoupled experiment and also MERRA. This analysis allows us to understand which errors can be attributed to coupling and which errors result from deficiencies in the AGCM. The ocean state is validated using observations and the fields from the GMAO ocean data assimilation system.

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The idea to have a multi-scale modeling system with unified physics is to be able to propagate improvements made to a physical process in one component into the other the components smoothly and efficiently. In addition, this model system has been coupled to a *Satellite Data Simulation Unit* that can compute satellite-consistent radiances or backscattering signals from simulated atmospheric profiles and condensates consistent with the unified microphysics within the multi-scale modeling system (Fig. 1).

3. Results

The 150-year integration produced a stable, realistic mean climate and inter-annual climate variability. The key features of climate simulated by the model are summarized below.

The mean atmospheric state simulated by the AOGCM is similar to atmospheric state simulated by the GEOS5 AGCM forced by the observed sea surface temperature (SST). Errors in the coupled simulation primarily have the same structure as errors in the uncoupled simulation, but usually with larger magnitude. These errors include: too strong surface wind stress in high latitudes; too strong cloud radiative forcing in low latitudes, and too weak cloud radiative forcing in high latitudes; errors in precipitation typical of most state-of-the-art climate models, *e.g.*, a strong double Inter-Tropical Convergence Zone (ITCZ).

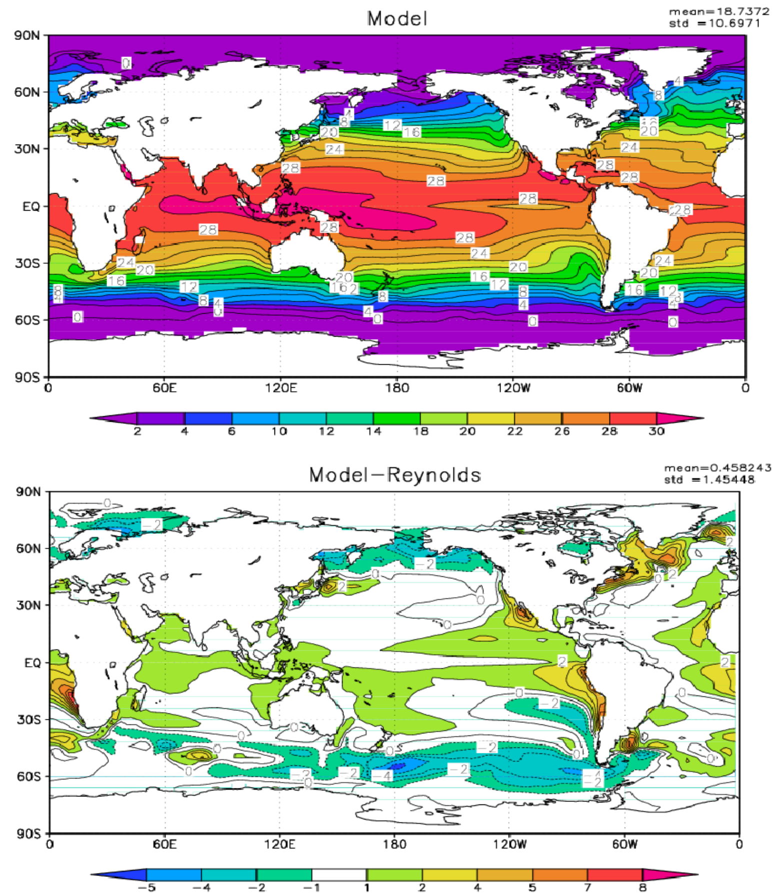

Fig. 2 Sea surface temperature (top) from the GEOS-5 coupled integration, and the bias relative to the Reynolds climatology (bottom).

On the ocean side, the upper ocean circulation and surface climate reach equilibrium in several decades, while the deep ocean circulation still exhibits a drift after 150 years of integration. SST is an important measure of the realism of the model climate, since it is used by the atmospheric component as a boundary condition. Figure 2 shows that the model SST simulation is quite realistic. The dominant errors shown in Figure 2 are typical for state-of-the-art climate models. For example, the warm SST bias near the eastern boundaries of the oceans is due to deficiencies in simulating the orientation of the wind stress and the coastal upwelling. SST errors in the regions of western boundary currents result from deficiencies in simulating the strength of the western boundary currents and the separation location. These types of errors are typically reduced with the increased resolution.

The leading mode of global SST variability is shown in Figure 3. This mode exhibits the prominent El Nino - Southern Oscillation pattern which varies on inter-annual time scales. Compared to observations, the model El Nino pattern is narrower and extended further into the western Pacific. In addition to the dominant signal in the equatorial Pacific, the model also captures the co-variability in the sub-tropical Pacific. Comparison between the model and observed time series of the leading SST mode shows that model ENSO has reasonable time scale and irregularity with a tendency to have slightly higher frequency than observed. Analysis of correlation between ENSO time series and 300mb geopotential height (not shown) demonstrates that the model simulates realistic tropical-extratropical ENSO teleconnections.

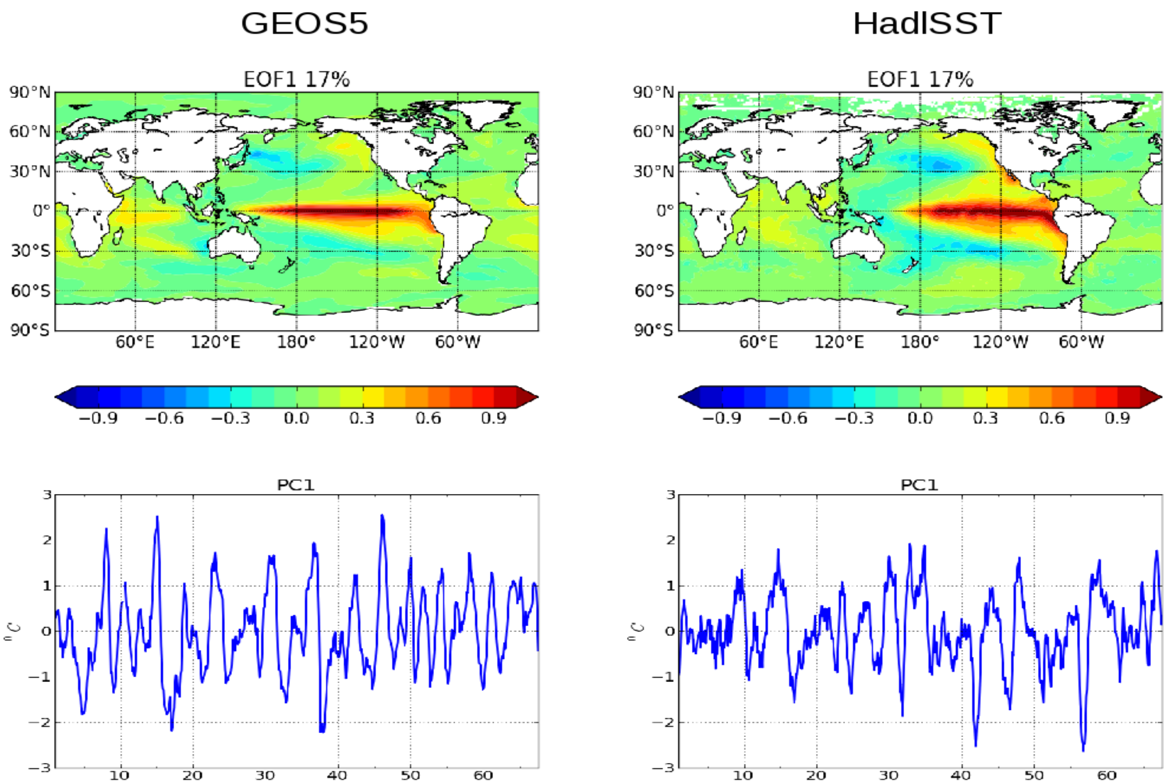

Fig. 3 The leading mode of global SST variability from the GEOS-5 AOGCM (left) and the Hadley center (right). Top panels show the leading empirical orthogonal functions of the global SST. Bottom panels show corresponding principal components.

4. Conclusions

Development of the GEOS-5 AOGCM is a significant advance in NASA's climate modeling. Current performance of the model is comparable to performance of the state-of-the art coupled climate models being used for the next IPCC assesment report. The model now routinely runs on the supercomputing clusters at the NASA Center for Climate Simulation (NCCS) and the NASA Advanced Supercomputing Division (NAS). Projects underway with the GEOS-5 AOGCM include weakly coupled ocean-atmosphere data assimilation, seasonal climate predictions and decadal climate prediction tests within the framework of Coupled Model Intercomparison Project Phase 5 (Program for Climate Model Diagnosis and Intercomparison). The decadal climate prediction experiments are being initialized using the weakly coupled atmosphere-ocean data assimilation based on MERRA. The results of these experiments will be distributed through the NCCS Earth Grid System node.

References

Rienecker, M. M., and Coauthors, 2008: The GEOS-5 Data Assimilation System - Documentation of Versions 5.0.1, 5.1.0, and 5.2.0, Technical Report Series on Global Modeling and Data Assimilation, NASA/GMAO.

Griffies, S. M., and Coauthors, 2005: Formulation of an ocean model for global climate simulations. Ocean Science, 45-79.

Hunke, E. C., and W. H. Lipscomb, 2008: CICE: The Los Alamos Sea Ice Model, Documentation and Software Manual, Version 4.0. Techniocal Report, Los Alamos National Laboratory.

Program for Climate Model Diagnosis and Intercomparison: CMIP5 - Coupled Model Intercomparison Project Phase 5 - Overview, http://cmip-pcmdi.llnl.gov/cmip5/index.html?submenuheader=0