Geophysical Research Abstracts, Vol. 9, 10025, 2007
SRef-ID:

Using high-frequency ARM observations to evaluate land-atmosphere interactions in climate models

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Improving the parameterizations of physical processes in climate models is key to enhancing their simulations of the historical record, as well as their projections of potential climate change. However, the origins of parameterization-based errors are usually not evident from inspection of a climate model's output statistics, since these reflect the nonlinear interactions of the model dynamics with multiple physical parameterizations over climate timescales. Specific parameterization deficiencies are instead more clearly perceived at the shorter timescales that are the natural domain of numerical weather prediction (NWP) models. Nevertheless, it is possible to operate an atmospheric climate model in NWP mode by:

1) initializing the model's atmospheric state variables realistically from a global NWP (re)analysis that is interpolated to the model's horizontal and vertical grids,

2) running the climate model as if it were a coarse-resolution weather-forecast model, and outputting its predicted variables at short timescales,

3) applying high-frequency observations to identify systematic errors in forecast variables that are strongly impacted by the parameterizations (e.g. heat/moisture/ momentum fluxes, clouds, precipitation, etc.).

Analysis of the systematic forecast errors then can guide efforts to improve the model parameterizations. Attendant reductions in forecast errors will, in the experience of NWP centers, also often enhance overall model performance at climate timescales.

The U.S. Department of Energy (USDOE) 'CAPT' project is currently applying this NWP-inspired method to identify systematic errors in weather forecasts made with two atmospheric climate models, the NCAR 'CAM3' and the GFDL 'AM2'. Central to our ability to identify model systematic errors are high-frequency field observations recorded by the USDOE's Atmospheric Radiation Measurement (ARM) program at different sites. Especially valuable are "continuous forcing" datasets of land/atmosphere variables which are available from ARM's U.S. Southern Great Plains (SGP) site at hourly frequencies for the entire year 2000. At those model grid points situated near the SGP site, therefore, it is possible to conduct unusually fine-grained evaluation of land-atmosphere interactions over a wide range of synoptic conditions.

In this study, we focus on identifying systematic errors in model forecasts of radiative and hydrological forcings, as well as of land-surface response variables such as turbulent fluxes, temperatures, and humidities. By applying appropriate statistical metrics, we also distinguish bias from phase errors at different timescales. The systematic errors are found to vary perceptibly according to process, season, and model. In the year-2000 summer season, for example, precipitation at the SGP site in the CAM3 model is excessive, while it is too weak in AM2, leading to qualitatively different errors in land-surface turbulent fluxes. Implications of such case studies for needed further parameterization development in these models also will be discussed.

Acknowledgments

This work was performed under the auspices of the U.S. Department of Energy (USDOE) at the University of California's Lawrence Livermore National Laboratory under contract W-7405-Eng-48. It was supported through the USDOE's Atmospheric Radiation Measurement and Climate Change Prediction Programs which are directed by the Biological and Environmental Research program at the USDOE Office of Science.