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Third Quarter 2009 Modeling Program Metric: Coupled model comparison with observations using improved dynamics at coarse resolution

Quantifying the impact of a finite volume dynamical core in CCSM3 on simulated precipitation over major catchment areas

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Summary

Climate model simulations are routinely compared with available observations, and increasingly at regional scales. Such model evaluation serves to identify the relative strengths and weakness of different models or newer model versions, and ultimately contributes to building confidence in the reliability of simulations of past, present and future climate. In this report we evaluate a coupled model with improved dynamics at coarse resolution by comparing it to observed estimates of precipitation. Specifically, we examine the impact of implementing a Finite Volume dynamical core in the Community Climate System Model (CCSM 3.0) on simulated precipitation over major catchment areas. Using quantitative performance metrics that compare observed and simulated precipitation, we examine the simulated annual cycle as well as inter-annual variability. It is demonstrated that the Finite Volume version of the model has similar precipitation characteristics to the standard model even at regional scales.

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FY09 ANNUAL TARGET: Provide improved climate simulations on sub-continental, regional, and large watershed scales, with an emphasis on improved simulation of precipitation

Q3: Undertake model-obs comparison with improved dynamics of the coupled model at coarse resolution.

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1. Introduction

Climate model simulations are routinely compared with available observations. This serves to identify the relative strengths and weakness of different models or newer model versions, and ultimately contributes to building confidence in the reliability of simulations of past, present and future climate. Employing a broad spectrum of model diagnostics reveals model deficiencies, and sometimes provides insight into the root cause of model errors. Increasingly, comparison of model simulations with observational data is taking place regional scales - a much tougher test of model performance than traditional large-scale diagnostics. In this report we evaluate the impact of a new dynamical core on regional scale precipitation as simulated by a community climate model.

2. The CCSM3 Simulations

The Community Climate System Model (CCSM) is a Coupled Ocean-Atmosphere General Circulation Model (OAGCM) sponsored by the National Science Foundation (NSF) and the U.S. Department of Energy (DOE). It is administratively maintained by the National Center for Atmospheric Research (NCAR) Climate and Global Dynamics Division (CGD). Simulations performed with the third major release of the model – CCSM3.0 – have been extensively evaluated (e.g., Collins et al., 2006). In the second quarterly report we evaluated a "present day" control run of CCSM3.0 that was integrated for several centuries. The focus of that report was on the annual cycle of simulated precipitation on catchment scales.

In this report we compare our CCSM3.0 control run with a version of the model where the Eulerian spectral method has been replaced with a Finite Volume (FV) numerical technique for solving the equations governing the atmospheric dynamics. The atmospheric component in the simulation uses a 1° latitude x 1.25° longitude grid, which is a slightly finer resolution than the T85-grid used in the spectral transform. The ocean and ice components of both models use a nominal 1-degree grid. Although the physical parameterizations are the same and the resolution is comparable to the standard (T85) model, substantial testing and slight retuning were required to obtain an acceptable control simulation (see Bala et al., 2008 for details).

3. Data and Methods

We evaluate the simulated precipitation in the standard and FV versions of CCSM3.0 performance over the major water catchment areas of the globe. As in the Second Quarterly (Q2) report, we make use of a 1º longitude by 1º latitude data set of continental watersheds (Graham et al., 1999) used in the Land Surface Model (LSM) CCSM3. The 50 watershed areas we examine are illustrated in Figure 1 of the Q2 report. Two reference data sets are used to help to demonstrate the sensitivity of our results to available precipitation estimates. The first comes from the Global Precipitation Climatology Project (GPCP, e.g., Alder et al., 2004). The second is commonly known as the CPC Merged Analysis of Precipitation (CMAP, Xie, P., and P.A. Arkin, 1997). We construct 20-year climatologies from monthly mean "present-day" control run data from both the standard and FV versions of CCSM3. In each case, we define an "early" and "late" 20-year climatology (constructed from years 31-50 and 91-110 of the each control run). Our metric for quantifying the quality of the simulated annual cycle is the same as used in the Q2 report. For the evaluation of the inter-annual variability amplitude, we use a similar measure to that in Gleckler et al. (2008).

4. Results

We begin with an examination of the simulated annual cycle of precipitation, analyzing the same catchment areas and using the same performance metrics as in the Q2 report. Our emphasis here is on comparing the standard and FV versions of CCSM3. **Figure 1** is a scatter plot of our annual cycle metric under four conditions. The first and second provide comparisons of the standard and FV "early" and "late" climatologies (black and red symbols respectively) with respect to the GPCP data. The third and fourth are similar, but with respect to the CMAP data, with blue symbols for the "early" and green symbols for the "late" climatologies. Although there are some differences in the quantitative evaluation of the two model versions, the following can be summarized from the figure: 1) Twenty years appears adequate for sampling as the differences between climatology periods (black vs. red and blue versus green) are minimal, 2) the choice of observational dataset matters more than the climatology period, and 3) the two simulations are very similar in skill, with similar distributions on either side of the unity line. For selected catchment areas, **Figure 2** shows the annual cycle for both observational datasets as well as "early" and "late" climatologies for the standard and FV model simulations. This figure demonstrates the challenge of simulating the annual cycle of precipitation on these scales. The two blue and green lines are nearly always superimposed on one another, again demonstrating the robustness between the "early" and "late" climatolgies. This same set of lines illustrates the similarity between the standard and FV simulations. **Figure 3** compares (as a ratio) the inter-annual variability amplitude of observed and simulated precipitation. The variability ratio is shown for each catchment area for both the standard and FV runs as compared to the CMAP data set. The range in skill is varied. In a few regions the variability is over-estimated, in many others it is under estimated, and in some the model variability compares well with observations. Note that the differences between the standard and FV simulations are generally small. Comparisons with GPCP (not shown) yield similar results.

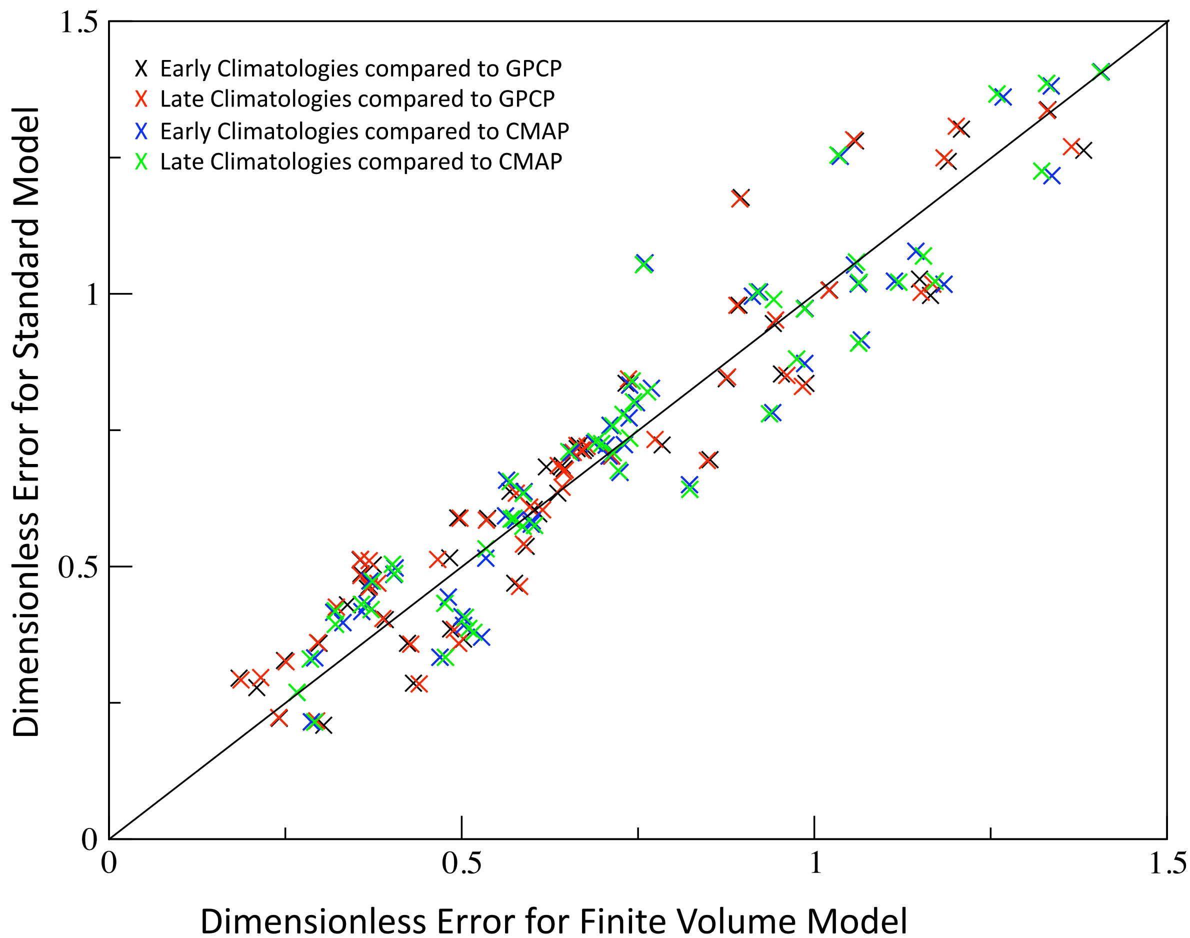

Figure 1: Comparison of annual cycle errors between the standard and FV versions of CCSM3 for the simulated annual cycle of precipitation in 50 (un-identified) catchment areas. The dimensionless error measure was defined in the Q2 report.

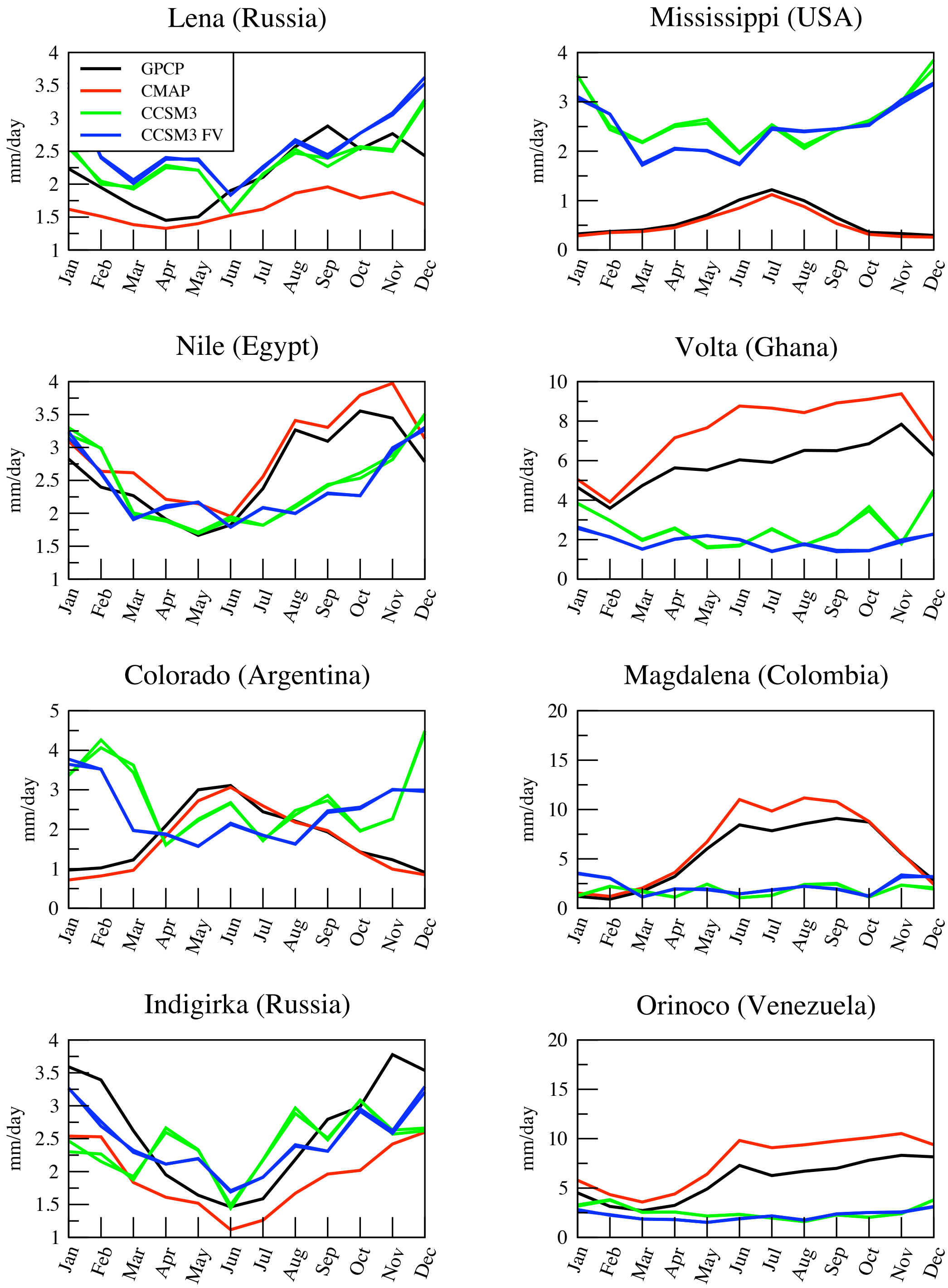

Figure 2: Model and observation area-averaged annual cycle time series for select catchments. Black and red lines represent GPCP and CMAP observations respectively. Blue and green lines (2 of each) represent results for 2 different climatological periods of the standard and FV CCSM3. Units are in mm/day.

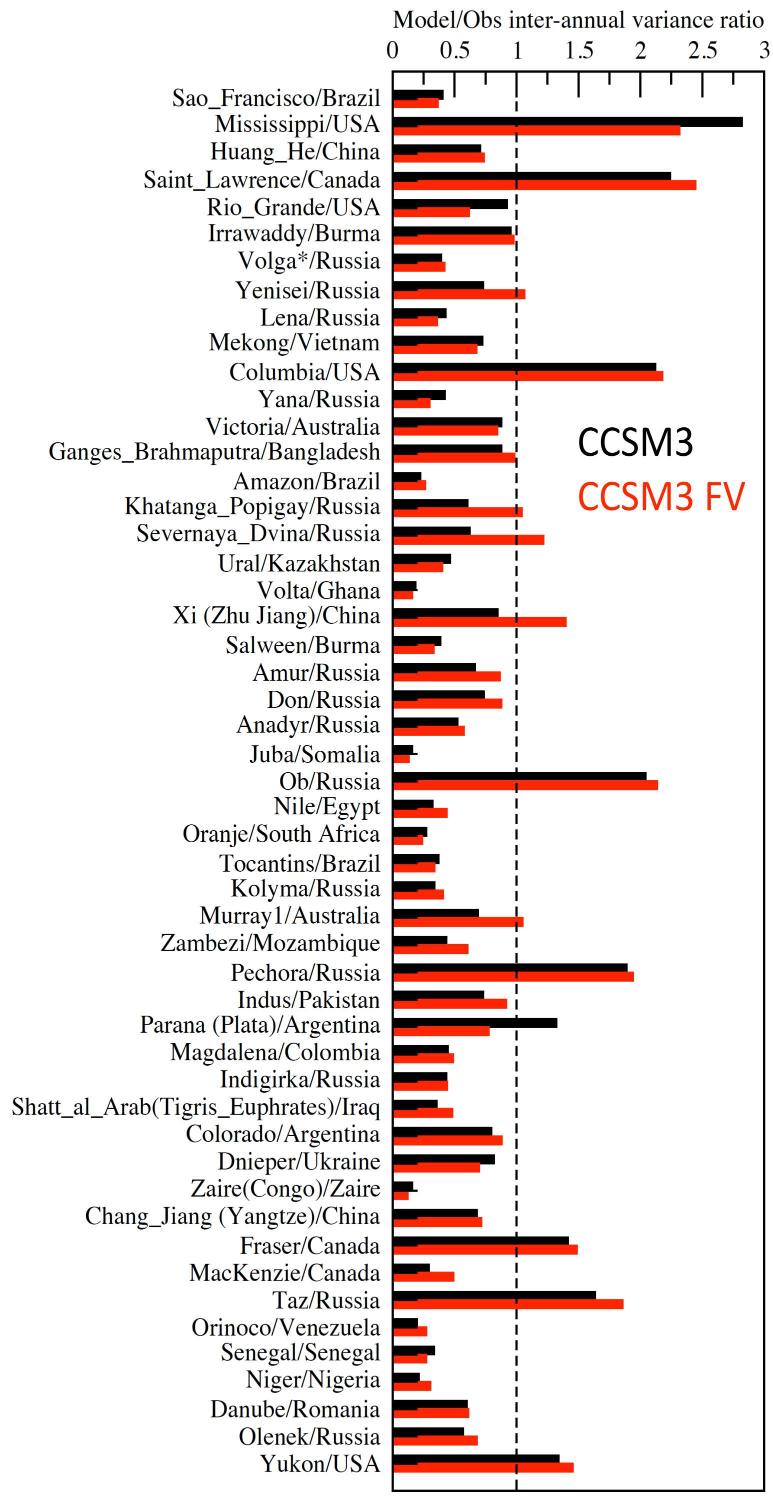

Figure 3: Model/Observation inter-annual variance ratio for select catchment areas. Black bars represent ratio for the standard CCSM3. Red lines are for the CCSM3 FV simulation. Units are dimensionless.

4. Summary

In this report we evaluate the impact of implementing a Finite Volume dynamical core in the Community Climate System Model (CCSM 3.0). The focus of our evaluation is on simulated precipitation over major catchment areas. Using quantitative performance metrics that compare observed and simulated precipitation, we examine the simulated annual cycle as well as the amplitude inter-annual variability. It is demonstrated that the Finite Volume version of the model has similar precipitation characteristics to the standard model even at regional scales.

5. References

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