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Evaluation of Simulated Precipitation in CCSM3: Annual Cycle Performance Metrics at Watershed Scales

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Summary

Climate model simulations are routinely and extensively 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. Increasingly, models are being tested at regional scales – well known to be a much tougher test of model performance than traditional larger scale diagnostics. In this report we evaluate the regional scale precipitation as simulated by version 3.0 of the Community Climate System Model (CCSM). Quantitative performance metrics of the simulated annual cycle are computed for all of the major catchment areas of the world. It is demonstrated that the model's skill at capturing the annual cycle of precipitation is highly region dependent. These results serve as a benchmark for the evaluation of future model versions.

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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

Q2.: Undertake model-observation comparison with the baseline coupled model.

P. Gleckler and D. Bader (PCMDI/LLNL)

1. Introduction

Climate model simulations are routinely and extensively 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, models are being tested at regional scales – well known to be a much tougher test of model performance than traditional larger scale diagnostics.

2. The CCSM3.0 Simulation

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 Climate and Global Dynamics Division (CGD) at the National Center for Atmospheric Research (NCAR). Simulations performed with the third major release of the model – CCSM3 – have been extensively evaluated (e.g., Collins et al., 2006). In this report we evaluate our benchmark simulation, a “present day climate” control run of CCSM3 that was integrated for several centuries.

3. Data and Methods

We evaluate model performance of simulated precipitation in regions that have previously been defined by identification of the major water catchment areas of the globe. We make use of 1º longitude by 1º latitude data set of continental watersheds (Graham et al., 1999) used in the Land Surface Model (LSM) CCSM3. Figure 1 illustrates the 50 watershed areas that we will examine.

We make use of two reference data sets to help to demonstrate the sensitivity of our results to available of 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).

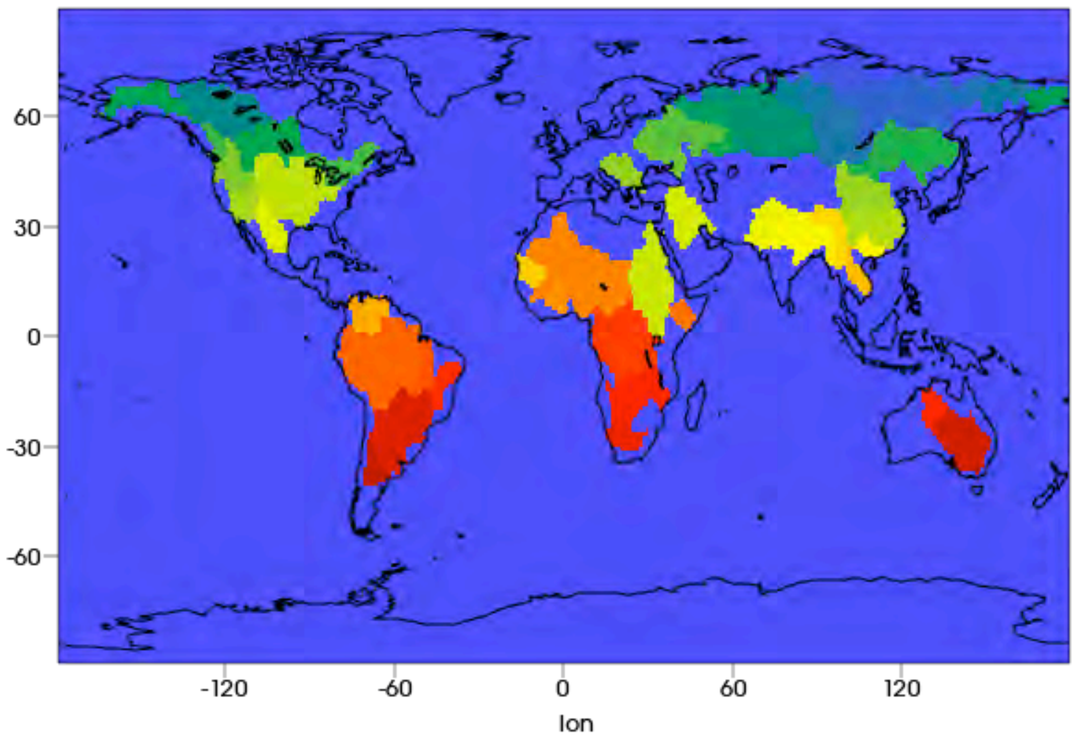

Figure 1: Major watersheds of the world, distinguished by color.

Our focus in this report is on the simulated annual cycle. For both observationally-based data sets, annual cycle climatologies are constructed for the period of 1980-1999. The simulation we are evaluating is from a control run without time varying external forcings, and there is no reason to expect any 20-year period of the model to exactly match our single 20-year record from observations. To test how our results might depend on which portion of the control run we evaluate, we will examine four different 20 year model climatologies, selected from the following years of the simulation: 0-29, 50-69, 80-99, 120-139.

All model results are interpolated to the common grid of the observational data sets (2.5º degrees in longitude and latitude). The catchment mask is also transformed to this grid. We then define our monthly mean annual cycle error measure, *E*, from:

$$E^2 = \frac{1}{12}\sum_{i=1}^{12}\left(\frac{M_i - O_i}{O_{avg}}\right)^2$$

where M_i and O_i are the catchment area-average model and observations for calendar month *i*, and O_{avg} is the climatological annual mean of the observations. This is similar to the familiar root-mean-square-error used for large-scale model metrics (cf., Gleckler et al., 2008, Taylor, 2001). The normalization factor, O_{avg}, is useful for evaluating precipitation in that it guards against errors in dry areas from being under valued.

4. Results

Figure 2 shows the model errors as defined above for 50 catchment areas. The solid bars in the plot represent model errors with respect to the GPCP data, and the hatched bars the same but with CMAP data. Two main features stand out from this figure. First, in most areas there is little impact by choosing the alternate observations. It should be noted however that this does not necessarily reflect observational uncertainty as both data sets are largely based on the same direct measurements. The second conclusion to be drawn from this figure, not surprisingly, is that model skill is highly regionally dependent. These results do not strongly depend on whether or not a region is relatively wet or dry, nor they do they correspond to the spatial scale examined (there is a wide range of surface area in the 50 catchment areas). They are also not overly sensitive to different choices made to define our metric. Put simply, the regional scale error structure is complex. To illustrate this, annual cycle time series from eight regions are shown in Figure 3. The GPCP and CMAP observations are respectively identified by the red and green lines. The model results are shown in black lines, three of which are thin lines and represent model climatologies constructed from different time slices of the present day control run. For the most part we see this has very little impact, suggesting that the control run is quite stable. In some areas the model does approximately capture the mean annual cycle, but in others it clearly does not.

In summary, the annual cycle of precipitation as simulated by CCSM3 has been evaluated at 50 selected catchment regions. Model skill is highly dependent on the region evaluated, and weakly sensitive to the choice of observations and the portion of the control run evaluated.

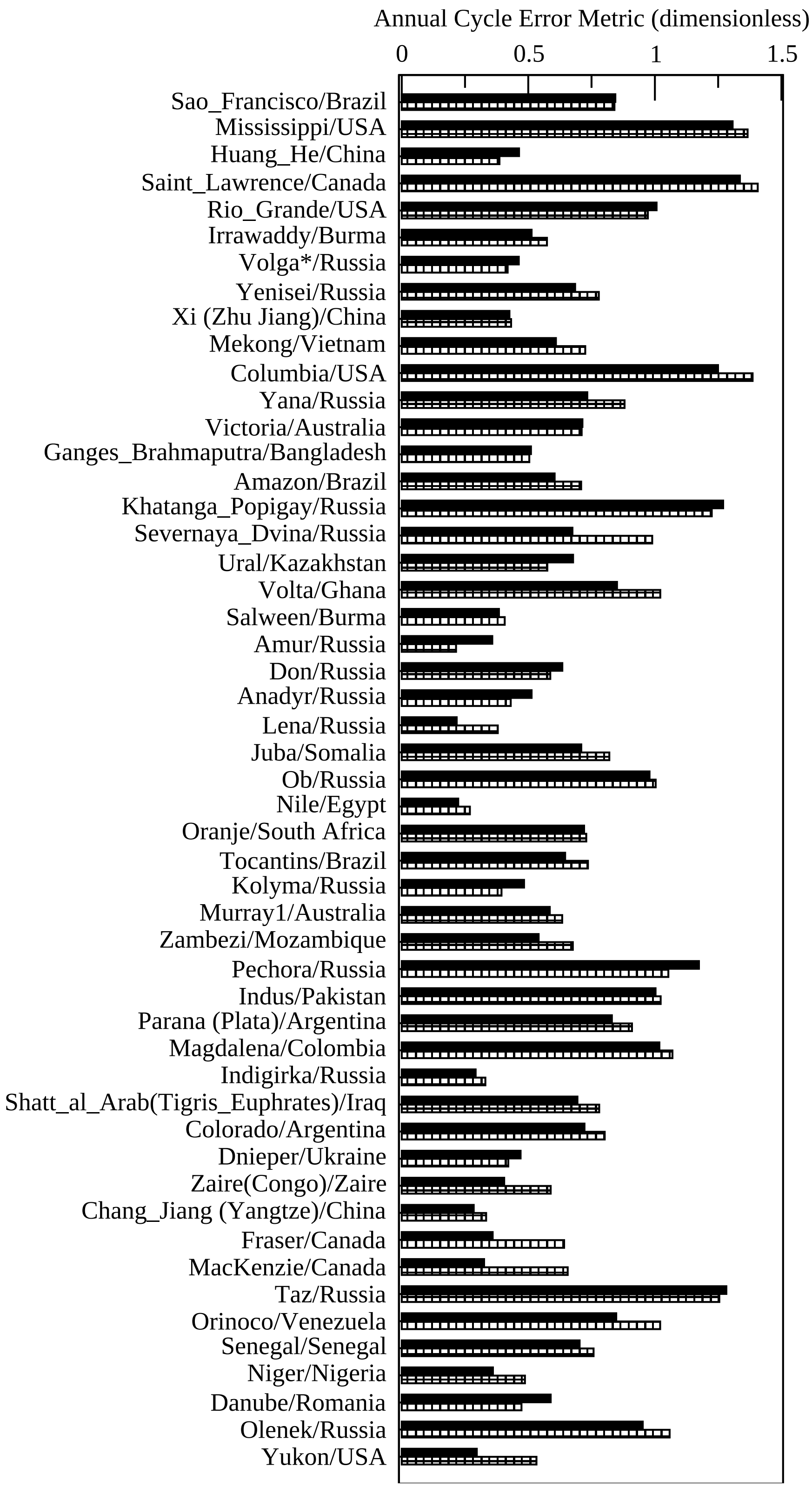

Figure 2: Major watersheds of the world, distinguished by color. The solid and hatched bars represent model error with respect to the GPCP and CMAP datasets respectively.

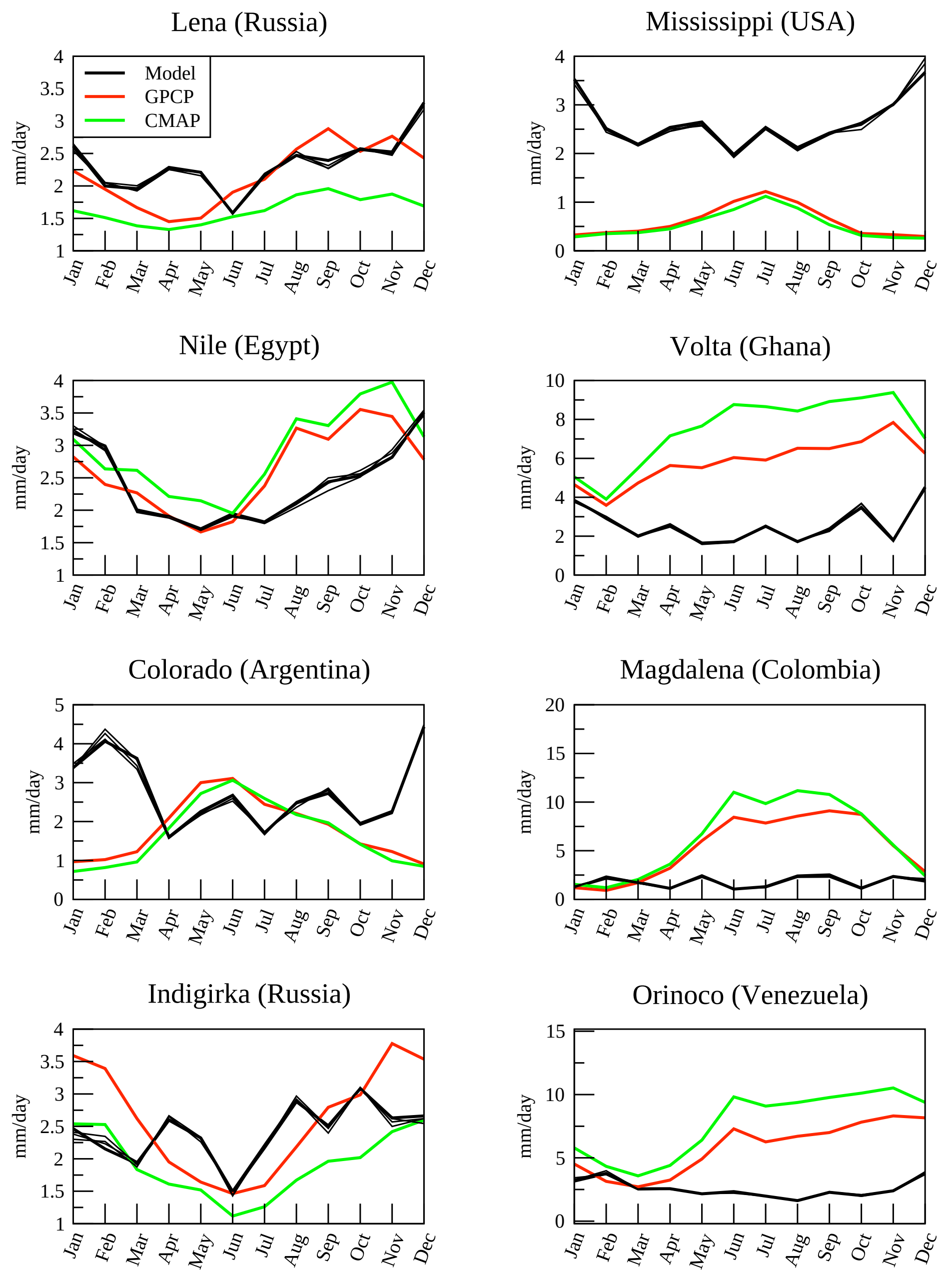

Figure 3: Model and observation area-averaged annual cycle time series for select watersheds. Red and green lines represent GPCP and CMAP observations respectively. Black lines (1 thick and 3 thin) represent results for four different periods of the CCSM present day control run. Units are in mm/day.

4. References

Adler, R. F., G. J. Huffman, A. Chang et al. (2003), The Version-2 Global Precipitation Climatology Project (GPCP) monthly precipitation analysis (1979– present), J. Hydrometeorol., 4, 1147– 1167.

Graham, S.T., J. S. Famiglietti, and D.R. Maidment, Five-Minute, 1/2º, and 1º Data Sets of Continental Watersheds and River Networks for Use in Regional and Global Hydrologic and Climate System Modeling Studies, Water Resources Research, 35(2), 583-587, 1999.

Collins WD, Bitz CM, Blackmon ML, Bonan GB, Bretherton CS, Carton JA, Chang P, Doney SC, Hack JJ,Henderson TB (2006) The Community Climate System Model Version 3 (CCSM3). Journal of Climate 19(11): 2122.

Gleckler, P. J., K. E. Taylor, and C. Doutriaux (2008), Performance metrics for climate models, J. Geophys. Res., 113, D06104, doi:10.1029/2007JD008972.

IPCC (2007), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Taylor, K. E. (2001), Summarizing multiple aspects of model performance in a single diagram, J. Geophys. Res., 106, 7183 – 7192.

Xie, P., and P.A. Arkin, 1997: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimMeteor. Soc., 78, 2539 - 2558.