Update on Activities of the CAPT Project

Gerald Potter, Jim Boyle, Stephen Klein, Tom Phillips, and Shaocheng Xie
Atmospheric Sciences Division, Lawrence Livermore National Laboratory, Livermore, CA

Dave Williamson and Jerry Olsen
National Center for Atmospheric Research, Boulder, CO

Guang Zhang
Scripps Institution for Oceanography, University of California at San Diego, La Jolla, CA

Introduction

The DOE CAPT project has as its goal the improvement of climate models through diagnostic assessment of climate models run as weather forecast models (Phillips et al. 2004). In this project, climate models are initialized with the state of the atmosphere from high quality weather analyses and integrated for a few days. The output of the model which is run at the same resolution as the standard climate model, is then thoroughly evaluated using ARM data primarily from the Southern Great Plains (SGP) site.

In this update, the poster describes several new activities of the project. These include

- Comparisons between simulations of the July 1997 Intensive Observing Period (IOP) at the SGP by the National Center for Atmospheric Research (NCAR) Community Atmosphere Model Version 3 (CAM3) and the CAM3 with modifications to the cumulus parameterization provided by Guang Zhang (2002)
- Comparisons between the simulations of the March 2000 IOP at the SGP by the NCAR CAM3 and the Atmospheric Model Version 2 (AM2) of the Geophysical Fluid Dynamics Laboratory (GFDL)
- Comparisons between CAM3 and AM2 simulations of the March 2-4, 2000 storm at the SGP with the simulations of the same storm by the CAM3 and AM2 Single Column Models (SCMs) driven with observed large-scale dynamics from the Variational Analysis (Xie et al. 2005)

Impacts of a revised convection parameterization on CAM3 simulations of the July 1997 IOP

Figure 1 shows the time series of surface precipitation averaged over the SGP site for the July 1997 IOP from observations and two simulations of the CAM3 model. The observations (black line) are based upon radar precipitation estimates and are averaged over the domain of the SGP encompassed by the radiosonde network. For the CAM3 model, data from hours 12 to 36 of the forecasts which started at 00Z every day is concatenated to form a single time series. In addition, note that the model precipitation is averaged over the 4 grid boxes nearest the SGP site, which effectively covers an area significantly larger than that of the radar observations.

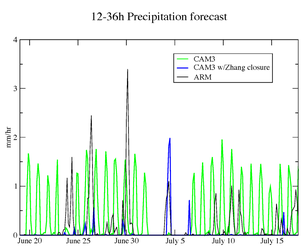

Figure 1. Time series of surface precipitation over the SGP site for June/July 1997 from ARM observations and the CAPT simulations by the CAM3 and the CAM3 model with the Zhang modification.

For the control CAM3 model (green line), the model has a tendency to precipitate nearly everyday near midday. Such behavior is consistent with the closure of the convection scheme which produces precipitation whenever positive convective available potential energy is present, regardless of the conditions of the large-scale flow. Such a behavior is clearly inconsistent with the observations which show intermittent precipitation.

Professor Guang Zhang has developed an alternate closure for the convection scheme in which the amount of convective heating is proportional to the rate at which the atmospheric column is destabilized by 'large-scale' processes. With this new closure, the presence of convective available potential energy is not sufficient for convection, a large-scale circulation must also support convection. The impact of this modification is substantial, as precipitation occurs far less frequently with the modification (blue line in Figure 1). The magnitude of the precipitation however is generally considerably smaller than observed.

Figure 2 shows the impact of these changes on the errors in the vertical soundings of temperature and humidity. For the original CAM3 (top panels), the overly frequent precipitation leads to very large warm biases in the upper troposphere as well as large dry biases in the lower troposphere and moist biases in the upper troposphere. The lower panels of Figure 2 show that reducing the frequency of convection substantially reduces the biases of the original model, demonstrating that the improved precipitation simulations directly reduces the temperature and moisture errors in the atmosphere.

Figure 3 shows the distribution of precipitation accumulated from the first day of each CAM3. The simulation with the Zhang modification has dramatically less precipitation in better accord with the observations.

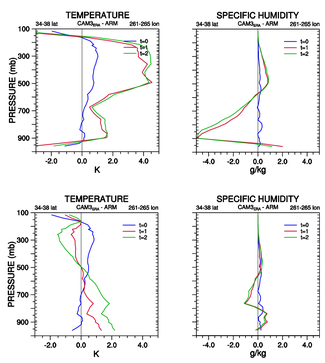

Figure 2. Temperature (left) and moisture (right) errors at the ARM SGP site averaged over all July 1997 forecasts at the initial time of the forecast (t=0), and after one and two days (t=1, t=2). The upper panels show the original CAM3 whereas the bottom panels show the modified CAM3.

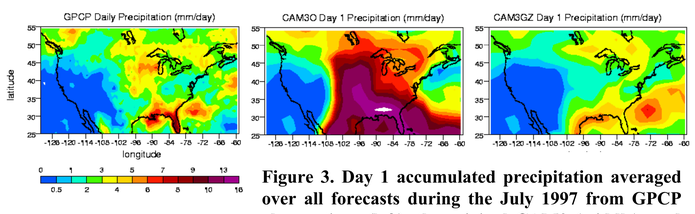

Figure 3. Day 1 accumulated precipitation averaged over all forecasts during the July 1997 from GPCP observations (left), the original CAM3 (middle), and the modified CAM3 (right).

References

Phillips, T. J. and 9 co-authors, 2004: Evaluating parameterizations in general circulation models: Climate simulation meets weather prediction. *Bull. Amer. Met. Soc.*, 85, 1903-1915.

Xie, S., and 24 co-authors, 2005: Simulations of midlatitude frontal clouds by SCMs and CRMs during the ARM March 2000 Cloud IOP. *J. Geophys. Res.*, in press.

Zhang, G. J., 2002: Convective quasi-equilibrium in midlatitude continental environment and its effect on convective parameterization. *J. Geophys. Res.*, 107, DOI: 10.1029/2001JD001005.

This work was performed under the auspices of the U. S. Department of Energy at the University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. This poster is UCRL-POST-xxxxx.

❑ Simulations of the March 2000 IOP with NCAR CAM3 and GFDL AM2 models

Figure 4 shows the time series of surface precipitation for the SGP site for March 2000 from the observations and the NCAR CAM3 and GFDL AM2 models. For these plots, hours 12 to 36 of the daily forecasts which started at 00Z are concatenated to form a single time series. The models are quite successful in capturing the timing of the major precipitation events although the magnitude of the model's precipitation is often less than observed, perhaps reflecting the greater area covered by the model averages.

Figure 5 shows the time-height distribution of cloud fraction from the ARM Cloud Radar and the CAM3 and AM2 models. It is quite important to keep in mind that the radar data which is averaged to one hour effectively sees only a tiny fraction of the area of the model averages and thus it can be expected that its cloud fractions are more likely to be 0 or 1 than those from the models. Despite this difference the models seem quite successful in reproducing the main structures observed by the radar. For example, the decreasing cloud top altitude to the low clouds observed in the 18-20 March period is well simulated by the CAM3. For these winter frontal clouds, the models are quite successful in reproducing the main cloud occurrence structures.

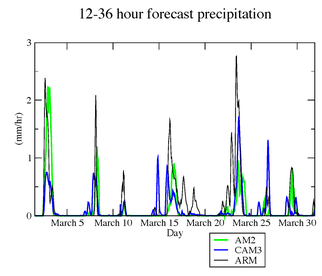

Figure 4. Time series of surface precipitation over the SGP site for March 2000 from ARM observations and the CAPT simulations by the CAM3 and AM2 models.

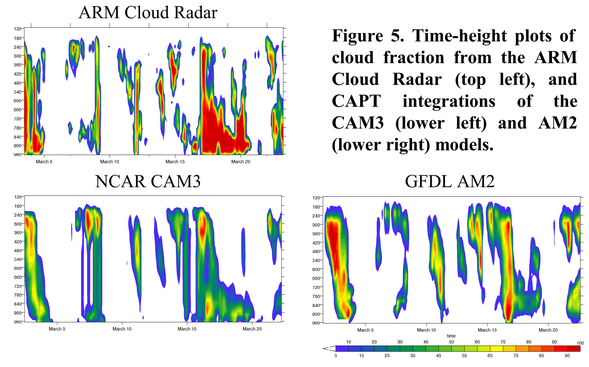

Figure 5. Time-height plots of cloud fraction from the ARM Cloud Radar (top left), and CAPT integrations of the CAM3 (lower left) and AM2 (lower right) models.

❑ Comparison between SCM and GCM simulations of the March 2, 2000 Storm

With the possibility of simulating actual weather events using climate models initialized from weather analyses, one may wonder how this technique compares to the alternative popular technique of using Single Column Models (SCMs) to simulate weather. The difference between these techniques lies in the fact that the observed large-scale forcing of the atmosphere must be determined. The figures below illustrate some of the differences between the CAPT and SCM approaches using both CAPT and SCM simulations of the March 2-3, 2000 storm for the CAM 3 and AM2. All model integrations begin at 18Z 1 March 2000.

Figure 6 shows the vertical motion field averaged over the SGP from the Variational Analysis ("ARM Omega") and from the CAPT integrations of the CAM3 and AM2 models. While the models clearly simulate the storm's occurrence, the peak vertical motion in the models is 12 hours later than observed. Furthermore, the magnitude of the uplift differs markedly from the observations with the CAM3 simulating a much weaker storm and the AM2 simulating the maximum upward motion at too low an altitude. The lower right panel of Figure 6 shows the time series of surface precipitation. Consistent with the vertical motion plots, the CAPT integrations simulate peak precipitation too late with the CAM3 simulating much less precipitation than observed. Note that prescribing the vertical motion field from the ARM Variational Analysis, leads to precipitation simulations by the SCMs that are much closer to observation.

Figure 7 shows the temperature errors from the CAPT and SCM integrations. As expected, CAPT integrations have generally smaller temperature errors than the SCM simulations, particularly aloft and near the surface where the Variational Analysis is known to be less certain.

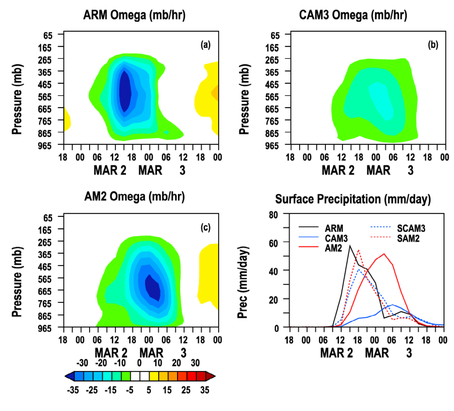

Figure 6. The time height plots of the vertical velocity over the Southern Great Plains site from the variational analysis (upper left), and the CAPT simulation from the CAM3 (upper right) and AM2 (lower left) GCMs. The panel on the lower right shows the time series of surface precipitation from the ARM observations and the GCM and SCM integrations of the CAM3 and AM2 models.

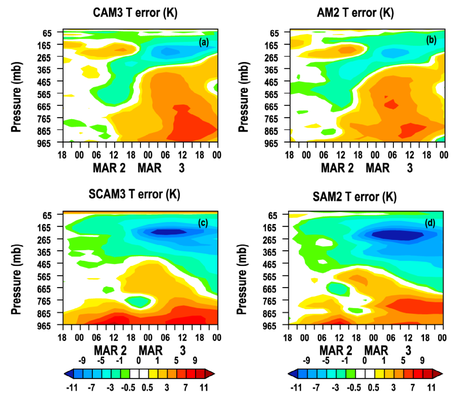

Figure 7. Time-height plots of the temperature error over the Southern Great Plains site for the simulation of the March 2-4 storm. The upper panels show the errors for the CAPT integrations from the CAM3 (left) and AM2 (right) GCMs . The lower panels show the temperature errors from simulations by the SCMs of the CAM3 (left) and AM2 (right) models.