Comparison of Simulated and Observed Clouds and Radiation at the SGP Site

S. J. Ghan and L. R. Leung
Pacific Northwest National Laboratory
Richland, Washington

J. McCaa
University of Washington
Seattle, Washington

Introduction

The Atmospheric Radiation Measurement (ARM) Program is collecting measurements useful for evaluation of cloud parameterizations in regional and global circulation models. However, the most widely used testbed for evaluating cloud parameterizations in the ARM Program is the Single Column Model (SCM), which is essentially a single-column version of a GCM, driven by observed lateral boundary conditions. Unfortunately, the measurements necessary to drive the SCM are proving difficult to obtain with adequate accuracy. We are therefore exploring the use of alternate cloud parameterization testbeds, namely regional and global circulation models that assimilate observed winds throughout their model domains. We evaluate the cloud parameterization in the global model because that is the model the cloud parameterization is ultimately designed for. We evaluate the cloud parameterization in the regional model to demonstrate that, give the same treatment of model physics, the regional model can be used as a faster testbed for the cloud parameterization.

Approach

We have applied simple nudging of winds and temperature to the Pacific Northwest National Laboratory's (PNNL) versions of both the National Center for Atmospheric Research (NCAR)/Penn State MM5 and the NCAR CCM2. Note that we do not nudge humidity because that would compromise the independent evaluation of the simulated moisture balance. Both models have been run with the same model physics, namely, the Colorado State University regional atmospheric modeling system (CSU RAMS) cloud microphysics parameterization (Ghan and Easter 1992), the Grell cumulus parameterization, the CCM2 radiation parameterization, the Holtslag and Boville (1993) non-local mixing scheme, and the BATS1E (Biosphere-Atmosphere Transfer Scheme Version 1e) land surface transfer scheme (Dickinson et al. 1993). The MM5 and CCM2 are run at approximately the same horizontal (300 km and T42, respectively) and vertical (23 and 24 levels, respectively) resolution, but the two models are quite different in their numerical representation of large-scale dynamics and moisture transport.

We have also run the SCM for the same period, namely October 25 through November 14, 1994. The SCM has the same treatment of cloud microphysics and cumulus convection, but somewhat different treatments of radiative transfer, vertical mixing, and surface processes. We find that these differences have a smaller impact on the simulated clouds than differences in the large-scale forcing, which is from Zhang and Lin's (1997) variational analysis. To treat the feedback of the simulated temperature and water vapor on the horizontal advection of those fields, nudging toward the observed fields is applied, using the advective time scale for the nudging coefficient. The advective time scale is based on the observed wind speed and an assumed grid scale of 300 km.

Results

Figure 1 compares the simulated and observed daily mean column water vapor, column liquid water, column ice, precipitation, outgoing solar, outgoing long-wave, surface downward solar, and surface downward long-wave at the Southern Great Plains (SGP) site for the 21 days of the Fall 1994 Intensive Observation Period (IOP). Column water vapor and liquid water measurements are from the Microwave Radiometer at the central facility. Column ice measurements are not available. Observed precipitation is from the network of Oklahoma and Kansas mesonet stations. Outgoing long-wave and solar radiation are from Pat Minnis's analysis of

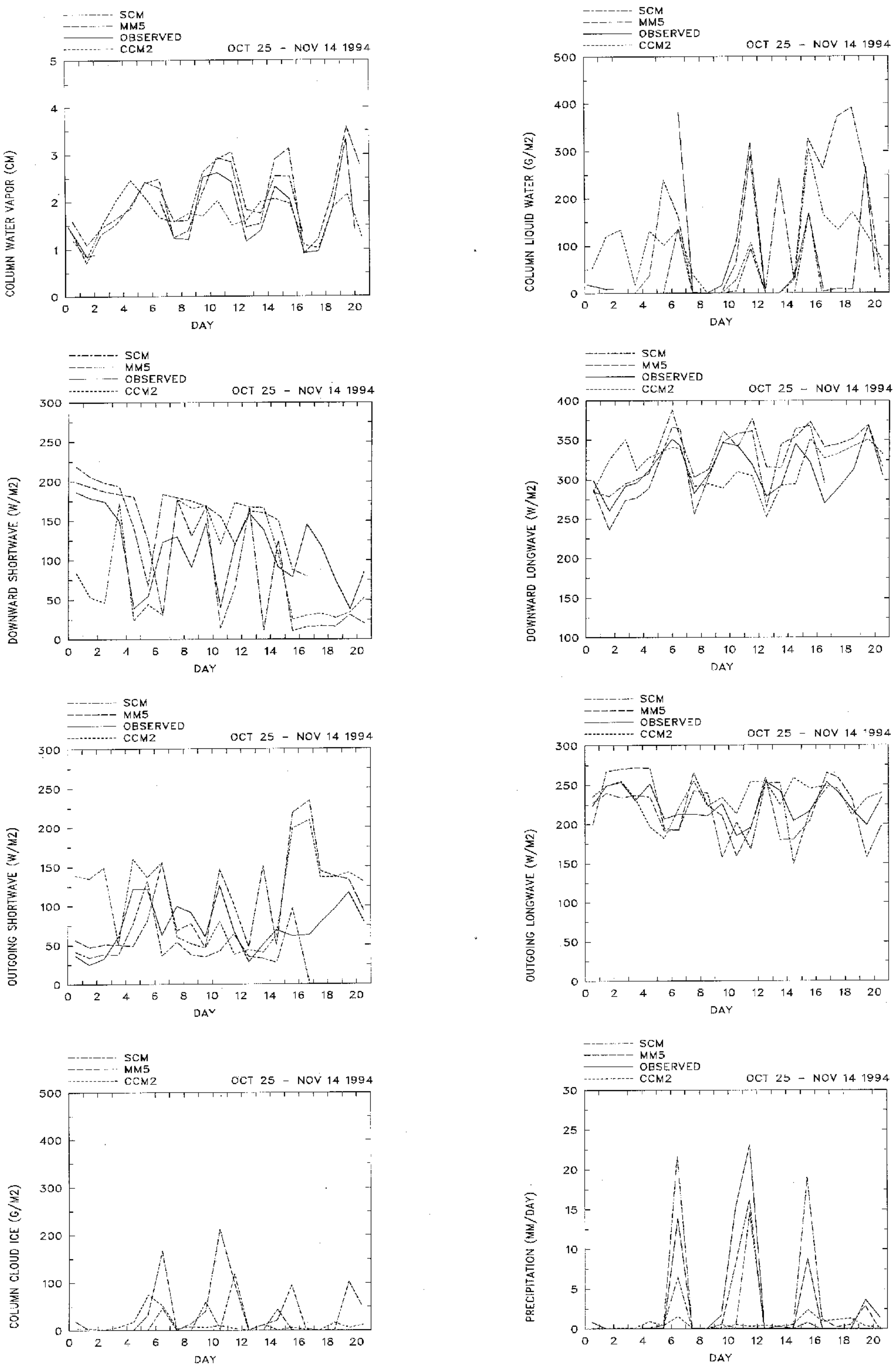

Figure 1. Daily mean column water vapor, column cloud water, column cloud ice, precipitation, outgoing solar radiation, outgoing long-wave radiation, surface downward solar radiation, and surface downward long-wave radiation observed at the ARM SGP site (solid line) and simulated by the Single Column Model (dashed-dotted line), the PNNL version of the NCAR CCM2 (dotted line), and by the PNNL version of the NCAR/Penn State MM5 (dashed line) at the ARM SGP site, for the period October 25 through November 14, 1994.

Geostationary Operational Environmental Satellite (GOES) measurements. Downward solar and long-wave at the surface are from the network of solar and infrared observing system (SIROS) broadband instruments and the central and extended CART facilities.

The column water vapor simulated by the SCM is consistently higher than observed, in spite of nudging the simulated humidity toward radiosonde measurements. The column water vapor simulated by the SCM and MM5 is in good agreement with the observations, following the day-to-day variability quite well. The column water vapor simulated by the CCM2 tracks the phase of the observed variations correctly, but underestimates the amplitude.

Each model simulates the column liquid water well at some times and poorly at other times. However, all three models reproduce the timing of the cloud events fairly well. The CCM2 simulates much less cloud ice than does MM5, in spite of the same physical parameterizations in each model.

All three models simulate the timing of precipitation quite well. The precipitation simulated by the MM5 and SCM are generally in good agreement with observations, with differences of less than 50%. The precipitation simulated by the CCM2 is far too weak.

None of the models simulate the temporal variability of short-wave and long-wave radiation very well. This is particularly true for days 16-18, when both MM5 and CCM2 simulate excessive liquid water and hence overestimate the outgoing solar and underestimate the downward solar at the surface.

These results suggest that, although the data assimilation procedure for each model permits a satisfactory simulation of the timing of clouds and precipitation events, the quantitative agreement with observations is not satisfactory. Differences between simulated and observed fields are probably due to a combination of errors in observations, assimilation of observations, and in model physics. Intermodel differences can be larger than differences between model and observations, indicating that neither the SCM nor the MM5 is yet able to serve as a reliable testbed for the cloud parameterization developed for CCM2.

References

Dickinson, R. E., A. Henderson-Sellers, and P. J. Kennedy, 1993: "Biosphere-Atmosphere Transfer Scheme (BATS) Version 1e as Coupled to the NCAR Community Climate Model." *National Center for Atmospheric Research Technical Note*, NCAR/TN-387+STR, Boulder, Colorado.

Ghan, S. J., and R. C. Easter, 1992: "Computationally Efficient Approximations to Stratiform Cloud Microphysics Parameterization." *Mon. Wea. Rev.*, **120**, 1572-1582.

Holtslag, A.A.M., and B. A. Boville, 1993: "Local Versus Non-Local Boundary-Layer Diffusion in a Global Climate Model." *J. Climate*, **6**,1825-1842.

Zhang, M. H., and J. L. Lin, 1997: "Constrained Variational Analysis of Sounding Data Based on Column-Integrated Budgets of Mass, Heat, Moisture and Momentum: Approach and Application to ARM Measurements." *J. Atmos. Sci*. (in press).