Test of Midlatitude Cumulus Ensembles and Diurnal Cycle of Advection, Temperature, and Moisture Simulated by Regional and Global Models with ARM Data

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Introduction

It is well known that existing general circulation model (GCM) parameterizations and resolutions (order of 200 km) are not sufficient to correctly describe important climate processes such as convection, cloud-radiation interactions, precipitation, and even particular continental-scale dynamic patterns like the low-level nocturnal jet. Even in data assimilations, some of these features are significantly different from observations.

The rapid increase in the power of computations and important practical need in regional climate change predictions has forced two pronounced tendencies in recent atmospheric numerical modeling studies. In global-scale modeling, the resolution of GCMs, especially those with variable resolution, is dramatically increasing. In regional-scale modeling, Limited Area Models (LAMs) previously used for short-term calculations have been computationally enhanced to conduct long-term regional climate calculations. As a result, very soon parameterizations in both GCMs and LAMs will be forced to work in the same range of spatial resolution of 50 km (at least in the part of the global domain for GCMs with variable resolution), and beyond the range of their original applicability.

GCM parameterizations were developed originally for global-scale calculations with resolution of the order 200 km. These parameterizations were devoted to conduct long-term calculations and therefore were adjusted to keep accurate radiative balance of the climate system. Applied on a fine resolution grid, however, they can produce incorrect cloud statistics and fail to keep accurate radiative balance.

Physical parameterizations in regional models were developed to work on a resolution of a few tens of kilometers. But regional and weather prediction calculations have been conducted for relatively short time periods with frequent updating of initial and boundary conditions, when accurate description of the radiative balance of the regional system is not crucially important. Therefore, some of the radiation parameterizations are often very primitive. Using these parameterizations for long-term calculations could cause serious artificial trends of modeled climate.

Both types of parameterizations are not perfect even in their original range of resolutions because radiation transport, cloud radiative forcing, cloud radiative properties, and convective mixing of water vapor are not well understood. The adequate description of these processes is the most important obstacle to improving numerical weather prediction (NWP) and regional climate predictions. Study of these processes is the main purpose of the Atmospheric Radiation Measurement (ARM) Program, and we address them here.

In this study, we test global GCM and regional model calculations with the unique observations from single-column model (SCM) ARM intensive observation periods (IOPs) of July-August 1995 and June-July 1997. We use Goddard Earth Observing System (GEOS)-1 reanalysis data calculated with 2° x 2.5° resolution and ETA model forecasts calculated with 50-km resolution, and focus on the effect of spatial resolution on accuracy of the calculated meteorological fields. The resolution of 50 km is in the range of existing NWP and regional models, and the upper limit of current GCM resolution.

Results and Conclusions

- Spatial resolution plays an important role in improving accuracy of the calculated hydrodynamical fields. The ETA model forecast calculated with a resolution about 50 km is in better agreement with ARM observations than the GEOS-1 reanalysis calculated on a 2° x 2.5° grid.

- The time and spatial structure of temperature and water vapor mixing ratio are captured fairly well by both the regional ETA model and global GEOS-1 GCM.

- Precipitation and wind patterns are significantly better in the ETA model calculations with higher spatial resolution.

- Advective heat and moisture convergences are much more sensitive to the spatial resolution than basic meteorological variables like temperature and water vapor mixing ratio.

- The ETA model forecast fields are in reasonably good agreement with ARM IOP observations and can be used to initialize regional downscaling calculations with Regional Atmospheric Modeling System (RAMS) to produce detailed structure of the circulation and convection in the ARM site regions for the IOP periods.

In the future, we plan to conduct regional calculations using RAMS with different resolutions from 50 km (when cloud processes are parameterized) to 1 km to 2 km when nonhydrostatic convection is calculated explicitly. We will study the sensitivity of calculated cloud field and cloud radiative effects to the spatial resolution. We will initialize these calculations using ETA model forecast and analysis fields, available from National Center for Atmospheric Research (NCAR) since 1995, blended objectively with ARM soundings. In this work, we will extensively use ARM IOP data to initialize the calculations and test the results.

The study will contribute to the ARM SCM and cloud modeling group activities, and has important theoretical and practical applications to numerical weather prediction, regional climate modeling, and cloud-radiation interaction studies. We will work to improve convection, cloud, and radiation parameterizations in the important range of spatial resolutions suitable for regional climate modeling both with GCMs and limited-area models. We will test convective and radiation parameterizations in the NWP ETA model and three-dimensional nonhydrostatic RAMS with ARM IOP data and provide recommendations to improve ETA and RAMS cloud and radiation parameterizations.