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Impacts of cloud microphysics and radiation on the cloud and precipitation in a simulated Meiyu-frontal system

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Meiyu frontal system that formed and moved over the Huai River basin of China on 7-8 July 2007 is investigated using weather radar observations, Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar and CloudSat Cloud Profiling Radar measurements, and brightness temperatures from the MTSAT-1R satellite. These results are used to evaluate cloud-resolving simulations performed using the Weather Research and Forecasting (WRF) model. Sensitivity experiments are conducted to explore impacts of cloud microphysics and radiation on the cloud and precipitation structure.

At its mature stage, the observed convective system consisted of a west-east oriented leading convective line with stratiform precipitating and non-precipitating cloud regions trailing off to the north and east. While the cloud system extending hundreds kilometers from west to east, the widths of the convective and stratiform raining regions are of 10-20 km and 100-200 km, respectively. During the system's development stage, newer convection occurred on the western edge of the convective line. The convective centers progressed through a period of rapid growth when propagated eastward, with echo tops penetrating to maximum heights of 16-km, then decreasing to height of 13-km, which corresponds to the height of the stratiform precipitating cloud top with which the convective elements merged at the end of their lifetimes.

Results from four simulations are analyzed: CONTROL, Lin, Thompson, and noRad. The three sensitivity experiments are identical to CONTROL except that the Lin and Thompson simulations employ the 1-moment microphysics schemes of Lin and Thompson, respectively, rather than the 2-moment microphysics scheme of Morrison as in CONTROL, and the noRad simulation turns off the radiative cooling/warming effect.

The CONTROL reasonably reproduces not only the magnitude and spatial distribution of the accumulated surface precipitation, but also the evolution of the leading convective lines and trailing stratiform cloudy regions revealed by the observations. In contrast, the Lin and Thompson simulations produce too small regions of stratiform precipitation that dissipate too fast, resulting in underestimate in the accumulated stratiform precipitation. They also produce more intense convection, causing larger maxima of the total precipitation rate than the CONTROL and observations. In the noRad simulation, the total surface precipitation rate is reduced by 14% compared to CONTROL.

To explore the impacts of cloud microphysics schemes and radiation on the clouds and precipitation, interactions among the cloud dynamical, microphysical and radiative processes in the four simulations are analyzed and compared, including the transport of condensate from the convective region to the stratiform region, the depositional growth due to meso-scale updrafts in the stratiform cloud, the convective updrafts/downdrafts, as well as the rain evaporation rate and radiative cooling rate in the convective and stratiform regions, respectively.