Impact of Precipitating Ice Hydrometeors on Longwave Radiative Forcing Estimated by a Global Cloud-system Resolving Model

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Satellite observation and general circulation model (GCM) studies suggest that precipitating ice makes non-negligible contributions to the radiation balance of the earth. However, precipitating ice is diagnosed and its radiative effect is not taken into account in most of GCMs. Here we examine the longwave radiative impact of precipitating ice using a global non-hydrostatic atmospheric model (NICAM) with a double-moment cloud microphysics scheme. The simulation reproduces observed distributions of clouds, as shown by the figure; Figure shows meridinal distributions of ice water content (IWC) for all ice hydrometeors, and IWC attributed to cloud ice, snow, and graupel. CloudSat-observed IWC from June to August 2004. IWC is in mg m−3. Also shown is the meridional distribution of effective radius (Re) for cloud ice, snow, and graupel, in μm. Black and gray lines denote temperature in K and pressure in hPa, respectively.

An offline radiation model is employed to break down cloud radiative effects into amount and altitude of each ice category. Results show that the snow radiative effect reaches 2 W m^{-2} in the tropics, which is about half that estimated by previous studies. This effect is strongly dependent on the vertical separation of ice categories, and it is partially generated by differences in terminal velocities, which are not represented in GCMs with diagnostic precipitating ice. Results from sensitivity experiments that change the categories and the existing altitudes of precipitating ice showed that the simulated longwave heating profile and longwave radiation field are sensitive to the treatment of precipitating ice in models. The long-term circulation behavior in models may change due to the heating behavior changes. This study emphasizes that it is the important for cloud and radiation schemes in GCMs to incorporate appropriate treatments for the radiative effects of precipitating ice in order to simulate cloud radiative effect by upper-level clouds.

Interannual variability of high clouds and their future changes will also examined by comparing NICAM simulations and observations.

Keywords: cloud ice, cloud resolving model, radiation, Nonhydrostatic Icosahedral Atmospheric Model