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Sensitivity of ice-phase cloud microphysics in the NCAR WRF Model

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Two advanced bulk cloud microphysics schemes, namely, Thompson and Morrison schemes, are evaluated based on observations gathered from the Tropical Warm Pool International Cloud Experiment (TWP-ICE). Because of large uncertainties related to observational retrievals during the “wet” monsoon period (January 17-25, 2006), we have focused on the subsequent “dry” monsoon period (January 26 to February 2, 2006), when deep convections are absent. Compared with the 35-Ghz millimeter wavelength cloud radar (MMCR) and NASA satellite retrievals, all BCMSs tend to simulate more high-level cirrus clouds during the “dry” monsoon period. Therefore, sensitivity tests are carried out to evaluate the issues associated with the ice-phase cloud microphysical parameterizations.

Three sensitive tests are carried out to investigate the sensitivity of 1) the maximum number of cloud ice concentration (referred to as the intercept parameter, IP), 2) prescribed size distributions (SD) of cloud ice (Thompson scheme only), and 3) the empirical functions of water and ice saturation threshold (ST). One suite of “convective resolving or cloud-permitting” (4.0 km) simulations of the TWP-ICE “dry” monsoon period illustrates the significant difference among simulated cirrus cloud fraction, cloud ice, snow, and graupel contents for both Thompson and Morrison schemes. These differences are further investigated in another suite of high-resolution “cloud-resolving” (1.5 km) simulations for five days within the TWP-ICE “dry” monsoon period. Based on “cloud-permitting” simulations, we found that Thompson scheme is not sensitive to gamma or exponential SD. Hence the following results are for the exponential SD only. Thompson scheme is more sensitive to ST than Morrison scheme, especially when the temperature drops below minus 40-60oC. Morrison scheme is more sensitive to IP than Thompson scheme. Based on “cloud-resolving” simulations, we found that the above sensitive dependencies on IP and ST for Thompson and Morrison schemes become diminished at high vertical and horizontal resolutions, which infers the importance of future generations of “cloud-resolving” models. Future work is inferred also with respects to other ice-phase cloud microphysical constraints, such as terminal velocities of ice/snow/graupel hydrometros and cloud ice nucleation processes, including explicit aerosol interactions.

Keywords: Cloud Microphysics; High-Resolution Cloud Modeling; Cirrus Clouds; Cloud Ice Number Concentration; Cloud Ice Size Distribution