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Budget Comparison of Parameterized Microphysical Processes in Tropical Cyclone Simulations

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Despite the fact that microphysics parameterization schemes used in numerical models for tropical cyclone (TC) prediction can be as complex as being capable of resolving the evolution of hydrometeor size spectra, operational centers still cannot computationally afford to run any TC prediction models with spectrum-resolving schemes operationally. To strike an optimal balance between computational cost and physical effect, there is a need to understand what minimal complexity of microphysics parameterizations is required in operational TC prediction models that are run at affordable resolutions. In order to address this need, we have been investigating whether or not the microphysics schemes currently used in NOAA's operational TC models are complex enough to enable us to use these models for high-resolution prediction of tropical cyclones.

In this study, we used the Weather Research and Forecasting (WRF) model to investigate the impact of parameterized warm-rain processes in four widely-used bulk microphysics parameterization schemes on the model-simulated tropical cyclone (TC) development. The schemes investigated, ranging from a single-moment simple 3-category scheme to a complex double-moment 6-category scheme, produce different TC intensification rates and average vertical hydrometeor distributions, as well as different accumulated precipitation. By diagnosing the source and sink terms of the hydrometeor budget equations, we found that the differences in the warm-rain production rate, particularly by conversion of cloud water to rain water, contribute significantly to the variations in the frozen hydrometeor production and in the overall latent heat release above the freezing level. These differences in parameterized warm-rain production reflect the differences of the four schemes in the definition of rain droplet size distribution and consequently in spectrum-dependent microphysical processes, such as accretion growth of frozen hydrometeors and their sedimentation. We will show that the hydrometeor budget analysis of the four schemes indicates that the assumed pathways to the production of frozen hydrometeors are quite sensitive to the amount of available super-cooled rain water and, thus, the uncertainties in the parameterized warm-rain processes can affect the intensification and structure of the model-simulated tropical cyclone. Furthermore, we will show that the results from this study strongly suggest that the advantage of double-moment formulations can be overshadowed by the uncertainties in the spectral definition of individual hydrometeor categories and spectrum-dependent microphysical processes.