Impacts of aerosol-cloud interactions on simulated thunderstorm events over Metro Manila and Ilocos Norte, Philippines

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ABSTRACT

Aerosols play a significant role in regulating earth's climate by acting as cloud condensation nuclei and influencing the planet's radiative balance. They enhance or suppress precipitation depending on meteorological conditions. This study investigated the effects of varying aerosol concentrations on precipitation and cloud microphysics of simulated convective systems over Ilocos Norte and Metro Manila formed in the months of June, July, and August of 2019 and 2020. Using Chemistry-coupled Weather Research and Forecasting (WRF-Chem) model with the framework of Morrison Two-Moment Bulk Microphysics Scheme, three cases - clean, control, and polluted - were simulated and analyzed for their effect in the timing and rain rates, as well as the distribution of cloud droplets, ice, and other water particles at different heights in the atmosphere. The simulations reproduced the observed seasonal rainfall magnitude reasonably well over Ilocos Norte, while larger differences were found over Metro Manila. Across both domains, rainfall generally peaked during the afternoon, with varying aerosol concentrations having little effect on the timing of peak precipitation, but modifying rainfall intensity and precipitation efficiency. The clean scenario produced larger droplets and more efficient warm-rain formation, resulting in earlier and more frequent light rainfall. Higher aerosol loading (polluted scenario) increased cloud droplet concentrations, suppressed collision–coalescence, and favored the upward transport of condensates, strengthening mixed-phase processes and producing less frequent but more intense rainfall. These responses were observed to be stronger over Metro Manila, where aerosol loading was higher and hydrometeor structures were more vertically extensive. In contrast, Ilocos Norte exhibited weaker aerosol sensitivity and more efficient warm-rain processes. The results demonstrate that aerosol effects on thunderstorm precipitation are nonlinear and environment-dependent, highlighting the importance of representing aerosol–cloud–precipitation interactions in numerical weather prediction and climate models.

Keywords*: aerosols, cloud microphysics, precipitation, WRF-Chem*