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Role of CCN representation in simulating an Extreme Rainfall event over Chennai (India) in WRF

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Extreme rainfall events are strongly influenced by aerosol-cloud interactions (Lin et al., 2018); however, the representation of aerosols in convection-permitting numerical weather prediction models remains highly uncertain due to computational constraints. This study examines the influence of cloud condensation nuclei (CCN) representation on the December 2015 extreme rainfall event over Chennai (India), using a high-resolution Weather Research and Forecasting (WRF) model.

CCN concentrations for the event are derived from long-term MERRA2 reanalysis data. A high-resolution CCN map was generated within the innermost 1-km domain to capture the urban-scale aerosol characteristics over the Chennai metropolitan region. Three sensitivity experiments are conducted: a baseline simulation using long-term CCN data (BASE-Exp), and two additional experiments in which CCN levels are reduced by factors of 10 (BASEby10-Exp) and 100 (BASEby100-Exp), respectively. These reductions are implemented to represent below-cloud aerosol scavenging processes prior to the event (Laakso et al., 2003). The results demonstrate a strong sensitivity of simulated rainfall to CCN loading in the region, with reduced CCN simulations exhibiting improved agreement with GPM-IMERG rainfall observations. Relative to the BASE-Exp, the mean rainfall bias over the region is reduced by approximately 21% in BASEby10-Exp and 26% in BASEby100-Exp.

With the growing rise of extreme rainfall events in the future, these findings highlight the importance of CCN representation in operational weather forecasting models for improved simulation of extreme rainfall.