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Machine-learning the parcel-model simulations of the paths from aerosols to raindrops: activation, condensation, and collision-coalescence

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Processes that convert small cloud droplets, on the order of tens of micrometers, into raindrops, on the order of millimeters, consist of condensational growth and collision-coalescence: the former is efficient for small droplets, whereas the latter becomes predominant later in the growth stage when droplets are larger than about 30 micrometers. Thus, how droplets can quickly grow to 30 micrometers solely by inefficient condensation has been a topic of discussion for a long time. As a result, many parameterizations used in current models that cannot directly resolve these processes are actually based on empirical estimates. Recently, some studies have shown the impact of turbulences that can enhance collision-coalescence for droplets smaller than 30 micrometers, explaining the fast growth of cloud droplets into raindrops as observed. We have implemented these new equations of collision-coalescence in a parcel model where the activation of aerosol particles and their condensational growth are also explicitly calculated based on physical equations across numerous size bins. After the successful implementation of these processes, we have then applied machine-learning algorithms of training a machine to mimic the behavior of the explicit physical model to model-simulated mass and number of raindrops alongside ten dynamical and microphysical variables as input features. The machine-learned results are also compared with those from existing parameterizations frequently used in regional and climate models. Furthermore, the use of this new machine-learning-based parameterization, covering processes from aerosol activation to the formation of raindrops, in a regional model will be discussed.