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Approximation error correction for drizzle formation in bulk microphysical parameterizations

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The so-called autoconversion is a key numerical process used to describe the coalescence growth of cloud droplets to drizzle and rain in atmospheric models. Together with further growth of drizzle through accretion, these processes are typically represented by relatively simple two-moment bulk parameterizations. One of the shortcomings of this approach is that most often the parameterizations do not explicitly consider the impact of coarse mode aerosol and giant cloud condensation nuclei (GCCN), even though they are known to be important in marine cloud regimes. More elaborate sectional models, such as the Sectional Aerosol Module for Large-Scale Applications (SALSA) solve the coalescence growth equations and are able to account for the effect of large aerosol particles on droplet growth and drizzle formation.

In this work, the autoconversion and accretion rates diagnosed from SALSA are compared with the process rates from bulk parameterizations run simultaneously within a large-eddy simulation model (UCLALES-SALSA). The model is used to create an ensemble of simulations comprising varying aerosol conditions in terms of the coarse mode particles in marine stratocumulus and shallow cumulus regimes. The difference between SALSA and bulk process rates is taken as the approximation error in the bulk parameterizations. The dependence of this error term on the coarse mode aerosol concentration is shown by a multivariate sensitivity analysis based on the ensemble data. Further, machine learning methods, notably the neural networks, are used to represent the approximation error term. The trained networks are shown to successfully capture the main features of the model-based approximation error. As an outlook, the machine learning-based representation of the approximation error allows to enhance the existing bulk microphysical parameterizations for drizzle formation and to introduce an explicit dependence on coarse model aerosol and GCCN.