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Retrieval of cloud and drizzle microphysical properties using ground-based radar, lidar, and microwave radiometer

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Owing to their large aerial extent, low-level liquid water clouds have a strong impact on the Earth's energy balance. Observations of these clouds to characterize the microphysical and radiative processes are therefore needed for climate studies. In such clouds, drizzle is recognized to be a common occurence and an accurate retrieval of the cloud physical properties has to account for its possible presence. We develop a retrieval technique that exploits the synergy of different remote sensing systems to simultaneously profile the cloud and drizzle properties using ground-based measurements of radar reflectivity, lidar attenuated backscatter and microwave brightness temperatures. This technique first identifies the presence of drizzle above the cloud base in an optimized and a physically-consistent manner. Subsequently, physical forward models, coupled to cloud and drizzle structure parametrization are used in an optimal-estimation type framework to derive the best-estimate for the cloud and drizzle properties as a function of height. The cloud retrieval is evaluated using simulated signals generated from large-eddy simulation output, from which it is found that the cloud properties can be retrieved within 5% of the mean truth. The full cloud-drizzle retrieval method is then applied to a selected ACCEPT campaign that took place in the Fall of 2014 in Cabauw, the Netherlands. One-to-one comparisons with three independent cloud-only or drizzle-only retrieval methods from the literature show that the results of our method are generally consistent with what is derived using the three independent methods.