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A Depolarisation lidar based method for the determination of liquid-cloud microphysical properties

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The fact that polarisation lidars measure a depolarisation signal in liquid clouds due to the occurrence of multiple-scattering is well-known. The degree of measured depolarisation depends on the lidar characteristics (e.g. wavelength and receiver field-of-view) as well as the cloud macrophysical (e.g. cloud base altitude) and microphysical (e.g. effective radius, liquid water content) properties. Efforts seeking to use depolarisation information in a quantitative manner to retrieve cloud properties have been undertaken with, arguably, limited practical success. In this work we present a retrieval procedure applicable to clouds with (quasi-)linear liquid water content (LWC) profiles and (quasi-)constant cloud droplet number density in the cloud base region. Thus limiting the applicability of the procedure allows us to reduce the cloud variables to two parameters (namely the derivative of the liquid water content with height and the extinction at a fixed distance above cloud-base). This simplification, in turn, allows us to employ a fast and robust optimal-estimation inversion using pre-computed look-up-tables produced using extensive lidar Monte-Carlo multiple-scattering simulations. In this paper, we describe the theory behind the inversion procedure and successfully apply it to simulated observations based on large-eddy simulation model output. The inversion procedure is then applied to actual depolarisation lidar data corresponding to a range of cases taken from the Cabauw measurement site in the central Netherlands. The lidar results were then used to predict the corresponding cloud-base region radar reflectivities. In non-drizzling condition, it was found that the lidar inversion results can be used to predict the observed radar reflectivities with an accuracy within the radar calibration uncertainty (2–3 dBZ). This result strongly supports the accuracy of the lidar inversion results. Results of a comparison between ground-based aerosol number concentration and lidar-derived cloud droplet number densities are also presented and discussed. The observed relationship between the two quantities is seen to be consistent with the results of previous studies based on aircraft-based in situ measurements.