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Using the sub-adiabatic model as a concept for evaluating the radiative effects of low-level clouds in a High-Resolution Model

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Clouds play a crucial role in the global energy budget via their shortwave (SW) and longwave (LW) radiative effects. Despite decadal efforts, the processes and climate impact of clouds have not been reliably assessed, partly owing to incomplete understanding of their properties and their corresponding distributions (IPCC, 2013). A widely used approximation in most General Circulation Models (GCMs) is the so-called plane-parallel model for the parameterization of clouds (Di Giuseppe and Tompkins, 2003). Accordingly, the computation of cloud radiative effects is conducted not fully accounting horizontal and vertical internal heterogeneities. Hence, in order to enhance the scientific understanding of different cloud types and improve their representation in General Circulation Models (GCMs), high-resolved simulations should be employed. Our aim is to assess the capability of the high-resolved ICON-LEM (ICOsahedral Nonhydrostatic Large Eddy Model) atmospheric model that recently developed within the HD(CP)2 (High Definition Clouds and Precipitation for advancing Climate Prediction) project (Dipankar et al., 2015, Heinze et al., 2017) to realistically simulate low-level clouds and to accurately represent the resulting cloud radiative effects. In this work, we illustrate that the vertical variability of the cloud microphysical properties is well approximated with the sub-adiabatic model for the computation of the cloud radiative effects with a special emphasis on low-level liquid water clouds. Within this conceptual model, the key quantities are the droplet number concentration, the sub-adiabatic fraction, the cloud geometrical thickness, and the liquid water path, which determines the cloud optical depth. For the aforementioned quantities, the uncertainties in their derivation are interpreted and their impact to the computation of the radiative effects is assessed. The latter enables us to attribute errors in the cloud radiative effects to errors in the model representation of clouds. For the radiative transfer simulations the RRTMG model has been employed. Results are presented for two cases as simulated by ICON-LEM: an overcast of low-level clouds and a broken cloud field. Correlations between the cloud radiative effects and cloud properties are also shown.