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Entrainment and anisotropic turbulence in the stratocumulus-topped boundary layer: A large-eddy simulation study

Jesper G. Pedersen and Szymon P. Malinowski
Institute of Geophysics, University of Warsaw, Warsaw, Poland

Recent analysis of data from the Physics of Stratocumulus Top (POST) field campaign indicate that turbulence in the interfacial layer between the cloud top and the free troposphere (FT) is generally anisotropic at scales larger than approximately 1 m. Motivated by this finding, we perform series of high-resolution large-eddy simulations to study details of small-scale processes in the cloud-top region with focus on entrainment and turbulence anisotropy. The POST data set includes examples of the classical stratocumulus-topped boundary layer (STBL) characterized by a strong inversion separating the moist STBL from a stable and dry FT, as well as of the non-classical STBL with different characteristics.
Simulations are based on data from flight 1 of the DYCOMS-II campaign, which is considered a classical STBL case, and from flight 13 of the POST campaign considered a non-classical case. The applied vertical grid spacing is on the order of meters, and in both sets of simulations we find that decreasing the ratio between horizontal and vertical grid spacing towards unity makes the simulated cloud-top turbulence increasingly isotropic. In simulations with cubic or nearly cubic grid boxes, isotropy over a wide range of scales leads to high entrainment rates tending to reduce the domain-averaged liquid water path, and in some simulations nearly dissolve the cloud completely. This is most pronounced in the classical STBL case. Simulations are performed with the 3D nonhydrostatic anelastic Eulerian/semi-Lagrangian (EULAG) model, and we discuss results from both conventional large-eddy simulation and implicit large-eddy simulation.