Geophysical Research Abstracts
Vol. 17, EGU2015-6032, 2015
EGU General Assembly 2015


# Parameterization of precipitating shallow convection

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Shallow convective clouds play a decisive role in many regimes of the atmosphere. They are abundant in the trade wind regions and essential for the radiation budget in the sub-tropics. They are also an integral part of the diurnal cycle of convection over land leading to the formation of deeper modes of convection later on. Errors in the representation of these small and seemingly unimportant clouds can lead to misforecasts in many situations. Especially for high-resolution NWP models at 1-3 km grid spacing which explicitly simulate deeper modes of convection, the parameterization of the sub-grid shallow convection is an important issue.
Large-eddy simulations (LES) can provide the data to study shallow convective clouds and their interaction with the boundary layer in great detail. In contrast to observation, simulations provide a complete and consistent dataset, which may not be perfectly realistic due to the necessary simplifications, but nevertheless enables us to study many aspects of those clouds in a self-consistent way. Today's supercomputing capabilities make it possible to use domain sizes that not only span several NWP grid boxes, but also allow for mesoscale self-organization of the cloud field, which is an essential behavior of precipitating shallow convection.
By coarse-graining the LES data to the grid of an NWP model, the sub-grid fluctuations caused by shallow convective clouds can be analyzed explicitly. These fluctuations can then be parameterized in terms of a PDF-based closure. The necessary choices for such schemes like the shape of the PDF, the number of predicted moments, etc., will be discussed. For example, it is shown that a universal three-parameter distribution of total water may exist at scales of O(1 km) but not at O(10 km).
In a next step the variance budgets of moisture and temperature in the cloud-topped boundary layer are studied. What is the role and magnitude of the microphysical correlation terms in these equations, which govern the evolution of the convective boundary layer? Being able to parameterize these processes would make it feasible to formulate a higher-order closure boundary layer scheme that includes sub-grid precipitating shallow convection.
Finally, it is shown that the stochastic variability cannot be ignored for shallow convection as the variance of the process rates is larger than the ensemble mean at km-scale grid spacings. Possible approaches to include stochasticity in mass flux or higher-order closure schemes are discussed.