Project: **682**

Project title: **Large-eddy simulations of cloud and convective processes**

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The project takes place at the Max Planck Institute for Meteorology at the Hans Ertel Zentrum for clouds and convection, which benefits of a funding from BMVI (Federal Ministry of Transport and Digital Infrastructure). After a successful first phase (2011-2014) the project has been renewed for a second phase (2015-2018).

The overall goal of the project is to improve our understanding and modeling ability of cloud and convective processes using large-eddy simulations (LES) and a multi-resolution approach. Comparison of simulations performed at various resolutions especially allows a better understanding of biases that arise at lower resolution due to poorly resolved or incorrectly parameterized processes. Main focuses in 2014-2015 lay on the representation of a cold air outbreak, on the formulation of a stochastic scale adaptive shallow convection scheme based on LES results, and on the development of deep convection.

We participated in the WGNE/GASS "Grey Zone" project, which examines the scale dependency of current convection and boundary layer parameterizations in model run with resolutions from 1 to 10 km for a cold air outbreak. Simulations have been performed with the large-eddy simulation model UCLA-LES and with the global model ICON. The results of these simulations have been compared to each other and to the results of other models participating in the Grey Zone project. The findings were presented, discussed and summarized in an international workshop that we organized in December 2014 (see http://www.mpimet.mpg.de/en/science/the-atmosphere-in-the-earth-system/working-groups/clouds-and-convection/wgnegass-workshop-the-grey-zone-project.html).

Our stochastic scale-aware parameterization of shallow cumulus clouds for use in the ICON model on a range of horizontal model resolutions has been further developed and shown to perform well for a case of isolated shallow convection over the ocean (Sakradzija 2015). The parameterization bases on the microscopic statistics of the cloud ensemble derived from UCLA-LES. As a next step we considered a case of shallow convection that organizes over the ocean. The cloud ensemble statistics from the LES is shown in Fig. 1. It can be clearly seen how the distribution of cloud mass flux changes as organization sets in after 36 hours of simulation.

On the deep convection side, interactions between surface heterogeneity and the development of deep convection have been investigated (Rieck 2015). Earlier results showed that surface heterogeneity can accelerate the development of deep convection through the generation of thermally induced circulations (Rieck et al. 2014). But the developing convection was found to also strongly affect the characteristics of the thermally induced circulation, both through a dynamical effect of clouds and through a thermodynamical effect of cold pools. The latter are generated by evaporation/melting of hydrometeors. Furthermore the relative importance of heterogeneity present at the land surface, due to different surface conditions (e.g., forest versus grass), and of heterogeneity generated by falling precipitation, has been quantified.

Our work on the effects of cold pools on the development of deep convection has been published (Schlemmer and Hohenegger 2014). As a new direction we started to perform coupled convection-permitting (grid spacing of 3 km) simulations to investigate the effect of interactive sea surface temperature (SST) on the organization of deep convection. To that aim an ocean mixed layer model was coupled to the UCLA-LES model. The coupling affects the organization of convection and leads to a much slower organization of convection (Hohenegger and Stevens 2016). Moreover the simulation has been run until an equilibrium state was reached (180 days) and compared to a simulation using a similar experimental set-up but performed with the ECHAM6 model at lower resolution (T63) and with parameterized convection. The two models support a distinct equilibrium state. The equilibrium state of ECHAM6 is significantly colder and moister than UCLA-LES due to the production of numerous clouds by the parameterized cloud cover scheme in ECHAM6.

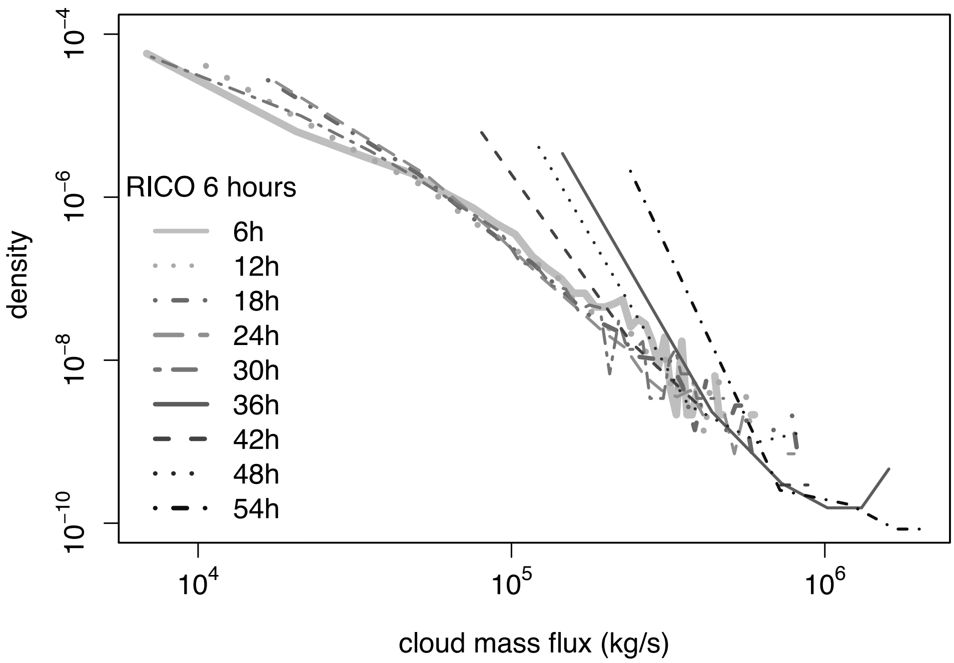

Fig. 1 Probability density of cloud mass flux from a LES simulation with 2048x2048 grid points in the horizontal and a grid spacing of 25 m.

Publications

Hohenegger C. and B. Stevens, 2016: Coupled radiative convective equilibrium simulations with explicit and parameterized convection. *J. Adv. Model. Earth Syst. Sci.*, to be submitted.

Rieck M., 2015: The role of heterogeneities and land-atmosphere interactions in the development of moist convection. *Reports on Earth System Science*, **167**, 95 pp.

Rieck M., C. van Heerwaarden and C. Hohenegger, 2014: The influence of land surface heterogeneity on cloud size development. *Mon. Wea. Rev.*, **142**, 3830-3846.

Schlemmer L. and C. Hohenegger, 2014: The formation of wider and deeper clouds as a result of cold-pool dynamics. *J. Atmos. Sci.*, **71**, 2841-2858.

Sakradzija M., 2015: The role of heterogeneities and land-atmosphere interactions in the development of moist convection. *Reports on Earth System Science*, **167**, 95 pp.