Project: **620**

Project title: **Multiskalen-Simulationen mit EULAG**

Project lead: **Andreas Doernbrack**

Report period: **1.1.2014 - 31.12.2015**

Most of the computer time was used to study the self-aggregation in the master thesis of Antonia Kempf and to develop new approaches to parameterize entrainment and detrainment of ensemble of cumulus clouds (subproject called EUL-MES). Results of the later simulations were the basis of the PhD thesis of Katrin Scheufele which results are reported here in form of the following summary.

A theoretical model describing equilibrium fluctuations within a field of cumulus clouds is the basis for a stochastic parameterisation of cumulus convection. High-resolution simulations of an idealised ensemble of cumulus clouds over a uniform sea surface wre performed to validate the theoretical model in radiative-convective equilibrium. First, a set of control simulations with a horizontal resolution of 2 km was conducted by applying five different radiative cooling rates in the range of -2 K/day to -12 K/day. Evaluating fluctuations within the equilibrium convective ensembles, the frequency distributions of cloud size and cloud vertical mass flux were validated to fit an exponential over a wide range of heights as well as the entire range of the prescribed forcing. Furthermore, a linear increase of the number of clouds in the domain with the magnitude of the prescribed forcing was obtained. In contrast, only a weak dependence on the forcing was observed for cloud size and cloud vertical velocity. These findings agree well with the theoretical model.

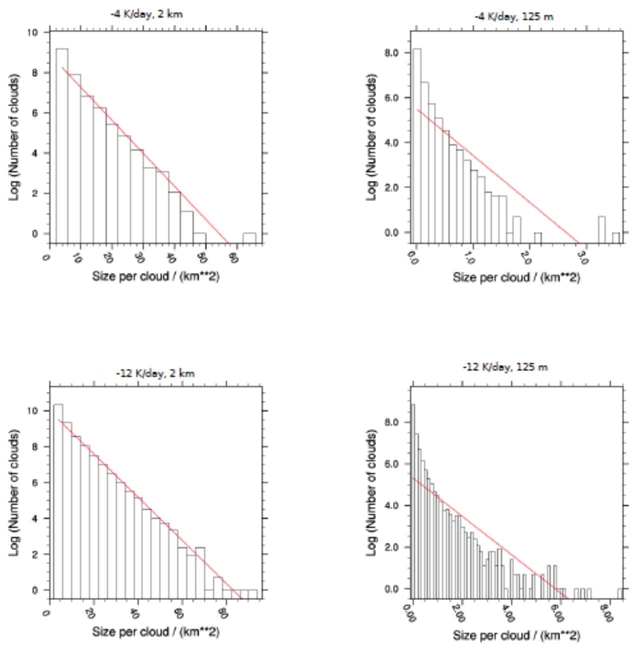


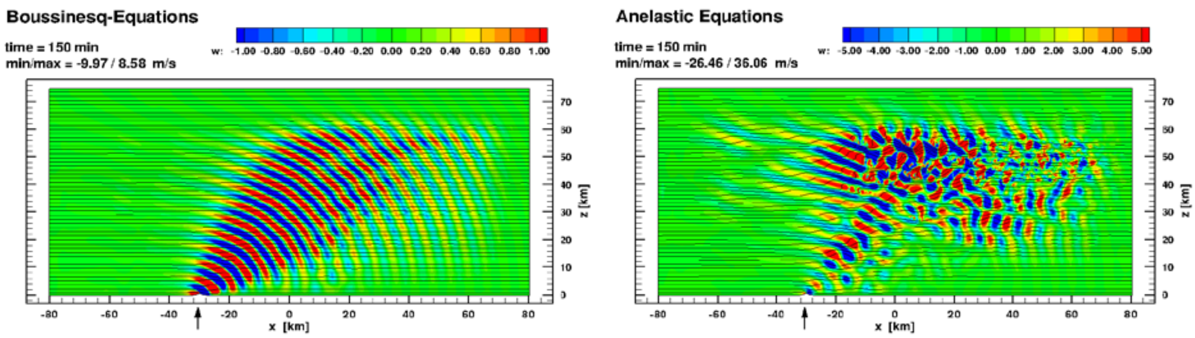
Figure 4.12: Histograms of the cloud size frequency distribution in log-linear space for -4 K/day (top) and -12 K/day (bottom) simulations at 2 km (left) and 125 m resolution (right). Red lines denote least squares best fits to the cloud data in log-linear space.

In the second part of this study, the full set of control simulations is repeated with smaller grid spacings of 1 km, 500 m, 250 m and 125 m. Significant changes in cloud statistics and the structure of the cloud fields were obtained. Cloud size systematically decreases, whereas the number of grid points per cloud increases as the clouds and their turbulent, subcloud processes become better resolved with increasing resolution. In contrast to the randomly distributed cloud fields in the control simulations, clouds were observed to cluster and organise in band-like structures around cloud-free areas in the high-resolution simulations. This clustering of convective clouds in the near-cloud environment systematically increases with increasing horizontal resolution. However, the area surrounding each cloud where the clustering occurs, was found to be insensitive to changes in the grid spacing. Furthermore, strong deviations from the exponential distributions become apparent at smaller grid spacings. A transition from an exponential to a power law-like distribution is observed for cloud size and cloud mass flux with increasing horizontal resolution. However, applying a cloud search algorithm that separates large clusters of spatially connected clouds into their single updrafts, restores the exponential distributions of cloud mass flux and cloud size. Thus, the theoretical model was validated in this resolution-sensitivity study when partitioning large cloud clusters into the single updrafts.

K. Scheufele, 2014: *Resolution dependence of cumulus statistics in radiative-convective Equilibrium*, PhD Thesis, LMU München.

Kempf, A., 2013: *Investigation of Self-Aggregation of Tropical Convection*, Master Thesis, LMU München.

Furthermore, computer time was used to study the vertical propagation of mountain waves into the middle atmosphere. This work is part of the project “Investigation of the life cycle of gravity waves (GW-LCYCLE)” (PI: M. Rapp) in the BMBF-initiative ROMIC[1] and of the project “Modification of gravity waves propagating across the tropopause” (PIs: A. Dörnbrack, P. Spichtinger, R. Klein) in the DFG research group MSGWaves (Multiscale Dynamics of Gravity Waves). As these projects were focusing mainly on the experimental work (two conducted field campaigns in December 2013 and June/July 2014) during the recent months, the numerical simulations are still ongoing and will be pushed forward in the next months.



Numerical results of the deep vertical propagation of non-hydrostatic mountain waves in a Boussinesq fluid and and in anelastic flow (Master thesis H. Grogger).

[1] ROMIC: *Role of the middle atmosphere in climate*, a research initiative funded by the German Ministry for Education and Research.