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) for the period 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. The planned work was (i) to study the interactions between soil moisture and precipitation for isolated convective cells, (ii) to study the interactions between soil moisture and precipitation for organized systems (squall lines) and (iii) to further develop our stochastic shallow convection scheme. Work happened on all three topics (see Cioni and Hohenegger 2016, Peters and Hohenegger 2016, as well as Sakradzija and Hohenegger 2016), although we ended up doing the simulations related to (ii) on thunder and used the so saved computing time to perform further sensitivity experiments related to the topics of (i) and (iii).

Our first study focused on the feedback between soil moisture and precipitation. The goal was to determine under which conditions an increase in precipitation over drier soils (negative soil moisture-precipitation feedback) may occur. The work was inspired by an earlier study by Findell and Eltahir (2003) who showed that, depending on the atmospheric conditions, the triggering of precipitation may be favored over wet or over dry soils. Findell and Eltahir (2003) nevertheless didn't explicitly considered the effect on precipitation amounts. To that aim, the large-eddy version of the ICON model was coupled to a land-surface model and several idealised experiments mimicking the full diurnal cycle of convection were performed starting from different homogenous soil moisture conditions. The results pin point to the presence of a positive coupling regardless of the atmospheric state. Although convection can be triggered earlier over dry soils under certain atmospheric conditions, as in Findell and Eltahir (2003), total precipitation is found to always decrease over dry soils (see Fig. 1). Splitting the total precipitation response into its magnitude and duration component, it is found that the magnitude strongly correlates with surface latent heat flux, hence implying a positive feedback between precipitation magnitude and soil moisture. Changes in precipitation duration, due to the changes in convection triggering, on the other hand, can be either positively or negatively correlated to soil moisture. However these changes are too small to overcompensate the response of the precipitation magnitude, thus implying an overall positive feedback between soil moisture and total precipitation. These results were further validated using two additional atmospheric soundings and a series of perturbed experiments which considered the effect of cloud radiative effects, large-scale forcing, winds and plants. This study has been submitted to the Journal of Hydrometeorology (Cioni and Hohenegger, 2016).

For the study related to the stochastic shallow convective parameterization, we investigated the dependency of the statistics of the cumulus ensemble, in particular the distributions of cloud area, cloud base mass flux and cloud lifetime, on the chosen case set-up. Twelve LES cases were set up to represent different surface conditions and large-scale forcings. Different cases, especially cases of shallow convection over land versus shallow convection over ocean, were found to exhibit distinct distributions. These differences could be related to the sole value of the ratio between surface sensible heat flux and surface latent heat flux, the surface Bowen ratio. This ratio controls the efficiency of the moist convective heat cycle in the subcloud layer, which in turn sets the average mass flux per cloud. Other potential factors, like magnitude of surface fluxes, degree of convective organization, had no effect on the shape of the mass flux distribution. Based on these results, our stochastic parameterization of shallow clouds has been updated. The results have been written up and will be submitted soon (Sakradzija and Hohenegger, 2016).

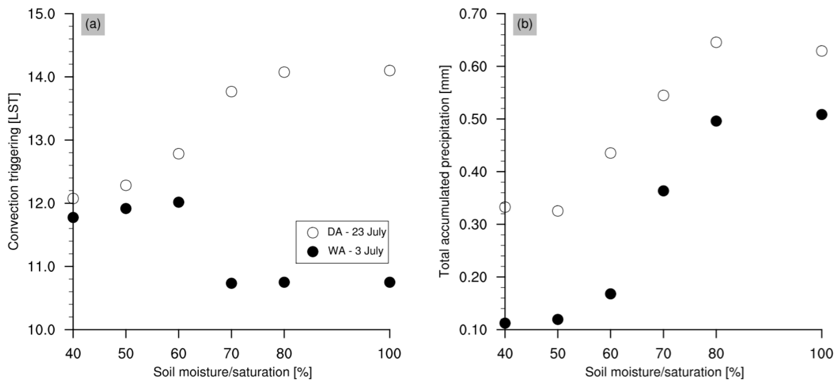

Fig. 1 (a) Time of convection triggering and (b) total accumulated precipitation for six simulations starting from different soil moistures and two different initial soundings (open and full circles). Note the potentially earlier triggering over dry soil for the 23 July case, although the precipitation amounts always increase with soil moisture.

Publications

Cioni, G. and C. Hohenegger, 2016: Effect of soil moisture on diurnal convection and precipitation in large-eddy simulations. *J. Hydromet.*, submitted.

Findell K. L. and E. A. B. Eltahir, 2003: Atmospheric controls on soil moisture-boundary layer interactions. Part I: framework development. *J. Hydromet*. **4**, 552-570.

Peters, K. and C. Hohenegger, 2016: On the Dependence of Squall Line Characteristics on Surface Conditions, *J. Atmos. Sci.*, submitted.

Sakradzija, M. and C. Hohenegger, 2016: What determines the distribution of shallow convective mass flux through cloud base?, to be submitted.