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 is funded by BMVI (Federal Ministry of Transport and Digital Infrastructure) for the period 2019-2022. The overall goal of the project is to improve our understanding and modelling ability of cloud and convective processes using large-eddy simulations (LES) and a multi-resolution approach. The planned work was first to study the circulations driven by radiative heating anomalies in the planetary boundary layer by using the stochastic representation of the shallow convection in a realistic and in an idealised setup. In the previous funding periods, we developed and tested the stochastic scheme performance in an idealized case study and for realistic continental conditions, while the experiments under oceanic conditions were not performed. In the report period of the year 2019, we first assessed the performance of our new stochastic shallow convection scheme in a realistic case over the Atlantic ocean by using the NARVAL simulation setup (Klocke et al., 2017), and second, in a global setup following the DYAMOND initiative (Stevens et al., 2019).

Our focus was to assess how the stochastic shallow convection scheme, which we developed using large-eddy simulations over the past allocation periods, interacts with the resolved flow dynamics and other atmospheric processes in a high-resolution configuration of ICON. These tests are using a realistic setup of ICON over the tropical Atlantic and are exploiting satellite observations to validate the model performance. We conducted multiple numerical experiments using different configurations of ICON to isolate the effects of different features of the convection scheme, such as disabling the limiters of the convective mass-flux or applying the stochastic perturbations to the mass-flux. Based on these tests, we demonstrated that our new stochastic scheme corrects the spatial and temporal distribution of cloudiness over the tropical Atlantic to a significant extent. The cloud cover is reduced by 20% on average and it matches the observed values more closely. By correcting the subgrid shallow convection, other processes in the modelled tropical Atlantic are also corrected. For example, the precipitation band in the Inter-Tropical Convergence Zone (ITCZ) matches the observations closely in the selected case study. The emphasis of these experiments was on a local interaction of the stochastic shallow convection and resolved deep convection in contrast to a well known remote effect that shallow convection in subtropics has on the deep convection in the ITCZ. These results are currently being prepared for a publication in collaboration with colleagues from TROPOS in Leipzig and DWD in Offenbach (Sakradzija et al., in preparation).

A disadvantage of the area-limited experiments is that the interactions with the large scale atmospheric flow can only be tested partially because the large scale circulation is imposed through boundary conditions and shallow convection cannot entirely feed back to the circulation. For this reason, we also performed preliminary global experiments following the setup of the DYAMOND initiative. These experiments are used to test the coupling of the stochastic shallow convection with the large scale circulations versus the local coupling between subgrid shallow and resolved deep convection. As local interactions proved to be extremely important and beneficial for resolved deep convection, we ask if the effects of the local interaction also translate to a large-scale interaction between the subgrid and resolved flow. Due to the high computational costs of the DYAMOND simulations, we limit the simulation period to only six instead of forty days. These experiments are still ongoing.

We also planned to investigate a second type of shallow circulation as related to the presence of cold pools. In this context and a first step we isolated cold pools in the DYAMOND simulations and compared their properties across models. The models exhibited vastly different cold pool properties. In the meantime we also gathered observations of cold pool properties in a test campaign that took place in Lindenberg in August 2019. As a next step, we will simulate some of the observed days with large-eddy simulations to assess the realism of the simulated cold pools.

Publications

Sakradzija, M., F. Senf, L. Scheck and D. Klocke, in preparation: Local interaction of subgrid shallow and resolved deep convection is the key for correct dynamics in tropical Atlantic.

Klocke, D., M. Brueck, C. Hohenegger and B. Stevens, 2017: Rediscovery of the doldrums in storm-resolving simulations over the tropical Atlantic. *Nat. Geoscience*, **10**, 891-896.

Stevens, B., Satoh, M., Auger, L., Biercamp, J., Bretherton, C., Chen, X., Dueben, P., Judt, F., Khairoutdinov, M., Klocke, D., Kodama, C., Kornblueh, L., Lin, S.-J., Putman, W., Shibuya, R., Neumann, P., Roeber , N., Vanniere, B., Vidale, P.-L., Wedi, N. & Zhou, L. (2019). DYAMOND: The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains. Progress in Earth and Planetary Science, Vol. 6: 61, doi:10.1186/s40645-019-0304-z