Project: **1137**

Project title: **Radiative Effects of Mixed-Phase Clouds Over the Oceans**

Principal investigator: **Anna Possner**

Report period: **2020-01-01 to 2020-12-31**

Due to special circumstance the resource report of this project is submitted before the end of the third quarter of the current allocation period. I am a young research group leader of a new group with two PhD students and two Masters students and will be on maternity leave from August 7th until the end of November 2020. This encompasses the normal submission times for project reports and resource requests of ongoing projects. Neither of my students is sufficiently advanced for this task, and thus I am grateful to DKRZ to offer me this opportunity of an early submission, which in this particular case will cover the period until July 31st 2020.

Resource Utilisation first two quarters (01.01. - 30.06.2020):

For the entire allocation period of 2020 a total resource budget of 128 kNh was granted, which corresponds to a resource allocation of 64 kNh during the first two quarters of this reporting period. This total resource allocation was split into an allocation for planned kilometre-scale simulations: 14 kNh (i.e. 7 kNh during reporting period), and semi-idealised cloud-resolving simulations: 114 kNh (i.e. 57 kNh during reporting period) for the "*Clouds, Aerosols, Precipitation, Radiation, and Atmospheric Composition over the Southern Ocean" (*CAPRICORN) field campaign. An overview of the requested and consumed resources for this reporting period is given in Table. 1.

Resources requested:	**64**
Kilometre-scale simulations	7
Cloud-resolving/LES simulations	57
Resources consumed:	**22**
Kilometre-scale simulations	22
Cloud-resolving/LES simulations	0
Resources expired	**42**

Table 1: Overview of resources during the 01.01.2020 – 30.06.2020 reporting period. All entries are given in kNode hours [kNh]. {Full resource utilisation is expected during second half of allocation period – see last paragraph}

Contrary to sub-tropical and Arctic stratocumulus, stratocumulus clouds in the Southern Ocean are embedded in regions of very strong advection. Wind speeds of up to 72km/h are not uncommon in this region. This strong advection posed unforeseen challenges in the setup and configuration of idealised cloud-resolving, or large-eddy simulations of limited domain size in these regions. Having reached out to collaborators at the University of Washington that were simulating a different case of Southern Ocean mixed-phase stratocumulus under similarly strong advection, it became clear that one had to impose considerable nudging tendencies throughout the simulation domain in order to keep the idealised setup stable under these strong advection conditions. It thus followed that our initial modelling strategy had to be revised and that instead a real-case nesting approach would be preferential under these conditions.

However, this meant that a more complete evaluation of the kilometre-scale simulations had to be performed before the far more computationally expensive high-resolution domains could be nested. Previously these sets of experiments were conceived as independent and could have been run in parallel. The more extensive evaluation before the grid nesting down to cloud-resolving scales, was again related to the strong advection. Even in domains of 900x900km2 in horizontal extent (which is larger than we budgeted for), the air mass will cross the domain in about half a day. This means that adjustments to boundary layer height and inversion strength, which typically adjust on timescales of 1-2 days (Bretherton et al. 2010) are unlikely to occur inside the high-resolution domain. Thus the cloud-resolving simulations would only capture rapid adjustments to boundary layer and cloud profiles occurring on the timescales of a few hours. Thus the kilometre-scale simulations had to be evaluated extensively first in order to provide realistic boundary conditions to the nested cloud-resolving model.

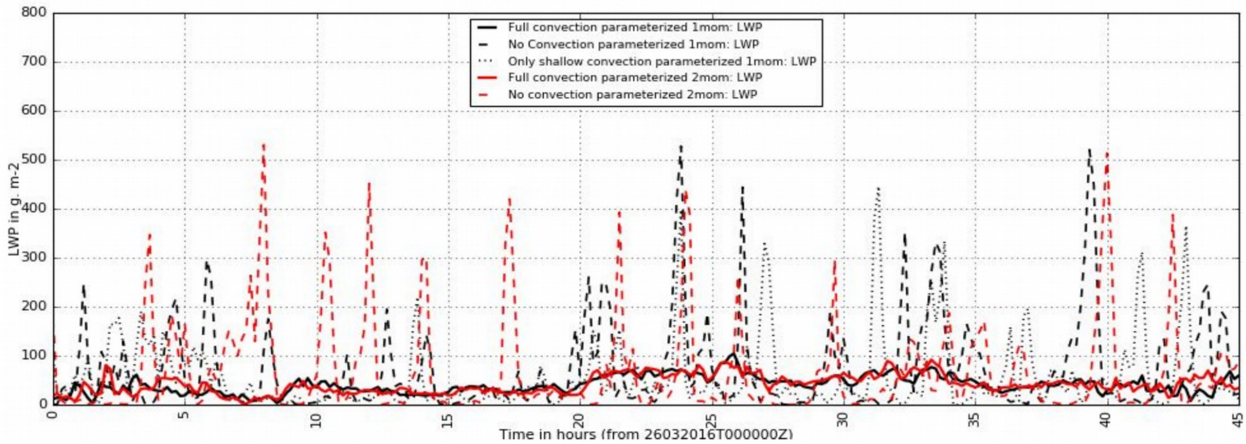
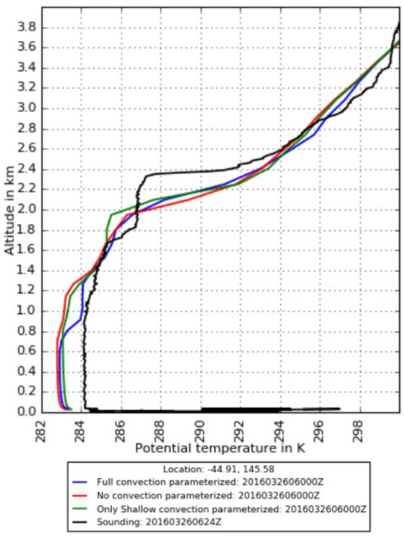


Figure 1: LWP variability along ship route for simulations utilizing 1-moment microphyics (black) and two-moment microphysics and different levels of parameterised convection.



In addition to developments of the microphysics scheme for primary and secondary ice formation within ICON, extensive testing was performed with respect to boundary layer parameterisation parameters and the representation of shallow convection. The overall cloud-variability is improved in all simulations not parameterising deep convection (Figure 1), showing the observed peaks in liquid water path (LWP) against a low background LWP. Meanwhile, a most realistic boundary layer structure is simulated when shallow convection is still parameterised (Figure 2). Albeit all simulations still estimate boundary layer depth.

Figure 2: Potential temperature profile for simulations with different levels of parameterised convection.

We thus only performed kilometre-scale simulations during the first two quarters of the allocation period (consumption of 22 kNh instead of the 7 kNh budgeted) and did not get to start any cloud-resolving simulations (consumption of 0 kNh of the budgeted 57 kNh). This necessary revision of the modelling strategy and unfortunate hold up of the planned resource intensive cloud-resolving simulations, lead to the net under-utilisation of resources of 42 kNh during the first two quarters.

<u>Resource Utilisation current quarter (01.07. - 31.07.2020):</u>

Within the current quarter (July – September 2020), we have started LES experiments and have already consumed 88% of the resource allocation for the 3rd quarter during the first month. We thus expect to fully utilise the requested resources for this project until the end of the year.

<u>References:</u>

Bretherton, C. S., Uchida, J., and Blossey, P. N. (2010), Slow Manifolds and Multiple Equilibria in Stratocumulus Capped Boundary Layers, *J. Adv. Model. Earth Syst.*, 2, 14, doi:10.3894/JAMES.2010.2.14.