Project: **1137**
Project title: **Radiative Effects of Mixed-Phase Clouds Over the Oceans**
Principal investigator: **Anna Possner**
Report period: **2023-01-01 to 2023-10-27**

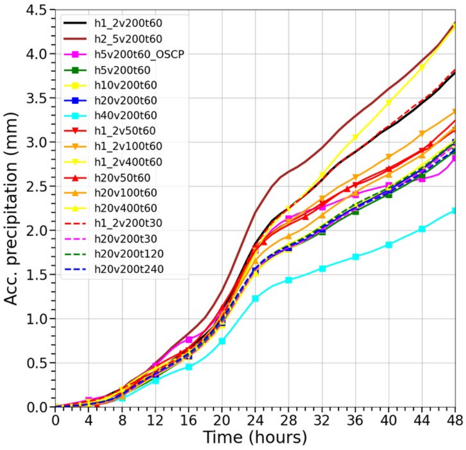
Resource Utilisation

Resources requested	14
Resources consumed	10
Resources expired (incl. in consumed)	2
Resources remaining	4

Table 1: Overview of resources during the 01.01.2023 – 31.10.2023 reporting period. All entries are given in kNode hours [kNh].

Around 2.8 kNh were used for major revisions incl. additional simulations for Possner et. al (in rev.) and Ramadoss et al. (in rev.). At this stage we anticipate publication of both studies during the remaining allocation period and no additional simulations.
An additional 1.4 kNh were used for the numerical ICON experiments exploring the resolution sensitivity of cloud physical processes and properties in Southern Ocean low clouds observed during CAPRICORN. An example of the findings is given below in section 1.
0,9kNh were used for a case study investigating the representation of marine stratocumulus at mesocale resolutions (~10km grid spacing) in ICON. Different numerical tests with respect to the triggering of shallow convection and cloud cover parameterisations were tested. The progress of these initial experiments is summarised in section 2.
The remaining 2 kNh were used for GOES analysis section 3.

Section 1: Sensitivity Experiments of Simulated Southern Ocean Precipitation Structures to Model Resolution



Vertical resolution (m)							
	400	h1.2v400t60				h20v400t60	
	200	h1.2v200t30	h2.5v200t60	h5v200t60	h10v200t60	h20v200t30	h40v200t60
						h20v200t60	
		h1.2v200t60		h5v200t60_OSCP		h20v200t120	
						h20v200t240	
	100	h1.2v100t60				h20v100t60	
	50	h1.2v50t60				h20v50t60	
		1.2	2.5	5	10	20	40
		Horizontal resolution (km)					

Figure 1: left: Time series of accumulated precipitation averaged over a 4°x4° degree domain centred on 46°S and 145°E in the Southern Ocean. right: Table of combinations of tested vertical (maximum grid spacing in the lowest 4km of the atmosphere) and horizontal resolution. Prescribed time step is given in the format tXXX (e.g t60 implies a timestep of 60s). "OSCP" stands for "Only Shallow Convection Parameterized"

Numerical experiments were conducted over a 72h period on a nested grid going from Domain-1 (outer domain) with 264948 cells at a horizontal resolution of 5 km to Domain-2 with 304100 cells at a resolution of 2.5 km to Domain-3 for which the statistics are shown in Figure 1. For coarser resolutions, the inner domains were dropped and the resolution of the outer domain increased.
The experiments show that increasing horizontal resolution below 10km has a strong impact on the simulated domain mean total water path and the fractional contribution of large frozen hydrometeors (i.e. graupel and snow). Above 10km, changes in horizontal resolution do not further impact this statistic. Meanwhile, increases in vertical resolution from a maximum grid spacing of 200m within the lowest 4km of the troposphere down to 50m significantly increase the

occurrence of cloud events, while the domain mean water path remains unchanged. Thus, increasing the vertical resolution yields to a more uniform broken cloud deck associated with overall lower total water paths and localised peaks in condensate+ice, which results in an overall lower accumulated precipitation amount (Figure 1). These results, will be published within a PhD thesis.

Section 2: Northeast Pacific Stratocumulus Sensitivity Experiments

Initial experiments with ICON investigating the representation of marine stratocumuli (Sc) in the subtropical north-east (NE) Pacific on the mesoscale show that ICON struggles to simulate low level Sc in this region in its default configuration. ICON's shallow convection parametrisation was identified to inhibit Sc formation in regions of stability. Thus, in further experiments we constrained the shallow convection parametrisation only to be active in regions where the estimated inversion strength (EIS) was below a critical threshold. Furthermore, adjustments in the cloud cover (CC) parametrisation, in which the diagnosed CC is now a function of EIS, were tested and found to decrease the bias in the CC.

The shown results indicate that ICON's ability to simulate marine Sc in the NE Pacific strongly depends on the specific conditions under which the shallow convection parametrisation is allowed to be active. Ongoing research includes statistical analysis of the impact of the critical EIS parameter on cloud properties, which will form the basis of a future scientific publication.

Section 3: Low Liquid Cloud Adjustments: A Perspective from GOES-East

We performed a statistical analysis of cloud adjustments for the South American stratocumulus deck using GOES-EAST retrievals between 10–30°S and 75–95°W. Here we tested the hypothesis to which extend the lateral detrainment of aerosol-perturbed clouds impacts the diagnostic of the liquid water path adjustment, which is mechanistically understood in terms of vertical mixing and entrainment of free tropospheric air.
Since the recovery of cloud physical properties such as liquid water path, effective radius or droplet number concentration are not obtainable in the optically think detrainment regions of low-level marine clouds, we analysed this in terms areal fraction of optically thin clouds (F_{thin}), changes in boundary layer sulfate mass loading, and changes in overall cloud fraction (CF). Different thresholds of cloud optical depth (COD) were used to characterise F_{thin}.
The analysis for one month of statistics for August 2020 shows that we tend to see lower contributions of F_{thin} to the overall cloud fraction in situations with a larger than average aerosol loading. A higher than average F_{thin} is associated with lower than average SO4 loading. The analysis is published within a BSc thesis and will base the foundation of extended analysis and a future publication.

Publications in review:

Possner et al. „Interplay between Primary and Secondary Ice Formation in Arctic Mixed-Phase Clouds in the ICON model during M-PACE“ [current status: minor revisions in JAS]

Ramadoss et al.: „An evaluation of kilometer-scale ICON simulations of mixed-phase stratocumulus over the Southern Ocean during CAPRICORN [current status: major revision in JGR]

Completed BSc thesis:

Frederik Viera-Fischer: „Exploring cloud adjustments in south-east pacific subtropical stratocumuli using geostationary satellite data“

Expected Resource Utilisation remaining quarter (01.10. - 31.12.2022):

We expect a full resource utilisation during the remaining two quarters of this allocation. This will include testing of our setups on the new Levante computing system.