Project: **1358**

Project title: **Marine Boundary-Layer Cloud Physics in ICON (MBL-ICON)**

Principal investigator: **Anna Possner**

Report period: **2025-05-01 to 2026-04-30**

Resource utilisation

Table 1: Resources for 01.07.2025–15.04.2026, in kNode hours (kNh).

Resources granted	46
Resources consumed	35
Resources expired (incl. in consumed)	6
Resources remaining	11

The resources were distributed across the three tasks as follows: task 1 consumed 2.2 kNh and task 2 consumed 26 kNh. The remaining 0.8 kNh were consumed in task 3. The loss of 6 kNh arose from the change in project plans in task 1 (for which originally 10kNh were granted applying the 57% cut to the overall proposal). The requested 19 TiB for long-term archiving were not accessed during this allocation period, as both studies (Pfannkuch et al. (in rev.) and Schnelke et al. (Preprint)) for which it was requested are still under review.

Task 1: Aerosol-aware low-cloud radiative effect in ICON-NWP

The decadal runs planned with ICON-NWP and different aerosol climatologies were delayed. For one we had to revise the triggering formulation of the shallow convection scheme and run further analyses for the publication that was submitted in December 2025 (Pfannkuch et al. in rev.). We improved the representation of marine stratocumulus in the ICON model by extending the estimated inversion strength (EIS)-based restriction of shallow convection with a critical moisture-decoupling threshold (Δqv, crit). The combined EIS-Δqv criterion classifies grid points into stratocumulus (Sc), late-transition, and cumulus (Cu) regimes, with shallow and mid-level convection restricted only in Sc conditions. The approach was evaluated for JJA 2015 in the Northeast Pacific using Moderate Resolution Imaging Spectroradiometer (MODIS) observations via COSP and radiation data from Clouds and the Earth's Radiant Energy System (CERES), complemented by six case studies from the Cloud System Evolution in the Trades (CSET) Campaign. The modification substantially reduces cloud-radiative biases: mean top-of-atmosphere shortwave flux biases in Sc regions decrease from 9 W m^{-2} in the control simulation to 3 W m^{-2} for Δqv, crit =2.5 g kg^{-1} and nearly 0 W m^{-2} for Δqv,crit = 3.0 g kg^{-1} . The climatological cloud-fraction gradient across the stratocumulus-to-cumulus transition is also improved, although Sc cloud fraction remains somewhat underestimated and partly compensated by an albedo bias. Around 1kNH were used to finalise these experiments.

The remaining 1.2kNh were used on the aerosol-aware formulations. We opted for a simpler and computationally cheaper integration of the aerosol climatology for cloud condensation nuclei (CCN) activation. Originally the approach developed by Bock et al.(2024) was to be used. Instead aerosol climatologies relevant to CCN activation are coupled to 2-D near-surface fields (computationally cheaper) obtained from the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) reanalysis. Meanwhile aerosol-cloud interactions for warm-phase clouds are now coupled in the ICON-ART framework, where ART stands for "Aerosols and Reactive Trace Gases". Thus in addition to anthropogenic climatologies, sea-salt is treated as an active tracer in these simulations. This new modelling capability allowed us to revise our scientific objective to explore the aerosol-cloud-radiative effect in the context of numerical regional marine cloud brightening experiments. The scientific objectives of these are laid out in the next resource request.

Task 2: MBL regime transitions in subtropical stratocumuli

Following the initial setup and pre-analysis stage, a final setup tuning phase together with the main droplet sedimentation simulations consumed about 11kNh from May 2025 to December 2025. The final runs concentrate on the pre-breakup stage of the SCT (48h in-model time) with a horizontal resolution of 50m and a vertical resolution of 9m in the lowest 3km of the atmosphere on a 8km by 8km domain for ten different cases. The main result is that droplet sedimentation leads to opposite effects depending on the amount of liquid water in the stratocumulus. The manuscript is currently under revision at ACP (Schnelke et. al, 2026). The other 15kNh from December 2025 to April 2026 were used for the setup and initial tests of the next project addressing large-domain simulations of the full transect (see request document). In addition a Master thesis on “Classification of Stratocumulus-to-Cumulus Transition Regimes from Passive Geostationary Satellite Retrievals in the Northeast Pacific” was supported analysing long-term satellite records with 0.1kNh.

Task 3: Mixed-phase cloud regime transitions during COMBLE

We participated in the “Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE)” initiative completing the following model intercomparison experiments:

i. liquid-only case, where cloud ice formation is artificially suppressed
ii. diagnostic ice where ice crystal number concentration is set to $25l^{-1}$ (minimum total) where the total liquid water mixing ratio (cloud and rain) exceeds $1.0e^{-6}$ kg/kg and the grid box temperature is below 268.15 K,
iii. prognostic immersion freezing using the time-scale relaxation for prescribed INP in ICON-NWP microphysics

Experiments i) and ii) are included in the submitted publication currently under review in ACPD. For these experiments 0,8kNh were used. Experiments including secondary ice formation were shifted into the following year. These experiments were delayed due to required bug fixes regarding surface fluxes in ICON COMBLE simulations and code transfer of parametrisations of secondary ice microphysics between different ICON versions, which is now complete.

Next steps

The remaining 11 kNh will be used for task 1 to complete the first one-year simulations with ICON-ART for testing with a computational resource demand of 2 kNh per simulation and further large-domain MAGIC simulations (5 kNh per simulation) in preparation for the scientific runs proposed in the next allocation period.

Preprint publications:

Schnelke, M., Ahlgrimm, M., Possner, A.: Opposing entrainment effects of cloud droplet sedimentation during the pre-breakup stage of the stratocumulus to cumulus transition, EGUsphere [preprint], doi:10.5194/egusphere-2026-479, (2026)

Juliano, T. W. et al.: The Cold-Air Outbreaks in the Marine Boundary Layer Experiment model-observation intercomparison project (COMBLE-MIP), Part I: Model specification, observational constraints, and preliminary findings, EGUsphere [preprint], doi:10.5194/egusphere-2025-6217, 2026.

Pfannkuch, K., Ahlgrimm, M., Scheck, L., Schnelke, M., and Possner, A.: Reducing Radiation Biases in the Northeast Pacific Stratocumulus Deck: A New EIS-Moisture-Decoupling-Based Diagnostic to Constrain Parameterized Convection in ICON, Monthly Weather Review, in review

Presentations:

Schnelke M. “Exploring the influence of cloud droplet sedimentation on the stratocumulus to cumulus transition in high-resolution ICON simulations”, ICCARUS, Offenbach, 2025.

Schnelke M. “Exploring the impact of cloud droplet sedimentation on the pre-breakup phase of the stratocumulus to cumulus transition in high-resolution ICON simulations”, ACPC workshop, online, 2025.

Possner A. “Cloud Physics Representations of the Northeast Pacific Stratocumulus-Cumulus Transition in ICON”, (invited talk) DACH, Bern, 2025.

Possner A. “From Warm to Mixed: Exploring the Physics of Marine Stratocumulus Clouds”, (invited talk) KIT colloquium, 2025.