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Resolution Dependence of Southern Ocean Mixed-Phase Clouds in ICON

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Extratropical low-level mixed-phase clouds are difficult to represent in global climate models and generate substantial uncertainty in global climate projections (Zelinka et al. 2020). In this study we evaluate the simulated properties of Southern Ocean (SO) boundary layer mixed-phase clouds for August 2016 in the ICOsahedral Nonhydrostatic (ICON) model (Zängl et al. 2015). The bulk of the simulations are part of the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domain (DYAMOND) initiative (Stevens et al. 2020). Within DYAMOND, ICON was run with the German Weather Service (DWD) physics packages at resolutions ranging from the global climate scale to the convection-permitting scale. All simulations are evaluated with respect to their radiative and cloud properties using Clouds and the Earth's Radiant Energy System (CERES, Su et al. 2015), Moderate Resolution Imaging Spectroradiometer (MODIS), and the raDAR-liDAR (DARDAR) version 2 (Ceccaldi et al. 2013) retrievals.

The analysis shows that previous and current versions of ICON overestimate cloud ice occurrence in low-level clouds across all latitudes in the SO. Furthermore, ICON, like many other global climate models, underestimates the reflectivity of SO boundary layer clouds. We can show that this effect is resolution dependent and largely due to an underestimation in cloud occurrence, rather than optical depth. Additional sensitivity experiments with respect to temporal model resolution and convection scheme assumptions were performed. We find a stronger model sensitivity with respect to spatial versus temporal resolution. Assumptions made within the convection scheme with respect to detrained cloud ice were found to impact the simulated total ice water content, but had a marginal impact on cloud-radiative properties.

In summary, while increases in model resolution increase cloud water content, cloud occurrence and cloud optical depth, considerable radiative biases remain in SO clouds in ICON at the convection-permitting scale. Furthermore, cloud ice forms to readily in state-of-the-art DWD ICON simulations at all spatio-temporal resolutions analysed.