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Improved cloud parameterization for Arctic climate simulations based on satellite data

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The defective representation of Arctic cloud processes and properties remains a crucial problem in climate modelling and in reanalysis products. Satellite-based cloud observations (MODIS and CPR/CALIOP) and single-column model simulations (HIRHAM5-SCM) were exploited to evaluate and improve the simulated Arctic cloud cover of the atmospheric regional climate model HIRHAM5. The ECMWF reanalysis dataset "ERA-Interim" (ERAint) was used for the model initialization, the lateral boundary forcing as well as the dynamical relaxation inside the pan-Arctic domain. HIRHAM5 has a horizontal resolution of 0.25° and uses 40 pressure-based and terrain-following vertical levels. In comparison with the satellite observations, the HIRHAM5 control run (HH5ctrl) systematically overestimates total cloud cover, but to a lesser extent than ERAint. The underestimation of high- and mid-level clouds is strongly outweighed by the overestimation of low-level clouds. Numerous sensitivity studies with HIRHAM5-SCM suggest (1) the parameter tuning, enabling a more efficient Bergeron-Findeisen process, combined with (2) an extension of the prognostic-statistical (PS) cloud scheme, enabling the use of negatively skewed beta distributions. This improved model setup was then used in a corresponding HIRHAM5 sensitivity run (HH5sens). While the simulated high- and mid-level cloud cover is improved only to a limited extent, the large overestimation of low-level clouds can be systematically and significantly reduced, especially over sea ice. Consequently, the multi-year annual mean area average of total cloud cover with respect to sea ice is almost 14% lower than in HH5ctrl. Overall, HH5sens slightly underestimates the observed total cloud cover but shows a halved multi-year annual mean bias of 2.2% relative to CPR/CALIOP at all latitudes north of 60°N. Importantly, HH5sens produces a more realistic ratio between the cloud water and ice content. The considerably improved cloud simulation manifests in a more correct radiative transfer and better energy budget in the atmospheric boundary layer and results also in a more realistic surface energy budget associated with more reasonable turbulent fluxes. All this mitigates the positive temperature, relative humidity and horizontal wind speed biases in the lower model levels.