Geophysical Research Abstracts
Vol. 21, EGU2019-8174-1, 2019
EGU General Assembly 2019

High-Resolution Large-Eddy Simulation of Arctic Stratocumulus: Linking Cloud Properties to Surface Heterogeneity

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Arctic stratocumulus significantly affects the surface energy and water budget both of which in turn drive their development. These clouds, however, must be parameterized in climate models and are far from being wholly understood; both cause a large share of the uncertainty in current Arctic climate projection (Kay et al., 2016: Recent Advances in Arctic Cloud and Climate Research. *Curr. Clim. Change. Rep.* (2:159)). Stratocumulus extends vertically only over a few hundreds of meters and their key processes, such as cloud-top entrainment or turbulent mixing, act on even smaller scales of only a few meters. Thus, investigating and representing these processes is challenging from both an observational and a numerical simulation perspective. Observations suffer from limited spatial and temporal representativity as well as from challenging environmental conditions. On the contrary, a well-established numerical simulation can act as a virtual laboratory. Once a model represents a cloud and its processes sufficiently, the atmospheric state, the cloud properties, and or the surface conditions can be modified straightforwardly to study related processes. Therefore, a correct process-level representation of Arctic stratocumulus including turbulent processes and their interaction with microphysical and radiative processes requires resolution on the order of meters and microphysical schemes supporting liquid, solid, and mixed-phase hydrometeors. For lower latitudes, numerical studies with suitable resolution exist and unfold improved physical understanding. In the Arctic region, however, highly resolved simulations of cloud-surface coupled systems are still missing.

We investigate mixed-phase stratocumulus in Arctic summer over sea ice in a neutral boundary layer capped by a strong temperature inversion. Our study consists of three parts. First, we define a reference case based on data from the recent ACLOUD and PASCAL campaigns of the DFG-funded $(AC)^3$ research initiative (Wendisch et al., 2018: The Arctic Cloud Puzzle: Using ACLOUD/PASCAL Multi-Platform Observations to Unravel the Role of Clouds and Aerosol Particles in Arctic Amplification. *Bull. Amer. Soc.* (in press)). Initializing and benchmarking our modified version of WRF-LES V4.0.3 with the campaign data grants insight to the cloud-driving processes beyond what can be learned from observational data or large-eddy simulation alone. Second, we perform a resolution sensitivity study to identify the driving scales of cloud-top entrainment. Therefore, we apply different horizontal resolutions ranging from 35 m to 3.5 m where the vertical resolution is kept constant at 3 m. These simulations enable us to analyze cloud-driving non- or under-resolved microphysical, radiative, and turbulent processes and their interaction. In a third step, we investigate the implications of this set-up for the coupling between sea-ice properties and the cloud-microphysics and thermodynamics.