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The coldest days of MOSAiC – an LES study

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The polar-night stable boundary layer, observed during MOSAiC, gives rise to extreme stabilities not found in typical mid-latitude SBLs. In a steady or near-steady synoptic environment, the boundary layer even attains a quasi-steady state for several hours, i.e., boundary-layer processes and profiles are equilibrated.

Such lab-like conditions of extreme stability remain a major challenge for turbulence modelling across scales. Previously, we have demonstrated that such situations can be qualitatively modelled by carefully-designed large-eddy simulations, using wintertime observations from Dome C, Antarctica (Van der Linden et al., 2020: J. Atmos. Sci., 77, 3343–3360). However, a quantitative comparison remained elusive due to a lack of turbulent flux observations at Dome C.

The high-frequency observations of wind, temperature, radiation and turbulent fluxes during the MOSAiC-campaign do allow us to quantitatively disentangle different mixing processes facilitating a one-to-one comparison between observation and simulation. Here, we will show the results of our simulations and discuss the specific challenges of performing large-eddy simulations of such harsh, but fascinating conditions.

Our results show that atmospheric radiation, which is usually neglected in large-eddy simulations of very stable cases, is a key thermal process in the evolution of the boundary layer due to the large thermal inversion near the surface. Radiative exchanges result in a deeper boundary-layer, which is in line with the observed boundary-layer height, as compared to the simulations without radiative exchanges. Although a larger boundary-layer depth is obtained, discrepancies between the observed more exponentially-shaped temperature profile and the simulated temperature profile still persist.

This is suspected to be caused by a wrong magnitude of the turbulent mixing near the surface, related to the interplay of roughness lengths, Monin–Obukhov similarity theory and the extreme surface-layer stratification. Initial tests, however, remain inconclusive on this complex interplay.