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Non-eddy-resolving modelling and parametrization of turbulent convection over sea ice leads and evaluation with airborne observations

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The polar ocean regions are characterised by a large variety of interactions between sea ice surfaces, open water, and the atmosphere. Especially between late autumn and spring, leads (open-water channels in sea ice) may play a crucial role within this system: Due to large temperature differences between the surface of leads and the near-surface atmosphere, strong turbulent convective plumes are generated with an enhanced turbulent transport of heat, moisture, and momentum. In consequence, lead-generated convection has a strong impact on the characteristics of the polar atmospheric boundary layer (ABL).

We apply a plume- but non-eddy-resolving, microscale model to study the convection over three different leads, which had been observed during the aircraft campaign STABLE over the Arctic Marginal Sea Ice Zone in March 2013. Model simulations are performed using a local and a non-local turbulence closure. The latter represents a lead-width-dependent approach for the turbulent fluxes based on large eddy simulation and it is designed for an idealised, lead-perpendicular, and near-neutral inflow in an ABL of 300m thickness. The observed cases from STABLE are also characterised by lead-perpendicular inflow conditions, but the ABL is much shallower than in the idealised cases and the inflow stratification is partly (slightly) stable. Our main goal is to study the quality of both parametrizations and to evaluate, if the non-local parametrization shows advantages as compared to the local closure.

We show that the basic observed features of the lead-generated convection are represented with both closures despite some minor differences that will be explained. However, the advantages of the non-local closure become clearly obvious by the physically more realistic representation of regions with observed vertical entrainment or where the observations hint at counter-gradient transport. Moreover, we also show that some weaknesses of the simulations can be almost overcome by introducing two further modifications of the non-local closure. We consider our results as another important step in the development of atmospheric turbulence parametrizations for non-eddy-resolving, microscale simulations of strongly inhomogeneous convective boundary layers.