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Atmospheric boundary layer evolution and associated low-level baroclinicity during cold-air outbreaks in high latitudes

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The evolution of the atmospheric boundary layer (ABL) height, temperature and wind speed downwind the marginal sea ice zone during cold-air outbreaks is studied using observations in the Arctic and idealized nonhydrostatic modelling. Moreover, a simple dry quasi-analytical mixed-layer model (ML) is presented and used to interpret observations and get more insight into the effect of low-level baroclinicity on the ABL wind. A good agreement between the ML model results and observations is demonstrated with respect to the ABL height and temperature. Although, ML underestimates the ABL warming by about 10% which might be due to neglect of condensational heating and subsidence. It is concluded that the latter factors play a secondary role for the ABL development compared to the warming due to surface sensible heat flux, at least over the first few hundred kilometres downwind the ice edge. Also, the ML model reproduces well baroclinicity related with the ABL heating. Such baroclinicity has a dominant effect on wind speed and qualitatively explains the observed wind speed variability. However, baroclinicity associated with the sloping of the inversion at the ABL top and baroclinicity above the ABL are not negligible. It is shown, that all the three baroclinic terms have to be taken into account in the ML model in order to obtain a good quantitative agreement of its results with those of a 3D nonhydrostatic model. Using the ML analytical solution, an expression for the horizontal length scale of the cold-air mass transformation is obtained. It is shown that this scale also describes the decay of the low-level baroclinicity downwind the ice edge. This scale is shown to vary from 400 to 1000 km for typical high-latitude CAOs.