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Impact of Forced Roll Convection on Turbulent Fluxes in Cold Air Outbreak Situations

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Roll convection is a common phenomenon in atmospheric convective boundary layers (CBL) with background wind. It is often argued that the presence of roll vortices may increase vertical transports which should be considered in parameterizations of weather and climate models. At least, in case of roll convection within cold air outbreaks (CAOs), our study does not support this idea.

Gryschka et al. [2008, Geophys. Res. Lett., 35] showed with large eddy simulations (LES) that in strong CAOs, roll vortices develop only under the presence of heterogeneities in the sea ice distribution. These rolls extended up to several hundred kilometers downstream over open water. Since they are generated at the heterogeneities, they called them forced rolls. Roll vortices due to pure self organization of the flow occurred only in weak and moderate CAOs and were called free rolls in their study (not triggered by the sea ice distribution).

Due to these findings, we were able to simulate CAOs with and without rolls under the same meteorological conditions. We performed a parameter study of strong CAOs with LES using non-cyclic lateral boundary conditions in flow direction. For each case, we carried out two simulations, one with a sharp ice edge so that no rolls are generated and one with an idealized heterogeneous ice edge in order that forced rolls arise. We chose twelve cases with varying geostrophic wind speeds and temperature differences between ice and water. Furthermore, we varied the wavelength of the rolls which can be controlled by the heterogeneity.

Our results show no significant differences in the development of the CBL and total vertical fluxes between the roll and non-roll cases. However, the rolls take over a part of the turbulent transport. In some cases, the vertical transport of momentum by rolls is larger than the transport by small scale turbulence.

These findings suggest that there is no need to consider roll convection in parameterizations of weather and climate models in case of CAOs.