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Interaction of diabatic processes in numerical simulations of extratropical cyclones

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Diabatic processes determine the evolution of the atmosphere through the modification of mesoscale circulations and vice versa. Diabatic processes cannot be directly resolved in numerical weather forecast and climate models. Instead, they have to be parameterised in terms of resolved variables at grid scale. Nevertheless, the parameterised version of diabatic processes play a similar role in shaping the evolution of a model's atmosphere. Basic research comparing the ways in which diabatic processes interact in numerical models and in the real atmosphere is paramount to improve the quality of weather and climate forecasts.
In this contribution, the interaction between the convection parameterisation and the cloud microphysics parameterisation is investigated through the analysis of numerical simulations of a mid-latitude cyclone. The methodology is based on the use of tracers of potential temperature. A by-construction conserved component of potential temperature serves to identify distinct air masses and track their vertical displacement, in isentropic coordinates, in an approximate Lagrangian specification of the flow field. In addition, the tracer method decomposes diabatic changes in potential temperature in terms of parameterised processes, enabling the determination of the relative importance of different parameterisation schemes for the simulation. Trajectory analysis is also used in order to determine the timing and location where diabatic processes become important. The cyclone has been simulated using two different settings of the convection parameterisation scheme. The first setting corresponds to a standard configuration of the parameterisation scheme; the second setting corresponds to a reduction in the response of the scheme to large-scale convective forcing.
It is shown that the convection parameterisation interacts with the cloud microphysics parameterisation to regulate the action of large-scale latent heat exchange through the release of convective available potential energy. Furthermore, it is shown that with reduced parameterised convection, the cloud microphysics parameterisation tends to eliminate convectively unstable regions in an abrupt manner. As a result, there are differences in the way mass is redistributed by vertical motion in the vicinity of the cyclone. The potential implications of these results for longer-term simulations are also discussed in the context of recent studies on the structure of the warm conveyor belt and model biases in the simulation of Rossby waves and cyclones in mid-latitudes.