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Cloud radiative impact on the dynamics and predictability of an idealized extratropical cyclone

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Extratropical cyclones drive midlatitude weather, including extreme events, and determine midlatitude climate. Their dynamics and predictability are strongly shaped by cloud diabatic processes. While the cloud impact due to latent heating is well known and much studied, little is known about the impact of cloud radiative heating (CRH) on the dynamics and predictability of extratropical cyclones. Here, we address this question by means of baroclinic life cycle simulations performed at a convection-permitting resolution of 2.5 km with the ICON model. The simulations use a newly implemented channel setup with periodic boundary conditions in the zonal direction. Moreover, they apply a new modeling technique for which only CRH interacts with the cyclone, which circumvents changes in the mean state due to clear-sky radiative cooling. To understand the CRH impact on the upper-tropospheric circulation, we diagnose sources and the evolution of differences in potential vorticity (PV) between a simulation with and without CRH.

We find that CRH increases the intensity of the cyclone with the impact being more prominent at upper levels. The mechanism by which CRH affects the cyclone operates mostly via a modification of other diabatic processes, in particular an intensification of the latent heating associated with cloud microphysical processes. This changes PV tendencies, and these changes are then advected by the upper-tropospheric divergent flow to the tropopause region, where the large-scale rotational flow further changes the tropopause structure.

Our results indicate that although CRH is comparably small in magnitude, it can affect extratropical cyclones by changing cloud microphysical heating and subsequently the large-scale flow similar to a previously identified multi-stage upscale error growth mechanism. Our results further indicate that CRH can impact the predictability of the cyclones. This impact may be especially important in storm-resolving models, for which simplified radiative transfer calculations might bias CRH.