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Impact of diabatic processes on the tropopause inversion layer formation in baroclinic life cycles

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Observations of temperature profiles in the extratropical upper troposphere/lower stratosphere (UTLS) show the presence of an inversion layer just above the thermal tropopause, i.e. the tropopause inversion layer (TIL). In recent studies both diabatic and adiabatic processes have been identified to contribute to the formation of this layer. In particular, adiabatic simulations indicate a TIL formation without the explicit simulation of diabatic, i.e. radiative or humidity related, processes after wave breaking during baroclinic life cycles. One goal of this study is to assess the additional contribution of diabatic processes to the formation and strength of the TIL in such life cycles. Moreover, since irreversible stratosphere-troposphere exchange (STE) is another inherent feature of baroclinic life cycles and a consequence of diabatic processes, we study whether there is a relationship between STE and TIL.
We use the non-hydrostatic model COSMO in an idealized mid-latitude channel configuration to simulate baroclinic life cycles. In a first step contributions of individual diabatic processes from turbulence, radiation, and cloud microphysics to the formation of the TIL are analyzed. These results are compared to those from adiabatic simulations of baroclinic life cycles in which the TIL forms during the life cycle with the limitation of being less sharp than in observations. In a second step the combined effects of several diabatic processes are studied to further include interactions between these processes as well as to advance towards a more realistic model setup.
The results suggest a much more vigorous development of the TIL due to microphysics and the release of latent heat. Moreover, radiative effects can foster an increase in static stability above the thermal tropopause when large gradients of either water vapor or cloud ice are present at the level of the tropopause. By additionally adding subgrid scale turbulence, a co-location of high static stability and increased turbulent kinetic energy is found in the vicinity of cirrus clouds at the tropopause level. The potential relation between STE and high static stability is further discussed based on results from trajectory calculations and the distribution of passive tracers of tropospheric and stratospheric origin.