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Tracers of diabatic changes in potential temperature and potential vorticity: Integral interpretation in terms of net heating and circulation and applications to model consistency across resolutions

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Diabatic processes in the atmosphere can be characterised by the changes they produce on potential temperature (θ) and potential vorticity (PV) following an air parcel. Diabatic tracers of θ and PV track the changes undergone by those two variables due to the action of diabatic processes in a Lagrangian frame by splitting θ and PV into components that are materially conserved and components that are diabatically generated. Since diabatic tracers are subject to advection by the three-dimensional wind field, they are useful tools for the investigation of the interaction of diabatic processes with the atmospheric flow and the impact of diabatic processes on the evolution of the atmosphere. In this contribution, we present a novel integral interpretation of diabatic tracers over suitably defined control volumes, which depend on the weather system under consideration. Using two contrasting extratropical cyclones as examples, it is shown that θ tracers can be used to assess and systematically compare the cross-isentropic mass transport around each cyclone, which is related to the amount and distribution of heat produced during each cyclone's development. PV tracers are related to circulation and area-average isentropic vorticity through the application of Stoke's theorem. Using the impermeability theorem for PV, which states there can be no PV flux across isentropic surfaces, it is also shown that cross-isentropic motion within the control volumes does not directly influence circulation. Instead, the influence of diabatic processes on the circulation crucially depends on the balance between the fluxes along isentropic surfaces of the materially-conserved and diabatically-generated PV components across the lateral boundaries of the control volumes. Finally, the application of the integral interpretation of diabatic tracers for the assessment of model consistency across different model resolutions is discussed.