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The diabatic heat budget of the upper troposphere and stratosphere in ECMWF ERA-40 and ERA-Interim reanalyses

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We present an analysis of the diabatic terms in the thermodynamic energy equation from ERA-40 and the ECMWF reanalysis ERA-Interim. We analyse the clear sky radiative heating, the cloud radiative effects, and the impact from latent heat exchange and mixing. The diabatic heat budget is closed with the calculation of the temperature assimilation increment. The previously noted excessive tropospheric circulation at low latitudes in ERA-40 is also reflected in the diabatic heat budget. The temperature increment acts to cool the excessive model heating. Conversely, ERA-Interim requires heating from the assimilation increment at low latitudes, suggesting too little convection. In the tropical tropopause layer (TTL), both reanalyses show a strong heating from the interaction of clouds with radiation, but lack of reliable independent estimates renders the role of clouds uncertain. Both reanalyses show cooling in the TTL by the assimilation increment, suggesting that the models may overestimate the cloud radiative heating, or that the convective parameterization scheme has difficulties to capture the thermal effects of deep convection. In the stratosphere, ERA-40 shows unrealistic radiative heating due to problems in the temperature profile. The diabatic heat balance is dominated by the the assimilation increment, and the residual circulation is much faster than in ERA-Interim. Conversely, ERA-Interim is better balanced and requires a substantially smaller temperature increment. Its structure and magnitude of radiative heating/cooling at low/high latitudes is quite realistic. Overall, ERA-Interim provides a much improved residual circulation, but uncertainties in the magnitude of terms in particular around the tropical tropopause remain large.