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Diabatic generation of negative potential vorticity and its impact on the jet stream

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Localised regions of negative potential vorticity (PV) are frequently seen on the equatorward flank of the upper-tropospheric jet streams in analysis and forecast products. Their positioning, on the anticyclonic side of the jet and often close to the jet core, suggest they are associated with an enhancement of jet stream maximum winds. Given that PV is generally positive in the northern hemisphere and is conserved under adiabatic conditions, the presence of negative PV is indicative of recent diabatic activity. However, little is understood on the mechanisms for its generation and subsequent lifecycle.

In this study, aircraft measurements from a recent field campaign are used to provide direct observational evidence for the presence of negative PV on the anticyclonic side of an upper-tropospheric jet. Theory is then developed to understand the process by which PV can turn negative. The key ingredient is diabatic heating in the presence of vertical wind shear, and the resulting PV anomalies are shown to always result from a flux of PV directed 'down the isentropic slope'. This explains why, for the typical situation of heating in a warm conveyor belt, negative PV values appear on the equatorward side of the upper-tropospheric jet stream close to the jet core. These ideas are illustrated with a semi-geostrophic model and the processes responsible for the observed negative PV are explored using an operational forecast model with online PV tracer diagnostics.

The diabatic influence on jet stream winds and shear is of interest because it is pertinent to the predictability of extreme jet stream events and associated flight-level turbulence, and is crucial to the propagation of Rossby waves at tropopause level, development of mid-latitude weather systems and their subsequent impacts at the surface.