On the Role of Inertial Instability in Cyclones: Stratosphere - Troposphere Exchange, Jet Acceleration, and PV Dipoles

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Abstract. The University of Wisconsin Nonhydrostatic Modeling System (UWNMS) is used to investigate the effects of negative potential vorticity (PV) in the upper troposphere and lower stratosphere (UTLS) in tropical cyclone Talas and in the Super Tuesday midlatitude cyclone. In Super Tuesday, deep convection along the cold front leads to regions of inertial instability in the UTLS which facilitate stratosphere – troposphere exchange (STE) by accelerating upper tropospheric air over stratospheric air. Gravity waves emanating from inertially unstable regions modulate the subpolar and subtropical jets simultaneously. In Talas, STE occurs around the periphery, with inertially unstable outflow overriding stratospheric air in a "medusa" configuration. At convective scales, PV dipoles and gravity waves are generated, with enhanced STE. In Super Tuesday, a two-stage synoptic evolution is diagnosed as a signature of inertial instability: meridional flow accelerates in a poleward surge approaching the ridge, then the supergeostrophic poleward flow leads to a zonal "jet flare-up". The poleward surge involves a distinctive "head" of high angular momentum, with the region of inertial instability enclosing the jet maximum. Inertial instability helps determine the shape of the ridge.

PV dipole structures are compared with a view toward underlying dynamical similarity. Temperature dipoles in the UTLS are diagnosed as being due to deflection of the flow over the updraft (cold), and subsidence behind it (warm). As in Chagnon and Gray (2009), horizontal PV dipoles are linked to vortex tilting. We hypothesize that vorticity associated with vertical shear of the ambient wind is bent into a horseshoe shape by the updraft. This suggests a rule that low PV lies to the left of the wind shear. Tall gravity waves radiate from the PV dipole, which accentuate the convective updraft and downdraft. The extratropical transition of Talas illuminates the relationship between convective PV dipoles and filament pairs along the jet.

Key words: inertial instability, stratosphere-troposphere exchange, midlatitude jets, cyclones, potential vorticity dipoles

References

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