Understanding the Relationship between Stratospheric Polar Vortex Disturbances and Lower Tropospheric Cold-Air Outbreaks

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We are investigating the dynamical relationship between stratospheric polar vortex disturbances (PVDs) and lower tropospheric cold-air outbreaks (CAOs). It is known that PVDs, such as splits or displacements of the polar vortex, can be preceded or followed by CAOs, but details concerning the location and timing of PVDs relative to CAOs, or how they are dynamically connected, are not well understood. We are pursuing several approaches to this problem. First, we are investigating cases of apparent PVD-CAO coupling from the most recent winter season. In these cases, the first in November 2018 (elongation and near-split of the stratospheric polar vortex) and the second during January 2019 (polar vortex split), the lower tropospheric CAO was located south and west of the disturbed polar vortex. The onset of the CAO, defined by spatially coherent 850-mb temperature anomalies below -10C, was locally preceded in each case by 1000-mb geostrophic cold-air advection (CAA) that increased in magnitude with time. This CAA tendency in turn was hydrostatically induced in each case primarily by the advection of anomalously cold air in the stratosphere, with tropospheric CAA playing a lesser role in the inducement. Thus, it appears that, in these cases, the lower tropospheric CAA associated with the CAO was initiated by anomalous stratospheric CAA.

In a second line of inquiry, we are constructing a climatology of PVD-CAO coupling in the MERRA data set. This comprehensive climatology will show (1) how frequently PVDs are preceded or followed by CAOs; (2) how frequently CAOs are preceded or followed by PVDs; and (3) the location and timing of CAOs relative to PVDs.

Finally, we are repeating the above climatological study in an extended run of the Community Atmosphere Model (CAM) with sufficient wave forcing from the troposphere to generate PVDs. This inquiry may lead to experiments with CAM to test the ideas emerging from the PVD-CAO case studies during the most recent winter season.