Antecedent Synoptic Environments Most Conducive to North American Polar/Subtropical Jet Superpositions

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1. Motivation

- The atmosphere often exhibits a three-step pole-to-equator tropopause structure, with each step in the tropopause associated with a unique jet stream. The polar jet stream (PJ) typically resides in the break between the polar and subtropical tropopause and is positioned atop the strongly baroclinic, tropospheric-deep polar front around 30°N.
- The subtropical jet stream (STJ) resides in the break between the subtropical and the tropical tropopause and is situated on the poleward edge of the Hadley cell around 30°N.
- On occasion, the large-scale flow pattern can evolve in such a way to eliminate the latitudinal separation between the PJ and the STJ, resulting in a vertical jet superposition and an environment conducive to high-impact weather (Fig. 1).
- Considerable variability characterizes the antecedent environments conducive to jet superpositions, motivating a comprehensive study into the dynamical mechanisms that support jet superposition.

Methodology:

1. Jet Superposition Event Identification

- Isolate CFSR grid points over North America characterized by a jet superposition during Nov–Mar 1979–2010 using the Christenson et al. (2017) scheme (Fig. 2).
- Identify jets based on the magnitude of both the vertically integrated wind speed and horizontal PV gradient within predetermined isolatic layers.
- Retain times that rank in the top 10% in terms of the number of grid points characterized by a jet superposition.
- Filter retained analysis times to group together jet superpositions that are <30 h and ∼1500 km apart.

2. Jet Superposition Event Types

- The position of a jet superposition at the start of an event is compared to the climatological position of the 2-PVU contour on the 320-K and 350-K isotropic surfaces in order to classify events (Figs. 3a,b,c).
- **Polar dominant** events require a substantial deviation of the PJ from its climatological position and occur most frequently over Texas and the Gulf Coast (Fig. 3d).
- **Subtropical dominant** events require a substantial deviation of the STJ from its climatological position and occur most frequently over the Pacific Northwest and Northeast U.S. (Fig. 3e).
- **Hybrid** events require a substantial deviation of both the PJ and STJ from their climatological positions and occur most frequently over the Southeast U.S. (Fig. 3f).

3. Jet Superposition Event Composites

- **Polar Dominant Events**
  - An upstream anticyclonic wave breaking event amplifies the downstream flow pattern over North America prior to jet superposition (Figs. 5a,b,c).
  - Geostrophic cold-air advection (CAA) upstream of a deep upper-level trough indicates strong forcing for quasi-geostrophic (QG) descent (Fig. 5e).
  - Collocated OLR and precipitable water anomalies downstream of the upper-level trough suggest that diabatic processes slow the propagation of the upper-level trough (Figs. 5b,d,f).

- **East Subtropical Dominant Events**
  - Antecedent precipitation and anomalous southerly flow amplify a strong upper-level ridge prior to jet superposition (Figs. 6a–f).
  - Geostrophic CAA upstream of a weak upper-level trough indicates forcing for QG descent beneath the jet core at the time of jet superposition (Fig. 6e).
  - QG descent aids the development of a jet superposition by steepening the tropopause (Fig. 7d).

4. Summary

- The two frequency maxima for **subtropical dominant** events motivates partitioning these events further into an east and west category (Fig. 3e).
- As a whole, **subtropical dominant** events are “1.5 times more frequent than polar dominant** events (Figs. 3d,e).
- Jet superposition events are most frequent during November and December across all event types (Fig. 4).