# 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 break in the tropopause associated with a 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 50°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.

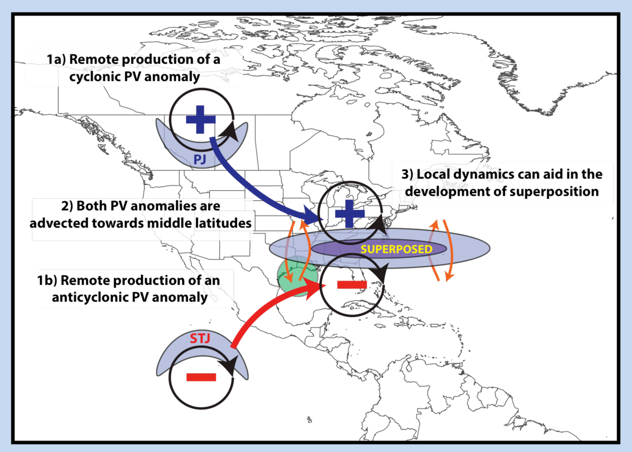


*Figure 1: Conceptual model illustrating the development of a North American jet superposition. The blue '+' (red '–') signs indicate cyclonic (anticyclonic) potential vorticity (PV) anomalies, isotachs of the upper-tropospheric wind are shaded purple, an area of convection is shaded green, and ageostrophic jet tranverse circulations are indicated by the orange arrows (Adapted from Winters and Martin 2017).*

## 2. Jet Superposition Event Identification

**Data:**

1. 0.5° x 0.5° NCEP Climate Forecast System Reanalysis (CFSR; available every 6 h) during 1979–2010.
2. 2.5° x 2.5° NOAA Interpolated Outgoing Longwave Radiation (OLR) dataset (available every 24 h) during 1979–2010.

**Methodology:**

1. 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).
2. Identify jets based on the magnitude of both the vertically integrated wind speed and horizontal PV gradient within predetermined isentropic layers.
3. Retain times that rank in the top 10% in terms of the number of grid points characterized by a jet superposition.
4. Filter retained analysis times to group together jet superpositions that are < 30 h and < 1500 km apart.

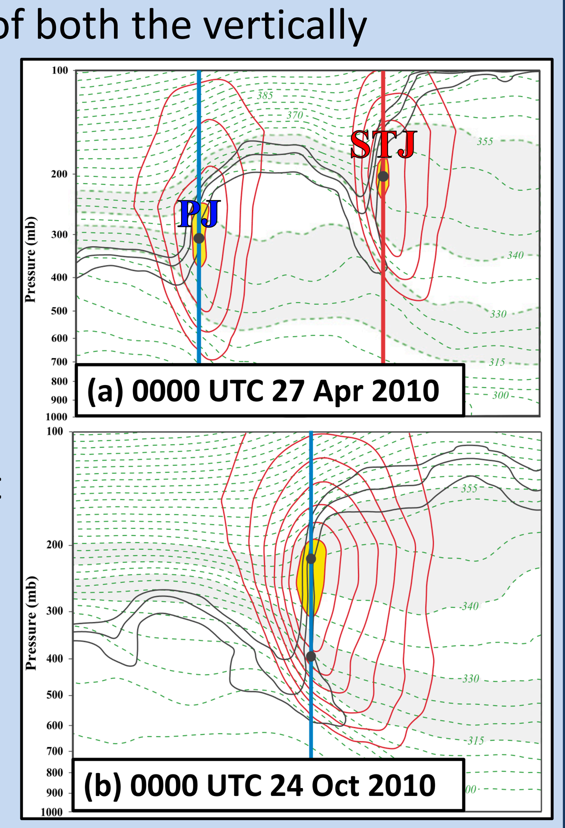



*Figure 2: (a) Vertical cross section through a separate PJ and STJ with 1–3 PVU contoured in black, isentropes contoured in green, isotachs contoured in red, jet cores shaded in yellow, and the 315–330- and 340–355-K isentropic layers shaded in gray. The blue (red) line corresponds to a grid column in which the black dot confirms a PJ (STJ) identification. (b) As in (a), but for a jet superposition (Adapted from Christenson et al. 2017).*

## 3. Jet Superposition Event Types

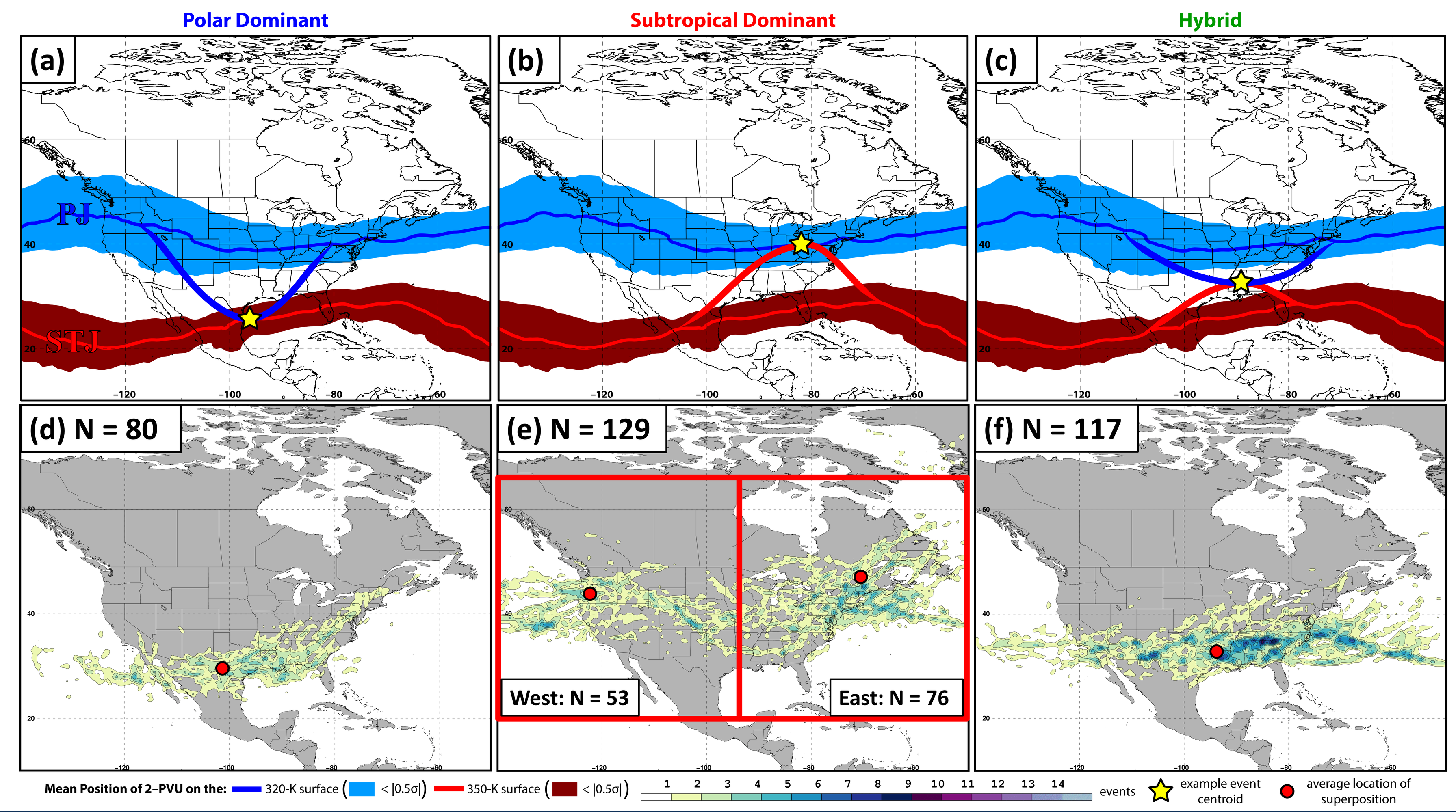



*Figure 3: (a,b,c) The mean position of the 2-PVU contour on the 320-K and 350-K isentropic surfaces at 0000 UTC 1 January is indicated by the thin blue and red line, respectively, and represents the mean position of the polar and subtropical waveguides. Shaded areas bounding each mean 2-PVU contour indicate locations at which an observation of 2-PVU would be <|0.5σ| anomaly on a particular isentropic surface. Hypothetical deviations of the 2-PVU contour from its mean position on an isentropic surface are indicated by the thick blue or red contours to illustrate the event classification scheme. (d,e,f) The spatial frequency of jet superposition events associated with the event type listed above each column. The red boxes shown in (e) indicate the partition of subtropical dominant events into an east and west category.*

- 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 isentropic 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).
- 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).

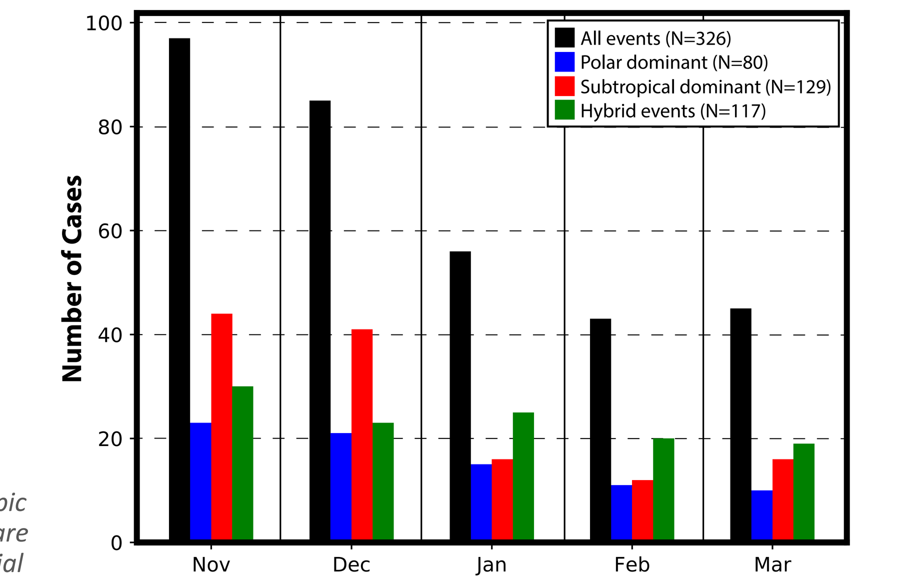



*Figure 4: Monthly count of jet superpositions by event type.*

## 4. Jet Superposition Event Composites

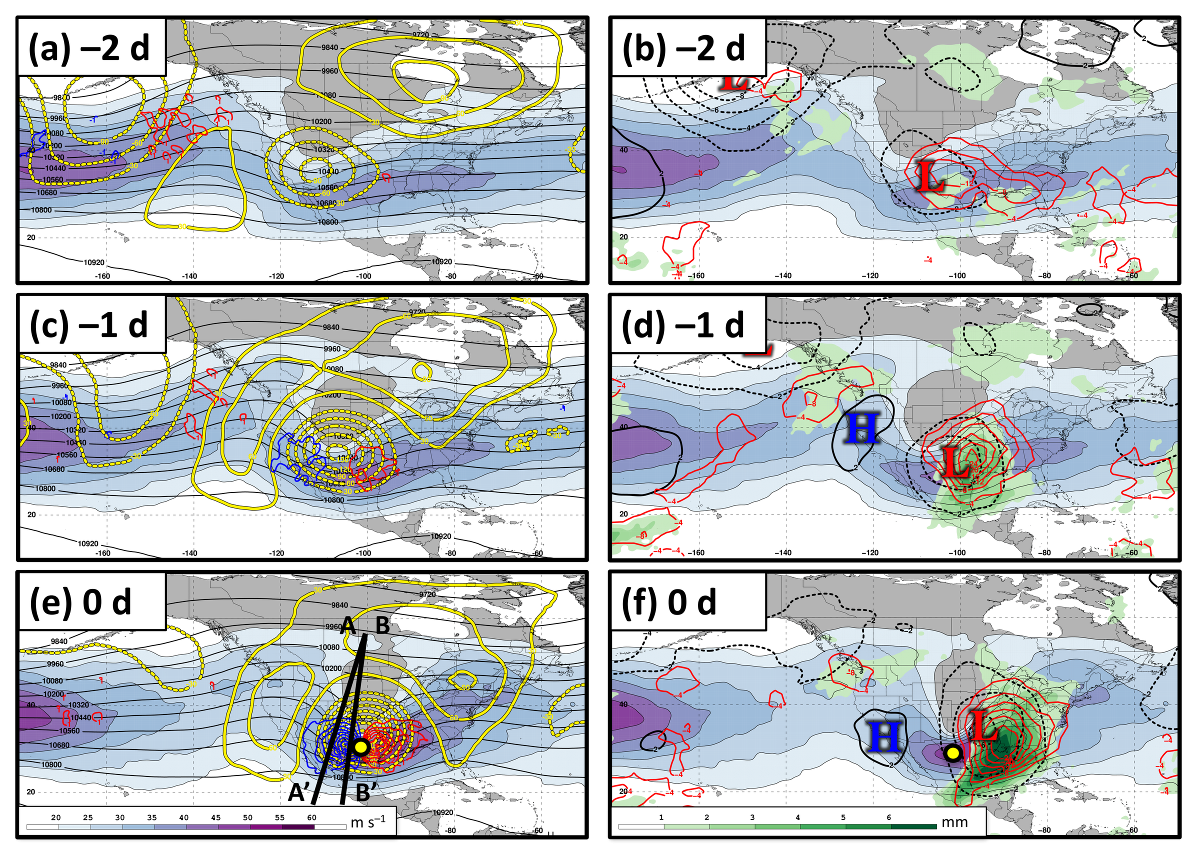



*Figure 5: Composite evolution for polar dominant jet superposition events. Refer to Fig. 6 caption for plotting conventions.*

### Polar Dominant Events

- An upstream anticyclonic wave breaking event amplifies the downstream flow pattern over North America prior to jet superposition (Figs. 5a,c,e).
- 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 further steepening the tropopause (Fig. 7d).

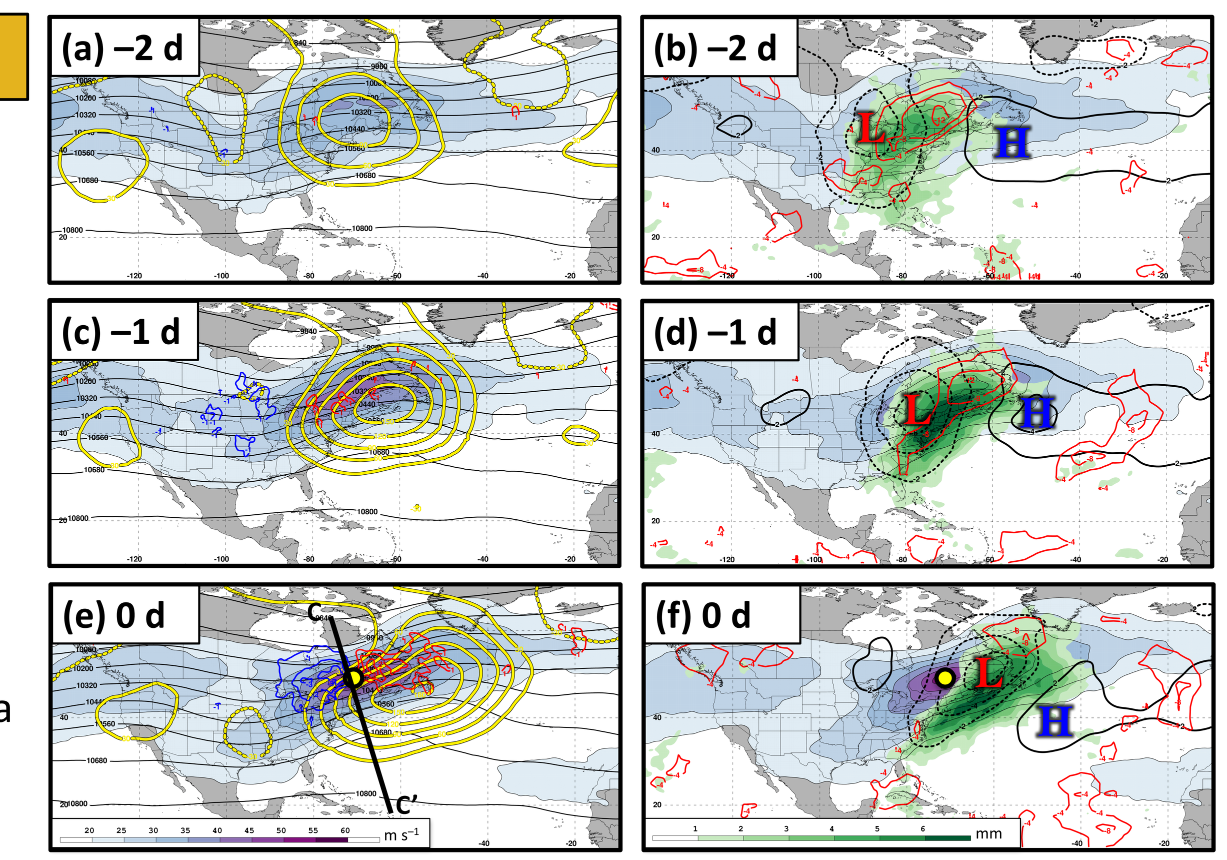
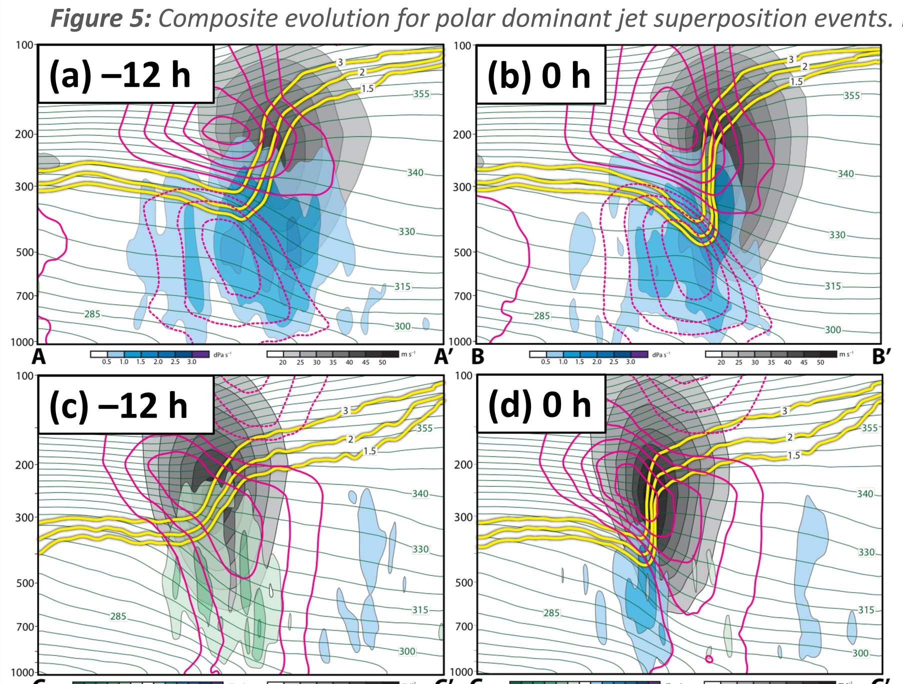



*Figure 6: 250-hPa wind speed shaded as indicated in the legend, 250-hPa geopotential height contoured in black, 250-hPa geopotential height anomalies contoured in yellow with negative values dashed, and 300-hPa geostrophic cold- (warm-) air advection contoured in blue (red) (a) 2 days, (c) 1 day, and (e) 0 days prior to an east subtropical dominant jet superposition event. 250-hPa wind speed shaded as in (a), mean sea-level pressure anomalies contoured in black with negative values dashed, precipitable water anomalies shaded in green, and negative OLR anomalies contoured in red (b) 2 days, (d) 1 day, and (f) 0 days prior to a jet superposition event.*




*← Figure 7: Vertical cross sections, as identified in Fig. 5e, of wind speed shaded in gray, vertical motion shaded following the legend, potential temperature contoured in green, potential temperature anomalies contoured in magenta with negative values dashed, and 1.5,2, and 3 PVU contoured in yellow (a) 12 h and (b) 0 h prior to a polar dominant jet superposition event. (c) and (d) As in (a) and (b) but for the vertical cross section indicated in Fig. 6e through a developing east subtropical dominant jet superposition event.*

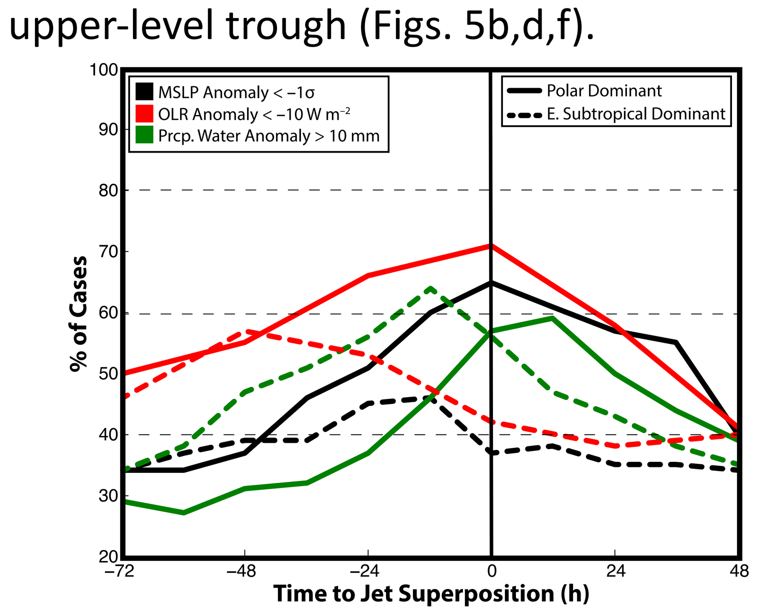



*Figure 8: The frequency that jet superposition events are characterized by mean sea-level pressure, precipitable water, and OLR anomalies exceeding a specified magnitude.*

- Descent beneath the jet core acts to steepen the tropopause throughout a **polar dominant** event (Figs. 7a,b).
- The diabatic erosion of upper-tropospheric PV that accompanies ascent directly beneath the jet core acts to steepen the tropopause prior to an **east subtropical dominant** event (Fig. 7c).
- The largest precipitable water, OLR, and mean sea-level pressure anomalies lead the development of **east subtropical dominant** events (Fig. 8).

## 5. Summary

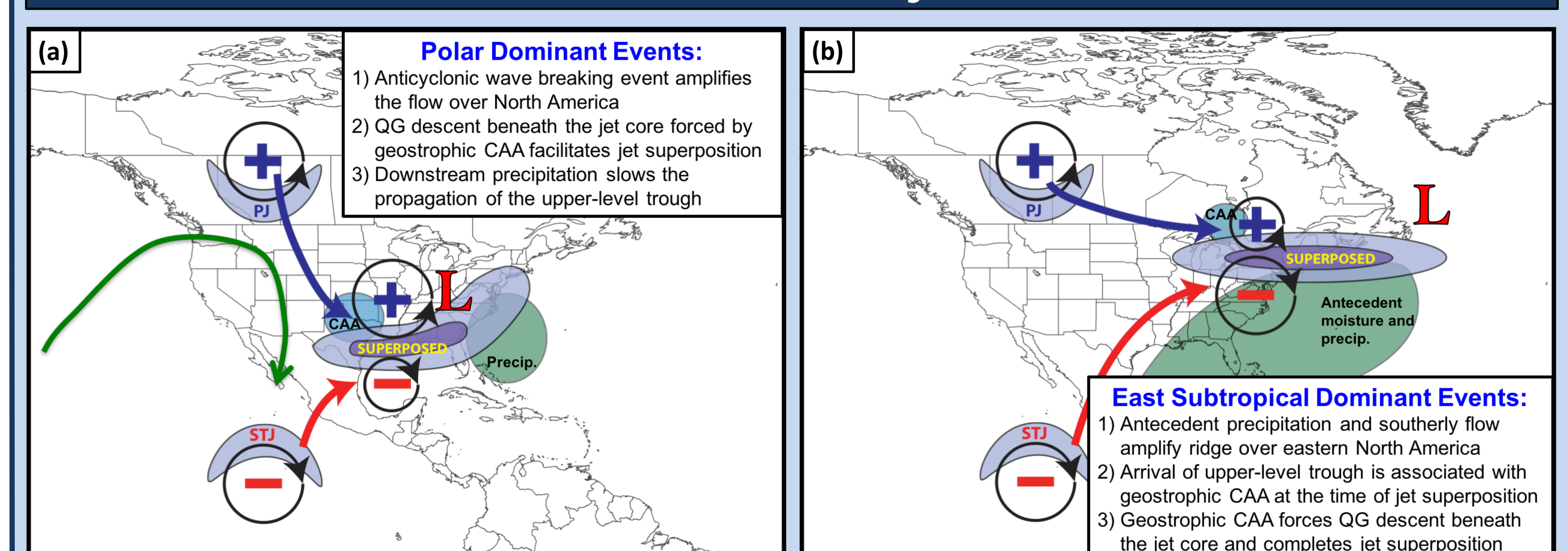



*Figure 9: Conceptual schematics illustrating the development of (a) polar and (b) east subtropical dominant jet superposition events.*