

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

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San José State University

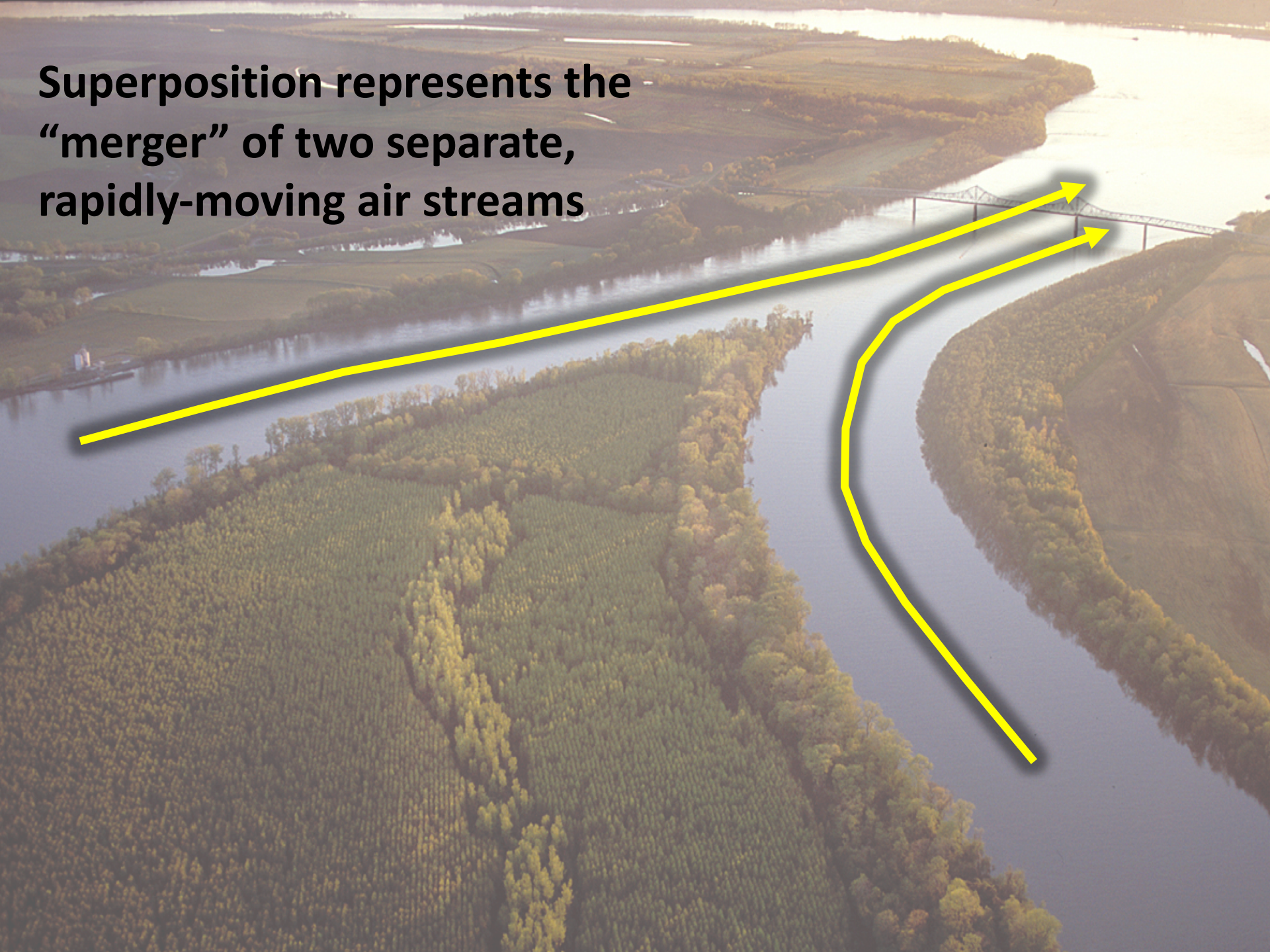
San José, CA

5 December 2018

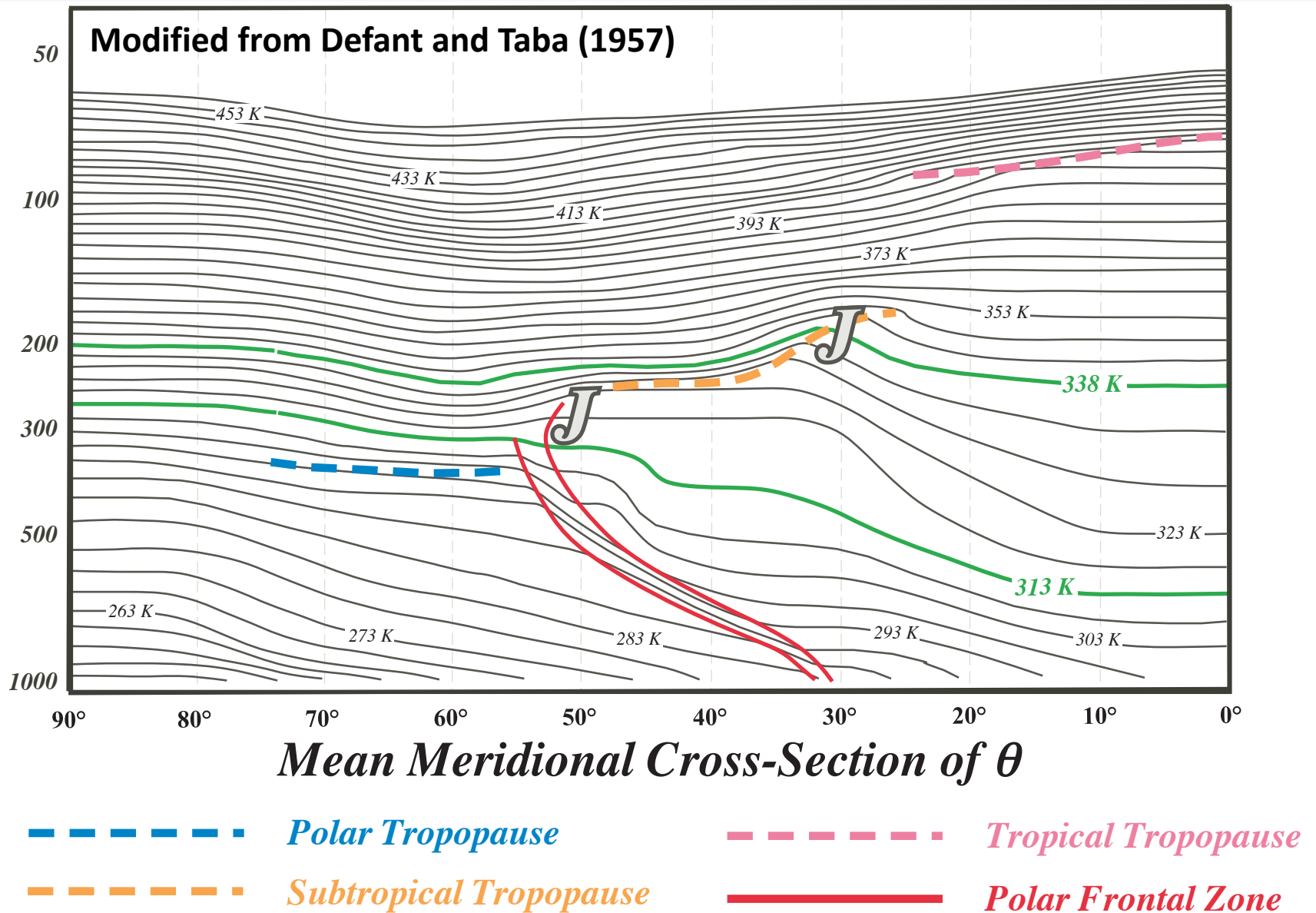


This work is funded by an NSF-PRF (AGS-1624316)

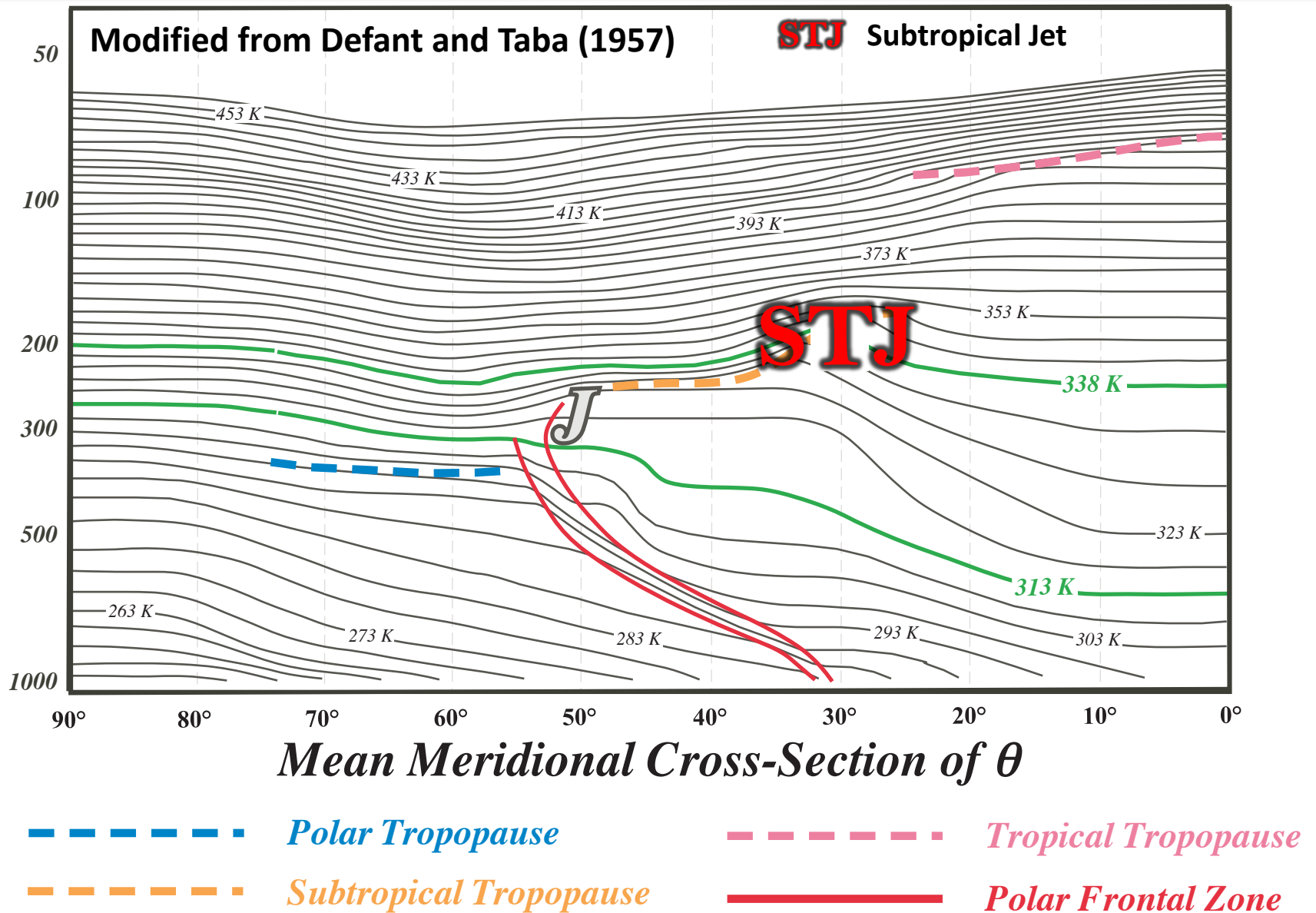
Superposition represents the “merger” of two separate, rapidly-moving air streams



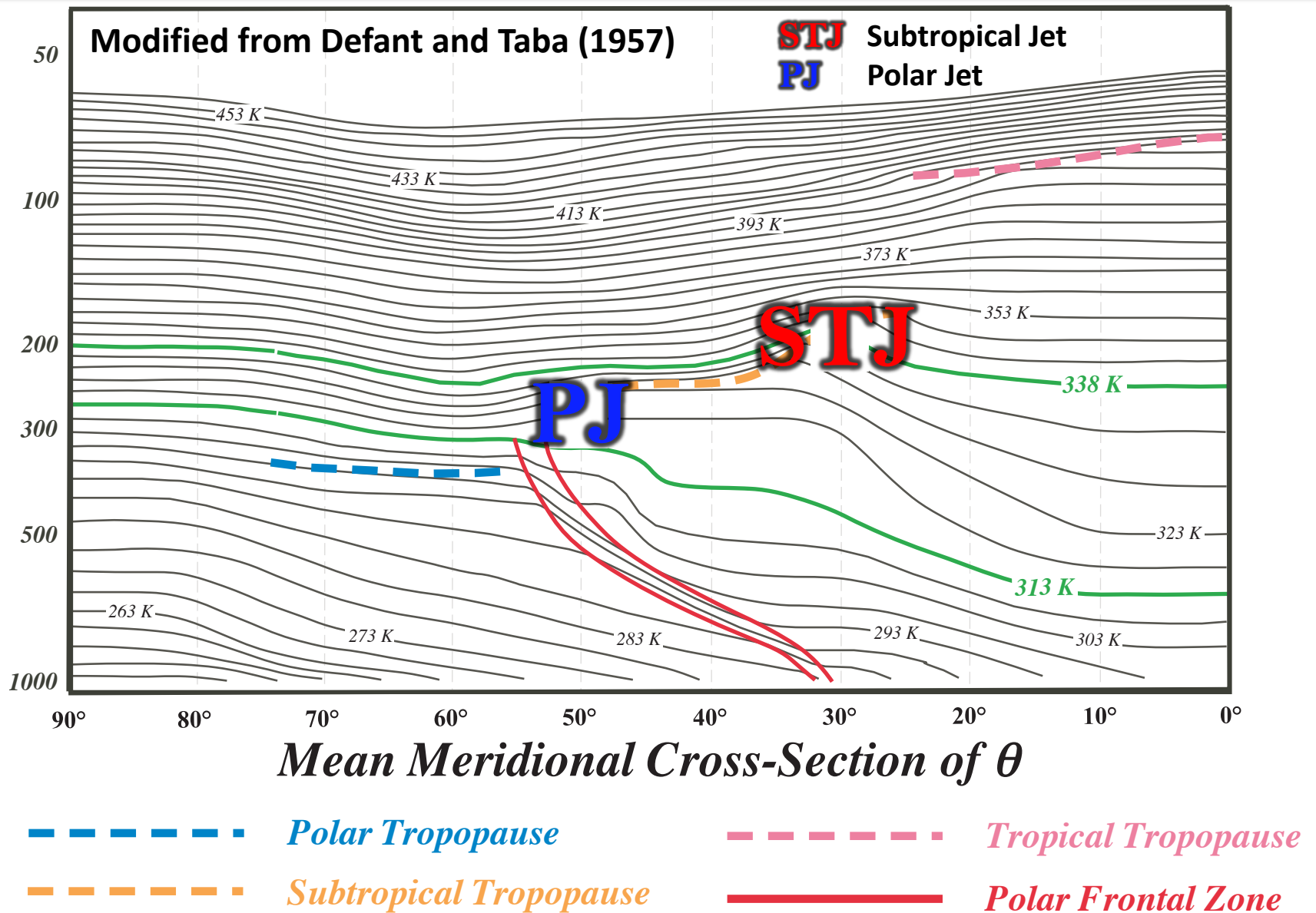
Background



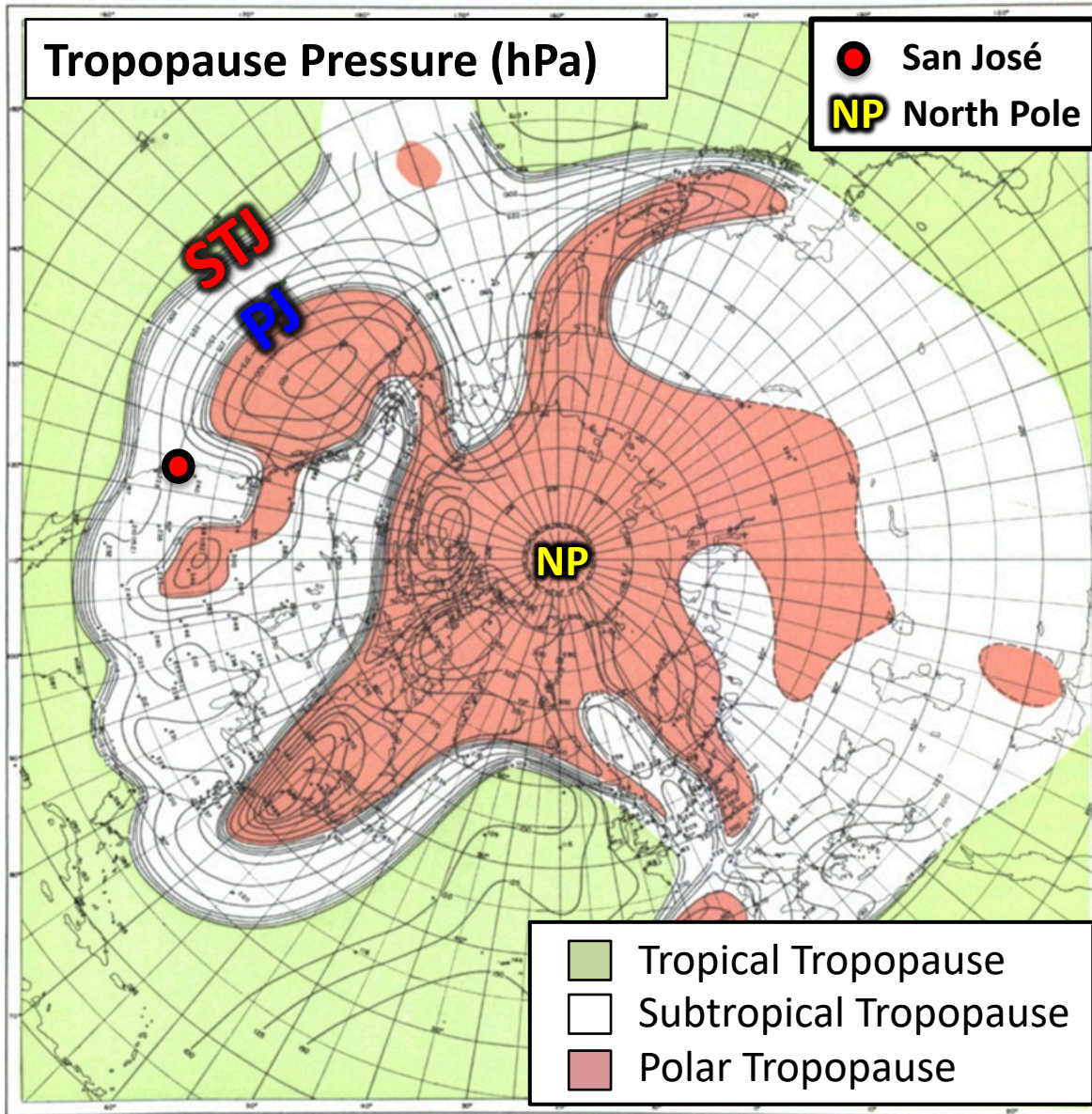
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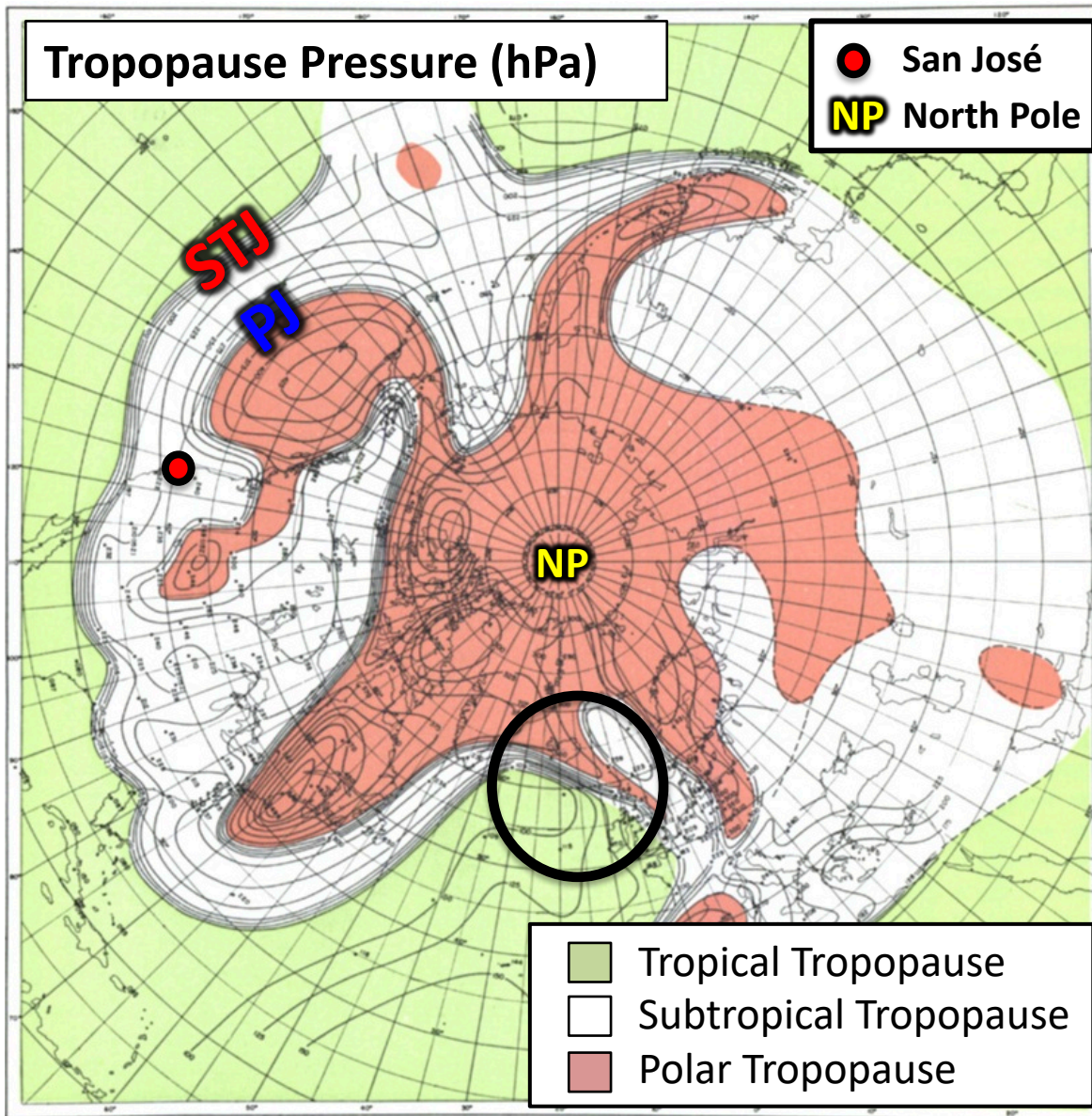


Maps of tropopause pressure help to identify the location of the jets.

While each jet occupies its own climatological latitude band, substantial meanders are common.

**Modified from Defant and Taba
(1957)**

Background



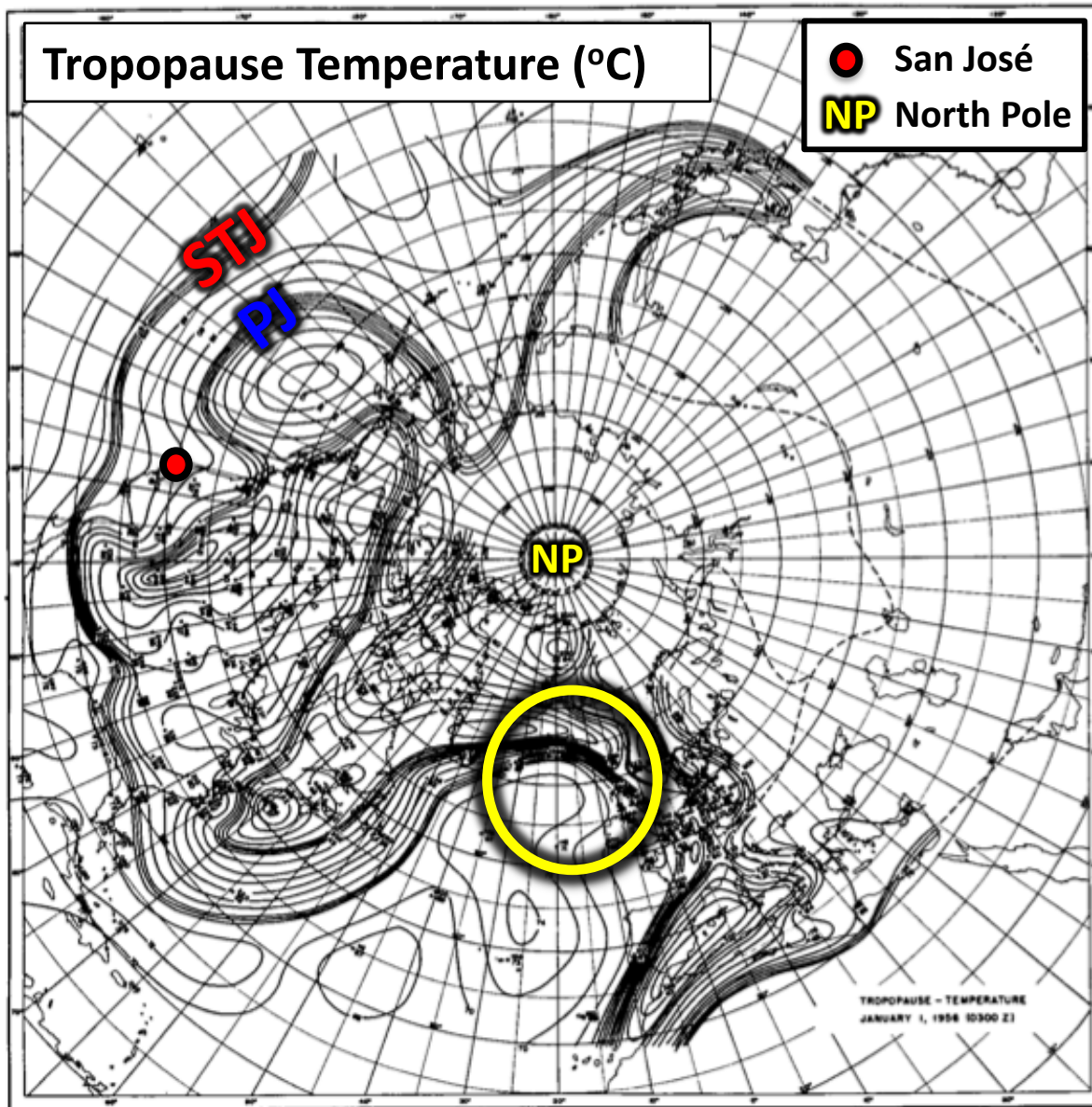
Maps of tropopause pressure help to identify the location of the jets.

While each jet occupies its own climatological latitude band, substantial meanders are common.

Occasionally, the latitudinal separation between the jets can vanish resulting in a vertical **jet superposition**.

Modified from Defant and Taba (1957)

Background



The pole-to-equator baroclinicity is combined into a much narrower zone of contrast in the vicinity of a jet superposition.

Intensified frontal structure is often attended by a strengthening of the superposed jet's transverse circulation.

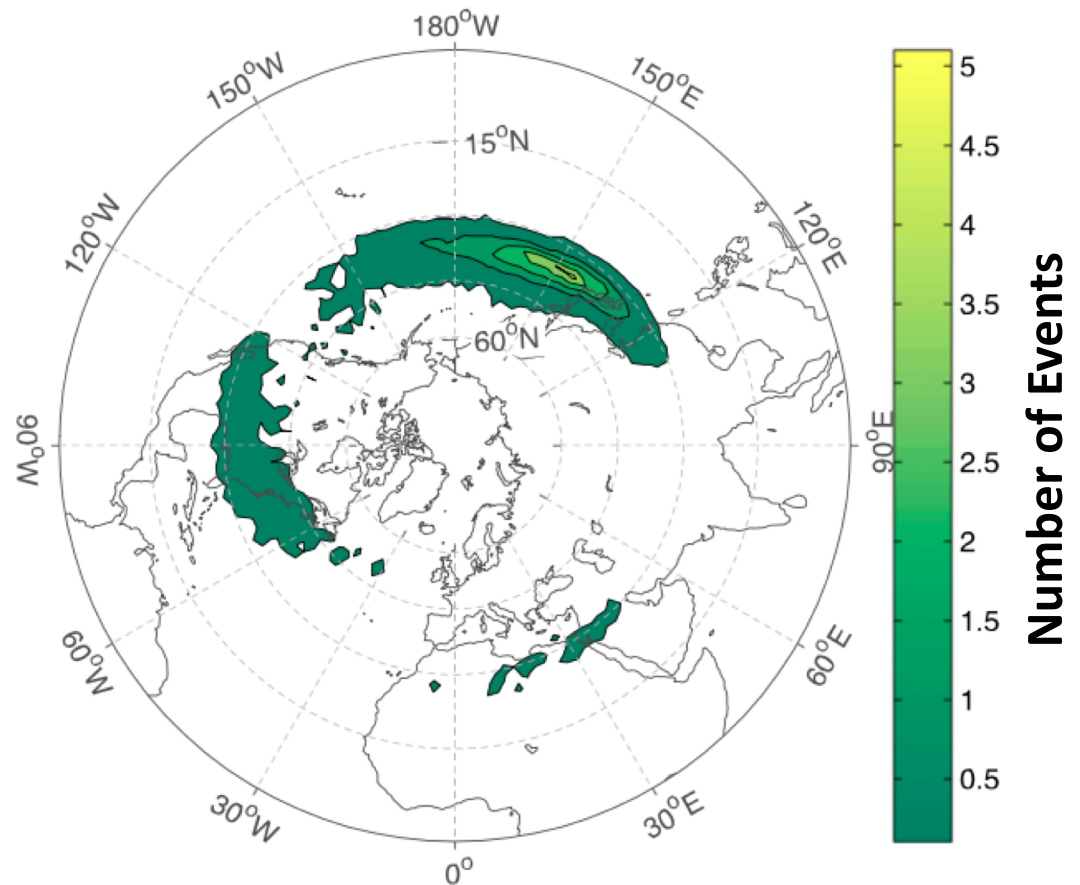
Modified from Defant and Taba (1957)

Background

Christenson et al. (2017) highlight three locations that experience the greatest frequency of jet superpositions:

- 1) Western Pacific
- 2) North America
- 3) Northern Africa

Climatological frequency of Northern Hemisphere jet superposition events per cold season (Nov–Mar) 1960–2010



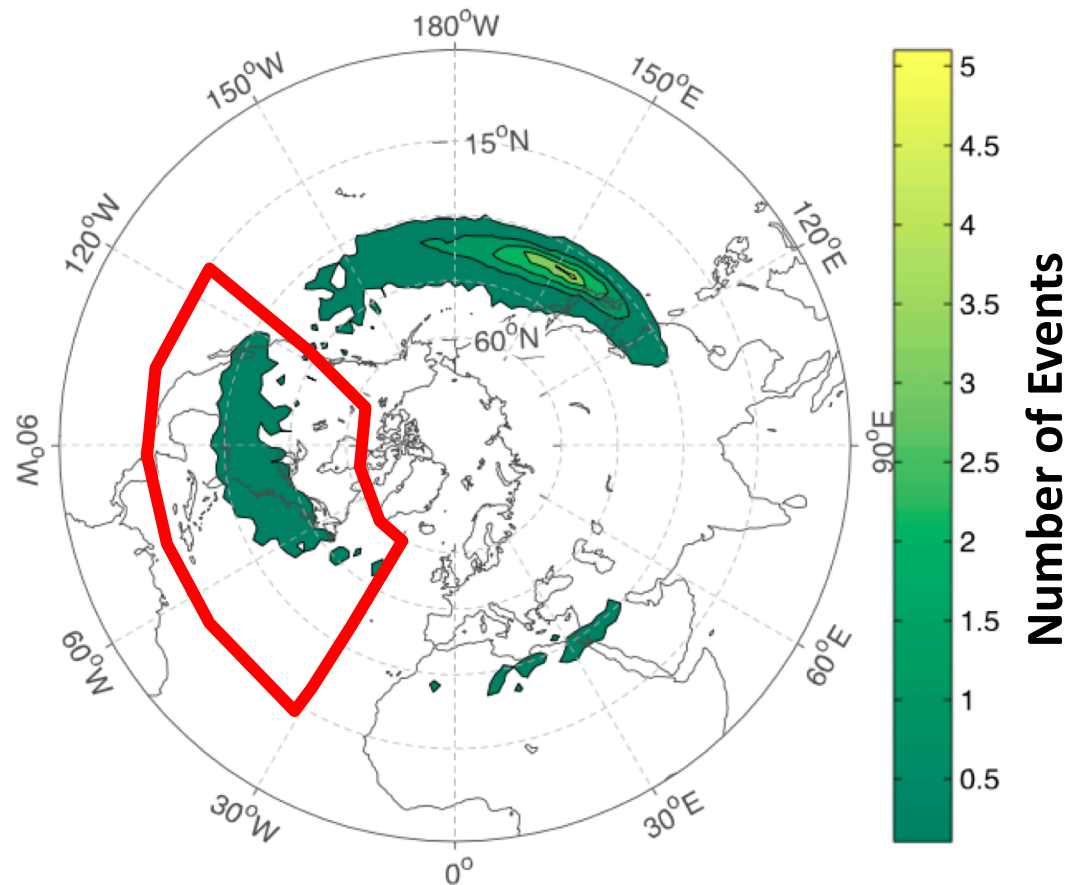
Christenson et al. (2017)

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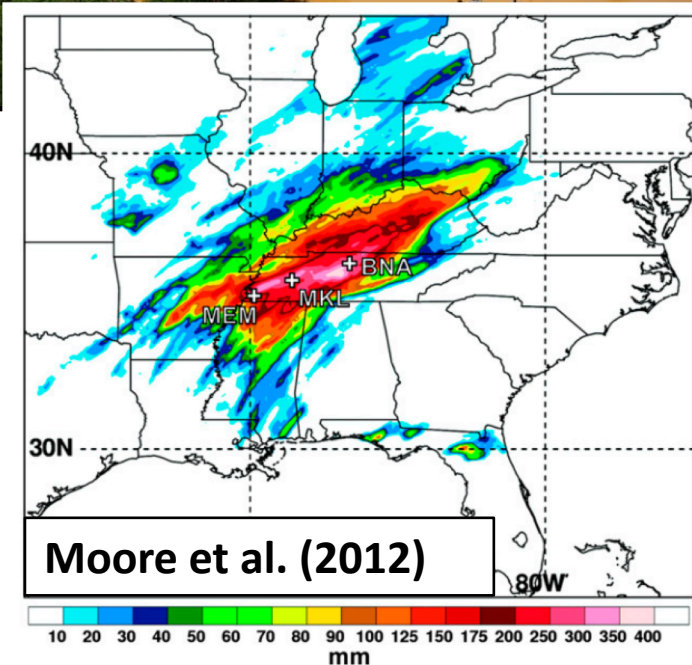
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Christenson et al. (2017)

Jet Superpositions and High-Impact Weather

The Tennessean

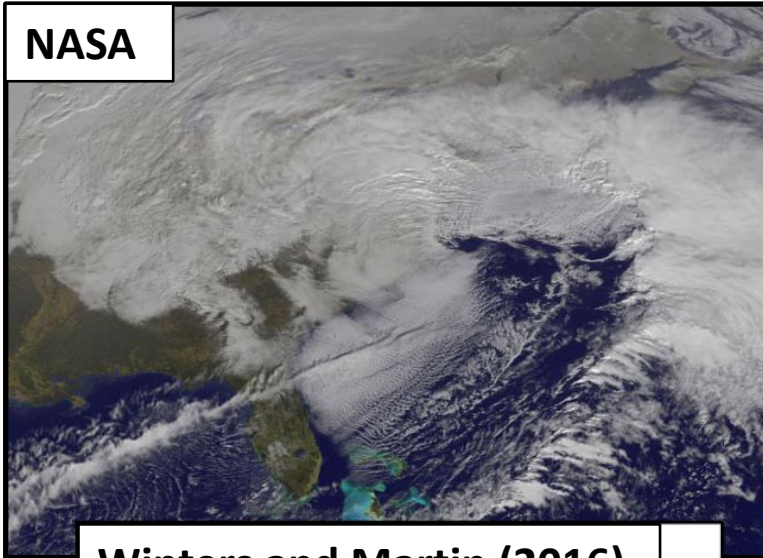


Jet superpositions can be an element of high-impact weather events

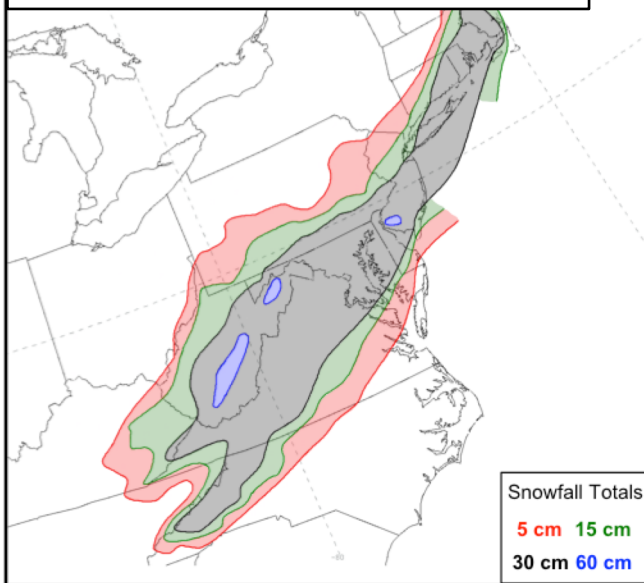
1–3 May 2010 Nashville Flood

- Jet superposition enhanced the poleward moisture transport via its ageostrophic circulation (Winters and Martin 2014; 2016).

Jet Superpositions and High-Impact Weather



Winters and Martin (2016)



Jet superpositions can be an element of high-impact weather events

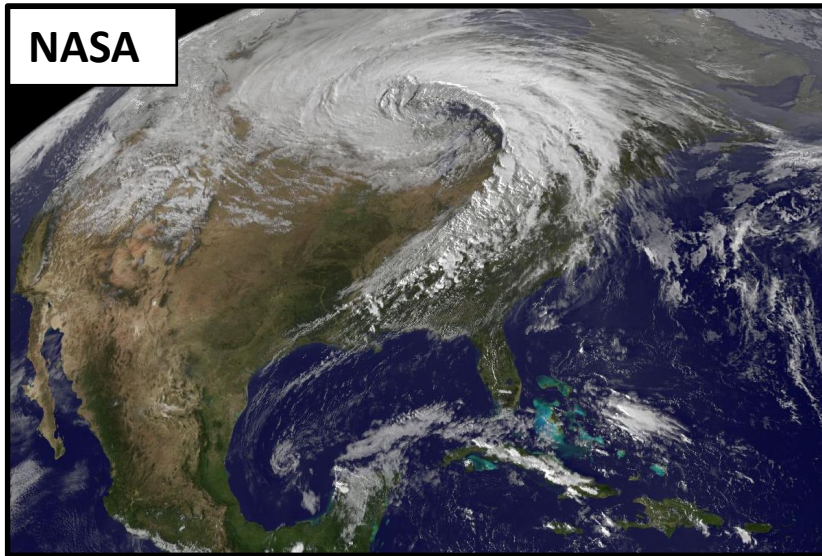
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18–20 December 2009 Mid-Atlantic Blizzard

- Jet superposition was associated with a rapidly deepening East Coast cyclone (Winters and Martin 2016; 2017).

Jet Superpositions and High-Impact Weather



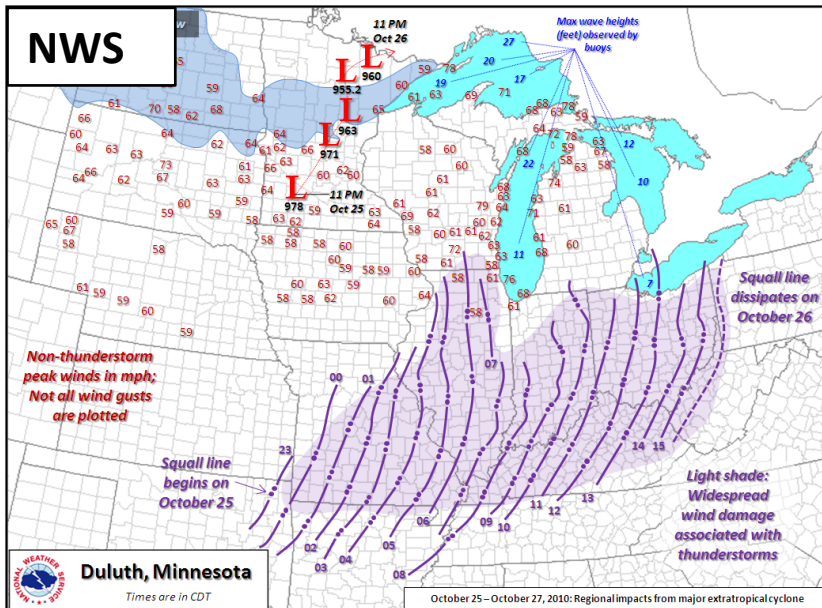
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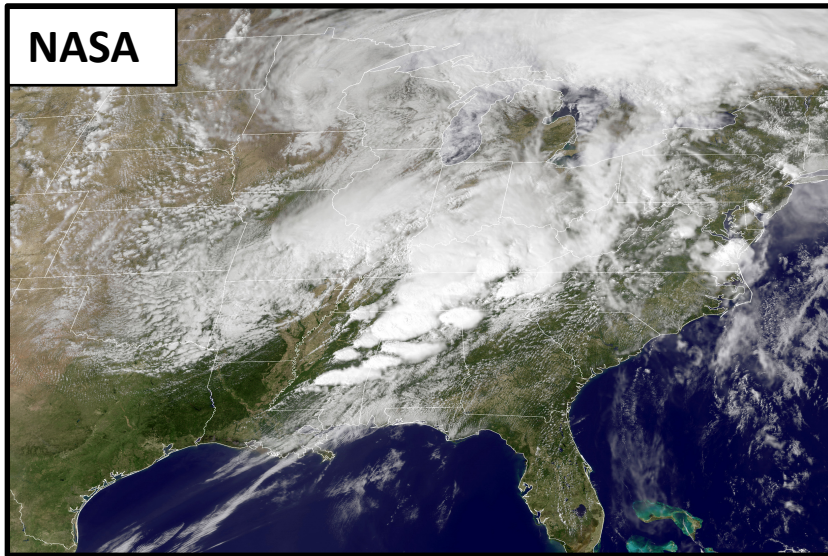
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26 October 2010: Explosive Cyclogenesis Event

- Jet superposition preceded the development of an intense Midwest U.S. cyclone.

Jet Superpositions and High-Impact Weather



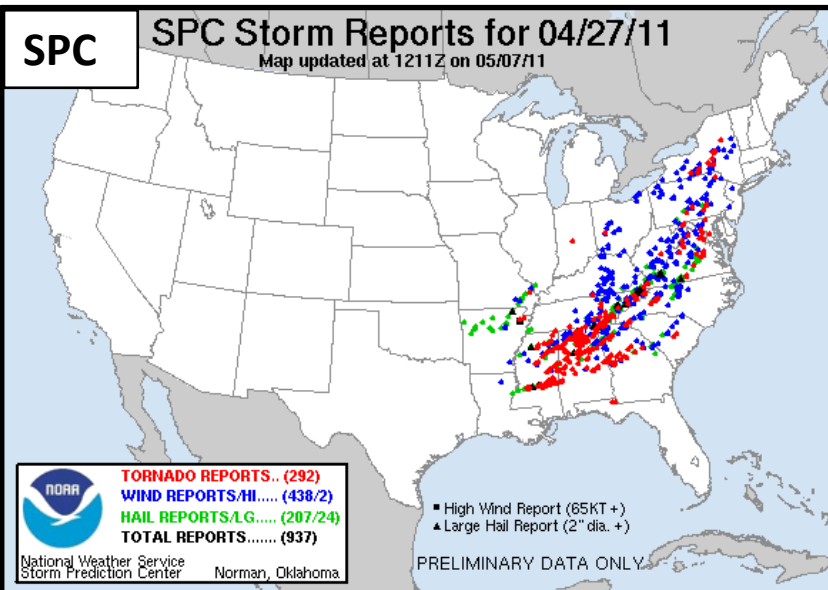
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- Jet superposition over the West Pacific preceded the development of an intense Midwest U.S. cyclone.

25–28 April 2011 Tornado Outbreak

- Jet superposition occurred over the West Pacific prior to the outbreak (Knupp et al. 2014; Christenson and Martin 2012).

Jet Superpositions and High-Impact Weather

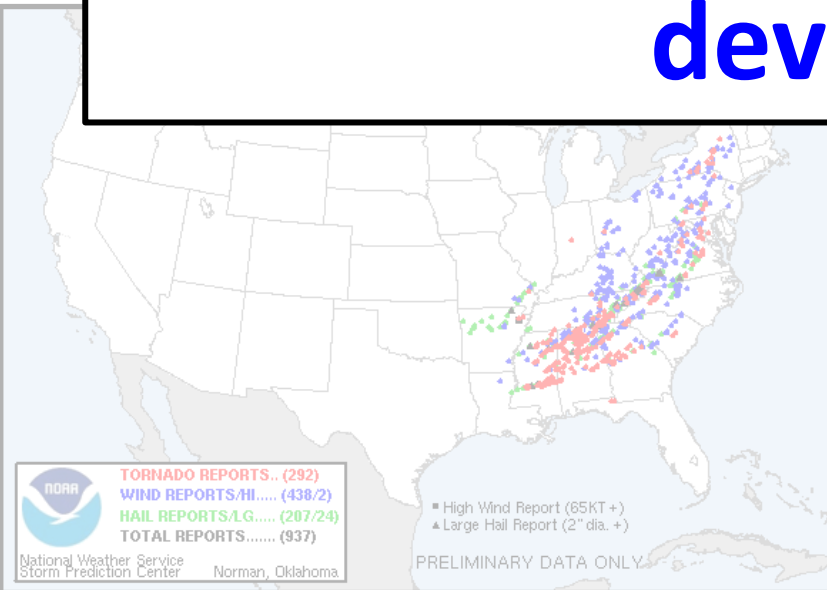


Jet superpositions can be an element of high-impact weather events

1–3 May 2010 Nashville Flood

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How do these structures develop?



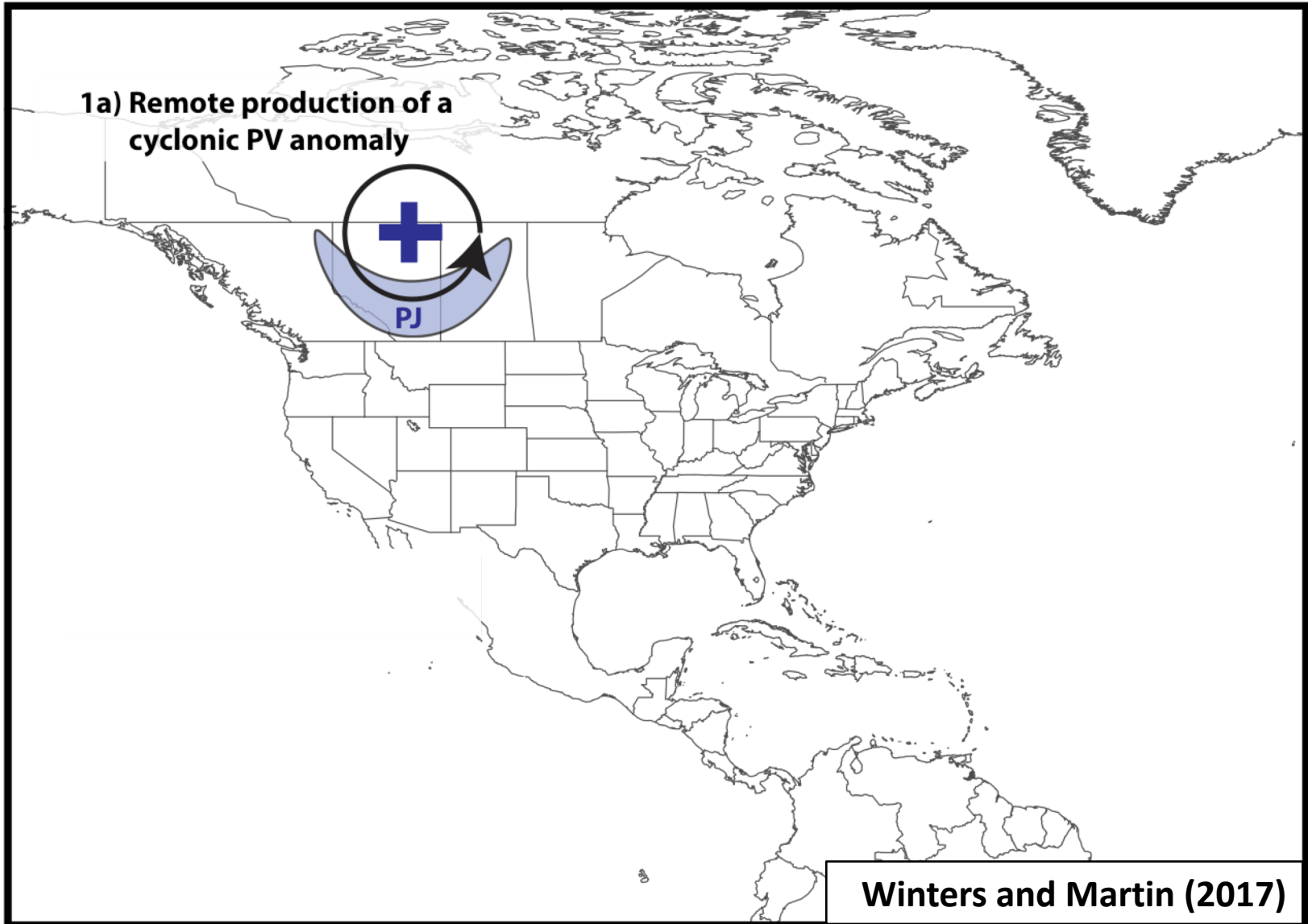
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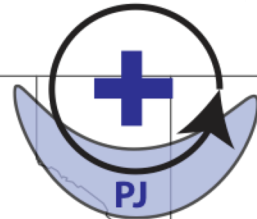
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Jet Superposition Conceptual Model



Jet Superposition Conceptual Model

1a) Remote production of a cyclonic PV anomaly

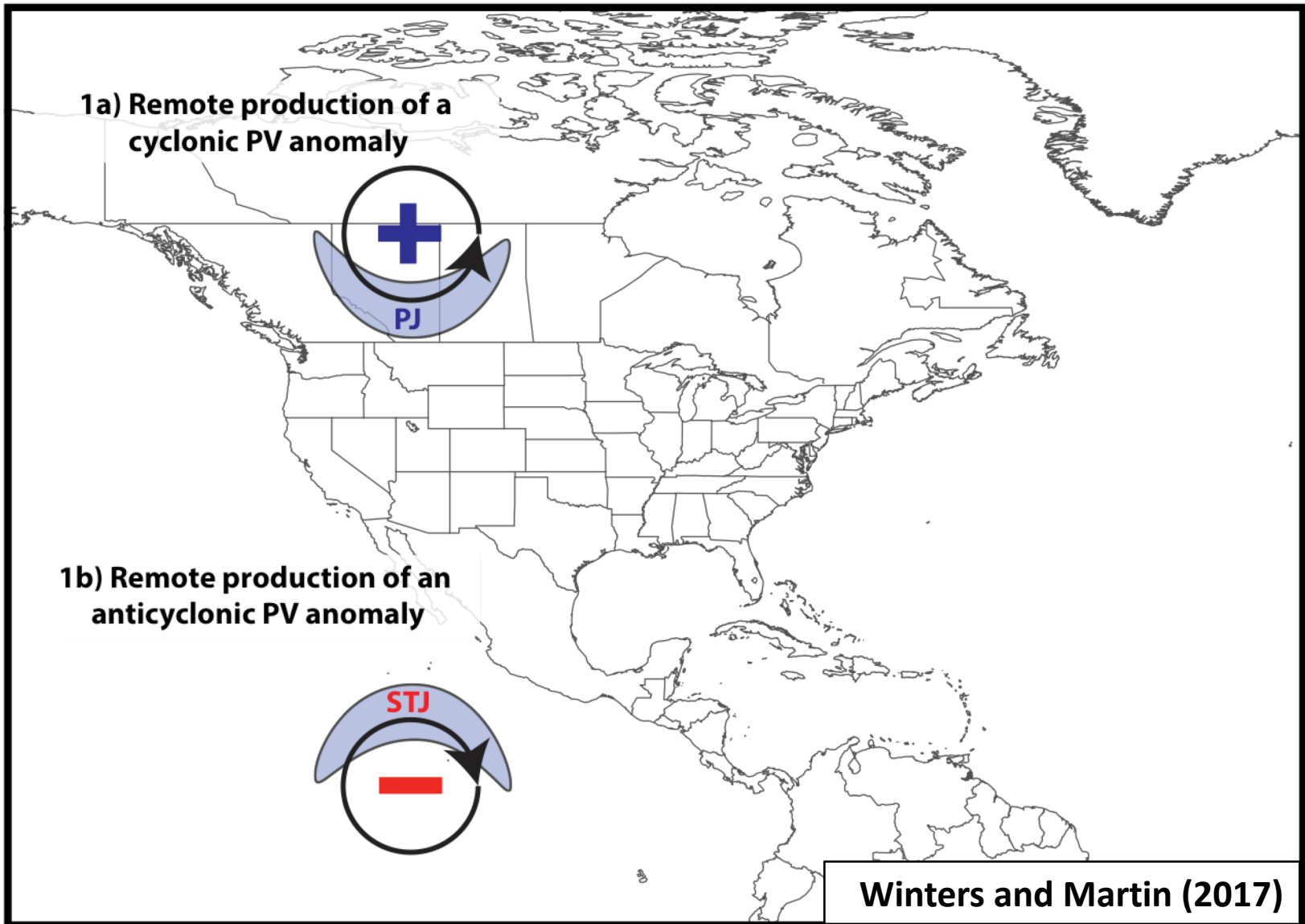


Polar cyclonic PV anomalies:

- 1) Often referred to as coherent tropopause disturbances (Pyle et al. 2004) or tropopause polar vortices (Cavallo and Hakim 2010).
- 2) Typify a dynamical environment conducive to midlatitude cyclogenesis.

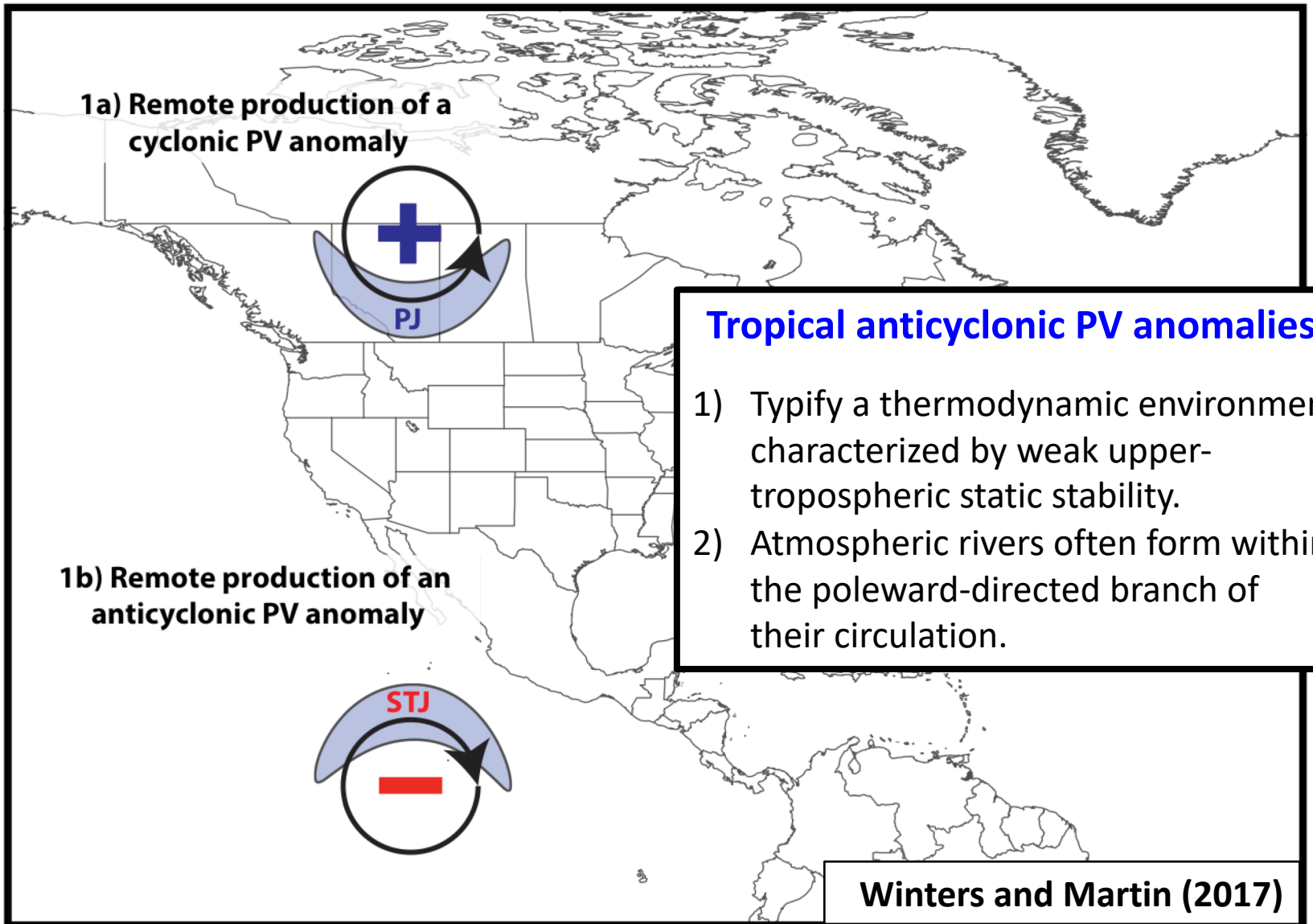
Winters and Martin (2017)

Jet Superposition Conceptual Model

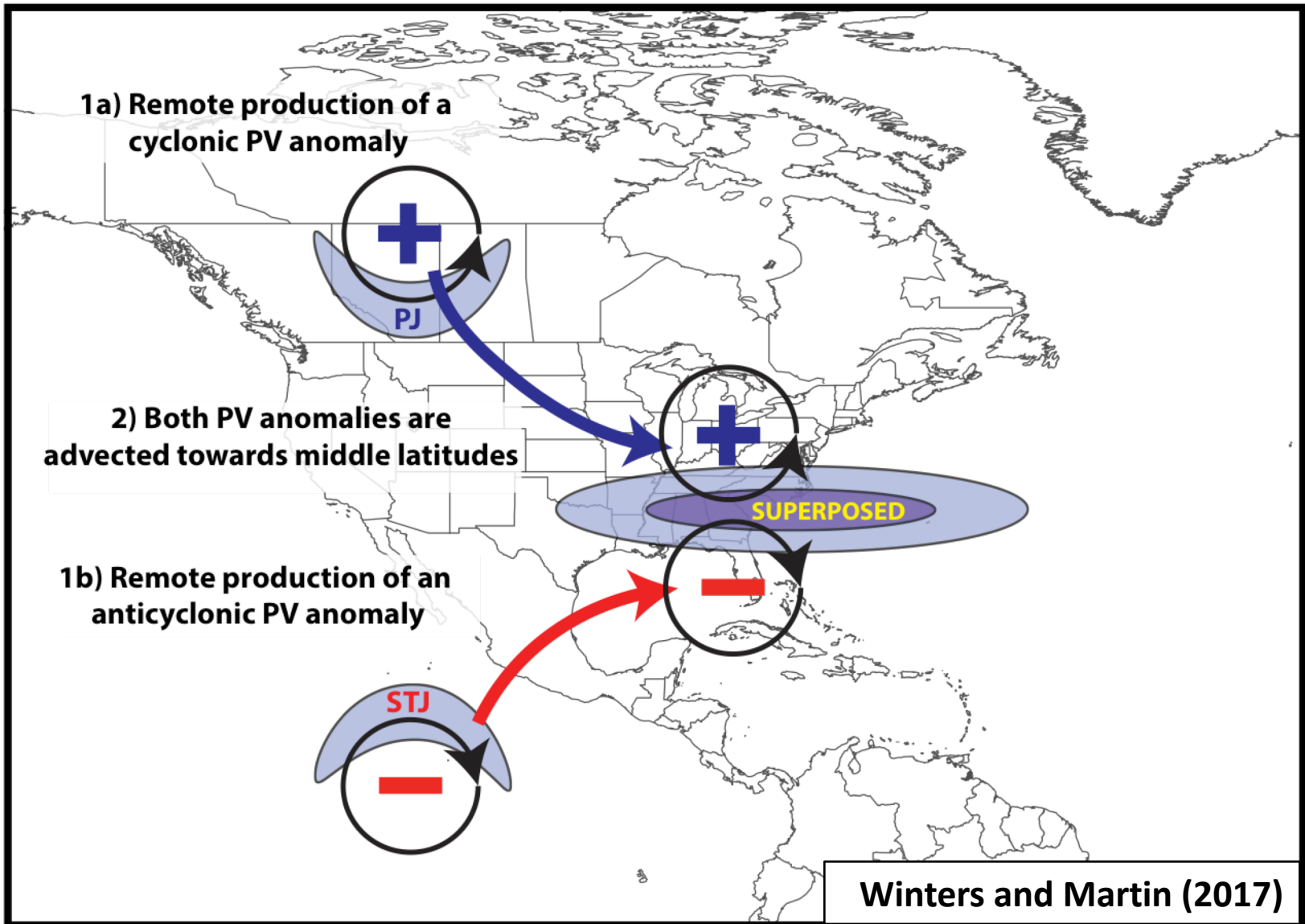


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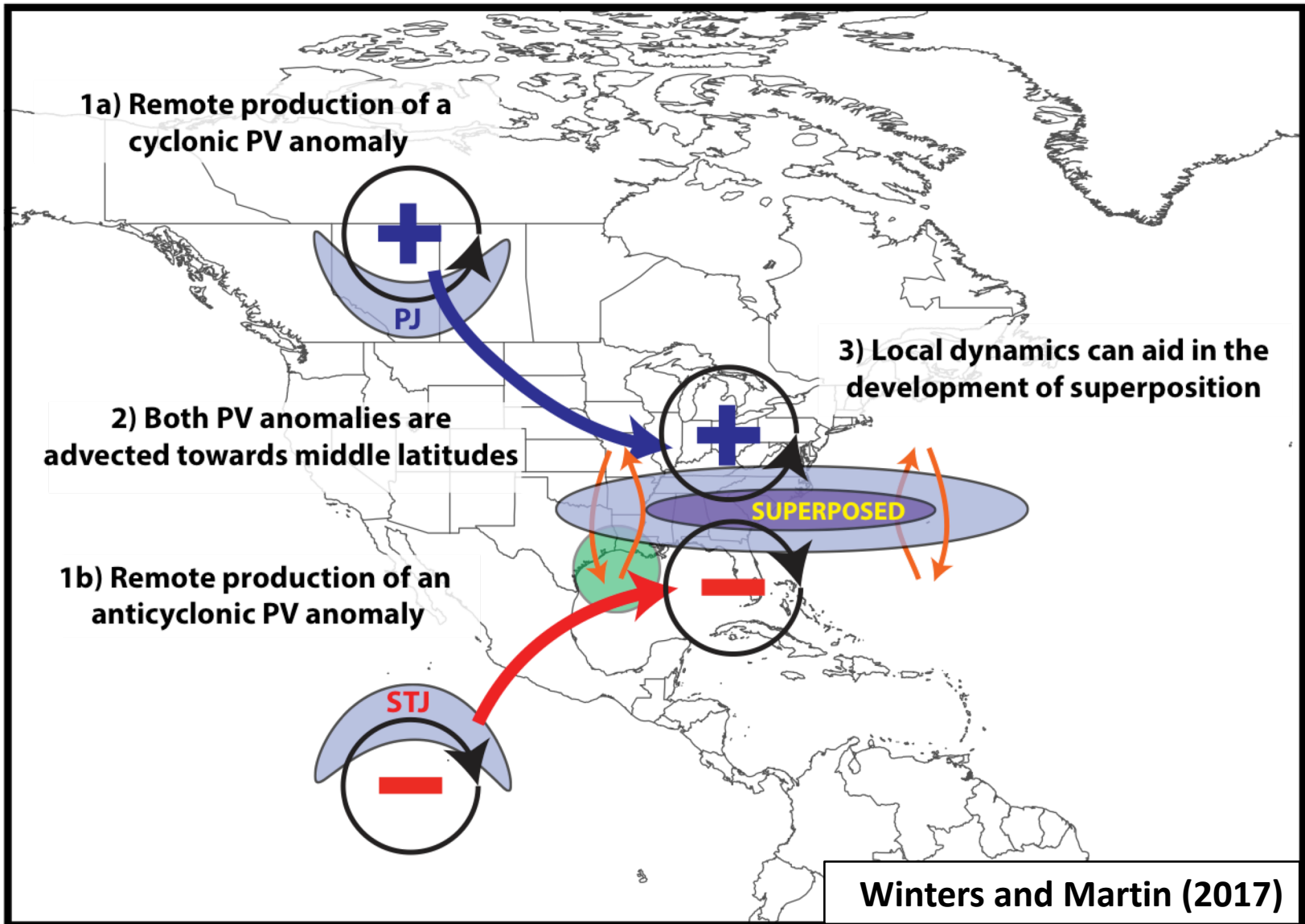
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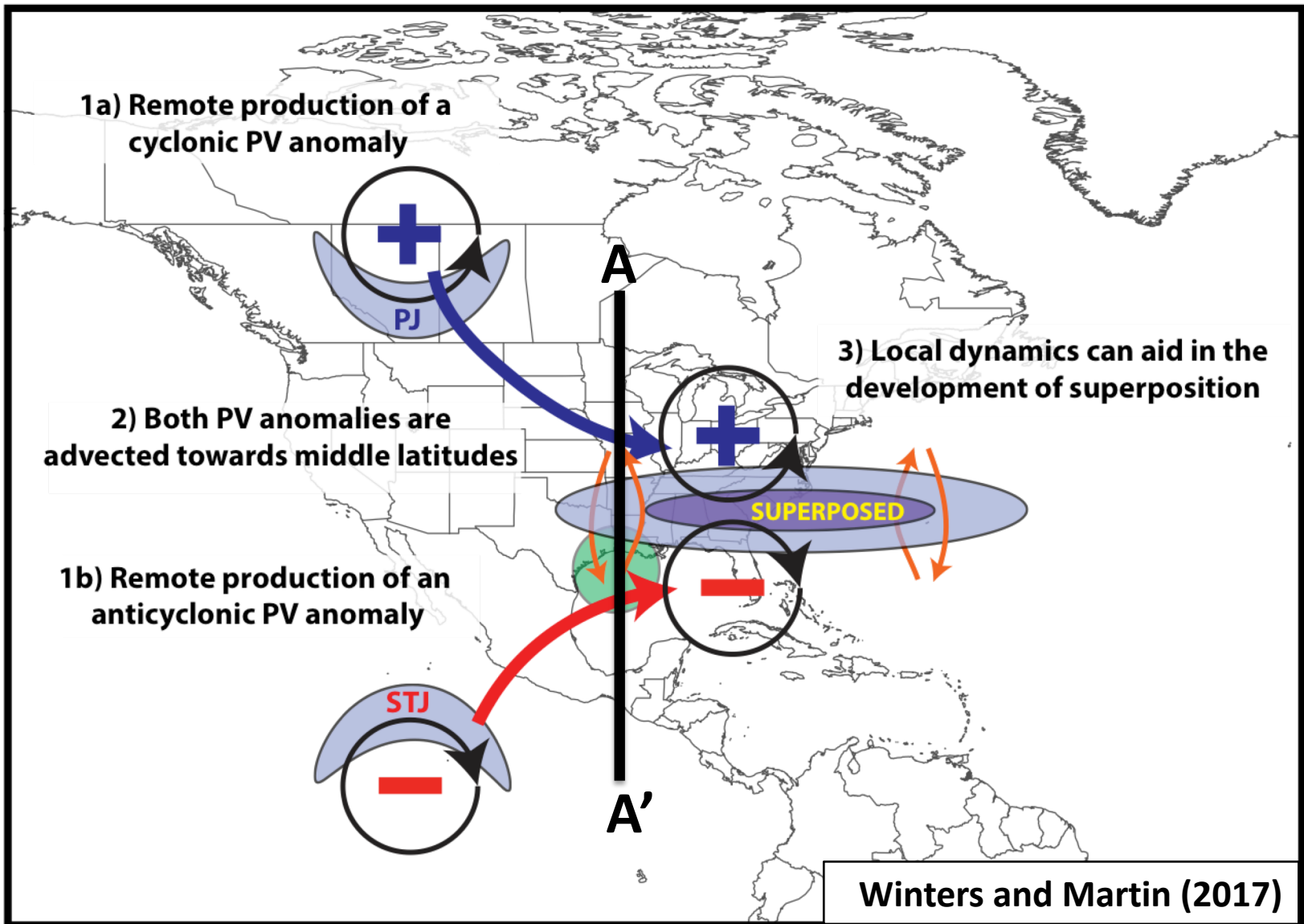
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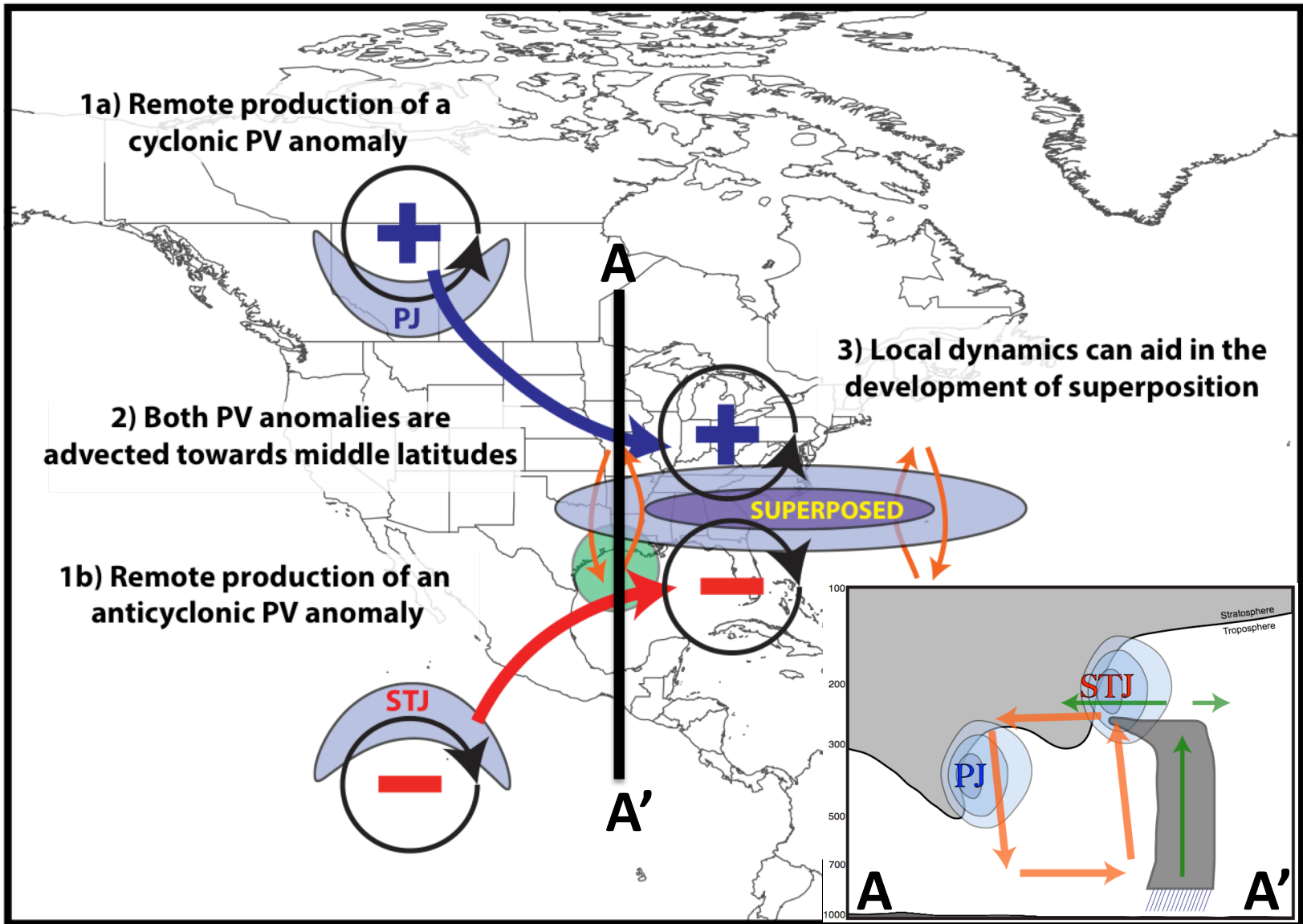
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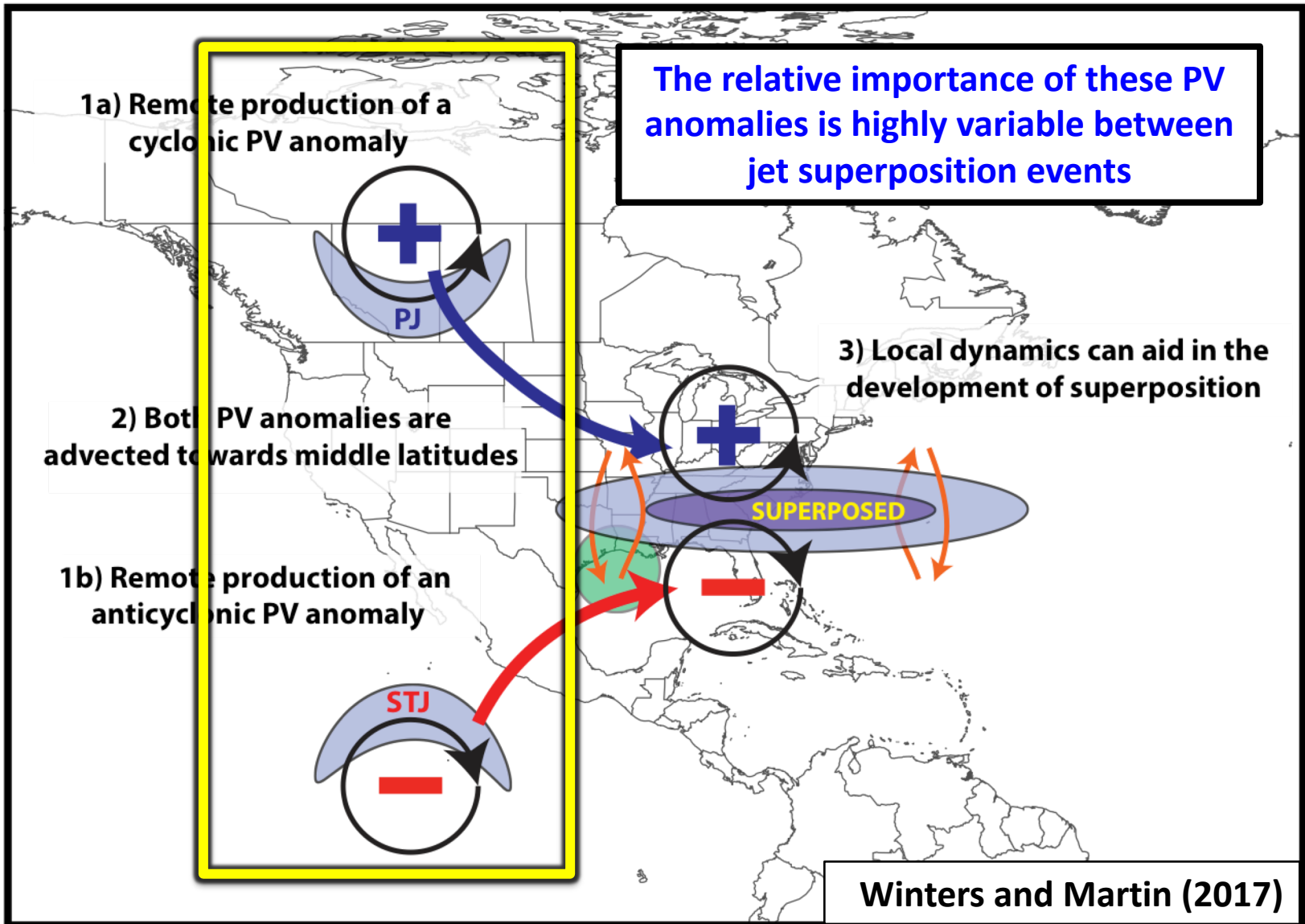
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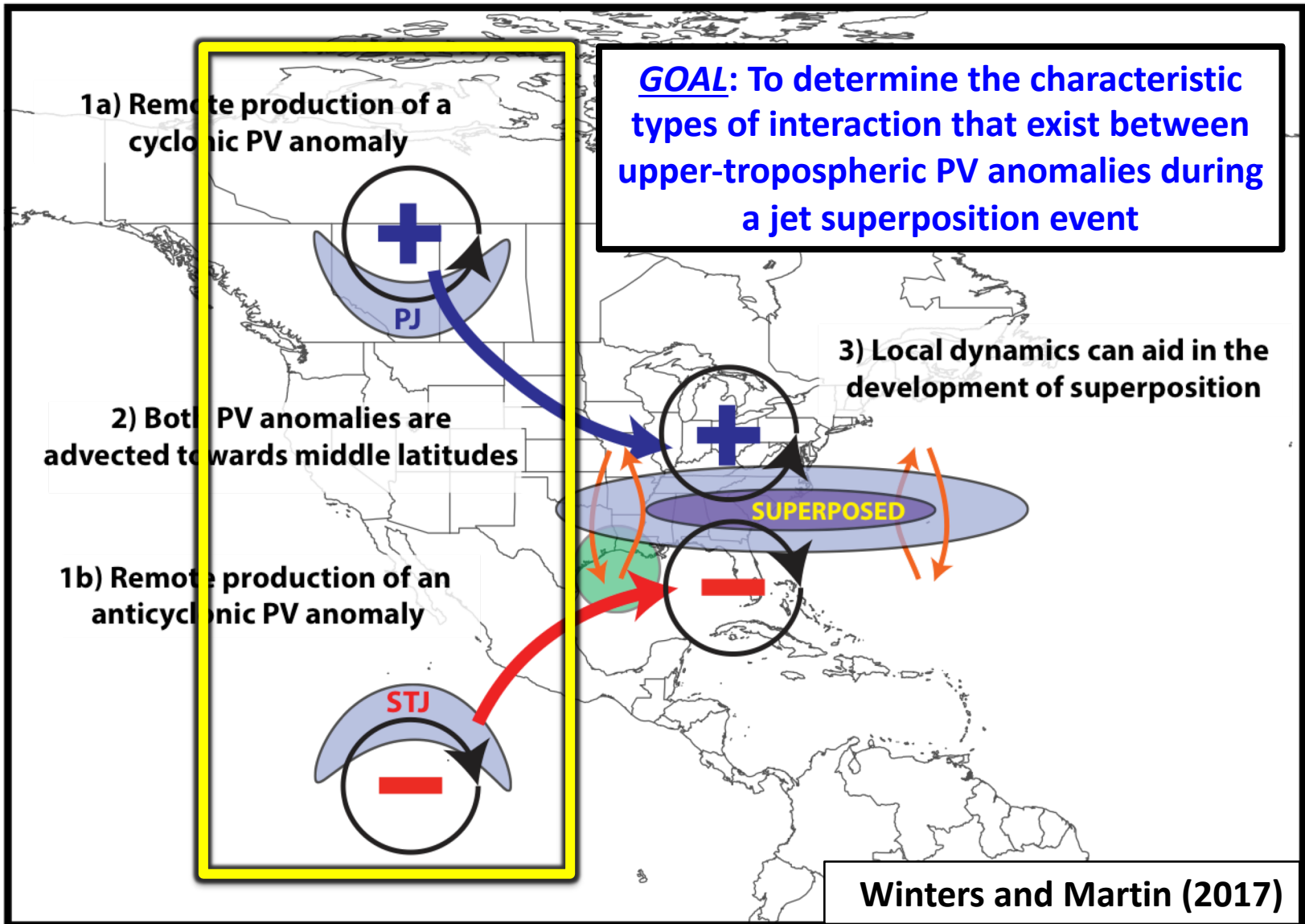
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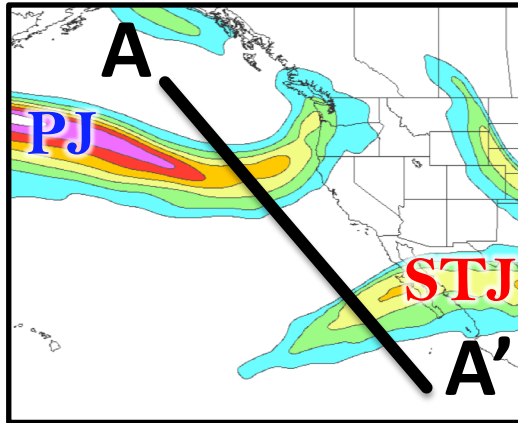
Jet Superposition Conceptual Model



Jet Superposition Event Identification and Classification

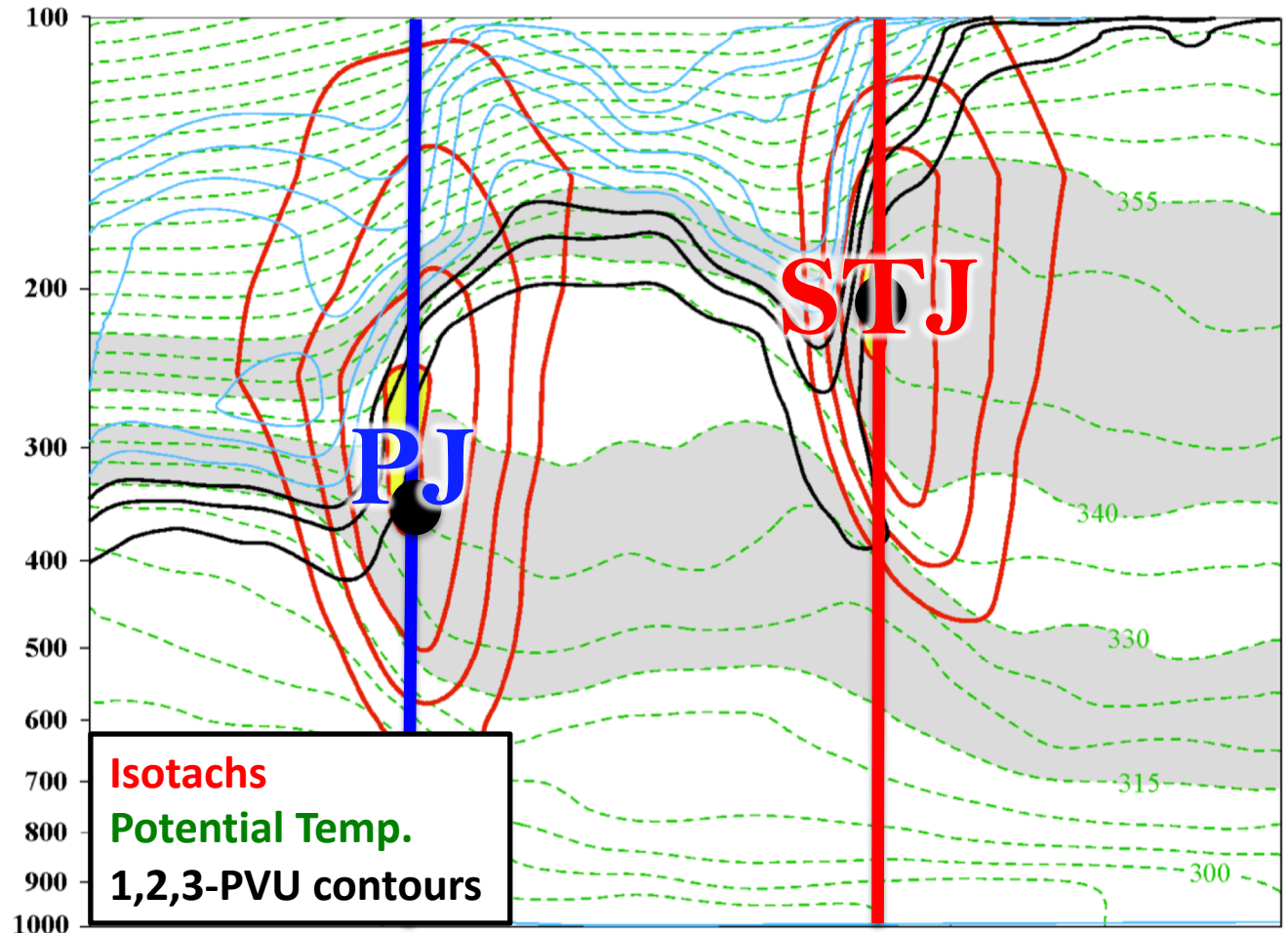
Jet Superposition Event Identification

0000 UTC 27 April 2010



250-hPa wind speed

Isolated grid points over North America in the CFSR (Saha et al. 2014) characterized by polar and subtropical jets during Nov–Mar 1979–2010.

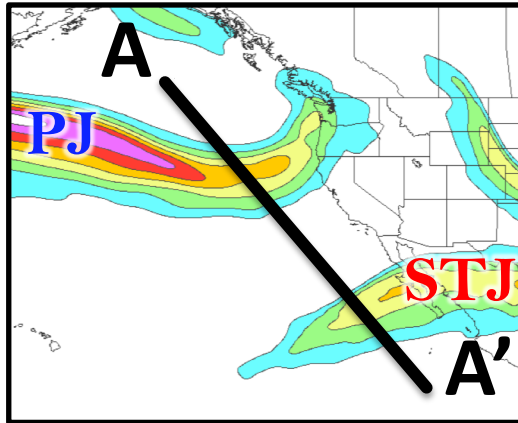


Isotachs
Potential Temp.
1,2,3-PVU contours

A Winters and Martin (2014, 2016, 2017); Christenson et al. (2017); Handlos and Martin (2016) **A'**

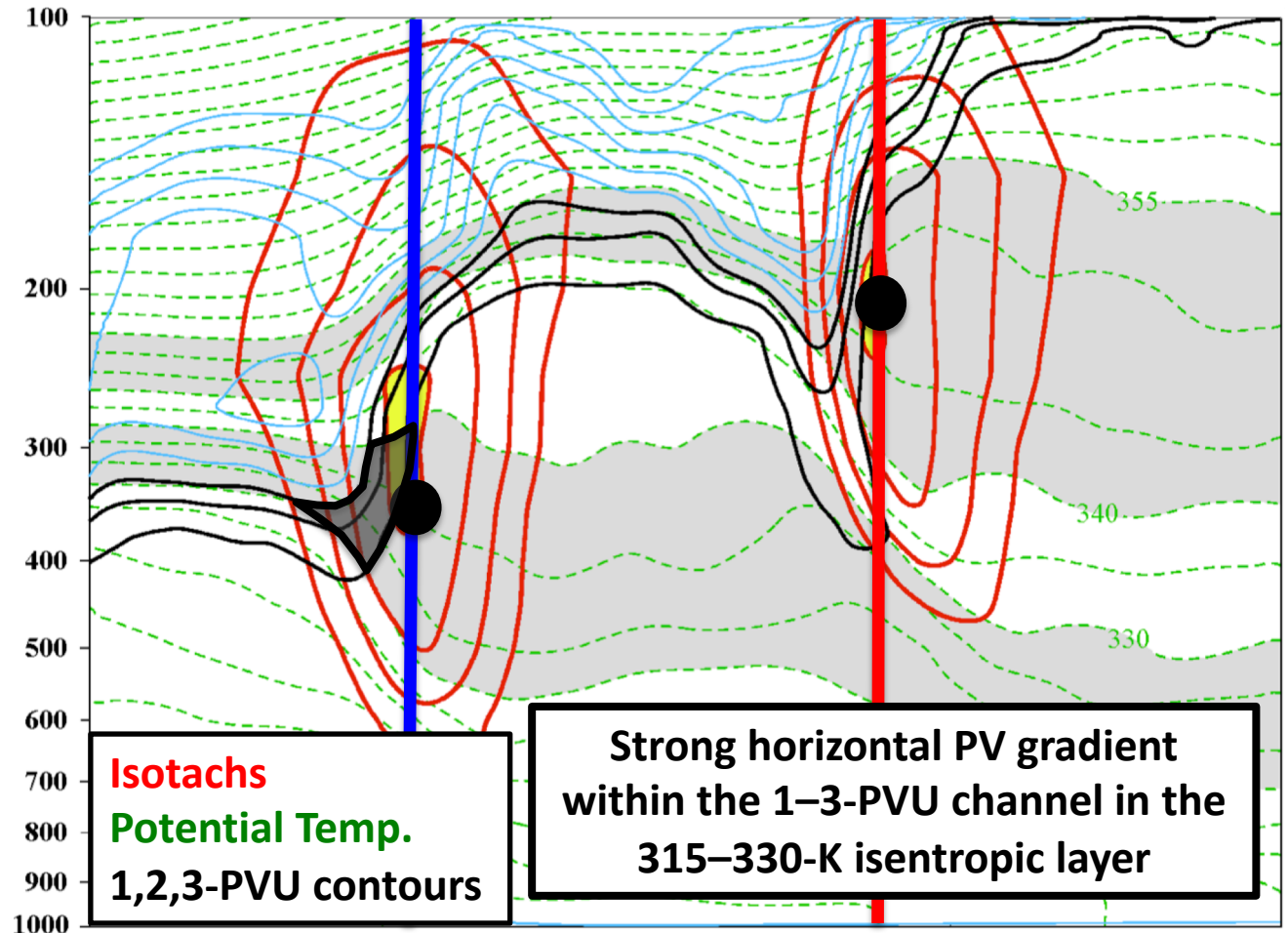
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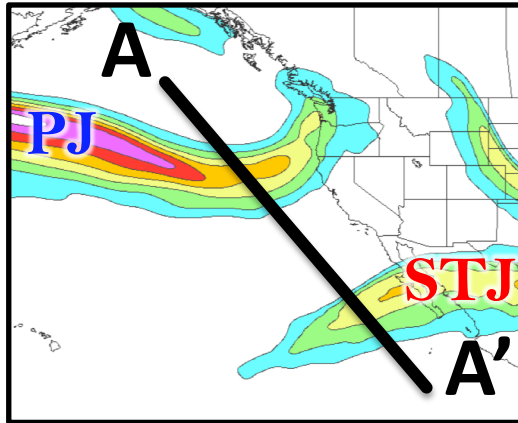
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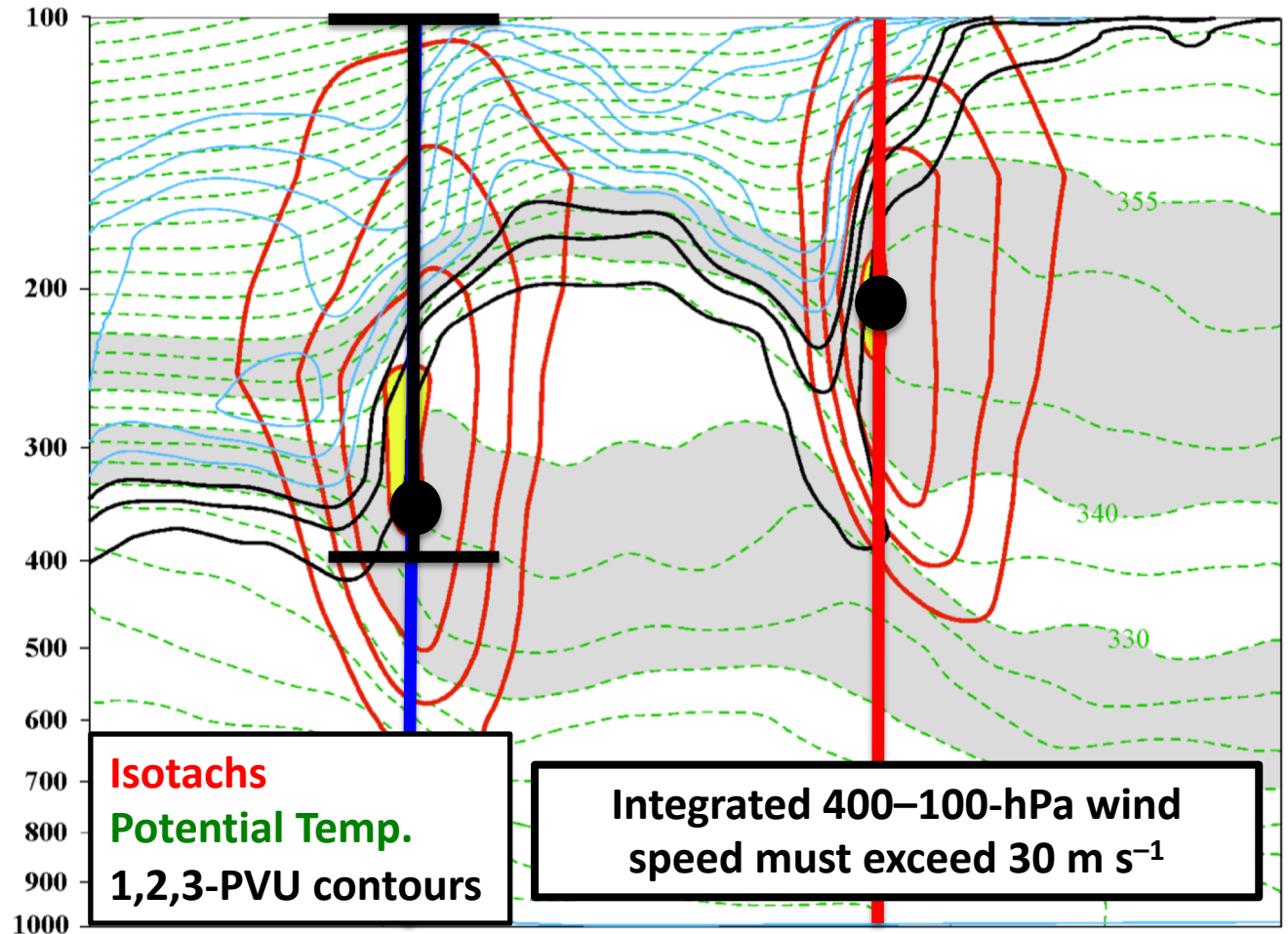
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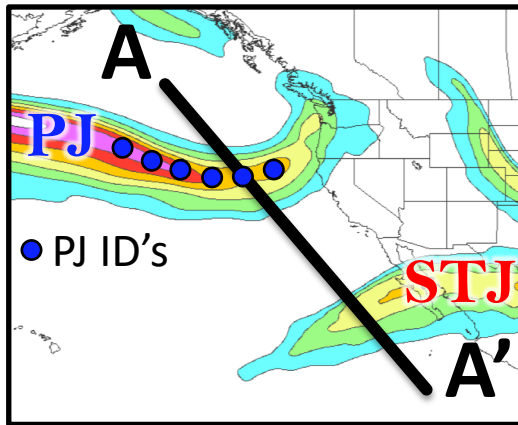
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Integrated 400–100-hPa wind speed must exceed 30 m s^{-1}

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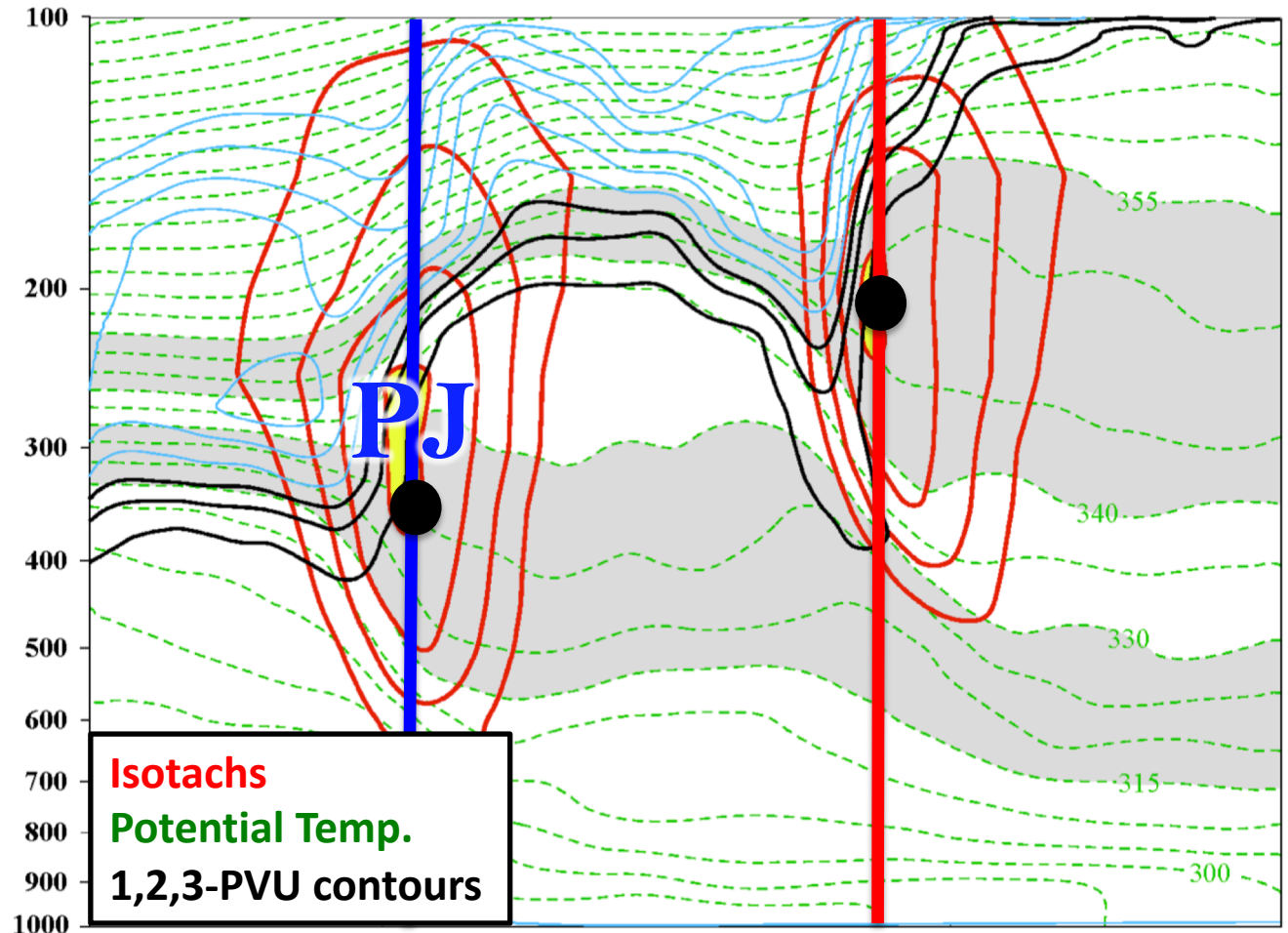
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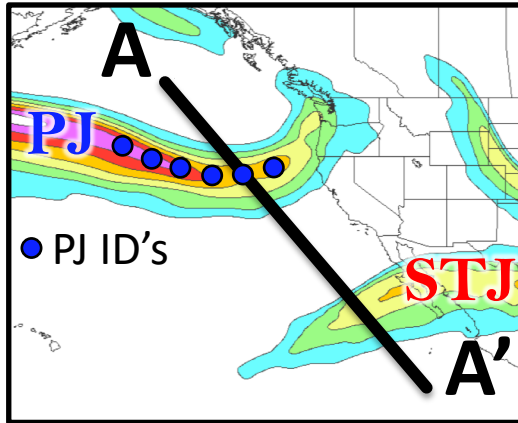


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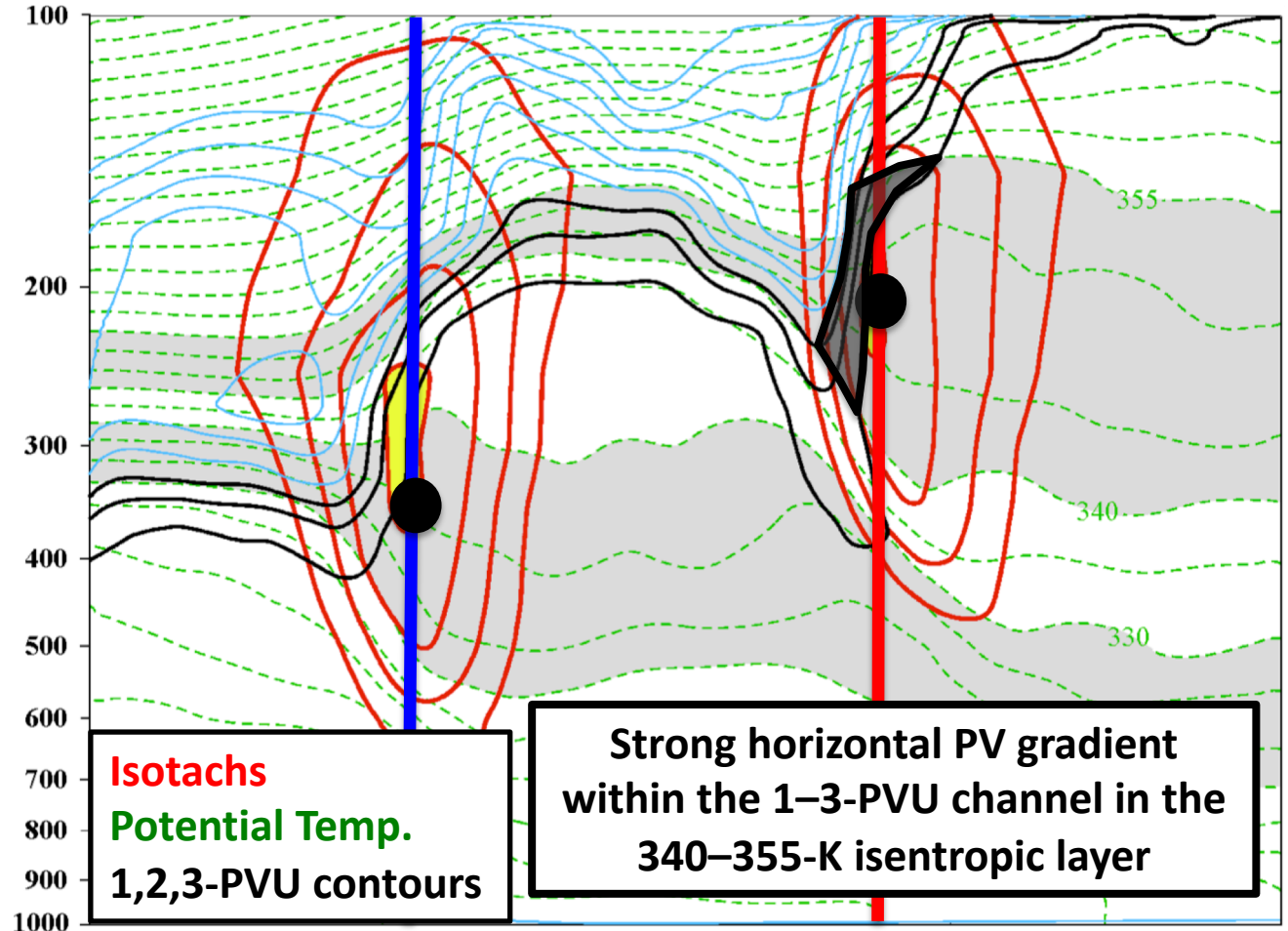
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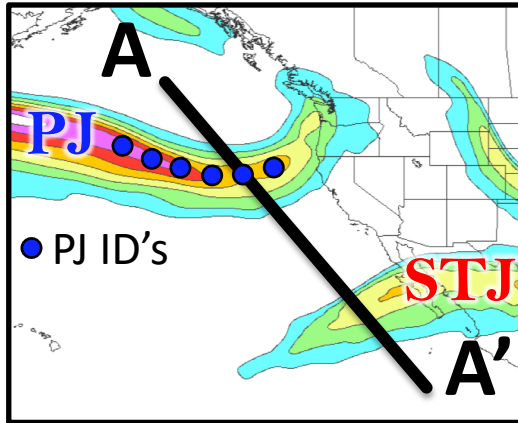
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Strong horizontal PV gradient
within the 1–3-PVU channel in the
340–355-K isentropic layer

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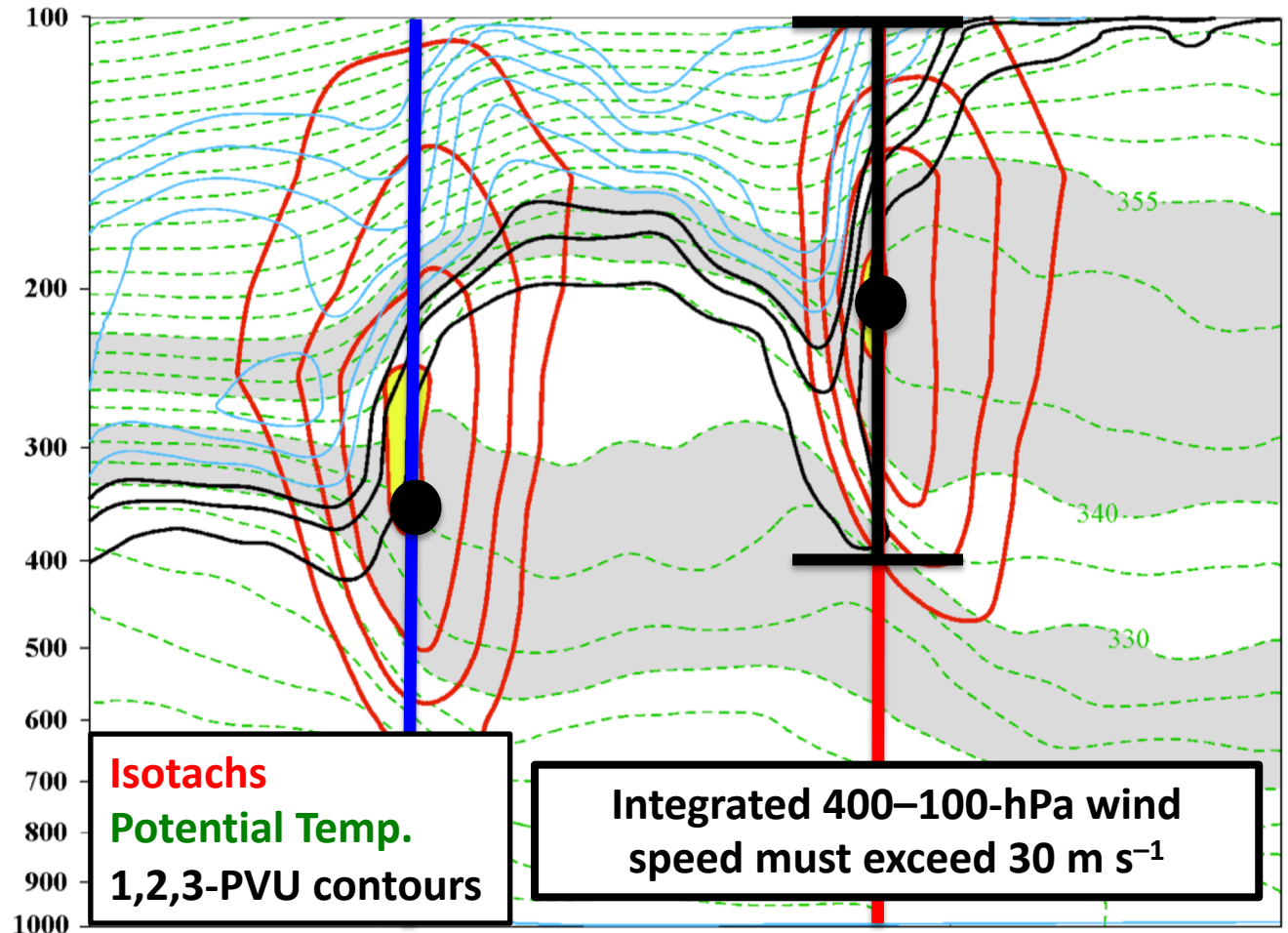
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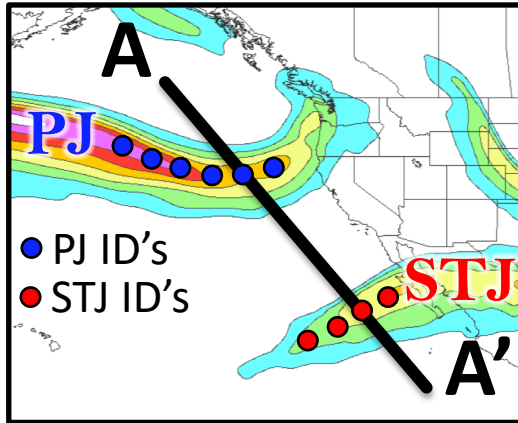
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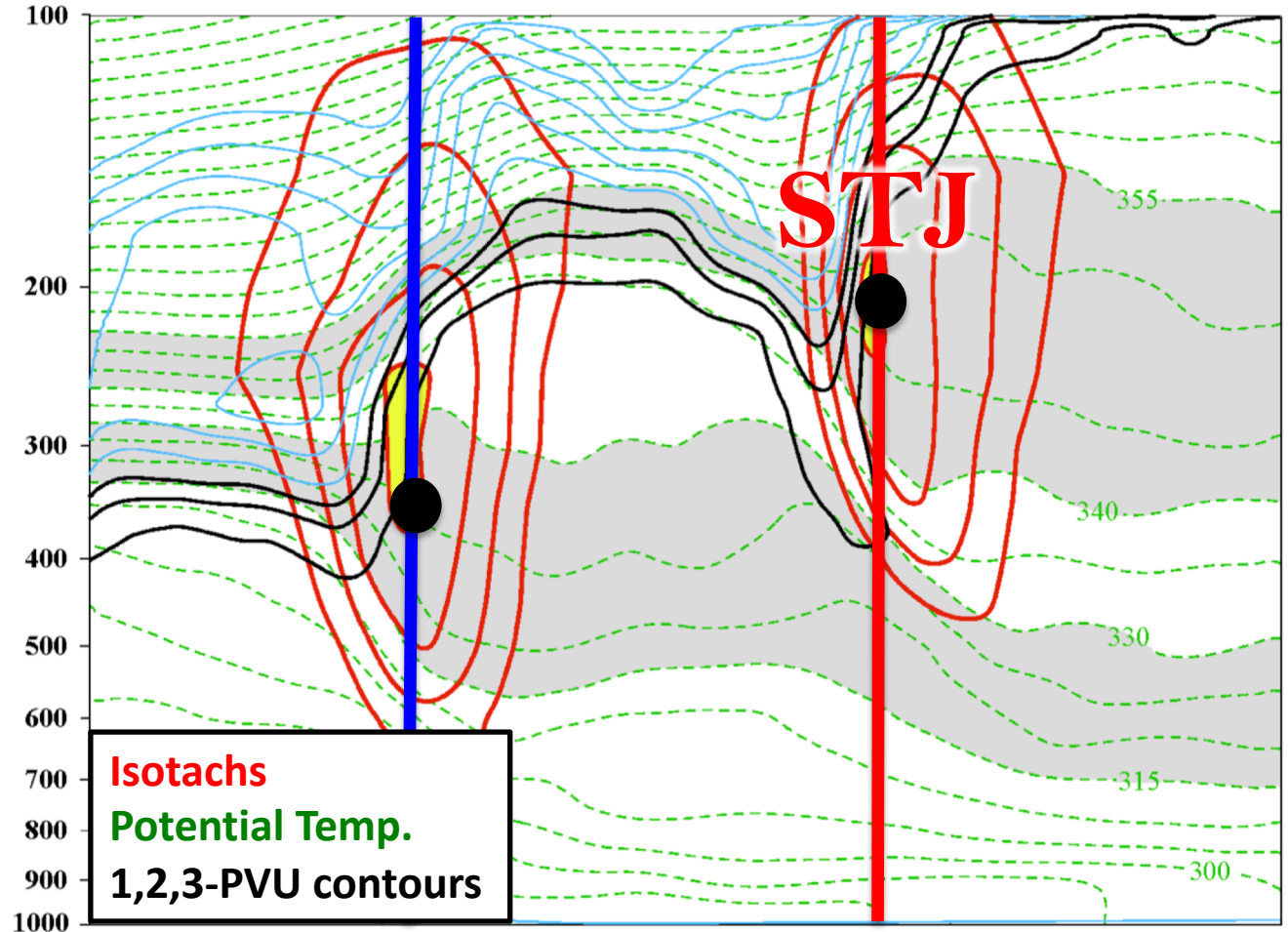
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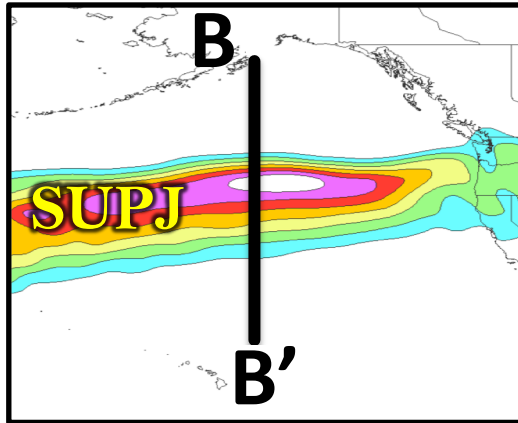


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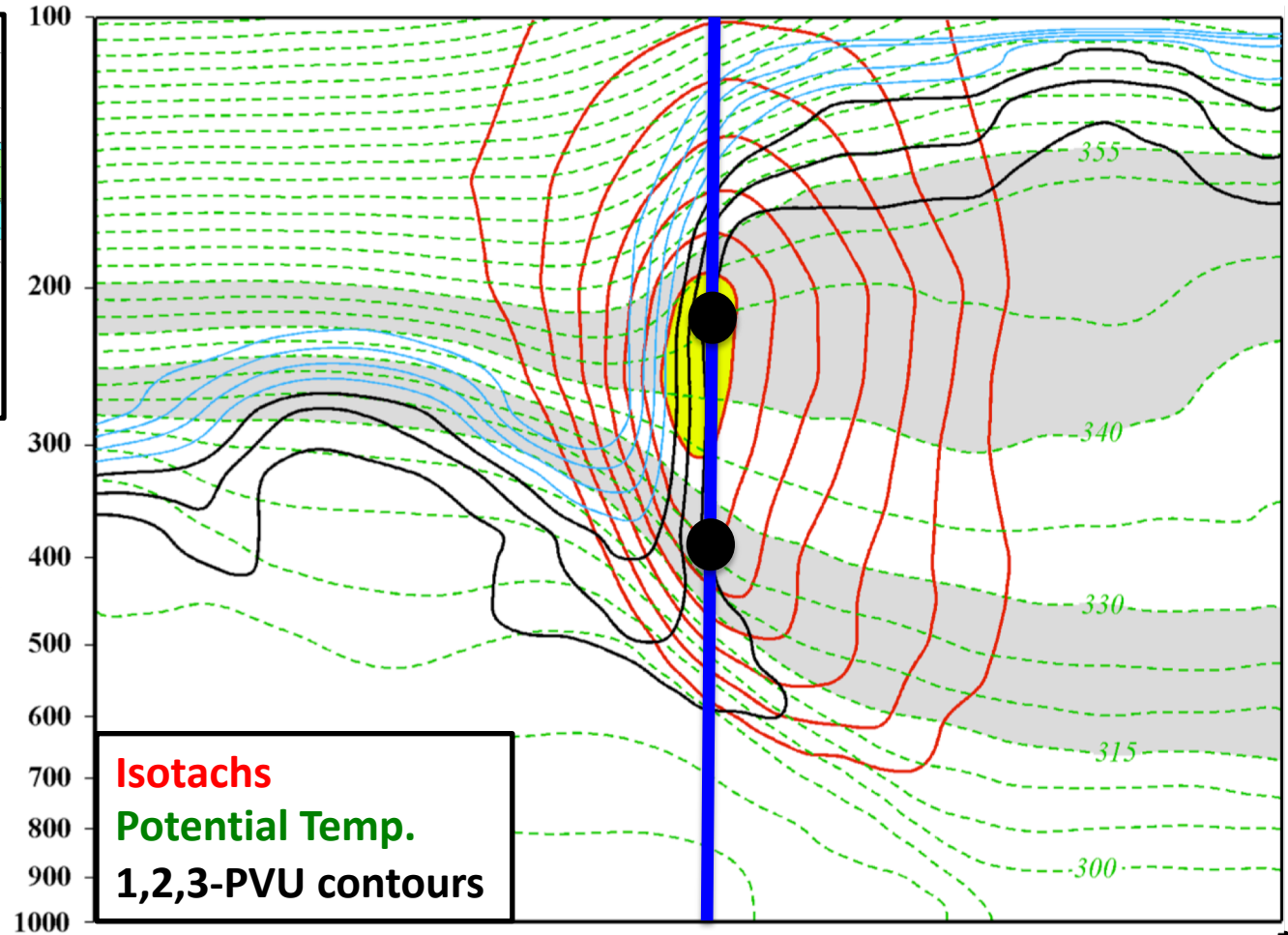
Jet Superposition Event Identification

0000 UTC 24 October 2010



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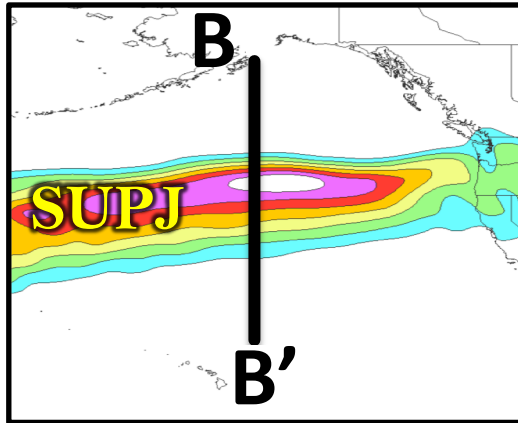
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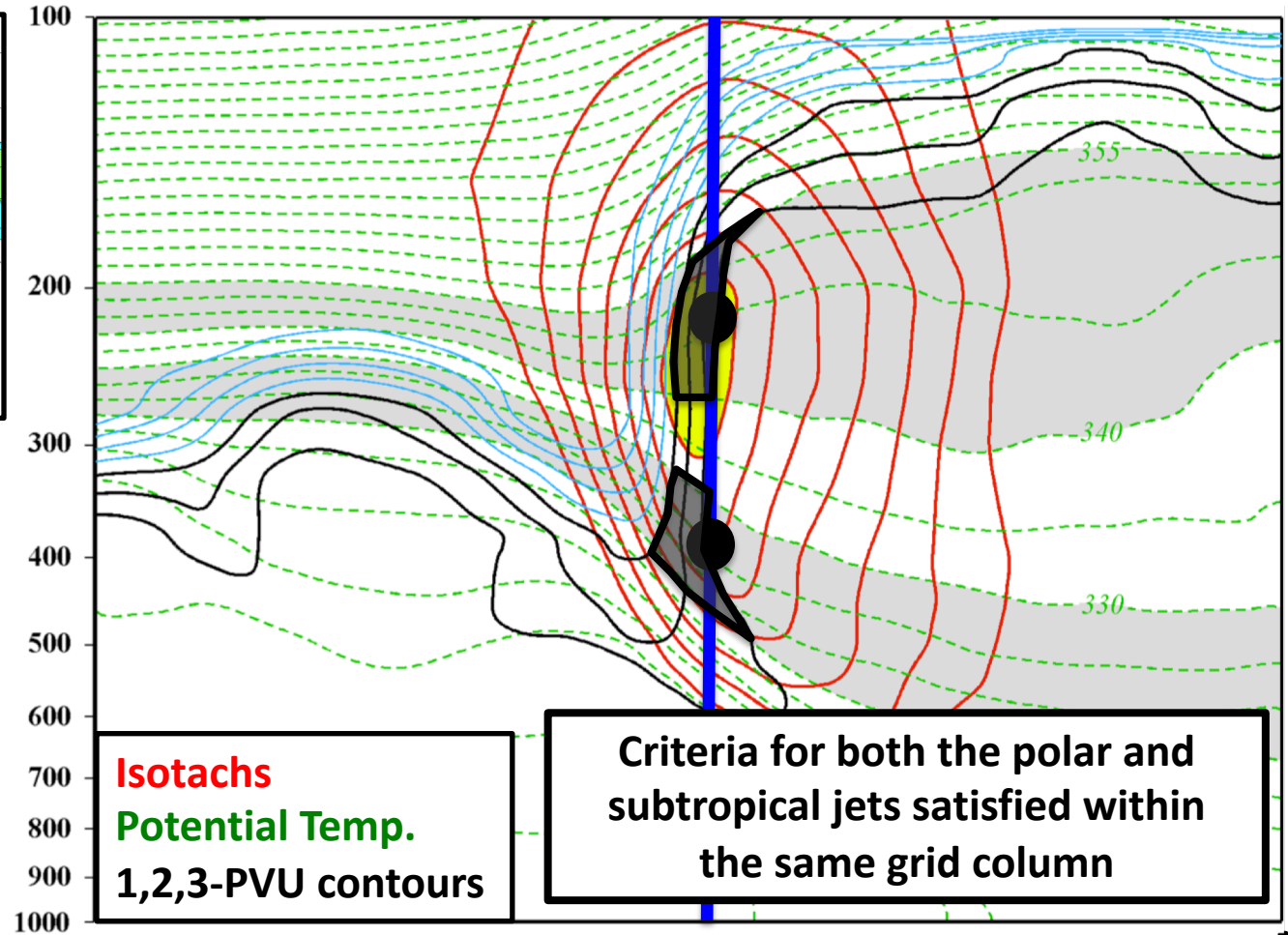
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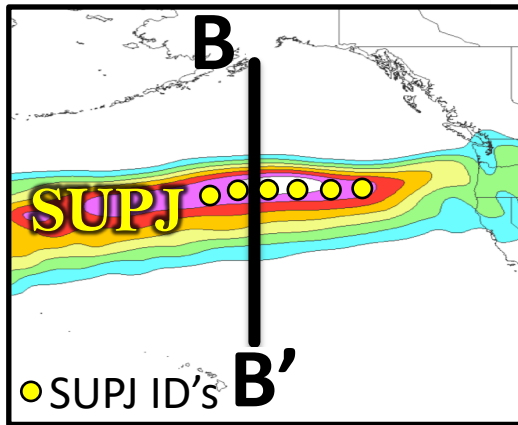
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Criteria for both the polar and subtropical jets satisfied within the same grid column

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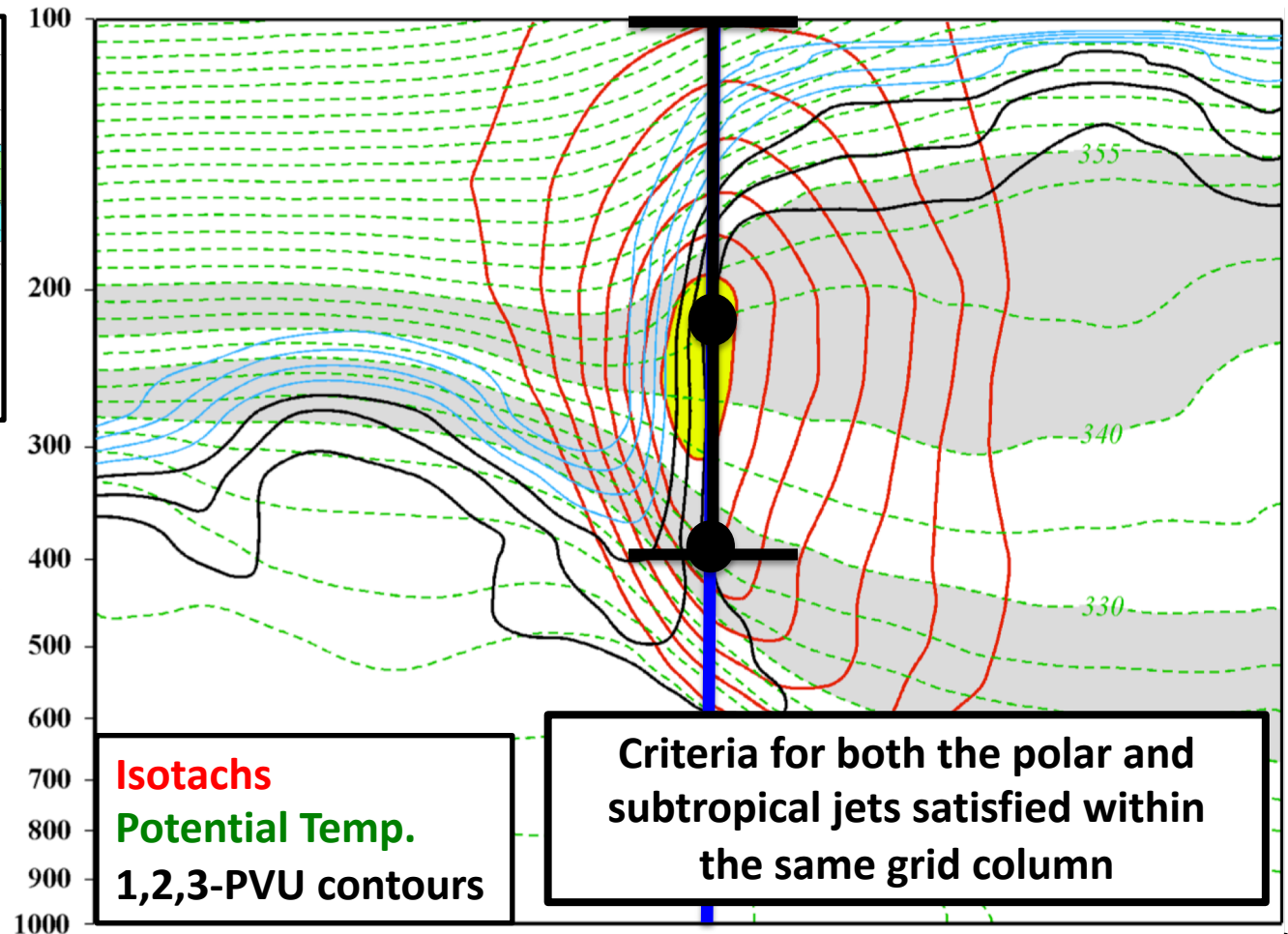
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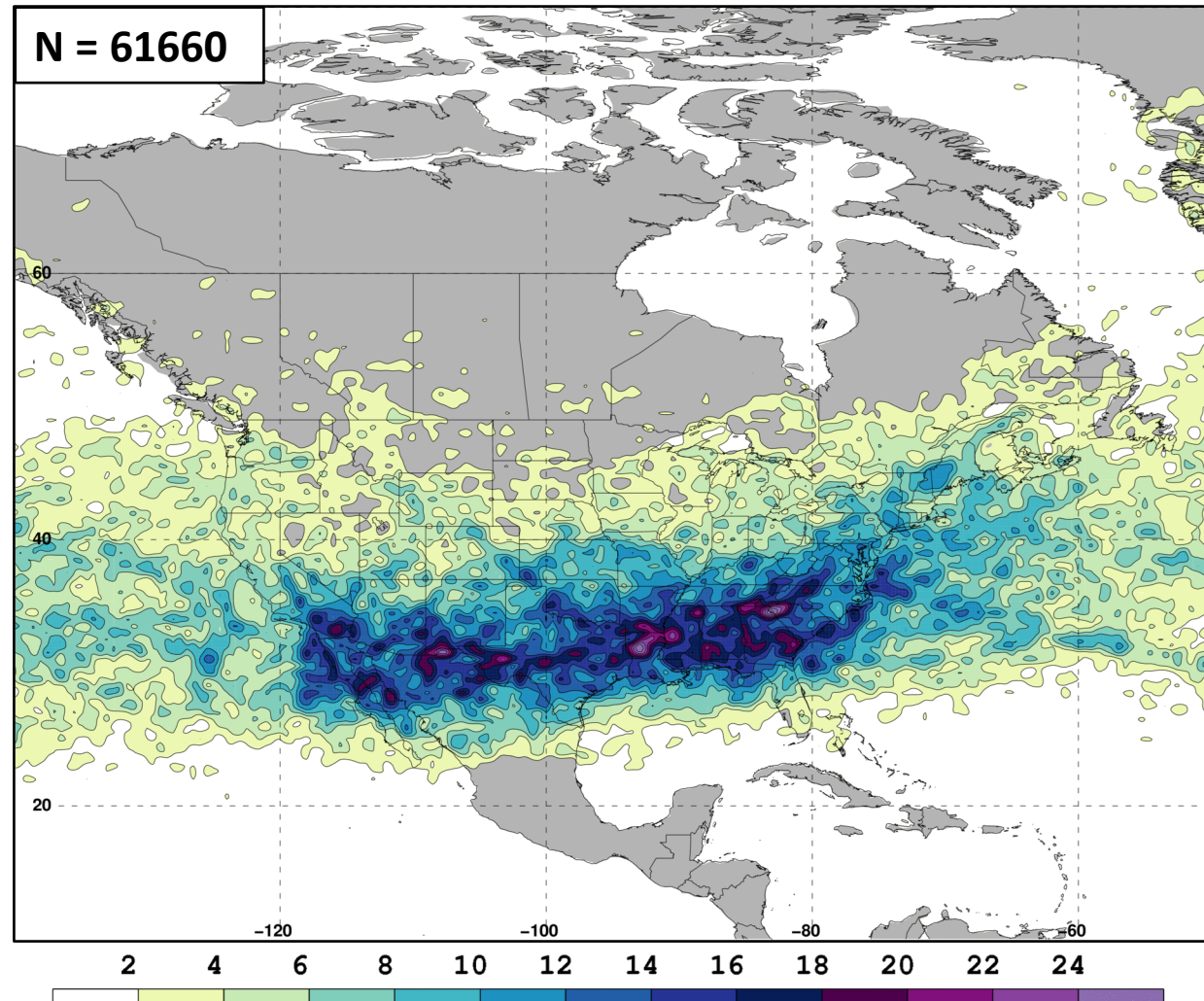
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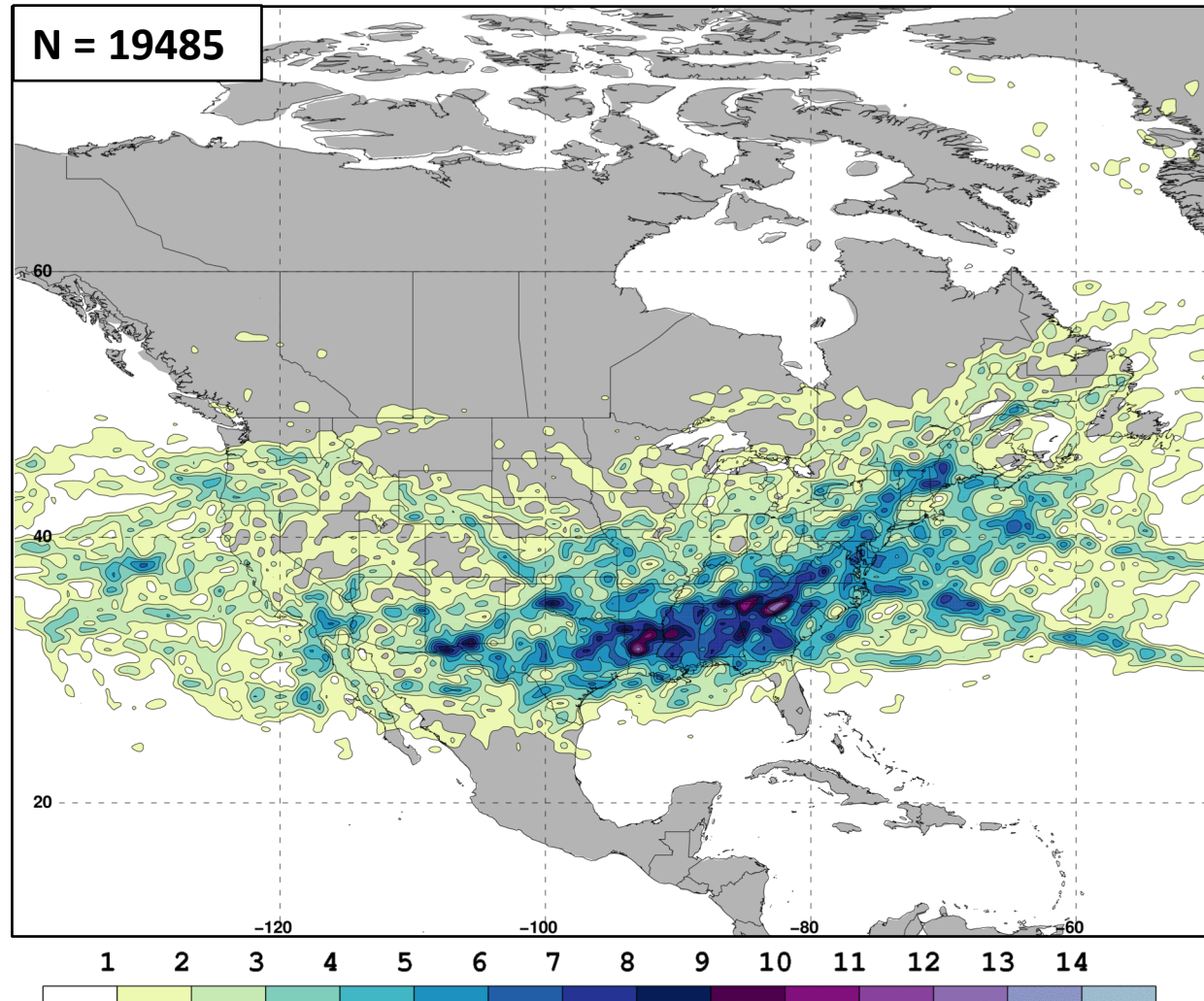
Jet Superposition Frequency – All Times



Jet Superposition Event Identification

1. Isolated grid points over North America in the CFSR (Saha et al. 2014) characterized by a jet superposition during Nov–Mar 1979–2010.
2. Retained analysis times that rank in the top 10% in terms the number of grid points characterized by a jet superposition.

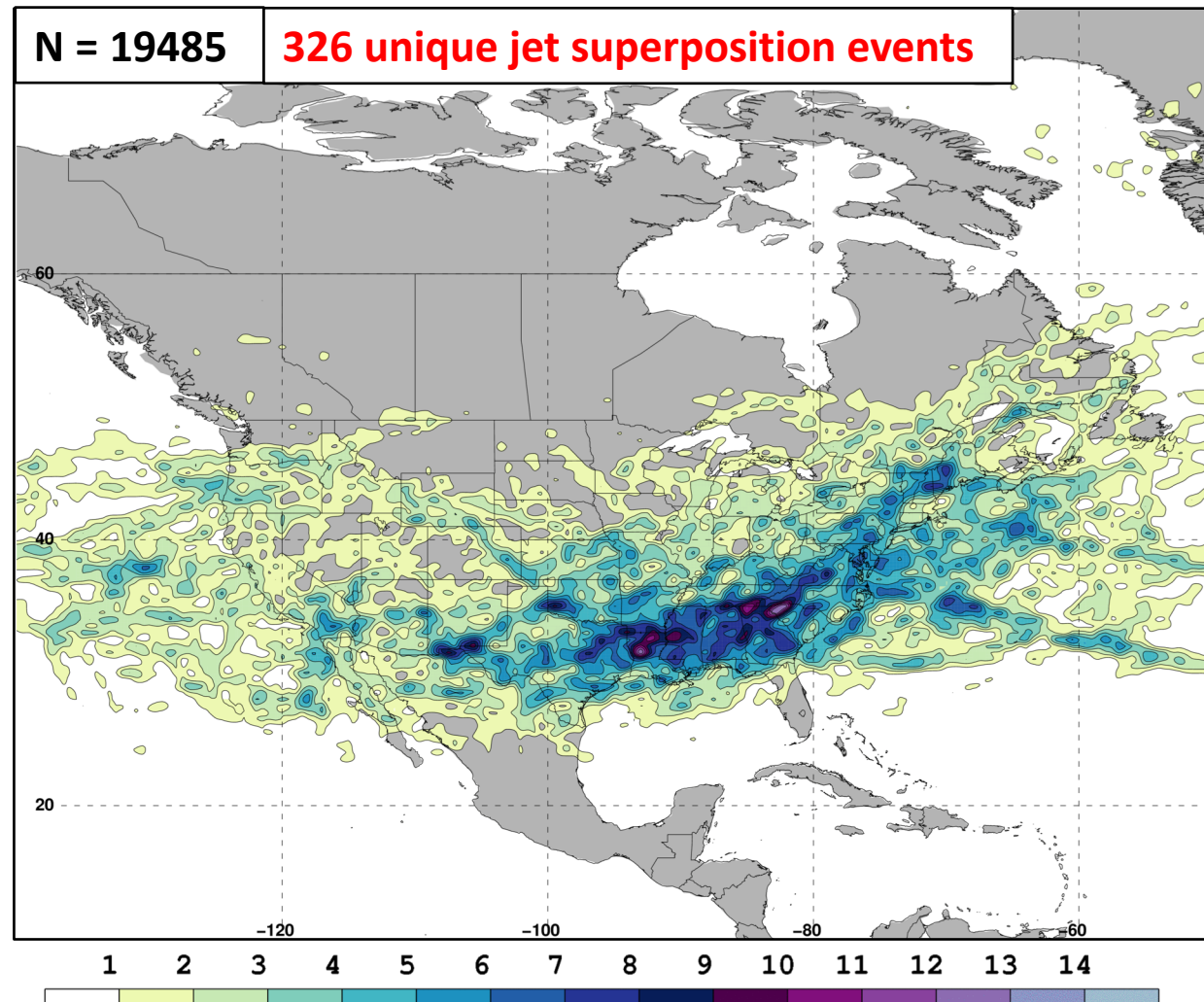
Jet Superposition Frequency – Top 10% Times



Jet Superposition Event Identification

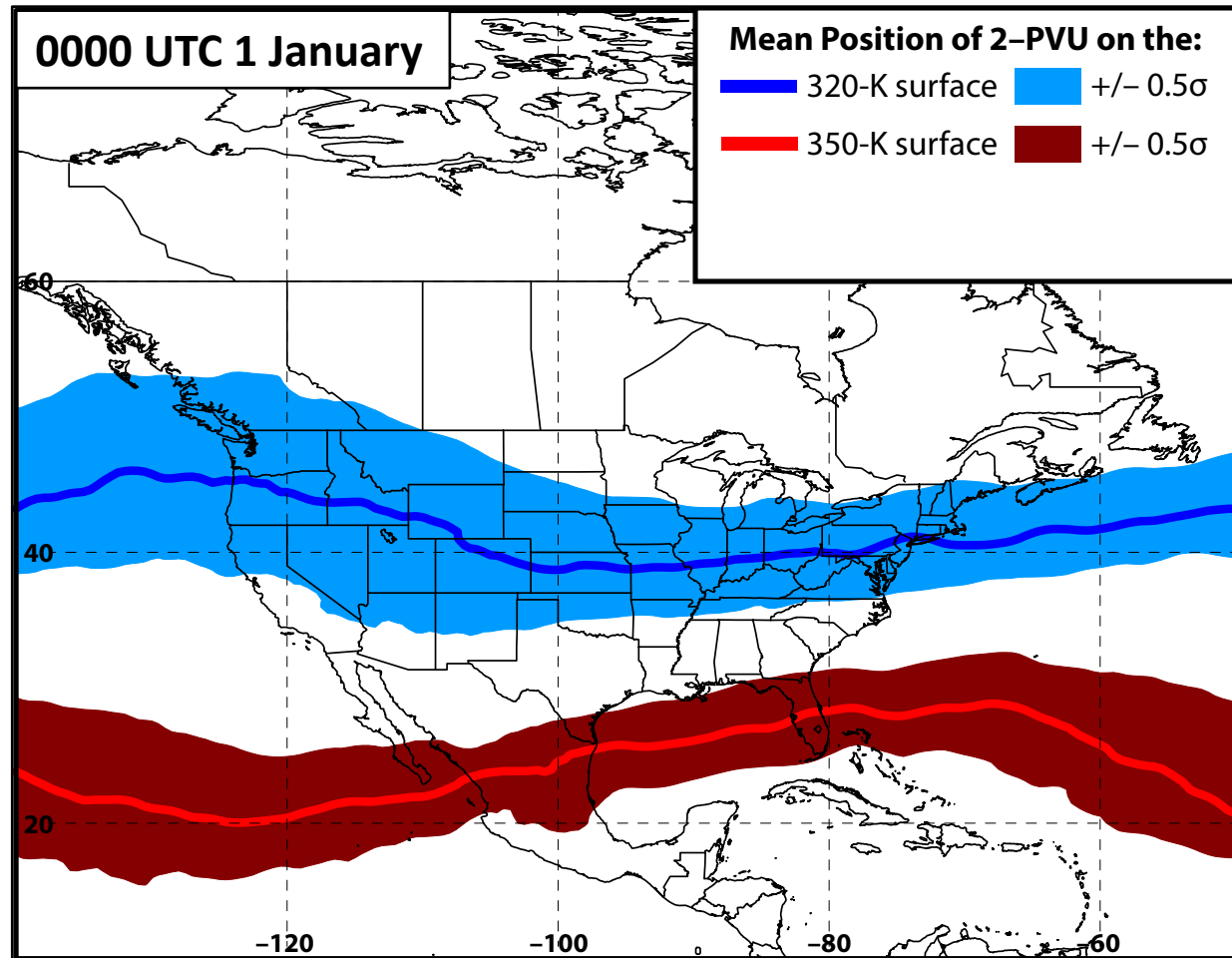
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2. Retained analysis times that rank in the top 10% in terms the number of grid points characterized by a jet superposition.
3. Filtered retained analysis times to group together jet superpositions that are < 30 h and < 1500 km apart.

Jet Superposition Frequency – Top 10% Times



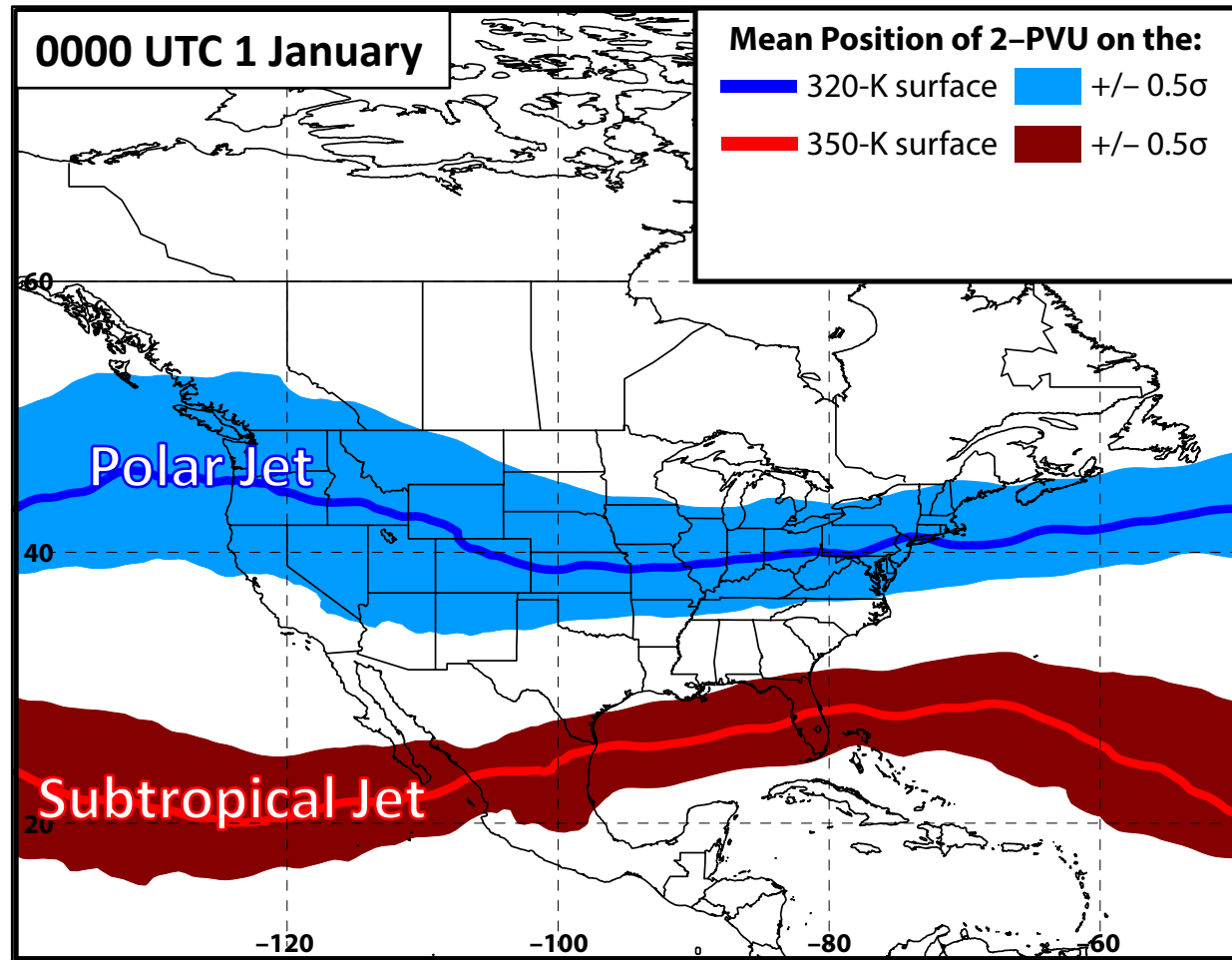
Jet Superposition Event Classification

1. Determined the mean position of the 2-PVU contour on the 320-K and 350-K surfaces at each analysis time in the CFSR.



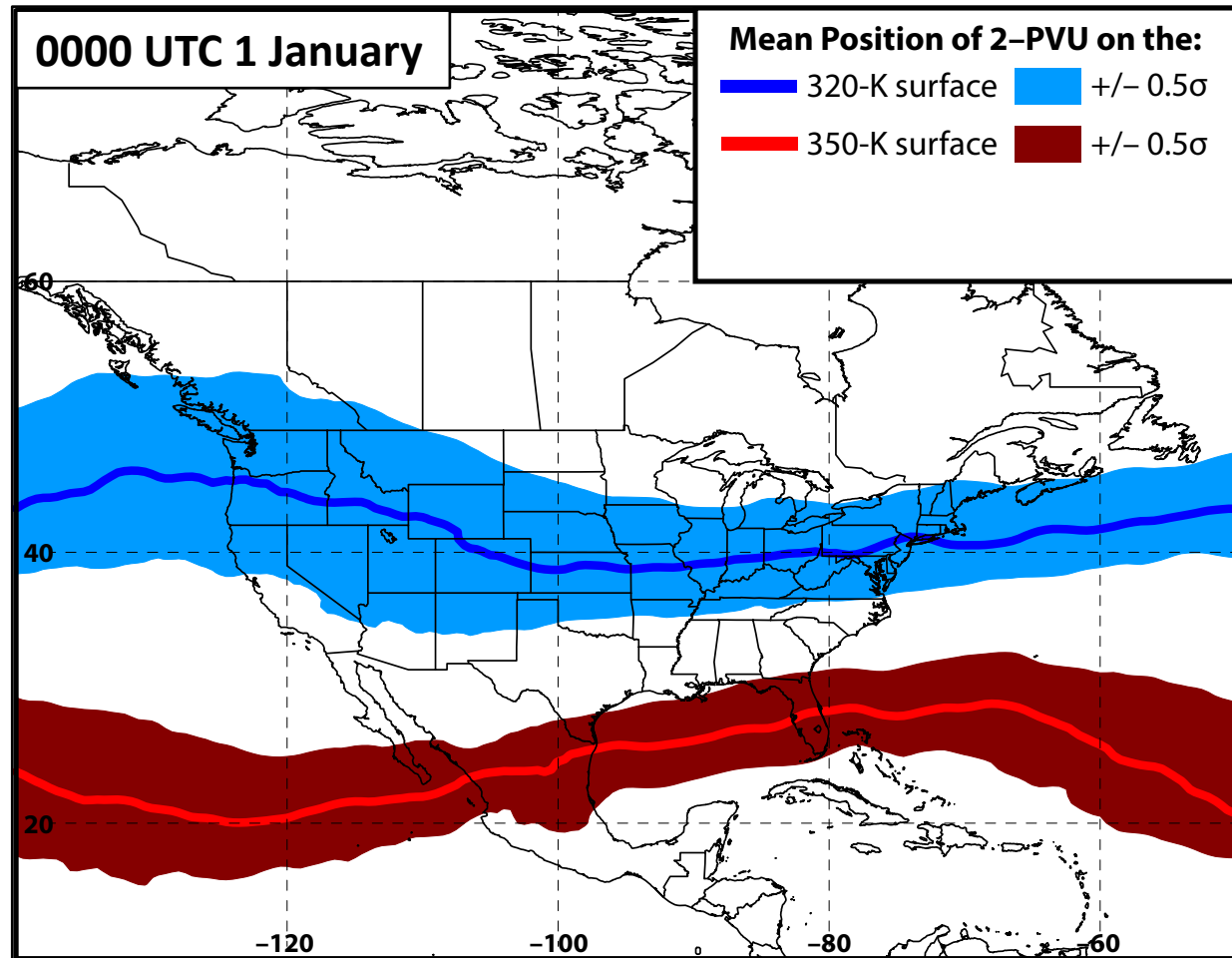
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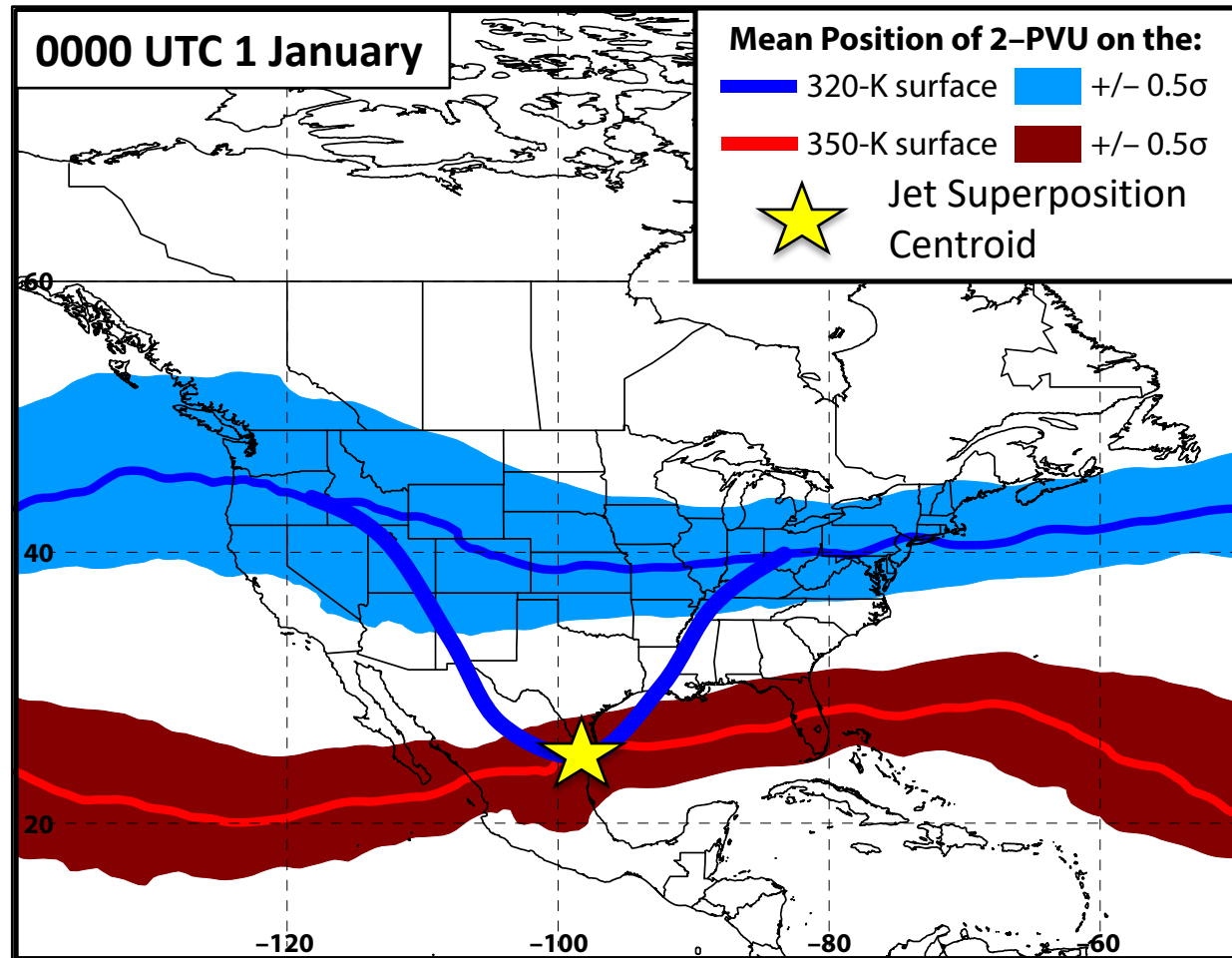
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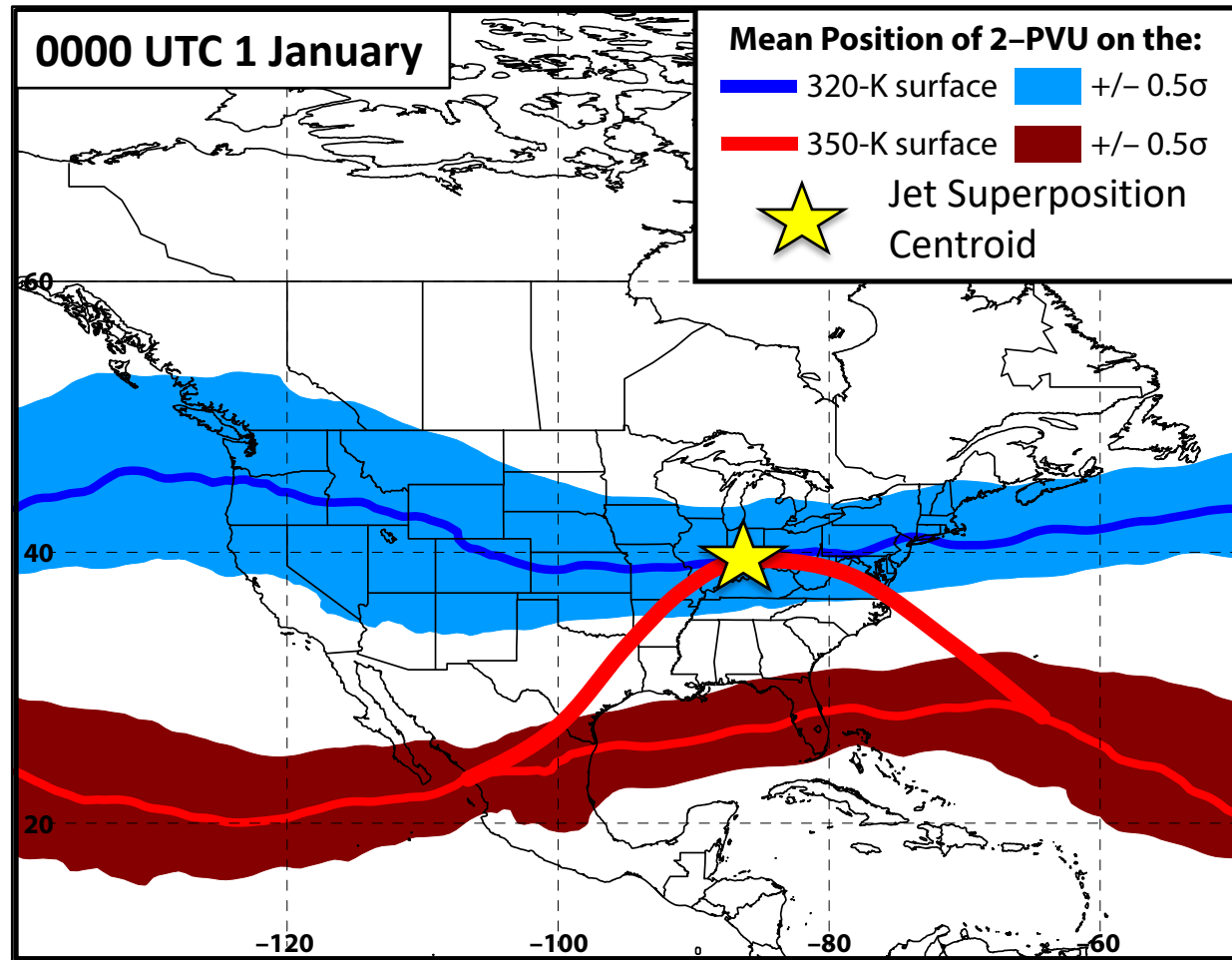
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- **Polar Dominant**



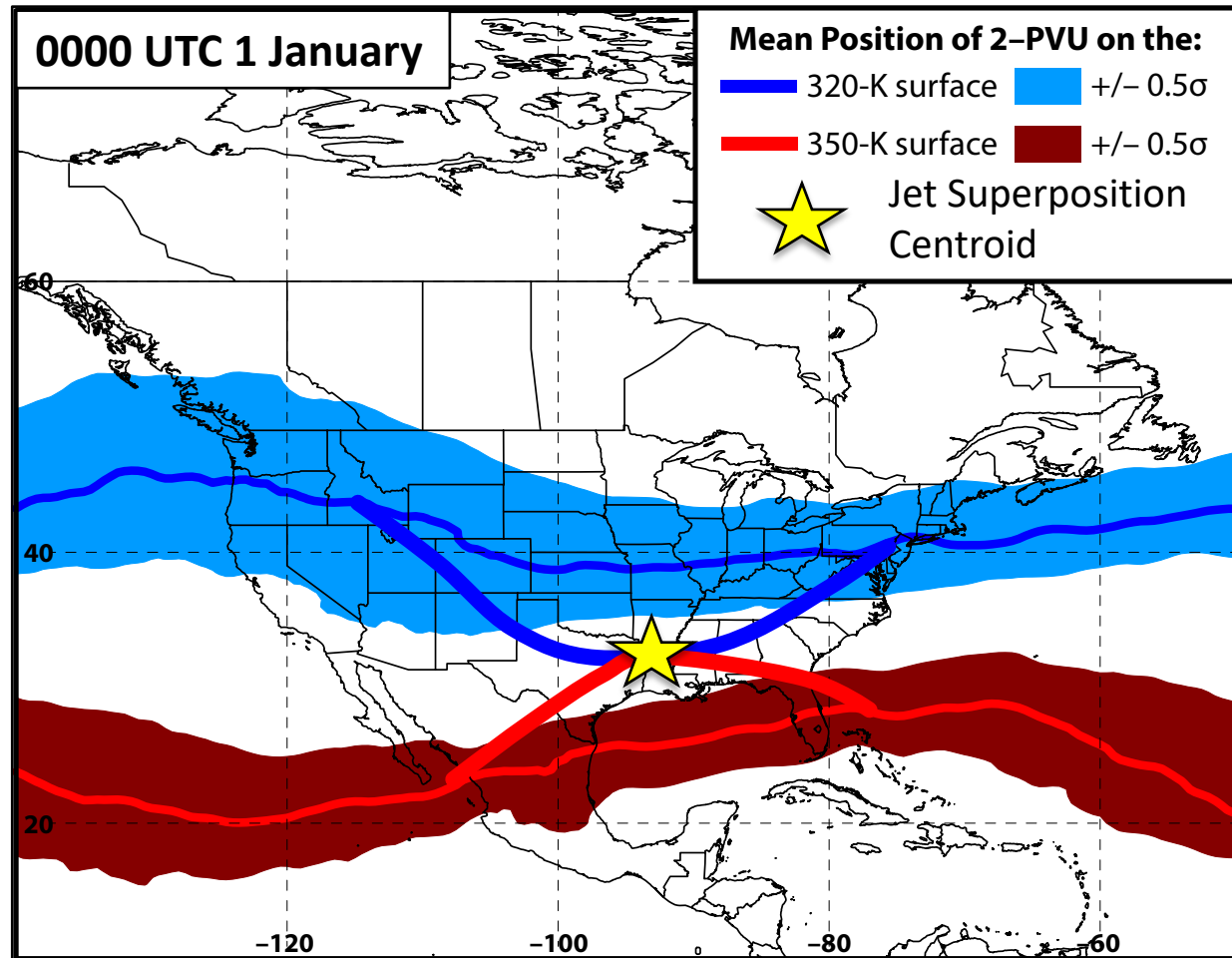
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- Polar Dominant
 - **Subtropical Dominant**



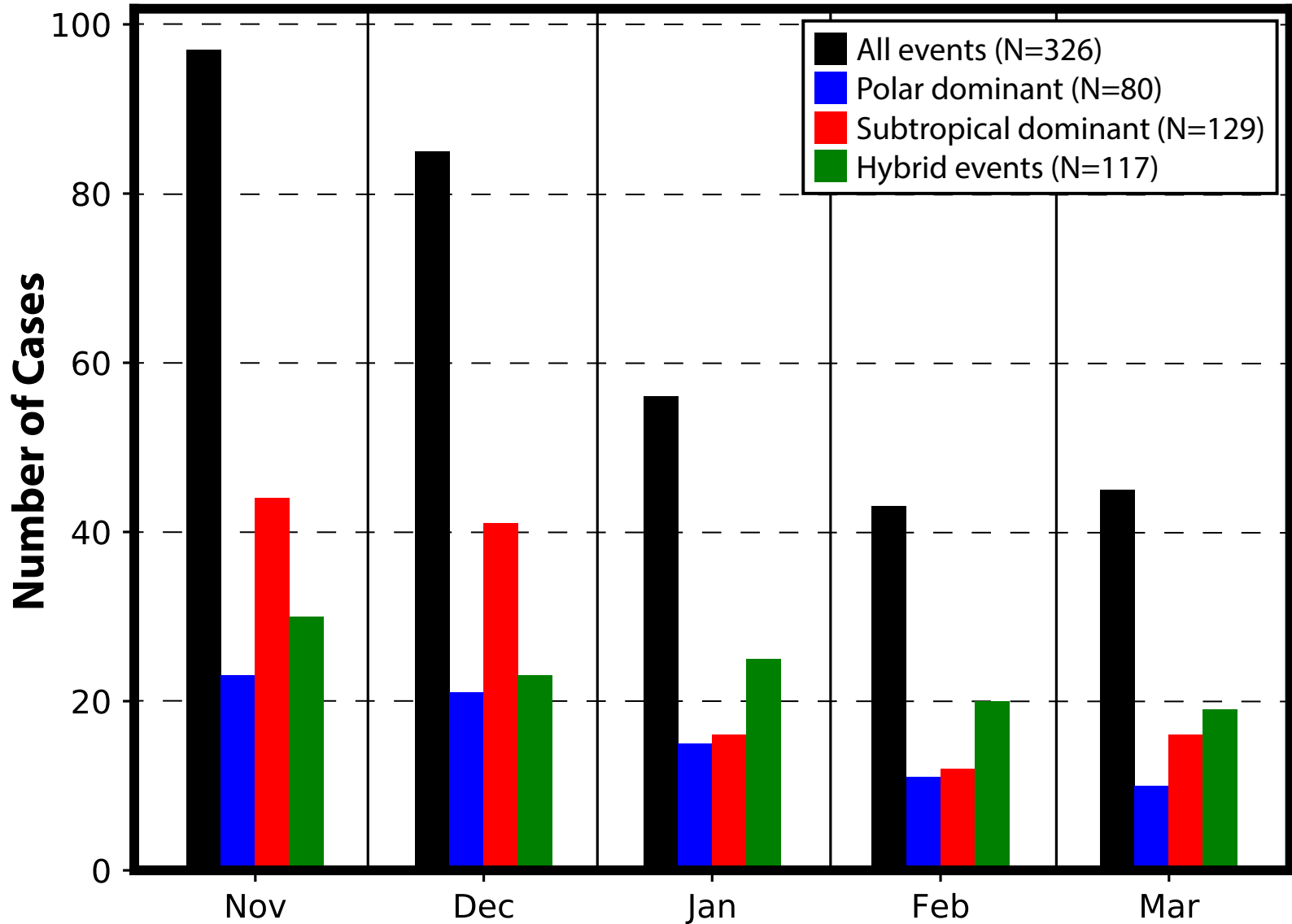
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- Polar Dominant
 - Subtropical Dominant
 - **Hybrid**

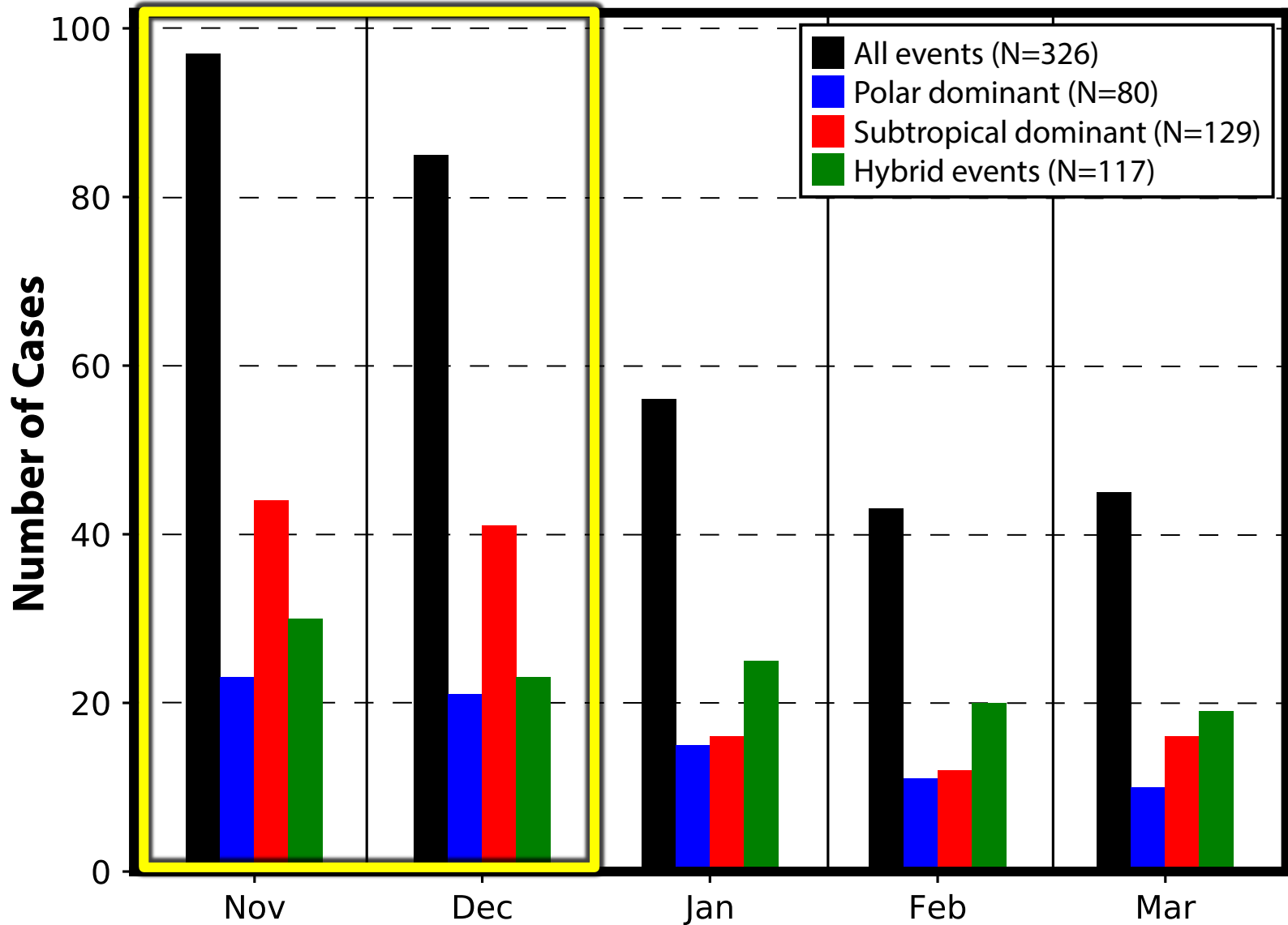


Climatological Characteristics of Jet Superposition Events

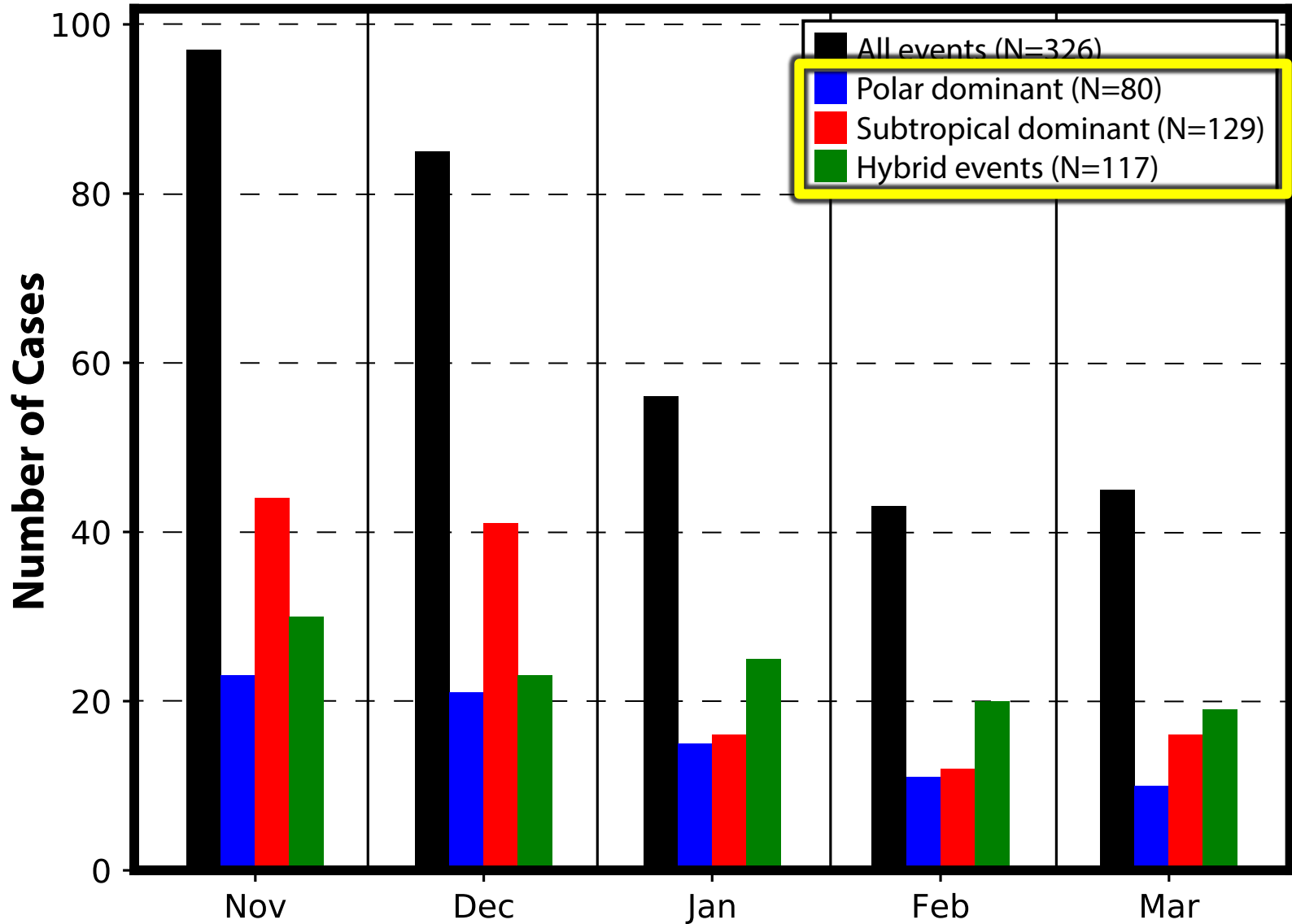
Jet Superposition Event Characteristics



Jet Superposition Event Characteristics

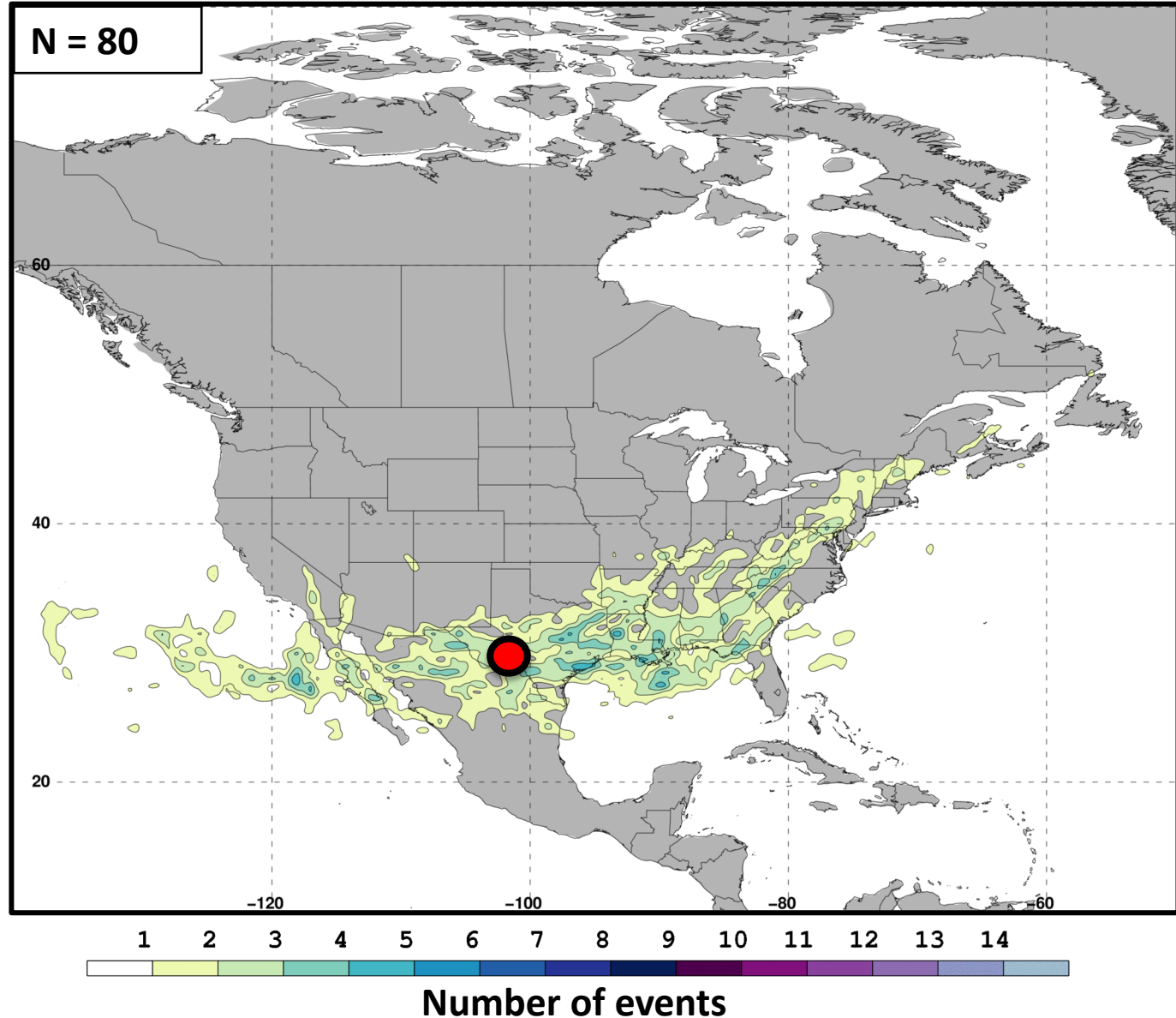


Jet Superposition Event Characteristics



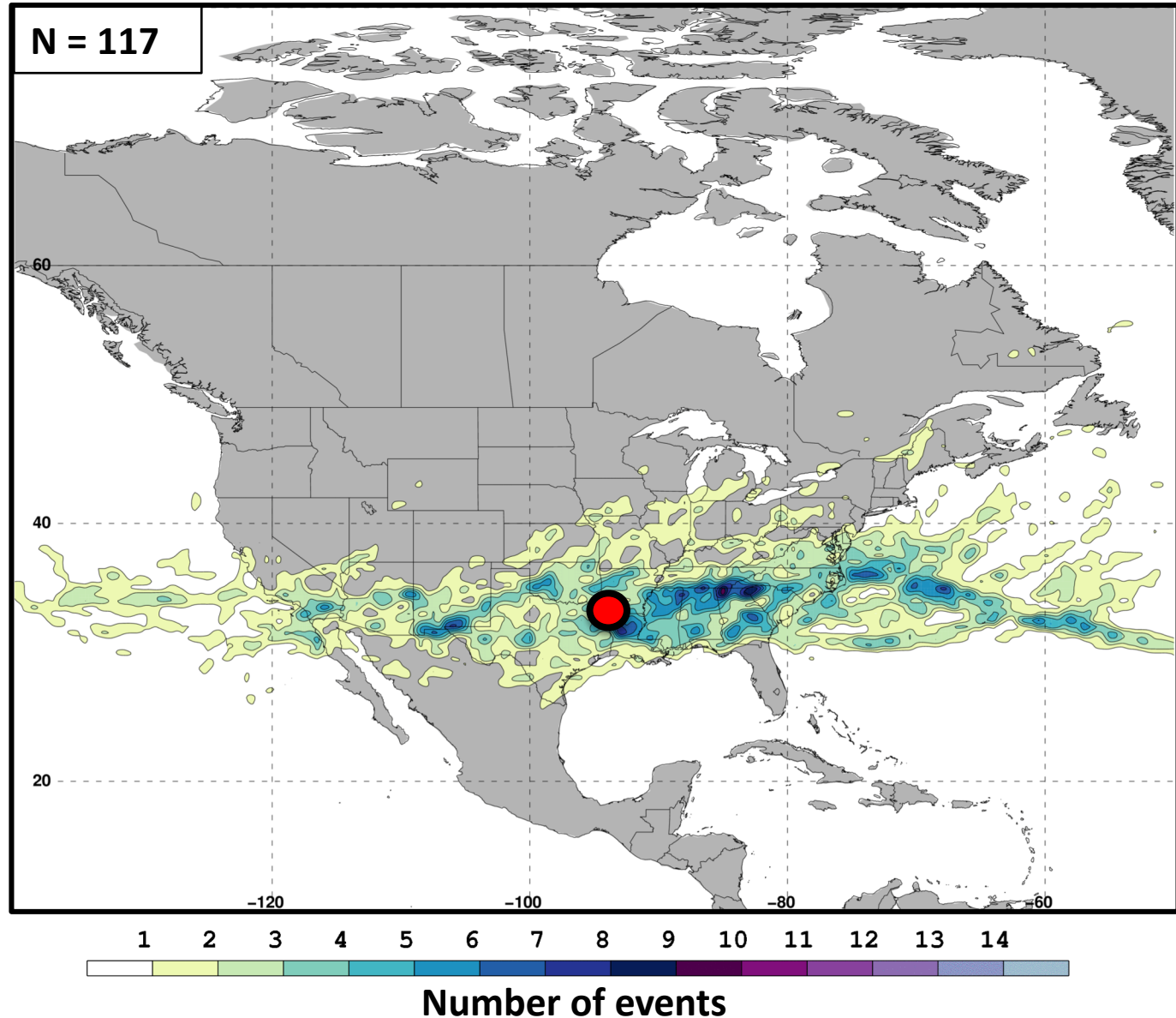
Jet Superposition Event Characteristics

Frequency of
Polar Dominant
Jet
Superposition
Events



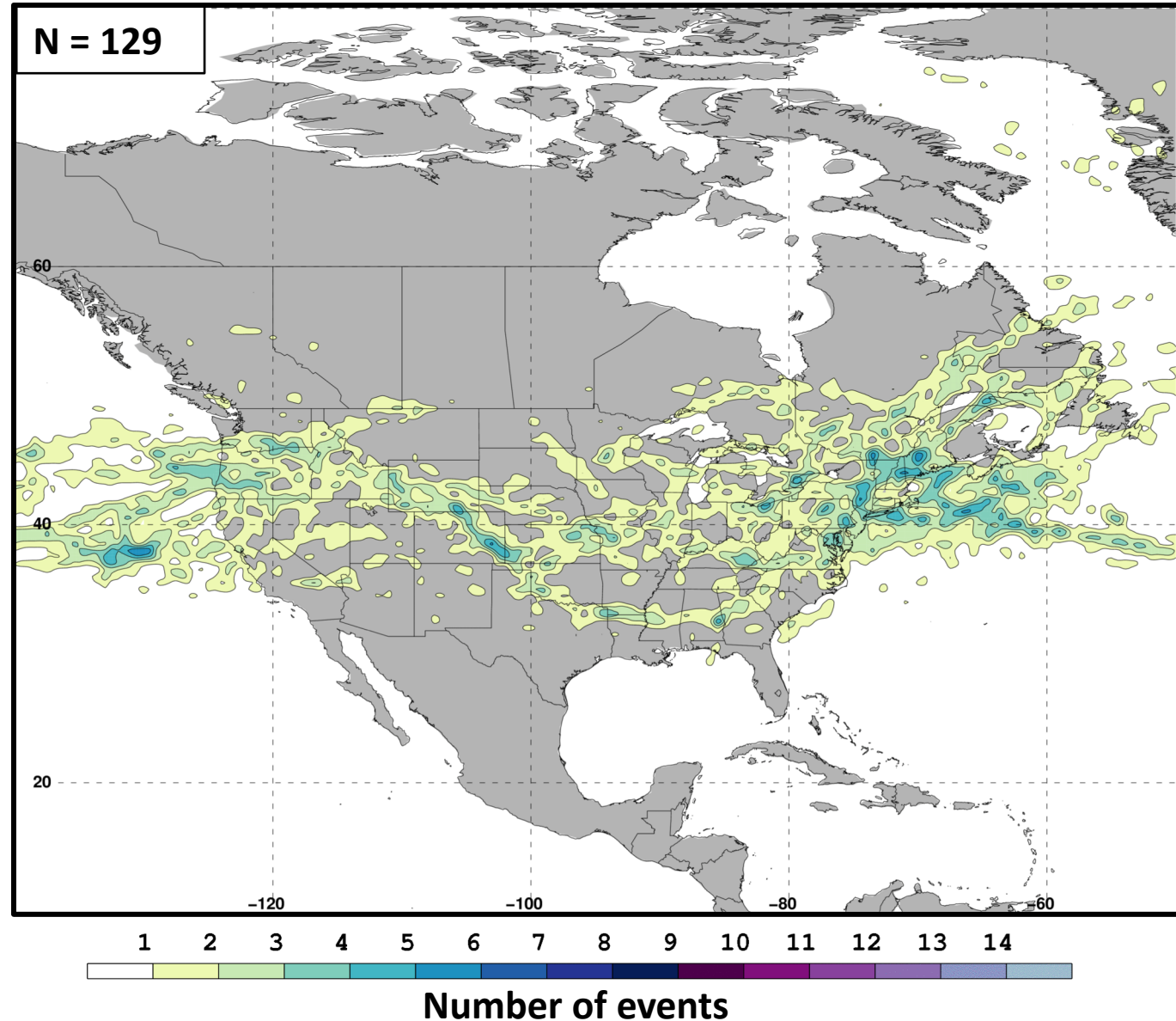
Jet Superposition Event Characteristics

Frequency of
Hybrid
Jet
Superposition
Events



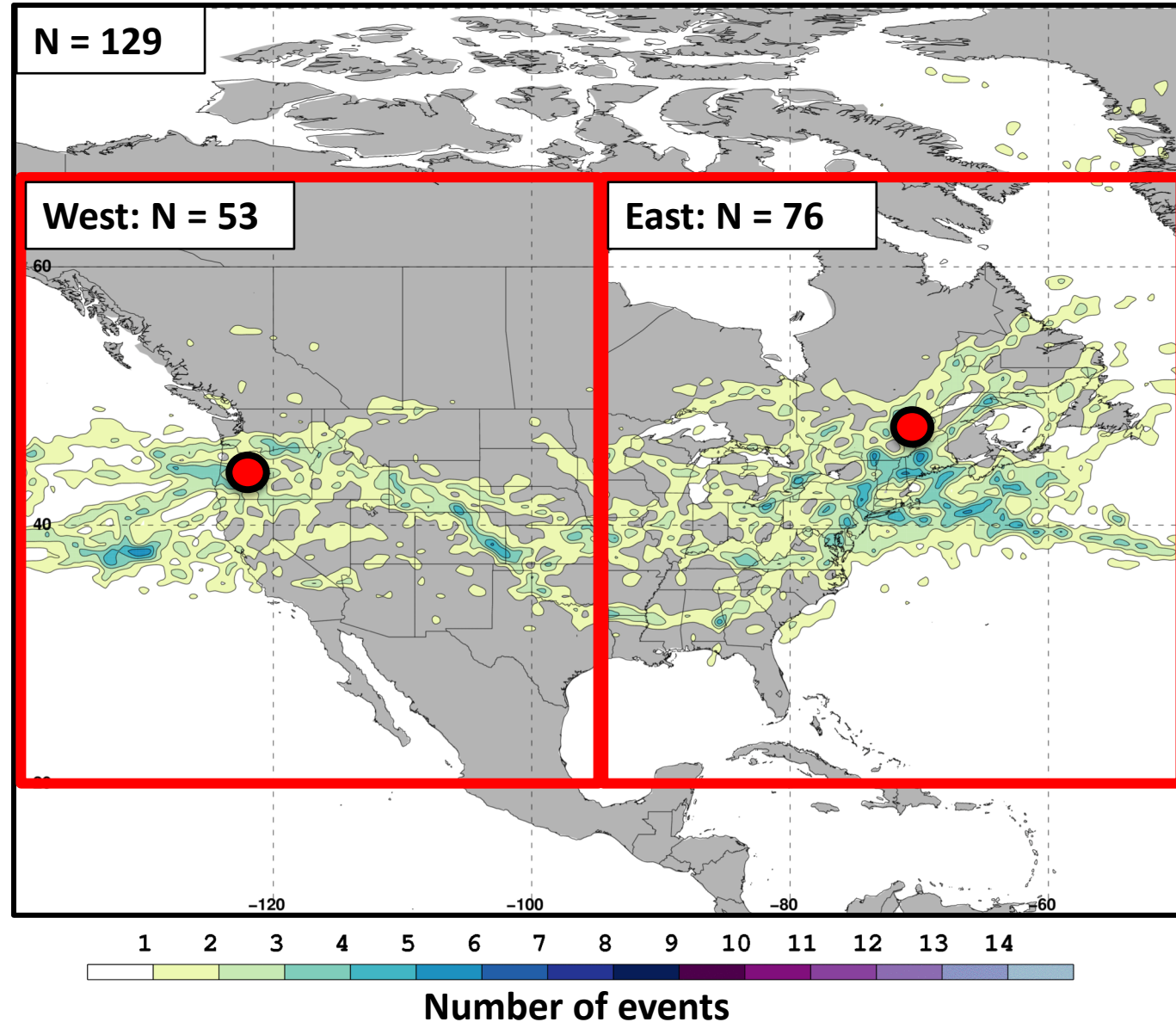
Jet Superposition Event Characteristics

Frequency of
**Subtropical
Dominant** Jet
Superposition
Events



Jet Superposition Event Characteristics

Frequency of
Subtropical
Dominant Jet
Superposition
Events



**Jet Superposition Event
Composites:**

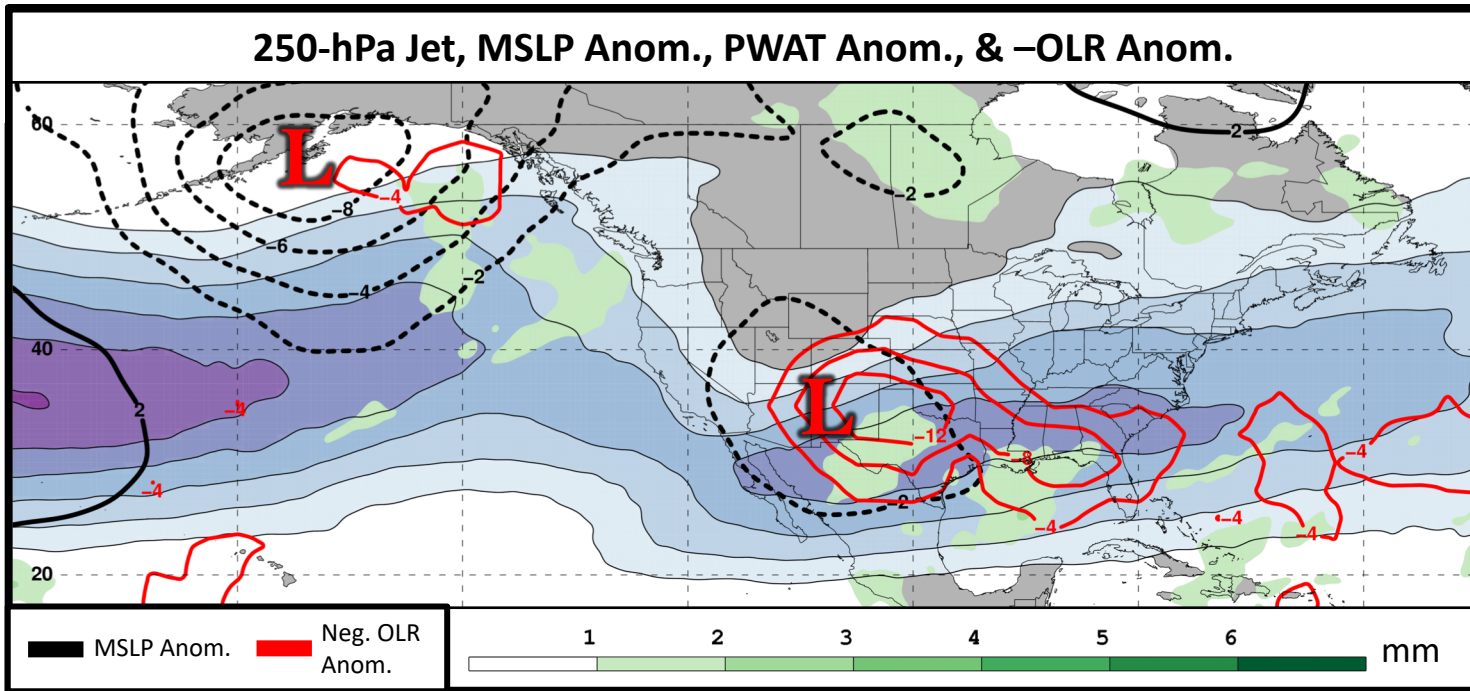
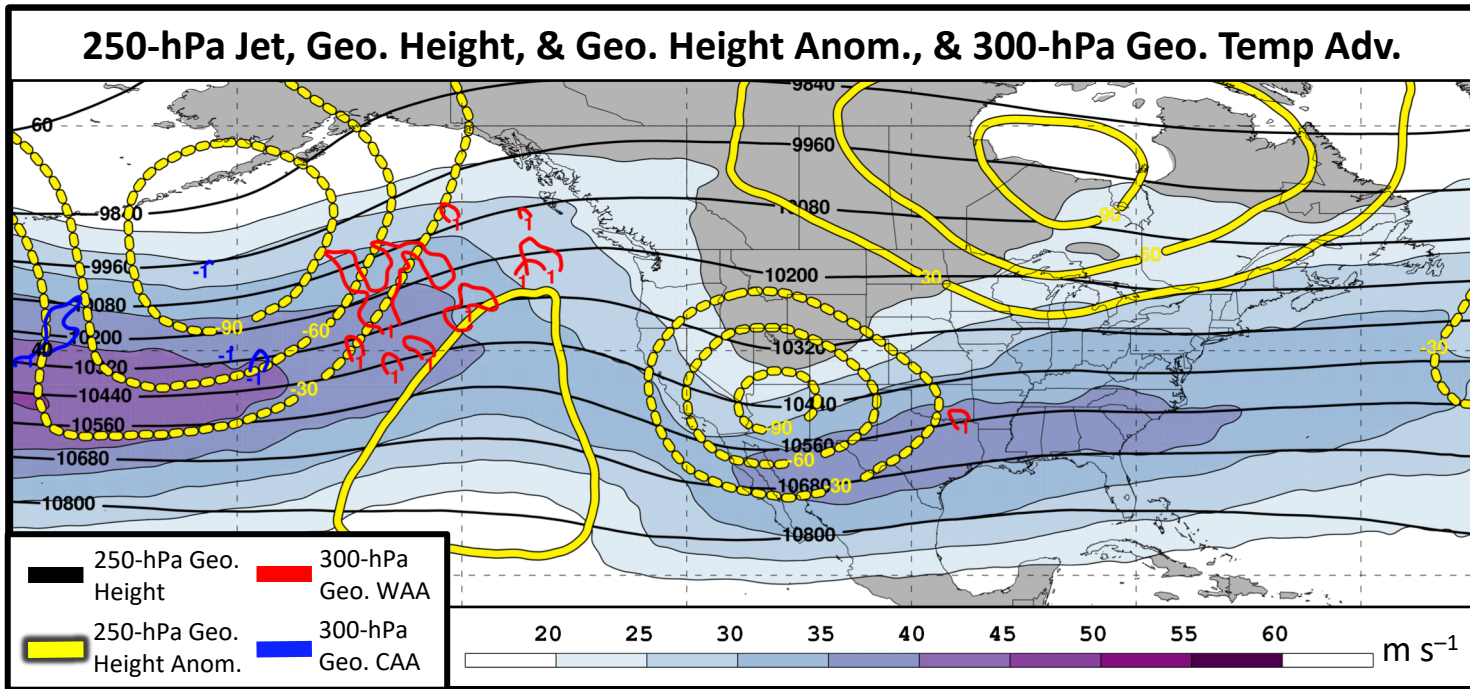
Polar Dominant

vs.

East Subtropical Dominant

Polar Dominant Jet Superposition Events

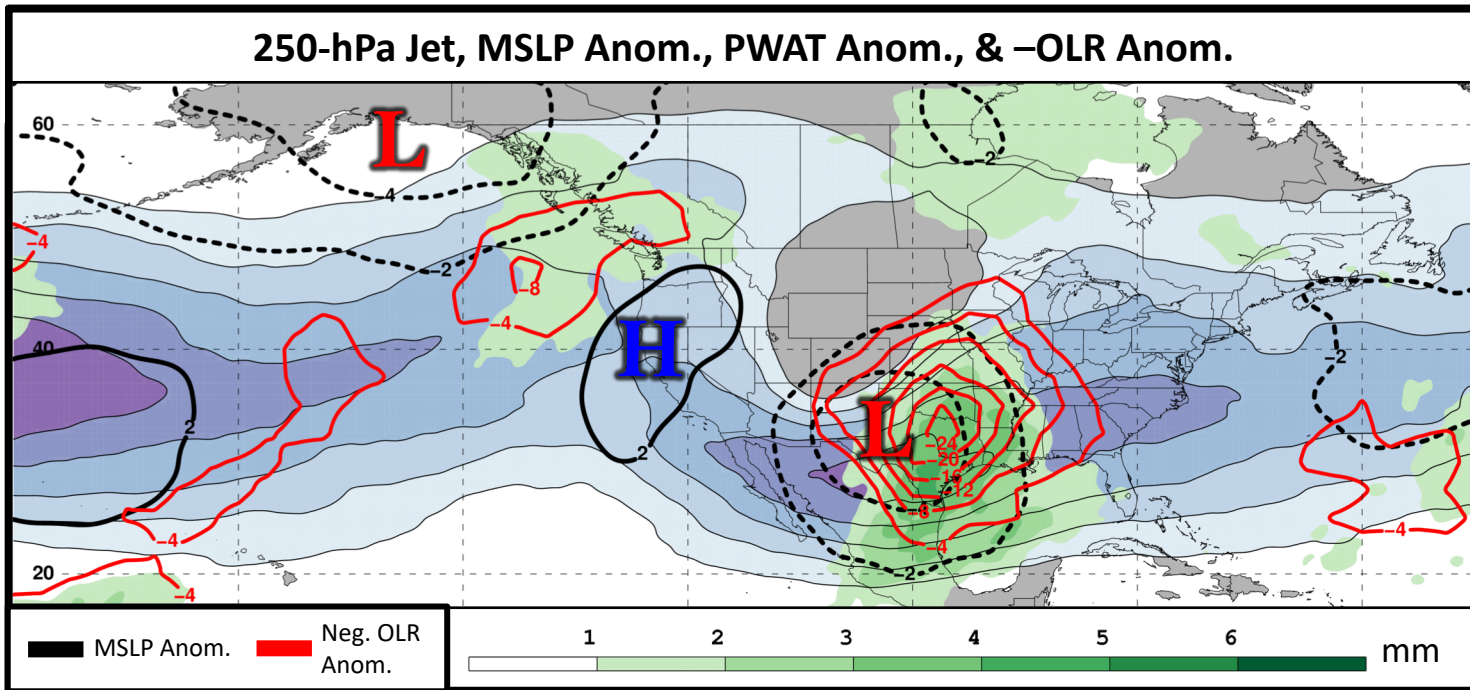
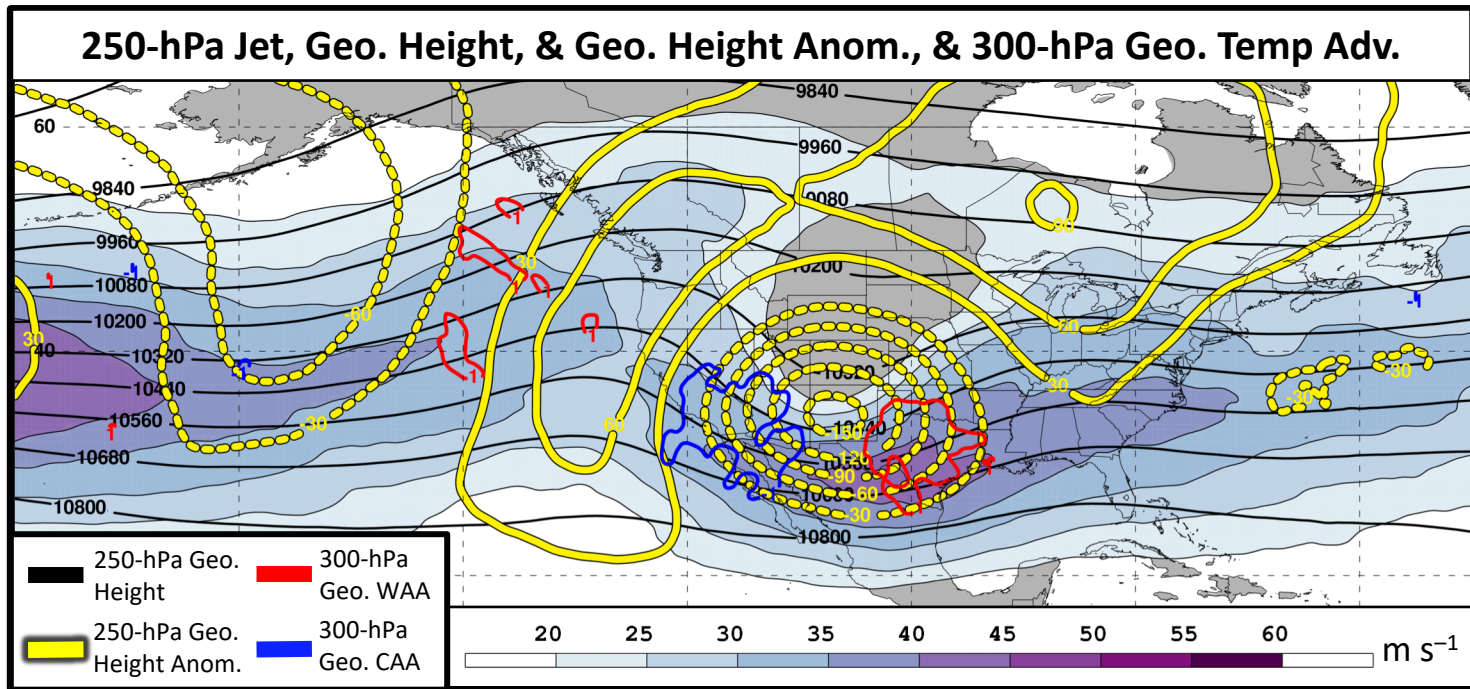
2 Days
Prior to Jet
Superposition



N=80

Polar Dominant Jet Superposition Events

1 Day
Prior to Jet
Superposition



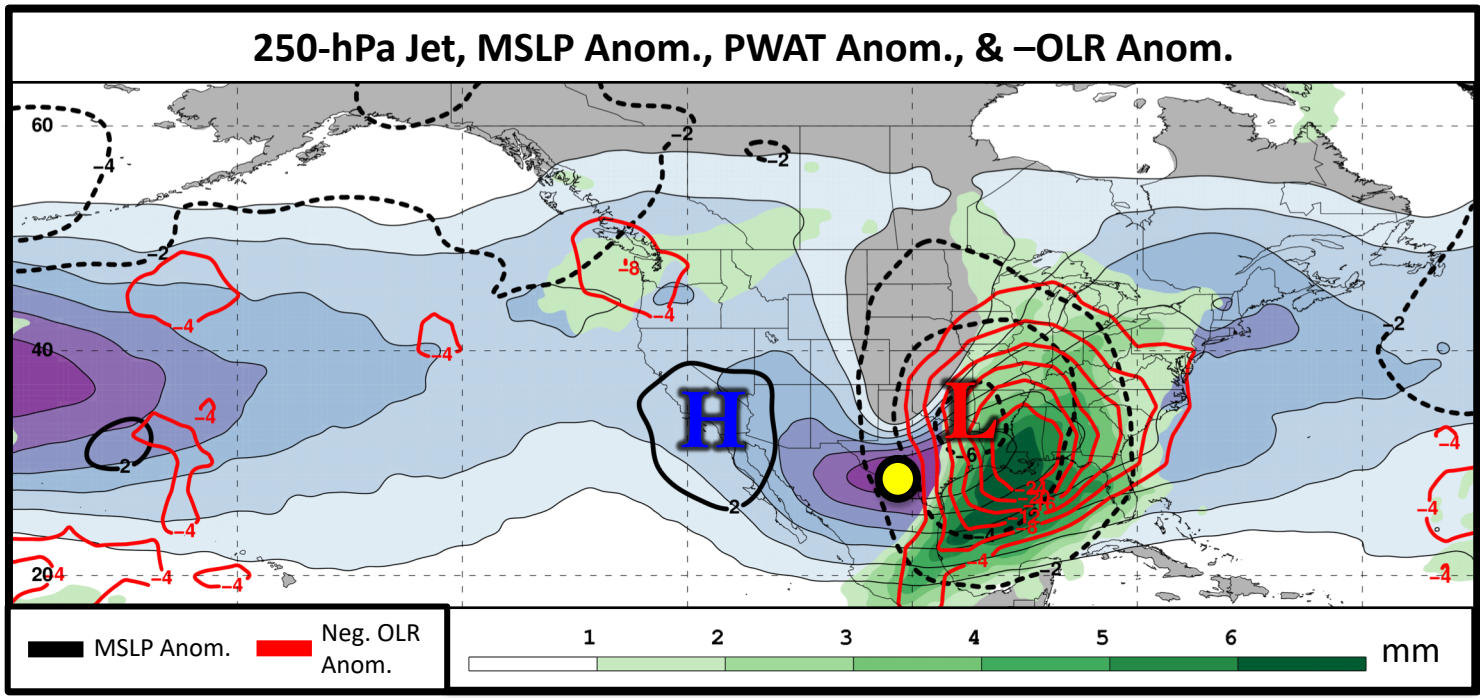
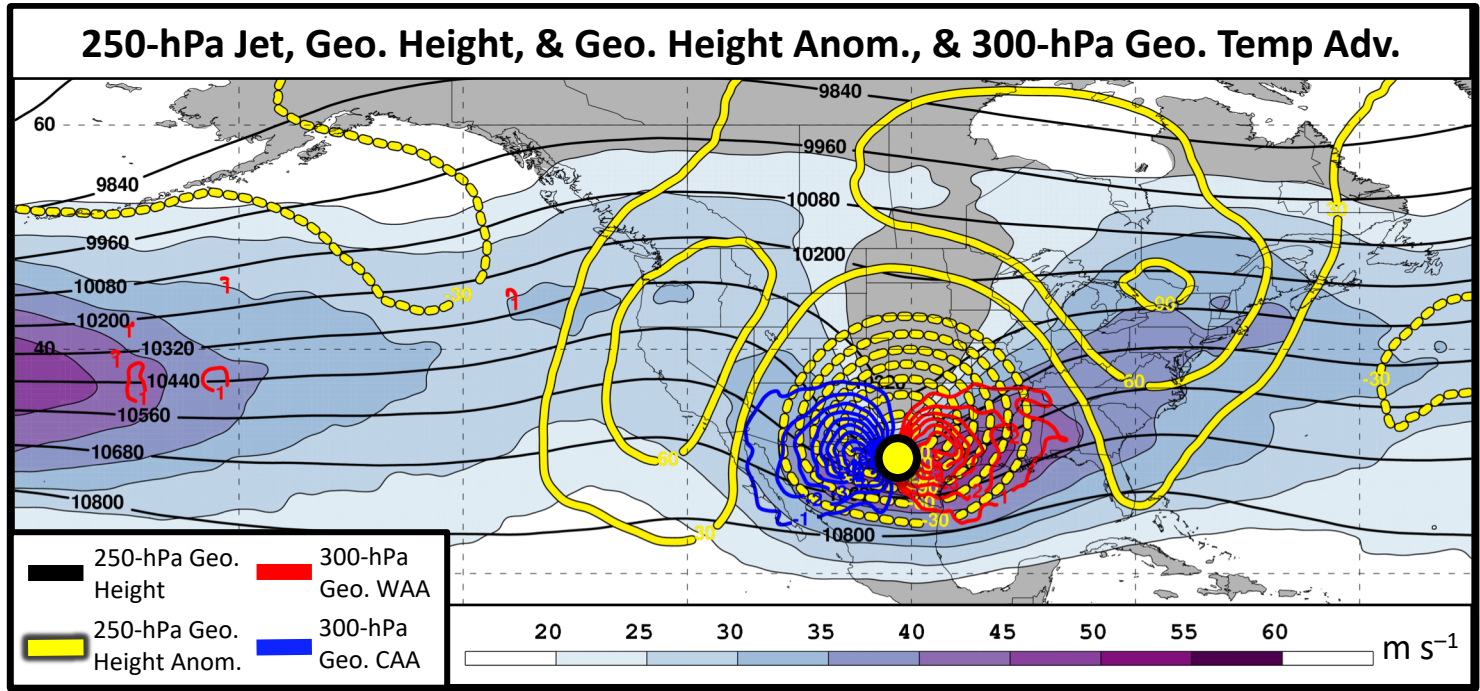
N=80

Polar Dominant Jet Superposition Events

0 Days
Prior to Jet
Superposition

Jet
Superposition
Centroid

N=80

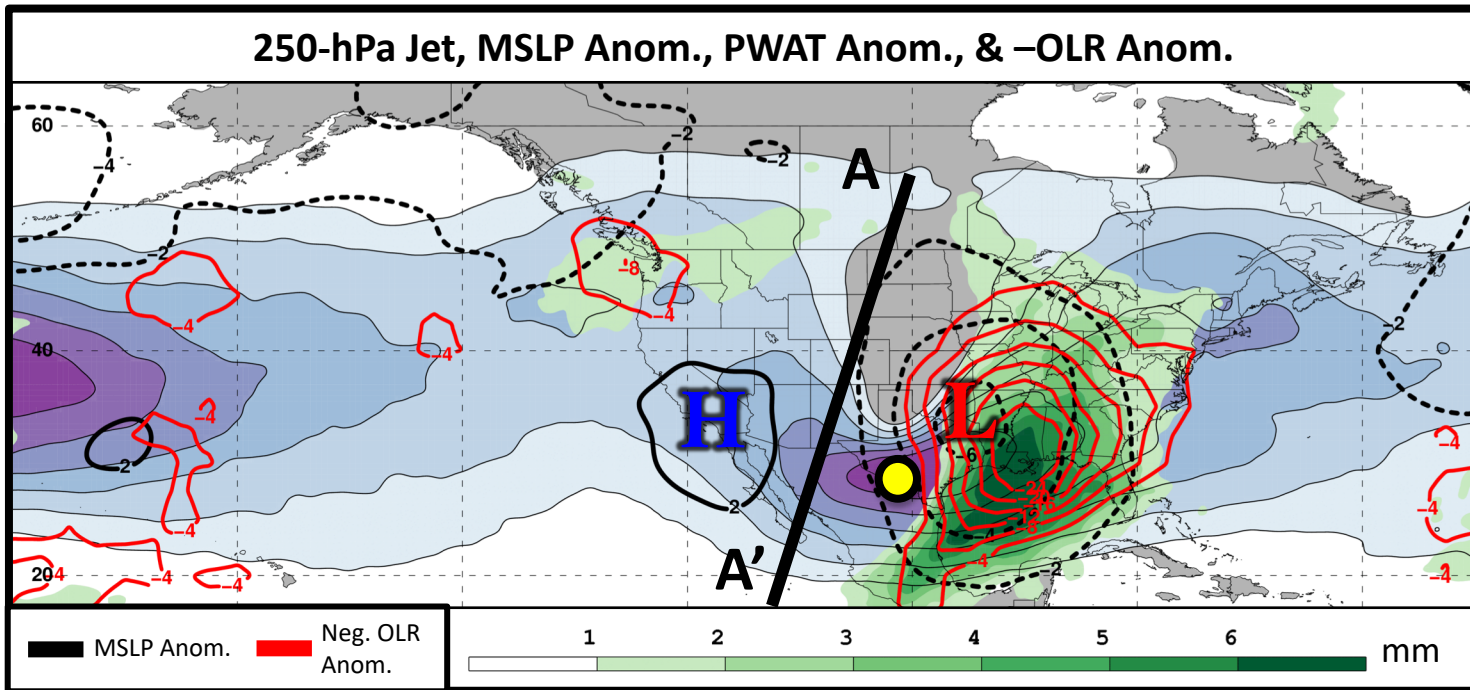
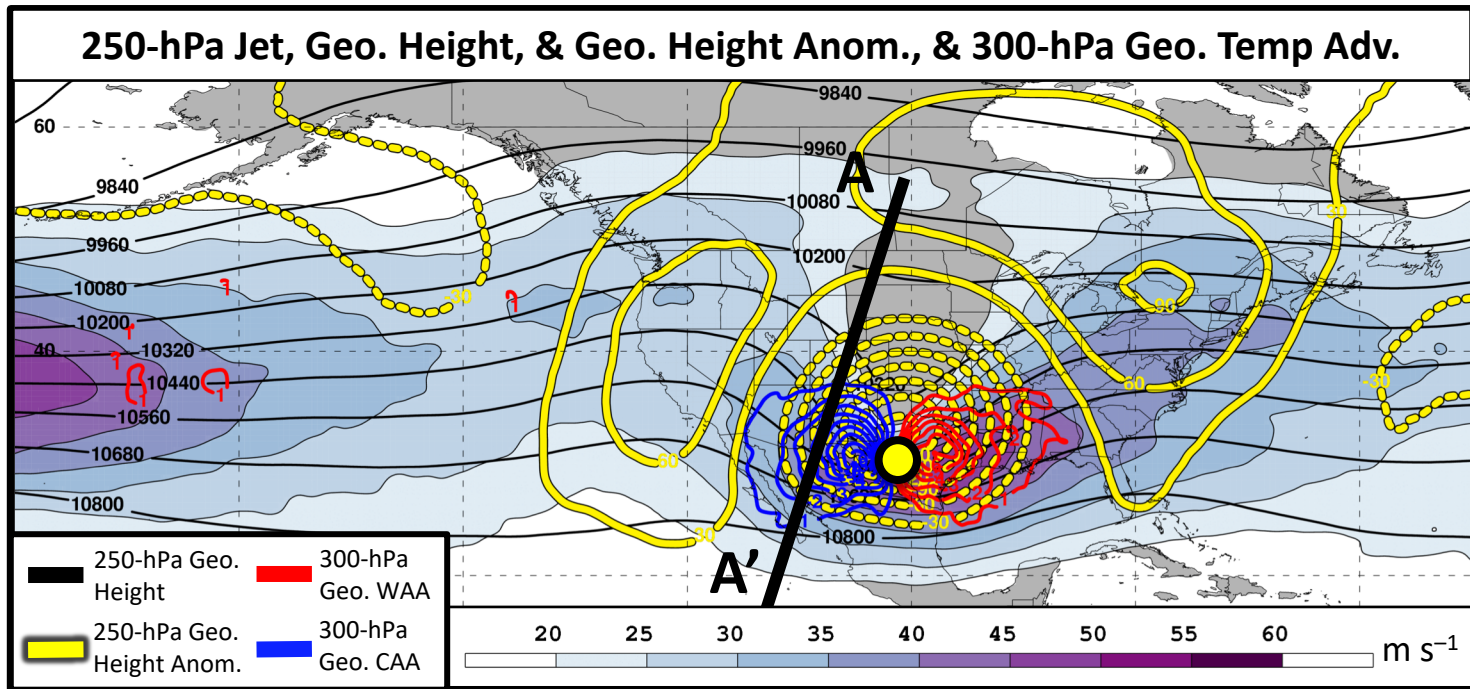


Polar Dominant Jet Superposition Events

0 Days
Prior to Jet
Superposition

Jet
Superposition
Centroid

N=80

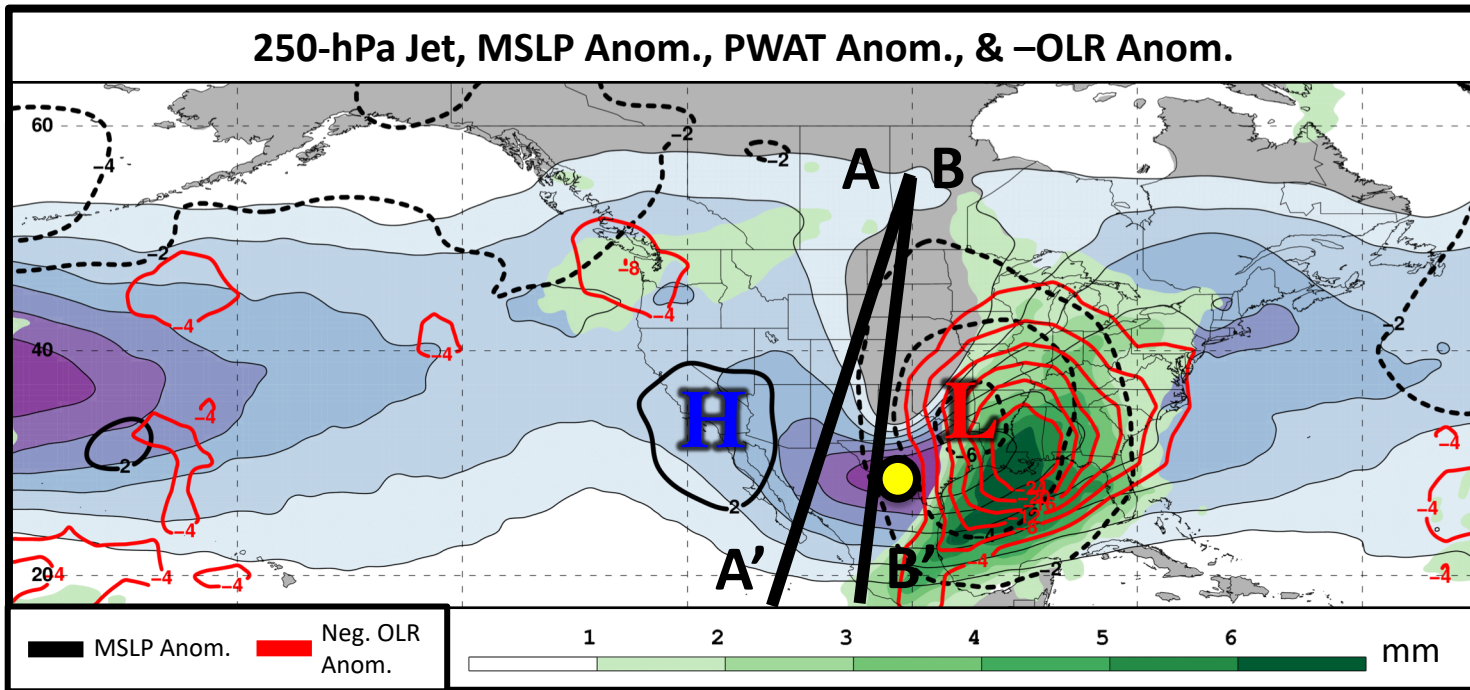
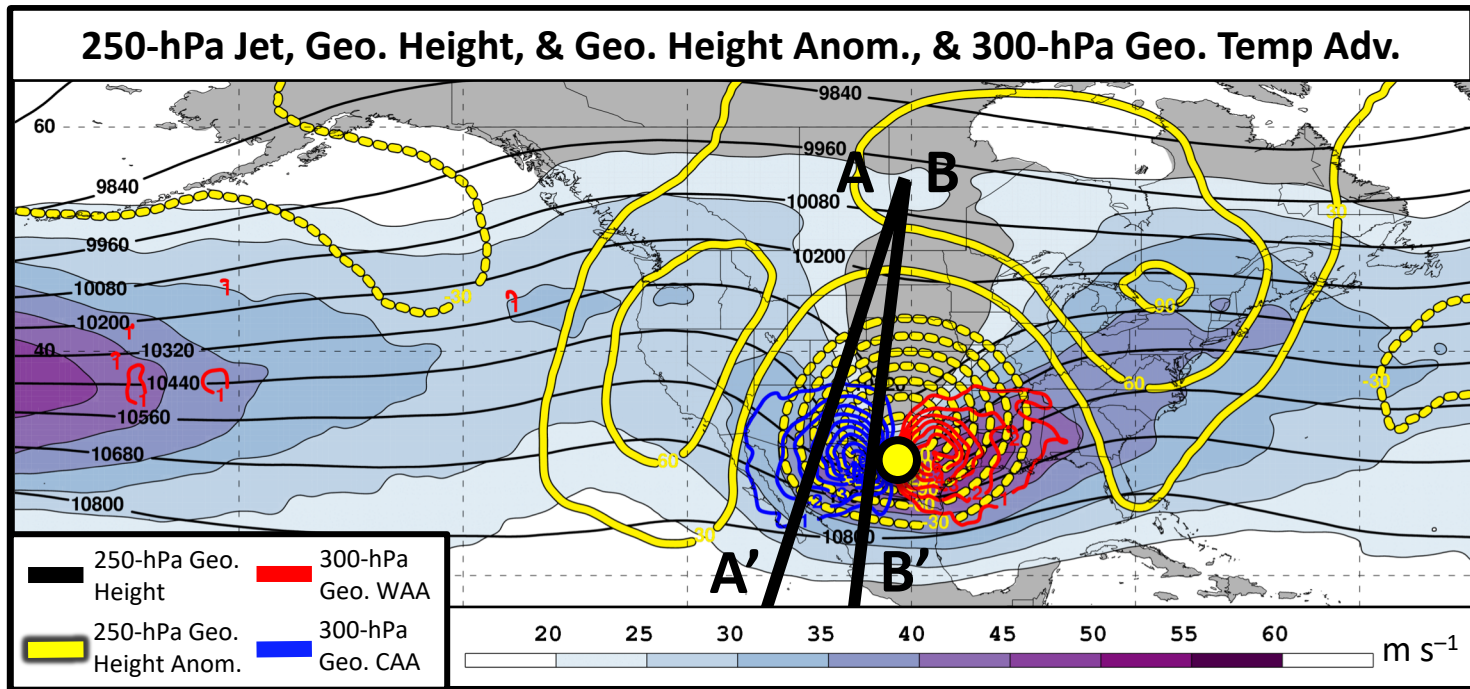


Polar Dominant Jet Superposition Events

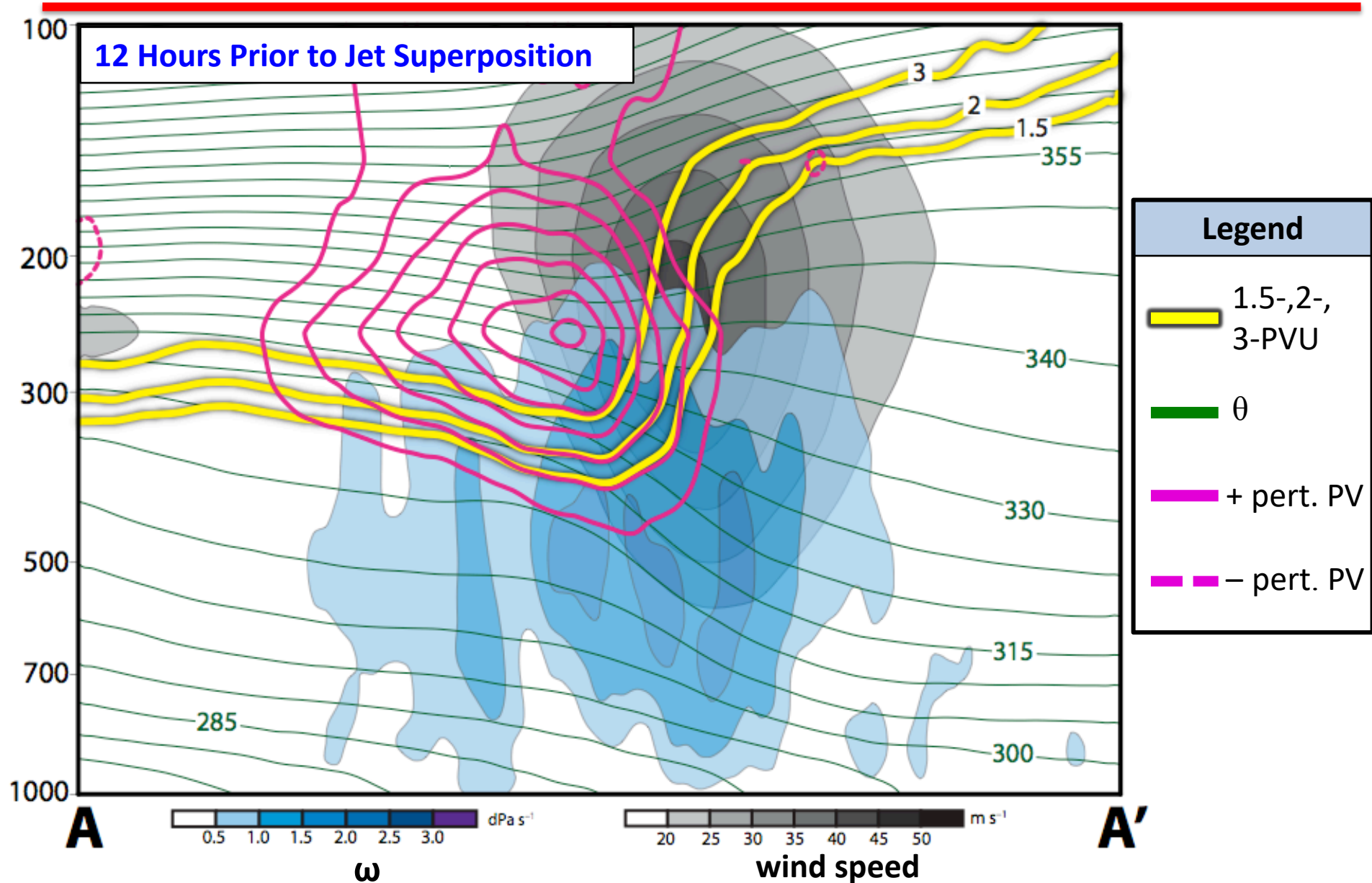
0 Days
Prior to Jet
Superposition

Jet
Superposition
Centroid

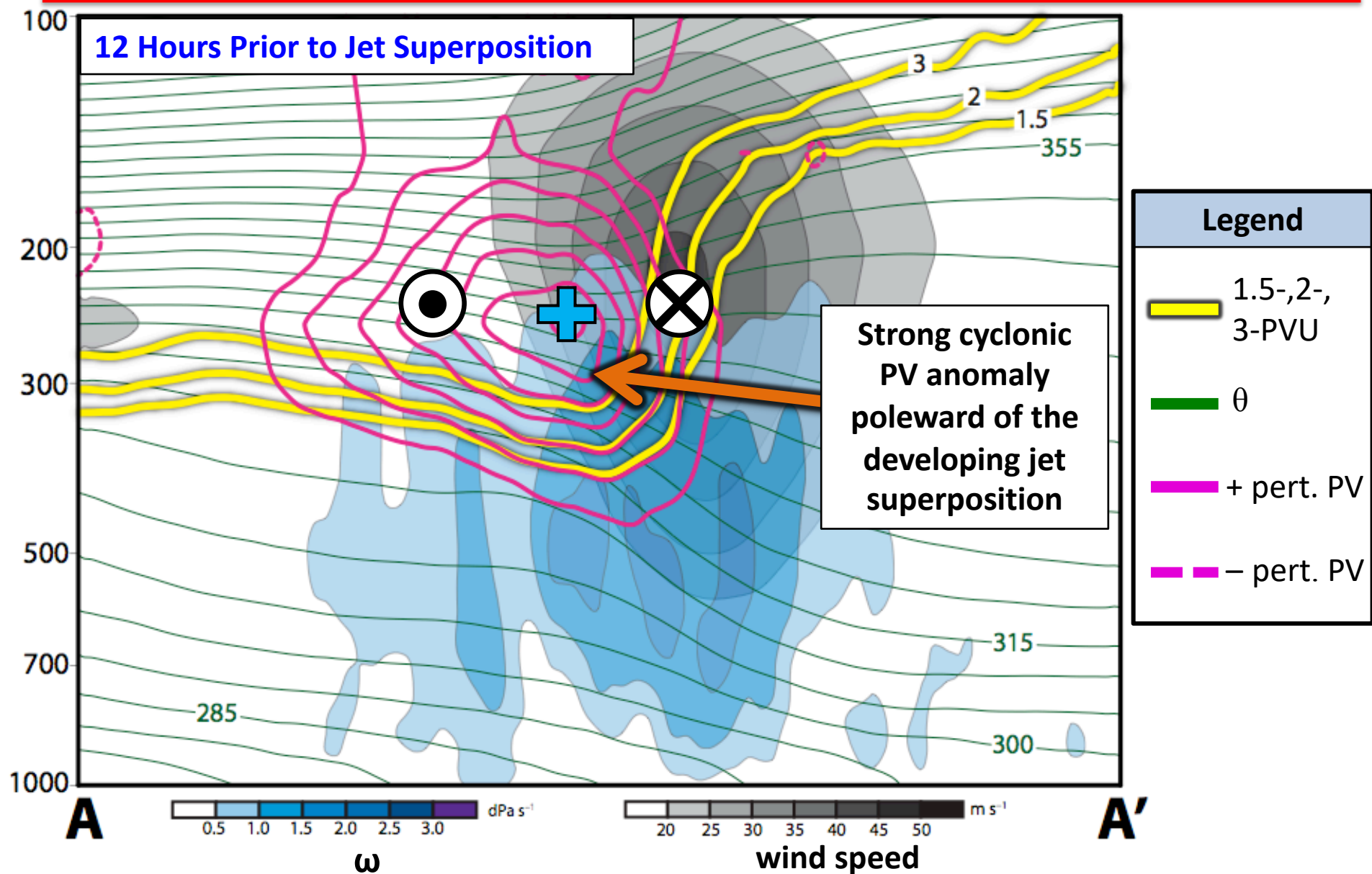
N=80



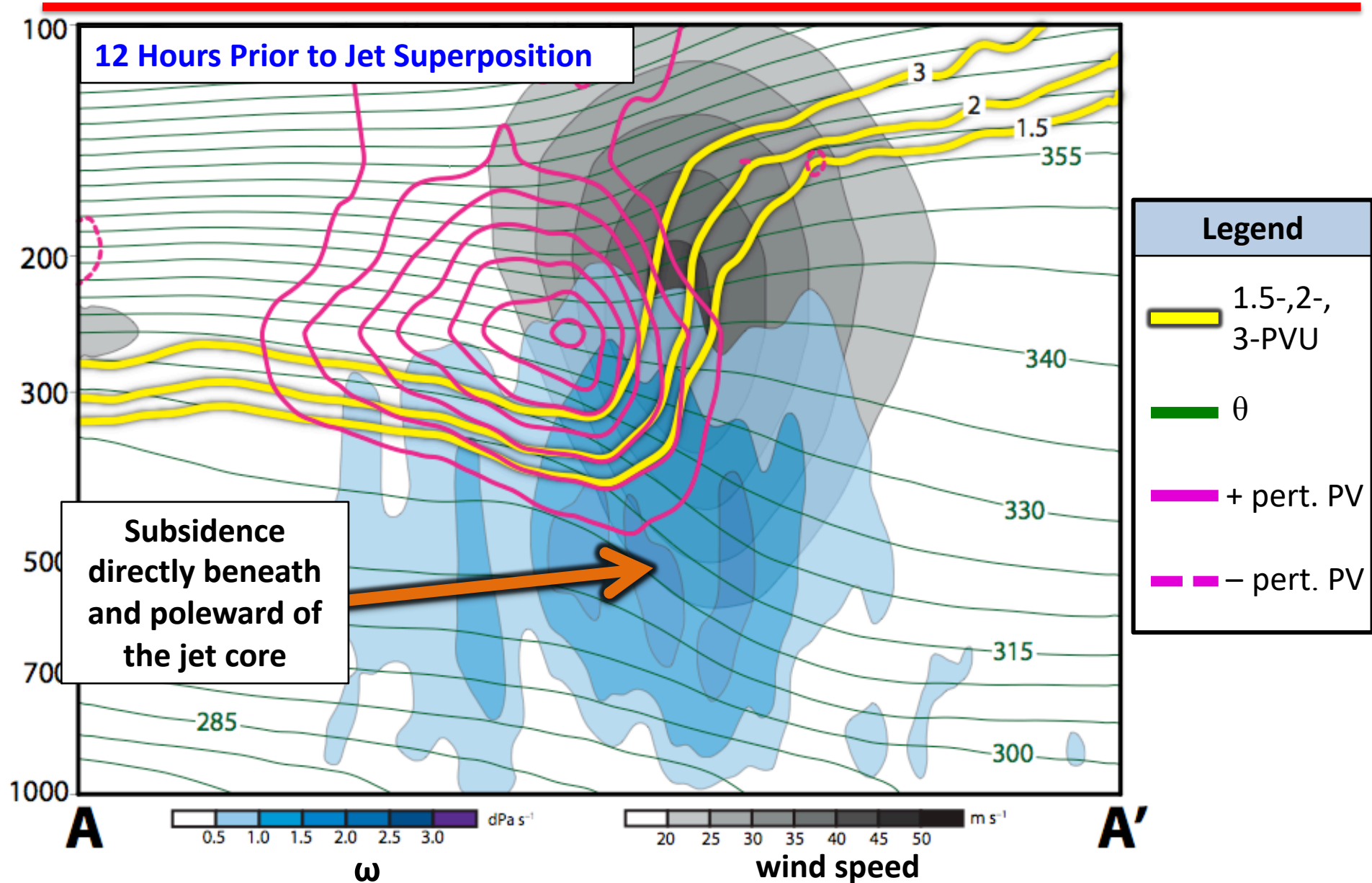
Polar Dominant Jet Superposition Events



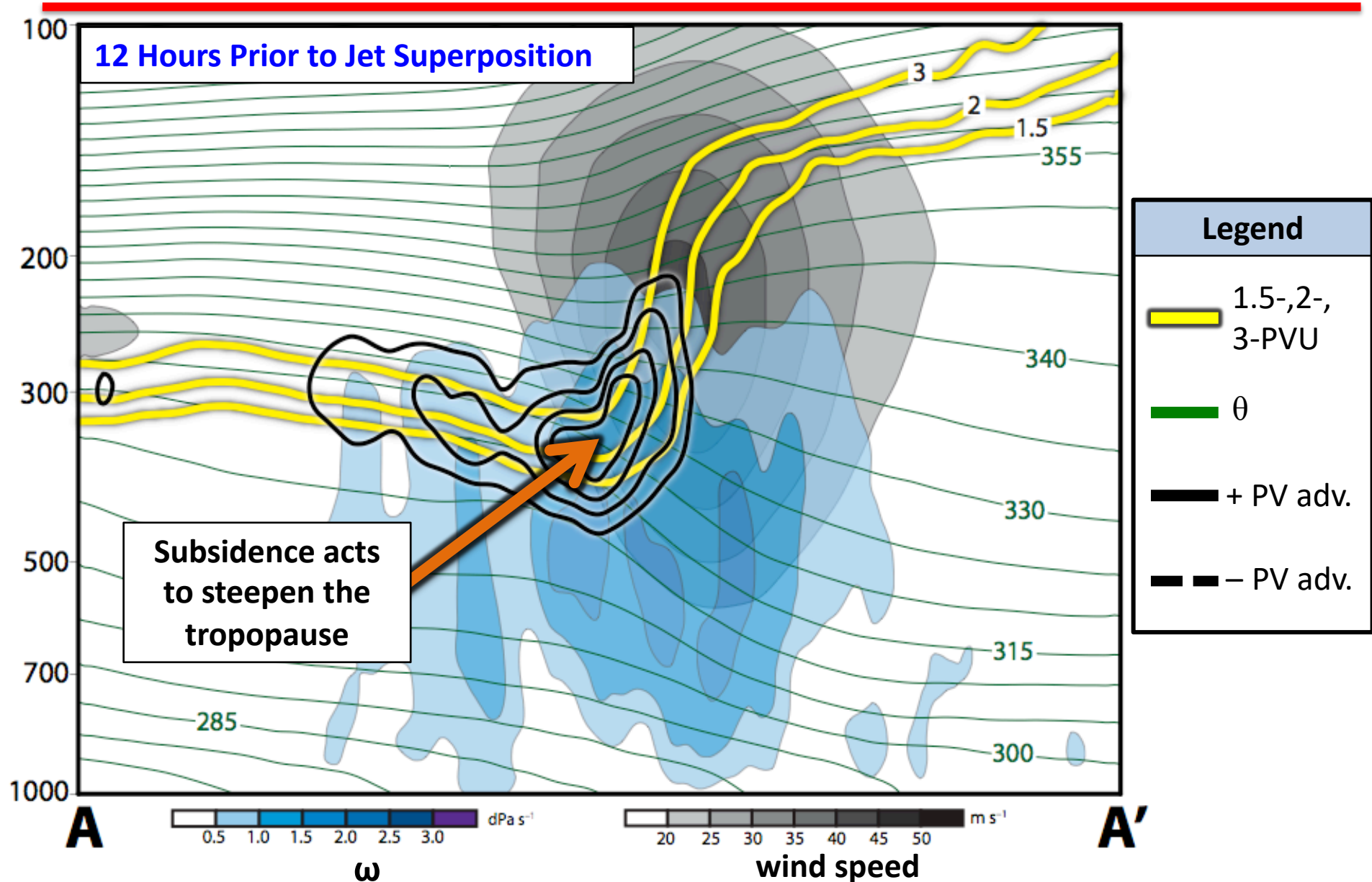
Polar Dominant Jet Superposition Events



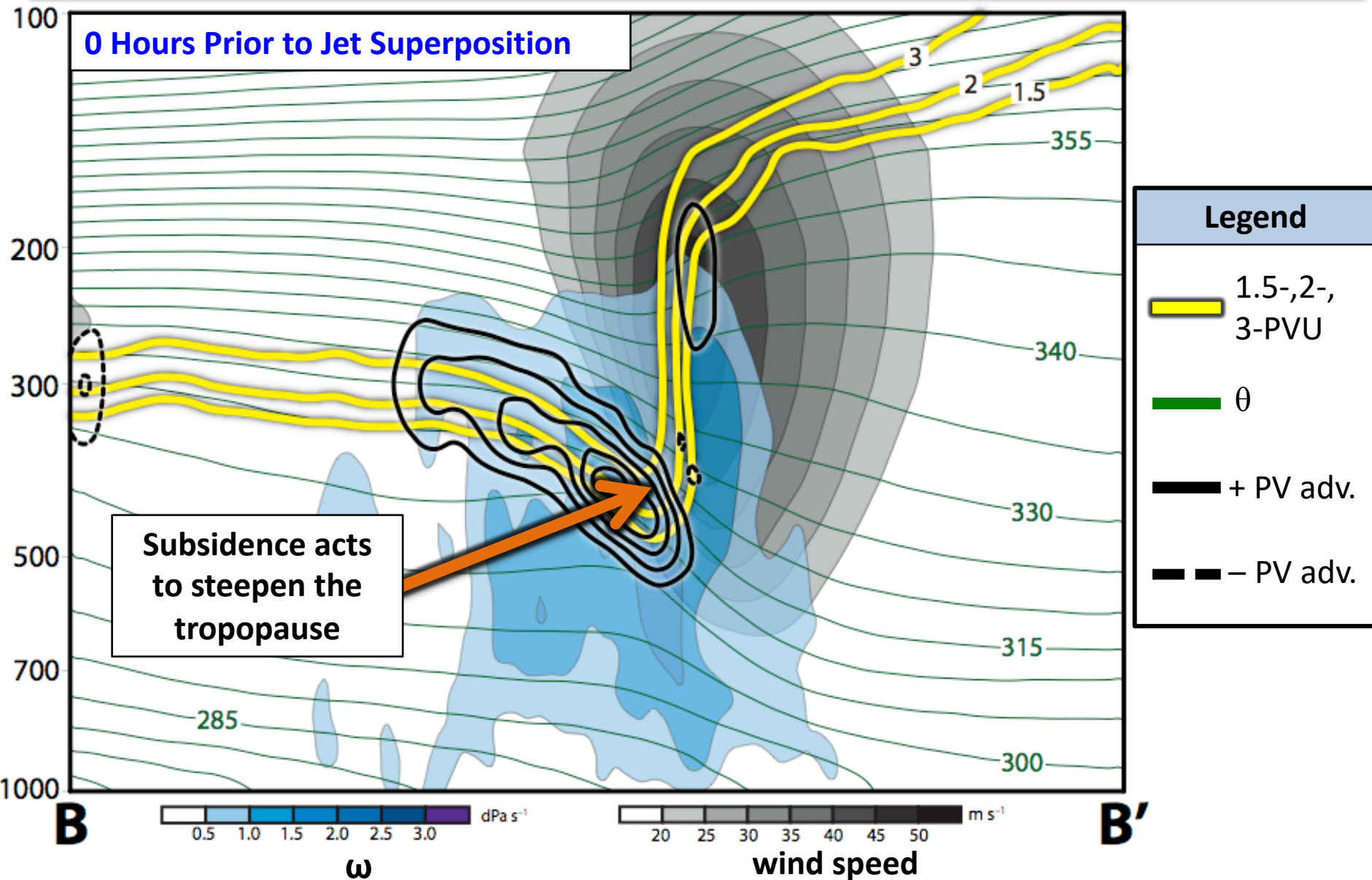
Polar Dominant Jet Superposition Events



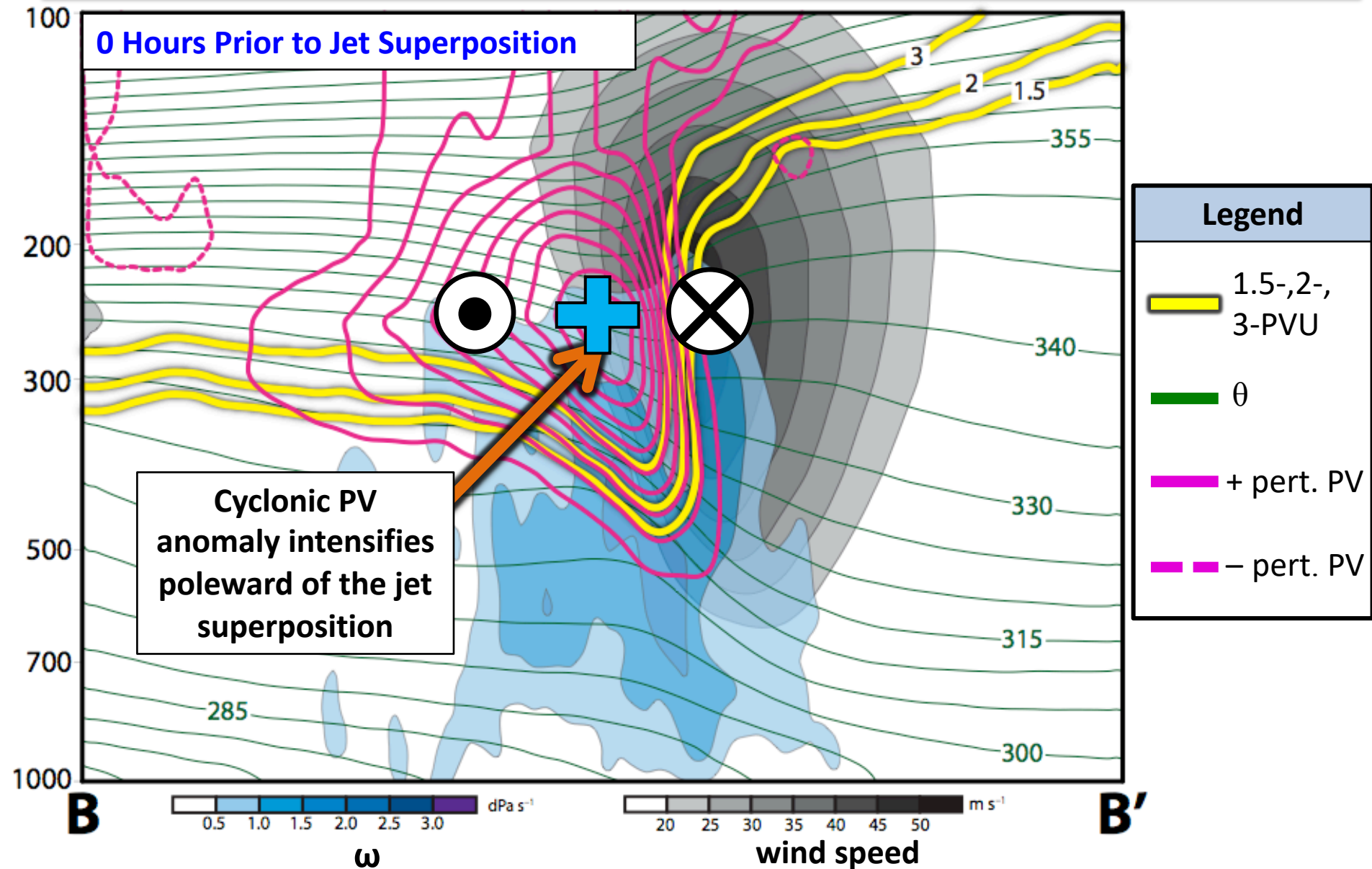
Polar Dominant Jet Superposition Events



Polar Dominant Jet Superposition Events

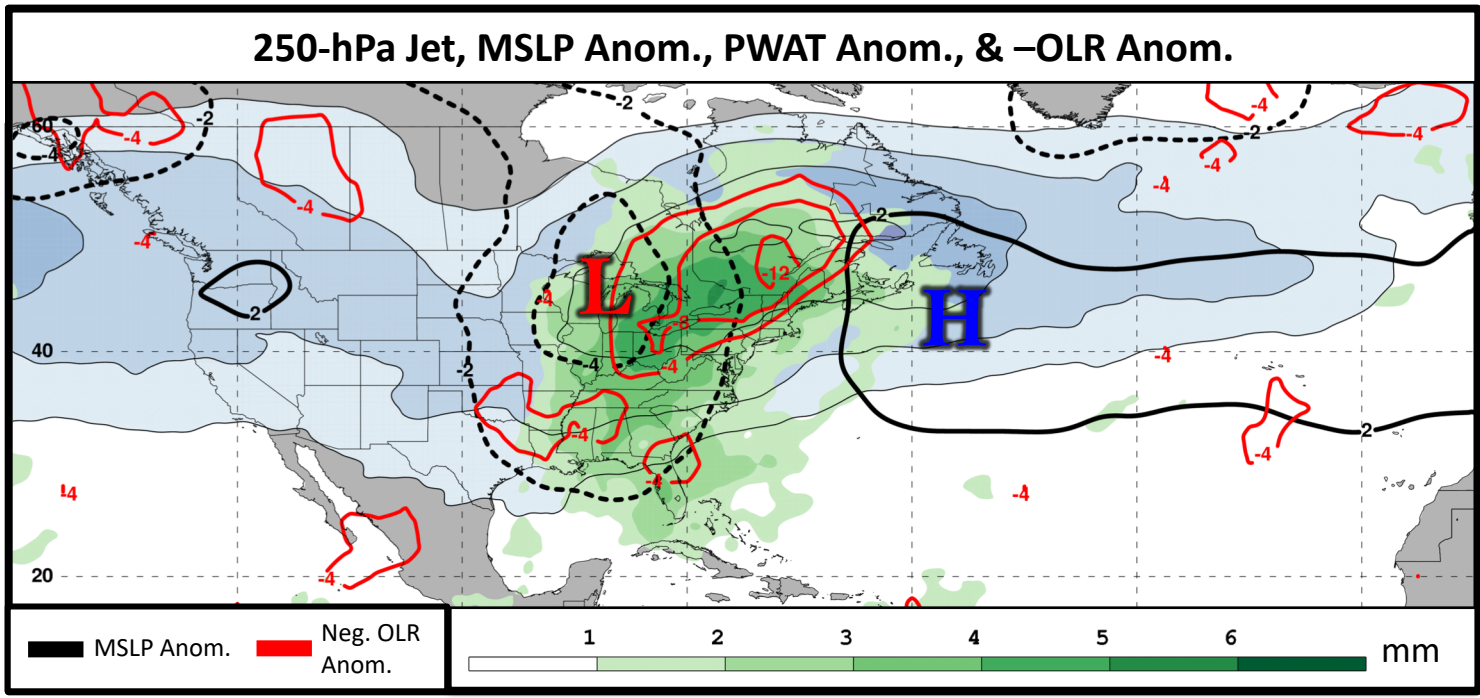
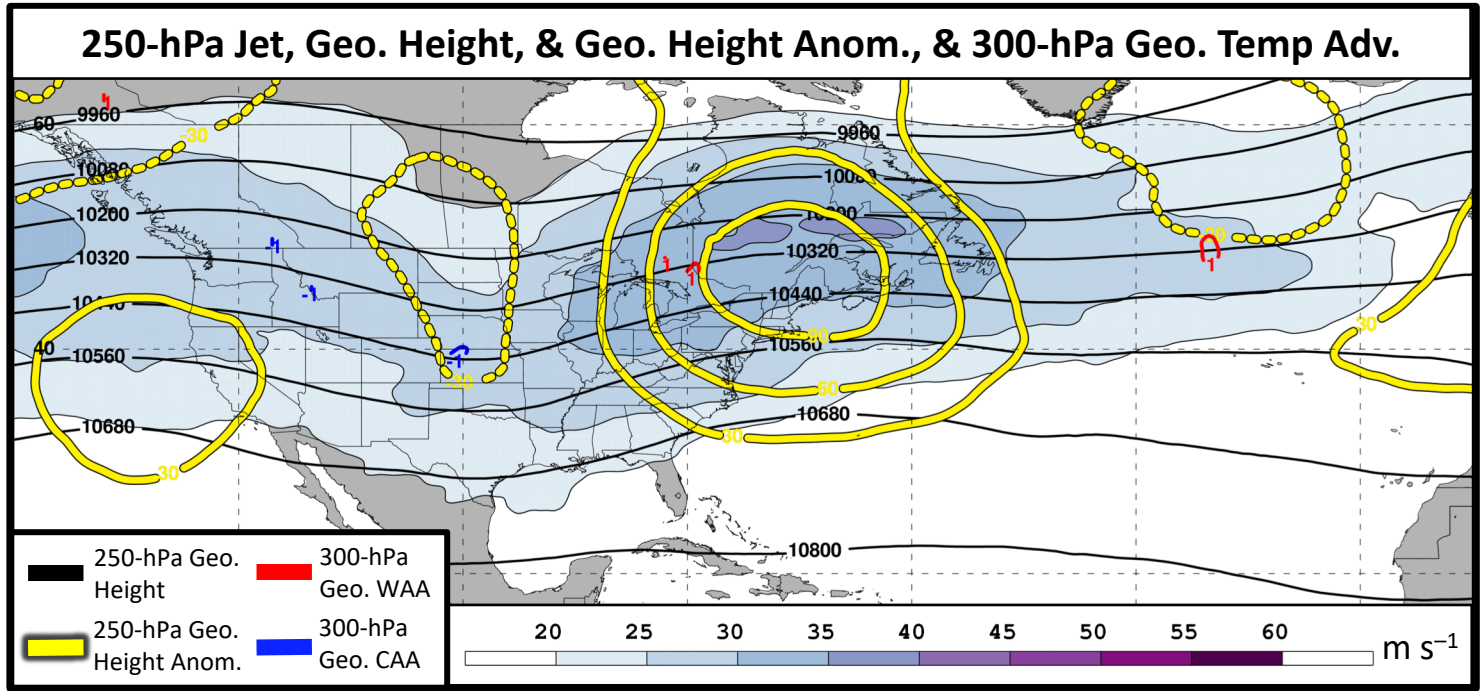


Polar Dominant Jet Superposition Events



E. Subtropical Dominant Jet Superposition Events

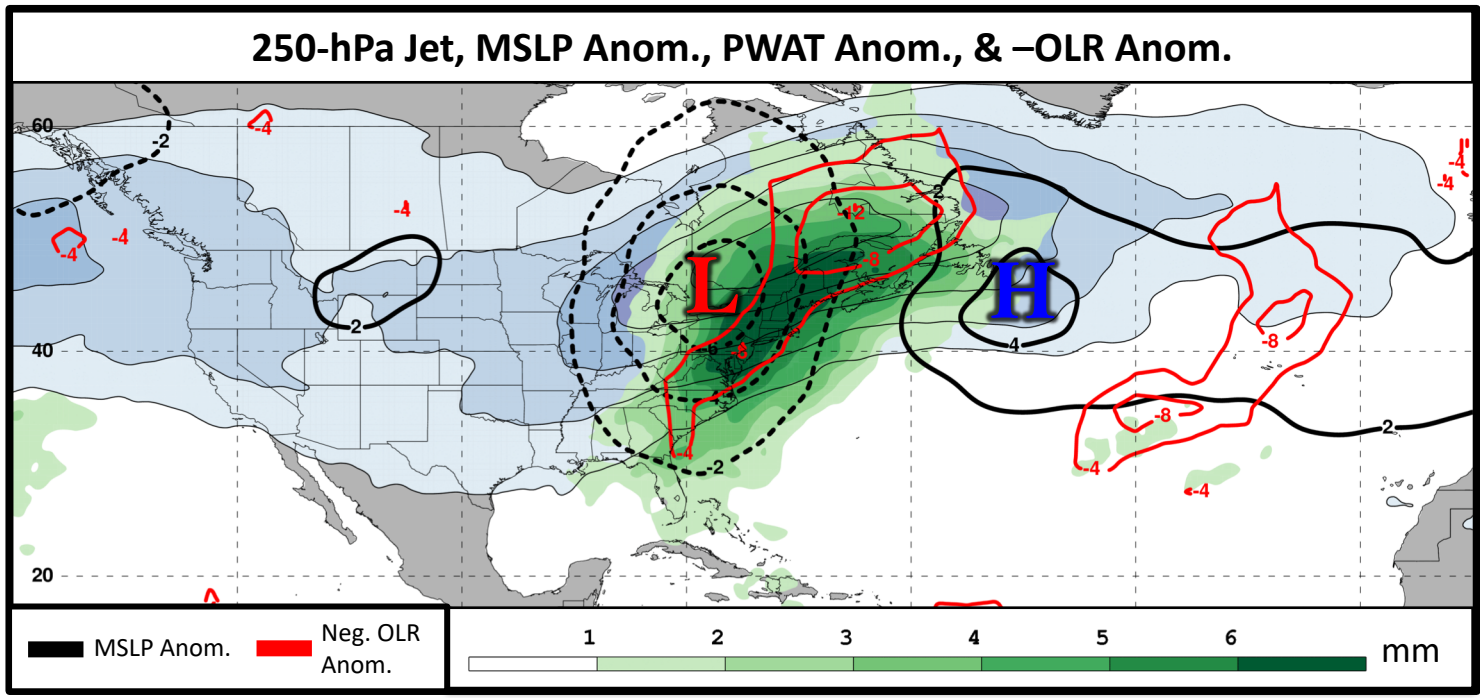
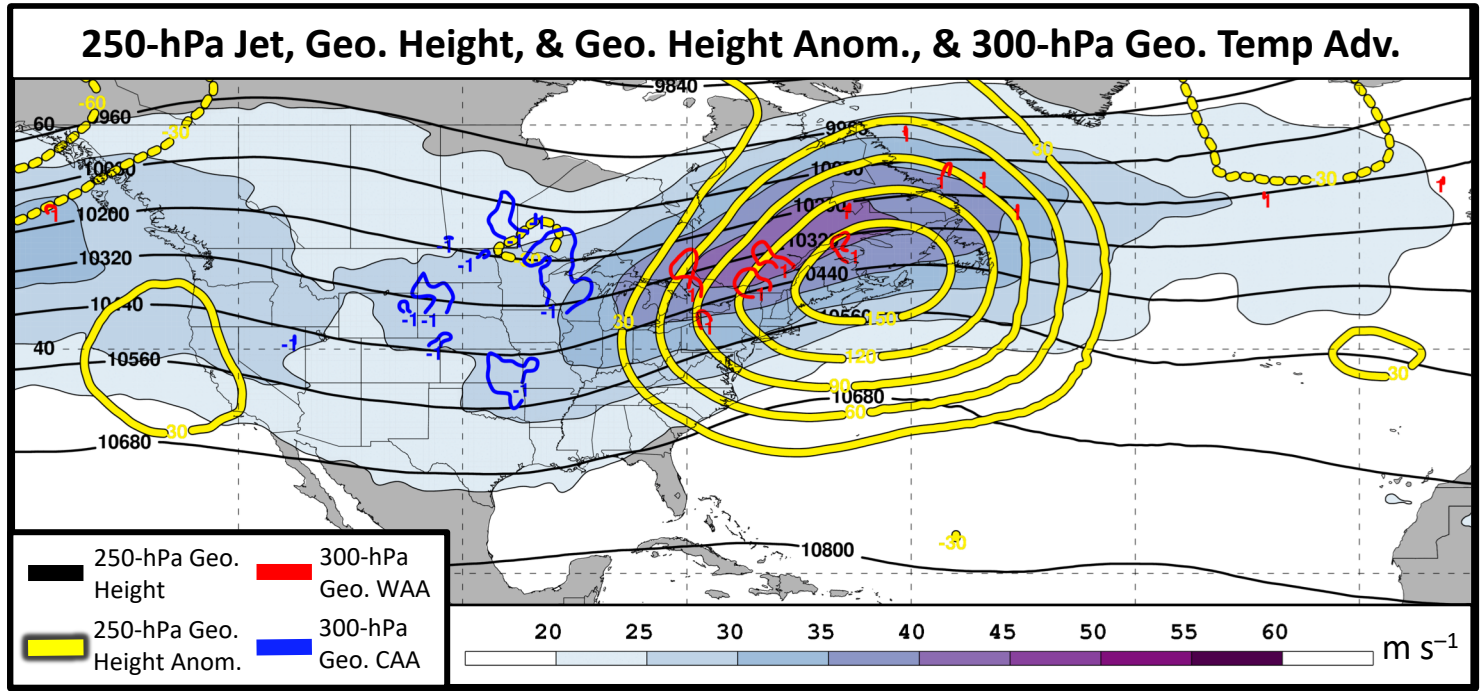
2 Days
Prior to Jet
Superposition



N=76

E. Subtropical Dominant Jet Superposition Events

1 Day Prior to Jet Superposition



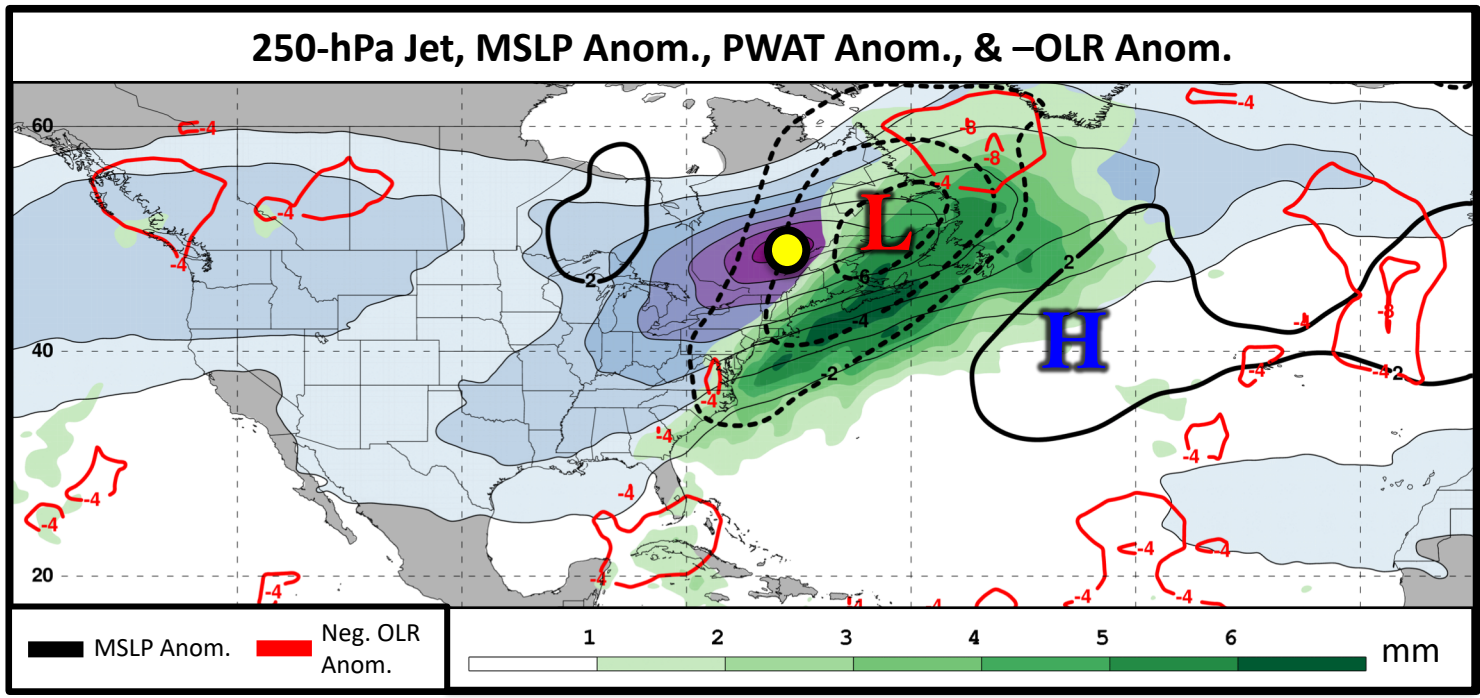
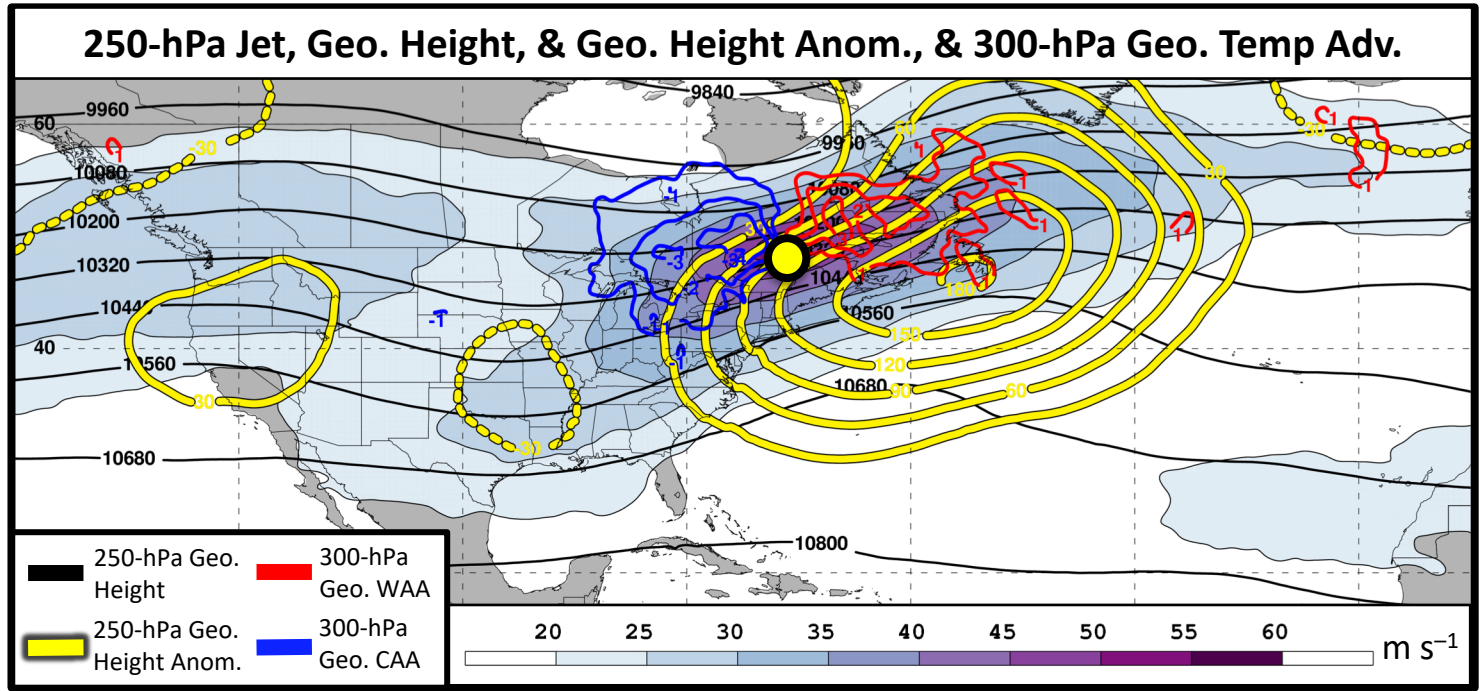
N=76

E. Subtropical Dominant Jet Superposition Events

0 Days
Prior to Jet
Superposition

Jet
Superposition
Centroid

N=76

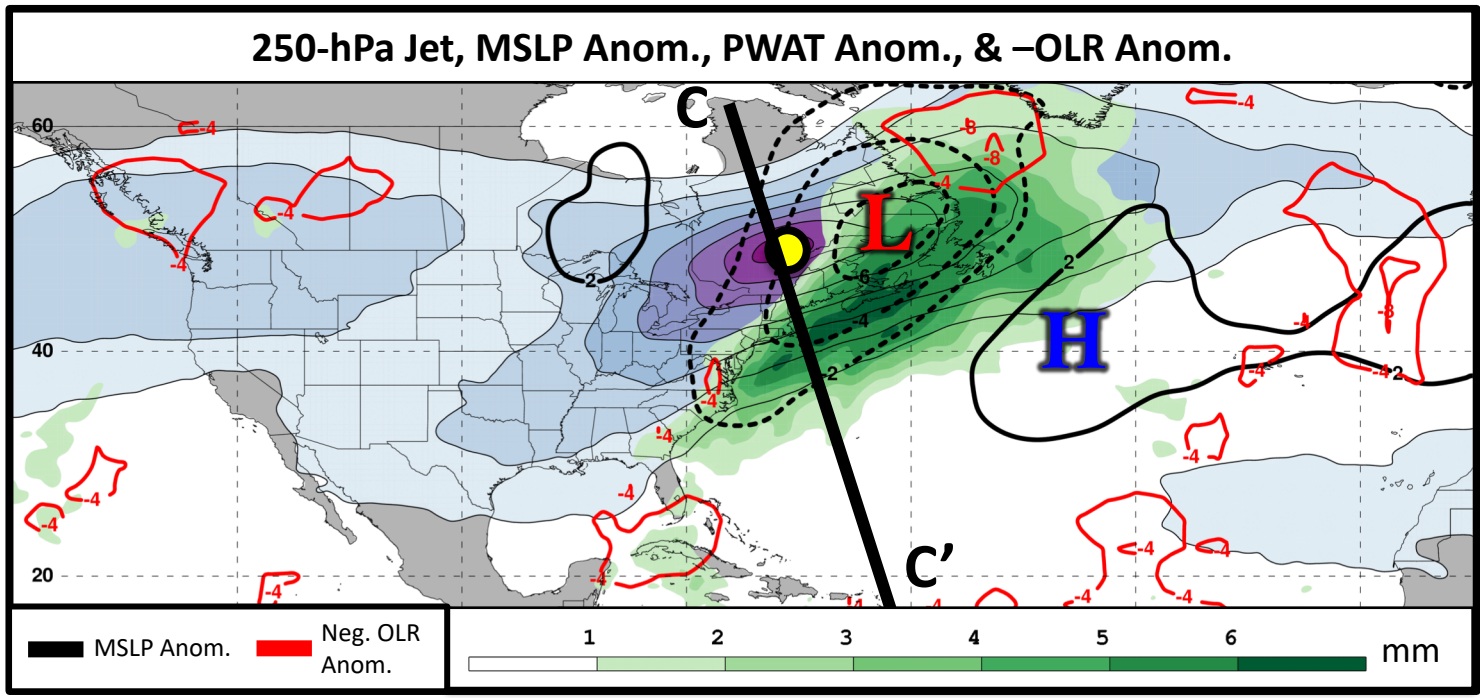
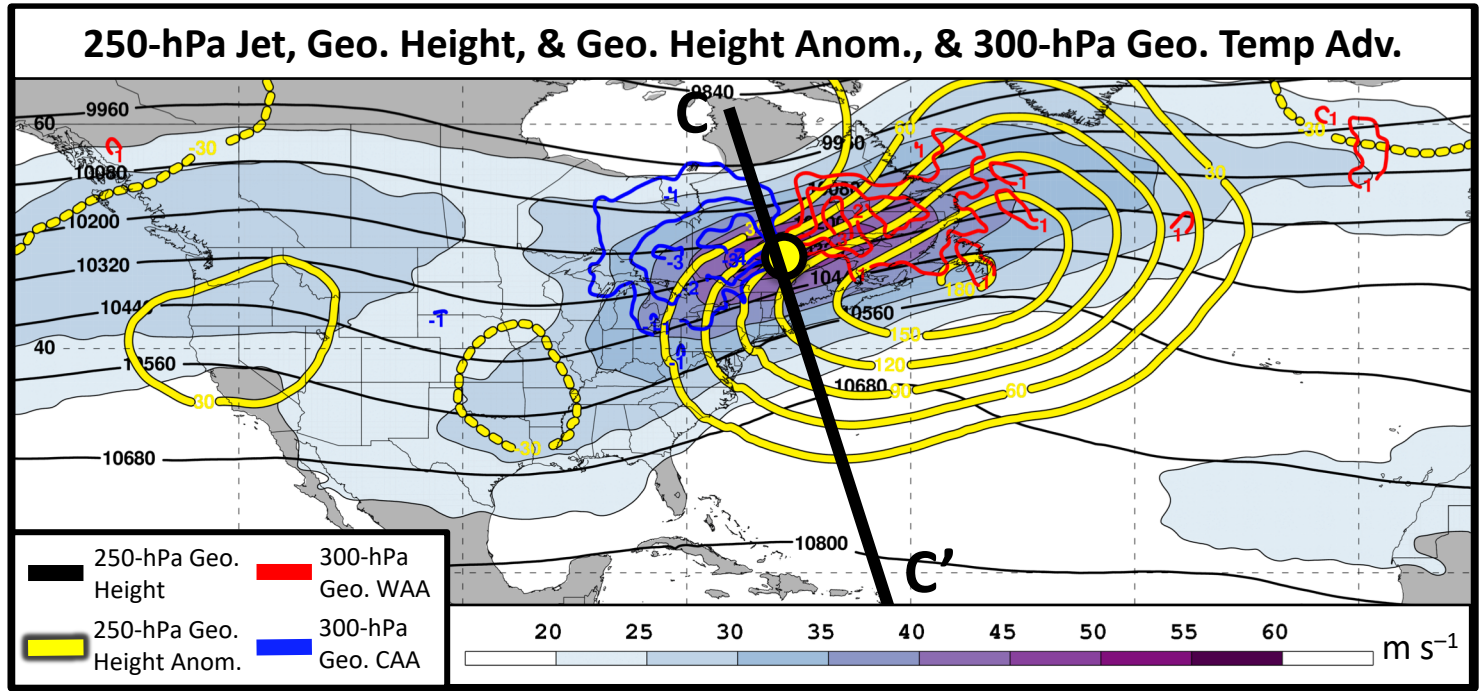


E. Subtropical Dominant Jet Superposition Events

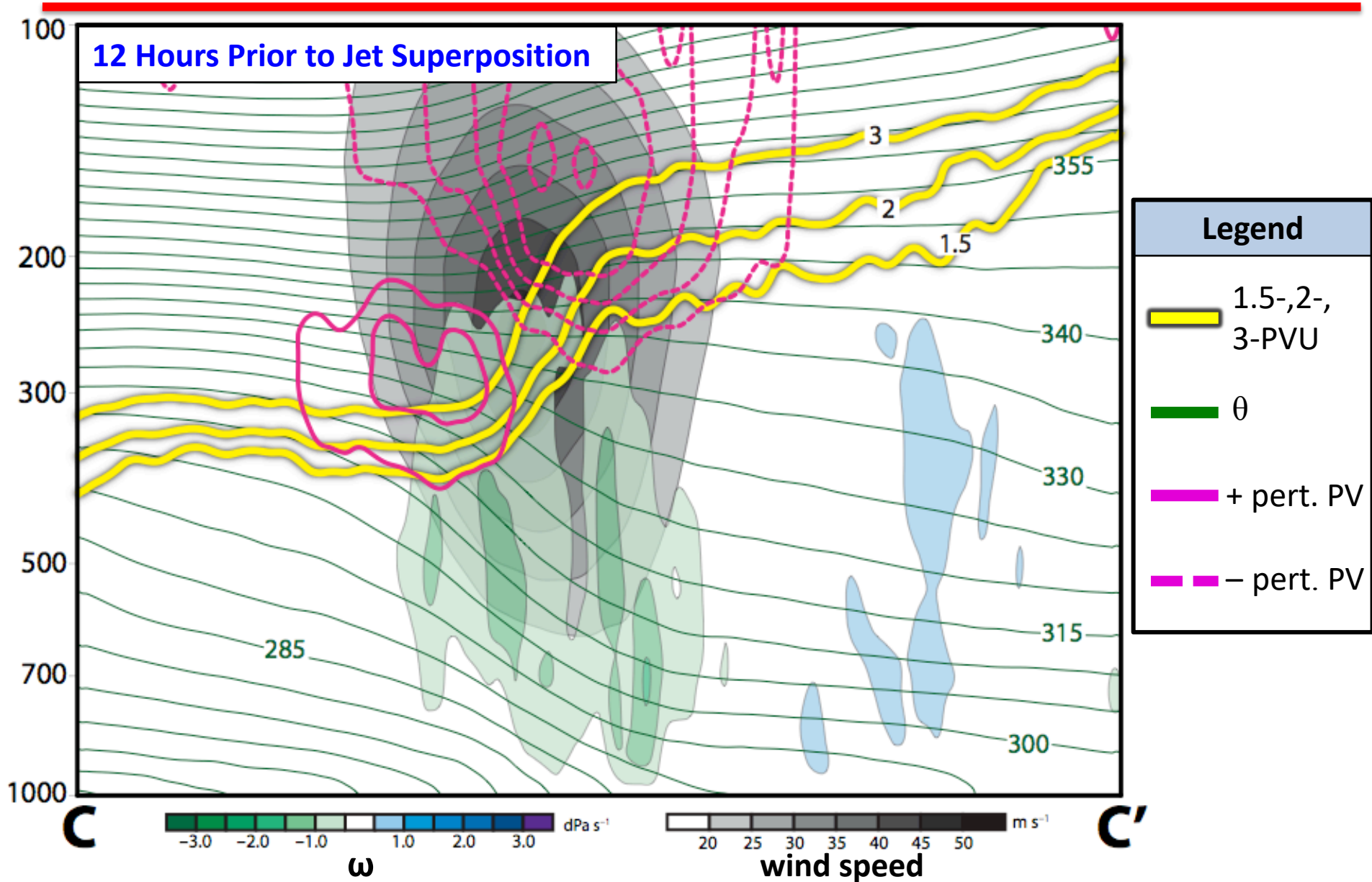
0 Days
Prior to Jet
Superposition

Jet
Superposition
Centroid

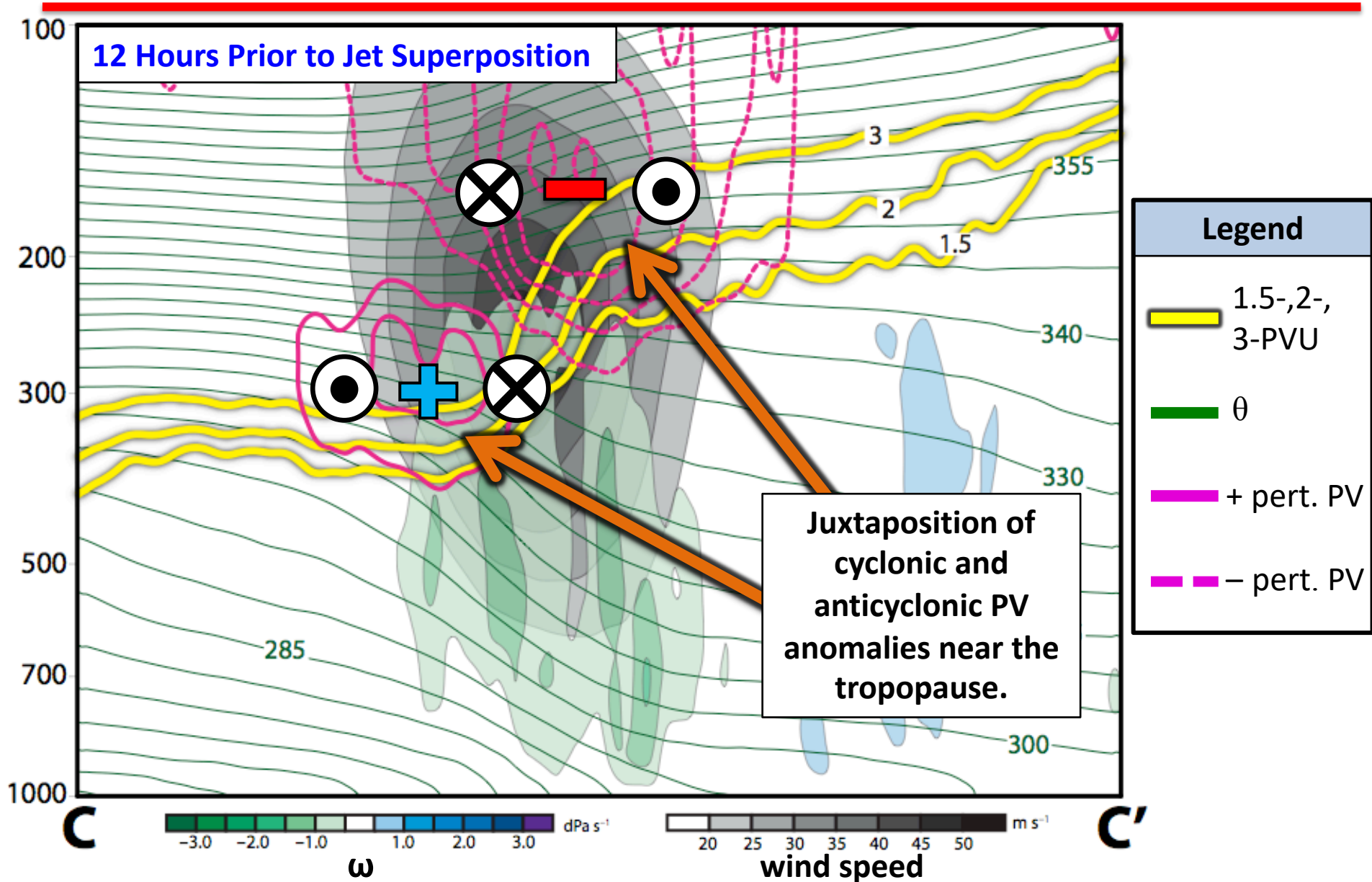
N=76



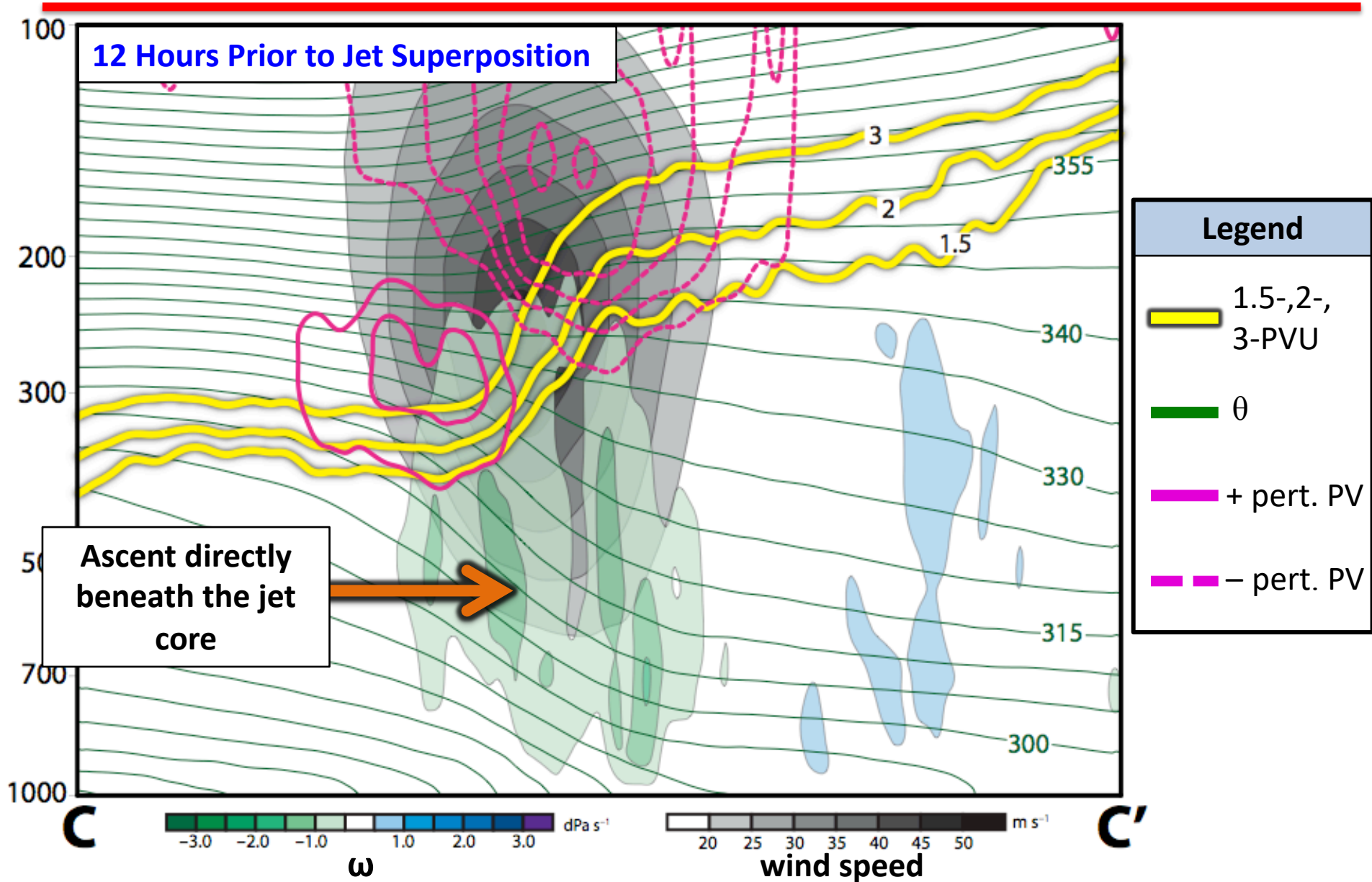
E. Subtropical Dominant Jet Superposition Events



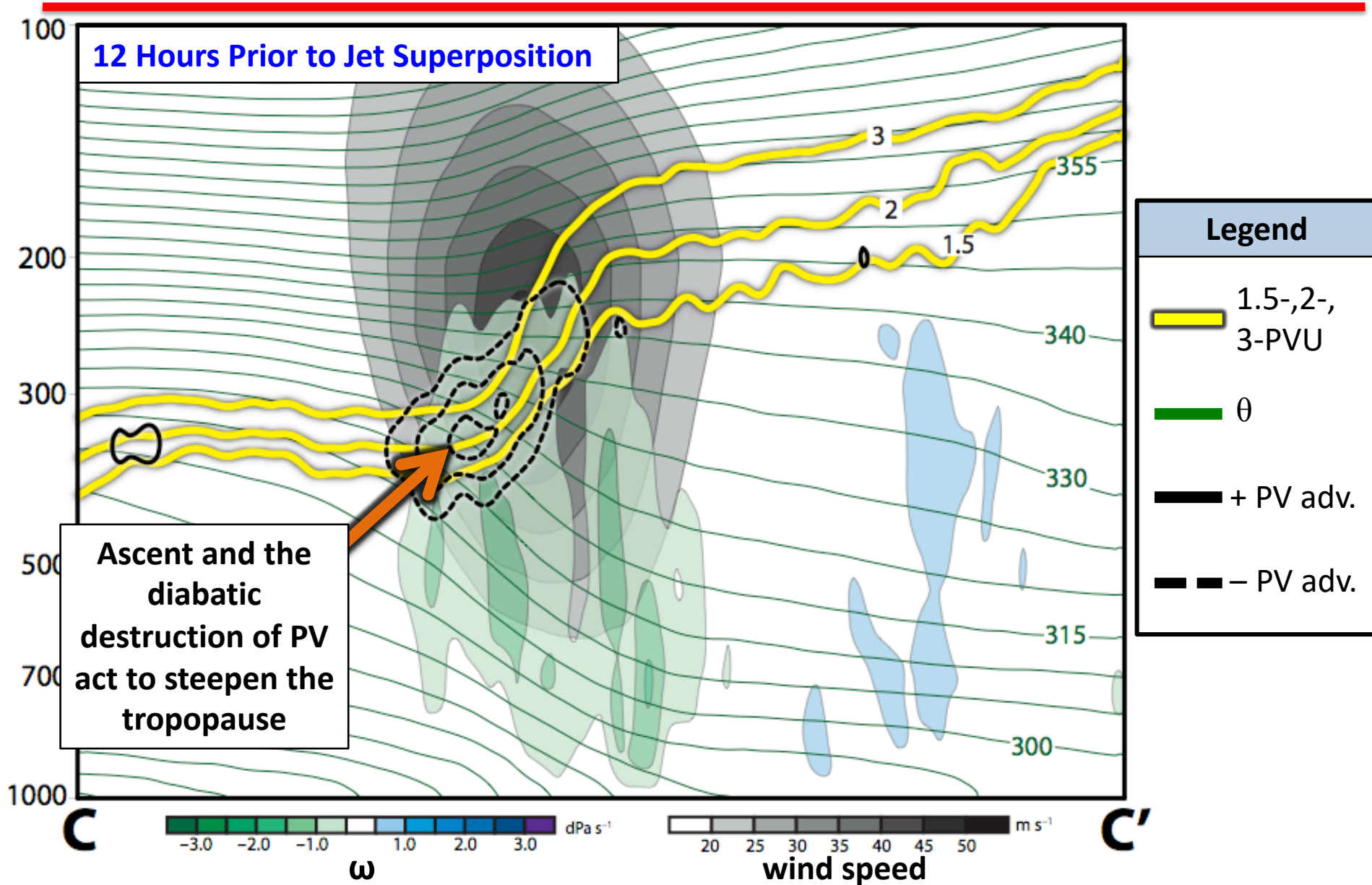
E. Subtropical Dominant Jet Superposition Events



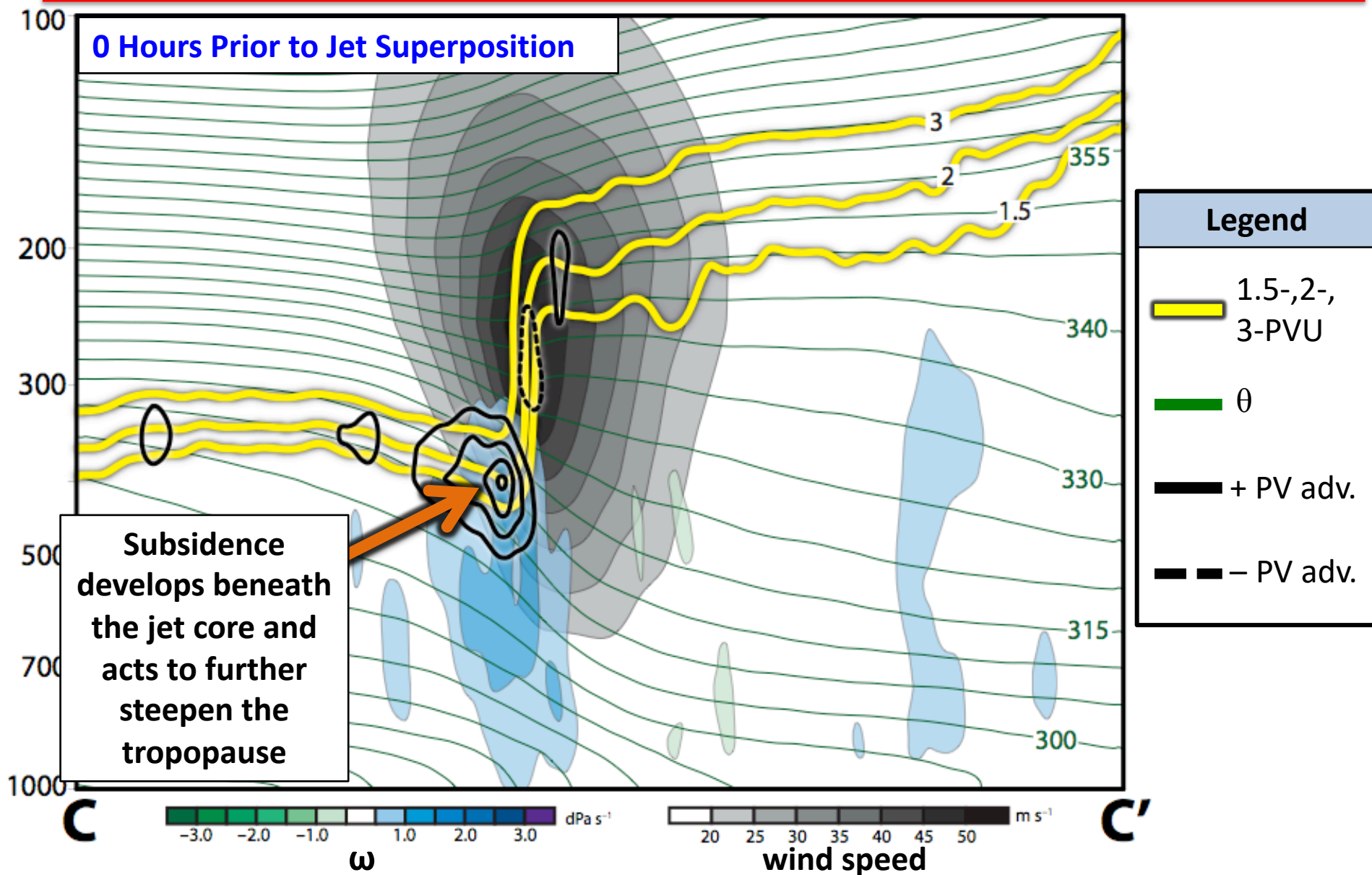
E. Subtropical Dominant Jet Superposition Events



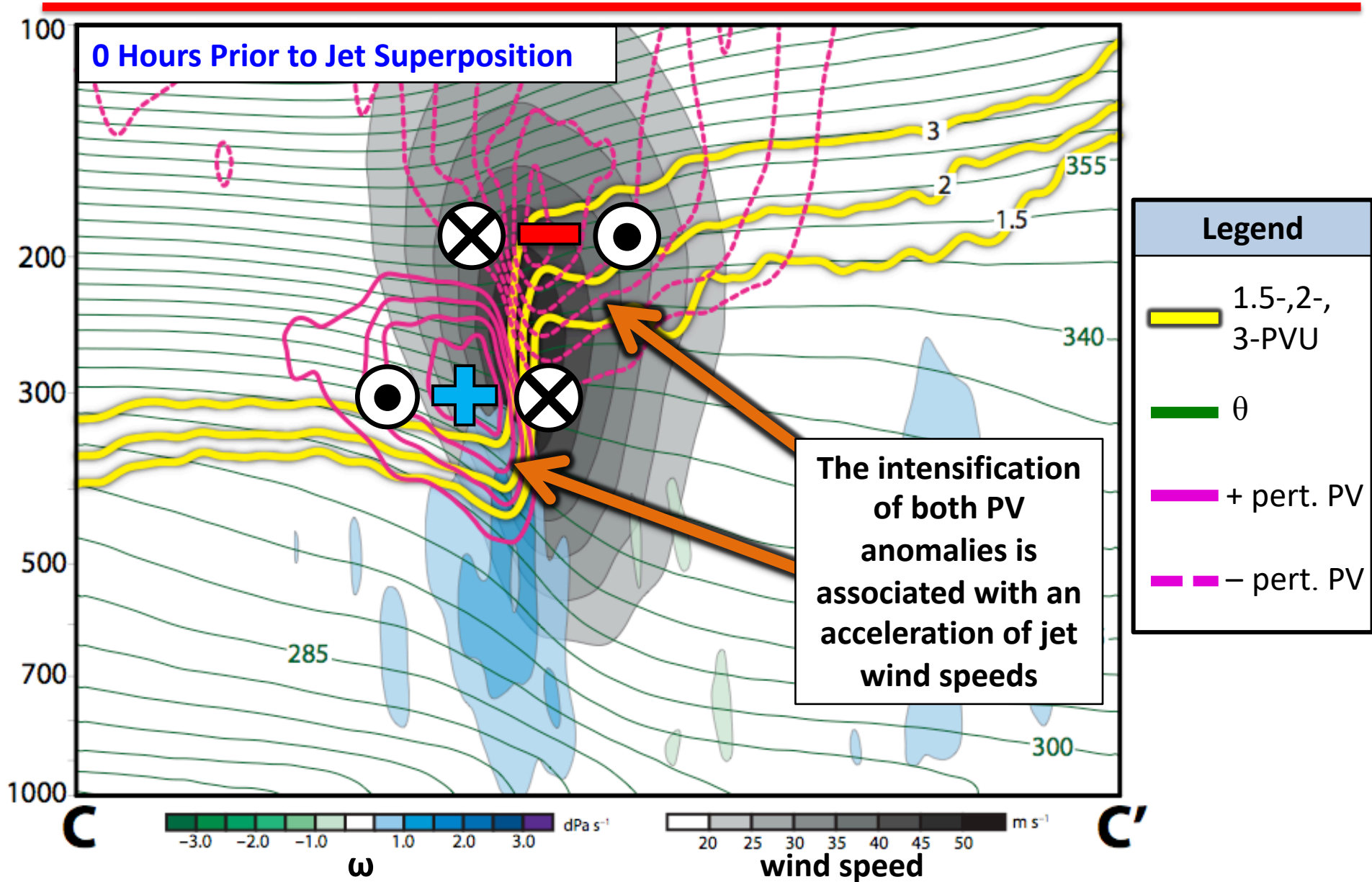
E. Subtropical Dominant Jet Superposition Events



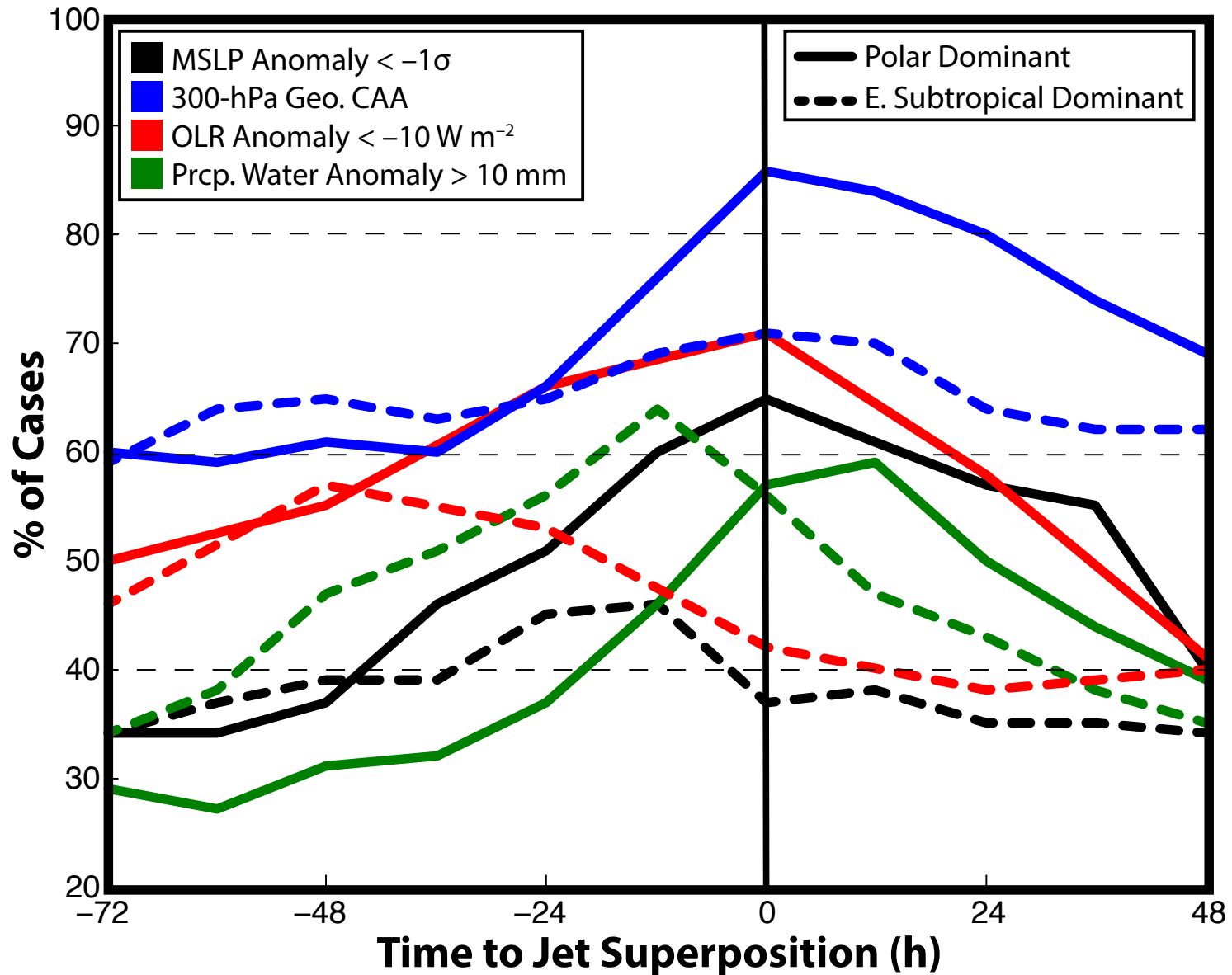
E. Subtropical Dominant Jet Superposition Events



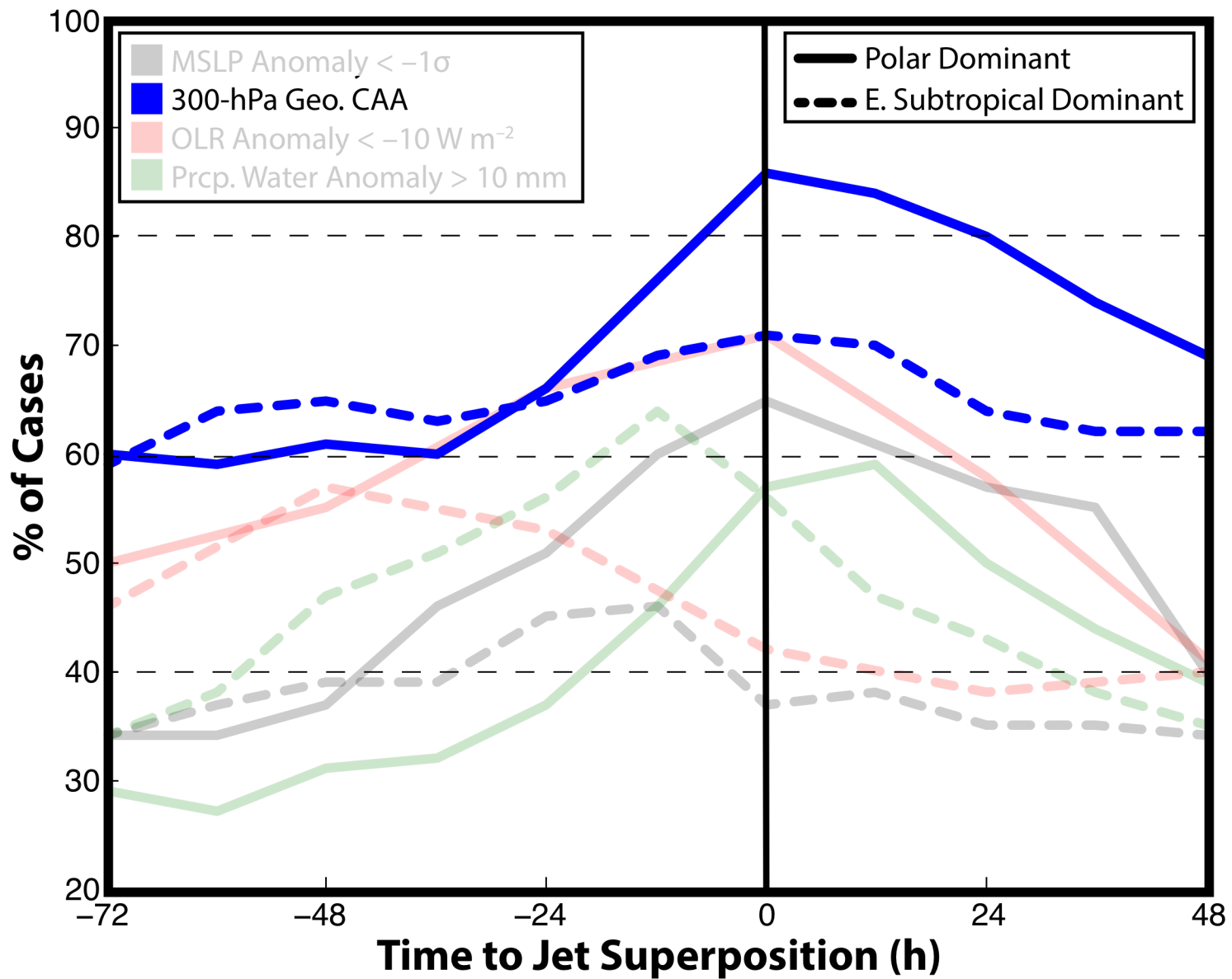
E. Subtropical Dominant Jet Superposition Events



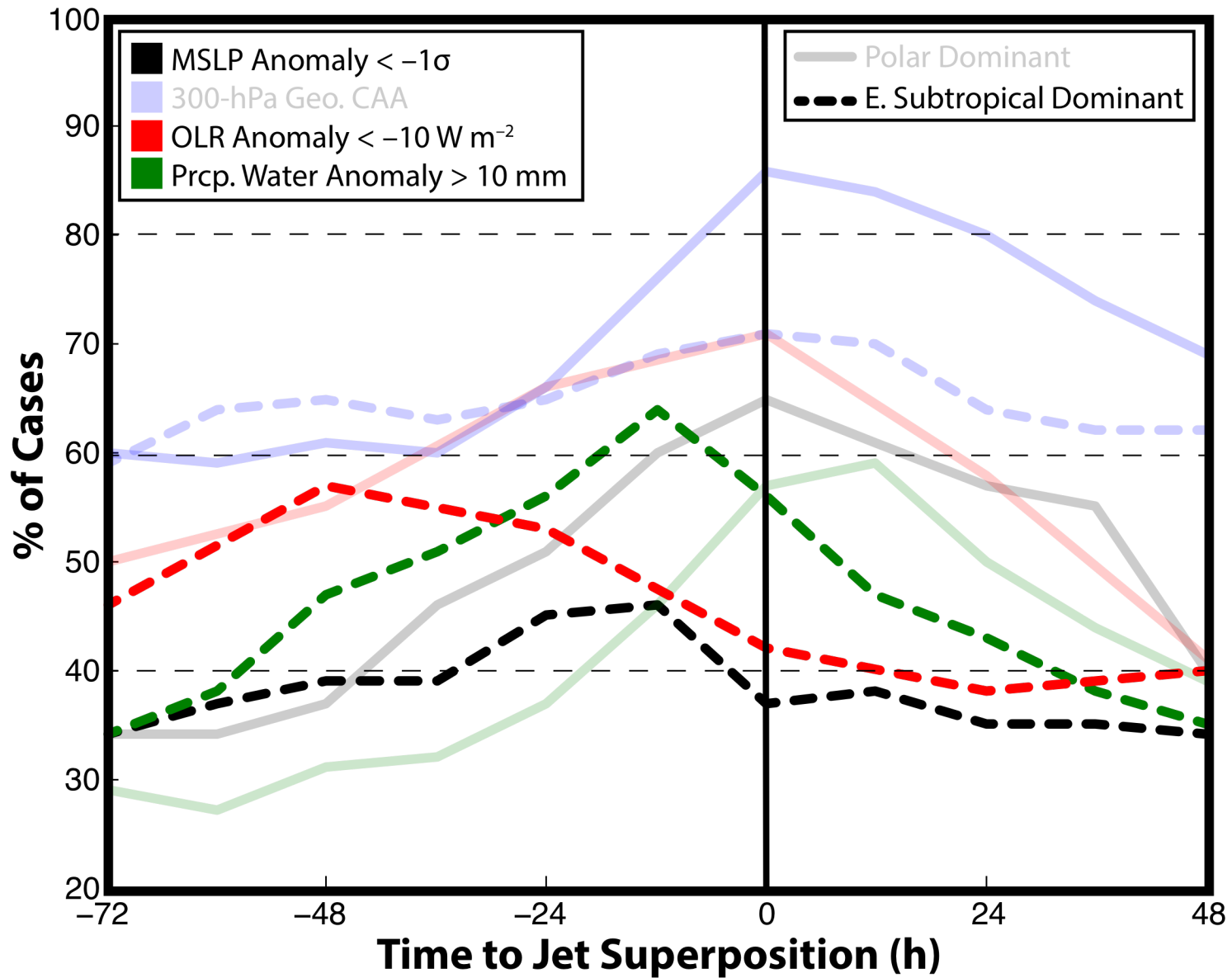
Synthesis



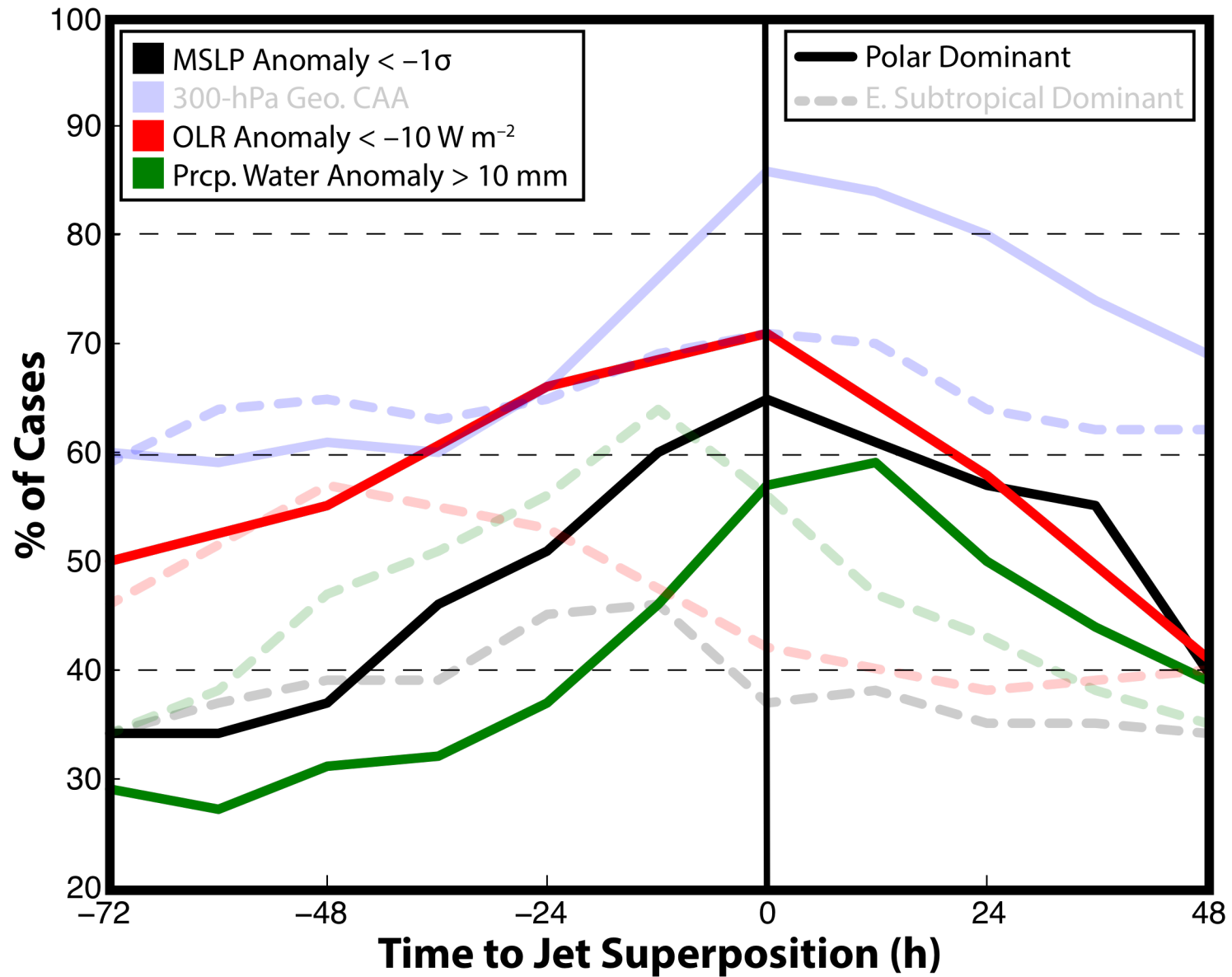
Synthesis



Synthesis



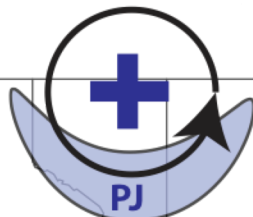
Synthesis



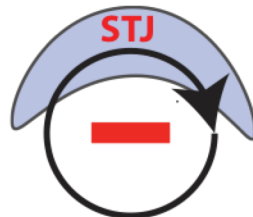
Summary

Polar Dominant Events:

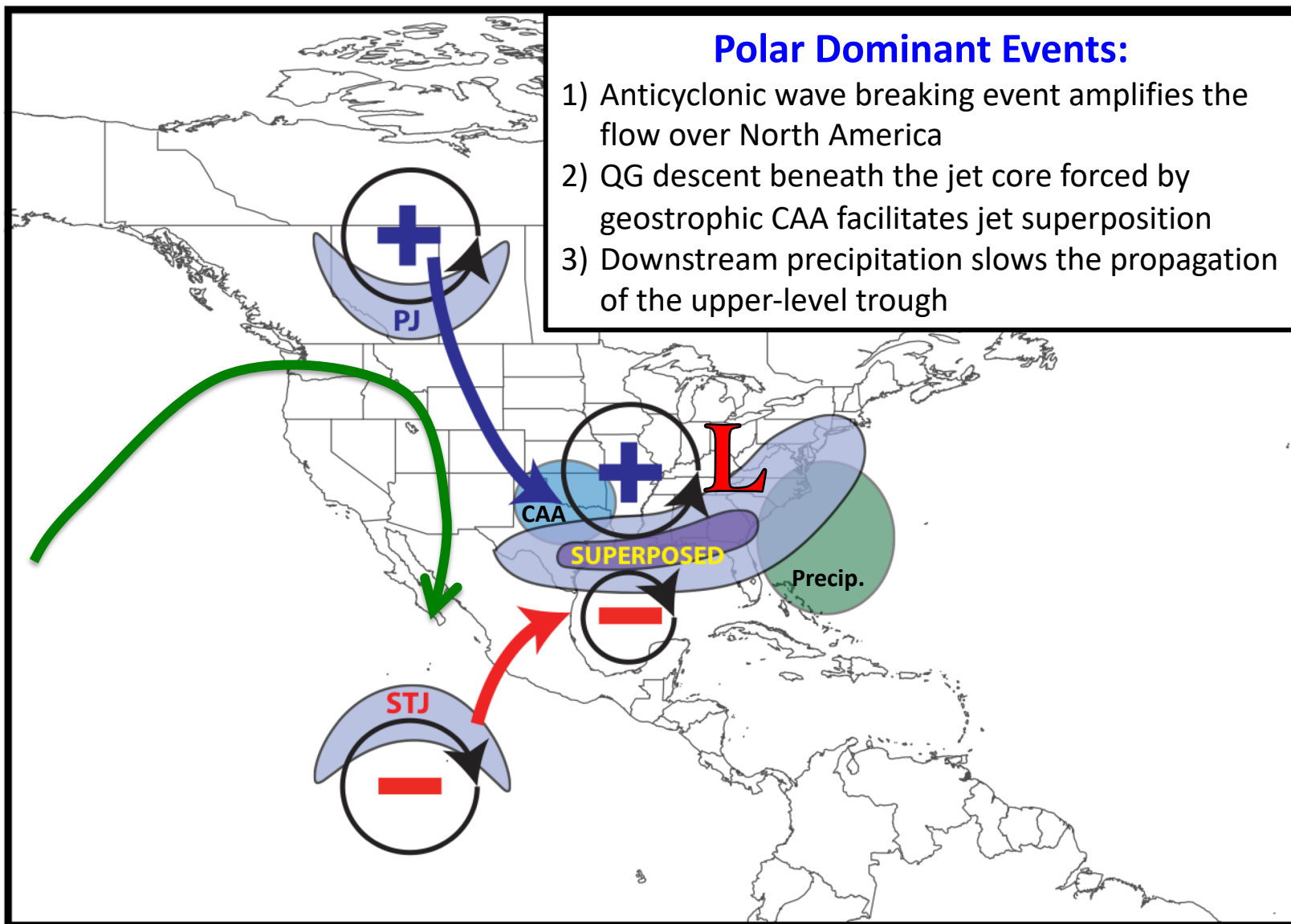
1a) Remote production of a cyclonic PV anomaly



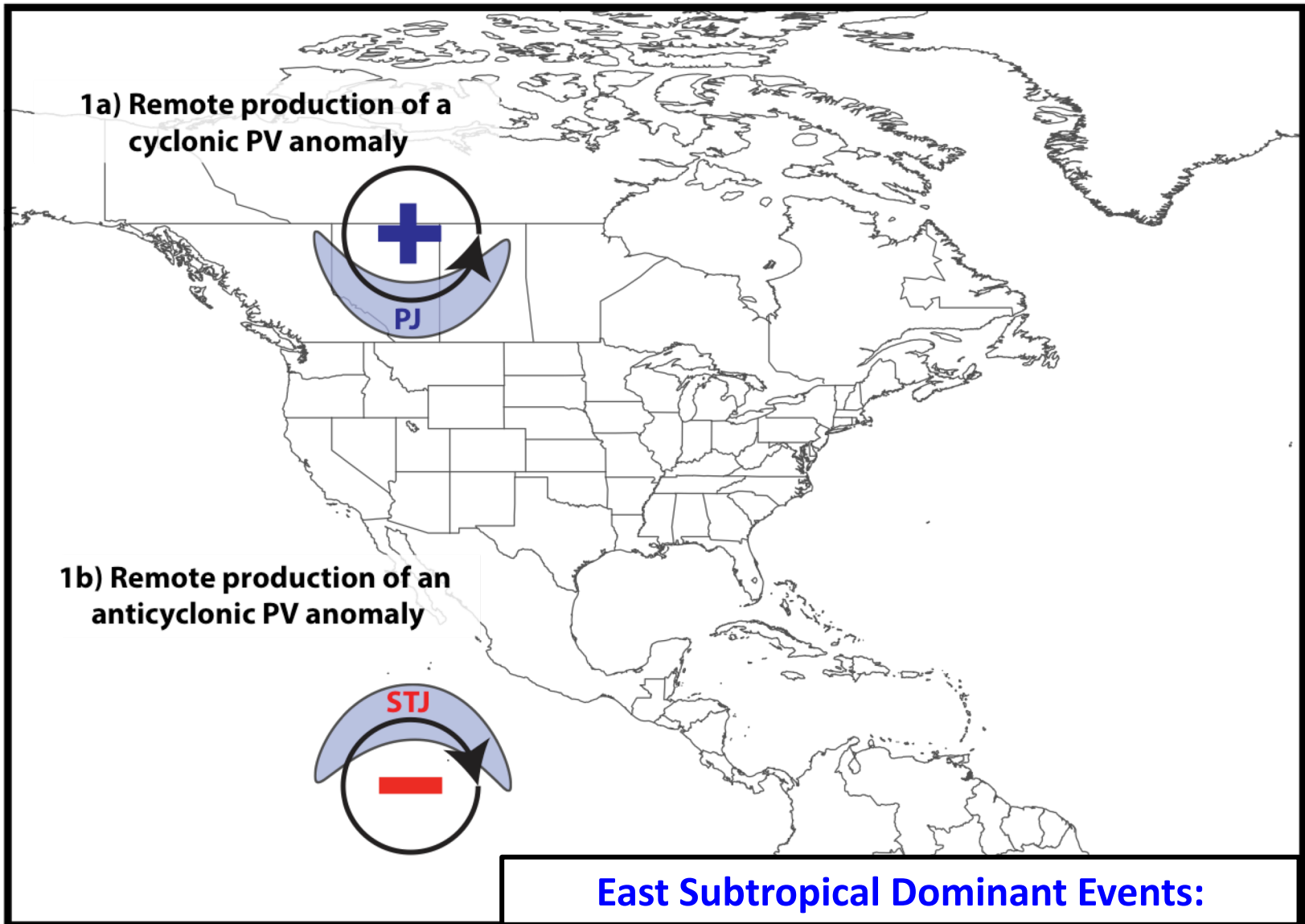
1b) Remote production of an anticyclonic PV anomaly



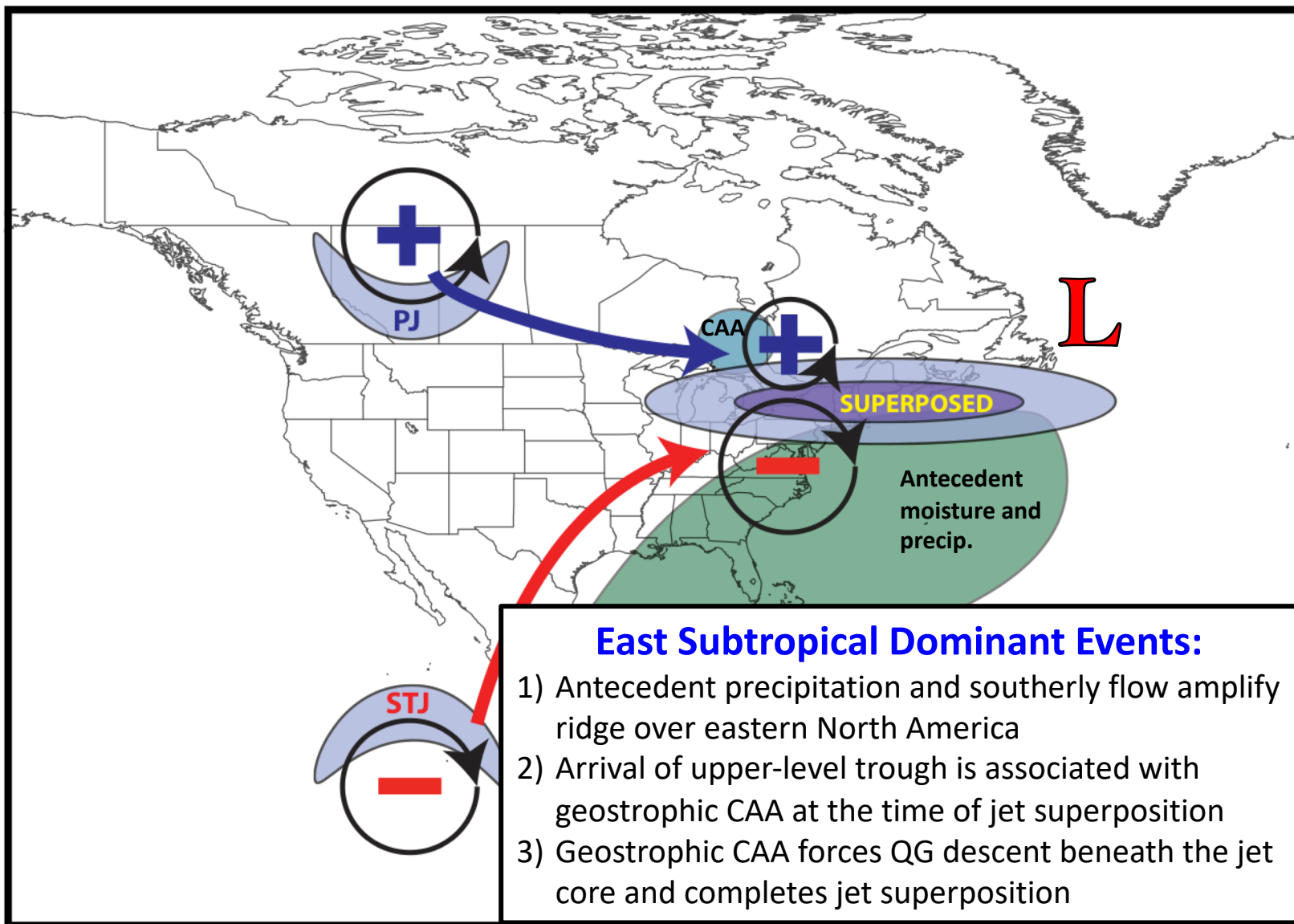
Summary



Summary



Summary



Future Work

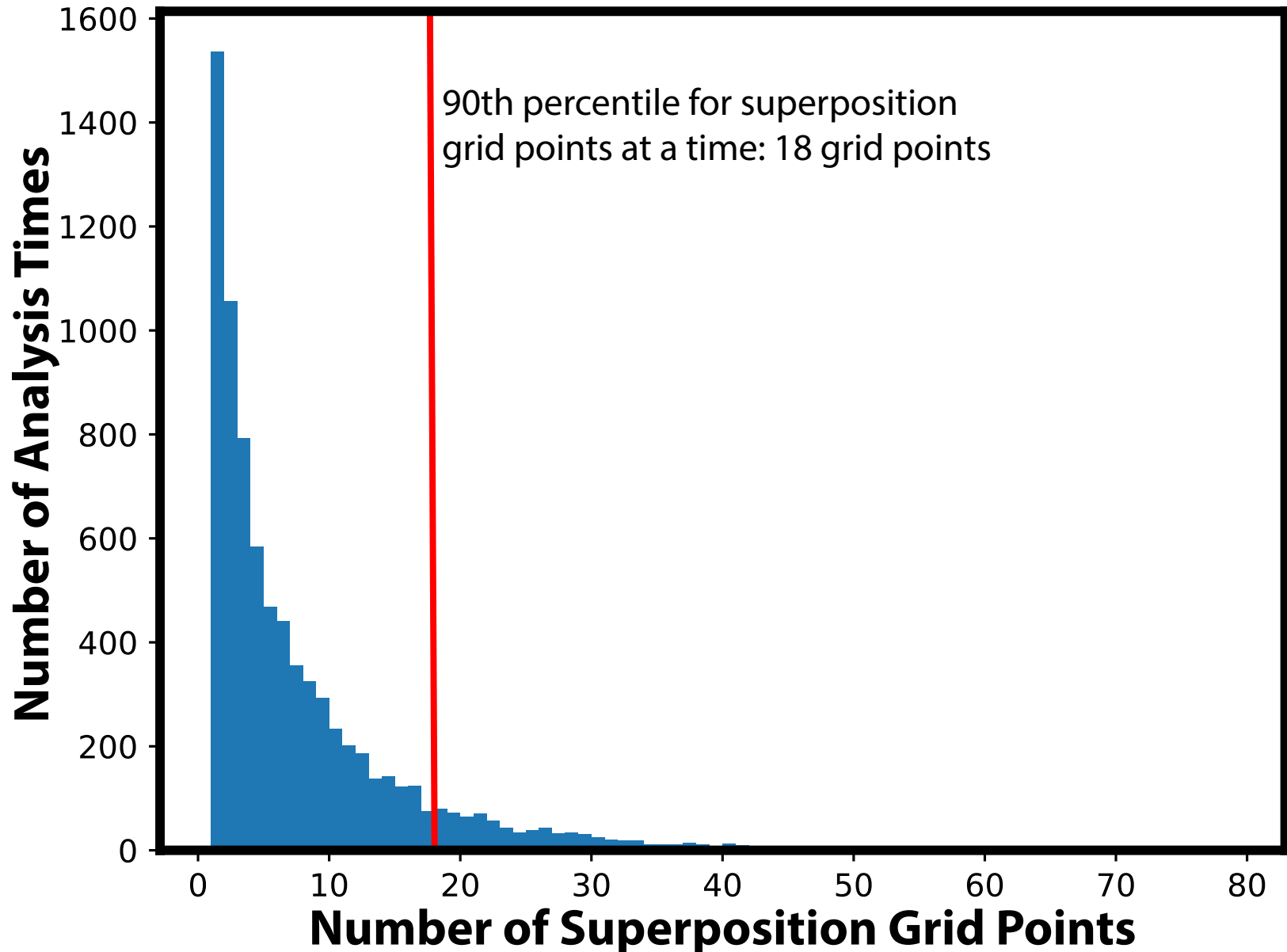
- Apply piecewise PV inversion (e.g., Davis and Emanuel 1991) to quantify the influence that polar cyclonic and tropical anticyclonic PV anomalies have on restructuring the tropopause during each type of superposition event.
- Examine the impact that each type of jet superposition event has on the evolution of the downstream large-scale flow pattern.
- Utilize numerical simulations of jet superposition events to examine the sensitivity of jet superposition to diabatic processes.
- Examine the frequency and characteristics of jet superposition events within future climate scenarios.

Supplementary Slides

References

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Jet Superposition Event Identification

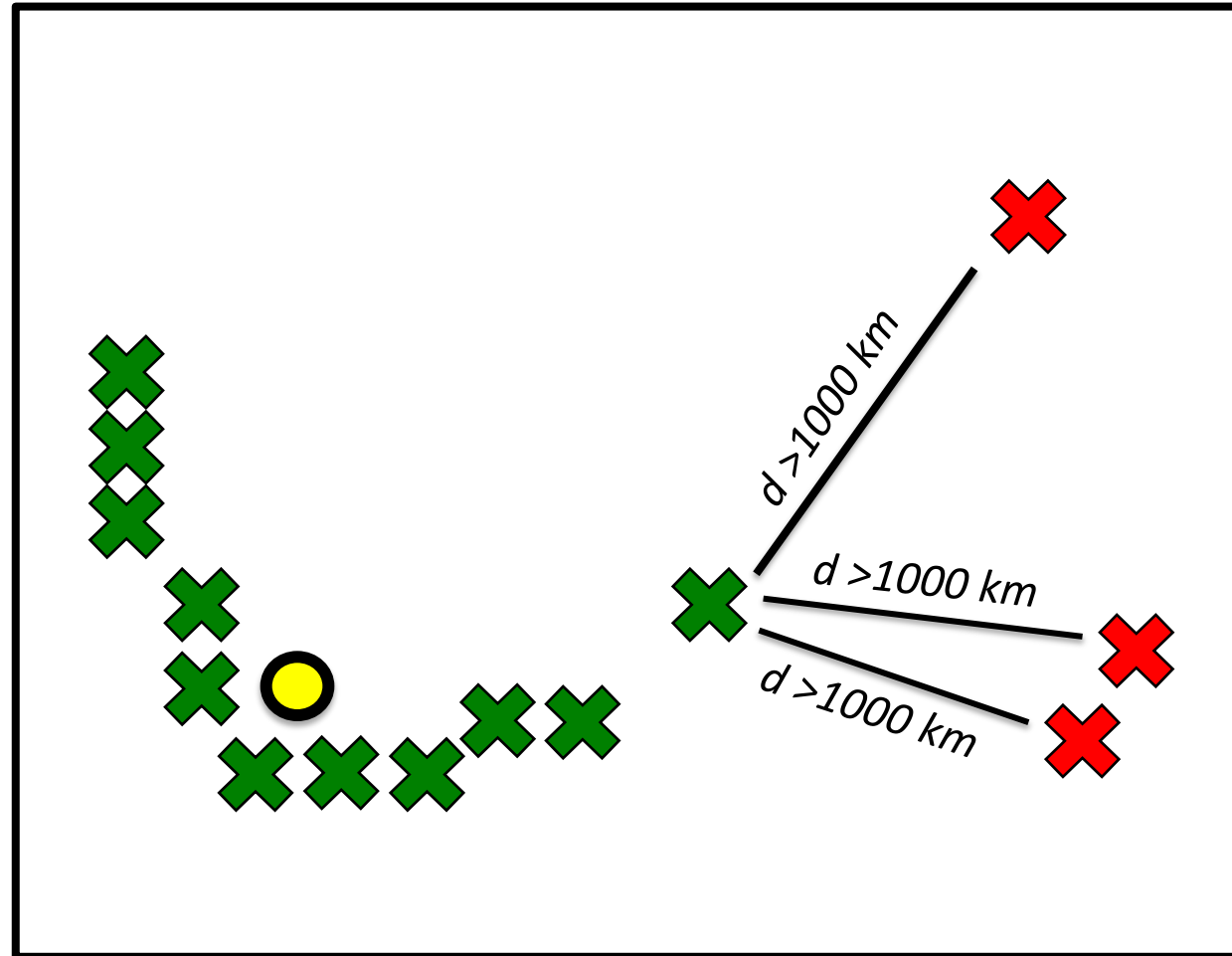


Jet Superposition Event Identification

Sample Jet Superposition Centroid Calculation

Calculated the centroid of each jet superposition based on all valid grid points at a particular analysis time.

To calculate the centroid, there must exist a group of 18 superposition grid points, of which no superposition grid point is >1000 km away from another superposition grid point.



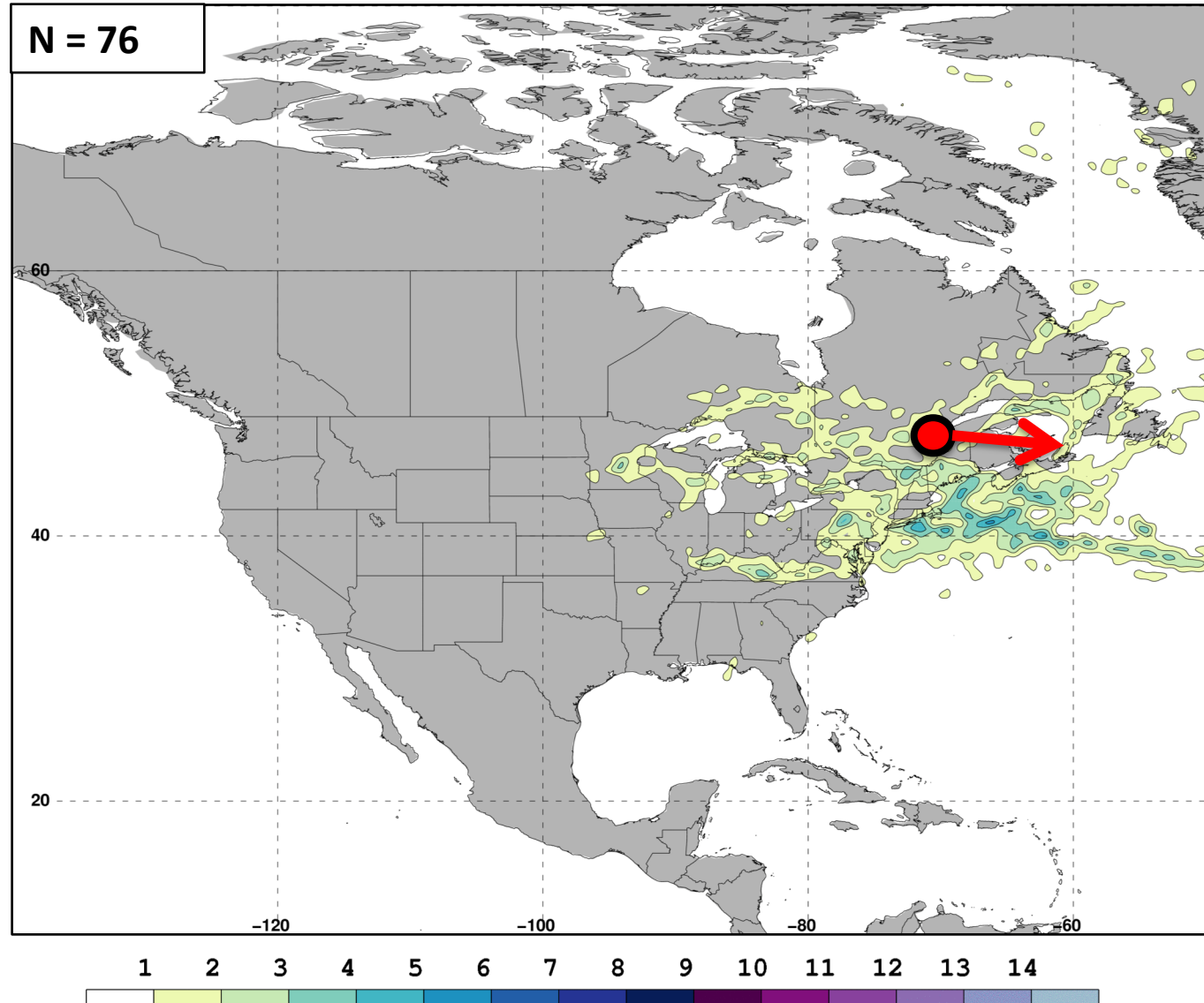
✕ Used for calculation

✕ Not used for calculation

● Jet superposition centroid

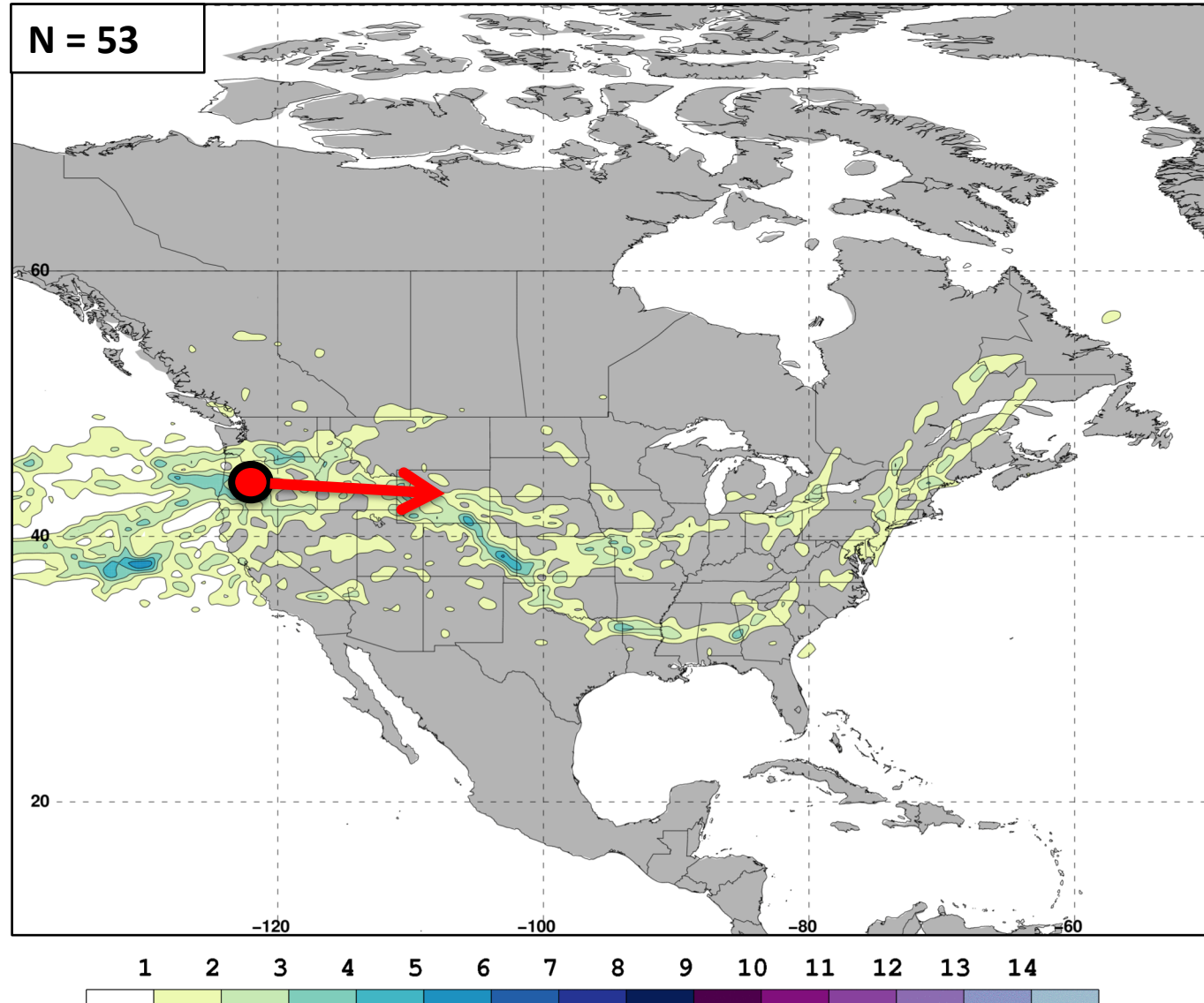
Jet Superposition Event Identification

Frequency of East Subtropical Dominant Jet Superposition Events

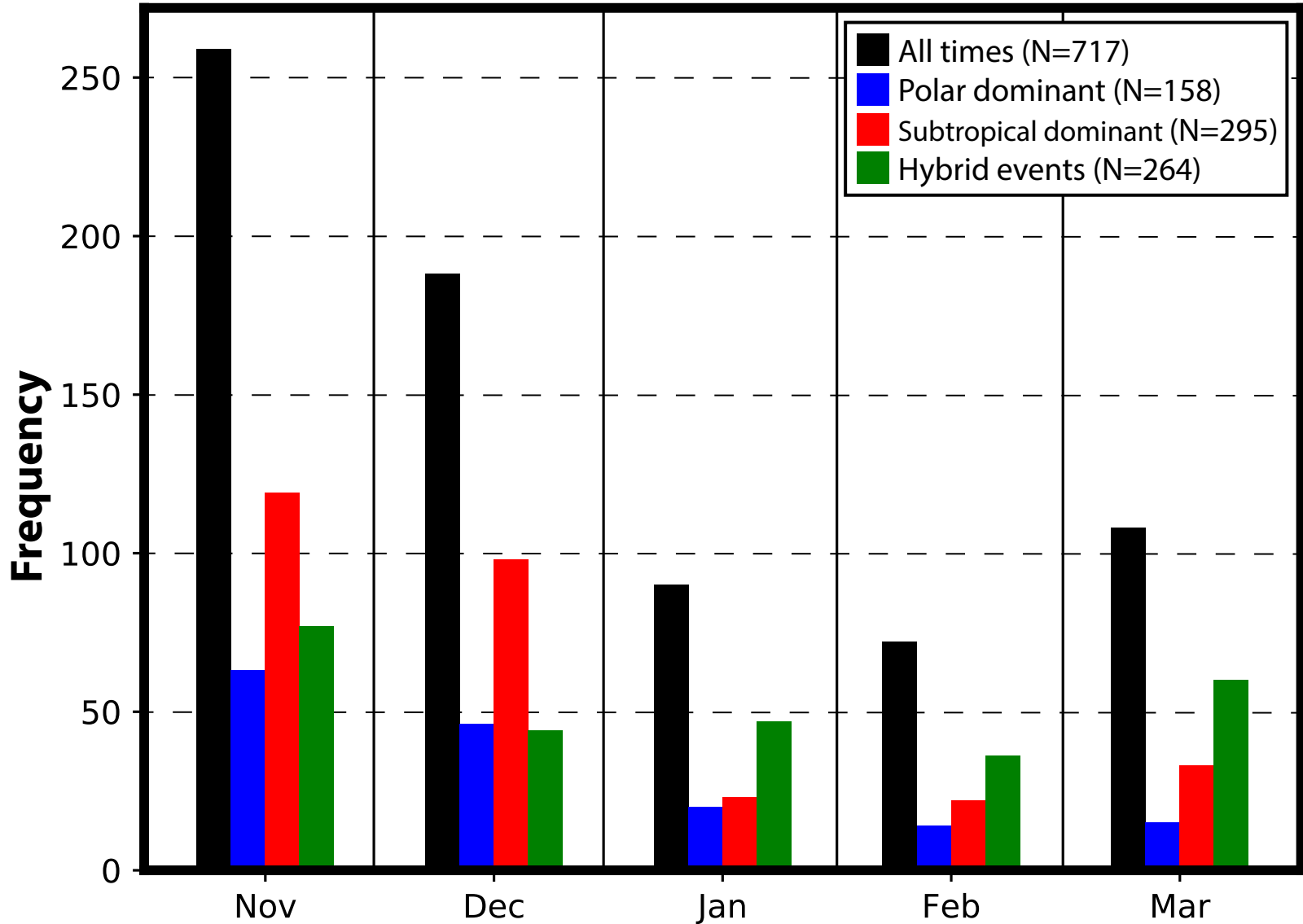


Jet Superposition Event Identification

Frequency of West Subtropical Dominant Jet Superposition Events

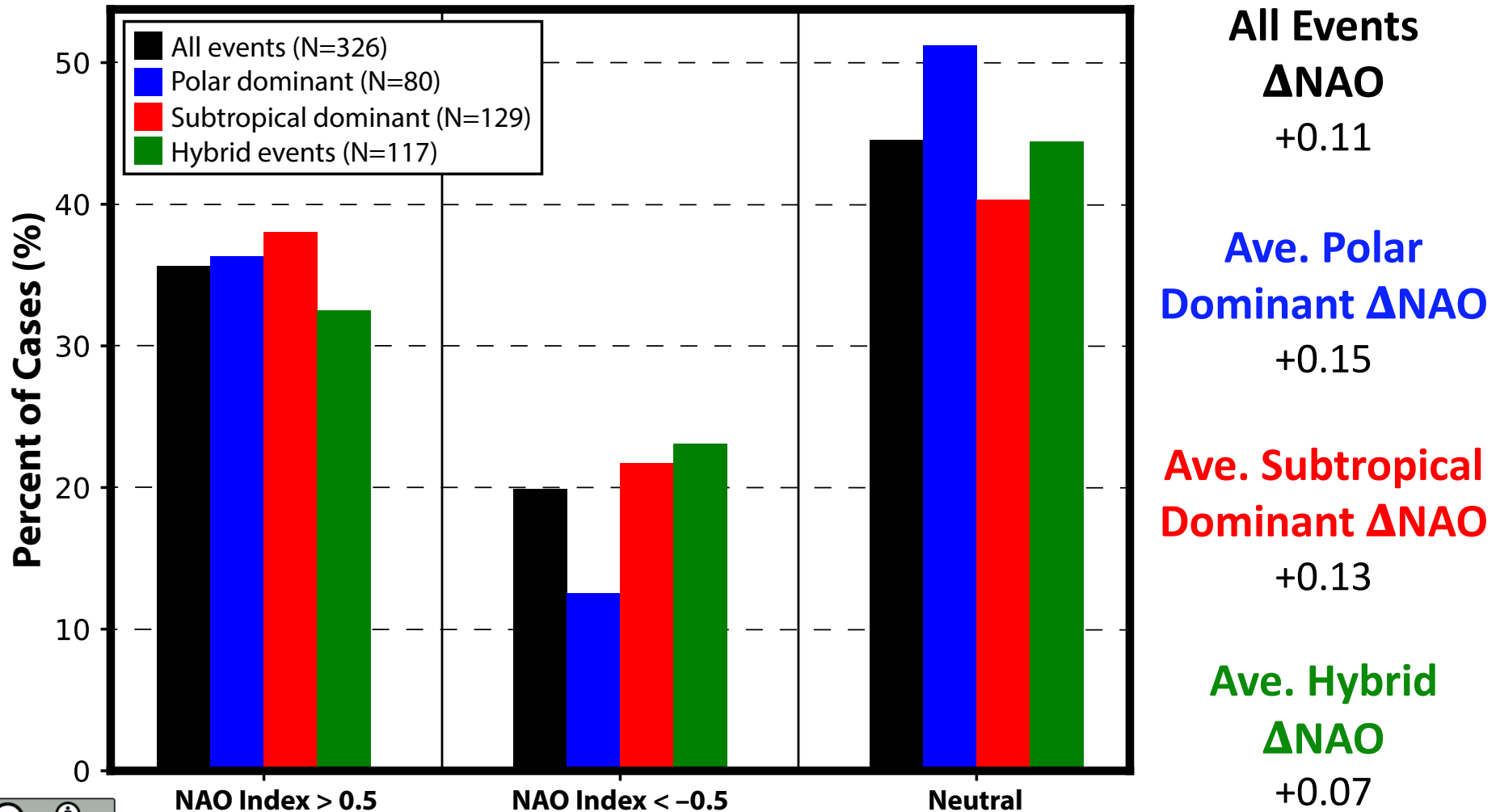


Jet Superposition Event Classification



Downstream Consequences

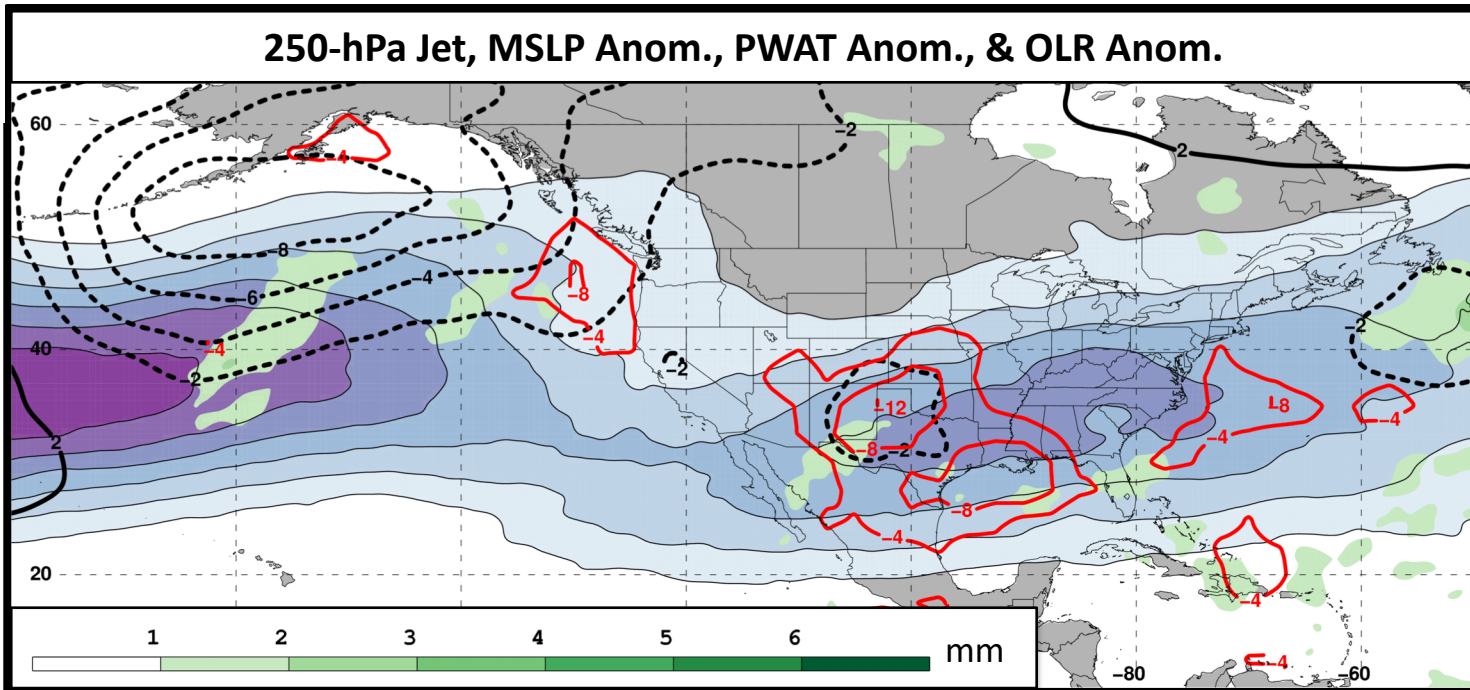
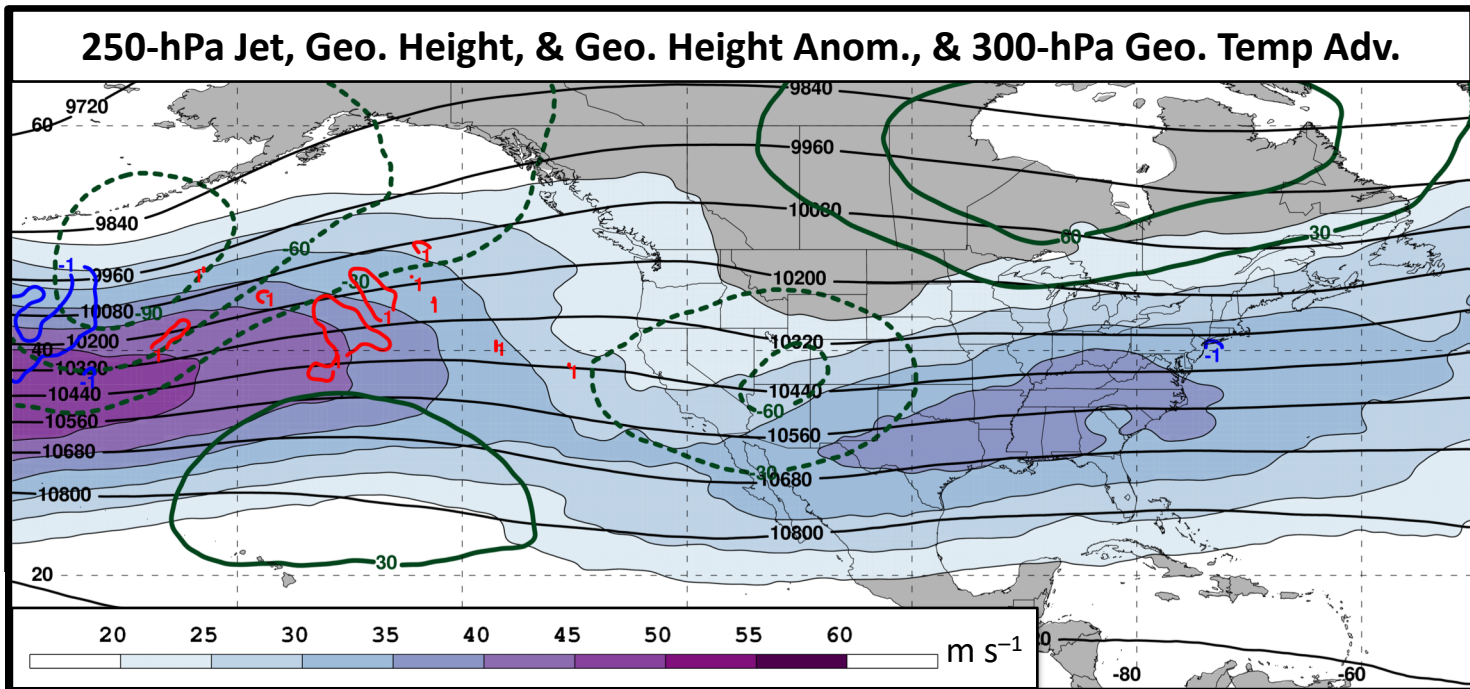
North Atlantic Oscillation: 5 Days After Jet Superposition



Polar Dominant Jet Superposition Events

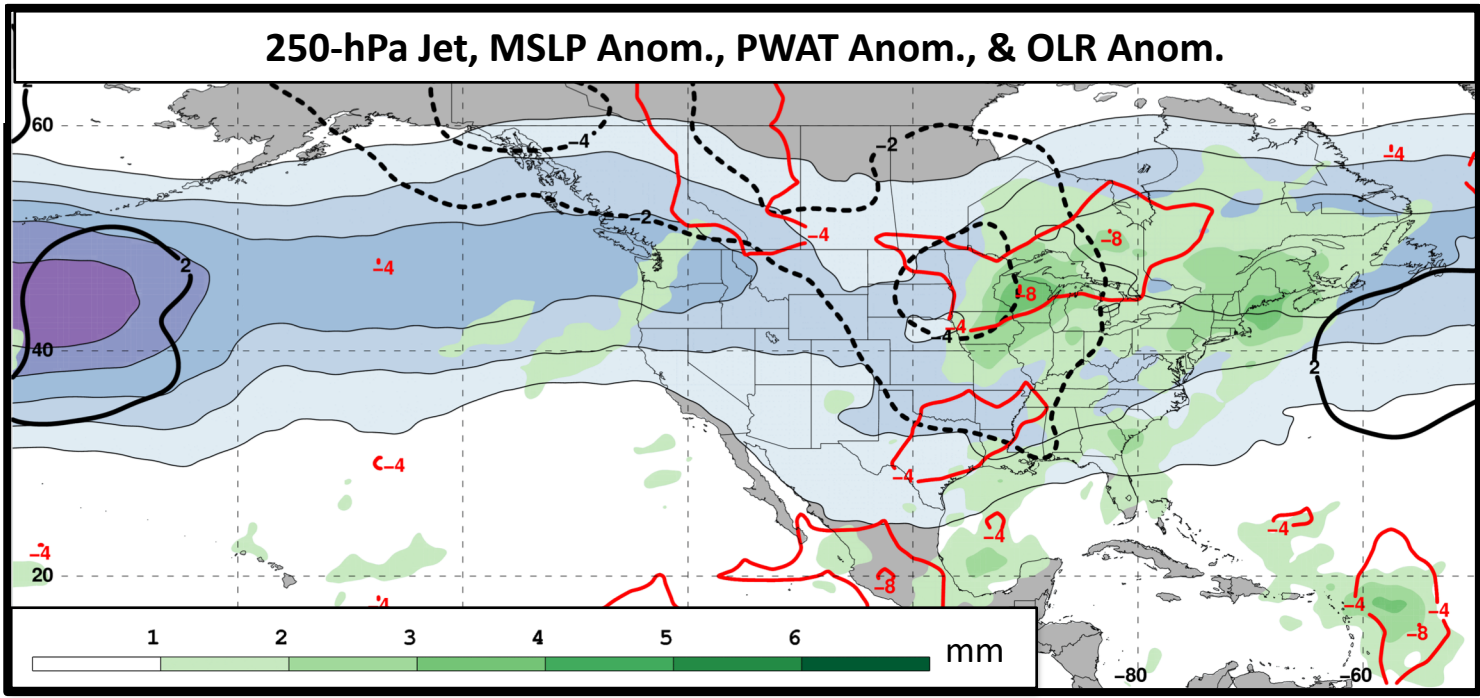
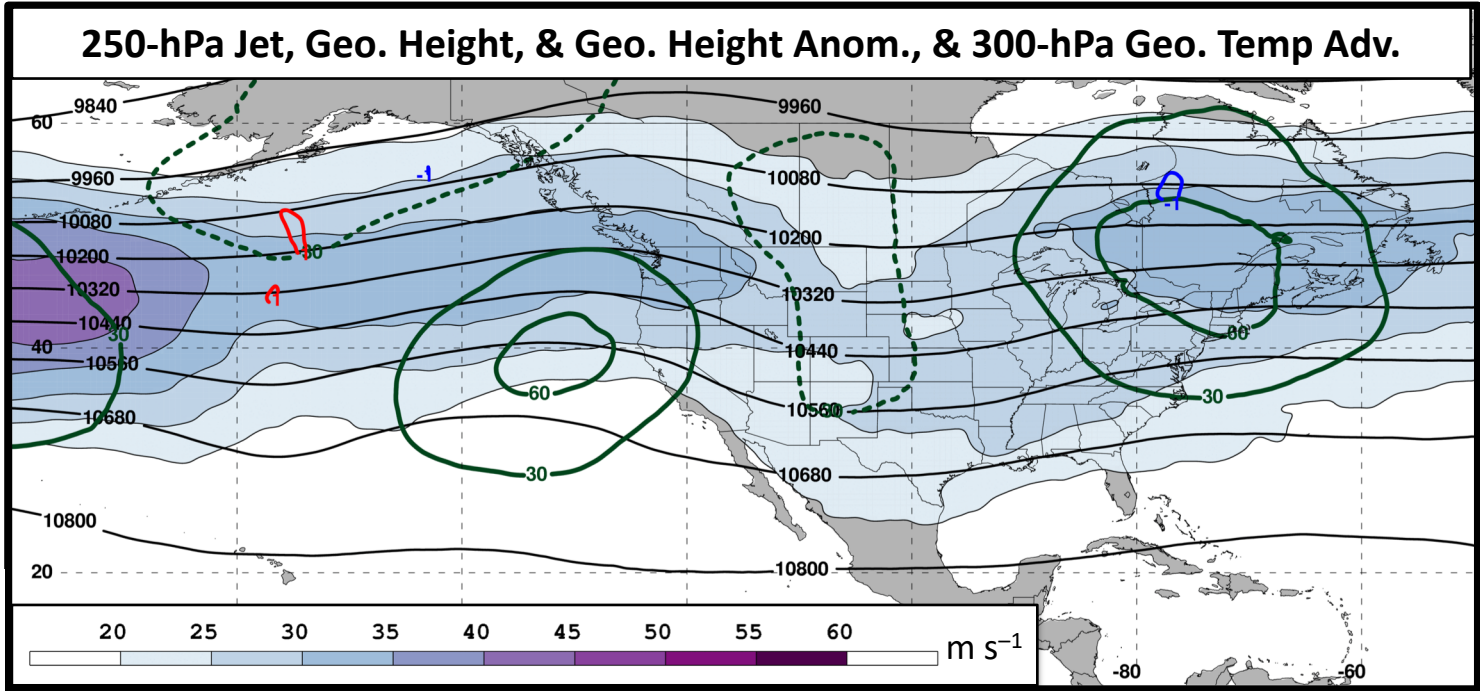
3 Days
Prior to Jet
Superposition

N=80



E. Subtropical Dominant Jet Superposition Events

3 Days
Prior to Jet
Superposition

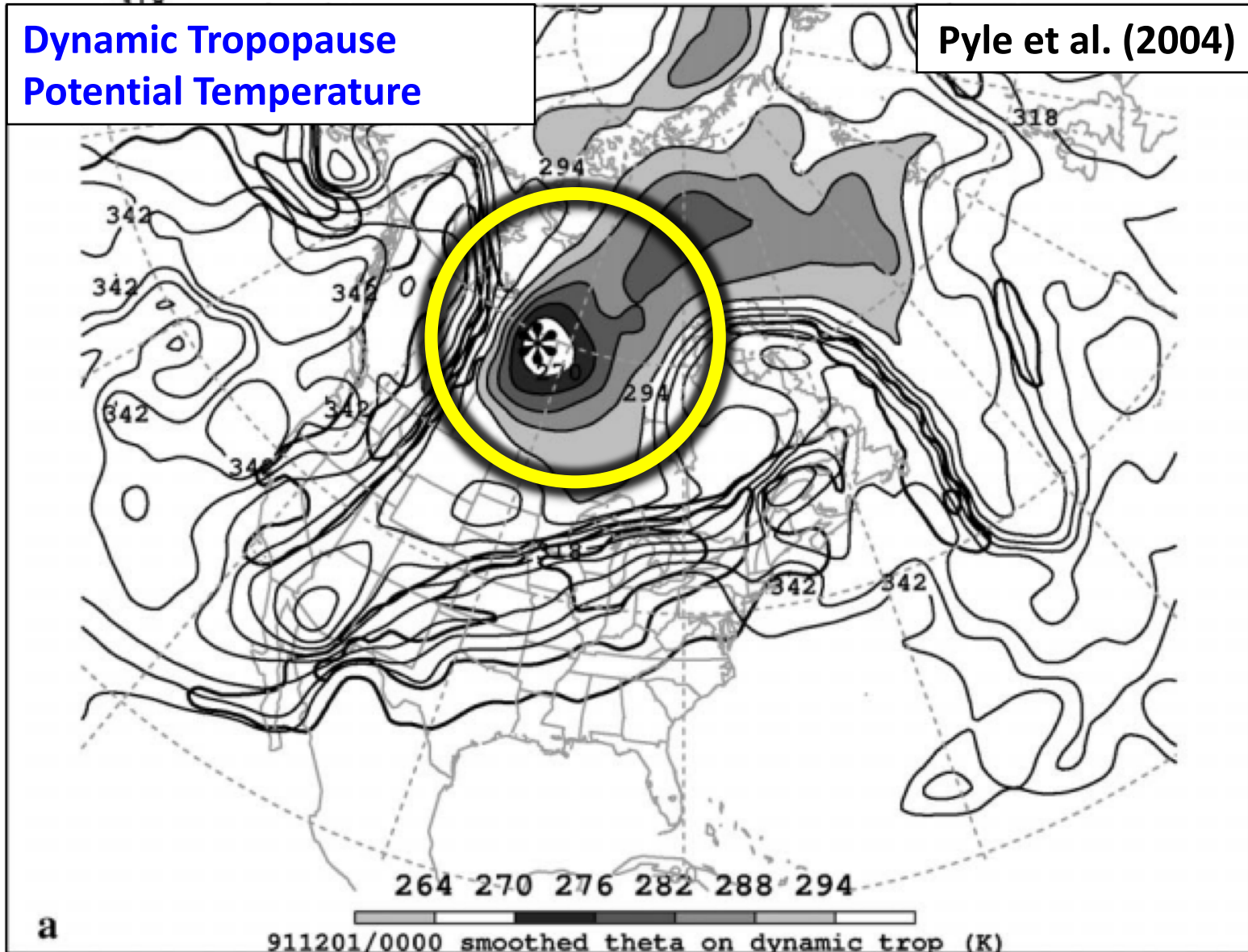


N=76

Jet Superposition Conceptual Model

Dynamic Tropopause
Potential Temperature

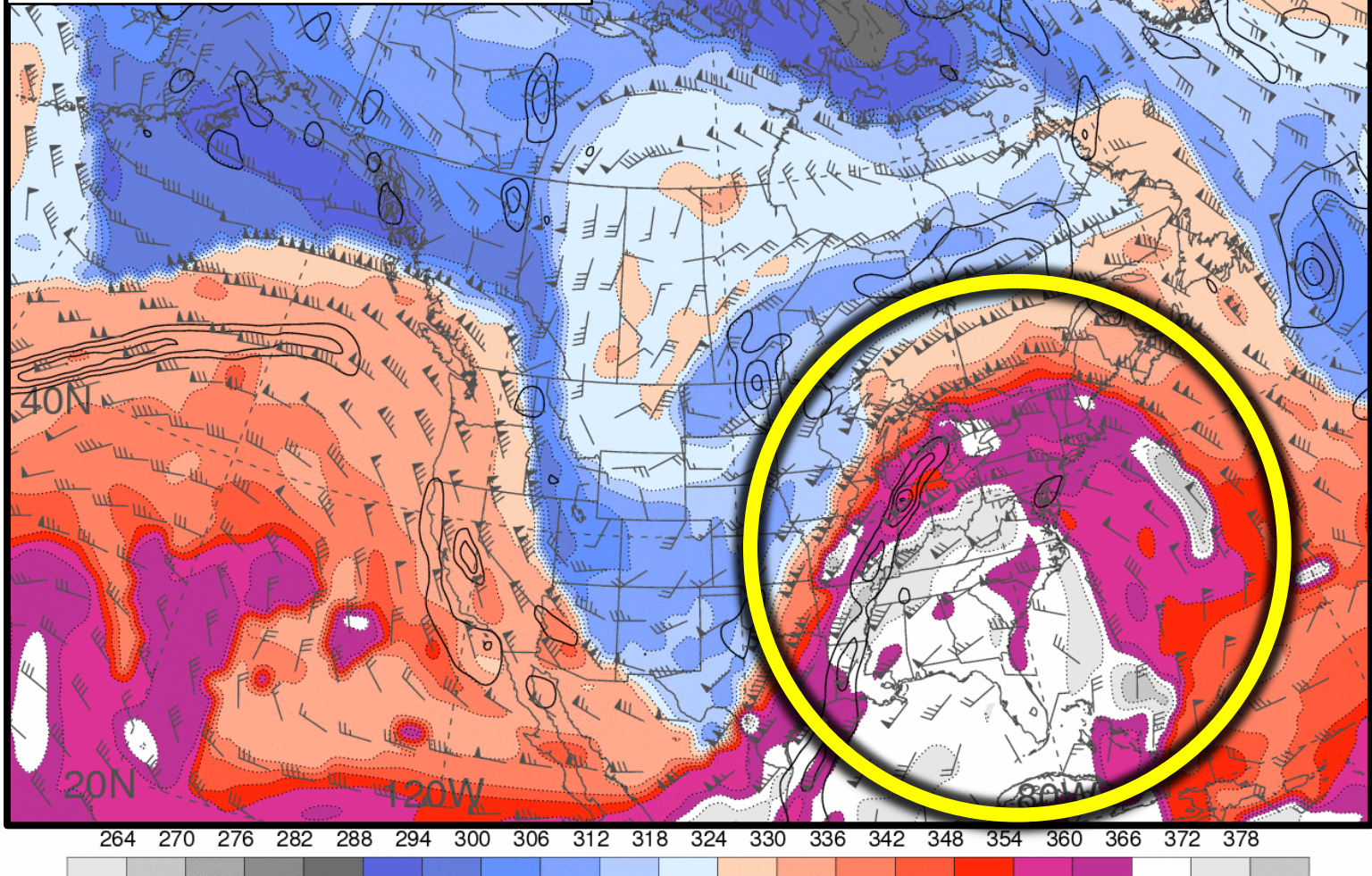
Pyle et al. (2004)



Jet Superposition Conceptual Model

Dynamic Tropopause
Potential Temperature

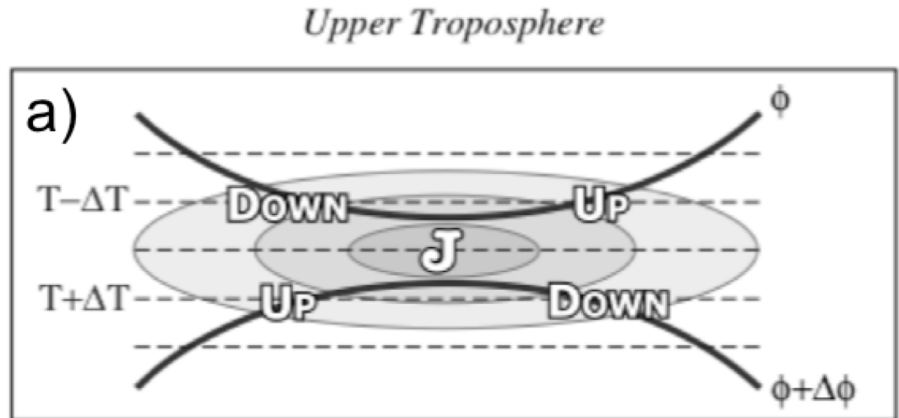
Heather Archambault



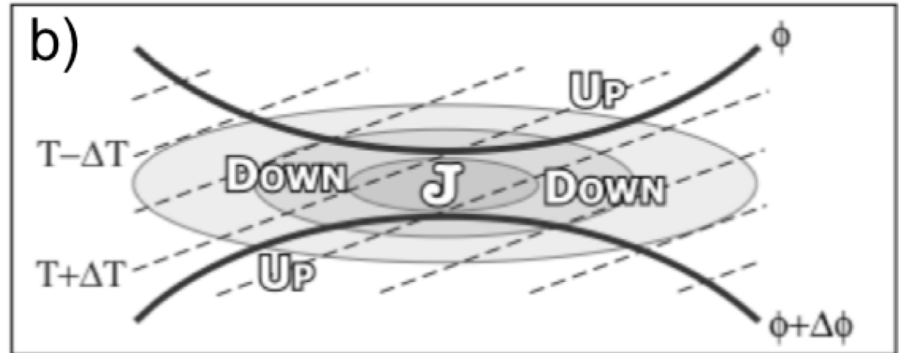
DT THTA & WND; LL REL VORT 100502/1200

Ageostrophic Transverse Jet Circulations

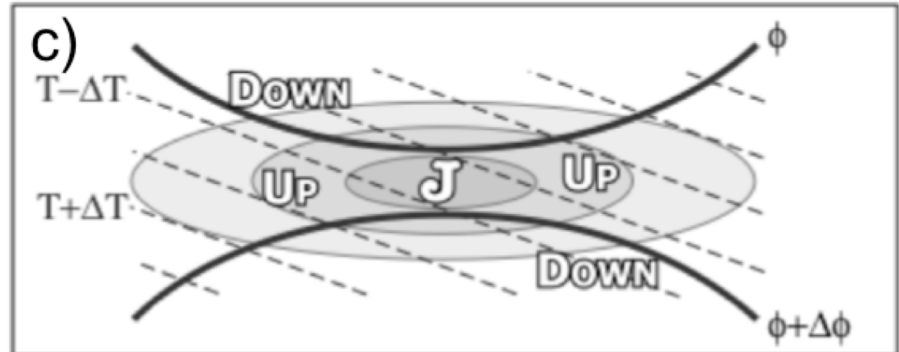
Traditional four-quadrant model



Geo. cold-air advection (CAA)
along the jet axis promotes
subsidence through the jet core



Geo. warm-air advection (WAA)
along the jet axis promotes
ascent through the jet core

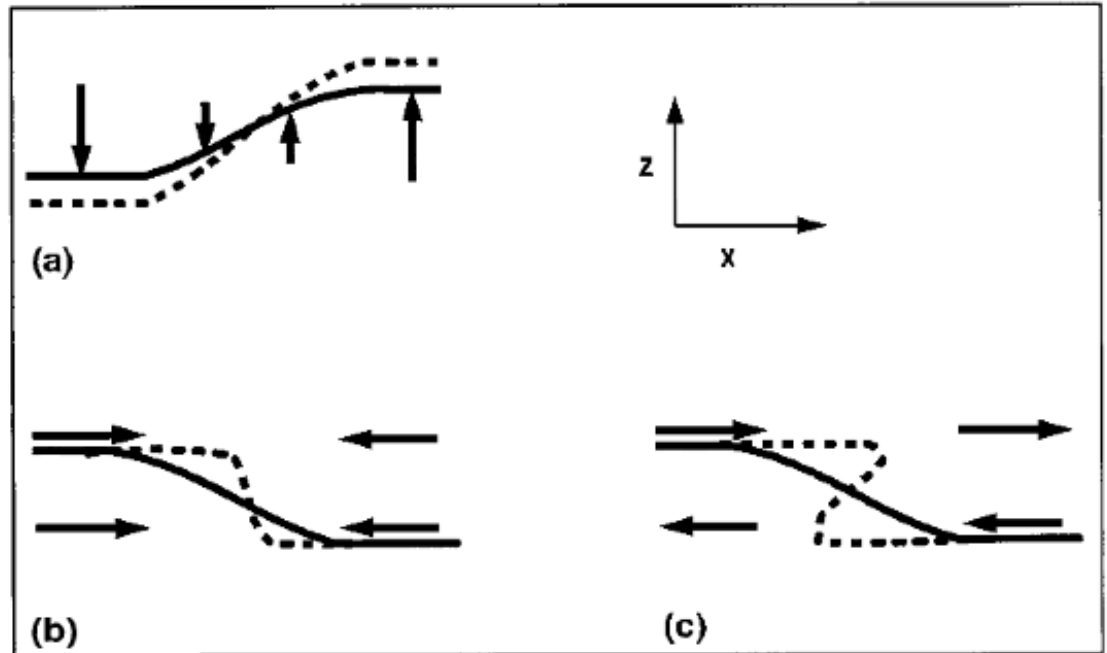


Background

Insight into how the tropopause can be restructured from a PV perspective can be found by consulting Wandishin et al. (2000)

Two processes can account for “foldogenesis”:

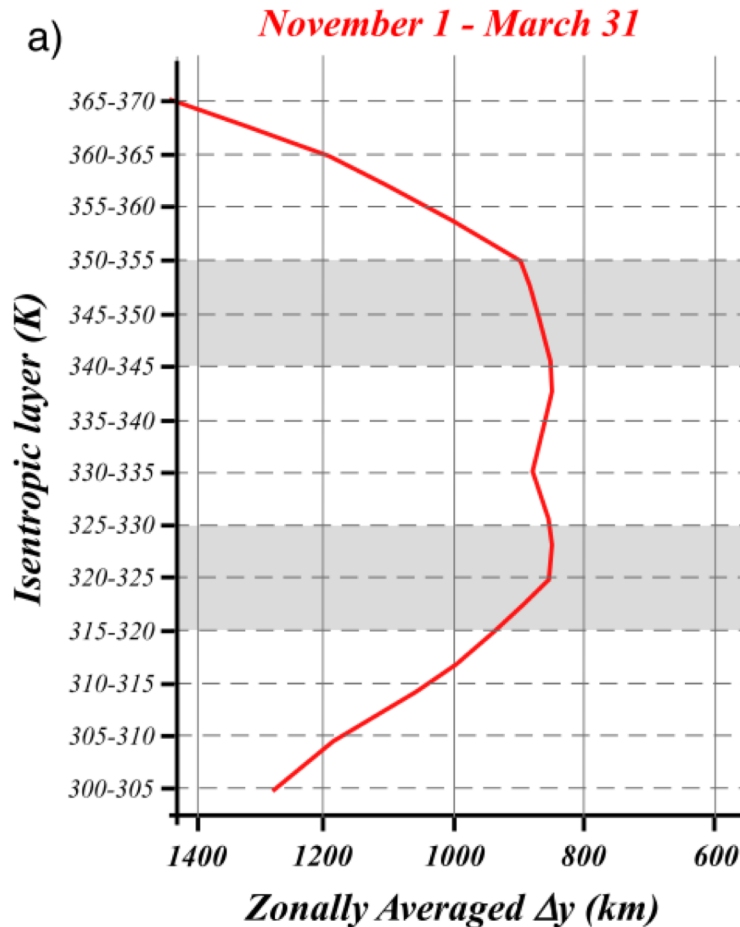
- 1) **Differential vertical motions** can vertically steepen the tropopause.
- 2) **Convergence or a vertical shear** can produce a differential horizontal advection of the tropopause surface.



Wandishin et al. 2000

These same mechanisms are also likely to play an important role in superpositions.

Background



Christenson et al. (2017)

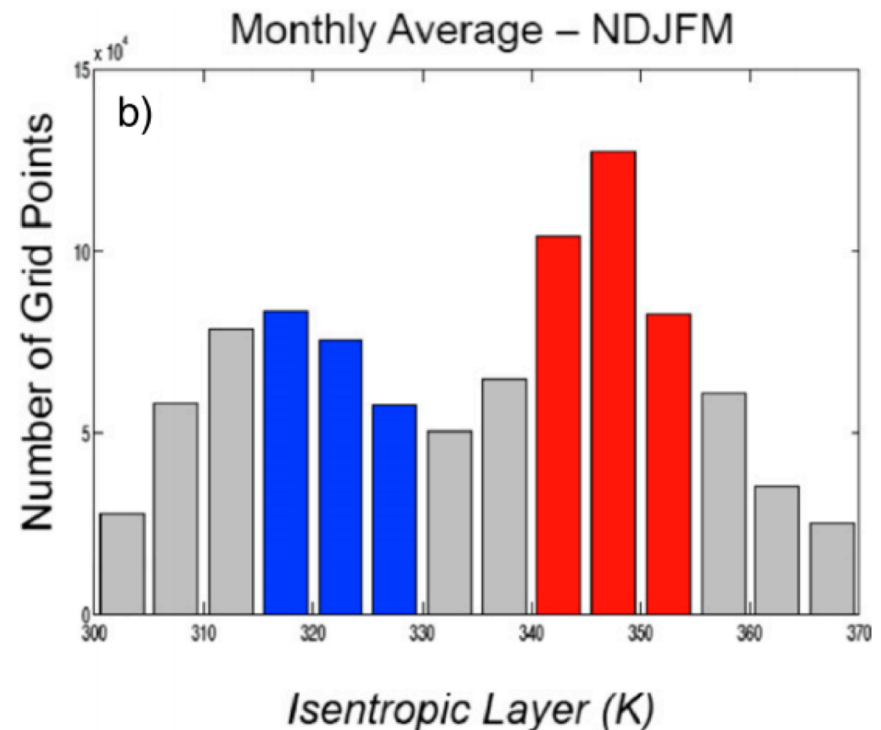


FIG. 2. (a) Cold season average of zonally averaged Δy (km) for 5-K isentropic layers ranging from 300–305 to 365–370 K. The 315–330- and 340–355-K layers are highlighted in light gray shading. (b) The average frequency of occurrence of grid points with a maximum wind speed value within the 5-K isentropic layers along the abscissa per cold season. The 315–330- and 340–355-K layers are shaded in blue and red, respectively.