# Current and Future Perspectives on North American Polar–Subtropical Jet Superposition Events

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**In a Changing Climate Workshop**

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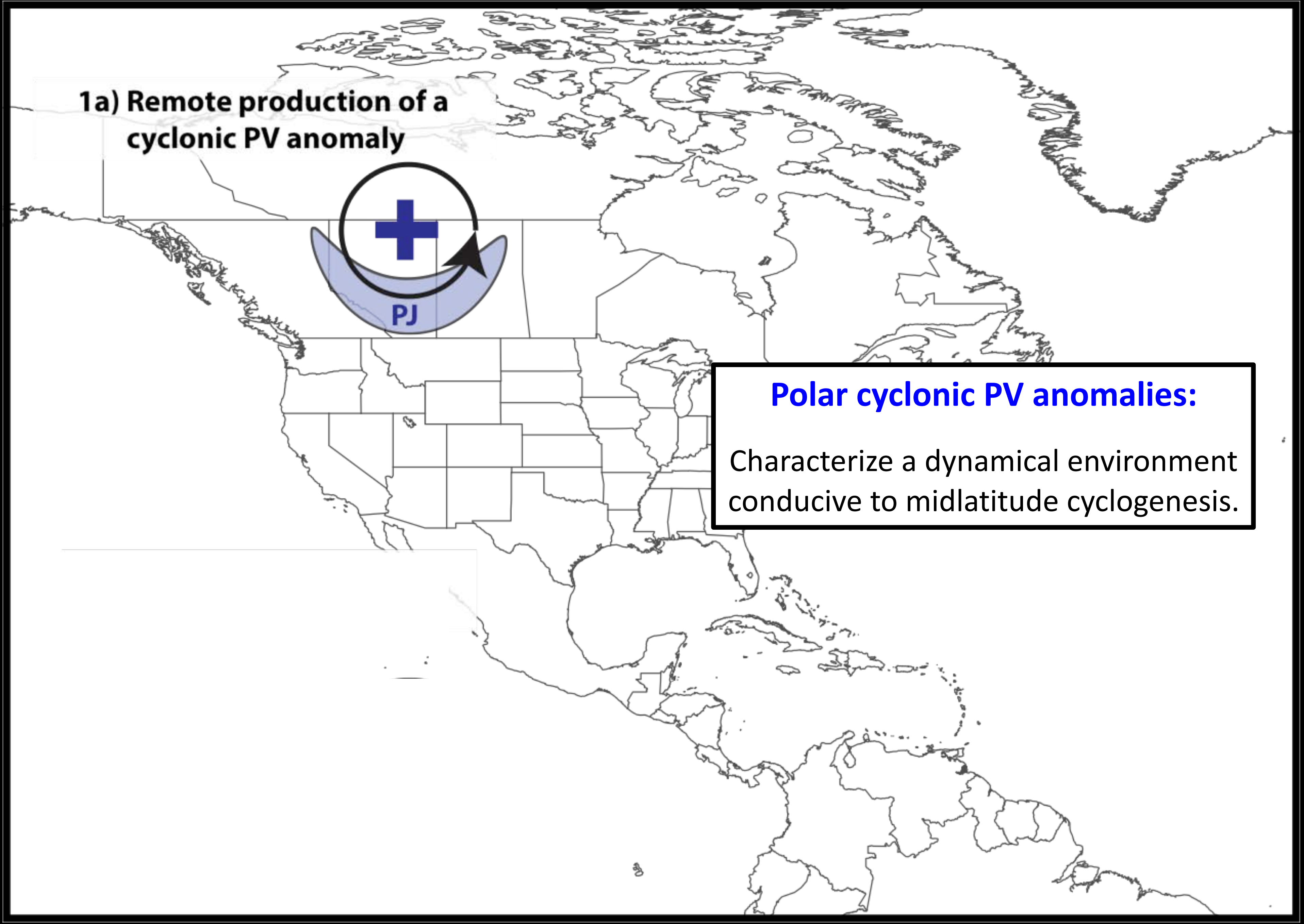
# Jet Superposition Development




Winters and Martin 2017
Winters et al. 2020

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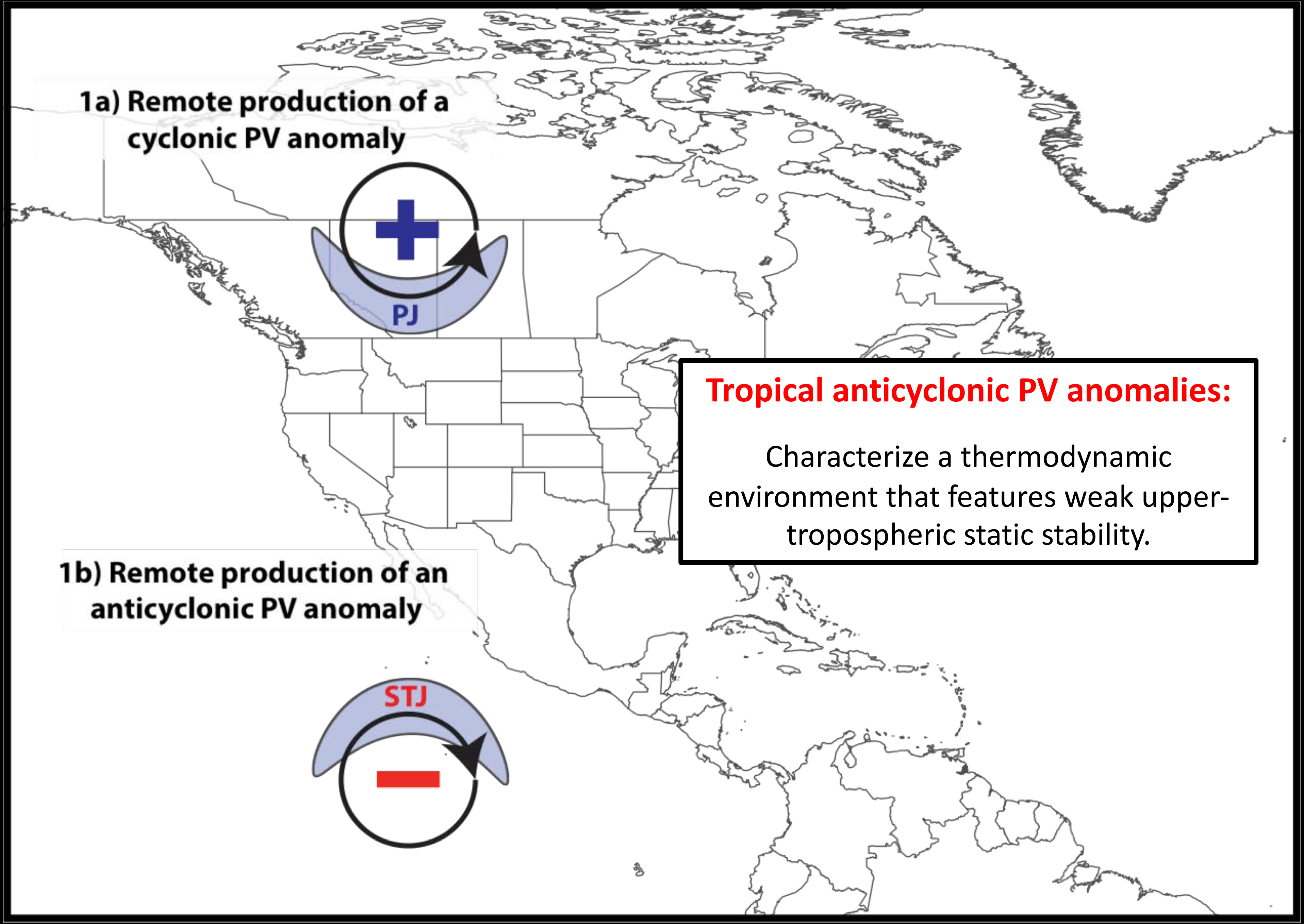


**Tropical anticyclonic PV anomalies:**

Characterize a thermodynamic environment that features weak upper-tropospheric static stability.

Winters and Martin 2017
Winters et al. 2020

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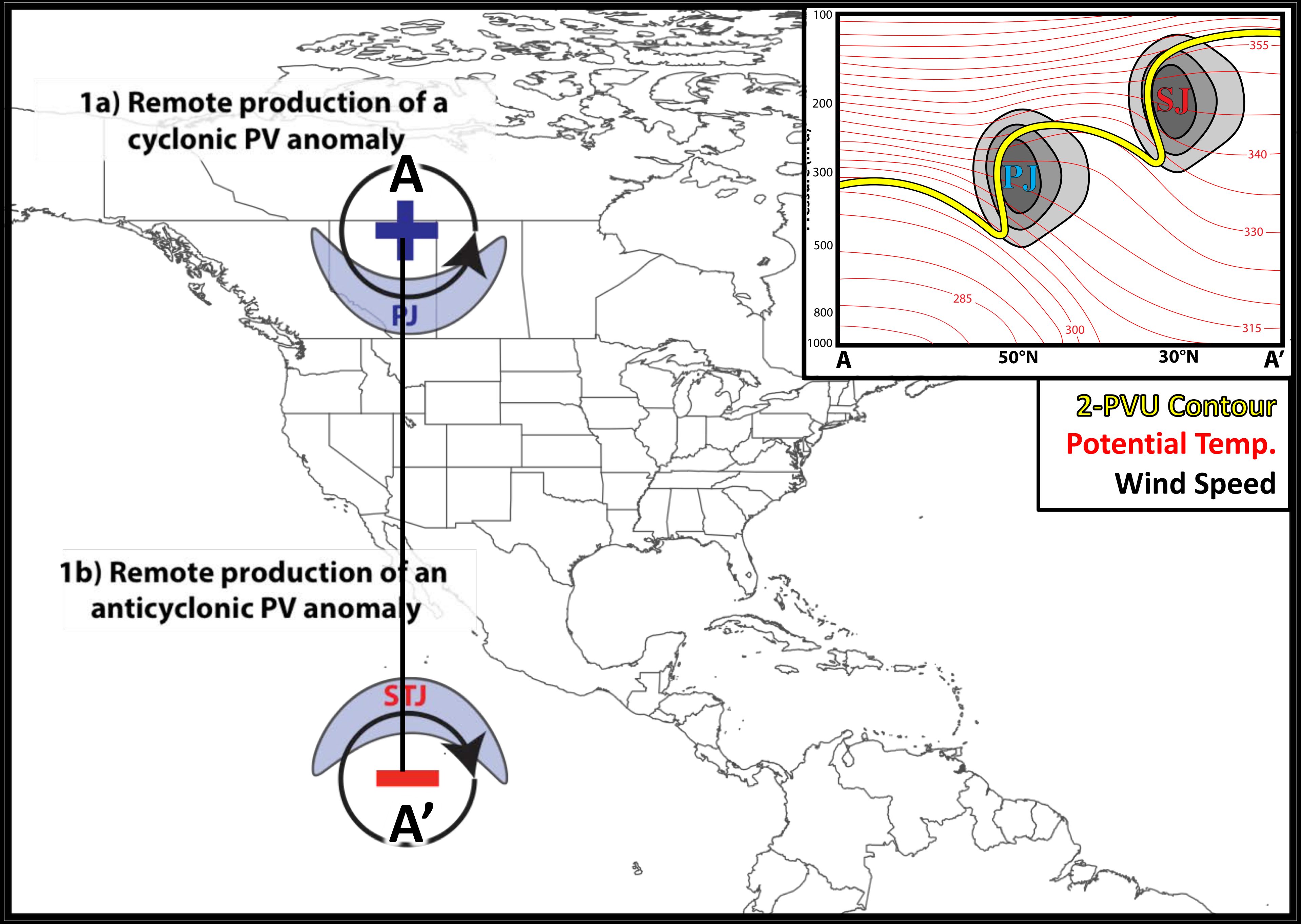


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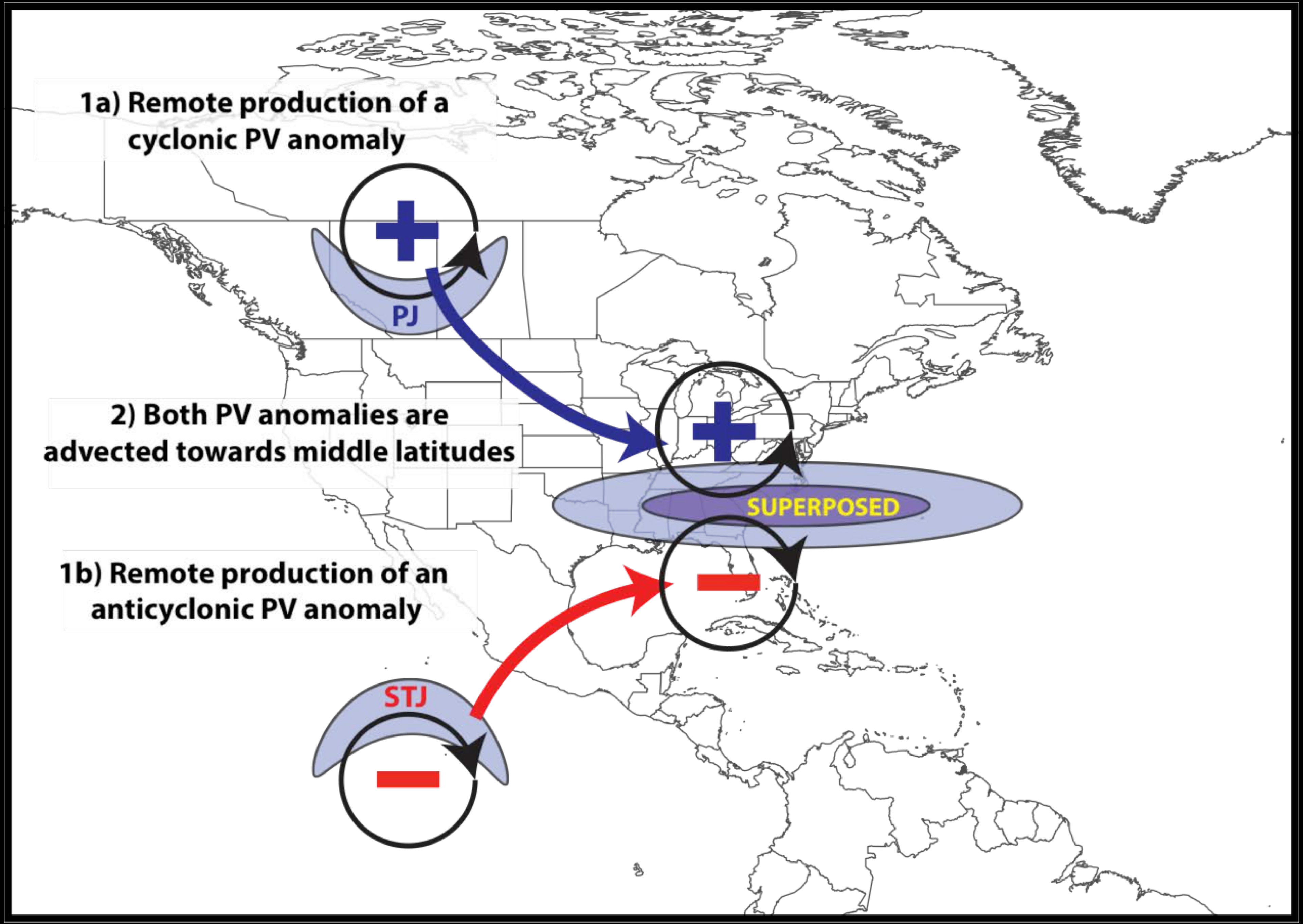


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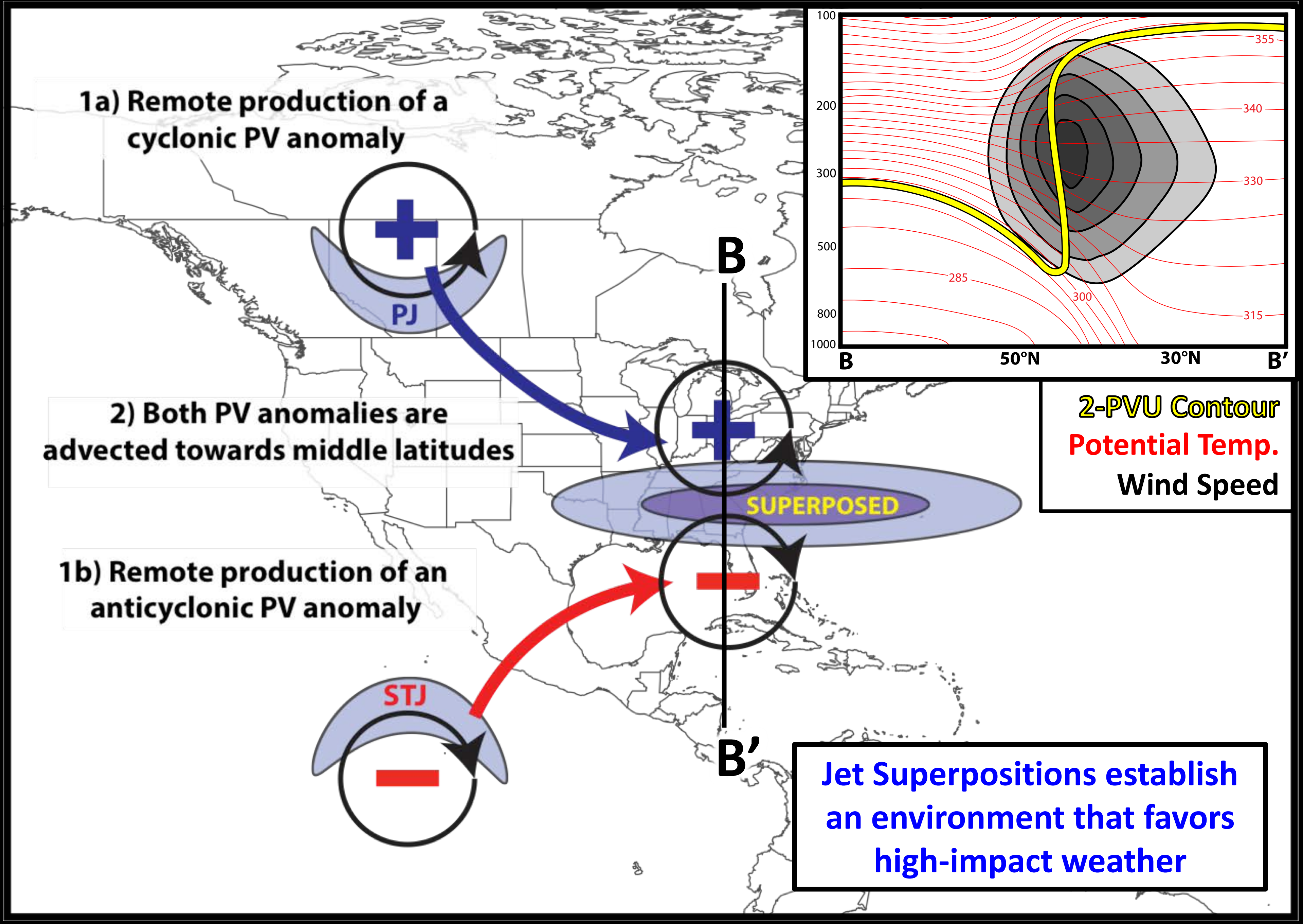


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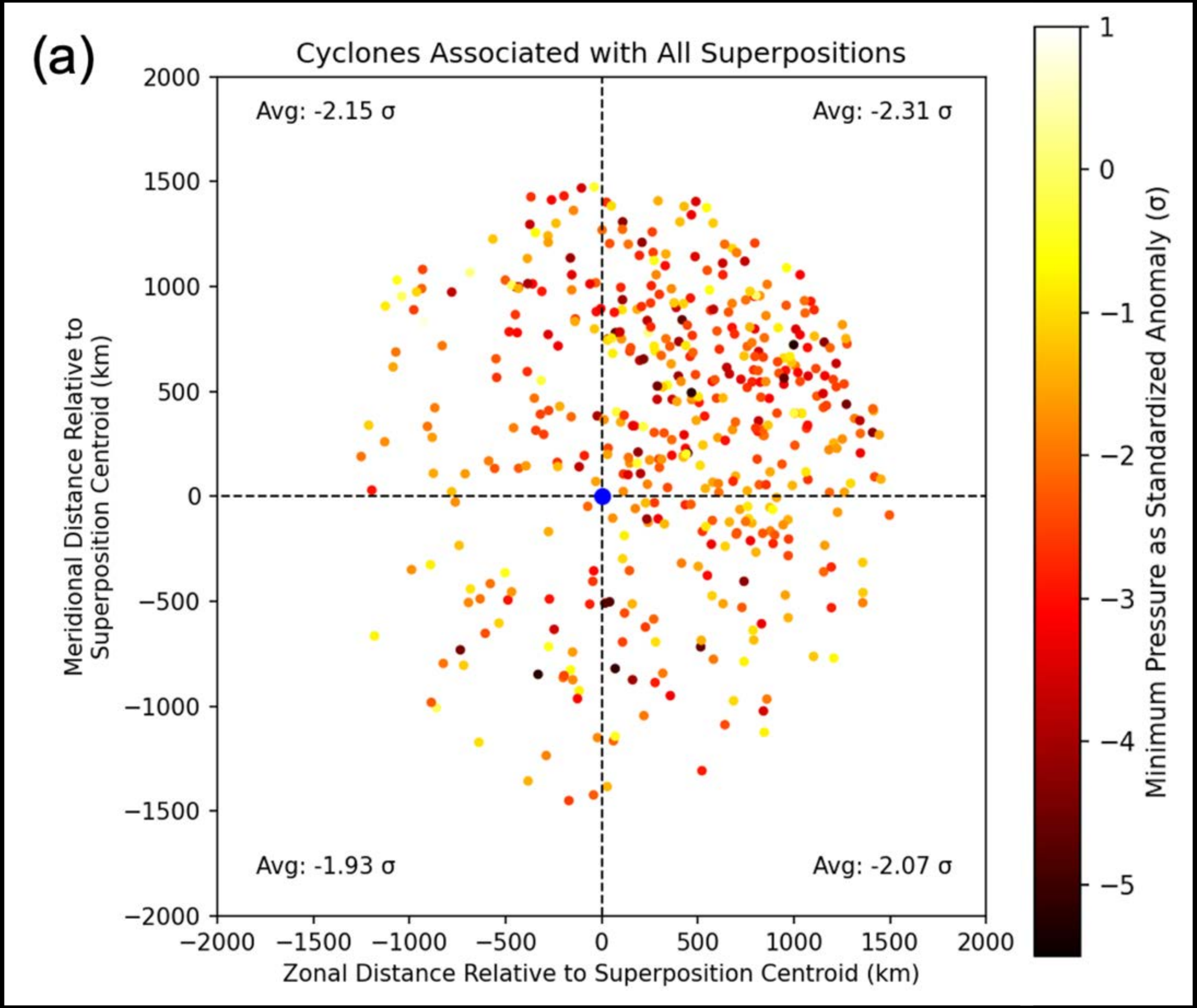
# Jet Superposition Impacts

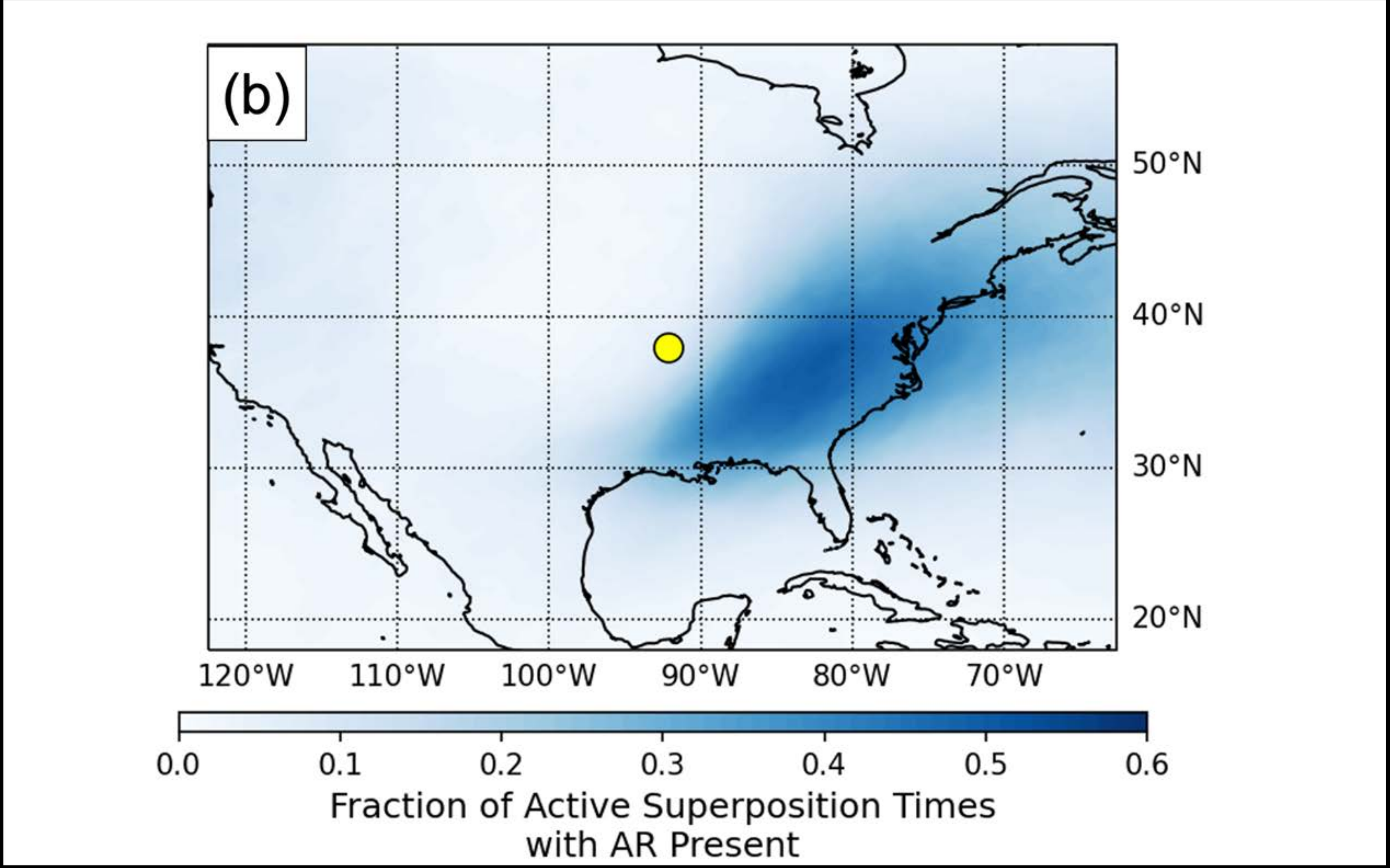



Cyclones that develop in association with jet superpositions are **statistically deeper** than the average North American cyclone.

**68%** of jet superposition cases feature **10-m wind speeds** that exceed the 95$^{th}$ percentile over a synoptic-scale area.

**Reiher and Winters 2024**

# Jet Superposition Impacts




**Reiher and Winters 2024**

**54–84%** of jet superpositions feature an association with an **atmospheric river**, depending on the AR detection algorithm.

**64%** of jet superposition cases feature **24-h accumulated precipitation** that exceeds the 95th percentile over a synoptic-scale area.

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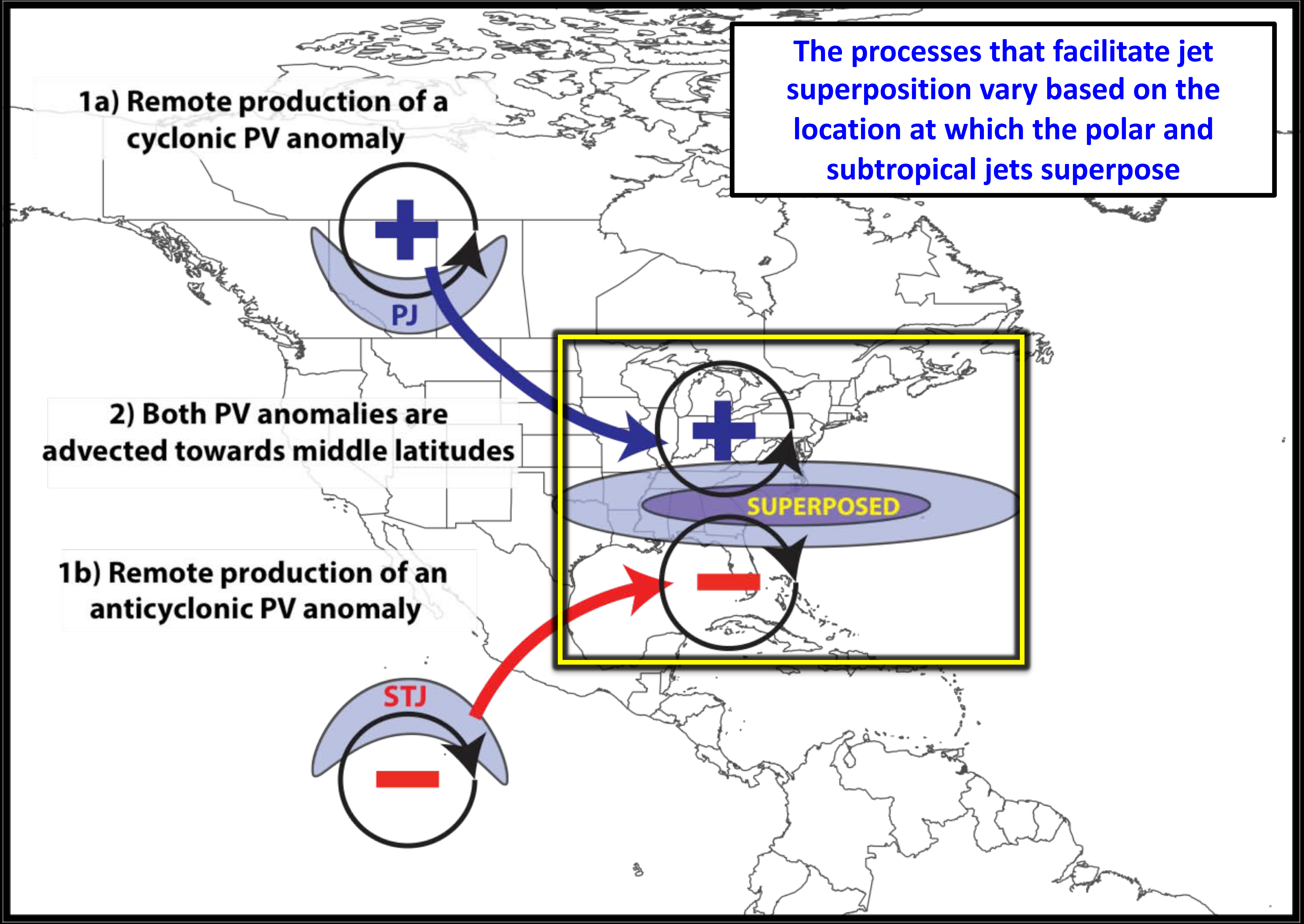


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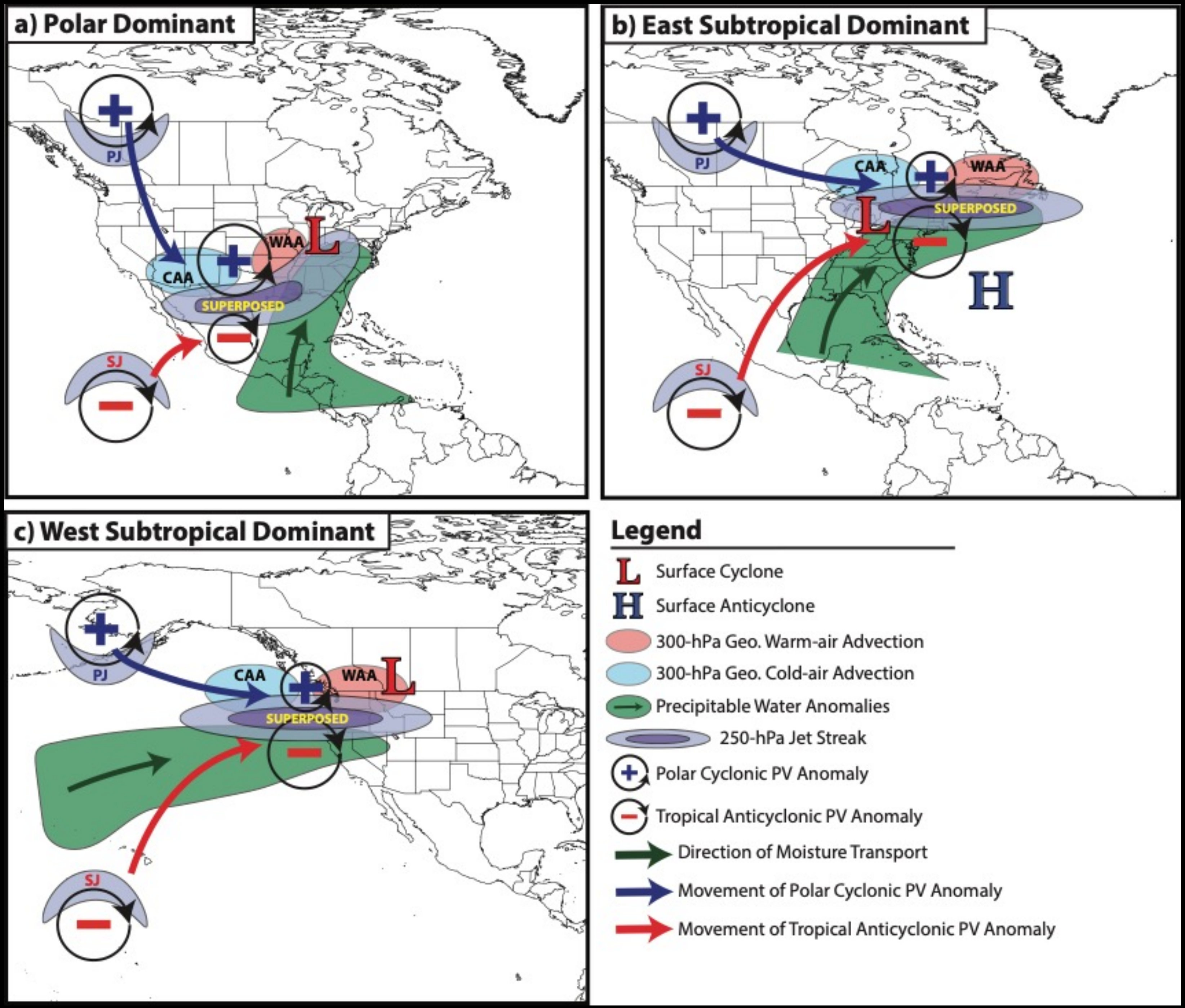


Winters et al. 2020

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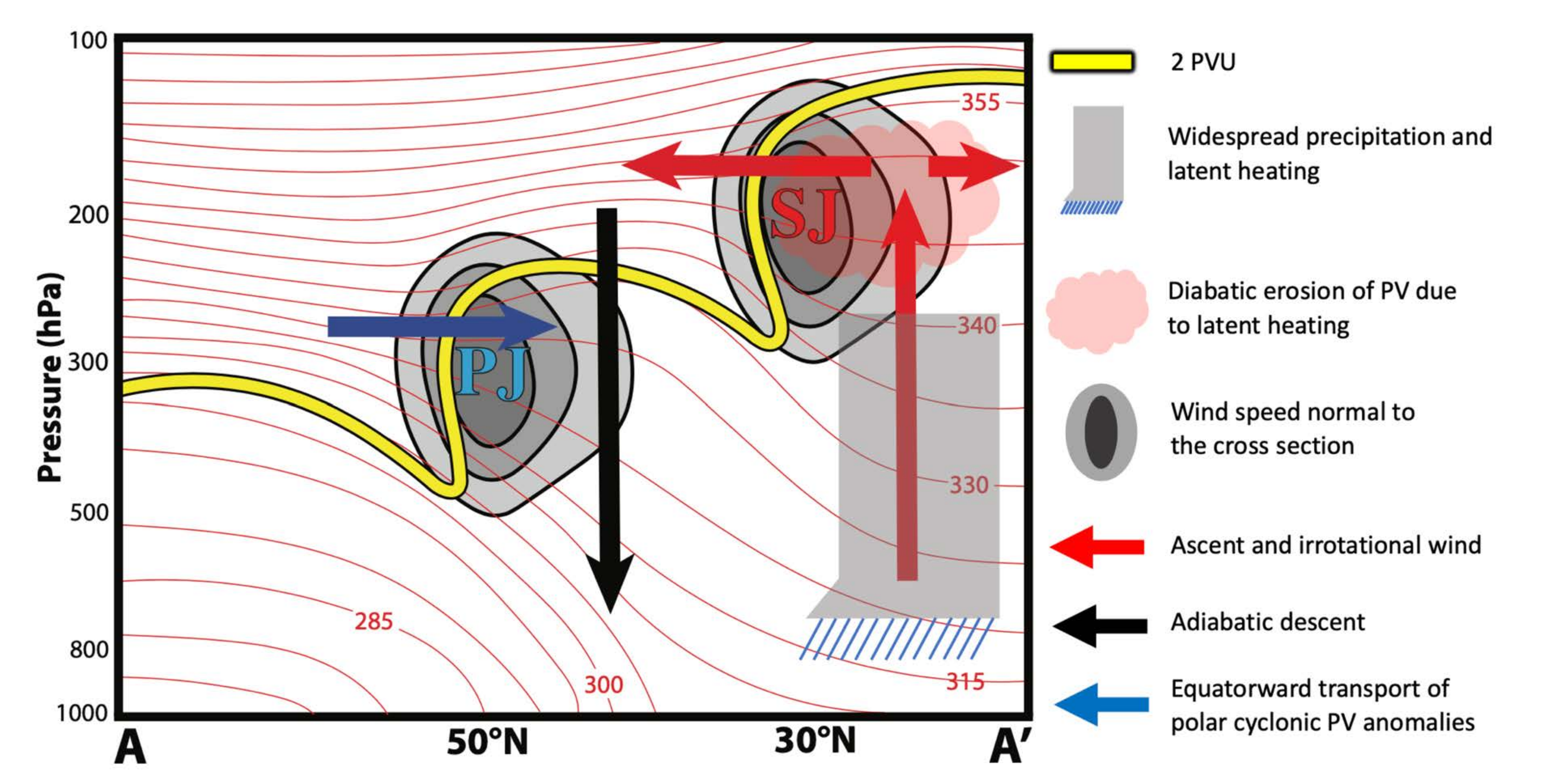

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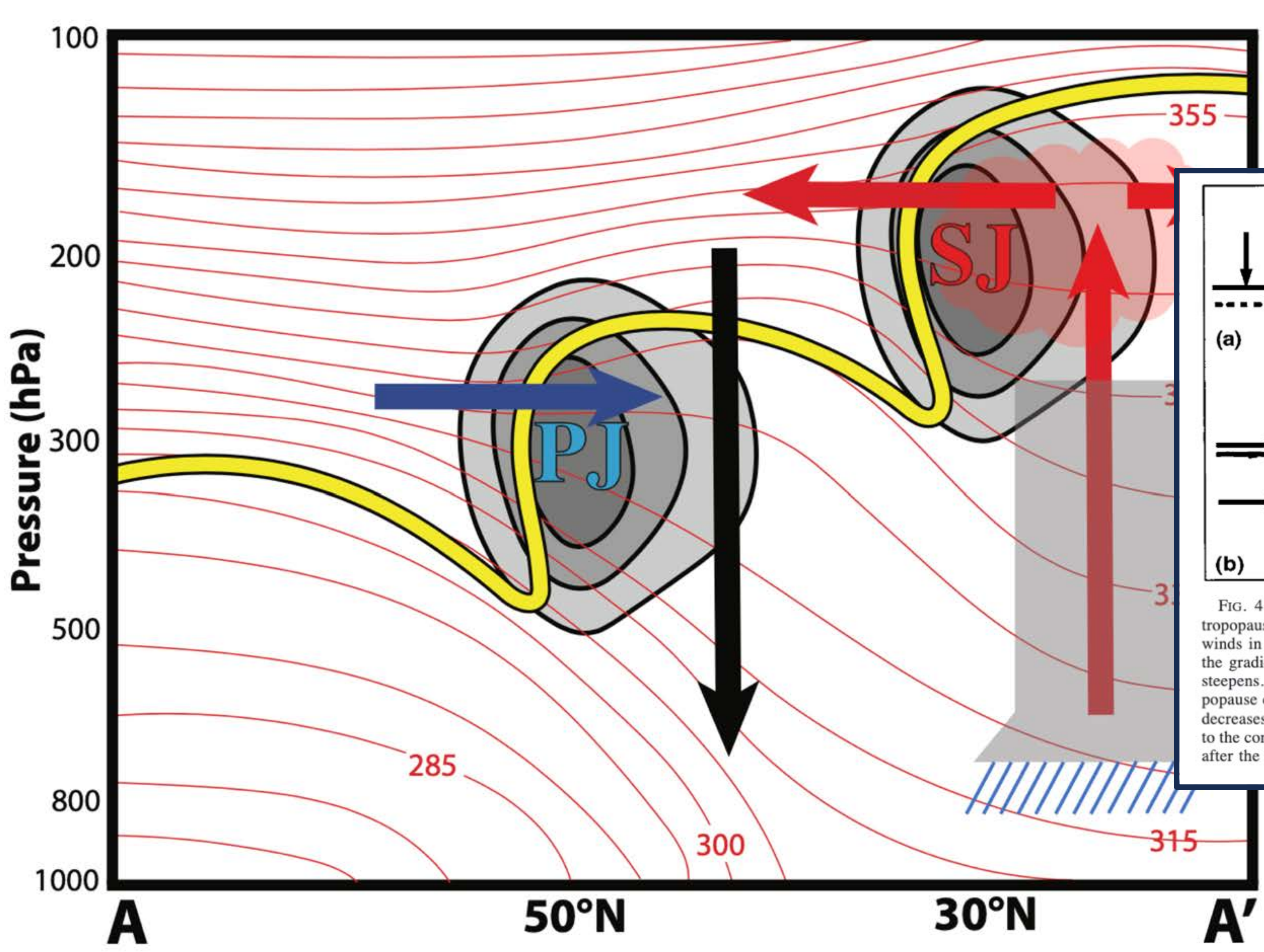



**"Foldogenesis"**

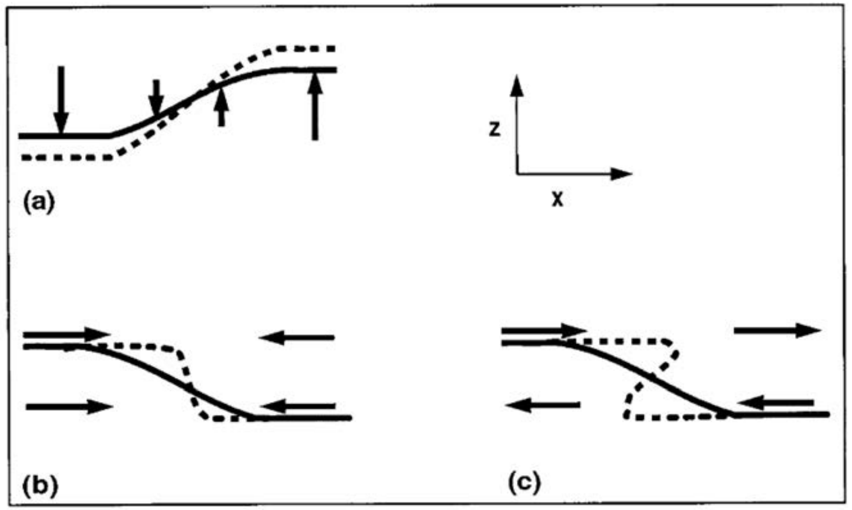
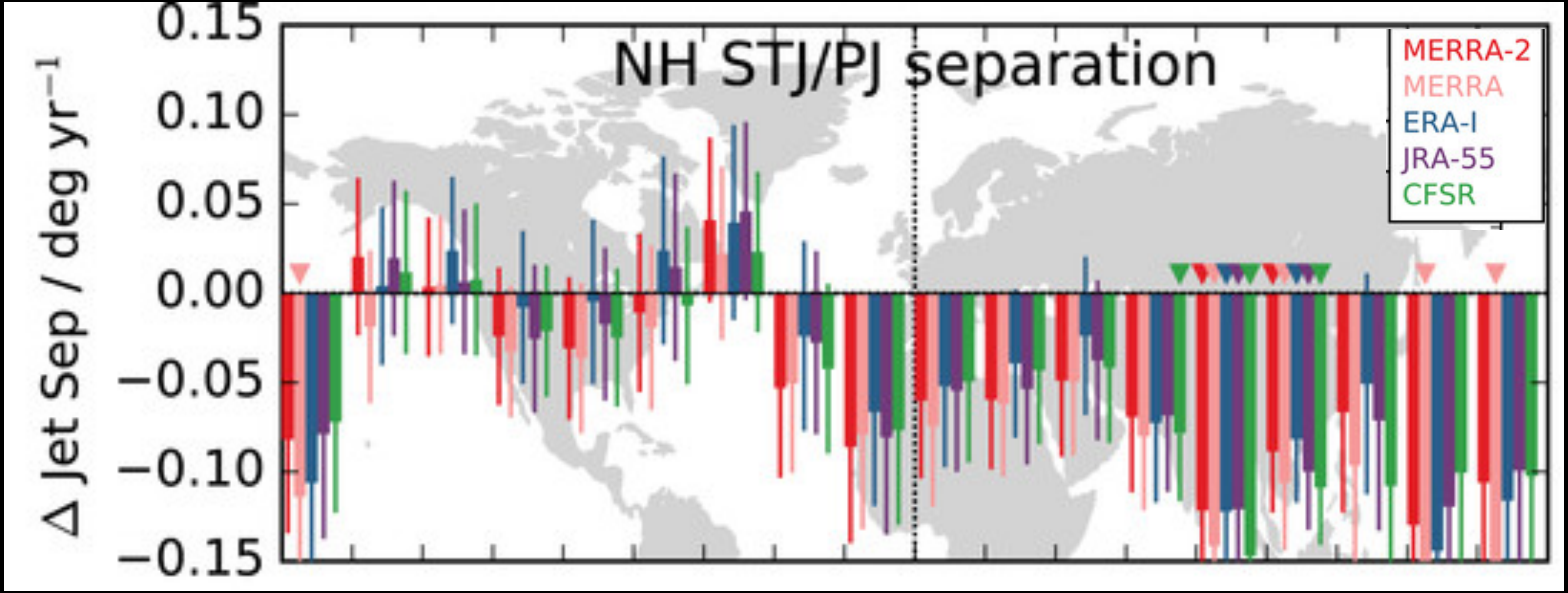



FIG. 4. Schematic diagrams of foldogenesis. The thick solid and dashed lines denote the tropopause at times $t_0$ and $t_0 + \Delta t$, respectively. Arrows indicate sense and magnitude of the winds in the vicinity of the tropopause. (a) Diagram illustrating differential vertical motion. If the gradient of the vertical motion is of the same sense as the height gradient, the tropopause steepens. (b) Diagram illustrating confluence/convergence. The differential advection of the tropopause causes it to steepen, but as the tropopause approaches vertical the differential advection decreases. (c) Diagram illustrating vertical shear. The winds along the tropopause are identical to the confluence/convergence case at $t_0$, but differential advection by the vertical shear continues after the tropopause becomes vertical to produce a tropopause fold.

**Wandishin, Nielsen-Gammon, and Keyser, 2000**

# Future Changes in Jet Superpositions

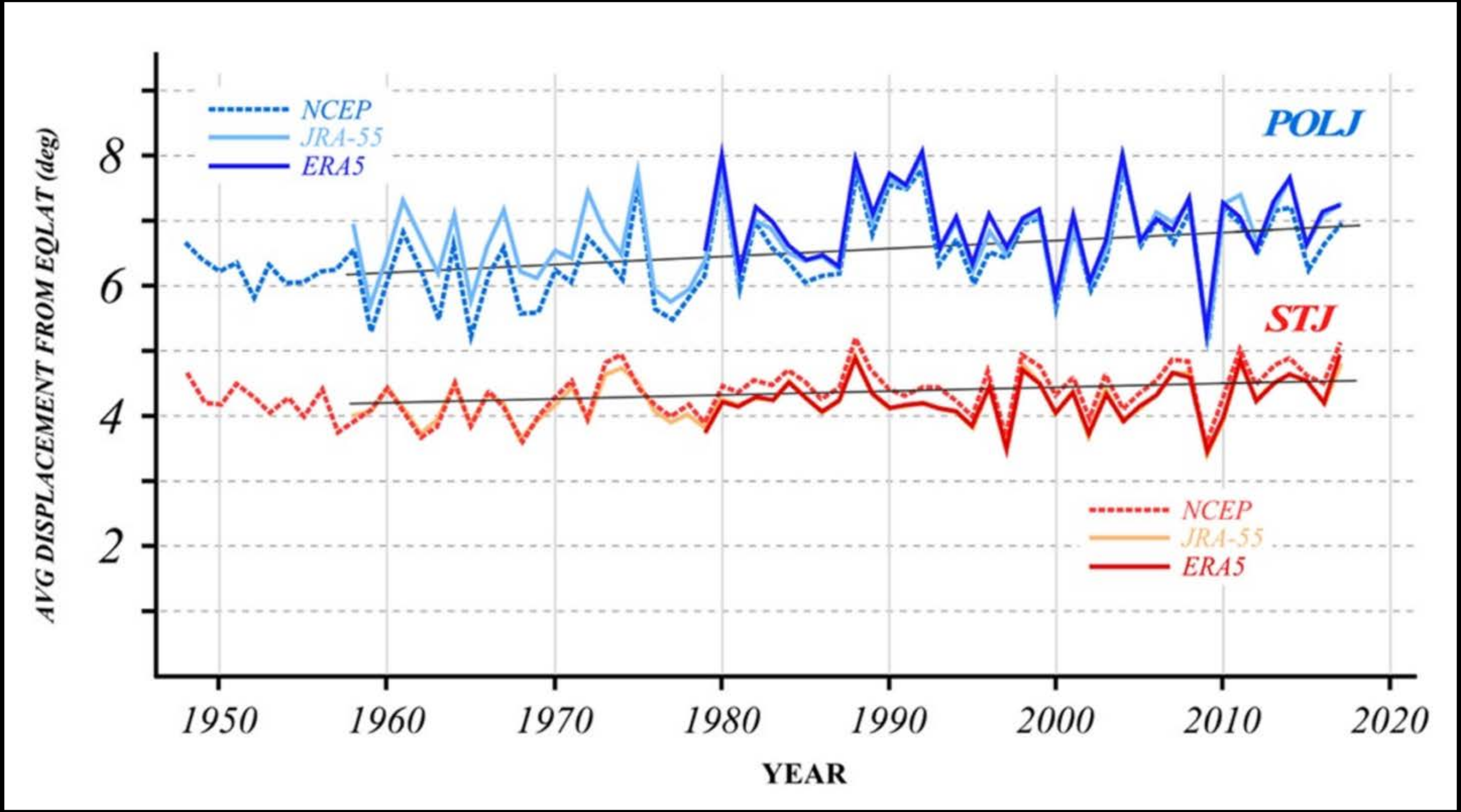
Reanalysis trends suggest the polar and subtropical jets are getting closer together over North America and the North Atlantic




**Manney and Hegglin 2018, their Fig. 13**

# Future Changes in Jet Superpositions

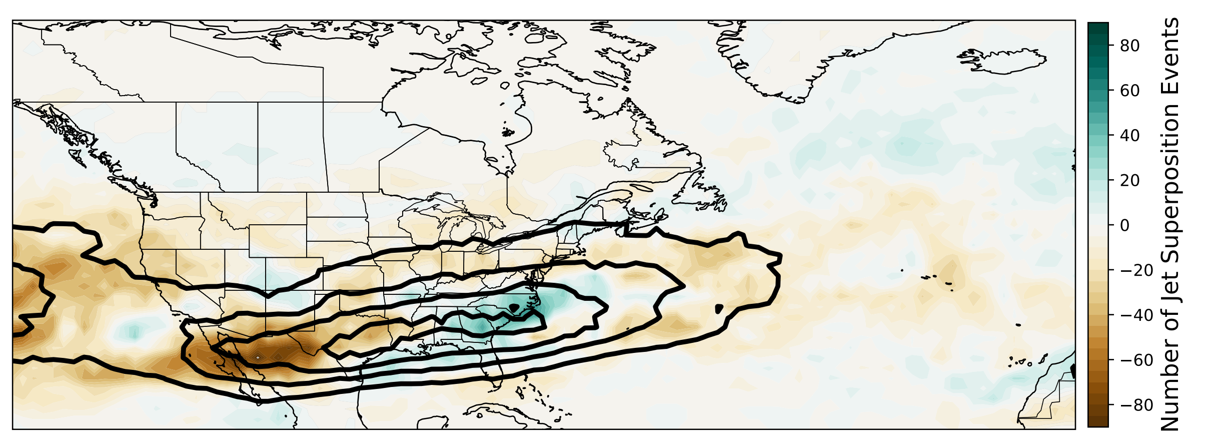
Reanalysis trends suggest the Northern Hemisphere polar and subtropical jets are becoming wavier



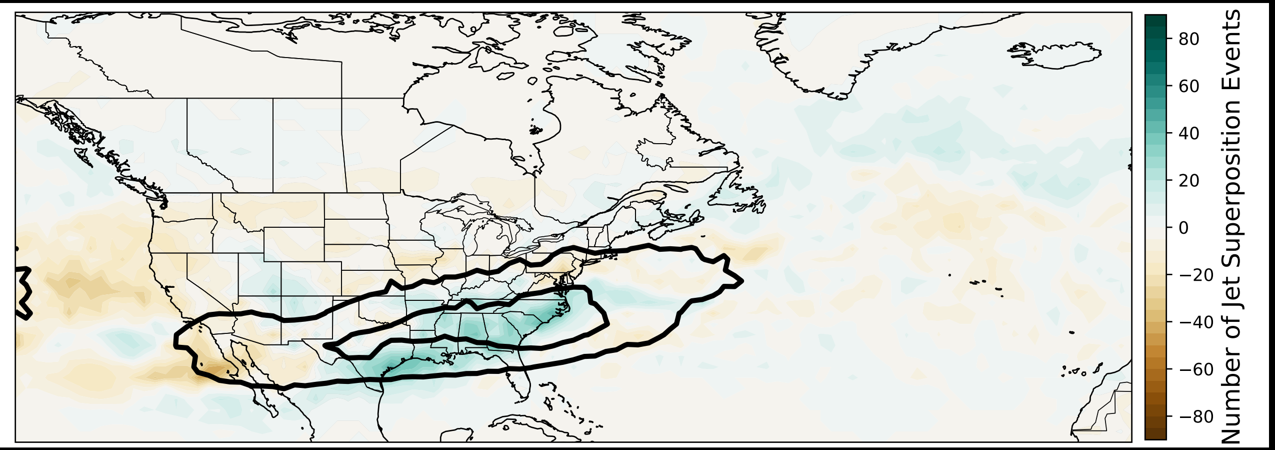

**Martin 2021, their Fig. 6**

# Future Changes in Jet Superpositions

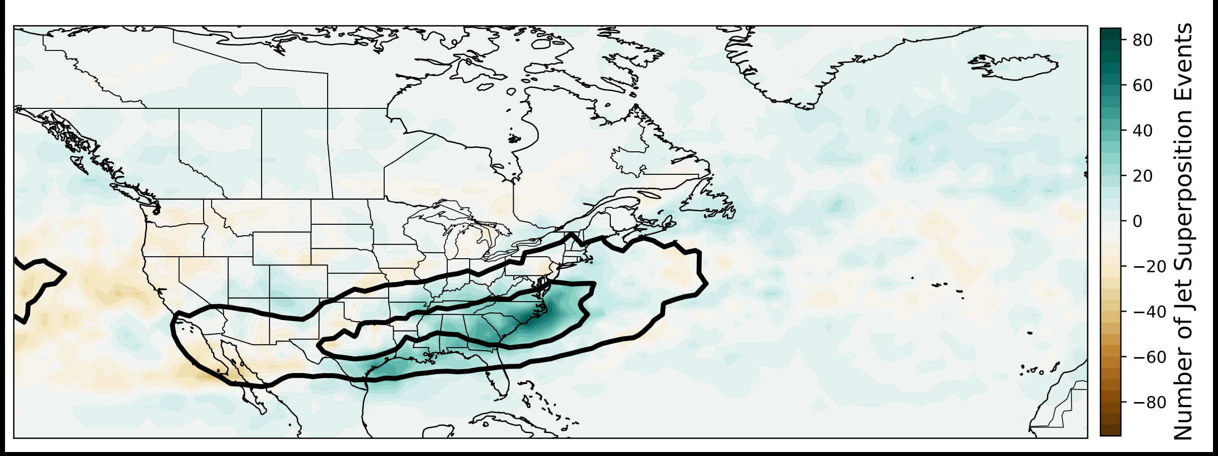
## ERA5 (using 315 K and 350 K)




## JRA55 (using 310 K and 350 K)




## CFSR (using 310 K and 350 K)




**Shading: Differences in jet superposition frequency between 2003–2022 and 1979–1998**

**Contours: 1979–2022 jet superposition frequency every 100 events**

Jet superpositions are identified in a similar manner as in Winters and Martin 2014; Christenson et al. 2017.

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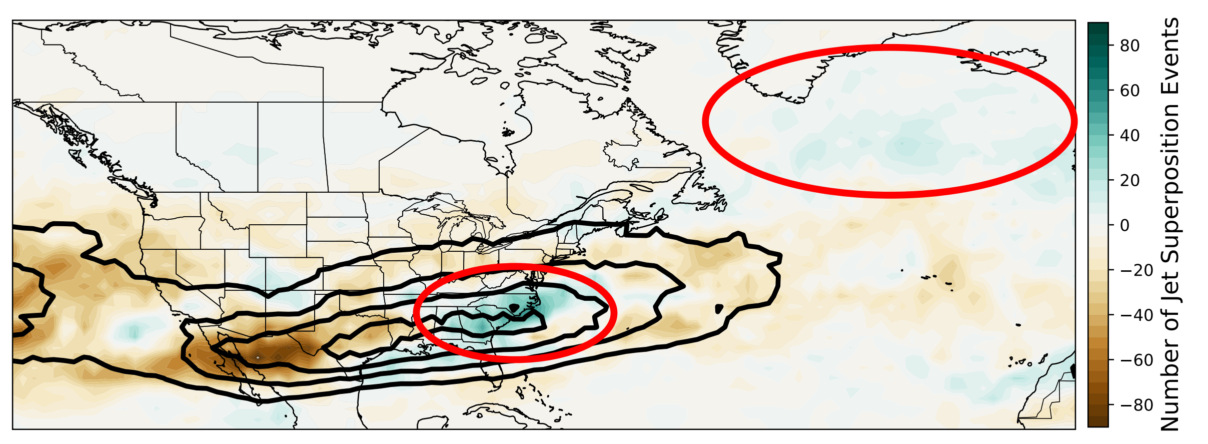


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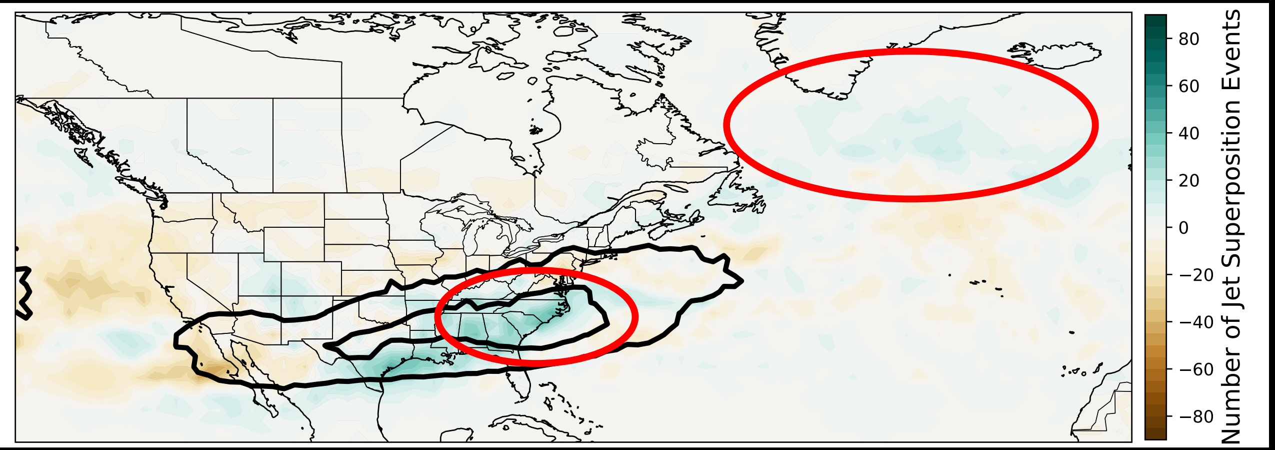


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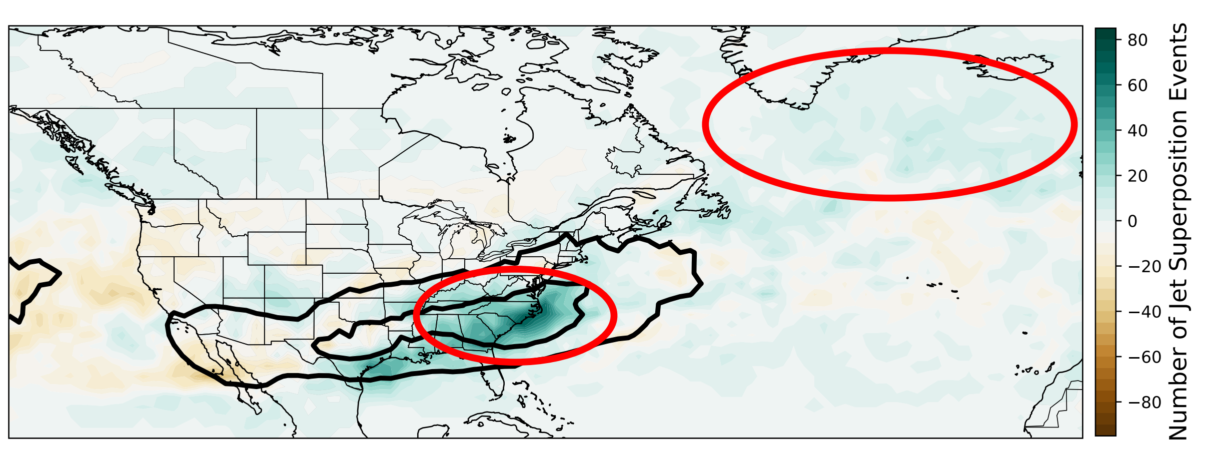


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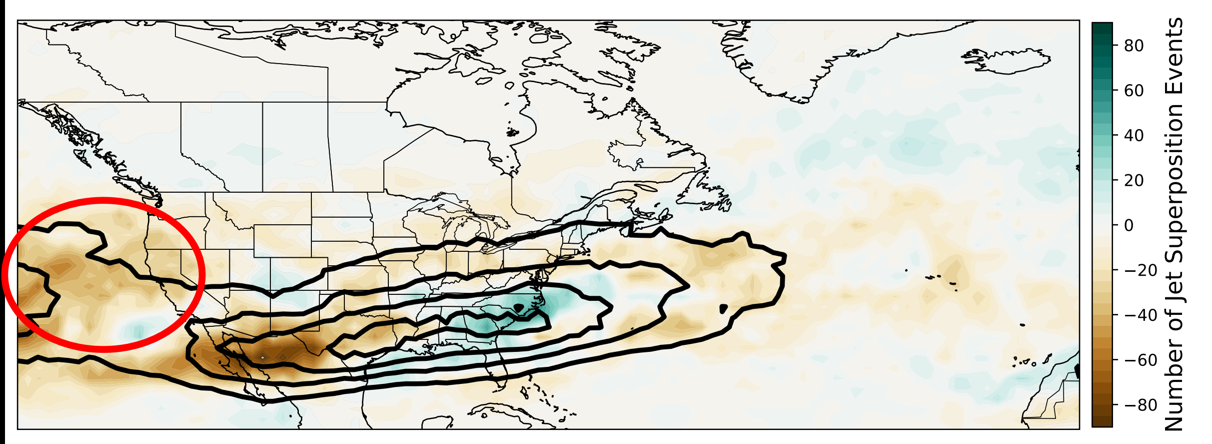


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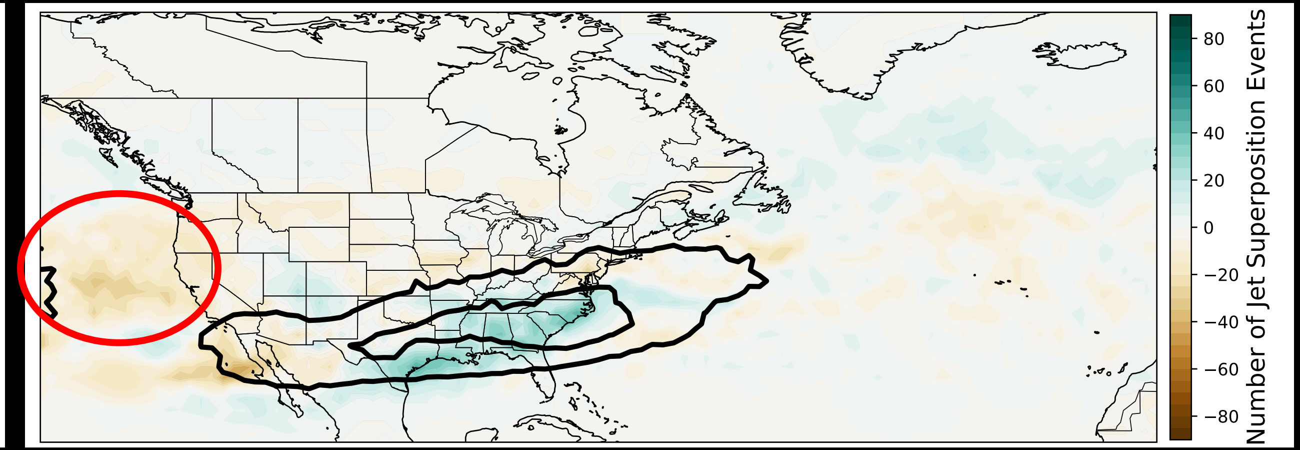


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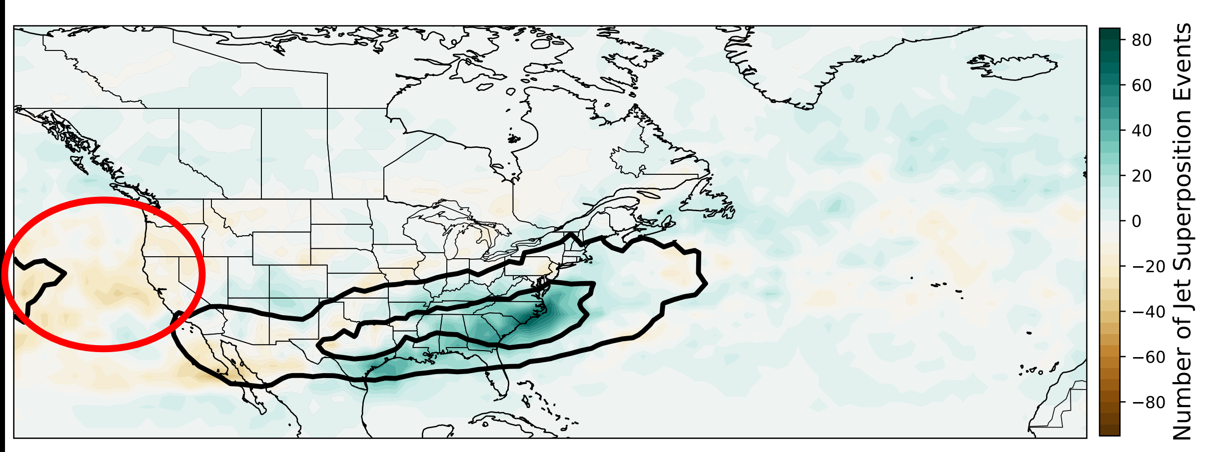


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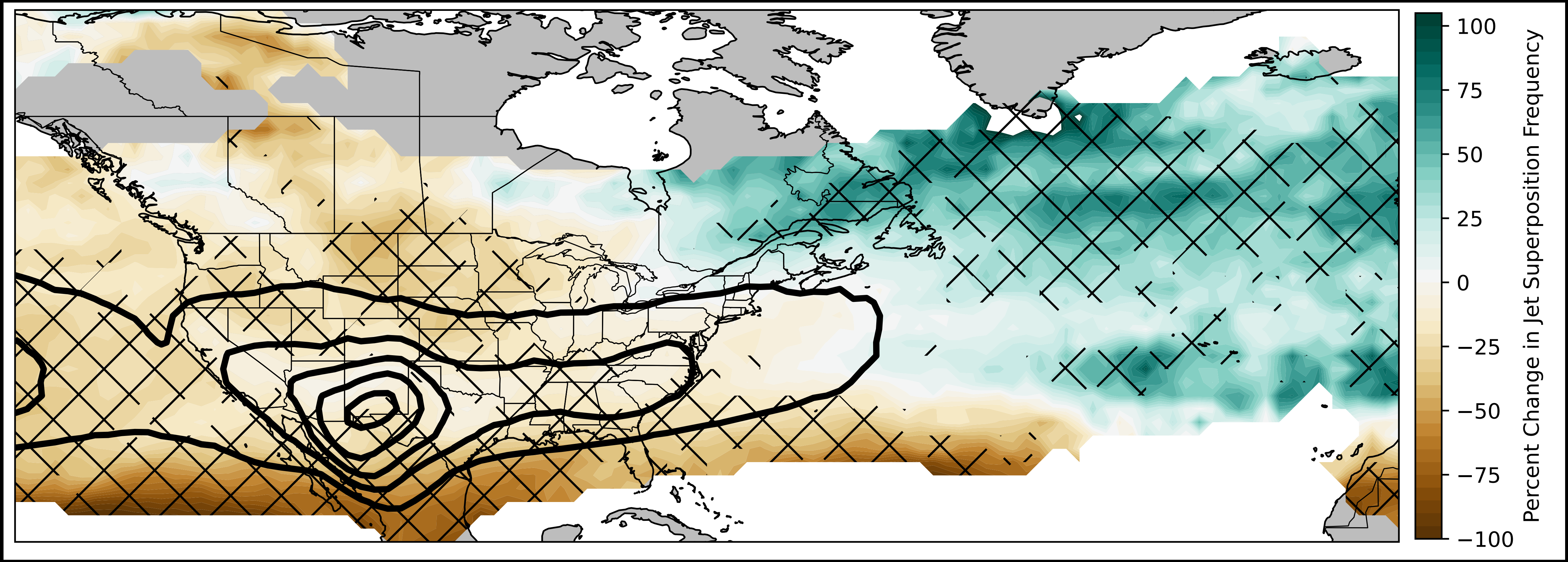
# Future Changes in Jet Superpositions

## CESM2-LENS2 (using 315 K and 350 K)




Shading: Percent change in jet superposition frequency from 1979–2014 to 2065–2099

Contours: Ensemble mean jet superposition frequency between 1979–2014 every 100 events

Hatching: Locations where 8 of 10 total ensemble members agree on the change in jet superposition frequency

# Future Changes in Jet Superpositions

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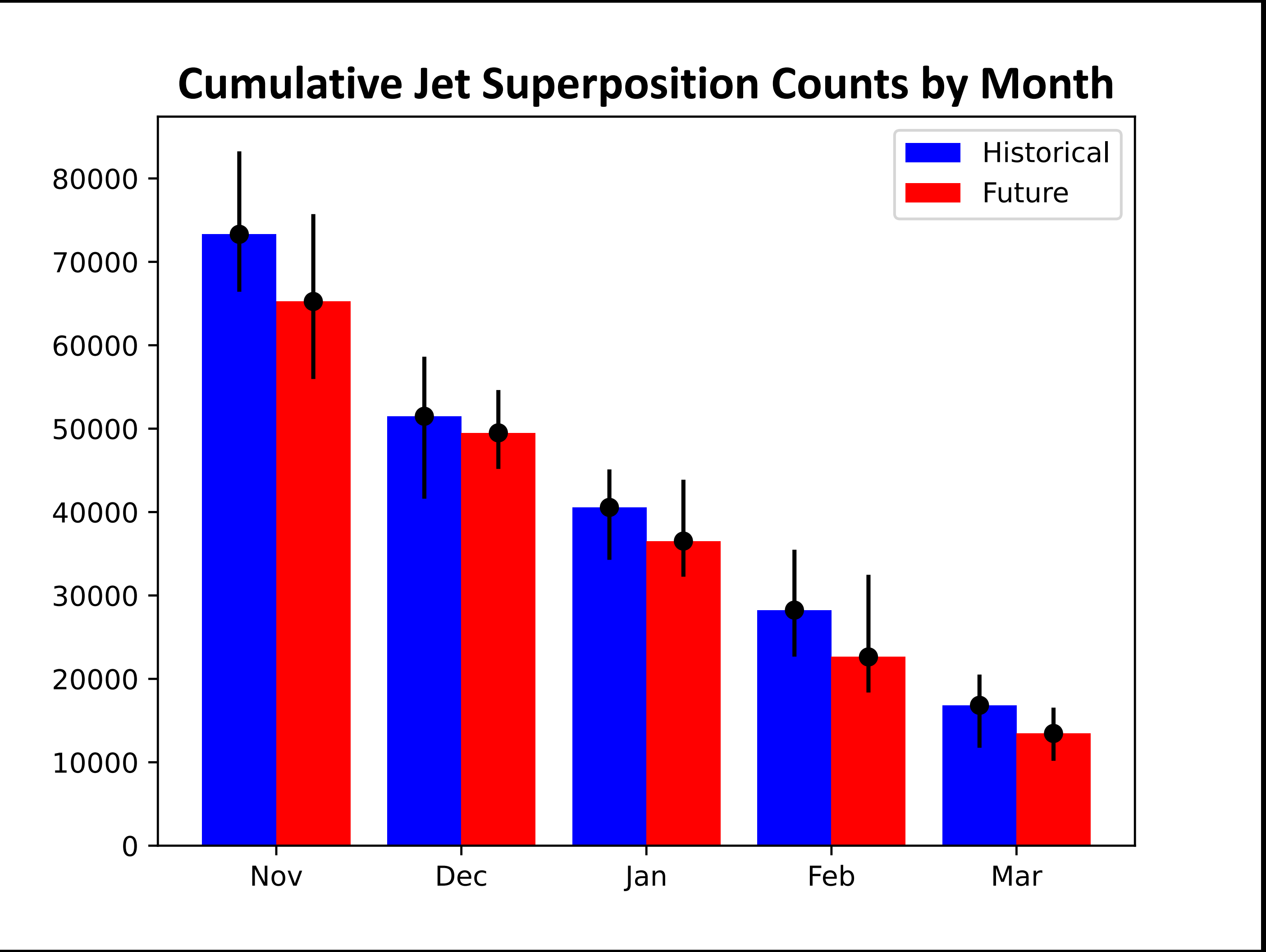



Aggregate jet superposition frequencies over North America/North Atlantic are projected to **decrease**.

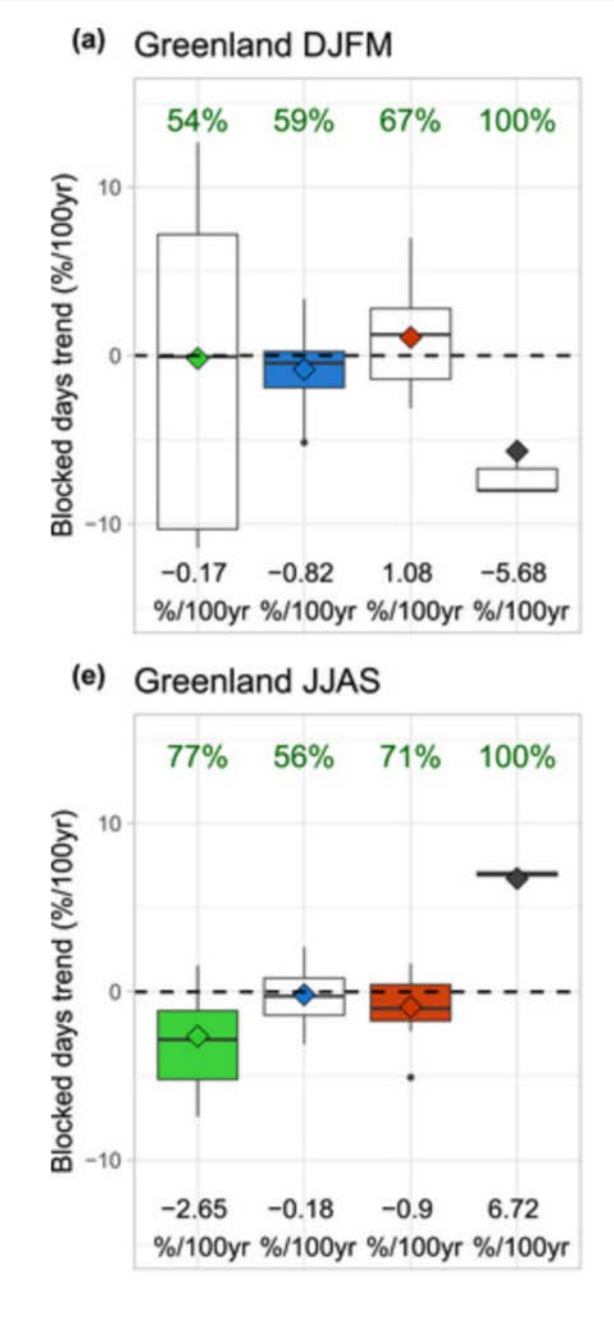
350-K wind speeds at grid points featuring a jet superposition exhibit an **average increase of 7.99 m $s^{-1}$** relative to the historical period.

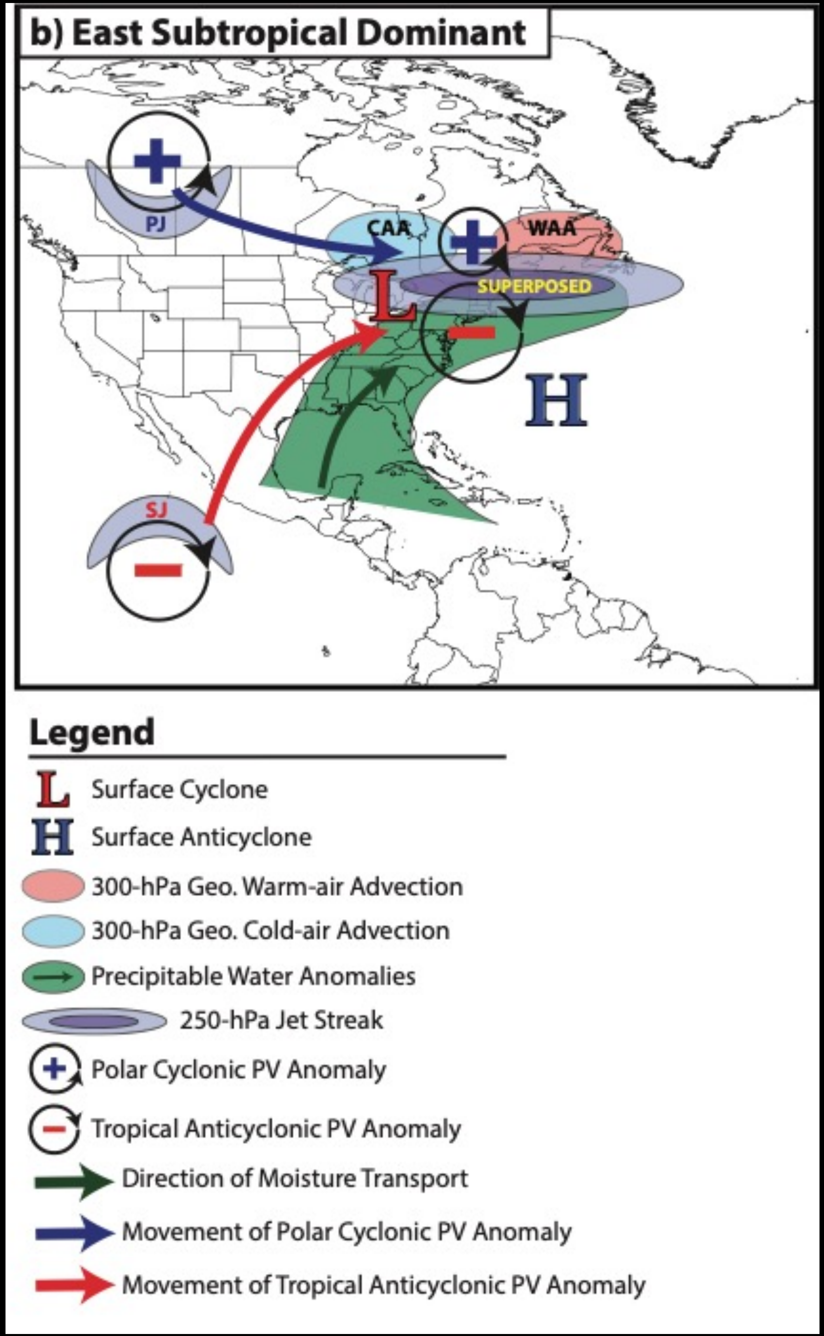
315-K wind speeds at grid points featuring a jet superposition exhibit an **average decrease of 2.38 m $s^{-1}$** relative to the historical period.

# Relationship to Blocking

Historical changes in Greenland blocking frequency derived from climate models diverge from observations.

There are arguments for how jet superpositions over the North Atlantic may enhance or suppress Greenland blocking.




**Davini and D'Andrea 2020, their Figs. 8a,e**

# Remaining Questions

- What processes are responsible for changes in jet superposition frequency?
- How might climate change influence the dynamical processes that restructure the tropopause during jet superpositions?
- How might the association between jet superpositions and high-impact weather change in a future climate?
- What role do blocking events play during the development/evolution of jet superpositions?