A moist potential vorticity perspective on the presence of inertial instability along the subtropical jet during the extratropical transition process

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Inertial instability in the PV[1] framework

Inertial instability is present when the local absolute vorticity is signed oppositely the Coriolis parameter

$$(\zeta_g + f)f < 0$$

In a statically stable atmosphere, inertial instability is present when the PV is negative (in the Northern Hemisphere)

$$P = -g\zeta_a \frac{\partial \theta}{\partial p}$$

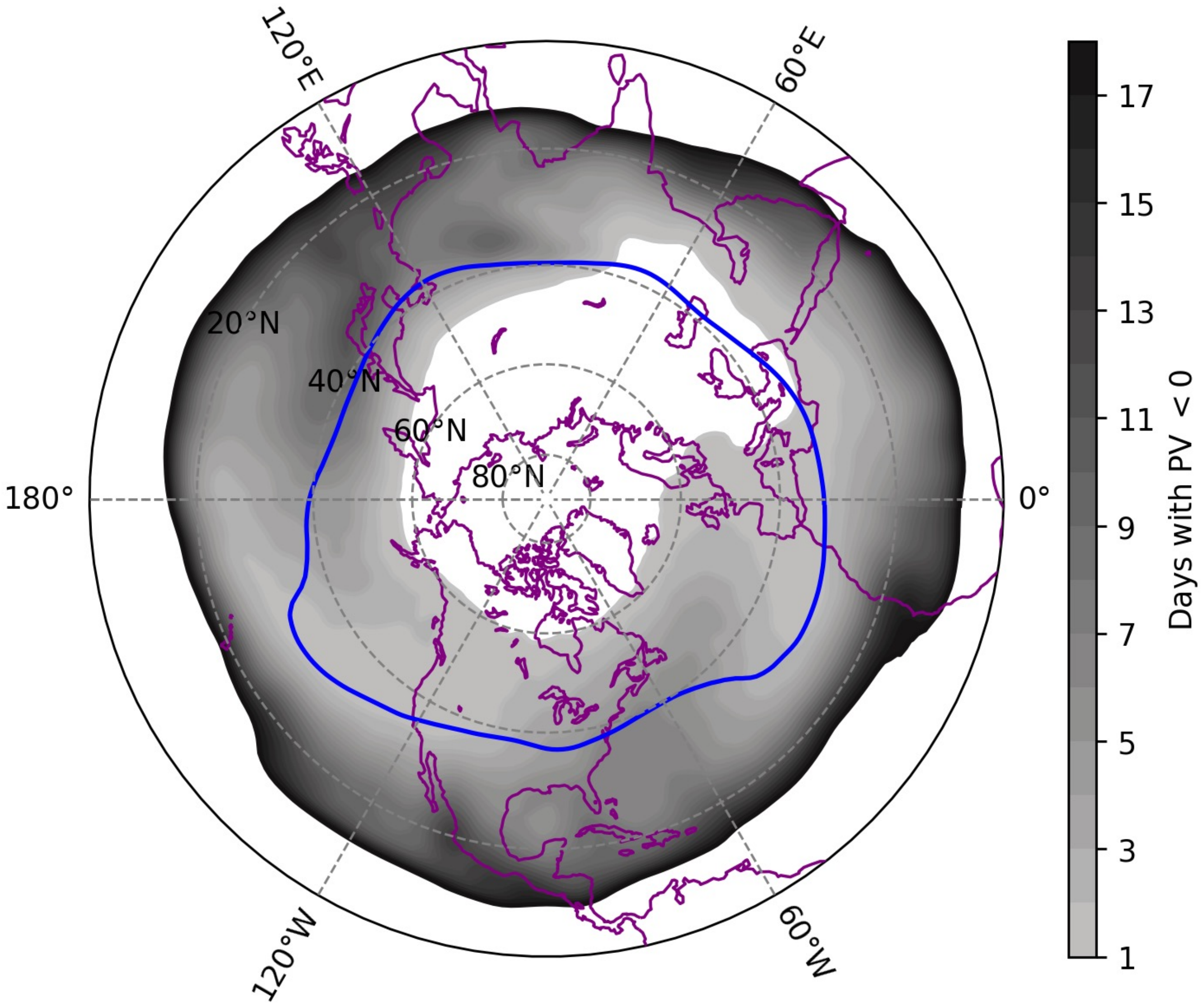

Fig. 1 – The number of September days with PV < 0, and the mean location of the September subtropical jet (blue line) in the 330-360K isentropic layer over the period 1995-2020 in the JRA reanlysis

[1] potential vorticity

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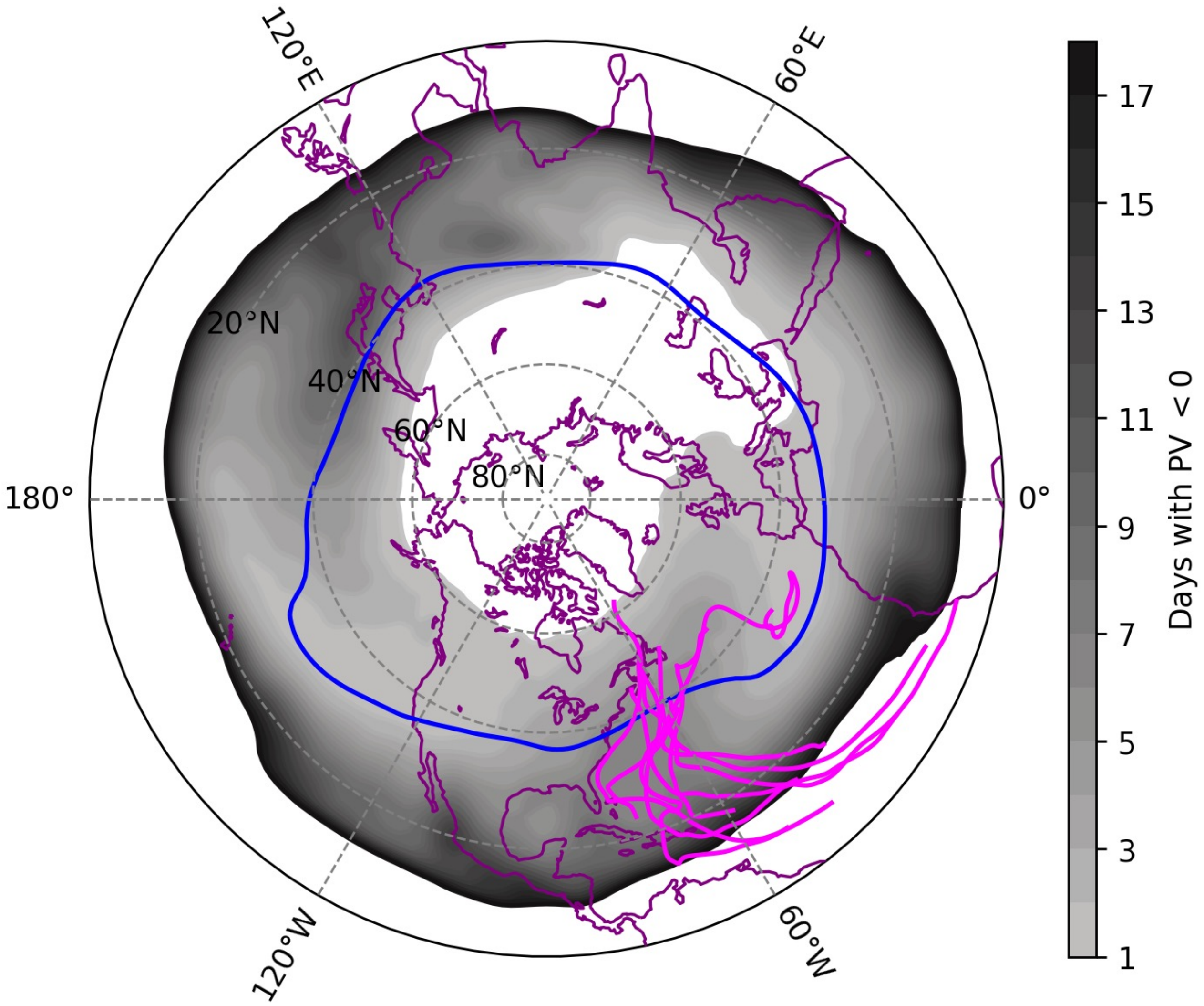

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[1] potential vorticity

Humberto

16 Sep 2019

Decent environment for extra-tropical transition

- Deepening upper-level trough
- Ample precipitable water

Fig. 2a & 2c – 850 hPa geopotential height (black), 1000-500 hPa thickness (dashed red/blue), geostrophic relative vorticity (shaded oranges), and precipitable water (shaded greens)

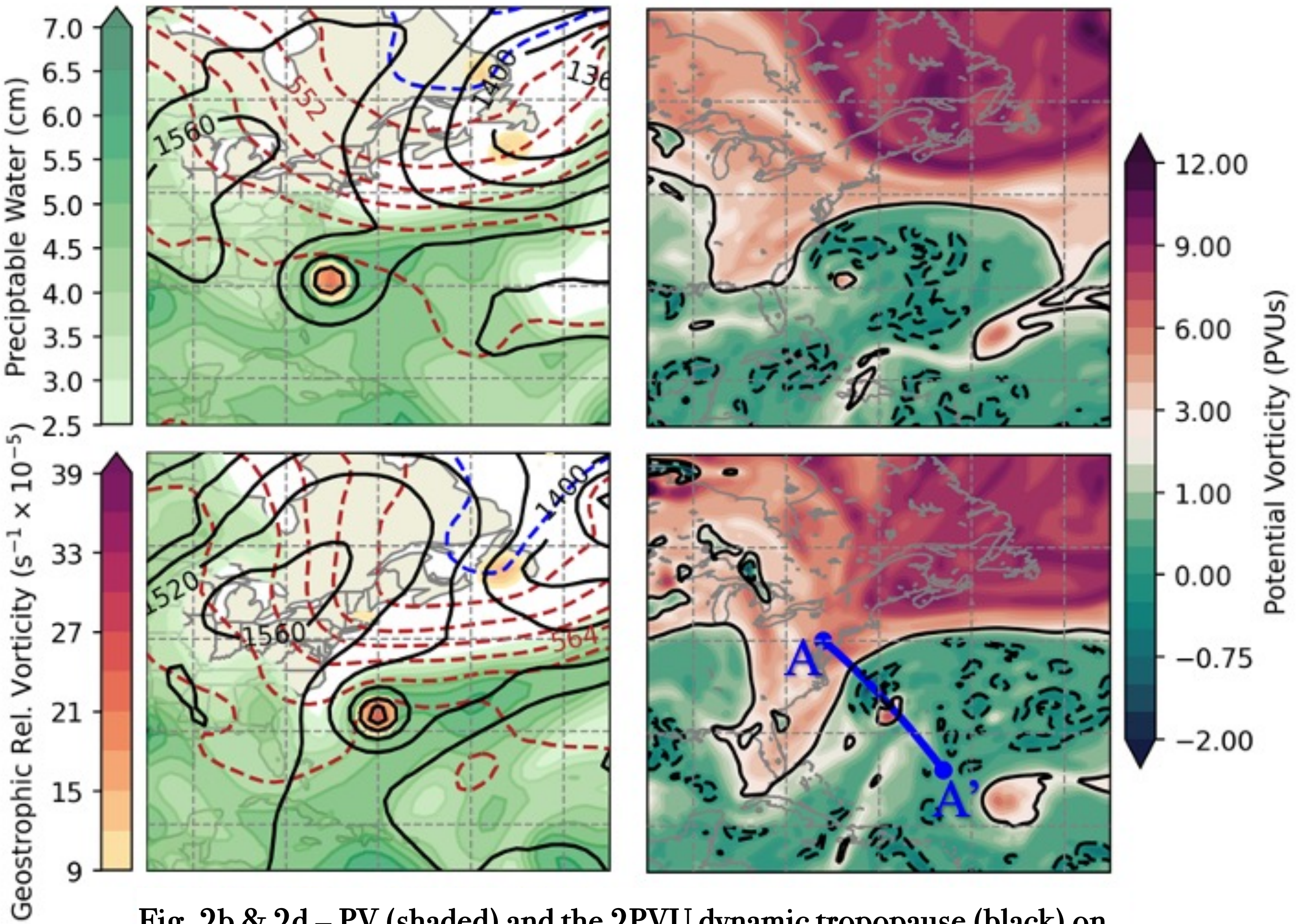

Fig. 2b & 2d – PV (shaded) and the 2PVU dynamic tropopause (black) on the 350K isentropic surface

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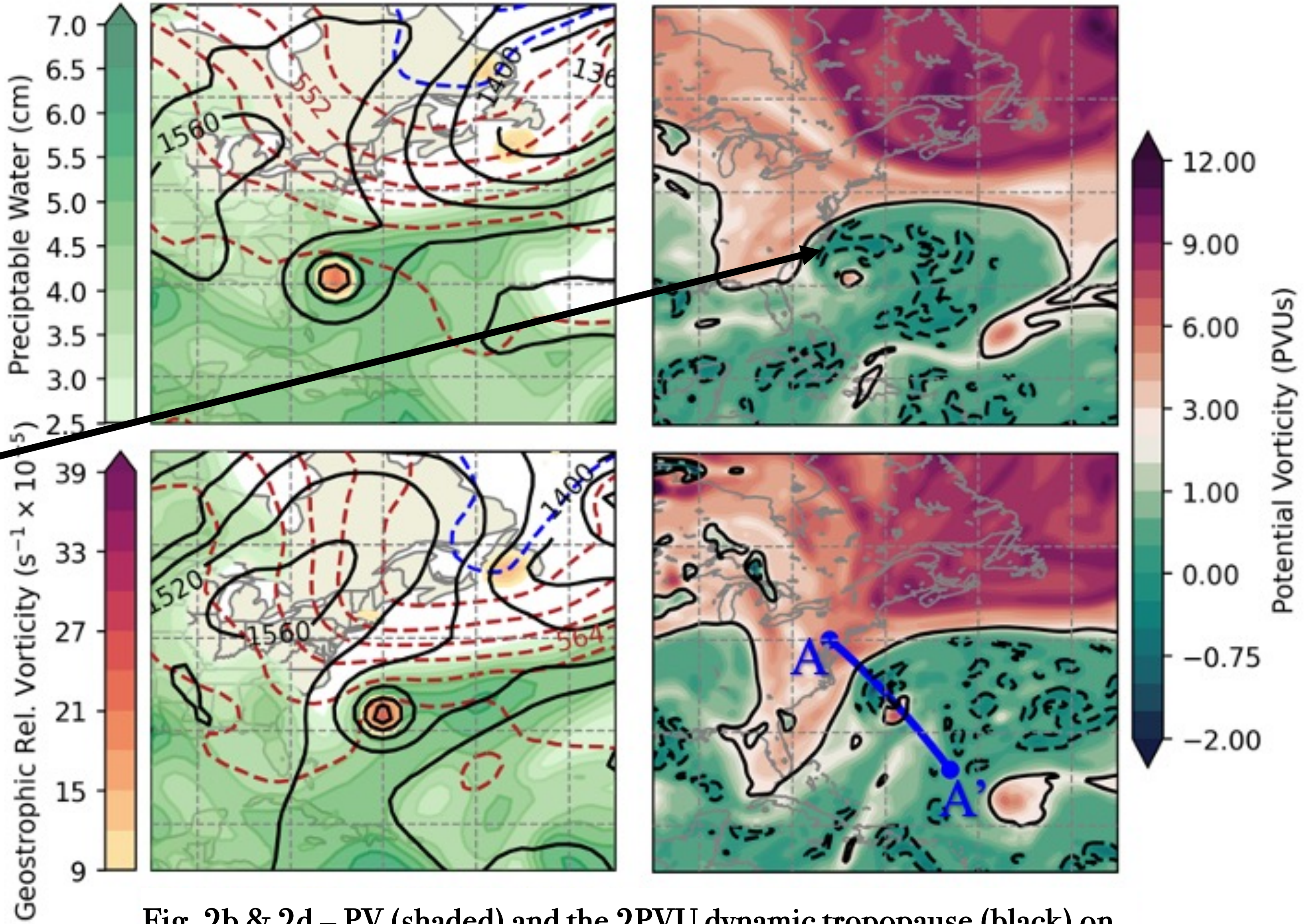
Large-scale, semi-coagulated NPV streamer in the upper-level ridge



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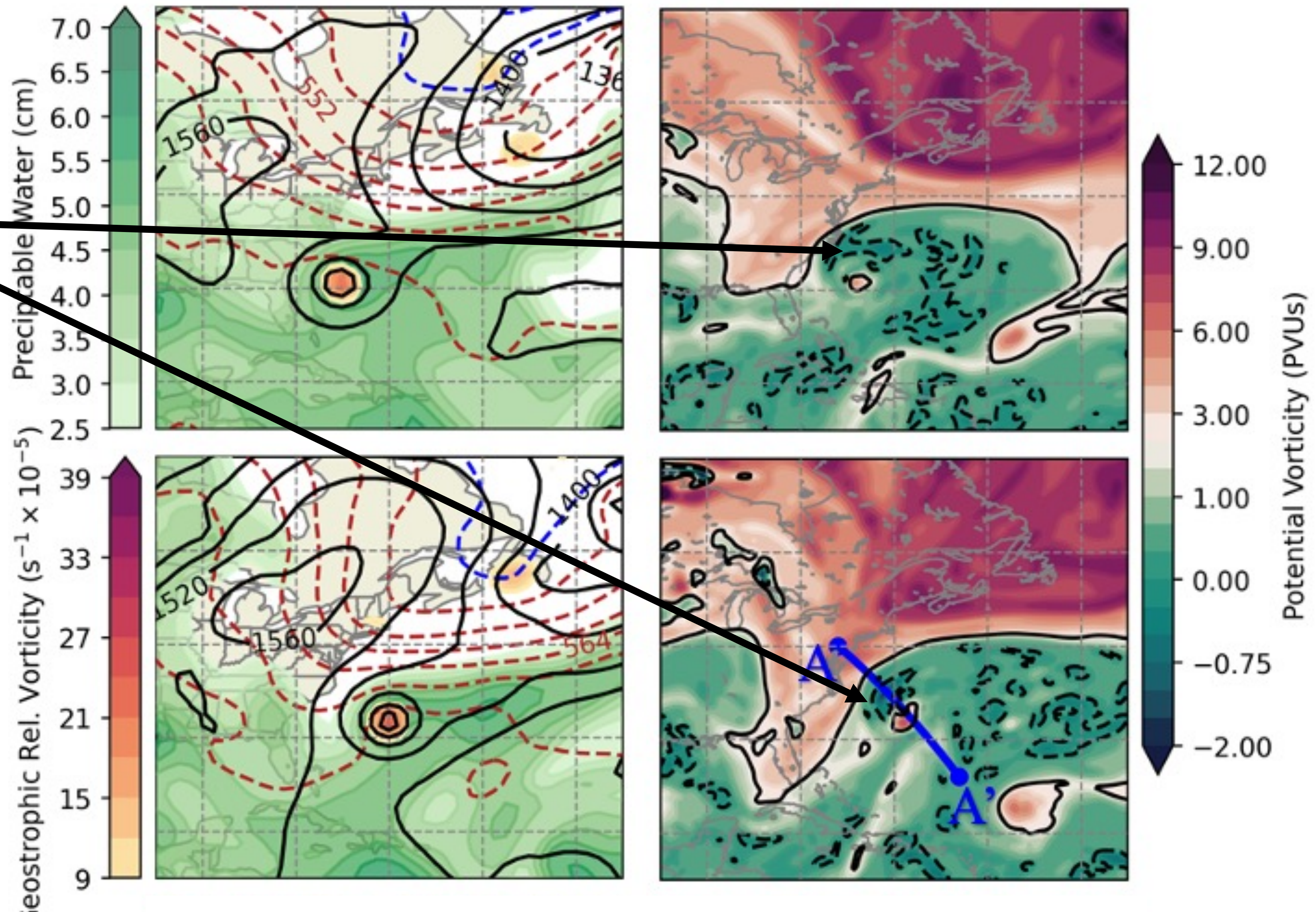
Persistent NPV feature between Humberto and the subtropical jet



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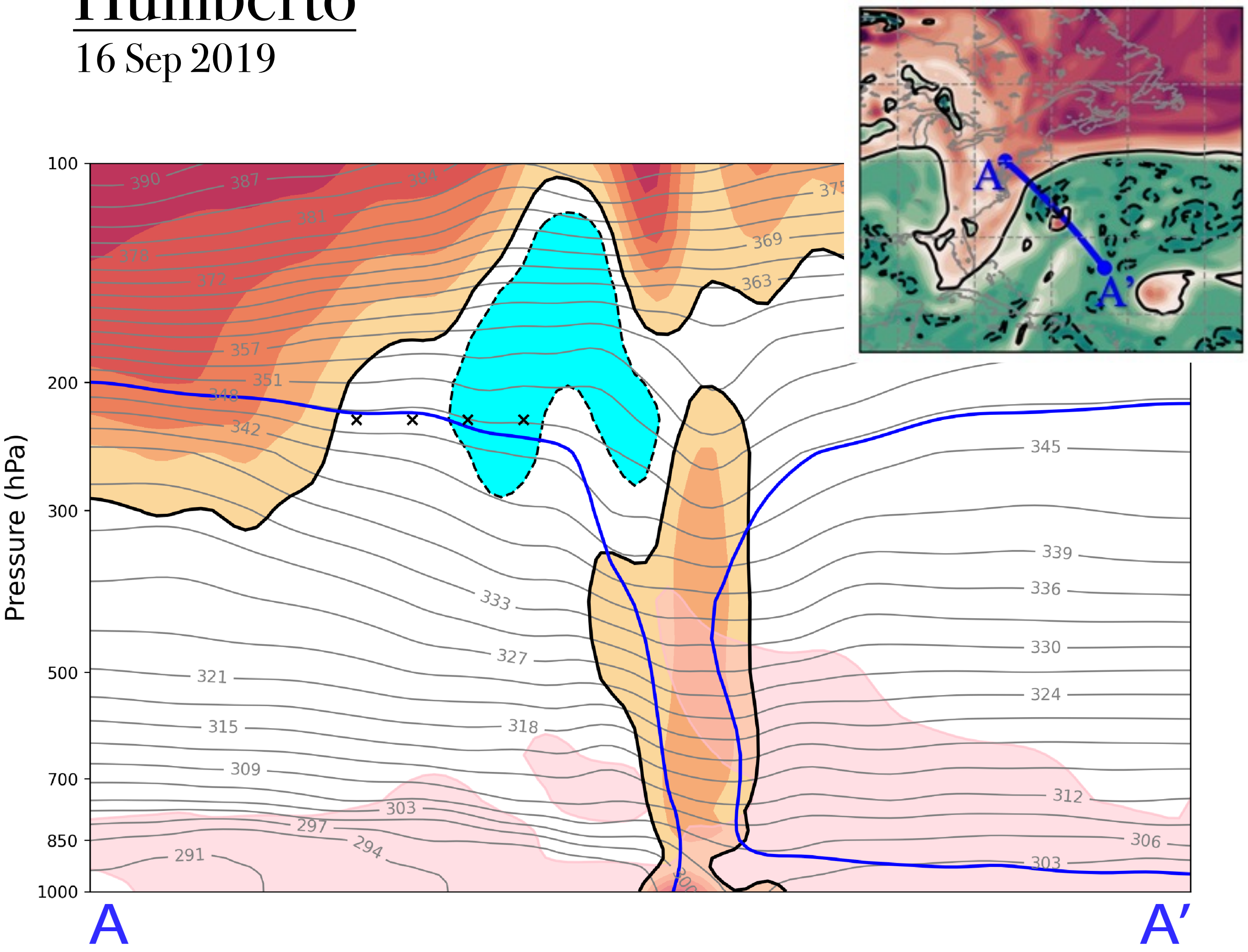

Fig. 3 – The 2PVU dynamic tropopause (black) and PV > 2 (shaded orange), potential temperature (grey), PV < -.4 (dashed black and shaded blue), the 348 K moist isentrope (blue), and the portion of the atmosphere that is convectively unstable (pink)

Grey lines - isentropes

Orange shading – PV > 2PVU

Teal – Negative PV/inertial instability

Pink – Convective instability

Blue line – Moist entropy current

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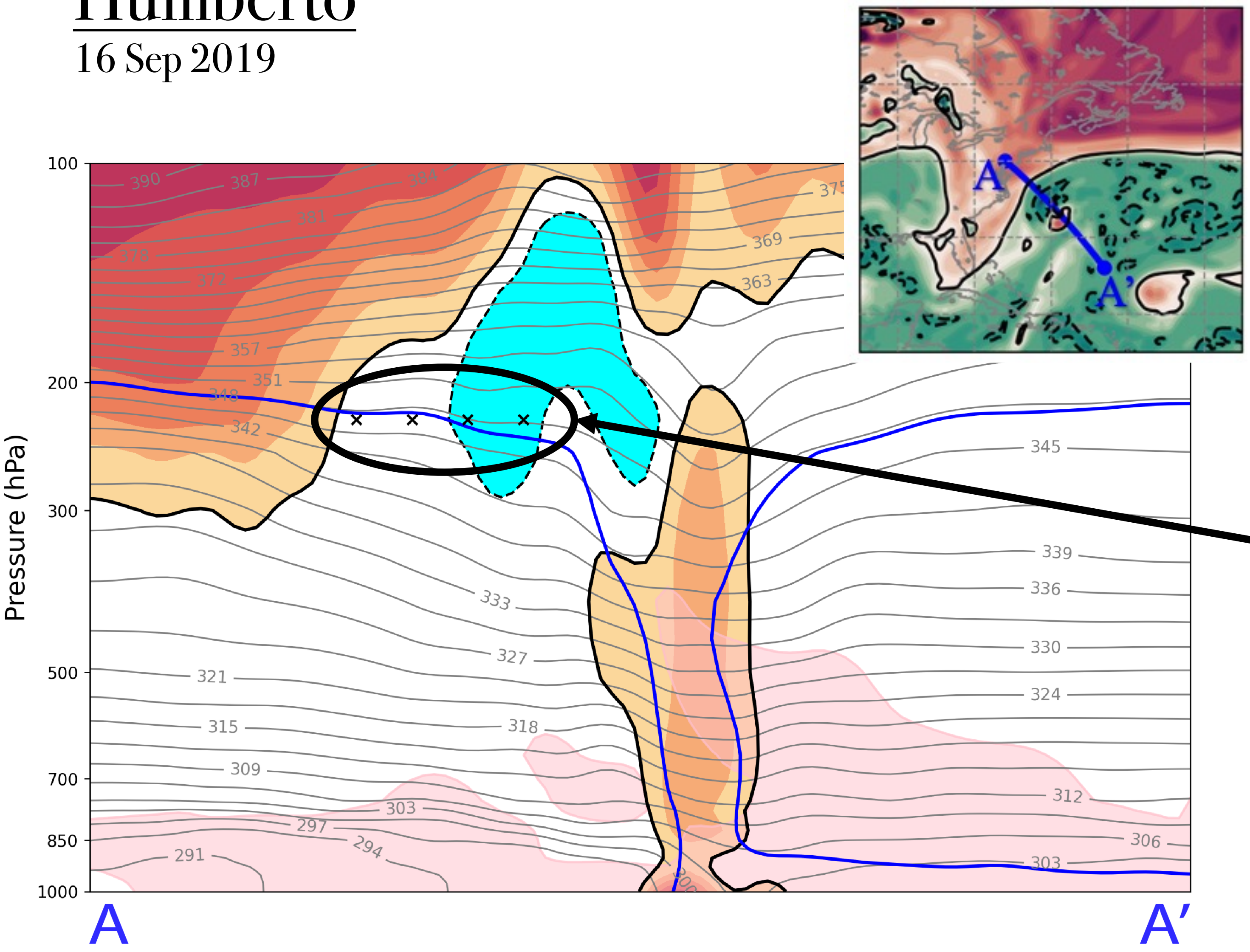

Let's confirm that inertially unstable parcels took this path

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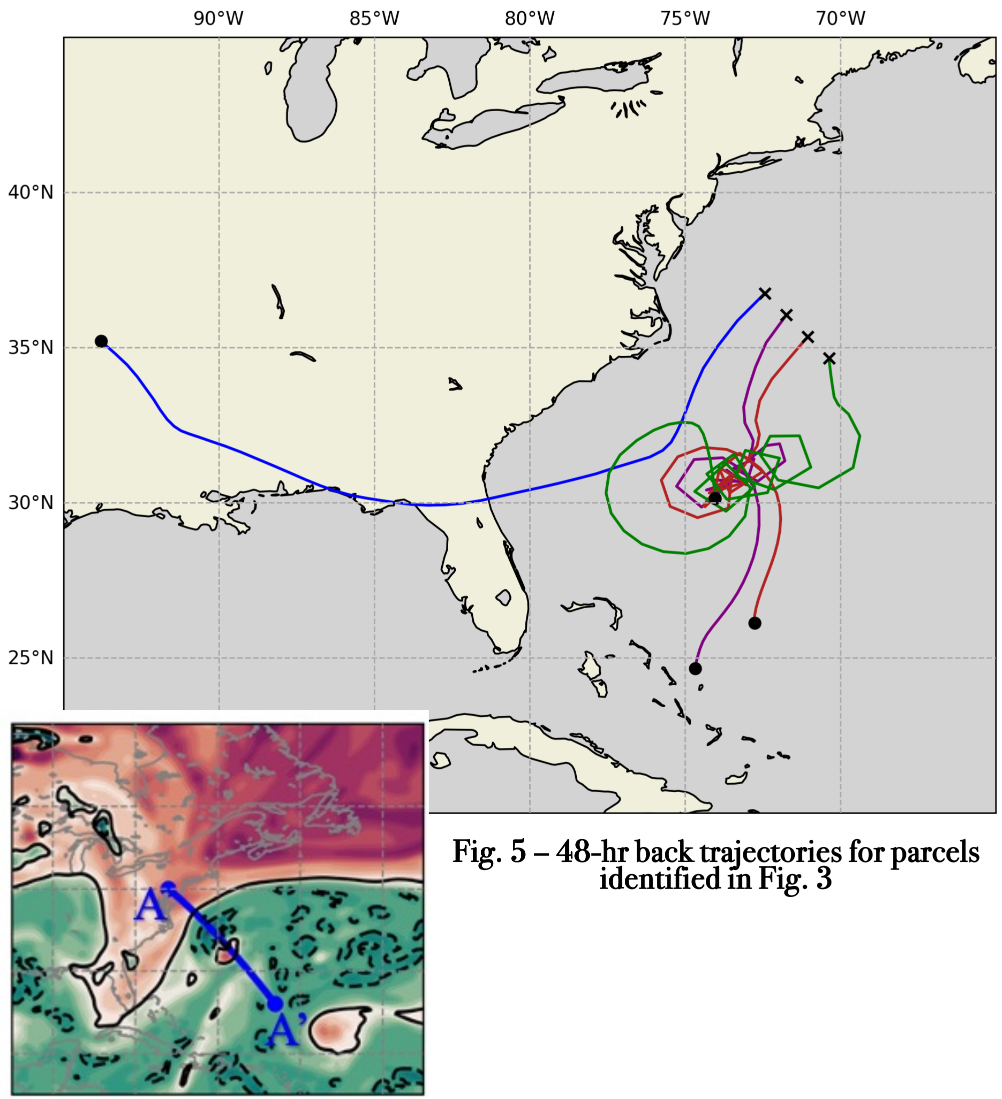
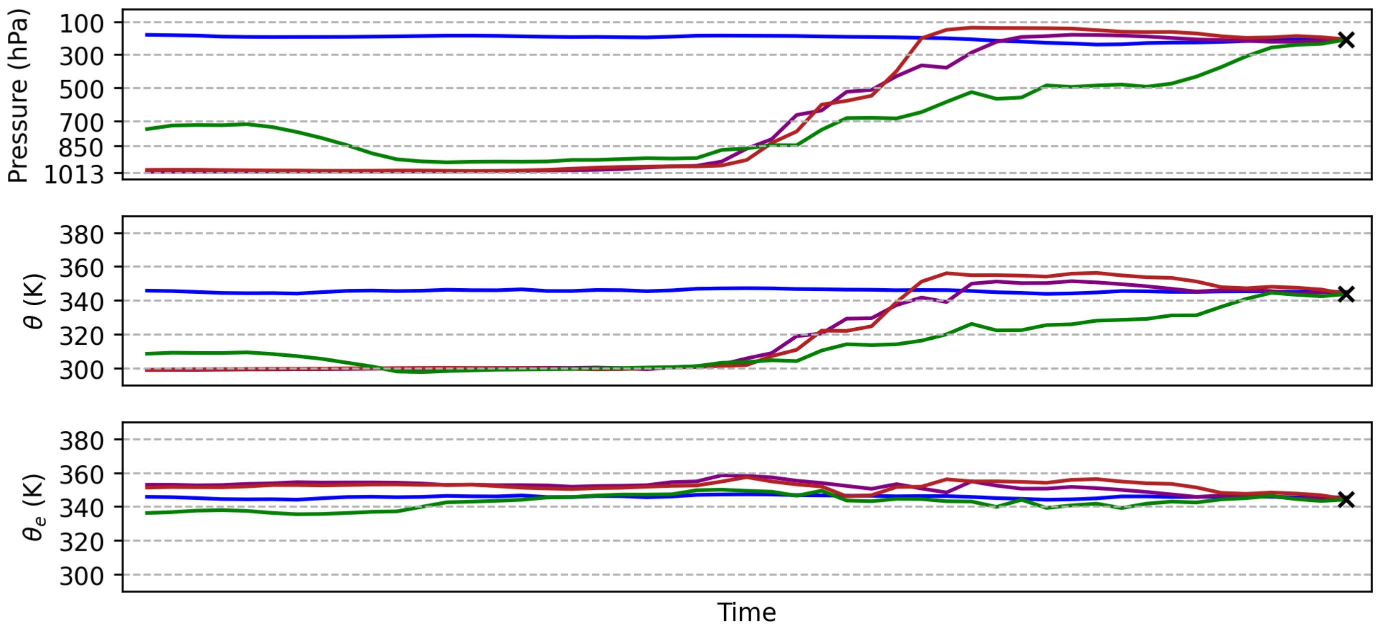
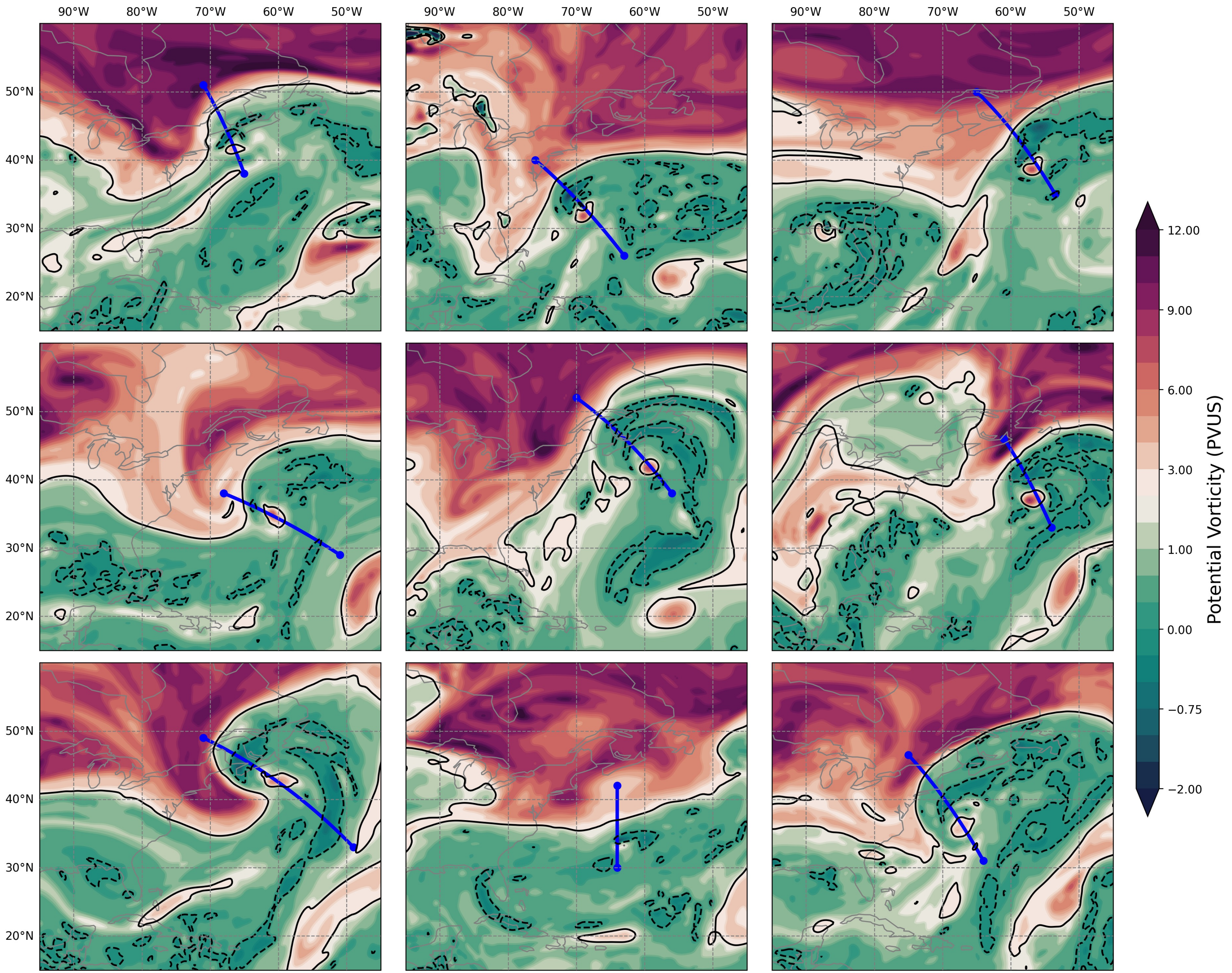
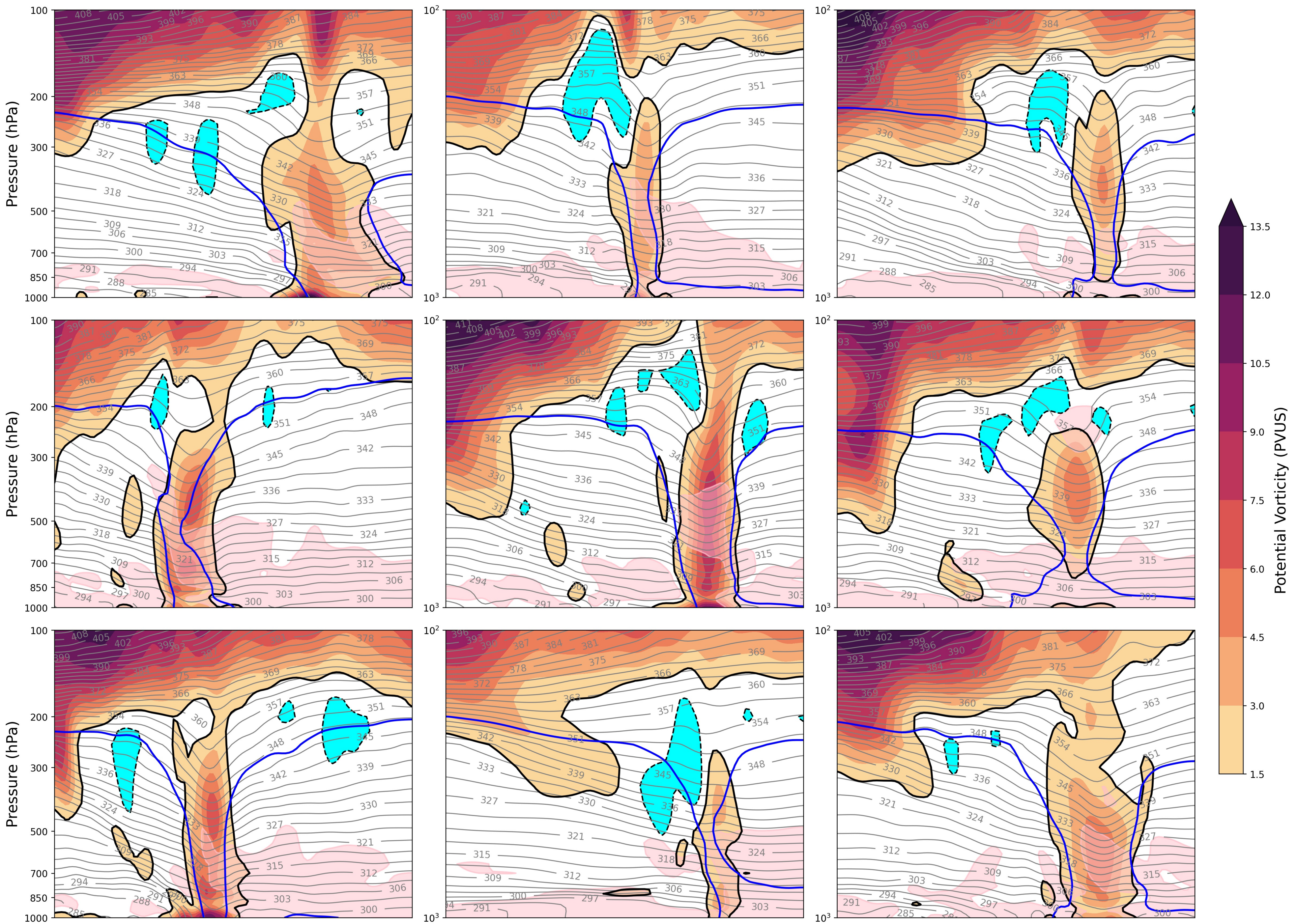


Fig. 5 – 48-hr back trajectories for parcels identified in Fig. 3




90°W
80°W
70°W
60°W
50°W
50°N
40°N
30°N
20°N
Potential Vorticity (PVUS)
12.00
9.00
6.00
3.00
1.00
0.00
−0.75
−2.00



Pressure (hPa)
100
200
300
500
700
850
1000
10^2
10^3
Potential Vorticity (PVUS)
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5

Conceptual Model

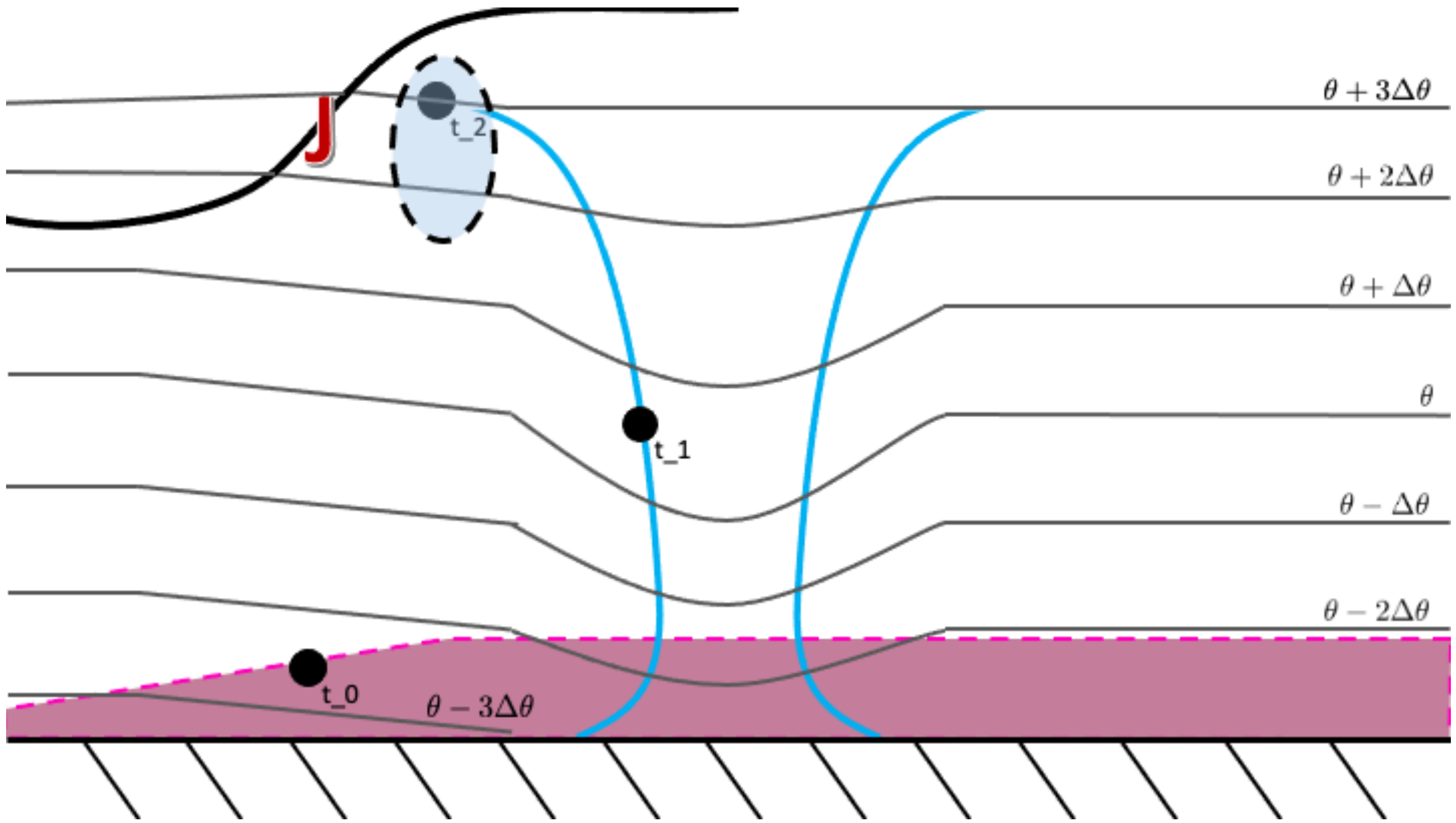


Fig. 4 – As in Fig. 3, except for an arbitrary tropical cyclone near the subtropical jet.

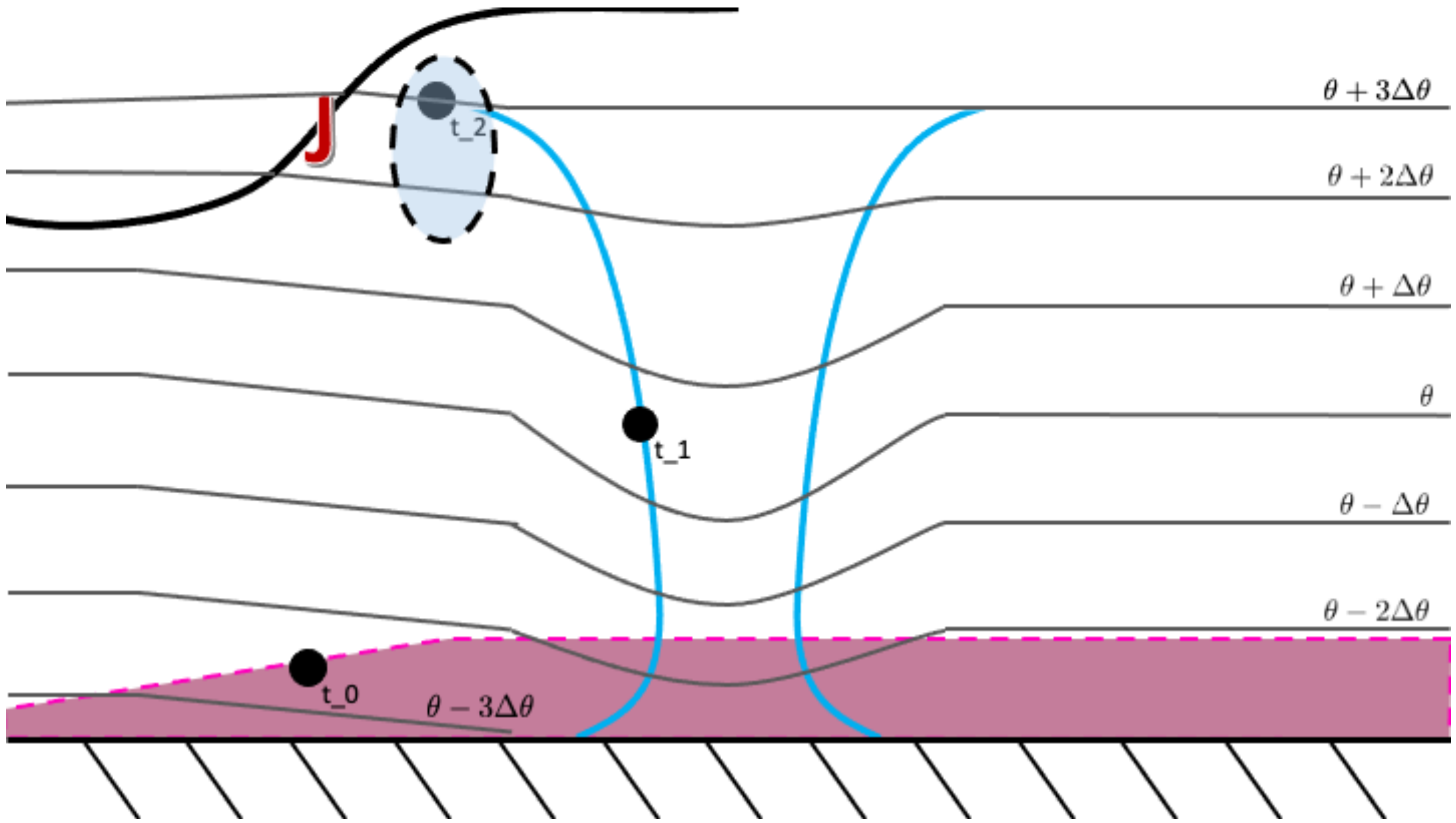
Consider the vertical component of equivalent potential vorticity (MPV)

$$P_e = -g\zeta_a \frac{\partial \theta_e}{\partial p}$$

Let's check the sign of the boundary-layer MPV

$$- = -(+)(+)$$

Conceptual Model



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Conserving MPV for frictionless, saturated processes

$$\left(\zeta_a \frac{\partial \theta_e}{\partial p}\right)_0 = \left(\zeta_a \frac{\partial \theta_e}{\partial p}\right)_2$$

Boundary-layer convective instability was "traded" for inertial instability aloft

Wrapping up

Funding is provided under Ángel F. Adames Corraliza's NSF CAREER grant titled "Understanding how moist processes shape tropical motions

1) The "end-points" method presented here requires a full-3D, along-flow perspective
2) This moist PV framework must be consistent with an Ertel's PV perspective which includes diabatic PV tendencies following

$$\frac{dP}{dt} = \nabla \cdot \vec{\zeta_a} \dot{\theta}$$

Stop by poster #42 to see this term in action!