The Influence of an Upper-Tropospheric Potential Vorticity Anomaly on Rapid Tropical Cyclogenesis

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1. Introduction

- Tropical cyclones (TCs) that undergo rapid tropical cyclogenesis (RTCG) close to land are especially dangerous due to the short advanced warning time
- Many pre-genesis disturbances interact with an upper-tropospheric potential vorticity (PV) anomaly
- The location, magnitude, and spatial scale of the PV anomaly relative to the TC has a profound effect on the environmental favorability for TC genesis and subsequent intensification by modifying environmental wind shear and moisture
- We hypothesize that an upper-level PV anomaly is typically favorable for intensification, if the scale of the PV anomaly is similar to the scale of the TC, by providing forcing for vertical motion over a more concentrated area, which will result in surface pressure falls, genesis, and subsequent intensification

2. Methodology

- Synoptic-scale environments of the analyzed TCs and their pre-existing disturbances are examined over a 72-hour period, commencing 48 hours prior to tropical cyclogenesis (TCG) as per the ERA-Interim Reanalysis
- TCs in the North Atlantic basin from 1980–2013 are classified into three groups based on the maximum sustained surface wind change (ΔV_{max}) 24 hours after TCG from the best-track database:
  - Rapid (RTCG): $\Delta V_{max} \geq 25$ kt
  - Slow (STCG): 5 kt < ΔV_{max} < 25 kt
  - Neutral (NTCG): -5 kt ≤ ΔV_{max} ≤ 5 kt
- The environment that genesis occurred in is defined according to time-averaged maxima in PV on the 350 K isentropic surface within 1000-km of the genesis location
  - High-PV: PV anomaly max > 1.5 PVU
  - Low-PV: PV anomaly max < 1.5 PVU

3. Storm Tracks

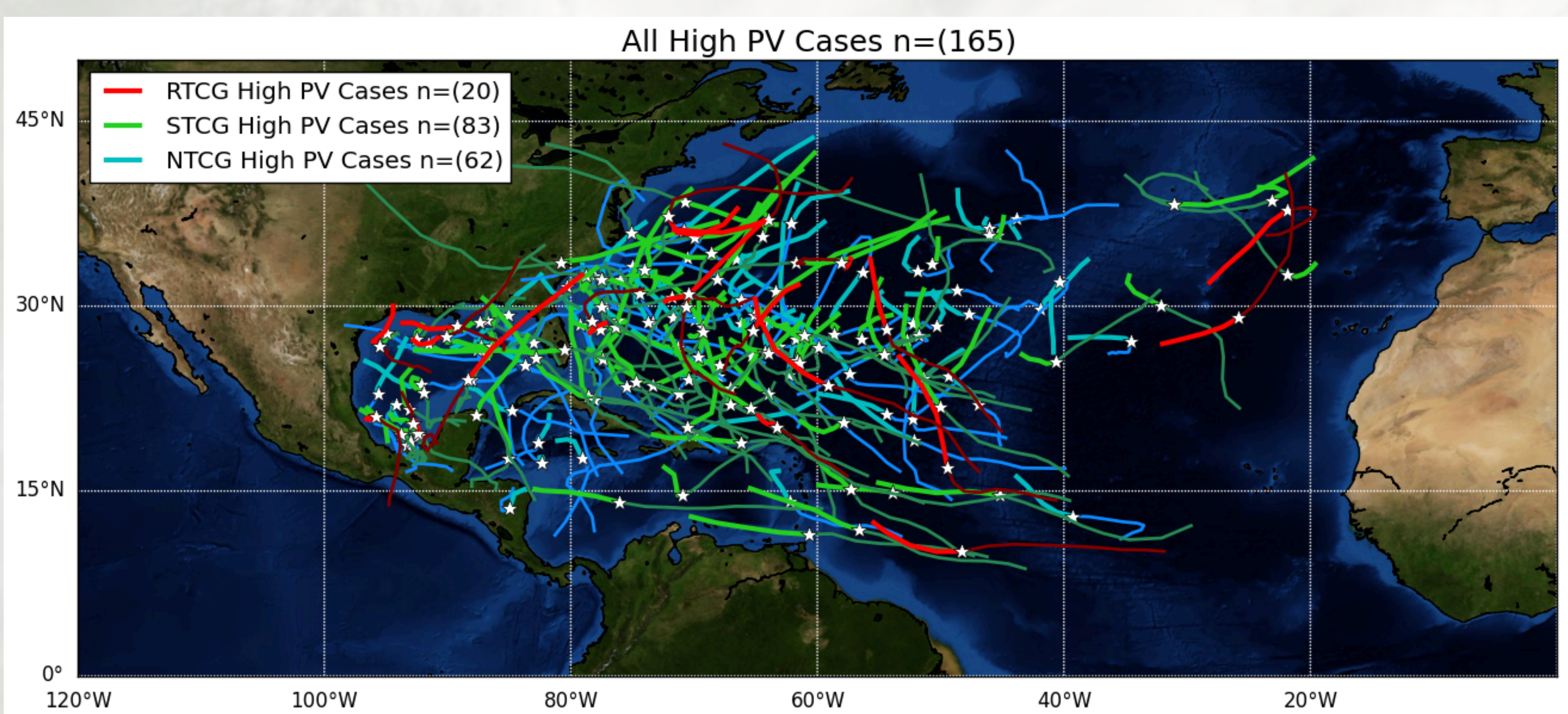


Figure 1. Tracks of the 850-hPa relative vorticity centroids for RTCG (red), STCG (green), and NTCG (blue) high-PV cases. Thicker and brighter lines represent the tracks of the cyclones post-genesis while thinner and darker lines display the pre-genesis tracks. White stars denote the genesis location.

4. PV Evolution

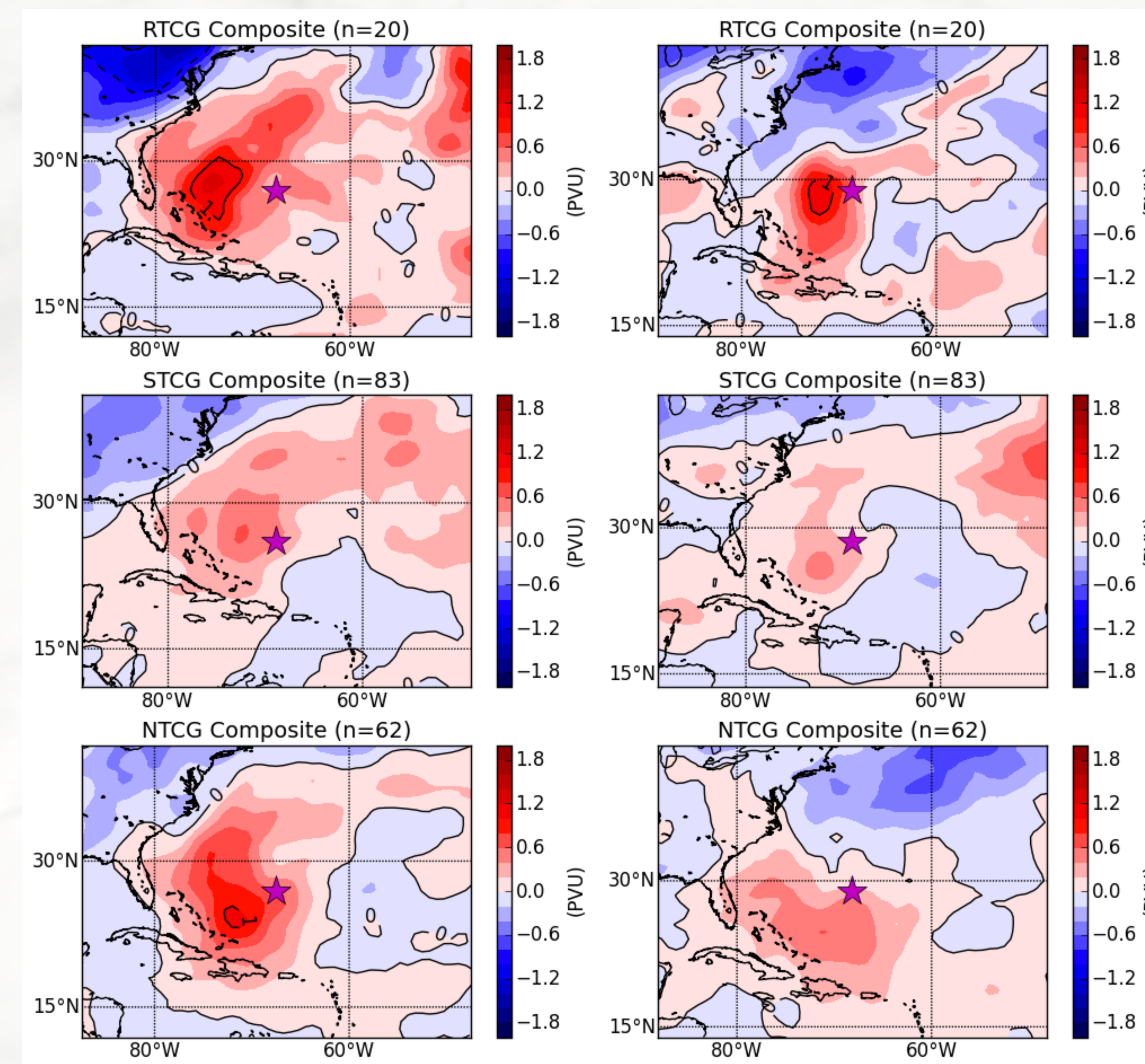


Figure 2. Composite maps of potential vorticity (PV units) on the 350 K isentropic surface for RTCG, STCG, and NTCG cases at the time of genesis (left column) and 24 hours after genesis (right column). The mean TC location is shown by the magenta star. The number of storms in each group is denoted by n.

- RTCG cases have a small but robust PV anomaly in the composite, compared to the other intensity change groups
- Differences in zonal spatial scale, especially 24 hours post-genesis

5. Vertical Motion

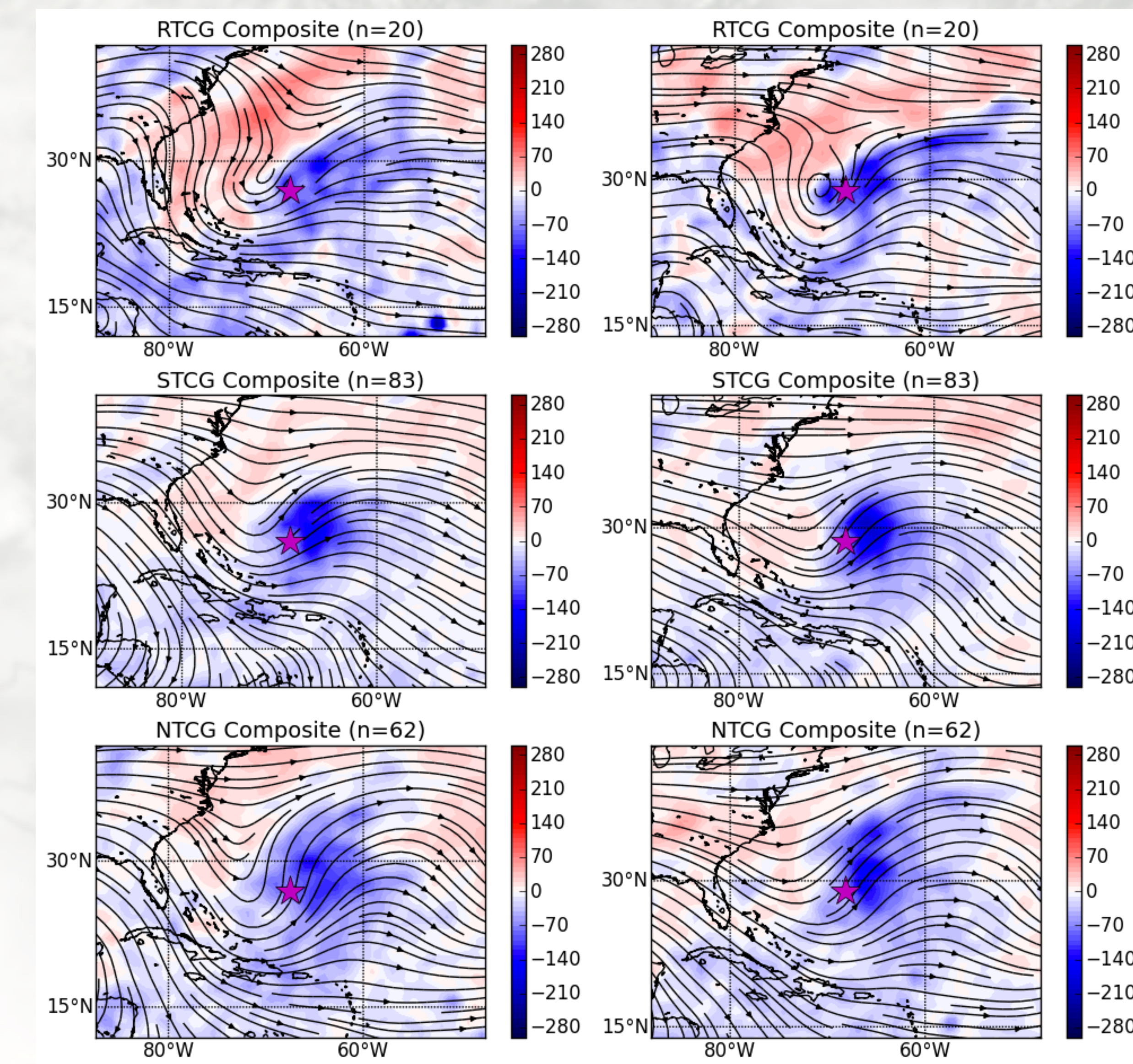


Figure 3. Composite maps of 200-hPa streamlines and 500-hPa vertical motion (hPa day^{-1}) for RTCG, STCG, and NTCG cases at the time of genesis (left column) and 24 hours after genesis (right column). The mean TC location is shown by the magenta star. The number of storms in each group is denoted by n.

- RTCG cases have a more concentrated and symmetric area of vertical motion
- More concentrated pressure falls in RTCG cases; similar to scale of trough

6. Moisture

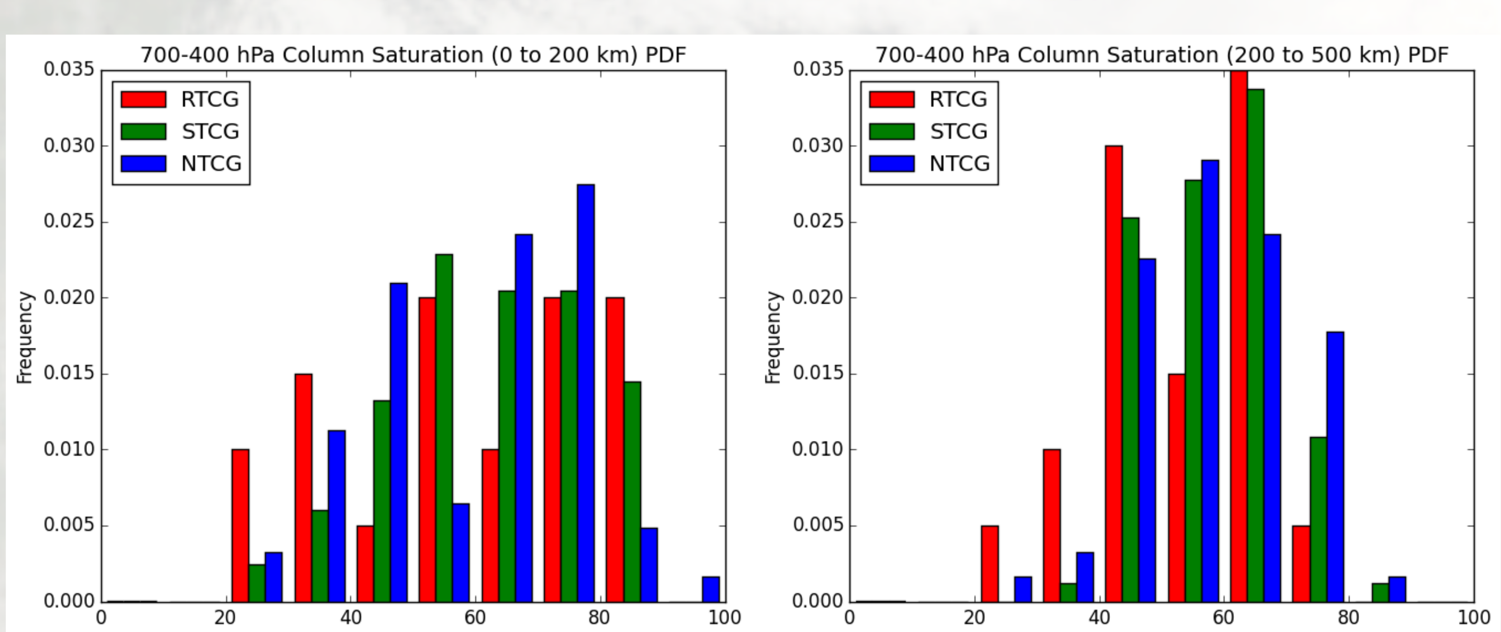
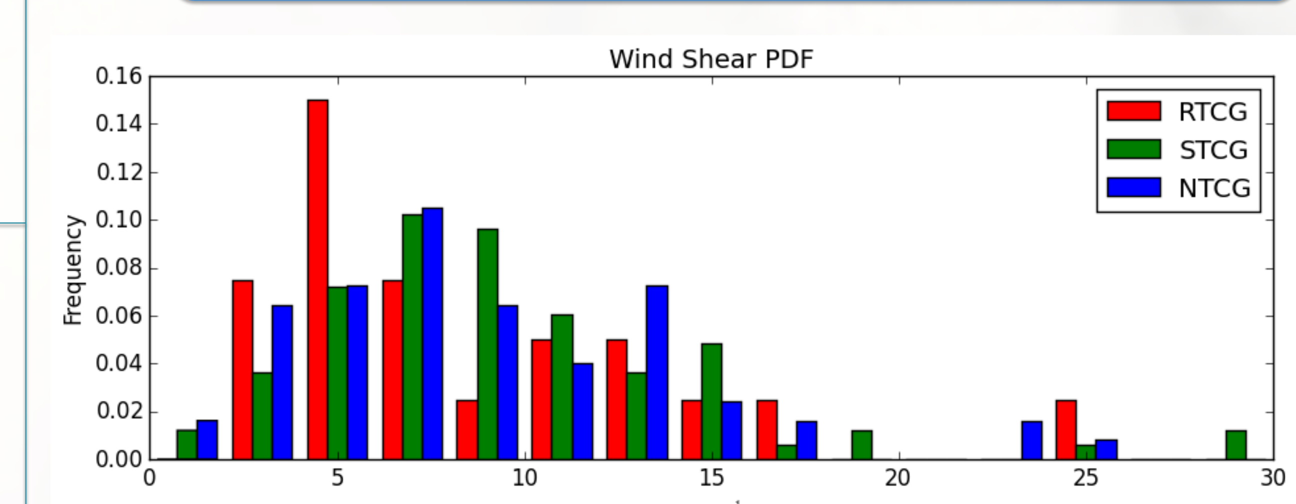


Figure 4. Probability density function of azimuthally averaged 700—400-hPa column saturation fraction (%) for RTCG (red), STCG (green), and NTCG (blue) events within 0 to 200-km of the TC center (left) and 200 to 500-km of the TC center (right).

- RTCG events are typically embedded in environments of less midlevel moisture compared to STCG and NTCG storms

7. Wind Shear



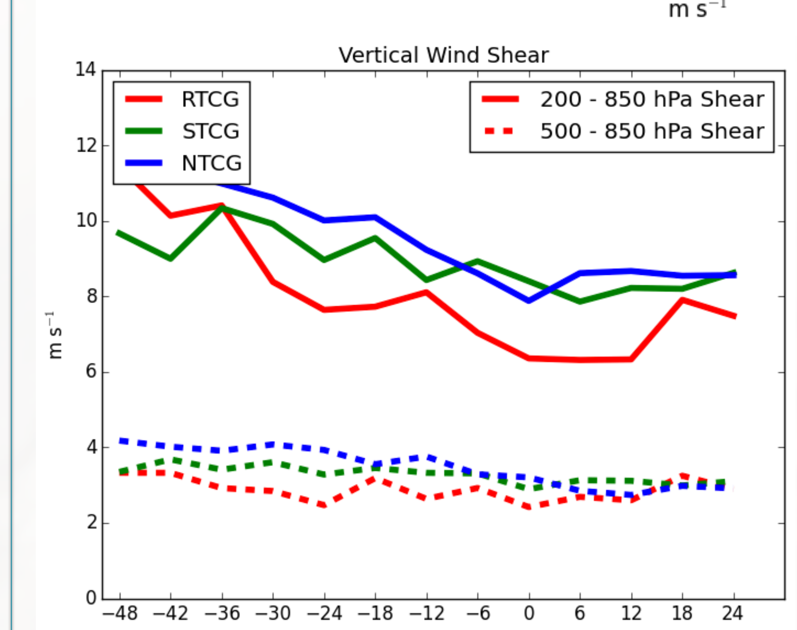


Figure 5. (top) Probability density function of vertical wind shear (m s^{-1}) in the annulus of 200—800-km from the TC center for RTCG (red), STCG (green), and NTCG (blue) cases.
(bottom) Median vertical wind shear (m s^{-1}) for RTCG (red), STCG (green), and NTCG (blue) cases. Solid lines represent 200—850-hPa shear and dashed lines depict 500—850-hPa shear.

- RTCG events occur more frequently in low wind shear environments than the other two intensity change groups

8. Results

- An upper-tropospheric PV anomaly is typically favorable for intensification if the spatial scale of the PV anomaly is similar to the scale of the TC
- A spatially confined trough provides forcing for ascent over a more concentrated area, which results in more focused pressure falls via diabatic heating and subsequently greater rates of intensification
- A higher percentage of RTCG cases are embedded in a high-PV environment (~45%) compared to ~38% of STCG cases and ~31% of NTCG cases
- Future work seeks to take advantage of high-resolution numerical modeling to elucidate how a high-PV environment would affect the inner-core of the tropical cyclone, and consequently, intensity change following genesis

Acknowledgements

- Thanks to Casey Peirano and Kevin Tyle for providing computational and dataset assistance

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