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

Michael S. Fischer, Kristen L. Corbosiero, and Brian H. Tang
Department of Atmospheric and Environmental Sciences
University at Albany, SUNY

Tropical cyclones (TCs) that undergo rapid tropical cyclogenesis (RTCG) close to land are especially dangerous due to the short advanced warning time. Hurricane Humberto (2007) was an example of a RTCG event as the storm intensified by 45 kt in the 19 hours between genesis and landfall on the northwest Gulf Coast. In order to better understand the environments in which RTCG has been observed, the ERA-Interim is utilized to examine upper-tropospheric differences among newly formed TCs in the North Atlantic basin from 1980 to 2013. This study classifies TCs into three groups based on the maximum sustained surface wind change (ΔV_{max}) 24 hours after genesis from the best-track database. The groups are: 1) RTCG, if $\Delta V_{max} \geq 25$ kt; 2) slow tropical cyclogenesis (STCG), if $\Delta V_{max} < 25$ kt, but > 5 kt; and 3) neutral tropical cyclogenesis (NTCG), if $\Delta V_{max} \leq 5$ kt, but ≥ -5 kt. The synoptic-scale environments of the analyzed TCs and their pre-existing disturbances are examined over a 72-hour period, commencing 48 hours prior to genesis.

Many pre-genesis disturbances interact with an upper-tropospheric potential vorticity (PV) anomaly. If a time-averaged PV anomaly spanning the 12-hour period centered on the genesis time exceeds 1.5 PV units within 1000 km of the TC center, the TC is placed into a "high-PV" subgroup. Otherwise, the TC is placed into a "low-PV" subgroup. Results from this study show 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.

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. The mean spatial scale of the upper-tropospheric PV anomaly in the high-PV cases appears anticorrelated with ΔV_{max}, particularly by the end of the intensification period. By 24 hours after genesis, high-PV RTCG cases feature a mean PV anomaly of a spatial scale of approximately 600–800 km in the zonal direction, while high-PV NTCG cases display a mean PV anomaly of approximately 1500–1800 km in the zonal direction. High-PV RTCG cases have more concentrated vertical motion at 500 hPa near the center of the TC, compared to high-PV STCG and NTCG cases, as seen in Figure 1. By having a more concentrated region of vertical motion near the core of the TC, greater rates of latent heat release are focused over a smaller area, promoting stronger pressure falls and greater rates of intensification.

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. Both a dynamic and thermodynamic perspective would be implemented to document the evolution of the convective structure of TCs as they interact with upper-tropospheric PV anomalies of varying spatial scales.

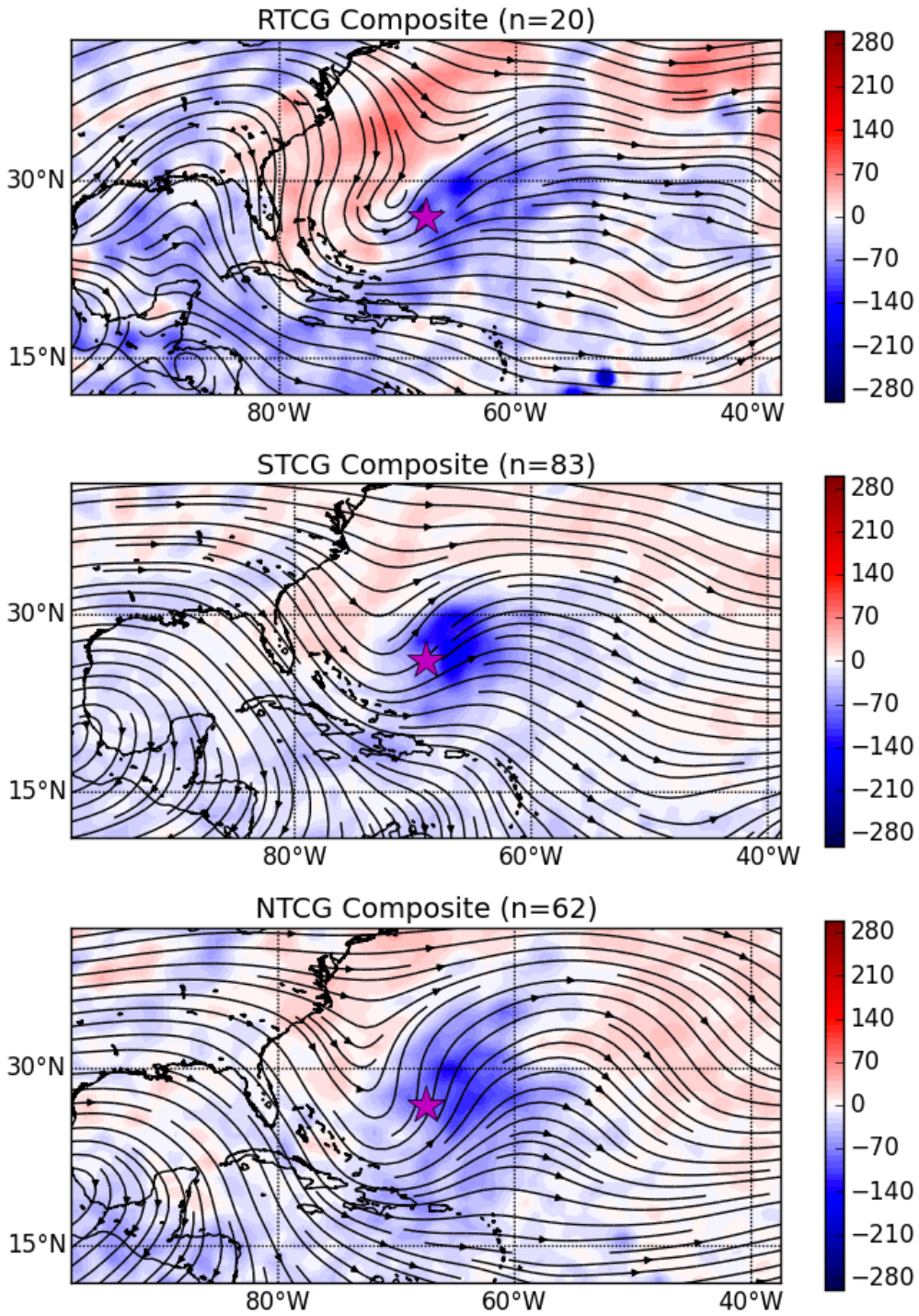

Figure. 1. *Composite mean 200-hPa streamlines and 500-hPa vertical velocity (hPa day^{-1}, shaded) for high-PV cases at the time of genesis. The number of TCs in each group is denoted by n.*