8C.3 ANALYZING THE THERMODYNAMIC IMPACT OF SHEAR ON TROPICAL CYCLONES USING DROPSONDES

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1. INTRODUCTION

Accurately forecasting the intensification of tropical cyclones is a challenge, particularly in moderate shear environments. Case study research (Nguyen et al. 2017, Rogers et al 2016, and Zawislak et al 2016) find a connection between the intensification of tropical cyclones and the symmetrization of the azimuthal precipitation distribution. Intensifying storms exhibit symmetric azimuthal precipitation distributions, whereas non-intensifying storms exhibit an asymmetric azimuthal precipitation distribution with convection located in the downshear region and no convection located in the upshear region. The following three hypotheses were formulated from the previous case study research (Nguyen et al. 2017, Rogers et al. 2016, and Zawislak et al. 2016) about the shear-related processes that might prevent the symmetrization of the azimuthal precipitation distribution and intensification: (1) Strong downdrafts from downshear convection bring cold, stable air into the boundary layer which is advected upshear, (2) Upshear subsidence leads to decreased relative humidity and the formation of a capping inversion, and (3) Dry air is advected into the upshear region from the environment.

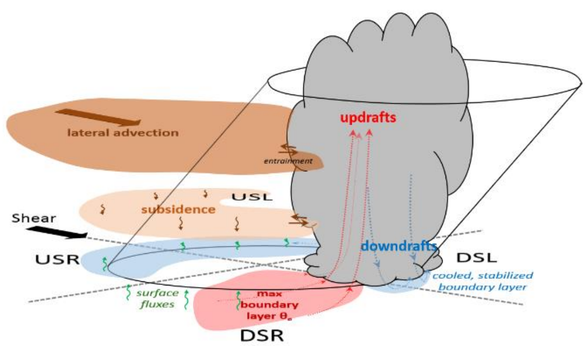

Figure 1. Schematic of the three case study hypotheses. Credit: Nguyen et al 2017

This study tests the generalizability of these case study hypotheses.

2. METHODOLOGY

This study uses a dataset of 20,733 dropsondes dropped from various aircraft over the Atlantic or Pacific Oceans from 1996-2016. The dataset also includes information about the tropical cyclones' position interpolated between aircraft fixes, intensity from NHC's best track, and environmental parameters, such as shear, from the SHIPS developmental dataset. Only observations between 50 km and 200 km from the tropical cyclones' centers were used. Observations within 50 km were excluded due to uncertainty in position of the centers of the tropical cyclones Observations greater than 200 km were excluded to focus on the structure of the tropical cyclones, rather than their environment. Dropsondes were then separated by intensity using the maximum sustained wind speed values. The 'Hurricanes' category corresponds to Categories 1 and 2 on the Saffir Simpson Scale. The 'Major Hurricanes' category corresponds to Categories 3-5 on the Saffir Simpson scale.

Intensity Category	Maximum Sustained Wind Speed (knot)
Tropical Depressions and Storms	< 64
Hurricanes	64 - 95
Major Hurricanes	> 95

The dropsonde data was further separated by the magnitude of the deep vertical wind shear.

Shear Category	Deep Vertical Wind Shear Magnitude (m/s)
Low	<5
Moderate	5 - 10
High	>10

Visual graphics of equivalent potential temperature and relative humidity were created in a shear relative framework. Results from these graphics were tested for statistical significance using the Bootstrap method.

3. RESULTS

Figure 2 shows the mean equivalent potential temperature in each shear-relative quadrant for low shear and high shear hurricane cases. The left of shear quadrants have low equivalent potential temperatures as they are the first to be impacted by the intrusion of cold, stable air via downdrafts. An increase in equivalent potential temperature is observed as the air is advected counterclockwise into the upshear right region as surface fluxes from the ocean work to moisten the air. This process of recovery continues as the air is advected into the downshear right region where a maximum in equivalent potential temperature is observed.

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Two differences are identified when Figures 2a and 2b are compared. First, there are greater equivalent potential temperature differences between the quadrants in hurricanes experiencing high shear. Second, the average equivalent potential temperature of hurricanes in high shear environments is lower than in low shear environments. These observations indicate that colder, more stable air is present in the boundary layer of tropical cyclones experiencing high shear.

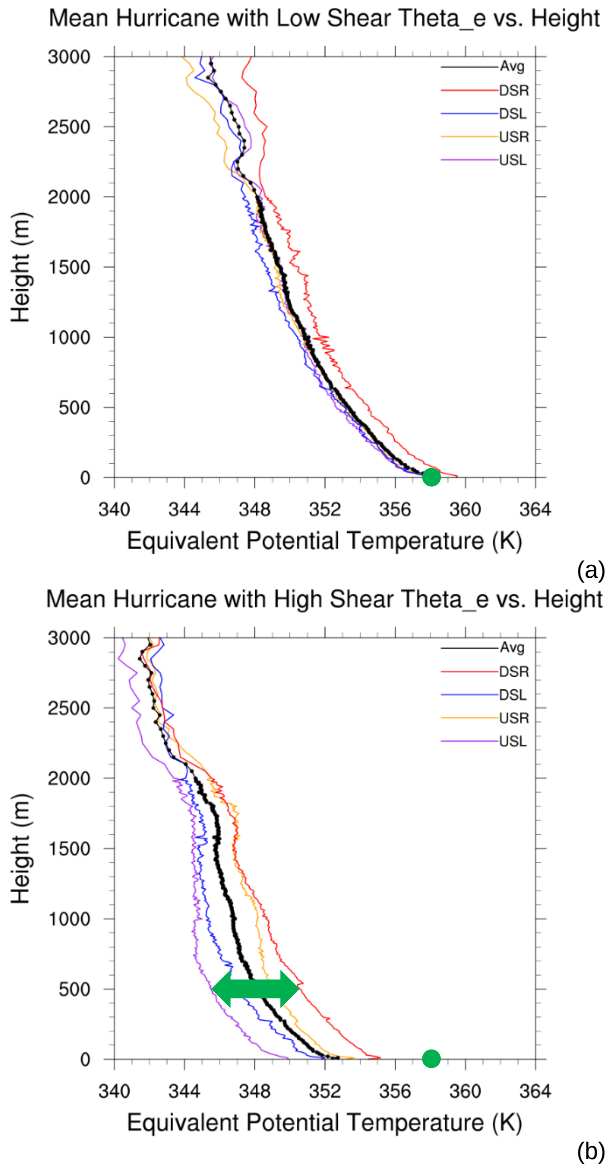

Figure 2. The average equivalent potential temperature for each shear-rotated quadrant for (a) low shear and (b) high shear hurricane cases. The blue line represents the downshear left. The purple line represents the upshear left. The orange line represents the upshear right. The red line represents downshear right. The black line represents the average of all the quadrants. The thicker portions of the black line indicate that there is a statistical significant difference between the average equivalent potential temperatures in the low shear cases and those in the high shear cases to the 95th percentile. The green dot represents the average surface equivalent potential temperature for the low shear cases. The length of the double arrow emphasizes the increase in the difference between the average equivalent potential temperature in each quadrant.

Figure 3 shows the mean relative humidity for each shear category for the downshear right and upshear left quadrants of tropical depressions and storms. There are relatively small differences between the average observed relative humidities in Figure 3a. Statistically significant drying throughout the mid-upper levels of the troposphere as shear increases is observed in Figure 3b.

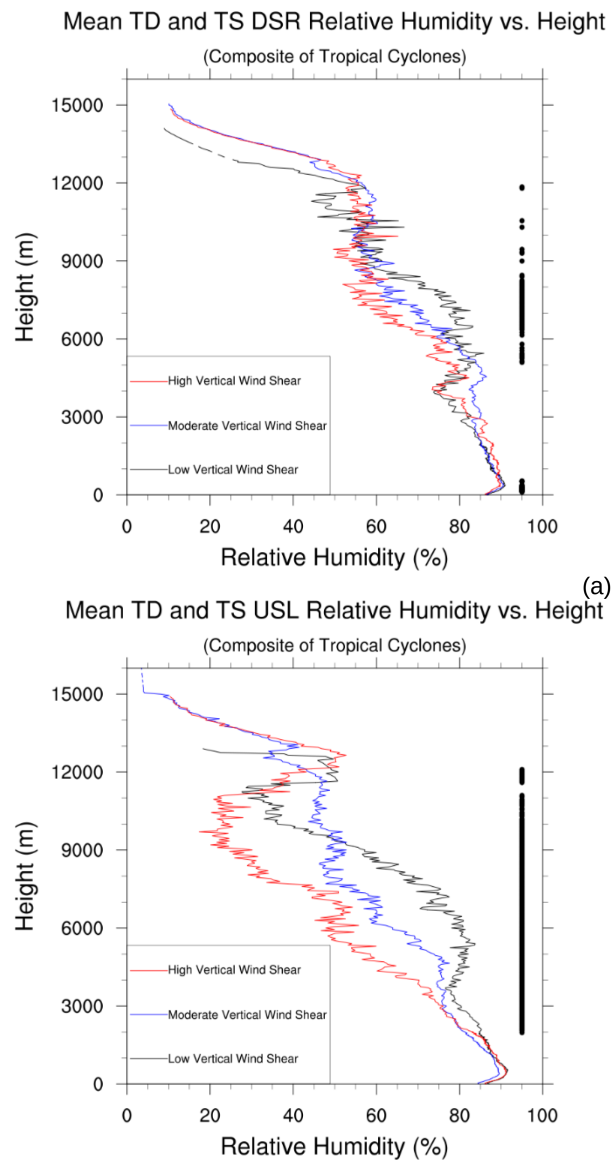

Figure 3. The average relative humidity in each deep vertical wind shear category for the (a) downshear right

quadrant and (b) upshear left quadrant of tropical depressions and storms. The black line represents the low shear cases. The blue line represents the moderate shear cases. The red line represents the high shear cases. The thick black lines on the right indicate the difference between the low and high shear cases is statistically significant.

4. CONCLUSIONS

This study found that cooler, more stable air is present in the boundary layer in high shear cases. It is speculated that this air is brought into the boundary layer by downshear convective downdrafts. Either stronger downdrafts are bringing more cold, stable air into the boundary layer or colder, more stable air is entering into the boundary layer in the high shear cases. The study also found that mid-upper tropospheric, upshear relative humidity decreases with increasing shear. It is speculated that this observation is due to the presence of stronger subsidence or the advection of greater amounts of dry air from the environment in high shear cases.

5. REFERENCES

Nguyen, L., R. F. Rogers, and P. D. Reasor, 2017: Thermodynamic and Kinematic Influences on Precipitation Symmetry in Sheared Tropical Cyclones: Bertha and Cristobal (2014)

Rogers, R. F., J. Zhang, J. Zawislak, H. Jiang, G. Alvey, E. Zipser, and S. Stevenson, 2016: Observations of the structure and evolution of Hurricane Edouard (2014) during intensity change. Part II: Kinematic structure and the distribution of deep convection. *Mon. Wea. Rev.*, **144**, 3355-3376, doi: 10.1175/MWR-D-16-0017.1.

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