5D.5 EXAMINATION OF TROPICAL CYCLONE STRUCTURE AND INTENSIFICATION WITH THE EXTENDED FLIGHT LEVEL DATASET (FLIGHT+) FROM 1999 TO 2012

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1. INTRODUCTION

The structure of a tropical cyclone (TC) is influenced by both internal dynamical and external environmental processes. These physical processes are actively linked to the intensification of the TC and often manifest themselves as structural changes at various stages in the TC's life cycle. Therefore, analyzing the feedback mechanisms between TC structure and intensification remains crucial to improving our understanding of these physical processes and ultimately improving our intensity forecasts.

This study seeks to provide additional insight into the relationship between structure and intensification through the construction of kinematic and thermodynamic axisymmetric composite structures using aircraft data. In contrast to previous studies that have investigated the structural differences between TCs that are intensifying and remaining steady-state (Kossin and Eastin 2001; Rogers et al. 2013), the current work stratifies an updated dataset based on both TC intensity and intensity change, providing a novel approach to examining TC structure.

2. DATA AND METHODS

The stratification of TCs by intensity and intensity change was performed using the National Hurricane Center's Best Track (BT) database. The TC intensities were extracted directly from the BT data as the maximum 1-min sustained 10-m wind speed. This variable was then used to calculate the centered 12 hour intensity change around each BT synoptic time. BT fixes recorded at synoptic times (excluding extratropical transition and those near landfall) from 1999 to 2012 were then binned by intensity and intensity change.

The kinematic and thermodynamic radial structure of TCs were examined using flight level data gathered from the Extended Flight Level Dataset (FLIGHT+), a comprehensive database containing in situ data recorded by the NOAA WP-3D and USAF WC-130 aircraft during flight missions through TCs (Vigh et al. 2016). The average date and time of a given flight was rounded to the nearest synoptic time and flights were subsequently matched to the binned BT fixes. The azimuthal mean structure of each binned flight was computed from all of the individual radial legs at 700 hPa comprising that flight. The radial coordinate of each azimuthal mean was normalized by the radius of maximum tangential wind (RMW) to provide uniformity when calculating the composite-means and is given by r^*.

Composite-mean kinematic and thermodynamic structures were then computed by averaging all of the azimuthal means in each intensity and intensity change bin. The hurricane bin contains Category 1 and 2 TCs on the Saffir-Simpson scale and the major hurricane bin contains Category 3 and above. The centered 12 hour intensity change bins were defined as intensifying [IN, intensity increase $\geq$ 10 kt (12 h)$^{-1}$], steady-state [SS, intensity change between $\pm$ 5 kt (12 h)$^{-1}$ inclusive], and weakening [WK, intensity decrease $\leq$ -10 kt (12 h)$^{-1}$]. A two-tailed Wilcoxon-Mann-Whitney rank-sum test was carried out in each intensity bin to determine radial locations of statistically significant differences amongst the composite-means at the 5% level.

3. RESULTS

A total of 241 flights comprised of 1545 radial legs were included in the creation of the composite-mean structures. Figure 1 shows the composite-mean structures of storm-relative axisymmetric tangential wind speed, revealing that IN hurricanes had a steeper increase of tangential wind speed inside the RMW compared to SS or WK hurricanes. Similar distinctions were reported by Shea and Gray (1973) and Kossin and Eastin (2001) using different datasets and compositing techniques, suggesting this structural difference is a robust feature of intensifying hurricanes. In contrast, major hurricanes

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exhibited larger differences radially outward of the RMW, where IN major hurricanes had the steepest decay of tangential wind speeds followed by SS and then WK major hurricanes. Rogers et al. (2013) also found that SS TCs have higher tangential wind speed in this region compared to IN TCs.

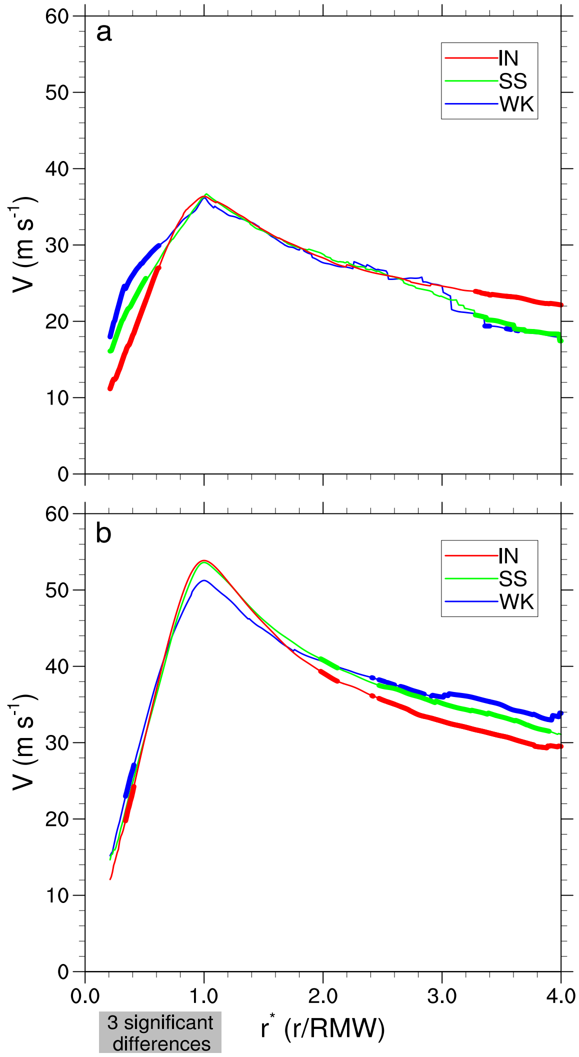

Figure 1: Axisymmetric tangential wind speed composite-means for hurricanes (a) and major hurricanes (b). Radial locations where all composite-means were significantly different at the 5% level are shaded in gray and two significantly different composite-means are denoted in bold.

Figure 2 shows the composite-mean structures of axisymmetric vertical vorticity. IN TCs (hurricanes and major hurricanes) possess a ring-like structure of vorticity with vorticity maximized radially inward of the RMW, a feature attributed to the steep increase of tangential wind speeds inside the RMW. A ring-like structure of vorticity was also documented by Kossin and Eastin (2001) and Rogers et al. (2013) for intensifying TCs. Interestingly, WK major hurricanes also have a ring-like structure of vorticity while WK hurricanes do not. The vorticity structure for WK major hurricanes could be the manifestation of high barotropic instability leading to the breakdown of the vorticity ring (Schubert et al. 1999) and the consequential weakening of the system.

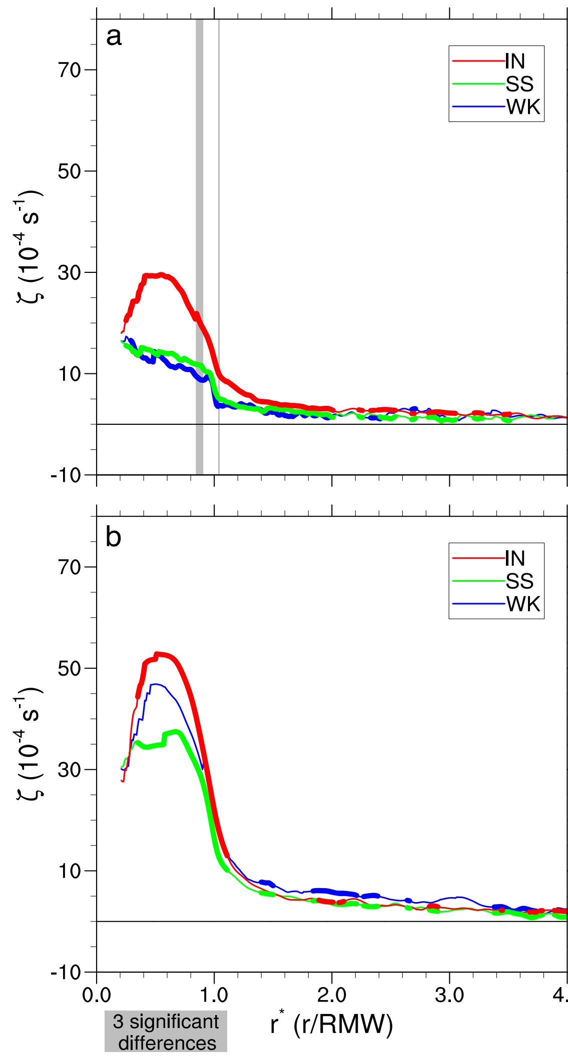

Figure 2: As in Figure 1, but for axisymmetric vertical vorticity.

Thermodynamic differences across the intensity and intensity change spectrum were also apparent in the composite-mean structures. Figure 3 illustrates the composite-mean structures of dewpoint depression, revealing that both IN hurricanes and major hurricanes had higher moisture radially outward of the RMW compared to SS or WK TCs. IN major hurricanes had drier eyes compared to SS or WK TCs.

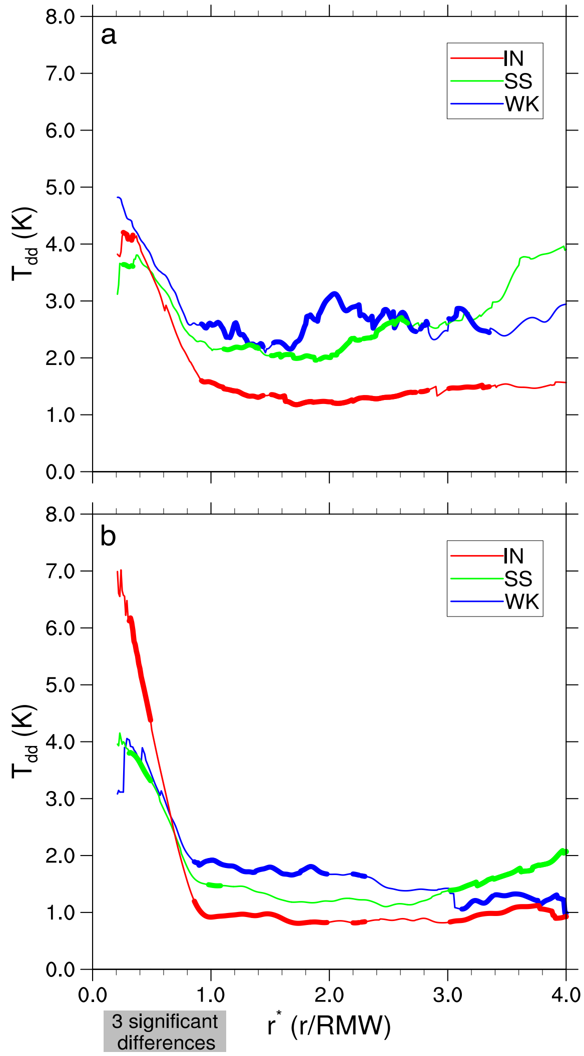

Figure 3: As in Figure 1, but for dewpoint depression.

4. CONCLUSIONS

Axisymmetric composites of TCs were constructed using the FLIGHT+ database from 1999 to 2012. Statistically significant differences in the composite-mean kinematic and thermodynamic structure of TCs were observed when stratified by intensity and intensity change. These results suggest that different physical processes may be involved in intensification or weakening depending on the intensity of the TC. Furthermore, the composites suggest that aircraft observations of TC axisymmetric radial structures could be applied to intensity forecasting. IN hurricanes had the characteristics of steep tangential wind gradients in and outside of the RMW, a ring-like structure of vorticity inside the RMW, and high moisture content radially outward of the RMW. These features distinguished IN hurricanes from SS and/or WK hurricanes, implying that the radial structure of these TCs can provide information about potential intensification. Major hurricane intensity composites showed a similar but distinct set of structural differences. This study has established relationships between structure and intensification for TCs during different intensification phases. Continued analysis will investigate these relationships through further examination of the physical processes at different intensification phases aimed towards improving intensity change forecast guidance.

5. REFERENCES

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