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THERMODYNAMIC STRUCTURE OF TROPICAL CYCLONES FROM AIRCRAFT RECONNAISSANCE

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1. INTRODUCTION

The study of tropical cyclone structure has been proceeding steadily for well over half a century, and with the introduction of routine penetrations into tropical disturbances a large dataset of basic measurements now exists. This research uses this data to provide a broad insight into tropical cyclone structure.

This paper shows how the thermodynamic structure of tropical cyclones varies as a function of radius with increasing storm intensity and height, with emphasis on the equivalent potential temperature (θ_e) field.

2. DATA AND METHODOLOGY

The US Air Force collected the data used in this study on routine reconnaissance flights into tropical and subtropical disturbances in the Atlantic, Caribbean and Gulf of Mexico region. From temperature and dewpoint information collected during such investigations, the equivalent potential temperature was calculated, following Bolton (1980). This research focuses only on named storms in this region, in the period 1995-2002, giving a total 67 storms containing 551 flights with usable data.

The θ_e data used in this study has a temporal resolution of 30 seconds. Combining this with 6-hourly Best Track positions produced by the National Hurricane Center (NHC), linearly interpolated to 1-minute storm-centre positions, scatter plots of θ_e as a function of radius from the storm centre have been produced, similar to those from Raymond et al. (1998).

For simplicity, only the axisymmetric structure is considered, i.e. all azimuths are projected along one radial line, enabling the results to be plotted as a function of radius. This gives a range of θ_e values at each radius, since each reconnaissance flight is comprised of a number of different flight legs into the storm, from various directions. A compositing method was employed to produce profiles of "average" radial θ_e structure for each storm intensity.

To make each storm-category composite, the individual flights were sorted into groups of particular storm intensities. This was done using the Best Track intensities produced by NHC, and noting that if storm category changed during the flight, the new category was assumed to begin at the 6-hour best-track time at which it was first defined. Storm strength was assumed to be at the previously defined category up until then.

The influence of instrument wetting (Eastin et al. 2002) will be addressed in the talk.

3. RESULTS

Figure 1 shows some examples of the θ_e scatter plots for Hurricane Bret (1999), which formed in the Bay of Campeche in mid-August and tracked northwards to make landfall on Padre Island, TX as a category three hurricane at approximately 00Z on 23rd August. The four panels of Fig. 1 show consecutive flights into Bret; the first two panels show scatter plots below 500m and the second two near 1500m. During the flight shown in a), Bret was strengthening from a tropical depression (TD) to a tropical storm (TS), and in b) Bret was at TS strength. These θ_e plots both show very uniform values at all radii, except that in panel b) core values (i.e. within 25km of the centre) have elevated by around 5K.

Panels c) and d) show θ_e profiles with Bret as a TS in c), and strengthening to a category-one hurricane (H1) in d). Both these profiles show a much larger radial θ_e gradient inside of 100km than the profiles in a) and b). The lower θ_e values observed at outer radii, i.e. at radii greater than 100km, are a result of the increase in the mean flight altitude.

Figure 2 shows two plots resulting from compositing all the 67 storms. Both panels consider only TS and H1 strength storms. The change of inward radial gradient of θ_e with radius and storm strength is shown in a). Both curves in this panel exhibit a structure with very weak radial θ_e gradients outside approximately 150km, and inside this radius the gradient increases with decreasing radius. The rate of increase of this radial gradient is faster for H1 strength than for TS strength.

To appreciate the vertical structure of TS and H1 strength tropical cyclones, the difference between composite θ_e values at 2 levels was determined. Sufficient data were present to allow this to be calculated between 0-500m and 0.5-2km for TS

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strength, and between 0.5-2km and 2-3.5km for H1 strength. Both of these curves are illustrated in Figure 2b. The θ_e difference was calculated as lower-level minus upper-level so that a positive value indicates an upward decrease of θ_e. Both strengths of cyclones are convectively unstable at all radii and the magnitude of the convective instability decreases with increasing intensity. In both profiles, convective instability increases with radius such that at inner radii both storm strengths are close to convective neutrality.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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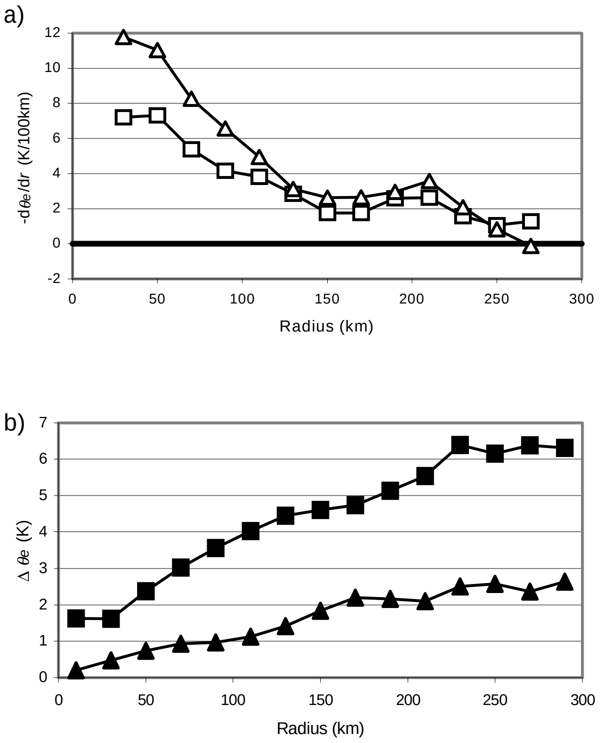

Figure 2: Elements of thermodynamic structure as a function of radius, for composite tropical storms (squares) and category one hurricanes (triangles), a) inward radial gradient of θ_e and b) vertical θ_e difference (see text for further details).

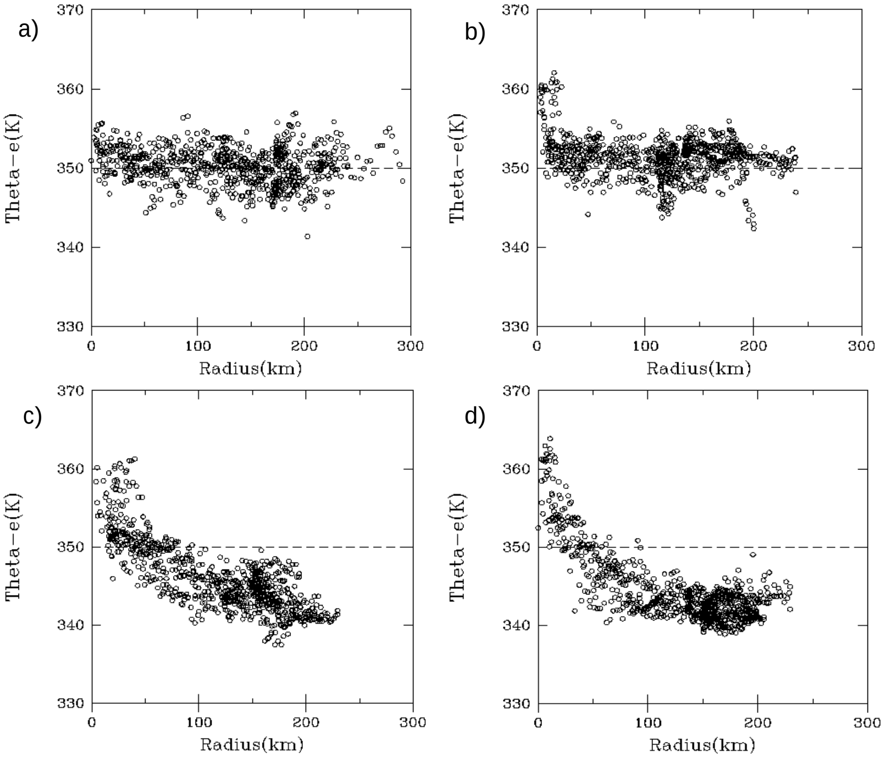

Figure 1: Scatter plots of θ_e plotted as a function of radius for four reconnaissance flights into Hurricane Bret (1999), a) 0-500m, 08-19Z 19th August, b) 0-500m, 21Z 19th - 07Z 20th August, c) 0.5-2km 09Z- 20Z 20th August, and d) 0.5- 2km, 21Z 20th - 07Z 21st August (see text for further details).