6D.2 OBSERVED VORTEX AND THERMODYNAMIC STRUCTURE OF HURRICANE ISABEL AT MAXIMUM INTENSITY

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I. Introduction

Hurricane Isabel was at or near category 5 intensity on the Saffir-Simpson scale from September 11th – 14th. A comprehensive observational dataset was obtained during this period through multiple aircraft reconnaissance missions by the NOAA Hurricane Research Division (HRD) and Air Force Hurricane Hunters. Multiple NCAR GPS dropwindsondes, in situ flight level data, Doppler radar data, and high-resolution satellite imagery were recorded, detailing an unprecedented look at the kinematic and thermodynamic structure of Isabel at maximum intensity over three days.

On September 13th, the strongest known wind (107 ms^{-1}) ever recorded in a hurricane was obtained by a dropsonde at 1752 UTC (see Aberson et. al. 2004 for details). This observation, along with satellite and radar imagery, suggests the possibility of strong mesovortices in the eyewall that have been predicted by laboratory and numerical simulations (Montgomery et al., 2002; Kossin and Schubert, 2001). One consequence of these mesovortices is the potential for mixing of high entropy air from the eye to the eyewall, providing an additional energy source for the hurricane engine. By utilizing this energy, the hurricane can obtain a "superintense" state (Persing and Montgomery, 2003 hereafter referred to as PM) that exceeds the maximum potential intensity (MPI) proposed by Emanuel (1986). A preliminary analysis of the dropsonde and flight-level data was performed here to determine whether Isabel meets the criteria for superintensity.

II. Hurricane Structure

59 HRD dropsondes from the 13th were processed with a preliminary quality control and their GPS locations were compared to storm centers calculated from flight level data. A subset of 28 eye and eyewall soundings from 1600 – 2000 UTC containing wind and thermodynamic data from nearly all radials from the storm center were used to diagnose the tropical cyclone (TC) structure. Their locations and trajectories relative to the center are shown in Figure 1.

By averaging the data in 10 km horizontal and 500 m vertical bins, an estimate of the axisymmetric TC intensity can be obtained. This is shown in Figure 2. The radius of maximum wind (RMW) slopes outward with height from the surface to the 1000 – 1500 m level. At the 1000 – 1500 m level the peak mean wind speed of 76.5 ms^{-1} is found, at an RMW between 50 and 60 km. The mean wind speed has a standard deviation of 5 ms^{-1}.

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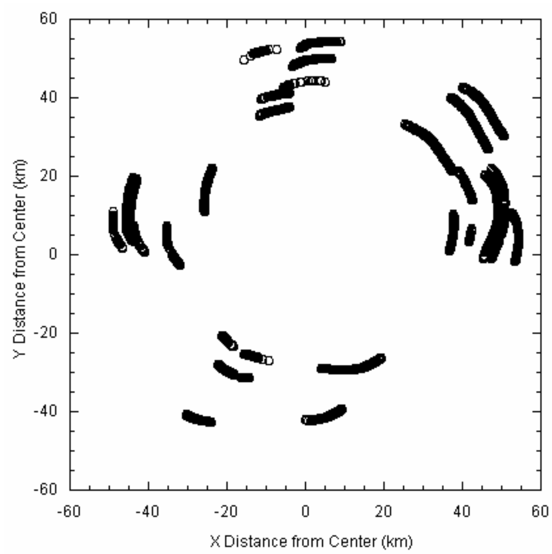

Figure 1. Location and trajectories of GPS Dropsondes relative to storm center.

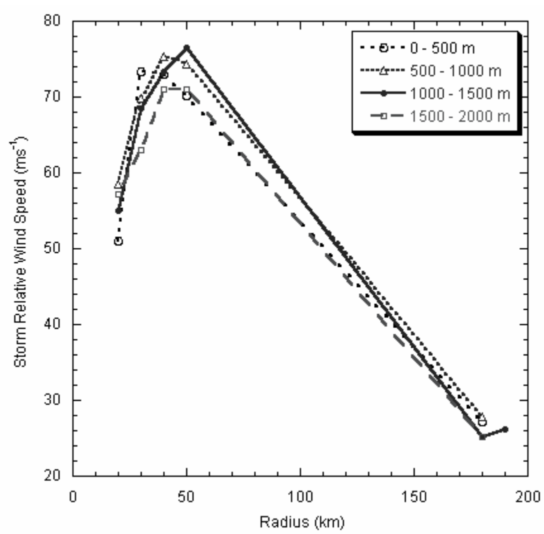

Figure 2. Radial profile of storm relative winds derived from GPS dropsonde data from 1600 – 2000 UTC 13 September 2003, averaged over 10 km horizontal and 500 m vertical bins.

A radial mean profile of equivalent potential temperature can also be obtained using this compositing technique, and the results are shown in Figure 3. A reservoir of high theta-e (high entropy) air is evident just inside the eyewall. The surplus of ~8 K in the eye region is consistent with previous composites of

TCs which have reached their maximum intensity (LeeJoice, 2001) and with the PM results found using a high-resolution numerical model. In the presence of eyewall mesovortices, this thermodynamic potential could be utilized to provide additional energy which exceeds the weakening tendency associated with barotropic instabilities at the eyewall.

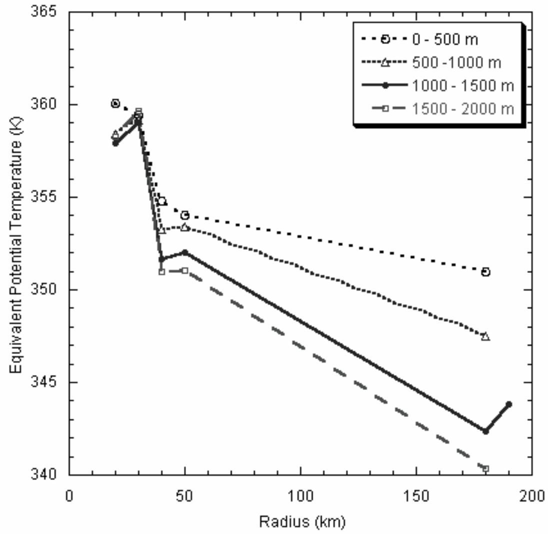

Figure 3. Radial profile of equivalent potential temperature derived from GPS dropsonde data from 1600 – 2000 UTC 13 September 2003, averaged over 10 km horizontal and 500 m vertical bins.

III. Discussion

To determine the MPI for Hurricane Isabel at this time, accurate outflow and sea surface temperature estimates are required. From the PM numerical model results, a reasonable estimate of the mean outflow layer was determined to be from 10 – 14 km altitude. Analysis of sonde data from these altitudes obtained from the NOAA G-IV indicates that the mean temperature in this layer around this time period was -45º C, with a standard deviation of 6º C. For sea surface temperatures, MODIS satellite thermal imagery (not shown) averaged over the previous week was near 28º C for the region. ARGOS buoys floating near this area on the 13th confirm this remote estimate. From the dropsondes, a mean relative humidity in the eyewall inflow layer was found to be between 80 - 85%. From Fig. 4, (similar to Fig. 2 in PM), these estimates indicate an MPI of 52 - 56 ms^{-1}. Since this figure does not take into account dissipative heating (Bister and Emanuel, 1998), a more accurate estimate might be nearer to 65 ms^{-1}. In either case, the observed intensity is between 6 - 17 ms^{-1} greater than this theoretical upper bound, and suggests that the superintensity mechanism is operative.

While there is some uncertainty in these initial estimates, this appears to be the first detailed observational evidence of the attainment of the superintense regime first predicted and explained by PM. Additional analysis of the dataset, including the three-dimensional Doppler derived winds, is in progress and should provide further insight into the structure, intensity, and dynamics of Isabel.

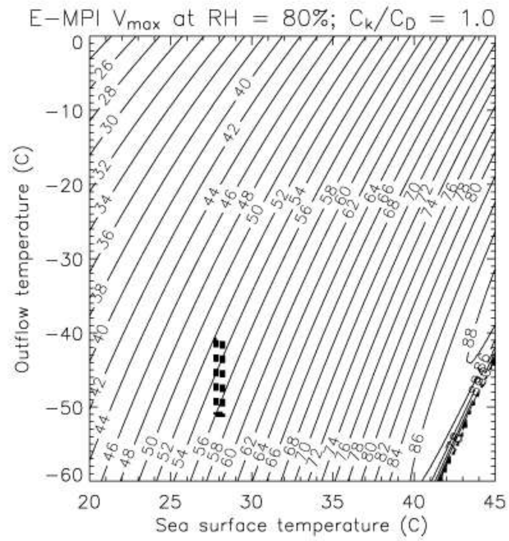

Figure 4. Maximum Potential Intensity as a function of sea surface and outflow temperatures at 80% relative humidity; the ratio of enthalpy and momentum exchange coefficients is assumed to be unity (Ck/Cd =1). Dashed region indicates range of observed values in Isabel.

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