P1.55 EYEWALL BOUNDARY LAYER STRUCTURE IN HURRICANES FABIAN AND ISABEL

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1. INTRODUCTION[1]

A Coupled Boundary Layer Air-Sea Transfer Experiment (CBLAST) was conducted in Hurricanes Fabian and Isabel during the 2003 hurricane season. The purpose of CBLAST is to improve the understanding and parameterization of high-wind, air-sea fluxes and subsequently improve hurricane intensity forecasting. The experiment was sponsored by the Office of Naval Research, the NOAA Hurricane Research Division, NOAA Office of Atmospheric Research, United States Weather Research Program and the Ocean Winds program of the NOAA/NESDIS Office of Research and Applications. The experiment utilized two NOAA/Aircraft Operations Center WP-3D Orion aircraft flying in tandem in Fabian on Sept 2,3 and 4 and in Isabel on Sept 12,13 and 14. In each flight, a series of stair-step flight patterns were flown for the purpose of obtaining in-situ measurements of air-sea fluxes in gale force winds. The twelve successful flight level mean profiles obtained by the low-level stepping WP-3D aircraft (43RF) and concurrent GPS dropsonde profiles obtained during over flights by the higher level WP-3D (42RF) are reported by Uhlhorn and Black (2004).

Here we focus on the mean boundary layer profiles that were obtained during another phase of the experiment that involved multiple, short-interval dropsondes deployed in the hurricane eyewall during figure 4 survey patterns of the hurricane. Anywhere from 8 to 12 GPS sondes were deployed in four eyewall penetrations. A total of 308 eyewall sondes were deployed nearly doubling the available archive of hurricane eyewall dropsondes deployed in the GPS dropsonde era.

Here we focus on only one representative pass from Hurricane Isabel on Sept 12. During the inbound leg in the southwest quadrant 7 successful GPS sondes were deployed in Isabel's eyewall from the two aircraft spanning the deployment time interval from 1655 – 1700 UTC. During the outbound leg in the northeast quadrant, 12 successful GPS eyewall sondes were deployed from the two aircraft spanning the deployment time interval from 1724 – 1726 UTC. The deployment locations and sonde trajectories are shown in Fig. 1.

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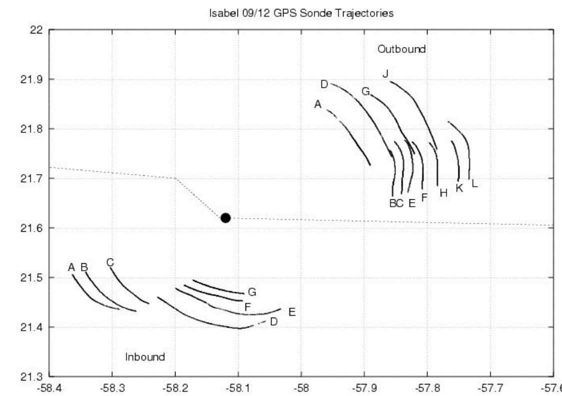

Figure 1. GPS dropsonde trajectories deployed from the two WP-3D aircraft flying in tandem in Hurricane Isabel, Sept 12, 2003.

The radar and satellite images for this pass depicting the eyewall location are shown in Black, et al. (2004). They show that the sondes were deployed from the reflectivity maximum inward to roughly the radius of maximum winds at the surface depicted by the Stepped Frequency Microwave Radiometer (SFMR). They also show the existence of two well-defined mesovortices. The first group of eyewall sondes were deployed just to the rear of the prominent mesovortex in the southwest quadrant of the eye. The GOES rapid-scan animations show that the outbound sondes were also deployed to the rear of the same mesovortex after it had rotated half way around the edge of the eye.

2. EYEWALL BOUNDARY LAYER STRUCTURE

The two WP-3D aircraft flying the SW to eye and then eye to NE legs on 12 Sept in Isabel deployed their sondes from 3700m (43RF) and 2100m (42RF) respectively. The aircraft flew an upwind pattern around the inner edge of the eye to allow time for the first set of high-density sondes to splash while the second set was readied for deployment on the outbound leg. At the same time the pattern extensively sampled the eyewall mesovortices that were discovered to be present in Isabel from the early morning GOES rapid scan satellite imagery (Black, et al., 2004).

The thermal boundary layer structure in Isabel's eye, as indicated by profiles of potential temperature, (theta) relative humidity (RH) and specific humidity (q) in Fig. 2 are markedly different from the profiles obtained during the gale force wind stepped descents discussed in Uhlhorn and Black, 2004.

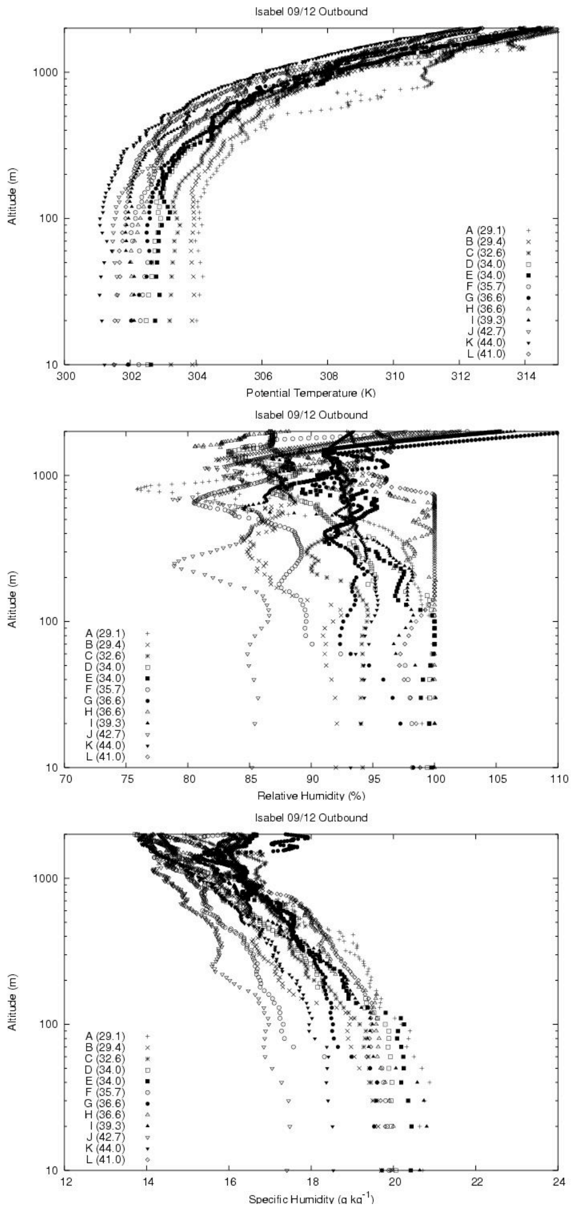

Figure 2. Profiles of potential temperature, relative humidity and specific humidity vs log altitude (m) for a 15 km segment of the outbound (NE) eyewall flight leg in Isabel, 1723-1725 UTC 12 Sept, 2003. Radial distance (km) for each profile is indicated on the left in each panel.

These profiles, as well as those in the inbound leg, reveal a shallow well mixed layer extending from the surface to 120 m with an extensive transition layer extending upward to approximately 700 m, a structure likely a result of the strong eyewall convection. The mixed layer appears characterized by two types of moisture profiles: 1) one where relative humidity is a constant, implying a constant gradient in q as well as equivalent potential temperature (thetae) and 2) another where there appear to be two constant q and thetae layers (implying a constant gradient in RH), the shallowest extending from the surface to 40 m. The cause of these two profile shapes is uncertain. The dual constant q layers may be related to a source of very high spray concentrations thought to be generated by the 70-75 m/s surface winds (Fairall, et al., 2004). The constant RH layers, also observed by Wroe and Barnes (2003) in Hurricane Bonnie, may be an artifact of the dropsonde measurements as shown by the in-situ comparison of mean and sonde q values during the Isabel stair-step pattern (Uhlhorn and Black, 2004). In-situ values seemed to show constant q where sonde values showed constant RH in the Isabel mixed layers. The Fabian comparisons were unclear.

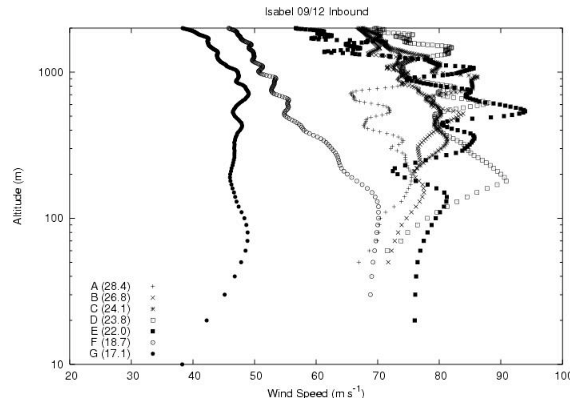

Figure 3. Wind speed (m/s) vs log altitude (m) for a 11 km segment of the inbound (SW) eyewall flight legs in Isabel, 1625-1700 UTC 12 Sept, 2003. The 18.7 and 17.1 km profiles (F and G) are inside the eye.

The wind profiles for the inbound leg (Fig. 3) as well as the outbound leg show the primary wind maximum near the top of the transition layer (700-1000 m) as well as a secondary wind maximum near the top of the constant theta layer (120-200 m). The surprising result is that at these high, near-surface winds of 70 – 75 m/s, the profiles show almost constant wind with height in the constant theta layer below 100 m, a significant departure from assumed log profiles. This is a surprising result in a neutrally stratified boundary layer filled with spray that should be robbing the lower levels of momentum instead of adding to it. If true, using a log-law profile to estimate surface roughness and a resulting surface drag coefficient may be questionable (Powell et al., 2003).

4. REFERENCES

Black, M. L. , J. P. Kossin, W. H. Schubert, C. S. Velden, J. P. Dunion, S. D. Aberson, P. G. Black, and R. Zehr, 2004: Mesovortices in Hurricane Isabel (2003): A comparison of satellite, radar, and photographic observations. 26th Conf. On Hurr. And Tropical Meteorol., AMS, Miami Beach, FL.

Fairall, C. W., J. E. Hare and A. A. Grachev, 2004: Sea spray droplet measurements in Hurricanes Fabian and Isabel. 26th Conf. On Hurr. And Tropical Meteorol., AMS, Miami Beach, FL.

Powell, M. D., P. J. Vickery and T. A. Reinhold, 2003: Reduced drag coefficien for hig wind speeds in tropical cyclones. Nature, **422**, 20 March 2003, 279-283.

Uhlhorn, E. W. and P. G. Black, 2004: Comparison of boundary layer profiles in Hurricanes Fabian and Isabel observed by GPS dropwindsonde and aircraft during CBLAST "stepped-descents", 26th Conf. On Hurr. And Tropical Meteorol., AMS, Miami Beach, FL.

Wroe, D. R. and G. M. Barnes, 2003: Inflow layer energetics of Hurricane Bonnie (1998) near landfall. Mon. Wea. Rev., **131**, 1600-1612.