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COMPARISON OF BOUNDARY LAYER PROFILES IN HURRICANES FABIAN AND ISABEL OBSERVED BY GPS DROPSONDE AND AIRCRAFT DURING CBLAST "STEPPED-DESCENTS"

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1. Introduction

During the 2003 CBLAST research flights in Hurricanes Fabian and Isabel, the atmospheric boundary layer (BL) vertical structure was sampled using a "stepped-descent" strategy. The flight pattern involved two NOAA P-3 aircraft. NOAA-42 flew a single leg at an altitude of approximately 2100 m for 25 km and deployed a series of GPS dropwindsondes. NOAA-43, which was instrumented with a number of turbulence measuring equipment, flew a number of legs of the same length while descending at the end of each leg through the BL. The lowest altitude attained was 63 m.

This study compares mean profiles of atmospheric variables estimated by GPS dropsondes to mean quantities measured at flight-level by the descending aircraft. Typically, 3-4 sondes were deployed along a leg by the higher aircraft, from which an average profile is computed. Flight level quantities are computed as 5-7 min averages of 1 Hz estimates. Whenever possible, patterns were executed both along- and cross-wind. A full stepped-descent pattern typically takes around 45 minutes to execute. Therefore, the sonde-measured profile more accurately approximates steady conditions than the aircraft profiling method.

2. Observations

Vertical profiles of potential temperature, specific humidity, and radial and tangential wind components are examined. A total of six profiles were observed (five in Fabian, one in Isabel). For each average GPS profile, 10 m measured quantities are identified. Also, the depth of the (approximately) constant potential temperature layer adjacent the sea surface is subjectively estimated, and defines the BL depth. These values are used as non-dimensionalization factors for both the sonde and aircraft-observed profiles when comparing structure between all descent patterns flown. The figures on the following page show the normalized vertical profiles for the six coordinated stepped-descent patterns flown during CBLAST missions in 2003.

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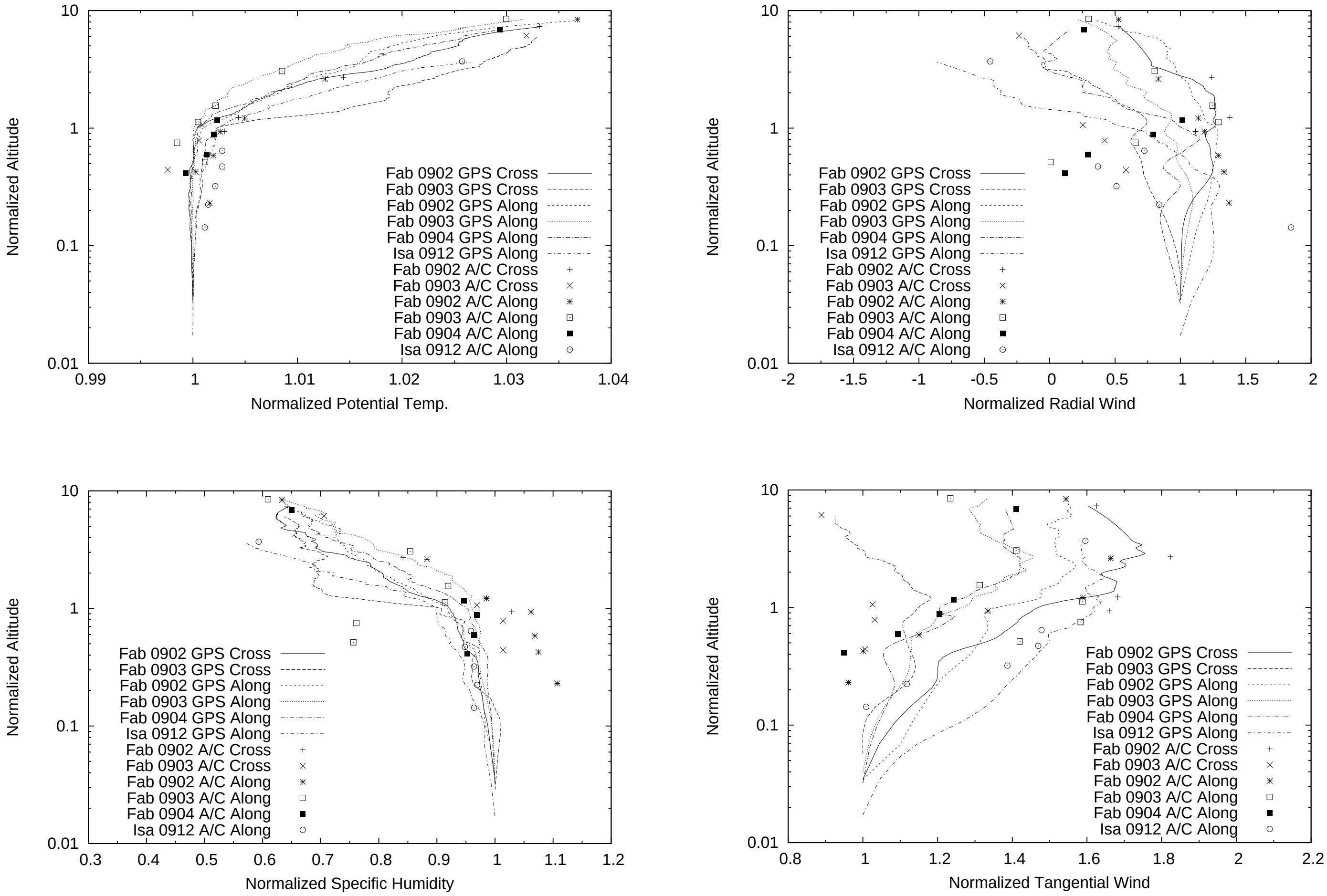
In general, the observations of atmospheric variables measured from the aircraft show a bit more scatter than from the sonde profiles. This is presumably due mostly to mesoscale variability over the time necessary for the aircraft to complete the flight pattern. Of special note is the Fabian 03 September along-wind profile, which shows significantly drier air within the BL than is measured by GPS sondes. This highlights the difficulty of profiling an assumed steady state BL when conditions vary quite rapidly. As there are several types of moisture sensors on board the P-3, the possibility of instrument biases can also be explored as a reason for these differences.

The normalized potential temperature vertical profile shows neutral to slightly stable thermodynamic conditions within the BL, and depths ranged from 290 to 580 m. Comparison of individual temperature profiles indicates remarkable similarity within the BL. The humidity profiles all indicate a slight logarithmic decrease of around 5% from the surface to the top of the BL, and the profiles begin to dry significantly above the BL.

The vertical profiles of radial and tangential winds show much larger variability in their BL structures, both in the sonde profiles and the aircraft observations. As is typical, the tangential wind (and wind speed) show a general logarithmic increase from the surface to a maximum above 1 and as high as 3 or more BL depths, and then a decrease above. Often though, multiple maxima are observed. The large variation in the slope of the individual tangential wind profiles within the BL is obvious. This is noteworthy since the surface winds for 5 of the 6 cases (the exception being Fabian 03 Sept. cross-wind) were fairly close to equal (25 $\mathrm{m\,s^{-1}}$), while at the top of the BL, wind speeds varied by a factor of two. An additional observation is the consistent tendency near the surface for the winds to approach a constant value with height, indicating a departure from logarithmic behavior. Previous studies (Powell et al. 2003; Franklin et al. 2003) using much larger sample sizes indicate that this phenomenon is not atypical.

In contrast to the tangential wind profiles, the radial winds do not show a consistent increase with height. Any peaks in the profile tend to occur below 1 BL depth, and speeds decrease above. Inflow is evident throughout the depth of most profiles (7-10 BL depths), indicating the measurements are



usually below gradient wind level. Again, large differences between the flight level measurements and GPS sondes occur in some of the observations, probably due to the evolution of the larger mesoscale environment.

3. Discussion

The difficulties associated with using profile methods to estimate surface fluxes are clear, based on the profiles of tangential winds measured during CBLAST. With the exception of one particular profile, each was observed under surface wind speeds of 23-26 $\mathrm{m\,s^{-1}}$. Interestingly though, the slopes of the individual profiles within the log-layer vary widely, indicating large differences in roughness lengths when extrapolating profiles to the sea surface. That the observed variability can be attributed to azimuthal changes in surface roughness from surface wave asymmetries is presently unclear, but will be explored.

A primary goal of the CBLAST experiment is to improve the parameterization of momentum, heat, and moisture fluxes at the air-sea interface in tropical cyclones. Reaching this goal requires measurements of turbulent fluxes and relating these quantities to the observed mean variables. Profiles of mean variables can be measured quite accurately from the GPS dropwindsonde, and the suite of turbulence measuring instruments on the NOAA aircraft will provide highly accurate vertical flux profiles within the BL. Preliminary analysis indicates that during the 2003 CBLAST missions, the upper 90% of the BL was observed a number of times under surface windspeeds of 25-35 $\mathrm{m\,s^{-1}}$. This work shows the particular profiles under which steady-state conditions were well-approximated when executing the stepped-descent patterns.

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References

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