1A.6 TURBULENT FLUX MEASUREMENTS WITHIN A HURRICANE BOUNDARY LAYER FROM AN INSTRUMENTED AIRCRAFT

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1. INTRODUCTION

Numerical models are only able to adequately model hurricane strength by imposing constraints on the turbulent flux of heat and momentum in high wind regimes (Emanuel, 1999). How fluxes vary with wind speed in winds greater than 20 m s^{-1} is unknown. Bulk parameterizations of fluxes in these wind regimes generally rely on extrapolations to measurements made at or below 18 m s^{-1} (Large and Pond, 1981). Until recently, obtaining direct measurements of turbulent fluxes in higher winds has not been possible. A major component of the Coupled Boundary Layer Air Sea Transfer (CBLAST) Hurricane program is to obtain these measurements and to the lay the groundwork to describe how fluxes and bulk transfer coefficients may vary as a function of wind speed.

2. MEASUREMENTS

2.1 Wind

A NOAA P3 research aircraft was instrumented with two gust systems designed to obtain high frequency and high precision measurements of air velocity. A system mounted on the nose radome of the aircraft has flown on both NOAA P3s since 1992 (Khelif et al., 1999**)**. Winds computed from the radome system have been shown to compare favorably to calculations from a fuselage-mounted Rosemount 858Y probe. Further, the radome system provides a higher frequency response, necessary for resolving all of the turbulent eddies and the inertial subrange.

For the 2002 and 2003 hurricane seasons a specially modified version of the NOAA/ARL designed "Best" Aircraft Turbulence (BAT) probe (Crawford and Dobosy, 1992; Hacker and Crawford, 1999) was mounted on a nose boom that protrudes roughly 5 m to the front and right of the aircraft nose. The BAT probe is flown on several small research aircraft and is generally used to obtain boundary layer turbulent fluxes in weak to moderate wind environments over land and water. The probe provides 50 Hz measurements of aircraft relative air velocity in three dimensions. Several modifications to the original BAT probe were necessary to obtain measurements in a hurricane environment (French et al., paper P1.42, this conference).

Aircraft ground velocity is calculated by mixing measurements from dual frequency P-code GPS and 3 solid-state orthogonally mounted accelerometers, all of which are mounted on the BAT. Two IRS units from the P3 provide measurements of the orientation of the BAT probe. All of these measurements are combined post-flight to determine the three dimensional earth relative wind velocity.

2.2 Temperature

The standard P3 instrumentation contains three Rosemount temperature probes. Two 102a deiced probes that have relatively slow response. A third device uses a small thermistor bead replacing the original Rosemount sensor and provides a much higher frequency response.

The BAT probe contains three temperature sensors. A YSI thermo-linear bead provides accuracy for the system, but has a fairly low frequency response (~0.5 to 1 Hz). Two YSI-VECO micro-bead thermistors provide a high degree of precision with response of roughly 10 Hz as ventilated in the probe. All of these probes are contained in a 'fast-flow' port of the BAT probe to protect them from impact of ice and rain. Temperature recovery factors are determined by examining the measured temperature during periods of varying airspeed in regions of little or no temperature gradient.

2.2 Humidity

Two fast response humidity sensors were installed on the P3 for the 2003 hurricane season to augment data from the standard chilled mirror dew point sensors. A LICOR 7500 owned by a group from RSMAS, Univ. of Miami was modified to operated as a close path device. A NOAA/ARL designed Infared Gas Analyzer (IRGA) was mounted on the underside of the nose. Both devices use a measurement of extinction over a known path length to determine water vapor content.

3. DATA

During the 2003 hurricane season six flights were flown into hurricanes Fabian (Sep. 2, 3, 4) and Isabel (Sep. 12, 13, 14). Water intrusion into the BAT resulted in some data loss for most of these flights. However, much of the data is still usable, particularly when taken in combination with other systems on the P3. For

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example, in some instances it is necessary to replace the BAT measured static pressure with the P3 static pressure. In such cases, careful comparisons between data from the two systems were conducted to ensure the integrity of the calculations. A detailed description of the evolution of the BAT probe and several of the problems initially encountered is discussed in French et al., 2004 (P1.42 this conference).

4. RESULTS

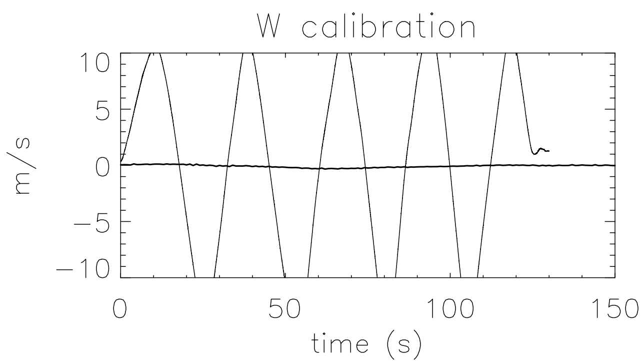

Fig 1: Vertical wind and vertical motion of the BAT probe during pitch up/dn calibration.

Calibration flights were conducted in mid-August, 2003 over the Gulf of Mexico. These flights include maneuvers used to determine empirical constants for the BAT probe installation. The maneuvers performed were pitch up/downs, dynamic sideslip (yaw), 'speed' runs, a wind box and two wind circles (one clockwise, the other counter-clockwise). In general, the maneuvers should be done in relatively smooth air at air densities similar to those expected during actual measurements.

Fig.1 shows results from data collected during the calibration maneuvers. The top figure is the resultant vertical wind calculated during the pitch up/down maneuver (thick line) overlaid on the vertical velocity of the probe. The residual vertical wind variations are less than 4% of the peak to peak variation of the vertical velocity of the probe.

Figure 2 is an example of data collected during a boundary layer flux leg in Hurricane Isabel. The leg was flown at an altitude of 600 ft MSL with a 35 m/s headwind. The top graph shows the 50 Hz vertical wind, the second and third show horizontal components of the wind (u and v, respectively) and the bottom shows the temperature.

5. ACKNOWLEDGEMENTS

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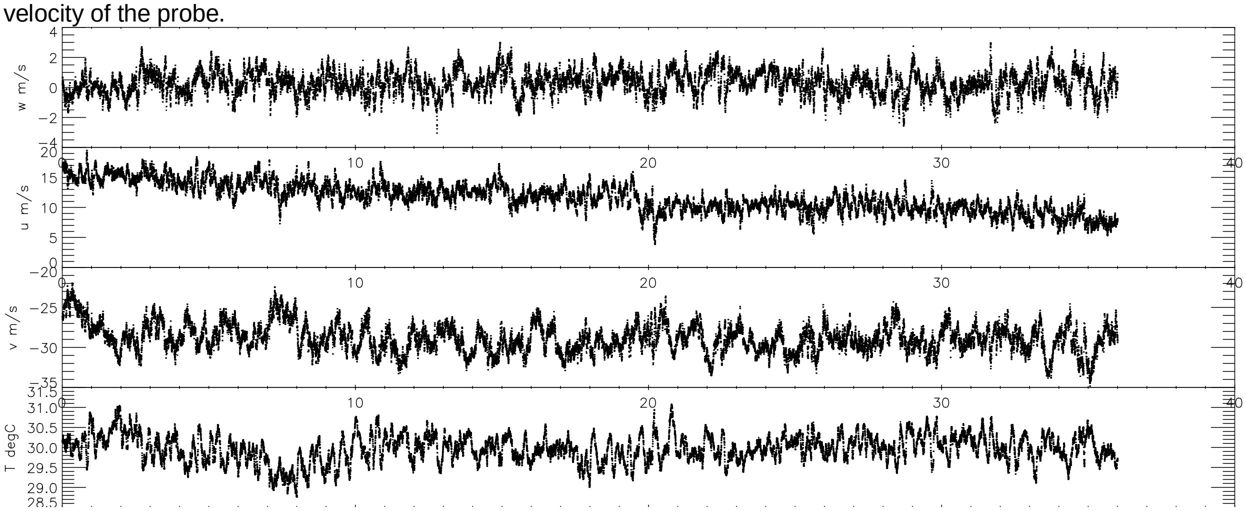

Fig 2: Vertical (top) and horizontal (U and V, respectively) winds and Temperature for flux run at 600 ft in Isabel.