A SUMMARY OF WIND SPEED MEASUREMENTS AS COLLECTED BY TEXAS TECH DURING THE LANDFALL OF HURRICANE ISABEL

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1. INTRODUCTION

The goal of the Wind Engineering Mobile Instrumented Tower Experiment (WEMITE) at Texas Tech University (TTU) is to collect high-resolution wind speed data from landfalling tropical cyclones by placing instrumented towers into their paths. Sixteen tropical cyclones have been sampled in this manner since the program's inception in 1998.

During the 2003 Atlantic Hurricane Season, five towers were available for deployment. WEMITE 1 is a 10 m tower with wind instrumentation at three levels, WEMITE 2 is a 15 m tower with wind instrumentation at five levels, and the three SBCCOM towers are each 10 m tall with wind instrumentation at one level. In addition to wind speed and direction, each of the five towers sampled temperature, relative humidity, and barometric pressure (BP). WEMITE 1 and WEMITE 2 sampled wind data at 10 Hz. Due to data storage limitations, two of the SBCCOM towers sampled at 5 Hz and the third sampled at 0.5 Hz. In addition to the towers, two Shared Mobile Atmospheric Research and Teaching Radars (SMART-Radars) were available for deployment during the 2003 Atlantic Hurricane Season. A collaborated effort between TTU and the University of Oklahoma successfully deployed each radar in Hurricane Isabel.

2. HURRICANE ISABEL DEPLOYMENT

Three deployment sites were chosen for the instrumented towers based on experimental plans, exposure, and location relative to the anticipated point of landfall: the Craven County Airport in New Bern, the Beaufort-Morehead City Airport in Beaufort, and Atlantic Field in Atlantic. The three deployment sites represented at least two different roughness exposures. The Atlantic site was characterized by tall pine trees located near the tower while the New Bern and Beaufort sites were characterized by mainly open, airport exposure. Three SBCCOM towers were deployed at the New Bern site as part of an experiment to characterize hurricane boundary layer rolls. The three towers experienced nearly identical conditions, so only one dataset from New Bern will be used in this study.

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3. METHODOLOGY

3.1 *Turbulence Statistic Calculation*

Several turbulence statistics enabled comparison of the data collected at different deployment sites: gust factor (GF), turbulence intensity (TI), and roughness length (Z_o). A GF is the ratio of the peak 2-second to 10-minute wind speed. The TI is the ratio of the standard deviation of the wind record to the mean. The roughness length (Z_o) was calculated using the TI method, which relates TI and the observation height. The TI method assumes the log-law profile and that the ratio of the standard deviation of the wind record to the friction velocity is 2.5 (Beljaars, 1987).

3.2 *Stratification*

To examine the effect of upstream terrain roughness on turbulence statistics, the data from each deployment site was stratified into four roughness regimes (Table 1). Additionally, data with a mean 10-minute wind speed less than 5 ms^{-1} were removed to reduce scatter and produce more meaningful statistics.

Table 1. Roughness regimes.

Name	Roughness Length (m)
Smooth	0.005-0.0199
Open	0.020-0.0499
Open to Roughly Open	0.050-0.0899
Roughly Open to Rough	0.090-0.1899

4. RESULTS

4.1 *Wind Speed and Turbulence Results*

The mean wind speeds recorded at the Atlantic, Beaufort, and New Bern sites were 9.28, 12.80, and 9.44 ms^{-1}, respectively. A summary of the mean 10-minute wind speed, peak 1-minute wind speed, and peak 2-second windspeed at each of the deployment sites is provided in Table 2.

Although the Atlantic site experienced the inner eyewall of Hurricane Isabel as it made landfall (Figure 1) it had the lowest 10-minute mean wind speed and only the second highest peak 1-minute wind speed and peak 2-second gust. The Beaufort site, despite being further from the center of the storm than the Atlantic site, had

the highest 10- and 1-minute means and the highest 2-second gust of all three sites. The reason for the difference can be seen in Table 3. The average Z_o at the Atlantic site is nearly ten times that of the Beaufort site. Results have consistently shown an increase of GF and a decrease in mean wind speed with increasing roughness. There is evidence of this in Table 3. Additionally, at each site, the mean GF increases with increasing roughness.

Table 2. Summary of wind speeds recorded in Hurricane Isabel.

Site	Mean 10-min WS (ms^{-1})	Peak 1-min (ms^{-1})	Peak 2-s (ms^{-1})
Atlantic	9.28	23.32	36.64
Beaufort	12.80	28.92	37.89
New Bern	9.44	20.90	28.37
Combined	10.54	28.92	37.89

Table 3. Summary of turbulence statistics recorded in Hurricane Isabel.

Site	GF	TI	Z_o (m)
Atlantic	1.75	0.25	0.2108
Beaufort	1.47	0.16	0.0259
New Bern	1.55	0.19	0.0531
Combined	1.60	0.20	0.1007

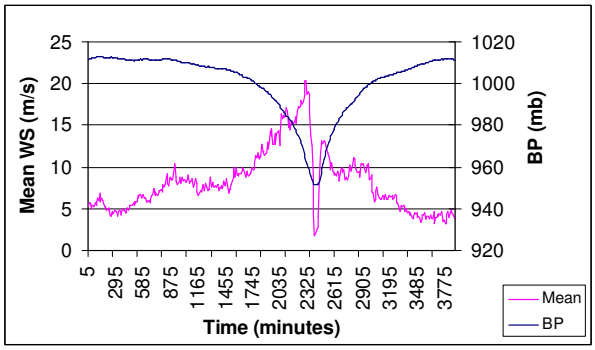

Figure 1. Time history of 10-minute means recorded at Atlantic, NC in Hurricane Isabel.

4.2 *Comparison with historical data*

The mean GF for the combined dataset, open roughness regime, was 1.50, which is slightly higher than the average GF from the mean GF from open roughness regime data from previous storms, 1.44. It is not likely that this mean was affected by higher GF's from the Atlantic site because only three observations from the Atlantic site fell into this category. The average Z_o for the two datasets was similar; 0.0326 m from the historical data and 0.0318 m from the Isabel data.

Data was also collected at the Atlantic and Beaufort sites by TTU during Hurricane Dennis in 1999. The mean GF for the Atlantic site in Dennis was 1.78, compared with 1.75 in Isabel. The mean GF at Beaufort was 1.58, compared with 1.47 in Isabel. The mean Z_o's for Atlantic in Dennis and Isabel were very similar, 0.2107 m and 0.2108 m, while the two Z_o's at the Beaufort site were very different, 0.0818 m in Dennis and 0.0259 m in Isabel. This difference can be attributed to the exact location of the tower and the wind direction. In Dennis, the tower was located between the tarmac and one of the runways, less than 200 m to the west of several airport buildings and a residential area, but with extensive open terrain to the west. In Isabel, on the other hand, the tower was located between two runways on the south side of the airport with a long fetch of open terrain to the north and northwest. Given the hurricane's track, these differences had a significant impact on the turbulence characteristics observed by the towers.

5. CONCLUSIONS

TTU collected wind data in Hurricane Isabel using five instrumented towers and one SMART-Radar at three sites on the coast of North Carolina. The three sites were characterized by different terrain exposures and experienced different parts of the hurricane. The data collected from each site was stratified by wind speed and roughness, then compared with the other sites and data from past hurricanes and tropical storms. Conclusions from these comparisons include:

- The mean wind speeds recorded at the Atlantic, Beaufort, and New Bern sites were 9.28, 12.80, and 9.44 ms^{-1}, respectively.
- Upstream terrain roughness has a direct effect on the mean and gust wind speeds observed at a location.
- Data from Hurricane Isabel matched well with data collected by TTU in previous tropical cyclones. In particular, data collected in Hurricane Dennis in 1999 matched well with the Isabel data collected at the same sites when terrain differences are considered.

6. AKNOWLEDGEMENTS

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7. REFERENCES

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