15D.6 EQUIVALENT 10-METER WIND SPEEDS IN HURRICANE FABIAN

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1. INTRODUCTION

Hurricane Fabian's center of circulation passed approximately 15 miles west of Bermuda on the afternoon and evening of 5 September 2003, with an estimated peak wind speed of 100 kts. The eastern portion of the eye wall passed over the majority of the Bermuda archipelago, resulting in light to moderate residential and commercial damages from wind and severe damage from storm surge in isolated locations.

Wind speed(s) were observed at four points on the island. The official measurement at Bermuda airport terminated due to storm surge inundation approximately half an hour before the peak of the storm. Continuous records were obtained at Warwick Camp, Cable and Wireless, and Bermuda Harbour Radio. The record at Bermuda Harbour Radio was unfortunately subsequently lost due to computer malfunction. The anemometers at all three locations were located considerably above the standard 10 m elevation above ground level (AGL) recommended by the WMO and were located on or near significant topographic features that are likely to have affected the observed wind speeds.

In this abstract we use a model for boundary layer flow over low-slope topography to assess the impact of the surrounding topography on the observed wind speeds at Warwick Camp during the passage of Fabian. The modeled topographic effect is then removed from the data and wind speeds are adjusted to estimate the equivalent 1-minute wind speeds at 10 m AGL.

2. DATA

Warwick Camp is located fairly near the shoreline on Bermuda's south coast, with an open water exposure to the east and south. The base of the mast is located at an elevation of 40 m above sea level, with the anemometers located at 47 m (anemometers 3 and 4) and 68 m (anemometers 1 and 2) AGL. A sonic anemometer was also located at an elevation of 68 m AGL, but this instrument failed at an early stage of the storm and will not be considered further.

Although there is evidence that the anemometers on the west side of the mast were in the lee of the mast for a short period, the wind speeds appear unaffected by the mast during the peak of the storm (Fig. 1). Wind measurements by all four anemometers are generally consistent. One anemometer seems to have anomalously low wind speeds at the peak of the storm, and wind direction measurements made by a second anemometer seem to have partially failed at the same time.

3. METHODOLOGY AND RESULTS

The effects of boundary layer flow over low-slope topography have been well documented, see for example Walmsley and Taylor (1996). One of the most well understood features of such flows is the significant increase in wind speed, or 'speed-up', that occurs very near the surface on the crests of topographical features such as hills and ridges. Several analytical models have been developed based on the original theory of Jackson and Hunt (1975) allowing these effects to be quantified using a digital representation of the underlying terrain. The effect of the underlying topography on wind speeds is described by a speed-up factor, *?S*, defined as

$$\Delta S = \frac{U(z) - U_0(z)}{U_0(z)} \qquad (1)$$

where $U(z)$ is the wind speed at elevation z above the local hill surface and $U_0(z)$ is the wind speed at the same elevation above flat level terrain.

Directional speed-up factors for each anemometer elevation were calculated using the MS-Micro code developed by Walmsley *et al.* (1986), in conjunction with a digital terrain model (DTM) of Bermuda obtained from the Bermuda Ministry of Works and Engineering and Housing. The digital representation of the underlying terrain required by MS-Micro was obtained by resampling the DTM to create a grid with sides of length 5120 m, and a horizontal resolution of 5 m, centred on the site. The calculated speed-up factors were then used to remove the effects of the underlying topography from the observed wind speeds. For the Warwick Camp site, the maximum wind speed reduction at 68 m AGL is 0.90, while at an elevation of 47 m it is 0.86.

The resulting wind speeds were then adjusted to the standard height of 10 m AGL using the standard log-law of

$$U(10) = U(z)\frac{\ln(10/z_0)}{\ln(z/z_0)} \qquad (2)$$

where $U(z)$ is the wind speed at elevation z and z_0 is the roughness length associated with the anemometer surroundings.

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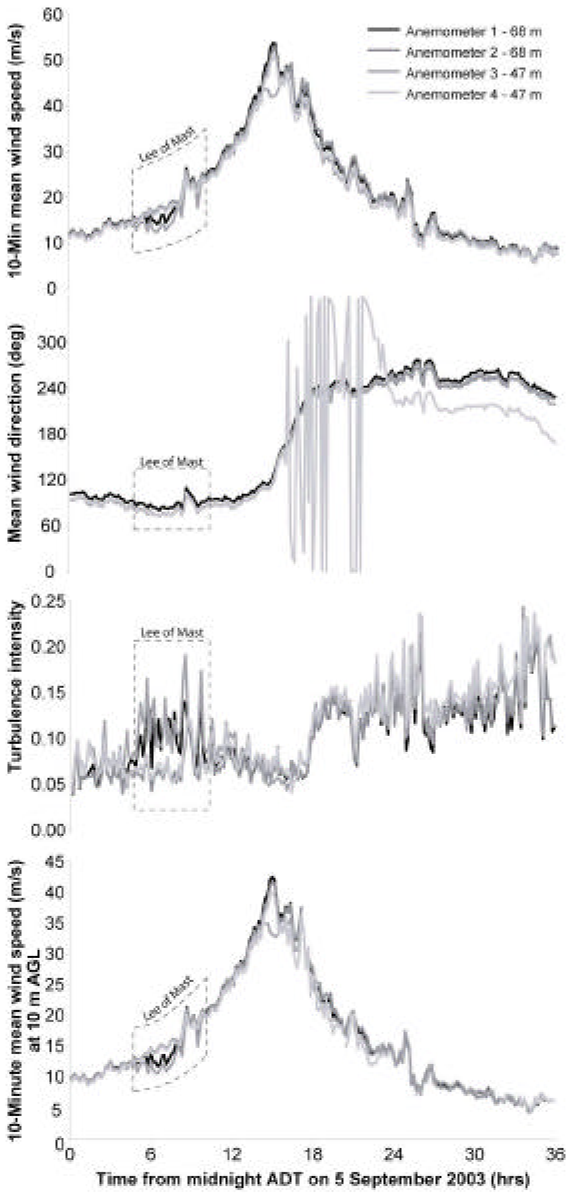

FIGURE 1: Wind measurements and derived quantities at Warwick Camp

Estimates of the roughness length z_0 were made at Warwick Camp by considering the turbulence intensity values observed at each level. If the turbulence intensity measured at elevation z is I_u, then an estimate of the roughness length can be obtained using

$$\ln(z_0) = \ln(z) - \frac{1}{I_u}. \qquad (3)$$

The resulting roughness length estimates of 0.00015 m and 0.045 m for the overwater and overland exposures respectively were found to be somewhat lower than expected. Using these roughness lengths, the maximum observed 10-minute mean wind speeds at the site were then adjusted to the equivalent 10-minute mean wind speeds at a height of 10 m (Table 1).

TABLE 1: Wind speeds at Warwick Camp

Max wind speed (m/s)	Anemometer 1	2	3	4
Observed 10-min mean	53.7	52.5	46.9	50.6
Adjusted 10-min mean	49.8	48.8	40.6	45.3
10-min mean at 10 m	42.5	41.6	35.6	39.8
1-min mean at 10 m	46.7	45.8	39.8	43.8

These wind speeds can be converted to an equivalent 1-minute mean wind speed using a gust factor. This factor depends on both the ratio of the averaging periods and the turbulence intensity, which generally is a function of the roughness length, z_0. We choose to use the formulation of Cook (1985) defined as

$$GF = 1 + 0.42 I_u \ln(600/60). \qquad (4)$$

For the Warwick Camp site this results in a maximum 46.7 m s^{-1} (91 kts) 1-minute mean wind speed at 10 m AGL. As the wind at this point was coming from over open water, this wind speed can be considered to be representative of open water conditions. This is consistent with Saffir-Simpson Category Two maximum 1-minute wind speeds at this particular site.

A similar analysis will be presented at the conference for two other sites, Cable and Wireless and Bermuda Harbour Radio, which are located on or near significant topographic features that likely influenced the observed wind speeds at those locations.

4. ACKNOWLEDGEMENTS

We thank BELCO (Bermuda Electric Light Company), as well as, Rodney Johnson and Paul Lethaby of the Bermuda Biological Station for Research for providing the Warwick Camp data. We also thank Roger Williams at the Bermuda Weather Service for his invaluable assistance in data collection and interpretation, and the Bermuda Ministry of Works and Engineering and Housing for providing the digital terrain model of Bermuda.

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