P1.25 ADDITIONAL INSIGHTS INTO HURRICANE GUST FACTORS

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1. INTRODUCTION

A gust factor (GF) is defined as the ratio between the peak and mean wind speeds. Several studies have included analysis of GF's in hurricanes, and yielded conflicting results. For instance, Krayer and Marshall (1992) noted higher GF's within hurricanes than compared with extratropical winds, while Sparks and Huang (1999) indicated little difference between GF's within hurricanes and extratropical systems.

Krayer and Marshall standardized wind speed records from numerous hurricanes with respect to exposure (open terrain, roughness length = 0.03 m), and height (10 m) and compared the resultant GF's with Durst's (1960) analysis. The results indicated there were higher GF's for hurricane winds especially when considering peak wind gusts of duration less than approximately 90 seconds (using a mean hourly wind to normalize). The average GF (2-second peak to 10-minute mean) was found by Krayer and Marshall to be 1.55 within hurricanes compared to 1.40 as determined by Durst for extratropical cyclones.

Sparks and Huang (1999), on the other hand, examined numerous wind speed records from offshore and onshore sites, and concluded that there was little evidence of an increase in GF's generated within hurricanes compared to their extratropical counterparts. They concluded that Marshall and Krayer's results, which were generated from numerous airport sites, resulted from differences in roughness compared to those determined by Durst from data collected at Cardinton in the United Kingdom, and that a hurricane wind was essentially the same as any other wind.

One of the main limitations for evaluating hurricane GF's is a lack of high-resolution wind speed data from within hurricanes. Although a large data void still exists, several institutions including Texas Tech University (TTU), Clemson University and the University of Florida have developed field programs to gather hurricane wind speed data. The data collected by TTU is used in this research to examine the sensitivity of hurricane GF's to the surrounding terrain conditions and provide additional results for comparison to extratropical winds.

2. METHODOLOGY

Combining several datasets collected over the past four Atlantic Hurricane Seasons enabled direct determination of GF's over a variety of surrounding terrain conditions. The deployment locations for each hurricane are noted in Table 1. For this study we have concentrated on GF's determined from anemometer heights ranging from 9.15-10.67m (~10m).

Table 1. Deployment Locations

Storm	Location
Bonnie – WEMITE #1	Wilmington, NC
Dennis – WEMITE #1	Atlantic, NC
Dennis – WEMITE #2	Beaufort, NC
Floyd – WEMITE #1	Southport, NC
Floyd – WEMITE #2	Wilmington, NC
Gordon – WEMITE #2	Cedar Key, FL

The majority of TTU's field deployments from 1998-2001 occurred at airports, including all of those used in this study, but various terrain conditions are often found in the records. The combined data set was therefore broken into corresponding roughness regimes as indicated by Table 2.

Table 2. Roughness Regimes

Name	Roughness Lengths (m)
Smooth	0.005-0.0199
Open	0.02-0.0499
Open to Roughly Open	0.05-0.0899
Roughly Open to Rough	0.09-0.1899

Stratification of the wind records into various roughness regimes occurred using two methods. When applicable, data from multiple anemometer heights were used to determine the roughness length, Z_o, assuming the log-law profile. In other cases, this was not feasible and the Z_o was determined from direct calculation of the 10-minute turbulence intensity. This method not only assumes the log-law profile, but also that the ratio of the standard deviation of the wind record to the friction velocity is 2.2 (Beljaars, 1987). While these methods often give conflicting results, the purpose of this research is not to resolve these differences. Rather we employ both methods, stratifying the results.

3. RESULTS AND DISCUSSION

A scatter plot of the GF's (2-second peak wind speed to 10-minute mean wind speed) versus turbulence intensity indicates a linear relationship as shown in Figure 1. If all of the data is incorporated regardless of roughness, these fully segmented 10-minute wind speed segments provide 1046 observations, a mean GF of 1.74 and standard deviation of 0.62. However, histograms of the entire data set indicate a distribution largely skewed to the right. Removing all data with turbulence intensities greater than 0.20 (corresponding to data segments where Z_o>0.12m) and the Hurricane Gordon data (which provided an exceedingly smooth roughness regime) yields a much more symmetric histogram as shown in Figure 2 with a mean GF value of 1.49 and standard deviation of 0.109. This falls in between the values of 1.55 and 1.40 proposed by Krayer and Marshall and Durst, respectively. From the linear fit of the hurricane data, a turbulence intensity of 0.15, which corresponds

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to a $Z_o \approx 0.03$m under the assumptions stated early, would generate an average GF of 1.43.

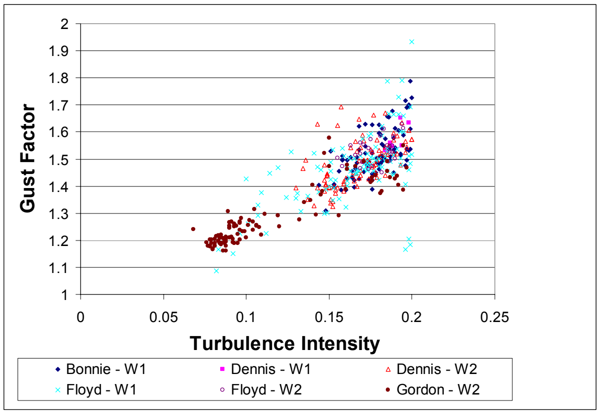

Figure 1. Scatter plot of turbulence intensity (limited to less than 0.20) versus gust factor (2-second peak to 10-minute mean) from various hurricane deployments.

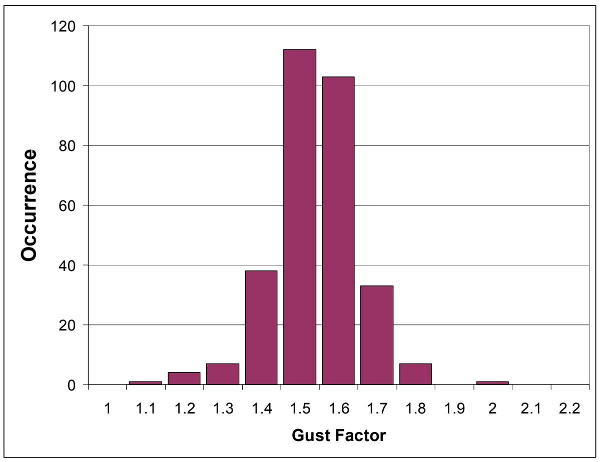

Figure 2. Histogram of gust factors (2-second peak to 10-minute mean).

To continue an evaluation of the sensitivity due to roughness from a slightly different perspective, the data was segmented into hourly segments using a 50% offset approach. These hourly segments were then stratified into the various roughness regimes (Table 2) using the two separate methods discussed earlier. The resulting averaged GF curves, stratified by Z_o (based on turbulence), are shown in Figure 3. From these curves one can observe the sensitivity of the GF's to the various roughness regimes; increasing roughness effectively increases the GF. As one might expect, the sensitivity is greatest when considering short peak durations, and is reduced when one moves beyond durations of approximately 200 seconds.

Given the sensitivity to roughness, the data from the "open," "open to roughly open," and "roughly open" regimes ($0.02 \leq Zo \leq 0.19$) were combined for comparison to the Krayer and Marshall, and Durst GF curves. In this sense, the data from the roughest and smoothest regimes (based on turbulence) were ignored. The resulting curve (not shown), falls between those produced by Krayer and Marshall, and Durst except at peak durations <2-3 seconds for which it is higher than both. With the exception of the "smooth" regime, the hurricane wind records produce GF curves (regardless of roughness) with higher mean values than those described by Durst. This is true even when only considering segments with open exposure.

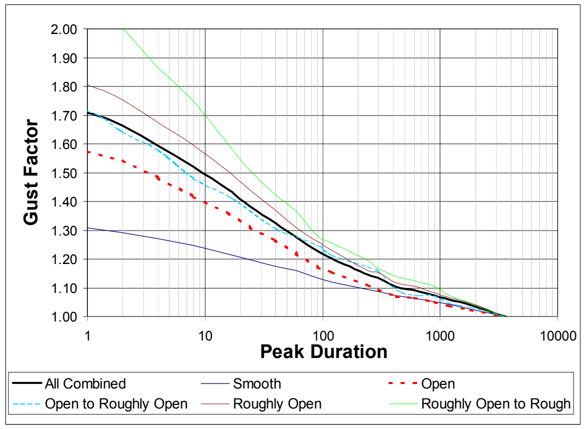

Figure 3. Gust factor curves (various peak durations with respect to an hourly mean wind speed) generated from various roughness regimes.

It should be noted that the hourly data compiled for this study were not examined for tends in the mean wind speed. Any nonstationary trends that exist could have artificially increased the GF's found within this study. It should also be noted that although each deployment took place within a hurricane environment, the records do not contain hurricane-force winds based on examination of 1-minute average wind speeds. In this respect, data from an intense hurricane, especially a Category 3 or greater, is still badly needed for analysis. As noted earlier, two methods for calculating Z_o were employed. The results from the least squares fit, assuming the log-law profile, usually resulted in lower Z_o values for the same data segment compared to the turbulence method. Therefore, stratification using the profile method tends to increase the value of the mean GF found within a given roughness regime.

4. ACKNOWLEDGEMENTS

The authors wish to thank Becca Paulsen of TTU for providing help with the analysis.

5. REFERENCES

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