Comparison of Gust Factor Data from Hurricanes

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1. INTRODUCTION

The relationship between short-duration gusts and the average wind speed (the *gust factor*) is important in the determination of the magnitude of wind loads that are experienced by structures in high wind events. Currently, engineers and meteorologists in the United States use relationships established by Durst (1960) and Krayer and Marshall (1992) to calculate the ratio of a gust measurement of a short duration to the corresponding mean wind speed. In both studies, the mean 10-min and mean hourly wind speeds are used as the basis of comparison.

The Krayer and Marshall curve was derived from 11 wind records taken from 4 different hurricanes and is used to standardize wind speeds taken from hurricane landfalls. It represents an upward adjustment from the Durst curve that may be associated with increased turbulence in convective regions of the hurricane. Current engineering practice assumes that at high wind speeds, the boundary layer profile can be considered neutrally stratified, i.e. that mechanical turbulence dominates over convective turbulence. However, the latest research suggests that hurricanes contain regions of high wind speeds that correspond to unstable or even irregular boundary layers where current standardization procedures may not apply.

For the last 2 years, Wind Engineering researchers at Texas Tech have carried out research into the hurricane boundary layer by way of mobile, multi-level instrumented towers that are placed in the path of landfalling hurricanes. The high-resolution data obtained from this experiment can be used to construct wind speed averaging curves. This paper presents such analysis from the 1998 Atlantic Hurricane season.

2. DATA AND METHODOLOGY

The Texas Tech hurricane deployment teams placed instrumented towers in the paths of Hurricanes Bonnie, Earl and Georges, as well as Tropical Storm Charley. For each storm the tower was set up in the projected path of the eyewall. Propeller anemometers mounted on a telescoping mast at heights of 3.05, 6.1 and 10.7 meters obtained data. The wind speed data was recorded at 5-Hz for each height level continuously for the duration of the storms with the exception of Hurricane Georges, where a computer malfunction caused the loss of data over a significant portion of the storm. Overall, over 150 hours of wind data > 10 m/s were recorded.

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Originally, wind speed data of less than tropical storm force strength was filtered from the data of Hurricanes Bonnie and Georges. However, there were not sufficient amounts of data over that speed from Hurricane Earl and TS Charley so that a minimum speed of 10 m/s was chosen for this analysis. The minimum wind speed criteria was adjusted for the different heights using the log-law. For each deployment, the tower was placed at an airport or an open area. Thus, no adjustments were applied to account for variations in terrain roughness. However, results from this study and others suggest that the roughness length "experienced" by the anemometer may be affected by the roughness regime at a greater upwind distance (>2 km) than that which is usually taken into consideration.

3. RESULTS

Gust factors were calculated for all the data for Comparison with those obtained by Krayer and Marshall. Histograms of the gust factors are shown in Figures 1a. and 1b. As can be seen from Figure 1b, the distribution of gust factors from Hurricane Georges and Hurricane Earl and TS Charley are roughly similar. However, those from Hurricane Bonnie are significantly higher than for the other data. It is theorized that the although the data from Bonnie was collected at the Wilmington Airport, the upwind fetch across a large forested and urban region created a wind speed profile corresponding to a greater roughness.

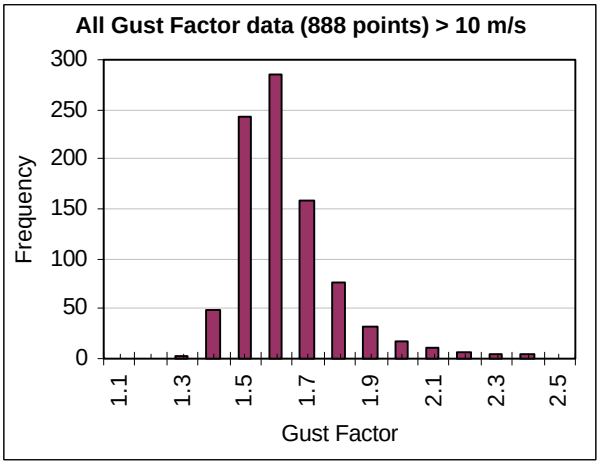

Fig. 1a. Histogram of gust factors calculated by taking the ratio of peak 2-sec. gusts to the corresponding 10-min mean speed.

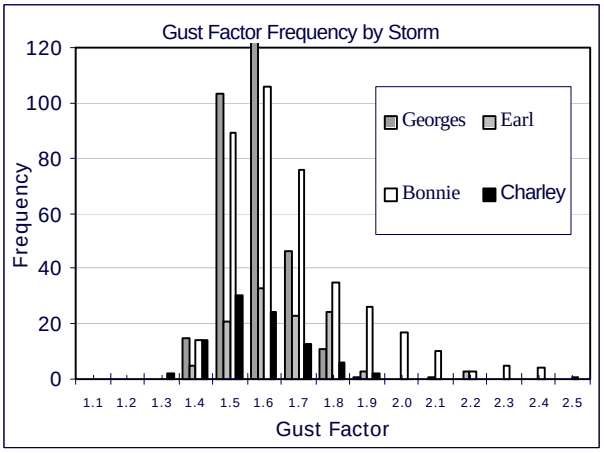

Fig. 1b. The breakdown of the 2-sec/10-min gust factors by storm.

Gust-factor curves have been developed by Krayer and Marshall and Durst to show the ratio of different wind speed averaging times to the mean hourly wind speed. These graphs are often used to determine the statistically probable maximum gust of a short duration (usually measured in seconds) when the gusts closely follow a Gaussian distribution about a stationary mean. Krayer and Marshall appropriately point out that hurricane wind data does not contain stationary means for averaging times greater than ~ 10 minutes – and even less in the presence of convective elements. Figure 2 shows a comparison between the two curves.

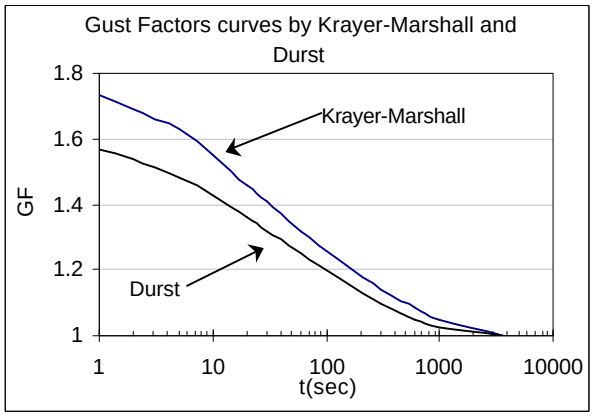

Fig. 2. The Krayer-Marshall and Durst curves based on an hourly mean wind speed.

For this study, all the data was analyzed in a similar manner and gust factor curves produced. For each of the four storms, the data from the three heights were averaged and the resulting gust factor curves are shown in Figure 3. The graphs show a rather small range of variation between the four storms with all of them sharing a profile similar to the Krayer-Marshall curve. Comparisons of the different height data show a similar degree of uniformity. Figure 4 shows a comparison of the average of all the Texas Tech data compared to the Krayer-Marshall and Durst curves.

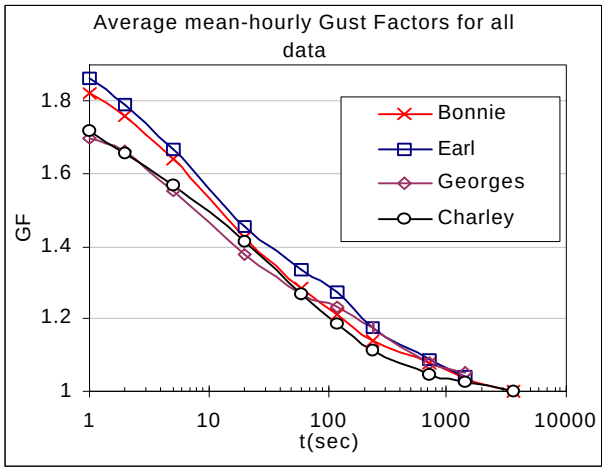

Fig. 3. Texas Tech hurricane gust factor curves based on an hourly mean wind speed.

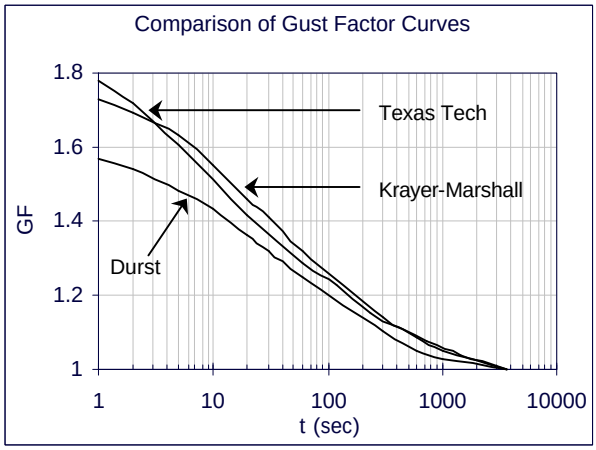

Fig 4. Comparison of the gust factor curves from Texas Tech, Krayer-Marshall and Durst.

4. SUMMARY

The 2-sec to 10-min gust factor is often used as a reference factor in wind engineering applications. The corresponding values are 1.62, 1.55 and 1.40 for the Texas Tech, Krayer-Marshall and Durst studies respectively. More data is being collected by Texas Tech and should be incorporated into the analysis.

5. REFERENCES

Durst, C.S., 1960: Wind Speeds over short periods of time. *Meteor. Mag*., **89**, 181-187.

Marshall, R.D. and W.R. Krayer, 1992: Gust Factors applied to hurricane winds. *Bull. Amer. Meteor. Soc*., **73**, 613-617.