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Gust Speeds in Hurricanes

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Abstract

Based on strip-chart records of wind speeds representing 11 recording stations and four hurricanes, it is concluded that gust factors for hurricanes generally exceed the gust factors proposed by Durst more than 30 years ago for well-developed extratropical storms. When put in terms of dynamic pressure, these higher gust factors suggest increases in gust loads of as much as 20 percent. More data will be needed to establish the probability distribution of hurricane gust factors and to discern any significant differences for locations within and outside of the hurricane eyewall.

Introduction

For purposes of structural design, it is essential that the wind speed averaged over some reference period be convertible to the probable maximum wind speed averaged over some shorter interval within that reference period. To accomplish this, a gust factor G(t), averaged over several sets of observations, is defined as the ratio of the maximum gust speed $\hat{u}$ of duration t to the corresponding mean speed $\bar{U}$ averaged over period T:

$$G(t) = (1/N)\sum_{1}^{N} \hat{u}_t/\bar{U}_T$$

In this paper, gust factors obtained from selected hurricane wind speed records are compared with gust factors obtained by Durst (1960) for extratropical storms.

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Sources of Data

Data used for this assessment of gust factors were obtained from four hurricanes as follows: Hurricane Frederic along the Gulf coast from Florida to Mississippi in 1979; Hurricane Alicia in the Galveston - Houston area in 1983; Hurricane Elena along the Gulf coast from Florida to Mississippi in 1985; and Hurricane Hugo in Puerto Rico and South Carolina in 1989. The recording stations and the 10-min record segments, classified by mean speed, are listed in Table 1.

Table 1. Distribution of 10-min Record Segments by Recording Station and Mean Wind Speed

Recording Station	No. of 10-min Segments	$\bar{U}_{600}$ (m/s) ≥ 10	> 15	> 25
Hurricane Frederic				
Mobile, AL	78	78	54	11
Pensacola, FL	78	78	46	0
Pascagoula, MS	71	70	53	9
Hurricane Alicia				
Alvin, TX	110	93	43	0
Houston, TX	118	71	34	0
Hurricane Elena				
Mobile, AL	120	83	27	0
Dauphin Is, AL	33	33	22	8
Pensacola, FL	145	72	22	0
Hurricane Hugo				
Roosevelt Rds, PR	78	78	58	16
San Juan, PR	139	73	35	3
Charleston, SC	54	40	26	4
Columbia, SC	85	62	13	0
Charlotte, NC	91	45	5	0
Total	1200	876	438	51

Because the wind speed records used in this study are in the form of conventional closed-scale strip charts, only the 10-min (600 sec) mean speeds and the corresponding maximum gust speed within each 10-min segment of record could be determined with confidence. In view of the response characteristics of the anemometers and recorders, the gust speeds are associated with averaging times of at least 2 seconds. The recording stations were selected to be consistent with a Category C wind exposure as defined in

ASCE 7-88 (1990). The one exception is Alvin, Texas, where the surface roughness length is believed to be described best by $z_0 = 0.10$ m rather than the nominal value of $z_0 = 0.03$ m. Anemometer heights ranged from 6.7 to 10 m, and the gust speeds and mean speeds were adjusted to a standard height of 10 m during the data analysis. For more detailed descriptions of the recording stations and sources of wind speed data, see Krayer and Marshall (1992).

Data Analysis

Initially, statistical analyses were carried out on all data sets without regard to the anemometer height or level of wind speed. The analyses were repeated after adjusting the gust and mean speeds for the standard height of 10 m. Two additional sets of analyses were carried out after discarding those 10-min segments with mean speeds less than 15 and 25 m/s, respectively. A mean gust factor and standard deviation, weighted to account for station sample size, were calculated for each analysis and the results are summarized in Table 2. Histograms of the resulting gust factors, based on 10-min means, are shown in Fig. 1.

Table 2. Results of Analysis

Data Set	No. of 10-min Segments	Mean Gust Factor $G = \hat{U}_2/\bar{U}_{600}$	Standard Deviation
Actual Exposure			
All Data	1,200	1.587	0.151
Standard Exposure			
All Data	1,200	1.556	0.148
$\bar{U}_{600}$ > 15 m/s	438	1.517	0.108
$\bar{U}_{600}$ > 25 m/s	51	1.536	0.090

Durst's Analysis

Durst (1960) computed gust factors using strong-wind data obtained at Cardington, England. Sequential mean speeds $\bar{U}_t$ were obtained from open-scale anemometer records for averaging times ranging from 10 min down to 0.5 sec. According to Durst, for each averaging time t, the frequencies of departures from the mean, $\bar{U}_t - \bar{U}_{3600}$, were found to be consistent with a Gaussian distribution.

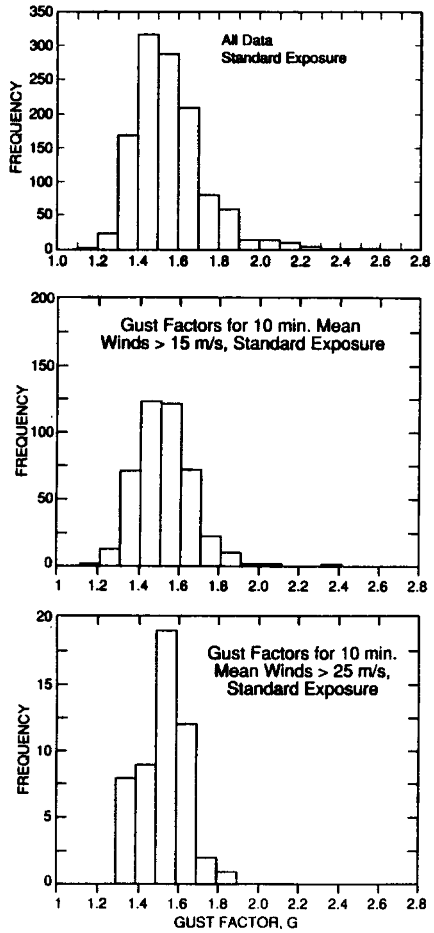

Fig. 1. Histograms of gust factors based on 10-min mean speeds adjusted to standard wind exposure.

The standard deviations of $(\bar{U}_t - \bar{U}_{3600})/\bar{U}_{3600}$, denoted hereafter as SD(1 h, t), were calculated and values of the standardized normal deviate, SU, associated with 1 - t/3600 were determined. Durst then obtained the gust factors which he defined as G = 1 + [SU][SD(1 h, t)]. The values of G so determined are the basis for the gust factor curve labeled B in Fig. 2. A variation of this gust factor distribution is the log/linear dependence of duration and intensity proposed by Cook (1985) and labeled A in Fig. 2.

Based on the hourly mean speed, Durst's analysis yields a gust factor G(1 hr, 2 sec) = 1.53. When based on the 10-min mean speed, G(10 min, 2 sec) = 1.40. From Table 2, the mean 2-sec gust factor based on the 10-min mean for hurricane winds is seen to be about 1.55, and the corresponding value based on the hourly mean speed is 1.69 (see Krayer and Marshall (1992) for details). When adjusted to the higher mean gust factors indicated by the results of this study, the Durst gust factor curve might have the shape suggested by curve C in Fig. 2. However, it must be emphasized that the database used in this study is extremely limited, resulting in only one gust averaging time on which to base a comparison. In addition, the stationary hourly mean for an extratropical storm does not have a physical counterpart in hurricane winds. Nevertheless, gust factors for hurricane winds appear to differ significantly in both magnitude and distribution from gust factors for extratropical cyclones.

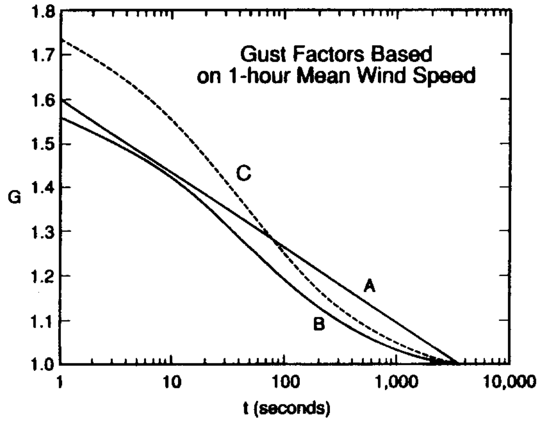

Fig. 2. Comparison of gust factor curves proposed by Cook (A) and by Durst (B), and as hypothesized on the basis of this study (C).

Conclusions

The data described in this paper suggest that the gust factor relationship proposed by Durst, while entirely satisfactory for well-developed extratropical storms, will underestimate gust speeds in hurricanes. In addition, it is clear that the probability distribution for hurricane gust factors is non-Gaussian. More data are needed to establish the actual distribution and to discern any systematic differences in gust factors for locations within and outside the hurricane eyewall. The availability of wind speed records only in the form of traditional strip-chart records seriously limits the amount of useful information that can be extracted.

Future Work

The possibilities for obtaining hurricane wind speed records in digital form should increase dramatically with the deployment of the Automated Surface Observing System (ASOS) by the National Weather Service over the next few years. Ideally, this system will store on site the sequential 2-min means and the corresponding peak 5-sec gust. However, as has been noted by Powell (1993), the maximum wind speed capable of measurement by ASOS is 65 m/s; the stored data will be overwritten and destroyed if not downloaded to some other device within 12 hours; and the system has no backup supply in the event of a power outage. The 65 m/s limitation on wind speed would be most unfortunate for extreme events such as Hurricanes Hugo and Andrew where the gust speeds in certain areas substantially exceeded this level.

Appendix I. References

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