

## ESTIMATING HURRICANE WIND SPEEDS FROM SATELLITE PICTURES

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### ABSTRACT

The empirical relationship between the maximum wind speed (MWS) of tropical storms and their characteristics pictured from satellites has been employed routinely since 1964. A large number of cases accumulated since then now enables these relationships to be put on a more firm statistical basis and revised MWS curves are presented.

An empirical method of estimating the maximum wind speed (MWS) in tropical storms from their characteristics pictured on satellite photographs has been in use since July 1, 1964. The development of this technique was reported by Fritz in collaboration with the present authors (1965, 1966).

The technique was devised from only 47 storms and was tested with the independent data of an additional 27 storm cases. Now these speed estimates have been made on 430 cases for which maximum wind speeds have been observed by hurricane reconnaissance; thus the statistics can be reexamined with a much larger sample. The purpose of this note is to report the results of this reexamination. It is encouraging to note that the new (computed) relationships are only slightly different from the "eye-fit" made on the original 47 cases.

The nature of these data, discussed in the original report (1965), should be kept in mind. Both the size of the "overcast diameter" and the classification of a storm into a given category are somewhat subjective.<sup>1</sup> It is significant, however, that experienced analysts agree on classifications in a majority of cases. The operational analysts in the National Environmental Satellite Center routinely make such classifications, which are issued as Miscellaneous Satellite Bulletins, and the research analyst has made independent classifications of these patterns. In nearly all cases, these two classifications have not differed significantly.

The research analyst's classifications have been used in this reexamination of the technique because they tend to be less influenced by operational procedures. The operational classifications tend to be influenced by the analyst having the latest hurricane advisories. The classifications by the research analyst, however, were made without his seeing the latest advisories. (In many cases he did have the advisories from the previous day.) The influence of the most recent additional information can be discerned by comparing the wind estimates made from the operational classifications with those made by the researcher. During the 1964 season, the former estimates scattered about the observed MWS of  $\pm 15$  kt while the estimates based on the researchers' classifications had a mean dispersion of  $\pm 17$  kt.

The measurement of wind speed by aircraft also has a degree of error. Seldom is the maximum wind observed simultaneously with the satellite picture, so time changes produce some uncertainty. In order to minimize differences due to interpolating between observations, cases were used here only if a wind determination had been made within 6 hr of the satellite observation. Furthermore, the postanalysis wind speeds were taken as the "true" maximum wind speed. Even with these precautions it is unlikely that the best "measurement" represents the actual wind speed more accurately than within 10 to 20 percent. All of these data imperfections contribute to the wind dispersion to an unknown degree.

Table 1 shows the distribution and various characteristics of the cases used to compute curves of the form  $MWS = a + bD + cD^2$  where MWS is the maximum wind speed (the postanalysis speed derived from aircraft reconnaissance penetrations) and  $D$  is the diameter of overcast circle (measured from satellite pictures (Timchalk et al., 1965)).

A separate set of constants,  $a$ ,  $b$ , and  $c$ , were computed for each of the four categories, for three groupings of the data: Atlantic storms, Pacific storms, and a combination of both areas. Table 1 shows that the average dispersion is about the same for each of the groupings; therefore, the data do not justify use of separate regression curves for Atlantic and Pacific storms. Standard least-squares curves fit to the combined data yielded the following equations:

category 1	$MWS = 25.9 + 17.3D - 3.24D^2$ ,
2	$MWS = 46.2 + 4.08D + .004D^2$ ,
3	$MWS = 47.3 + 9.39D - .270D^2$ ,
4	$MWS = 60.9 + 11.7D - .270D^2$ .

Figures 1a through 1d display the curves computed for each category for the combined Atlantic and Pacific cases as well as the original eye-fit lines for comparison. The heavy solid segment of each curve extends over the range of overcast diameters actually measured. The thin lines are the original eye-fit curves (Timchalk et al., 1965).

The computed relationships for the upper three categories are somewhat different from those derived from the original small sample and are believed to represent an improvement. Category-1 storms apparently have not yielded an improved correlation, and the data imply that these poorly organized patterns are not well handled by this technique. The computed curve has its maximum at  $D = 2.7^\circ$  where  $MWS = 49$  kt so that wind speeds less

<sup>1</sup> See Timchalk et al. (1965) and Fritz et al. (1966) for the definition of "overcast diameter," measured in units of degrees of latitude and for the description of organizations classified as "Category 1 through 4."

TABLE 1.—Distribution and characteristics of tropical storms

Category classification*	Location and total number											
	Atlantic (138)				Pacific (292)				Combined (430)			
	1	2	3	4	1	2	3	4	1	2	3	4
Number of storms.....	13	28	68	29	22	55	138	77	35	83	206	106
Mean diameter (deg. of lat.)*.....	2.5	3.2	3.9	4.6	2.9	3.7	4.3	4.9	2.8	3.5	4.2	4.9
Mean maximum wind speed (kt)*.....	47	57	79	101	46	62	83	114	46	61	81	111
Mean deviation of MWS from regression curves (kt).....	12.5	14.1	13.5	14.9	15.3	16.8	18.4	19.9	14.6	16.2	16.9	19.4

\*As defined in Timchalk et al. (1965) and Fritz et al. (1966).

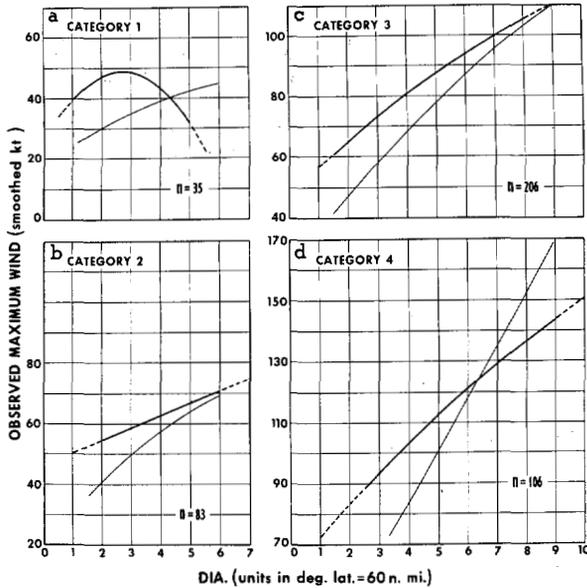


FIGURE 1.—Computed (heavy line) and original (Timchalk et al., 1965) eye-fit curves (light line) for estimating maximum wind speed (MWS), Pacific and Atlantic data combined. Unbroken portion of the heavy lines indicates the diameter (DIA.) ranges of the samples.

than 49 kt correspond to two diameters. On the basis of these data the use of an average speed (46 kt from table 1) would provide an estimate as accurate as the use of a regression line, that is, the same average error would be made.

It is the authors' opinion that the 35 cases available for this investigation were not representative. A majority of all storms classified as category 1 were excluded because no independent wind measurement was obtained within  $\pm 6$  hr. For example, during the 1967 season only 11 of 36 category-1 storms were used here. According to the Annual Hurricane and Typhoon Reports many of these excluded cases were believed to be only marginally of tropical storm intensity, that is, about 35 kt. The intense storms are more likely to have reconnaissance observations so that the sample is probably biased toward storms of high MWS. Consequently, it is the authors' recommendation that the original eye-fit curve be used for category-1 storms until better data are available.

Figure 2 combines the best available relationships for use with this technique; only the category-1 curve is unchanged from the original. Prospective users should take into consideration the tentative and unproven corre-

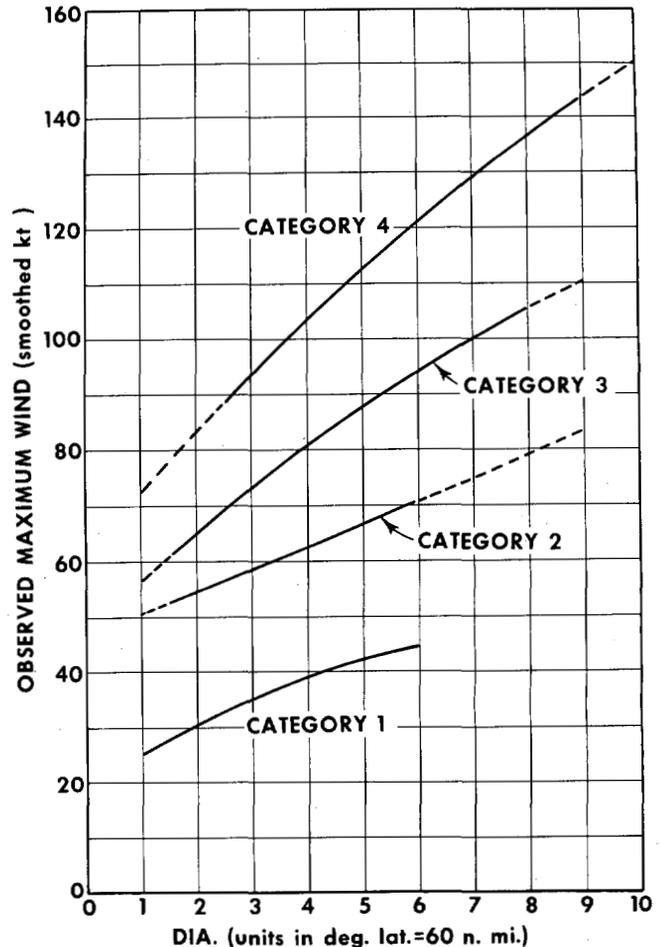


FIGURE 2.—Recommended diameter (DIA.) versus maximum wind speed (MWS) regression. Computed curves (same as in fig. 1) for categories 2 through 4 and original (Timchalk et al., 1965) eye-fit curve for category 1.

lation represented by the category-1 line, and they should use the other curves with caution when the overcast diameter falls outside the diameter range encompassed by the unbroken lines.

REFERENCES

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