U. S. DEPARTMENT OF COMMERCE
Environmental Science Services Administration
Weather Bureau

ESSA Technical Memorandum WBTM SR-45

ON THE MAXIMUM SUSTAINED WINDS OCCURRING IN ATLANTIC HURRICANES

SOUTHERN REGION HEADQUARTERS
SCIENTIFIC SERVICES DIVISION
FORT WORTH, TEXAS
May 1969

ON THE MAXIMUM SUSTAINED WINDS OCCURRING IN ATLANTIC HURRICANES

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The method most frequently used to estimate maximum surface winds occurring in Atlantic hurricanes has been Fletcher's equation (1). The formula is based on the pressure gradient between the storm's central pressure (P_c) and peripheral pressure (P_n). (The constant value of 1010 mb for P_n is commonly used for the outer closed isobar, since this value has been observed to be fairly consistent for Atlantic hurricanes. Many meteorologists feel that Fletcher's equation, Vmax (knots) = $16\sqrt{P_n - P_c}$, tends to overestimate the sustained wind and more closely approximates gust velocities (2). Other formulas based on the same concept are listed in Table 1. It is the object of this paper to consider which of the various equations available yields the most reasonable values for sustained winds.

In order to form a basis for comparison of the formulas, reliable observations of maximum sustained winds and central pressure were needed. Since most aircraft observations are either of flight level winds or estimations of surface wind from the state of the sea, it was thought that observations obtained from coastal and island stations during the passage of a hurricane's center would be the most reliable. Data were compiled from back issues of the Monthly Weather Review over the past 66 years. All stations with a record of minimum central pressure and measured maximum sustained wind (fastest mile) were used. Estimated winds were not used due to the variability from one individual's observation to another's plus the difficulty which exists in accurately judging speeds of hurricane force. An effort was made to choose only those stations which were located in the right front quadrant of the storm, and to select cases in which the hurricane was just making landfall and had not become greatly influenced by land friction. Forty-three cases were selected which met these requirements. These ranged in years from 1915 to 1966. The majority of the data were confined to latitudes 24°N-32°N. In a few cases, aircraft and ship observations of the central pressure near the station were used when the station pressure was not available. A few estimations of minimum central pressure computed as described in NHRP. report No. 5 (3) were used when the station observations were not available.

It was interesting to see that the data, when plotted on a graph, (Fig. 1) appeared to fit a linear relationship over the pressure interval, 997-914 mb. A regression line (Fig. 2) was computed for the data giving Vmax(mph) = $1431 - 1.37P_c$ with a standard deviation of 7.1 mph and an average error of 5.6 mph. However, values which lie outside the data range are open to question. It appears obvious that extrapolation of the line for values above 1000 mb would give winds much too high for the pressure involved. With only one case available below 930 mb uncertainty also exists in that area.

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Fletcher's formula, when plotted with respect to the data, fits along the upper limit of the data sample. The curve had a standard deviation of 14 mph with an average error of 11.4 mph too high. The graph of the formula computed by Myers (4) $Vmax(kts) = 11\sqrt{P_n - P_c}$, lies well below the data sample with an average error of 24.5 mph and a standard deviation of 27.4 mph. Since he based the value of the constant factor on data gathered in the 1949 hurricane over Lake Okeechobee (5) it may be that his wind estimates fit better for hurricanes which have moved inland.

Takahashi's formula (6) $Vmax(kts) = 13.4\sqrt{1010 - P_c}$ when plotted with the data fits within the lower limits of the sample in pressures ranging above 950 mbs. However, the curve falls away for pressures below 950 mbs. A standard deviation of 15.5 mph was computed for the curve with an average error of 10.6 mph.

The Joint Typhoon Warning Center at Guam developed an equation (7) using the pressure field and a factor taking the latitude Ø, into consideration:

$$Vmax(kts) = \left(20 - \frac{\varnothing}{5}\right)\sqrt{1010 - P_c}$$

When checked with the data sample this formula yielded a standard deviation of 9.6 mph and an average error of 7.6 mph. Using a latitude of 28° N, which is about the average latitude of the data sample, the resultant curve fits through the middle of the plotted data. Fletcher's constant of 16 gives the same values for a storm at 20° N in the JTWC formula.

Finally, a similar equation with slightly different constants:

$Vmax(kts) = 14\sqrt{1013 - P_c}$, formulated by Kraft (8), is plotted. The standard deviation and average error of 8.8 and 6.7 mph respectively are the smallest of the formulas cited in this study. Kraft's equation is the one currently used by forecasters at the National Hurricane Center. The regression line also yields good results for storms with central pressures in the range 930-995 mbs.

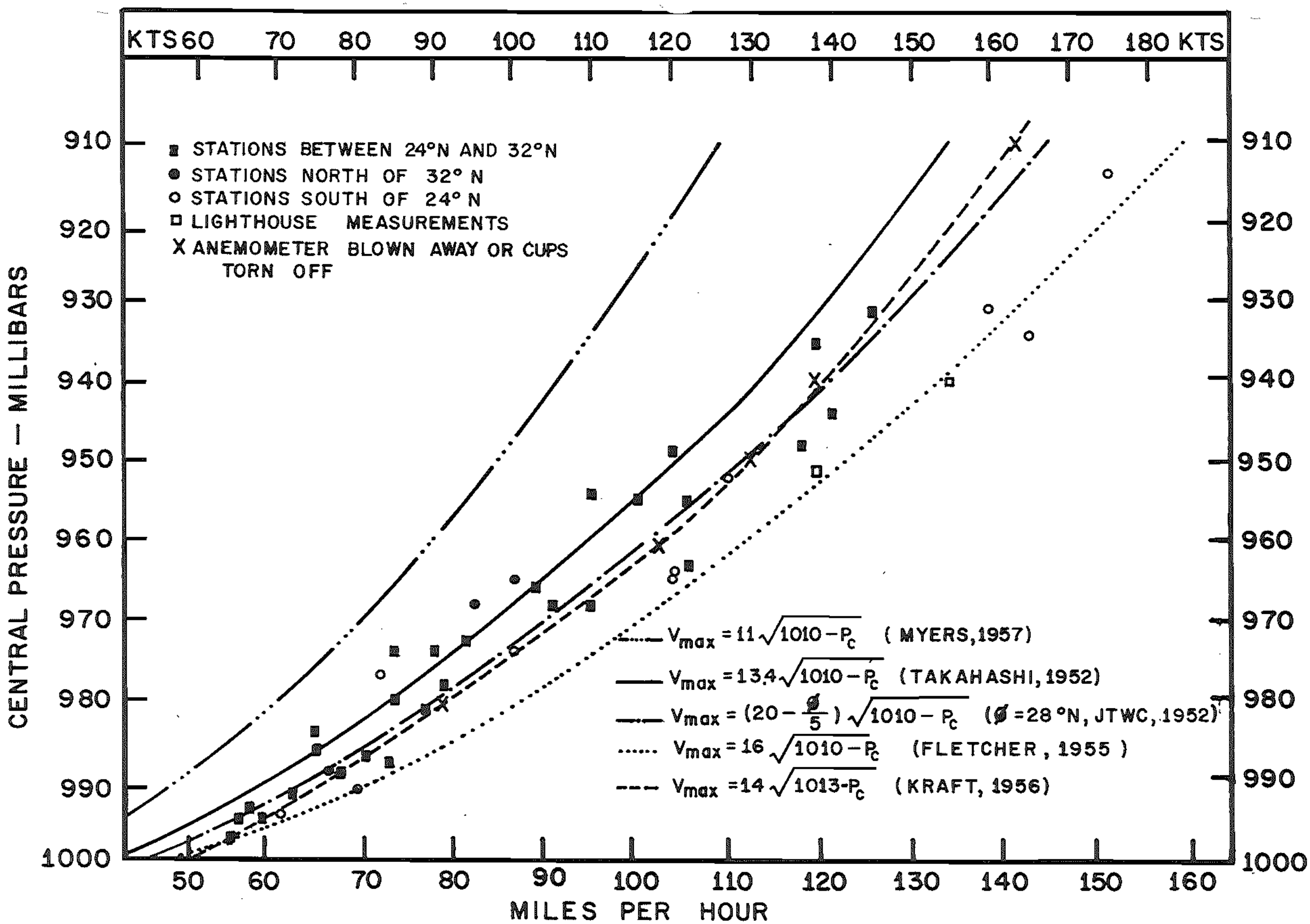

FIGURE 1. EQUATIONS USED FOR DETERMINING MAXIMUM SURFACE WINDS FROM CENTRAL PRESSURE IN TROPICAL CYCLONES

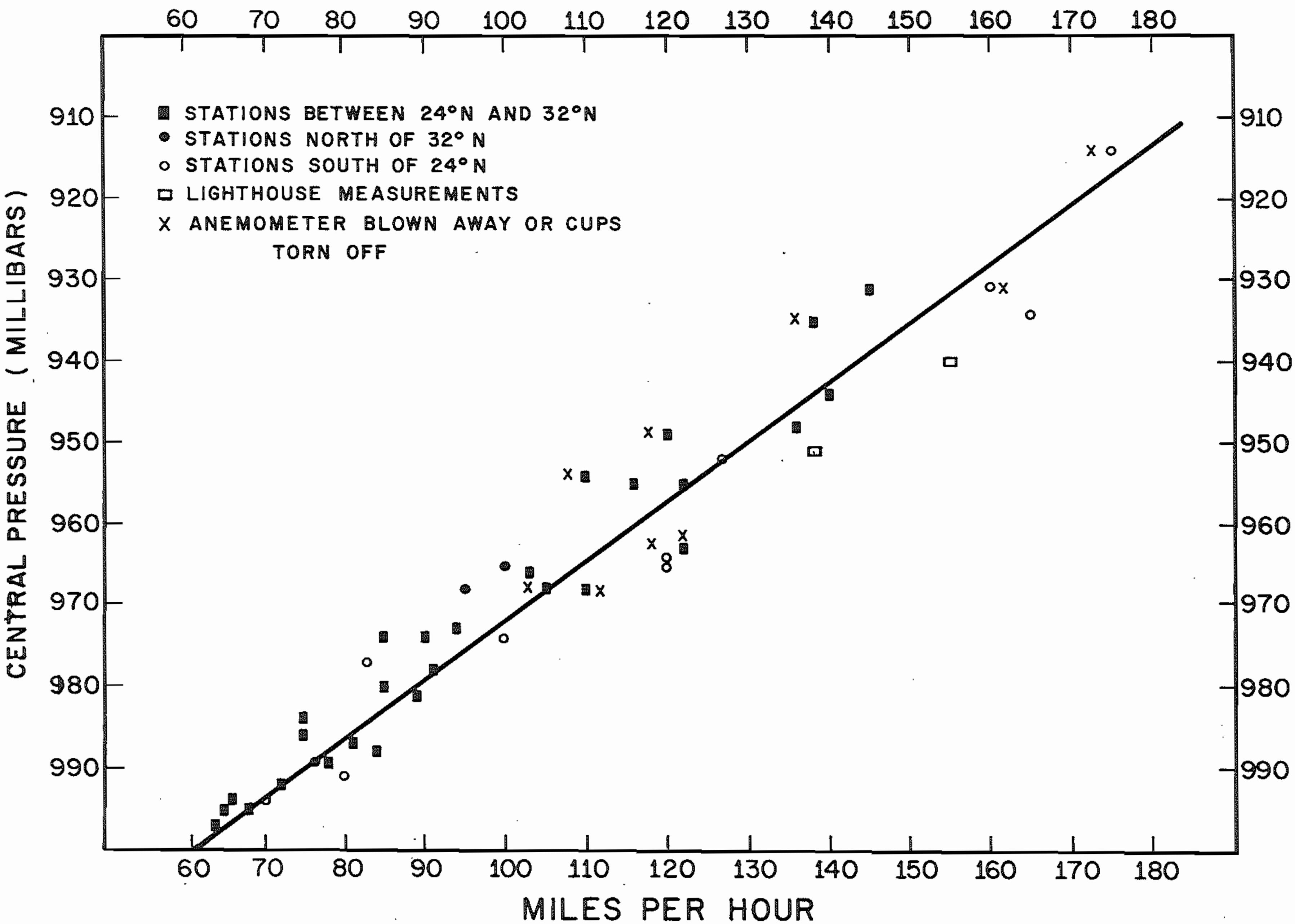

FIGURE 2. MAXIMUM SUSTAINED WINDS vs CENTRAL PRESSURE AS OBSERVED BY ISLAND AND COASTAL STATIONS IN THE ATLANTIC WITH PASSAGE OF THE CENTER OF A TROPICAL CYCLONE

TABLE I

STATISTICS CONCERNING EQUATIONS USED TO DETERMINE MAXIMUM WINDS IN HURRICANES WHEN CHECKED WITH DATA SAMPLE

EQUATION Vmax(kts) =		STANDARD DEVIATION (mps)	AVERAGE ERROR (mph)	PROBABLE ERROR (mph)
Fletcher's	$18\sqrt{1010-P_c}$	14.0	11.6	9.4
Takahashi	$13.4\sqrt{1010-P_c}$	15.5	10.6	10.5
Relationship From Fig. 2	$1431-1.37P_c$	7.1	5.6	4.8
JTWC	$(20-\frac{\phi}{5})\sqrt{1010-P_c}$	9.6	7.3	6.5
Myers	$11\sqrt{1010-P_c}$	27.4	24.5	18.5
Kraft	$14\sqrt{1013-P_c}$	8.8	6.7	5.9

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(3) "Survey of Meteorological Factors Pertinent to Reduction of Loss of Life and Property in Hurricane Situations", National Hurricane Research Project Report No. 5, USWB, 1957 pp. 29-30

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(5) "Characteristics of United States Hurricanes Pertinent to Levee Design for Lake Okeechobee, Florida", Hydrometeorological Report No. 32, USWB, March 1954

(6) Takahashi equation for maximum winds in hurricanes - from files at Weather Bureau Forecast Center, Suitland, Md.

(7) Mcknowan, R., and Collaborators, Fifth Annual Report of the Typhoon Post Analysis Board, Anderson Air Force Base, Guam, M. I. 1952, 52 pp

(8) Kraft, R. H., "The Hurricane's Central Pressure and Highest Wind", Mariners Weather Log, Vol. 5, No. 5, Sept. 1961