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INVESTIGATION OF GUST FACTORS IN TROPICAL CYCLONES.(U)

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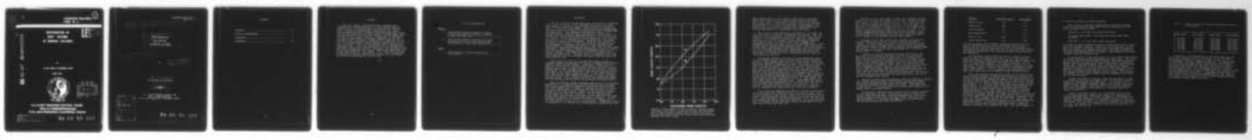

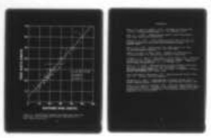

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INVESTIGATION OF GUST FACTORS IN TROPICAL CYCLONES

by

LT COL GARY D. ATKINSON, USAF

JUNE 1974

U.S. FLEET WEATHER CENTRAL GUAM
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ABSTRACT

The 1972 Tropical Cyclone Conference requested that FLEWEACEN/JTWC include peak gusts in the warnings when sustained surface wind speeds equal or exceed 50 kts. During 1972, a sustained wind/peak gust graph derived by former JTWC personnel was used. Details on how this graph was derived were not available and there was a general feeling among JTWC forecasters that the gust factors derived from this graph were too high for open water conditions. Therefore, at the 1973 Tropical Cyclone Conference, FLEWEACEN/JTWC requested that all 7th Fleet ships equipped with anemometers include peak gusts as well as sustained winds in their weather reports during strong wind conditions. These ship observations and a comprehensive literature survey led to the derivation of a new sustained wind/peak gust relationship which was introduced into operational use by the JTWC during the 1973 season. This study showed that for strong wind conditions, gust factors (i.e., ratio of peak gusts to one-minute average sustained wind speeds) over open water should fall in the range of 1.20 to 1.25.

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DISCUSSION

The 1972 Tropical Cyclone Conference requested that FLEWEACEN/JTWC include peak gusts in the warnings when sustained surface wind speeds at warning or forecast times equaled or exceeded 50 knots. To meet this requirement, JTWC was faced with determining representative gust factors for sustained one-minute average winds over open water. Even though not specifically stated, it is assumed that the sustained winds and peak gusts would apply to a normally accepted standard anemometer height of 30 feet above the sea surface. Before proceeding, several definitions are required. The peak gust is the maximum, nearly instantaneous, wind speed measured by standard wind equipment. Normally, gusts would have to persist on the order of a few seconds to be recorded on most wind equipment. Sustained wind speed is simply the mean wind speed during some averaging period such as one, five, or ten minute increments. Department of Defense meteorological services normally use a one minute averaging period for sustained surface winds; however, synoptic wind observations from most countries use a ten minute averaging period. The gust factor is defined as the ratio of the peak gust to the sustained wind speed occurring during the same period of time.

The structure of the air flow near the earth's surface is extremely complex and has been the subject of numerous micrometeorological studies and experiments. From these studies, some of which are cited herein, several generalizations pertinent to this problem can be made. At any location, the gust factor is directly proportional to the averaging period used to derive the sustained wind speed, e.g., a gust factor for a one minute sustained wind is less than for ten minute sustained wind. At any given elevation above the surface, the rougher the surrounding terrain the higher the gust factor. Also, the gust factor at any location decreases with increasing elevation due to the decreased frictional effect.

When the JTWC was tasked to provide peak gusts in the warnings, Headquarters, 1st Weather Wing provided several studies and peak wind versus sustained wind graphs for consideration by the JTWC. One of the graphs (Curve A Figure 1) had been derived by personal experience and studies of Air Weather Service personnel formerly assigned to the JTWC; however, details of the original research and the data used were not available. The National Hurricane Center (NHC) also provided a peak gust versus sustained wind graph derived from Atlantic hurricane data (Curve B Figure 1). The NHC cautioned against its use without verification, however, due to the small amount of data used in its derivation. Independent studies by Headquarters, 1st Weather Wing showed general agreement with the

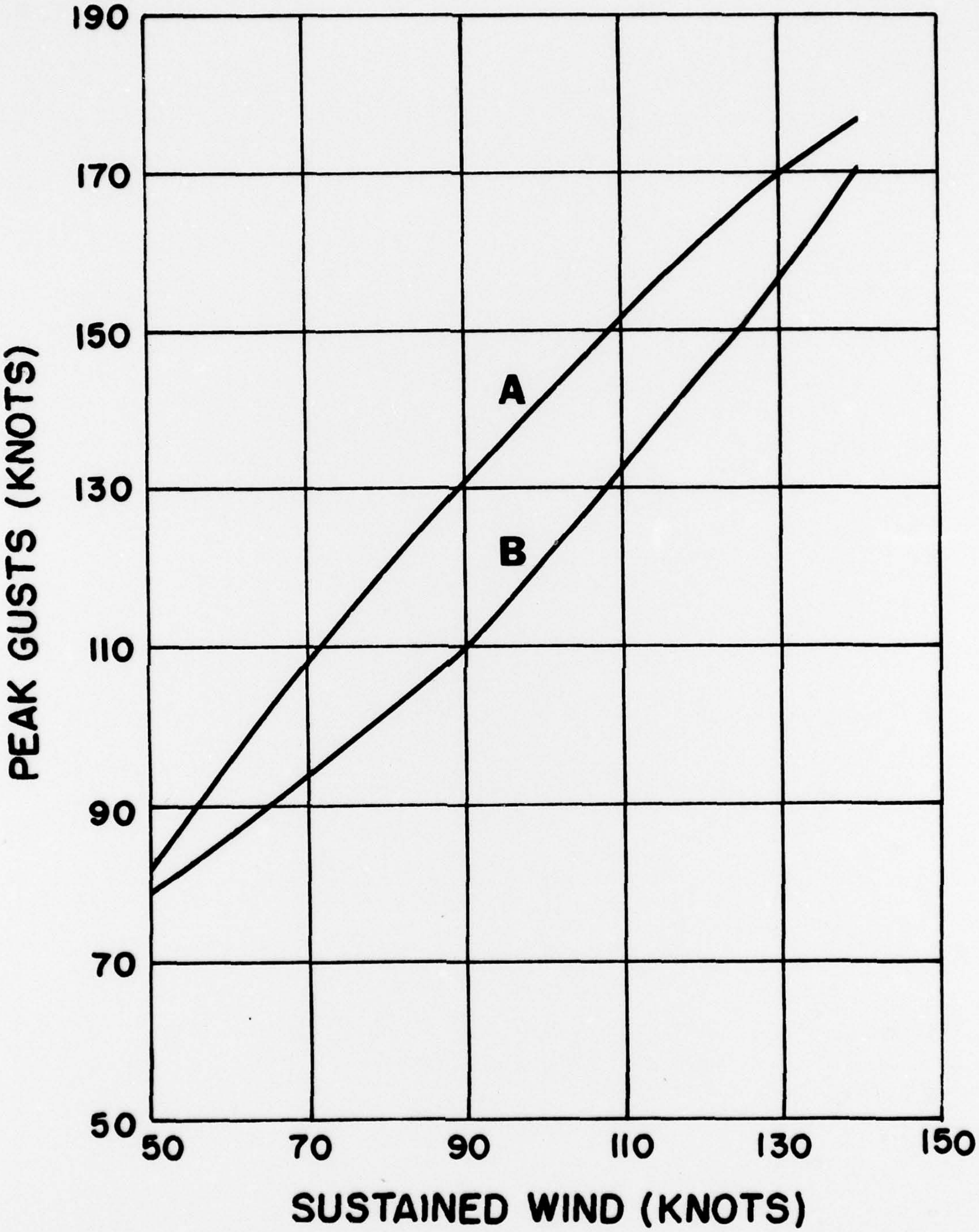

Figure 1. Relationship between sustained 1-minute average wind speeds over water in tropical cyclones and peak gusts. Curve A was derived by former JTWC personnel and Curve B, derived from Atlantic hurricane data, was obtained from the National Hurricane Center.

above graphs; however, these studies were based on wind data taken from various Pacific Island stations which undoubtedly have a wide range of anemometer elevation heights and exposure. For example, much of their data was taken from Kadena Air Base, Okinawa which is located at an elevation of approximately 150 feet several miles from the coastline and should not be considered representative of conditions over open water.

Due to lack of more definitive information at the time, the JTWC used Curve A in Figure 1 during the 1972 season. There was a general feeling among JTWC forecasters, however, that the gust factors in this graph were too high for open water conditions. Therefore, at the 1973 Tropical Cyclone Conference, FLEWEACEN/JTWC requested that all Seventh Fleet ships equipped with anemometers include peak gusts as well as sustained winds in their weather reports during strong wind conditions. These ship observations and a comprehensive literature survey led to the derivation of a new sustained wind/peak gust relationship which was introduced into operational use by the JTWC during the 1973 season. Following is a discussion of the reasoning from which this new relationship was derived.

The biggest problem is the lack of a representative sample of reliable wind observations over open water during typhoon conditions. Ships normally avoid areas of strong winds if possible. When ships encounter typhoon force winds, the accuracy of the observations is open to serious question due to problems associated with a moving platform on a rolling sea surface. Additionally, many ships do not have anemometers and must estimate wind speeds based on observed sea state. Even for ships with anemometers, few have wind recording equipment so the averaging period used to derive the sustained winds may vary considerably. Most populated islands which have meteorological stations are large enough that their wind observations undoubtedly differ, to some degree, with those taken nearby over the open water. Large-scale deployment of meteorological/oceanographic buoys in future years may provide more reliable observations related to this problem. For now, however, representative gust factors for open water conditions must be estimated from studies and data currently available.

One of the most comprehensive studies of surface wind observations associated with tropical cyclones was made by Myers (1954). He made a detailed study of the surface winds and pressures during a hurricane which passed through a dense surface observational network at Lake Okeechobee, Florida during August 1949. He found that the average gust factor (peak gust divided by ten minute sustained wind) at stations on the lake shore during periods when the wind blew from off the water was 1.43.

Kitaoka, et. al. (1971) made a study, for structural design purposes, of extreme wind speeds at 124 weather stations in Japan with periods of record exceeding 20 years. This study included data from the Ryukyus and other island stations near Japan. The data were not separated according to cause of the extreme winds; however, it can safely be assumed that many of the annual extreme winds recorded at stations along with the southern coast of Japan and at island stations were caused by tropical cyclones. This study concluded that coastal areas where the wind blows from the sea and where the surroundings are flat have a mean gust factor of 1.4 (based on a ten minute sustained wind speed).

Taniguchi (1962) also studied gust factors associated with tropical cyclones at stations in Japan including the Ryukyu Islands. His work showed a tendency for the gust factor (associated with ten minute average winds) to decrease with increasing wind speeds; however, he had few observations with sustained winds over 50 knots. His results show a gust factor of 1.4 for sustained winds of 50 knots.

A number of detailed micrometeorological wind studies have been made at mid-latitude locations in extratropical cyclones. While they may not be directly applicable, it is deemed worthwhile to briefly discuss the results of several of these studies. Deacon (1955) studied the variation of gust factors with height based on observations made at three levels on a radio mast near Sale, Australia (located near 38°S, 147°E 20 miles from the coast). The surrounding terrain is gently rolling grassland with few trees. This study showed that the mean gust factor during strong wind conditions decreased with increasing height, being 1.44, 1.30, and 1.24 at 40, 210, and 503 feet respectively. The duration of the periods used to determine the mean wind varied from run to run but averaged eight minutes.

Based on detailed wind observations taken at Cardington, England, Durst (1960) derived probable relationships between wind speeds for various averaging periods from five seconds to ten minutes, stratified according to mean hourly wind speed. These data show a gust factor of 1.4 during strong wind periods when comparing five second versus ten minute speeds.

As previously mentioned, gust factors are critically dependent on the surrounding terrain. During Typhoon Rose in August 1971, surface winds were recorded at various meteorological stations in Hong Kong (Royal Observatory, Hong Kong, 1973). The mean gust factors (based on a ten minute sustained wind) and elevation of the various stations are listed as follows:

STATION	ELEVATION (feet)	GUST-FACTOR
Waglan Island	180	1.41
Cheung Chau	236	1.50
Cape Collinson	151	1.52
Hong Kong Airport	13	1.67
Tate's Cairn	1889	1.72
Royal Observatory	105	2.08

Of these stations, only at Waglan Island would easterly winds have an unrestricted fetch over water before hitting land. Cheung Chau and Cape Collinson have the next best exposure for easterly winds; however, easterly winds at the other three stations are greatly influenced by the rough surrounding terrain and man-made obstacles.

All the above studies indicated that for coastal stations, when the wind is blowing off the water, or for land stations, where the terrain is fairly flat, the mean gust factor between peak gusts and ten minute sustained wind ranges from about 1.40 to 1.45 in strong wind situations. For unrestricted air flow over open water, the gust factors would probably be somewhat less than this range of values: however, to be on the conservative (high) side, a gust factor is 1.40 is assumed to be representative of open water conditions for ten minute average sustained winds.

Since the sustained maximum wind speeds in the JTWC warnings are one minute averages, an appropriate relationship between one minute and ten minute average wind speeds must now be derived. In the Durst (1960) study referenced earlier, the mean ratio between ten minute and one minute average wind speeds was 0.86 for strong wind speeds, i.e., the ten minute speed equals 0.86 times the one minute speed. In a similar study of extreme winds measured over many years at the Royal Observatory Hong Kong, Faber and Bell (1963) present a graph of wind speed relationships for various averaging periods. From their Figure 9, the ratio of the ten minute and one minute average wind speed is derived to be 0.82. As previously mentioned, however, the Royal Observatory is surrounded by fairly rugged terrain and numerous buildings. Therefore, this ratio of 0.82 is probably too low for over water conditions. In fact, Bell addresses this problem directly in a recent unpublished memorandum (1973). In this he estimates the ratio of the ten minute to the one minute average wind speed over a rough sea typical of typhoon force winds to be 0.88. This ratio appears to be realistic based on available evidence.

The results of the above studies can be combined as follows to derive an appropriate gust factor between peak gusts and one minute average sustained winds.

Peak Gust = 1.40 times ten minute wind speed;

Ten minute Wind Speed = 0.88 times one minute wind speed; therefore;

Peak Gust = 1.23 times one minute wind speed.

It should be clearly understood that all these studies and estimates deal with average conditions. Therefore, on the average, the peak gusts over water in tropical cyclones should be about 23% greater than the sustained one minute wind speed. Individual observations, if proper instrumentation were available, would naturally show some variation from this average ratio.

As noted earlier, there have been very few reliable observations of extreme tropical cyclone wind speeds over open water. One unique set of such observations were made, however, when severe hurricane Camille passed very near an oil rig off the coast of Louisiana in August 1969. Thom and Marshall (1971) reduced the winds recorded at 100 feet elevation to the 30 foot level using the commonly accepted 1/7 power law for the variation of wind speed with height. With this adjustment, peak gusts at 30 feet were estimated to be 144 mph and sustained winds (fastest mile) 115 mph. The resulting gust factor of 1.25 agrees closely with the estimated gust factor of 1.23 derived above.

Another validation of the gust factor derived above is taken from an article by Baker and Quayle (1971) on extremes of various parameters experienced over ocean areas. In this article, the authors state, "Typhoons probably generate the highest peak gusts known over the oceans. These have not been accurately measured but can be estimated by miltiplying the sustained winds by a factor of about 1.2."

Based on the above results, it is determined that 1.20 to 1.25 is an appropriate range of gust factors for sustained one minute winds over water of 50 knots or greater. Using these gust factors, estimated peak gusts for sustained winds of 50 knots or greater are given in Table 1 for five knot increments of sustained wind speed. For sustained winds of 50 to 60 knots, the gust factor is 1.25. Gust factors for sustained winds over 60 knots fall in the range of 1.20 to 1.25.

Table 1. JTWC sustained one minute wind-peak gust (knots) relationships.

WIND (GUST)	WIND (GUST)	WIND (GUST)	WIND (GUST)
50-(65)	85-(105)	120-(145)	155-(190)
55-(70)	90-(110)	125-(150)	160-(195)
60-(75)	95-(115)	130-(160)	165-(200)
65-(80)	100-(125)	135-(165)	170-(205)
70-(85)	105-(130)	140-(170)	175-(210)
75-(90)	110-(135)	145-(170)	180-(220)
80-(100)	115-(140)	150-(180)	185-(225)

During 1973, 114 observations of sustained winds and peak gusts were received from U.S. Navy ships. A plot of these observations is given in Figure 2 along with the line of best fit determined by linear regression analyses. The maximum sustained surface wind speed with a reported gust was 48 knots. The linear relationship fits the data very well and leads to a decreasing gust factor with increasing wind speed, the gust factors ranging from 1.37 for sustained winds of 20 knots to 1.22 for sustained winds of 50 knots. Thus while these observed ship wind observations should not be extrapolated too far, they do confirm the results of previous studies and the JTWC choice of gust factors in the range of 1.20 to 1.25 for strong sustained (one minute average) winds over water.

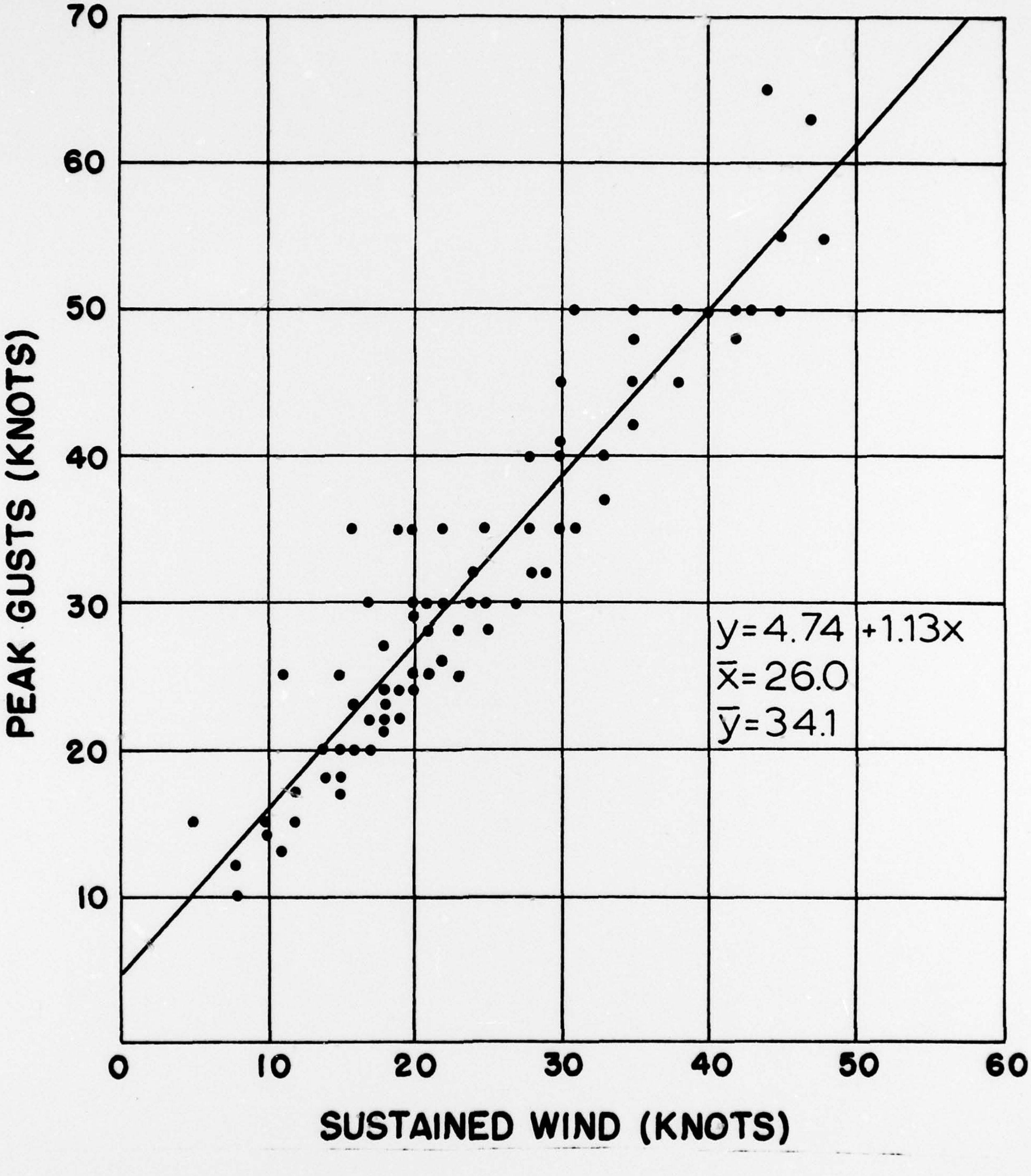

Figure 2. Relationship between sustained wind speed and peak gusts derived from observations provided by U.S. Navy ships during 1973.

REFERENCES

Baker, S.E. and R.G. Quayle, 1971: "Extremes of the maritime climate", Mariners Weather Log, Vol. 15, September 1971.

Bell, G. J., 1973: "Reconniassance Winds", Royal Observatory, Hong Kong, Unpublished Memorandum.

Deacon, E. L., 1955: "Gust variation with height up to 150 m," Quarterly Journal of the Royal Meteorological Society, Vol. 81, October 1955.

Durst, C.S., 1960: "Wind speeds over short periods of time," The Meteorological Magazine, Vol. 89, July 1960.

Faber, S.E. and G.J. Bell, 1963: "Typhoons in Hong Kong and building design", The Engineering Society of Hong Kong.

Kitaoka, T., S. Soma, H. Kikuchibara, and M. Okuta, 1971: "Regional characteristics of high winds for structural design," Papers in Meteorology and Geophysics, Vol. 22, November 1971.

Myers, V. A., 1954: "Characteristics of United States hurricanes pertinent to levee design for Lake Okeechobee, Florida," Hydrometeorological Report No. 32, U.S. Dept. of Commerce, Weather Bureau, Washington, D.C. March 1954.

Royal Observatory, Hong Kong, 1973: "Meteorological Results 1971, Part III - Tropical Cyclone Summaries."

Taniguchi, G., 1962: "Investigation of typhoon surface gusts," Annual Typhoon Report, FLEWEACEN/JTWC, Guam Marianas Islands, 1962.

Thom, H.C.S. and R.D. Marshall, 1971: "Wind and surge damage due to hurricane Camille," Journal of the Waterways, Harbors and Coastal Engineering Division, Proceeding of the American Society of Civil Engineers, Vol. 97, May 1971.