NOCC/JTWC
TECH NOTE 91-2

# TROPICAL CYCLONES AFFECTING GUAM

## (1671-1990)

PREPARED BY

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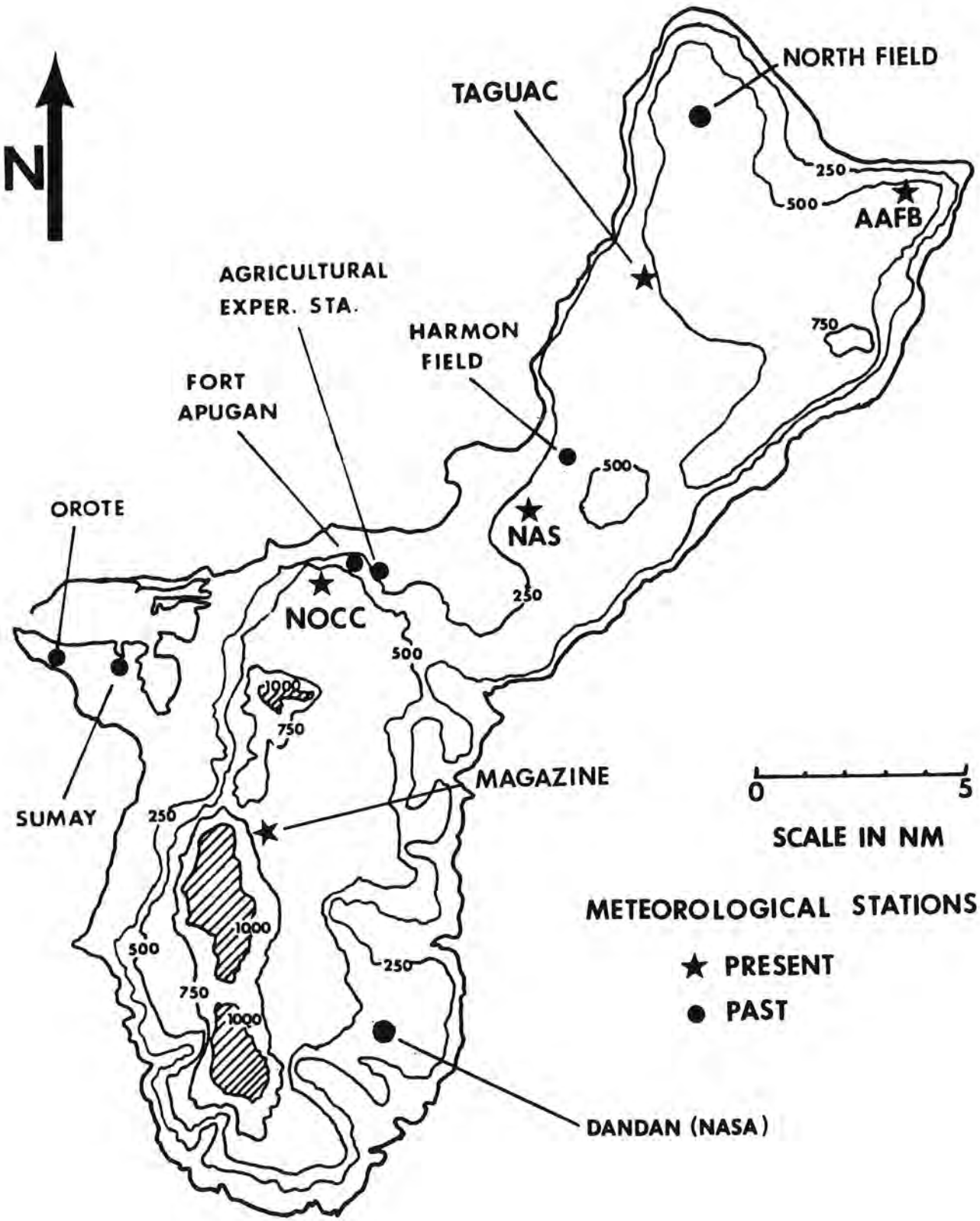


Topographical map of Guam (elevations in feet above mean sea level). Present and past locations of meteorological stations are shown.


Following the typhoon of 1918, a surviving palm tree at the mouth of the Agana River inspired the design of Guam's official seal, which was later adopted in 1930 (Carano & Sanchez, 1964).

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## ABSTRACT

A climatology of tropical cyclones passing near Guam is presented for the period 1945 to 1990. A review of all typhoons affecting Guam is carried back to 1800 and some noteworthy typhoons of the 1600's are included. The survey encompasses the frequency, behavior, meteorological effects and descriptive chronicles of Guam tropical cyclones. The major emphasis is on the period following World War II.

## ACKNOWLEDGMENTS

This survey by Mr. Frank H. Wells updates and expands the efforts of Herbert L. Hansen (Slusser and Kinney, 1970), Charles R. Holliday (1975) and Robert C. Weir (1983). A special note of thanks to Lieutenant Colonel Charles P. Guard and Lieutenant Commander Lester E. Carr III for their suggestions and review of this manuscript; to Daniel N. Shoemaker, Captain (USAF), for his able programming assistance; and to Sgt. Brian McDonald for his graphics support.

# 1. INTRODUCTION

Guam, the southernmost island of the Mariana group, lies within the breeding ground for tropical cyclones, and thus, may be threatened on a year-round basis by the passage of a developing tropical cyclone, and on occasion, by a full strength typhoon. Because of their destructive potential, these cyclones are of concern to both the military and civilian communities on the island. This report presents an overview of tropical cyclone behavior, frequency, and extremes, as well as individual chronicles of those cyclones which have significantly affected Guam. The intent of this publication is to serve as a reference for general information purposes. After the initial document, Typhoons on Guam by Hansen (Slusser and Kinney, 1970), Fleet Weather Center Technical Note (JTWC 75-3) by Holliday (1975) expanded the original material by adding data from 1970 through 1975, and the Naval Oceanography Command Center/Joint Typhoon Warning Center (NOCC/JTWC) Technical Note (83-1) by Wier (1983) updated the material through 1980. This report adds another ten years to the study. Some gaps in information exist, most notably, the 1700's and the period from 1942 to 1944 when Guam was occupied by Japanese forces.

## 1.1 Tropical Cyclone Classification and Units of Measure

The typhoon belongs to a family of atmospheric cyclonic circulations known as tropical cyclones which originate over the tropical oceans. As opposed to cyclones in mid-latitudes, tropical cyclones develop a relatively narrow band of maximum winds encircling a calm center or, for tropical cyclones that reach typhoon intensity, an eye. Tropical cyclones also develop spiral cloud bands that produce torrential rain and high winds, often causing structural damage, floods, and sea inundation. Figure 1 is a satellite view of a typhoon which depicts the markedly clear weather surrounding the cyclone's cloud mass and coil-like cloud banding about the

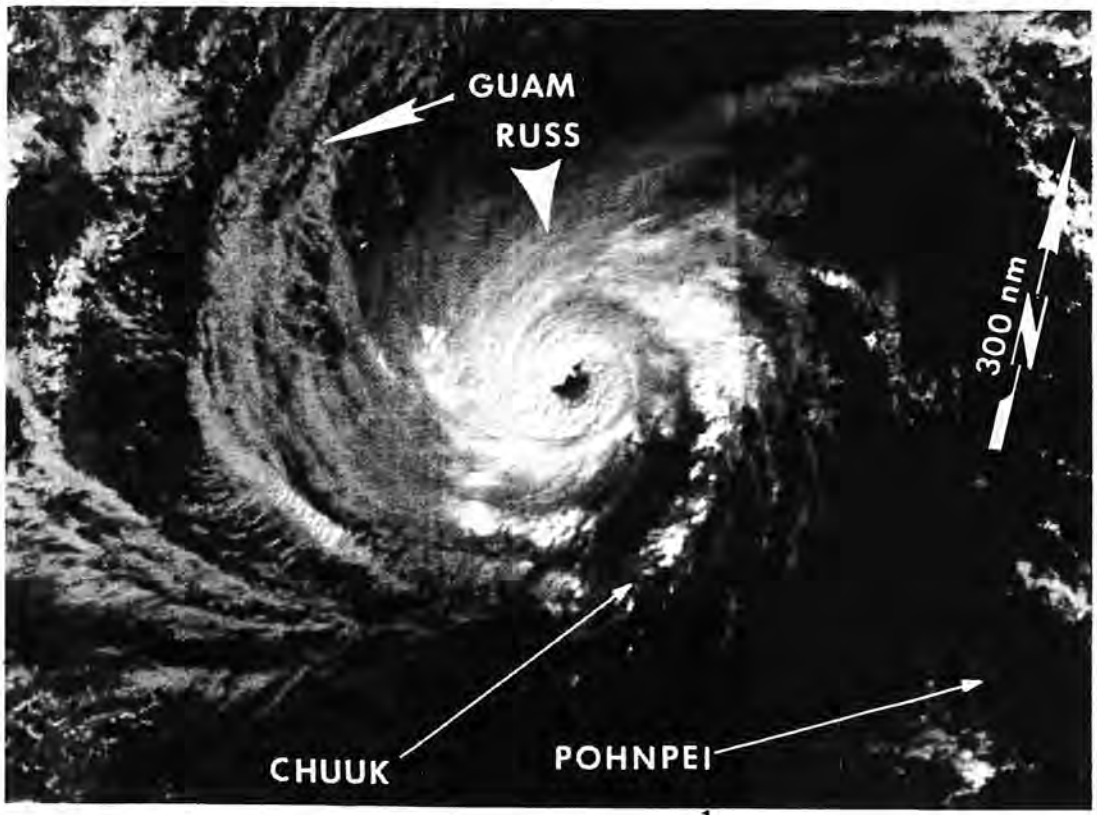


Figure 1. Typhoon Russ at peak intensity approaches Guam (182307Z December DMSP visual imagery).

center. Figures 2a and 2b show a closeup radar presentation revealing the spiraling rainbands beneath the typhoon's high cloud canopy and the rain free area within the eye, respectively. The ring-like structure of the cloud wall encompassing the eye bears the most intense winds of the typhoon's circulation.

To distinguish intensities of tropical cyclones, the commonly used U.S. intensity classifications will be used. These classifications categorize tropical cyclones in terms of sustained surface wind speed (one minute average at ten meters (approximately 33 feet) elevation over water):

super typhoon (>129 kt), typhoon (64 - 129 kt),
tropical storm (34 - 63 kt) and tropical depression (<34 kt)

The term knots (abbreviated kt), meaning a nautical mile per hour, is used exclusively throughout this text as a measurement of wind speed or speed of movement. It is a unit of measurement similar to (statute) miles per hour (mph), but slightly larger (to convert kt to mph, multiply by 1.15). For example, a tropical cyclone reaches typhoon intensity at 64 kt or approximately 74 mph.

Local time on Guam is Universal Time Coordinated (UTC) or Greenwich Mean Time (GMT or Z-Time) plus 10 hours. For example, military records show the closest point of approach (CPA) of Typhoon Russ (1990) to Guam as 1700Z on 20 December; however, this would be 0300 on 21 December local Guam time.

Distance between points is expressed in nautical miles. If a conversion is needed, the relationship that one statue mile equals 1.15 nautical mile (nm) is used.

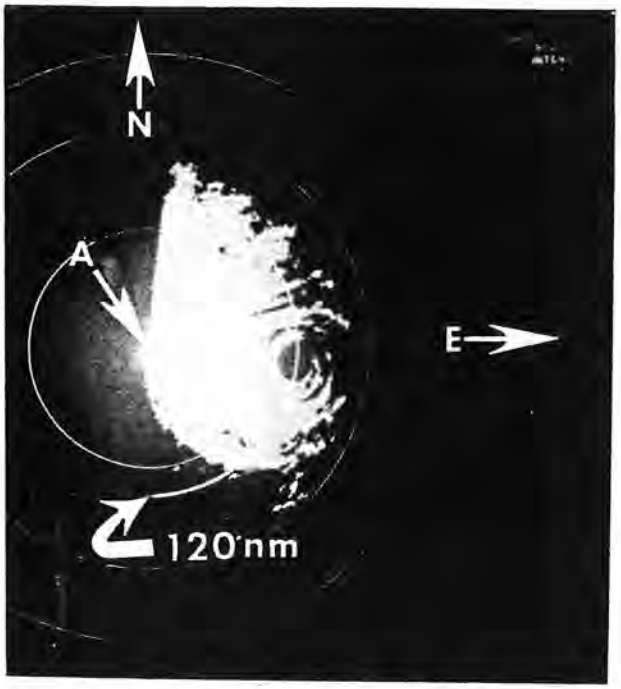


Figure 2a. Spiral rainband echoes define the typhoon's eye at 112310Z January 120 nm east-southeast of the radar site. The weather radar (at point A) is located at Andersen AFB on the northeastern tip of Guam (photo courtesy of MSgt Robert W. Yates).

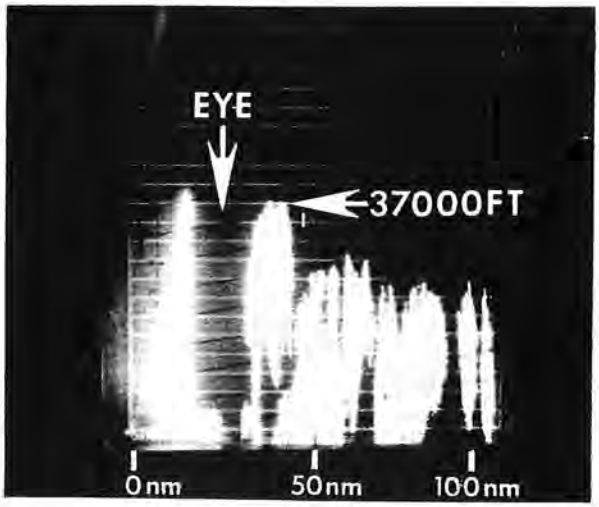


Figure 2b. At 110838Z January the Andersen AFB weather radar display paints 37,000 feet rain echo tops in the outer eye wall cloud. The radar returns in the lower left of the picture and the closest to the radar site are attenuated due to heavy rain (photo courtesy of MSgt. Robert W. Yates).

## 1.2 Data Discussion

Adequate data on tropical cyclone frequency in the western North Pacific, particularly in the vicinity of the Mariana Islands and the Philippine Sea were generally lacking until the mid-1940's when aircraft reconnaissance of tropical cyclones became available. (First introduced in the region in 1945, aircraft reconnaissance of tropical cyclones expanded to become a full-scale, year-round effort by 1948.) Figure 3 is a plot of all the 6-hourly positions in the tropical cyclone climatology for 1945-1990 used in this survey. No attempt has been made to include those cyclones of less than tropical storm intensity (less than 34 kt), since sufficient data on the early stages of tropical cyclone tracks were not available prior to routine satellite observations in 1966. The geographical area under consideration is restricted to within 180 nm of Guam, since

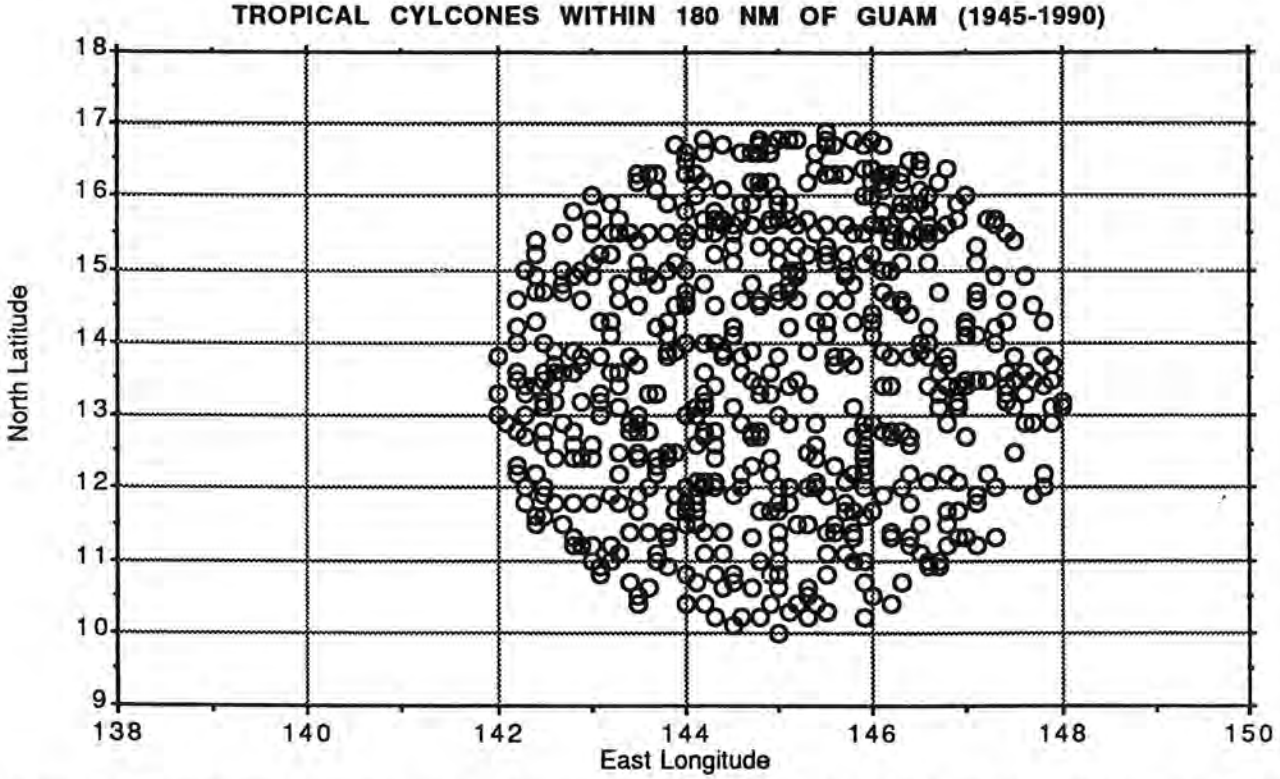


Figure 3. A plot of all the 6-hourly positions of tropical cyclones (>33 kt) within 180 nm of Guam for the period 1945-1990.

generally speaking, the center of a tropical cyclone must pass within this distance to significantly affect the island with high winds and seas, and heavy rainfall. There have been exceptions, however, and these are mentioned as necessary. Also, not all occasions which produced high wind and seas, and heavy rainfall were associated with the approach of a tropical cyclone. However, this discussion will focus only on those events which can be directly associated with tropical cyclone activity. An effort was made by Hansen (Slusser and Kinney, 1970) and Holliday (1975) to survey all cases of typhoons significantly affecting Guam since 1800 in order to construct a long term picture of frequency and severity. In most of these cases, we must assume the typhoons passed within 60 nm of Guam. All documented typhoons affecting Guam have been listed in the Appendices with a narrative account. For the period since 1946, significant tropical cyclones have been added in the narrative summary, and a

separate listing with specific meteorological data has also been included.

In four cases (all prior to 1963), intensity estimates of tropical cyclones passing near Guam have been reevaluated and reclassified from typhoon to tropical storm intensity based on the available data and classification techniques which have been used at the Joint Typhoon Warning Center (JTWC), Guam since 1977. This reclassification was accomplished by Holliday (1975) and is reemphasized here because of the apparent conflict between the Annual Typhoon Reports for those affected years and the data contained in this publication. The reclassified cyclones are suffixed with an asterisk in Appendix E.

## 2. Frequency of Occurrence

Although Guam is located within the breeding ground for tropical cyclones in the western North Pacific, it is located east and southeast of the primary area of activity (Figure 4). An

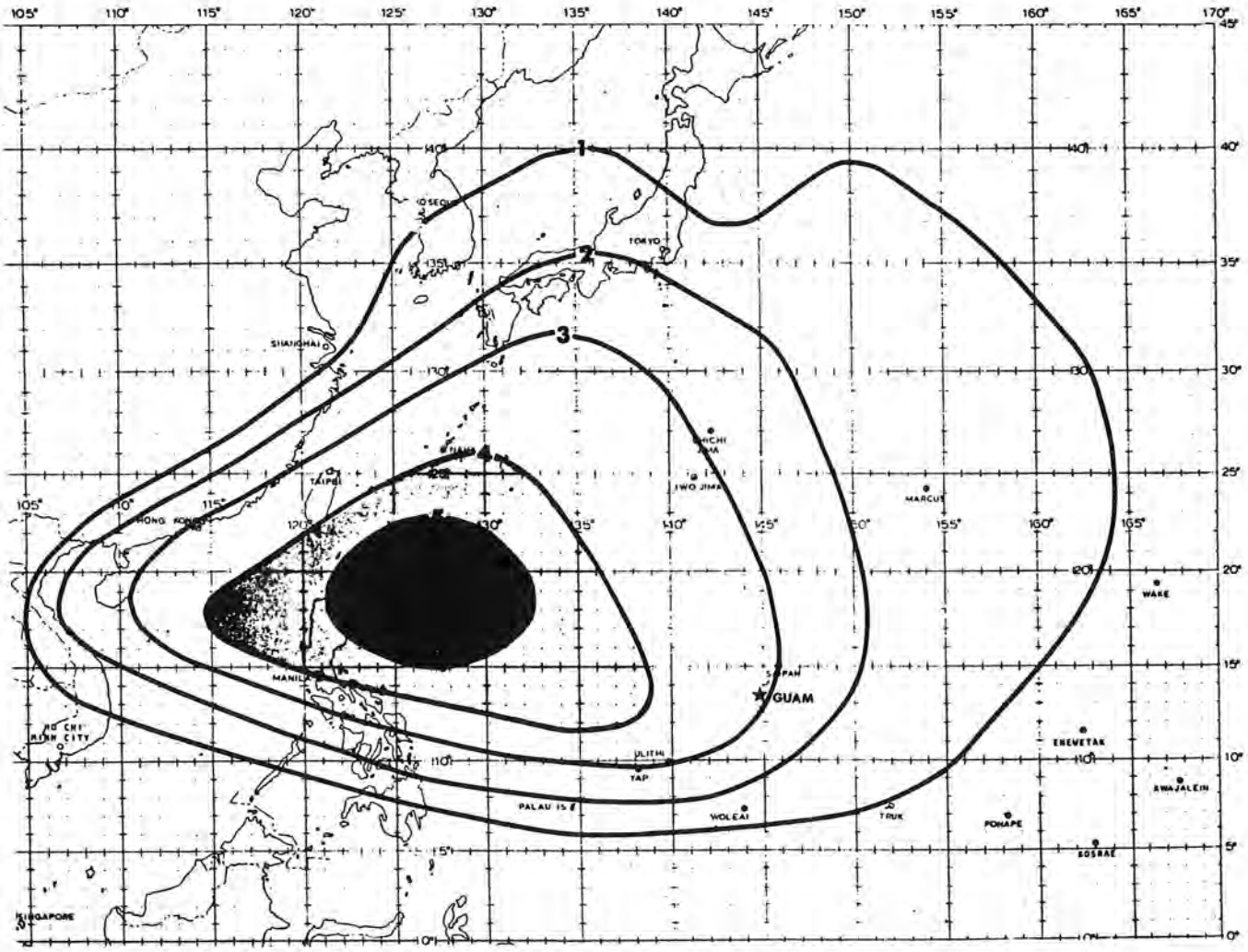


Figure 4. Mean annual number of tropical storms and typhoons traversing 5 degree latitude/longitude squares. (Based on Crutcher and Qualyle, 1974)

average of 31 tropical cyclones (28 are tropical storms and typhoons, and 3 tropical depressions) occur annually across the western North Pacific Ocean and South China Sea (NOCC/JTWC, 1990). Several of these, in various stages of development, threaten Guam each year. During the 46-year period (1945-1990), which is taken from the NOCC/JTWC data base, 162 tropical cyclones with at least tropical storm intensity have developed or tracked within 180 nm of Guam. This is an average of 3.5 cyclones per year, or 13% of the mean annual count for the western North Pacific. Table 1 shows that only 36 (22%) were of typhoon and 8 (5%) of super typhoon intensity at their closest point of approach to Guam. This suggests a much greater (73%) likelihood of a developing tropical cyclone of tropical storm intensity threatening Guam rather than one of typhoon or super typhoon intensity.

Table 1. Relative intensity of tropical cyclones (>33 kt) within 180 nm of Guam (1945-1990)

| Intensity at CPA | Intensity Range | Cases | (Percent) | Total Cases | Total (Percent) |
|---|---|---|---|---|---|
| Tropical Storm | 34 to 49 kt | 85 | (53%) | | |
| | 50 to 63 kt | 33 | (20%) | 118 | (73%) |
| Typhoon | 64 to 99 kt | 24 | (15%) | | |
| | 100 to 129 kt | 12 | (7%) | 36 | (22%) |
| Super typhoon | 130 kt or greater | 8 | (5%) | 8 | (5%) |
| | | | Totals | 162 | (100%) |

## 2.1 Monthly Frequency

Figure 5 displays the temporal distribution of tropical storms and typhoons in the Guam area. Although cyclones have passed through the area during all months of the year, the majority (66%) have occurred during the rainy-season months of August through November, with the peak activity (23% of the annual) in October. The commencement of Guam's main

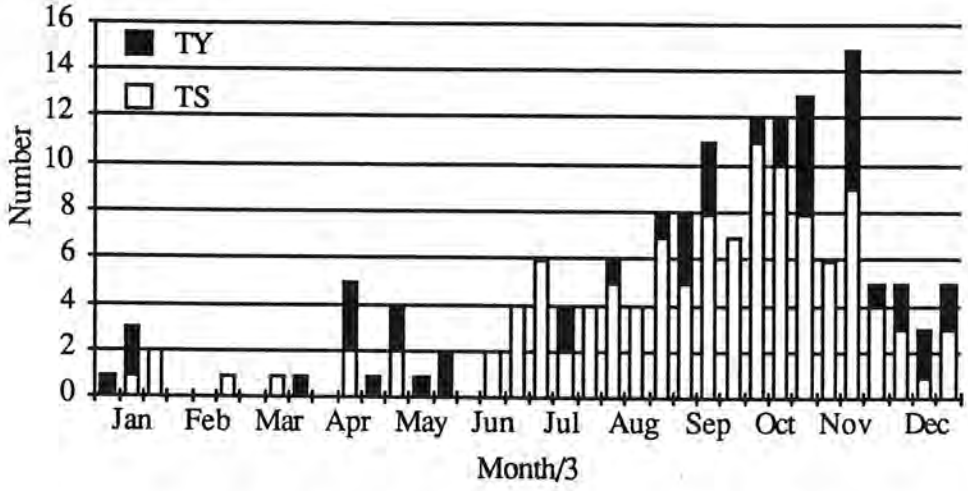


Figure 5. Total number of tropical storms and typhoons within 180 nm of Guam for the period (1945-1990) by thirds of a month.

tropical cyclone season is linked to the eastward migration of the summer monsoon trough towards the longitude of the Mariana Islands, usually by the end of August (Figure 6). This trough provides the favorable environment for the generation of tropical cyclones which may progressively develop into tropical storms and typhoons. Figure 7 shows the distribution of tropical storms near Guam and their increase to a peak in October as the monsoon trough extends eastward towards the date line. In the autumn, the trough is displaced southward and by December usually becomes absent, as winter trade winds from the east dominate to near the equator. The trough reappears at low latitudes (5°N) in the spring as winds from the west occur along the equator (due to the migration of the Southern Hemisphere trough towards the equator; similar to the Northern Hemisphere October and November displacement). This situation is temporary, and by late May, winds from the east once again dominate until the summer southwest monsoon migrates into the area. The presence of this low latitude trough in the eastern Caroline Islands in the late spring accounts for the secondary peak in typhoon frequency (Figure 8) near Guam from mid-April to May. Although the total number of tropical cyclones in the spring is small, when they do develop, they have more time to mature before nearing Guam, which explains the predominance of typhoons affecting Guam during this period.

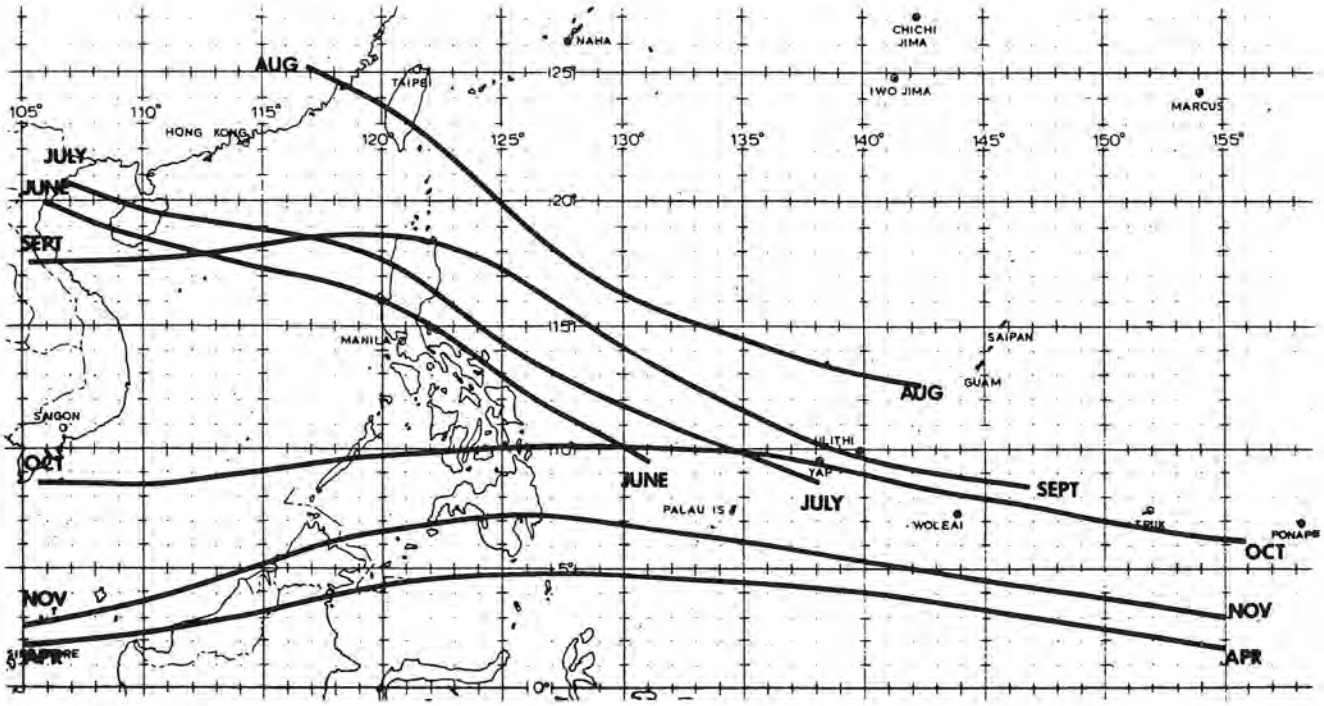


Figure 6. Mean climatological positions of monsoon trough based on Atkinson (1970), Sadler and Harris (1970).

Table 2 gives a breakdown of the probability of a tropical storm, typhoon, super typhoon or all tropical cyclones (>34 kt) center passage within 60 nm increments of Guam.

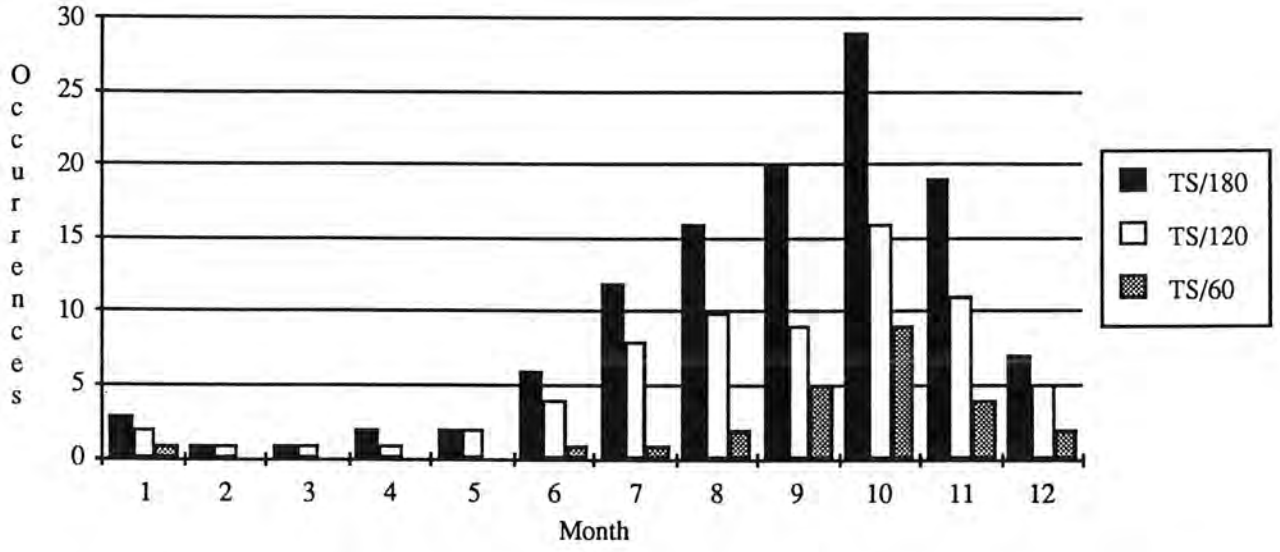


Figure 7. Distribution of tropical storms within 60, 120 and 180 nm of Guam by month (1945-1990).

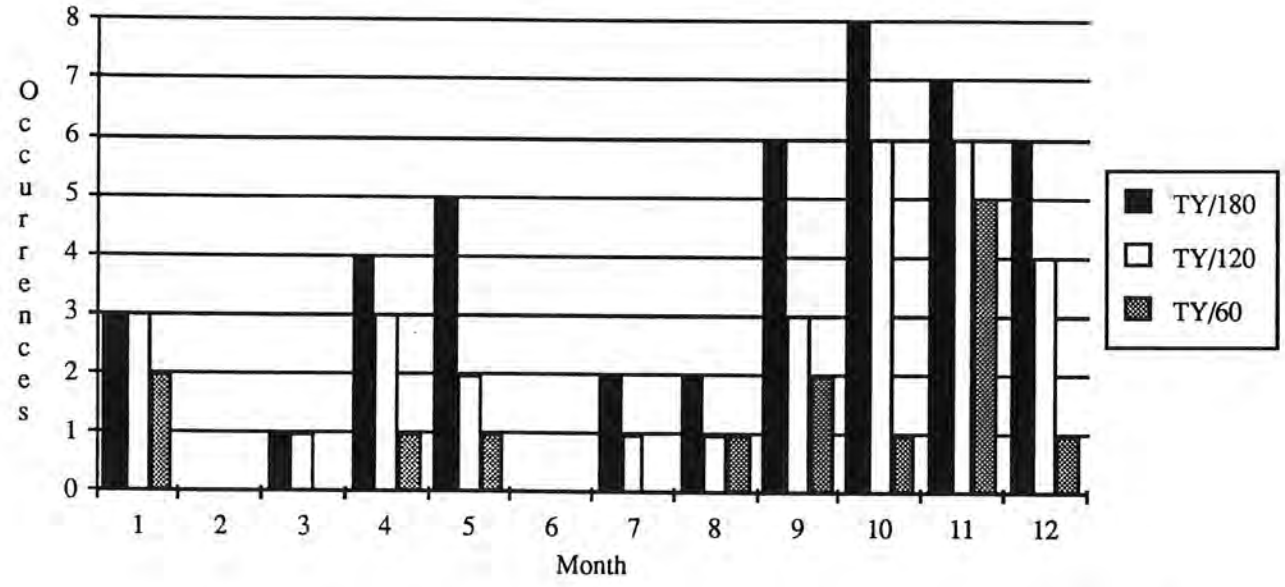


Figure 8. Frequency of tropical storms within 60, 120 and 180 nm of Guam by month (1945-1990).

Table 2. Probability of tropical cyclone (>33 kt) passage by month and distance (1945-1990)

Probability of TROPICAL STORM (TS) (34 - 63 kt) passage near Guam by month (1945-1990)

| MONTH | TS/year | TS w/i 180 nm | TS/year | TS w/i 120 nm | TS/year | TS w/i 60 nm |
|---|---|---|---|---|---|---|
| JAN | 1 in 15 | 3 | 1 in 23 | 2 | 1 in 46 | 1 |
| FEB | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| MAR | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| APR | 1 in 23 | 2 | 1 in 46 | 1 | <1 in 46 | 0 |
| MAY | 1 in 23 | 2 | 1 in 23 | 2 | <1 in 46 | 0 |
| JUN | 1 in 8 | 6 | 1 in 12 | 4 | 1 in 46 | 1 |
| JUL | 1 in 4 | 12 | 1 in 6 | 8 | 1 in 46 | 1 |
| AUG | 1 in 3 | 16 | 1 in 5 | 10 | 1 in 23 | 2 |
| SEP | 1 in 2 | 20 | 1 in 5 | 9 | 1 in 9 | 5 |
| OCT | 1 in 2 | 29 | 1 in 3 | 16 | 1 in 5 | 9 |
| NOV | 1 in 2 | 19 | 1 in 4 | 11 | 1 in 12 | 4 |
| DEC | 1 in 7 | 7 | 1 in 9 | 5 | 1 in 23 | 2 |
| | | 118 | | 70 | | 25 |

Probability of TYPHOON (TY) (64 - 129 kt) passage near Guam by month (1945-1990)

| MONTH | TY/year | TY w/i 180nm | TY/year | TY w/i 120 nm | TY/year | TY w/i 60 nm |
|---|---|---|---|---|---|---|
| JAN | 1 in 15 | 3 | 1 in 15 | 3 | 1 in 23 | 2 |
| FEB | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| MAR | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| APR | 1 in 15 | 3 | 1 in 23 | 2 | 1 in 46 | 1 |
| MAY | 1 in 9 | 5 | 1 in 23 | 2 | 1 in 46 | 1 |
| JUN | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| JUL | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| AUG | 1 in 23 | 2 | 1 in 46 | 1 | 1 in 46 | 1 |
| SEP | 1 in 9 | 5 | 1 in 23 | 2 | 1 in 23 | 2 |
| OCT | 1 in 7 | 7 | 1 in 9 | 5 | 1 in 46 | 1 |
| NOV | 1 in 12 | 4 | 1 in 15 | 3 | 1 in 23 | 2 |
| DEC | 1 in 9 | 5 | 1 in 15 | 3 | 1 in 46 | 1 |
| | | 36 | | 23 | | 11 |

Probability of a SUPER TYPHOON (STY) (>129 kt) near Guam by month (1945-1991)

| MONTH | STY/year | STY w/i 180 nm | STY/year | STY w/i 120 nm | STY/year | STY w/i 60 nm |
|---|---|---|---|---|---|---|
| JAN | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| FEB | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| MAR | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| APR | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| MAY | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| JUN | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| JUL | 1 in 46 | 1 | 1 in 46 | 0 | <1 in 46 | 0 |
| AUG | <1 in 46 | 0 | <1 in 46 | 0 | <1 in 46 | 0 |
| SEP | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| OCT | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| NOV | 1 in 15 | 3 | 1 in 15 | 3 | 1 in 15 | 3 |
| DEC | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| | | 8 | | 7 | | 3 |

Probability of TROPICAL CYCLONE (TC) (>33 kt) passage near Guam by month (1945-1990)

| MONTH | TC/year | TC w/i 180 nm | TC/year | TC w/i 120 nm | TC/year | TC w/i 60 nm |
|---|---|---|---|---|---|---|
| JAN | 1 in 8 | 6 | 1 in 9 | 5 | 1 in 15 | 3 |
| FEB | 1 in 46 | 1 | 1 in 46 | 1 | <1 in 46 | 0 |
| MAR | 1 in 23 | 2 | 1 in 23 | 2 | <1 in 46 | 0 |
| APR | 1 in 8 | 6 | 1 in 12 | 4 | 1 in 46 | 1 |
| MAY | 1 in 7 | 7 | 1 in 12 | 4 | 1 in 46 | 1 |
| JUN | 1 in 8 | 6 | 1 in 12 | 4 | 1 in 46 | 1 |
| JUL | 1 in 3 | 14 | 1 in 5 | 9 | 1 in 46 | 1 |
| AUG | 1 in 3 | 18 | 1 in 4 | 11 | 1 in 14 | 3 |
| SEP | 1 in 2 | 26 | 1 in 4 | 12 | 1 in 7 | 7 |
| OCT | 1 in 1 | 37 | 1 in 2 | 22 | 1 in 5 | 10 |
| NOV | 1 in 21 | 26 | 1 in 3 | 17 | 1 in 5 | 9 |
| DEC | 1 in 4 | 13 | 1 in 5 | 9 | 1 in 14 | 3 |
| Total cases | | 162 | | 100 | | 39 |

2.2 Annual Frequency

Although the mean would indicate one typhoon per year, the character of typhoon frequency has been quite irregular (Figure 9). Eighteen years (39%) of the 46-year period have been devoid of typhoons. The most significant absence of activity was in the eight-year period (1969-1975) in which only one typhoon (Amy, 1971) passed with 180 nm of Guam. Conversely, 28 years have produced 61% of the total typhoons. Years with multiple typhoons clustered about 1962-1964 and 1967-1968, and in the single years 1946, 1957, 1976, 1980, 1984, 1986 and 1990. It is interesting to note that during the 15-month period commencing with Gilda in November 1967 and ending with Phyllis in January 1969, 12 tropical cyclones traveled within 120 nm of the island. The period of highest frequency occurred between 22 October and 22 November 1968. In November 1968, four tropical cyclones with at least 35-kt maximum winds and one developing tropical cyclone - Irma, Judy, Kit, Ora, and Tropical Depression 31 (later Nina) - all passed within 180 nm of Guam.

The aperiodic high tropical tropical cyclone frequency appears to be associated with the abnormal extension of a persistent monsoon trough in the vicinity of the eastern Caroline and Marshall Islands. This extension provides a fertile ground for tropical cyclone development which could later affect the Mariana Islands. The development of this abnormal extension of the monsoon trough may be linked to a specific change in the ocean environment, such as higher than normal sea surface temperatures.

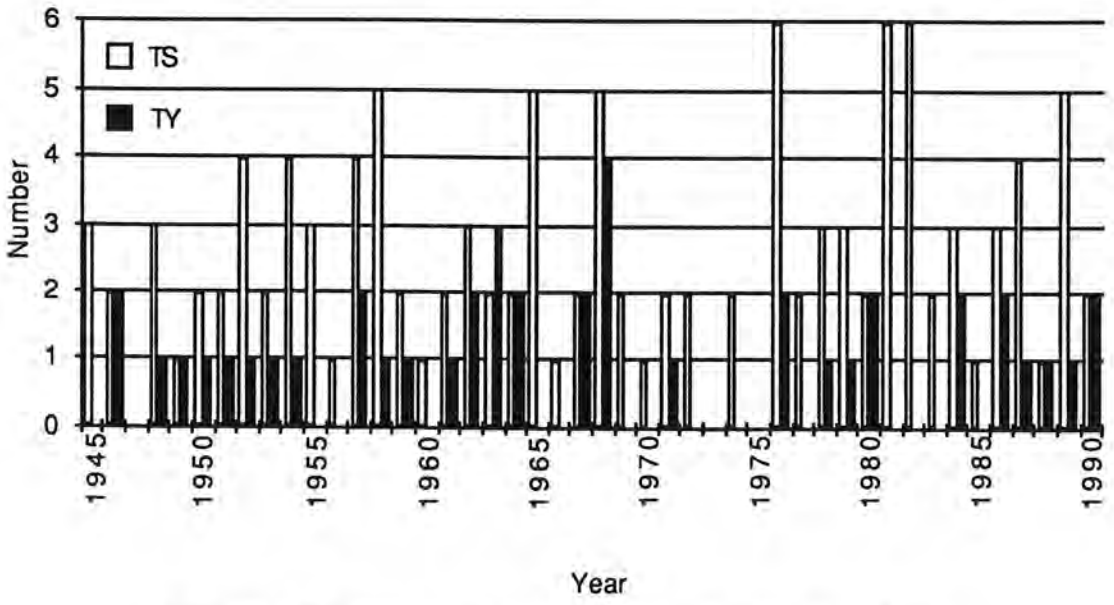


Figure 9. Number of tropical storms and typhoons per year (1945-1990).

2.3 Typhoons Passing Near Guam

Figure 10 depicts the points (open circles) where typhoons (65-95 kt) first reached tropical storm intensity (>33 kt). With the exception of eleven cases, all typhoons affecting Guam attained tropical storm intensity east of 150°E longitude and south of 15° N latitude, with the majority of those points in the Chuuk-Kwajalein area (south of 10° N latitude). Typhoons attaining tropical storm intensity in this area have accounted for approximately 75% of all the typhoons which have affected Guam during the 46-year period. Thus, the Chuuk-Kwajalein region is the source of tropical cyclones which present the greatest eventual threat to Guam.

The April typhoons - Georgia (1962), Olive (1963) and Andy (1989) were the only typhoons to have threatened Guam from the south. Typhoon Wendy (July 1963) was an anomaly. As a tropical storm 50 nm east-northeast of Guam, it continued to intensify, took a south-southwesterly track, reached typhoon intensity, and passed 80 nm south of Guam.

The open square symbols in Figure 10 identify where those typhoons with 100-125 kt sustained winds at CPA initially attained tropical storm intensity (>33 kt). In addition, gusts of at least 120 to 130 kt, nearly twice that of minimum typhoon intensity, occurred with these tropical cyclones (Atkinson, 1974). These gusts are capable of exerting a static wind loading force of four times as great as a minimum typhoon because the pressure force increases with the square of the wind speed (Faber and Bell, 1963). Such gusts are capable of inflicting very significant damage on most structures that are not reinforced. And finally, in Figure 10 the solid triangles indicate where super typhoons (130 kt or greater) initially reached tropical storm intensity.

Since the maximum winds of these typhoons are normally confined to a tight ring about the eye (usually not more that 40 to 50 nm in diameter), essentially a direct passage of the typhoon's circulation center over, or very near, the island is required for the extreme forces to be experienced on Guam. Subsequent to 1946, Karen (1962) has been the only typhoon to cross the island at super typhoon intensity. Typhoon Pamela (1976) came close to Karen with

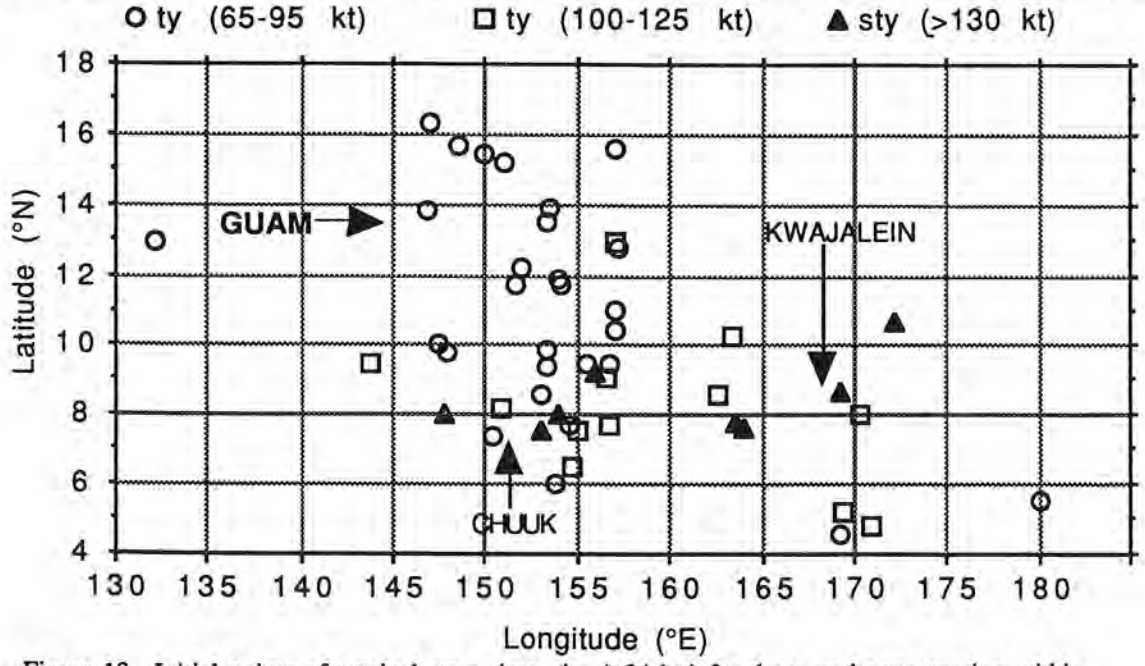


Figure 10. Initial points of tropical storm intensity (≥34 kt ) for those typhoons passing within 180 nm of Guam.

maximum winds estimated at 120 kt. These typhoons had an estimated minimum sea-level pressures of 908 millibars (mb) (Karen, 1962), 930 mb (Pamela, 1976). There is a relationship (Table 3) between the typhoon's minimum sea-level pressure and its maximum intensity (Atkinson and Holliday, 1977).Typhoons Allyn (1949), Lola (1957), Olive (1963), Gilda (1967), Roy (1988), and Russ (1990) could be considered near misses; each had maximum sustained winds of 100 kt or greater at their CPA to Agana. Generally, typhoons reach the 130-kt super typhoon category between 932 mb and 898 mb.

Table 3. Maximum sustained surface winds and equivalent minimum sea-level pressure (Atkinson and Holliday, 1977)

| MAXIMUM SUSTAINED SURFACE WIND (KT) | MINIMUM SEA-LEVEL PRESSURE (MB) |
|---|---|
| 30 | 1000 |
| 35 | 997 |
| 40 | 994 |
| 45 | 991 |
| 50 | 987 |
| 55 | 984 |
| 60 | 980 |
| 65 | 976 |
| 70 | 972 |
| 75 | 967 |
| 80 | 963 |
| 85 | 958 |
| 90 | 954 |
| 95 | 948 |
| 100 | 943 |
| 105 | 938 |
| 110 | 933 |
| 115 | 927 |
| 120 | 922 |
| 125 | 916 |
| 130 | 910 |
| 135 | 906 |
| 140 | 898 |
| 145 | 892 |
| 150 | 885 |
| 155 | 879 |
| 160 | 872 |
| 165 | 865 |
| 170 | 858 |
| 175 | 851 |
| 180 | 844 |

Table 4 lists individual cases of typhoons adversely affecting Guam (causing widespread major structure damage) and provides the distribution since 1800. It is limited to cases where the center passed over or just south of the island (within 60 nm). A compilation of all tropical cyclones appears in the Appendices. The 28 cases noted in 190 years indicate a probability of one damaging typhoon every seven years. However, for the period 1800-1899 13 damaging typhoons occurred for an average of 1 every 8 years, and for 1900-1990 17 occurred for an average of 1 in 6 years. The high threat months are also of interest. November appears a maximum of nine times and the only month that doesn't appear is January. Evaluating the relative extent of damage, Pamela (May 1976), Karen (November 1962), and the typhoons of November 1940, July 1918 and November

Table 4. Typhoons adversely affecting Guam (1800-1990)

| 1800's | | | | 1900's | | | |
|---|---|---|---|---|---|---|---|
| Apr | 1807 | Jun | 1868 | May | 1900 | Aug | 1941 |
| May | 1847 | **NOV** | 1870 | **NOV** | 1900 | Sep | 1946 |
| Aug | 1848 | Aug | 1872 | Oct | 1911 | **NOV** | 1949 |
| Sep | 1855 | Dec | 1876 | **NOV** | 1913 | **NOV** | 1957 |
| Apr | 1859 | Oct | 1891 | Jul | 1918 | **NOV** | 1962 |
| **NOV** | 1860 | | | Mar | 1923 | Apr | 1963 |
| **NOV** | 1861 | | | **NOV** | 1940 | May | 1976 |
| Feb | 1864 | | | | | Dec | 1990 |
| | **1 in 8 yrs.** | | | | | **1 in 6 yrs.** | |

1900 were particularly severe. The typhoons of April 1807, May 1848, September 1855 and October 1891 were also notably destructive. For comparison, Pamela (1976) was the most destructive since the November 1900 typhoon. Looking into the early years of record, the typhoon of November 1693 was probably the most catastrophic.

## 3. DIRECTION OF APPROACH AND MOVEMENT

### 3.1 Direction of Approach

The great majority (79%) of the tropical cyclones that passed within 180 nm of Guam have approached from the east through south (Figure 11). Of these, 35(60%) approached from the east-southeast octant and 9 (16%) approached from the southeast-south octant. Westward movers, i.e. those approaching Guam from the northeast and southeast quadrants, account for all but five of the tropical cyclones which passed within 120 nm of the island; of those five, four approached from the southwest quadrant. Olive (April 1963) was the only tropical cyclone during the 46-year period which originated south of Guam and adversely affected the island. As indicated earlier in Figure 10, three other tropical cyclones developed within 120 nm of Guam but did not approach closer to the island before moving out of the area.

Not all approaching tropical cyclones have been as well behaved as Figure 11 may suggest. Many tropical cyclones have displayed loops, have stalled near their points of closest approach, or have performed major deviations in track, making it difficult to assign a distinct direction of approach. Figures 12 and 13 display the tracks of some of these tropical cyclones, with Lola (October 1963) being one of the most erratic. Lola passed over Guam while a tropical depression, only to return as a tropical storm, skirting just west of the island on a northward track. Several other unusual cyclones were Violet (October 1961), Wendy (July 1963) and Carmen (August 1978); each approached Guam from the northeast. It is not unusual for tropical cyclones in the months of October and November to exhibit track changes of 45° or more when

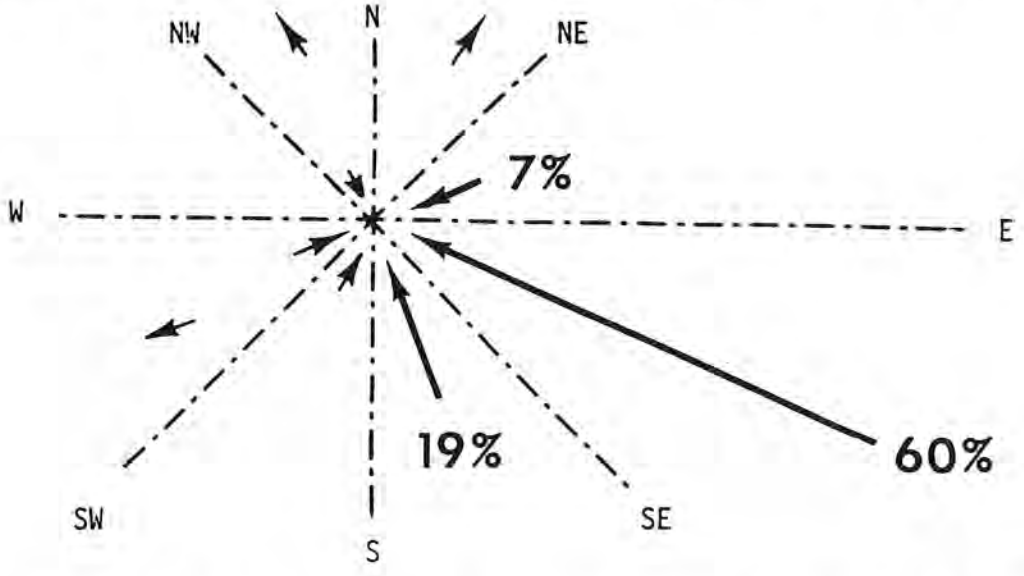


Figure 11. Direction of approach of tropical cyclones (>33 kt) passing within 120 nm of Guam (1948-1980). Length of each line is proportional to the number of occasions in which cyclones approached from each octant of the compass as viewed from Guam.

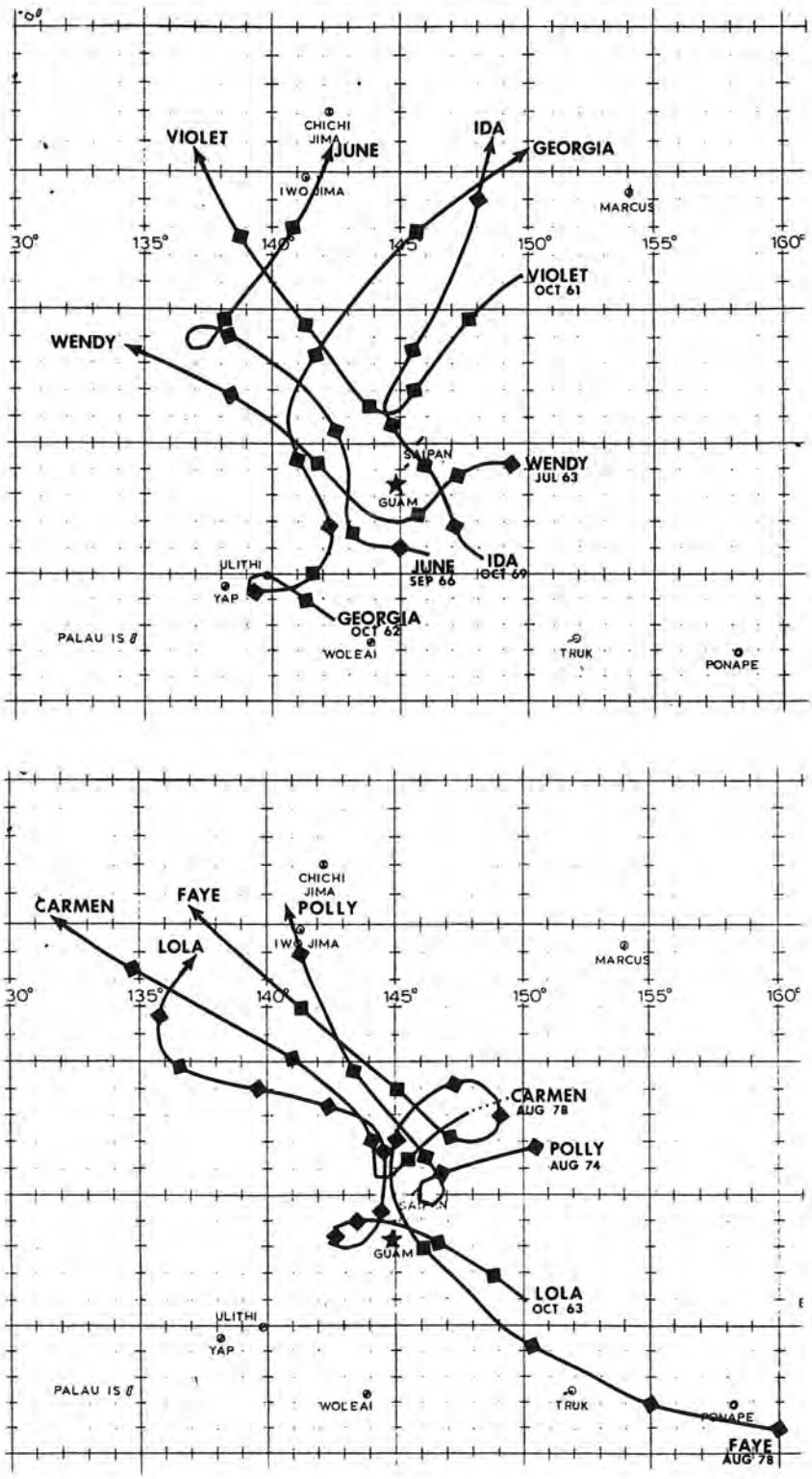


Figure 12. Tracks of looping or stalling tropical cyclones in vicinity of Guam. ◆- position of tropical cyclone at 0000Z (1000 Guam) each day.

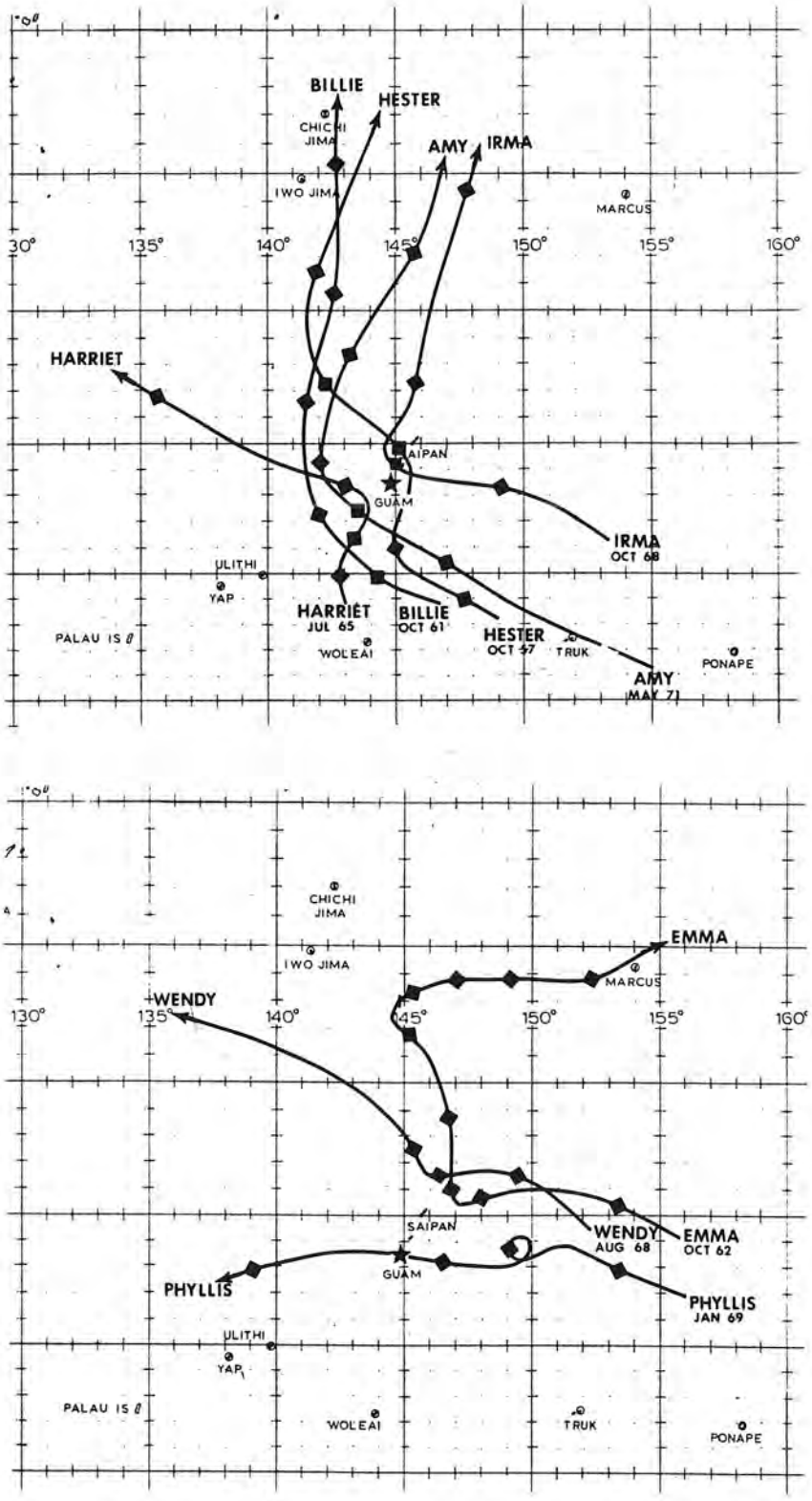


Figure 13. Major changes in the direction of tropical cyclone movement in vicinity of Guam.

◆- position of tropical cyclone at 0000Z (1000 Guam) each day.

within 180 nm of Guam.

3.2 Speed of Movement

The majority of the tropical cyclones passing within 180 nm of Guam had, at their points of closest approach, a mean speed of movement near 12.5 kt. Some seasonal variability is evident as shown in Figure 14. In general, the movement and speed of a tropical cyclone is influenced by its proximity to the prevailing steering feature, primarily the subtropical ridge.

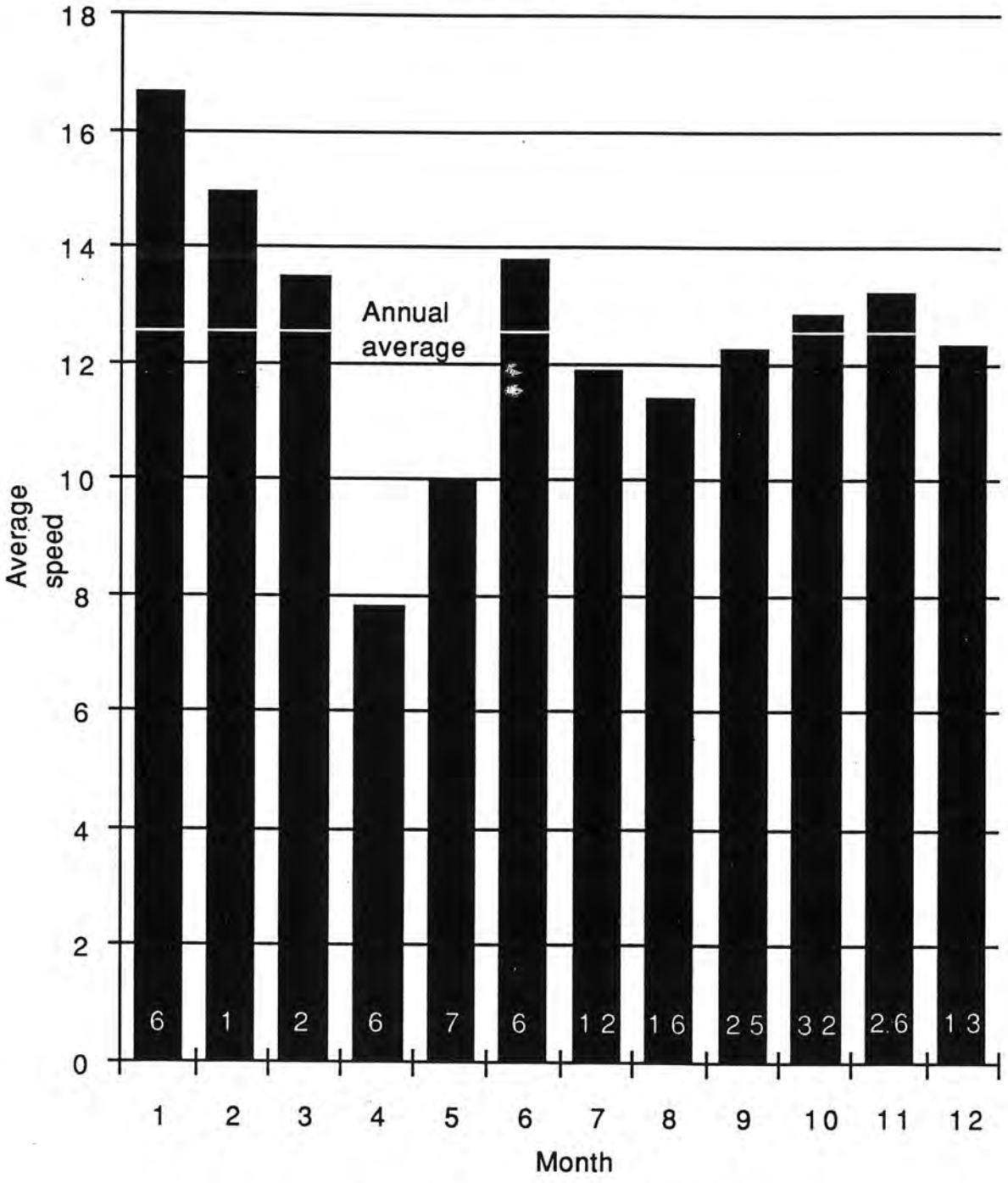


Figure 14. Average speed (kt) by month.

This ridge is a semi-permanent feature of the mid-latitudes throughout the year; however, the ridge is displaced towards the equator in the Northern Hemisphere winter and towards the pole in the Northern Hemisphere summer. The higher speeds in the late fall and winter months (November-February) reflect the equatorward displacement of the subtropical ridge. Conversely, the lower than average speeds of the tropical cyclones near Guam during the summer months (July-August) show evidence of the poleward displacement of the subtropical ridge. The apparent short-term trend from April to June (of increasing speeds of movement) cannot be as easily explained by the season and location of the subtropical ridge. During this period, the southern periphery of the ridge gives way to an early development of the near-equatorial trough, which then collapses in late May or early June to the Philippine Sea, west of Guam. Thus by June, tropical cyclones tend to move more rapidly near Guam because of a brief return to a winter-like trade wind environment over the region. The spring months (March and April) have had relatively few tropical cyclones, although April, with six, has the lowest average speed with 7.8 kt. Two of the fastest moving tropical cyclones were Tropical Storm Winona (January 1989) which passed 90 nm north-northwest of Guam at 28 kt and Tropical Storm Faye (October 1971) which passed 125 nm north of Guam at 27 kt. Within 180 nm of Guam, 15 cyclones in all have been observed to travel at speeds of 20 kt or greater. By contrast, a higher number (28) have displayed unusually slow speeds (<8 kt), including some in loops. One of the slowest moving tropical cyclones passing near Guam was Alice (October 1953); the center of this developing tropical storm passed over the northern portion of the island at 6 kt, resulting in a 24-hour rainfall of 18.33 inches.

### 3.3 Acceleration

The majority of tropical cyclones approaching Guam have moved at a rather uniform rate; however two cyclones, Phyllis (January 1969) and Karen (November 1962), exhibited marked acceleration. Phyllis stalled as a weakening typhoon, 270 nm northeast of Guam, then proceeded on a small looping track for 18 hours before accelerating towards Guam and reaching a speed of 20 kt before passing over the island. Fortunately, Phyllis had weakened to a minimal tropical storm before passing over Guam. Karen, on the other hand, was slowly drifting northward at 5 kt as a 120 kt typhoon. At a point 480 nm east-northeast of Guam, Karen abruptly started a track to the west-southwest, accelerated to 17 kt, and struck Guam 36 hours later.

During its period of development, Tropical Storm Tip (October 1979) meandered for several days in the Chuuk district (about 600 nm southeast of Guam). After completing several loops near Chuuk Atoll, Tip accelerated to 20 kt. Then, just 8 hours prior to the closest point of approach (CPA) to Guam, Tip slowed to less than 10 kt and passed south of the island. Fortunately for Guam, Tip began to rapidly intensify after passage and reached super typhoon intensity 465 nm west-northwest of the island.

## 4. METEOROLOGICAL ASPECTS

### 4.1 Gale conditions

Since 1945, tropical cyclones passing Guam have resulted in at least 56 occurrences of gale force winds (>33 kt), with a duration of one hour or more. Distances of center passage have varied, but the majority passed within 180 nm of the island. However, tropical cyclones

passing as far as 450 nm have, on occasion, given Guam gale-force gusts. Figure 15 shows the number of TC-induced gales stratified by direction of CPA. A greater occurrence of these gales is shown for those tropical cyclones which passed over, or just south of Guam. Those cyclones which passed south of the island have brought strong gusts from distances greater than those which passed north of Guam. This is not unusual since the normal distribution of winds about a tropical cyclone ordinarily extend much further to the right of the direction of motion (Figure 16). Since the overwhelming majority of tropical cyclones passing Guam have been westward movers, it stands to reason that this relationship would be reflected in the recorded data. However, the wind distribution about individual tropical cyclones can vary based on the

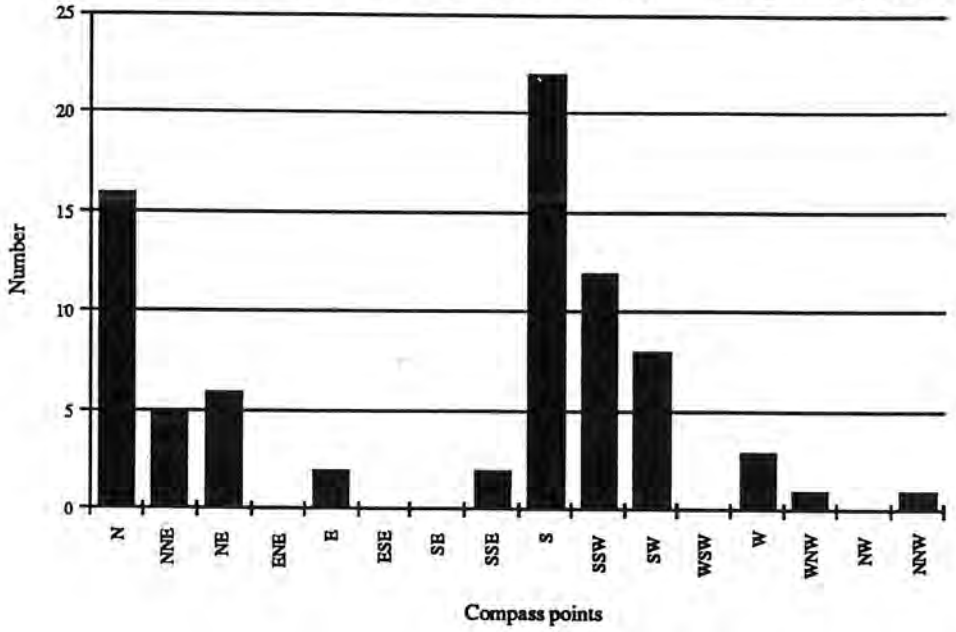


Figure 15. Direction of CPA for tropical cyclone causing gales (1 hour or more) on Guam.

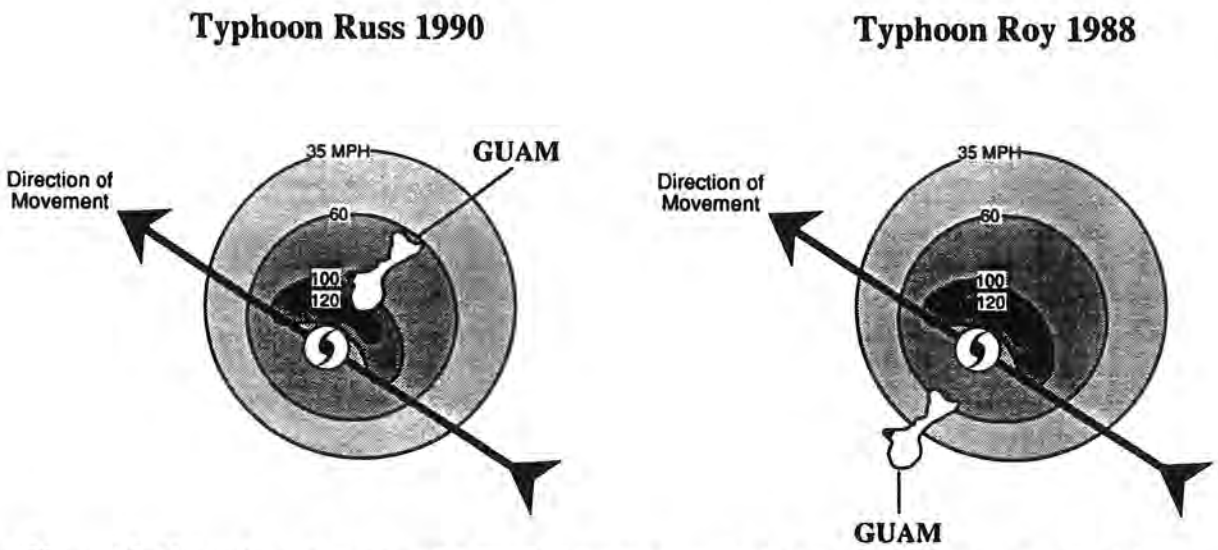


Figure 16. If a typhoon is moving, the speed of motion causes wind speeds to be greater to the right side of the direction of motion and less on the left side. Typhoons Russ and Roy, while having about the same intensities, affected Guam differently because the island was on the north (to the right) side of Russ and on the south (to the left) side of Roy.

distribution of the gales about the center and the different recording locations on the island. For example, Super Typhoon Rita (October 1978) passed 82 nm south of Guam with maximum winds of 150 kt and produced a maximum gust of 72 kt. Just 12 nm to the north of 72-kt observation, the maximum gust recorded was only 35 kt.

By contrast, Typhoon Opal (December 1964) tracked 450 nm to the southwest of Guam and brought a gust to 43 kt on the island. This was the result of an unusually tight pressure gradient between the typhoon and a zone of high pressure to the north. Tropical Storm Mary (August 1974) presented an unusual distribution of strong winds in the southern portion of the circulation, brought about by a strong southwest monsoonal flow across the Philippine Sea. Although Mary's circulation center was located 450 nm northeast of Guam, a band of tropical gales in the southwest monsoonal flow produced gusts of 57 kt on the island. Monsoonal gale or near gale force winds occurred for a period of 67 hours, a record for any cyclone affecting the island since 1945. This compares with an average duration of 13 hours for all 81 cases with gales lasting an hour or more. Typhoons which produce gale, or near gale, conditions for a period of 40 hours or more include: Olive (April 1963), Gilda (November 1967), Jean (April 1968), Amy (May 1971), Mary (August 1974), Pamela (May 1976), and Russ (December 1990).

Tropical cyclones causing strong gusts of 50 kt or greater have been experienced on 40 occasions since 1945. With the exception of Doris (May 1950), Mary (December 1977), June (November 1975), Lorna (September 1954), Mary (August 1974) and Abby (December 1979), all CPAs have been within 120 nm of Agana.

## 4.2 Maximum Winds

The strongest wind gust ever recorded in a typhoon was 166 kt near the eye of Cora (September 1966), at the Japanese Meteorological Station on Miyako Jima (24.6°N, 125.3°E elevation 132 feet). Wind gusts undoubtedly have been higher, but during the rare occurrence of a super typhoon passing over or near a meteorological station, weather conditions become so extreme that the anemometer (wind recording instrument) often fails or is blown away. Table 5 lists some of the wind extremes recorded on Guam, with the casualty toll on wind instruments

Table 5. Wind Extremes (1923-1990)

| TYPHOON | DATE | PEAK GUSTS(KT) | LOCATION | ELEVATION(FT) |
|---|---|---|---|---|
| Pamela | May-76 | 138 | Taguac (NWS) | 365 |
| Karen | Nov-62 | 125* | Nimitz Hill (FWC) | 634 |
| No name | 23-Mar | 122* | Sumay (MCAS) | 25 |
| Russ | Dec-90 | 111 | Naval Magazine | 282 |
| No name | Nov-40 | 110* | Agana (Fort Apugan) | 182 |
| Allyn | Nov-49 | 110* | Harmon Field | 300 |
| No name | Aug-41 | 108 | Agana (Fort Apugan) | 182 |
| Roy | Jan-88 | 98 | Andersen AFB | 612 |
| Olive | Apr-63 | 87 | Nimitz Hill (FWC) | 634 |
| Lola | Nov-57 | 84* | Naval Air Station | 255 |
| Querida | Sep-46 | 82 | Naval Air Station | 255 |
| Betty | Nov-80 | 79 | Naval Air Station | 255 |
| Ora | Nov-68 | 77 | Andersen AFB | 612 |
| Kim | Nov-77 | 77 | Nimitz Hill (FWC) | 634 |

* Anenometer failed.

rather evident.

With the exception of the November 1900 typhoon, Karen (November 1962) was the most intense (greatest maximum sustained wind speed) typhoon to strike the island this century. The winds were estimated at 135 kt with gusts to 165 kt. Then came Typhoon Pamela (May 1976) with an estimated central pressure of 930 mb and an estimated intensity of 120 kt with gusts to 145 kt when it crossed the island. However, Pamela became the most destructive typhoon so far this century because of its slow (7 kt) movement across Guam and prolonged (30 hour) period of 50-kt or greater winds. Although Typhoon Russ (December 1990) didn't pass directly over the island, its destructive winds demolished structures that weren't reinforced (Figure 17).

A notable characteristic of the wind speeds accompanying typhoons like Karen and Pamela was their non-steady nature. This gustiness - peaking, then dropping to a relative lull - is seen to vary as much as 80 kt in a matter of minutes (Figure 18). This pulsating and gusty nature of the wind results in an uneven, intermittent pressure pumping and wrenching effect on structures. It is also significant that the wind not only causes a pressure on the windward side but it also causes a suction effect on the leeward side of structures. During each of these typhoons, this fluctuation of wind strength resulted in extremely large pressure differences on the opposite sides of structures (60 to 70 pounds per square foot) in less than a minute. Few structure that were not reinforced could resist such blasts.

Figure 17. The steel girders of this temporary warehouse on Naval Station, Guam, were twisted by the high winds and collapsed during Russ's passage.

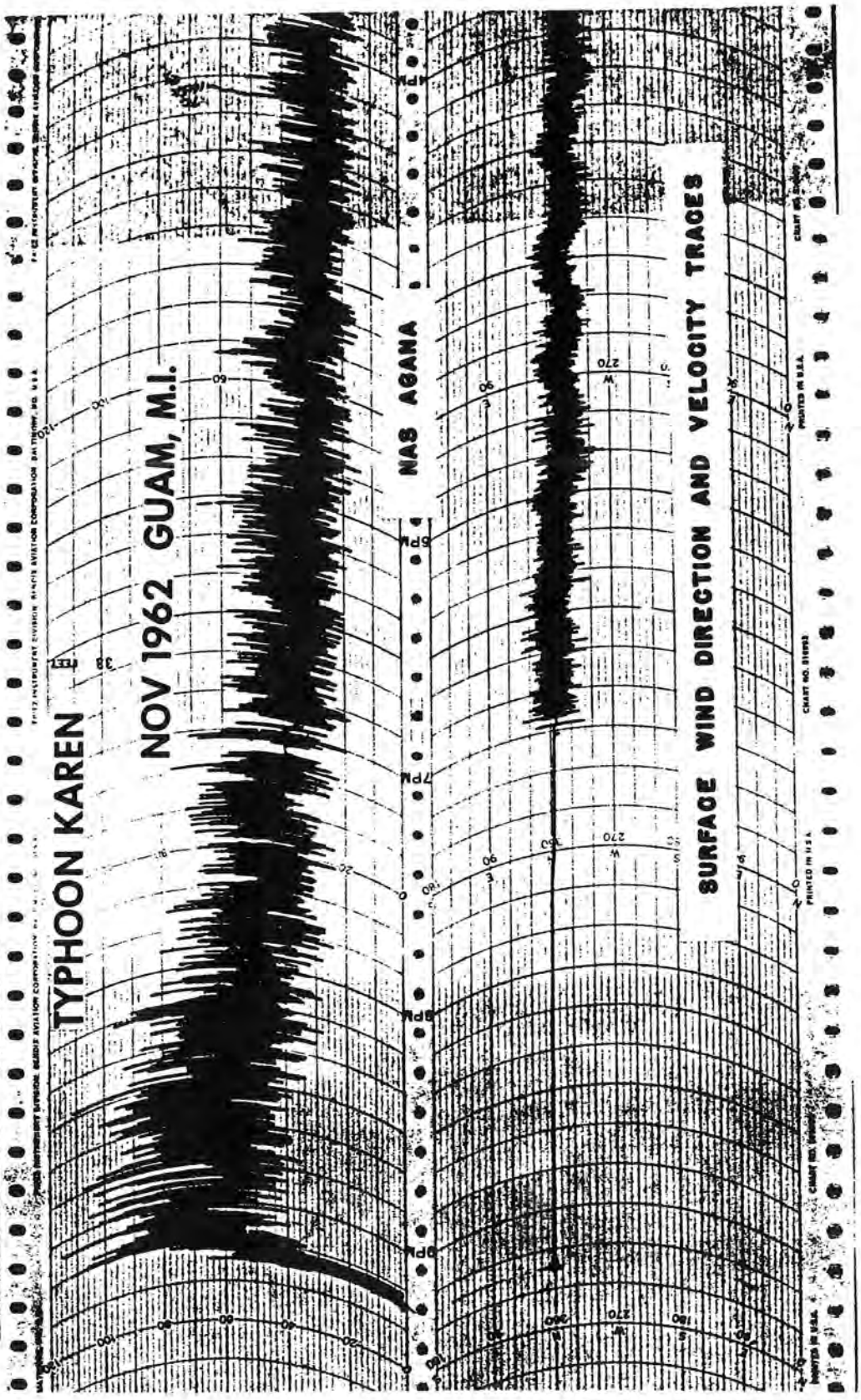


Figure 18. Surface wind direction and velocity traces for Super Typhoon Karen (Nov. 1962).

## 4.3 Atmospheric Pressure

Table 6 shows the minimum sea-level pressures recorded on Guam, for values less than 980 mb, based on available records since 1900. Both the November 1900 typhoon and Karen (November 1962) had unusually low pressures. Actual recordings of the lowest pressures in the eye for most tropical cyclones listed were not available since the meteorological stations were north or south of the center. In the case of Karen, the central pressure was estimated at 908 mb based on interpolation from aircraft measurements made shortly before and after landfall. Although such a low pressure is relatively infrequent for typhoons, it is still considerably above the lowest sea-level pressure on record which was 870 mb measured by aircraft reconnaissance in Super Typhoon Tip (October 1979) when it was located 465 nm west-northwest of Guam.

Figure 19 is the Fleet Weather Central (now NOCC/JTWC), Nimitz Hill, Guam

Table 6. Measured sea-level pressures (less than 980 mb) on Guam (1800-1990)

| Typhoon | Date | Pressure(mb) | Location |
|---|---|---|---|
| No name | Nov-1900 | 926 | Agana |
| Pamela | May-1976 | 932* | Naval Air Station |
| Karen | Nov-1962 | 932** | Naval Air Station |
| Betty | Oct-1980 | 933 | Naval Air Station |
| No name | Jul-1918 | 954 | Agana (Agricultural Experimental Station) |
| No name | Nov-1940 | 956 | Agana (Fort Apugan) |
| Marge | Aug-1951 | 966 | Naval Air Station |
| No name | Aug-1941 | 970 | Agana (Fort Apugan) |
| Russ | Dec-1990 | 971 | Andersen AFB |
| Allyn | Nov-1949 | 972 | North Field |
| Querida | Sep-1946 | 972 | Harmon Field |
| No name | Dec-1876 | 975 | Agana |
| Olive | Apr-1963 | 977 | Nimitz Hill (FWC) |
| Lola | Nov-1957 | 978 | Naval Air Station |
| Kim | Nov-1977 | 978 | Andersen AFB |

* Estimated minimum was 930 mb

** Estimated minimum was 908 mb

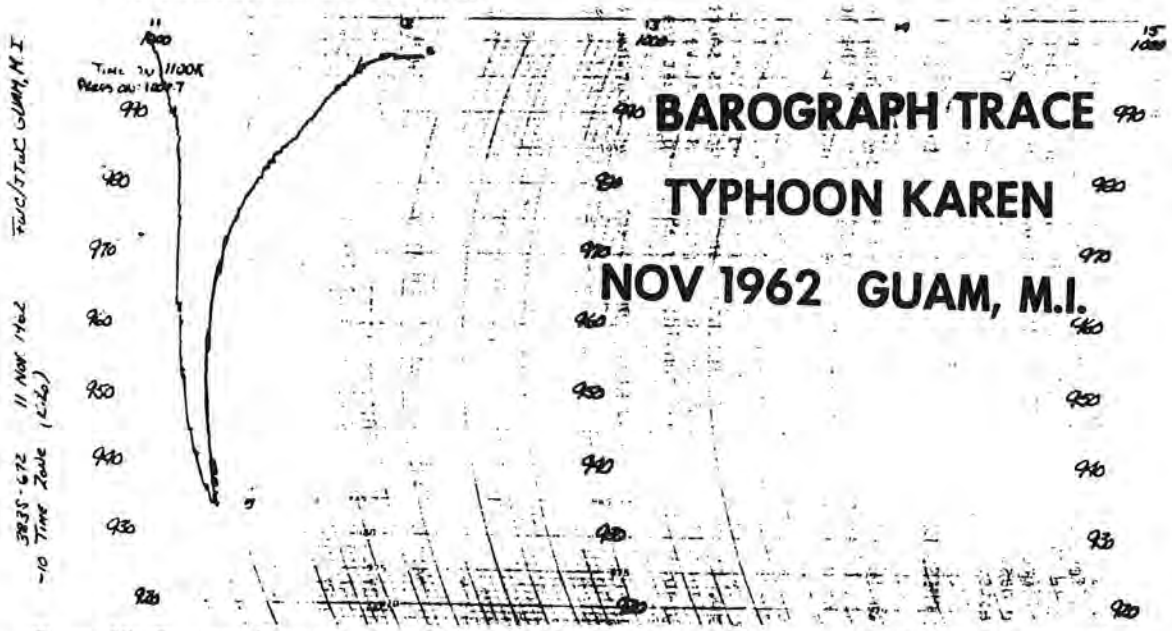


Figure 19. Barograph trace for Super Typhoon Karen, (Nov. 1962), taken at FWC/JTWC, Nimitz Hill.

(unofficial) microbarograph trace during Typhoon Karen's passage. The minimum pressure was recorded as the center of the eye passed 10 nm to the south. (At the same time, the (official) the sea-level pressure at the Naval Air Station, Agana, was 931.9 mb, which indicated an extreme gradient of pressure of 27 mb per nautical mile existed over the southern half of the island.) Due to Karen's above normal (17 kt) forward motion the pressure fell at a rapid rate. From a reading of 1000 mb at 1100 local Guam time on 11 November, the pressure fell 66 mb in 11.5 hours, a rate of 5.7 mb per hour. Later that day, for a period of an hour (2130 and 2230 local Guam time) the pressure fell 29 mb - a drop rarely recorded at a meteorological station. This sudden pressure fall and extreme gustiness of the wind resulted in explosive pressures on even reinforced concrete structures. "Window panes and /or entire louvered casements were forced outward, including doors and/or frames, particularly the French doors in living quarters," (FWC/JTWC, 1962).

4.4 Rainfall

The amount of rainfall associated with the passage of a tropical cyclone can be highly variable, and is dependent on several factors including the rate of forward motion of the tropical cyclone and the position of the rain gauge with respect to the topography and the tropical cyclone's track. Normally the highest rainfall measurements in tropical cyclones are usually recorded in mountainous areas. This is the result of lifting of the moisture laden air over the mountains that are a barrier to the low-level flow. It should be noted that the actual measurement of rainfall during typhoon conditions is difficult, as significant amounts of rain blow out of the rain gauge and as much as 50% of the volume may be lost (Dunn and Miller, 1964). Another factor inhibiting accurate measurement is the sharp angle of incidence between the driving rain and the opening at the top of the rain gauge. During the passage of Pamela (1976), an observer reported rain being driven horizontally. This would result in the records of total rainfall for Pamela to be lower than what actually occurred.

Figure 20 shows the frequency distribution of the maximum 24-hour rainfall brought by each of the tropical cyclones passing with 180 nm of Guam. The bulk of the cases (67%)

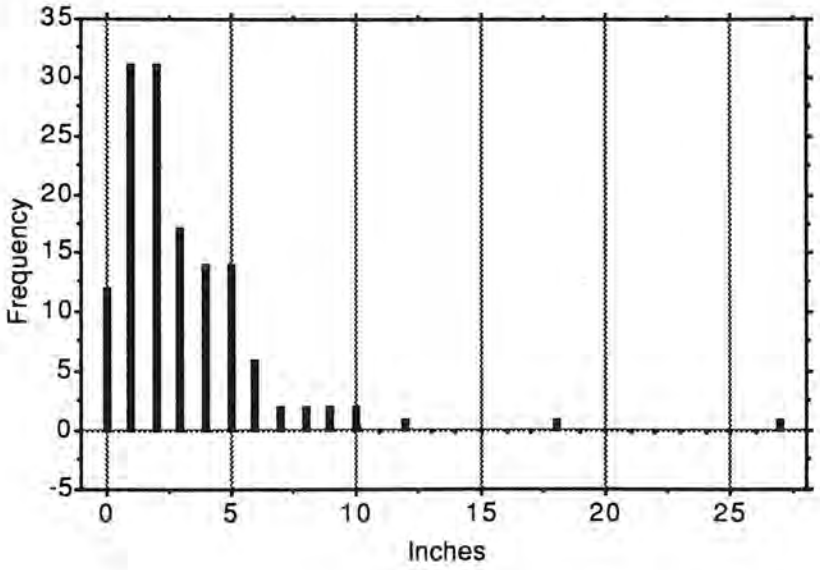


Figure 20. Frequency distribution of 24-hour rainfall from tropical cyclones within 180 nm of Guam.

indicate that amounts up to four inches are fairly common during center passage with the mean 24-hour rainfall near 4.5 inches. As an example of rainfall variability, Typhoon Jean (April 1968), while passing to the north over Saipan, produced only 0.33 inches in 24 hours on Guam, whereas, developing Tropical Storm Carla (May 1974), on a similar track over Saipan dropped 4.3 inches of rain in 24 hours. Table 7 lists those tropical cyclones which caused 24-hour rainfall amounts of six inches or more on Guam since 1924. For purposes of comparison, six inches is almost half the monthly average (13.4 inches) for the month of September, which is the wettest month of the year (based on the data from 1945-1987). With the exception of Mary (August 1974) and Vernon (September 1980), all the tropical cyclones passed within 120 nm of Agana. In all cases except Karen (November 1962), Irma (February 1953) and Vernon (September 1980), the rate of forward motion was near or below the average rate of 12 kt, allowing longer than normal exposure to the tropical cyclone's rain. It is interesting to note that over half of these cases (18) of heavy rainfall were produced by tropical cyclones of depression or tropical storm intensity rather than those of typhoon intensity.

Table 7. Maximum 24-hour rainfall totals @ on Guam (1924-1990)

| TROPICAL CYCLONE | DATE | AMOUNT(IN) | LOCATION | CPA |
|---|---|---|---|---|
| TY PAMELA | May-76 | 27.01 | TAGUAC | 0 |
| TS ALICE | Oct-53 | 18.33 | ANDERSEN AFB | N 15 |
| TS CARMEN | Oct-86 | 11.98 | TAGUAC | WNW 14 |
| TS TIP | Oct-79 | 10.14 | TAGUAC | S 40 |
| TY AMY | May-71 | 9.92 | TAGUAC | SSW 90 |
| TS IDA | Oct-69 | 9.38 | TAGUAC | NNE 90 |
| TS IRMA | Feb-53 | 7.88 | ANDERSEN AFB | S 90 |
| TS PEGGY | Jul-86 | 7.86 | TAGUAC | W 12 |
| TD (POLLY)* | Aug-71 | 7.81 | TAGUAC | NNE 85 |
| TS VIRGINIA | Sep-65 | 7.48 | TAGUAC | NE 130 |
| TS MARY** | Aug-74 | 7.36 | TAGUAC | NNE 485* |
| TY NINA | Aug-53 | 7.07 | ANDERSEN AFB | N 15 |
| TY ROY | Jan-88 | 6.45 | TAGUAC | WNW 12 |
| TD (BABE)* | Apr-74 | 6.37 | TAGUAC | E 40 |
| TS ORCHID | Sep-80 | 6.34 | TAGUAC | N 75 |
| TY KAREN*** | Nov-62 | 6.32 | TAGUAC | S 10 |
| TY RUSS | Dec-90 | 6.12 | NIMITZ HILL | SSW 50 |
| TY SUSAN | Dec-63 | 6.09 | TAGUAC | N 75 |

@ Exceptions: 1) On 1 Oct 1924 the second highest 24-hour rainfall of 24.5 inches was recorded at the Agana Agricultural Station.
2) On 6 July 1918, 10.5 inches occurred in 24 hours during a typhoon.
3) On 26 February 1980 a tropical disturbance produced 10.89 inches in 24 hours at Nimitz Hill.

* These tropical depressions do not appear in the data.

** TS Mary was not within 180 nm of Guam.

*** Power to the rain gauge failed during Karen. This observation was taken the day after Karen's passage. Significantly higher amounts may have occurred the previous day near CPA.

The maximum 24-hour rainfall was 27 inches recorded in Pamela (May 1976), when the circulation center passed slowly (7 kt) over the middle of the island. Other significant rain producers have been the October 1924 typhoon with 24.5 inches and Typhoon Alice (October 1953) with 18.33 inches. By comparison, this is still well short of the record measured on Okinawa, an island of relatively low relief, where 42.4 inches fell in 24 hours during Typhoon Emma (Jordan and Shiroma, 1959). Typhoons Pamela (May 1976), Alice (October 1953) and the October 1924 typhoon caused considerable damage, as extensive runoff due to the prolonged rains caused rivers to overflow their banks, washed out bridges and inundated the adjacent low lying areas. Excessive rain coupled with poor drainage in other areas also caused significant flooding.

The information on rainfall amounts accumulating in a period of an hour is quite limited as records of hourly readings are only available since 1957. Table 8 lists those tropical cyclones which caused one-hour rainfall totals of 1.5 inches or greater, with Virginia (September 1965) heading the list at 3.43 inches. It should be noted that accumulations of up to one inch per hour are occasionally recorded in heavy rainshowers which are not associated with tropical cyclone activity. Records for one-hour rainfall extremes are somewhat sketchy for cases of tropical cyclones affecting relatively flat areas. However, Dunn and Miller (1964) cite a 6-inch accumulation for a period of 75 minutes at Hialeah, Florida in connection with the passage of a hurricane on 12 October 1947.

Table 8. Some maximum hourly rainfall (>1.5 inches per hour) amounts (1957-1980) at the Weather Service Meteorogical Observatory, Taguac, Guam.

| Tropical cyclone | Date | Rainfall (in) |
|---|---|---|
| TS Virginia | 13-Sep-65 | 3.43 |
| TD (Ivy) | 19-Oct-77 | 3.21 |
| TD (Joan) | 25-Aug-59 | 2.82 |
| TS Emma | 2-Oct-62 | 2.13 |
| TY Amy | 12-May-71 | 1.83 |
| TY Wendy | 11-Jul-63 | 1.79 |
| TS Ida | 16-Oct-69 | 1.73 |
| TS Tip | 10-Oct-79 | 1.61 |
| TS Orchid | 9-Sep-80 | 1.54 |

Note: During Typhoon Pamela (May 1976) rain rates were estimated to have been greater than 1.5 inches per hour; however, due to instrument failure no data are available.

## 4.5 Storm Surge

Inundation of low-lying coastal areas by the sea has occurred during the passage of severe cyclones near Guam. An inspection of the narrative accounts since 1946 would indicated that significant inundation should be expected in low-lying coastal areas with the passage of the center of a tropical cyclone of typhoon force within 60 nm of Guam. However, specific information on Guam storm surges is quite sketchy, since little reliable documentation as to their extent and height is available. Another problem in documentation is separating the combined effect of flooding by rainfall runoff and sea inundation.

Based on narrative reports, the southern coastline of Guam is quite susceptible to flooding by the passage of typhoons as distant as 200 nm south of Agana. Reports of the Inarajan-Merizo road being awash have been frequent. Inarajan and Talofofo Bays have suffered from inundation with the close passage of several typhoons during this century. The village of Inarajan was swept away with the loss of 28 lives in the typhoon of November 1900. In Merizo, water was reported four to five feet deep during Lola (November 1957) and Cocos Island was completely inundated by Allyn (November 1949). On the western coast, the village of Agat suffered severe damage by sea action during the September 1946 typhoon and Typhoon Karen (November 1962). In Agana, major inundation has occurred at least three times this century from the November 1900 typhoon, and Typhoons Karen (November 1962) and Pamela (May 1976). During the 1900 typhoon, water reached the plaza in front of the Palace near the present site of the Agana Cathedral. Both Karen and Pamela brought the sea in at least the same distance. During Karen and Pamela, the storm surges washed boats, docks and debris from the Agana boat harbor several blocks inland, leaving fishing boats weighing several tons on Marine Drive, with sand deposits nearly a foot deep along the drive between Tamuning and Anigua. During Pamela, ten small ships and tugs which had sought refuge in Apra Harbor were either sunk or run aground, and numerous other craft were sunk or damaged (Figure 21). Typhoon Russ (December 1990) inundated much of the low-lying coastal areas along the southeast coast of Guam (Figure 22). Probably the most catastrophic sea inundation on Guam was during the typhoon of November 1693 which engulfed and washed away all the existing coastal structures and vegetation!

Figure 21. Two grounded tugs at the U.S. Naval Station, Guam. The powerful wind and wave action produced by Typhoon Pamela affected even the inner Apra Harbor. (Official U.S. Navy photograph).

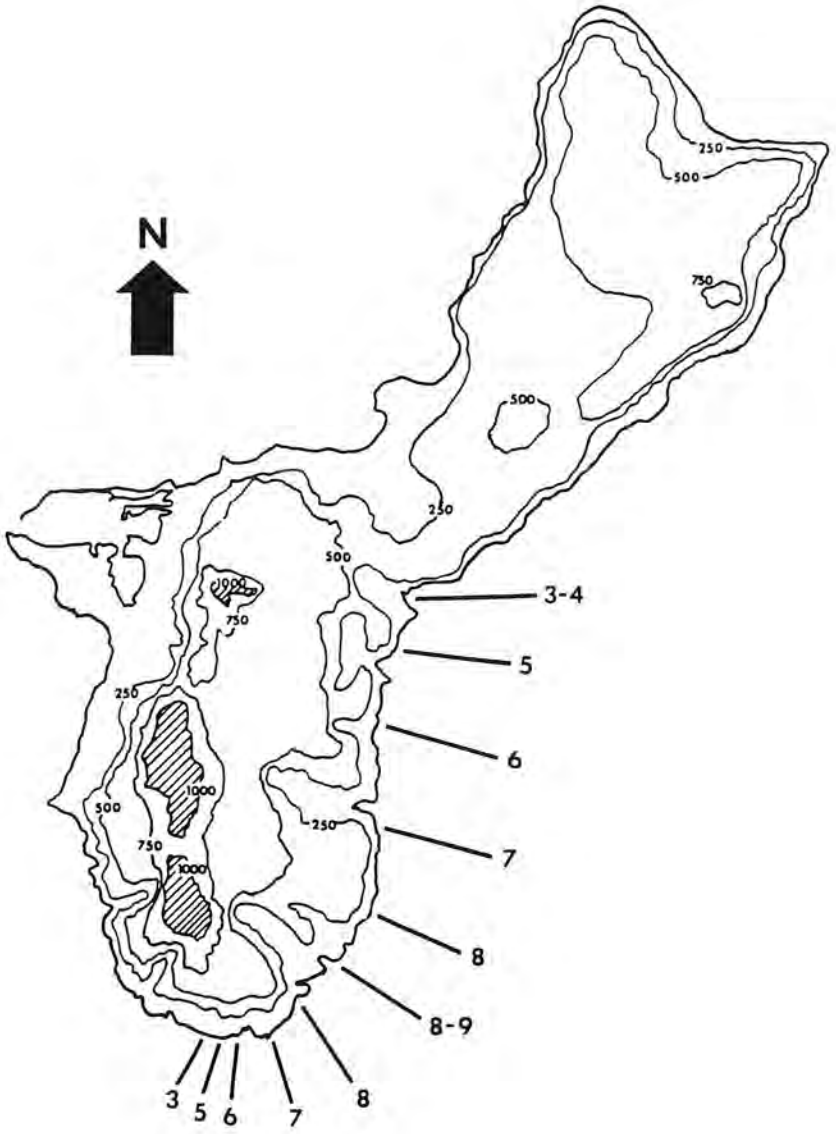


Figure 22. Estimation of sea inundation heights (ft) above the mean high water level for Typhoon Russ (December 1990).

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## APPENDIX A - Some Early Guam Typhoons

Year Date — Remarks

**1671 3 October*** - First recorded mention of typhoon affecting Guam. "Eye passed directly over island, with most of the homes on the island toppled, as well as the church and the rectory suffering the same fate. A great many people were killed by falling debris and inadequate shelter while the damage to agriculture crops was a serious loss to the people."

**1680 11 November** - "A hurricane rose on the northern side on 11 November. Although storms were frequent in the islands, a more violent one had never been seen. It lasted two days and caused frightful disorder. Almost all the houses were toppled over, canoes smashed, trees and crops ruined. To add to the disaster, the sea became so swollen that the people were obliged to flee to the mountains."

**1693 20 November** - "In 1693 a terrible typhoon occurred. It began at dusk on the night of November 20 with a deluge of rain. The wind moved from north to south and whipped up the sea to such a manner that it seemed as if the island of Guam would be submerged. The sea broke its bounds and spread inland taking trees, houses and churches with it. Even the fortress at Agana toppled and was washed away. Those who saved themselves did so by taking refuge in the hills or by swimming about all through the night. Not a house nor building remained standing on the island. Inland from the shore the soil was covered with sand and stones left there by the subsiding sea."

Source: History of the Mariana Islands, by Father Charles Le Gobien, S.J., Paris, 1700 (translation at Micronesian Area Research Center, University of Guam).

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* Data based on "The First Typhoon Recorded in Guam", translation of research by Father Paster, Guam Recorder, April 1938.

## APPENDIX B - Typhoons Affecting Guam During the 1800'S

Year Date Remarks

**1807 7 April** - "All the houses destroyed by the strong typhoon."

**1822 9 September** - Strong typhoon affects Guam, Rota, Tinian and Saipan.

**1824 11 November** - No details.

**1831 9 November** - No details.

**1835 7 March** - Typhoon affected Guam and Rota.

**1842 26 September** - No details.

**1847 23 May** - "A typhoon of horrible wind destroyed a greater part of the houses. No one killed."

**1848 10 August** - "Violent typhoon causing extensive damage, flood and famine."

**1855 23 September** - "A severe hurricane accompanied by earthquakes from time to time. All native wooden houses destroyed, those of stone and tile were dismantled. The fields and plants were as if burned, without leaves or fruit."

**1857 11 April** - No details.

**1859 17 April** - "Strong typhoon - a ship, although having two anchors, was thrown against the reef."

**1860 18 November** - No details.

**1861 23-24 November** - "Very strong typhoon."

**1864 14 February** - "Damage to roads and houses, crops lost due to salt spray."

**1868 21-23 June** - "Roofs of houses went off, but no casualties. One ship was thrown onto another in harbor."

**1870 14 November** - "Center passed north of island, many houses, roads and bridges damaged."

**1872 19 August** - "Ship Maria del Rosario thrown onto reef, three drowned."

**1873 24 June** - "Rota, Tinian, Saipan suffered much damage."

**1875 7 August** - "Destroyed houses and plantations on Tinian and Saipan."

**1876 2 December** - Agana in eye at 1500 local, minimum sea-level pressure 974.9 mb, "125 houses destroyed on island, many lost roofs in Agana."

**1891 27 October** - Very strong typhoon which caused much damage, leper colony demolished. Center passage over island. The ship Yap was demolished and another ship lost."

Sources: Micronesian Area Research Center (MARC), University of Guam
1807-1842, 1848 Records of the Spanish Colonial Government in the Mariana Islands (excerpts from files at U.S. Library of Congress).
1847, 1855-1860 Cronica de las Islas Marianas, Father Aniceta Ibanez.
1861-1891 Cronica de las Islas Marianas, Father Francisco Resano.

## APPENDIX C - Typhoons Affecting Guam 1900-1941

Year Date Remarks

**1900 26-27 May** - Buildings were demolished in Sumay, Agat, Merizo, and Inarajan with three bridges awash. Trees were uprooted or torn to shreds with extensive damage toll to all crops. In Apra Harbor, the USS Brutus was torn from her moorings and blown upon the reef.

**1900 13 November** - Most severe typhoon since 1855 with center passing over southern portion of island. Pressure fell to 926.0 mb at Agana. "Agana and most of the other towns were laid in ruins, nearly all houses except of coral masonry were practically destroyed. In Agana the sea reached the Plaza in front of the Palace. A huge wall of water coming in from the sea overwhelmed the village of Inarajan, killing or drowning 28 persons." The station ship USS Yosemite (6000 tons) parted from her moorings and was driven upon the reefs of Apra Harbor, and later sank. Total of 34 deaths resulted from typhoon with the ruined crops being a severe economic loss.

**1901 19 October** - Center passed between Guam and Rota. Several native houses unroofed and several feet of bank along Agana beach were washed away. Some wharfs destroyed or badly damaged in Agana. Major damage sustained on Rota. Minimum pressure recorded on Rota was 946.5 mb.

**1911 31 October** - Center passed some distance south of Guam. Southern part of island affected most with many telephone poles downed. In Merizo, many houses were unroofed.

**1912 26-30 August** - Principal damage to crops by fringe effects of typhoon.

**1912 15-17 December** - Principal damage to crops by fringe effects of typhoon.

**1913 17-19 September** - Center passed north of Guam. Fringe winds damaged copra crop.

**1913 10 November** - Center passed near Rota. Minimum pressure measured at Rota was 940.1 mb, while Agana recorded 983.4 mb. Many trees and telephone poles downed and houses unroofed on Guam. Storm waves washed away Agana waterfront wharf. Several sampans were sunk or beached at Agana and all low lying areas of town were flooded.

**1914 7 July** - Center passed north of Guam. Winds gusted near typhoon force and seas in Apra Harbor were the heaviest in years. Damage to crops, buoyage, boat channels was considerable.

**1914 8 October** - Center passed over Rota with a minimum pressure recorded at 925.2 mb. Although having little effect on Guam, Rota suffered considerably. A crust of salt from the ocean spray covered Rota's fields severely affecting crops, and later resulting in near-famine conditions due to lack of rain during the following six months.

**1915 2-3 September** - Gusty winds and heavy rains from fringe of typhoon. Considerable damage done to standing crops in the northern part of the island.

**1918 6 July** - Eye passed directly over Agana with a calm lasting one hour. Minimum pressure recorded in the center was 954.0 mb. Six persons were killed, thousands of persons were left homeless and property valued at many thousands of dollars received considerable damage. Hundreds of native homes were overturned while more substantial structures were either unroofed or demolished. A heavy toll was taken in terms of the numerous telephone and power poles as well as coconut trees downed. Crop losses were considered enormous.

**1918 17 September** - Gusty winds and heavy rains from fringe of typhoon passing to northeast of island. Some minor crop damage was sustained.

**1919 20-21 August** - Center passed some distance south of the island with a minimum pressure of 991.2 mb recorded at Agana. Only minor crop damage was reported.

**1923 26 March** - Center of slow moving typhoon passed south of island with a minimum pressure of 982.0 mb (26 Mar) and a maximum 24-hour rainfall of 4.84 inches (27 Mar) recorded at Sumay. Winds gusted above typhoon force with the majority of the damage confined to the southern portion of the island. Bridges and roads were washed out with evidence of the sea washing for distances of a quarter of a mile inland plentiful.

**1924 1 October** - Center of typhoon passed south of Guam with winds gusting near 60 kt over southern portion of island. Minimum pressure at Sumay was 999.7 mb. Extreme rainfall occurred during passage with as much as 19 inches in 15 hours and 28.25 inches within 30 hours being recorded on the island. A total accumulation of 33.09 inches was measured in 48 hours (all values at Agricultural Experimental Station, Agana). The resulting floods caused one death, the destruction of 50 buildings and a loss of hundreds of thousands of dollars. Rivers overflowed their banks sweeping away native houses, sections of roads and bridges.

**1925 30 August** - Fringe of typhoon passed south of island, minimum pressure 992.2 mb recorded. No details available.

**1925 25 October** - Center of typhoon passed south of island with minimum pressure of 991.5 mb recorded at Agana. Heavy waves washed along the southern coast between Inarajan and Merizo damaging roads and wrecking bridges. Strong gusty winds were responsible for downing hundreds of trees and unroofing several houses around the southern coast.

**1930 4 August** - Center of typhoon passed some distance northeast of the island. Minimum pressure of 996.6 mb was measured at Sumay with winds gusting to 36 kt and a maximum 24-hour rainfall of 4.48 inches. No further details available.

**1935 3 December** - Center of typhoon passed southwest of the island. Minimum pressure of 998.3 mb with gusts to 60 kt was recorded at Agana. Considerable damage was reported to trees and crops, but only slight damage to structures.

**1940 8 July** - Tropical cyclone center passed southwest of island. Wind gusts to 53 kt and a minimum pressure of 1001.7 mb were recorded at Agana. No significant damage reported.

**1940 3 November** - Most severe typhoon since 1918. Eye estimated to have passed near southern end of island with minimum pressure of 955.6 mb recorded at Agana (1400L). Wind gusts were estimated to have reached 130 kt. Damage was heavy, in the hundreds of thousands of dollars, with one death recorded. Almost all structures on the island were either unroofed or entirely destroyed leaving thousands homeless. Hundreds of trees were downed as the strong winds took a heavy toll on planted and natural crops.

**1941 3 August** - Eye of typhoon passed off northern end of the island. Minimum pressure of 969.9 mb (1230L) and a wind gust to 108 kt were recorded at Agana. A maximum 48-hour rainfall total of 12.42 inches was measured during passage. Most of structural damage was to roofs with no casualties reported. Telephone, electrical lines and many large trees were downed. Rain damage was extensive as many rivers overflowed, inundated nearby houses and washed out sections of road. This typhoon, however, was not as severe as the typhoon in November 1940.

Sources: 1900 The Guam Recorder
1911-1919 The Guam Newsletter
1923 West and Swartout, 1923: Typhoon at Guam,
M.I., March 19-27, 1923. *Monthly Weather Review*, September 1923.
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## APPENDIX D - Tropical Storms/Typhoons Affecting Guam 1945-1990
## (Producing 50 kt or greater winds on Guam)

Year Date Name Remarks

**1946 21 September - QUERIDA** - Eye of typhoon passed midway between Rota and Guam with peak gusts estimated at 85 kt on Guam. Extensive damage was inflicted on temporary buildings with many quonset huts demolished. At Orote Point Naval Air Station, 70% of the aircraft sustained damage and the barracks, BOQ (Bachelor Officers Quarters) and repair building were almost demolished. At Harmon Field, several large hangars received damage. The village of Agat was one of the most badly affected by the typhoon with 30 houses destroyed and 30 others seriously damaged. In spite of the havoc, only one injury was reported. Rota received the brunt of the typhoon with trees, crops and all building flattened.

**1948 14 November - AGNES** - Center of the developing typhoon passed just south of Rota. Winds gusting up to 55 kt occurred on Guam but no significant damage reported on either Guam or Rota. One casualty was sustained on Saipan.

**1949 '7 November - ALLYN** - Eye of typhoon passed 60 nm south of island bringing wind gusts greater than 100 kt. A total of $91.1 million in damage was caused to military and non-military property. Camp Witek, a Marine base on the south-east coast received 75% damage to its temporary installations. Severe damage to native houses and crops occurred in the southern section of the island. A total of 2500 homes were damaged, and in the town of Inarajan, 60% were destroyed by inundation from the sea. Additionally, Cocos Island was completely inundated by the typhoon. Four major bridges were destroyed and 55% were unusable. Although several injuries were reported, no fatalities occurred.

**1950 9 May - DORIS** - Typhoon passed 135 nm southwest of Agana with gusts of 63 kt recorded on the island. Overall damage was light; however, there was two feet of standing water in Inarajan, and high water washed out sections of the road between Inarajan and Merizo.

**1951 11 August - MARGE** - Center of tropical cyclone passed 25 nm south of Agana with peak gusts of 55 kt occurring on the island. Four inches of rain fell with a 4-hour period at the Naval Air Station; however, no significant damage from the gusty winds or heavy rains was reported.

**1952 31 December - HESTER** - Center of typhoon's eye passed 120 nm south of Guam and the island experienced gusts to 70 kt. The southern end of the island reported minor damage with only a few houses destroyed. However, scores of trees were uprooted or broken off, and both the vegetable and fruit crops were lost. Heavy seas caused both the Talofofo and Ylig river bridges to be awash and several small water craft were sunk at the commercial port.

**1953 22 February - IRMA** - Center of tropical cyclone passed 90 nm south of Agana with gusts to 55 kt reported on the island. Six inches of rain was recorded in 15 hours (NAS). Only minor damage to trees and crops was reported.

**1953 10 August - NINA** - Center of developing typhoon passed just offshore of the northern tip of the island and brought gusts to 57 kt to the island. The Inarajan road and Talofofo bridge were awash and trees were uprooted.

**1953 14 October - ALICE** - The developing tropical cyclone, Alice, passed just offshore of the island. Peak gusts recorded were 56 kt. Between 14 and 16 October, Alice drifted slowly by and subjected Guam to prolonged periods of torrential rain. In a period of 24 hours Andersen Air Force Base (AFB) recorded 18.87 inches and NAS 15.48 inches. During a 48-hour period 14-16 October), 32.51 inches fell at Andersen AFB, while NAS totaled 21.21 inches. Also, a severe electrical storm accompanied the passage of Alice with lightning striking Andersen AFB three times, with two airmen burned. The near-record rains resulted in significant flooding. Four bridges were washed away, isolating southern communities and four people drowned. Behind Marine Drive in Tamuning, all homes were inundated with depths of three to four feet of water reported. Large sections of Naval Station and Andersen AFB were also reported under water. Property damage was estimated in excess of $100,000.

**1954 14 September - LORNA** - Center of developing typhoon passed 180 nm south of Guam, causing wind gusts to 50 kt on island. No significant damage was reported.

**1957 16 November - LOLA** - Eye of super typhoon passed 40 nm south of Agana, bringing winds gusts in excess of 100 kt to the southern portion of the island. Estimates of civilian and military losses were placed near $5 million. Damage from the wind in the northern part of the island was mainly confined to the stripping of roofing material from structures and broken windows; however, several elephant (two storied) quonset huts were blown down (one on NAS and several in Anigua). In the southern part of the island scores of structures were unroofed or collapsed. High seas inundated land (particularly Inarajan) along the southern coast with waves damaging homes and toppling trees. Low-lying roads and bridges were awash. Several rivers overflowed and inundated nearby homes. No casualties were reported.

**1961 10 September - NANCY** - Eye of super typhoon passed 125 nm south of Agana and brought peak winds of 59 kt to the southern end of the island. Roads were damaged by wave action along the southern coast and 50% of crops in the southern part of the island were destroyed. The northern end of the island suffered little damage. No casualties were reported.

**1962 11 November - KAREN** - Most intense typhoon to strike Guam since 1900. As Karen approached Guam, it appeared to be headed for Rota; however, a last minute change in course took it to the west. The eye of this super typhoon passed over the southern end of the inland between Talofofo and Umatac. Wind gusts were estimated to have reached 150-160 kt over sections of the island. Approximately $250 million in damages were sustained. Ninety-five percent of all homes were destroyed, leaving 9,000 homeless, 100 injured and 9 dead. At Andersen AFB, 180 buildings were destroyed, while at Naval Station 80% of the Ship Repair Facility's buildings suffered moderate to severe damage. Other naval buildings sustained minor to major damage with many quonset hut structures collapsed and others were moved from their foundations. In Apra Harbor, three ships were sunk while two tug boats and a huge floating crane were wrenched from their moorings and driven ashore. The sea inundated Marine Drive

depositing boats from the Agana boat basin as far as one block inland. The following vivid description of the damage extent is extracted from the official Fleet Weather Central report on Karen: "The central portion of the island exhibited the eerie appearance of being completely denuded. Snapped and uprooted palm trees and shrubs liken the area to the scorched effects of a forest fire. Bark was stripped off tree trunks and branches as if they had been sandblasted. Utility poles followed the same destructive pattern as poles were snapped liked match sticks."

**1963 29 April - OLIVE** - One of the few typhoons approaching Guam from the south. The eye passed 35 nm west of Agana at a slow speed (5-7 kt). Peak gusts of 90 kt were were experienced on island. Temporary structures (quonset huts and wooden buildings) received severe damage or were destroyed completely in certain parts of the island. In total, 120 homes were destroyed, 1140 severely damaged, while 60 commercial buildings were partially damaged. As a result, at least 1000 people were left homeless. Many of those left homeless had been housed in tents and other temporary structures after the passage of Typhoon Karen just five months prior to Olive. Flooding by the sea was experienced in Inarajan, Merizo and Anigua. Several bridges were also awash (particularly the one over the Ylig River). Total damage was estimated $5 million with ruined crops accounting for 20% of the total. No casualties were reported. The center of the typhoon shifted to a northeastward track after passing Guam. Later, the eye crossed directly over Saipan an 30 October, with wind gusts estimated to 130 kt. Ninety-five percent of houses were badly damaged, power lines destroyed, water system inoperative, new hospital unroofed, supply and public works center badly damaged. Total damage to public and private sectors on Saipan was estimated at $4.4 million.

**1963 11 July - WENDY** - The typhoon's eye passed 65 nm southwest of Agana, with wind gusts to 50 kt recorded on island. Because the typhoon was small in size, the island was spared the maximum winds. Damage was confined mainly to crops.

**1963 24 December - SUSAN** - Forth major typhoon to pass within 180 nm in 13 months. The eye of the super typhoon tracked just north of Rota. Estimated wind gusts of 70 kt affected the northern part of the island. No significant damage was reported on Guam. However, moderate damage occurred on Rota, Tinian and Saipan with 25% to 90% of the homes suffering damage.

**1964 5 September - SALLY** - Center of developing typhoon crossed near the southern tip of the island bringing wind gust of 70 kt. Several homes in southern villages were unroofed and scores of trees downed. Some sea inundation was reported at Talofofo Bay. Crop damage was the major monetary loss.

**1967 13 November - GILDA** - Eye of typhoon passed over Rota bringing wind gust of 60 kt to the northern end of Guam. Winds were strong enough to cause extensive damage to crops, but no significant structural damage resulted. Heavy damage was sustained on Rota. The loss of 100 structures on Rota resulted in 500 homeless, eight injuries, but no fatalities.

**1968 11 April - JEAN** - Eye of typhoon passed 95 nm northeast of Agana. A wind gust to 54 kt was recorded at Andersen AFB. No significant damage was sustained on Guam. Jean, however, devastated Saipan with winds estimated as high as 150 kt. Thousands were left

homeless with 90% of the Saipan's houses destroyed. Although property damage was $16 million, only one person was severely injured and there we no deaths.

**1968 22 October - IRMA** - Center of the tropical storm passed just south of Rota and 50 nm north of Agana. Peak wind gusts of 56 kt swept the northern tip of Guam, however no significant damage was reported. Rota and Saipan experienced some minor damage.

**1968 27 October - JUDY** - Eye of typhoon passed 100 nm south of Agana. Peak gusts of 50 kt were experienced on the island, but no significant damage was reported.

**1968 23 November - ORA** - Center of fast-moving tropical storm passed directly over Agana. Seventy-five knot winds occurred over the northern portion of the island. Damage was limited to the loss of island power, some broken windows and downed trees. The roof of the Santa Barbara School in Dededo was reported to have caved in. Heavy rains temporarily caused rivers to overflow and flood some bridges.

**1969 22 January - PHYLLIS** - Center of weakening, but fast-moving, tropical storm passed over Agana with a brief period of wind gusts to 50 kt over the northern part of the island. Rainfall from the system was quite light (0.48 inch in 24 hours). No damage was reported.

**1971 3 May - AMY** - Eye of super typhoon passed 90 nm southwest of Agana. Amy's progress between 3 and 4 May was slow, resulting in prolonged gales (with gusts to 60 kt) and heavy rain (15.21 inches in 48 hours). Seas inundated many areas in the southern part of the island with Inarajan reporting significant flooding and several sections of the road washed out. Eighty percent of the estimated $902,000 loss was due to wind damaged crops.

**1974 11-13 August - MARY** - Although tropical Storm Mary's center was located 450 nm northeast of Guam, a band of gales extended far to the south and west. Guam was exposed to gales for three days and recorded wind gusts to 55 kt on 12 and 13 August. The persistent strong southwesterly winds were responsible for significant damage to marine interests. The Caribia, a 40,000 ton passenger liner being towed to Taiwan for salvage, was cut loose from her tug at the entrance to Apra Harbor, ran aground on the breakwater, and sank, resulting in a $3.3 million loss. The heavy seas also took their toll on small craft. Of those that were lost, one yacht was valued at $250,000. Some flooding by the sea was reported along the coasts from Merizo northward to Tamuning. Two lives were lost due to drowning, and property damages exceeded $542,000.

**1975 19 November - JUNE** - Eye of super typhoon passed 215 nm west-southwest of the island. Wind gusts of 70 kt were recorded at Andersen AFB. Wave action inundated several sections of the seacoast highway between Merizo and Umatac. Sections of the road between the Ylig Bridge and Talofofo were blocked by high water and debris. Wind accounted for most of the damage with apparent tornadic effects experienced in the central part of the island. Mangilao was the hardest hit with several homes destroyed and some structures unroofed. This severe damage appeared to be confined to a narrow path which extended westward towards Tamuning, and included downed power poles and parked cars being blown about. Damage

estimates were near $1.3 million with crop loss accounting for 38% of the total. Twenty-nine people were left homeless.

**1976 21 May - PAMELA** - Most devastating typhoon to affect Guam since Typhoon Karen in 1962. Pamela's slow (the eye passage took 3 hours) progression across the center of the island caused this typhoon to be more destructive than Typhoon Karen. Andersen AFB was not included in the eye, but remained in the eye wall during Pamela's closest approach. Winds in excess of 100 kt were observed for 6 hours; typhoon force for 18 hours; and 50 kt for 30 hours. One death was recorded. Estimated maximum sustained winds were 120 kt with gusts to 145 kt. Despite extensive preparation, damage to civilian and military facilities was estimated to be near $500 million. The National Weather Service observatory at Tagauc recorded 27 inches of rain in a 24-hour period. Ten small ships and tugs which sought refuge in Apra Harbor either sank or ran aground (FWC/NOCC, 1976).

**1977 8 November - KIM** - Eye tracked over the northern portion of Guam. The duration of the eye passage exceeded an hour. The peak wind gust of 77 kt was recorded after the eye had passed off shore. The greatest damage occurred to the southern part of the island where 22 homes were severely damaged. Total losses were estimated at $600,000.

**1978 23 October - RITA** - Center of this very compact super typhoon passed 82 nm south of Agana. Gale force winds were experienced for 10 hours. The maximum wind recorded was 72 kt at the National Aeronautics and Space Administration (NASA) facility at DanDan. High winds were restricted to the southern end of the island and rainfall was light. Total damages were less than $700,000.

**1979 17 August - JUDY** - Center of rapidly developing tropical depression surprised Guam. Although the damage inflicted on Guam was minor, this tropical cyclone reminded Guam that a significant tropical cyclone can develop in a matter of hours. Approximately 10 hours after reconnaissance aircraft located a weak circulation east of Guam, the developing cyclone moved over the island in the middle of the night and produced wind gusts over 40 kt for several hours. A peak wind of 60 kt was recorded at the Naval Air Station.

**1979 9 October - TIP** - Center of developing typhoon passed 38 nm south of Agana. The maximum wind observed was a gust to 68 kt at NASA DanDan. After passing Guam, Tip rapidly deepened to a super typhoon and brought sustained high seas to the western exposed shoreline for nearly a week. The total losses associated with Tip amounted to nearly $1.6 million.

**1979 8 December - ABBY** - Center of poorly organized tropical storm passed 108 nm south of Agana. A peak gust of 55 kt was recorded at Nimitz Hill. No significant damage was reported with the passage of this cyclone.

**1980 31 October - BETTY** - Center of this rapidly moving typhoon passed 25 nm south of Agana. Extensive flooding was reported on the southeastern portion of the island. Damage was moderate and generally restricted to the southern one-third of the island. Gale force winds

occurred just prior to the closest point of approach. The highest recorded wind gust was 79 kt at the Naval Air Station.

**1984 12 November - BILL** - The eye of the typhoon passed 20 nm south of Guam. As Bill approached from the east, it accelerated to 20 kt. Maximum wind gusts recorded on the island were 84 kt at Apra Harbor. Total crop damage was estimated at $7.7 million. Minor flooding occurred and electrical power was interrupted.

**1988 12 January - ROY** - Passing 30 nm north of Guam, this typhoon caused peak gusts to 98 kt at Andersen AFB. Rota was devastated. On Guam, buildings on the northern portion of the island sustained light-to-moderate structural damage. Three hundred families were left homeless. Crops and vegetation were heavily damaged with losses estimated as high as $23.5 million.

**1989 29 April - ANDY** - Unusual in that it approached Guam from the south-southwest, Super Typhoon Andy with estimated maximum sustained winds of 135 kt passed 70 nm to the southeast. Peak gusts to 58 kt were recorded at Taguac. Even though no major strustural damage of facilities were reported, heavy rains caused an estimated $1 million damage to crops.

**1990 20 December - RUSS** - With estimated maximum sustained surface winds of 120 kt, this typhoon became the most severe to strike Guam in 14 years. President Bush declared the island a natural disaster area. Damage was estimated as high as $120 million. The center of the eye passed just south of Guam and Cocos Island experienced winds estimated to be 100 kt gusting to 125 kt. The most devastation occurred on the southern portion of Guam where 341 houses were destroyed, 460 suffered major damage, and 1210 had minor damage. Russ left most of the island without water and power for days. On the southern part of Guam, residents were without power and water for more than a week. On the southeastern coastal areas, sea inundation reached 8 to 9 feet and extended 240 to 300 feet inland. In Apra Harbor, two ships broke their moorings and went aground in the break water. Offshore, 11 fisherman were lost from foreign long-line fishing vessels.

# Appendix E

| TC NAME | DATE(Z) | CPA (dir) | CPA (nm) | MAX WIND (kt)(at CPA) | EST MSLP (mb)(at CPA) | PK GUST (kt) DIR/SPD | GUAM MSLP (mb) | GALE HRS | 24HR RAIN (in) | MVMT (at CPA) | MVMT (kt) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IDA | 12-Sep-45 | SSW | 85 | 45 | 991 | | | | | WNW | 12 | |
| KATE | 1-Oct-45 | NE | 70 | 45 | 991 | | | | | WNW | 11 | |
| LOUISE | 4-Oct-45 | NE | 65 | 40 | 994 | | | | | WNW | 15 | |
| BARBARA | 30-Mar-46 | SSW | 85 | 70 | 972 | | | | | W | 15 | |
| INGRID | 11-Jul-46 | WSW | 140 | 35 | 997 | | | | | NW | 13 | |
| OPAL | 7-Sep-46 | SSW | 45 | 60 | 980 | | | | | W | 17 | |
| QUERIDA | 20-Sep-46 | N | 26 | 90 | 955 | WSW82@(n) | 972(h) | 25 | 4.68 | WNW | 13 | |
| PEARL | 1-Jul-48 | SSW | 125 | 35 | 997 | SSE 37 (n) | 1002 (n) | 8 | 1.21 | WNW | 15 | |
| PAT | 27-Oct-48 | N | 115 | 35 | 997 | SW 39 (a) | 1003 (nf) | 3 | 2.23 | WNW | 15 | |
| AGNES | 14-Nov-48 | NNE | 40 | 60 | 980 | N 65 (a) | 987 (nf) | 18 | 4.9 | WNW | 15 | |
| BEVERLY | 3-Dec-48 | SSW | 140 | 75 | 967 | | | | | W | 11 | |
| HESTER | 24-Jul-49 | NNW | 120 | 55 | 985 | SW 44 (n) | 1002 (nf) | 1 | 2.03 | - | 0 | Looped |
| ALLYN | 17-Nov-49 | S | 60 | 135 | 909 | ENE 110@(h) | 972 (nf) | 37 | 4.33(h)(16) | WNW | 12 | |
| DORIS | 9-May-50 | SW | 135 | 85 | 958 | SE 63 (a) | 998 (n) | 26 | 3.74 | NW | 11 | |
| KEZIA | 5-Sep-50 | N | 135 | 35 | 997 | SSW 38(a) | 1002(a) | <1/2 | 1.33(n) | - | 0 | Stalled |
| BILLIE | 5-Nov-50 | NE | 180 | 55 | 986 | SW 20 (a) | 1004(a) | | | WNW | 11 | |
| HOPE | 17-Apr-51 | W | 132 | 35 | 997 | | | | | N | 7 | Track change |
| MARGE* | 11-Aug-51 | S | 25 | 55 | 983 | ENE 55 (n) | 966 (n) | 9 | 2.51 | WNW | 8 | |
| THELMA | 27-Oct-51 | NNE | 120 | 65 | 978 | SE 40 (a) | 1009 (a) | 5 | 0.39 | WNW | 20 | |
| POLLY | 27-Sep-52 | NNE | 85 | 35 | 997 | | | | | NW | 17 | |
| AGNES | 30-Oct-52 | NW | 23 | 35 | 997 | - | 1003(a) | - | - | NW | 9 | 30 kt at CPA 10 nm to NE (29) |
| BESS | 9-Nov-52 | NW | 77 | 35 | - | - | - | - | 2.92 | WNW | 16 | 30 kt at 40 CPA to NNE (9) |
| CARMEN | 16-Nov-52 | SSW | 165 | 35 | 997 | - | - | - | - | NW | 18 | |
| HESTER | 31-Dec-52 | S | 120 | 100 | 945 | E 70 (a) | 995 (n) | 27 | 2.17 (n) | W | 22 | |
| IRMA | 21-Feb-53 | S | 90 | 55 | 985 | SE 55 (a) | 1006 (a) | 15 | 7.88 | WNW | 15 | |
| NINA | 10-Aug-53 | N | 15 | 65 | 976 | S 57 (n) | 982 (a) | 20 | 7.07 | NW | 12 | |
| ALICE | 14-Oct-53 | N | 15 | 35 | 997 | S 56 (a) | 1001 (a) | 9 | 18.33 | W | 6 | Track change |
| IDA | 24-Aug-54 | SSW | 70 | 35 | 997 | S 44 (a) | 1001 (a) | 8 | 1.6 | W | 16 | |
| LORNA | 14-Sep-54 | N | 180 | 70 | 975 | W 50 (a) | 977 (a) | 9 | 2.33 | W | 10 | |
| NANCY | 1-Oct-54 | N | 125 | 35 | 997 | | | | | W | 2 | |
| SALLY | 11-Nov-54 | WSW | 150 | 35 | 997 | | | | | W | 8 | |
| TILDA | 26-Nov-54 | S | 80 | 45 | 990 | E 38 (n) | 1006 (a) | 4 | 1.58 | W | 9 | |
| KATE | 18-Sep-55 | SSW | 170 | 35 | 997 | | | | | W | 15 | |
| LOUISE | 21-Sep-55 | NE | 110 | 55 | 984 | | | | | N | 4 | |
| MARGE | 27-Sep-55 | WSW | 31 | 55 | 984 | | | | | NW | 21 | |
| KAREN | 12-Nov-56 | SSW | 100 | 40 | 994 | | | | | WNW | 13 | |
| VIRGINIA | 19-Jun-57 | S | 100 | 45 | 993 | SE 43 (n) | 1005 (n) | 2 | 0.79 | WNW | 16 | |
| FAYE | 18-Sep-57 | SSW | 135 | 105 | 941 | E 35 (a) | 1007 (n) | 3 | 0.83 | WNW | 9 | |
| HESTER | 5-Oct-57 | NE | 25 | 55 | 987 | SW 48 (n)(6) | 993 (n) | 3 | 3.97 | NNW | 11 | Aprch S, turned NW at CPA |
| JUDY* | 21-Oct-57 | N | 125 | 55 | 985 | WSW 29 (n) | - | - | 3.48 | W | 13 | |
| KIT | 7-Nov-57 | SSW | 125 | 45 | 985 | - | - | - | 2.9 | WNW | 21 | |
| LOLA | 15-Nov-57 | S | 40 | 140 | 900 | NNE 84@(n) | 978 (n) | 34 | 5.61 | WNW | 12 | G 104 observed at Mt. Alutom |
| PHYLLIS | 28-May-58 | SW | 170 | 105 | 940 | SSE 37 (a) | 1006 (n) | 1 | 0.91 | NW | 11 | |
| SUSAN | 13-Jun-58 | NNW | 110 | 35 | 997 | SSW 18(a) | 1003 (a) | | | NW | 16 | 30 kt at CPA 10 nm to NE (13) |
| TESS | 1-Jul-58 | N | 105 | 50 | 987 | | | | | W | 18 | |
| VIOLA* | 8-Jul-58 | SW | 65 | 60 | 982 | SE 42 (n) | - | 1 | 1.92 | NW | 8 | |
| GRACE | 29-Aug-58 | SSW | 155 | 35 | 997 | ESE 36 (n) | - | - | 0.22 | WNW | 8 | |
| IDA | 20-Sep-58 | S | 20 | 35 | 997 | E 46 (n) | 999 (n) | 6 | 1.75 | W | 17 | |
| JOAN | 25-Aug-59 | NW | 150 | 45 | 991 | | | | | W | 10 | |
| DINAH | 16-Oct-59 | SSW | 125 | 90 | 953 | N 42 (n) | 1000 (n) | 5 | 1.01 | WNW | 20 | |
| EMMA | 6-Nov-59 | SSW | 120 | 45 | 993 | NE 35 (n) | 995 (n) | <1/2 | 2.27 | WNW | 10 | |
| MAMIE | 15-Oct-60 | NE | 175 | 40 | 996 | WSW 32 (n) | - | - | 0.54 (n) | NW | 11 | |
| NANCY | 10-Sep-61 | S | 95 | 130 | 910 | SSE 59 (nh) | 995 (n) | 25 | 3.68 | WNW | 15 | |
| VIOLET | 5-Oct-61 | NNW | 170 | 65 | 980 | SW 34 (n) | - | <1/2 | 1.59 | - | 0 | Track change |
| BILLIE | 23-Oct-61 | SW | 175 | 35 | 995 | ENE 39 (a) | 1001 (n) | 8 | 2.73 | NW | 8 | |
| GEORGIA | 19-Apr-62 | WSW | 160 | 85 | 956 | SW 39 (n) | 1001 (n) | <1/2 | 1.77 | SW | 7 | Aprch SSW, turned NNW at CPA |
| RUTH | 14-Aug-62 | NE | 100 | 40 | 993 | NW 34 (n) | - | - | 1.75 | N | 7 | Track change |
| EMMA* | 2-Oct-62 | NNE | 170 | 55 | 985 | W 46 (n) | 1001 (a) | 8 | 3.41 | - | 0 | Stalled |
| KAREN | 11-Nov-62 | S | 10 | 135 | 910 | N 125 (nh) | 932 (n) | 28 | 6.32 (12) | W | 17 | |
| NADINE | 8-Dec-62 | N | 15 | 45 | 990 | E 45 (a) | 991 (n) | 1 | 2.77 | ENE | 7 | Track change |
| OLIVE | 29-Apr-63 | W | 35 | 110 | 932 | SW 87 (nh) | 977 (nh) | 52 | 4.86 | N | 7 | |
| WENDY | 11-Jul-63 | SW | 80 | 80 | 947 | E 50 (nh) | 999 (n) | 26 | 3.17 | SW | 6 | Track change |
| IRMA | 18-Sep-63 | ENE | 135 | 35 | 997 | - | | | | W | 8 | |
| LOLA | 13-Oct-63 | W | 30 | 30 | 996 | WSW 35 | 998 (a) | 2 | 4.24 | - | 0 | Loop W |
| SUSAN | 25-Dec-63 | N | 75 | 75 | 948 | W 61 (a) | 992 (a) | 36 | 6.09 | WNW | 12 | |
| TESS | 20-May-64 | NW | 180 | 65 | 978 | WSW 35 (a) | 997 (a) | <1/2 | 2.03 | NE | 21 | |
| ALICE | 27-Jun-64 | SW | 50 | 45 | 993 | ESE 32 (n) | 1005 (n) | - | 0.55 | WNW | 8 | |
| SALLY | 5-Sep-64 | S | 10 | 65 | 976 | ESE 54 (a) | 998 (n) | 8 | 2.08 | WNW | 20 | |
| WILDA | 18-Sep-64 | NNE | 165 | 35 | 997 | - | | | | NW | 6 | |
| RUTH | 21-Jan-65 | SSW | 160 | 40 | 994 | | | | | WNW | 22 | |
| HARRIET | 22-Jul-65 | SW | 30 | 35 | 995 | S 40 (a) | 999 (n) | 10 | 3.75 | NNW | 13 | Aprch SSW, turned W at CPA |
| VIRGINIA | 13-Sep-65 | NE | 130 | 40 | 992 | SW 35 (a) | 1005 (a) | - | 7.48 | NW | 10 | |
| BESS | 28-Sep-65 | NNE | 150 | 45 | 998 | SW 41 (a) | 1001 (a) | 3 | 2.54 | WNW | 9 | Track change |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FAYE | 20-Nov-65 | S | 175 | 35 | 997 | E 35 (a) | 1006 (a) | 5 | 1.67 | W | 16 | | |
| JUNE | 22-Sep-66 | S | 145 | 45 | 988 | S 36 (a) | | | 2.18 | NNW | 12 | Track change | |
| THERESE | 20-Mar-67 | NNW | 90 | 35 | 998 | S 30 (a) | 1001 (a) | | 1.72 | ENE | 12 | | |
| DINAH | 17-Oct-67 | S | 40 | 35 | 997 | E 30 (a) | 1005 (n) | | 1.68 | W | 10 | | |
| GILDA | 13-Nov-67 | NNE | 55 | 100 | 945 | NW 60 (a) | 981 (a) | 46 | 5.09 | WNW | 10 | | |
| HARRIET | 19-Nov-67 | NNE | 100 | 65 | 978 | SE 30 (a) | 1007 (a) | | 1.55 | WNW | 11 | | |
| JEAN | 11-Apr-68 | NE | 95 | 115 | 935 | NNW 54 (a) | 999 (a) | 44 | 0.33 | NW | 9 | | |
| LUCY | 27-Jun-68 | NNW | 130 | 35 | 998 | ENE 27 (a) | | | 0.9 | WNW | 19 | | |
| MARY | 21-Jul-68 | NE | 155 | 40 | 994 | S 41 (a) | | <1/2 | 2.68 | NW | 9 | | |
| WENDY | 29-Aug-68 | NNE | 130 | 85 | 950 | | | | 0.79 | - | 0 | Stalled/looped | |
| AGNES | 2-Sep-68 | N | 180 | 75 | 965 | SW 37 (a) | | <1/2 | 1.3 | WNW | 11 | | |
| IRMA | 22-Oct-68 | N | 30 | 50 | 985 | W 66 (a) | 989 (a) | 31 | 4.82 | SE | 8 | Turned from W to N | |
| JUDY | 27-Oct-68 | S | 100 | 105 | 937 | E 50 (a) | 1005 (n) | 13 | 0.76 | WNW | 13 | | |
| KIT | 1-Nov-68 | E | 95 | 50 | 985 | NW 41 (a) | 1002 (n) | <1/2 | 0.29 | NNW | 8 | | |
| ORA | 22-Nov-68 | | 0 | 55 | 988 | NE 77 (a) | 988 (n) | 8 | 3.18 | WNW | 20 | | |
| PHYLLIS | 22-Jan-69 | | 0 | 35 | 1000 | SE 55 (a) | 1000 (a) | 1 | 0.48 | W | 20 | | |
| IDA | 16-Oct-69 | NNE | 90 | 35 | 997 | S 36 (a) | 1006 (a) | | 9.38 | NW | 6 | | |
| PATSY | 15-Nov-70 | NW | 90 | 50 | 987 | W 21 (a) | 1003 (a) | | 2.72 | WSW | 12 | | |
| AMY | 2-May-71 | SSW | 90 | 120 | 920 | E 60 (a) | 998 (nh) | 43 | 9.92 | WNW | 9 | Track change | |
| ROSE | 9-Aug-71 | NW | 90 | 35 | 1000 | NE 24 (a) | 1006 (a) | | 1.63 | WNW | 10 | | |
| FAYE | 6-Oct-71 | N | 125 | 55 | 992 | SE 36 (a) | 1002 (a) | 3 | 2.18 | W | 27 | | |
| RITA | 7-Jul-72 | S | 170 | 35 | 998 | SE 40 (a) | 1005 (n) | <1/2 | 2.97 | W | 7 | | |
| BETTY | 10-Aug-72 | NE | 150 | 50 | 985 | NE 18 (a) | 1006 (a) | | 1.05 (a) | NW | 13 | | |
| CARLA | 3-May-74 | NNE | 105 | 45 | 989 | NNW 35 (a) | 1005 (a) | <1/2 | 4.39 | WNW | 8 | | |
| POLLY | 26-Aug-74 | NNE | 150 | 45 | 991 | SW 35 (n) | 1001 (a) | <1/2 | 5.14 | - | 0 | Stalled/looped | |
| NANCY | 1-May-76 | NW | 80 | 35 | 1000 | SW 16 | 1007 | - | - | SW | 12 | | |
| PAMELA | 21-May-76 | | 0 | 120 | 930 | 138 (t) | 932 (n) | 49 | 27 | NW | 7 | | |
| SALLY | 24-Jun-76 | SW | 180 | 35 | 999 | SE 35 (a) | 1007 (n) | | 0.5 | NW | 14 | | |
| THRESE | 13-Jul-76 | NE | 140 | 130 | 913 | ENE 40 (a) | 998 (n) | <1/2 | 0.82 | NW | 16 | | |
| BILLIE | 3-Aug-76 | NW | 105 | 50 | 988 | S 30 (a) | 1001 (n) | | 3.6 | SW | 14 | Track change and stall | |
| FRAN | 5-Sep-76 | SW | 30 | 50 | 985 | S 30 (a) | 992 (n) | 12 | 3.18 | NW | 13 | | |
| GEORGIA | 12-Sep-76 | S | 45 | 35 | 995 | E 30 (a) | 997 (n) | | 1.34 | WSW | 12 | | |
| LOUISE | 31-Oct-76 | SSW | 180 | 45 | 993 | ESE 37 (a) | 1006 (a) | 10 | 1.25 | WNW | 14 | | |
| KIM | 8-Nov-77 | N | 5 | 60 | 979 | SE 77 (a) | 978 (a) | 7 | 4.44 | NNW | 15 | | |
| MARY | 29-Dec-77 | SSE | 145 | 55 | 978 | ENE 39 (a) | 1008 (a) | 12 | 0.57 | WSW | 14 | | |
| CARMEN | 11-Aug-78 | NNW | 75 | 45 | 991 | | | | 4.21 | SSW | 4 | | |
| FAYE | 28-Aug-78 | ENE | 40 | 35 | 998 | NW 16 (a) | 1004 (a) | | 0.82 | NNW | 10 | | |
| RITA | 23-Oct-78 | S | 75 | 140 | 899 | ESE 72 (d) | 1005 (n) | 8 | 1.1 | W | 17 | | |
| VIOLA | 18-Nov-78 | SSW | 180 | 45 | 991 | | | | | WNW | 14 | | |
| ALICE | 9-Jan-79 | S | 85 | 70 | 972 | ESE 45 (nh) | 1003 (a) | 12 | 1.22 | W | 11 | | |
| JUDY | 17-Aug-79 | WNW | 80 | 35 | 997 | NE 60 (n) | 997 (n) | 3 | 2.35 | NNW | 15 | 30 kt at CPA 5 nm SSW (16) | |
| TIP | 9-Oct-79 | S | 40 | 60 | 980 | ENE 68 (d) | 994 (d) | 15 | 10.14 | W | 14 | | |
| ABBY | 8-Dec-79 | S | 145 | 35 | 997 | ESE 55 (nh) | 1000 (n) | <1/2 | 1.01 | WNW | 9 | 30 kt at CPA 110 nm SSW (8) | |
| ORCHID | 6-Sep-80 | N | 155 | 35 | 998 | SW 34 (n) | 998 (a) | 1 | 6.34 | NNW | 11 | | |
| WYNNE | 6-Oct-80 | ENE | 60 | 45 | 994 | WSW 25 (a) | 1005 (a) | | 1.72 | NW | 10 | | |
| BETTY | 30-Oct-80 | S | 30 | 70 | 984 | ESE 79 (n) | 933 (n) | 11 | 1.78 | WNW | 21 | | |
| DINAH | 22-Nov-80 | NNE | 125 | 100 | 950 | WSW 23 (a) | 1004 (a) | | 0.6 | NW | 16 | | |
| GERALD | 18-Apr-81 | E | 75 | 45 | 991 | N 49 (a) | 1005(n) | 2(a) | 4.26(a) | NNE | 6 | | |
| ELSIE | 24-Sep-81 | SSW | 125 | 35 | 997 | SE 31(n)(25) | 1005 (24) | 0 | 1.69 (t)(25-26) | NNW | 7 | | |
| GAY | 15-Oct-81 | NE | 145 | 40 | 994 | S 36 (n)(16) | 999 (15) | 1(a) | 1.95 (a)(16) | NW | 10 | | |
| HAZEN | 15-Nov-81 | NNW | 70 | 60 | 980 | SE 26 (n)(16) | 1004(15) | 0 | 0.42(a) | SW | 12 | | |
| IRMA | 19-Nov-81 | N | 25 | 40 | 994 | S 48 (n)(20) | 998 (n)(20) | 5(a) | 3.66 (t)(20-21) | W | 9 | | |
| KIT | 13-Dec-81 | S | 60 | 55 | 984 | E 54(n) | 994 (n)(13) | 8(a) | 1.39(a) | W | 11 | | |
| RUBY | 22-Jun-82 | W | 90 | 35 | 997 | S 43 (a)(23) | 1000 | 4(a) | 4.99 (a)(23) | NNE | 10 | Track change | |
| ANDY | 22-Jul-82 | S | 75 | 40 | 994 | E 37 (a)(23) | 996 (n)(24) | 1(a) | 0.89 (t)(23-24) | - | 0 | Looped | |
| DOT | 9-Aug-82 | SSW | 155 | 40 | 994 | SSE 30 (a)(16) | 1004 (10) | 0 | 1.12 (t)(9-10) | WNW | 21 | | |
| JUDY | 5-Sep-82 | SW | 65 | 35 | 997 | S 44 (a)(7) | 1000 (6) | 2(a) | 5.27 (a)(6) | W | 7 | 30 kt at CPA 40 nm to S (5) | |
| MAC | 2-Oct-82 | SSW | 25 | 60 | 980 | SE 46 (n)(3) | 996 (n)(3) | 11(a) | 3.44 (a)(3) | WNW | 10 | | |
| PAMELA | 1-Dec-82 | S | 85 | 45 | 994 | E 40(n) | 1007 | 1(a) | 0.79 (t)(1-2) | W | 20 | | |
| FORREST | 20-Sep-83 | SSW | 175 | 40 | 994 | SE 34 (a)(21) | 1004 (n)(20) | 1(a) | 2.84 (t)(20-21) | NW | 17 | | |
| MARGE | 31-Oct-83 | SSW | 160 | 35 | 997 | SE 33 (a)(01) | 1007(n) | 1(a) | 2.14 (a)(01) | WNW | 14 | | |
| IKE | 27-Aug-84 | SW | 100 | 50 | 987 | SE 21(a) | 1006 | 0 | 3.00 (t)(27) | NW | 8 | Track change | |
| ROY | 11-Oct-84 | W | 90 | 35 | 997 | S 27 (a)(12) | 1003 | 0 | 0.29(a) | N | 9 | | |
| THAD | 19-Oct-84 | ENE | 160 | 45 | 991 | ENE 28 (a)(08) | 1000(a) | 0 | 1.37(n) | NNW | 14 | | |
| VANESSA | 24-Oct-84 | SSW | 105 | 80 | 963 | ESE 50(a) | 1001 (a) | 9(a) | 0.82(a) | WNW | 18 | | |
| BILL | 12-Nov-84 | S | 20 | 85 | 958 | E 65 (T)(13) | 995 (13)(n) | 7(a) | 4.83 (n)(12-13) | W | 19 | | |
| DOT | 13-Oct-85 | S | 130 | 40 | 994 | ESE 31(14)(a) | 1004 (14)(n) | 0 | 2.47 (t)(13-14) | W | 14 | | |
| PEGGY | 4-Jul-86 | N | 70 | 60 | 980 | WSW 44(a) | 1002(a) | 5(a) | 7.86 (t)(4-5) | W | 12 | | |
| CARMEN | 3-Oct-86 | NE | 65 | 50 | 987 | W 49(a) | 1004(a) | 5(a) | 11.98 (t)(3-4) | WNW | 14 | | |
| KIM | 3-Dec-86 | N | 120 | 130 | 910 | W 44(n) | 995(a) | 6(a) | 1.56 (t)(3-4) | W | 12 | | |
| MARGE | 17-Dec-86 | SSW | 165 | 70 | 972 | N 43(n) | 1003(n) | 5(a) | 1.89 (t)(17-18) | WNW | 7 | | |
| NORRIS | 26-Dec-86 | S | 105 | 55 | 984 | E 55 (27)(n) | 1004 (27) | 20(a) | 4.50 (t)(26-27) | W | 13 | | |
| THELMA | 8-Jul-87 | N | 80 | 35 | 997 | WSW 40(10)(a) | 1003(a) | 1(a) | 4.28 (t)(10-11) | WNW | 17 | Track change | |
| FREDA | 5-Aug-87 | W | 115 | 35 | 997 | E 25 (n)(4) | 1008(a)(4) | 0 | 0.21 (t)(6) | WNW | 12 | 30 kt at CPA 35 nm to WSW (4) | |
| DINAH | 22-Aug-87 | S | 140 | 40 | 994 | E 46(n) | 1007(a) | 0 | 1.12(n) | W | 15 | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IAN | 24-Sep-87 | NNE | 175 | 45 | 991 | SW 24(25)(a) | 1007(n) | 0 | 0.41 (t)(25) | WNW | 14 | |
| LYNN | 18-Oct-87 | NE | 90 | 75 | 968 | NW 57(n) | 993(a) | 7(a) | 5.11 (t)(18-19) | NW | 11 | |
| ROY | 12-Jan-88 | N | 35 | 110 | 933 | W 98(a) | 980(a) | 19(a) | 6.45 (t)(12-13) | W | 13 | |
| WARREN | 13-Jul-88 | S | 70 | 35 | 997 | E 28(n) | 1008 | 0 | 2.47 (t)(13-14) | W | 9 | Track change |
| WINONA | 19-Jan-89 | NNW | 90 | 55 | 984 | E 27(n) | 1006(n) | 0 | 0.49(a) | WSW | 28 | |
| ANDY | 20-Apr-89 | SSE | 80 | 135 | 904 | NE 58(21)(t) | 992(21)(a) | 16(a) | 4.93 (t)(20-21) | NE | 11 | Track change, stall |
| COLLEEN | 3-Oct-89 | ENE | 155 | 45 | 991 | SW 32(n) | 1001(a) | 0 | 4.52(n) | NNW | 9 | Track change |
| FORREST | 24-Oct-89 | NE | 80 | 60 | 980 | W 36(a) | 996(a) | 2(a) | 4.09 (t)(23-24) | NW | 10 | |
| IRMA | 26-Nov-89 | SSE | 180 | 35 | 997 | E 28(n) | 1004(a) | 0 | 0.96 (t)(26) | WSW | 8 | |
| JACK | 27-Dec-89 | NE | 95 | 35 | 997 | N 20(n) | 1007 | 0 | 0.09 (t)(27) | NW | 11 | Stall |
| KORYN | 14-Jan-90 | E | 50 | 65 | 976 | 70 (n) | 991 (a) | 26 (a) | 9.15 (a) | NNW | 6 | |
| KYLE | 16-Oct-90 | NE | 165 | 35 | 997 | WNW 16 (a) | 1004 (a) | - | 0.16 (a) | NNW | 4 | Track change |
| PAGE | 22-Nov-90 | SSW | 160 | 40 | 994 | SE 40 (a)(23) | 1004 (a) | <1/2 (a) | 5.17 (a)(23) | WNW | 13 | Track change |
| RUSS | 20-Dec-90 | SSW | 50 | 120 | 922 | ENE 111 (m) | 971 (a) | 42 (a) | 6.12 (nh) | WNW | 12 | |

## Legend (Appendix E)

CPA - closest point of approach in nautical miles to Agana (13.45°N, 144.75°E).

MAX WIND - estimated maximum sustained 1-minute surface winds (kt) near the center of the tropical cyclone.

EST MSLP - estimated minimum sea-level pressure (mb) at the center of the tropical cyclone.

PK GUST
DIR SPD - direction and speed of peak gusts observed on Guam
Legend: @ = anemometer failed, a = Andersen AFB, d = DanDan, h= Harmon Field, m = Naval Magazine, nf = North Field, n = Naval Air Station, nh = Nimitz Hill (NOCC/JTWC), t = Taguac.

GUAM MSLP - minimum sea-level pressure observed on Guam during the passage of a tropical cyclone. Legend: same as above.

GALE HRS - Duration in hours of gusts of gale force (>33 kt).

24HR RAIN - Maximum 24-hour rainfall observed on Guam during the passage of a tropical cyclone. Sites used: North Field (1946-1949), Andersen AFB (1950-1990), Taguac (1957-1990). If the maximum rain fell on a day before or after CPA, or the 24-hour period included part of two days, the date or dates are included in parenthesis.

MVMT AT CPA - Direction and speed (kt) of movement of the tropical cyclone at CPA.

* - originally classified as a typhoon at CPA to Guam. Available data was reevaluated and MAX WND values were adjusted accordingly.

## APPENDIX F

Tropical Cyclones (>33 kt) producing gusts to gale force (1 hour or more) but passing outside 180 nm of Guam

| NAME | DATE | CPA | MAX WND | EST MSLP | PK GUST DIR SPD | GALE HRS | REMARKS |
|---|---|---|---|---|---|---|---|
| Jean | 21 Dec 47 | SSW 300 | 45 | 991 | ENE 43(a) | 2 | |
| Kit | 28 Jun 53 | SW345 | 85 | 958 | E 35 (a) | 3 | |
| Tilda | 16 Apr 59 | SSW230 | 105 | 938 | ENE 38(n) | 4 | |
| Ophelia | 30 Nov 60 | SSW200 | 80 | 963 | E 39 (n) | 2 | |
| Opal | 11 Dec 64 | SW410 | 65 | 976 | E 43 (n) | 1 | |
| Olga | 28 Jun 70 | SW240 | 35 | 997 | E 42 (a) | 3 | |
| Mary | 12 Aug 74 | NE455 | 40 | 994 | SW 57 (a) | 67 | 24hr rain=7.36 |
| Gloria | 4 Nov 74 | SW450 | 55 | 984 | SE 43 (a) | 4 | |
| June | 19 Nov 75 | WSW215 | 155 | 879 | SE 70 (a) | 25 | 24hr rain=3.16 |
| Kathy | 20 Jan 76 | SW355 | 40 | 994 | ESE 38 (a) | 3 | |
| Viola | 18 Nov 78 | SSW195 | 45 | 991 | ESE 45 (a) | 1 | |

See Appendix E for an explanation of columns and coding

## Appendix G

Definitions

Center - the vertical axis or pivot of a tropical cyclone. Usually determined by wind, temperature and/or pressure.

Eye - the central area of a tropical cyclone when it is more than half surrounded by wall cloud.

Intensity - the maximum sustained 1-minute mean surface wind speed, typically within one degree of the center of a tropical cyclone.

Knot(s) - (kt) a unit of measure for speed equal to one nautical mile per hour.

Maximum sustained wind - the maximum surface wind averaged over a one-minute period of time. Peak gusts over water average 20 to 25 percent higher than the sustained wind.

Millibar - (mb) a unit of measure of atmospheric pressure equal to 1,000 dynes per square centimeter. Standard atmospheric pressure at sea level is 1013 mb.

Monsoon trough - a synoptic scale low pressure trough associated with the summer Asian southwest monsoon. Typically this surface trough extends across the Philippine Islands and eastward through the Caroline Islands.

Nautical mile - (nm) a unit of measure (6076 feet) equal to 1.15 statute (land) miles.

Ridge - an area of relatively high atmospheric pressure. The winds move clockwise in the Northern Hemisphere around its periphery and are frequently light and variable near it axis of highest pressure. Fair weather is usually associated with ridges.

Sea-level pressure - the weight of the atmosphere measured at sea level. Although 1013 mb is the standard, the tropical latitudes usually have 1010 to 1004 mb.

Super typhoon - a tropical cyclone with maximum sustained 1-minute mean winds of 130 knots or greater. The term was chosen because it is twice minimum typhoon intensity (65 knots).

Trade wind - an enhanced flow of easterly winds in the Northern Hemisphere which frequent the subtropical and tropical latitudes. For Guam the winter trade winds are northeasterly and the summer trade winds are southeasterly.

Tropical cyclone - A non-frontal, migratory low-pressure system, usually of synoptic scale, originating over tropical or subtropical waters and having a definite organized circulation.

Tropical depression - a tropical cyclone with maximum sustained 1-minute surface winds of 33 knots or less.

Tropical storm - a tropical cyclone with maximum sustained 1-minute surface winds in the range from 34 to 63 knots, inclusive.

Trough - an extension of relatively low atmospheric pressure in which the winds move counterclockwise in the Northern Hemisphere. Winds are usually light along the axis of lowest pressure in the trough. The trough is usually an area of disturbed weather.

Typhoon - A tropical cyclone with maximum sustained 1-minute surface winds of 64 to 129 knots.

Wall cloud - an organized band of cumuliform clouds that immediately surrounds the central area of a tropical cyclone. The wall cloud may entirely encircle or partially enclose the center.

# REPORT DOCUMENTATION PAGE

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A climatology of tropical cyclones passing near Guam is presented for the period 1945 to 1990. A review of all typhoons affecting Guam is carried back to 1800 and some noteworthy typhoons of the 1600's are included. The survey encompasses the frequency, behavior, meteorological effects and descriptive chronicles of Guam tropical cyclones. The major emphasis is on the period since World War II.

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