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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study is an evaluation of the Japanese harbors of Buckner Bay and Naha, Okinawa as typhoon "havens." Characteristics of the harbors discussed include wind and wave action, storm surge and the topographical effects on winds prior to and during the passage of tropical cyclones. Problems to be considered when remaining in port and evasion procedures are examined.

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20. ABSTRACT (continued)

The tracks of tropical cyclones from 1947-1973 for the western North Pacific were analyzed to determine the probability of threat to the harbors. Observations by the authors and information obtained in conversations with harbor authorities are utilized in reaching conclusions.

The conclusion reached by this study is that all vessels should evade from Buckner Bay and Naha when threatened by a typhoon.

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# AN EVALUATION OF THE HARBORS OF BUCKNER BAY AND NAHA, OKINAWA AS TYPHOON HAVENS

by

DIETER K. RUDOLPH, FRANK J. BLAKE,
SAMSON BRAND, AND JACK W. BLELLOCH

DECEMBER 1975

NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY
MONTEREY, CALIFORNIA 93940

# CONTENTS

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The assistance received by Dr. G. J. Haltiner, Chairman, Department of Meteorology, Naval Postgraduate School (NPS) is also gratefully acknowledged.

# 1. INTRODUCTION

Severe tropical cyclones, also known as typhoons or hurricanes, are one of the most destructive weather phenomena a ship may encounter whether it be in port or at sea. When faced with an approaching tropical cyclone, a timely decision regarding the necessity and method of evasion must be reached. Basically, the question is: should the ship remain in port, evade at sea, or, if at sea, should it seek the shelter offered by the harbor? This paper will examine the Japanese harbors of Buckner Bay and Naha, Okinawa, and evaluate their potential as typhoon havens.

In general, it is an oversimplification to label a harbor as merely good or bad. Consequently, an attempt will be made to present enough information about the harbors to aid a commanding officer in reaching a sound decision with respect to his ship. The decision should not be based on the expected weather conditions alone, but also on the ship itself, as well as characteristics of the harbor. These characteristics include: natural shelter provided, port congestion, and support facilities (normal and emergency) available to individual type commands.

# 2. TROPICAL CYCLONES

## 2.1 DEVELOPMENT

Tropical cyclones are warm-core, nonfrontal low-pressure centers that develop over tropical or subtropical waters. Although the tropical cyclone formation process is not fully understood, it is well known that they require tremendous amounts of energy to develop and sustain the high wind velocities present. Only the warm moisture-laden air of the tropics possesses this quantity of energy. For this reason, tropical cyclones usually develop within 20° of the equator and begin to dissipate as they move into mid-latitudes.

## 2.2 WIND CIRCULATION

The wind circulation associated with tropical cyclones is counterclockwise about the eye in the Northern Hemisphere and clockwise in the Southern Hemisphere. Figure 1 depicts the wind pattern around the eye of a typical large, intense 150-kt typhoon. Note that the more intense winds are located in the right semicircle of the circulation. For this reason the right side of a tropical cyclone is known as the "dangerous semicircle."

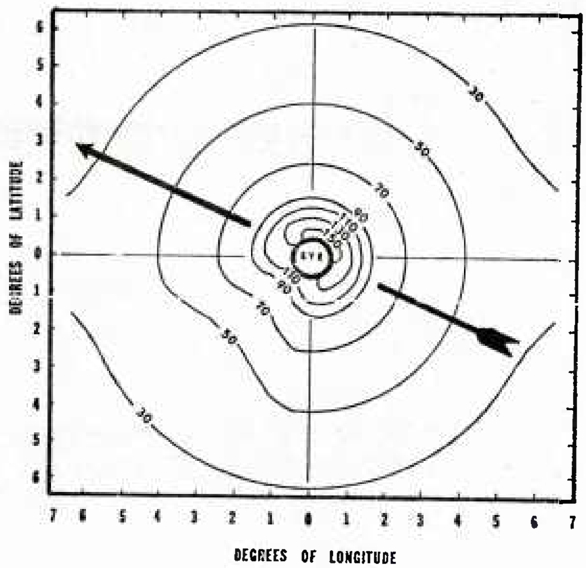



Figure 1. Distribution of surface wind speeds (in knots) around a large, intense typhoon in the Northern Hemisphere over open water. The arrow indicates direction of movement (after Harding and Kotsch, 1965).

The highest winds associated with tropical cyclones have never been accurately measured; however, based on data from past storms, tropical cyclone winds may attain speeds well in excess of 150 kt. The following classification system concerning the intensity of tropical cyclones has been established by international agreement:

| | |
|---|---|
| Tropical Depression: | Maximum sustained winds no greater than 33 kt |
| Tropical Storm: | Maximum sustained winds in the range 34-63 kt |
| Typhoon: | Maximum sustained winds in excess of 63 kt |

## 2.3 MOVEMENT

The majority of tropical cyclone tracks conform to a general pattern by initially moving west-northwest from the source region. Steered by the prevailing easterlies, the tropical cyclone moves at speeds from 8 to 14 kt. Normally, upon reaching latitudes between 20-30N, tropical cyclones are influenced by the prevailing westerlies and undergo "recurvature." This implies that the west-northwest movement gradually shifts to a northeasterly direction. After recurvature, the tropical cyclone's speed of movement can accelerate within 48 hours to as much as 2 to 3 times the speed at the point of recurvature (Burroughs and Brand, 1972). However, in conjunction with the increase in speed of movement, a gradual weakening occurs as the tropical cyclone moves over cooler waters or when cool surface air enters the storm system. Approximately 40% of WESTPAC tropical cyclones recurve.

It is important to keep in mind that the course of individual storms cannot be said to follow any standardized pattern. Numerous typhoons have followed extremely erratic courses, even making occasional loops in their tracks. For this reason, the progress of each typhoon should be closely monitored for changes in intensity, direction and speed of movement. The western North Pacific average typhoon tracks, track limits, and average speed of movements for the months of May-December are presented as Appendix A.

It is important to realize that sea conditions affecting ship movement will extend well beyond the wind field associated with a tropical cyclone, and that a miscalculation concerning sea conditions could result in a destructive rendezvous with the storm. The extent of the sea state generated by a tropical storm is primarily a function of storm size, duration, and intensity. Figure 2 shows the

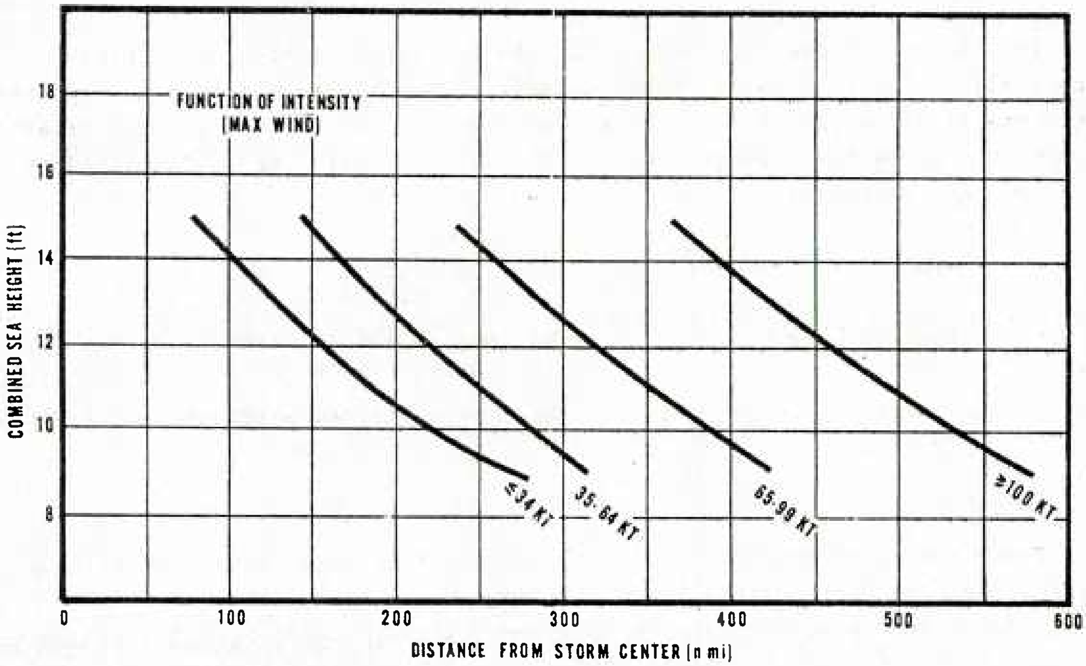
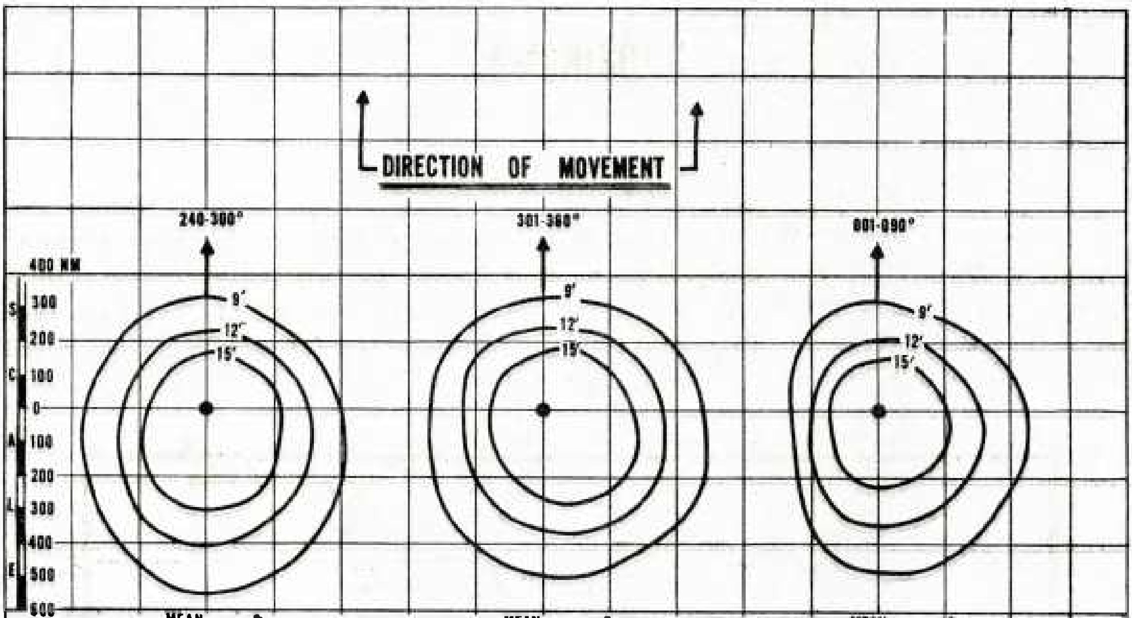



Figure 2. Combined sea height plotted against distance from storm center and given as a function of storm intensity (Brand, et al., 1973).

combined sea height[1] associated with 21 tropical storms and typhoons (based on 173 analyses for the year 1971) plotted as a function of distance from the storm center and storm intensity (Brand, et al., 1973). There is a large variation in the sea state with storm intensity. A tropical storm (winds 35-64 kt) could produce 12-ft seas 217 n mi from the storm center; while an intense typhoon (winds ≥ 100 kt) could produce 12-ft seas 454 n mi from the center. The distances given are mean distances since the isopleths of combined sea height are not symmetric about the storm center. Brand, et al. (1973) found that the actual wave heights are at least partially dependent on the direction in which the storm is moving. For example, Figure 3 shows the average combined sea height isopleth pattern for storms moving on headings between 240° and 300°, 301° and 360°, and 001° and 090°, and is based on sea-state analyses for tropical storms and typhoons that occurred during 1971. Note that the greatest area of higher seas (9-15 ft range) exists to the rear and toward the right semicircle of the storm.

---

[1]The combined sea height is defined as the square root of the sum of the squares of "significant" sea and swell height. Sea is wind waves and swell consists of wind generated waves which have advanced into regions of weaker or calm winds. "Significant" is defined here as the average height of the highest one third of the waves observed over a specified time.




| | MEAN | σ | MEAN | σ | MEAN | σ |
|---|---|---|---|---|---|---|
| DIRECTION (°) | 283.5 | 10.8 | 328.9 | 18.1 | 019.8 | 13.9 |
| SPEED (KT) | 10.4 | 4.3 | 9.2 | 4.5 | 12.1 | 7.7 |
| INTENSITY (KT) | 76.5 | 34.1 | 69.2 | 30.7 | 64.6 | 20.5 |
| SIZE (°LAT) | 5.0 | 1.6 | 4.6 | 1.9 | 3.3 | 1.4 |
| DURATION | 5.9 | 3.8 | 5.8 | 4.3 | 7.5 | 5.3 |
| NUMBER OF ANALYSES | 81 | | 66 | | 24 | |

Figure 3. The combined sea height isopleths (9-15 ft) about tropical storms and typhoons given as a function of direction of movement associated with the storms.

# 3. OKINAWA

Okinawa is the principal island in the Ryukyu Islands chain which extends in an arc from off the northeastern coast of Taiwan to the southern end of Kyushu. This chain of islands forms the southeastern boundary of the East China Sea. Okinawa is located 350 n mi south of Kyushu or approximately in the middle of the Ryukyu Island chain as shown in Figure 4.

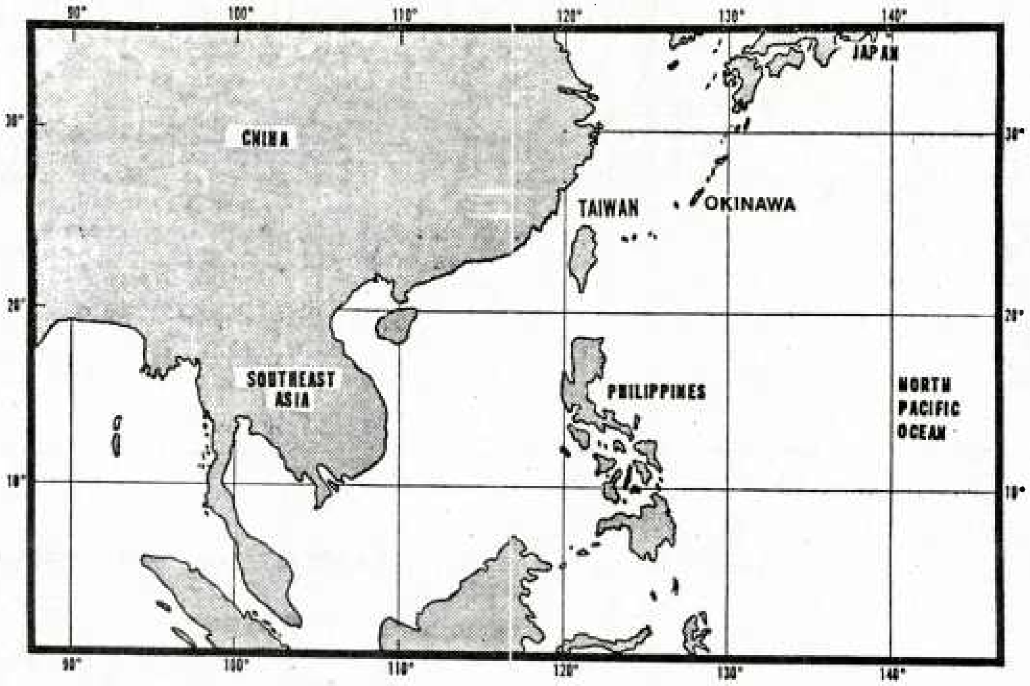



Figure 4. Map of the western North Pacific Ocean showing the positions of major land masses.

Oriented roughly northeast to southwest, Okinawa is 58 n mi long and 2.6 to 17 n mi wide. The northern part of the island is rugged, mountainous, and wooded, with few inhabitants and very little cultivated land. The southern part, where Naha and Buckner Bay are located, consists of hills and plateaus, is highly cultivated and thickly settled. The topography of Okinawa is depicted in Figure 5.

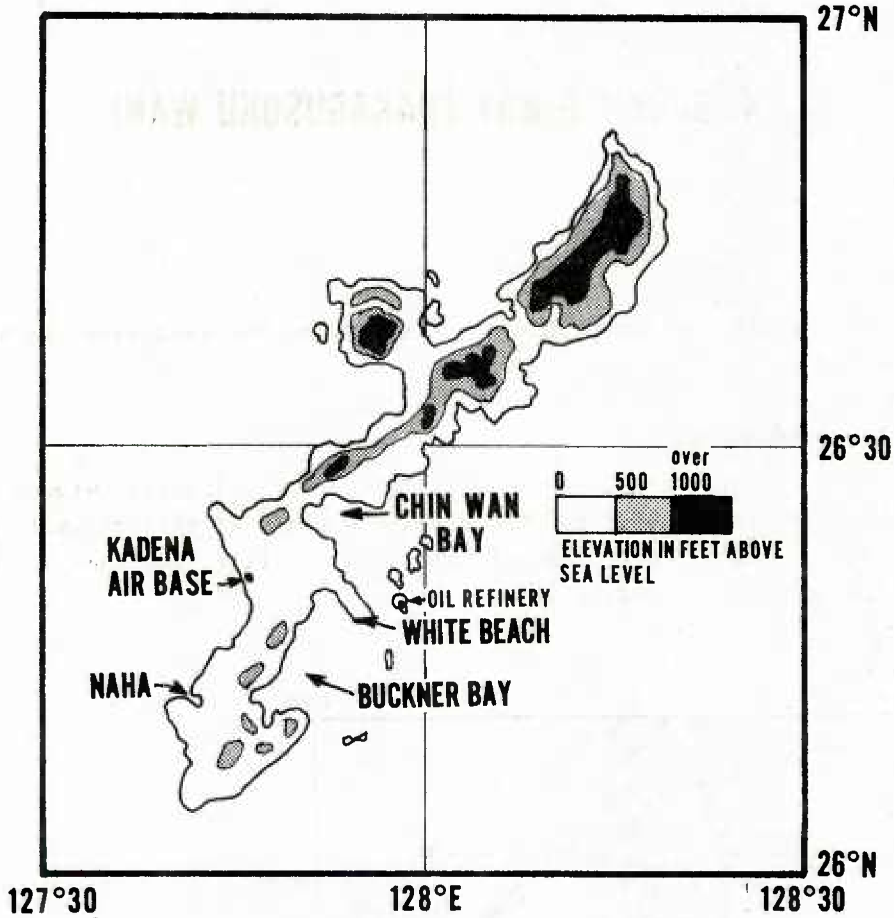



Figure 5. Topography of Okinawa.

A detailed study of the coast and harbors of Okinawa is included in H.O. Pub. 156, Sailing Directions (Enroute) for Japan, sector 20. For specific comments on navigation aids and coastal features near Buckner Bay and Naha, the reader is referred to the above mentioned publication.

# 4. BUCKNER BAY (NAKAGUSUKU WAN)

4.1 LOCATION

Figure 5 shows the location of Buckner Bay on the east coast of the southern tip of Okinawa.

4.2 BUCKNER BAY HARBOR

The main entrance to Buckner Bay is Tatsu Guchi, located between Ufu Bishi and Tsuken Shima (see Figure 6). The navigable width of this channel is almost 2 n mi. The second entrance, Kudaka Kuchi, is a little less than 1/2 n mi wide and is located south of Kudaka Shima.

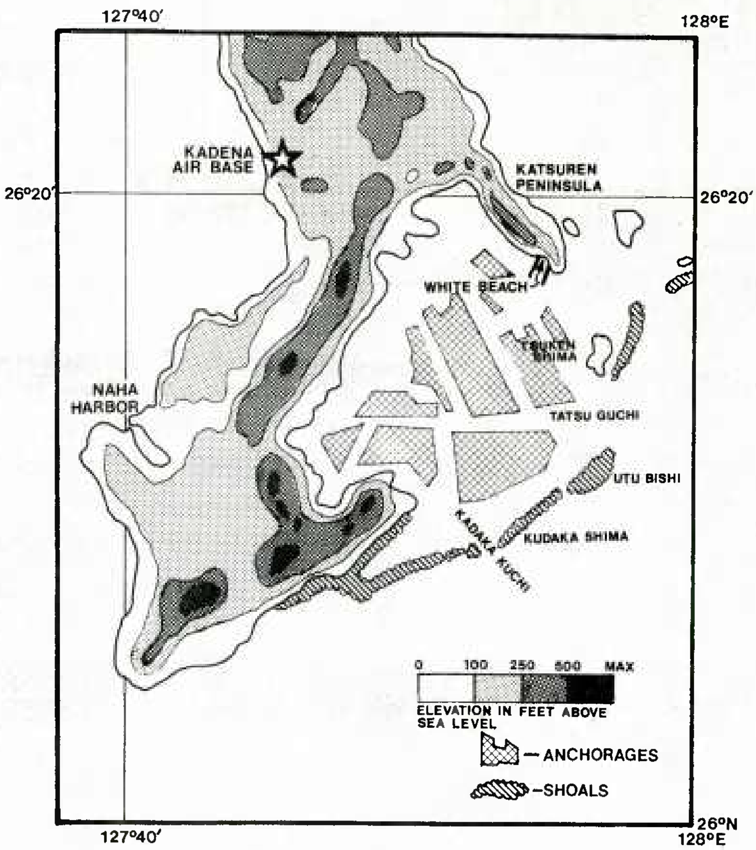



Figure 6. Topography of southern Okinawa.

There are numerous anchorages available throughout the bay in a sand, mud and shell bottom. The greater part of Buckner Bay has been wire dragged to a depth of 11 fathoms. Pier area is available at White Beach, the principle facility serving the U.S. Navy.

## 4.3 TOPOGRAPHY

Figure 6 depicts the topography of the land masses surrounding Buckner Bay. It is evident that there is virtually no wind protection afforded by topography for winds from the east-southeast to south-southwest.

## 4.4 HARBOR FACILITIES

There are two piers at White Beach (see Figure 7). The older of the two, Pier Bravo is an asphalt-surfaced causeway connecting to a steel pier reinforced with concrete. A newer pier, the Navy Pier located east of pier Bravo is used primarily by U.S. Navy vessels while part of pier Bravo is used by the Japanese Maritime Self Defense Force. Information as to pier length and alongside depth can be obtained from the CINCPACFLT Port Directory, Volume V, section C1, or the Far East Port Directory, MSTSFE Instruction 3170.4A, section IV-8. There are no mooring buoys located within Buckner Bay.

Buckner Bay does not have a tug/pilot available. If tug/pilot assistance is required it must come from Naha harbor (6 tugs available) or the oil refinery ( 4 tugs available) located at Kinmu Bay (see Figure 5). When threatened by a typhoon these tugs will undoubtedly be used first at their primary location before rendering assistance to ships in Buckner Bay. The Port Services Officer at White Beach does have four LCM-6 type pusher boats available which could be of some use during an emergency.

Buckner Bay is not a logistics support port. However, fuel oil, fresh water, and food can be obtained in limited quantities.

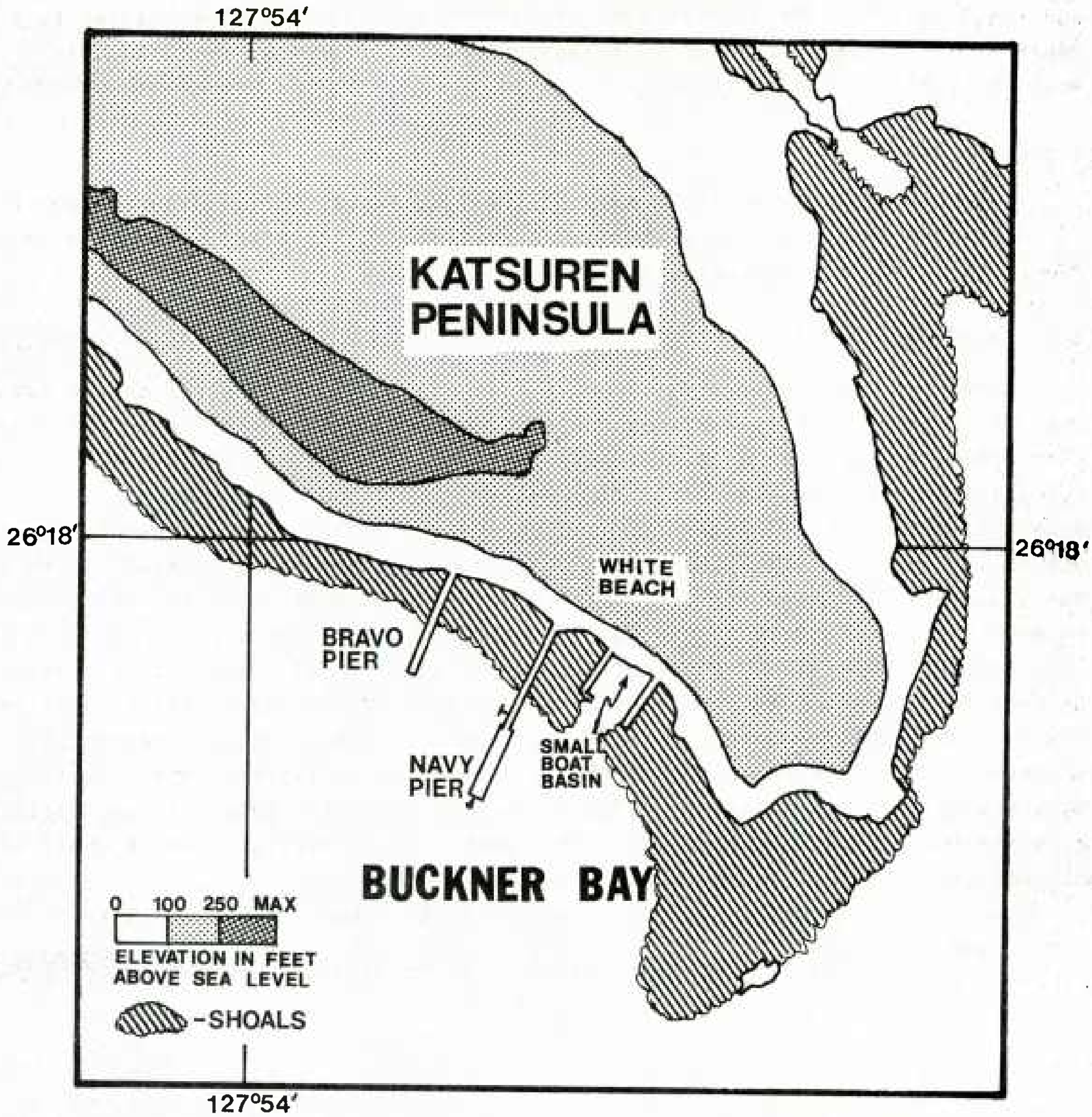



Figure 7. Pier area of White Beach.

# 5. TROPICAL CYCLONES AFFECTING BUCKNER BAY

## 5.1 CLIMATOLOGY FOR BUCKNER BAY/NAHA HARBORS

The climatology of tropical cyclones for Buckner Bay and Naha Harbors are combined here since the two harbors are less than 13 n mi apart. The midpoint of a line between the two harbors was used for the following climatology. For purposes of this study, any tropical cyclone that entered a 180 n mi circle radially outward from this midpoint was considered to be a threat to Buckner Bay/Naha Harbors and designated as a "threat" tropical cyclone.

Tropical cyclones can occur during any month of the year in the western North Pacific area. However, the majority of those that pose a threat to Buckner Bay/Naha occur during the months of May-December. Climatological records indicate that during this period Okinawa is either within or closely adjacent to the mean tropical cyclone track (see Appendix A) and therefore has the dubious distinction of being located in the middle of "Typhoon Alley."

The peak "threat" period for Buckner Bay/Naha extends from July through September. This is indicated in Figure 8 which depicts the monthly summary by 5-day periods of tropical cyclone occurrences and is based on data from May-December, 1947-1973. During this 27-year period, 115 tropical cyclones

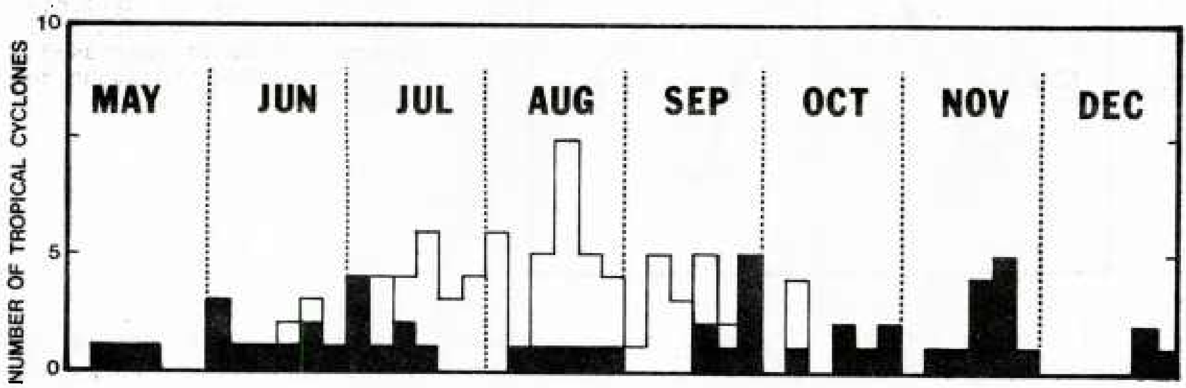



Figure 8. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha. Subtotals are based on 5-day periods, for tropical cyclones that occurred during 1947-1973. The shaded area indicates the number of recurving tropical cyclones per 5-day period (northeasterly direction of motion at their closest point of approach to Buckner Bay/Naha after an initial northwesterly direction of motion).

"threatened" Buckner Bay/Naha, an average of approximately four tropical cyclones per year. August is the peak "threat" period (27%) followed by July and September. Only 5% of the "threat" tropical cyclones occurred during May and December. Figure 8 also indicates that almost half of the "threat" tropical cyclones are "recurvers" (had a northeasterly component of motion at their closest point of approach to Buckner Bay/Naha after an initial northwestward component of motion).

Figure 9 displays the "threat" tropical cyclones according to the compass octant from which they approached Buckner Bay/Naha. The circled numbers indicate the total that entered from an individual octant. The adjacent numbers express this as a percentage. It is evident that 60% of the "threat" tropical cyclones entered the threat area from a sector extending from SW to SE.

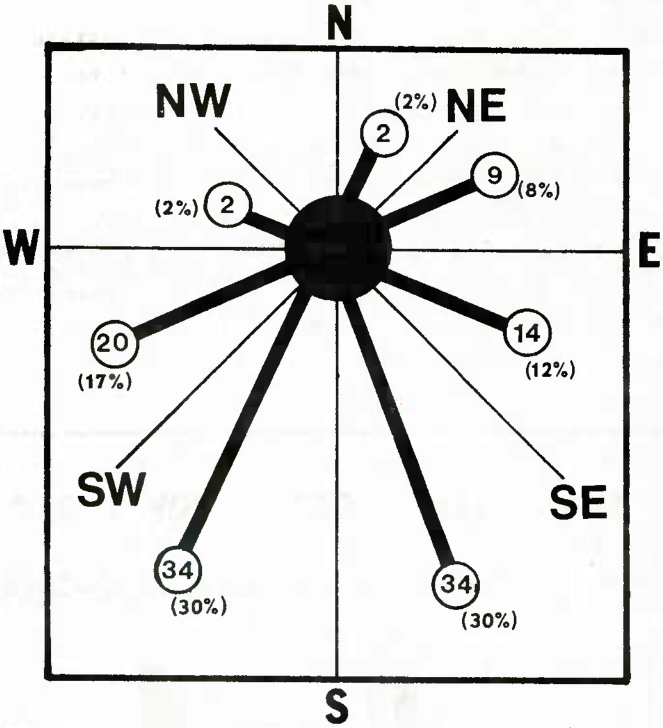



Figure 9. Directions from which tropical cyclones entered threat area (a 180 n mi radius circle centered at the middle of a line between Buckner Bay and Naha during the period May-December, 1947-1973. Numbers circled indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage adjacent to the circled number.

Table 1 indicates that out of the 115 "threat" tropical cyclones during May-December, 1947-1973, 57 passed the midpoint of a line connecting Buckner Bay/Naha to the east and 58 passed to the west. Therefore, the chance of having a "threat" tropical cyclone pass to the west or east of Buckner Bay/Naha during the typhoon season is equal. However, it is interesting to note that during June, July, and September, the majority of "threat" tropical cyclones pass to the west of Buckner Bay/Naha, while during May, August, October, November, and December the likelihood of having a tropical cyclone pass to the east of Buckner Bay/Naha is greater.

Table 1. "Threat" tropical cyclone passage relative to the mid point of a line between Buckner Bay and Naha.

| | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|
| Passed east of midpoint | 3 | 2 | 7 | 18 | 9 | 6 | 9 | 3 | 57 |
| Passed west of midpoint | 0 | 9 | 18 | 13 | 12 | 3 | 3 | 0 | 58 |

An overall statistical summary of the tropical cyclone climatology of Buckner Bay/Naha for the years 1947-1973 is provided in Figures 10 to 17. This summary is based on tropical cyclone tracks grouped by months, May through December. Exact calendar months could not be used because the tracks were recorded for 5-day periods. To accurately assess the threat to Buckner Bay/Naha, the following parameters were used:

- N - The total number of storms that passed through each 3° lat/long box for a given month,
- RAD - The percent of those tropical cyclones that passed through the box and subsequently passed within 180 n mi of Buckner Bay/Naha,
- $R_1$ - Percentage of all tropical cyclones that passed through the box and subsequently crossed the line east of Buckner Bay/Naha within a distance of 60 n mi (1° latitude),
- $R_3$ - Percentage of all tropical cyclones that passed through the box and subsequently crossed a line east of Buckner Bay/Naha within a distance of 180 n mi (3° latitude),
- $L_1$ - Percentage of all tropical cyclones that passed through the box and subsequently crossed a line west of Buckner Bay/Naha within a distance of 60 n mi (1° latitude),
- $L_3$ - Percentage of all tropical cyclones that passed through the box and subsequently crossed a line west of Buckner Bay/Naha within a distance of 180 n mi (3° latitude).

Note: The $R_3$ value and the $L_3$ value will not always equal the percentage of all tropical cyclones to enter the circle since some of the cyclones passed through the area of the circle, but failed to cross the line.

N and RAD are printed on the top and bottom of the box, respectively. The other parameters are printed at the left and right edges of the box.

As an example, the 3° box outlined in Figure 10 (located between 126E and 129E, 24N and 27N) had 4 tropical cyclones pass through it during the years 1947-1973. All of these approached within 180 n mi of Buckner Bay/Naha. None crossed the line 60 n mi to the east, but 25% (1 tropical cyclone) crossed the line 180 n mi to the east of Buckner Bay/Naha. None of the "threat" tropical cyclones passed to the west of Buckner Bay/Naha.

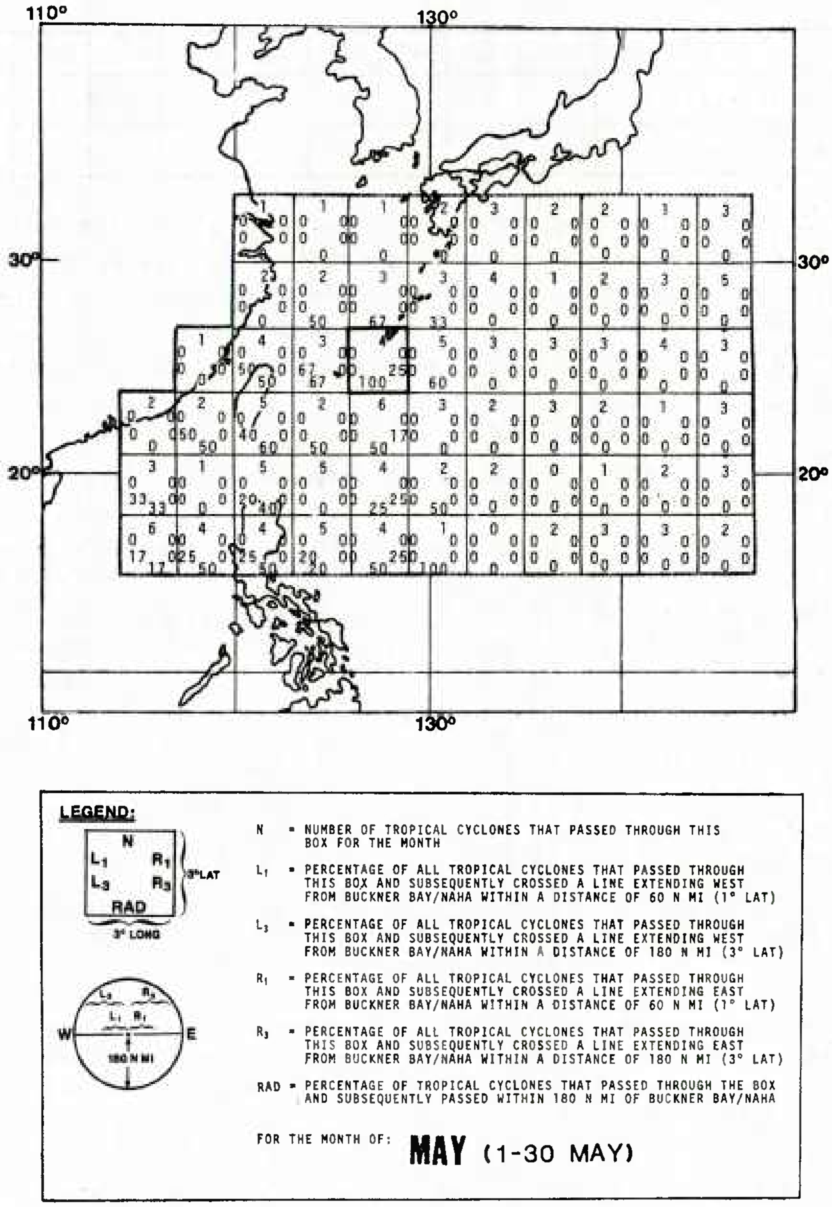
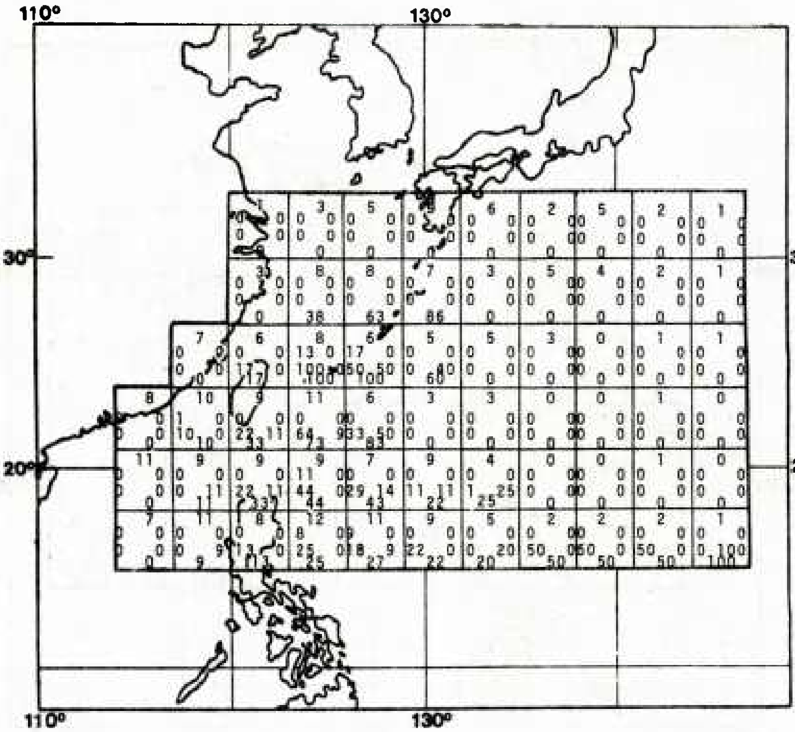



Figure 10. Statistical summary of tropical cyclones for the month of May (based on data from the years 1947-1973).

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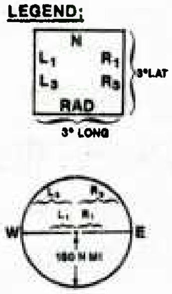



N = NUMBER OF TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX FOR THE MONTH

$L_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$L_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

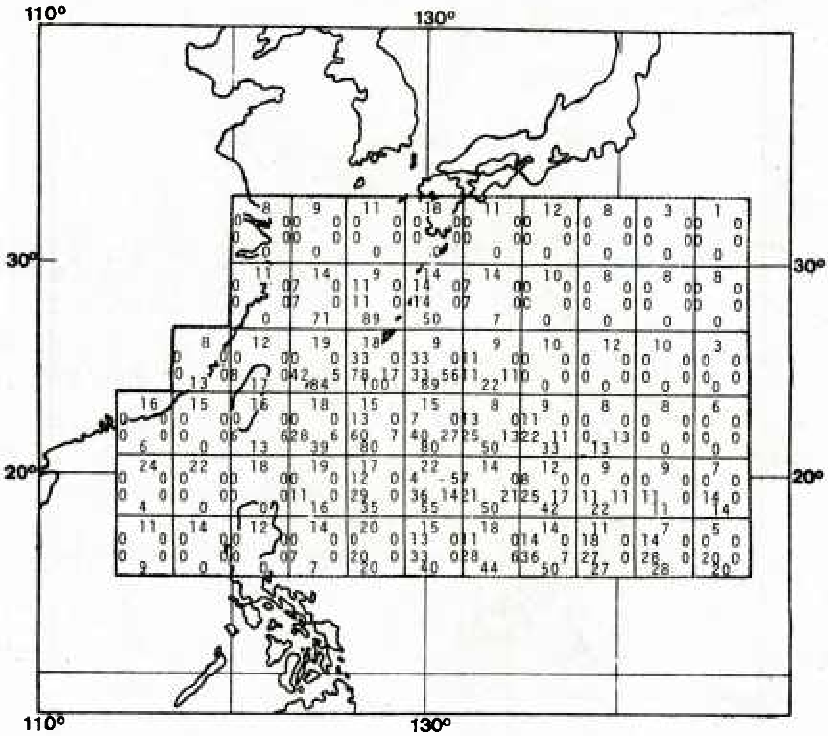
$R_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$R_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

RAD = PERCENTAGE OF TROPICAL CYCLONES THAT PASSED THROUGH THE BOX AND SUBSEQUENTLY PASSED WITHIN 180 N MI OF BUCKNER BAY/NAHA

FOR THE MONTH OF: **JUN** (31 MAY-29 JUN)

Figure 11. Statistical summary of tropical cyclones for the month of June (based on data from the years 1947-1973).

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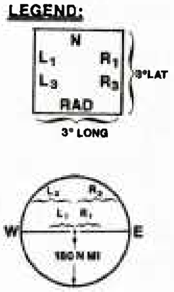


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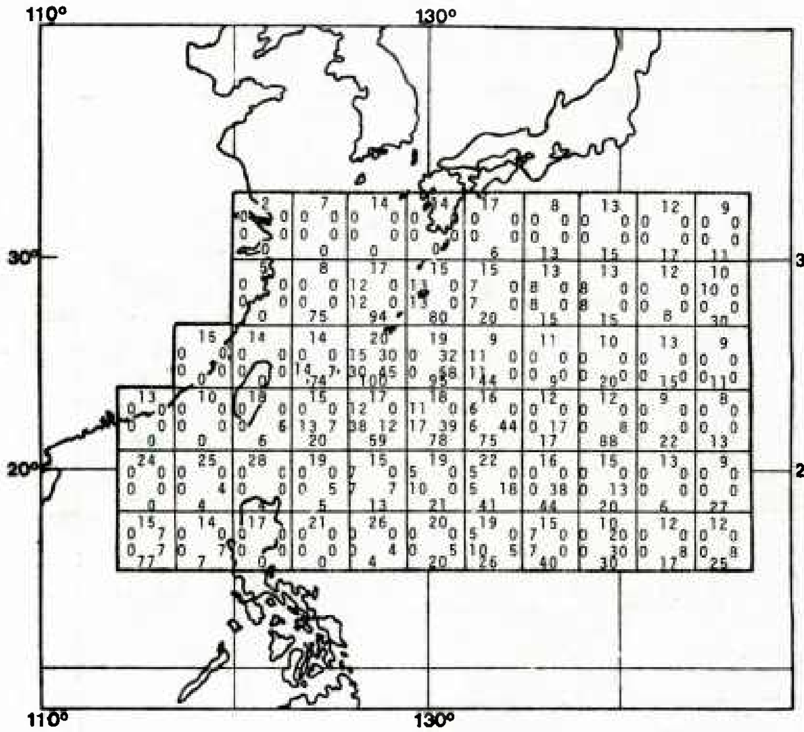
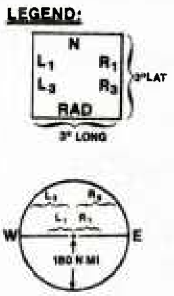
RAD = PERCENTAGE OF TROPICAL CYCLONES THAT PASSED THROUGH THE BOX AND SUBSEQUENTLY PASSED WITHIN 180 N MI OF BUCKNER BAY/NAHA

FOR THE MONTH OF: **JUL** (30 JUN-29 JUL)

Figure 12. Statistical summary of tropical cyclones for the month of July (based on data from the years 1947-1973).




N = NUMBER OF TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX FOR THE MONTH

$L_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$L_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

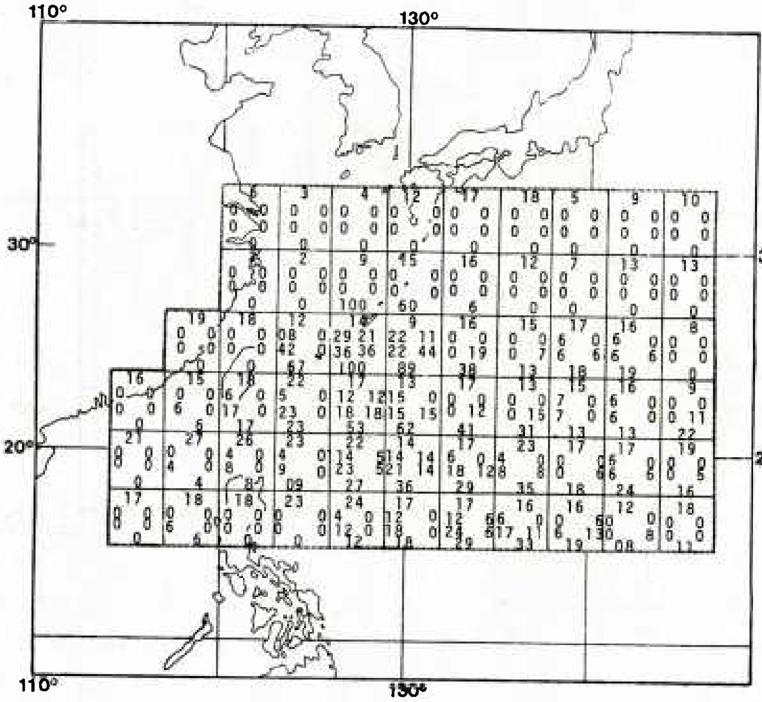
$R_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$R_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

RAD = PERCENTAGE OF TROPICAL CYCLONES THAT PASSED THROUGH THE BOX AND SUBSEQUENTLY PASSED WITHIN 180 N MI OF BUCKNER BAY/NAHA

FOR THE MONTH OF: **AUG** (30 JUL-28 AUG)

Figure 13. Statistical summary of tropical cyclones for the month of August (based on data from the years 1947-1973).

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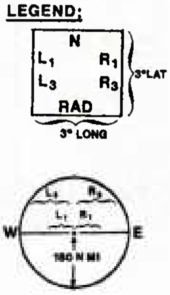



N = NUMBER OF TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX FOR THE MONTH

$L_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$L_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

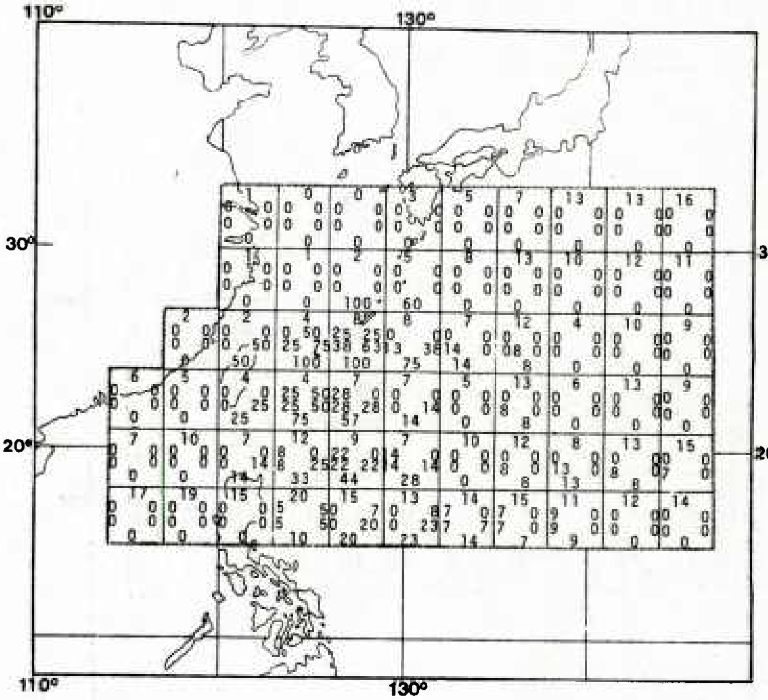
$R_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$R_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

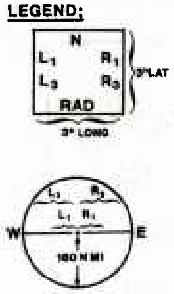
RAD = PERCENTAGE OF TROPICAL CYCLONES THAT PASSED THROUGH THE BOX AND SUBSEQUENTLY PASSED WITHIN 180 N MI OF BUCKNER BAY/NAHA

FOR THE MONTH OF: **SEP** (29 AUG-27 SEP)

Figure 14. Statistical summary of tropical cyclones for the month of September (based on data from the years 1947-1973).




**LEGEND;**




N = NUMBER OF TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX FOR THE MONTH

$L_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$L_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING WEST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

$R_1$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 60 N MI (1° LAT)

$R_3$ = PERCENTAGE OF ALL TROPICAL CYCLONES THAT PASSED THROUGH THIS BOX AND SUBSEQUENTLY CROSSED A LINE EXTENDING EAST FROM BUCKNER BAY/NAHA WITHIN A DISTANCE OF 180 N MI (3° LAT)

RAD = PERCENTAGE OF TROPICAL CYCLONES THAT PASSED THROUGH THE BOX AND SUBSEQUENTLY PASSED WITHIN 180 N MI OF BUCKNER BAY/NAHA

FOR THE MONTH OF: **OCT** (28 SEP-27 OCT)

Figure 15. Statistical summary of tropical cyclones for the month of October (based on data from the years 1947-1973).

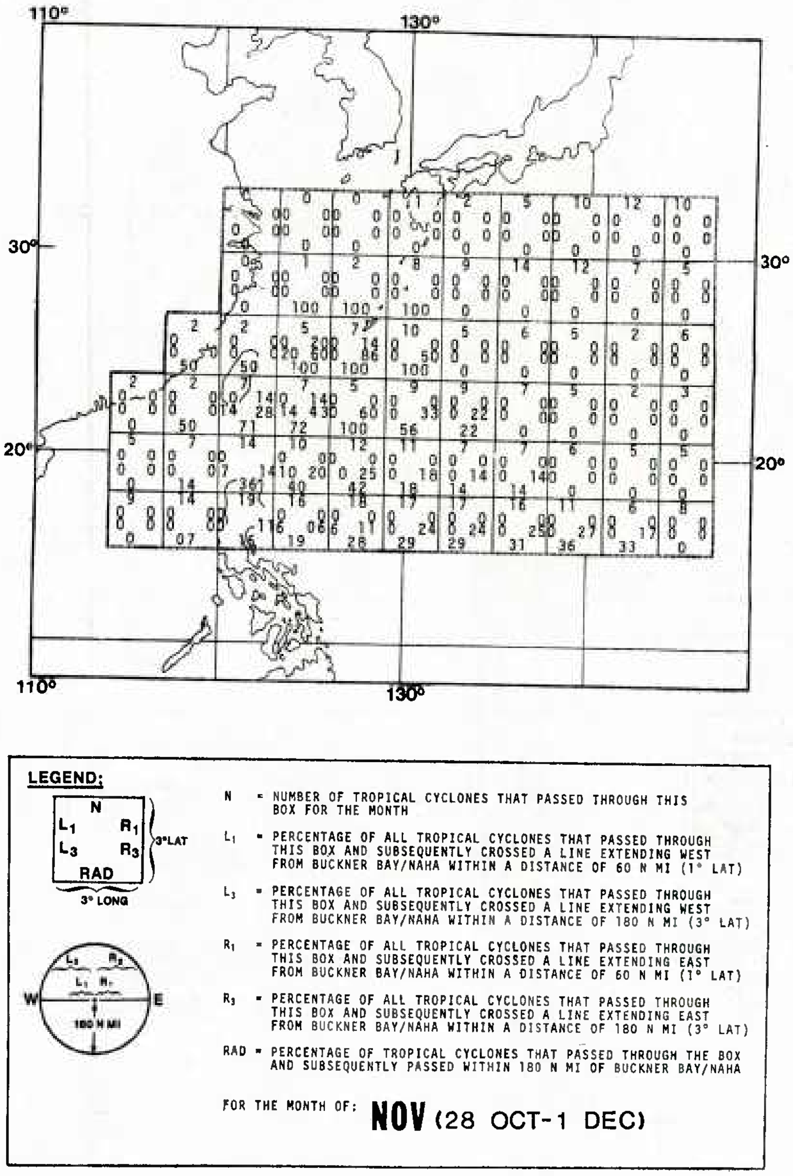



Figure 16. Statistical summary of tropical cyclones for the month of November (based on data from the years 1947-1973).

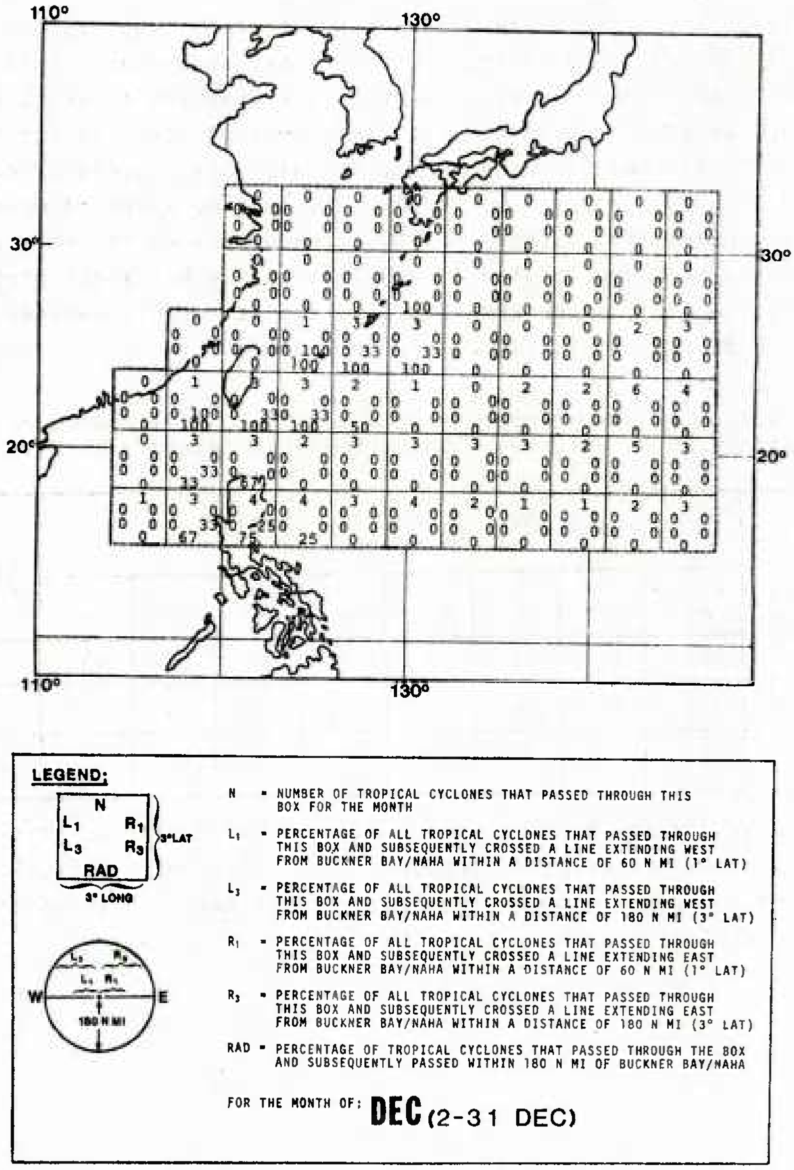



Figure 17. Statistical summary of tropical cyclones for the month of December (based on data from the years 1947-1973).

Figures 18-25 are based on an analysis of "threat" tropical cyclones during May-December, 1947-1973. The solid lines represent percentage isolines of "threat." The dashed lines represent approximate approach times to Buckner Bay/Naha, computed from average tropical cyclone speeds of movement for tropical cyclones affecting Buckner Bay/Naha during May-December (speeds of movement were derived from U.S. NWSED, Asheville, 1973). The average speed of movements of tropical cyclones affecting Buckner Bay/Naha are presented in Table 2. For example, a tropical cyclone located at 20N/119E in May has a 40% probability of coming within 180 n mi of Buckner Bay/Naha and it can hit Buckner Bay/Naha in about 1 1/2-2 days (see Figure 18).

Table 2. Listing of May-December average climatological speeds of tropical cyclones affecting Buckner Bay/Naha by 5-degree latitude bands.

| Latitude Band (°N) | Average Forward Speed of Movement (kt) | | | | | | | | Average of the 8 Months (kt) |
|---|---|---|---|---|---|---|---|---|---|
| | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| 20-35 | 15 | 14 | 11 | 11 | 13 | 13 | 18 | 13 | 13.5 |
| 15-20 | 11 | 13 | 10 | 10 | 11 | 12 | 13 | 10 | 11.2 |
| 10-15 | 10 | 10 | 9 | 9 | 10 | 12 | 12 | 9 | 10.1 |

Note the significant shift in direction from which "threat" tropical cyclones approach Buckner Bay/Naha (Figures 18-25). In May, June, November, and December the "threat" is generally from the southwest, whereas in July-October the "threat" is generally from the south to southeast.

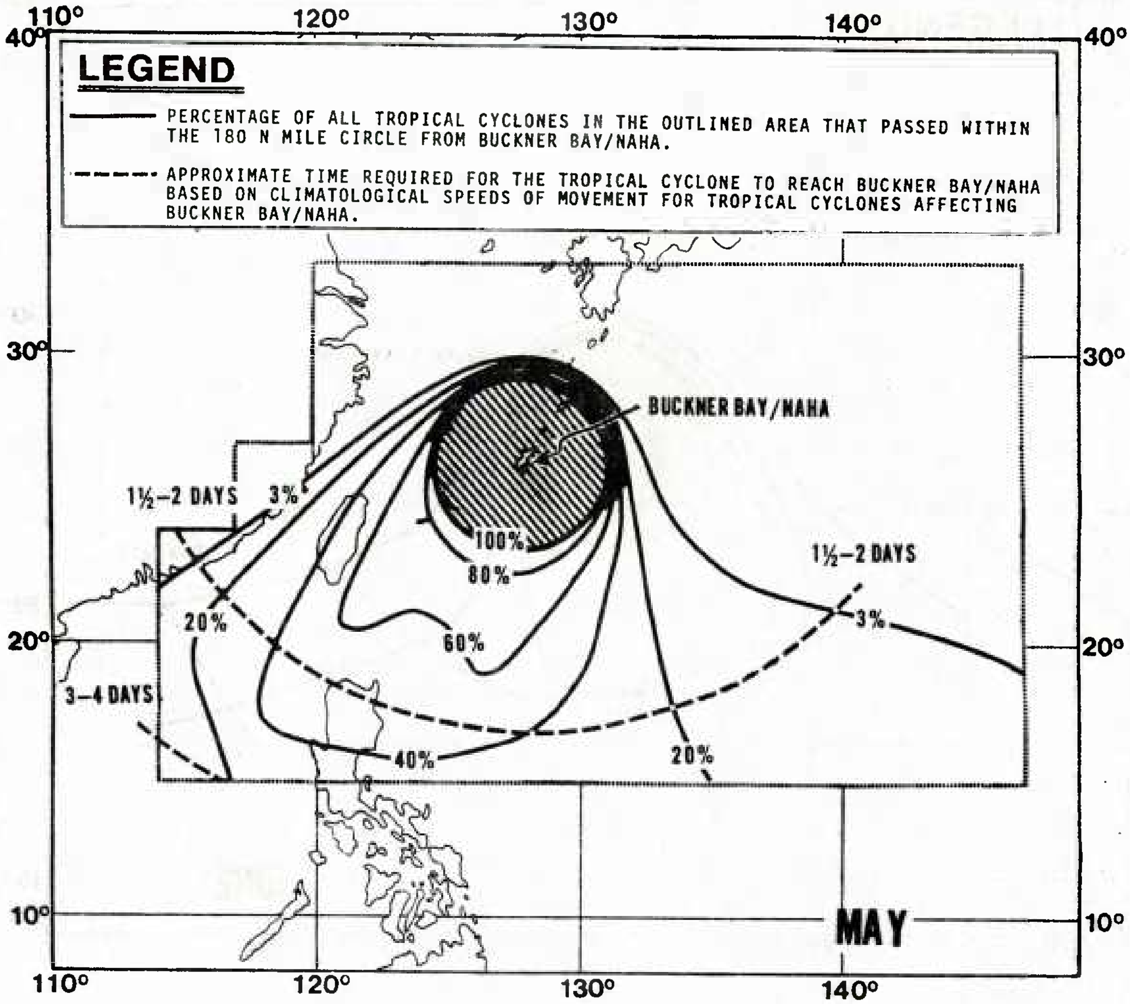



Figure 18. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of May (based on data from 1947-1973).

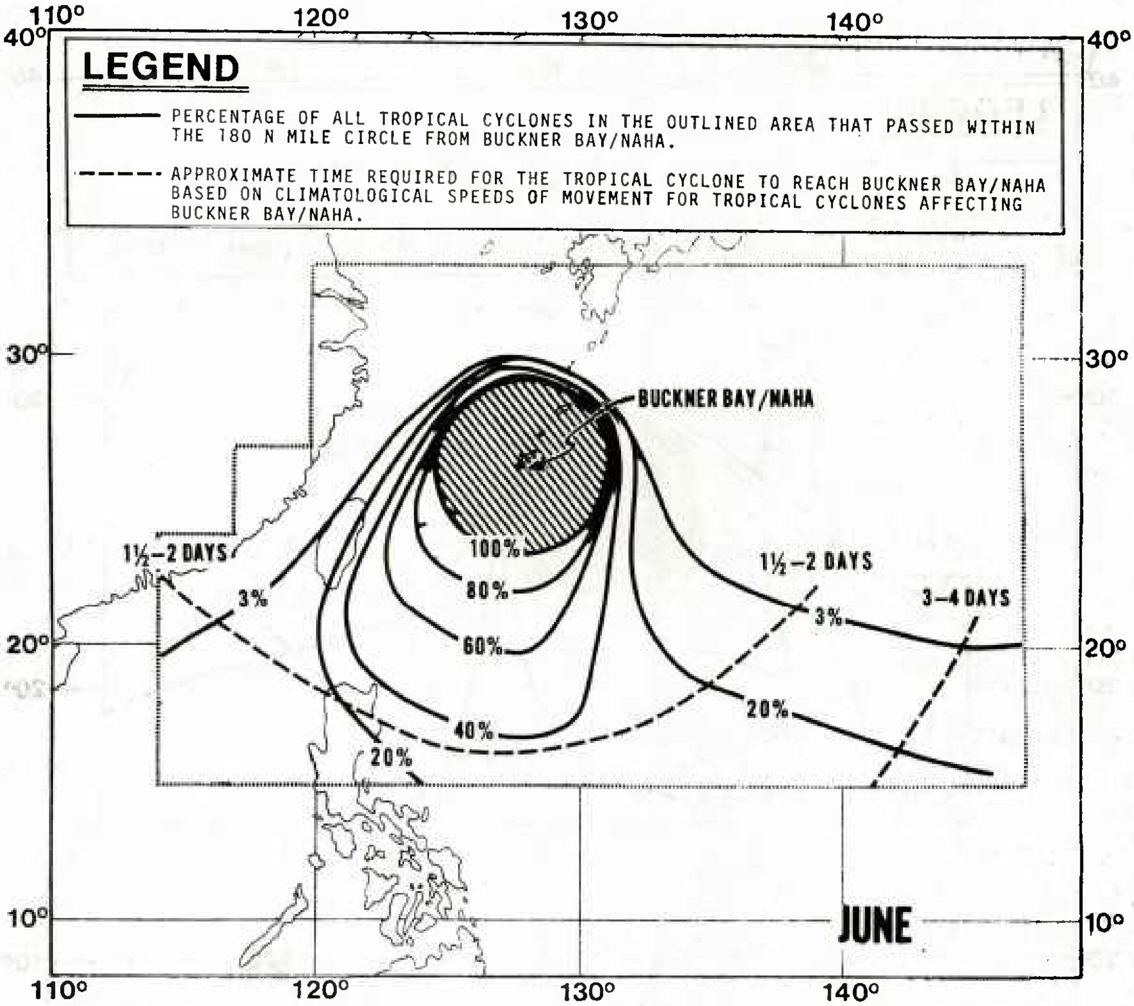



Figure 19. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of June (based on data from 1947-1973).

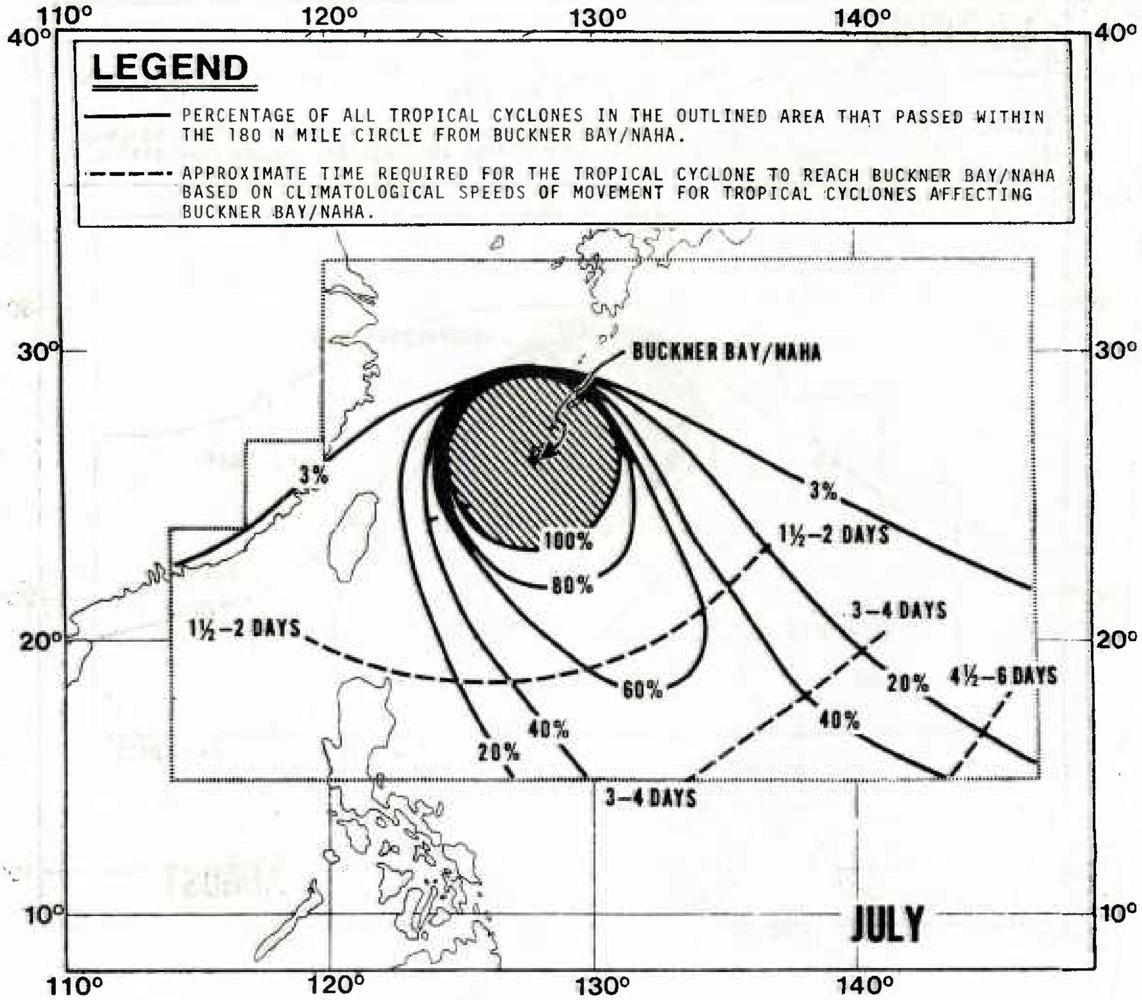



Figure 20. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of July (based on data from 1947-1973).

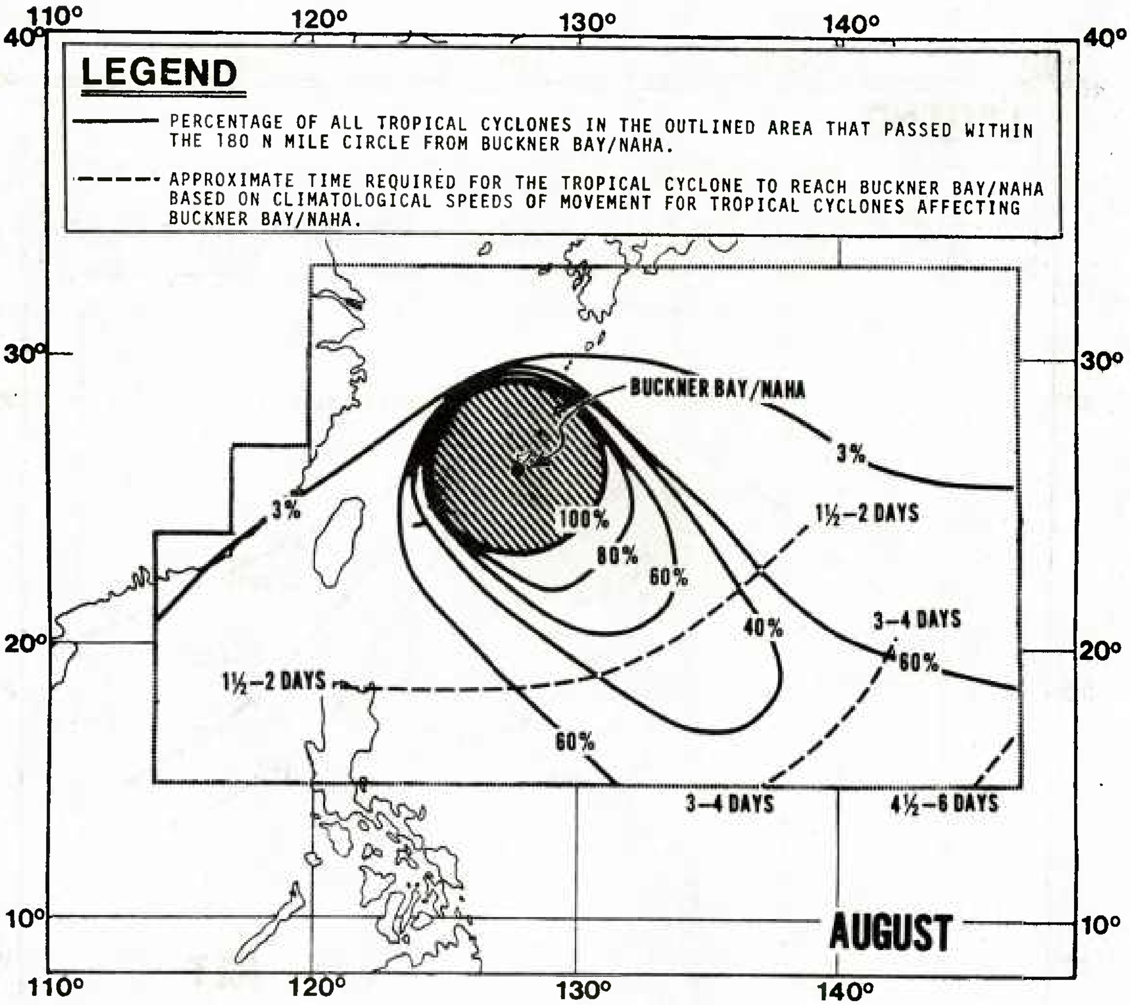



Figure 21. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of August (based on data from 1947-1973).

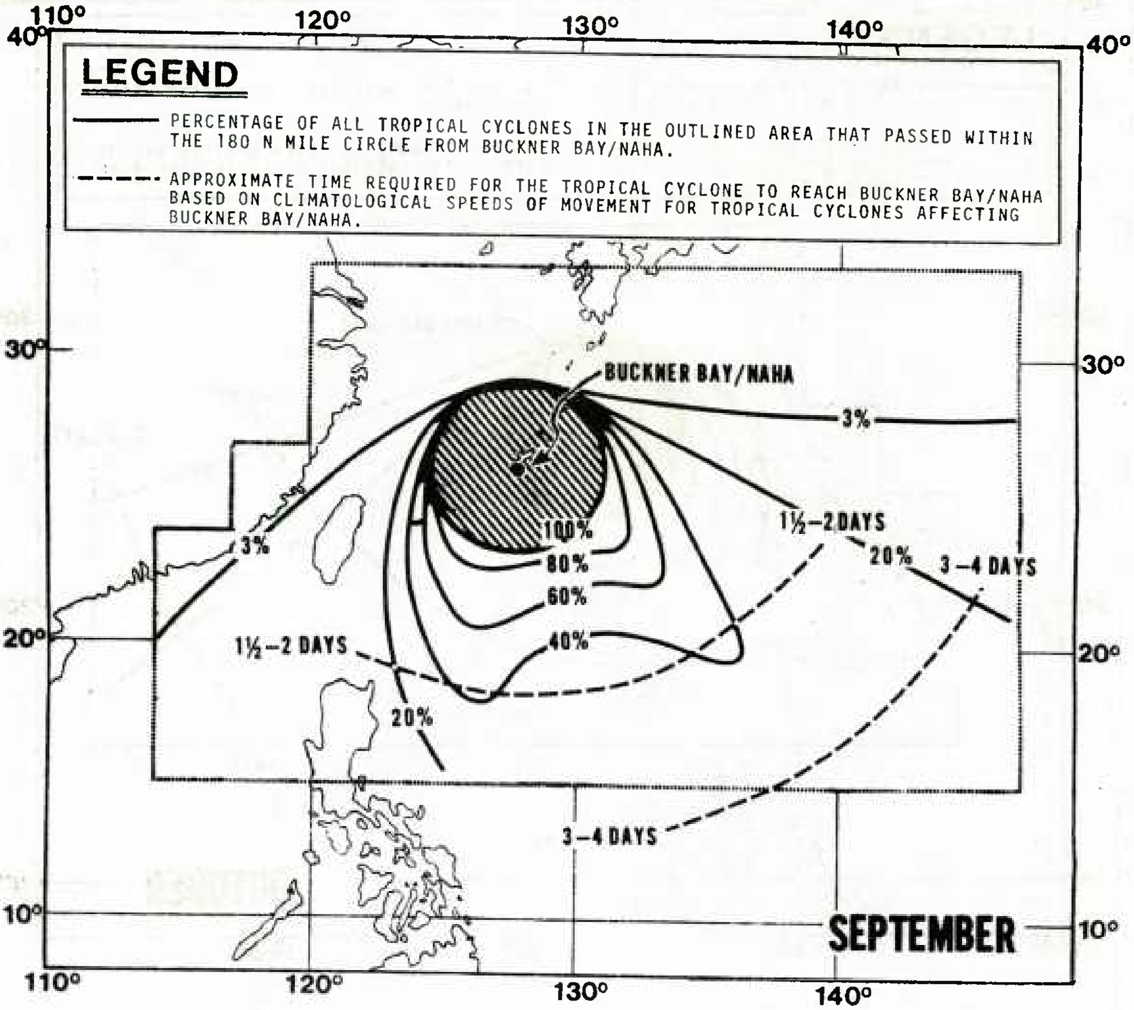



Figure 22. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of September (based on data from 1947-1973).

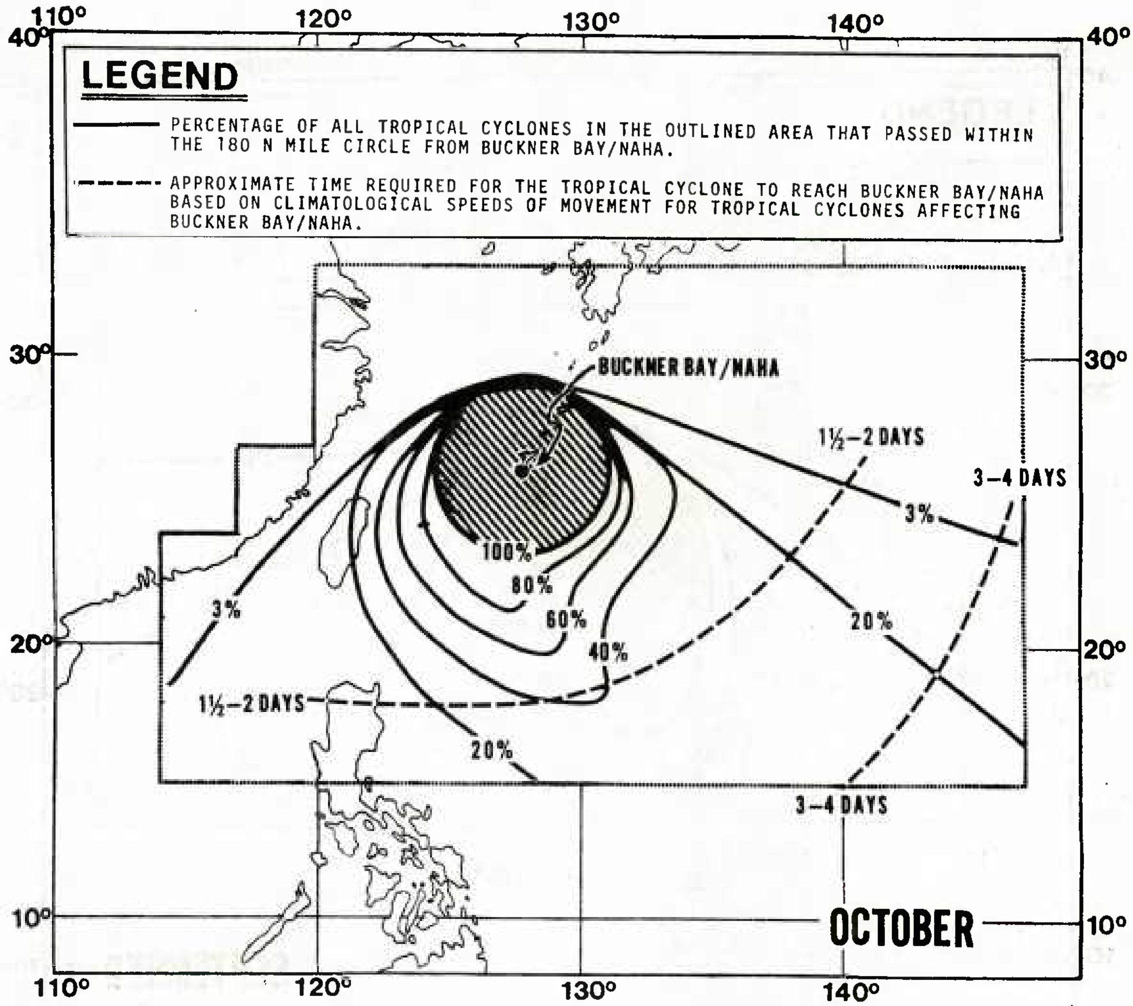



Figure 23. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of October (based on data from 1947-1973).

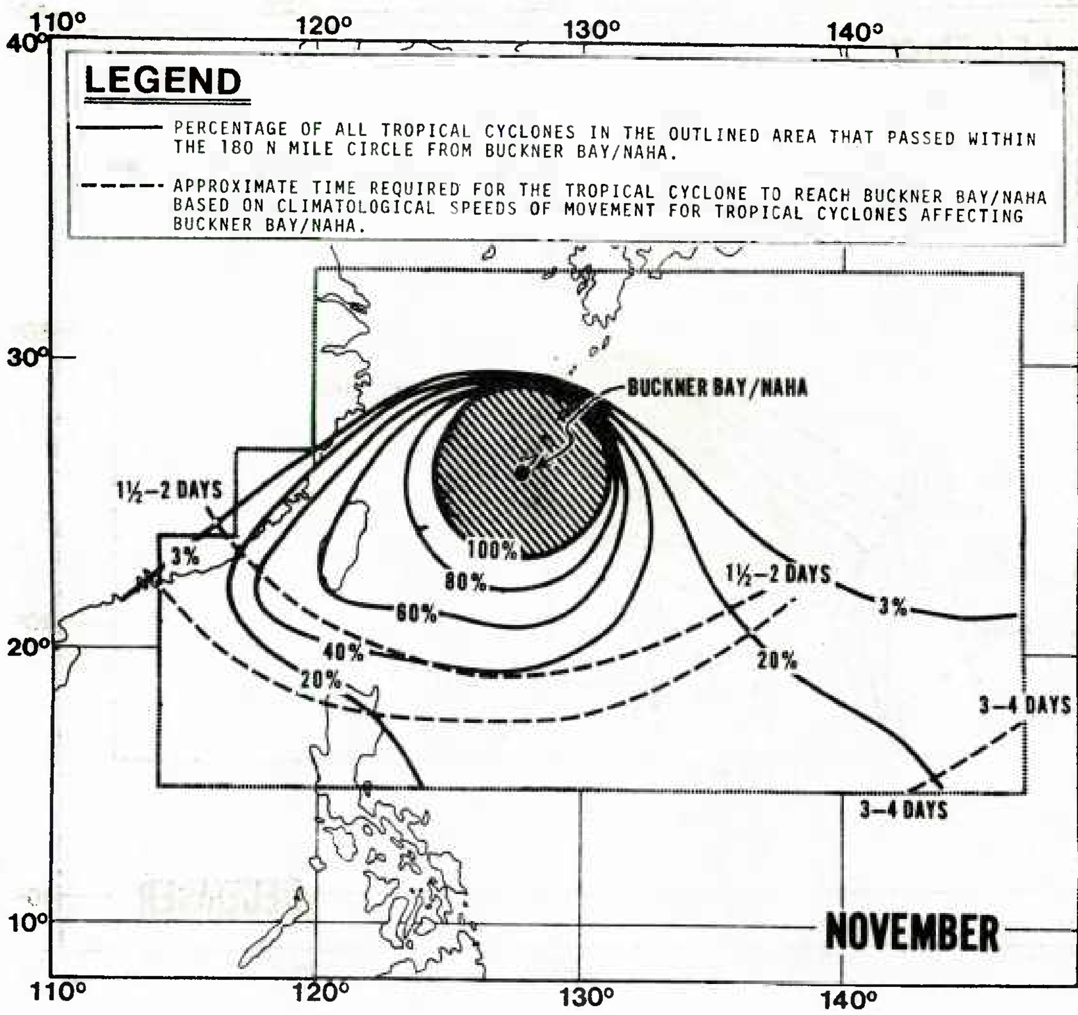



Figure 24. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of November (based on data from 1947-1973).

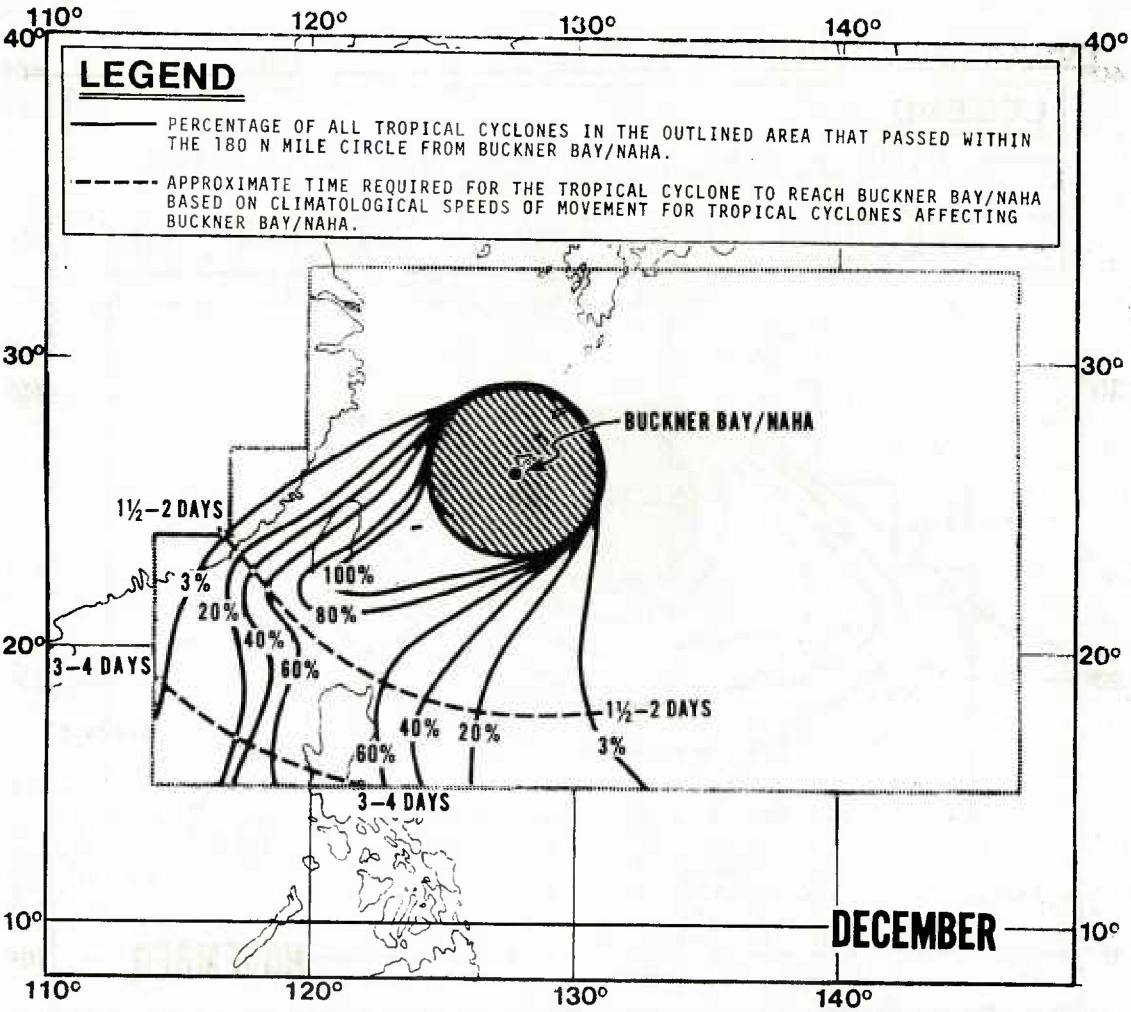



Figure 25. Percentage of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha for the month of December (based on data from 1947-1973).

5.2 WIND AND TOPOGRAPHICAL EFFECTS

Based on topographical considerations, strong winds can be expected from a sector extending from the east to the south since little topographic protection is available from these directions (see Figures 6 and 7).

To determine the extent to which "threat" tropical cyclones produced strong winds (≥ 22 kt) or gale force winds (≥ 34 kt) in Buckner Bay, the wind observations from Kadena Air Base (26°21'N, 127°45'E) were analyzed for the period May-December, 1947-1972. Figure 6 shows the location of Kadena Air Base and surrounding topography. It must be noted that winds generally from the east and south will be 10-20% stronger in Buckner Bay than at Kadena Air Base due to the local topography. In addition, winds generally from the west will be 10-20% less at Buckner Bay than the winds recorded at Kadena Air Base. This "bias" must be kept in mind in the following paragraphs.

Table 3 groups the 110 tropical cyclones that "threatened" Buckner Bay during the 26-year period, May-December, 1947-1972 according to the extent to which they affected Buckner Bay. Approximately two thirds of the tropical cyclones that came within 180 n mi of Okinawa produced ≥ 22 kt winds at Kadena and one third produced gale force winds or greater (≥ 34 kt).

Table 3. Extent to which "threat" tropical cyclones affected Buckner Bay during June-October, 1947-1972.

| | | |
|---|---|---|
| Number of tropical cyclones that "threatened" Buckner Bay | 110 | % |
| Number of "threat" tropical cyclones resulting in strong (≥ 22 kt) winds in Buckner Bay | 75 | 68% |
| Number of "threat" tropical cyclones resulting in gale force (≥ 34 kt) winds in Buckner Bay | 38 | 34% |

Figures 26-36 depict the tracks of the "threat" tropical cyclones during May-December, 1947-1972. The "threat" tropical cyclones that resulted in gale force winds at Buckner Bay are indicated by a dashed line. "Threat" tropical cyclone tracks resulting in winds less than 34 kt are depicted by a solid line. From analyses of the "threat" tropical cyclone tracks (Figures 26-36) the following is apparent: (1) Gale force winds resulting from a "threat" tropical cyclone occurred in each month during June-December and (2) August had the greatest number of "threat" tropical cyclones which produced gale force winds in Buckner Bay.

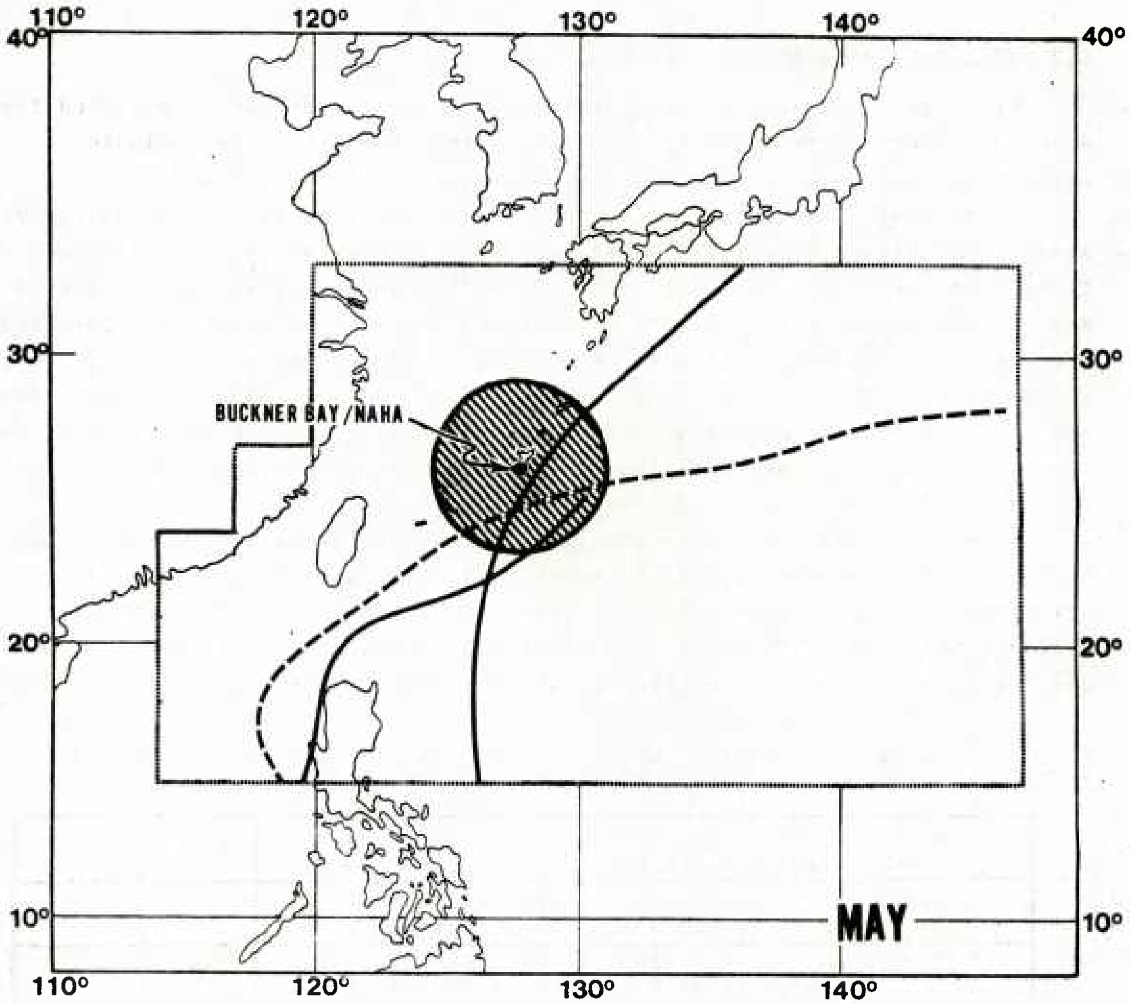



Figure 26. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of May (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

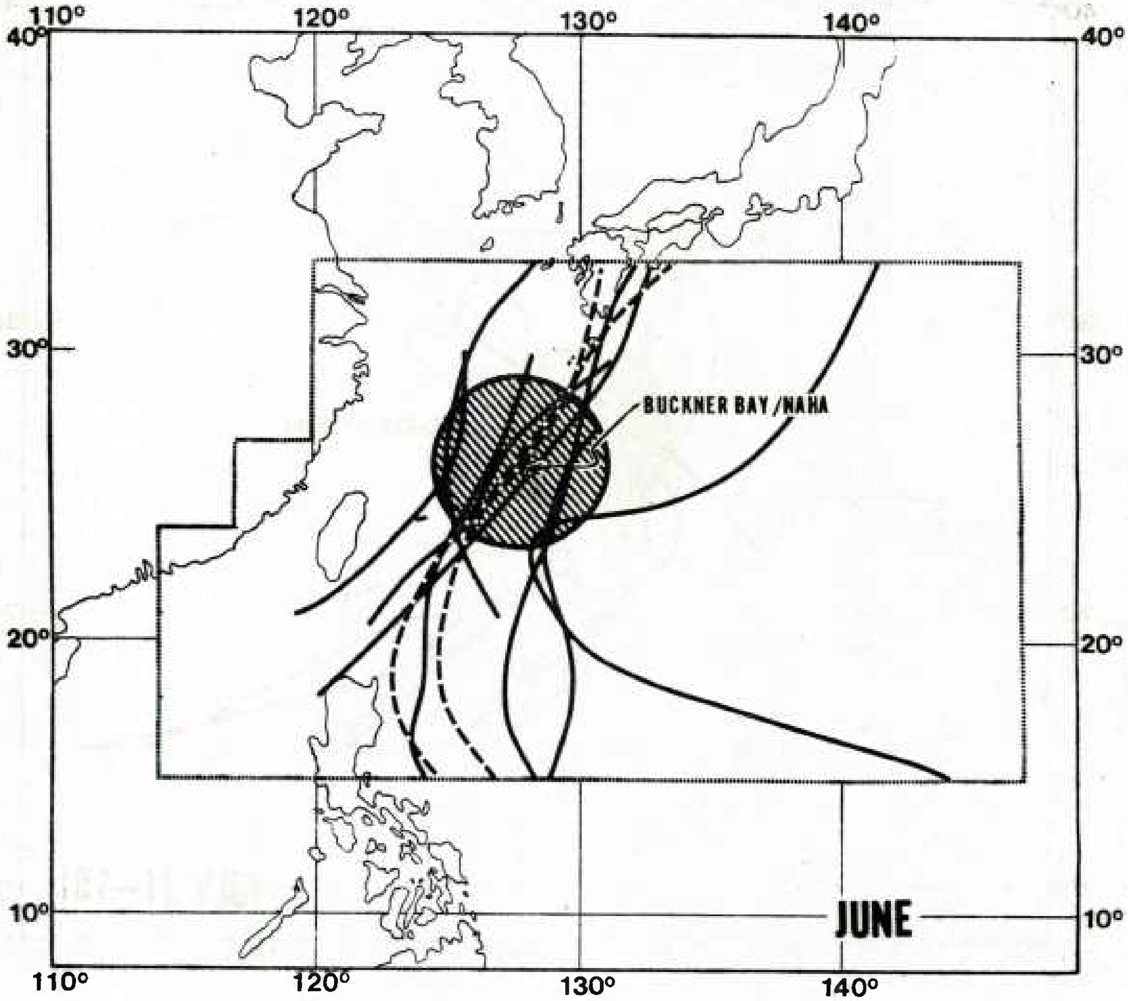



Figure 27. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of June (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

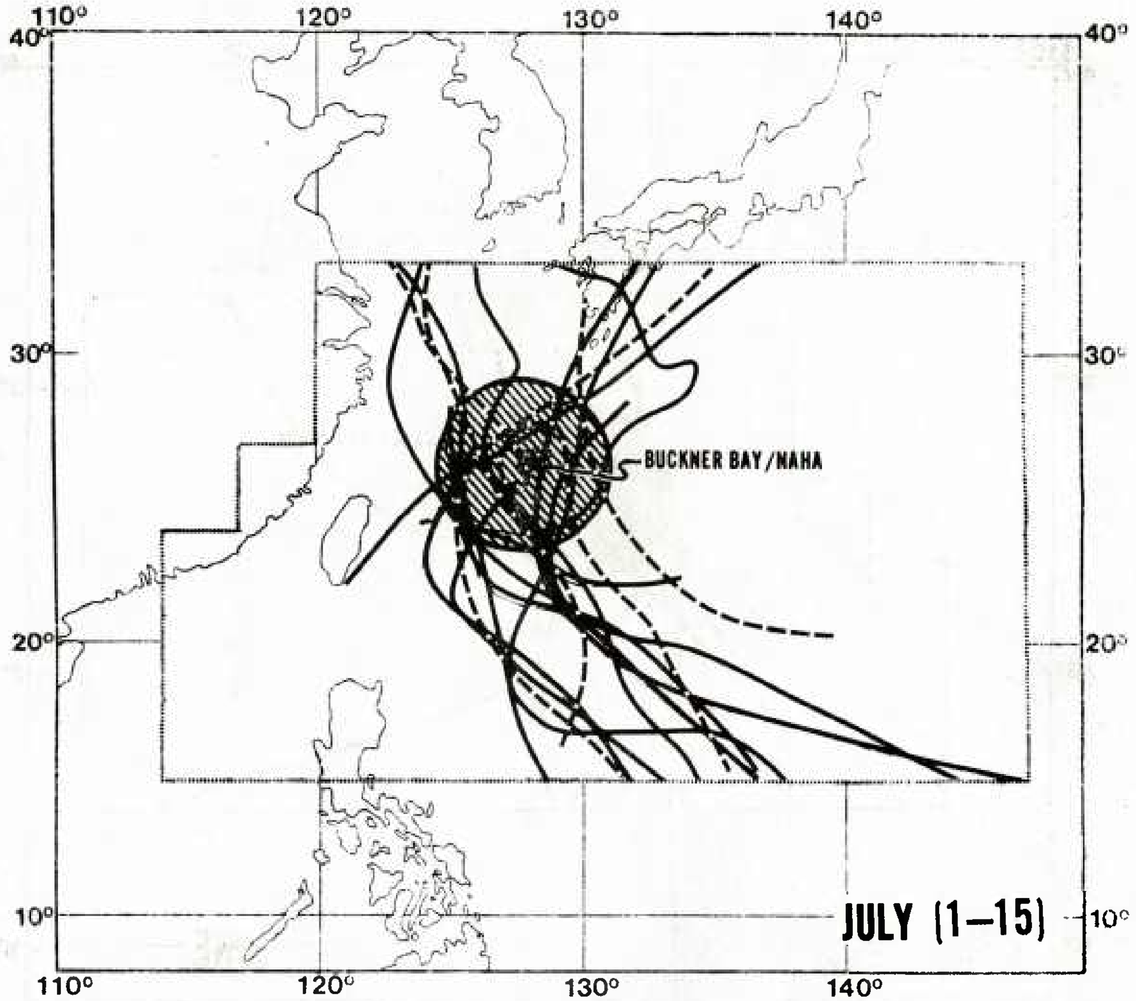



Figure 28. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of July (1-15) (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

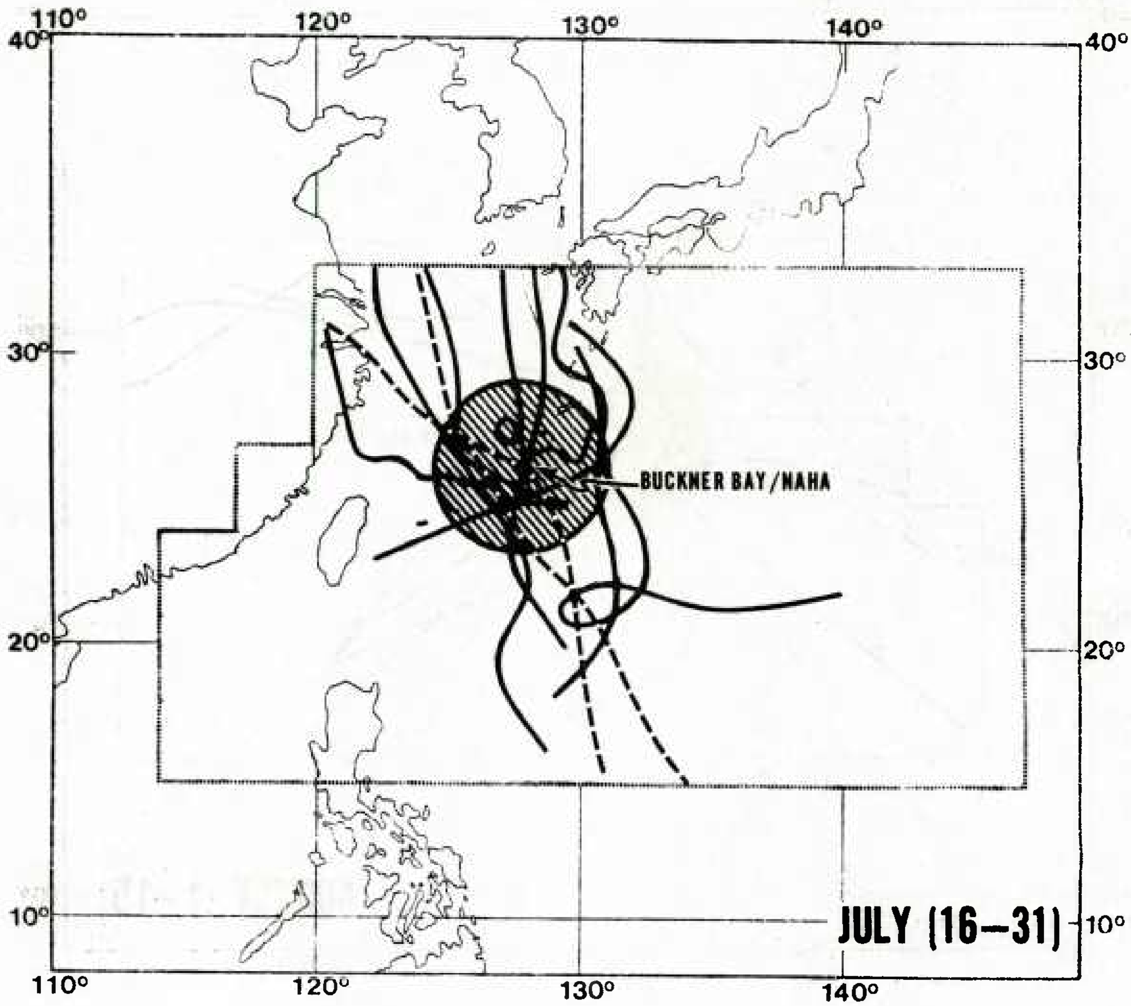



Figure 29. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of July (16-31) (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

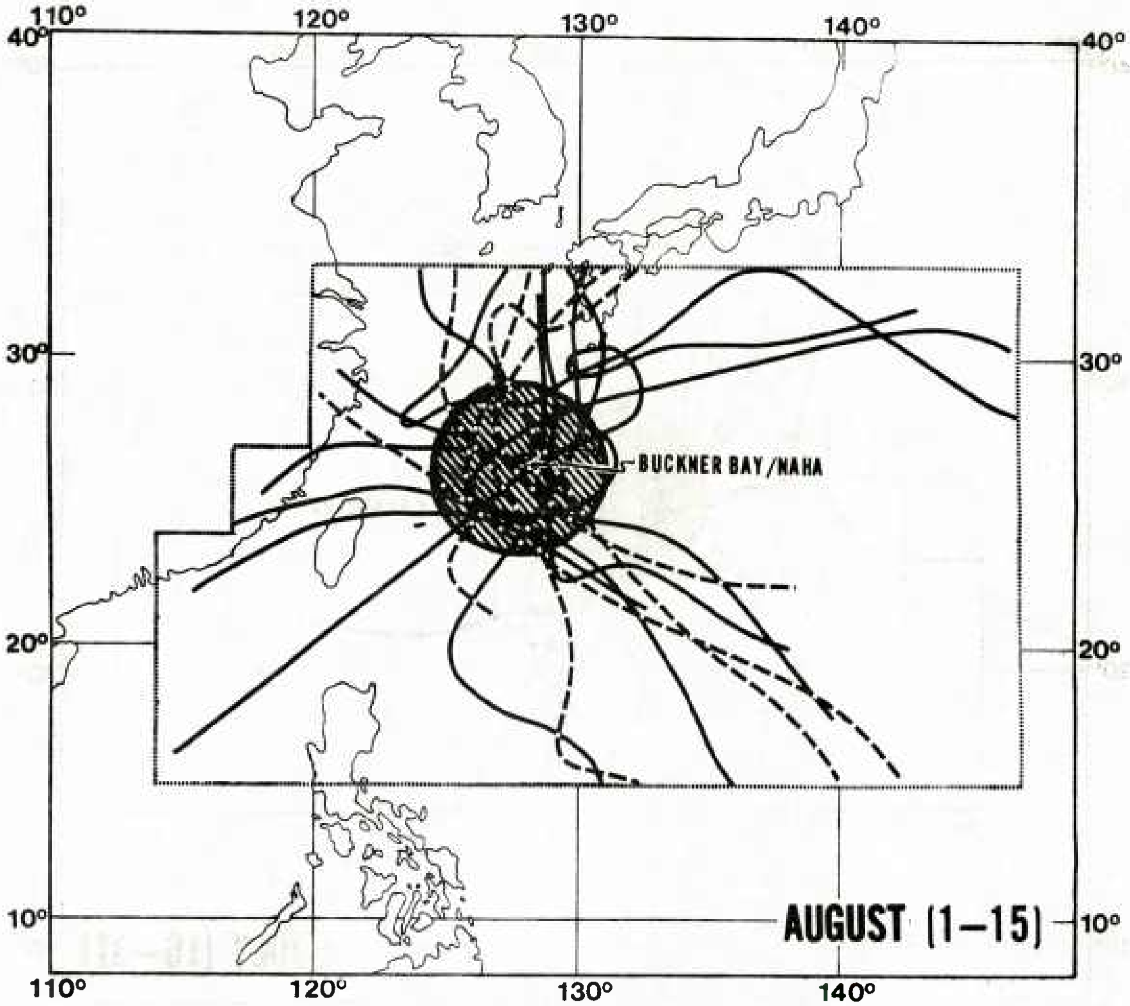



Figure 30. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of August (1-15) (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

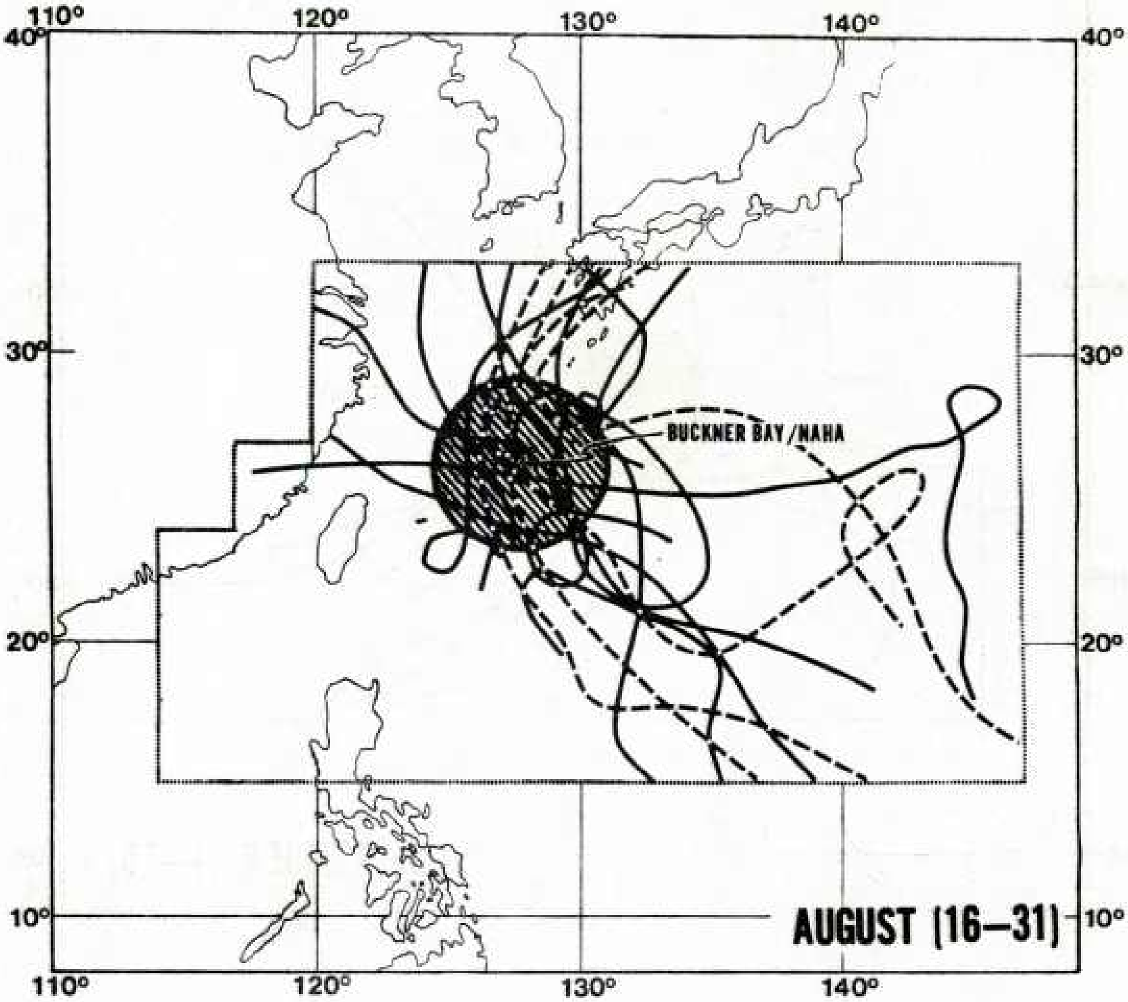



Figure 31. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of August (16-31) (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

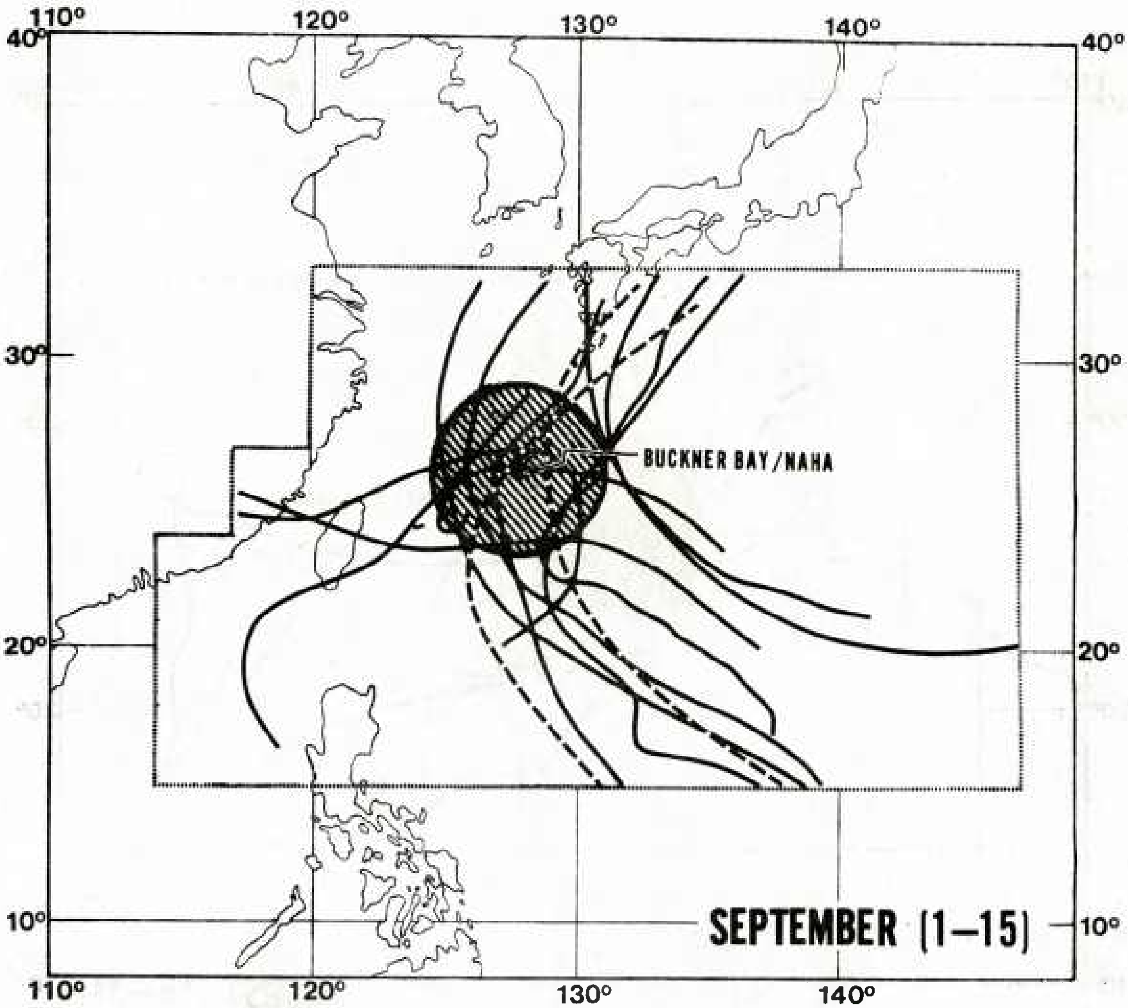



Figure 32. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of September (1-15) (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

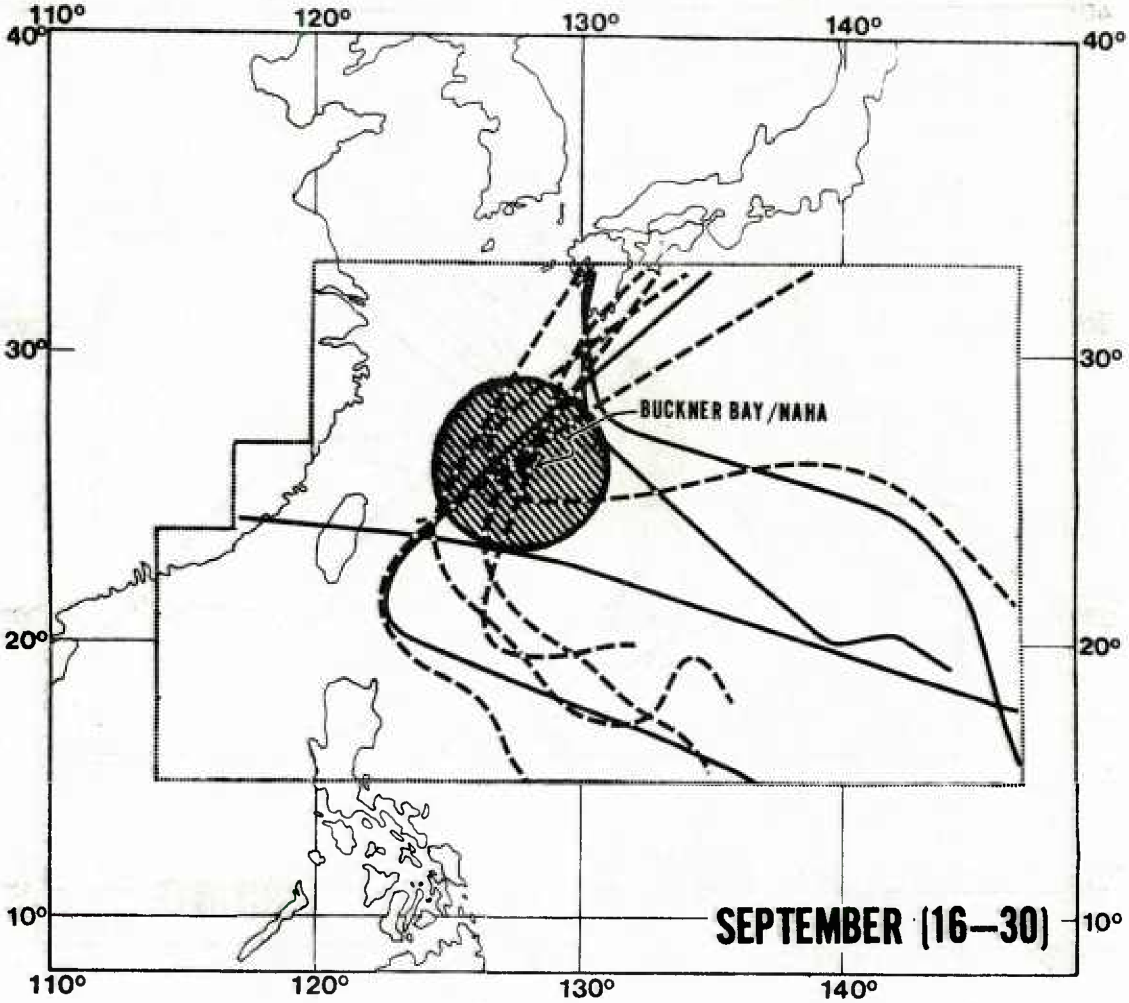



Figure 33. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of September (16-30) (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

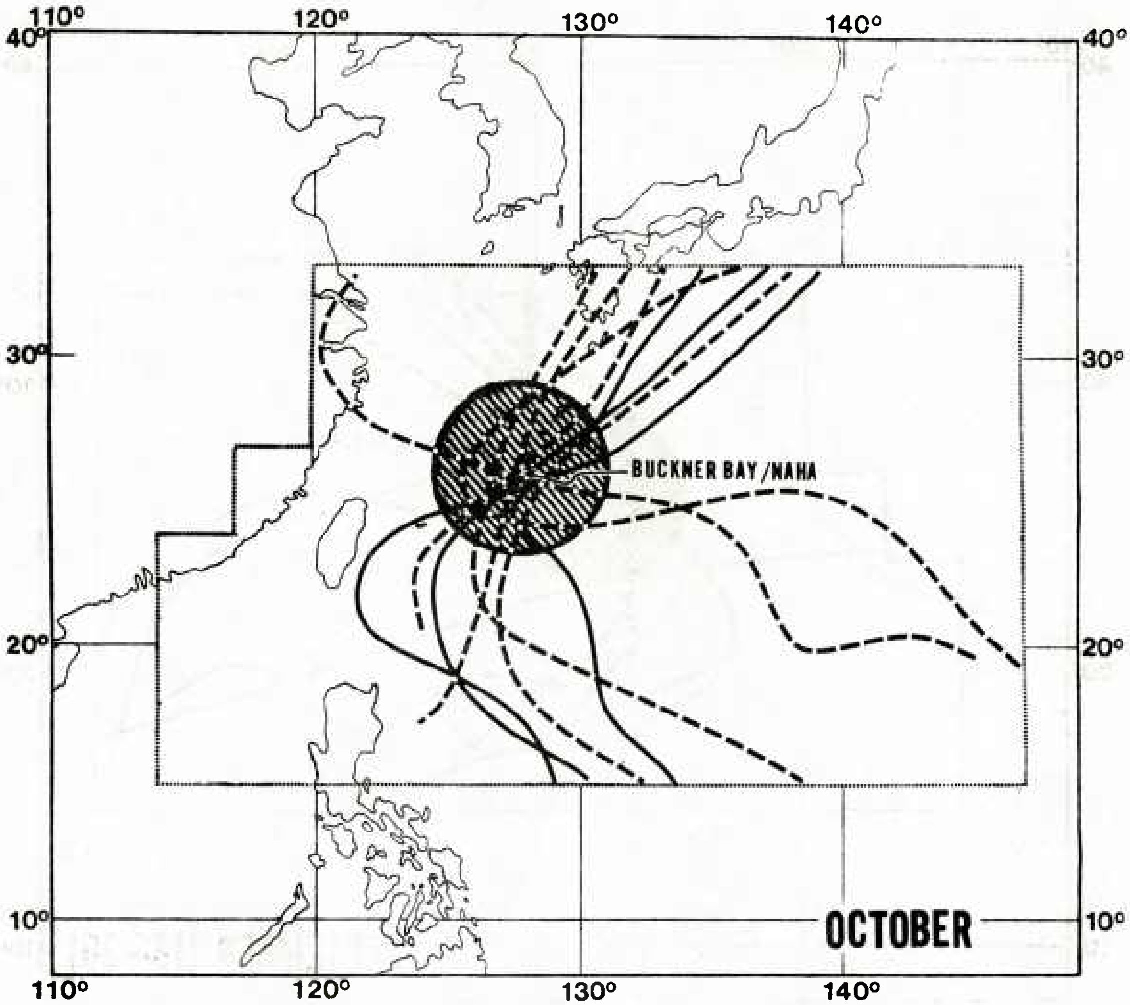



Figure 34. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of October (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

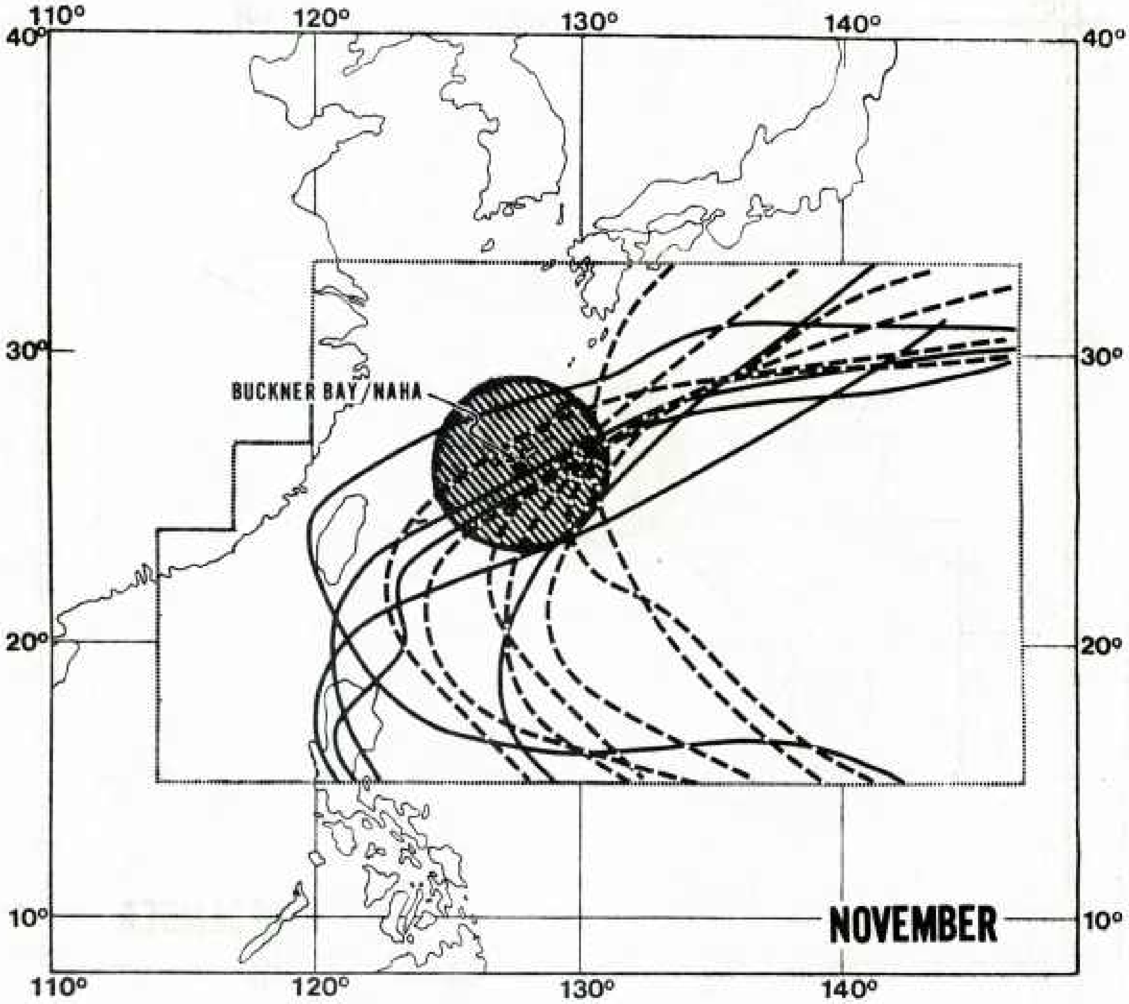



Figure 35. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of November (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

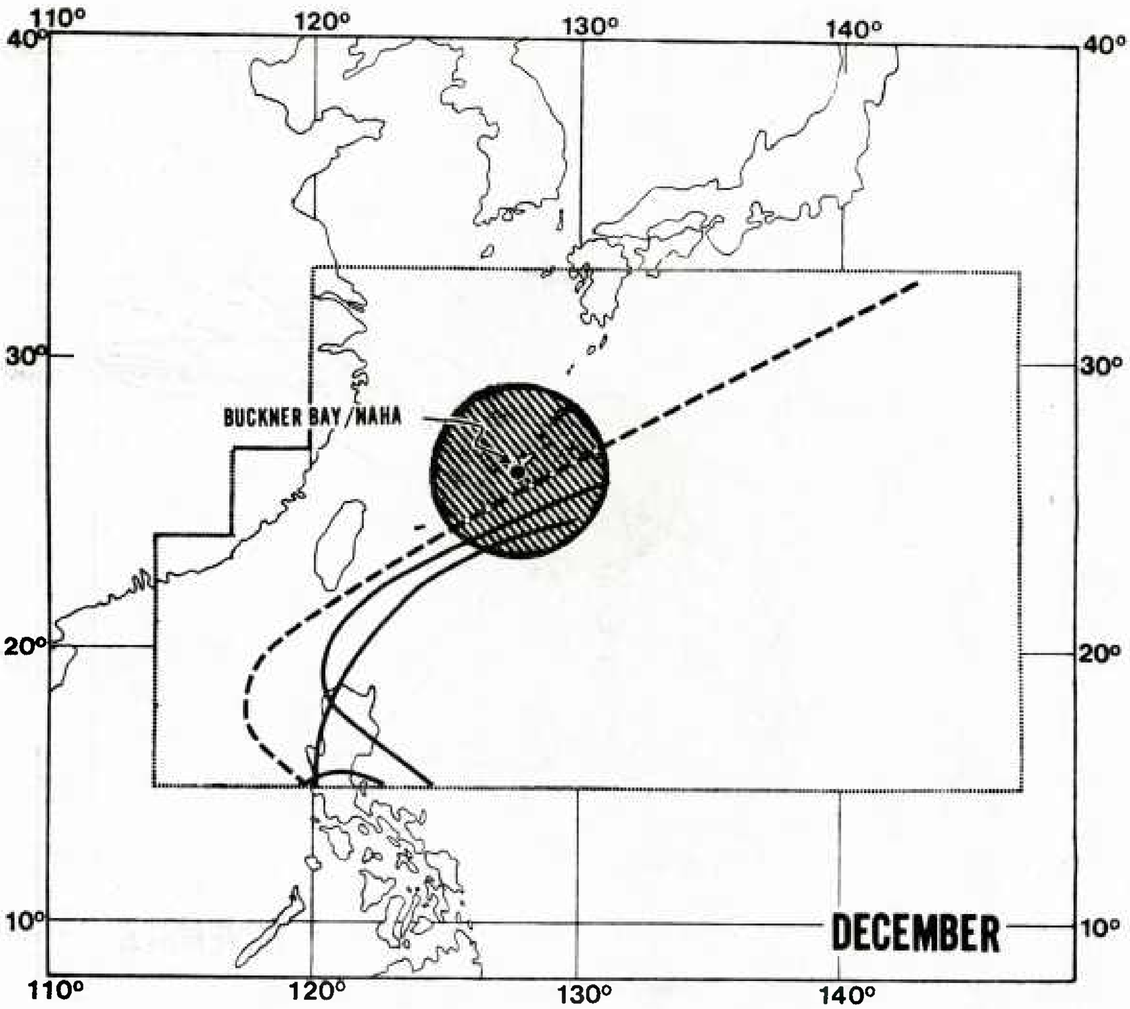



Figure 36. Tracks of tropical cyclones which approached within 180 n mi of Buckner Bay/Naha for the month of December (based on data from 1947-1973). Dashed lines are tracks of tropical cyclones which produced winds greater than 34 kt. Solid lines are tracks of tropical cyclones which did NOT produce winds greater than 34 kt.

Figure 37 shows the positions of "threat" tropical cyclone centers when strong winds (≥ 22 kt) first began and ended at Buckner Bay. It is apparent that "threat" tropical cyclones as far south as 21-22N and as far north as 30N can produce strong winds at Buckner Bay.

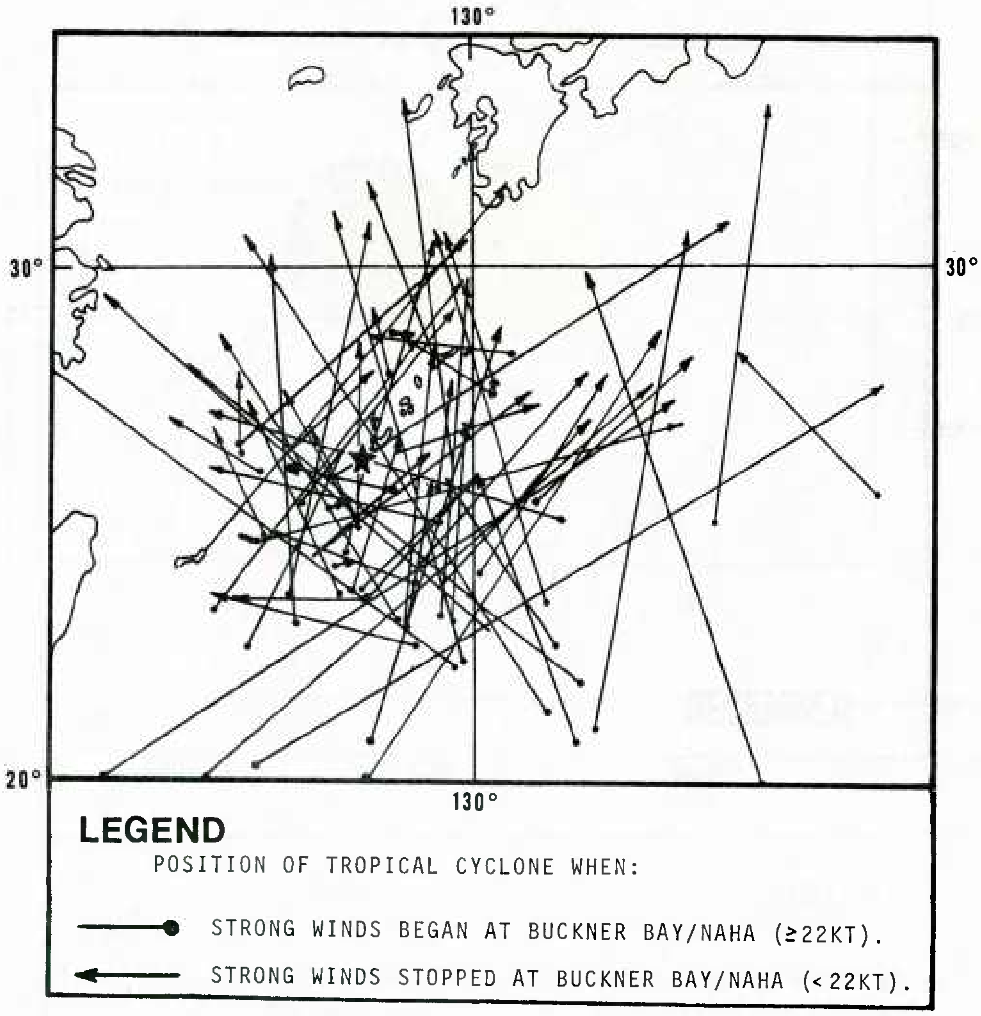



Figure 37. Positions of tropical cyclone centers when ≥ 22 kt winds first and last occurred at Buckner Bay/Naha (based on May-December data from the years 1947-1972).

Figure 38 shows tropical cyclone center positions when gale force (≥ 34 kt) winds were first and last experienced at Buckner Bay. It can be seen that gale force winds (≥ 34 kt) generally do not begin until the "threat" tropical cyclone is at a latitude of 24 to 25N. Also, the almost symmetric distribution of arrows indicates that Okinawa's topography has little effect in reducing the intensity of the winds produced by the "threat" tropical cyclone.

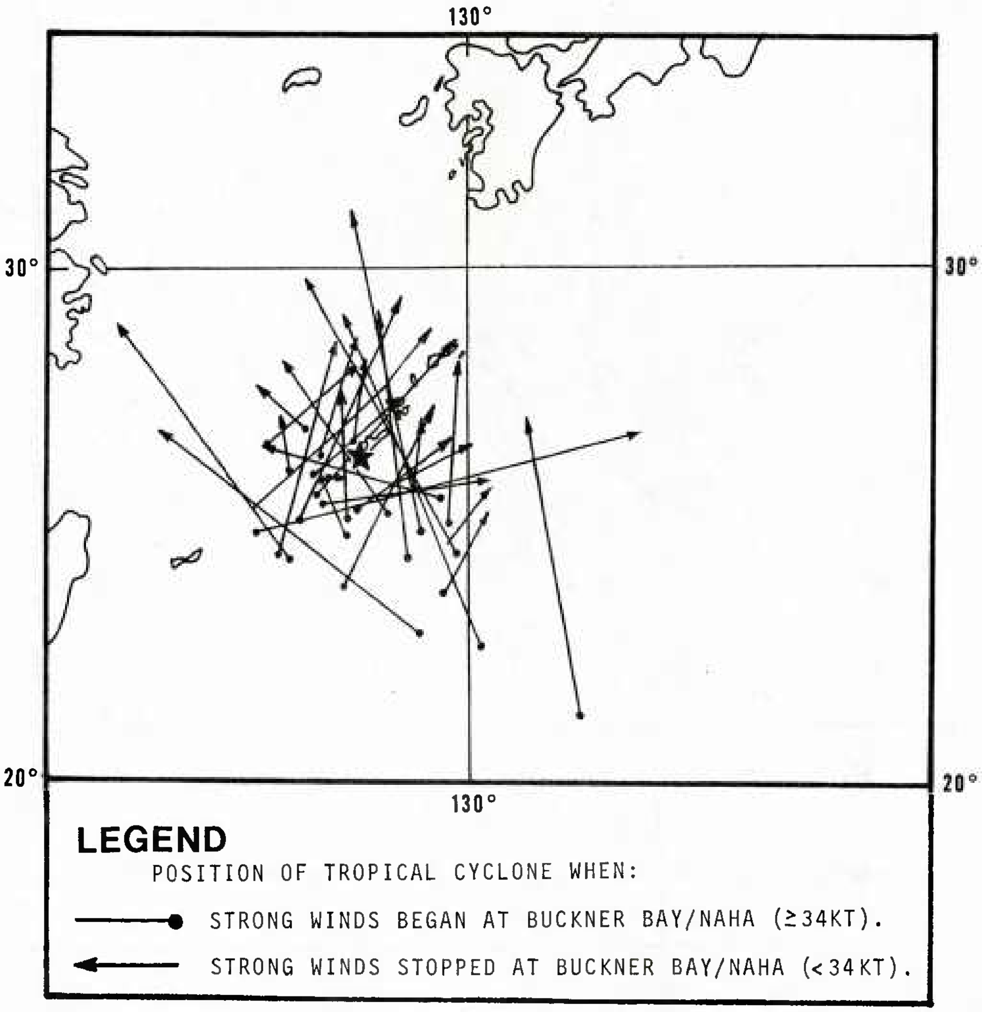



Figure 38. Positions of tropical cyclones centers when ≥ 34 kt winds first and last occurred at Buckner Bay/Naha (based on May-December data from the years 1947-1972).

5.3 WAVE ACTION

The maximum wave heights that can be expected with typhoon strength winds ($\geq$ 64 kt) in Buckner Bay Harbor are presented as Table 5.

Table 4. Maximum wave heights that can be expected with typhoon strength winds ($\geq$ 64 kt) in Buckner Bay (based on research conducted by the U.S. Naval Oceanography Office, 1964).

| | White Beach | Middle of Bay |
|---|---|---|
| Winds generally from the north (tropical cyclone passage east of Buckner Bay) | 4 ft | 6 ft |
| Winds generally from the south (tropical cyclone passage west of Buckner Bay) | 20 ft | 16 ft |

Maximum wave heights of up to 20 ft can be expected from a typhoon passing within 20 n mi to the west of Buckner Bay. The resulting southerly winds generate waves which are virtually unopposed before reaching White Beach, although the coral reefs and islands surrounding Buckner Bay offer some resistance.

5.4 STORM SURGE AND TIDES

When a tropical cyclone crosses a coastline, a rise in water level may occur. This is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. For storms approaching Okinawa from the south, this surge effect will be maximum in bays which open to the south and east and if the harbor is located in the dangerous semicircle.

According to statistical information gathered by the U.S. Naval Oceanographic Office (1964), a maximum storm surge of 7.8 ft can be expected. Generally some flooding is associated with typhoons approaching from the east. The maximum tide at Buckner Bay is 5.7 ft.

# 6. PREPARATION FOR HEAVY WEATHER AT BUCKNER BAY

## 6.1 TROPICAL CYCLONE WARNINGS

Through aircraft reconnaissance and satellite observations, modern techniques for locating tropical cyclones and monitoring their progress have become quite sophisticated. Nevertheless, the present state of meteorological knowledge does not permit a perfect prediction of storm movements. As stated previously, many variables exist which can alter the path of a typhoon; hence every typhoon should be treated with the utmost respect.

COMSEVENTHFLT OPORD 201, Annex H (Environmental Services), describes the techniques to be used when plotting the FWC/JTWC, Guam tropical cyclone warning track positions. An average 24-hr forecast error of 135 n mi should always be incorporated when plotting the 24-hr forecast position in order to expand the radius of 30-kt winds, given in the warning, by the average forecast error.[2] Figure 39 demonstrates this procedure and utilizes the 135 n mi average 24-hr forecast position error in obtaining the "danger area." Note the radius of 30-kt winds is greater on the right side of the storm track -- the dangerous semicircle. In this example the radius to the 30-kt isotach is 200 n mi to the north and 150 n mi to the south of the storm at the current position. The radius to the 30-kt isotach is forecast to expand to 225 n mi to the north and 175 n mi to the south of the storm at the 24-hr forecast position. At the 24-hr forecast time the danger area is then 360 n mi (225 plus 135) to the north and 310 n mi (175 plus 135) to the south of the storm. The 48- and 72-hr forecasted positions given in the FWC/JTWC warning provide a planning forecast, but must also be adjusted to consider a 275 n mi and 400 n mi average forecast error, respectively.

The responsibility for overall coordination of action to be taken by Naval activities on Okinawa has been assigned to the Commanding General, Marine Corps Base, Camp Butler.[3] The established procedures in the event hazardous weather is expected is contained in SOPA (OKINAWA) INSTRUCTION 5000.1 (series). For easy reference, portions of this instruction concerning conditions of readiness have been included as Appendix B to this study.

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[2] This figure is based on 18 years of forecasts.

[3] Storm/typhoon doctrine and coordination procedures for naval forces operating in the COMNAVFORJAPAN area of responsibility has been established by COMNAVFORJAPAN INST 3140.1J of 26 February 1974.

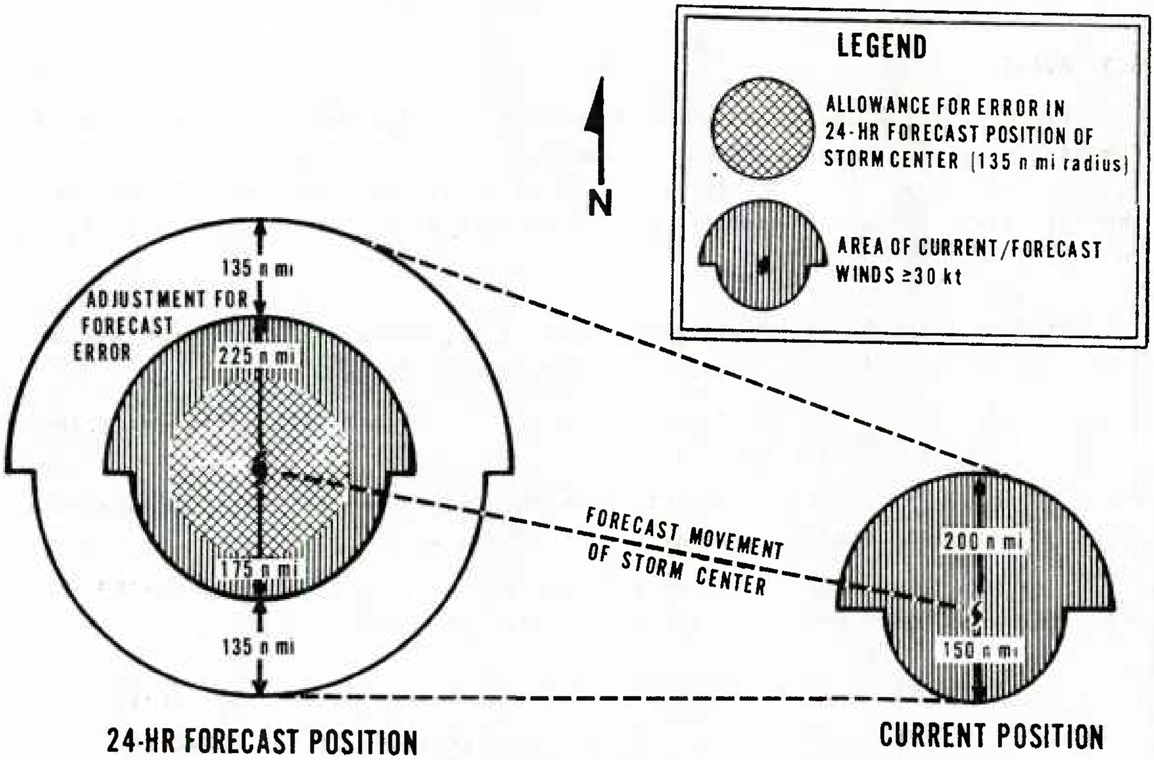


Figure 39. Method of calculating the danger area for moving typhoons and tropical storms (from Commander, Seventh Fleet, OPORD 201-YR).

## 6.2 REMAINING IN PORT

Remaining in Buckner Bay when threatened by a typhoon is not the recommended course of action for the following reasons:

(1) There is almost no protection available in the bay for winds with an easterly or southerly component.

(2) Sea states up to 20 ft are possible in Buckner Bay.

(3) A storm surge is experienced when a typhoon approaches. This surge may be in excess of 7 ft.

(4) Ships moored at the White Beach piers may not have tug services available to get underway if needed.

## 6.3 EVASION

Evasion from Buckner Bay when threatened by a typhoon is the recommended course of action for all ships to follow.

To correctly assess the threat posed by an approaching tropical cyclone, the following timetable incorporating Figures 40-47 has been constructed for this purpose.

I. An existing tropical cylone moves into, or development takes place in, area A with forecast movement toward Okinawa.

  a. Review material condition of ship. A sortie may be desirable 2-4 days hence.

  b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

  c. Plot FWC/JTWC, Guam warnings and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters area B moving toward Buckner Bay/Naha.

  a. All ships begin planning course of action to be taken if sortie should be ordered.

  b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

  c. Anticipate Storm/Typhoon Condition III (see Appendix B).

III. Tropical cyclone enters area C moving toward Buckner Bay/Naha.

  a. Execute sortie plan made in previous step.

  b. Anticipate Storm/Typhoon Conditions II and I (see Appendix B).

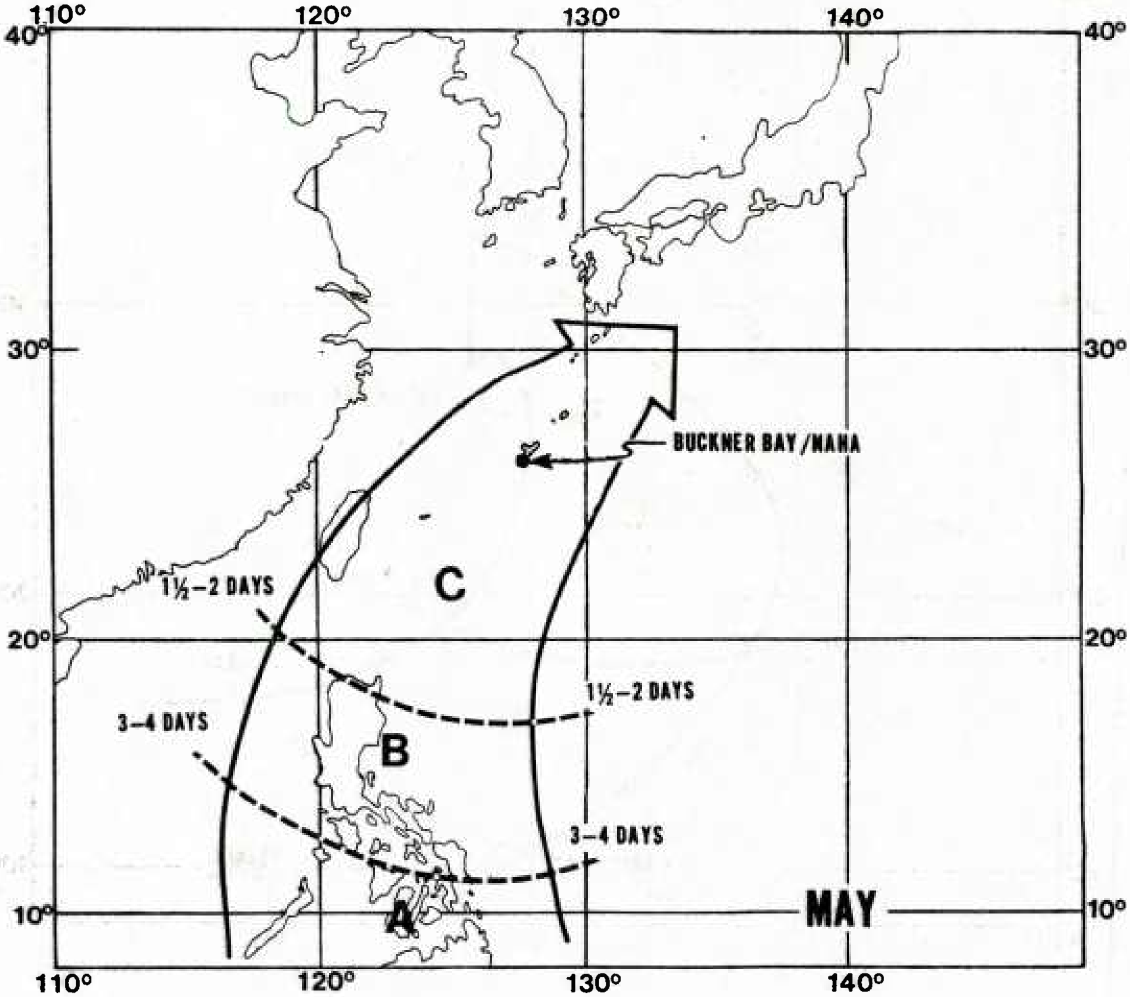


Figure 40. Tropical cyclone threat axis for Buckner Bay/Naha for the month of May. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

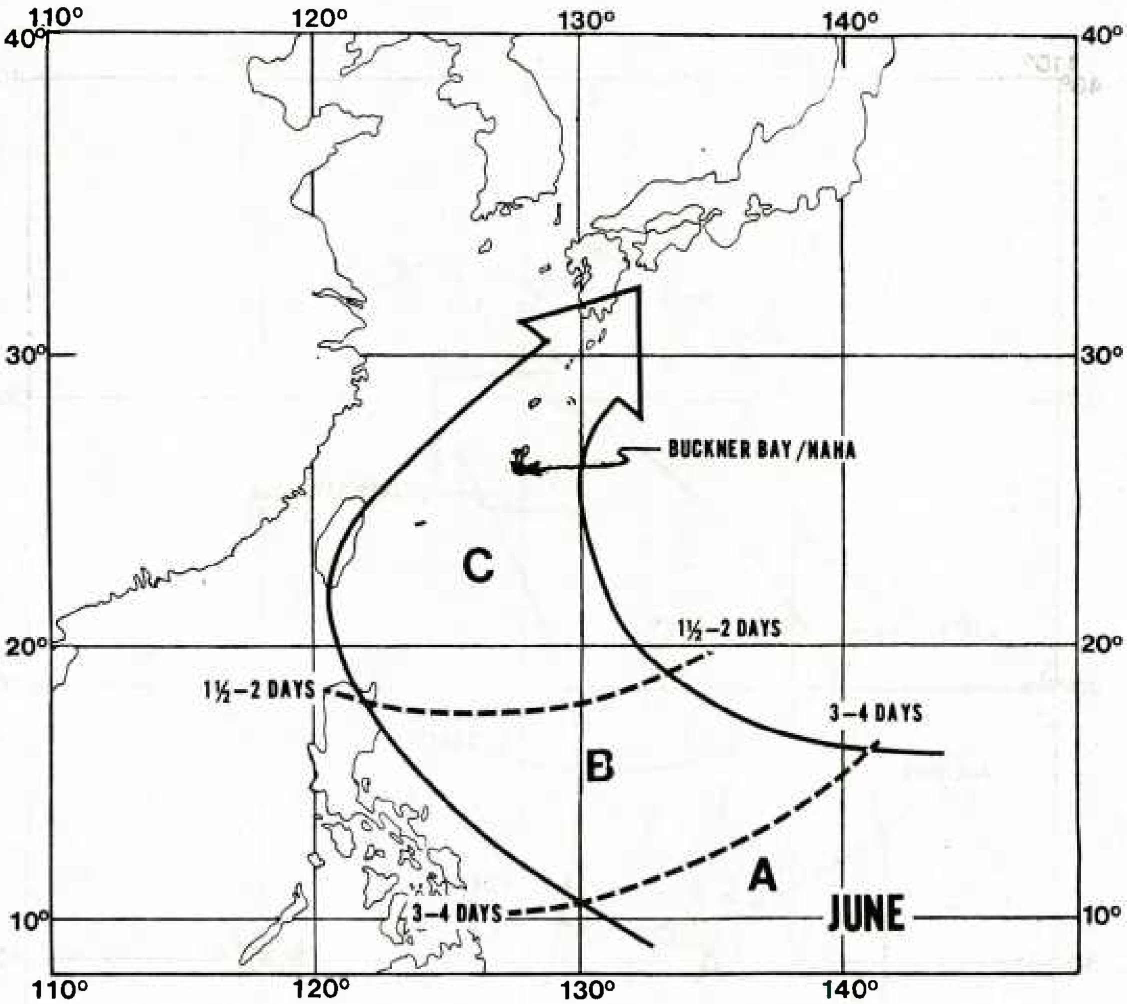


Figure 41. Tropical cyclone threat axis for Buckner Bay/Naha for the month of June. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

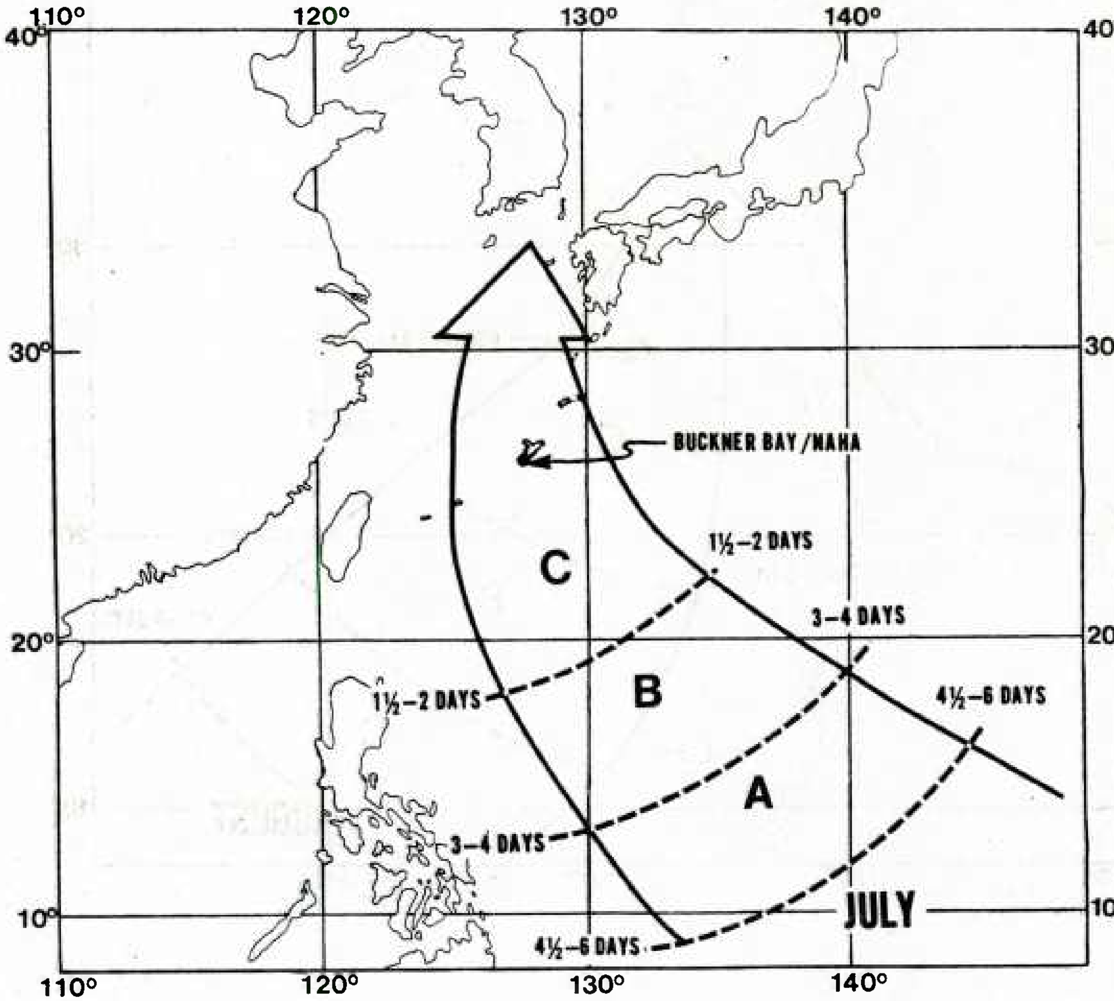


Figure 42. Tropical cyclone threat axis for Buckner Bay/Naha for the month of July. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

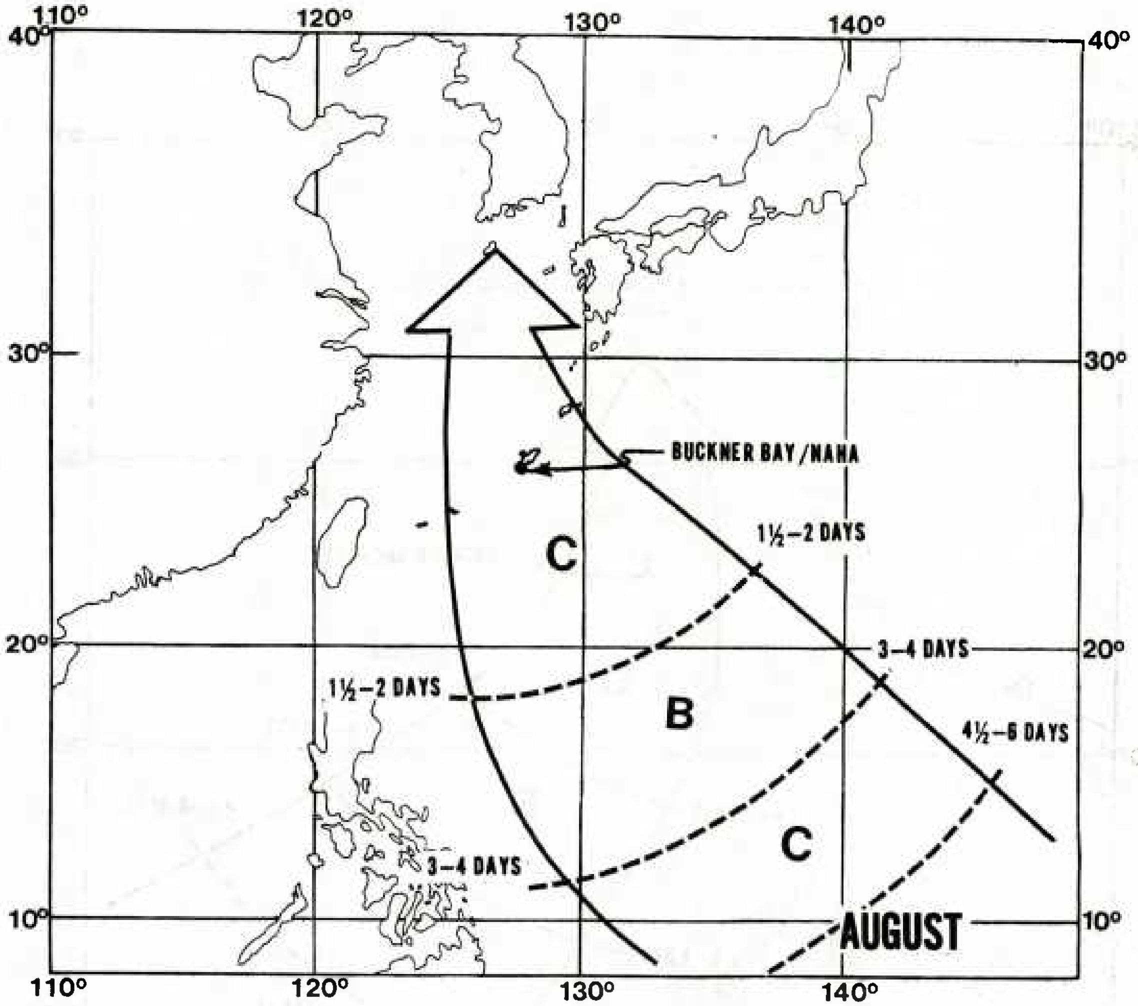


Figure 43. Tropical cyclone threat axis for Buckner Bay/Naha for the month of August. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

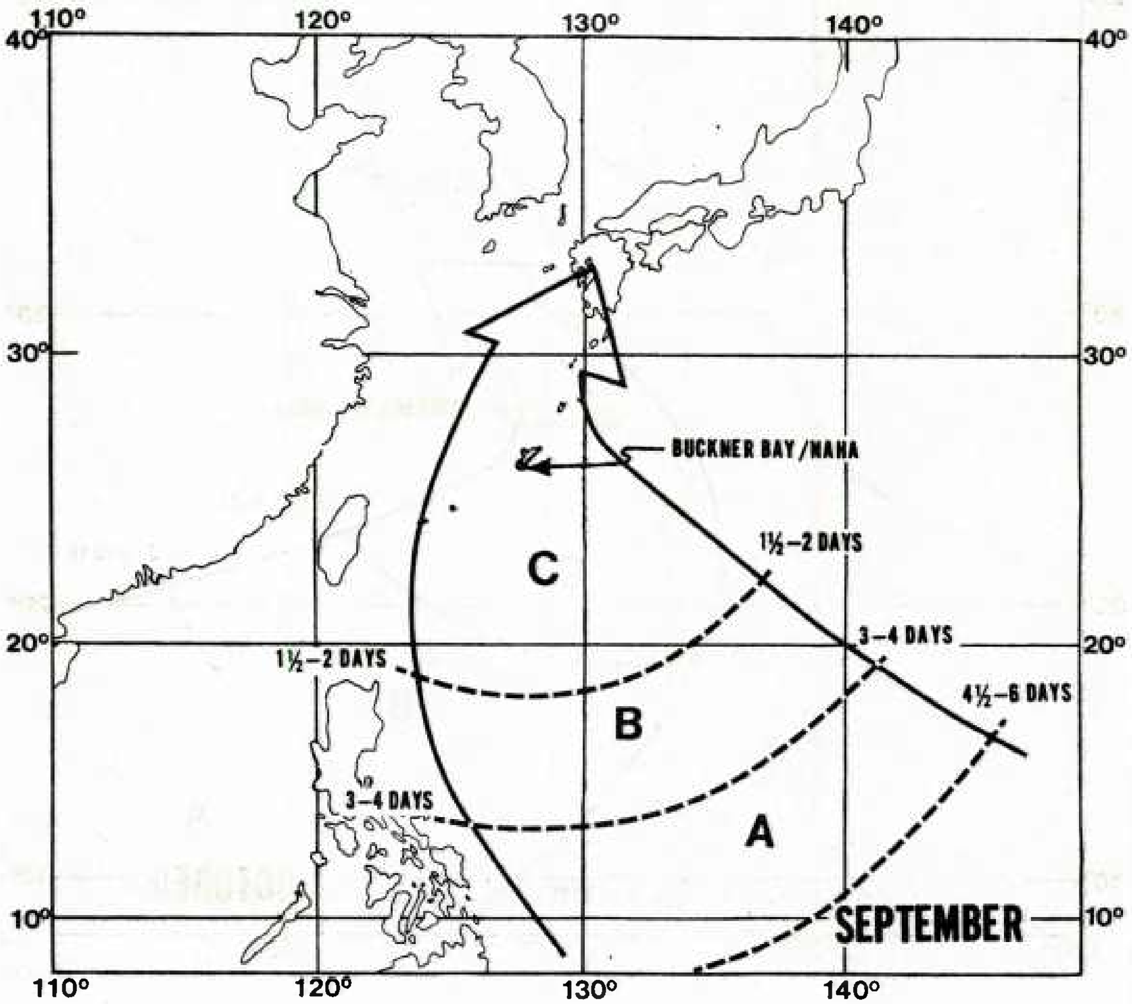


Figure 44. Tropical cyclone threat axis for Buckner Bay/Naha for the month of September. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

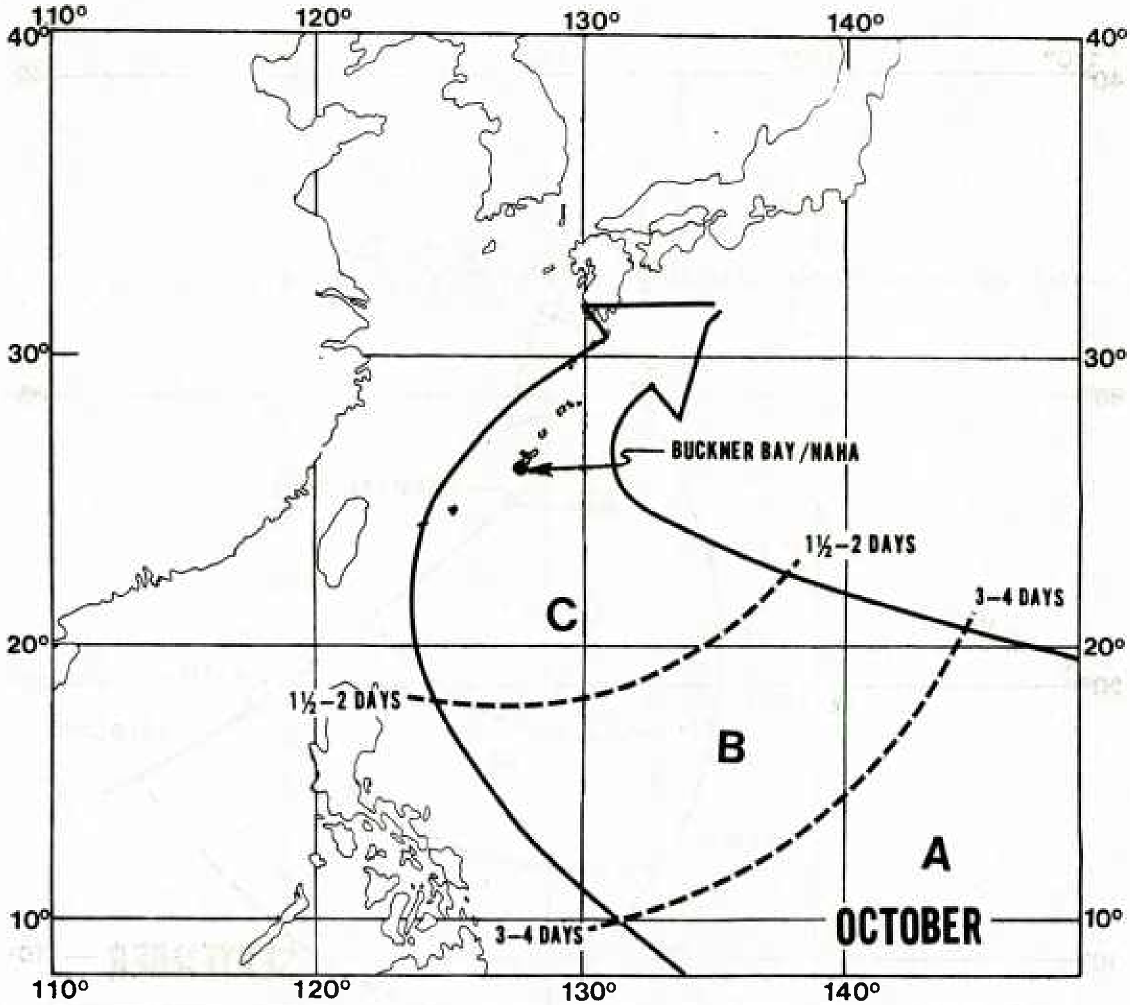


Figure 45. Tropical cyclone threat axis for Buckner Bay/Naha for the month of October. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

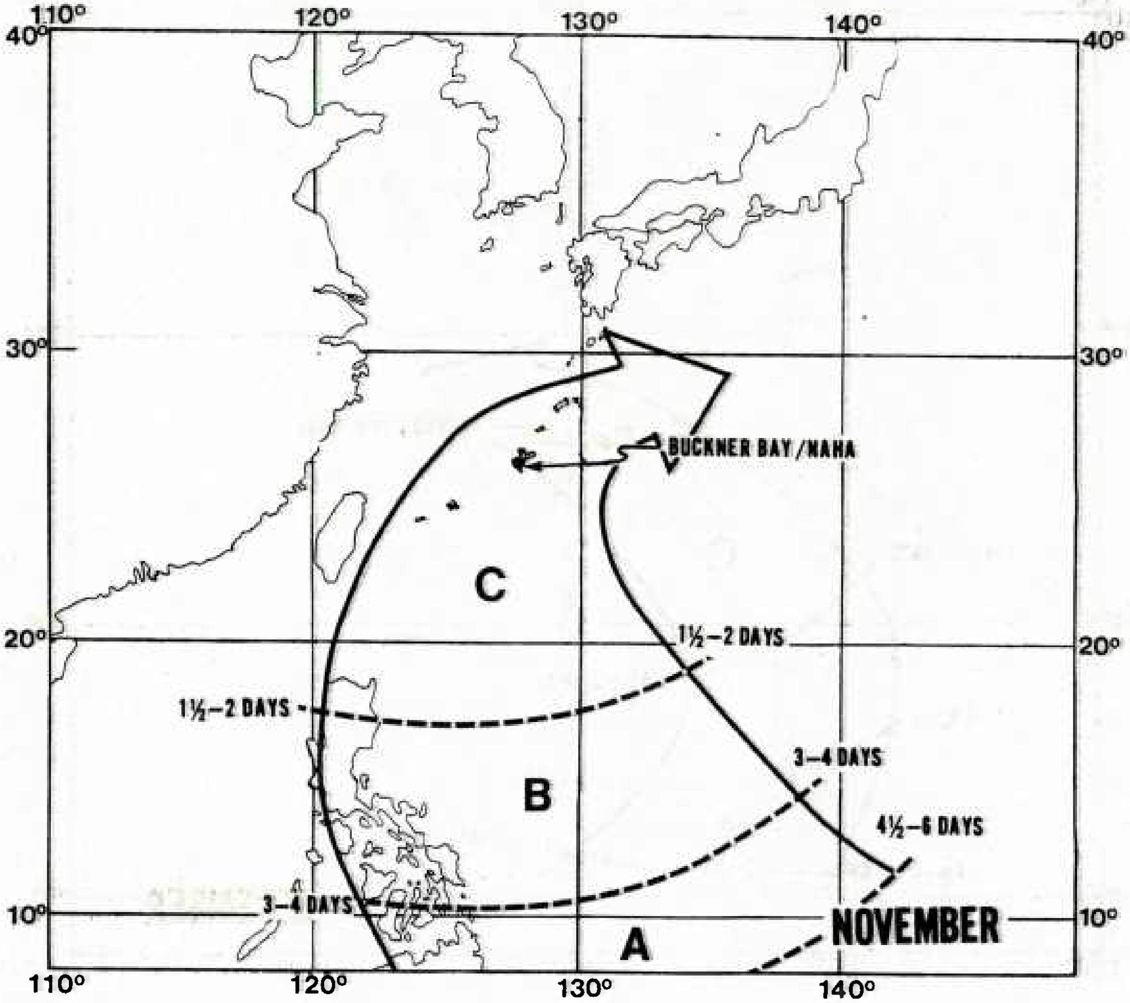


Figure 46. Tropical cyclone threat axis for Buckner Bay/Naha for the month of November. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

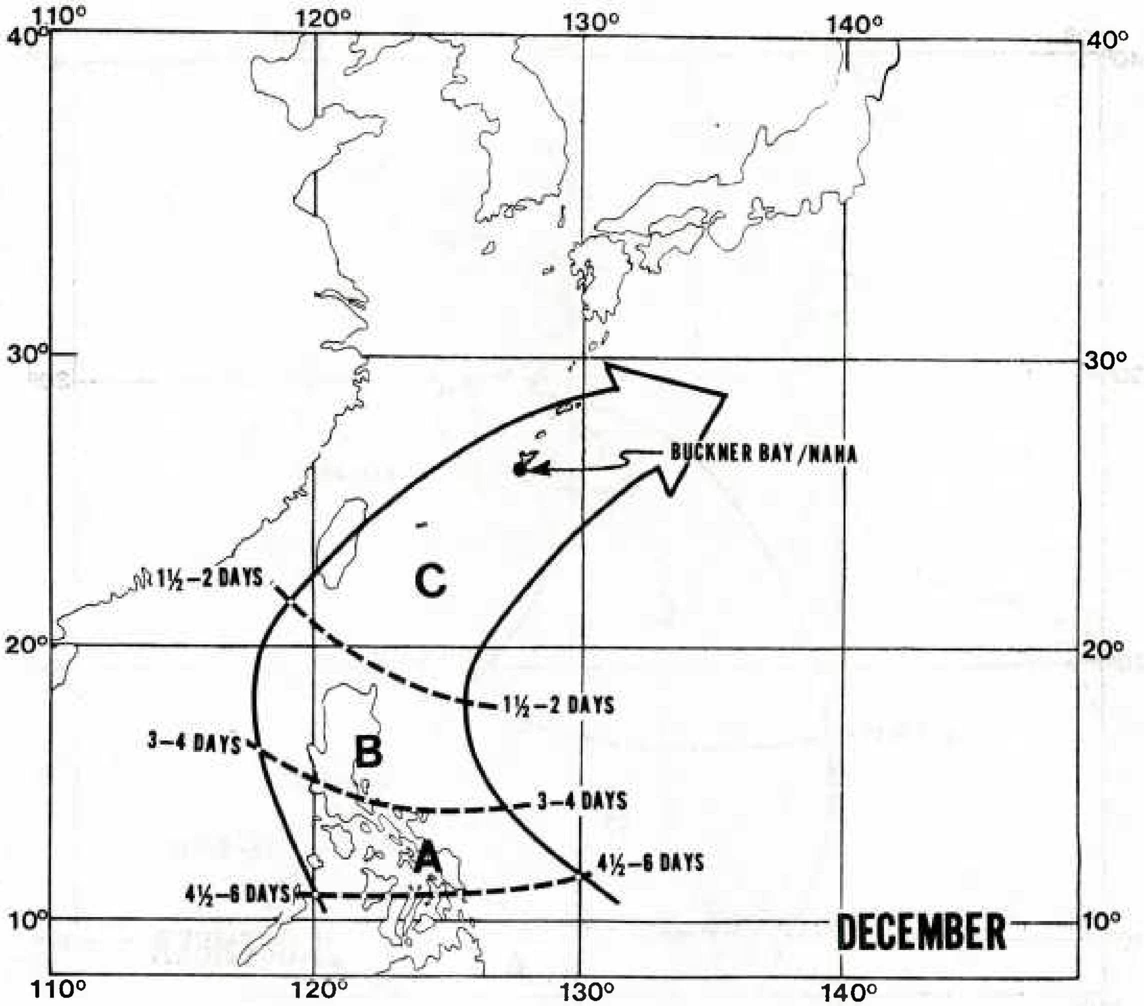


Figure 47. Tropical cyclone threat axis for Buckner Bay/Naha for the month of December. Approach times are based on average climatological speeds of movements for tropical cyclones affecting Buckner Bay/Naha.

Whatever evasion decision is made, the following general comments should be considered.

1. When departing Buckner Bay/Naha Harbor, ample time should be given to combat the heavy sea condition likely to be encountered at the entrance to Buckner Bay/Naha Harbor.

2. Crossing ahead of a typhoon should be accomplished well in advance. Heavy swells may be encountered ahead of an advancing typhoon long before the occurrence of strong winds. Such swells may decrease a ship's maneuverability and speed of advance, preventing avoidance of the typhoon track.[4]

3. At certain times of the year, particularly in the peak typhoon season, the possibility exists that two or more tropical cyclones will be present at one time. This will greatly complicate any evasion planning and execution.

4. A looping tropical cyclone can cause a false sense of security as evading ships attempt to return. A looping storm after initial passage can return and cause as high or higher winds/seas upon its return (see Appendix D).

## 6.4 EVASION TECHNIQUES

The final decision involving evasion of a tropical cyclone rests with the commanding officer of the vessel involved. One of the more successful Pacific Ocean evasion techniques involves running downwind and downsea relative to the typhoon in order to reach a latitude south of the storm and be located in the navigable semicircle. The success of this method depends upon almost continuous reconnaissance coverage and the relatively slow movement and gradual expansion of the initially small area affected by severe winds which is characteristic of typhoons at low latitudes (Somervell and Jarrell, 1970).

For a ship in or near Buckner Bay/Naha the following evasion routes for the more common threat situations (depicted in Figure 48) are suggested.

1. Tropical cyclone is forecast to pass east of Buckner Bay/Naha (Figure 48 (a)).

   Evasion should be to the southwest. This allows the ship to gain a latitude south of the storm center in the safe semicircle.

---

[4] See Appendix E for discussions and examples of the extent to which sea state and wind speed reduce the speed of advance of a vessel.

2. Tropical cyclone is forecast to pass west of Buckner Bay/Naha (Figure 48(b)).

   Evasion should be to the east-southeast. This provides ample maneuvering room and allows course modification to the east or north as the storm movement/intensity varies. A WORD OF CAUTION -- the ship is operating in the dangerous semicircle and wind and sea will be between bow and beam and may adversely affect the ship speed (see Appendix E). Sufficient separation from the storm center must be maintained to stay outside the 30-kt wind radius.

3. Tropical cyclone is forecast to recurve and pass south of Buckner Bay/Naha (Figure 48(c)).

   Evasion should be to the north or northwest. This will place the ship in the safe semicircle and also make available a second option -- to proceed to Sasebo Harbor, a typhoon haven for all but the largest of ships (Rudolph, 1975).

4. Tropical cyclone is forecast to recurve and pass north of Buckner Bay/Naha (Figure 48(d)).

   Evasion should be to the east-southeast. This will provide ample maneuvering room and place the ship south of the tropical cyclone. A WORD OF CAUTION -- the ship will be operating in the dangerous semicircle and ships speed may be reduced significantly (see Appendix E).

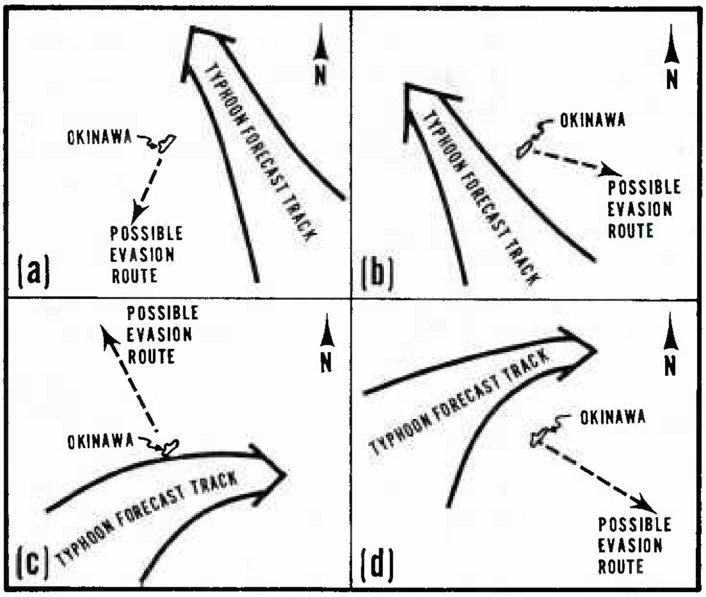


Figure 48. Common typhoon threat situations experienced at Buckner Bay/Naha and possible evasion routes.

Since the general movement of tropical cyclones varies from month to month, the appropriate information presented in Figures 18-25 (percent "threat" lines), Figures 26-36 ("threat" tropical cyclone tracks), Figures 40-47 ("threat" axis diagrams) and Appendix A (the mean monthly tropical cyclone tracks, track limits and average speeds of movement), in conjunction with the warnings issued by FWC/JTWC Guam, should all be used in developing a viable evasion route.

# 7. CONCLUSIONS FOR BUCKNER BAY

The conclusion reached by this study is that Buckner Bay is not considered to be a haven during typhoon conditions. The lack of extensive protection from wind due to the relatively low topography of the surrounding land mass and the exposure of ships to wind and seas with any easterly component severely limits Buckner Bay as a storm refuge.

It is recommended that all U.S. Navy ships capable take action to evade at sea when typhoon conditions threaten Buckner Bay, Okinawa.

# 8. NAHA

## 8.1 LOCATION

Naha, the principal port of Okinawa, is located on the southwestern coast of the island at 26°13'N, 127°41'E (see Figures 5 and 6).

## 8.2 NAHA HARBOR

Naha Harbor consists of an Outer Harbor, with outer and inner anchorages, and two inner harbors (Figure 49). The main inner harbor (Naha Ko) is used by ocean-going vessels with a draft up to 31.5 ft, while the new inner harbor is used by coastal vessels under 3,000 tons.

Figure 50 depicts the main inner harbor which is divided into a commercial area (northern part) and an Army area (southern part) which has eight piers. The commercial wharfs are letter designated A through L. Piers A-D and J-L are "small craft" piers while pier E is not used.

The inner and outer anchorages are not individually charted and several sunken wrecks within the anchorages are hazards to those vessels lacking local knowledge. The anchorages are exposed to wind and sea and the bottom is considered very poor holding ground.

The tidal range in the harbor is about 6 ft while mean currents do not exceed 2.5 kt.

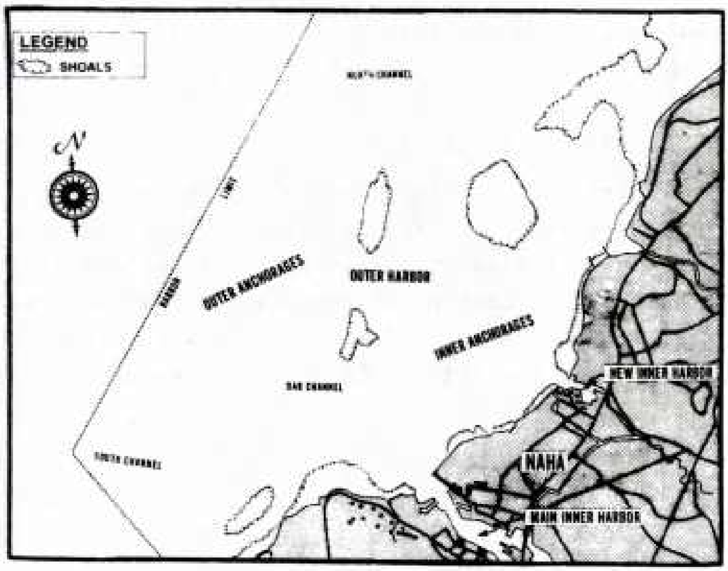


Figure 49. Naha Harbor.

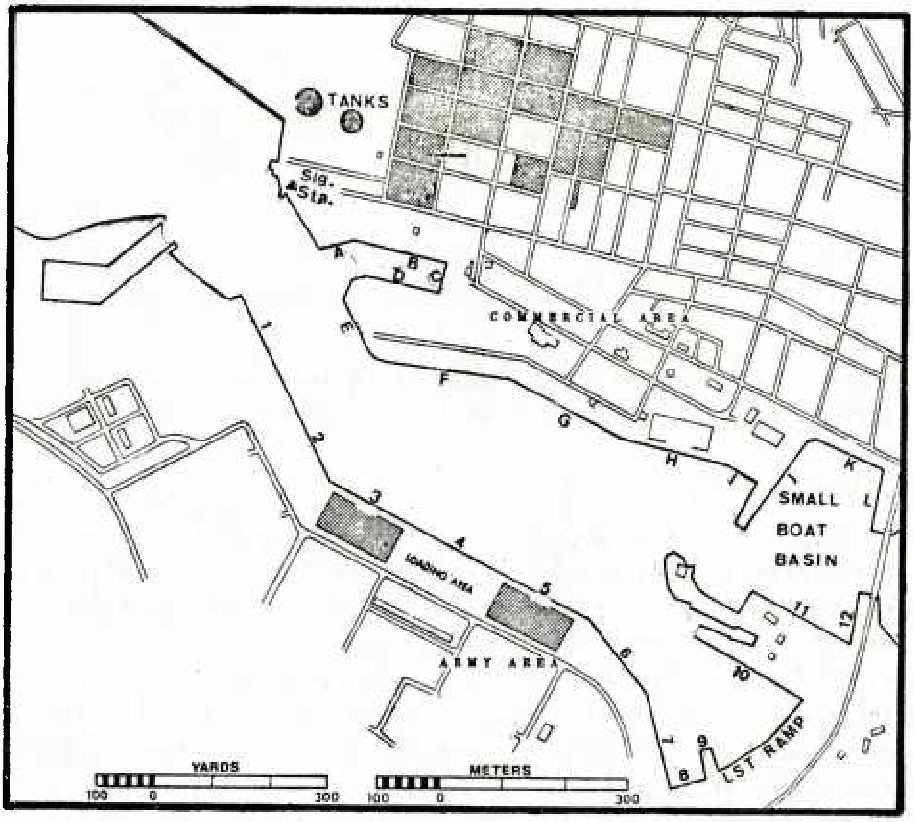


Figure 50. Naha main inner harbor (Naha Ko)

8.3 TOPOGRAPHY

Figure 6 indicates that Naha Harbor is unprotected to the northwest, receives some protection from hills less than 250 ft to the north and south while more protection is available to the east.

8.4 HARBOR FACILITIES

The Director for Terminal Operations, 2nd Logistical Command, U.S. Army, is responsible for the operation of facilities and services in the military terminal complex of the port, while the Japanese Maritime Safety Agency (JMSA) controls the commercial complex. For a detailed description of harbor facilities available in Naha, refer to Appendix C, CINCPACFLT Port Directory, Volume V, Section C2 and the Far East Port Directory, MSTSFE Instruction 3170.4A Section IV-35.

# 9. TROPICAL CYCLONES AFFECTING NAHA

## 9.1 CLIMATOLOGY

Refer to Section 5.1 for the tropical cyclone climatology of Naha.

## 9.2 WIND AND TOPOGRAPHICAL EFFECTS

Maximum winds can be expected from the northwest at Naha since the harbor opens to the ocean in this direction. Thus, tropical cyclones to the north of Okinawa are severe problems to Naha.

To determine the extent to which threat tropical cyclones produced strong winds (≥ 22 kt) or gale force winds (≥ 34 kt) in Naha Harbor, the wind observations from Kadena Air Base (26°21'N, 127°45'E) at an elevation of 152 ft were analyzed (refer to Section 5.2). Since both Naha Harbor and Kadena Air Base are located on Okinawa's western coastline and the surrounding topography is similar, winds recorded at Kadena Air Base are representative of wind conditions experienced in Naha Harbor.

## 9.3 WAVE ACTION

Wave action in Naha Harbor area is severe enough to halt all traffic with the onset of 25 kt or greater winds. Although ships have been moved in winds up to 50 kt during emergency conditions, wave action in the harbor can be destructive enough to necessitate clearing the port of all vessels when winds of 50 kt or greater are expected within 24 hours.

The maximum wave heights that can be expected with typhoon strength winds (≥ 64 kt) in Naha Harbor are presented as Table 5.

Table 5. Maximum wave heights that can be expected with typhoon strength winds (≥ 64 kt) in Naha's main inner and outer harbor (based on information from U.S. Army Coastal Engineering Research Center, 1973).

| | Main Inner Harbor | Main Outer Harbor |
|---|---|---|
| Winds generally from the north (tropical cyclone passage east of Naha) | 8 ft | 15 ft |
| Winds generally from the south (tropical cyclone passage west of Naha) | 4 ft | 12 ft |

## 9.4 STORM SURGE AND TIDES

During periods of moderate to strong northwesterly winds, a surge effect of 2-3 ft is evident in the main inner harbor. This is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. When this surge effect coincides with high tide, an abnormal rise in water level occurs.

# 10. PREPARATION FOR HEAVY WEATHER AT NAHA

## 10.1 TROPICAL CYCLONE WARNINGS

For general information about tropical cyclone warnings the reader is referred to Section 6.1.

## 10.2 REMAINING IN PORT

Naha is a confined, generally unsheltered harbor. The anchorages are exposed to wind and sea and the bottom is considered very poor holding ground. Several merchant ships may be present at any given time in Naha Harbor, and some of these vessels may have inadequate or poorly maintained mooring gear. As a result, it is possible for them to break loose during typhoon conditions and cause damage to other ships. As a consequence, it is recommended that U.S. Navy ships sortie when typhoon conditions threaten. If a ship is unable to get underway and evade at sea, every effort must be made to obtain a berth within Naha Ko, the main inner harbor. If such a berth cannot be obtained well in advance of the onset of heavy weather, evasion at sea is strongly recommended.

## 10.3 EVASION

Evasion from Naha Harbor when threatened by a typhoon is the recommended course of action for all ships to follow. See Section 6.3 for general evasion comments.

## 10.4 EVASION TECHNIQUES

Due to the proximity of Buckner Bay and Naha Harbor, the evasion techniques presented in Section 6.4 are applicable.

# 11. CONCLUSIONS FOR NAHA

The conclusion reached in this study is that Naha Harbor is a poor haven during typhoon conditions. The key factors in reaching this conclusion were:

1. Lack of sheltered berths.
2. The threat of other vessels adrift in the confined harbor.
3. High sea states within the harbor area for winds of 25 kt and greater.
4. Poor anchor holding action of the harbor bottom.

It is recommended that all U.S. Navy ships capable take action to evade at sea when typhoon conditions threaten Naha, Okinawa.

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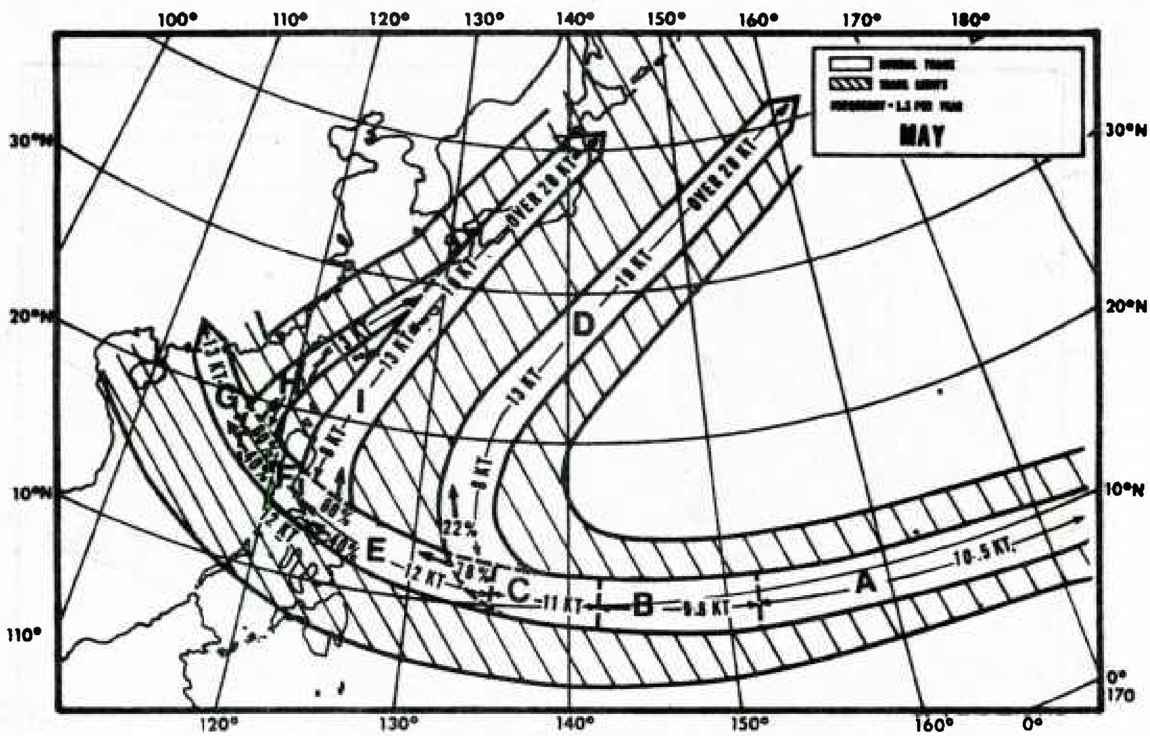
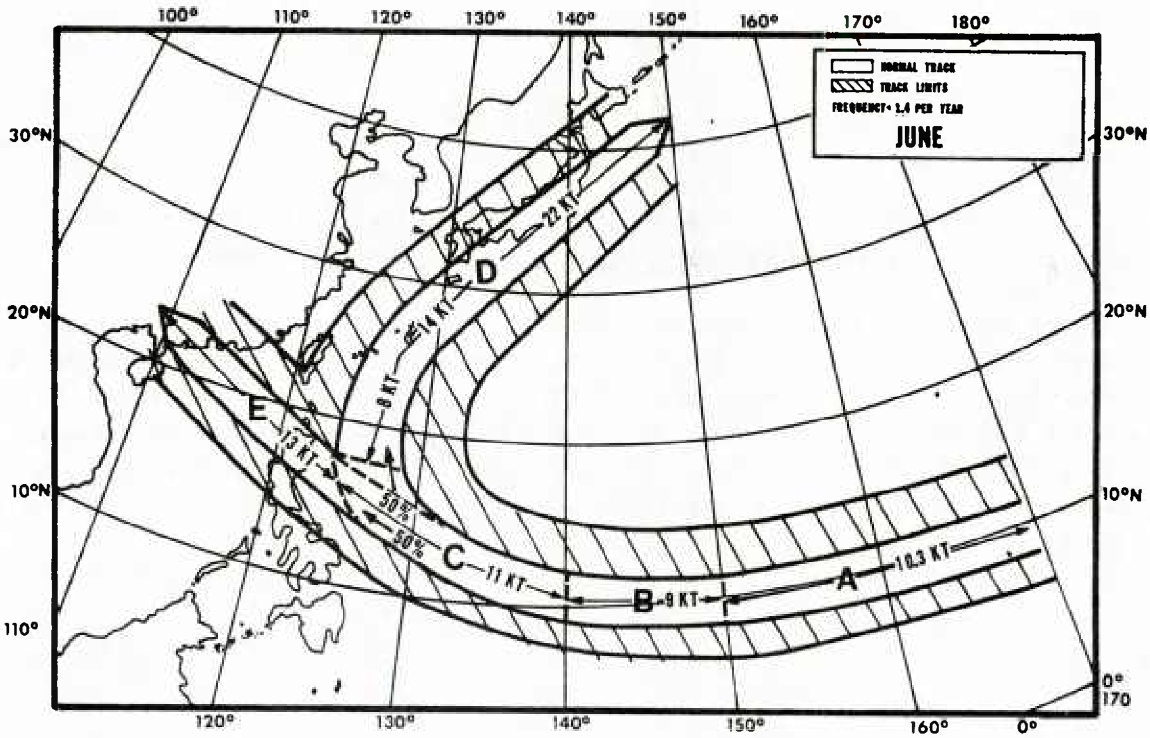
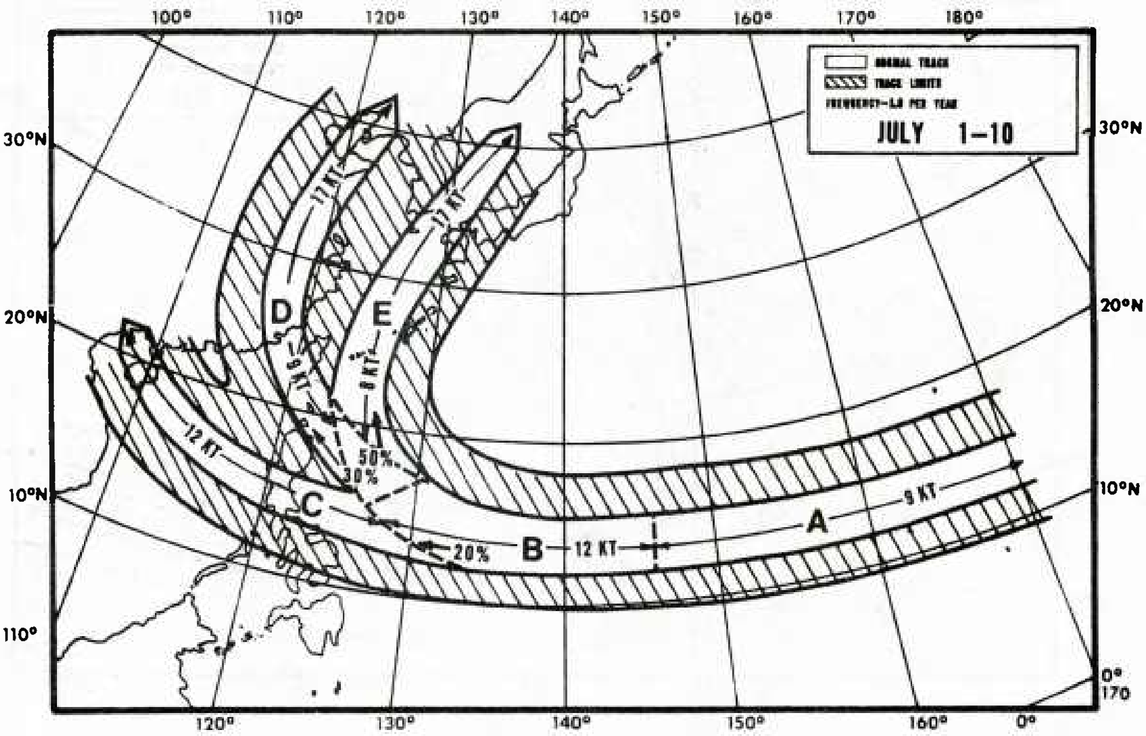
# APPENDIX A

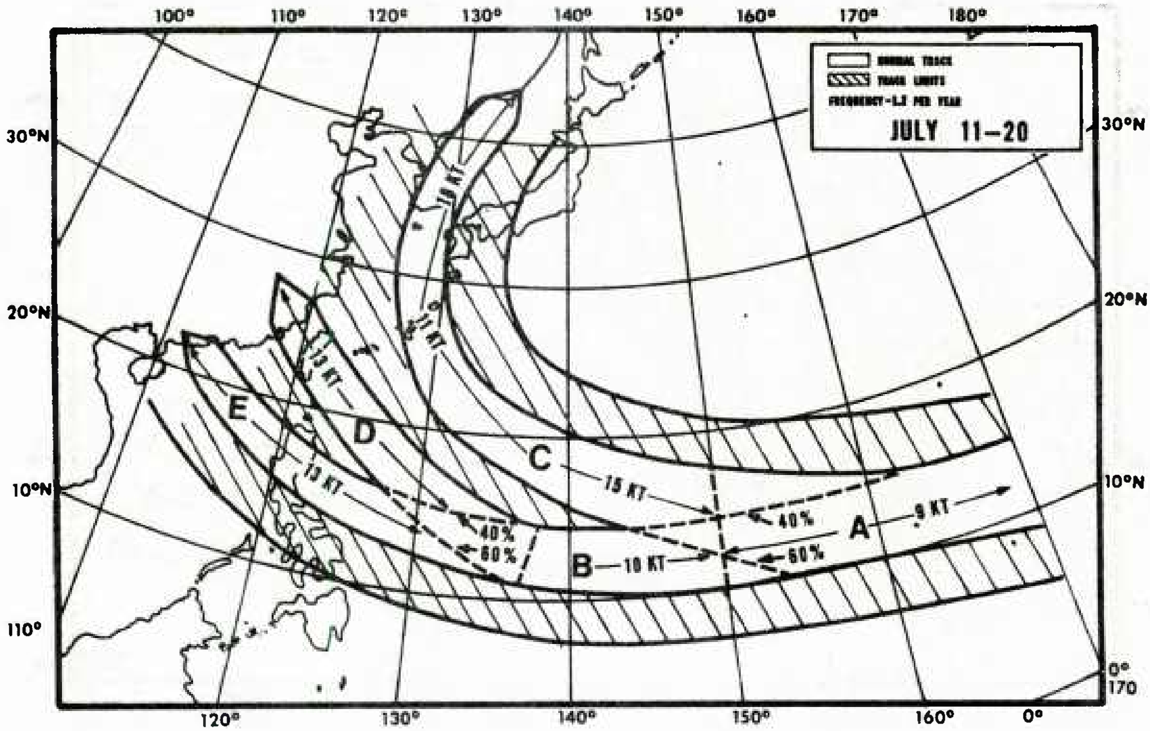
WESTERN NORTH PACIFIC AVERAGE TYPHOON TRACK LIMITS AND AVERAGE SPEED OF MOVEMENT FOR THE MONTHS OF MAY-DECEMBER

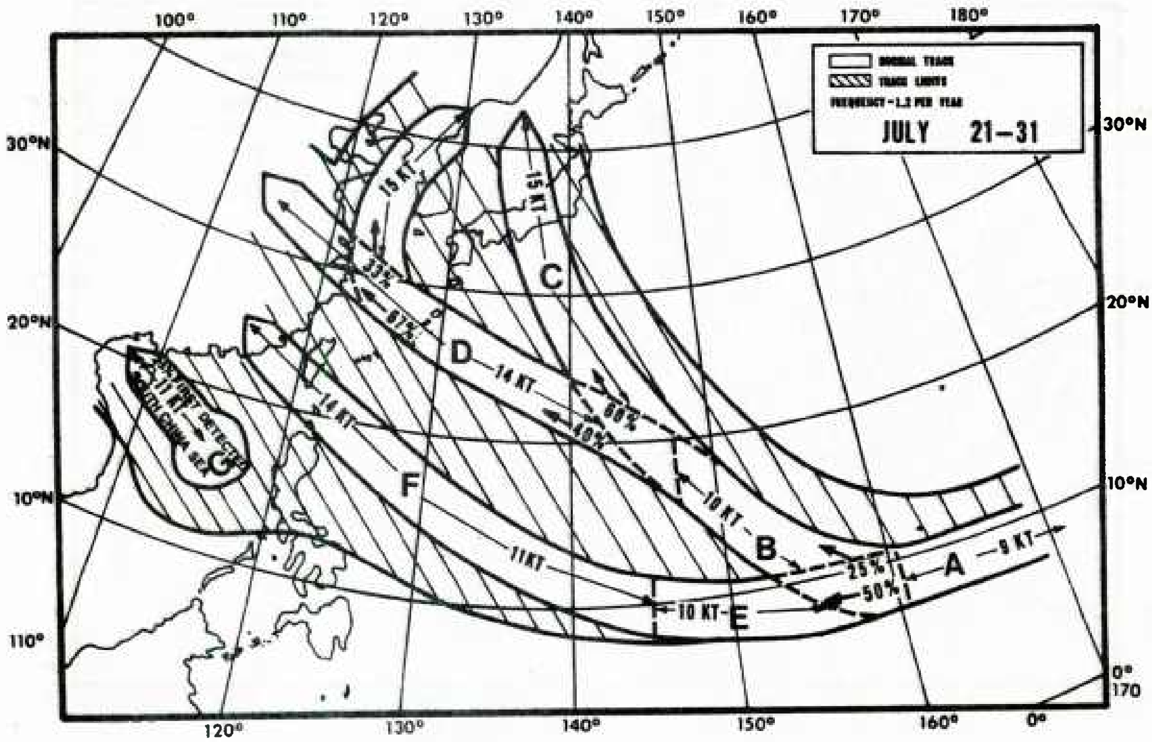
A series of maps showing mean typhoon tracks, track limits and average speeds of movement for the months of May through December are presented in this appendix. It must be realized that storms deviate from the mean tracks, but about 80 percent will fall within the track limits. The use of these tracks should be of particular benefit in long range (in excess of 48 hours) planning. The application of average tracks to the short range specific situation should be avoided (U.S. FWF, Sangley Point, 1967).

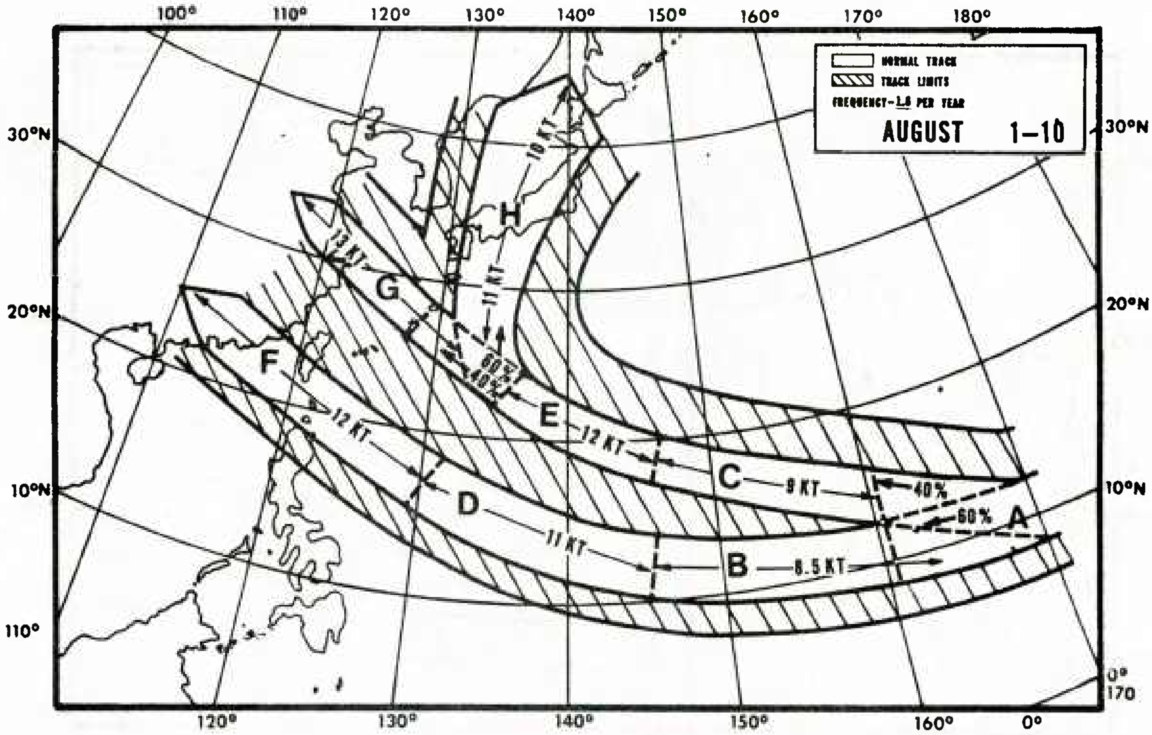


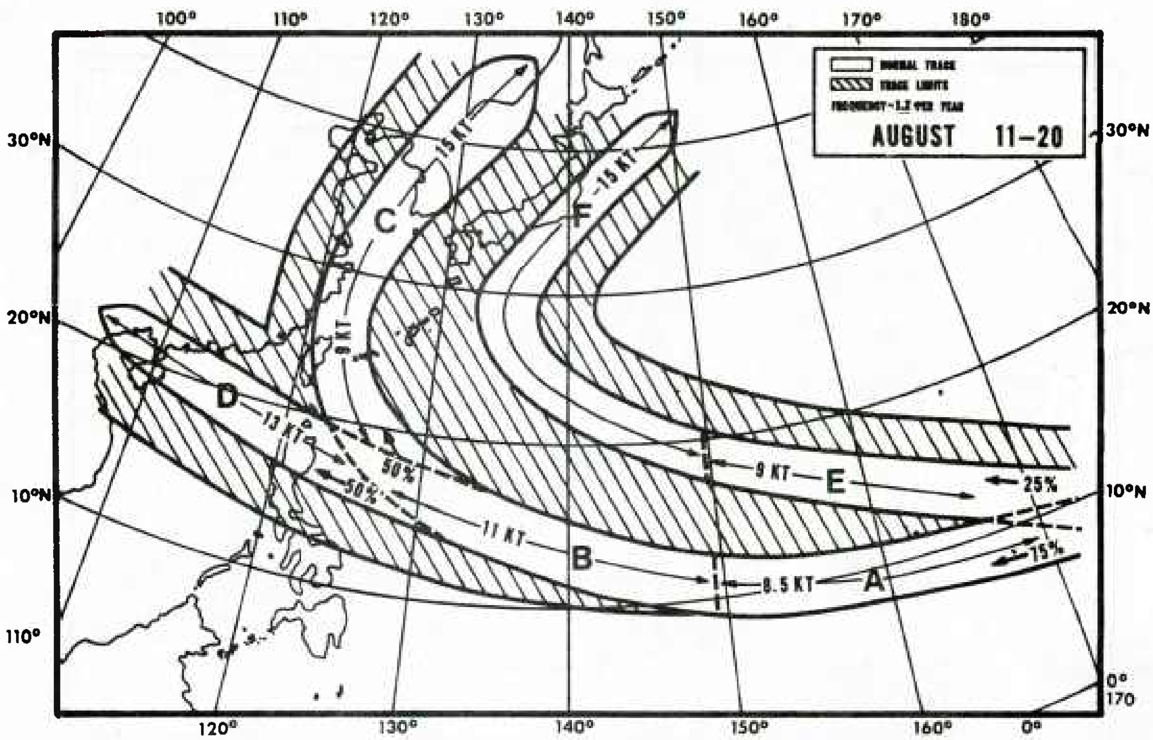

NORMAL TRACK
TRACK LIMITS
FREQUENCY- 1.4 PER YEAR
JUNE
A
10.3 KT
B
9 KT
C
11 KT
D
22 KT
14 KT
8 KT
E
13 KT
50%
50%
30°N
20°N
10°N
100°
110°
120°
130°
140°
150°
160°
170°
180°
0°
170

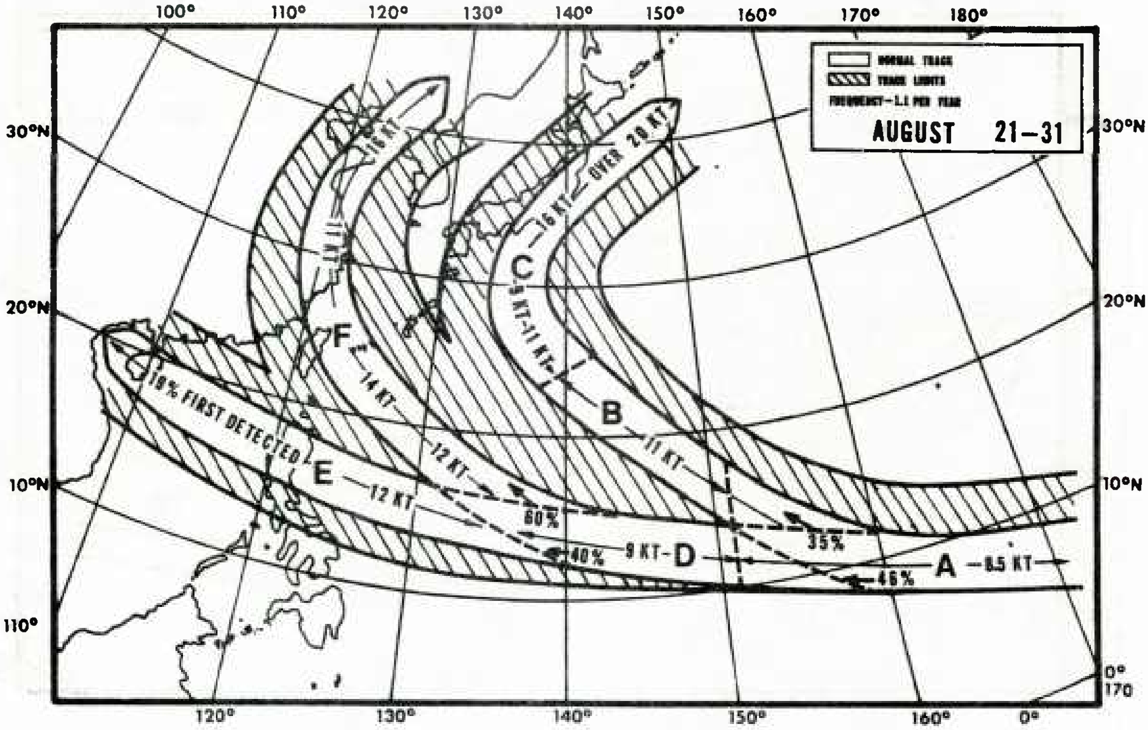

NORMAL TRACK
TRACK LIMITS
JULY 1–10
A
9 KT
B
12 KT
C
12 KT
D
E
50%
30%
20%
30°N
20°N
10°N
100°
110°
120°
130°
140°
150°
160°
170°
180°
0°
170

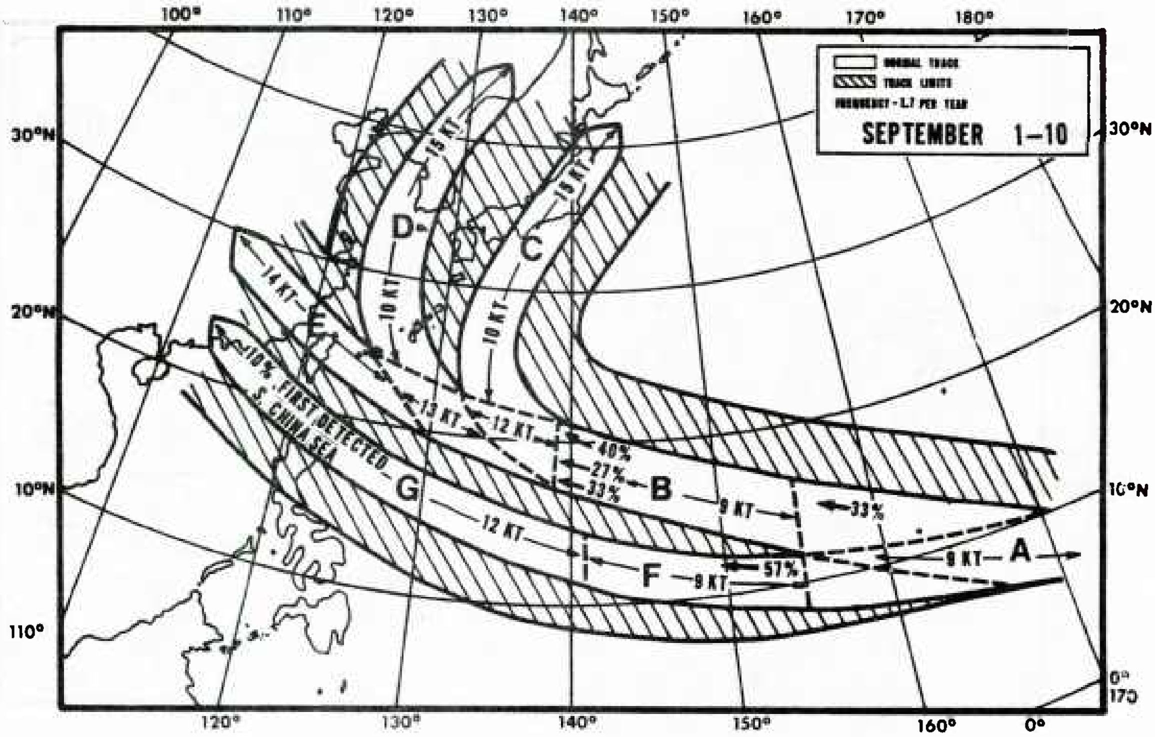

JULY 11–20
A
B
C
D
E
15 KT
10 KT
9 KT
13 KT
40%
60%
40%
60%

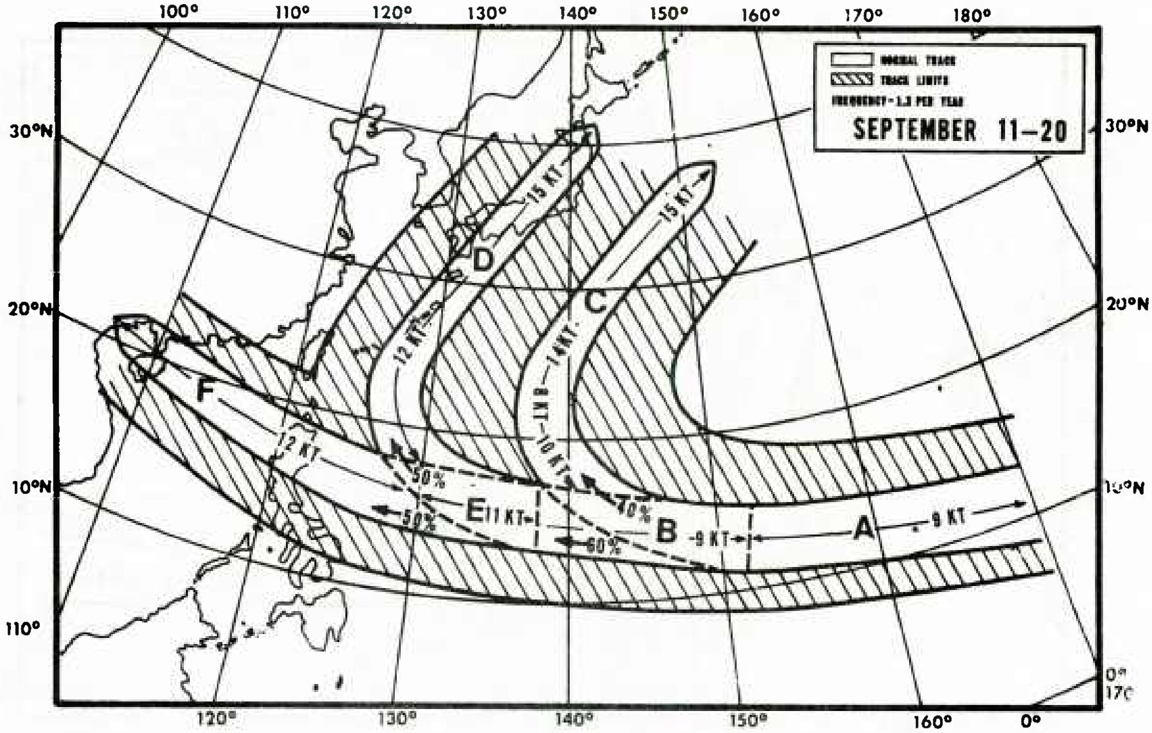

JULY 21–31
A
B
C
D
E
F
G
15 KT
14 KT
14 KT
10 KT
11KT
10 KT
9 KT
33%
67%
60%
40%
25%
50%

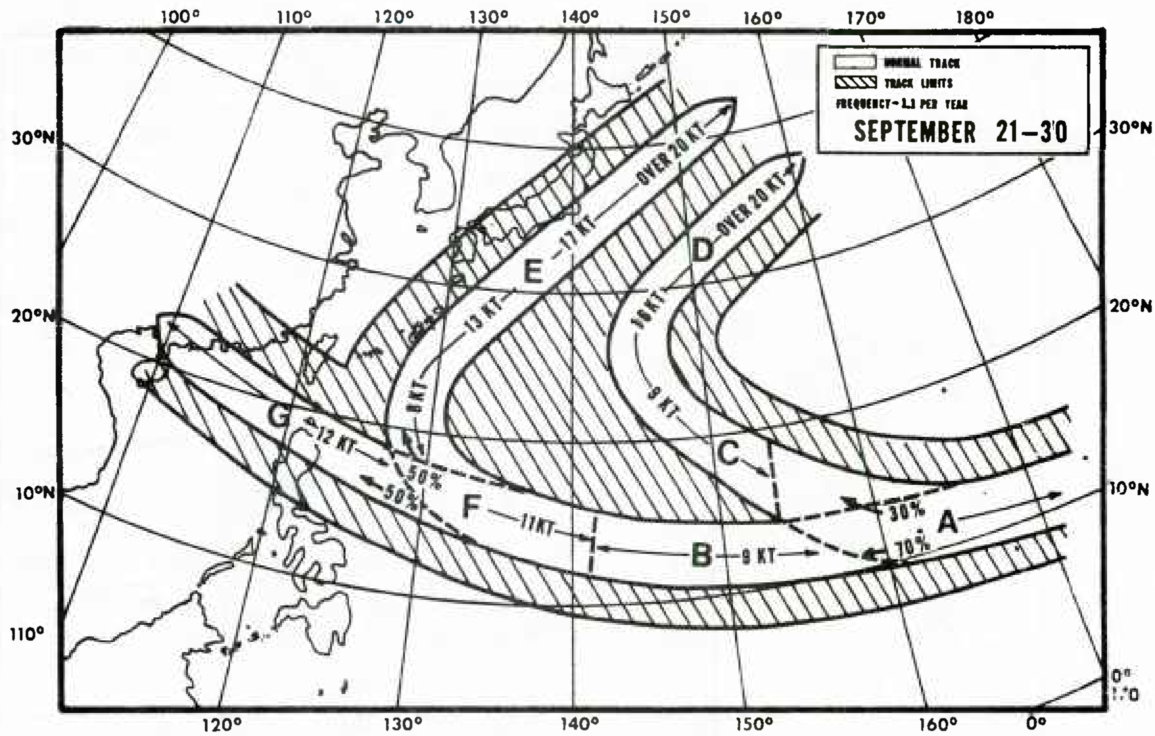

NORMAL TRACK
TRACK LIMITS
FREQUENCY-1.8 PER YEAR
AUGUST 1-10
13 KT
12 KT
11 KT
10 KT
12 KT
9 KT
8.5 KT
11 KT
60%
40%
40%
60%
A
B
C
D
E
F
G
H

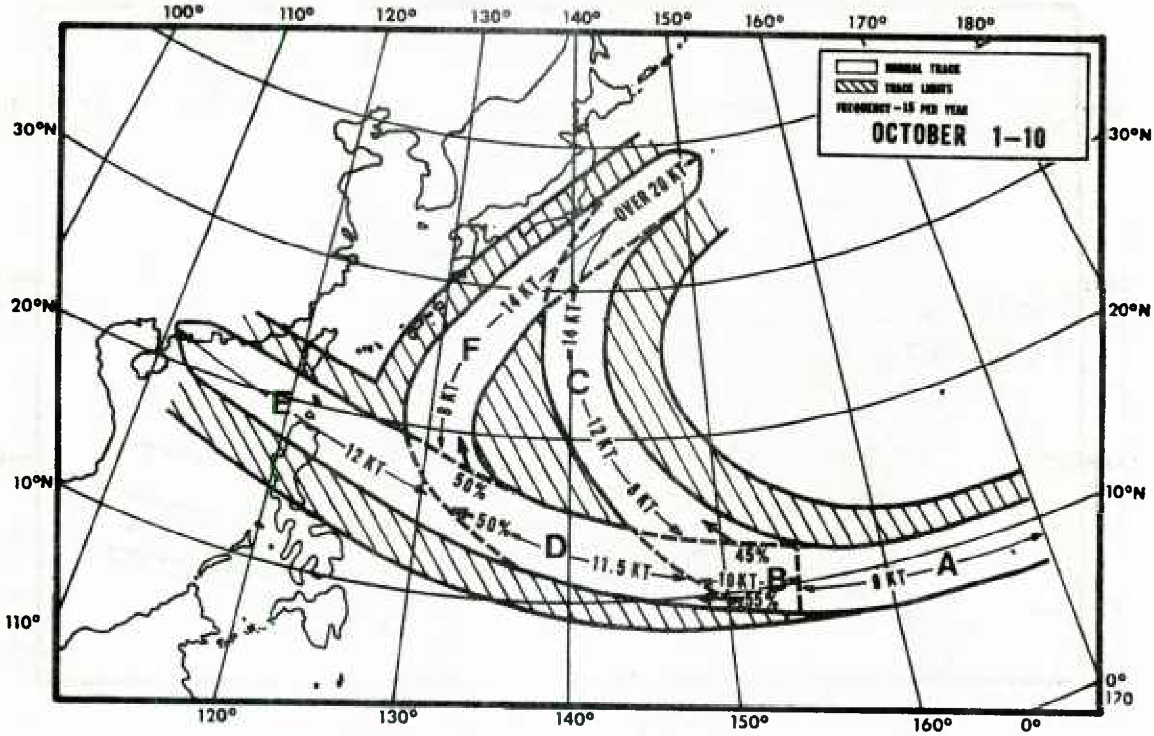

AUGUST 11-20
15 KT
15 KT
9 KT
13 KT
50%
50%
11 KT
9 KT
25%
75%
8.5 KT
A
B
C
D
E
F

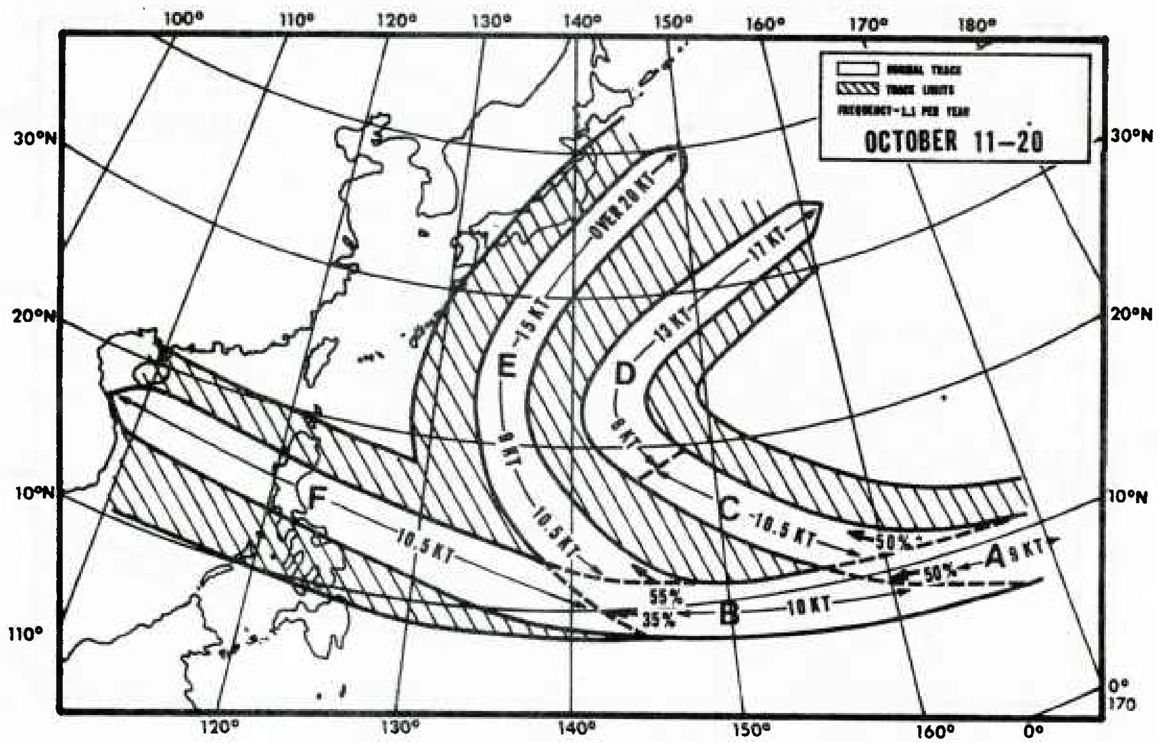

NORMAL TRACK
TRACK LIMITS
AUGUST 21–31
10% FIRST DETECTED
A
B
C
D
E
F
8.5 KT
9 KT
11 KT
12 KT
14 KT
16 KT
OVER 20 KT
9 KT–11 KT
60%
40%
35%
46%

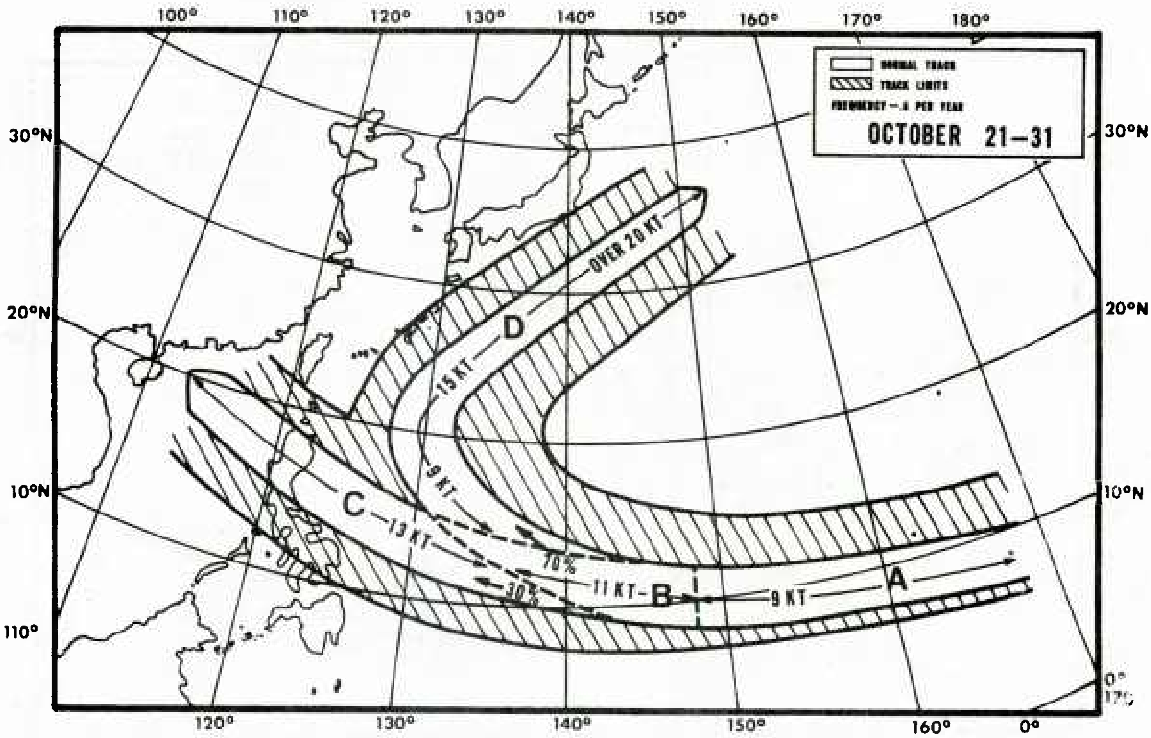

NORMAL TRACK
TRACK LIMITS
SEPTEMBER 1–10
10% FIRST DETECTED S. CHINA SEA
A
B
C
D
E
F
G
9 KT
10 KT
12 KT
13 KT
14 KT
15 KT
18 KT
40%
27%
33%
57%


SEPTEMBER 11–20
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
A
B
C
D
E
F
9 KT
15 KT
12 KT
14 KT
10 KT
11 KT
50%
60%
70%

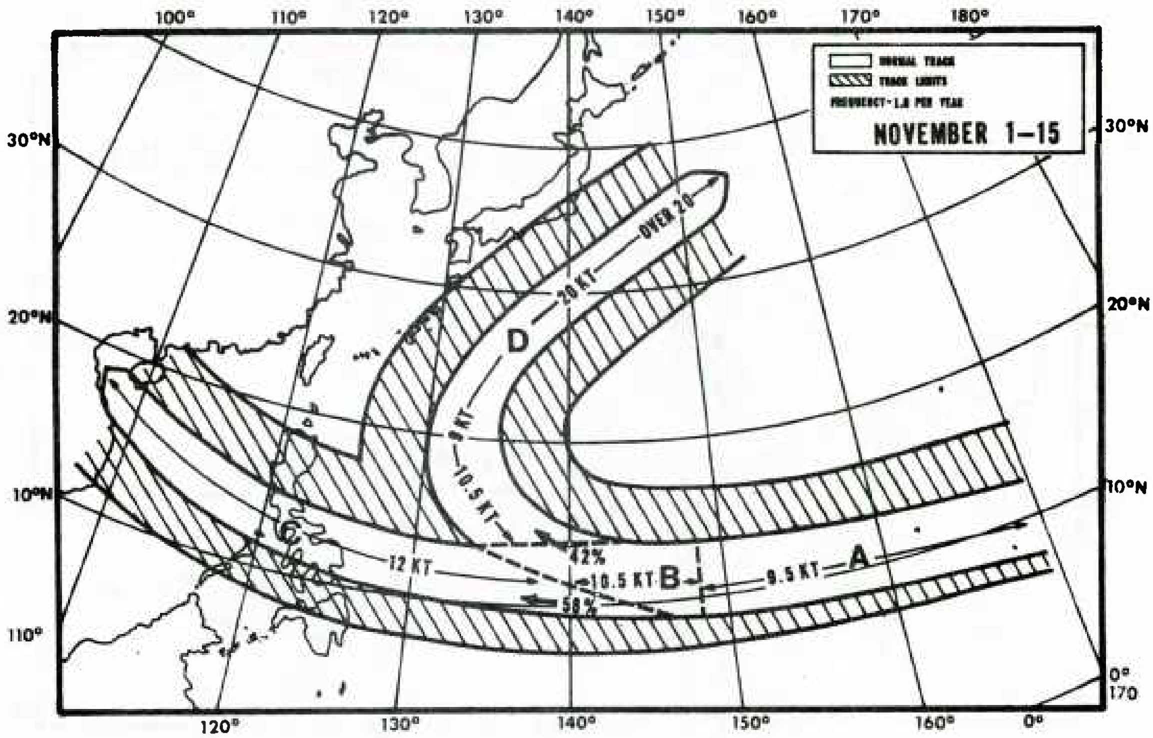

SEPTEMBER 21–30
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
A
B
C
D
E
F
G
OVER 20 KT
17 KT
13 KT
10 KT
9 KT
8 KT
12 KT
11KT
50%
30%
70%


OCTOBER 1–10
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
110°
0°
170
120°
130°
140°
150°
160°
0°
A
B
C
D
E
F
9 KT
10 KT
11.5 KT
12 KT
14 KT
OVER 20 KT
45%
55%
50%
50%

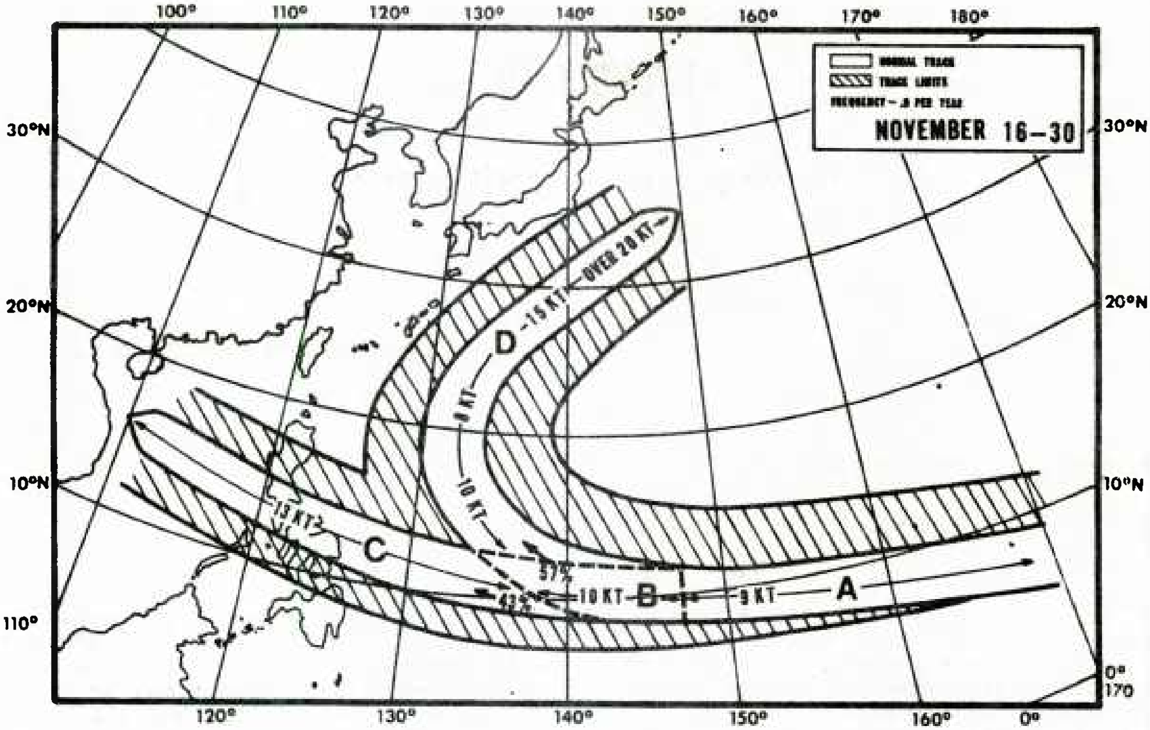

OCTOBER 11–20
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
110°
0°
170
120°
130°
140°
150°
160°
0°
A
B
C
D
E
F
9 KT
10 KT
10.5 KT
13 KT
15 KT
17 KT
OVER 20 KT
50%
50%
55%
35%

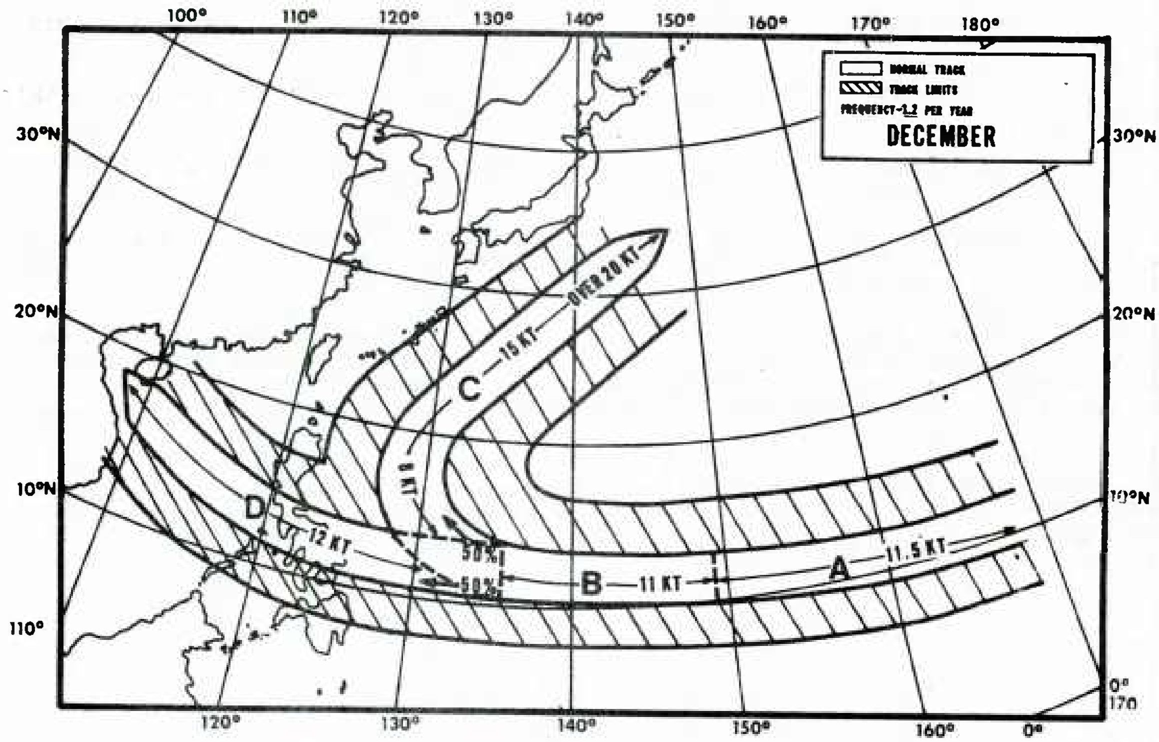


OCTOBER 21–31
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
110°
0°
OVER 20 KT
D
15 KT
9 KT
C
13 KT
70%
30%
11 KT
B
9 KT
A

NOVEMBER 1–15
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
110°
0°
170
OVER 20
20 KT
D
8 KT
10.5 KT
C
12 KT
42%
58%
10.5 KT
B
9.5 KT
A


NOVEMBER 16–30
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
0°
OVER 20 KT
15 KT
D
8 KT
10 KT
13 KT
C
57%
43%
10 KT
B
9 KT
A


NORMAL TRACK
TRACK LIMITS
FREQUENCY-1.2 PER YEAR
DECEMBER
100°
110°
120°
130°
140°
150°
160°
170°
180°
30°N
20°N
10°N
0°
OVER 20 KT
15 KT
C
8 KT
D
12 KT
50%
50%
B
11 KT
A
11.5 KT

# APPENDIX B

## HEAVY WEATHER PLAN AND INFORMATION FOR OKINAWA

SOPA OKINAWA INST 5000.1A

DESTRUCTIVE WIND WARNING

Weather

(1) Typhoon Conditions:

(a) Typhoon Condition One implies that destructive winds are anticipated within 12 hours and is divided into two phases: CAUTION, actual winds are 34 to 50 knots; EMERGENCY, actual winds are 50 knots or greater. Condition CAUTION means personnel at the discretion of the commanding officer may be secured in a duty status to their quarters. Condition EMERGENCY means all personnel will proceed and stay in their assigned typhoon shelters. All personnel are considered to be in a duty status.

(b) Condition Two implies that winds of 50 knots are possible within 24 hours.

(c) Condition Three implies that winds of 50 knots are possible within 48 hours.

(d) Condition Four implies that winds of 50 knots are a possible threat within 72 hours.

(2) General: Upon the setting of Typhoon Condition Three at Okinawa, Navy ships will prepare to get underway upon the direction of SOPA Okinawa or at the direction of the commanding officer.

(3) Information: The latest weather information may be obtained from the Navy Port Control Office, telephone 631-2244 and 632-2256 or from the Typhoon Command Post when activated upon the setting of Typhoon Condition Three, telephone 630-2298 or from CTF 76 Flag Command Center, telephone 631-2204 (when in port).

Note: The Naval Weather Service Environmental Detachment at Kadena has the latest "Typhoon Information Release" as received from Detachment 8, 20th Weather Squadron. The number is 634-4608.

DEPARTMENT OF THE NAVY
MILITARY SEALIFT COMMAND OFFICE
FPO SEATTLE 98770

MSCO/OKI/01
3140
14 August 1974

From: Commanding Officer, Military Sealift Command Office, Okinawa
To: Masters of MSC Interest Ships

Subj: Typhoon Evacuation Procedures at Okinawan Ports

Encl: (1) Listing of Typhoon Conditions & Definitions

1. Okinawa is presently under Typhoon Condition IV. Therefore, your ship could be required to get underway within 48 hours. It is imperative that you notify this office of any condition that could delay your sailing for more than 24 hours.

2. When Typhoon Condition III is set, you will be notified. You should prepare to get underway for storm evasion within the next 24 hours. As soon as practicable, you will be notified of the tentative sailing schedule to be followed upon the setting of Typhoon Condition II.

3. When Typhoon Condition II is set, you will be provided orders to sail within two hours in accordance with the schedule previously provided. At this time, also, a determination will be made as to whether you will proceed to your next port or sail for storm evasion. Prior to departure, you will be provided with all the latest storm information available.

4. When Typhoon Condition I is set, MSC Control will secure from 2825 KHZ, but emergency traffic to MSCO, Okinawa can be relayed by utilizing 2716 KHZ ("ADD-3" on west coast, "Port Control Buckner" on the east coast) or "JNB" on 500 KHZ CW.

5. If you sail for storm evasion and are to return to Okinawa, you will be contacted as soon as conditions permit, either by voice on 2825 KHZ or by message, notifying you that the port is open and requesting ETA. Approximately two hours prior to arrival, you should contact "MSC CONTROL" on 2825 KHZ for berthing instructions.

/s/ J. R. DOTHARD

Encl. (1) (from Disaster Preparedness summary CFAO/NAFKINST 3140.5 dated 23 May 1975)

TYPHOON AND DESTRUCTIVE WINDS
PRECAUTIONARY POLICIES AND PROCEDURES

a. Cyclone. A closed atmospheric circulation rotating about an area of low pressure (counterclockwise in the Northern Hemisphere).

b. Tropical Cyclone. A nonfrontal cyclone developing over tropical or subtropical waters having organized circulation and a warm core.

c. Typhoon/Hurricane. A tropical cyclone in which maximum sustained surface wind speeds are 64 knots or greater. West of 180° longitude, they are called typhoons and east of 180° longitude, they are called hurricanes.

d. Tropical Storm. A tropical cyclone with maximum sustained surface winds between 34 and 63 knots inclusive.

e. Tropical Depression. A tropical cyclone with maximum sustained surface winds of 33 knots or less.

f. Maximum Sustained Surface Wind. Highest surface wind speed of a cyclone averaged after a one minute period.

NOTE: Sudden temporary gusts may be of a substantially greater velocity, i.e., maximum sustained wind of 60 knots may include gusts of 85 knots.

g. Destructive Wind. Any tropical cyclone surface wind of 50 knots or greater, i.e., a momentary gust of 50 knots or greater.

Destructive Wind Conditions

a. The Commander, 18 TFWg is the sole declaring authority for all typhoon conditions. The following conditions alert US Forces Personnel to take necessary precautions to avoid injury and damage from destructive winds:

(1) Typhoon Condition 4 - Destructive winds possible within 72 hours.

(2) Typhoon Condition 3 - Destructive winds possible within 48 hours.

(3) Typhoon Condition 2 - Destructive winds anticipated within 24 hours.

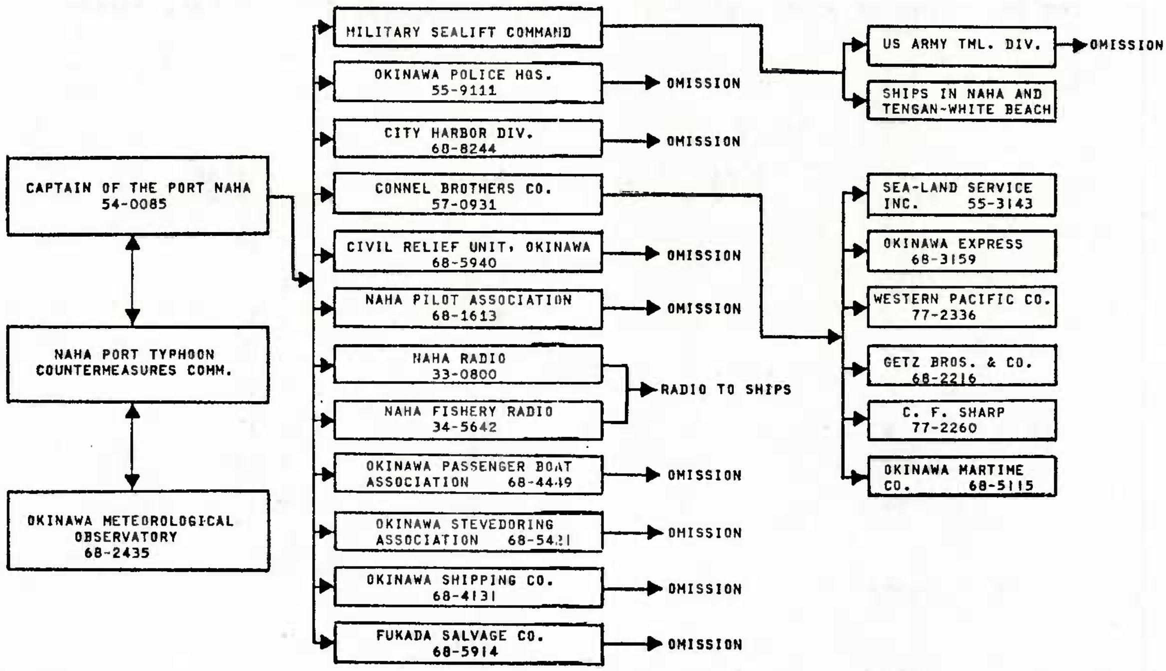
(4) Typhoon Condition 1 - Destructive winds anticipated within 12 hours.

(a) CAUTION - Actual wind is 34-49 knots.

(b) EMERGENCY - Actual wind is 50 knots or greater.

NOTE: Subcategories of Typhoon Condition 1 are normally declared based on actual peak velocity of the wind being experienced. However, the Commander, 18 TFWg may impose these conditions on the basis of factors other than wind velocity; e.g. existing and forecast precipitation, restrictions to visibility, road conditions, and darkness.

NAHA PORT TYPHOON INFORMATION NETWORK



# APPENDIX C

HARBOR FACILITIES AT NAHA HARBOR

The following is a list of piers and equipment available at Naha Harbor.

1. Piers

a. Military Piers

| Pier # | Depth (Ft) MLW | Length (Ft) | Pier Height Above MLW |
|---|---|---|---|
| 1 | 30 | 552 | 9'3" |
| 2 | 30 | 518 | 9'3" |
| 3 | 30 | 465 | 9'3" |
| 4 | 30 | 500 | 9'3" |
| 5 | 30 | 529 | 9'3" |
| 6 | 30 | 465 | 9'3" |
| 7 | 30 | 573 | 9'3" |
| 11 | 14 | 500 | 9'3" |

b. Commercial Piers

| Pier | Depth (Ft) MLW | Length (Ft) |
|---|---|---|
| A-D | Small craft only | |
| E | Not used | |
| F | 25 | 650 |
| G | 29 | 640 |
| H | 29 | 580 |
| I | 30 | 225 |
| J-L | Small craft basin | |

2. Tug Boats

The following commercial tugs are available through COMFLEACTS, Okinawa:

| | | |
|---|---|---|
| ONE | 2,600 hp | DIESEL |
| ONE | 2,400 hp | DIESEL |
| TWO | 1,900 hp | DIESEL |
| ONE | 750 hp | DIESEL |
| ONE | 210 hp | DIESEL |

3. Miscellaneous Equipment

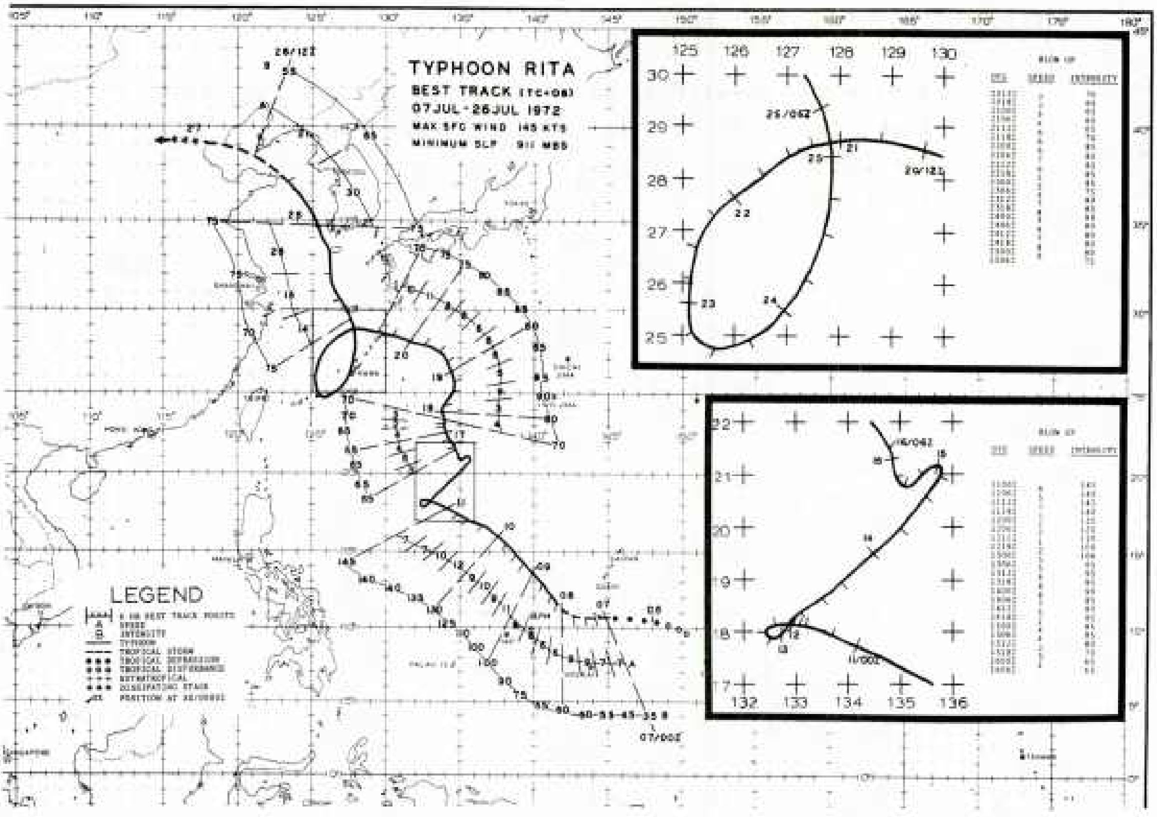
Arrangements may be made through COMFLEACTS, Okinawa for the following U.S. Army equipment:

Mobile and Crawler cranes from 20 to 40 tons capacity
Forklifts of 4000 lb to 15,000 lb capacity
ONE LCM
ONE LCU

# APPENDIX D

BEST TRACK OF TYPHOON RITA
(7-26 JULY 1972)

A best-track chart of Typhoon Rita in July of 1972 is presented in the below figure. The "loop" taken by Rita in the vicinity of Okinawa demonstrates the erratic behavior that may be observed in the movement of some tropical cyclones. The track of Rita emphasizes the need for continuous monitoring of tropical cyclone warnings and position reports.



# APPENDIX E

## CHARTS OF ENGINE SPEED VS WIND VELOCITY AND SHIP SPEED VS SEA STATE

Figure E-1 shows the engine speed required to offset selected wind velocities for various ship types (computed for normal loading conditions).

Figure E-2 represents the estimated resultant speed of advance of a ship in a given sea condition. The original relationships were based on data of speed versus sea state obtained from studies of many ships by James, 1957. They should not be regarded as truly representative of any particular ship (Nagle, 1972).

For example, from Figure E-2(a), for a ship making 15 kt encountering waves of 16 ft approaching from 030° (relative to the ship's heading) one can expect the speed of advance to be slowed to about 9 kt. Twenty feet seas, under the same conditions, would result in a speed of advance of slightly less than 6 kt. However, it is emphasized that these figures are averages and the true values will vary slightly from ship to ship.

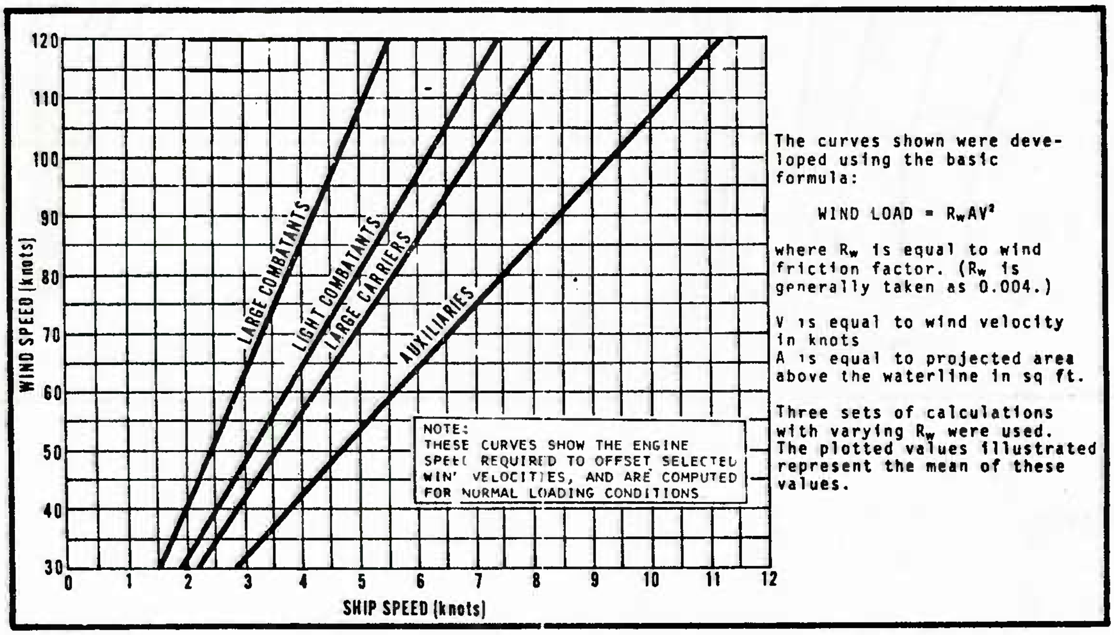



Figure E-1. Engine speed vs velocity for offsetting force of wind (from Crenshaw, 1965).

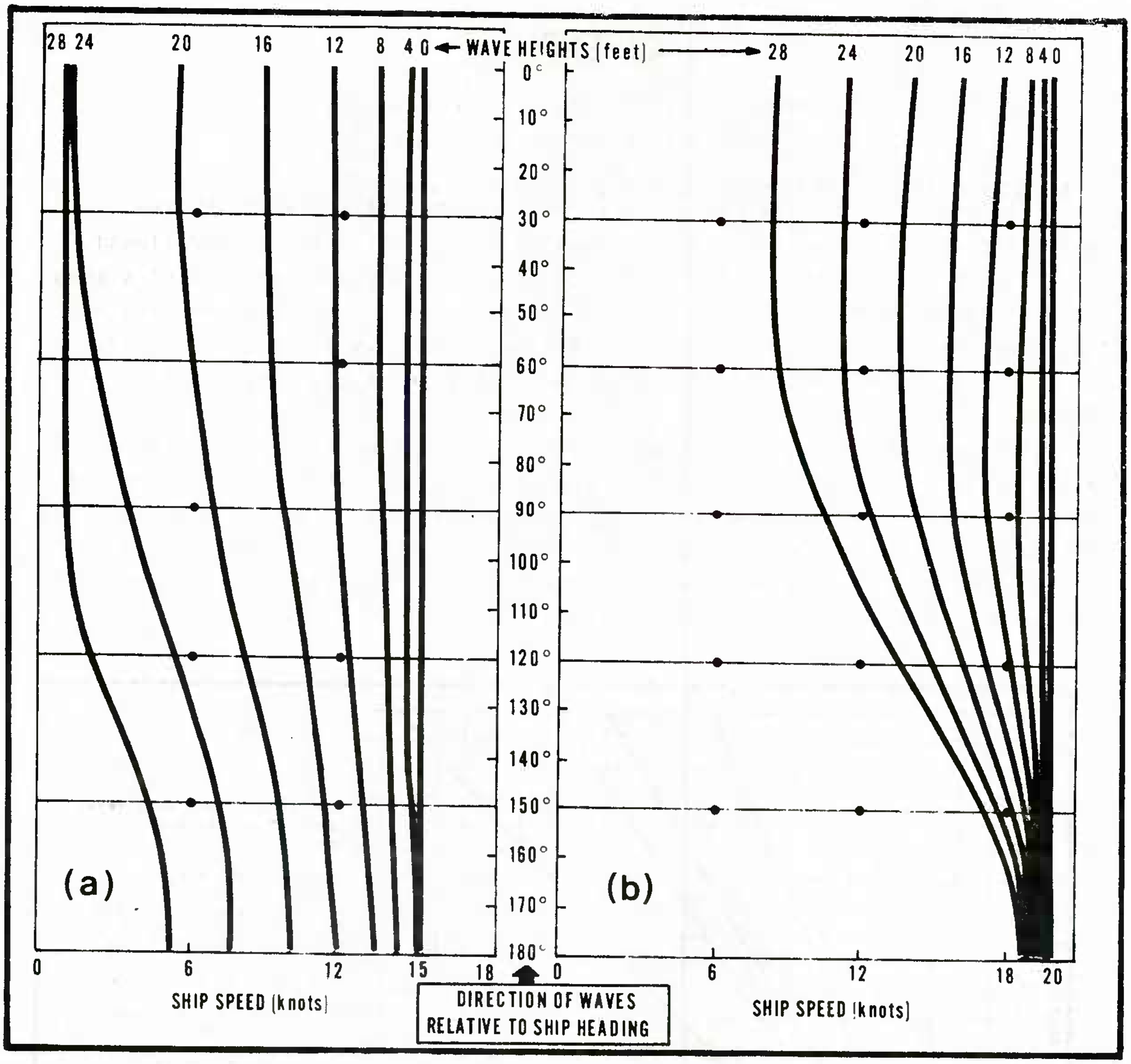



Figure E-2. Expected ship speed as a function of wave height and wave direction relative to ship's heading for (a) a ship making 15 kt and (b) a ship making 20 kt (from Nagle, 1972).

NEPERF