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A COMPILATION OF EASTERN AND CENTRAL NORTH PACIFIC TROPICAL CYCLONE DATA

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ABSTRACT. A collection of data concerning tropical cyclones in the Eastern and Central North Pacific Oceans has been compiled at the National Hurricane Center. This data set consists of dates, tracks, maximum sustained wind speeds (as available), and limited central pressure values of tropical cyclones occurring from 1949 to 1980. Sources, characteristics, and format of these data are discussed.

1. INTRODUCTION

The Research and Development Unit at the National Hurricane Center (NHC), located in Coral Gables, Florida, has developed and operationally implemented several techniques for prediction of tropical cyclone motion in the Eastern North Pacific Ocean. Among these are EPCLPR and EPANLG (Neumann and Leftwich, 1977) and EPHC77 (Leftwich and Neumann, 1977). Development of these statistically-based models required knowledge of historical tropical cyclone tracks. Accordingly, available data were compiled and stored on a magnetic tape for processing by electronic computer. Information concerning storm tracks in the Central North Pacific has recently been added to the data set. This report describes the sources and storage format and illustrates uses of these data. As an aid to the reader, technical terminology used throughout this report is defined in Appendix I.

For the 32-year period, 1949 through 1980, 369 cyclones are documented in the Eastern and Central North Pacific Oceans. Tracks of these storms are shown in Figure 1. The Eastern North Pacific (ENP) extends from the coasts of the United States, Mexico, and Central America westward to 140° west longitude and from approximately 5° to 35° north latitude. The Central North Pacific (CNP) is an extension of this area to 180° west longitude.

2. DATA SOURCES

An earlier study by Crutcher and Quayle (1974) indicated the lack of long-term records of tropical cyclones in the North Pacific Ocean east of 180°W. The period of available data (1949-71) was by far the shortest period

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[1] *Current affiliation: Student, Pennsylvania State University.*

[2] *Study partially supported by NOAA/ERL-AOML-National Hurricane Research Laboratory (NHRL).*

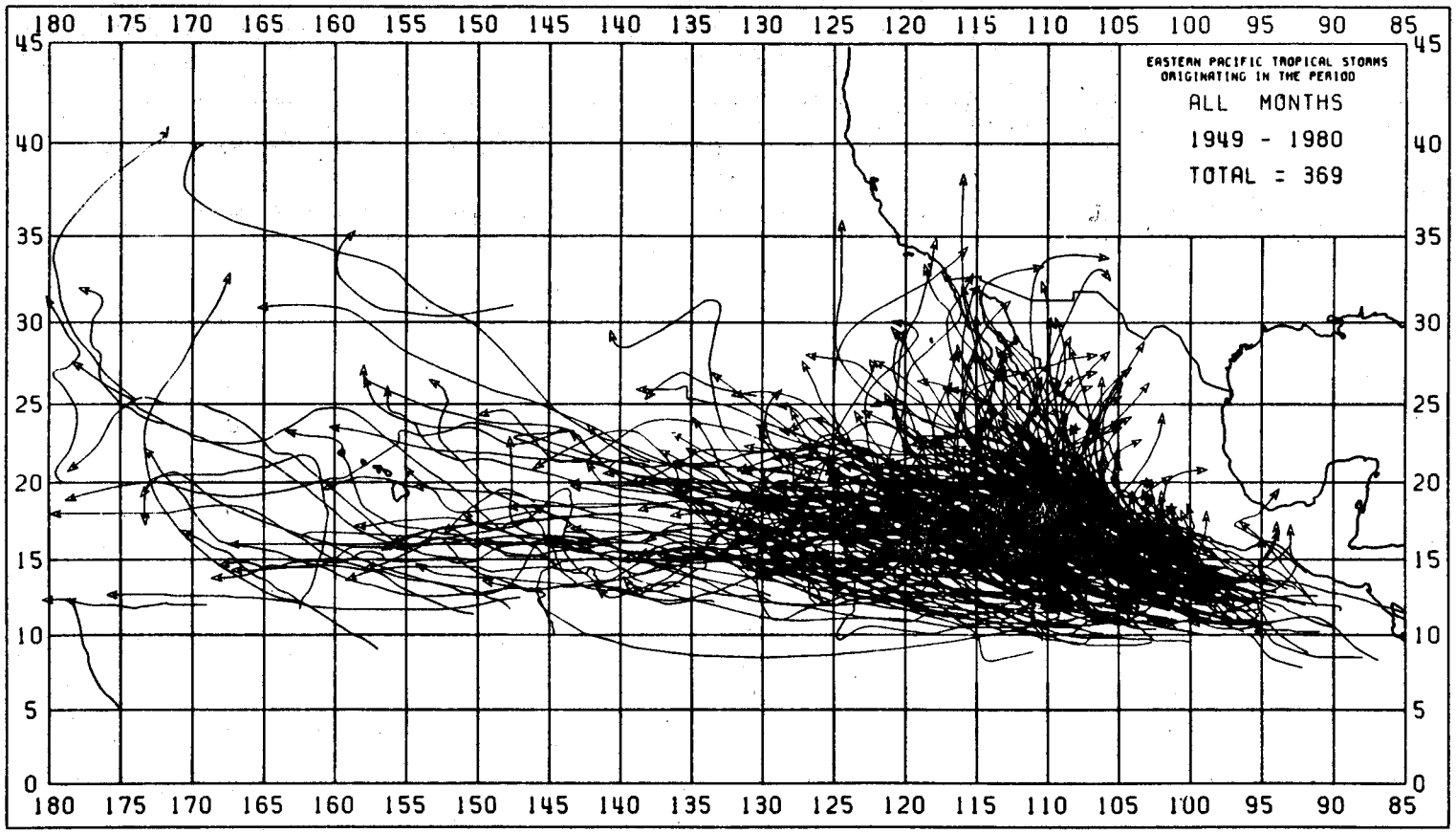

Figure 1. Composite computer plot of all 369 tropical cyclones included in the data set.

of record for any of the six recognized tropical cyclone basins around the world. Before the advent of meteorological satellites, which came into daily operational use in 1965, data on ENP and CNP tropical cyclones were limited to chance encounters of ships at sea, rare passages of storms over land stations, and infrequent aerial reconnaissance. The greatest number of reports was received from ships at sea. Generally, these ships were travelling in the periphery of a storm's circulation, so the distance to the storm center was unknown. As warnings became better, even fewer ships encountered storms. Aerial reconnaissance was confined to periods when a storm was threatening land. Undoubtedly, some storms were never detected.

The first location by satellite of a storm in the ENP was made by TIROS III on July 19, 1961 (Mull, 1962). Subsequent operational satellite coverage supplemented wind data and greatly increased the capability for detection and tracking of storms. The importance of satellites for detecting tropical cyclones in the ENP and CNP is supported by the increase in the mean number of observed tropical cyclones per year from 8.6 for 1949-64 to 14.5 for 1965-80.

The original impetus for compilation of these storm tracks was the statistical model, EPCLPR. Development of the model required tracks of past cyclones as a statistical base for its prediction equations. Under sponsorship of the United States Navy in 1971, the National Climatic Center revised and reissued its data as Tropical Cyclone Data Card Deck 993. These and additional storm tracks for the period 1949-75 were acquired from the U.S. Navy located in Monterey, California. Initially, storm positions were given at 12-hour intervals. Interpolations of these positions to 6-hour intervals were made by use of a scheme devised by Akima (1970), with some subjective modifications. Since 1976, storm positions, at 6-hourly intervals, have been obtained directly from the Eastern Pacific Hurricane Center (EPHC) located in Redwood City, California.

Criteria for constructing the tracks were based on the concept of the "best track." Through a process of careful post-analysis of all accessible sources of information including aircraft reconnaissance fixes, ship reports, advisories issued by EPHC, satellite data, and original operational tracks, these positions were subjectively smoothed. Resultant 6-hourly positions provided a reasonable rendition of actual continuous storm tracks.

Smoothing is performed for two reasons. First, small-scale oscillatory (trochoidal) motions of a storm's center are transitory in nature and not representative of the more conservative motion of the entire storm system. Recent evidence of such motion based on satellite imagery of Hurricane Belle (1976), in the Atlantic Ocean, is documented by Lawrence and Mayfield (1977). Actual errors in positioning tropical cyclones are a second consideration (Neumann, 1975; Sheets and Grieman, 1975). All data sources are subject to this problem whether it results from poor positioning of a satellite picture grid or navigational errors experienced by ships and aircraft. In all cases, therefore, 6-hourly positions represent large-scale motion, rather than precise locations of the eye.

Where possible, tracks have been extended to include land positions once a storm crossed a coastline. Rapid dissipation along the mountainous west

coast of the North American continent usually occurs, making storms difficul to track. Therefore extrapolations of earlier storm motions were performed with the aid of synoptic weather maps and satellite pictures. Extended stor are identified by an X in the last position of the title card (see Data Formats below). An X also precedes each position of extension.

In 1980, thorough review of the storm tracks was made by Arnold Court unde contract[3] from the National Weather Service. His work concentrated on extensions of tracks inland and resulted in additions and/or modifications to 81 storm tracks in the original data set. A final review, including checks for consistency as well as errors, was made once the data had been placed in a computer card deck.

3. CENTRAL NORTH PACIFIC STORMS

The majority of information concerning storms in the CNP was extracted from Shaw (1981). Although Shaw gathered information concerning storms as far back as 1832, only data from 1949 to 1980 were included in this data set. Systems which failed to attain at least tropical storm strength east of 180° west longitude were excluded. Those that attained at least minimum tropical storm strength and continued west of 180° were included through their dissipation stages. Additional information was obtained from a few editions of the Annual Typhoon Report of the Joint Typhoon Warning Center (JTWC) in Guam. Several CNP storms for which only one position was available were excluded because data for at least 12 hours are required in the development of statistical prediction models. Storms that traversed the CNP, whether they originated in the ENP or CNP, are denoted by W (WW if they went west of 180°) on the title card.

4. DATA FORMATS

All storms are listed in chronological order according to their first recorded day. Names are in alphabetical sequence except where CNP storms appear since they follow a separate naming system. The general format established for these data is also documented by Jarvinen and Caso (1978) for Atlantic Ocean tropical cyclone data. New data are added at the end of each successive tropical cyclone season.

The master card deck used to generate the computer tape consists of three types of cards: title, data, and classification. For each storm there is one title card which contains all identifying information. First is the sequence number for easy cataloging of the cards. The month, day (first recorded day of the storm), and year follow in that order. The next three integer quantities refer to the number of days the storm existed, the storm number for that year, and the cumulative storm number, where the first storm in 1949 is 1 and the last storm as of 1980 is 369. The following item, number 8, is the storm name. Before the naming of tropical cyclones in the ENP in 1960, a "NOT NAMED" message fills the space. Note that all CNP storms are named, even those as early as 1950. The final

[3] *Contract NA-79WD-C-00006.*

integer value is a land crossing index. This is either zero (0), indicating that the storm did not affect land, or one (1), indicating that it did. A storm is defined to have affected land if it came within approximately 50 nautical miles or crossed the coastline of the United States, Mexico, Central America, or the Hawaiian Islands. An index denoting CNP or extended storms is added to the title card when it is appropriate. These indices are listed in Table 1A.

The title card is followed by one or more data cards, one for each day of the storm's existence. Each contains four sets of values corresponding to the times 0000, 0600, 1200, and 1800 GMT. Included in each set are the

Table 1. Eastern and Central North Pacific Storm Data Notations

A. Indices for Columns 79-80 of the Title Card

W	Storm observed in the CNP
WW	CNP storm that travelled west of 180°W
X	Extended track

B. Sources of Wind Speed and Central Pressure Data

A	Advisories issued by the EPHC
C	Climatological National Data Summary
M	Ship report
R	Aircraft reconnaissance
S	Satellite estimate
E	Subjective estimate based on synoptic data
-	Estimate derived from archived storm track maps in Mariners Weather Log or Monthly Weather Review

Dotted lines (tropical depression) = 25 knots
Dashed lines (tropical storm) = 45 knots
Solid lines (hurricane) = 75 knots

( )	A blank preceding an entry denotes a value which accompanied "best tracks" received from the EPHC or the Central Pacific Hurricane Center (CPHC), Honolulu.
N	National Climatic Center data files

storm position (latitude and longitude[4], both to nearest tenth of a degree), maximum sustained wind speed, and the central pressure. A notation in the space to the left of a wind speed or pressure value indicates its source. These notations are listed in Table 1B.

The classification card's purpose is to classify the maximum intensity of the storm. This index is either TS (tropical storm) or HR (hurricane).

Tables 2 through 4 indicate the exact location of each parameter on the three types of cards. Computer cards for Liza, 1976, and an unnamed storm, 1951, are illustrated in Figure 2. Note the lack of wind data at each 6-h position for the 1951 storm. Cards such as these were transferred to tape in card image, 80-byte records. A short FORTRAN program which may be used to access data from the magnetic tape is given in Appendix II.

5. WIND SPEEDS

When data were available, wind speeds were assigned to corresponding storm positions. Wind values throughout this data set are subjective estimates of the maximum surface wind which ordinarily occurs at the eye wall. These values are specified in knots, rounded to the nearest 5-knot value. For example, 67 knots become 65 knots while 68 knots become 70 knots. By definition, these winds represent 1-minute averages rather than peak gusts; however, because of the subjective nature of estimates based on fragmented information available to forecasters, this definition implies a precision which never exists. Discussions concerning relationships of gusts to average winds in tropical cyclones may be found in papers by Dunn and Miller (1964), pp. 61-67; Padya (1975); and Atkinson and Holliday (1977).

For many years ship observations were the primary source of wind data over the ocean. Mariners favor state-of-the-sea determination via the Beaufort scale (U.S. Navy Oceanographic Office, 1966) because it is a one-step method. However, over the past 30 years some ships have been equipped with anemometers. A study by Shinners (1963) found that anemometer versus state-of-the-sea-measured winds were (1) lower up to about 20 knots, (2) approximately the same from 20 to 30 knots, and (3) greater above 30 knots. In essence, state-of-the-sea measured winds are underestimates of the actual wind at higher speeds.

The first wind data from aircraft reconnaissance in the ENP were obtained in 1956. Although aircraft reconnaissance measures the flight-level winds anywhere from 500 to 10,000 feet, the surface winds are subjective estimates based upon observation of the sea state and/or tables relating flight-level winds to surface winds.

Development of techniques to determine wind speed from the shape of the cloud field, as depicted in satellite pictures, by Dvorak (1973 and 1975), and Hebert and Poteat (1975), has tremendously increased credibility of wind estimates in recent years. Satellite imagery is now the major source of data in all tropical cyclone basins.

[4]*Degrees of longitude west of 180° are added to 180°, e.g., 160°E = 200°W.*

Table 2. Title Card - Format and Contents

Computer Card Columns	Contents
1 - 5	Card sequence number
7 - 8	Month
10 - 11	Day (first recorded day of the storm)
13 - 16	Year
20 - 21	Value of M (M = number of days storm existed)
23 - 24	Storm number for that year
31 - 34	Cumulative storm number
36 - 46	Storm name
47 - 52	Land crossing index
79 - 80	Central North Pacific or extended storm index

Table 3. Storm Data Card - Format and Contents

Computer Card Columns	Contents
1 - 5	Card sequence number
7 - 8	Month
10 - 11	Day
13 - 15	Latitude at 0000Z
17 - 19	Longitude at 0000Z
21 - 23	Wind speed at 0000Z
25 - 28	Central pressure at 0000Z
30 - 32	Latitude at 0600Z
34 - 36	Longitude at 0600Z
38 - 40	Wind speed at 0600Z
42 - 45	Central pressure at 0600Z
47 - 49	Latitude at 1200Z
51 - 53	Longitude at 1200Z
55 - 57	Wind speed at 1200Z
59 - 62	Central pressure at 1200Z
64 - 66	Latitude at 1800Z
68 - 70	Longitude at 1800Z
72 - 74	Wind speed at 1800Z
76 - 79	Central pressure at 1800Z
20,24,37,41,54,58,71,75	Source notations as given in Table 1

Table 4. Classification Card - Format and Contents

Computer Card Columns	Contents
1 - 5	Card sequence number
7 - 8	Maximum strength of storm

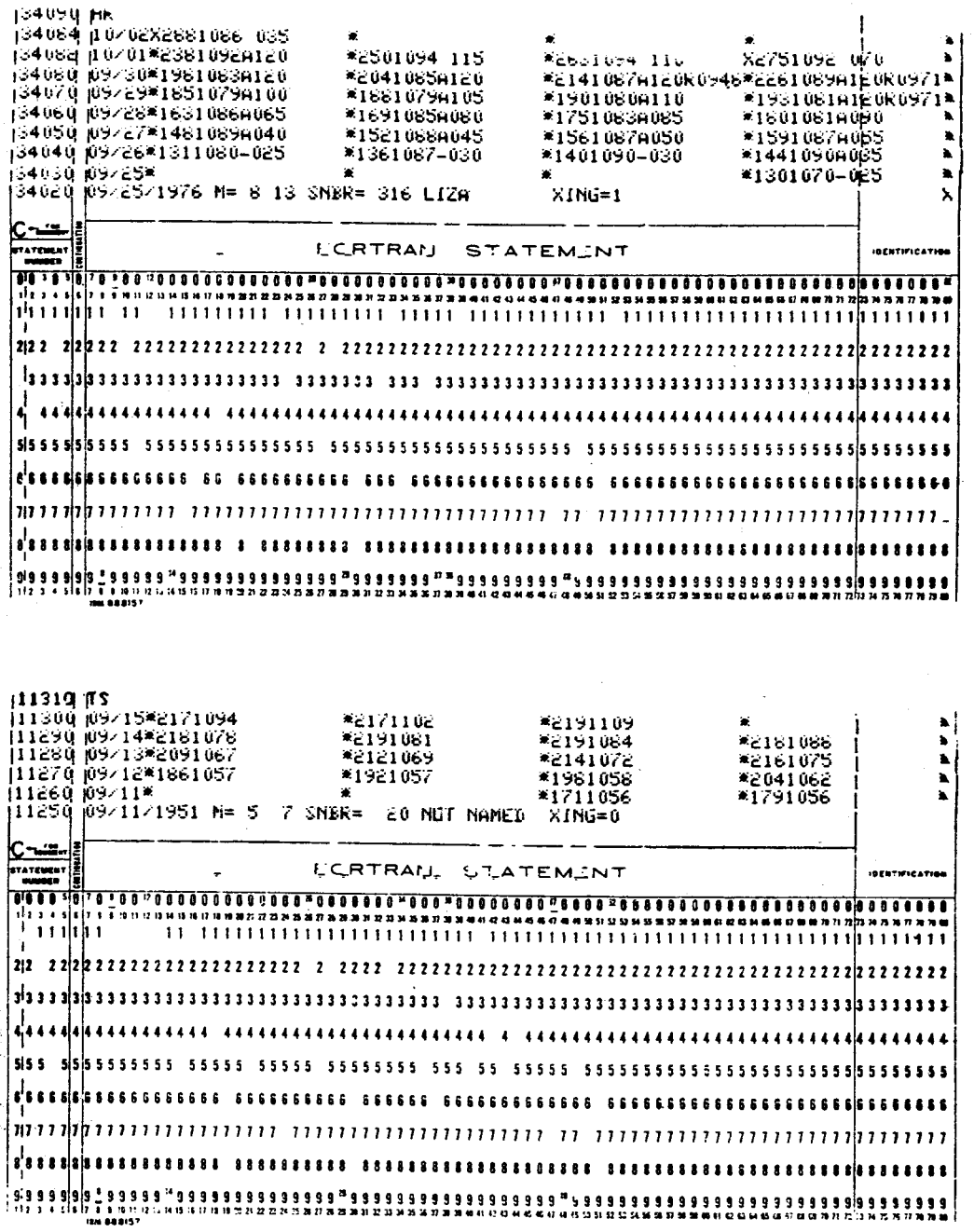

Figure 2. Computer cards for a) Hurricane Liza and b) unnamed cyclone, 1951.

Classifications (TS or HR) of storms prior to 1954 are from National Climatic Center data files. The quantity of wind speed data greatly increased in 1965 with documentation of intensity at various stages of the tracks by Mariners Weather Log (MWL) and later Monthly Weather Review (MWR). As a result, it was possible to distinguish depression stages of both formative and dissipative periods. A small quantity of wind speeds was found in the Climatological National Data Summary, but most data were estimated from MWL and MWR or taken from official advisories issued by the EPHC. Because of the extreme subjective nature of wind speed estimates, the user is cautioned not to make overly precise interpretations of these values.

6. CENTRAL PRESSURES

Central pressures of tropical cyclones are observed values specified in millibars. This parameter is a much more conservative property than the wind field. Aircraft reconnaissance reports were virtually the only source of these data. Generally, reconnaissance aircraft flew only if a storm threatened land (the west coast of the United States or the Hawaiian Islands). Some reports were received from ships and land stations. EPHC advisories and satellite pictures provided limited information as well. Therefore pressure data, particularly in the earlier years, are often missing.

7. APPLICATIONS OF THE DATA

Copies of the magnetic tape containing compiled data are available at the National Climatic Center in Asheville, North Carolina[5]. The data can be conveniently accessed via computer programs such as the one given in Appendix II. Attributes of the user's tapes must be specified in order to facilitate easy access. Pertinent information can then be extracted and displayed for interpretation or presentation as shown in Figures 3 and 4 and Table 5. Additional examples of graphical displays are presented in Leftwich and Brown (1981).

Figure 3 is the annual frequency of ENP storms for the period 1949-80. A total of 351 tropical cyclones includes 187 tropical storms and 164 hurricanes. Storms that formed in the CNP are not included here. This plot displays variations in storm frequency and relative frequencies of hurricanes versus tropical storms. The sparsity of data prior to 1965 is reflected in reduced frequencies during the earlier years of record.

As an aid in development of local tropical cyclone climatologies, a computer program can select storms passing within a specified distance of a particular point of interest. Figure 4 depicts tracks of tropical cyclones passing within 200 nmi of Honolulu, Hawaii. Other pertinent facts related to the selected storms can be derived from the data and listed as shown in Table 5.

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[5]*National Climatic Center, NOAA, Environmental Data and Information Service, Federal Building, Asheville, NC 28801.*

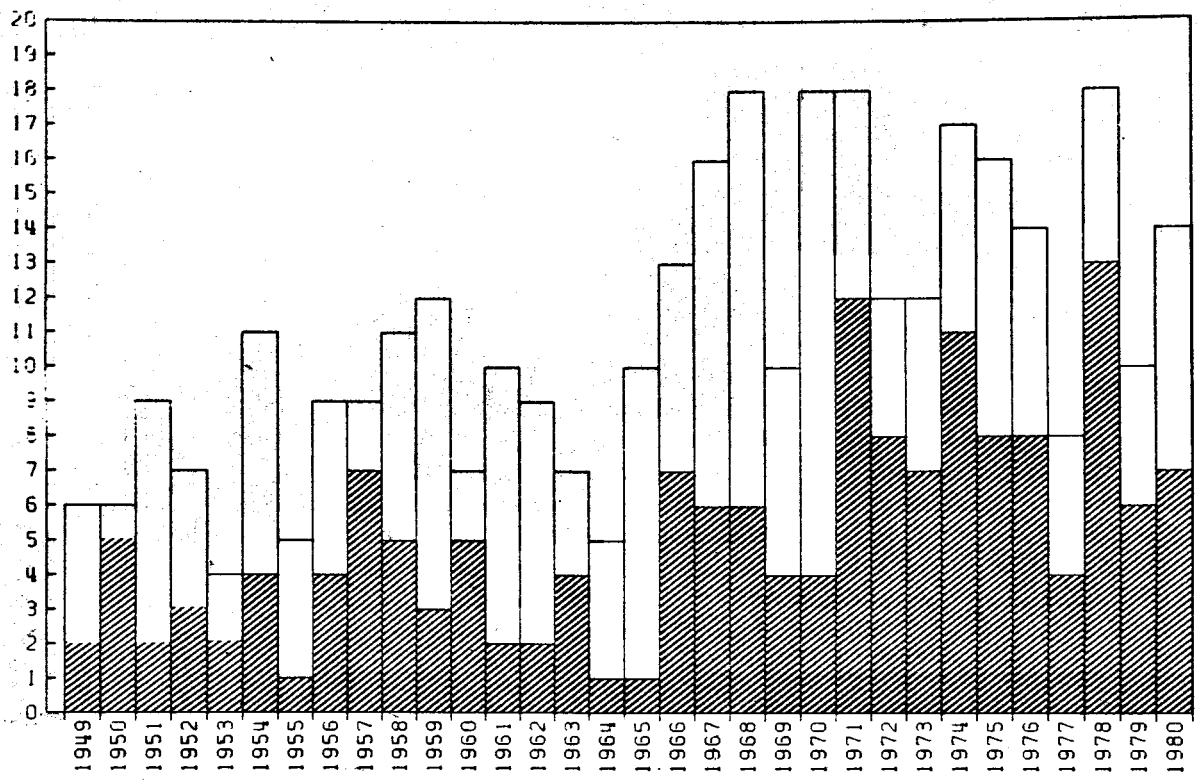

Figure 3. Annual frequency from 1949 to 1980 of 351 documented Eastern North Pacific tropical cyclones that reached at least tropical storm strength (open bar) of which there were 164 that reached hurricane strength (shaded bar).

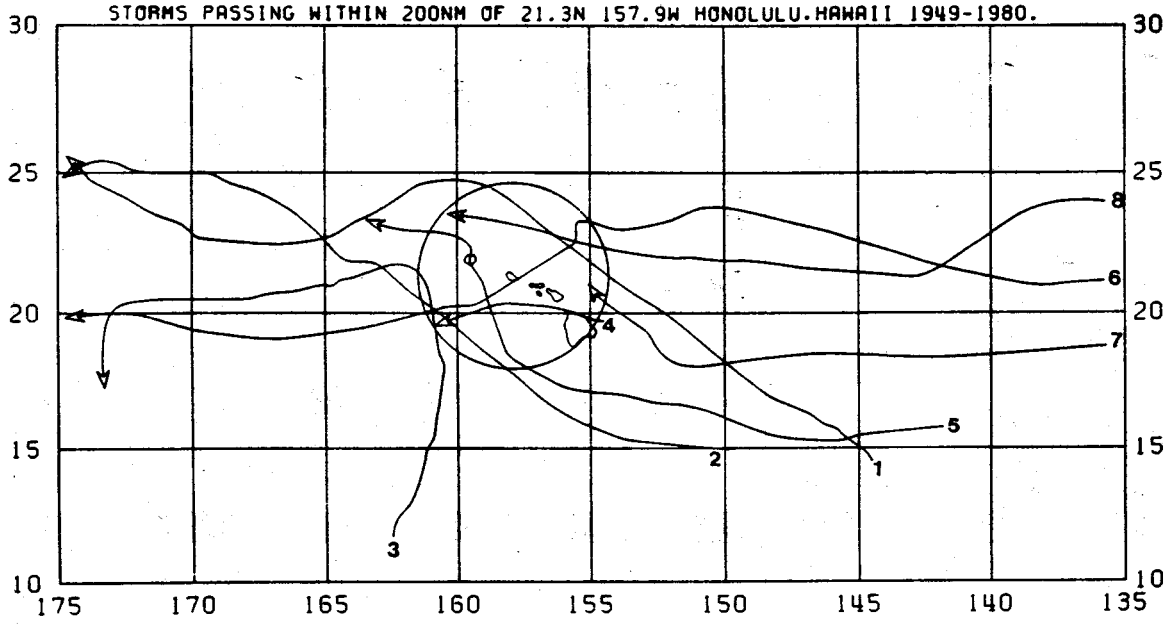

Figure 4. Plotted tracks of tropical cyclones listed in Table 5.

Table 5. Storms passing within 200 nmi of Honolulu, Hawaii, 1949-80.

ip dex	Starting Date	Storm Name	Closest Point of Approach (CPA)		Date at CPA	Distance at CPA (nmi)	Maximum Intensity	Intensity at CPA
	8/12/1950	HIKI	23.0N	156.6W	8/16	125	X	H
	9/01/1957	DELLA	19.4N	159.9W	9/03	161	X	T
	11/29/1957	NINA	20.6N	161.0W	12/02	181	X	H
	8/07/1958	NOT NAMED	20.3N	158.0W	8/08	58	T	D
	8/02/1959	DOT	21.0N	159.0W	8/07	64	X	H
	9/12/1963	IRAH	21.1N	157.8W	9/18	9	T	D
	8/11/1972	DIANA	20.7N	154.8W	8/20	177	X	T
	8/05/1976	GWEN	23.1N	157.5W	8/17	111	T	D

All information contained in this data set must be regarded as general estimates of the particular parameters rather than as precise measurements. Accordingly, users are cautioned to avoid formulation of overly precise conclusions from applications of these tropical cyclone data.

8. SUMMARY

Development of statistically-based tropical cyclone prediction models requires historical data including dates, tracks, maximum sustained wind speeds, and central pressures. Such information for tropical cyclones in the Eastern and Central North Pacific during the period 1949-80 has been compiled at the National Hurricane Center. Pre-1965 data are extremely limited; however, the advent of operational satellite coverage in 1965 greatly increased observational capabilities. Compiled data have been stored on computer cards and magnetic tape. Both sources are readily accessible via electronic computer. Data from succeeding tropical cyclone seasons will be added to the current data set.

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APPENDIX I. TERMINOLOGY

GMT: Greenwich Mean Time. Also called "Z" or Zulu time. Mean solar time of the meridian at Greenwich, England, used as the basis for standard time throughout the world.

HURRICANE: A tropical cyclone of which the center (eye) is the warmest area (warm-core) and in which the maximum sustained surface wind (1-min mean) is $\geq$ 64 kt (119 km/h).

KNOT (kt): A unit of speed equal to 1 nautical mi/h. One nautical mi/h is equivalent to 1.1508 statute mi/h or 0.5144 m/s.

MILLIBAR (mb): A pressure unit of 1000 dyne/cm^2, convenient for reporting atmospheric pressures. The average sea-level surface pressure is 1013.2 mb.

TROPICAL CYCLONE: A nonfrontal low pressure system developing over tropical or subtropical waters and having a closed circulation of winds rotating counterclockwise in the Northern Hemisphere (clockwise in the Southern Hemisphere). This term encompasses tropical depressions, tropical storms, and hurricanes.

TROPICAL DEPRESSION: A tropical cyclone in which the maximum sustained surface wind is $\leq$ 33 kt (61 km/h).

TROPICAL STORM: A tropical cyclone of which the center is the warmest area (warm-core) and in which the maximum sustained surface wind ranges from 34 to 63 kt (63 to 117 km/h).

APPENDIX II. A SAMPLE FORTRAN PROGRAM TO READ AND WRITE DATA

```
      DIMENSION REC(20)
C  THIS PROGRAM ASSUMES THAT THE DATA TAPE IS MOUNTED ON
C  UNIT 3 AND THAT THE LINE PRINTER IS UNIT 6.
      REWIND 3
C  INITIALIZE RECORD COUNTER.
      NRECS = 0
    5 CONTINUE
C  READ ONE RECORD AT A TIME.
      READ(3,10,END=30) REC
C  'END=30' STOPS READING OF TAPE AT 'END OF FILE' (EOF).
   10 FORMAT(20A4)
C  COUNT RECORDS.
      NRECS = NRECS + 1
C  PRINT DATA IN EACH RECORD.
      WRITE(6,15) REC
   15 FORMAT(10X,20A4)
      GO TO 5
   30 CONTINUE
      WRITE(6,35) NRECS
   35 FORMAT(35X, 19HNUMBER OF RECORDS =, I6)
      REWIND 3
      STOP
      END
```