NOAA Technical Memorandum NWS NHC 6

A TROPICAL CYCLONE DATA TAPE FOR THE NORTH ATLANTIC BASIN, 1886-1977: CONTENTS, LIMITATIONS, AND USES

Brian R. Jarvinen and Eduardo L. Caso
NHC, Miami, Florida

National Hurricane Center
Miami, Florida
June 1978

UNITED STATES
DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Richard A. Frank, Administrator

National Weather
Service
George P. Cressman, Director

CONTENTS

DEFINITIONS

Cyclone: An atmospheric closed-circulation rotating counterclockwise in the Northern Hemisphere.

Extratropical Stage: In tropical meteorology this refers to the period of time in which a tropical cyclone transforms from a warm core system to a cold core system. This process usually occurs poleward of the belt of tropical easterlies.

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

Hurricane: A warm-core tropical cyclone in which the maximum sustained surface wind (1-min mean) is $\geq$ 64 kt.

Knot: The unit of speed on the nautical system; 1 n.mi. h^{-1} It is equal to 1.1508 mi h^{-1} or 0.5144 m s^{-1}.

Millibar: A pressure unit of 1000 dyn cm^{-2} convenient for reporting atmospheric pressures.

Subtropical Cyclones: Nonfrontal, low pressure systems that comprise initially baroclinic circulations developing over subtropical waters. There are two types: (1) A cold low with circulation extending to the surface layer and maximum sustained winds generally occurring at a radius of about 100 mi or more from the pressure center. These cyclones sometimes undergo a metamorphosis and become tropical storms or hurricanes. (2) A mesoscale cyclone originating in or near a frontolyzing zone of horizontal wind shear, with radius of maximum sustained winds generally less than 30 mi. The entire circulation sometimes encompasses an area initially no more than 100 mi in diameter. These marine cyclones may change in structure from cold to warm core. While generally short-lived, they may ultimately evolve into major hurricanes or into extra-tropical cyclones.

Subtropical cyclones are classed according to intensity as follows:

a. Subtropical Depression: A subtropical cyclone in which the maximum sustained surface wind (1-min mean) is $\leq$ 33 kt.
b. Subtropical Storm: A subtropical cyclone in which the maximum sustained surface wind (1-min mean) is $\geq$ 34 kt.

Tropical Cyclone: A nonfrontal low pressure system of synoptic scale developing over tropical or subtropical waters and having definite organized circulation.

Tropical Depression: A tropical cyclone in which the maximum sustained surface wind (1-min mean) is $\leq$ 33 kt.

Tropical Storm: A warm-core tropical cyclone in which the maximum sustained surface wind (1-min mean) ranges from 34 to 63 kt.

A TROPICAL CYCLONE DATA TAPE FOR THE NORTH ATLANTIC BASIN,[1] 1886-1977: CONTENTS, LIMITATIONS, AND USES

Brian R. Jarvinen and Eduardo L. Caso[2]
NWS, National Hurricane Center, Miami, Florida

ABSTRACT

The National Hurricane Center has recently compiled a magnetic tape on North Atlantic tropical cyclones. The tape contains the dates, tracks, wind speeds, and central pressure values (if available) for all tropical cyclones occurring over the 92-year period, 1886 through 1977. The data organization, format, and limitations are discussed and several uses of the data are demonstrated.

1. INTRODUCTION

The National Hurricane Center (NHC) is essentially a forecasting, rather than a data collecting, agency of NOAA. However, pursuant to its operational responsibility in the detection, tracking, and forecasting of tropical cyclones, and its additional responsibility in the applied research and public service area, the Center maintains detailed computer files on North Atlantic tropical storms and hurricanes. This report describes the content, format, limitations, and uses of the data, hereafter referred to as the HURDAT (HURricane DATa) data set.

2. BACKGROUND OF DATA SET

The initial requirement for computerized tropical cyclone data at NHC can be traced to a requirement of the NASA Space Program in the mid-1960's. At the request of Space Program officials, Hope and Neumann (1968) of the Spaceflight Meteorology Group, formerly collocated with the National Hurricane Center, studied the climatological impact of tropical cyclones on the launches of space vehicles from the Kennedy Space Center. An extension to the authors' studies led to the operational HURRAN (HURRicane ANalog) program (Hope and Neumann, 1970) for the prediction of tropical cyclone motion out through 72 hr.

Originally, Hope and Neumann based their studies on a now obsolete card deck 988 (CD 988) obtained from the National Climatic Center.

---

[1]The North Atlantic tropical cyclone basin includes most of the North Atlantic, Gulf of Mexico, Caribbean Sea, and adjacent land areas.

[2]Present affiliation, student, University of Wisconsin.

However, the original card deck has been extensively revised by NHC and tailored to its specific needs. Under the sponsorship of the U.S. Navy, the National Climatic Center has also revised card deck 988 and reissued it as card deck 993. The tropical cyclone tracks for the 1886 through 1963 portion of this latter deck correspond to those given by Cry (1965). The tropical cyclone tracks in HURDAT correspond to those given by Neumann et al. (1978) in a revision to Cry, in which tracks are extended through the 1977 hurricane season. The revision also includes a few changes to some of Cry's original tracks.

3 THE HISTORY OF DATA OBSERVATIONS

The four basic pieces of information recorded on the magnetic tape are the tropical cyclone's position (latitude and longitude), maximum sustained wind speed in knots, the central pressure in millibars (if available), and the time and date. The availability of these parameters has by no means been continuous throughout the time period. Figure 1 indicates graphically the technical advances in observing systems that have occurred since the formation of the Hurricane Warning Service in 1871. This figure shows that, until organized reconnaissance began in 1944, the two major sources of information were land stations and ships at sea. Undoubtedly, during this early period some storms went undetected. In fact, ships encountered tropical cyclones more frequently in earlier years because they did not always have the benefit of forecasts. Many times a storm was detected and then "lost" for several days before it was encountered by another ship or observed from a land station. At other times a storm moved over land stations and through the major shipping lanes, thus allowing its track and intensity to be determined with a reasonable degree of accuracy. Therefore, during this early period of data the most useful information is track rather than wind data, although some of the tropical cyclones do have maximum wind information. The reader is referred to Neumann et al. (1978) for a list of additional references on tropical cyclone tracking. The analyst subjectively determined the maximum wind speed values and considered all reported wind information from a variety of wind measuring devices and methods. Consequently, the user of the wind information is cautioned not to make an overly precise interpretation of this parameter for the entire period of record and especially before 1944.

Organized aircraft reconnaissance has allowed continuous monitoring of the storm's track, maximum sustained wind field, and central pressure. This is reflected in the increase of pressure data beginning in 1944. The coastal radar network has improved the track information mainly for landfalling storms.

The largest single advance in the detection and tracking of tropical cyclones has been the introduction of weather satellites with their associated visible and infrared sensors. With the initial position of a tropical cyclone determined from satellite a reconnaissance aircraft is dispatched to measure the wind field, central pressure, and location of the center.

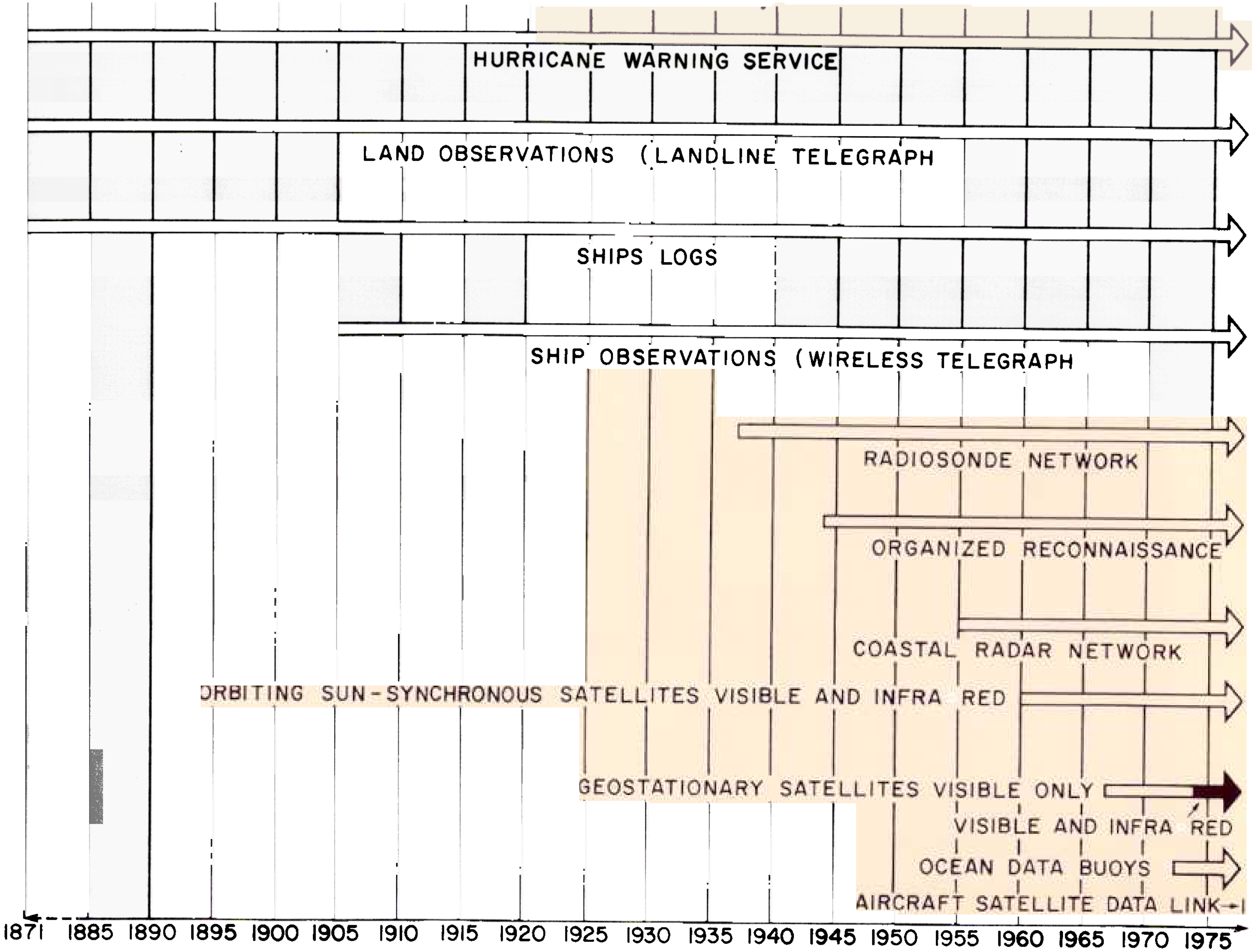


Figure 1. Technical advances in systems for observing tropical cyclones, 1871 through 1977.

Recently, the ocean data buoy has been developed as an observing platform. These buoys fall into two classes; drifting or anchored. The larger ones are generally anchored to the bottom in a data sparse region. Since oceanographic instruments are suspended from cables beneath the buoy, it provides data useful to oceanographers as well. Because tropical cyclones receive sensible and latent heat from the ocean, the ocean buoy offers a means of measuring these fluxes directly

In 1977, for the first time, continuous meteorological information was relayed from a reconnaissance aircraft to the National Hurricane Center through a geostationary satellite. This almost instantaneous reception of the tropical cyclone's position and information about its structure will undoubtedly aid the forecaster in improving his forecasts of movement and intensity.

POSITIONS

The tropical cyclone tracks are the "best tracks." Best tracks are constructed during careful post-analysis and all available information, including aircraft reconnaissance fixes, satellite imagery, land based radar fixes, ship reports, station reports, and ocean data buoy reports are considered. Figures 2 and 3 are examples of available information for determination of the best track. With the abundance of information available from these different observing platforms, discrepancies arise. Here, subjective interpretations are made by the analyst. The analyst, besides knowing the characteristics of the observing platforms, also takes into account two other phenomena associated with tropical cyclones.

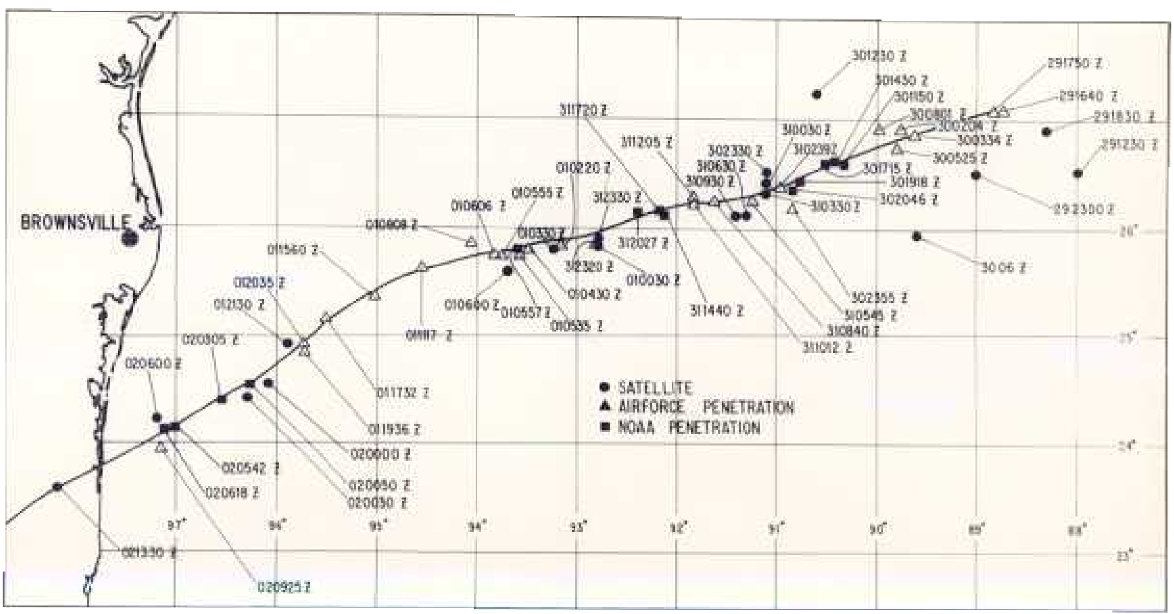


Figure 2. Satellite and aircraft center fixes for tropical cyclone Anita, 1977. The numerical value represents the day (leftmost two digits) and hour and minutes (rightmost four digits) Solid line represents the best track.

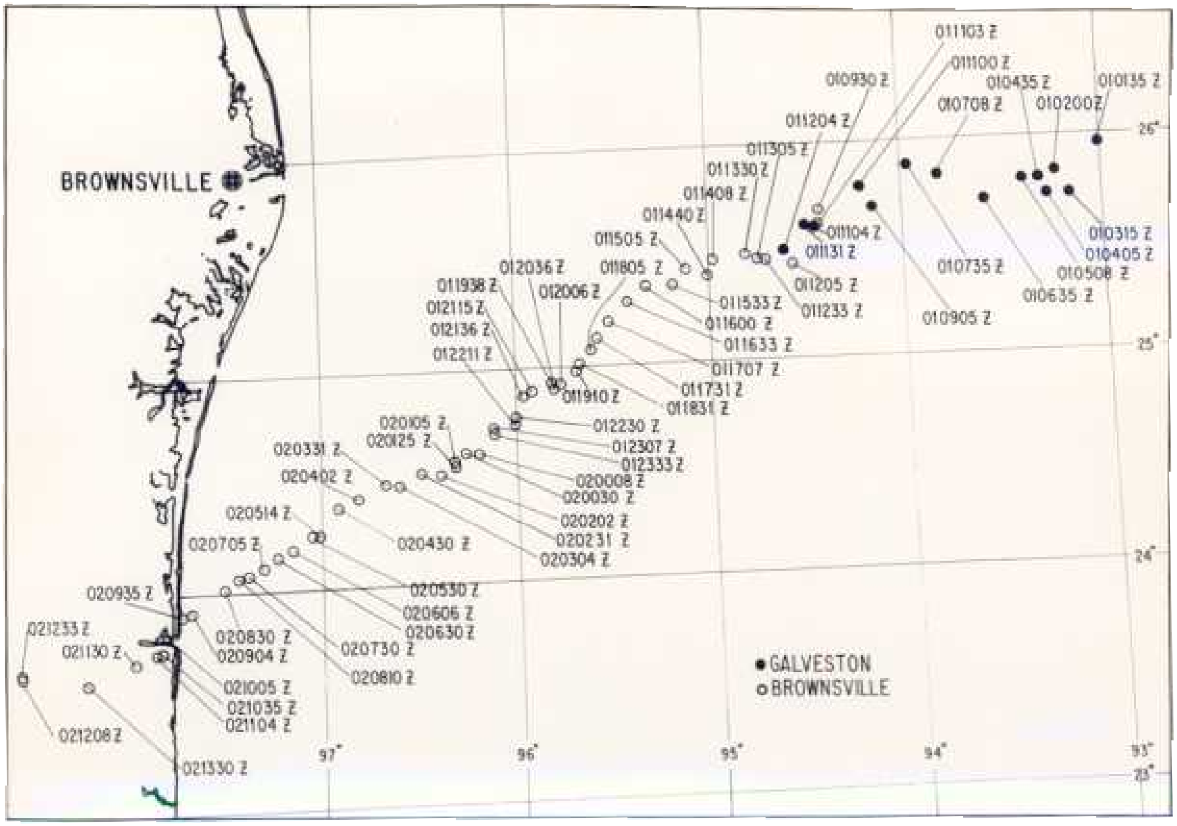


Figure 3. Radar center estimates for tropical cyclone Anita, 1977. The Galveston radar was able to make several estimates before the cyclone passed out of its range and into Brownville's range. Note the small-scale oscillations in the track and compare this with the best track in Figure 2.

First, small-scale oscillatory (trochoidal) motions occur which are transitory in nature and not representative of the more conservative motion of the entire storm envelope. Smoothing is necessary to remove these small-scale oscillatory motions, which are on the order of 5 to 20 n.mi. about some mean path. Radar documentation of these eye oscillations on tropical cyclone Carla, 1971, is presented in Figure 4 Recent evidence of similar motion based on satellite imagery of tropical cyclone Belle, 1976, is provided by Lawrence and Mayfield (1977) Therefore, final tracks should be considered as the best estimate of the larger scale storm motion, rather than precise locations of the eye.

Second, for a number of reasons, the pattern of wind, rainfall, and storm surge are typically higher in the right semicircle of a storm (looking towards the direction of motion) where the rotational and translational forces work in the same direction. Again, final tracks must take into account these asymmetries.

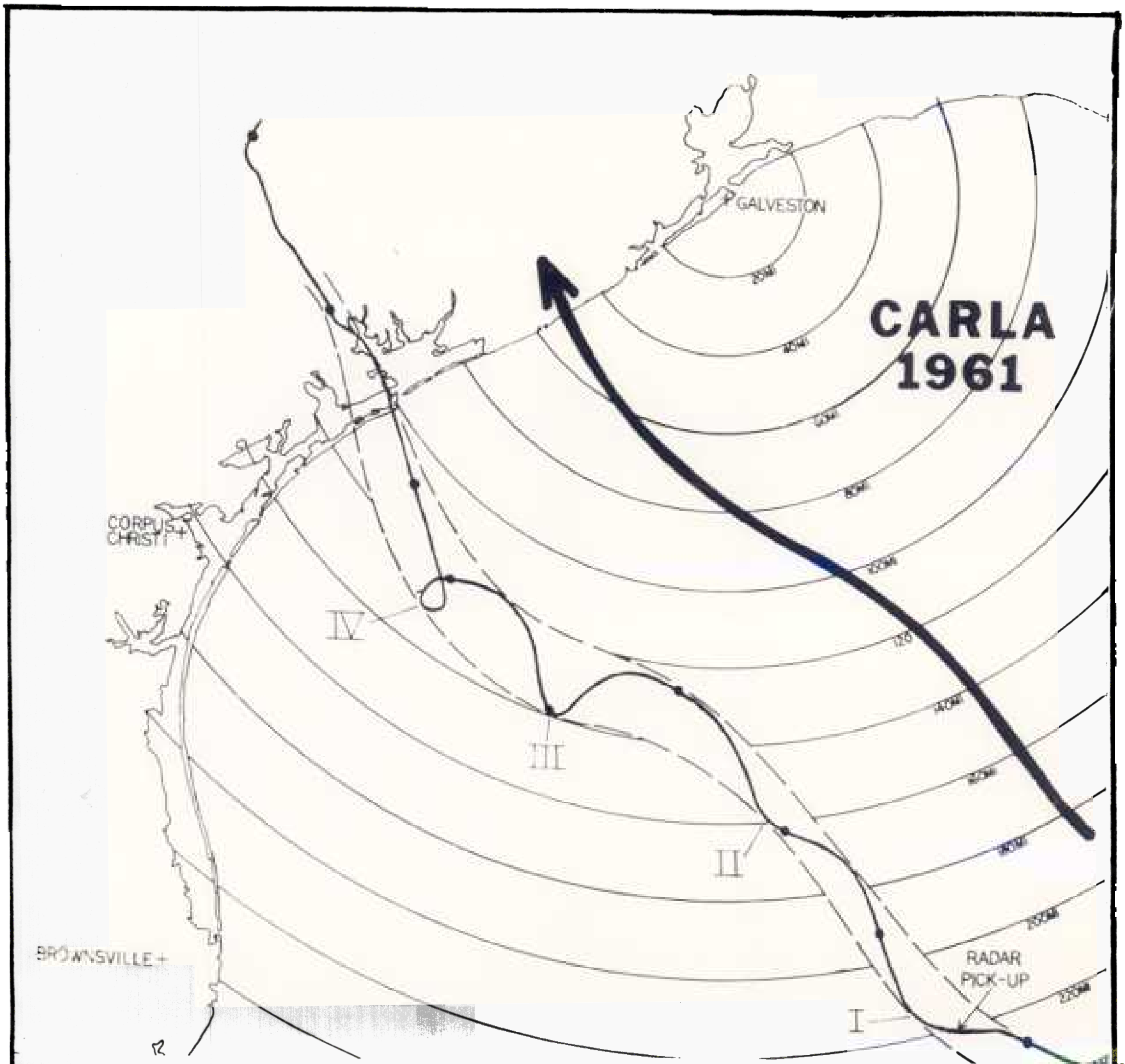


Figure 4. Portion of hurricane Carla track over Gulf of Mexico showing four unsmoothed trochoidal oscillations of storm center Track is based on "fixes" from three coastal radars. Heavy track, offset to northeast, shows portion of smoothed "best track." Range markers are at 20-n.mi. intervals. (Figure adapted from Weatherwise, *October, 1961.)*

When the analyst has finished the best track, he picks off storm positions at 6-hourly intervals. The times for the four positions per day are 0000, 0600, 1200, and 1800 Greenwich Mean Time (GMT). These are the positions that are stored on the HURDAT tape. Each position is given by latitude and longitude to the nearest tenth of 1 degree.

Before 1931, only the 1200 GMT position was recorded. The three intermediate positions were interpolated from the 1200 GMT positions. From 1931 through 1956, although four positions per day were determined by the forecaster, only the 0000 and 1200 GMT positions were recorded. Here it was necessary to interpolate for the 0600 and 1800 GMT positions. A nonlinear interpolation scheme was used to obtain these intermediate positions. The polynomial interpolation described by Akima (1970) gave highly satisfactory results. However, each track interpolation was carefully checked to insure that important features, such as loops in the track, were retained.

Beginning in 1956, storm positions were recorded four times per day for verification of official forecasts. The need for these positions increased during the 1960's with the coming of the computer age; they are required for many purposes, such as computer plotting of the tracks, implementation of the operational models, verification of the forecasts from the operational models, and verification of the official forecasts.

5. WIND SPEEDS

Each of the four daily storm positions has a corresponding wind speed. These wind values are specified in knots and rounded to the nearest 5-kt value. In other words, 68 kt becomes 70 kt while 67 kt becomes 65 kt. The wind values are estimated or measured averages over a 1-min period. Therefore, these values are not the peak winds or gusts For further information on the relationship of gusts to average winds, the reader is referred to the following: Dunn and Miller (1964), pp. 61-67; Padya (1975); and Atkinson and Holliday (1977).

To understand the limitations of the wind speed values, it is instructive to explore the various means by which the different observing platforms have actually measured the wind. First, for land stations, several types of wind recording devices have been used over the period of record. For example, in the 1890's triple register instruments were introduced. The wind speed was one of the parameters measured and recorded by a counter device utilizing a 3-cup anemometer. In the 1950's, the present day recording device used by the National Weather Service was introduced. Known as the F-420 system, it measures wind speed and direction and also records wind gusts. Several other types of anemometers have been used in the recording of the maximum wind speed. These include 4-cup and 22-cup anemometers. Although differences do exist among the various types of anemometers, it is felt that larger errors are introduced by the location and height of a particular anemometer.

The locations and heights of anemometers have varied at National Weather Service stations as the stations have been moved. The exposure of the anemometer to buildings can be very significant. For example, during the most destructive storm in the history of Miami, Florida, in 1926, the official recording anemometer was between several large buildings. It was estimated by the meteorologist in charge that the wind values recorded were approximately one-half of the actual value.

It should be noted that the chance of a tropical cyclone passing directly over a fully instrumented facility is remote. On many occasions even when a storm passes over a populated area, the maximum wind must be inferred from indirect evidence, such as peripheral wind measurements or damage profiles.

Estimations of the wind over the ocean by ships are determined by the state of the sea and given in the Beaufort scale. Over the past 30 years some ships have been instrumented with anemometers. However, because the ship is a moving platform (in three directions), corrections are necessary to determine a wind value. The state-of-the-sea determination is a one-step observation and is thus favored by mariners. A study by Shinners (1963) found that anemometer-measured winds versus state-of-the-sea-determined winds were (1) lower up to about 20 kt, (2) approximately the same from 20 to 30 kt, and (3) greater above 30 kt. In other words, state-of-the-sea-determined winds are underestimates of the actual wind at higher speeds. The magnitudes of these underestimates are approximately 6 kt for the range 36 to 45 kt, 13 kt for the range 46 to 55 kt, and 15 kt for the range 56 to 65 kt. However, both types of wind values are received in ship reports today.

Likewise, although aircraft reconnaissance measures the flight-level winds anywhere from 500 to 10000 ft, the surface winds are a subjective estimate based upon observation of the sea state and/or tables relating flight-level winds to surface winds.

Finally, wind speed values were computed on occasions from pressure values using the formula (Kraft, 1961):

$$V_{max} = 14*(1013-P_{center})^{\frac{1}{2}}$$

where:
V_{max} = *maximum sustained wind*
and
P_{center} = *pressure at center in millibars*

Since the advent of weather satellites, techniques have been developed by Dvorak (1973 and 1975) and Hebert and Poteat (1975) to determine wind speed from the shape of a tropical and subtropical cyclone's cloud field, respectively. This estimation, along with those received from aircraft reconnaissance, forms the main nucleus of information to determine the final wind field. Figure 5 contains final surface wind and pressure profiles for tropical cyclone Anita, 1977. Also shown are the original surface wind and pressure information which was used to determine the profiles. Time increases to the right. The wind speed is specified in knots and pressure in millibars. The scatter and discrepencies in the various wind reports is quite evident. Here, again, as in the best track determination, the analyst subjectively determines the profiles. It is extremely important for the analyst to understand the weaknesses and strengths of the various measuring platforms.

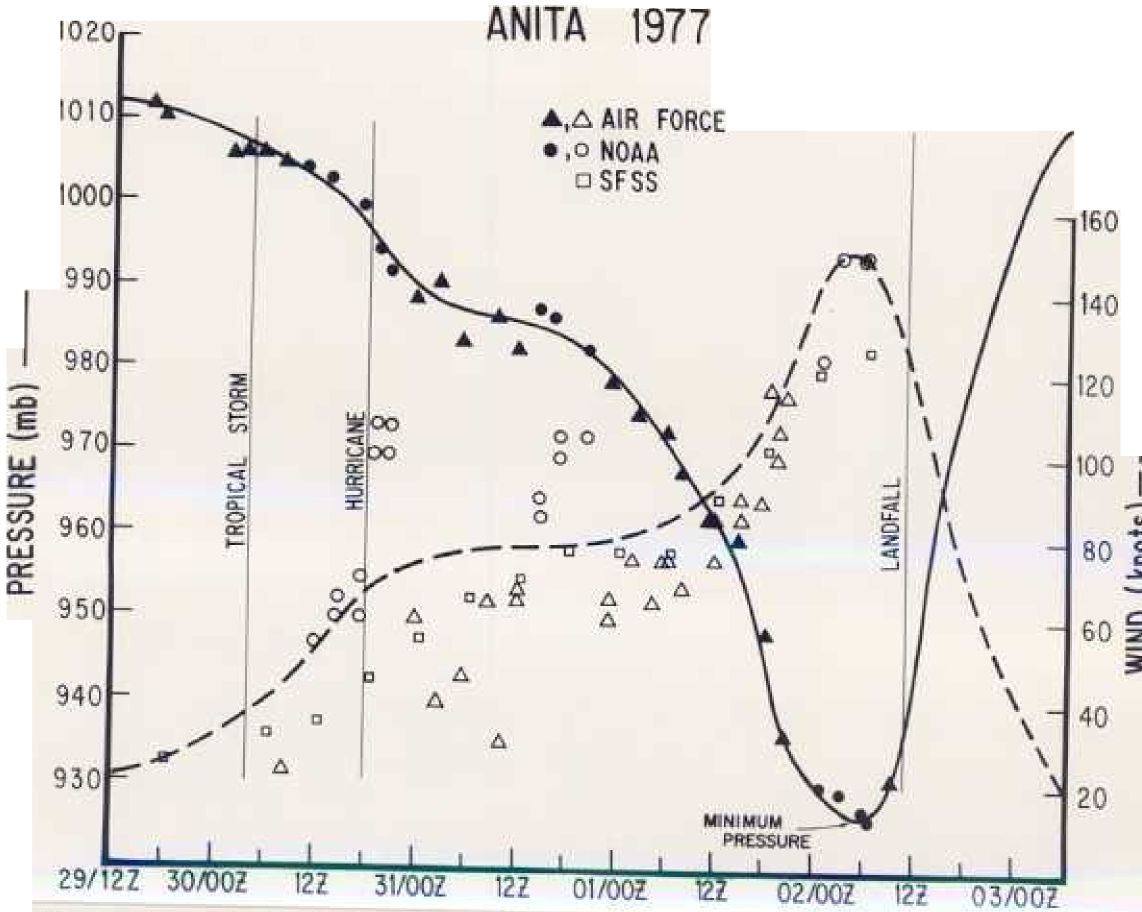


Figure 5. Final wind (dashed line) and pressure (solid line) profiles with actual data for tropical cyclone Anita, 1977.

6. PRESSURES

The tropical cyclone's central pressure on HURDAT is specified in millibars. Only reported central pressures within ±2 hr of one of the four reporting times are included in the data. As discussed earlier, the frequency of pressure values decreases as one goes back in the period of record. Thus, unlike wind speeds, central pressures are often missing

Pressures at populated centers affected by a storm may be well documented, even though the eye of the storm passed a good distance away. Those pressures <u>are not</u> part of this data set. It should be emphasized that all pressures on HURDAT are observed and that no pressures were determined from the winds.

Figure 5 shows the pressure profile and actual pressure data used to determine this profile. Since the satellite intensity classification determines the maximum sustained winds only, no pressure values are given. It is clearly evident from the raw pressure data that the central pressure is a much more conservative property of the tropical cyclone than the wind field.

7. DATA FORMATS

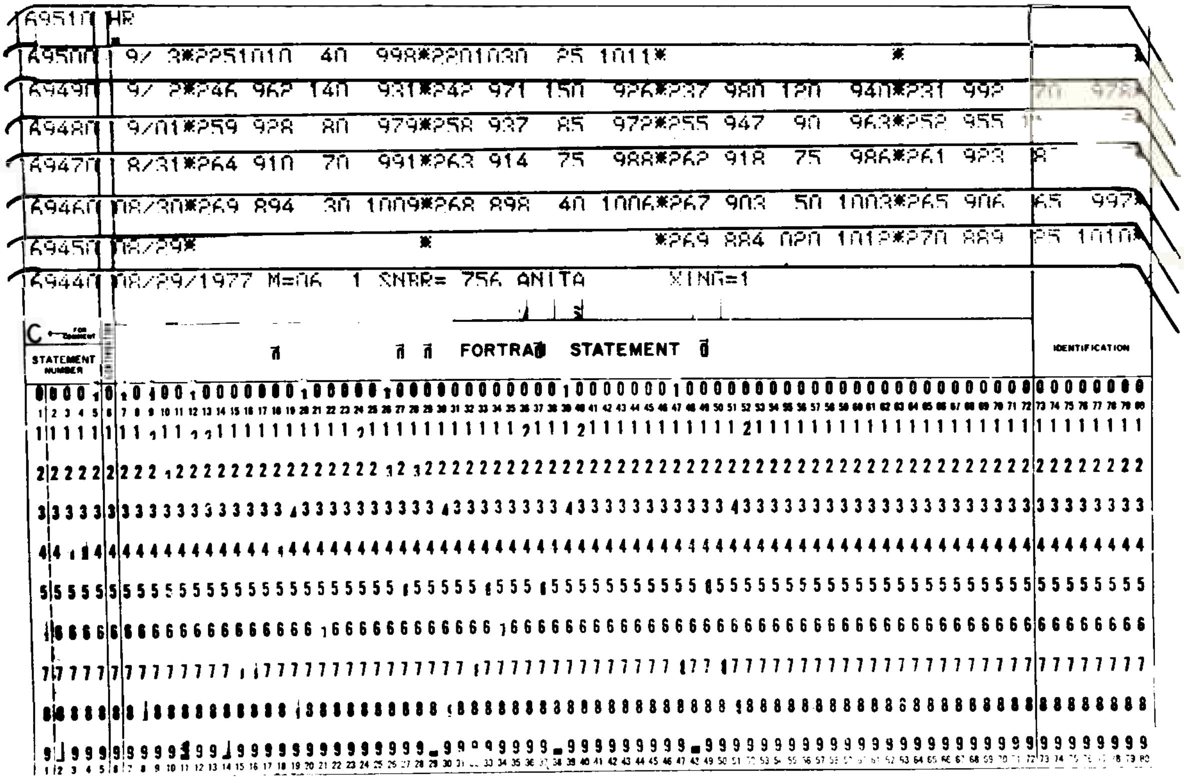
The master deck that was used to generate the computer tape consisted of three types of cards: Title, Data, and Classification. Each storm has one title card containing all required information to identify it. The first item on the card is the sequence number. The month, day, and year follow in that order. This is the first day on record for the storm. The next three numbers refer to the number of days the storm was in existence (M), the storm number for that year, and the cumulative storm number (SNBR), where the first storm in 1886 is 1 and the last storm number as of 1977 is 761. The next variable is the storm name. Before the naming of tropical storms in 1950, a "not Named" message fills the space on the cards. The final item on the card is a storm crossing index (XING). In the present version of the tape, this latter entry should be ignored.

A single Title card is followed by two or more Data cards, one for each GMT day of the storm's existance. Each contains four sets of numbers where each set contains the storm position (latitude in degrees north and longitude in degrees west), wind speed, and the central pressure. The sets correspond to the times 0000, 0600, 1200, and 1800 GMT.

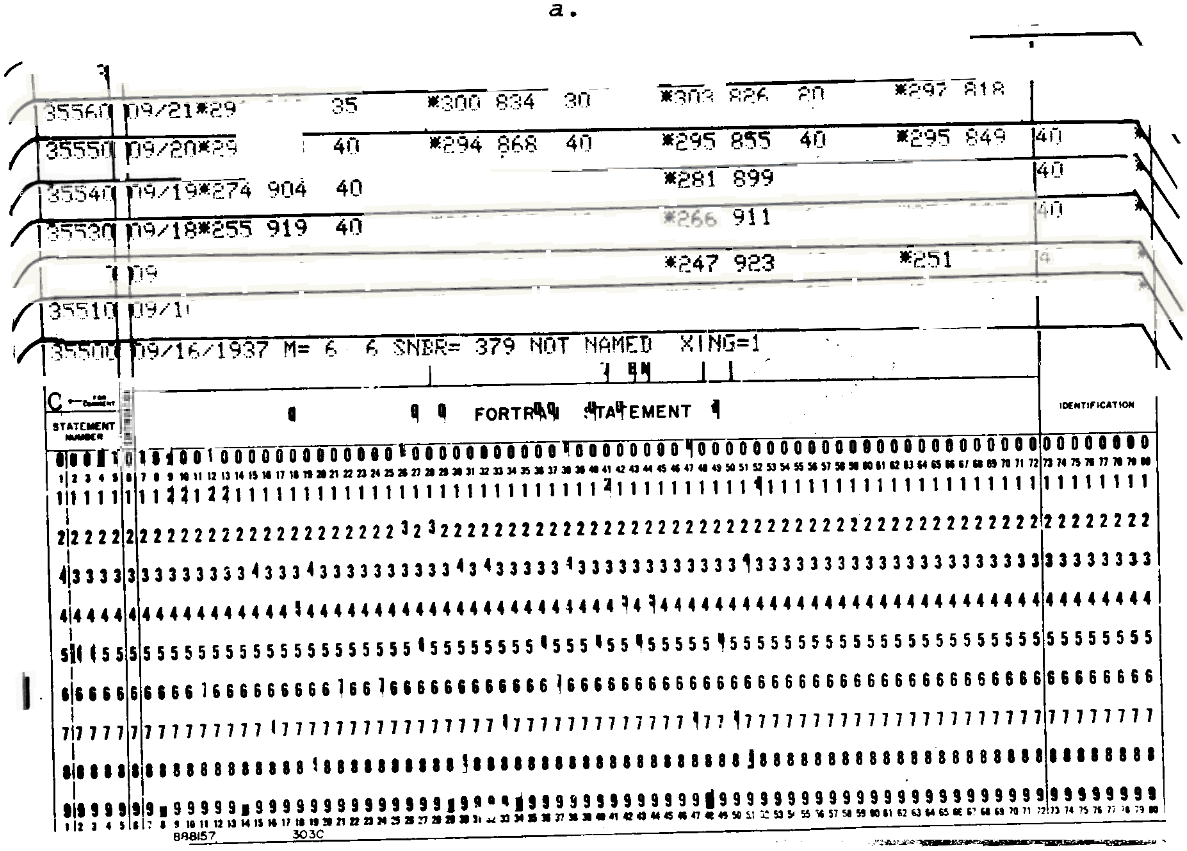
The Classification card's purpose is to classify the maximum status attained during a storm's life. The index can take on one of three values: Tropical Storm (TS), Hurricane (HR), or Subtropical Storm (SS).

Tables 1 through 3 indicate the exact location of each parameter on the three types of cards. Copies of the computer cards for Anita, 1977, and an unnamed tropical storm, 1937, are shown in Figure 6. Note the difference in the amount of central pressure data.

The record size on the magnetic tape is 80 bytes. This is done so that each data card is stored as a record (i.e., each record is a card image.) This allows the user to read the tape as if it is a card deck. The user may then want to store certain information in larger records which will reduce his input/output time. A fortran program to read and write the HURDAT tape, with formatted input and outputstatements, is given in Appendix I. The necessary physical parameters for reading the tape (i.e., density, parity, code, etc.) will be supplied by the National Climatic Center along with the tape.



a.



b.

Figure 6. Copies of computer cards giving the information for tropical Anita, 1977 (a.) and an unnamed tropical cyclone, 1937 (b.).

Table 1. Title Card - Format and Contents

Computer Card Columns	Contents
1 - 5	Card sequence number
7 - 8	Month
10 - 11	Day (first day of the storm on record)
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	Ignore

Table 2. Storm Data Card - Format and Contents
Latitudes and longitudes are rounded to the nearest tenth. Wind speed is rounded to the nearest 5 kt. Pressure is recorded to the nearest millibar.

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

Table 3. Classification Card - Format and Contents

Computer Card Columns	Contents
1 - 5	Card sequence number
7 - 8	Maximum status of storm during its life

8. USES OF THE DATA

This section highlights some of the uses of the HURDAT tape at the National Hurricane Center. The thousands of requests received over the years indicate a much broader usage of the data than presented here.

The most requested products are the tracks. Figure 7 shows the tracks for all tropical cyclones beginning September 1 through 5, 1886 through 1977.

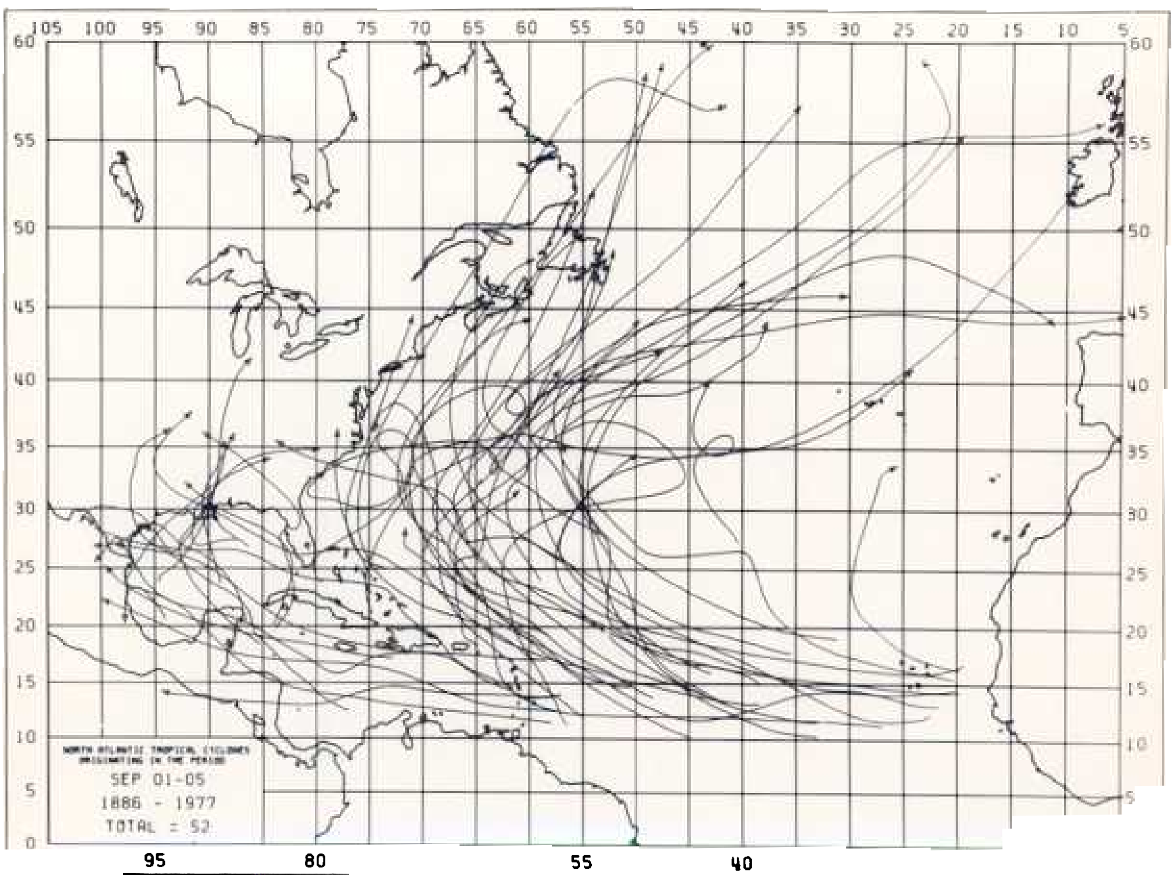


Figure 7. Tracks of tropical cyclones originating September 1 through 5, 1886 through 1977.

There are frequent requests for all tropical cyclones passing within a given distance from a particular location. Figure 8 shows all tracks of tropical cyclones of hurricane intensity when they were within 50 n.mi. of Miami, Florida, for 1886 through 1977. Table 4 is a copy of the printout giving additional information, such as the point and time of closest approach of the tropical cyclone to Miami and the maximum wind within the 50-mi circle. A legend is included to explain each value in the table.

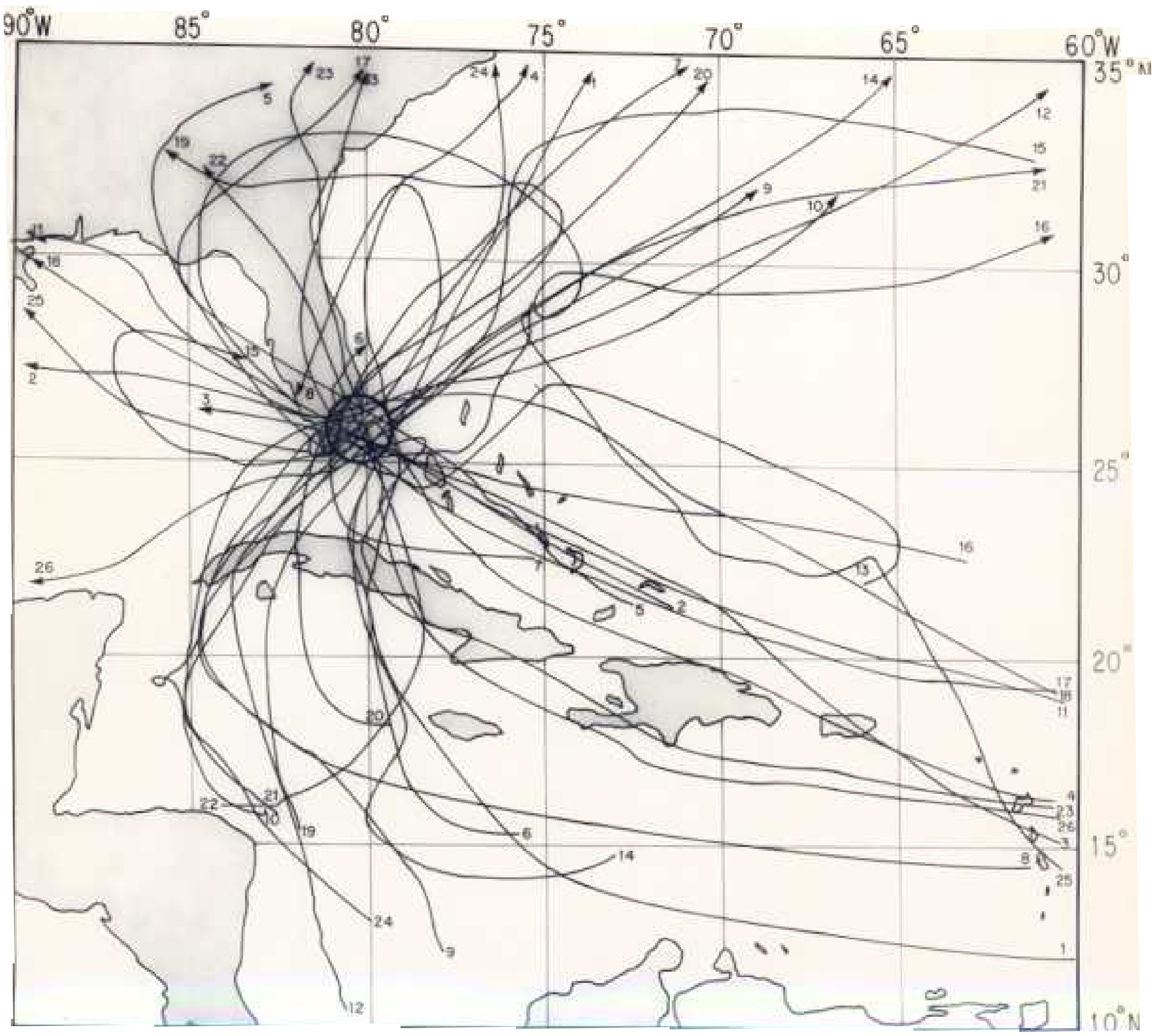


Figure 8. Tracks of all tropical cyclones of hurricane intensity passing within 50 n.mi. of Miami, Florida. The 50 n.mi. circle is also plotted. The numbers at the beginning and end of each track refer to column 1 of Table 4.

Standard statistical graphs showing frequency for various periods are often produced. Figure 9 gives an example of the annual tropical cyclone frequency, 1886 through 1977.

One of the many objective models in current operational usage at NHC is an analog model as described by Hope and Neumann (1970). This model scans the HURDAT tape and selects tropical cyclones that have characteristics similar to the current tropical cyclone in progress. These analog tropical cyclones are composited and a forecast track is generated. Figure 10 shows an example of an analog forecast for tropical cyclone Anita, 1977. Also included in the plot are the 50% probability elipses at the forecast intervals of 12, 24, and 36 hr.

Table 4. Computer Printout of All Hurricanes That Passed Within 50 n.mi. of Miami, Florida

MAP INDEX (1)	STARTING DATE (2)	LENGTH (DAYS) (3)	SEASONAL INDEX (4)	STORM'S NAME (5)	CLOSEST POINT OF APPROACH (CPA) (6)	(7)	DATE AT CPA (8)	TIME AT CPA (9)	DISTANCE TO CPA (10)	WIND (11)	REF # (12)
1	8/16/1886	12	6	NOT NAMED	25.4N	79.5W	8/23	0400Z	47.NM	84KT	6
2	8/14/1888	11	3	NOT NAMED	25.6N	80.2W	8/16	1600Z	14.NM	94KT	30
3	8/18/1891	8	3	NOT NAMED	25.4N	80.3W	8/24	1600Z	23.NM	75KT	49
4	8/ 3/1899	22	2	NOT NAMED	26.1N	79.3W	8/13	0100Z	50.NM	105KT	112
5	9/ 9/1903	8	3	NOT NAMED	26.2N	79.9W	9/11	2200Z	29.NM	84KT	141
6	10/12/1904	10	3	NOT NAMED	26.0N	80.1W	10/17	1500Z	12.NM	65KT	150
7	6/14/1906	10	2	NOT NAMED	25.9N	80.8W	6/17	0800Z	32.NM	70KT	159
8	10/11/1906	12	8	NOT NAMED	25.8N	80.3W	10/18	0900Z	6.NM	105KT	165
9	10/ 6/1909	8	9	NOT NAMED	25.4N	80.0W	10/11	2000Z	27.NM	84KT	189
10	10/14/1924	10	7	NOT NAMED	26.2N	80.3W	10/21	1100Z	23.NM	64KT	267
11	9/11/1926	12	6	NOT NAMED	25.6N	80.3W	9/18	1200Z	13.NM	118KT	276
12	10/14/1926	11	10	NOT NAMED	25.6N	79.7W	10/21	0600Z	30.NM	95KT	280
13	9/22/1929	13	2	NOT NAMED	25.0N	80.5W	9/28	1600Z	49.NM	86KT	296
14	9/23/1935	10	4	NOT NAMED	25.5N	79.4W	9/29	0200Z	46.NM	100KT	355
15	10/30/1935	10	6	NOT NAMED	25.8N	80.3W	11/ 4	1800Z	5.NM	65KT	357
16	10/ 3/1941	12	5	NOT NAMED	25.4N	80.2W	10/ 6	1000Z	25.NM	105KT	408
17	9/12/1945	9	9	NOT NAMED	25.6N	80.4W	9/15	2300Z	20.NM	119KT	449
18	9/ 4/1947	18	4	NOT NAMED	26.3N	80.4W	9/17	1800Z	32.NM	133KT	461
19	10/ 9/1947	8	8	NOT NAMED	25.9N	80.5W	10/12	0700Z	16.NM	75KT	465
20	9/18/1948	8	7	NOT NAMED	26.2N	80.7W	9/22	0600Z	36.NM	97KT	473
21	10/ 3/1948	14	8	NOT NAMED	25.7N	80.1W	10/ 6	0000Z	8.NM	96KT	474
22	10/13/1950	7	11	KING	25.8N	80.2W	10/18	0600Z	0.NM	93KT	499
23	8/20/1964	17	5	CLEO	25.9N	80.0W	8/27	0900Z	10.NM	90KT	629
24	10/ 8/1964	10	11	ISBELL	26.2N	80.8W	10/14	2300Z	42.NM	110KT	635
25	8/27/1965	18	3	BETSY	25.1N	80.3W	9/ 8	1000Z	44.NM	110KT	639
26	9/21/1966	21	9	INEZ	25.2N	80.0W	10/ 4	1400Z	38.NM	75KT	651

NOTES,
(1) INDEX NUMBER CORRESPONDS TO INDICIES GIVEN ON MAP AT BEGINNING AND END OF STORM TRACK,
(2) INITIAL DETECTION DATE OF THIS TROPICAL CYCLONE,
(3) RECORDED DURATION OF STORM IN CALENDAR DAYS,
(4) STORM NUMBER FOR GIVEN YEAR
(5) STORMS WERE NOT FORMALLY NAMED PRIOR TO 1950,
(6) - (10) THESE COLUMNS REFER TO CLOSEST APPROACH OF STORM CENTER TO SITE, THESE COLUMNS GIVE LOCATION AND TIME OF CLOSEST APPROACH AND DISTANCE OF STORM CENTER TO SITE,
(11) MAXIMUM SUSTAINED WIND SPEED NEAR STORM CENTER WHILE STORM CENTER IS WITHIN SPECIFIED DISTANCE FROM SITE, THIS IS NOT NECESSARILY THE WIND RECORDED AT GIVEN SITE,
(12) CUMULATIVE STORM INDEX NUMBER BEGINNING WITH STORM 1 IN 1886,

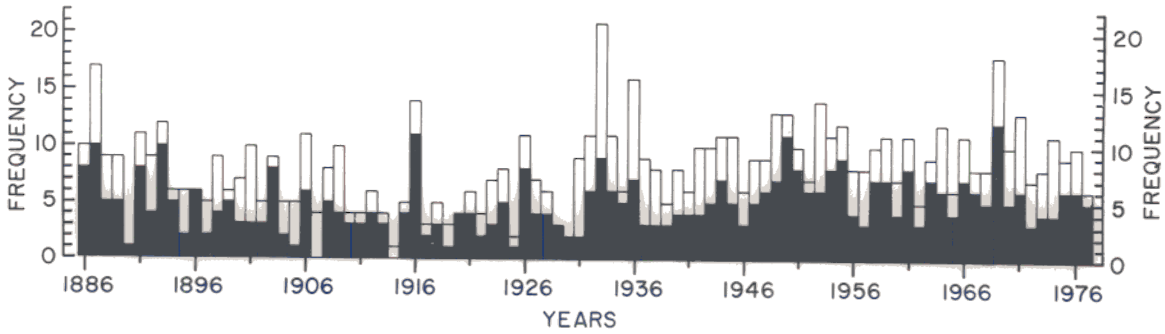


Figure 9. *Annual distribution of the 761 recorded Atlantic tropical cyclones that reached at least tropical storm strength (open bar) and the 448 that reached hurricane strength (solid bar), 1886 through 1977. The average number of such storms over the period of record is 8.3 and 4.9, respectively.*

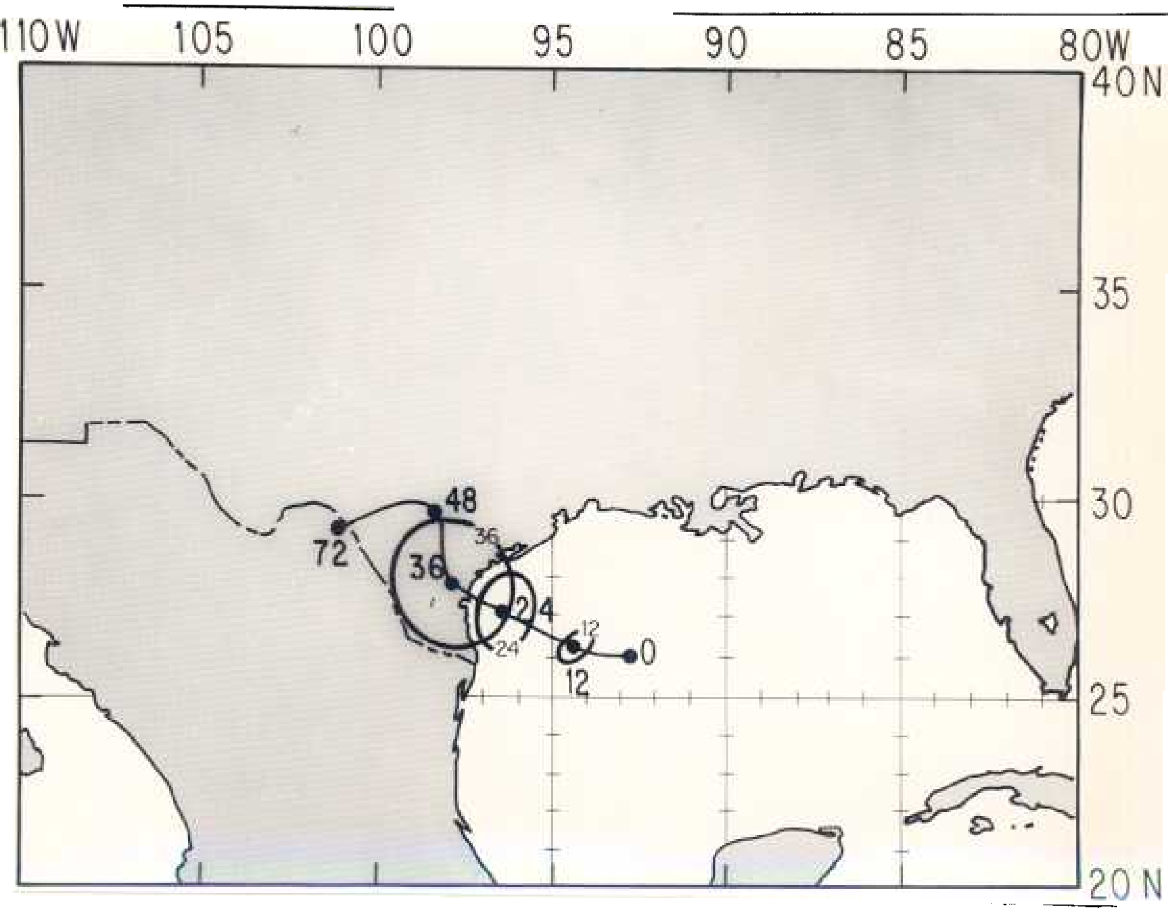


Figure 10. *Hurricane analog forecast for Anita, 1977. The initial time is 0000 GMT on September 1, 1977.*

These are determined from the scatter of the analog composites at the respective forecast interval. Other forecast models use the climatological information as one of many pieces of information to determine a forecast track.

Uses of the data also include intensity forecasts from regression analyses of the wind data and determination of pressure wind relationships.

REFERENCES

Akima, H., 1970: A New Method of Interpolation and Smooth Curve Fitting Based on Local Procedures, Journal of the Association for Computing Machinery, Vol. 17, No. 4, pp. 589-602

Atkinson, G. D. and C. R. Holliday, 1977: Tropical Cyclone Minimum Sea Level Pressure/Maximum Sustained Wind Relationship for the Western North Pacific, Monthly Weather Review, Vol. 105, No. 4, 421-427.

Cry, G. W., 1965: Tropical Cyclones of the North Atlantic Ocean, Technical Paper No. 55, U.S. Weather Bureau, Washington, D.C., 148 pp.

Dunn, G. E. and B. I. Miller, 1964: Atlantic Hurricanes, Louisiana State University Press, Baton Rouge, La., 377 pp.

Dvorak, V. F., 1973: A Technique for the Analysis and Forecasting of Tropical Cyclone Intensities from Satellite Pictures, NOAA Technical Memorandum NESS-45, Washington, D.C., 19 pp.

------, 1975: Tropical Cyclone Intensity Analysis and Forecasting from Satellite Imagery, Monthly Weather Review, Vol. 103, No. 5, 420-430.

Hebert, P. J. and K. O. Poteat, 1975: A Satellite Classification Technique for Subtropical Cyclones, NOAA Technical Memorandum NWS SR-83, Fort Worth, Texas, 25 pp.

Hope, J. R. and C. J. Neumann, 1968: Probability of Tropical Cyclone Induced Winds at Cape Kennedy, Weather Bureau Technical Memorandum SOS-1, Silver Springs, Md., 67 pp.

---- and ------, 1970: An Operational Technique for Relating the Movement of Existing Tropical Cyclones to Past Tracks, Monthly Weather Review, Vol. 98, No. 12, 925-933.

Kraft, R. H., 1961: The Hurricane's Central Pressure and Highest Wind, Mariners Weather Log, Vol. 5, No. 5, 157.

Lawrence, M. B. and B. M. Mayfield, 1977: Satellite Observations of Trochoidal Motion During Hurricane Belle 1976, Monthly Weather Review, Vol. 105, No. 11, 1458-1461.

Neumann, C. J., G. W. Cry, E. L. Caso, and B. R. Jarvinen, 1978: Tropical Cyclones of the North Atlantic Ocean, 1871-1977, (To be published as a NOAA Technical Memorandum).

Padya, B. M., 1975: Spatial Variability and Gustiness of Cyclone Winds: Gervaise, Mauritius, February 1975, Australian Meteorological Magazine, Vol. 23, No. 3, 61-69.

Shinners, W., 1963: Comparison of Measured and Estimated Winds at Sea, U.S. Member Working Group on Technical Problems, Commission for Maritime Meteorology, WMO, (unpublished manuscript).

APPENDIX I A SAMPLE PROGRAM TO READ AND WRITE HURDAT

```
      DIMENSION IDATE(50,5),ALAT(50,4),ALON(50,4)IPED(50,4),IPRE(50,4)
      DIMENSION IA(19),IB(32),ICE(50,4)
      WRITE(6,1)
    1 FORMAT(1H1)
      DO 50 I=1,1000
C     EACH PASS THROUGH DO LOOP 50 READS ONE STORM.
      READ(19,2,END=99) (IA(J),J=1,19),M,(IB(J),J=1,32)
C     19=HURDAT TAPE.  READ TITLE CARD.  OBTAIN M WHICH GIVES THE
C     NUMBER OF GMT DAYS THAT THE STORM WAS IN EXISTENCE.
    2 FORMAT(19A1,I2,32A1)
      DO 7 II=1,M
C     DO LOOP 7 READS M DATA CARDS AND STORES VALUES IN ARRAYS.
      READ(19,5) (IDATE(II,J),J=1,5),((ICE(II,J),ALAT(II,J),ALON(II,J),
     1IPED(II,J),IPRE(II,J)),J=1,4)
    5 FORMAT(6X,5A1,4(A1,F3.1,F4.1,1X,I3,1X,I4))
    7 CONTINUE
      READ(19,8) IQ
C     READ IDENTIFICATION CARD
    8 FORMAT(6X,A2)
C
C     DATA FOR ONE STORM READ INTO STORAGE.  THE FOLLOWING STATEMENTS
C     WRITE THIS DATA OUT.
C
      WRITE(6,11)
      WRITE(6,12) (IA(J),J=7,19),M,(IB(J),J=1,30)
      DO 9 J=1,M
      WRITE(6,13) (IDATE(J,K),K=1,5),((ICE(J,K),ALAT(J,K),ALON(J,K),
     1IPED(J,K),IPRE(J,K)),K=1,4)
    9 CONTINUE
   11 FORMAT(1H0,/,/,/,2X,40H----------------------------------------)
   12 FORMAT(1H0,10X,13A1,I2,30A1,/,/20X,5H0000Z,17X,5H0600Z,17X,
     15H1200Z,17X,5H1800Z,/,/,
     27X,4HDATE,2X,4(3HLAT,3X,3HLON,2X,3HVEL,1X,4HPRES,3X))
   13 FORMAT(1H ,5X,5A1,1X,4(A1,F4.1,1X,F5.1,1X,I3,1X,I4,2X))
   50 CONTINUE
   99 CONTINUE
      STOP
      END
```