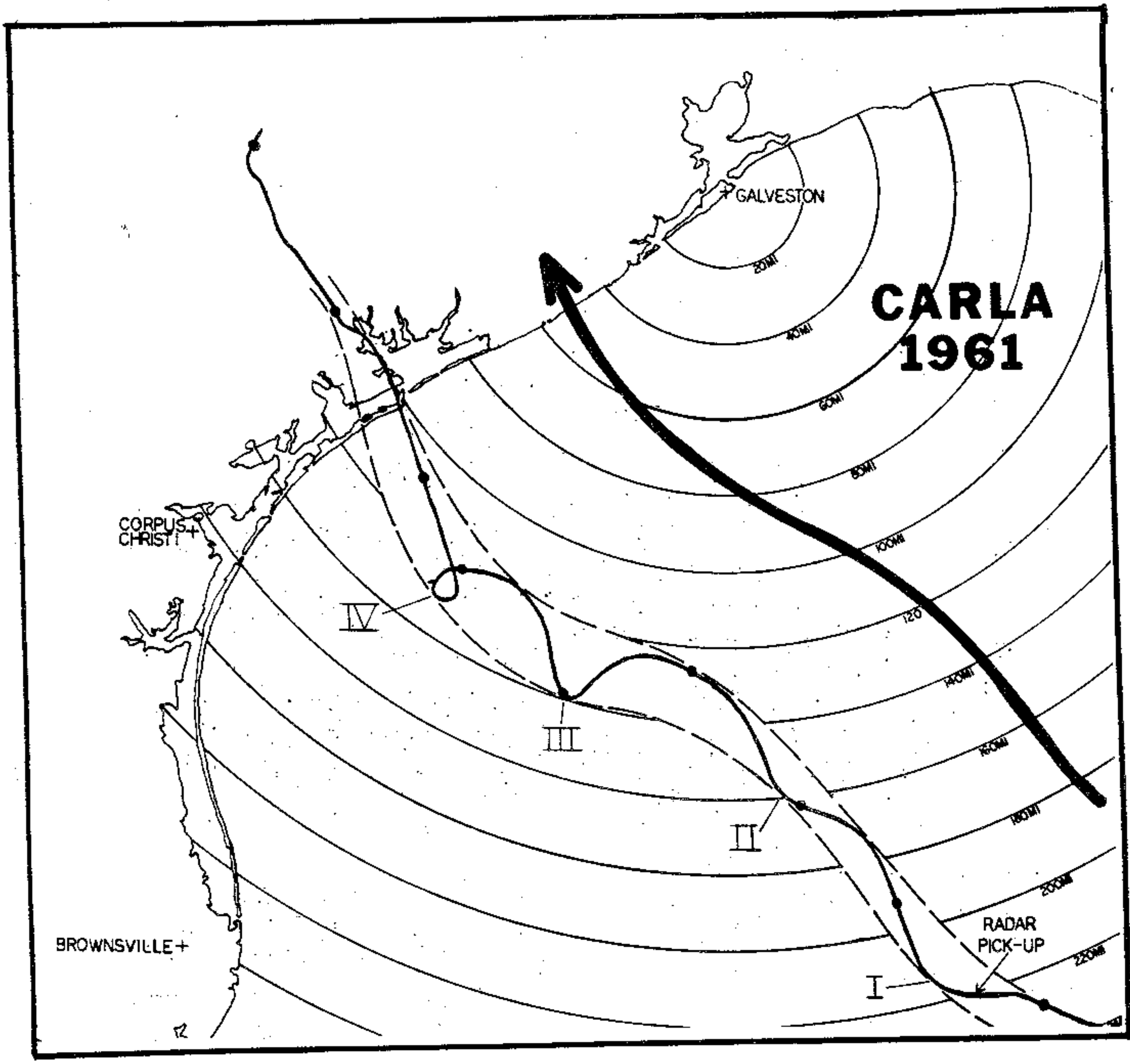

Figure 4. Portion of hurricane Carla track over Gulf of Mexico showing four smoothed trochoidal oscillations of storm center. Track is based on "fixes" from three coastal radars. Heavy track, offset to northeast, shows portion of smoothed "best track". Range markers are at 20-n.mi. intervals. (Figure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

When an analyst has finished constructing a best track, storm positions at 6-hourly intervals are noted. 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 1200 GMT positions were recorded on the original card deck 988 (see page 1). 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 which are also issued four times per day. 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, i.e., 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 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, 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.

41% 1 36%
18% 2 23%
32% 3 32%
7% 4 8%
1% 5

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.(Black and Adams, 1983)

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

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

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 discrepancies 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.

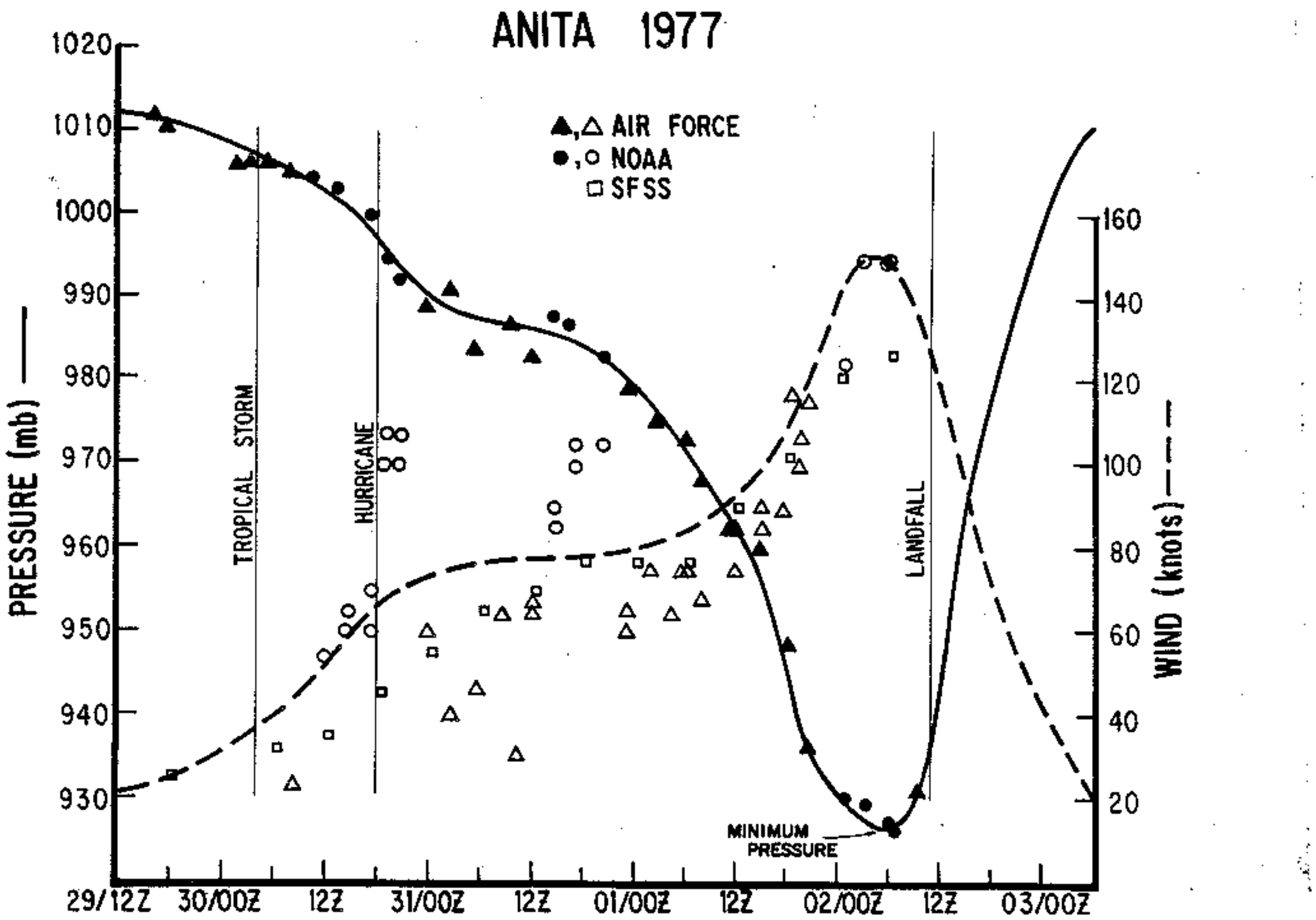

Figure 5. Final wind (dashed line) and pressure (solid line) profiles with actual data for tropical cyclone Anita, 1977.

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 a 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 file 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 in 1983 is 815. 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 next item on the card is a storm crossing index (XING). The final item on the card is the Saffir/Simpson Hurricane Scale (SSS). In the present version this number should be ignored before 1899. To relate hurricane intensity to damage potential, the National Hurricane Center has adopted the Saffir/Simpson Hurricane Scale. This descriptive scale, over a range of categories 1 through 5, is shown in Table 4. Saffir/Simpson scale numbers are given only for hurricanes that crossed the continental United States. In a few instances, a Saffir/Simpson number of zero appears. This indicates that the storm, although classified as a hurricane over coastal waters, weakened to below hurricane strength before crossing the immediate coast line. On the title card, column 80 is used to denote the last storm of the year if punched with an L.

The single Title card is followed by two or more Data cards, one for each GMT day of the storm's existence. Each contains four sets of numbers where each set contains the storm type, 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 storm types are *-Tropical Storm or Hurricane, D-Tropical Disturbance, S-Subtropical Storm, W-Tropical Wave, and E-Extratropical Storm.

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