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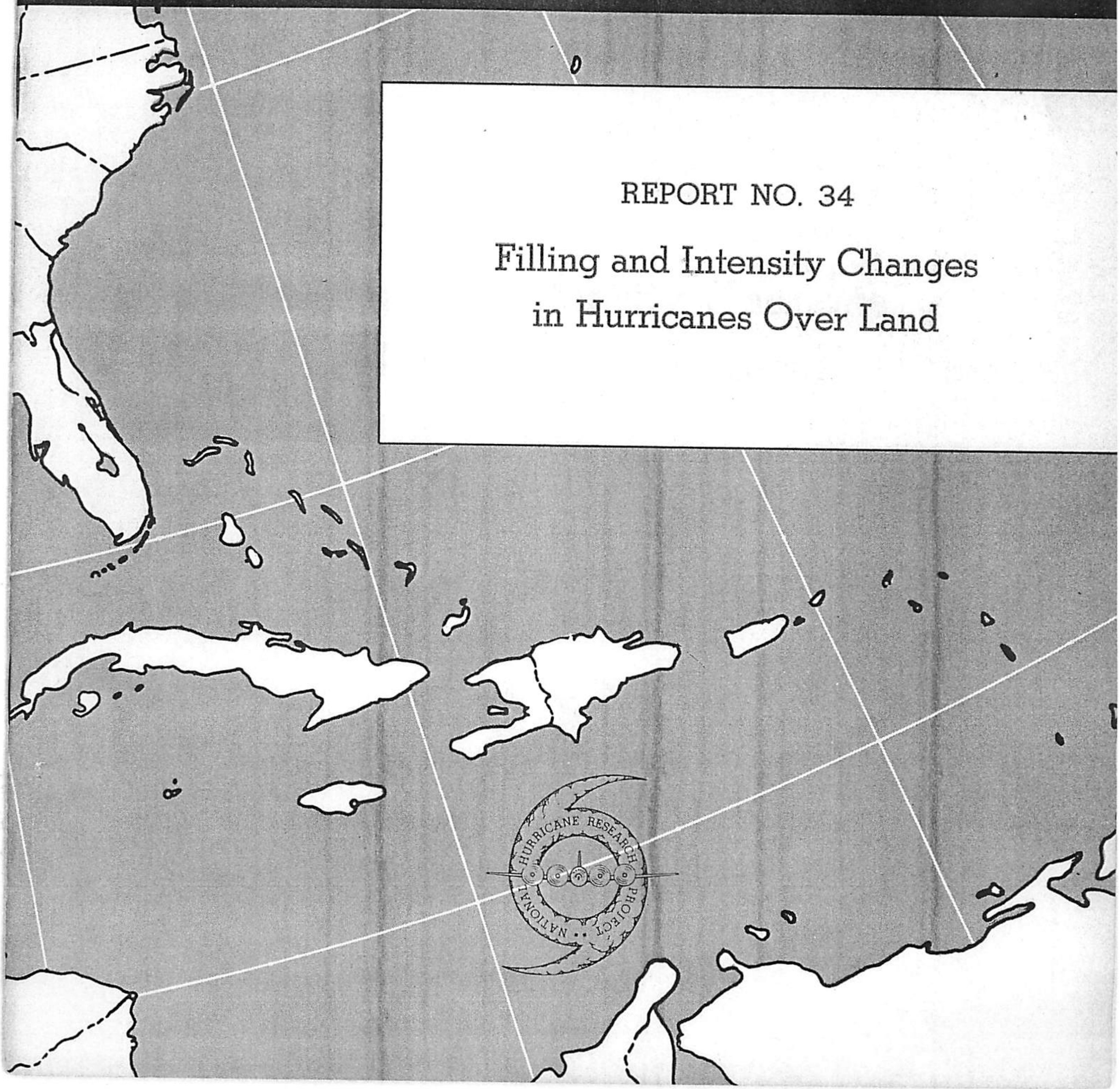

REPORT NO. 34

Filling and Intensity Changes in Hurricanes Over Land

U. S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, Secretary
WEATHER BUREAU
F. W. Reichelderfer, Chief

NATIONAL HURRICANE RESEARCH PROJECT

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Filling and Intensity Changes in Hurricanes Over Land*

by

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NATIONAL HURRICANE RESEARCH PROJECT REPORTS

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FILLING AND INTENSITY CHANGES IN HURRICANES OVER LAND

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ABSTRACT

The change in central pressure after landfall of 13 selected hurricanes is analyzed. A formula that fits the average filling curve is given. The average change in pressure gradient after landfall is also evaluated. One of several incidental findings pertains to the consistent values obtained when applying an objective definition for the pressure at the periphery of a hurricane.

1. INTRODUCTION

A knowledge of filling in hurricanes (change in central pressure) is of concern in assessing the behavior of storms for subsequent design of flood-control structures. There is an interlocking relationship between: (1) central pressure in hurricanes and pressure gradients, (2) pressure gradients and wind velocities, and (3) wind velocities and wave and tide heights - the latter must be considered in the location and design of protective works along bays and lakes. The nature of filling is also of importance for forecasting and in the preparation of prognostic charts. This report contains results from an analysis of filling and alterations in intensity observed in several hurricanes as they moved over land in the eastern United States.

2. FILLING, DEEPENING, AND INTENSIFICATION DEFINED

The terms "filling" and "deepening" are used here in the generally accepted sense (Petterssen [13], see especially page 51; Saucier [14], see page 217). As discussed by Petterssen, deepening and filling of a center of low pressure refer respectively to a decrease and an increase in the central pressure. This report presents some analyses of pressure changes at a particular location only - at the pressure center - in the tropical storm. By contrast, Wexler [17] reported on some studies of the mean filling over specified areal sections of hurricanes. Hubert [4] developed some interesting conclusions covering the rate of filling prior to and after landfall and also computed the average decrease in pressure gradient at the radius of maximum winds for several hours after landfall.

Petterssen [13] further distinguished deepening and filling from intensification and weakening; while the former terms apply to the pressure, the latter apply to the pressure gradient. Similarly in this study, intensification and weakening respectively denote an increase and a decrease in the magnitude of the pressure gradient around the center of the pressure system.

Changes in intensity or in pressure gradients are not dependent entirely on changes in central pressure. Nevertheless it has been generally "assumed that there is a high degree of correlation between changes in the central pressure of a storm and changes in the pressure gradients around it" (Hess, [3]). Because filling and deepening are apparently related to changes in intensity, selected aspects of variations in intensity have been included in this report.

3. BASIS OF SELECTION OF STORMS FOR STUDY

A list was prepared of all hurricanes having a minimum trajectory of 300 nautical miles (approximately 5° of latitude) over land, based on an examination of yearly composite maps of hurricane tracks prepared by the Office of Climatology [16]. The list was then pared to storms having a central pressure of 29.00 inches or less at landfall, using table 3.1 from [12]. This restriction was made in order to limit the study to fairly intense and well-developed hurricanes. An exception was made to include hurricane Diane, in August 1955, even though this storm had a central pressure slightly higher than 29.00 inches, because this hurricane met all other criteria, and data for it were readily available. The thirteen storms thus selected and used in the analysis appear in table 1.

4. OBSERVED FILLING OVER LAND AND EVALUATION OF CENTRAL PRESSURES

An examination was first made of the actual filling (or deepening) that had occurred in each storm beginning with landfall of the center. Two of the 13 storms were dropped from some of the filling compilations because the centers moved parallel to the coast after landfall instead of continuing on an inland path. The sequence of available synoptic maps was considered a logical source for extracting much of the data for this study. The computations were consequently made at intervals corresponding to the time between successive synoptic maps - every 3 hours for a majority of the storms, every 6 hours for one older storm, and every 12 hours for the three earliest storms. As landfall did not occur simultaneously with map time, except by coincidence, adjustments were made as necessary for the variation in time between landfall and the first succeeding synoptic map. For example, in one case, the rate of filling observed at the first synoptic map time after landfall was applied in reverse over the short period between landfall and the first map, to arrive at an initial estimate of the central pressure at the coast.

The track that agreed best with the data was the one used. All barograms available from stations within a reasonable distance of the track were examined to help fix the central pressure. Where the track passed directly over a station, the minimum point on the barogram was recorded as the central pressure at the corresponding time, and pressure profiles were constructed for such times for reference. Some central pressures were estimated by extrapolation inward toward the center, along an exponential profile fixed by nearby observations, using the technique described in [5]. Interpolation between these pressure profiles served as a means of estimating the central pressure for times when observations were lacking.

Table 1. - Range in pressure at periphery (p_n) of hurricanes

Hurricane Date	Range in pressure at periphery (mb.)	Number of computations	Period over land covered by the p_n computations (hours)
Sept. 16, 1928	1014.5 ± 2.5	8	84
Aug. 13, 1932	1011 ± 1	3	24
Sept. 21, 1938	1010.7 ± 3	4	36
Sept. 23, 1941	1007 ± 2	7	36
Oct. 19, 1944	1014 ± 1	18	51
Aug. 27, 1945	1013 ± 2	21	60
Sept. 15, 1945	1016 ± 2	22	63
Sept. 19, 1947	1011.5 ± 2.5	16	45
Aug. 26, 1949	1014 ± 2	21	60
Aug. 31, 1954 (Carol)	1014.2 ± 4.2	8	21
Oct. 15, 1954 (Hazel)	1009 ± 1	3	6
Aug. 12, 1955 (Connie)	1010.5 ± 2.5	18	51
Aug. 17, 1955 (Diane)	1013 ± 1	17	48

The average central pressure as a function of time after landfall for the remaining 11 hurricanes is presented in figure 1. The dashed lines show the range of one standard deviation at different points along the curve. The individual central pressure curves, shown in figure 2, reveal that, generally, the lower the central pressure, at landfall or after landfall, the higher the corresponding rate of filling, and vice versa.

An empirical formula that fits the average pressure curve of figure 1 is:

$$p_o = p_L + 2.3t - 0.03t^2 \qquad (1)$$

where

p_o is the central pressure (in millibars)

p_L is the central pressure at landfall (in millibars)

t is the time after landfall (in hours)

A computation of the coefficient of correlation between central pressure and the rate of filling gave a value of -0.45. While the magnitude of the correlation obtained was not large, it may nevertheless be advantageous for a forecaster to have an initial estimate of filling based on averages. Such an estimate may be obtained from formula 1 for the first 30 hours after landfall. In applying the formula, no provision has been made for further adjustments

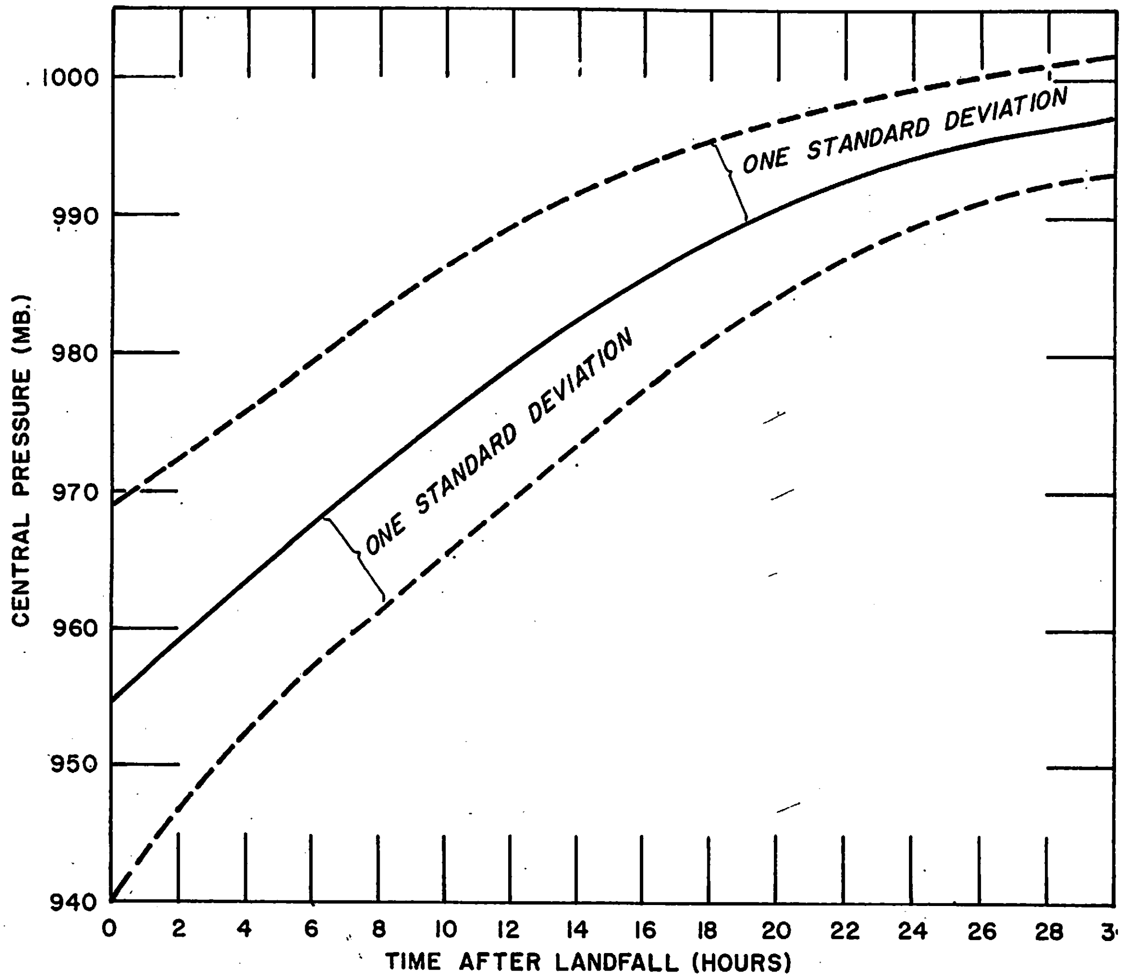

Figure 1. - Average central pressure (solid curve) of 11 hurricanes as a function of time after landfall. Dashed curves give the limits of one standard deviation from the average.

that might conceivably be required for other variables such as the speed or strength of the storm, because these factors have not been adequately studied.

The average central pressure curve (fig. 1) is everywhere concave downward. The average rate of filling at some particular time after landfall is given by the slope of the curve at the particular time. For the average hurricane, the rate of filling at landfall was 2.3 mb. per hour (fig. 1). Twenty-four hours after landfall, the average rate of filling was about 1 mb. per hour.

Examination of the changes in central pressure and intensity of individual hurricanes gave the impression that both filling and decrease in intensity proceeded at a lesser rate when the ratio of water to land of the underlying surface increased along the track. An examination was therefore made of filling data for those times when the hurricane tracks, while over land, were nevertheless moving parallel to the coast or moving coastward. The average

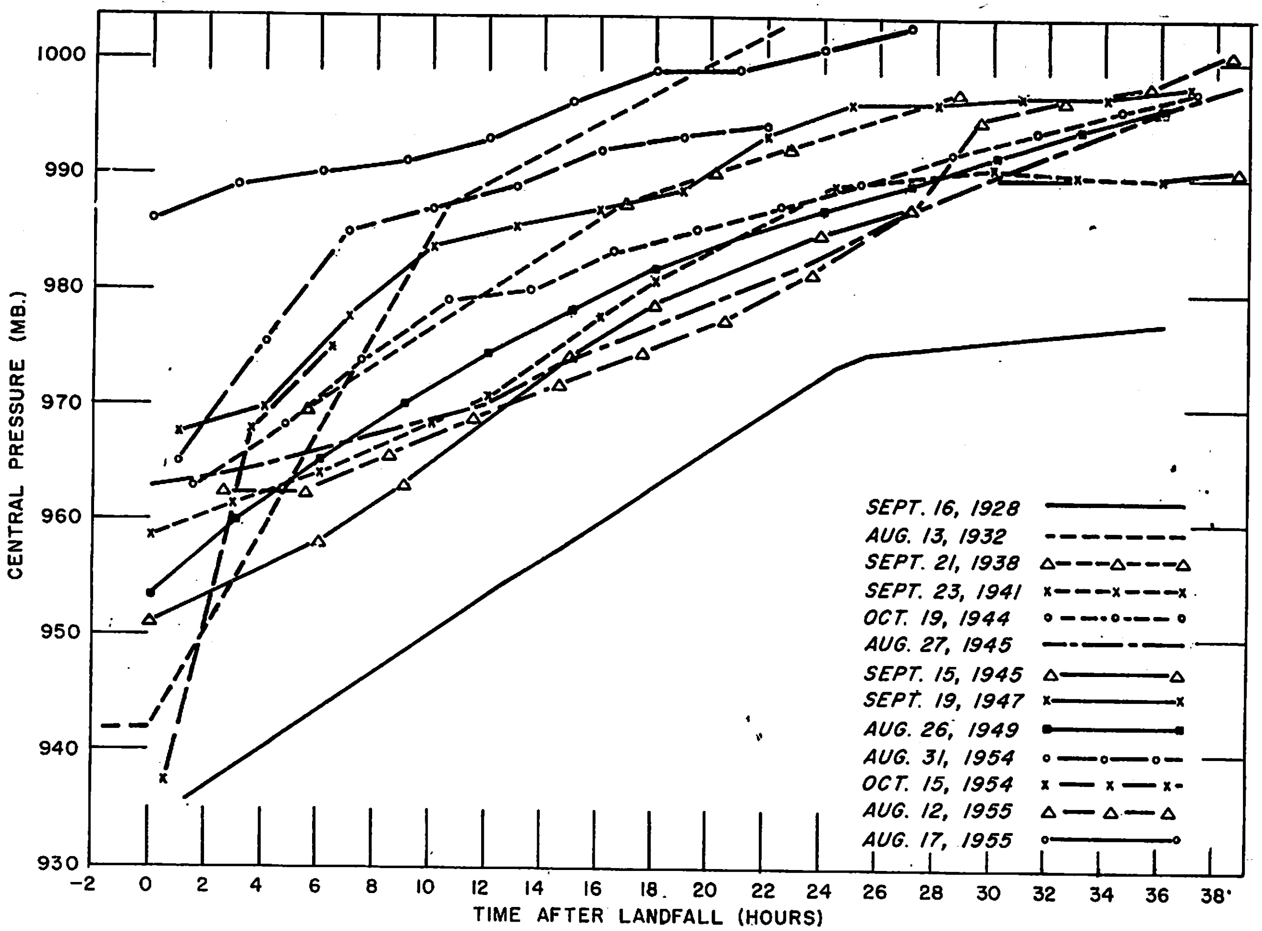

Figure 2. - Central pressure of 13 hurricanes as a function of time after landfall.

filling rate under these circumstances was found to be approximately constant at 2 mb. per 3 hours. The retardation in filling may be noted in curves II and III of figure 3. All the curves were arbitrarily shifted to a zero change position at landfall. Based on the few cases studied, the slopes of curves II and III, when compared to the slope of curve I, substantiate the generally-held impression that a higher ratio of water to land in the underlying surface helps maintain the strength of a hurricane.

5. PRESSURE EVALUATION AT PERIPHERY OF HURRICANE

James [6] spoke "of depressions as deep or shallow according to whether the central pressure is very low, or not so low, in relation to the average pressure over a wide area." In a subsequent article, the concept of pressure at some large distance from a storm center was used by James [7], when he defined the intensity of a vortex as the difference between the pressure at the center and at a very great distance therefrom. A similar concept was used in [5] where, in the discussion of the formula for the model radial sea level profile of a hurricane, one of the variables was defined as the pressure at some great distance from the center to which the profile is asymptotic. Knighting [8] and Gilman [2], in discussing the study by James [7], have commented on the vagueness of the pressure value at some great distance from a

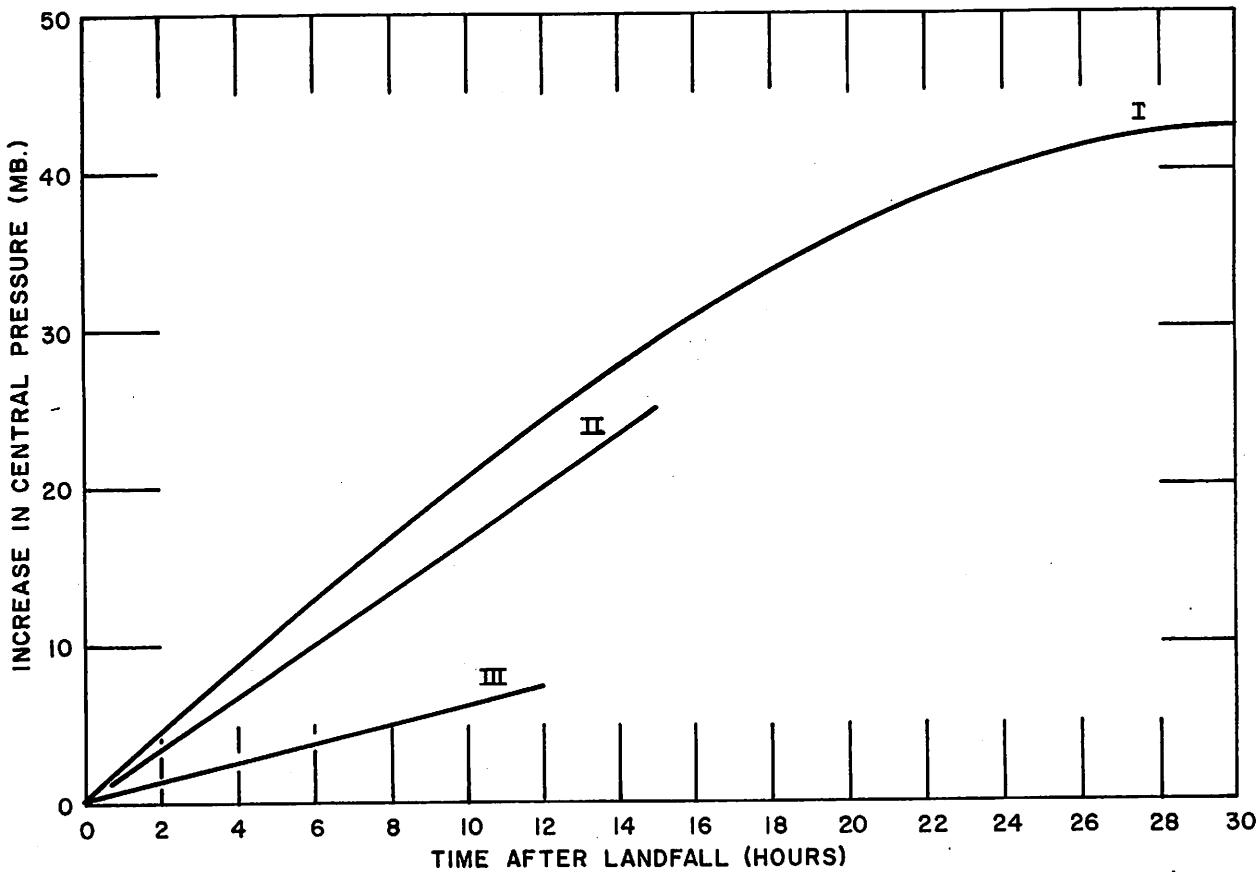

Figure 3. - Average filling (increase in central pressure) of selected hurricanes as a function of time after landfall. Curve I: Average of 11 hurricanes that continued to move away from coastline after landfall. Curve II: Average of 4 Florida hurricanes. Curve III: Average over several portions of original tracks over land during periods when ratio of water to land in underlying surface increased.

vortex. James [9], however, claimed that "two analysts agree reasonably close" on this parameter "under normal circumstances." Syōno [15] touched on the problem of defining the outer boundary of the Rankine-type vortex. He mentioned that for practical purposes the outer boundary might be defined by the outermost closed isobar. Syono claimed however that no theoretical basis had been given to support such a definition. Later, James [10] described an intensity factor, "specifying to what extent the surface pressure in a vortex falls below or exceeds what may be regarded as normal..."

With the above as a background, an attempt was made to select a more rigorous definition for the pressure value at the periphery of a hurricane. This value, designated p_n, was defined as the average value of the pressure at radial distances from the center where the sea level isobars first ceased to curve cyclonically around low pressure. Naturally, in making such evaluations from surface weather maps, small-scale irregularities in the isobars were disregarded. The pressure at the periphery was determined from an average of readings in four arbitrary, but for the sake of uniformity, definite

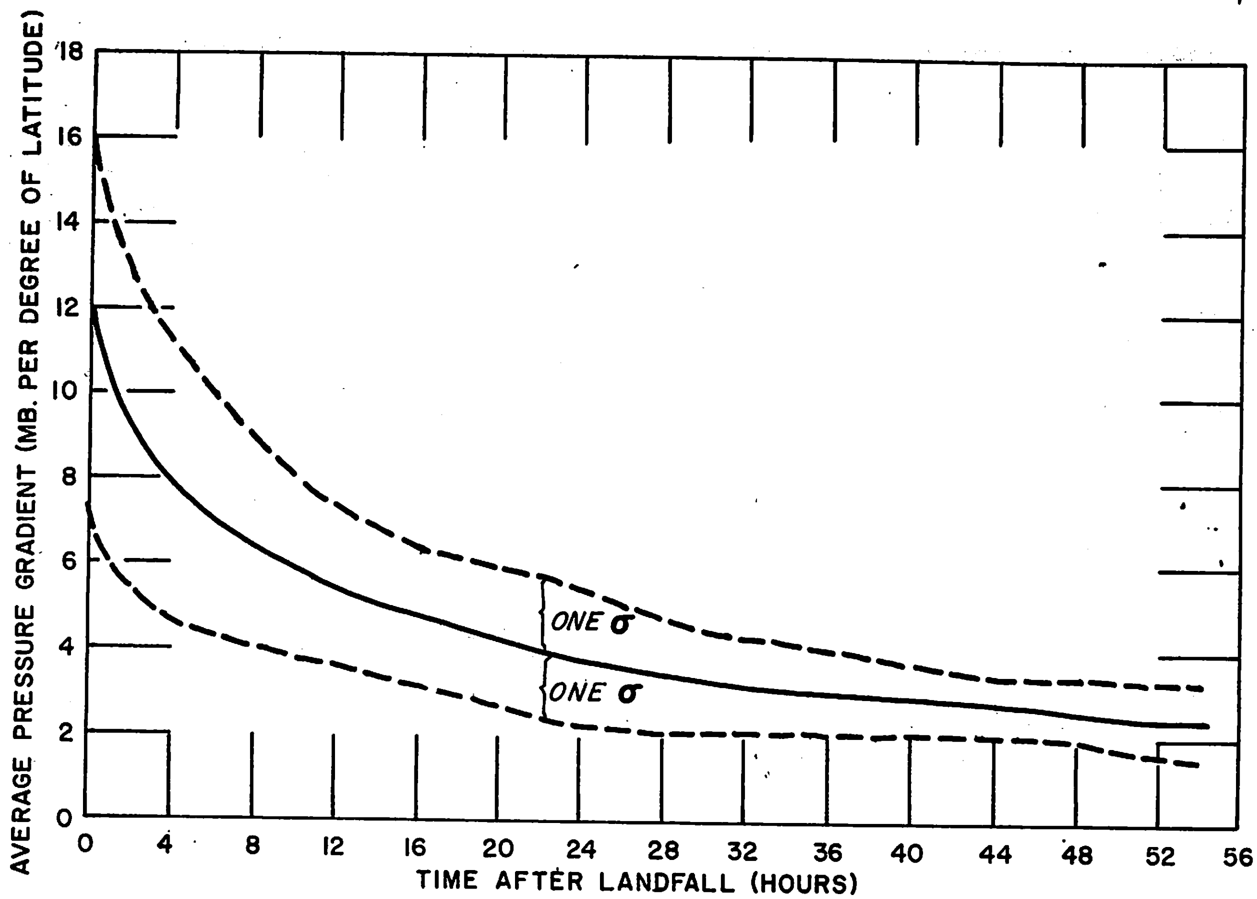

Figure 4. - Average pressure gradient (solid curve) of 13 hurricanes as a function of time after landfall. Dashed curves give the limits of one standard deviation from the average.

directions relative to the track of the storm: to the front, rear, left, and right of the center. Several trial comparisons in the evaluation of p_n, between two analysts, did not differ by more than 1 millibar. The above criteria therefore appeared to be useful in defining the pressure at the periphery of a hurricane.

The suggested method of determining p_n values may add objectivity and, therefore, usefulness in forecasting computations involving this parameter. For example, consider the following formula for computing the maximum surface wind in a hurricane (Fletcher [1]):

$$V_m = K_m (p_n - p_o)^{1/2} \tag{2}$$

where V_m is the maximum surface wind speed; K_m is a parameter which depends on several factors (Myers, [11]); p_n is the pressure along the periphery of the vortex; and p_o is the pressure at the center of the vortex. It can be seen that a reliable p_n value is one of the elements required for useful application of the relationship expressed by formula (2). Other examples of formulas

Table 2. - Factors for reducing wind speeds in hurricanes over land*

(a) - Due to change in pressure depth ($p_n - p_o$)

(1) Time (hours after landfall)	(2) Average Pressure depth (mb.)	(3) Square root of column (2)	(4) Adjustment Ratio for wind speeds (ratio of column (3) to landfall value of same column)
Landfall	58.3	7.6	1.00
1	56.2	7.5	.98
2	54.1	7.4	.96
3	51.5	7.2	.94
4	49.0	7.0	.92
5	46.7	6.8	.90
6	44.8	6.7	.88
7	43.4	6.6	.86
8	42.2	6.5	.85

(b) - Due to change in pressure gradient ($(p_n - p_o)/ D_n$)

(1)	(2)	(3)	(4)
Landfall	11.7	3.42	1.00
1	9.95	3.16	.92
2	9.07	3.01	.88
3	8.45	2.91	.85
4	7.92	2.82	.82
5	7.49	2.74	.80
6	7.10	2.67	.78
7	6.77	2.60	.76
8	6.45	2.54	.74

*Based on 13 selected storms

and calculations requiring a dependable evaluation of p_n may be found in the references given earlier in this section.

The variation in the value of p_n, from map to map, for any particular storm, was small. The range of p_n for each respective storm is shown in table 1. The average value for all 13 storms was 1013 mb., the same as the standard pressure at sea level. This lends some justification to the recommendation by James [9, 10] and others that satisfactory p_n values may be obtained from 5-day, monthly, or seasonal means for the respective region. It may be of interest to mention that the average value of the asymptotic pressure for the profiles of all the storms in table 3.1 of [12] was also 1013 mb.

6. WIND SPEED REDUCTION FACTORS

Adjustment factors that are applicable for estimating the decrease in the maximum wind speed with lapsed time after land fall are given in tables 2a and

Table 3. - Factors for reducing wind speeds in hurricanes over Florida*

(a) - Due to change in pressure depth ($p_n - p_o$)

(1) Time (hours after landfall)	(2) Average Pressure Depth (mb.)	(3) Square root of column (2)	(4) Adjustment ratio for wind speeds (ratio of column (3) to landfall value of same column)
Landfall	62.8	7.9	1.00
1	61.9	7.9	1.00
2	60.8	7.8	.99
3	59.1	7.7	.97
4	57.6	7.6	.96
5	56.1	7.5	.95
6	54.4	7.4	.94
7	52.5	7.2	.91
8	51.0	7.1	.90

(b) - Due to change in pressure gradient (($p_n - p_o$)/ D_n)

Landfall	9.35	2.98	1.00
1	9.1	2.90	.97
2	8.9	2.84	.95
3	8.6	2.74	.92
4	8.3	2.64	.89
5	8.0	2.55	.86
6	7.7	2.45	.82
7	7.4	2.36	.79
8	7.05	2.24	.75

*Based on 4 storms

3a. The factors were computed using the assumption that the speeds will be directly proportional to the square root of the average pressure depth, following Fletcher [1]. Tables 2b and 3b have been appended because it was noted that when average pressure gradient was substituted for pressure depth, the resulting adjustment ratios gave wind speeds that were reasonably consistent with some observations. For example, in Hazel, October 15, 1954, the maximum wind at landfall was 94 m.p.h. Approximately 7 hours later, the maximum wind, based on observations, was 72 m.p.h. Application of the appropriate factor (0.76) from table 2b gives an estimate of 71 m.p.h. Another instance involved Audrey, June 27, 1957, where the maximum wind at landfall was 105 m.p.h., 3 hours later 91 m.p.h. (both speeds adjusted to an anemometer height of 30 feet over water), and when estimated from table 2b, 89 m.p.h.

Tables 2 and 3 should be applicable for estimating speeds at other radii than that of the maximum wind, if we may assume only slight variations in shape of the wind speed profiles with time, in the hurricane.

7. VARIATION IN HURRICANE INTENSITY OVER LAND

The pressure gradient from the periphery to the center of a storm is one of the more important factors related to the storm's intensity. Pressure gradients along 4 radii were computed for each of the hurricanes at successive map times, beginning with the first map after landfall and continuing until the cyclonic circulation disappeared, or until the storm lost most of its tropical characteristics. The computed average pressure gradient as a function of time after landfall is given in figure 4. The dashed lines show the range of one standard deviation on either side of the mean.

The individual hurricane plots of pressure gradient against time seemed to indicate a positive relationship between the magnitude of the pressure gradient and the rate of decrease in the pressure gradient. The computed correlation between the above variables was 0.56, while the correlation between the change in the central pressure and the prevailing magnitude of the pressure gradient was 0.37.

8. INCIDENTAL RESULTS

The average radial distance, D_n, from the center to p_n, remained relatively constant from map to map for any one storm during the period while hurricane characteristics predominated. The average trend was in the direction of a slow diminution in D_n. By contrast, individual storms showed a large variation in D_n, the largest value recorded being 570 nautical miles, the smallest 150 nautical miles. A compilation of the detailed values of D_n, p_n, and p_o for all 13 storms is given in table 4.

A useful value for the average speed of forward movement of a hurricane over land in the first 36 hours after landfall is 17 m.p.h. In fact, 17 $\pm$ 11 m.p.h. will account for nearly all observed speeds, except in the rare instances when the movement is abnormally rapid.

The rate of filling (Δp_o/3 hr.) for each of the 13 storms was plotted against the pressure depth ($p_n - p_o$). The resulting curves for the individual storms were noticeably similar (fig. 5). All but one of the curves were confined to a relatively narrow region on the graph. The one conspicuously different curve represents hurricane Hazel, October 15, 1954. A reexamination of all the data failed to disclose any error that might account for the departure. A tentative hypothesis is that the excessive filling rates may have been related to the phenomenally high speed of translation of the storm center over land (averaging between 55 and 60 m.p.h. over a 6-hour period). Filling may be more rapid when there is greater exchange of air between the storm and the surrounding air. The likelihood that the greater the speed of the storm, the greater the exchange of mass between the hurricane and its environment, has been demonstrated in some hurricane trajectory studies carried out in the Hydrometeorological Section of the U. S. Weather Bureau.

Table 4. - Values of p_o, p_n, and D_n, for 13 selected hurricanes [1, 2]

Date	Time (GMT)	p_o (mb.)	p_n (mb.)	D_n (deg. Lat.)
Sept. 17, 1928	0000	934.5	-	-
	0100	935.0	1012.0	7.5
	1300	955.0	1013.5	8.5
Sept. 18, 1928	0100	974.0	1012.5	9.0
	1300	978.0	1011.0	7.0
Sept. 19, 1928	0100	981.0	1012.0	7.0
	1300	989.0	1014.0	6.0
Sept. 20, 1928	0100	1001.5	1013.5	4.5
	1300	1007.5	1016.0	4.5
Aug. 14, 1932	0100	942.0	1012.0	3.8
	1300	987.0	1011.5	3.6
Aug. 15, 1932	0100	1002.0	1010.0	3.3
Sept. 21, 1938	1945	943.0	-	-
Sept. 22, 1938	0030	968.5	1014.5	9.0
	1230	987.5	1010.5	9.0
Sept. 23, 1938	0030	997.0	1007.0	6.0
	1230	1004.0	1010.0	4.0
Sept. 23, 1941	1830	958.5	1009.0	5.0
Sept. 24, 1941	0030	964.0	1008.0	6.0
	0630	970.5	1009.0	6.0
	1230	980.5	1007.5	6.0
	1830	989.0	1007.0	6.0
Sept. 25, 1941	0030	990.5	1005.5	5.0
	0630	986.5	1008.0	6.0
Oct. 19, 1944	0800	962.5	[3](1012.5)	(7.5)
	0930	963.0	1013.5	8.0
	1230	968.0	1014.5	8.0
	1530	974.0	1015.5	8.0
	1830	978.0	1013.0	8.0
	2130	980.0	1014.5	9.0
Oct. 20, 1944	0030	983.5	1014.5	9.0
	0330	985.0	1014.5	8.0
	0630	987.0	1013.0	8.0
	0930	989.5	1013.0	8.0
	1230	992.0	1013.5	7.5
	1530	994.0	1014.0	8.0
	1830	996.0	1014.5	8.0
	2130	997.5	1013.5	7.5
Oct. 21, 1944	0030	998.0	1014.5	7.5
	0330	998.0	1014.5	7.0
	0630	997.0	1014.5	7.0
	0930	997.0	1013.5	7.0

(continued)

(Table 4. continued)

Date	Time (GMT)	p_o (mb.)	p_n (mb.)	D_n (deg. lat.
Aug. 27, 1945	1230	963.0	1012.0	3.0
	1530	964.0	1013.0	3.0
	1830	966.0	1013.0	3.0
	2130	970.0	1011.0	3.0
Aug. 28, 1945	0030	974.0	1011.0	3.0
	0330	977.0	1012.0	3.5
	0630	980.0	1012.0	3.5
	0930	983.0	1012.0	3.5
	1230	987.0	1011.0	3.0
	1530	990.0	1013.0	3.0
	1830	993.0	1012.5	3.0
	2130	996.0	1011.0	3.0
Aug. 29, 1945	0030	998.0	1011.0	2.5
	0330	1000.0	1012.0	3.0
	0630	1002.0	1012.5	3.0
	0930	1004.0	1012.5	3.0
	1230	1006.0	1013.0	3.0
	1530	1008.0	1015.0	3.0
	1830	1009.0	1015.0	2.5
	2130	1009.0	1012.5	2.0
Sept. 15, 1945	2130	951.5	1014.5	6.5
Sept. 16, 1945	0030	954.5	1015.0	7.0
	0330	958.0	1015.0	6.5
	0630	963.0	1014.5	7.0
	0930	968.5	1015.5	8.0
	1230	974.0	1016.0	8.5
	1530	979.0	1016.0	6.5
	1830	982.0	1014.5	6.5
	2130	985.0	1013.0	5.5
Sept. 17, 1945	0030	987.0	1014.5	6.5
	0330	989.0	1016.0	6.5
	0630	990.0	1015.0	6.5
	0930	990.0	1013.5	5.5
	1230	990.5	1015.0	5.5
	1530	993.0	1015.5	5.8
	1830	995.5	1016.5	7.0
	2130	998.0	1016.5	6.5
Sept. 18, 1945	0030	1000.5	1016.0	5.5
	0330	1003.5	1017.0	5.5
	0630	1006.0	1017.0	6.0
	0930	1008.0	1017.5	6.0
	1230	1012.0	1019.0	5.5
Sept. 19, 1947	1430	966.0	-	-
	1530	967.5	1014.5	6.0
	1830	970.0	1013.5	6.0
	2130	977.5	1011.0	6.0

(continued)

(Table 4. continued)

Date	Time (GMT)	p_o (mb.)	p_n (mb.)	D_n (deg. lat.)
Sept. 20, 1947	0030	984.0	1011.0	5.5
	0330	985.5	1012.0	6.0
	0630	987.0	1011.5	6.0
	0930	989.0	1011.5	6.0
	1230	993.5	1010.5	5.0
	1530	996.5	1012.5	5.5
	1830	996.5	1011.0	5.5
	2130	997.0	1010.0	5.5
Sept. 21, 1947	0030	997.0	1010.0	5.5
	0330	998.0	1011.5	6.0
	0630	999.0	1010.0	5.0
	0930	999.0	1009.0	4.5
	1230	1000.0	1009.0	4.0
Aug. 27, 1949	0030	953.5	1014.0	4.5
	0330	960.0	1014.5	4.5
	0630	965.0	1014.0	5.0
	0930	970.0	1013.5	5.0
	1230	974.5	1016.0	6.0
	1530	978.5	1016.0	6.0
	1830	982.0	1015.0	6.0
	2130	984.5	1013.0	5.5
Aug. 28, 1949	0030	987.0	1014.0	5.5
	0330	989.0	1014.0	5.0
	0630	992.0	1014.0	5.0
	0930	994.0	1013.0	4.5
	1230	996.0	1014.5	5.0
	1530	998.5	1015.0	5.0
	1830	1000.5	1014.0	5.0
	2130	1001.5	1012.0	4.5
Aug. 29, 1949	0030	1002.0	1013.0	5.0
	0330	1002.0	1014.0	6.0
	0630	1000.5	1013.0	6.0
	0930	999.5	1013.0	5.5
	1230	1000.0	1013.0	5.5
Aug. 31, 1954	1430	961.0	-	-
(Carol)	1530	965.0	1018.0	8.0
	1830	975.5	1018.5	9.0
	2130	985.0	1018.0	8.0
Sept. 1, 1954	0030	987.0	1016.0	8.0
	0330	989.0	1014.0	7.5
	0630	992.0	1013.0	7.5
	0930	993.0	1010.0	6.0
	1230	994.0	1011.0	5.5

(continued)

(Table 4. concluded)

Date	Time (GMT)	p_o (mb.)	p_n (mb.)	D_n (deg. lat.)
Oct. 15, 1954 (Hazel)	1500	937.0	-	-
	1530	937.0	1010.0	7.5
	1830	970.0	1008.5	8.0
	2130	975.0	1009.0	8.5
Aug. 12, 1955 (Connie)	1300	962.5	-	-
	1530	962.5	1012.5	7.0
	1830	962.5	1012.5	7.5
	2130	965.5	1012.5	9.5
Aug. 13, 1955	0030	969.0	1013.5	9.5
	0330	972.0	1013.5	8.5
	0630	974.5	1014.0	8.5
	0930	977.5	1014.0	7.5
	1230	981.5	1015.5	7.0
	1530	989.0	1016.5	6.5
	1830	995.0	1017.0	6.5
	2130	997.0	1017.0	6.0
Aug. 14, 1955	0030	998.0	1016.5	6.0
	0330	1002.0	1017.0	5.5
	0630	1002.0	1016.0	5.0
	0930	1003.0	1017.5	5.5
	1230	1006.0	1018.0	5.0
	1530	1006.0	1017.5	5.5
	1830	1010.0	1017.0	5.0
Aug. 17, 1955 (Diane)	1230	986.0	1013.0	6.5
	1530	989.0	1014.5	7.0
	1830	990.0	1013.0	6.0
	2130	991.0	1012.5	7.0
Aug. 18, 1955	0030	993.0	1013.0	6.0
	0330	996.0	1012.5	6.5
	0630	999.0	1012.5	5.5
	0930	999.0	1012.0	4.5
	1230	1001.0	1014.0	6.0
	1530	1003.0	1014.5	6.0
	1830	1004.0	1014.5	7.0
	2130	1003.5	1013.0	4.5
Aug. 19, 1955	0030	1003.0	1014.0	5.0
	0330	1003.0	1013.5	4.5
	0630	1002.0	1012.5	4.0
	0930	1000.5	1013.0	4.0
	1230	1000.0	1014.0	5.0

[1] D_n is the average distance from the pressure center to the point where p_n is observed.

p_o is the lowest pressure, in millibars.

p_n is the average pressure at the periphery of the storm in millibars.

[2] All values in the table have been rounded off to the nearest 0.5.

[3] Figures in parentheses are estimates.

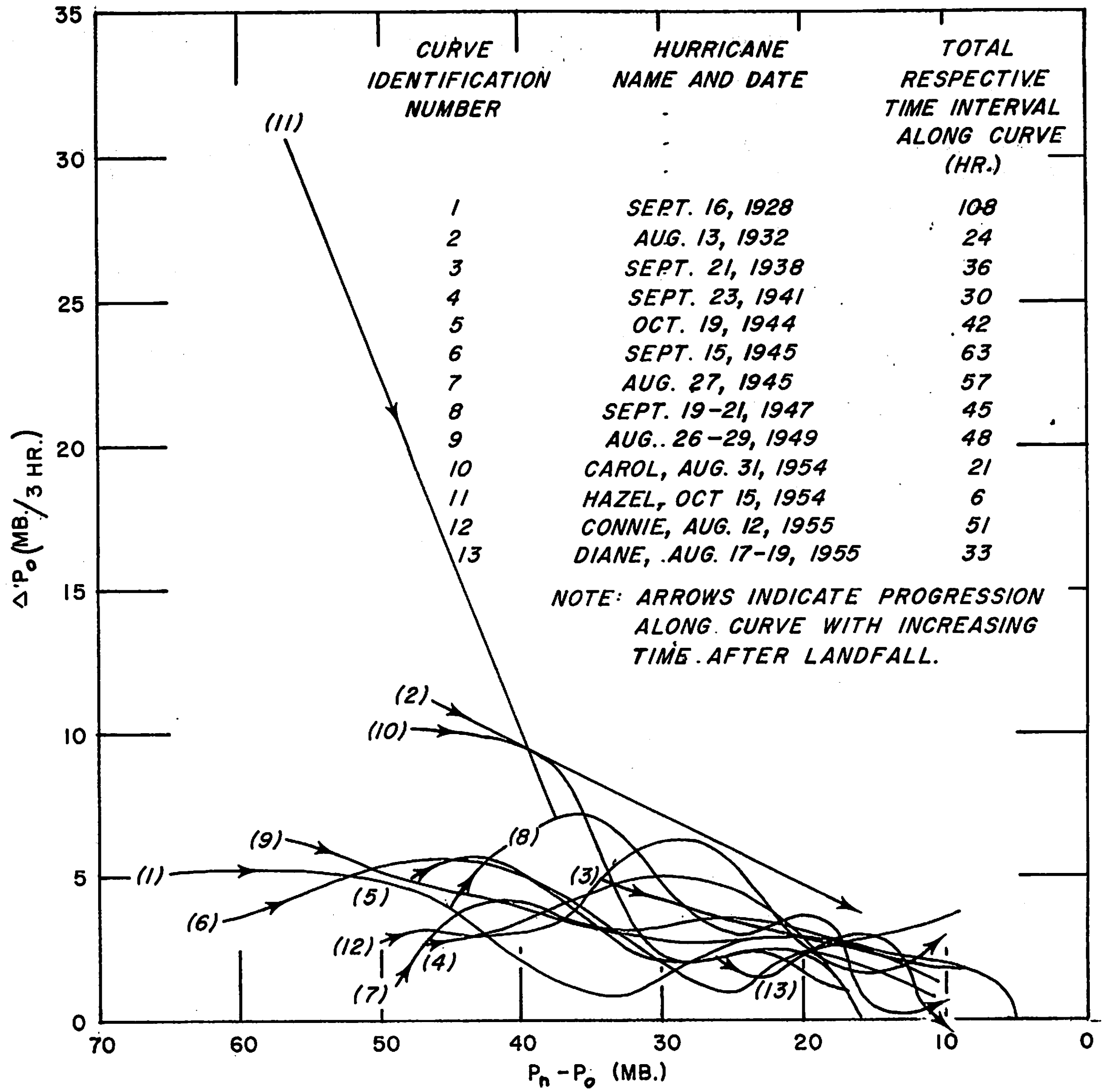

Figure 5. - Rate of central pressure change of 13 hurricanes as a function of pressure depth.

9. CONCLUSIONS

The average change in central pressure and pressure gradient with time has been evaluated for several hurricanes over land. An empirical formula has been suggested for forecasting the central pressure.

A new definition has been offered for evaluation of the pressure at the periphery of a hurricane. The method of evaluation has proved to be reasonably objective, fairly easy to compute, and the average of a number of computations was approximately equal to normal sea level pressure. The method of computation also gave values of p_n that were reasonably constant, from hour to hour, for any particular storm.

Limited data have been offered in support of the hypothesis that a hurricane tends to maintain intensity and fill at a lesser rate, the larger the ratio of water to land in the underlying surface.

10. SUGGESTIONS FOR FURTHER STUDY

Among the topics related to filling that could prove interesting and fruitful for further study are:

(1) Variation in pressure change with distance from the hurricane center (in continuation of this topic as treated in [5]).

(2) Possibility of a break or discontinuity in the curve showing rate of change in filling, or of intensity, with time, corresponding to the interval when the storm changes its charactor from tropical to extratropical.

(3) The effect upon filling, of atmospheric influences outside the hurricane circulation.

(4) A possible difference in the rate of filling:

(a) between night and day;

(b) based on size (areal extent) of the storm or the magnitude of other parameters, such as R, etc.;

(c) varying with the speed of the storm (One correlation coeffient was computed in the course of this study between the 3-hour change in central pressure and the corresponding distance traveled, the result being 0.038.);

(d) varying with the temperature of the surface over which the storm is passing.

(5) Is filling primarily due to a loss of a warm moist air source or to the increased friction of a land surface?

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