RELATIVE MOTION OF HURRICANE PAIRS

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ABSTRACT

It is found that the observed relative motion of Atlantic hurricanes occurring simultaneously as pairs is related to the orientation of their line of centers, and that the tendency to approach is more pronounced when the hurricane centers are positioned in an east-to-west through southeast-to-northwest line. Other orientations of hurricane pairs have been associated with a separation of the centers.

The relative motion of centers of pairs separated more than 600 nautical miles is found to be predominantly clockwise. Most of the cases of counterclockwise revolution of these hurricane pairs occurred when the centers were oriented in essentially an east-to-west line. Limited data suggest relative counterclockwise revolution existed in most cases with centers separated less than 600 nautical miles.

It is found that the predominant relative motion of Pacific tropical cyclone pairs in the vicinity of the Philippines is counterclockwise. It is suggested that this difference in relative motion of Pacific tropical cyclone pairs from that of Atlantic pairs may be due to differences in circulation patterns related to geographical features.

1. INTRODUCTION

The relative motion of vortices occurring simultaneously as pairs has been studied extensively by Fujiwhara [1]. He found that the relative motion was composed of the counterclockwise revolution of one vortex about another and the tendency for the approach of like circulations. Haurwitz [2] derived a mathematical expression showing that the counterclockwise revolution of one cyclonic vortex with reference to another was directly proportional to the intensity of the circulations and inversely proportional to the square of the distance between the two centers.

In the present study, the theories of Fujiwhara and Haurwitz were tested by observing the behavior of Atlantic hurricane pairs as shown in the convenient annual tracks of North Atlantic tropical cyclones for the period 1886–1959 [3], [4]. There were 5 cases in which the tracks showed hurricane pairs closer than 600 nautical miles. There was a total of 38 cases where two or more hurricanes occurred simultaneously for a period of 24 hours or more, separated by a distance of 1500 nautical miles or less in the area encompassed by the North Atlantic Ocean, the Gulf of Mexico, and Caribbean Sea.

2. PROCEDURE

The procedure which was used to determine the relative motion, illustrated in figure 1, is as follows:

(1) Indicate north and draw concentric circles with radii of 600 and 1200 nautical miles on tracing paper.

(2) Check the annual hurricane tracks for overlapping dates of hurricanes.

(3) Place the tracing paper over the track-map so that the center of concentric circles is positioned on the hurricane that was known to exist first, and orient on north at the longitude of this hurricane.

(4) Indicate the relative position and date of the second hurricane.

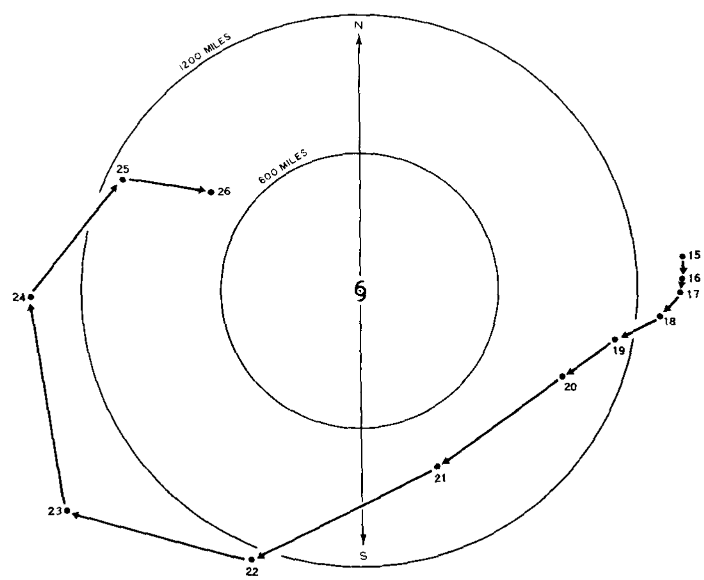

FIGURE 1.—The relative motion of an Atlantic hurricane pair, August 15–26, 1893. The first hurricane is centered at the center of the concentric circles. The path of the second hurricane relative to the first is given by the arrows connecting daily relative position points.

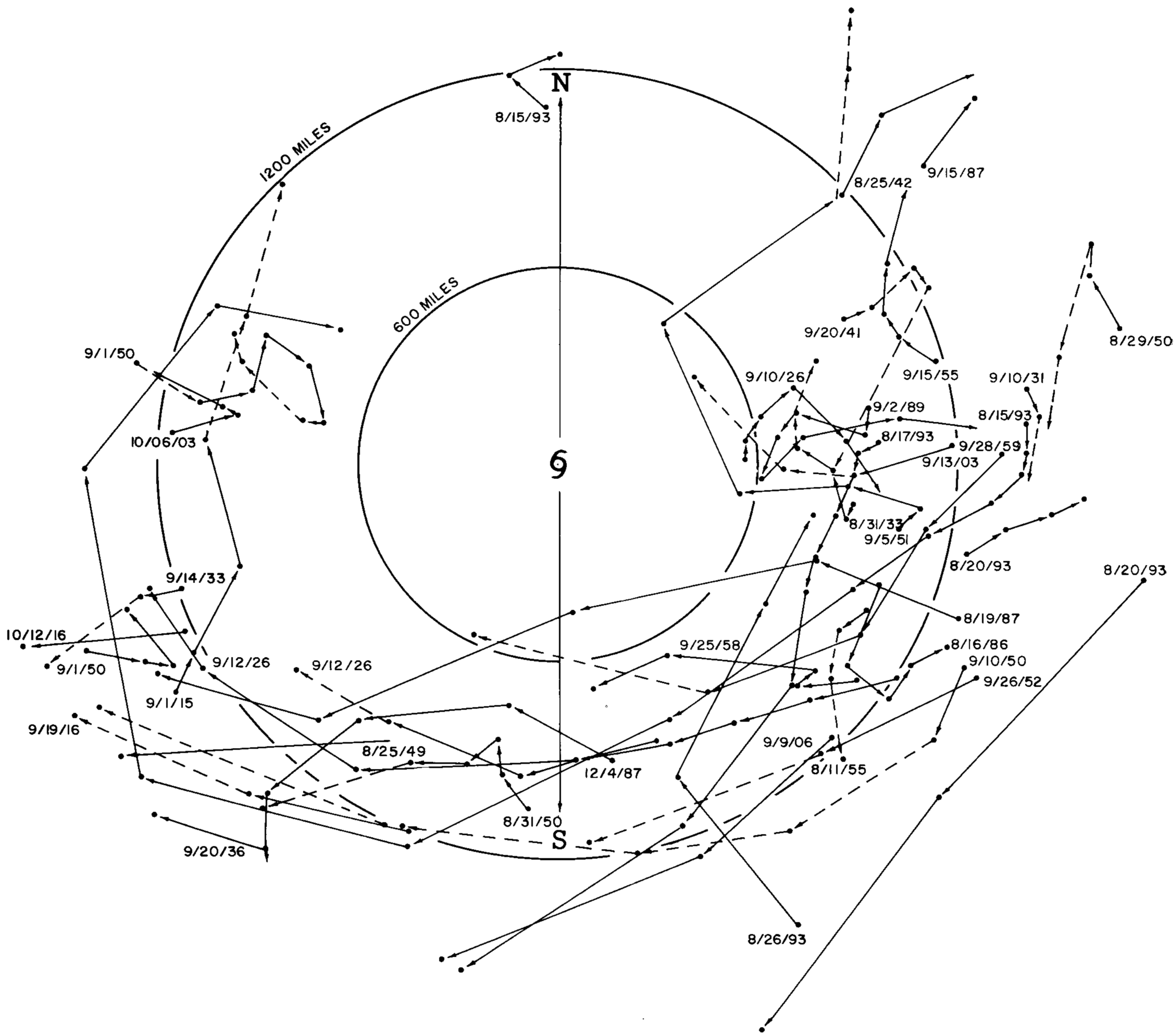

FIGURE 2.—Composite chart of relative motion of Atlantic hurricane pairs, 1886–1959. Dates correspond to first relative positions.

(5) Repeat steps 3 and 4 for each subsequent daily position as long as the tracks are available.

(6) Connect daily positions of relative motion.

The individual tracks, as illustrated in figure 1, were combined on a single chart, figure 2. Dashed lines were used when one or both of the hurricanes diminished below hurricane force. The direction of relative motion is indicated by the arrows.

3. RESULTS FOR ATLANTIC HURRICANES

The 38 cases of hurricane pairs contained 145 24-hour periods of relative motion between hurricane pairs. From these periods of relative motion, the following results, as summarized in figure 3, were obtained:

(1) A tendency to separate was observed in 80 periods (55 percent); a tendency to approach in 64 periods (44 percent); indeterminate in 1 period (1 percent).

(2) The maximum segregation of separation periods (81 percent) from the approach periods (19 percent) was obtained from quadrants with center orientation north-northeast to south-southwest.

(3) In the remaining quadrants, the centers were oriented west-northwest to east-southeast; these quadrants contained 58 percent approach periods, 41 percent separation periods, and 1 percent indeterminate.

(4) Clockwise revolving motion occurred in 104 periods (72 percent), counterclockwise in 41 periods (28 percent).

(5) The maximum segregation of clockwise periods (88 percent) from counterclockwise periods (12 percent) was obtained from quadrants with centers oriented north to south.

(6) The periods with east to west quadrant orientation were divided 65 percent clockwise, 35 percent counterclockwise.

In the quadrants whose centers were oriented east-to-west, the average speed of relative motion was 5 knots. Since the direction of relative motion was variable, the mean vector motion was small (approximately 1 knot clockwise approaching).

In the quadrants whose centers were oriented north-to-south, the average speed of relative motion was approximately 10 knots. The direction of the motion was relatively uniform and the mean vector indicated about 7 knots in a clockwise direction.

4. COMPARISON WITH PACIFIC TROPICAL CYCLONES

There is a difference between the predominant relative motion of simultaneous pairs of tropical cyclones in some areas of the Pacific region and hurricane pairs in the Atlantic. The results of this study show the predominant relative motion is clockwise for simultaneous hurricane pairs in the Atlantic region. The method described here was applied to the Pacific tropical cyclone pairs tabulated by Haurwitz [2] using the center positions indicated on the historical maps, and the results are combined in figure 4. Most of these cases were positioned around the Philippine Islands with one tropical storm centered in the South China Sea and the other in the Pacific, east or northeast of the Philippine Islands. The predominant relative motion of these tropical cyclones was found to be counterclockwise as suggested by Haurwitz [2] and Fujiwhara [1].

The explanation for the difference in the relative motion between tropical cyclone pairs in the Pacific and hurricane pairs in the Atlantic is believed to be a difference in the circulation pattern as suggested by the tropical cyclone track maps. In figure 5, note the double maxima of cyclone tracks in the Western Pacific and China Sea. The maximum to the left extends from the Philippine Islands west across the South China Sea to the coast of Asia. A second maximum of cyclone tracks approaches, then recurves northeast just to the east of the Philippine Islands. The predominant relative motion track in figure 4 is suggested by the relative motion of the two

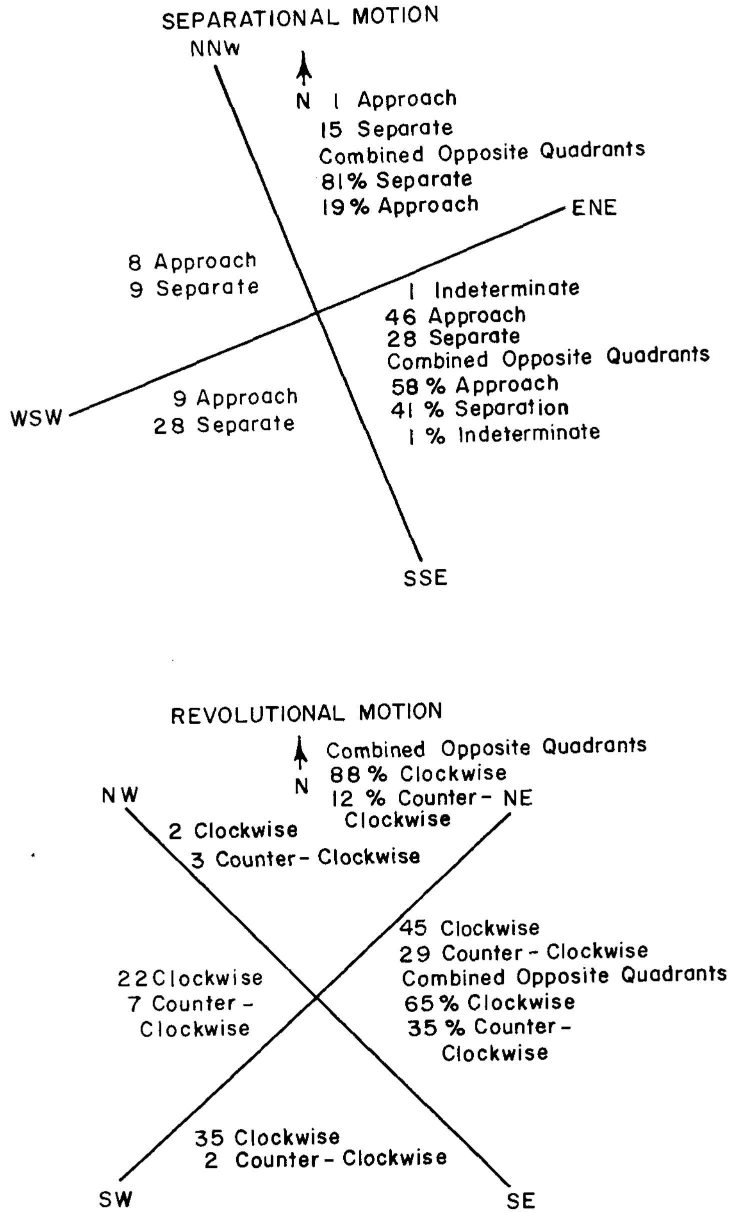

FIGURE 3.—Distribution of relative motion of Atlantic hurricane pairs by quadrants based on orientation of the lines connecting the centers. Percentages for cases in opposite quadrants are combined.

track maxima. If the reference or central point of figure 4 is placed over the track maximum in the South China Sea in figure 5, the second tropical cyclone maximum recurves into the northeast quadrant similar to the relative tracks in figure 4. In the Atlantic area this grouping of tropical cyclone tracks is not in evidence. The most striking feature of the hurricane tracks is the large number that follow a general pattern similar to the idealized track in figure 6. Figure 7 illustrates the relative motion of a

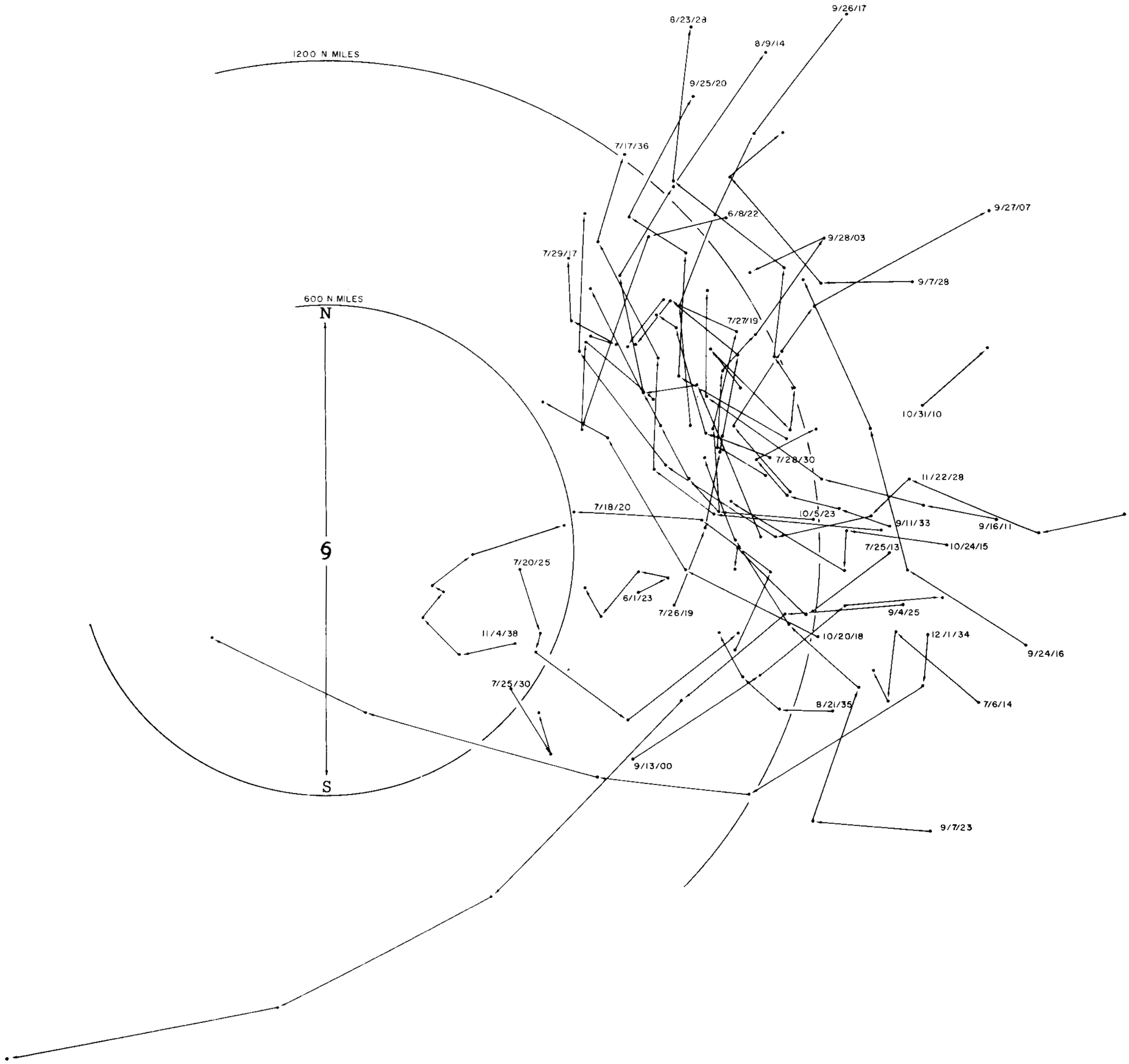

FIGURE 4.—Composite chart of relative motion of western Pacific tropical cyclone pairs (only cases tabulated by Haurwitz [2]). Dates correspond to first relative positions.

simultaneous hurricane pair where both hurricanes follow the idealized track displaced eight days apart. Note the similarity between the predominating pattern in figure 2 and motion in figure 7.

Thus far certain characteristics of tropical cyclone tracks peculiar to the geographical area have been suggested as explanations for the observed difference in the relative motion tracks between figures 2 and 4. It seems proper

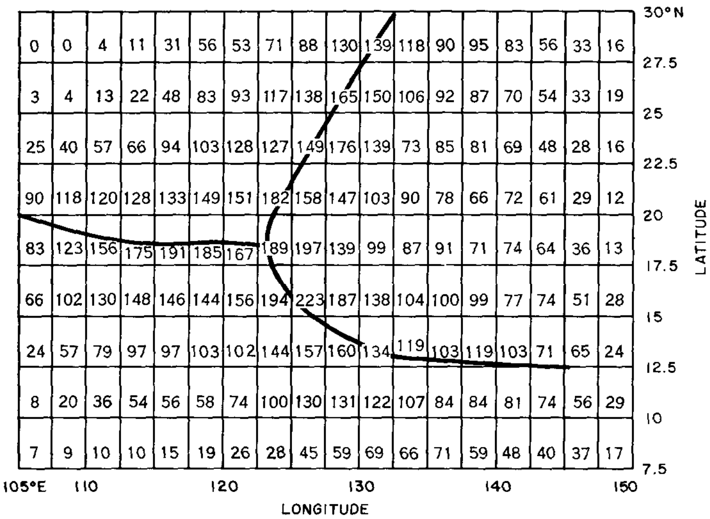

FIGURE 5.—Total number of tropical cyclone tracks passing through each 2.5° latitude-longitude "square," 1884–1953. The heavy lines are loci of maximum numbers. Data from Chin [5].

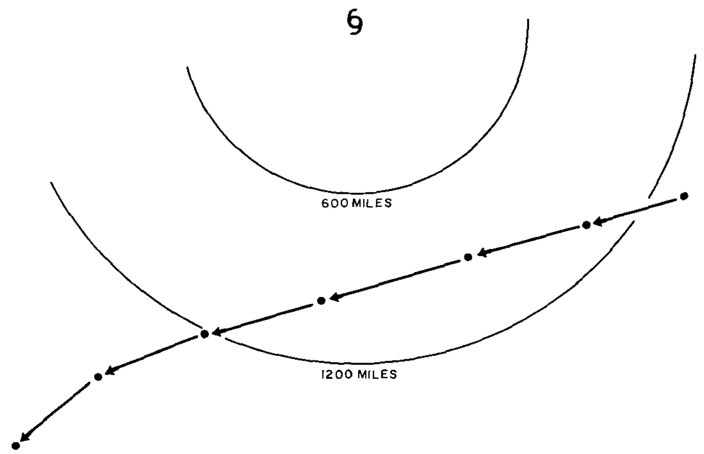

FIGURE 7.—Relative motion of a hurricane pair separated by eight days, both following the idealized track in figure 6.

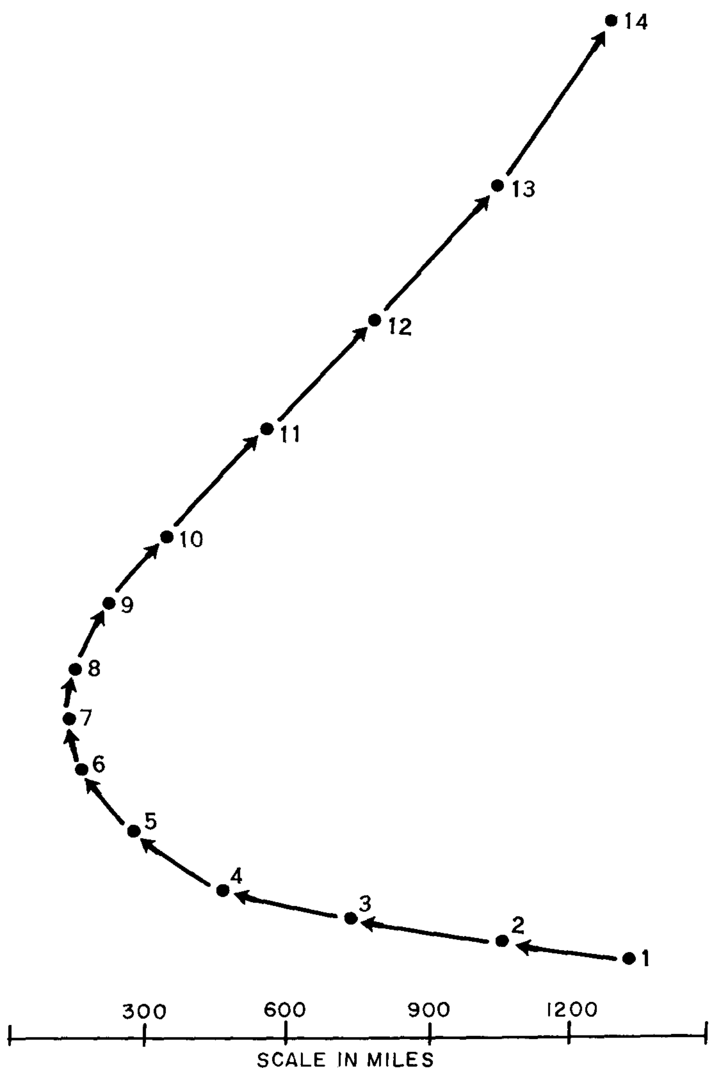

FIGURE 6.—Idealized track suggested by the general pattern of movement of Atlantic hurricanes.

to assume that the tracks are a function of the circulation pattern, which on this scale is likely due to geographical features. However, detailed explanations of the circulation differences are beyond the scope of this paper.

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