THE WEATHER AND CIRCULATION OF SEPTEMBER 1961

Including a Discussion of Tropical Storm Activity

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1. INTRODUCTION

September 1961 was characterized by pronounced temperature regimes in the United States—very cool in the West and unusually warm in the East. This pattern of temperature was an abrupt change from that which prevailed in August and the summer season 1961 [1]. The most dramatic change occurred in the Northwest where temperatures during September averaged as much as 12° F. cooler than those observed in August.

This reversal in temperature regimes was associated with a pronounced reversal in the circulation, with the strong ridge over western North America during August being replaced by a deep trough in September. Substantial amounts of precipation fell in the Northern Plains as a result of this circulation reversal, thus alleviating the severe drought in that area.

Four tropical storms developed in the Atlantic and western Caribbean early in September, in marked contrast to the single storm which formed in these areas during the previous three months of the 1961 hurricane season. All four storms developed to full hurricane intensity and dominated weather headlines during the entire month.

2. MONTHLY MEAN CIRCULATION AND WEATHER

A strong upper-level ridge developed in the eastern Pacific in September where 700-mb. heights were as much as 280 ft. above normal (fig. 1). This anticyclogenesis appeared to have a marked influence in shaping the general location and amplitudes of the downstream trough-ridge systems across North America to Europe.

The trough which is normally present along the west coast of the United States in September [2] was much farther east and extended from a deeper-than-normal primary Low over Baffin Island southwestward across central Canada and the western United States (fig. 1). This was associated with shearing of the mean trough which dominated eastern North America during August (fig. 1 of [1]). The higher-latitude portion of this trough deepened as it advanced eastward to the central and eastern Atlantic in September. Concomitant with these trough developments was the strong anticyclogenesis which took place over eastern North America and central Europe, where 700-mb. heights were as much as 180 ft. above September normals. The resulting planetary-wave pattern at 700 mb. in September 1961 consisted of well-defined trough and ridge systems from the central Pacific eastward to Eurasia. This feature is well indicated by the height departures from normal (dotted lines in fig. 1).

The pattern over the eastern Pacific and North America is of special interest since it represents a complete reversal of those circulation features which had dominated this portion of the Northern Hemisphere during August and most of the summer season (see fig. 6A of [1]). Thus the trough in the East was supplanted by a ridge and the exceptionally strong ridge in the West was replaced by a deep trough in September. This circulation upheaval is clearly indicated by the 700-mb. anomalous height changes from August to September (fig. 2). The large height falls over the West and the extensive positive changes in the eastern Pacific are especially noteworthy. The month of September was one of generally low zonal index conditions over the United States with strong meridional flow resulting in unseasonable temperature extremes in many parts of the country.

The well-defined temperature and precipitation patterns for the month of September (fig. 3) are easily related to the monthly mean 700-mb. height and anomaly patterns (fig. 1). Temperatures averaged from 2° to 8° F. below normal over nearly the entire western two-thirds of the Nation under below normal heights and strong cyclonic flow. Note the almost perfect correspondence between the temperature and 700-mb. height anomaly patterns in the West (figs. 1, 3A). Average temperatures in the Northwest changed by as much as four class intervals [1] from August to September (fig. 4), highlighting the dramatic temperature reversal which occurred in this area. It was the coolest September of record at Glasgow, Mont., Albuquerque, N. Mex., Bismarck, N. Dak., and Grand Junction, Colo.

Temperatures over the eastern third of the Nation averaged from 2° to 6° F. above normal under the influence of above normal 700-mb. heights and strong anticyclonic conditions. This warming was especially note-

[1] Of a maximum possible 4-class change ranging from much above to much below normal.

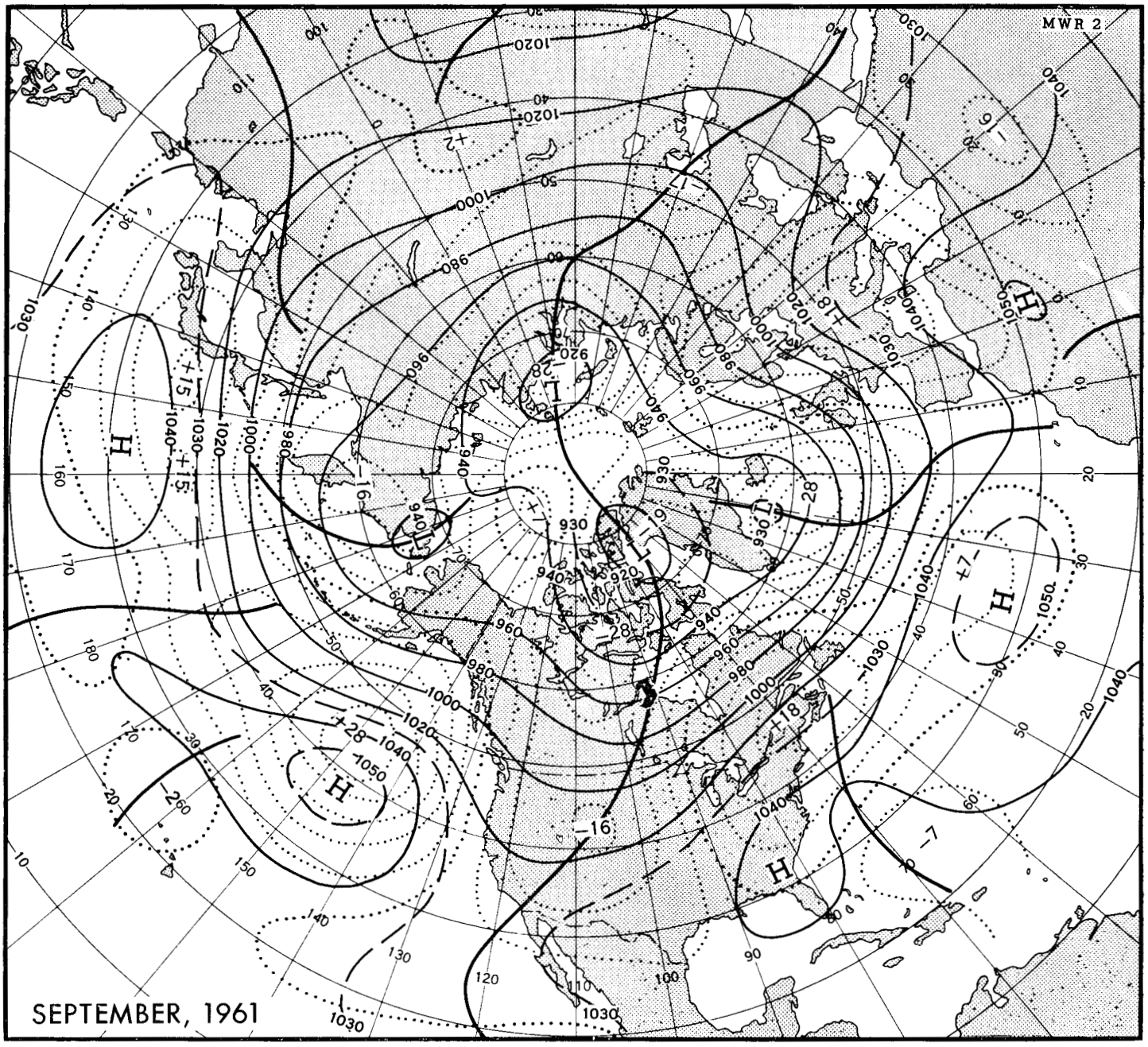

FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for September 1961. The predominance of meridional flow from the central Pacific eastward to Eurasia is especially noteworthy.

TABLE 1.—*Monthly mean high temperature records established in September 1961*

Station	Temperature (°F.)		Remarks
	Average monthly	Departure from normal	
New Haven, Conn.	70.2	+6.6	warmest of record (1873)*
Concord, N.H.	67.1	+8.3	warmest of record (1881)*
Burlington, Vt.	65.4	+5.5	warmest since 1884
Binghamton, N.Y.	69.2	+6.7	warmest of record (1891)*
Buffalo, N.Y.	68.6	+6.2	warmest since 1881
New York City (Met. Obs., Central Park)	73.6	+5.3	warmest since 1869
Baltimore, Md.	76.7	+6.3	warmest of record (1881)*

*Denotes year records began.

worthy in some areas of the Southeast where monthly temperatures had averaged below normal since April. Sections of the Northeast experienced their warmest weather of 1961 this September, with near to record high average monthly temperatures reported at many locations (table 1).

Heavy precipitation fell from the southern Plains northeastward to the western Lakes Region in association with the deep trough in the West and strong southerly anomalous flow from the Gulf of Mexico (figs. 1, 3B). Most of this precipitation resulted from tropical storm Carla early in the month and from frequent frontal rains associated

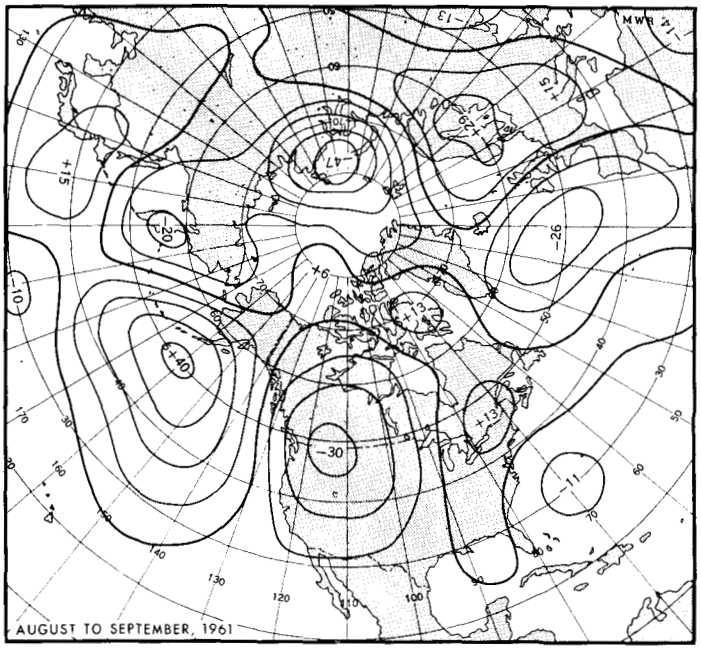

FIGURE 2.—Change in 700-mb. height departures from normal (tens of feet) from August 1961 to September 1961. Note the large height rises in the eastern Pacific and the corresponding height falls over western North America.

with strong thermal gradients in the mid-United States. Substantial precipitation amounts were also recorded from the northern Plains States southwestward across much of the central and western Rocky Mountain region (fig. 3B). This precipitation was also related to the deep trough over the West and occurred in conjunction with strong frontal systems which moved across the area at frequent intervals during the month. The heavy amounts in North Dakota and eastern Montana were especially beneficial, helping to alleviate general drought conditions in these areas. It was the wettest September of record in many sections of the Midwest (table 2).

Rainfall over much of the eastern third of the Nation was light (fig. 3B) as a result of the strong upper-level ridge which dominated the area (fig. 1). However, heavier amounts in extreme northeastern coastal sections resulted from tropical storm Esther during the latter part of the month. It was the driest September of record at Miami Beach, Fla., and at Knoxville, Tenn., as well as being notably dry at Greensboro, N.C. and Binghamton, N.Y.

TABLE 2.—*Heavy precipitation records established in September 1961.*

Station	Precipitation (in.)		Year records began
	Monthly total	Excess over normal	
Dubuque, Iowa	13.13	8.95	1905
Muskegon, Mich.	8.54	5.20	1905
Grand Rapids, Mich.	9.15	5.71	1904
Peoria, Ill.	13.09	9.36	1856
St. Joseph, Mo.	9.74	5.45	1910
Denver, Colo.	4.67	3.59	1871

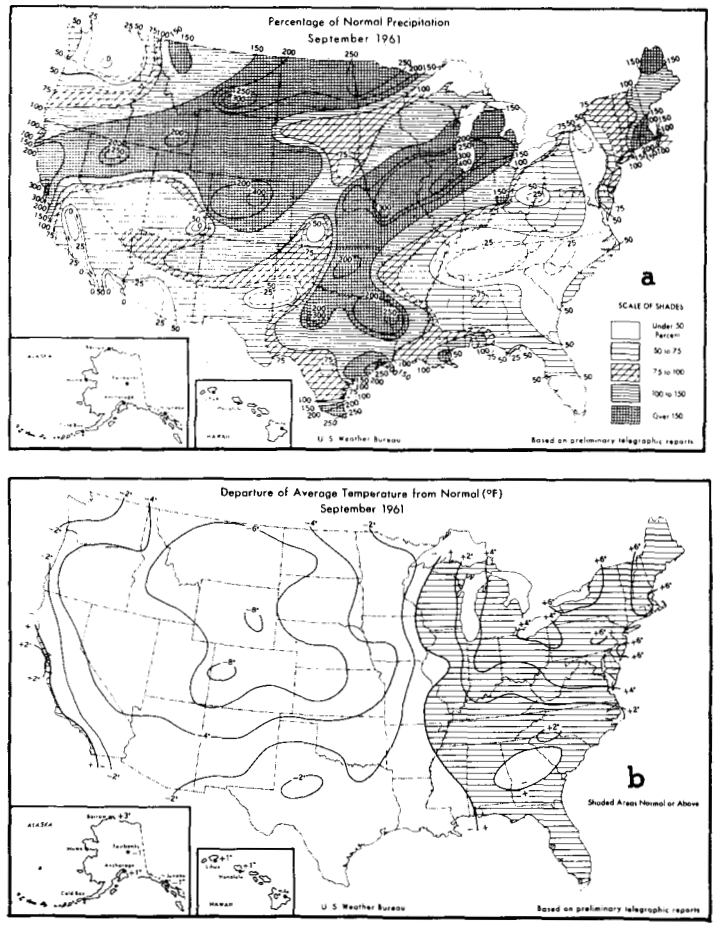

FIGURE 3.—(A) Departure of average surface temperature from normal (° F.) for September 1961. The pattern is noteworthy for the sharp demarcation between below-normal temperatures in the West (unshaded) and above-normal temperatures in the East (hatched). (B) Percentage of normal precipitation for September 1961. (From [9]).

3. TROPICAL STORMS RELATED TO THE MONTHLY CIRCULATION

ATLANTIC AND CARIBBEAN

Four tropical storms formed in the Atlantic and western Caribbean this September (fig. 5), all of which developed to full hurricane intensity. This is above the mean September frequency of three storms with two of hurricane intensity [3].

The month's circulation (fig. 1), from the central Atlantic to Europe, was apparently extremely favorable for storm formation in the eastern Atlantic, where three-fourths of the month's developments occurred. The pattern of 700-mb. height anomaly over the Atlantic and Europe resembled the circulation features in these areas found by Ballenzweig [4] as favoring tropical storm development in the eastern Atlantic.

The meridional character of the September circulation was also favorable for the transport of cooler-than-normal mid-tropospheric temperature and cyclonic vorticity into the Tropics, factors suggested by Namias [5] as conducive

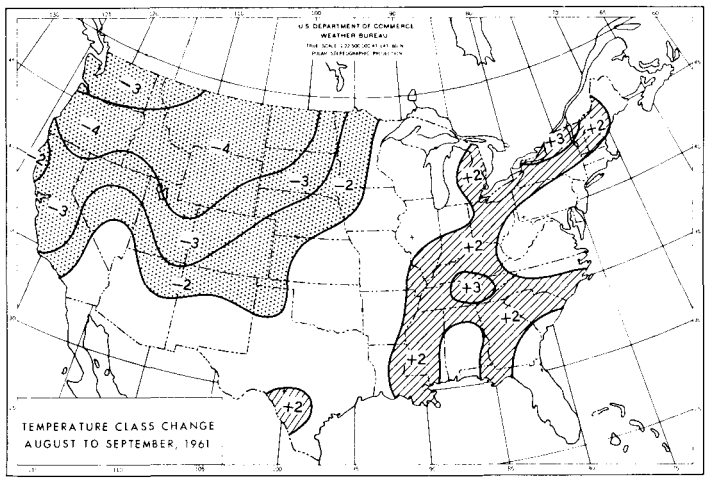

FIGURE 4.—Number of classes the anomaly of surface temperature changed from August to September 1961. Areas where the anomaly in September was two or more classes warmer are hatched; two or more classes cooler, stippled. The pattern represents a complete reversal in temperature regimes over the country from August to September.

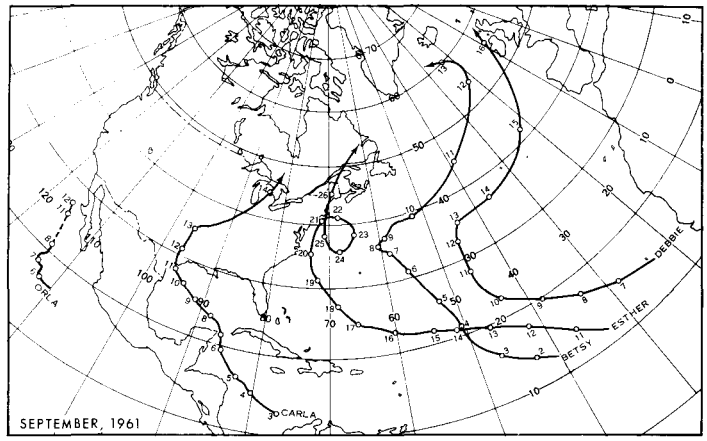

FIGURE 5.—Preliminary tracks of tropical storms during September 1961 in the Atlantic and eastern Pacific Oceans. Open circles and dates indicate 1200 GMT positions.

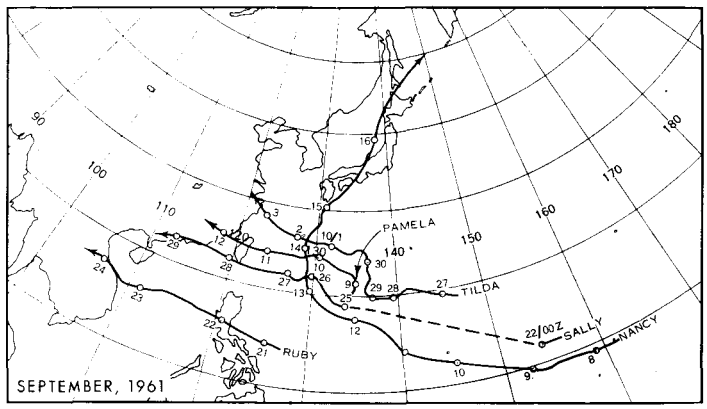

FIGURE 6.—Preliminary tracks of tropical storms during September 1961 in the western Pacific Ocean. Open circles and dates indicate 1200 GMT positions.

to storm formation, as well as allowing for a considerable degree of interaction between tropical and temperate-latitude activity.

The behavior of the tropical storms (fig. 5) can be interpreted, but only to a rather limited degree, in terms of the monthly mean circulation (fig. 1). The track of hurricane Betsy is fairly well indicated by the mean flow with the storm moving northwestward and then east-northeastward around the mean High in the eastern Atlantic. The motion of storm Carla, from the western Caribbean northwestward to southeastern Texas and then northeastward to the Lakes region follows the mean flow quite closely. The behavior of hurricane Debbie, however, is not well related to the monthly mean circulation, with the storm actually moving northwestward into and through west-central portions of the mean High in the eastern Atlantic.

The track of Esther, from the 11th to the 19th, parallels the mean flow across the South Atlantic with but little variation. The storm moved northward from the 20th to the 21st, then turned eastward and performed a complete loop which in four day's time brought it back to its original position off the southern New England coast (fig. 5). The mean Low and inverted trough off the east coast are, in major part, merely the reflection of hurricane Esther, the circulation of which dominated this area for over a week.

EASTERN PACIFIC

Tropical storm Orla, the only storm to develop in the eastern Pacific this September, was first detected on the 6th about 500 miles south of Baja California. The storm moved northwestward, as implied by the monthly mean flow, until the 8th when rapid disorganization of the circulation occurred. Weak remnants of the storm apparently continued northwestward to just west of Baja California where regeneration to tropical storm intensity occurred early on the 11th. Orla eventually dissipated on September 12 after moving only a short distance more to the northwest.

WESTERN PACIFIC

Five tropical storms were observed in this area during the month, four of which developed to typhoon intensity (fig. 6). This corresponds with a mean September frequency of five storms [3].

The monthly mean circulation in the Pacific was also apparently quite favorable for tropical developments this September, with the 700-mb. height anomaly pattern corresponding extremely well with the pattern suggested by Orgill [6] as favoring maximum typhoon development in the western Pacific.

Typhoon Nancy developed in the south-central Pacific on September 8 and moved west-northwestward with the mean flow until the 13th. The storm turned northward on the 13th and accelerated rapidly toward the north-

northeast, crossing central Japan by the 16th. This was the most devastating typhoon in the Pacific thus far this year. Maximum sustained winds well in excess of 200 m.p.h. were reported by aircraft on the 12th and 13th. Winds of 109 m.p.h. buffeted central Japan as the storm passed through the area on the 16th. This was the fastest moving storm ever to strike the main Japanese Islands. Its speed of translation was 31 m.p.h. when it crossed Honshu, increasing to over 50 m.p.h. as it moved into the Japan Sea. Typhoon Pamela was first detected south of Japan early on September 9. The storm moved west-northwestward as implied by the mean flow, crossing northern Formosa late on the 11th and eventually dissipating over eastern China on the 12th. Pamela was also a severe storm with winds up to 200 m.p.h. reported on the 11th. Tropical storm Ruby formed just southeast of Luzon in the Philippines on September 21. It moved west-northwestward with the mean flow, crossing central Luzon on the 22d. The storm then sped westward across the South China Sea, moving inland over Indo-China on the 24th without ever attaining typhoon intensity. The initial disturbance which eventually generated typhoon Sally was first detected well east of the Philippines on September 22. Because of the sparsity of data it was not picked up again until the 25th (dashed portion of track in fig. 6). It reached full typhoon intensity on the 26th just to the east of Formosa. The storm moved westward, brushing the extreme southern tip of Formosa early on the 28th, and dissipated over southeastern China on the 29th. Typhoon Tilda developed southeast of Japan on the 27th and 28th. This storm moved on a general west-northwestward track with the mean flow, passing just south of Okinawa early on October 2, and eventually moved inland into eastern China on the 4th.

4. TROPICAL STORMS RELATED TO THE 5-DAY MEAN CIRCULATION

The relation of the tropical storms of the Atlantic to the 5-day mean circulation is deserving of special attention this September, since their respective motions often were not readily apparent in the monthly mean circulation. Segments of each storm track corresponding to the period of each of a selected series of 700-mb. 5-day mean maps are reproduced in figure 7.

Conditions which attend and foster tropical storm development in the eastern Atlantic are usually shrouded in considerable uncertainty, because of the lack of data. The three developments in this area during September were not exceptions. A survey of 6-hourly surface charts revealed a considerable amount of thunderstorm and squall line activity over western Africa from late August into the early part of September. This activity probably developed in response to a trough of large amplitude which settled over the extreme eastern Atlantic during the latter part of August and which persisted through the first week of September (fig. 7A). Whether or not the initial disturbances which eventually evolved into hurricanes Betsy, Debbie, and Esther originated from these convective systems is conjectural, but there is some evidence in support of this possibility.

Tropical storm Betsy was first detected in the south-central Atlantic on September 2. The storm reached hurricane intensity on the 3d and moved northwestward to the mean trough position in the west-central Atlantic by the 6th (fig. 7A). Betsy slowly recurved in this trough area from the 7th to the 9th (fig. 7B) and then accelerated rapidly east-northeastward in the strong flow around the mean Low over southern Greenland (fig. 7B).

Hurricane Carla, one of the major storms of this century to threaten Gulf coastal areas, originated from an area of squally weather which was observed moving through the Windward Island group on the last day of August. This activity moved westward, with a weak circulation developing in the southwestern Caribbean northeast of Panama on September 3. The storm moved northwestward and had intensified to full hurricane strength just east of Yucatan by the 6th (fig. 7A). Moving northward through the Yucatan Channel during the 7th, Carla then turned west-northwestward and crossed the central Gulf of Mexico, striking the Texas coast on the 11th (fig. 7B). Rapid progression of the planetary wave train occurred over the United States at this time with the trough in the West (fig. 7B) advancing eastward to the Lakes region (fig. 7C). Carla turned sharply northward during the afternoon of the 11th, and moved up along the mean trough to northern Michigan from the 12th to the 14th (fig. 7C).

Hurricane force winds were reported from Galveston to Corpus Christi, Tex., a distance of approximately 200 miles, with winds in gusts in excess of 150 m.p.h. estimated at some coastal locations. The storm released 10 to 16 in. of rain along the first 50 miles of its path into southeastern Texas and also caused extensive flooding in many areas along the remainder of its track from Oklahoma to Michigan. In spite of the great size and severity of Carla, loss of life was held to a minimum by timely advices and evacuations, with an estimated 500,000 persons seeking safety inland from the low coastal areas and islands of Louisiana and Texas. Preliminary reports indicate about 46 fatalities, approximately half of which can be attributed to tornados and floods associated with the storm. The reader is referred to the *Weekly Weather and Crop Bulletin National Summary* [7] for a preliminary report on hurricane Carla.

Storm Debbie was first detected as an area of squally weather just west of the Cape Verde Islands on September 7 (fig. 7B). Surface data in the eastern Atlantic was sparse, with the storm position and intensity uncertain during the 8th and 9th. The storm's position on the 10th, however, was verified by TIROS III photographs. Debbie reached hurricane proportions late on the 10th and began recurving to the north in response to the progression of the mean trough from the western to the central Atlantic (figs. 7B, C). Eventual complete recurvature

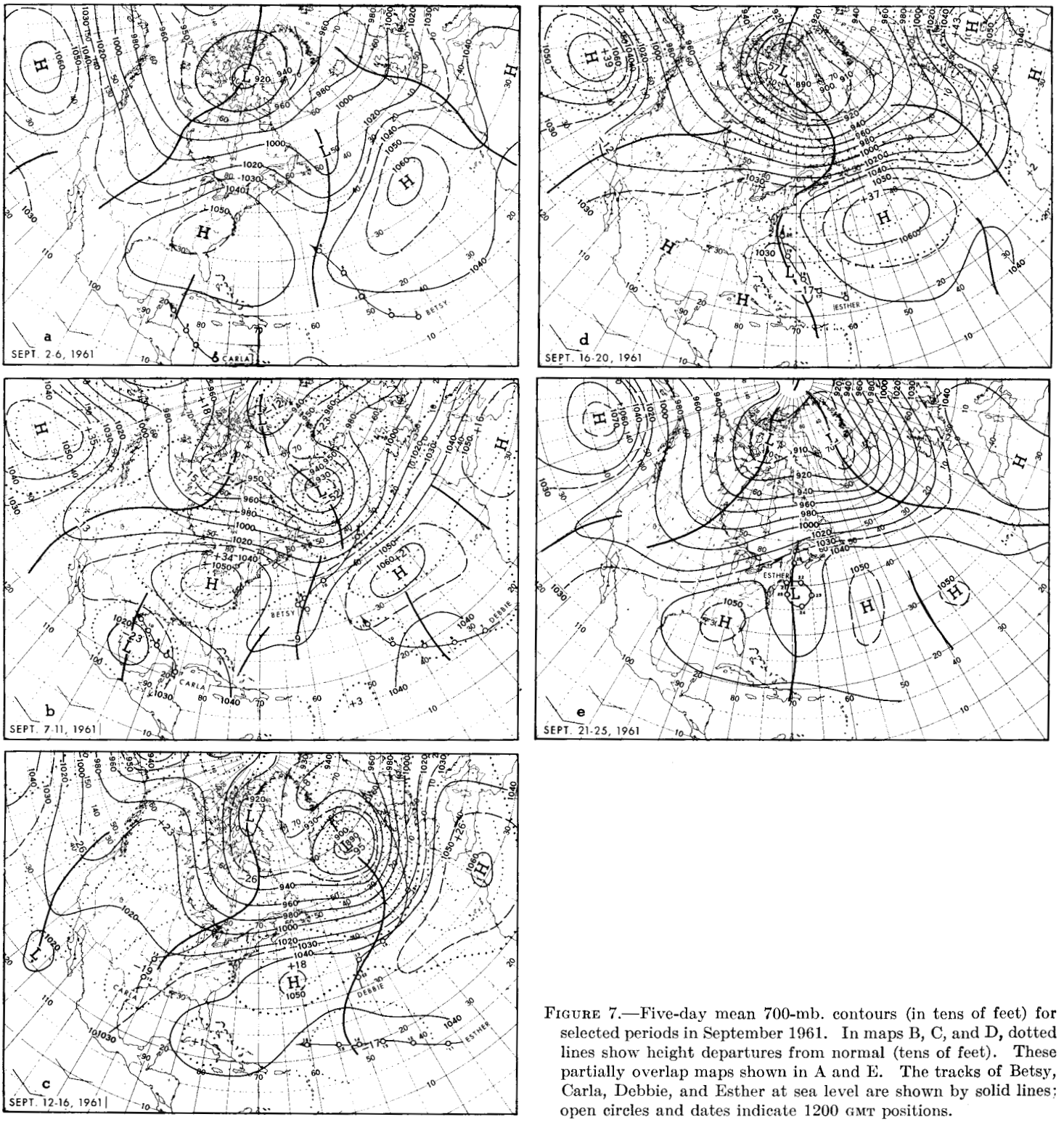

FIGURE 7.—Five-day mean 700-mb. contours (in tens of feet) for selected periods in September 1961. In maps B, C, and D, dotted lines show height departures from normal (tens of feet). These partially overlap maps shown in A and E. The tracks of Betsy, Carla, Debbie, and Esther at sea level are shown by solid lines; open circles and dates indicate 1200 GMT positions.

and rapid northeastward motion along and in advance of this trough occurred from the 12th to the 16th, with the storm causing considerable damage over Ireland as an intense extratropical system on the 16th.

Hurricane Esther was first detected when the weather satellite TIROS III on the afternoon of September 10 photographed a suspicious cloud area near 11° N., 30° W. Additional TIROS pictures and ship reports confirmed the existence of the storm on the 11th, with Esther having developed to full hurricane intensity when reconnaissance aircraft first entered the area on the 12th. This was the first hurricane discovered by means of a weather

satellite. The storm moved on a general west-northwestward track with the mean flow from the 12th to 16th (fig. 7C). Possible recurvature of Esther northward along the trough in the central Atlantic was apparently precluded by a strong ridge settling north of the storm (figs. 7C, D). This severe storm, with winds up to 140 m.p.h. accordingly continued to move west-northwestward, gradually turning to the north just east of Cape Hatteras on the 20th in the weak trough area along the east coast (fig. 7D). Moving north-northeastward, Esther approached Nantucket Island early on the 21st with gradually diminishing intensity. The storm then turned sharply eastward south of the Island, and by the afternoon of the 21st winds of barely tropical storm force were being reported. The unusually large, clockwise looping path of the storm, from the 22d to the 26th, occurred in a trough area (fig. 7E) which was, in major part, shaped by the storm's circulation. An influx of cool, dry air from mid-continent coupled with the notably cold ocean surface off New England may have been instrumental in causing the rapid diminution of storm intensity which occurred on the 21st. The *Weekly Weather and Crop Bulletin, National Summary* [8] contains a preliminary report on hurricane Esther.

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