THE WEATHER AND CIRCULATION OF SEPTEMBER 1966

Large-Amplitude Flow Over North America and Heavy Rain in the East

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1. MEAN CIRCULATION

Outstanding features of the average 700-mb. circulation in September were the large-amplitude ridges and troughs over the continents (fig. 1). Positive height anomalies prevailed the full length of the ridge axis over western North America from the Canadian Arctic to the tropical eastern Pacific (fig. 2). By comparison, the Asiatic ridge was much stronger at middle latitudes but did not extend as far northward. The trough over western Russia was extremely deep with height anomalies decreasing from near zero near the Black Sea to 500 ft. below normal in the polar Low over the Barents Sea.

Height changes (fig. 3) indicate considerable amplification of the circulation from August to September. Over the continents there were rises in the September ridges and falls in the troughs; over the oceans there were sizable falls in the principal troughs. Coastal troughs in the western Atlantic and Pacific amplified and storminess increased in these areas with consequences ranging from disastrous to beneficial. In the western Pacific a typhoon recurving northward through the deeper trough crossed Japan with great cost of life and property. Along the east coast of North America three wave cyclones brought widespread rainfall to dry areas. In the eastern Pacific the distribution of 1000–700-mb. thickness and sea-surface temperature favored cyclonic development. Two storms intensified there to remarkable sea level pressures of 950 and 955 mb. Barotropic response to this deepening was no doubt a factor in support of the North American ridge.

Abnormal storminess across the northern Pacific was reflected in the 700-mb. wind field with average speeds of more than 15 m.p.s. (5–8 m.p.s. above normal) from near Japan to 140° W. along the mean jet axis (fig. 4). The jet axis there was near its normal location. It was farthest from its average September location over Asia where the largest height departures occurred. Zonal westerlies at 700 mb. were 8.2 m.p.s. in the western sector of the hemisphere. This was slightly faster than normal and only a small increase over August despite the loss of blocking at high latitudes.

2. TEMPERATURE

Temperatures in September averaged below normal over most of the eastern two-thirds of the United States and above normal in the western third (fig. 5). Cool conditions were closely related to the anomalous northerly flow and below normal heights at 700 mb. (fig. 2). Negative temperature departures were greatest in the middle Mississippi Valley where the anomalous flow was strongly cyclonic. Above normal temperatures in the West occurred beneath the strong mean ridge. Largest departures, 6° F. or more in western Montana, were associated with the area of greatest positive 700-mb. height anomaly. Kalispell, Mont. averaged 59° F., the warmest September of record. It was the third warmest September of record at Missoula, Mont., with an average nearly 8° F. above normal. New daily maxima, some the highest so late in the season, were established the third week in the northern and central Rockies.

The largest change of temperature anomaly from August [1] to September occurred in western Montana. This was in good agreement with corresponding height changes (fig. 3). Cooling with respect to normal occurred in the Southwest and Northeast. In other areas the temperature anomaly patterns of the two months were quite similar.

3. PRECIPITATION

Moderate to heavy precipitation was reported over much of the Nation in September (fig. 6) including the Northeast where most of the water shortages caused by the long drought were erased, though water tables continued low. Drought severity was reduced by more than two classes of the Palmer Index by the end of the month. It was the second wettest September since 1893 at Wilmington, Del., and the wettest in 32 years at Harrisburg, Pa.

Increased rainfall in the East was associated with slight but apparently significant deepening (fig. 3) of the mean trough which extended into the Gulf of Mexico (fig. 1). Heaviest rainfall in the Middle Atlantic States occurred

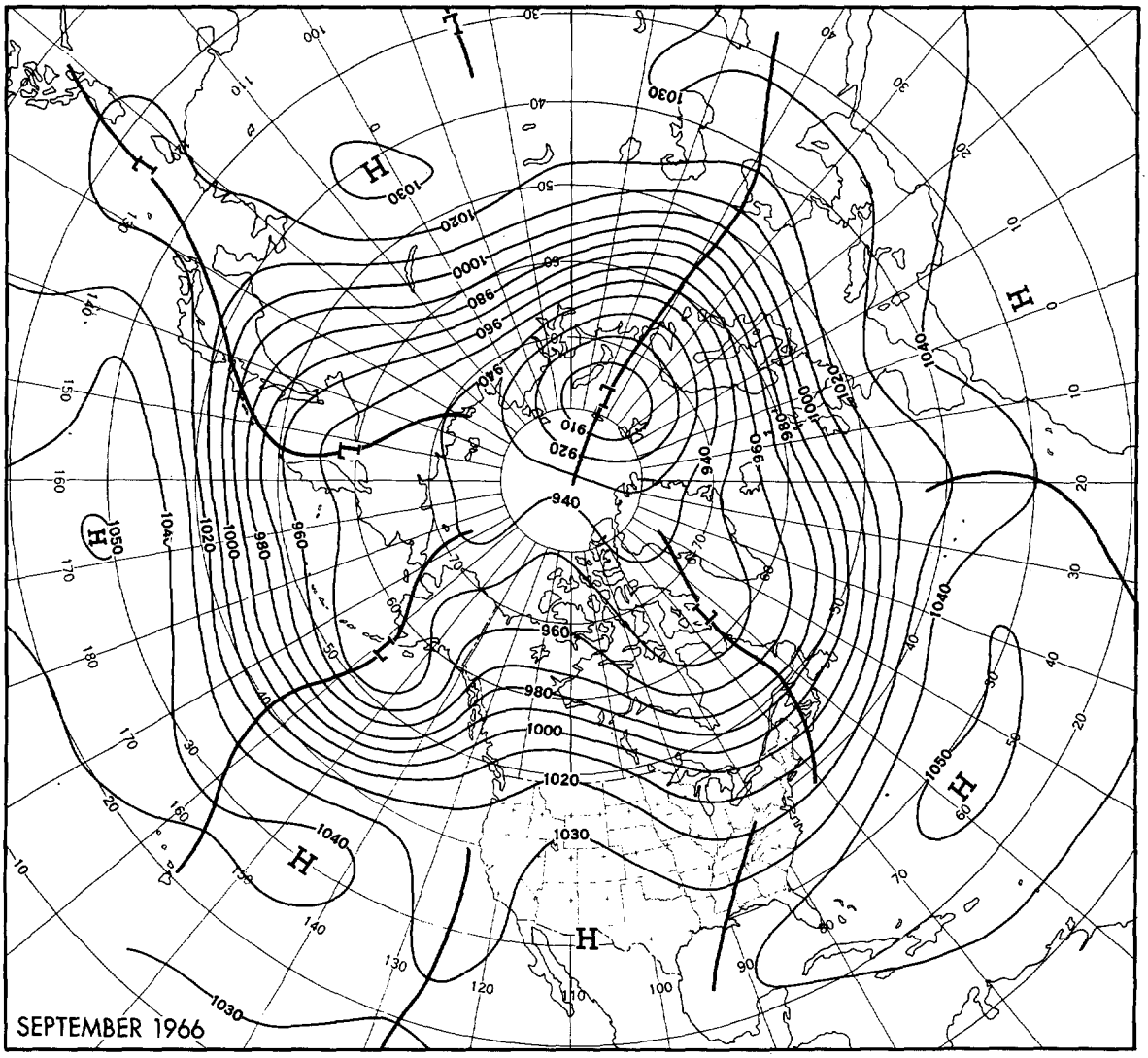


FIGURE 1.—Mean 700-mb. contours (tens of feet) for September 1966. Heavy lines indicate principal troughs.

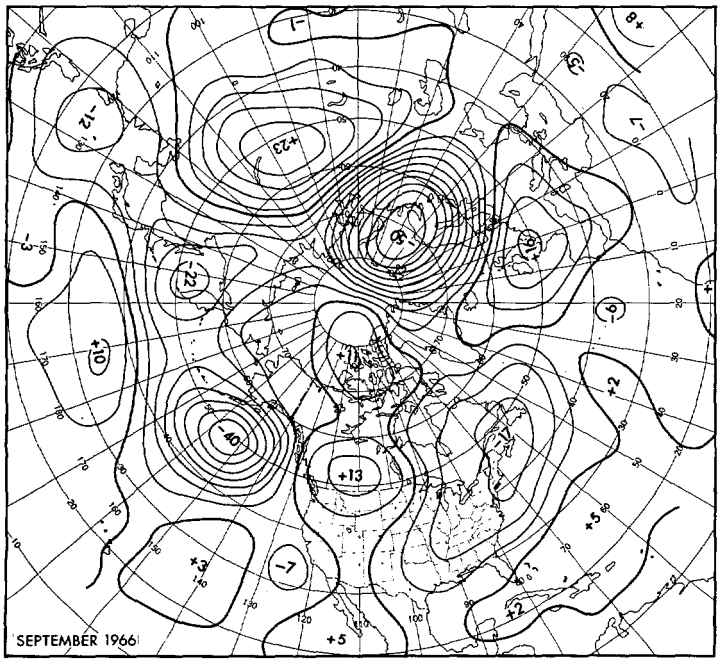


FIGURE 2.—Departure of 700-mb. height from normal (tens of feet) for September 1966.

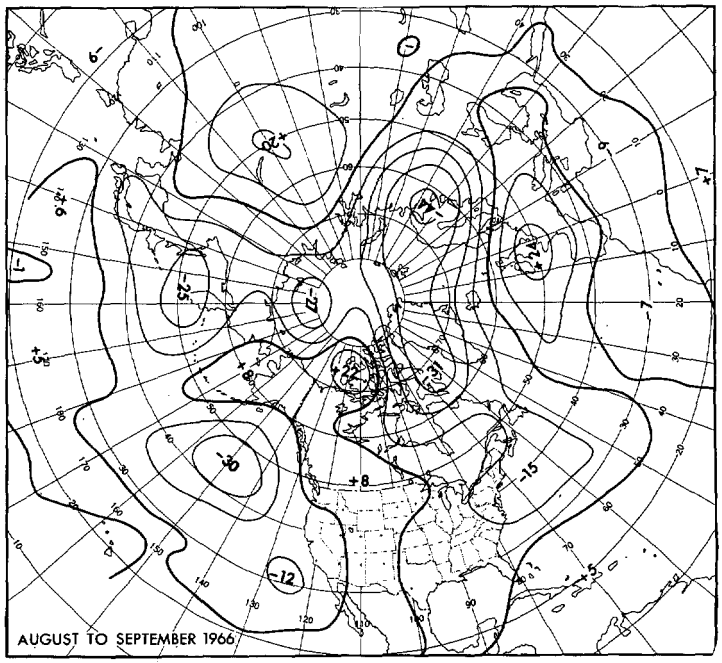


FIGURE 3.—Change in monthly mean 700-mb. height anomaly (tens of feet) from August to September 1966.

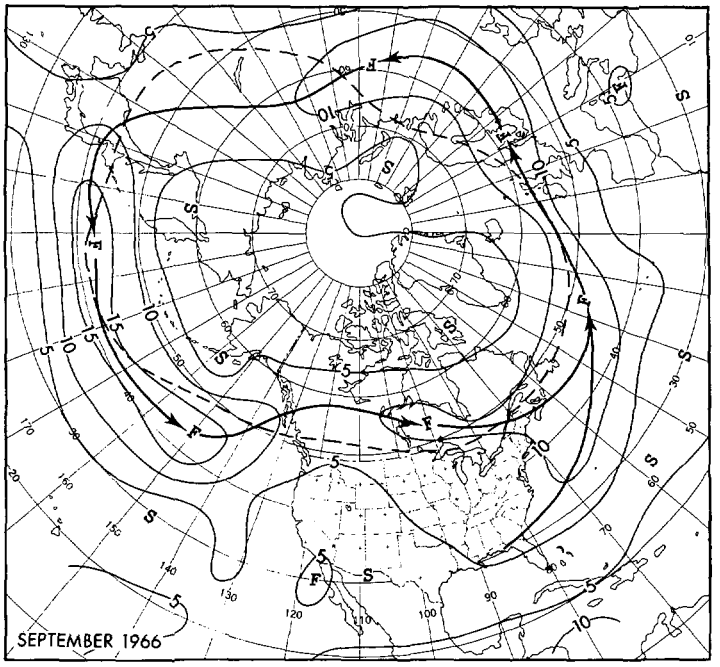


FIGURE 4.—Mean 700-mb. isotachs (meters per second) for September 1966. Solid arrows are axes of maximum speed, dashed line the normal axis.

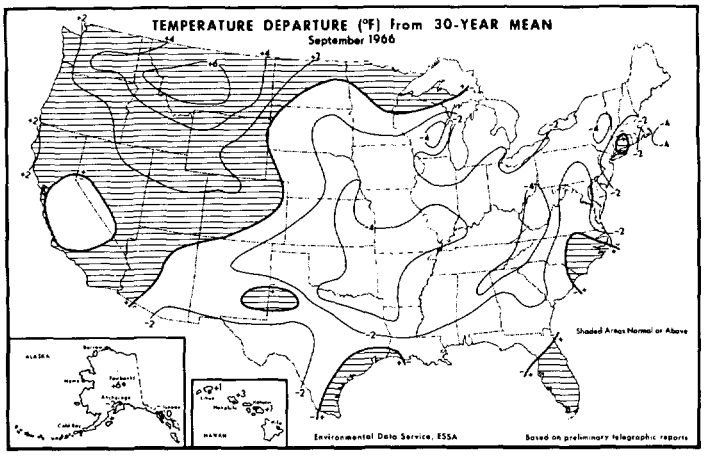


FIGURE 5.—Departure of average surface temperature from normal (°F.) for September 1966 (from [2]).

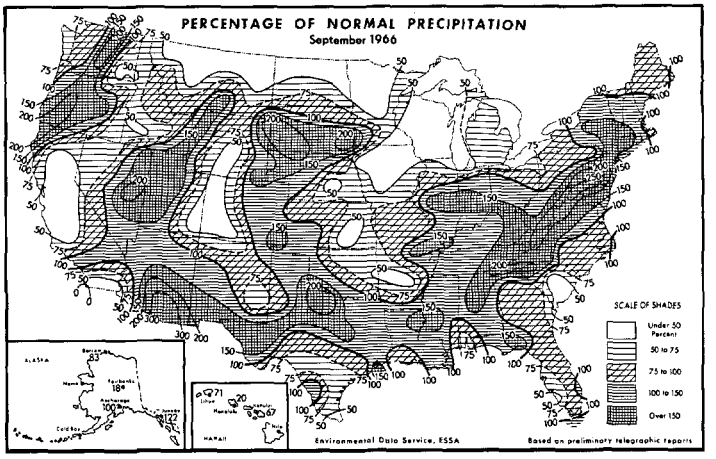


FIGURE 6.—Percentage of normal precipitation for September 1966 (from [2]).

September 13–21. At that time a blocking High was centered over south-central Canada, the westerlies dipped far southward in the United States, and anomalous 700-mb. flow was easterly over the Middle Atlantic Coast.

Rainfall was also heavier than normal in parts of the West. Some of this resulted from the mean trough near the California coast (fig. 1), and part was associated with upslope anomalous flow over western sections of the Plains. In Arizona, New Mexico, and western Texas the moisture supply was probably enhanced by two tropical storms which dissipated near Baja California.

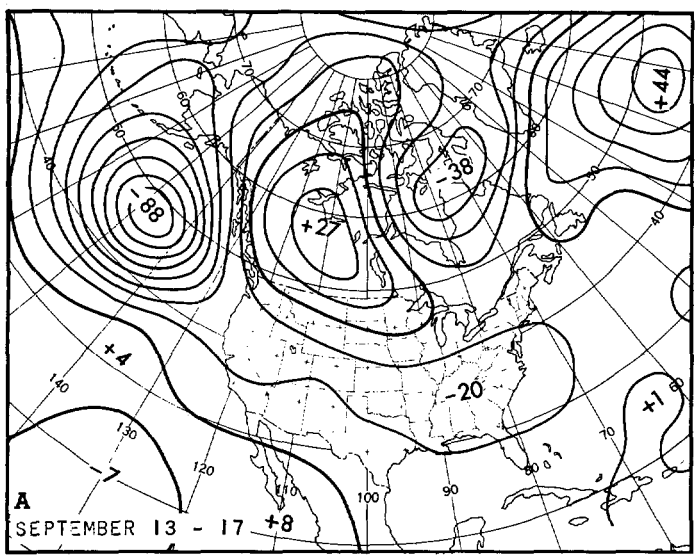
The largest area with light precipitation included the Upper Mississippi Valley and adjacent parts of the Northern Plains and Great Lakes regions where the average 700-mb. flow was northwesterly (fig. 1) and the anomalous flow was anticyclonic (fig. 2). Subnormal amounts also occurred in South Carolina and eastern Georgia where fast westerlies (5 m.p.s. above normal) descended the eastern slopes of the southern Appalachians and were apparently warmed and dried. An interesting aspect of this abnormality is the report from Charleston, S.C., that westerly surface winds prevailed for the first September since records began in 1871.

4. WEEKLY WEATHER IN NORTH AMERICA

Early this month the most outstanding circulation feature was a blocking High in northern Canada. The principal storm path lay across southern Canada, but a secondary wave from the Southwest crossed the Central Plains and the Great Lakes September 1–4. This storm caused generally heavy precipitation in the Plains, northern Great Lakes, and Northeast, followed by cooler air with subnormal temperatures spreading from the southern Rockies toward the Plains States.

An upper-level ridge dominated the circulation from September 5 to 11. This ridge extended from the southern Rockies to the Northern Plains, and was associated with stagnation of a sea level High and subnormal temperatures over the East, but warming with southerly sea level flow in the West. Heavy precipitation was confined mostly to the Gulf Coast States.

During the next week the upper-level ridge remained strong over southern Canada but with a separate band of westerlies across the southern United States. Thus developed a blocked circulation more typical of higher latitudes. This is illustrated in figure 7A, the pattern of mean 700-mb. height anomaly for September 13–17. Heights averaged above normal around a center in south-



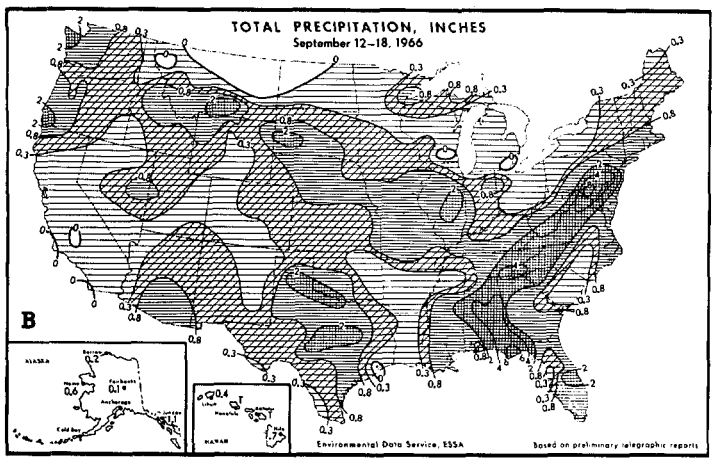


FIGURE 7.—(A) Departure of 5-day mean 700-mb. heights from normal (tens of feet) for September 13–17, 1966, and (B) total precipitation (in.) for September 12–18, 1966 (from [2]).

western Canada and below normal with cool wet weather over most of the United States. Rainfall was particularly heavy near the negative center over the southern Appalachians and northeastward from the center where southeasterly anomalous flow prevailed (figs. 7 A and B).

Surface synoptic activity this week included a strong front which pushed slowly eastward across the country, and a wave development on the old polar front in the northern Gulf of Mexico. The latter intensified northward along the Middle Atlantic Coast spreading 3 to 8 in. of rain in abnormally dry sections of the East. Behind the strong front which later joined the deepening coastal wave, temperatures fell to record minima on the 16th at many stations from Milwaukee, Wis. to Nantucket, Mass. and Norfolk, Va.

Mid-latitude blocking over North America continued through September 19 to 25. Early in the week another wave moved slowly up the Atlantic coast, associated with

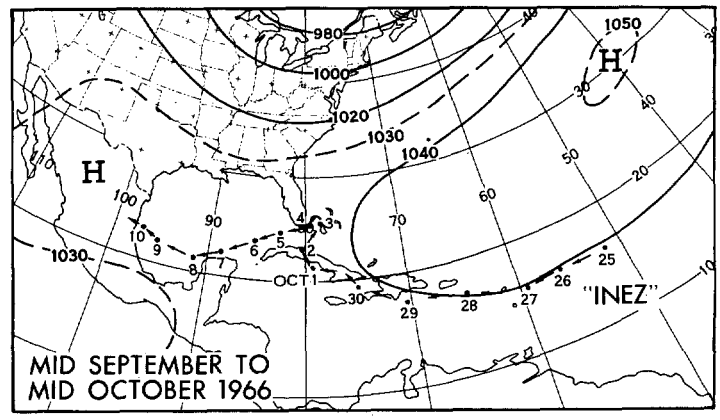


FIGURE 8.—Mean 700-mb. contours (tens of feet) for mid-September to mid-October 1966. Preliminary track of hurricane Inez is shown with 1000 GMT positions indicated by dated solid circles.

a well-defined upper Low. Precipitation with this storm totaled 2 in. or more in the Mid-Atlantic States, parts of New England, and the Midwest. Temperatures continued to rise and averaged above to much above normal in the West but remained below in the East.

During the final week the western ridge weakened while the eastern trough intensified, leading to cooling over most of the Country. Sault Ste. Marie, Mich. reported a record daily minimum (31° F.) on the 24th and Lansing, Mich. had the lowest September temperature of record (27° F.) on the 26th. A wave along the polar front emerged from Texas bringing heavy rains to parts of the East for the third straight week.

5. TROPICAL CYCLONES

ATLANTIC

A photograph from ESSA II weather satellite yielded the first report of the tropical depression which later became hurricane Inez. At the time of its discovery September 23, the depression was already well developed and was located about 1,100 mi. east of the Windward Islands. Reconnaissance the next day indicated that the depression had reached tropical storm intensity and was traveling west-northwestward at about 14 m.p.h.

Inez became a hurricane on September 26, and caused at least 40 deaths on Guadeloupe as it crossed the Lesser Antilles the following day. Further devastation occurred as Inez crossed the southern tip of the Dominican Republic and Haiti on the 29th and entered Cuba on the 30th. Figure 8 shows the subsequent erratic path of the hurricane as it crossed and recrossed Cuba, went northward nearly to Grand Bahama Island, curved sharply west-southwestward through the Florida Straits, grazed the Yucatan Peninsula, and finally disintegrated over the mountains west of Tampico, Mexico. For further details on this storm see [3].

Until the time of the sharp turn westward in the Florida Straits, Inez followed rather well the average 700-mb. flow along its path (fig. 8). Thereafter the storm was imbedded in a field of extremely weak mean 700-mb. flow in which no geostrophic component of flow could be discerned until it reached the southwestern Gulf of Mexico.

Another tropical storm named Hallie was reported in the southwestern Gulf of Mexico September 20. This storm dissipated the next day as it approached the Mexican coast.

Development of a third tropical storm, Judith, about 650 mi. east of the Windward Islands was verified by weather satellite pictures on September 28. Judith's path was several hundred miles south of and nearly parallel to that of Inez. This storm crossed the Windward Islands September 30 and weakened to extinction the following day.

PACIFIC

In the tropical western Pacific eight depressions reached tropical storm or typhoon intensity, compared with an expected frequency of four or five. Contrasted with an earlier tendency to continue westward into southeastern Asia this season, the September storms tended to curve northward well off the Asian coast. This trend toward early recurvature was related to amplification of the general circulation described in section 1.

There were six tropical storms in the eastern Pacific in September. The earliest three of these lasted longest and for two days they coexisted. Later storms were short-lived and lasted only one or two days. Here also there was a noticeable tendency for recurvature northward rather than westward as in August [1].

REFERENCES

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2. Environmental Data Services, ESSA, *Weekly Weather and Crop Bulletin, National Summary*, vol. 53, Nos. 38 and 42, Sept. 19 and Oct. 17, 1966.
3. R. N. De Angelis, "Hurricane Inez, September 21–October 11, 1966 (Preliminary Report)," *Weekly Weather and Crop Bulletin, National Summary*, vol. 53, No. 43, Oct. 24, 1966, pp. 6–7.