THE WEATHER AND CIRCULATION OF JULY 1965

A Cool Month Associated With A Large-Amplitude Wave Over North America

JAMES F. ANDREWS

Weather Bureau, Environmental Science Services Administration, Washington, D.C.

1. INTRODUCTION

The coolness of early summer continued through July as temperatures averaged below normal across most of the United States. Precipitation was generally adequate and was associated mostly with showers and thunderstorms, with heavy amounts contributing to cool weather in much of the West. The circulation was highlighted by a period of pronounced amplification late in the month, accompanied by temperatures substantially below normal over the eastern two-thirds of the country.

Drought continued in the Northeast where the long period of abnormally dry weather has resulted in unprecedented water shortage problems, especially in urban areas. Rainfall in July, however, even though below normal, was generally sufficient for most agricultural needs.

2. MEAN CIRCULATION

Considerable readjustment occurred in the planetary wave pattern from June to July over much of the Northern Hemisphere. The changes were related mostly to normal seasonal changes and to the unusual character of the June circulation, i.e., the extremely deep Aleutian Low and the trough in western Canada (fig. 1 in [1]). The trough was in part dynamically produced by the very fast westerlies prevailing in the northeastern Pacific, and was observed in an area of near zero frequency for monthly mean troughs in June [2]. In general, the evolution of the circulation from June to July was characterized by retrogression accompanied by an increase in amplitude.

Marked filling of the Aleutian Low and its displacement to northeastern Siberia in July (fig. 1) was related to retrogression (normally expected) of the mid-Pacific trough. At high latitudes retrogression of the trough was effected by westward motion of the blocking High which had been north of Alaska in June. Month-to-month 700-mb. height changes were as much as +400 ft. near the eastern Aleutians while there were falls at lower latitudes across most of the Pacific. As a result of this circulation transition the principal center of negative 700-mb. anomaly shifted from the eastern Aleutians in June to just east of Hokkaido, Japan, in July (fig. 2). At the same time the belt of maximum west wind was displaced south of normal over the Pacific (fig. 3) with greatest displacement and fastest speeds observed from Japan to the mid-Pacific.

The positions of circulation features over and adjacent to North America in July (fig. 1) were very similar to the normal [3], so that the retrogression from the June pattern was primarily seasonal in nature. Only the lower portion of the west coast trough was displaced westward from its normally expected position. Strong ridging occurred in western North America in July as below normal 700-mb. heights in June were replaced by above normal heights (fig. 2). The trough previously in western Canada moved to eastern North America and deepened in response to the ridging upstream. The principal 700-mb. jet axes over the continent were close to their normal positions (fig. 3). However, as may be inferred from the distribution of height anomaly in figure 2, the jet across the northern border was weaker than normal while the jet across Canada was stronger than usual.

In the Atlantic the deep trough in June sheared and moved to western Europe in July as another trough deepened over eastern North America. The strength of the ridge which developed between these troughs was related to the amplification over North America. Here again, the trend of the observed circulation changes was in agreement with that normally expected between June and July.

Most of Europe was dominated by the deep trough which extended from Scandinavia southwestward off the coast of North Africa (fig. 1). This trough, and the extensive area of below normal heights, brought cool weather to all but southern portions of Europe and the Mediterranean. These latter areas were under the influence of an usually strong North African anticyclone which was displaced north of its usual location. Wind speed departures from normal in the confluence area over southern Europe were as much as 6 m.p.s. above normal, comparable to those observed over Japan and the western Pacific. The circulation over Asia was dominated by the blocking High and area of positive height anomaly centered near the Laptev Sea (figs. 1 and 2). This was effective in blocking the Low east of Lake Baikal and producing the extensive area of negative height anomaly to the south.

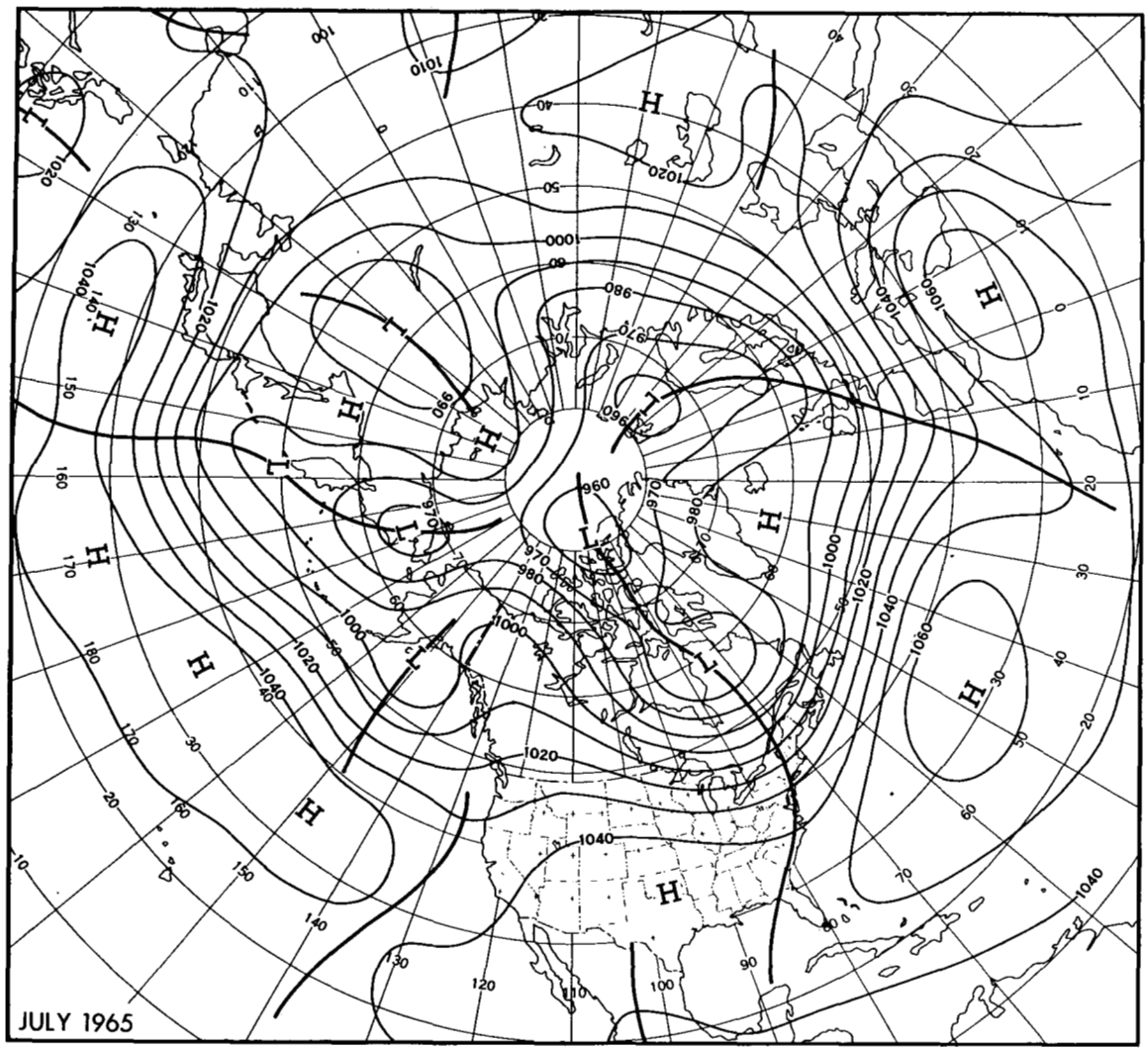


FIGURE 1.—Mean 700-mb. contours (tens of feet), July 1965.

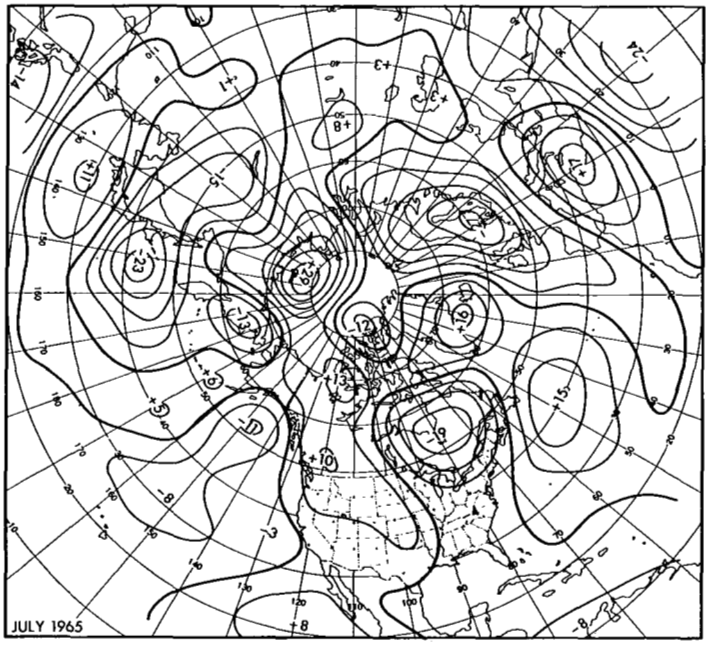


FIGURE 2.—Departure of mean 700-mb. heights from normal (tens of feet), July 1965.

3. AVERAGE WEATHER RELATED TO THE CIRCULATION

Temperatures were below normal over most of the Nation in July (fig. 4), a continuation of the cool conditions which were observed in June. This is not unusual since month-to-month persistence of temperature is normally highest during the summer [4]. Over the eastern half of the Nation the cool weather was closely related to the large-amplitude wave pattern which prevailed over North America (fig. 1). The stronger than normal northerly anomalous flow at 700 mb. (fig. 2) and sea level (not shown) was highly favorable for the southward transport of cool Canadian air masses. Greatest temperature departures from normal were in the Great Lakes region and Northeast where 700-mb. height anomalies were also lowest. This was the coolest July of record at Syracuse, N.Y., and the coolest since 1891 at Sault Ste. Marie, Mich., and Erie, Pa.

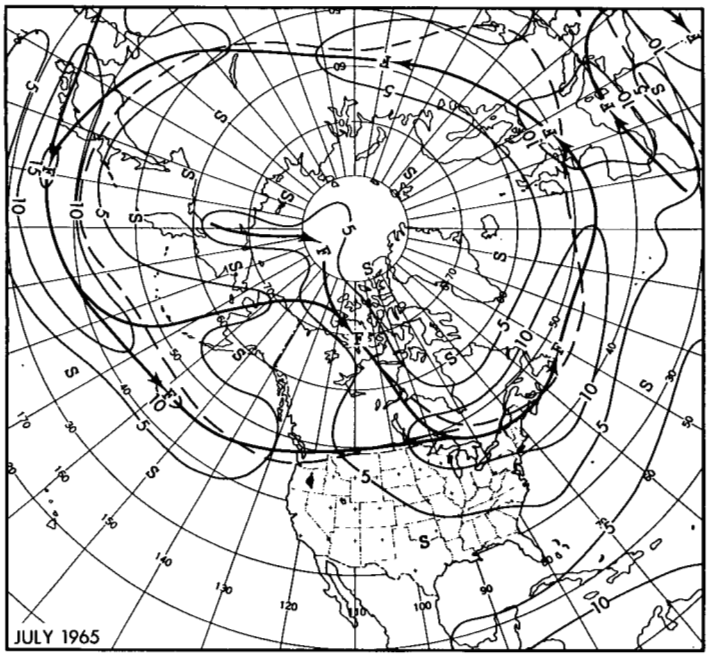


FIGURE 3.—Mean 700-mb. isotachs (meters per second), July 1965. Solid arrows indicate principal axes of maximum west wind speed and dashed lines the normal.

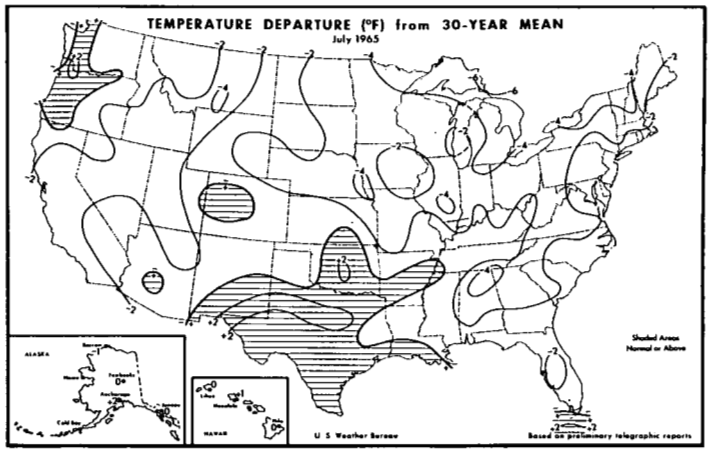


FIGURE 4.—Surface temperature departure from normal (°F.), July 1965 (from [8]).

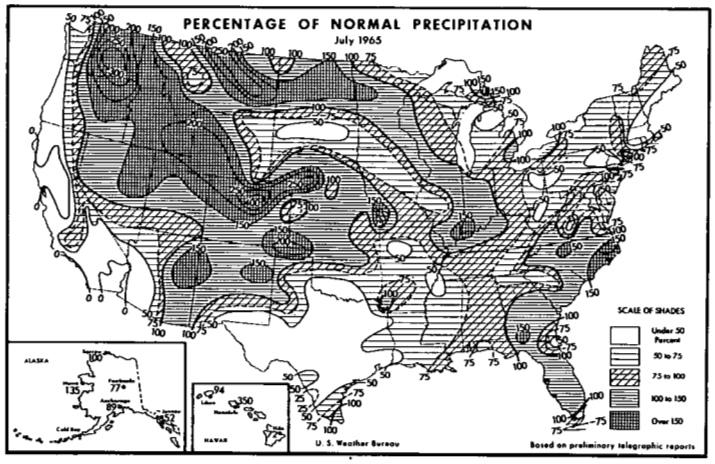


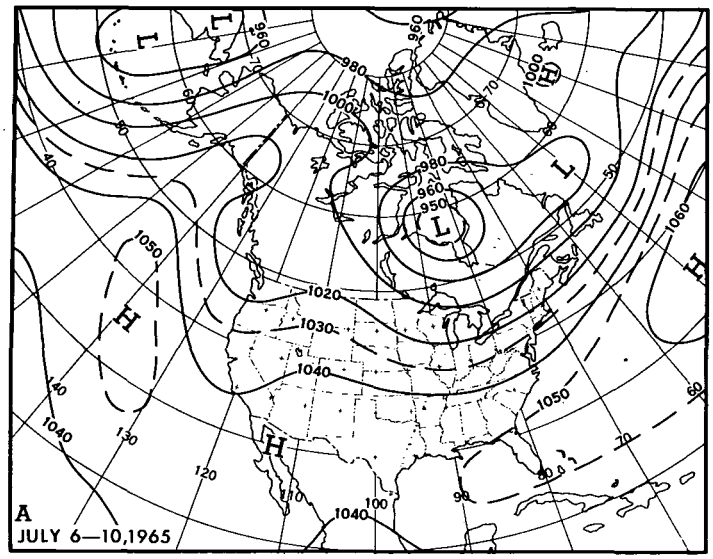
FIGURE 5.—Percentage of normal precipitation (in.), July 1965 (from [8]).

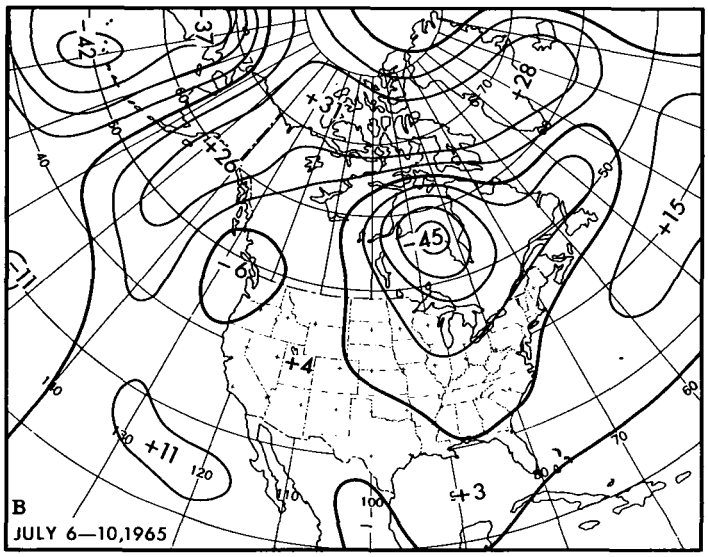
The long drought in the Northeast continued unrelieved in July as rainfall was generally well below normal (fig. 5). Redevelopment of the western Atlantic trough to a position over the Northeast in July should have been favorable for increased rainfall, provided the anomalous flow was southerly. But there was little difference in the rainfall patterns between June and July. Part of the answer lay in the westerly anomalous component of 700-mb. flow (fig. 2). This flow, from the relatively dry continent, was unfavorable for substantial rainfall. At Boston, Mass., this was the second driest July (0.55 in.) in 148 years, and the 1965 precipitation deficit was 10.1 in. by the end of the month. The dry area in the Northeast extended into much of the Great Lakes region where the driest conditions were in Michigan. Locally heavy rains fell in the extreme northern part of the State, however, where Sault Ste. Marie reported over 5 in.

Frequent showers and thunderstorms associated with the trough along the South Atlantic coast (fig. 1), resulted in near to above normal precipitation in the Southeast. Greatest amounts fell along coastal areas where the anomalous 700-mb. flow was southerly. This activity and its related cloudiness also favored below normal temperatures.

Temperature in July over the western United States, where 700-mb. heights were above normal, was not as well related to the circulation as it was in the East. This relationship was evaluated by specifying temperature by an objective screening method [5] which explained 40 percent of the variance. With observed July 700-mb. heights as input this method gave monthly mean temperatures 1°–4° F. too high in the Far West and Southwest, except 1°–2° F. too low over much of Texas. Partially responsible for the errors were the effects of cloudiness and precipitation on temperature. These influences are particularly important during the warm season. For example, it has been found that in July there is a negative correlation of 0.6 to 0.8 between temperature and precipitation departures from normal in much of the Plains States. This correlation is lower in the Far Northwest and Southwest, and near zero in much of the Great Basin.

Rainfall amounts were more than twice normal from the central Rocky Mountain States into the northern Intermountain Region, and also in parts of the Northern Plains. Much of this was shower activity associated with Pacific cold fronts. In addition, moisture transported northward from the Gulf of Mexico by southeasterly anomalous flow at 700 mb. also contributed to this activity.





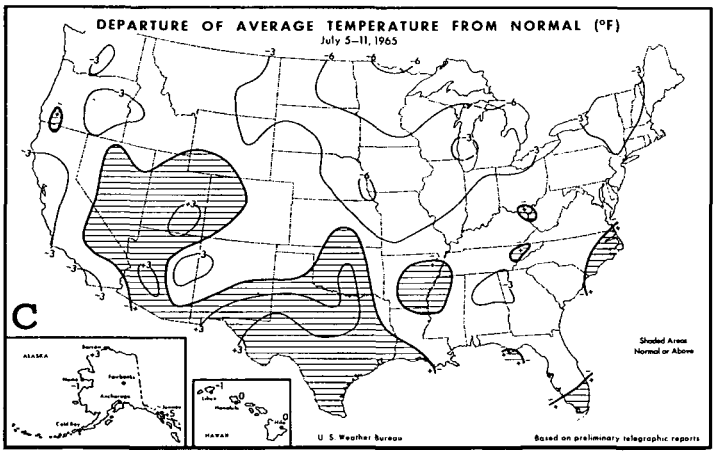


FIGURE 6.—(A) Mean 700-mb. contours and (B) height departures from normal, both in tens of feet, for July 6–10, 1965; (C) surface temperature departure from normal (°F.), July 5–11, 1965 (from [8]).

The Southern Plains were hot and dry, with much of Texas receiving less than half the normal July rainfall. Warm, dry conditions also prevailed west of the Cascade Range in Washington and Oregon, favored by above normal 700-mb. heights and easterly anomalous flow.

In California it was very dry, as is normal in July, but it was also cool. Here upper heights were lower than to the north and the anomalous flow was weaker, thus enhancing the sea breeze effect. The surface temperature of the coastal water was below normal, and this also contributed to the subnormal temperatures, at least along the coast.

4. WEEKLY EVOLUTION

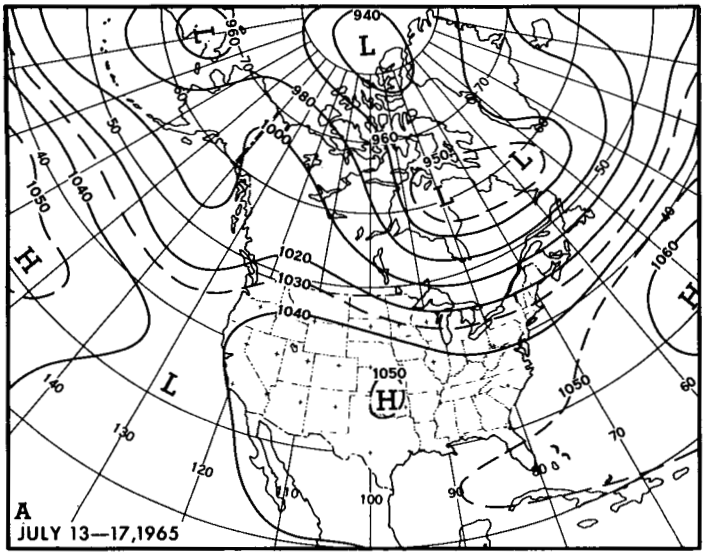
Early in the month the mean circulation across North America consisted of a weak ridge over the Rocky Mountain States and troughs along the west coast and over the eastern United States (figs. 6 A and B). The latter trough extended from a deep Low over Hudson Bay. Blocking was also present, as indicated by the strong ridges over northwestern North America and Greenland, associated with an extensive area of positive 700-mb. height anomaly at high latitudes.

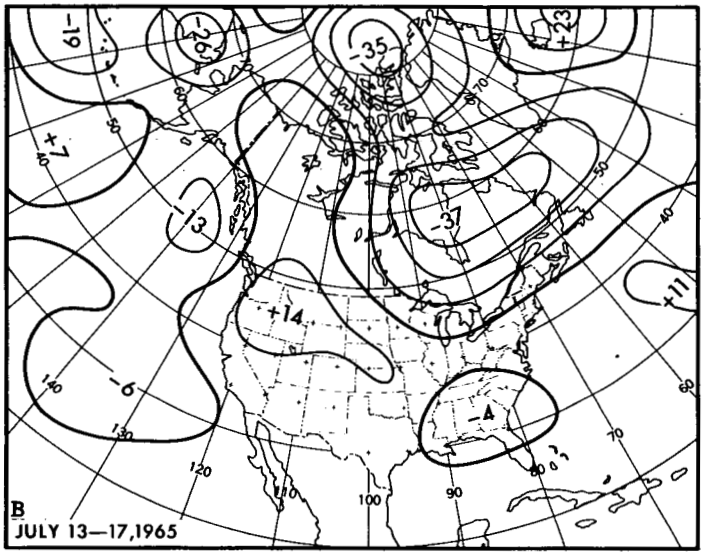
Temperatures were below normal over most of the country, except in the Southwest where it was warmer than normal (fig. 6C). There was little precipitation of consequence in the West, but there were widespread showers elsewhere. The coolest weather prevailed from the Upper Mississippi Valley through the Northeast where record minimum temperatures for July were observed at Milwaukee, Wis., on the 1st (40° F.), and at Caribou, Maine, on the 7th (37° F.). Frost occurred in parts of Wisconsin and Michigan on the 6th and in New England on the 7th as a cool Canadian anticyclone moved across the area.

During the second week there was marked weakening of the ridge in the Gulf of Alaska; this assisted retrogression of the Pacific coast trough and Rocky Mountain ridge (figs. 7 A and B). The latter ridge also increased in strength and, as a result of the change to southeasterly flow aloft, there was an increase in shower activity in the West with cooling in the Central and Southern Plateau. The West Coast States, however, had little rainfall and became warmer.

Temperatures remained below normal over most of the eastern half of the Nation, although there was warming in the Northern States as a result of weakening of the eastern trough at middle latitudes. Showers continued to be rather widespread in the East with greatest amounts in the Northeast and Southeast. Rains in the Northeast had little effect on water shortages, but were beneficial for agriculture.

The third week was marked by progression of the mean features in the Pacific and North America (figs 8A and B). Temperatures were below normal in the West and the East (fig. 8C) in association with coastal troughs; while





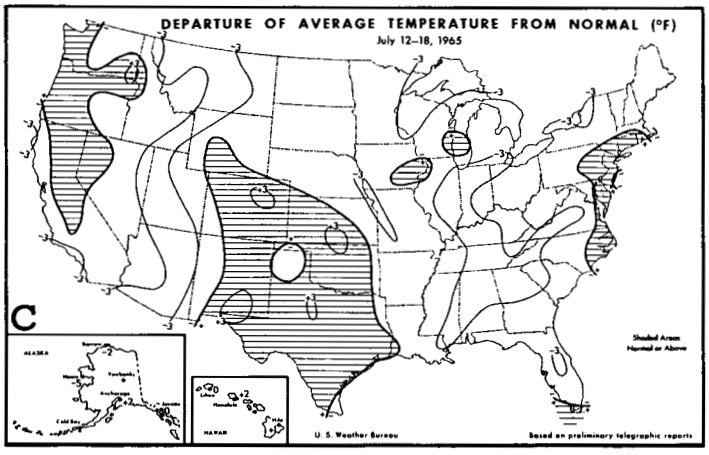
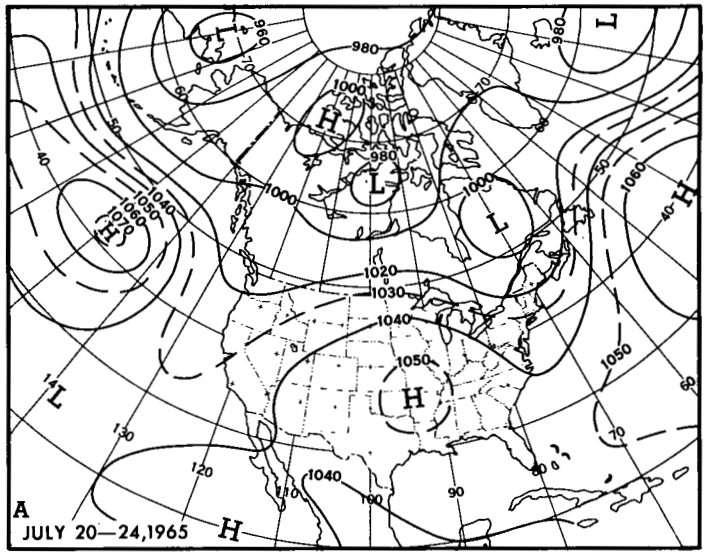
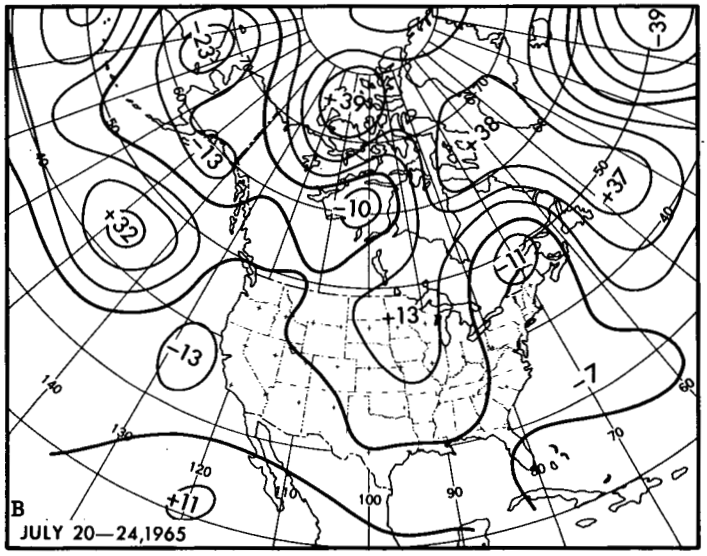


FIGURE 7.—(A) Mean 700-mb. contours and (B) height departures from normal, both in tens of feet, for July 13–17, 1965; (C) surface temperature departure from normal (°F), July 12–18, 1965 (from [8]).





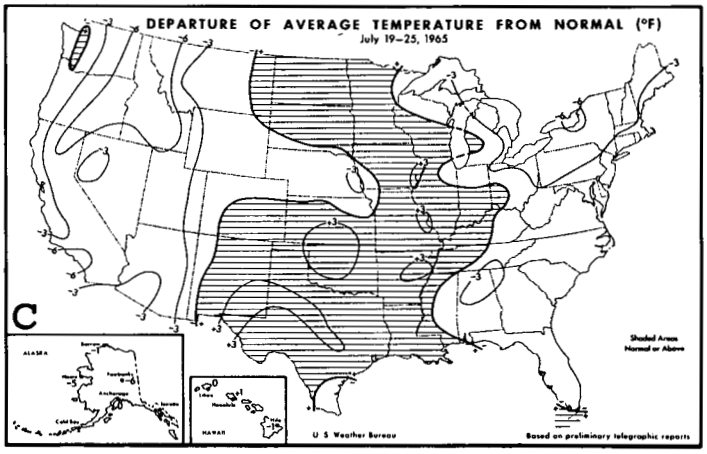
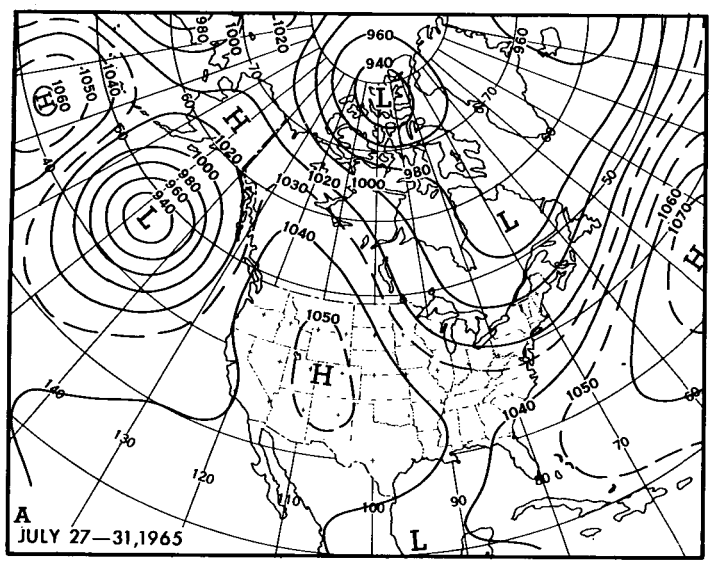
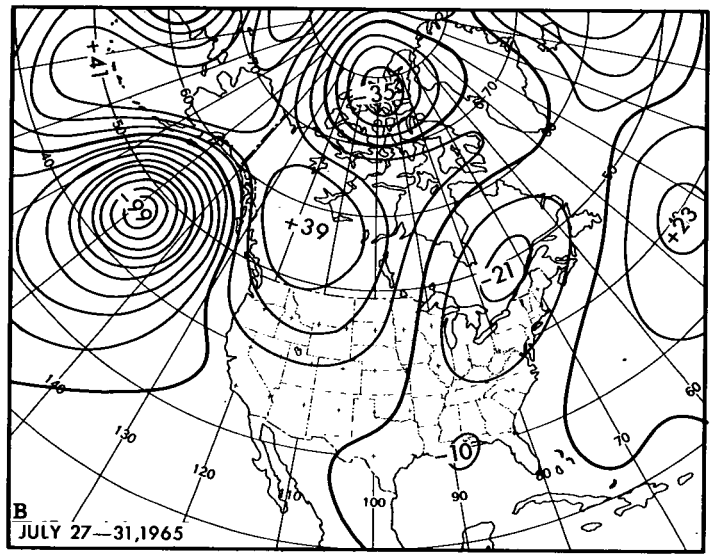


FIGURE 8.—(A) Mean 700-mb. contours and (B) height departures from normal, both in tens of feet, for July 20–24, 1965; (C) surface temperature departure from normal (°F.), July 19–25, 1965 (from [8]).





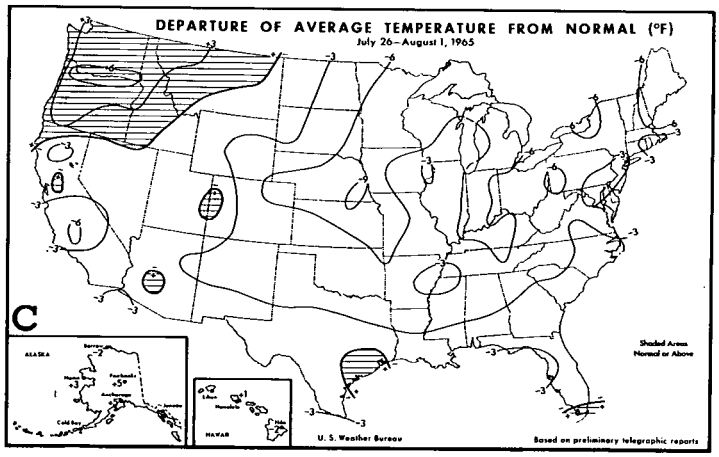


FIGURE 9.—(A) Mean 700-mb. contours and (B) height departures from normal, both in tens of feet, for July 27–31, 1965; (C) surface temperature departure from normal (°F.), July 26–August 1, 1965, (from [8]).

hot humid conditions prevailed in the central third of the Nation beneath the upper ridge. Temperatures of 107° F. were reported in parts of South Dakota on the 22d. Rainfall was generally light over most of the country, but locally heavy rains in northeastern Colorado, northwestern and west-central Missouri, and in the eastern portions of Kentucky and Tennessee produced flooding in these areas.

Late in July the mean circulation amplified and produced a deep Low with 990-ft. negative height anomaly center in the Gulf of Alaska (figs 9A and B), a record (since 1947) for the Northern Hemisphere in the summer season (June, July, August). Apparently the atmospheric upheaval in the Pacific and North America had its origin over northern Asia and the Arctic regions. Blocking here was a very persistent feature of the circulation, and was strongest during the last half of the month. An extension of this block to a strong ridge over the Sea of Okhotsk was associated with gradual deepening of the mean trough east of Japan. This deepening was accomplished without the injection of tropical cyclone energy into the system, since none of the observed tropical storms in the western Pacific recurved in July.

Rapid retrogression of blocking from the Sea of Okhotsk after July 20–24 allowed the upper Low east of Hokkaido to move to the Kamchatka Peninsula. At the same time the eastern Pacific ridge retrograded and built strongly northward where it merged with an extension of the Asiatic block (figs 9A and B). Height changes from July 20–24 to July 27–31 were unusually large in the Gulf of Alaska (−1,200 ft.), as the strong subtropical High was replaced by an intense mean Low.

The circulation over North America responded to the sudden change in the Pacific by also showing amplification and retrogression of the mean waves. Changes here, however, were not as pronounced as those upstream.

This example of amplification and retrogression is also shown in figure 10, which shows the position of the 10,300 ft. contour for three 5-day mean periods. The high zonal index character of the flow is evident during July 22–26 but low index conditions prevailed thereafter. Note that the trough near 85° W. continued to deepen after July 27–31 while there was loss of amplitude upstream.

The large-amplitude flow over North America at the end of July (figs. 9 A and B) brought the coolest weather of the month to many sections in the eastern half of the Nation as temperatures averaged mostly from 4° F. to 8° F. below normal (fig. 9C). Record daily minimum temperatures were observed in the Great Lakes area and also in Tennessee, Arkansas, and Texas, as cool air pushed to the Gulf Coast. In contrast, it was hot beneath the ridge in the Pacific Northwest where temperatures exceeded 100° F. in western Washington and Oregon near the end of the week. Showers fell over much of the Nation with heaviest amounts mainly in the Southeast and as far north as portions of the Middle Atlantic States. Amounts were generally light west of the Rockies, in the Northern Plains, and in New England.

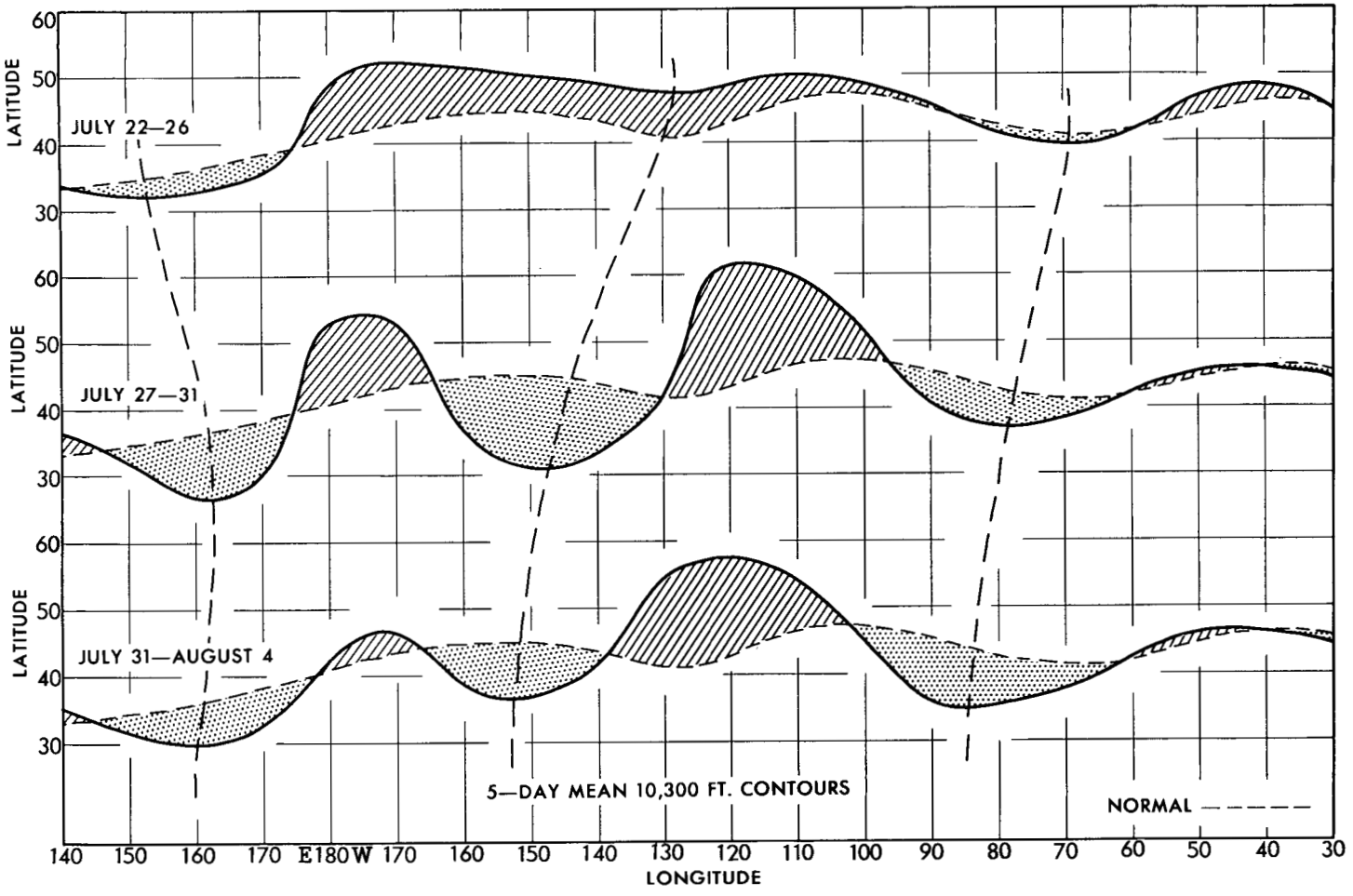


FIGURE 10.—Mean 10,300-ft. contours (solid) for the 5-day periods July 22–26, July 27–31, and July 31–August 4, 1965, with normal (dashed). Troughs are indicated by dashed vertical lines, with trough areas stippled and ridge areas hatched.

5. SUMMARY OF DROUGHT IN THE NORTHEAST

Inadequate rainfall in the Northeast in the last four years has created a major water crisis. Many rivers, whose water supply has been dropping steadily, were at their lowest levels for the year at the end of July. Emergency measures were being taken to conserve water, and also to seek new sources of supply.

An index to measure the intensity of drought has been devised by Palmer [6]. Analysis of this index as of July 25 shows that the drought has been most severe in northeastern Pennsylvania and southeastern New York (fig. 11). In the Hudson Valley the index has been in the extreme category since July 1964. At the end of July 1965 reservoirs supplying water to New York City were depleted to only 45 percent of capacity, compared to a normal 80 percent for this time of year. According to Palmer [7]: "From the standpoint of severity and duration, the current drought in the northeastern United States is such a rare event that we should ordinarily expect it to occur in this region only about once in a couple of centuries."

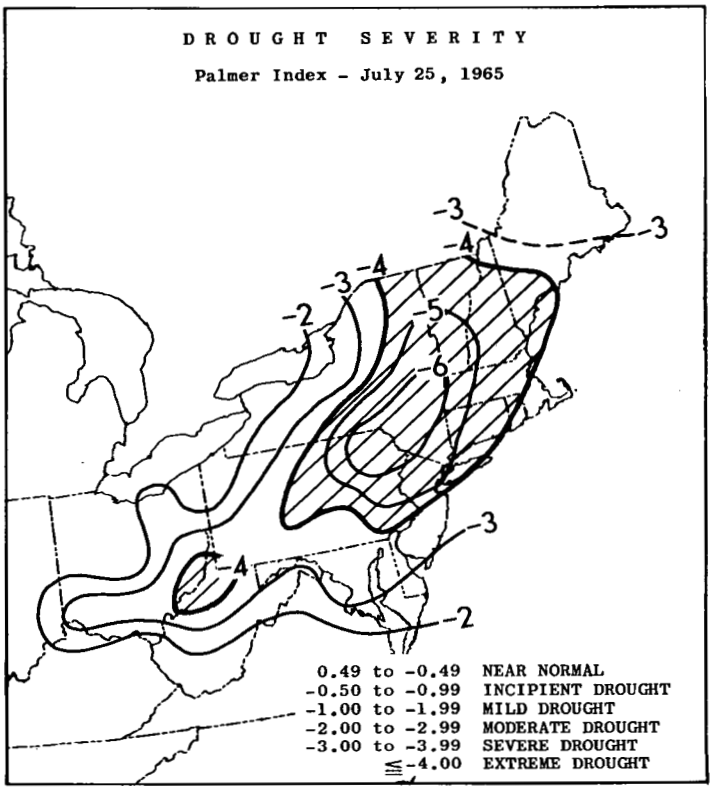


FIGURE 11.—Drought severity in the northeastern United States as of July 25, 1965 (from [7]).

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8. U.S. Weather Bureau, *Weekly Weather and Crop Bulletin, National Summary*, vol. 52, Nos. 28–32, July 12, 19, 26, Aug. 2, 9, 1965.

CORRECTION

Vol. 93, No. 4, April 1965: Equations (5) and (6) on page 216 should be as follows:

$$A2N(j)\cdot v_1(j+1)+B1N(j)\cdot v_1(j)+C0N(j)\cdot v_1(j-1)=DFN(j) \qquad (5)$$

$$A2N(j)\cdot v_2(j+1)+B1N(j)\cdot v_2(j)+C0N(j)\cdot v_2(j-1)=EFN(j) \qquad (6)$$

Also, on page 217, the second line after the equation (6b) should be as follows:

$$gL1N=2\cdot\delta\xi\cdot B_K=gL2N$$

Vol. 93, No. 8, August 1965:

p. 512, col 2, line 11: the equation for $\overline{m}$ for the case $x>z$ should read

$$\overline{m}=1+[y/(x-z)]$$

p. 513, col. 1, line 3: the left side of the equation should read $\overline{m}$ instead of m.

p. 514, col. 1, line 12: the equation for y_1 should read

$$y_1=\frac{y_R}{x_S+y_R}$$

pp. 514 and 515, figures 1 and 2: the drawings in these figures should be interchanged, but captions remain as printed.

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