THE WEATHER AND CIRCULATION OF JUNE 1967

A Cool Month With Excessive Rainfall in the Plains

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1. HIGHLIGHTS

The outstanding characteristic of the weather over the United States during June 1967 was its wetness. Many stations in a large area of the country extending from California to the Great Lakes reported record or near-record rainfall, which led to flooding in some sections of the Plains. There were 11 consecutive days during which tornadoes and funnel clouds were reported somewhere in the middle of the country. Thunderstorms occurred in the Denver area on 14 consecutive days.

Heavy showers also broke out in parts of the Southeast. In Florida, the rains were welcomed as they considerably relieved the severe spring drought which had plagued that area.

2. MEAN CIRCULATION

An anomalously deep trough near the west coast coupled with a strong ridge over the Northeast (figs. 1 and 2) dominated the 700-mb. circulation over the United States during June 1967. Below normal heights were also observed over the Gulf States. This is the type of pattern which usually accompanies wet weather over large portions of the Nation, as moist air masses are advected over the land both from the Atlantic and from the Gulf, the two principal moisture sources for the United States during the warm season.

One of the important features in the 700-mb. circulation for June 1967 was the blocking ridge which had developed in March and subsequently retrograded across the North Pacific [1], [2], and [3]. The 700-mb. positive anomaly centers of 160 ft. and 170 ft. found in Siberia (fig. 2) represent the remnants of this block.

Under the influence of the blocking and the seasonally decreasing westerlies, the troughs observed in the western Pacific and Gulf of Alaska during May [3] retrograded to the Sea of Japan and the central Pacific during June (fig. 1). A 200-ft. positive anomaly center, representing a new blocking component, developed over the Gulf of Alaska and contributed to the deep trough near the west coast as the wave train amplified. This development in effect re-established the strong trough which had been observed near the west coast in late March and April [1] and [2]. Compared with the normal May to June change, 700-mb. heights fell as much as 490 ft. over the Aleutians and rose 120 ft. over the Gulf of Alaska (fig. 3). At the same time, the 700-mb. height decreased by as much as 170 ft. with respect to the expected seasonal change along the California coast, and the jet stream was displaced far south of normal (fig. 4).

As the blocking which had been prevalent over Greenland during May [3] relaxed, a large and deeper than normal polar vortex developed in the area. The westerlies became quite strong over the North Atlantic (fig. 4), reaching their peak monthly mean value observed anywhere in the Northern Hemisphere. The deep trough which had been observed over the British Isles during May filled and moved eastward under the influence of the fast westerlies as higher than normal heights became established across the central Atlantic during June (figs. 2 and 3).

Late May and June marked the completion of the unusually late zonal index cycle which has been discussed by Posey [3] and Green [2]. Figure 5 is a continuation of the index graph shown in figure 1 of Posey's article. The 700-mb. mid-latitude westerly index in the western half of the Northern Hemisphere reached a minimum of 5.2 m.p.s. (2.4 m.p.s. below normal) during the 30-day period centered May 1 and subsequently recovered to near the seasonal normal during June. The low value of the index around May 1 represents a decrease of 7.8 m.p.s. from the peak value of 13 m.p.s. observed during the 30-day period centered March 1, only 2 months earlier. The sea level mid-latitude index actually reached a value of -0.1 m.p.s. (representing slight easterly flow in the mean) during the same period the 700-mb. index dropped to its minimum value. This was the first time the mid-latitude sea level index has become negative since the bitterly cold month of January 1963.

3. TEMPERATURE

The cloudiness and frequent precipitation occurring over most of the Nation contributed to widespread coolness during June 1967. Greatest temperature departures

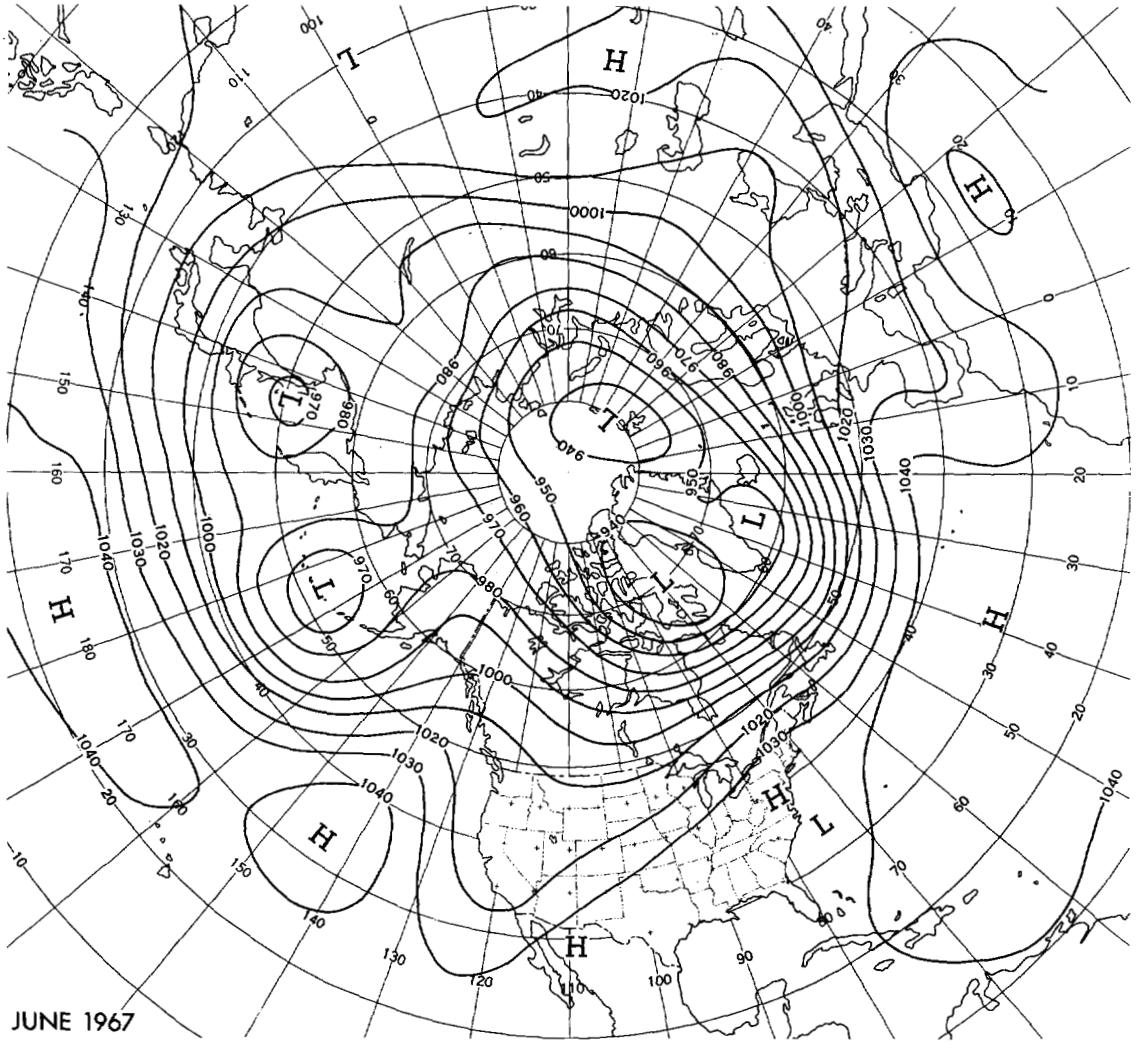

FIGURE 1.—Mean 700-mb. contours (tens of feet) for June 1967.

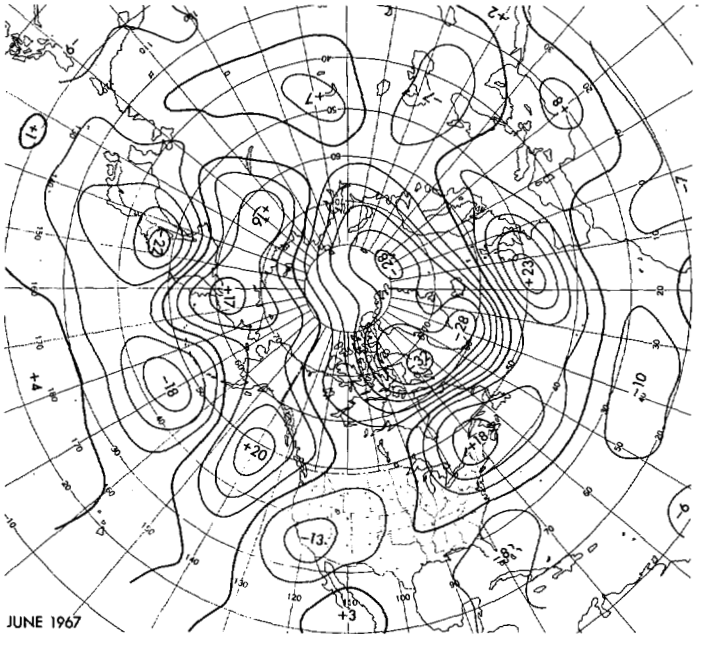

FIGURE 2.—Departure from normal of mean 700-mb. height (tens of feet) for June 1967.

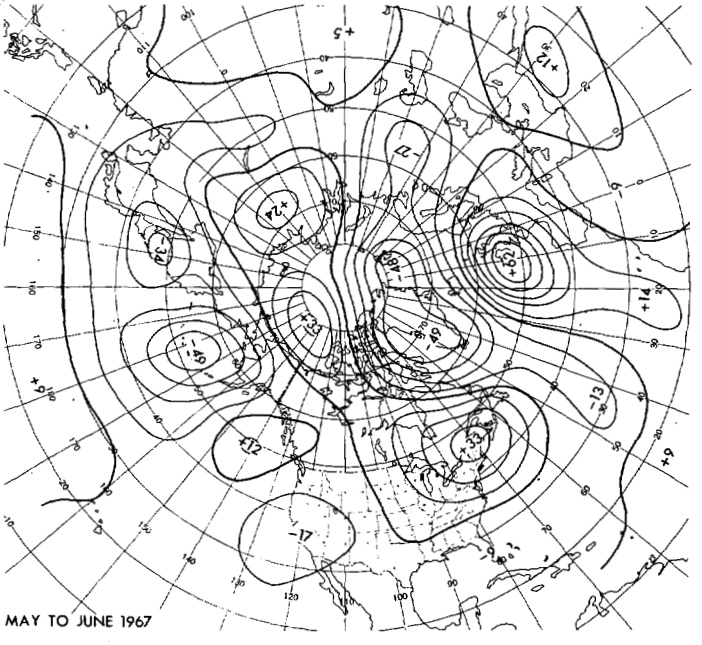

FIGURE 3.—Mean monthly 700-mb. height anomaly change (tens of feet) from May to June 1967.

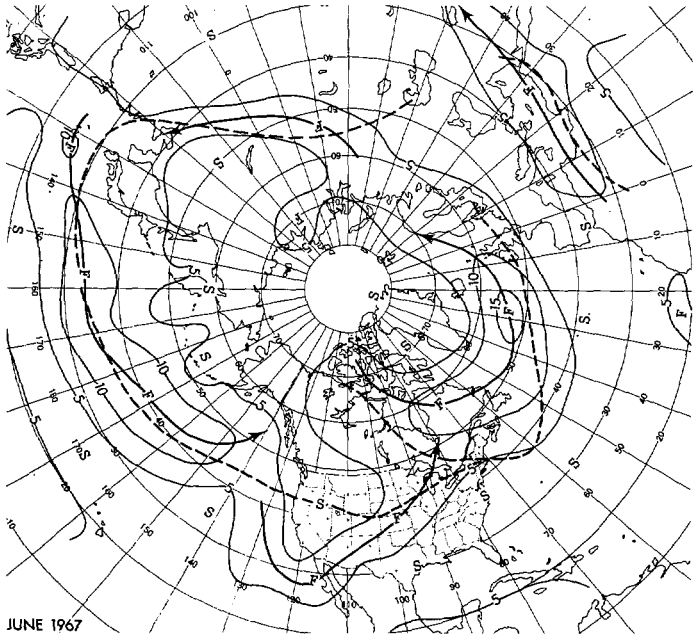

FIGURE 4.—Mean 700-mb. isotachs (meters per second) for June 1967. Solid arrows indicate principal axes of maximum wind speed and dashed lines the normal. Absolute maximum and minimum centers are labeled F (fast) and S (slow) respectively.

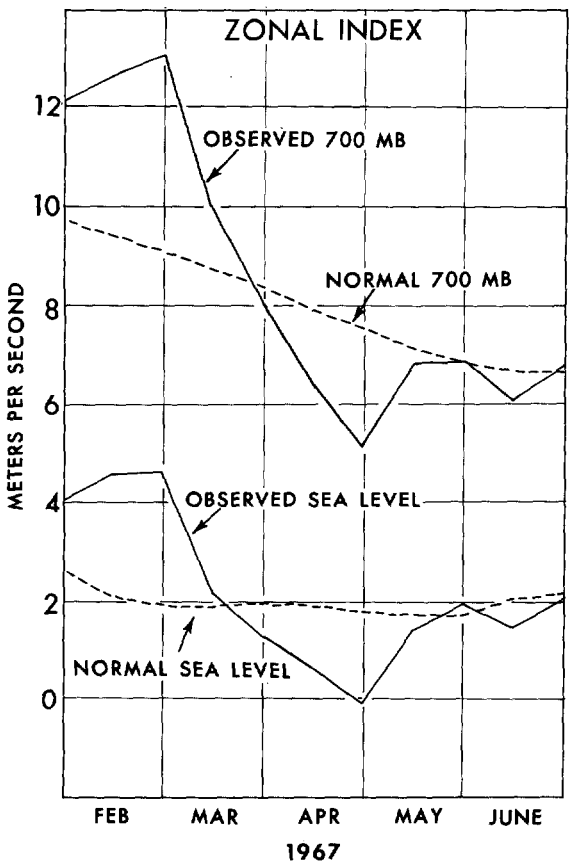

FIGURE 5.—Monthly mean zonal index (m.p.s.) at 700-mb. and at sea level, computed twice monthly between 35°N. and 55°N. and between 5°W. and 175°W.

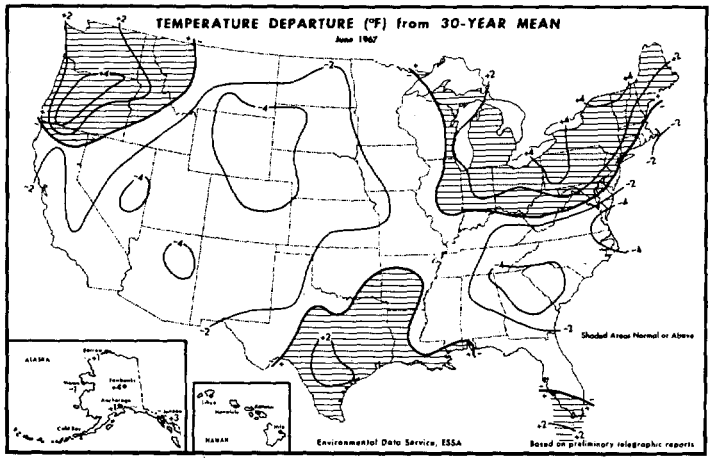

FIGURE 6.—Departure from normal of average surface temperature (°F.) for June 1967 (from [7]).

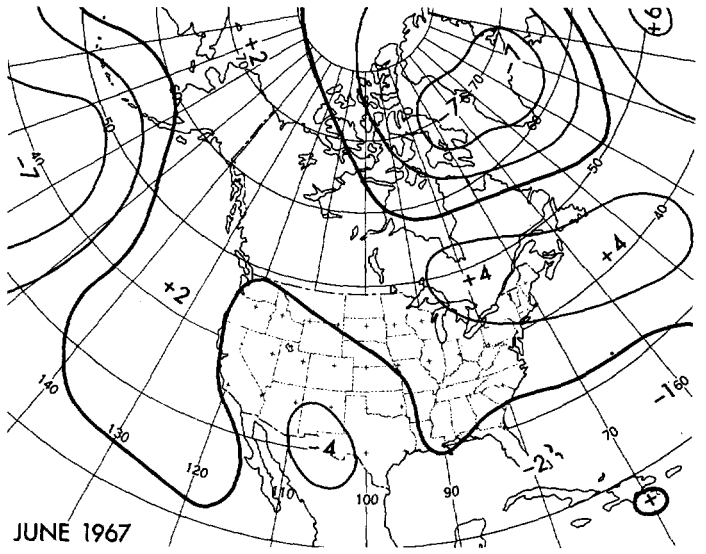

FIGURE 7.—Departure from normal of surface pressure reduced to sea level. Solid lines are drawn for every 2 mb. of pressure anomaly, and central values are in mb.

from normal (more than 4° F.) occurred over parts of the central Rockies, western Plains, and the Southeast (fig. 6). Denver, Colo., and Columbia, S.C., reported their coldest Junes of record, 5.9° F. and 6.2° F. below normal, respectively. A monthly mean temperature of 3.9° F. below normal was the lowest since 1884 at Charleston, S.C. The high temperature of only 80° F. at Sheridan, Wyo., for the whole month was the lowest June monthly maximum record there. This is an additional indication that much of the abnormal coolness was due to the suppression of daytime maximum temperature by cloudiness.

Higher than normal temperatures were observed in the Pacific Northwest, southern Texas and Louisiana, extreme southern Florida, and most of the Northeast and Great Lakes area. The greatest warmth relative to normal was at

Buffalo, N.Y., where the June 1967 monthly mean temperature was 72.5° F. (7.7° F. above normal). This constituted the warmest June and seventh warmest month of record since 1870. The Northeast was directly under the influence of the abnormally strong ridge (figs. 1 and 2) where subsidence warmed the air and suppressed cloudiness. The departure from normal of the sea level pressure (fig. 7) shows that greater than normal low-level easterly flow prevailed over most of the area, leading to subnormal temperatures over southeastern New England as a result of the still lower than normal (−4° F.) water temperatures off the coast. In contrast, the prevailing cooling breezes which reach Buffalo from Lake Erie were weakened.

4. PRECIPITATION

Most of the weather news this June came from the large area of excessively heavy precipitation extending from California to the Great Lakes (fig. 8). From two to more than three times the normal rainfall fell over extensive areas of the Central Plains and Rockies, while parts of the Plateau and California, which are usually quite arid in June, reported rainfall in excess of four times the monthly normal. Numerous stations reported their wettest June of record (table 1a) and Grand Island, Nebr., and Topeka, Kans., had their wettest month of record. Norfolk, Nebr., had its second wettest month with 12.22 in. This was more rain than fell there in the preceding 10 months. Several other cities reported their second or third wettest Junes of record. Flooding occurred along the Missouri River and some of its tributaries.

New 24-hr. June rainfall records were established at several localities (table 1b), many of which were also in the monthly record column. This was due primarily to the large number of severe local storms occurring in the middle of the country. Tornadoes and funnel clouds were observed on 11 consecutive days in the Plains area. Overall damage and casualties were relatively light, however, since many of the storms occurred in the more sparsely populated areas of the western Plains.

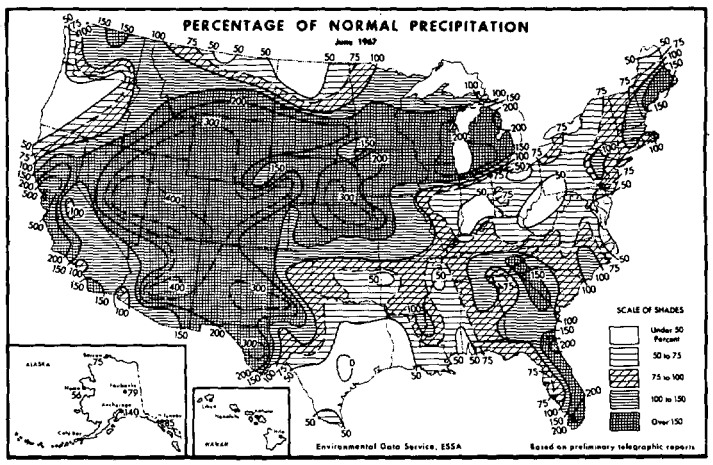

FIGURE 8.—Percentage of normal precipitation for June 1967 (from [7]).

A measure of the unusually high frequency of convective activity is afforded by the record of thunderstorm activity at several stations. Salt Lake City, Utah, reported thunder on a record 19 days, 12 of which were consecutive. Denver, Colo., had thunder on 20 days, including 14 in a row. Kansas City, Mo., Topeka, Kans., and Lander and Casper, Wyo., all reported at least 14 days of thunder during June 1967. The weather observer at the National Reactor Site west of Idaho Falls, Idaho, sighted funnel clouds on 3 different days.

It is interesting to note that the heaviest rainfall and most of the severe convective activity occurred near and to the north of the jet stream and in an area where there was an anomalous component of low-level flow from the southeast (compare figs. 4 and 8). The existence of these patterns in a monthly mean sense would imply the frequent occurrence of intersecting upper and lower level jet streams in the manner shown by Beebe and Bates [5] to be favorable for the release of convective instability.

Heavy rains also broke out over most of Florida, ending the acute drought which had plagued that State during

TABLE 1.—*Precipitation records established in June 1967*

a. Wettest June of record		b. Heaviest in 24 Hours during June			c. Driest June of record	
Station	Amount (in.)	Station	Date	Amount (in.)	Station	Amount (in.)
Muskegon, Mich	5.46	Muskegon, Mich	7–8	3.19	Akron, Ohio	1.01
Sioux City, Iowa	8.78	Huron, S. Dak	18–19	5.48	Parkersburg, W. Va	1.14
Rapid City, S. Dak	6.78	Topeka, Kans	20–21	5.52	Victoria, Tex	T
Grand Island, Nebr	[1] 13.96	Casper, Wyo	22–23	1.54	San Antonio, Tex	[4] .01
Topeka, Kans	[1] 15.20	Lubbock, Tex	1	5.70		
Denver, Colo	[2] 4.69	San Francisco, Calif	2	1.34		
Casper, Wyo	3.75	Raleigh, N.C	18	3.44		
Lubbock, Tex	7.95	Athens, Ga	4	9.93		
Milford, Utah	2.43	Portland, Maine	20–21	[3] 5.74		
San Francisco, Calif	1.42					
Athens, Ga	13.21					
Columbus, Ga	10.83					
Kahului, Hawaii	2.50					

[1] Also the heaviest total ever recorded during any month.
[2] Greatest since 1882, though not an all-time record.
[3] Greatest storm total ever recorded from storm which was not a hurricane. Fell in a little over 24 hr.
[4] Equaled record set in June 1914.

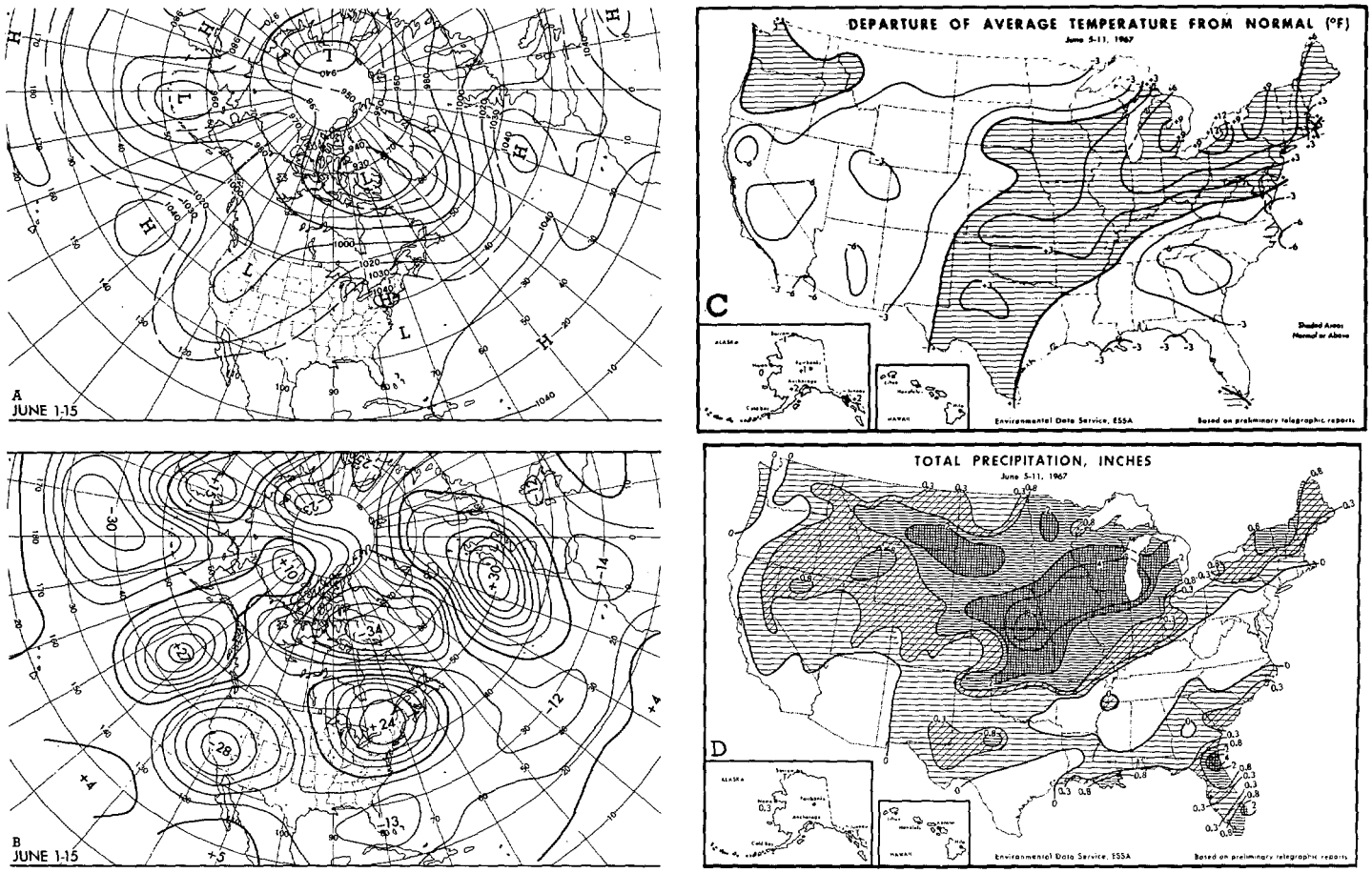

FIGURE 9.—(A) Mean 700-mb. contours and (B) 700-mb. height anomalies (both in 10's of ft.) for June 1–15, 1967; (C) departure of average surface temperature from normal (°F.), and (D) total precipitation (in.), for week of June 5–12, 1967 (from [7]).

the past spring. Some severe weather—including hail, funnel clouds, waterspouts, and strong winds—accompanied the showers, but the overall effects were decidedly beneficial. Monthly rainfall totals were as high as nearly 16 in. at Miami, but were not record breaking.

Even though over the country as a whole June 1967 will be remembered for its wetness, there were small areas of deficient precipitation in Oregon, southern Texas, and the Ohio Valley. A number of cities in the latter two areas reported the driest June of record (table 1c). In the Pacific Northwest and over the Ohio Valley, 700-mb. heights were above normal and the flow both aloft and at the surface had downslope components relative to the large-scale orographic features.

4. INTRA-MONTHLY VARIABILITY

JUNE 1–15

It was during the first half of the month that most of the widespread excessive rains and severe weather occurred. The western trough-eastern ridge pattern was of maximum amplitude then, with departures from normal of −280 ft. and +240 ft., respectively (fig. 9A, B). The ridge in the Northeast originated from a blocking High which moved slowly southeastward from central Canada the first few days of the month. The block had previously built up in response to the development of the trough off the west coast during the closing days of May.

As the trough moved into the Plateau, it produced record June rainfall at San Francisco (table 1a, b), a record-tying minimum temperature of 47° F. at Long Beach, Calif., and brought unusually low readings to the normally warm Central Valley of California. Abnormally heavy precipitation and below normal temperatures persisted over most of the West under the influence of the trough the first half of the month. Weather during the week of June 5-11 is representative of this regime (fig. 9C, D). Heavy precipitation, as much as 8 in. or more in parts of Kansas and Nebraska, fell across a wide area from the Rockies to Lake Michigan.

As the blocking High moved slowly toward the Northeast, temperatures rose from levels which had set new records for June cold at Concord, N.H. (31° F. on the 1st),

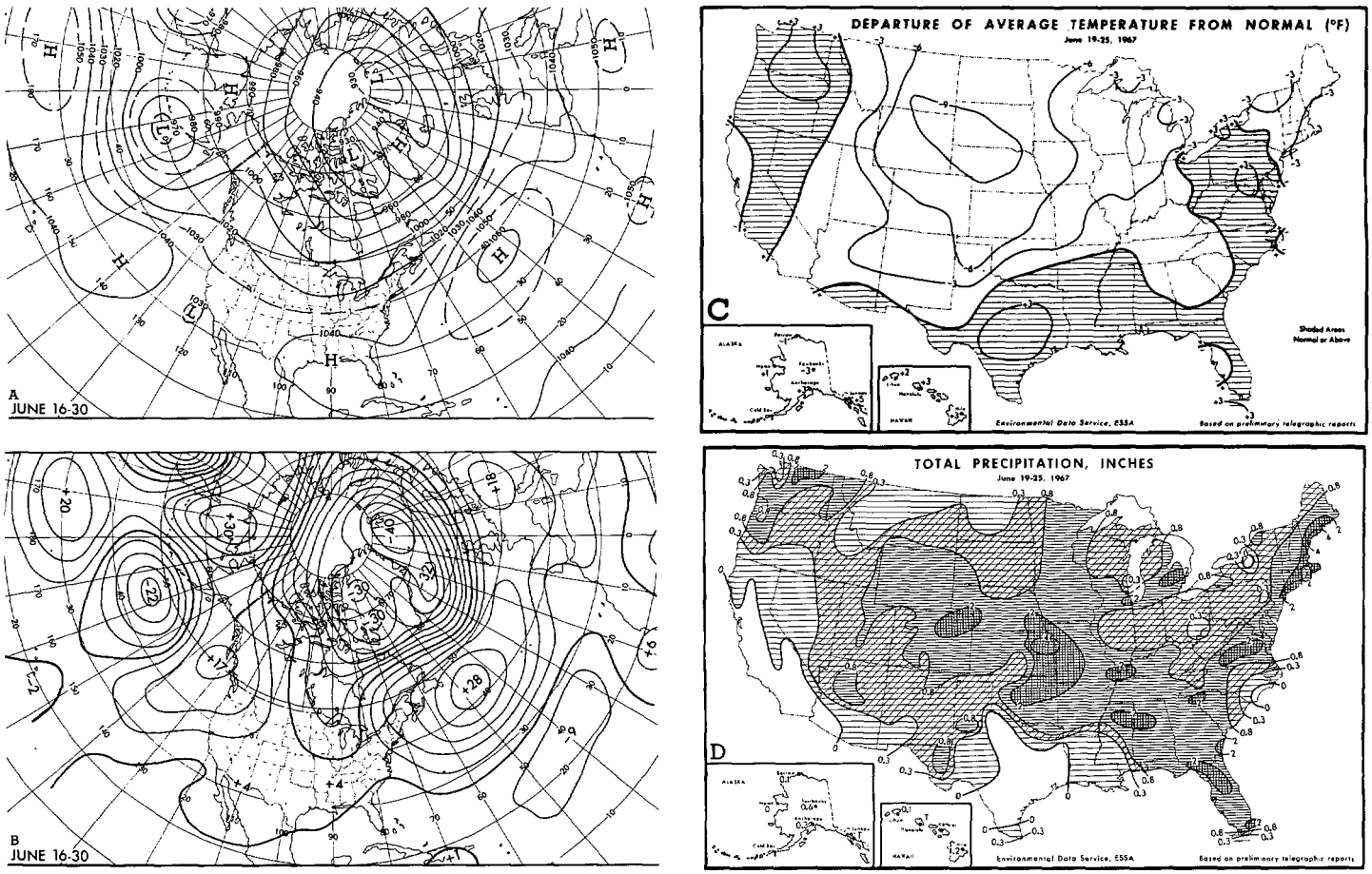

FIGURE 10.—Same as figure 9, (A) and (B) for June 16–30, 1967; (C) and (D) for week of June 19–25, 1967 (from [7]).

and at Norfolk and Richmond, Va. (45° and 40° F. respectively on the 2d), to readings in the low and middle 90's. Daily records for warmth were tied and in some cases exceeded at Youngstown and Akron, Ohio, and Albany, N.Y., and Newark, N.J. A record-breaking (for so early in the season) 16 consecutive days with maximum temperatures equal to or greater than 80° F. were observed at Buffalo, N.Y., from June 2–17, and Burlington, Vt., had maximum temperatures of 80° F. or above every day during the first week of June for the first time. Mean temperatures during the week of June 5–11 averaged as much as 12° F. above normal at Buffalo (fig. 9C).

Under the influence of the slowly moving block, precipitation was deficient or non-existent over parts of the Mid-Atlantic States. Beckley and Parkersburg, W. Va., and Washington, D.C., reported 16, 21, and 17 consecutive days respectively with no measurable rain. The dry spells established new June records at the latter two cities.

JUNE 16–30

Progression and deamplification of the 700-mb. systems from the eastern Pacific to Europe (fig. 10A, B) led to marked changes in the weather over some parts of the United States during the latter half of the month. The greatest changes in temperature occurred in the Southwest where readings rose to far above normal in the closing days of the month as a ridge began to move into the Great Basin. The magnitude of the change is brought out by the observations at mile-high Blue Canyon, Calif., where the daily mean temperatures rose from 21° F below normal on the 1st (with 3.5 in. of snowfall) to 13° F. above normal on the last day of the month. Elsewhere in California, monthly extreme temperatures similarly ranged from 29° F. to 103° F. at Bishop and from 48° F. to 106° F. at Red Bluff.

Heavy rains continued in the Central Plains (fig. 10D) as the anomalously strong southerly flow of the first half of the month was replaced by a trough and greater than normal cyclonic curvature (compare figs. 9A, B and 10A, B). Under the influence of the trough, cooler air moved into the Central Plains and Mississippi Valley (fig. 10C). A cool air mass set several daily minimum temperature records as it moved across the country from Montana on the 22d to South Carolina on the 28th.

Although the movement of the trough into the middle of the country was certainly influenced by upstream

dynamic effects, it is possible that the extremely wet ground left by the rains of the first two weeks may have been a factor inhibiting the formation of the warm continental High which often begins to develop in that area at the beginning of summer. A weak ridge was in evidence over southern Texas, which remained dry. The physical reasoning for this has been discussed by Namias [6]. The weather and circulation during the first half of June this year were more typical of spring than summer, and this may have been related to the unusually late index cycle.

Progression of the blocking ridge into the Atlantic to join the Bermuda High and movement of the west coast trough to the center of the country combined with the low heights prevailing off the South Atlantic Coast to give southeasterly anomalous flow over the Northeast. This circulation helped to produce heavy rains east of the crest of the Appalachians. A weak disturbance which seemed to show some tropical characteristics at the time of formation off the South Atlantic Coast just after the middle of the month produced most of the rain as it moved slowly north-northeastward near the coast (fig. 10D). It brought the greatest June 24-hr. precipitation of record at Raleigh, N.C., and the heaviest non-hurricane storm total of any month in the history of the Portland, Maine, weather station (table 1b).

Record rainfall in parts of Georgia earlier and later in the month was associated with intense localized convective activity. A cloudburst of 3.30 in. of rain in 3 hours at Allentown, Pa., on June 18 was connected with the passage of a cold front.

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