THE WEATHER AND CIRCULATION OF MAY 1964

Large Weekly Variations

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1. INTRODUCTION

During May 1964 there were two major reversals of weekly temperature anomaly over the United States. The first came early in the month when record-breaking cold in the West gave way to unseasonably high temperatures, while cooling took place in the East. More spectacular, however, was the second reversal when the abnormal warmth of the third week was almost entirely eliminated. Corresponding changes of weekly average temperature departure from normal were as much as −18 °F. in parts of Kansas and Ohio. New daily high temperatures were observed at numerous stations in the third week and some new lows were recorded at the end of the month.

Weekly circulation patterns showed similar reversals. The first was a phase shift of a mean wave from ridge to trough in the eastern Pacific and trough to ridge in western United States. The second reversal was a large-scale change of circulation from high-index, with fast westerlies near the Canadian border and warm anticyclonic conditions in the United States, to low-index, with high-latitude blocking and intrusions of cold air from Canada.

With large weekly fluctuations, new monthly temperature extremes were recorded at only two stations. For a similar reason, few extremes for the month were noted in April [1]. Persistence of temperature anomaly was very high between April and May, when such persistence is normally at a minimum.

2. WEEKLY WEATHER AND CIRCULATION

MAY 4–10

General features of the weather pattern over the United States for May 4–10 (fig. 1) were established in the first three days of the month when a short-wave trough and associated cyclogenesis moved into the northern Rocky Mountains from the Pacific. In this stormy area several new snowfall records were established for May. The 4 in. at Boise, Idaho on May 2 exceeded the previous May accumulation in 80 years of record, and all May records were broken with 5 in. at Salt Lake City Airport. In Montana, accumulations were 8 in. at Kalispell and 5 in. at Missoula on the 2d, and 10 in. at Helena on the 3d. Temperatures were extremely low behind the storm and high ahead of it. Several new minima were recorded, including an all-time low for May of 11° F. at Elko, Nev., on the 3d. Severe weather on these two days included a tornado at Scottsbluff, Nebr., on the 2d and another at West Palm Beach, Fla., on the 3d. The latter was associated with a developing wave over Georgia, where 24-hr. rainfall at Thomasville totaled 5.28 in. for a new May record.

This week the mean waves were strongly amplified in temperate latitudes from the central Pacific to Europe, especially the ridge in the eastern Pacific and the trough from southern California to Lake Winnipeg (fig. 1 A and B). Ahead of the trough two storms developed over the Central Plains and intensified as they moved northeastward toward Hudson Bay. The second storm became very deep near James Bay, and was followed by cool air that reached the Atlantic coast and as far south as central Georgia.

Accompanying the slowly moving deep mean trough was a sharp contrast in weekly average temperatures (fig. 1C) which ranged from more than 12° F. below normal in Arizona to 15° F. above in upper Michigan. New daily minima were observed this week in the Pacific Coast States and Far Southwest. Winslow, Ariz., reported 23° F. on the 8th, the lowest May temperature of station history. On the other hand, new daily maximum temperature records were established in Texas and the Northeast.

Many tornadoes were reported in the warm air east of the upper trough. They were most numerous on the 5th, causing 12 deaths, 400 injuries, and severe damage in southeastern Michigan. Other tornadoes on that day in Kansas, Nebraska, Iowa, and North Dakota caused little damage. Precipitation was heavy from Texas to Lake Superior with frontal activity and air mass showers east of the mean trough. Little if any precipitation fell in the Southeast after the earlier storm moved off the coast and weakened.

MAY 11–17

As the Aleutian ridge strengthened, the eastern Pacific ridge weakened rapidly. In the ensuing reversal (figs. 1 and 2) this ridge was replaced by a trough, the trough in

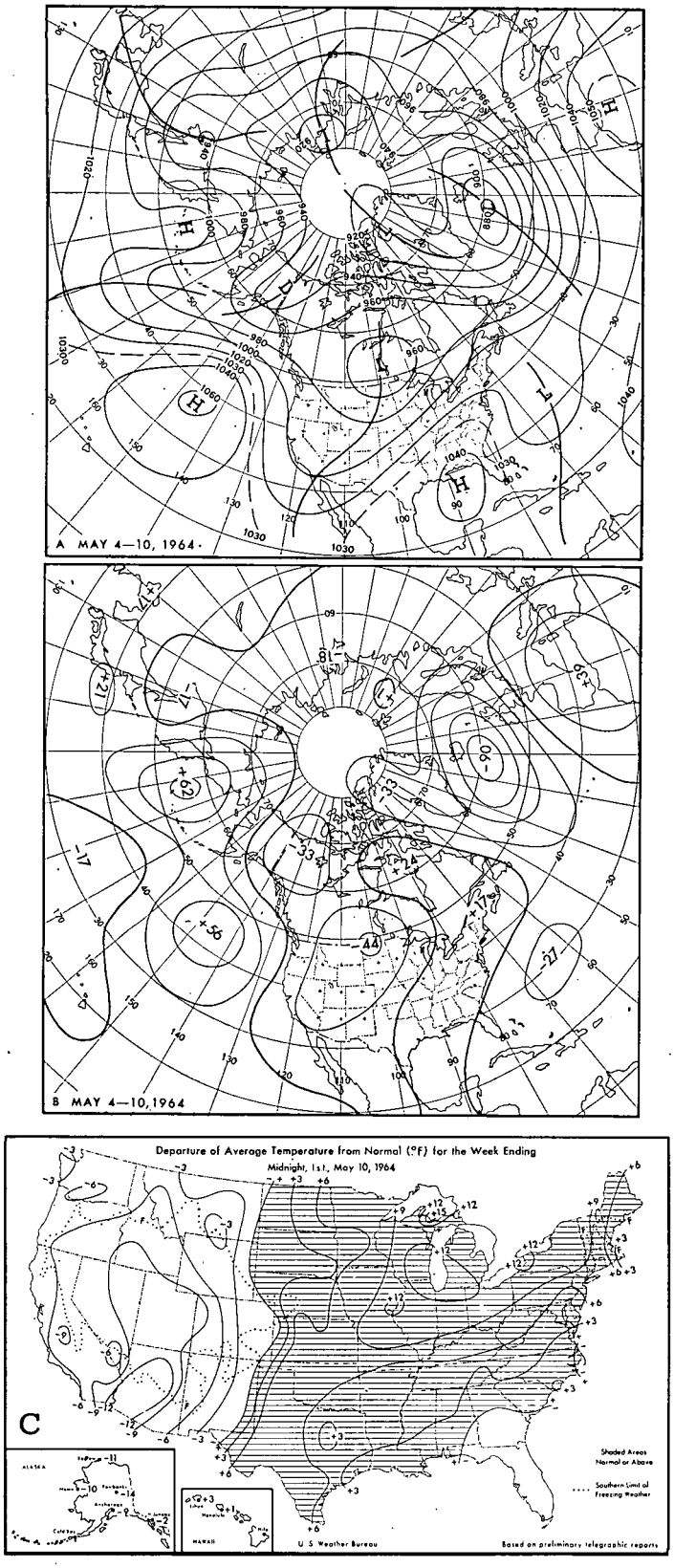


FIGURE 1.—(A) Mean 700-mb. contours (tens of ft.); (B) mean 700-mb. height departures from normal (tens of ft.); and (C) departure of average surface temperature from normal (° F.) (from [4]), all for week ending May 10, 1964. Stormy weather prevailed from the Central Plains northeastward.

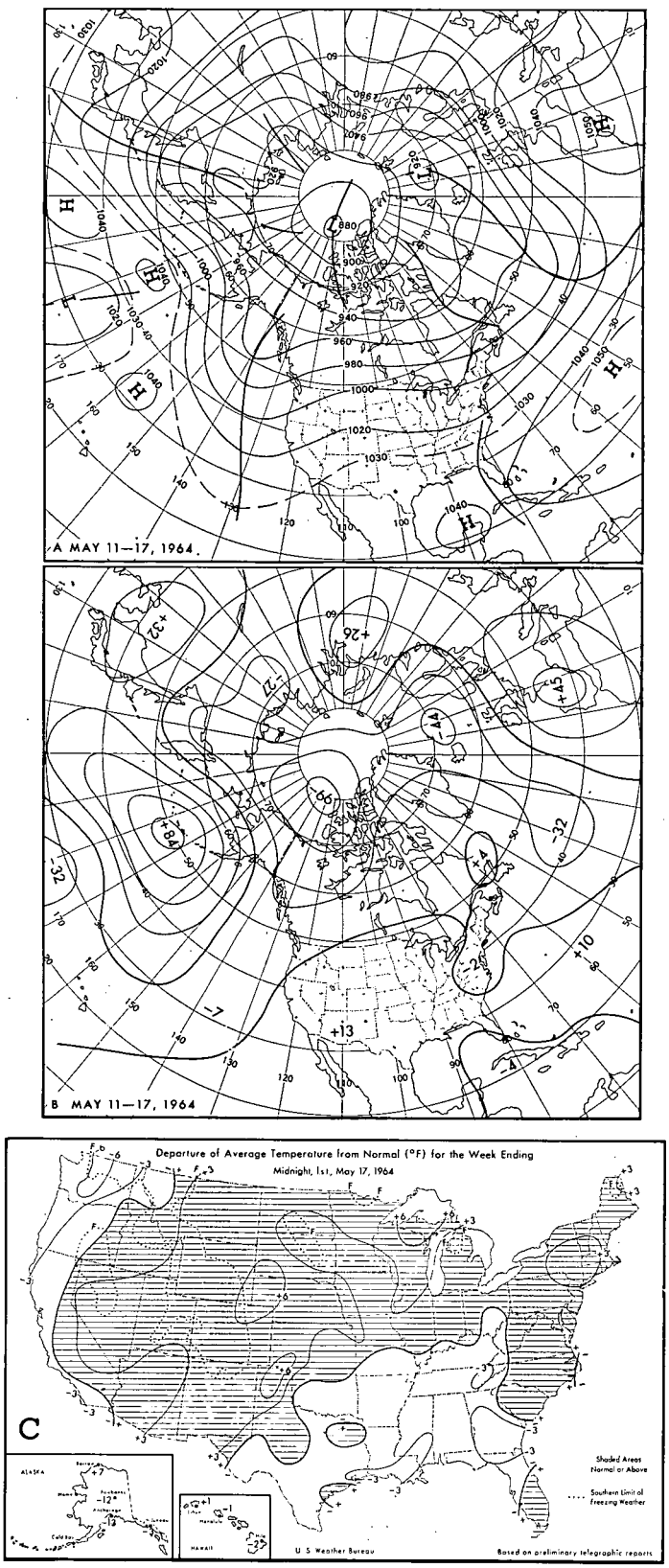
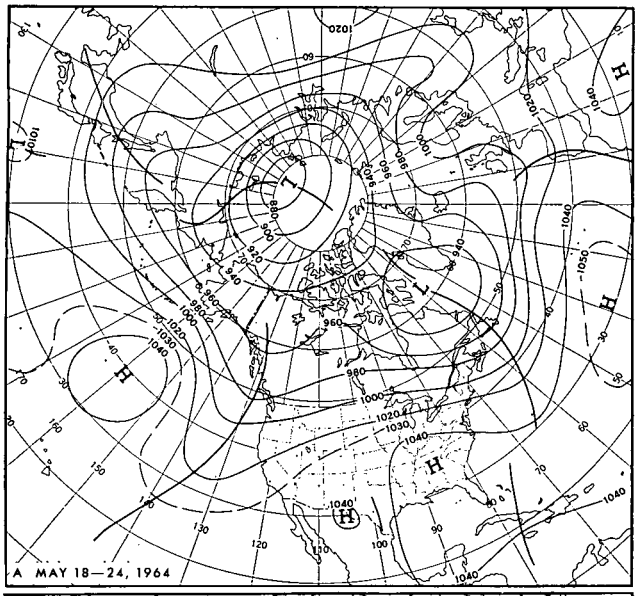
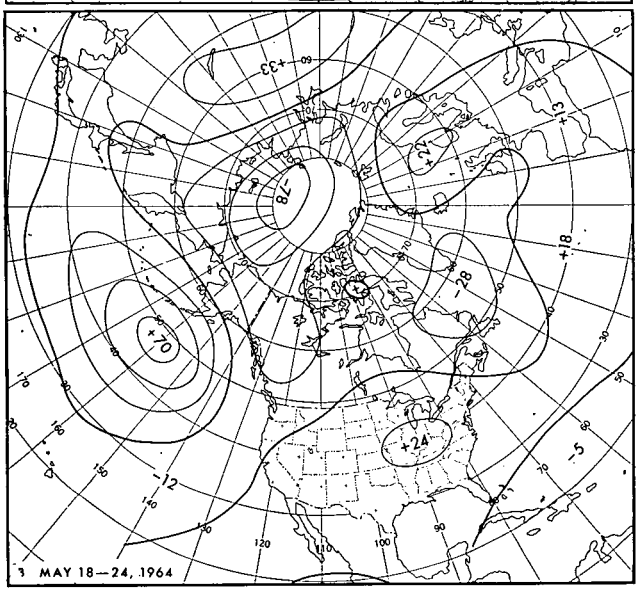


FIGURE 2.—(A) Mean 700-mb. contours (tens of ft.); (B) mean 700-mb. height departures from normal (tens of ft.); and (C) departure of average surface temperature from normal (° F.) (from [4]), all for week ending May 17, 1964. Circulation and temperature patterns were reversed from previous week.





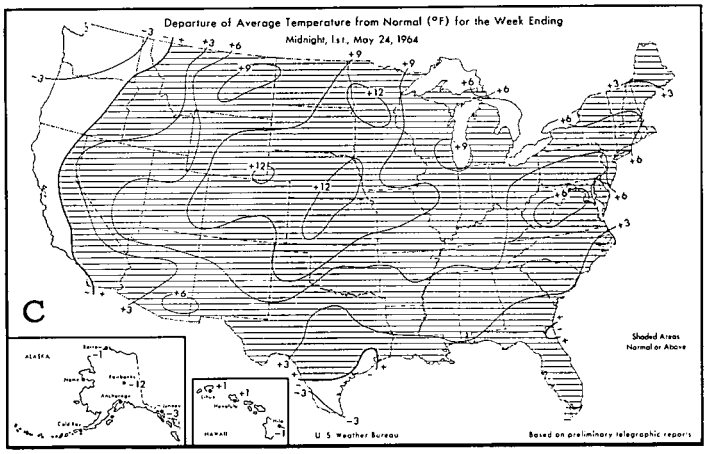
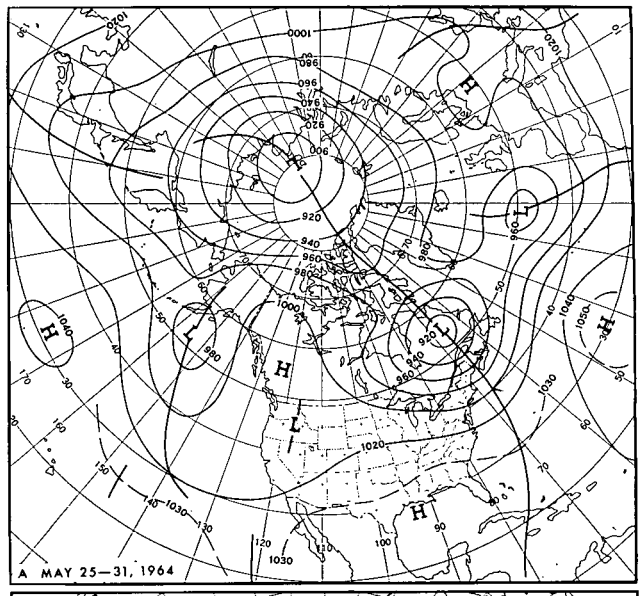
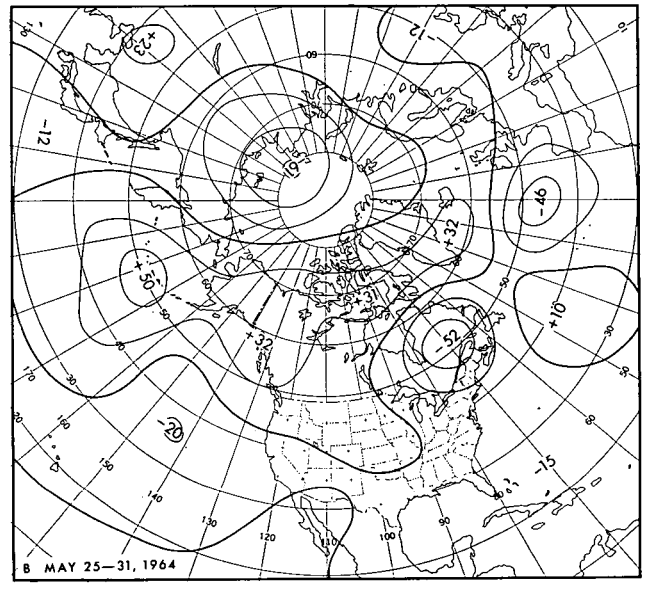


FIGURE 3.—(A) Mean 700-mb. contours (tens of ft.); (B) mean 700-mb. height departures from normal (tens of ft.); and (C) departure of average surface temperature from normal (° F.) (from [4]), all for week ending May 24, 1964. High index circulation and abnormal warmth were prevalent.





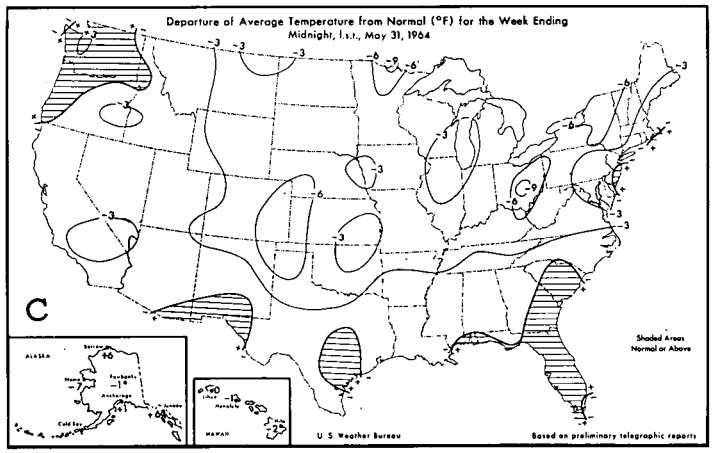


FIGURE 4.—(A) Mean 700-mb. contours (tens of ft.); (B) mean 700-mb. height departures from normal (tens of ft.); and (C) departure of average surface temperatures from normal (° F.) (from [4]), all for week ending May 31, 1964. Breakdown of zonal circulation brought rapid cooling.

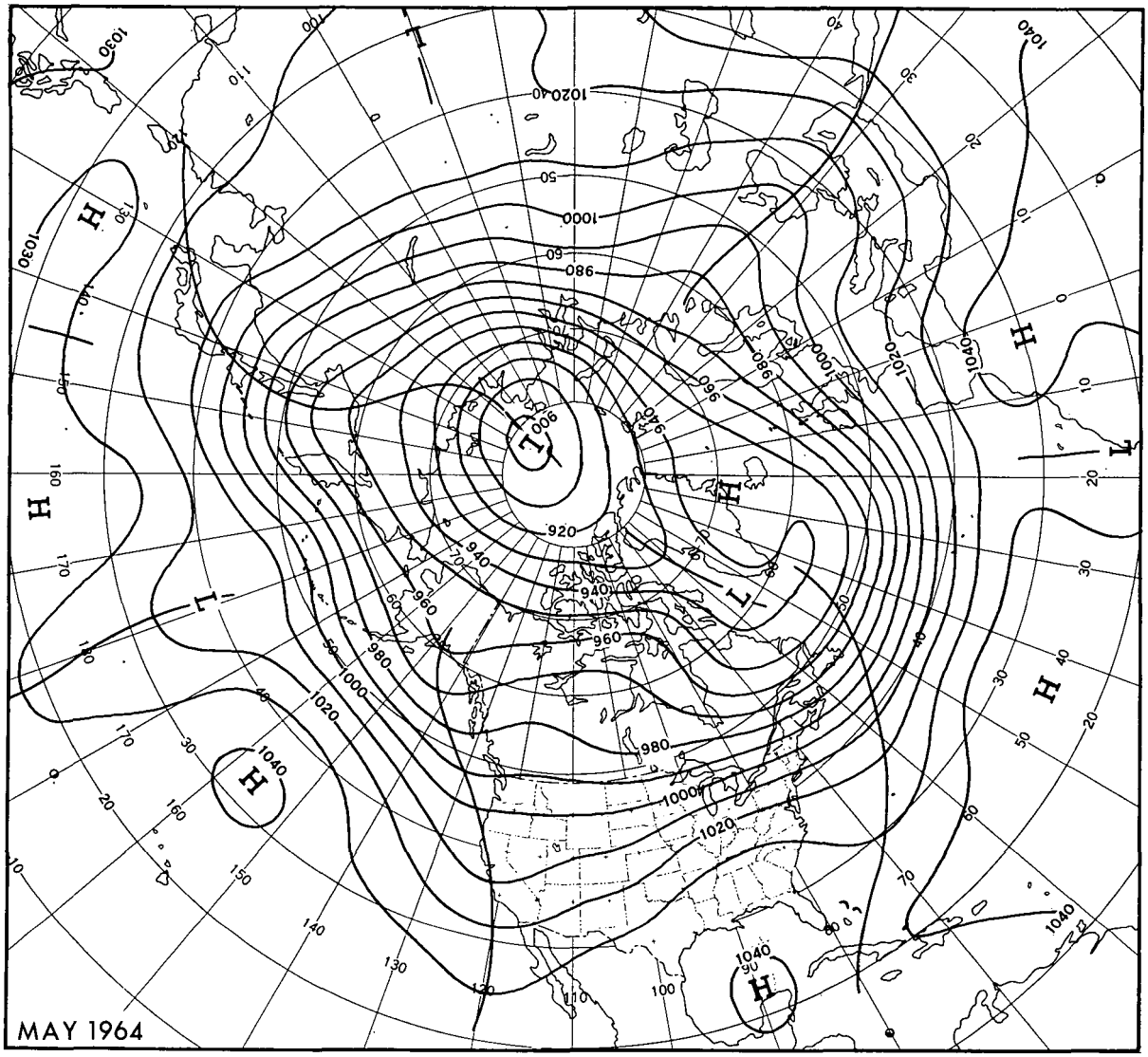


FIGURE 5.—Mean 700-mb. contours (tens of ft.) for May 1964. Outstanding features were the deep Polar Low and the ridge in the normal position of the Aleutian Low.

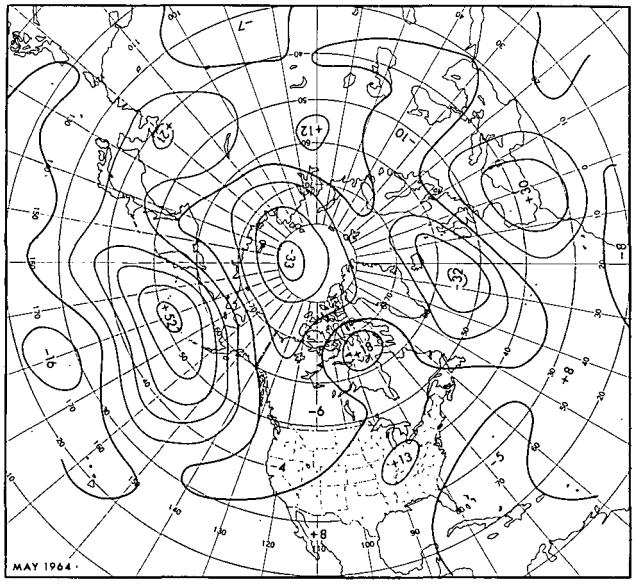


FIGURE 6.—Mean 700-mb. height departures from normal (tens of ft.) for May 1964. Intensity of anomaly center in the Aleutians was greatest of record for May in the Northern Hemisphere.

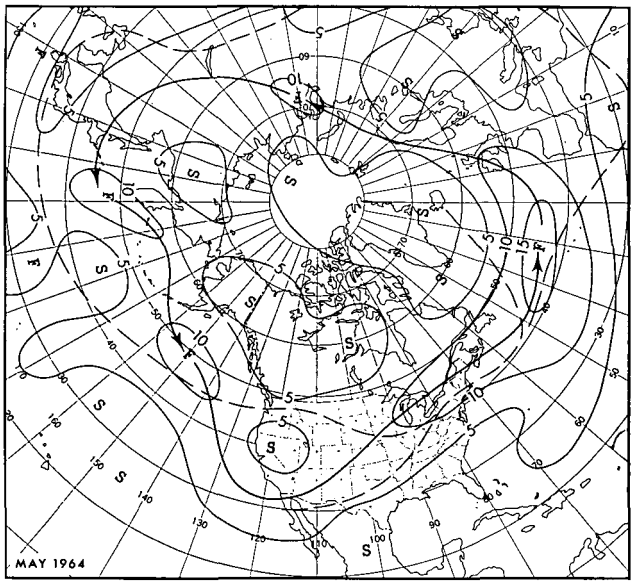


FIGURE 7.—Mean 700-mb. isotachs (m.p.s.) for May 1964. Solid arrows indicate principal axis of maximum wind and dashed lines the normal. Except in western United States and northeastern Atlantic principal jet was north of normal.

the western United States by a ridge, and the Appalachian ridge by cyclonic mean flow.

Following the trend of the circulation, temperatures increased rapidly over the Southwest where weekly departures (fig. 2C) rose as much as 15° F. in Arizona. Cooling in the East was less pronounced, ranging from 9° to 11° F. in western parts of New York, Pennsylvania, and West Virginia.

Sea level activity was relatively quiet this week. A stable wave from Texas crossed the Ohio Valley and New England, two Pacific fronts trailed across the United States from Canadian Lows, and a rather vigorous cyclone pushed into the Pacific Northwest on the last day. Precipitation was spotty, with scattered amounts of more than 2 in. in the Great Lakes Region.

MAY 18–24

Typical high-index features this week over the United States (fig. 3 A and B) were a ridge in the central portion of the country with troughs off both coasts and a narrow belt of fast westerlies across the northern border. Daily Lows were of the Alberta type, often associated with abnormal warmth over the United States. One continental High traversed the northeastern States and brought cooler air as far south as the Carolinas, but the coolness was quickly dispelled by a heat wave which began in the Northern Plains on the 20th and crossed the Great Lakes to New England by the 23d. New daily high temperatures were recorded at numerous stations and Hartford, Conn., reported its highest May temperature of record on the 23d. This was the warmest week of the month (fig. 3C) with departures well above normal over much of the country.

Among the few reports of severe weather were a tornado at Spokane, Wash., and severe winds to 106 m.p.h. at Minneapolis-St. Paul, Minn. Precipitation was light, except for 1–2 in. in a narrow band from western Missouri to upper Michigan. In addition 2–4 in. fell in southern Texas and extreme southern Florida.

MAY 25–31

A surge of high-latitude blocking accompanied the second major reversal of circulation from the third to the final week (figs. 3 and 4). Mean 700-mb. heights rose sharply from Greenland across northern Canada to Alaska and fell nearly as rapidly over the Maritime Provinces and much of the United States.

The temperature reversal was extremely pronounced and widespread. Weekly averages decreased 18°F. in southwestern Kansas and central Ohio, and 5-day temperature classes changed from above and much above normal to below normal over most of the country. Freezing was reported in the Dakotas and Nebraska on the last day of the month. An exception to the general cooling was warming in the Pacific Northwest where Washington had above normal weekly temperature for the first time this month.

The strong, rather slow-moving frontal zone in the Northwest on the 24th was followed by a massive sea level ridge of maritime and continental air. Thus, a mixture of cool air masses poured into the United States, and the wedge of cool air nosing into Texas behind a wave on the 28th resembled a typical winter "norther". The wave was stable, but rainfall was heavy north of its path across Arkansas and Tennessee. Precipitation this week ranged to 4 in. or more in Kansas, Missouri, and Kentucky.

3. MEAN CIRCULATION

A circulation feature common to all the 7-day means in May 1964 was the strong ridge over or near the Aleutian Islands. Therefore it was a prominent feature of the 700-mb. average circulation for the month (fig. 5). Since it coincided with the position of the normal mean Low, the height anomaly was very large. The intensity of this anomaly (+520 ft., fig. 6) has not been equaled in May anywhere in the Northern Hemisphere in more than 30 years of record. Sea level pressures in the same region were 17 mb. higher than normal, which is more than any May departure in the Hemisphere for at least 15 years. Negative departures were 330 ft. and 11 mb. in the Polar Low, and 170 ft. and 5 mb. near Midway Island.

The mean jet maximum was displaced more than a thousand miles northward from its normal Pacific location (fig. 7), and winds were as much as 7 m.p.s. faster than the long-term average in the Bering Sea. Near the usual path of the mean jet south of the Aleutians, winds averaged up to 11 m.p.s. slower than normal.

Amplification downstream from the Aleutian ridge is well indicated by the southward swing of the jet maximum to the latitude of northern Mexico, then back to lower Michigan (fig. 7). Negative 700-mb. height departures prevailed from northeastern Alaska to southern California, while positive anomalies were prevalent from Mexico through the Great Lakes to Baffin Island (fig. 6).

Confluence between northerly flow from the Baffin Island area and westerly flow across the Great Lakes (fig. 5) helped to support abnormally fast westerlies from the Maritime Provinces to western Europe. The northern branch of the mean jet predominated in the eastern Atlantic, with speeds up to 9 m.p.s. greater than normal near Scotland. In the absence of the southern branch, which ordinarily is the stronger in May, average wind speeds over northwestern Africa were 9 m.p.s. slower than normal. The mean jet continued north of normal as it traveled eastward across Asia and northern Japan to the Bering Sea (fig. 7).

In the western Pacific, positive height departures in the north and negative departures in the Tropics favored the development of tropical storms. There were two this month, one west of the Philippine Islands, the other east. The latter reached typhoon intensity before it became extratropical east of Japan. It passed within 70 miles of Marcus Island, causing wind gusts to 63 kt. and 3.7 in. of rain, but little damage. The circulation also favored

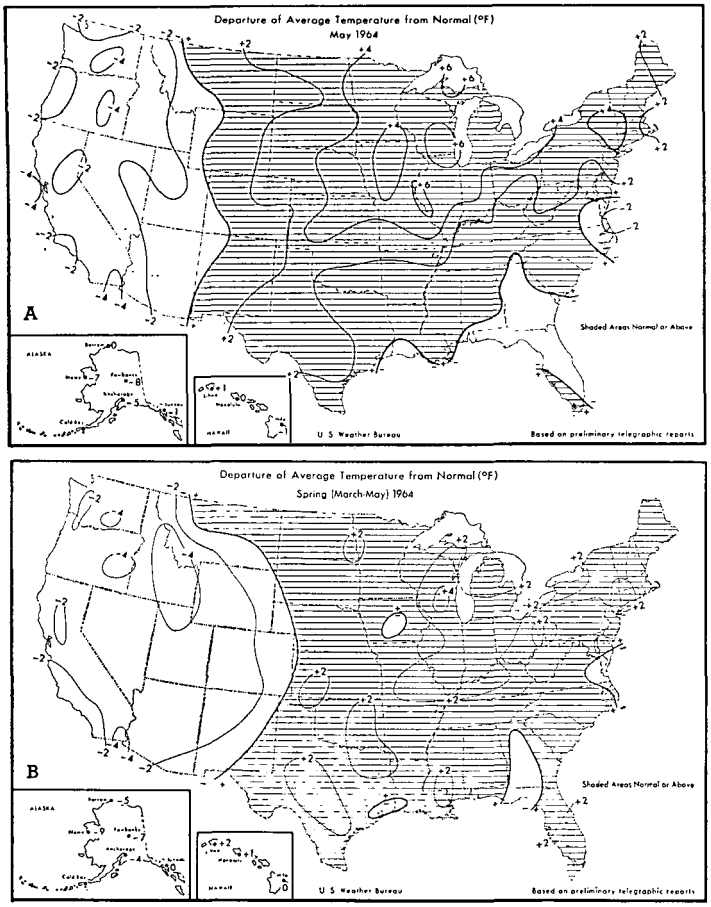


FIGURE 8.—(A) Departure of average surface temperature from normal (° F.) for May 1964 and (B) for spring 1964 (from [4]). Persistence of monthly temperature anomaly was high this spring.

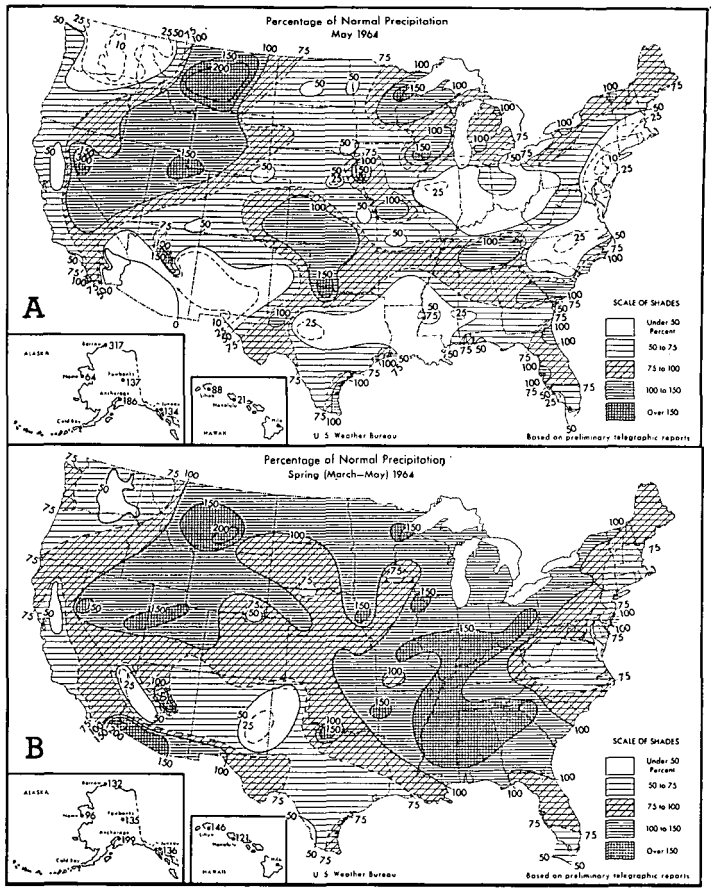


FIGURE 9.—(A) Percentage of normal precipitation for May 1964 and (B) for spring 1964 (from [4]). Deficiency of soil moisture was critical by the end of May in parts of the Northwest, Midwest, Northeast, and South.

heavy precipitation on windward Hawaii, where the total at Hilo for the month was 25 in., the most for any May.

4. TEMPERATURE

Temperature anomalies in May (fig. 8A) agreed in general with the mean circulation (figs. 5 and 6), with negative departures of both temperature and 700-mb. height in cyclonic flow west of the Rocky Mountains. East of the Rockies the anomalies were positive and the flow anticyclonic. In addition to the general agreement, the temperature departures were accurately specified by application of the Klein [2] objective method to observed 700-mb. heights, except in the Southeast and part of the middle Atlantic coast. In the Southeast temperatures may have been held below expected levels by the maritime influence suggested by the slight easterly drift of anomalous flow at 700 mb. Subnormal temperatures over coastal Virginia and North Carolina can be directly attributed to cold water that was 4°–8° F. below normal.

So great was the variability of circulation and temperature within the month that only Duluth, Minn. (+5.4° F.) and Los Angeles, Calif., Airport (−3.5° F.) reported new extreme temperatures for May. Persistence from the preceding month was unusually high, however. Using the customary test, it was found that 80 of 100 representative stations remained within one temperature class (out of five) from April to May. Normally, persistence between these two months is at a minimum with 62 percent in the category of change by no more than one class [3].

Spring temperature anomalies (fig. 8B) were distributed similarly to those of May. Coincidentally, persistence of temperature was also 80 percent from March to April. The anomaly patterns of all three months were grossly similar—cool in the West and warm in the East.

5. PRECIPITATION

May 1964 was dry over much of the Nation except for a number of relatively small areas (fig. 9A). One of the driest regions extended from southeastern New England, where serious drought was reported, to South Carolina. Soil moisture shortages delayed growth and caused some crop deterioration throughout the area. It was the driest May on record for the States of Maryland and Delaware and at stations in New Jersey, North Carolina, Pennsylvania, and West Virginia. It was the sunniest May at

Blue Hill Observatory, Mass., Concord, N.H., and Trenton, N.J.

By the end of the month shortages of soil moisture had developed over parts of New Mexico, Arkansas, Louisiana, and Alabama; and also in Illinois and Indiana. Dry weather continued in Washington, where Walla Walla reported its driest January-to-June period, and in north-central California, where the accumulation at Red Bluff in the last six months was the least of record. In addition, Pendleton, Oreg. reported its driest May.

Deficiency of precipitation east of the Rocky Mountains can be attributed to the anticyclonic character of the mean circulation (fig. 5). In the West the circulation was cyclonic and 1–2 in. of rain fell from California to Montana east of the mean trough. Scattered wet areas from Oklahoma to Wisconsin are less well related to the monthly circulation, but the weak anomalous flow from the south suggests the availability of moisture aloft. Irregular distribution of precipitation east of the Rocky Mountains indicates the lack of a well-defined storm path.

Comparison of the distributions for May and Spring (fig. 9B) shows the areas where deficiency in May was part of a longer-period dry state. In the critically dry region from New England to North Carolina totals for Spring were less than 75 percent of normal. In the Midwest and parts of the South the need for moisture was not so great, despite the shortage in May, because of adequate supplies in previous months.

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3. J. Namias, "Persistence of Mid-Tropospheric Circulation Between Adjacent Months and Seasons," *The Atmosphere and the Sea in Motion*, Rossby Memorial Volume, The Rockefeller Press in association with Oxford University Press, New York, 1959, pp. 240–248.
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Weather Note

LARGE HAIL IN CENTRAL MONTANA, JUNE 28, 1963

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1. INTRODUCTION

A fall of large hailstones at Flatwillow 4 ENE, a Montana climatological substation, about 0700 MST, June 28, 1963, provided an unusual opportunity for study of the stones when observer S. E. Wiggins, on his own initiative, carefully preserved several stones in his home freezer. When the station, located in central Montana's Petroleum County (fig. 1) was visited about two months later, Montana Field Aide, E. L. Stensland, examined and sketched several of the larger stones. The stones were dissected for study, and the purposes of this note are to record descriptions, to describe some of the atmospheric conditions probably involved in their formation, and to comment on some possible implications arising from stone size and structure.

2. DESCRIPTION OF STONES

Four stones were chosen for dissection, study, and measurement. Sketches of the four appear in figures 2–5; scales are shown for each. The stone sketched in figure 2 had an original average circumference of 9.8 in. (average diameter 3.2), with rings quite distinct about as shown. The stone sketched in figure 3 had an original circumference of 10.5 in. the long way, 4.7 in. the small way (diameters 3.4 and 1.5 in. respectively). The stone pictured in figure 4 had an average diameter 2.5 in., circumference about 7.9 in. The stone in figure 5 appeared to have melted flat on one side, but could originally have been the largest of the four, with an estimated 3.5-in.

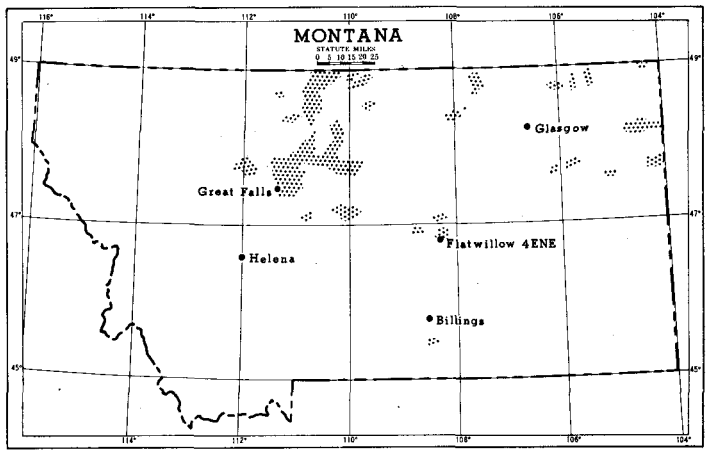

FIGURE 1.—Map of Montana showing location of Flatwillow 4 ENE, the station where the large hailstones fell, June 28, 1963. Shaded areas reported hail damage to crops that day.