

THE WEATHER AND CIRCULATION OF APRIL 1965

Disastrous Floods and Tornadoes in the Midwest

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1. HIGHLIGHTS

The greatest winter snowfall ever recorded in parts of the upper Midwest was climaxed by one of the coldest and snowiest Marches which left near-record snow depths on April 1 and ice conditions in the upper Great Lakes the worst in nearly a century. This was followed in April by a succession of storms from a deep Pacific coastal trough which brought very heavy rains and warmer temperatures to that region. The resulting runoff of snowmelt and heavy rains produced the most disastrous flooding ever recorded in the upper Mississippi River Basin. It continued throughout the month, during which an unprecedented flood crest moved slowly down the Upper Mississippi.

Another disaster struck the Midwest on Palm Sunday, April 11, when an intense storm produced the second greatest tornado disaster in the Nation's history in terms of the number dead (271) from 37 tornadoes in 5 States. In economic terms, this outbreak was probably the most costly on record, amounting to an estimated \$250,000,000 in damage. Coupled with flood damage estimates of about \$150,000,000, the two disasters totalled an estimated \$400,000,000, an enormous toll which does not reflect the misery of thousands of people injured and dislocated from homes and employment.

2. THE MONTHLY CIRCULATION

The average circulation in April 1965 was more amplified than usual and most of the planetary waves were west of their normal positions. An important feature was the ridge in the eastern Pacific which shifted westward to the Bering Sea (fig. 1), continuing a long-period retrogression from the western United States in January [1], and from the Gulf of Alaska in March [2]. This permitted the development of a deep trough along the California coast. The negative height departure center there (fig. 2) could be interpreted also as a counterpart of one near Baja California in winter, but with a corresponding shift northwestward.

Over North America heights were mostly above normal, with two maxima of positive height departure (fig. 2). The center near New Orleans, La., reflected a stronger than normal ridge over the Southeast, as well as a mean sea level high center near Florida (fig. 3), while the maxi-

mum in southern Canada was associated with a High at sea level near Hudson Bay.

The principal jet axes during the month were correspondingly amplified relative to the normal (fig. 4). In the eastern Pacific the jet axis associated with the strong ridge was north of normal and in the trough near the Pacific coast it was south of normal. In the Midwest the jet axis was north of its usual position, reflecting the stronger than normal southeastern ridge.

The confluence in the Midwest of southwesterly flow south of 40° N. and northwesterly flow farther north and over most of Canada was influential in converging the tracks of repeated disturbances from the West over that region, with severe weather consequences. The exceptional snow and ice conditions in the upper Midwest must also have been an important influence on the circulation, at least in determining the position of the confluence axis and the associated mean front.

In the Atlantic a deep trough from Greenland southward was flanked by a ridge and associated jet axis in the eastern Atlantic, the most strongly amplified feature (400 ft. above normal at 700 mb.) of the April circulation. This ridge helped maintain sharply depressed westerlies in the Mediterranean trough, which were out of phase with a strong blocking ridge and jet branch over northern Scandinavia.

3. TEMPERATURE

Considerable warming occurred in April (fig. 5), relative to normal, from the near record cold in March [2] over most of the interior, as a result of change from the predominantly northerly flow in March to stronger than normal southerly flow this month. In the South Central States "much above normal" temperatures replaced the "much below" values of the previous month, aided by the marked dryness and abundant sunshine. Despite the warming, temperatures in most of the north central region averaged slightly lower than normal in April. This was due in part to the prevalence of high pressure over Hudson Bay, together with the cooling effect of heavy snow and ice accumulations. Another factor was the greater than normal cloudiness associated with frequent disturbances. Confluent flow in the middle of the Nation was associated with a mean front from the Great Plains across the Mid-

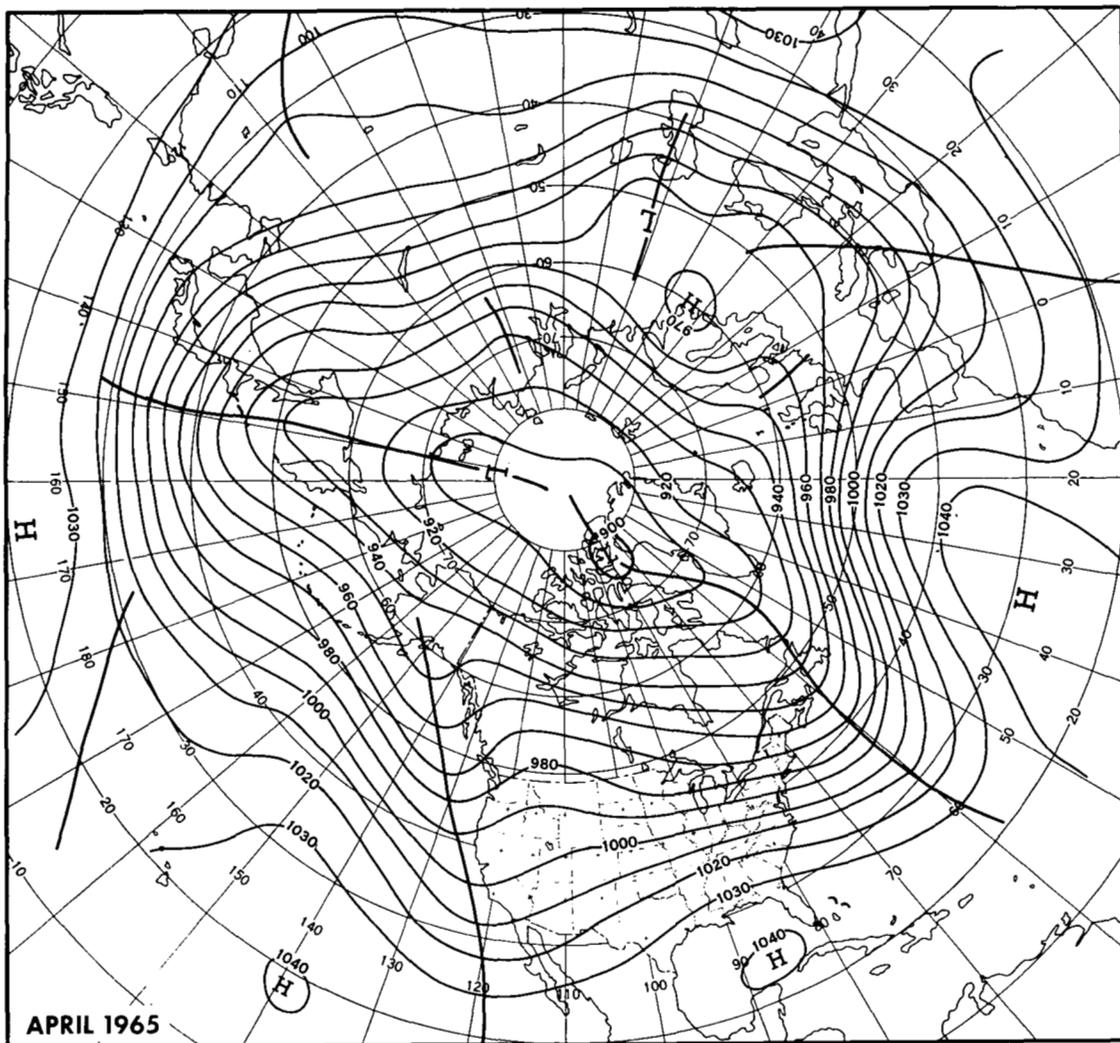


FIGURE 1.—Mean 700-mb. contours (tens of feet) for April 1965.

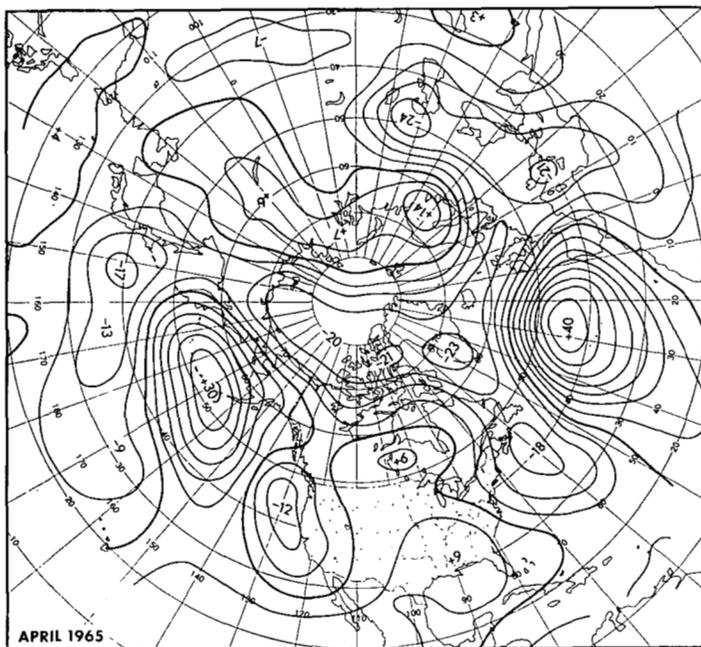


FIGURE 2.—Departure of mean 700-mb. heights from normal (tens of feet) for April 1965.

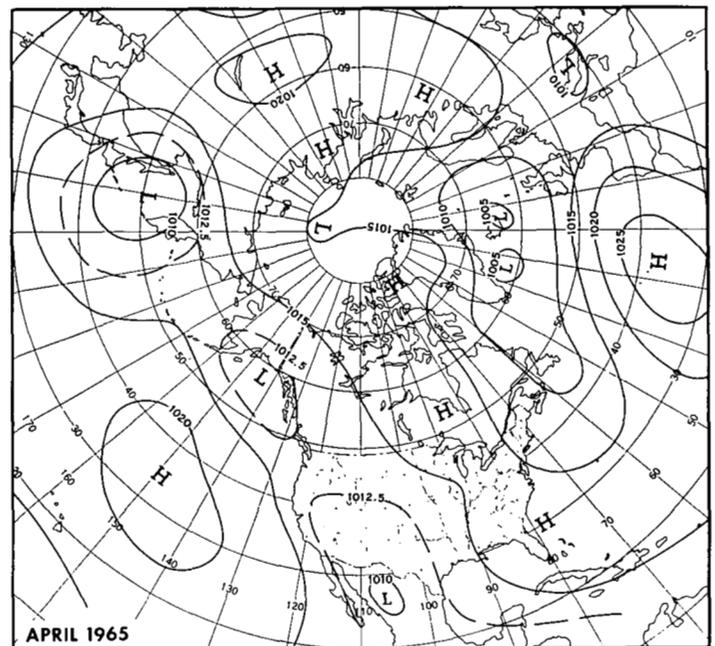


FIGURE 3.—Mean sea level isobars (mb.) for April 1965.

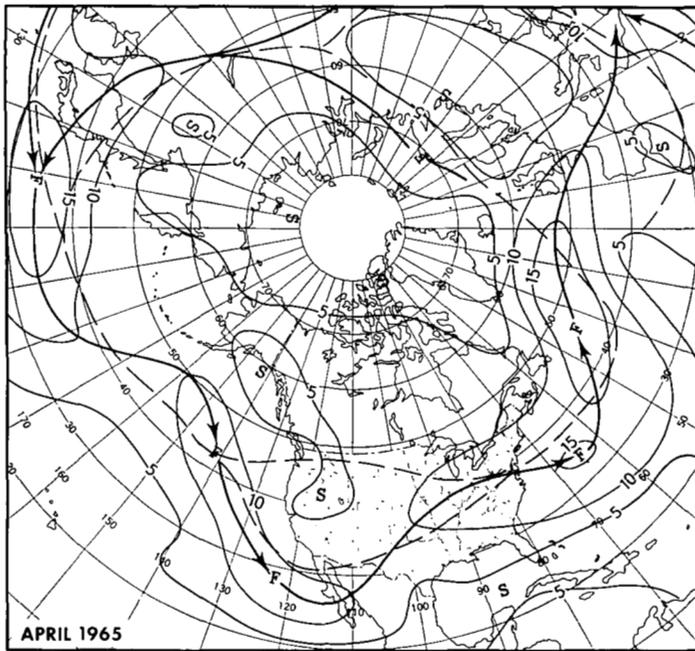


FIGURE 4.—Mean 700-mb. isotachs (meters per second) for April 1965.

west to the Carolinas, evident in the strong temperature anomaly gradients in figure 5.

In the Northeast and along the Middle Atlantic coast it turned colder in April in response to strong northerly flow between the Hudson Bay High and the deep trough near Newfoundland. Additional factors were the unusually cold coastal waters which averaged as much as 13° F. below normal near the Virginia Capes, as well as the fetch of the prevailing northerly flow over the abnormal snow cover to the north.

In the Far West, although heights were below normal, only the Southwest was unseasonably cold. The higher temperatures along the Northern Pacific coast may be attributed to the abnormal southeasterly component of the geostrophic flow implied by the height departures (fig. 2).

4. PRECIPITATION

Precipitation was heavy in April (fig. 6) in the Far West where more than twice the normal amounts fell over large areas, especially in California, and in Arizona, where over 10 times the normal amount fell in some desert areas. This was due to the deep mean trough near the coast and the associated more southerly than normal flow in the West (figs. 2, 4). It was the wettest April on record at Flagstaff, Ariz. (5.6 in.), Burbank, Calif. (5.7 in.), Grand Junction, Colo. (1.95 in.), Las Vegas, Nev. (2.44 in.), and Great Falls, Mont. (2.51 in.), and the second wettest on record at Los Angeles, Calif. (6.0 in.), San Diego, Calif. (3.58 in.), and Medford, Oreg. (3.1 in.). Record April snowfall also occurred at higher elevations in the Southwest, notably at Flagstaff, Ariz., where a total of 58.3 in. was measured. Severe weather

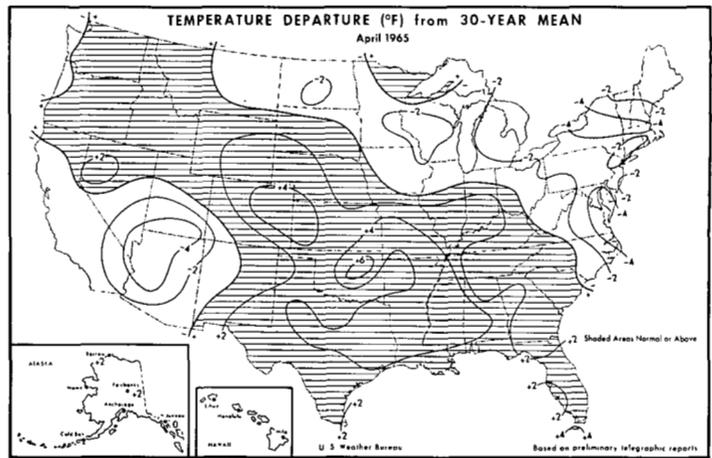


FIGURE 5.—Departure of average surface temperature from normal (° F.) for April 1965 (from [3]).

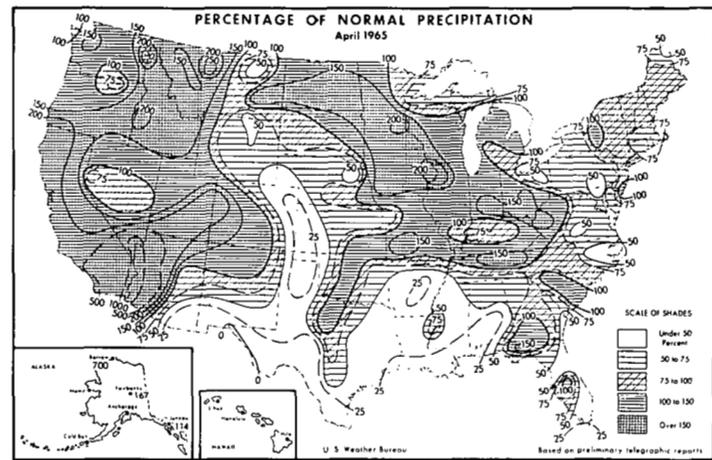


FIGURE 6.—Percentage of normal precipitation for April 1965 (from [3]).

was also reported along the California coast where Long Beach had a record number of thunderstorms (3).

Heavy precipitation also fell in the Midwest and upper Great Plains where more than twice the normal fell in some parts of the flood-stricken areas, associated with the confluent flow. The heaviest precipitation was generally located in or near the cooler than normal regions due to overrunning along the mean frontal zone.

Not surprisingly, the regions of heavy precipitation had more than the usual frequency of precipitation days. Burbank, Calif., reported a record number of consecutive days of rain (10), while Bakersfield reported 11 rainy days compared with a normal of 4. In Nevada, rain fell at Las Vegas on 8 days compared with a normal expectancy of only 1 day. In the Midwest, Minneapolis, Minn., and Aberdeen, S. Dak., had precipitation on 17 days compared with normals of 10 and 9 days respectively.

In the Southwest most of the precipitation occurred in the first part of the month when the maximum westerlies were farthest south of normal. At higher elevations heavy snows accumulated. Later in the month the

strongest westerlies in the coastal trough shifted northward along the coast as the upper High in the Gulf of Mexico retrograded to the Pacific; this resulted in more frequent rains along the Upper Coast.

In the Midwest the heavy precipitation occurred in greater part during early April when the jet stream was at its lowest latitude along the Pacific Coast. It was then that the most vigorous storms emerged from the Southwest and intensified in the Midwest in conjunction with a northwesterly jet from Alaska.

Rainfall was seriously deficient in frequency and amount in most of the Central and Southern Plains and Wyoming, associated with downslope flow in the lee of the Continental Divide. Cheyenne, Wyo., reported the first 4 months of 1965 were even drier than the same period in 1964, which was its driest year in this century. Rainfall was also deficient in the Gulf Coast States as a result of subsidence in the strong anticyclonic circulation near the Gulf Coast. The dryness was of record proportions at Alexandria, La., where only 0.29 in. of rain fell during the entire month.

Deficiencies of rainfall in the Atlantic States were due to the dry source of the unusually strong northwesterly flow coupled with downslope drying east of the Appalachians. In the Northeast, this was the 11th month with below normal precipitation at Portland, Maine, amounting to a deficit of 13.09 in. for that period, while Reading, Pa., reported that this was the fourth consecutive year of precipitation deficiency.

5. THE UPPER MISSISSIPPI FLOOD*

Early in April moderate to severe overflows occurred in most basins of the Upper Mississippi Valley in southern Minnesota, southwestern Wisconsin, and northeastern Iowa, principally from daytime melting of the heavy snow cover which had a water equivalent of 7 or 8 in. Record high stages also occurred in western Iowa along the Floyd and Big and Little Sioux Rivers, which were in flood most of the first half of April.

Heavier rainfall and substantial warming, which resulted in rapid snowmelt in the second week, produced a major flood disaster in southern Minnesota, Wisconsin, and northeastern Iowa, where thousands were forced from their homes and millions of dollars damage occurred. At Mankato, Minn., on April 10, the Minnesota River crested only 0.8 ft. below the greatest stage recorded in 1881. Record flooding also occurred in Iowa on the Cedar, Iowa, and Des Moines Rivers. The latter had the second highest crest of record, 28.7 ft. on the 10th.

Around mid-April, floods crested 3 to 5 ft. above the greatest stages previously recorded in the floods of April 1952 along the Minnesota River from Mankato to the mouth, and on the Crow and Stillwater Rivers. On April 16 a flood crest of 26 ft. occurred at St. Paul, Minn.,

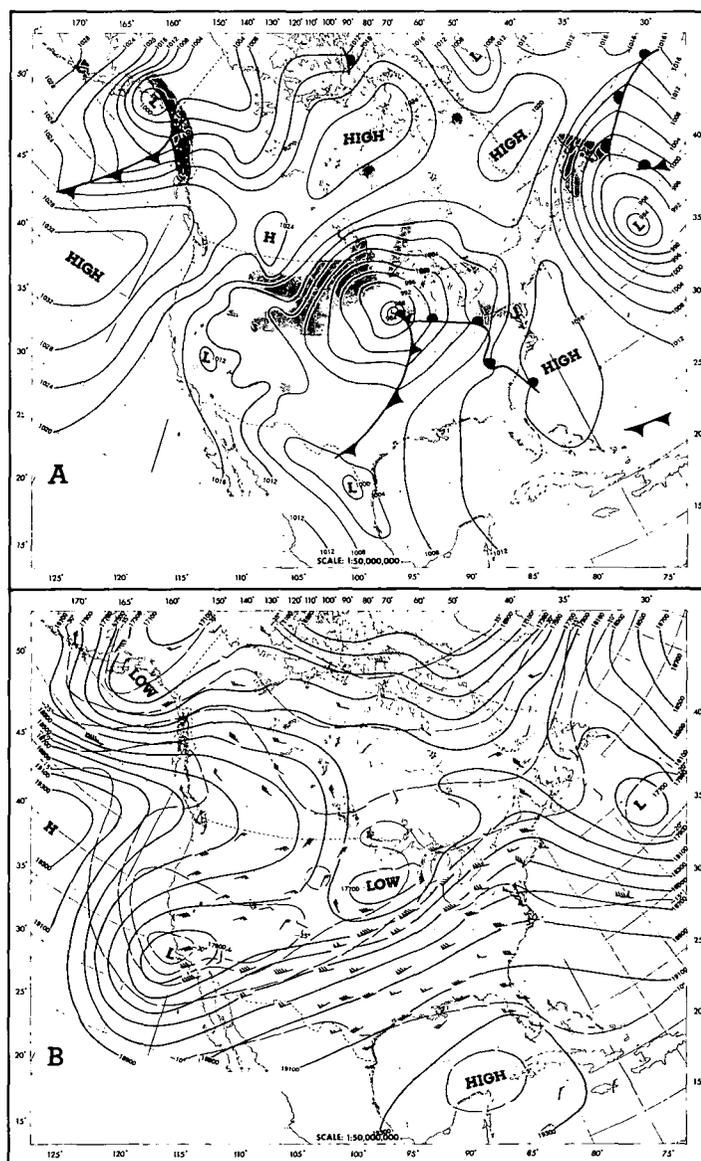


FIGURE 7.—(A) Sea level map for 1200 CST April 11, 1965. (B) 500-mb. map for 1800 CST April 11, 1965.

exceeding by 4 ft. the record 1952 flood peak, and overflow extended along the main stem of the Mississippi River from Aitken, Minn., to Carruthersville, Mo.

Later in April the flood crest moved down the Upper Mississippi, producing stages above any previously observed. The record flood for the 430 mi. from Minneapolis, Minn., to Keithsburg, Ill., occurred in 1952, with records back to 1880. In some places previous records were exceeded by as much as 4.5 ft. On April 26 the flood crest was approaching Clinton, Iowa, and early in May it was near Quincy, Ill., 3.5 to 4 ft. above previous records. Levee failures near Quincy, Ill., and Burlington, Iowa, flooded tens of thousands of acres, and one area of about 7,700 acres was covered by 15 ft. of water.

*The information in this section is based mainly on [3].

6. TORNADES

On Palm Sunday, April 11, 1965, at least 37 tornadoes were observed between 12:45 p.m. and 9:45 p.m. CST across adjacent parts of Iowa, Wisconsin, Illinois, Indiana, Michigan, and Ohio. The first were observed in eastern Iowa and the last near Cleveland, Ohio. They occurred near the path of the apex of a warm, moist, tropical air mass associated with the deepest storm of the month (982 mb.) shown over Iowa at 1200 CST (fig. 7A). At 500 mb. (about 18,000 ft.) at 1800 CST (fig. 7B) the highest wind speeds observed along the jet axis which entered Illinois were 135 kt. at Peoria, Ill., and Topeka, Kans. At Peoria this was one of two speed maxima in the vertical, with another maximum of 144 kt. at 31,000 ft. The unusually low level of such a strong jet maximum was an important factor contributing to the magnitude of the tornado outbreak, but also important was the great extent of the high speed winds along the jet axis which sustained the triggering action over the several hundred miles from Iowa to Ohio.

Most of the 271 deaths occurred in Indiana, Michigan, and Ohio, and over half the deaths occurred in Indiana. The only greater recorded tornado death toll occurred on March 18, 1925, when 689 perished in Missouri, Illinois, and Indiana.

During the entire month of April at least 82 tornadoes were observed on 14 days, according to preliminary reports, as shown in table 1. For comparison, the April average for the years 1916-1958 was 36 tornadoes on 10 days [4]. A detailed survey of the tornado area and of the forecasts and warnings issued is contained in [5].

7. WEEKLY EVOLUTION WEEK ENDING APRIL 4, 1965

A strong southerly flow between a deep low over California and a strong ridge in the Midwest (fig. 8A) brought warm weather to most of the West (fig. 8B) while the northeastern half of the country was cooled by northerly flow east of the strong Hudson Bay ridge.

The California Low brought cool weather and heavy rains of over 2 in. to the far Southwest (fig. 8C), which was equal to a 7-month supply in some areas. Heavy rains

TABLE 1.—Tornadoes observed during April 1965 (preliminary)

Date	Location	Total number
1	Monterey, Calif.	1
5	Arkansas, Oklahoma, Missouri	4
7	Texas, Oklahoma	3
7	Indiana, Kentucky	4
10	Indiana, Kentucky, Kansas, Missouri, Arkansas	8
11	Iowa, Illinois, Wisconsin, Michigan, Indiana, Ohio	37
14	Texas, Oklahoma	7
15	Tennessee, Alabama	4
19	Texas, Louisiana	3
23	Indiana, Illinois	3
24	Iowa, Texas	2
25	Indiana, Texas	4
26	Alabama	1
27	North Carolina	1
		82

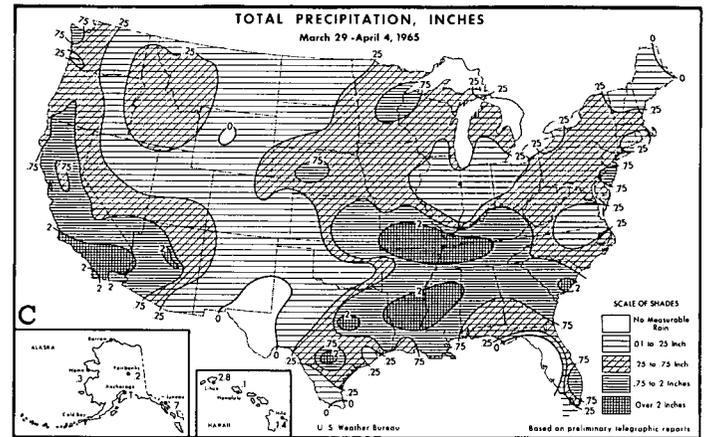
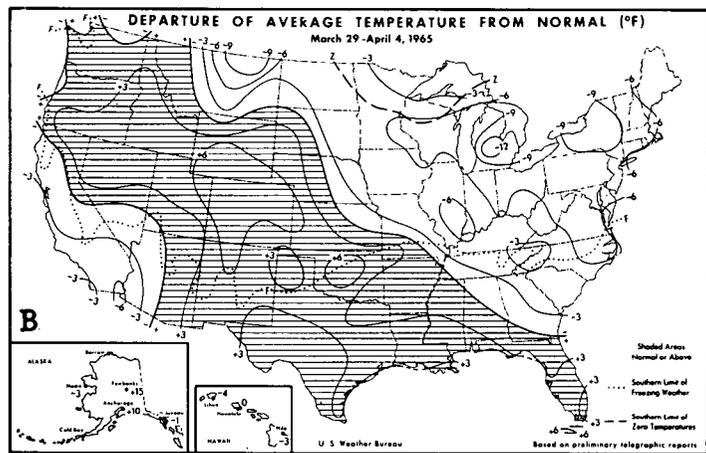
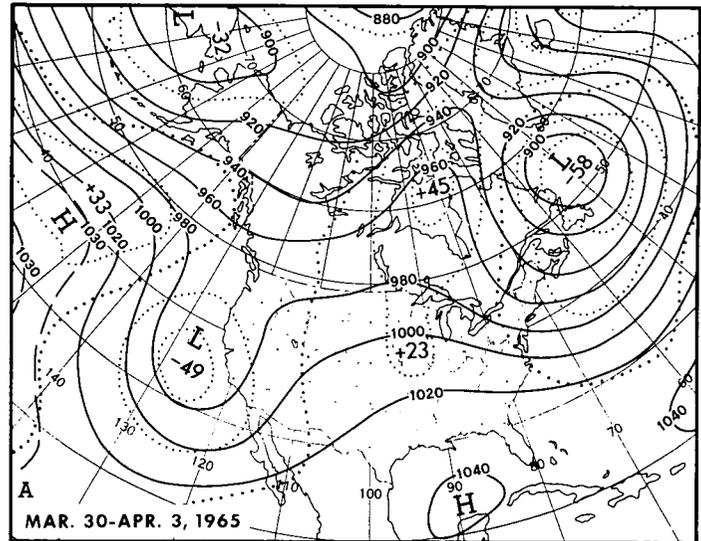


FIGURE 8.—(A) Mean 700-mb. contours (tens of feet) for Mar. 30-Apr. 3, 1965. (B) Surface temperature departure from normal (° F.), and (C) total precipitation (in.) for week ending April 4, 1965 (from [3]).

also occurred in the lower Mississippi Valley from over-running of the southwestern edge of cool air which oscillated from there to eastern Texas.

Highlights of the first few days of April were a tornado at Monterey, Calif., waterspouts off the coast, and heavy snows in the mountains of California. A snowstorm occurred from the Great Lakes region across southern

WEEK OF APRIL 5-11

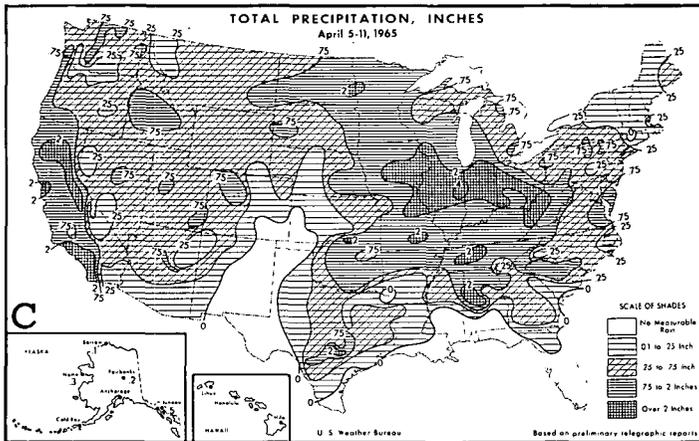
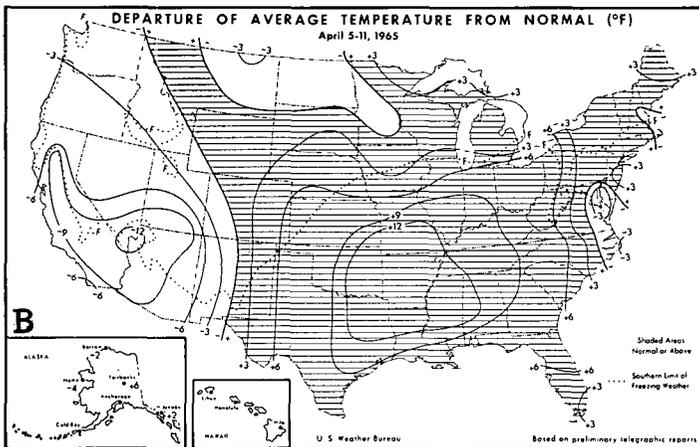
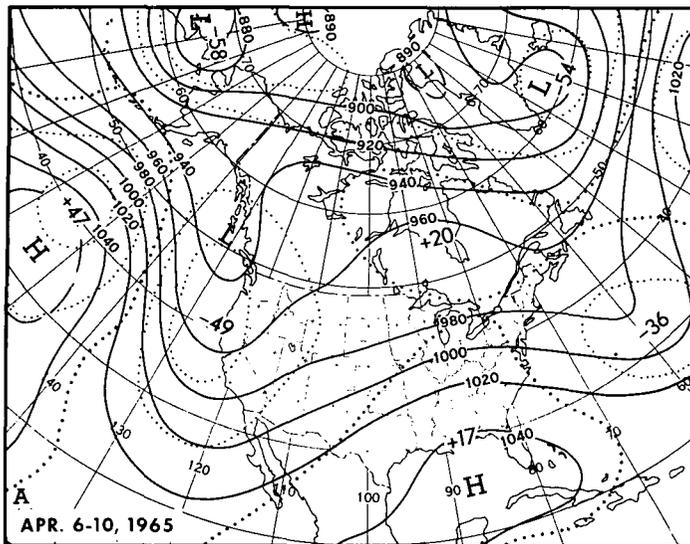


FIGURE 9.—Same as figure 8 for (A) April 6-10 1965. (B) and (C) for April 5-11, 1965.

New York on the 1st, followed by record low temperatures on April 3 in the northeastern quarter of the country. A record April low of 2° F. was observed at Lansing, Mich., and records for the date were reported at Pellston, Mich. (0° F.), Akron, Ohio (16° F.), and Charleston, W. Va. (22° F.).

During this week the Low near California shifted northward but the coastal trough remained deep as a result of a strong buildup of the High north of Hawaii (fig. 9A). Over North America the Hudson Bay High weakened while the Gulf of Mexico High strengthened. The increased southwesterly flow between the Pacific coastal trough and the eastern ridge provided strong warming east of the Rockies as cooler Pacific air moved into the intermountain region (fig. 9B). The long fetch of southwesterly flow also spread heavy precipitation from the Pacific coast to the Appalachians, while only the Gulf Coast, New England, and lee areas of the Divide were relatively dry (fig. 9C). The heavy rains were associated with three storms from the Pacific trough which added to the rapid snowmelt and compounded the flooding in Minnesota and Iowa to a major disaster. Rains occurred daily in parts of California, totaling 3 to 4 in. for a 2-week period, while heavy to record snows accumulated in mountain locations.

Highlights of the week were four tornadoes in Arkansas, Oklahoma, and Missouri and a windstorm of 81 m.p.h. at Springfield, Mo., on April 5, hailstones over hundreds of square miles in South Carolina on April 6, and three tornadoes and hailstorms in Texas and Oklahoma on April 7. On the 8th a storm from the mid-Mississippi Valley produced four tornadoes in Indiana and Kentucky, while another brought rains of over 1 in. to southern California and heavy snow in the mountains. On April 9 rains occurred for the 12th consecutive day in parts of California. On April 10 a deep Low crossed the Plains drawing moist tropical air, with temperatures in the 80's, northward into the Midwest and unleashing heavy rains and thunderstorms in the flooding areas and at least 8 tornadoes in Indiana, Kentucky, Kansas, Missouri, and Arkansas. On April 11 the deep Midwest storm spawned the disastrous outbreak of at least 37 tornadoes in 6 States from Iowa to Ohio.

WEEK OF APRIL 12-18

In this week a strong blocking anticyclone (1110 ft. above normal at 700 mb. from April 13-17, fig. 10A) developed near southwestern Alaska. This helped maintain a deep Low off the Pacific Northwest coast, resulting in almost daily rains on the coast. Dry weather in the southern Gulf States (fig. 10C), associated with a strong upper High, continued for the second week and contributed to above-normal temperatures in the Southeast (fig. 10B). The Northeast was again cooled to below normal, by the deepening of the mean trough over that region and also by virtue of being north of a mean front extending from Nebraska to the mid-Atlantic coast. A depressed track of disturbances along the frontal zone produced moderate to heavy rains from the middle and upper Mississippi Valley eastward.

Highlights of the week included much cooler weather in the Northeast on April 12, with strong winds in the wake of the deep storm from the Midwest. Philadelphia,

Pa., for example, reported gusts to 69 m.p.h. Golfball-sized hail occurred in parts of the Gulf States where record temperatures for so early in the season (92° F.) were reported at Tallahassee and Jacksonville, Fla. April 13 was the first day of the month with no precipitation in the extreme Southwest where temperatures dropped to a record low for April of 0° F. at Flagstaff, Ariz., over a 21-in. snow cover. The Southeast again had record heat with 91° F. at Miami, Fla. On April 14, a new storm brought very heavy rains to the Midlands, together with at least 7 tornadoes in Texas and Oklahoma. Record warmth continued in Florida with a 94° F. maximum at Sarasota, the highest ever recorded in April. On April 15 a deep storm brought heavy rain to the East together with 4 tornadoes in Tennessee and Alabama. On April 16 heavy snow hit Montana, as heavy rain moved out to sea from New England. On April 17 snow fell across northern sections and accumulated 5.9 in. at Albany, N.Y., on the 18th.

WEEK OF APRIL 19-25

A marked retrogression of circulation features occurred this week as the Alaskan block shifted to the Bering Sea and the Pacific Northwest Low shifted to near Kodiak, Alaska (fig. 11A). The High from the Gulf of Mexico retrograded off Baja California, and was replaced by a Low which ended the dry spell along the Gulf Coast. This circulation produced warmer-than-normal weather throughout the country except in the northern and eastern States (fig. 11B). This was the first week that temperatures were above normal in the Far Southwest during the month. Precipitation continued heavy along the middle and upper Pacific coast and in the Midwest (fig. 11C) from disturbances propelled by the strong westerly flow along the mean frontal zone between the cool air in the north and warmer air farther south.

Highlights of the week included a deep storm with heavy rains of over 2 in. in the Pacific Northwest on April 19. Heavy rains also fell in the South, together with 3 tornadoes in Texas and Louisiana and a record 89° F. temperature at Lake Charles, La. On April 20 temperatures rose to record levels in the clear Southwest, where 90° F. was recorded at Winslow, Ariz., the highest temperature recorded so early in spring. On April 21 a record high temperature for April (94° F.) occurred at Tulsa, Okla. On April 22 hot weather from the Southwest brought 90° F. temperatures as far north as Kansas City, Mo., and record temperatures for April (98° F.) to El Paso and Amarillo, Tex. On April 23 a strong front south of a Hudson Bay High stretched from Colorado to the mid-Atlantic Coast, with record temperatures south of the front at Kansas City and Columbia, Mo. (90° F.), and Memphis and Knoxville, Tenn. (89° F.), while 3 tornadoes were reported in Indiana and Illinois. On April 24 a disturbance on the strong front brought heavy thunderstorms (6.5 in. of rain at Muscatine, Iowa, in the flood area), high winds (gusts to 81 m.p.h. at Des Moines, Iowa),

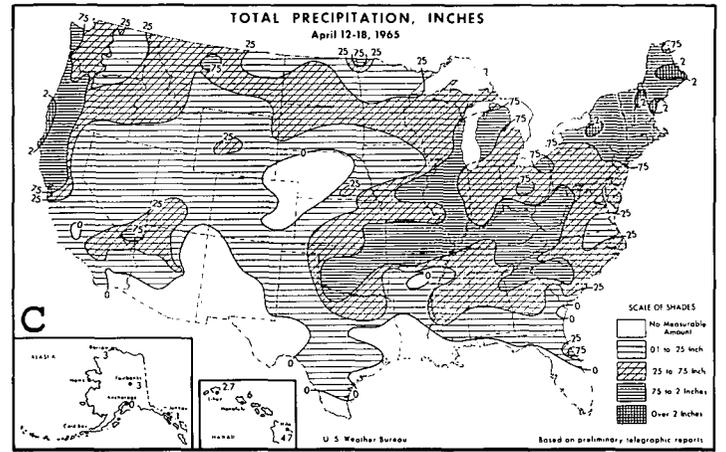
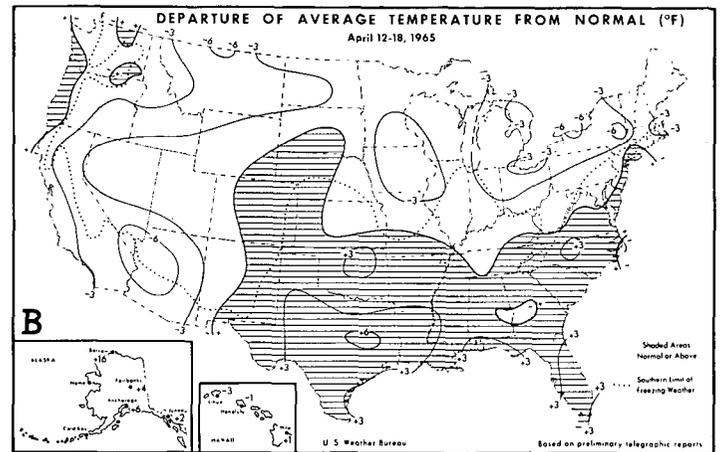
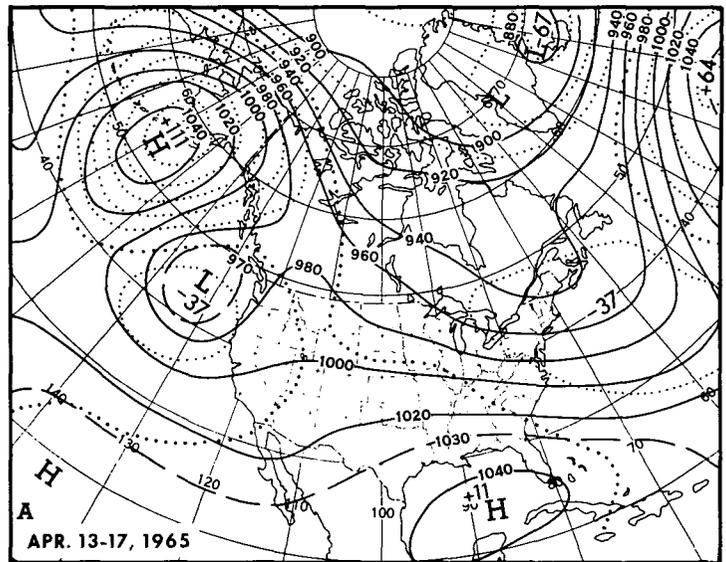


FIGURE 10.—Same as figure 8 for (A) April 13-17, 1965. (B) and (C) for April 12-18, 1965.

and tornadoes in Iowa and Texas, while the heat wave continued in the South; Memphis, Tenn., had its 3d consecutive day of record temperature (88° F.). On April 25, the Midwest disturbance deepened and moved to the Great Lakes region spreading heavy rains over the eastern half of the country including the flooded area, and ac-

western Atlantic during the previous week, was reduced by development of a new trough near the Pacific Coast. This was accompanied by amplification of a strong ridge over the western United States and a deepening trough off the east coast. The northerly flow east of the Rockies brought drier conditions to the Midwest (fig. 12C) associated with a strong continental polar High moving southward in the Plains after heavy precipitation during much of the month. Warm air from the western ridge spread eastward across the northern half of the country (fig. 12B) but temperatures averaged below normal in the South.

Highlights of the period included cool weather over most of the country on April 26 from a strong High in Montana, but with widespread rains in the eastern two-thirds of the country including heavy thundershowers in the Southeast and at least 1 tornado in Alabama. Cool weather continued on April 27 from a large High over the interior, although an upper disturbance produced snow in the central Rockies and rain in Iowa. Heavy rains also occurred in parts of the East associated with a frontal disturbance in North Carolina which produced at least one tornado and a hailstorm in that State. On April 28 a strong High centered over the southern Plains brought record low temperatures from the Gulf Coast to the Upper Mississippi Valley under clear skies. In the Far West,

Bakersfield warmed to a record maximum for April of 98° F. On April 29 clear skies and high pressure produced more record minimum temperatures in the South including 38° F. at Birmingham, Ala., and 34° F. at Fort Smith, Ark. On April 30, most of the country was fair under a ridge aloft. Record high temperatures for April occurred at Dubuque, Iowa (93° F.), and Norfolk, Nebr. (98° F.), while the lowest temperatures for so late in the season were recorded at Jackson, Miss. (30° F.), New Orleans, La. (49° F.), and Tampa, Fla. (48° F.).

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