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THE WEATHER AND CIRCULATION OF MARCH 1969

A Very Cold Month With a Developing Flood Threat in the Upper Midwest

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1. HIGHLIGHTS

The presence of unusually heavy and extensive snow cover during March was probably the most important weather phenomenon of the month (fig. 1). River forecasters and government and industrial interests along the Missouri-Mississippi River system became concerned about spring flooding as this snowpack melted. A special forecast program was started early in March by the Weather Bureau to aid in determining when the major flooding would occur.

Sioux Falls, S. Dak., reported a record seasonal snowfall of 94.7 in.; and at the beginning of March, 33 in. of snow remained on the ground. Only 11 in. of snowpack remained at the end of the month, but the water equivalent reported on March 28 was 5.8 in. On the same date, Huron, S. Dak., measured 4.6 in. of water equivalent with a total snow depth of 9 in. This water equivalent at Huron was approximately equal to the total precipitation since the first of December, indicating that little or no runoff had actually occurred. International Falls and Duluth, Minn., reported 5 to 6 in. of water equivalent on the 28th; and while these stations are not in the Mississippi River drainage, the snowpack reported was likely indicative of the snowpack and flood potential on the headwaters of the Mississippi, which lies just west of Duluth and southwest of International Falls. Heavy snowpack was also present in the watersheds of the Red River of the North and the Missouri River, adding to the total flood potential of the region. The heavy snowpack west of the Rockies in March presented flood threats on some western rivers as did the very heavy snowpack in the Northeast for New England rivers.

Extensive coldness, some of which was directly connected with the snow cover, was also prominent in March. In widespread areas the abnormally low temperatures represented a continuation of persistent coldness. Charleston, S.C., and Fort Myers, Fla., have reported below-normal temperatures for five consecutive months. Wilmington, N.C., has had 7 mo in a row with below-average temperatures, while Mount Shasta, Calif., experienced its eighth month without a break from unseasonably cold weather. Concordia, Kans., and Sheridan, Wyo., have had 11 and 12 mo, respectively, with below-normal temperatures.

2. MEAN CIRCULATION

The 700-mb circulation of the Northern Hemisphere during March (fig. 2) had trough and ridge patterns that closely resembled the normal (O'Connor, 1961). There were three major low centers—one over the Kamchatka Peninsula, another near Novaya Zemlya in the Arctic Basin, and a third near Baffin Island. Each of these Lows was in almost the exact location of its normal March counterpart. A broad trough extended southward from each of these Lows, also in a pattern quite similar to the normal. Yet, figure 3 reveals large differences from the normal circulation.

One of the most significant variations from the average March circulation was the very strong subtropical westerlies across the Atlantic (fig. 4). At the same time, the middle-latitude westerlies in this area were much lighter than normal, as evidenced by the easterly anomalous flow that extended from northeastern United States across the British Isles and into Europe (fig. 3). Weaker than normal midlatitude westerlies with strong subtropical westerlies have been features of the western part of the Northern Hemisphere circulatlon most of the winter (fig. 6). The subtropical westerlies have been above normal since November, if averaged for monthly periods, reaching the greatest average speed and the largest departure from normal from mid-February to mid-March, when the middle-latitude westerlies were weakest.

The patterns of 700-mb height anomaly of the Pacific and Atlantic Oceans were opposite. The Atlantic region had large positive departures across the north from North America to Scandinavia and large negative departures to the south, reaching from western United States across the Atlantic to the eastern Mediterranean. Positive height anomaly in the Pacific extended from the Philip-

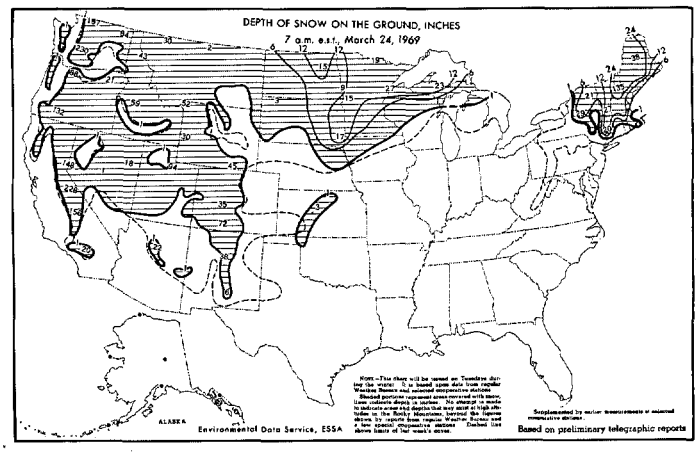

FIGURE 1.—Depth of snow on the ground in inches at 7 a.m. EST, Mar. 24, 1969 (from Environmental Data Service, 1969).

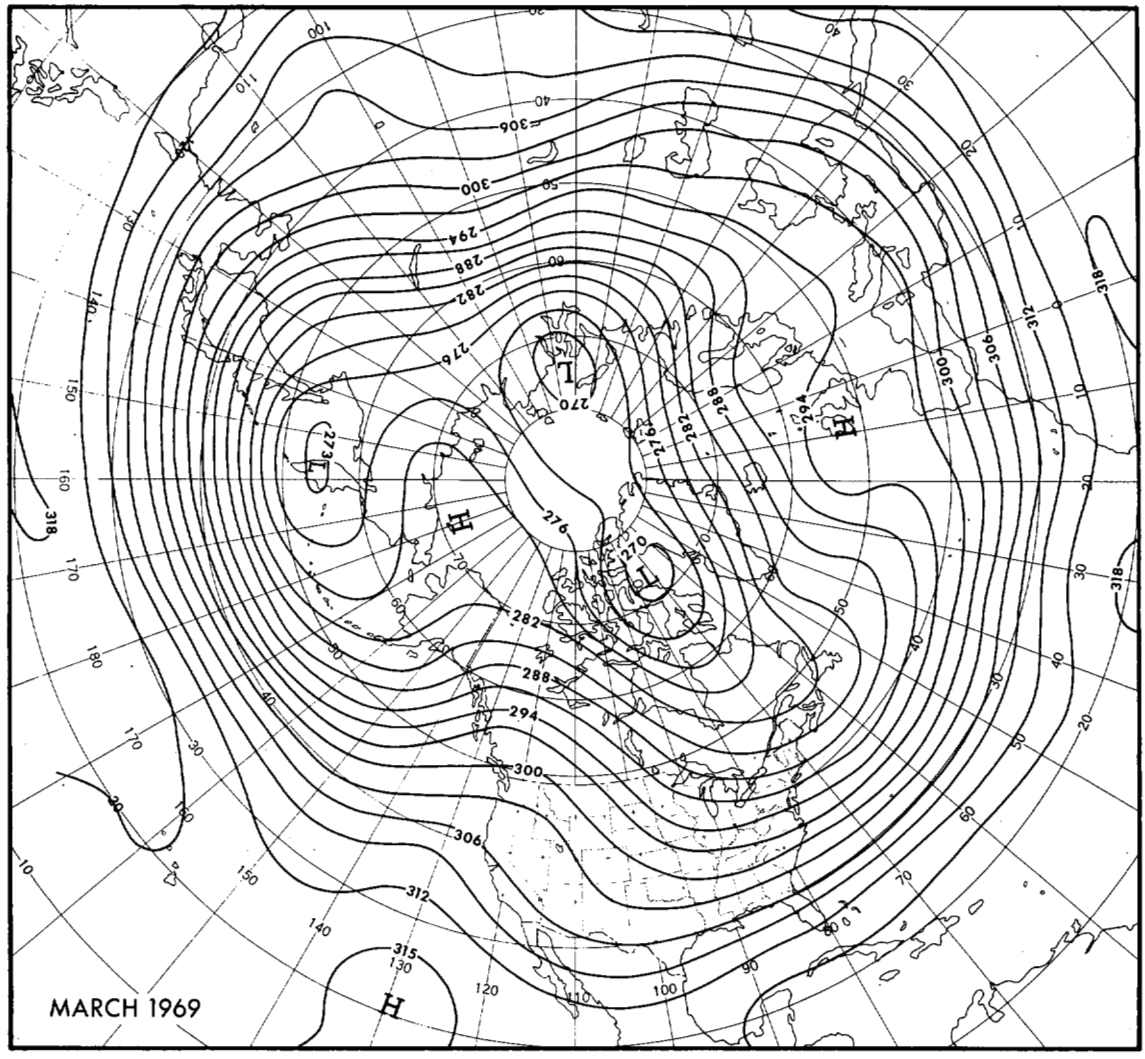

FIGURE 2.—Mean 700-mb contours (in decameters) for March 1969.

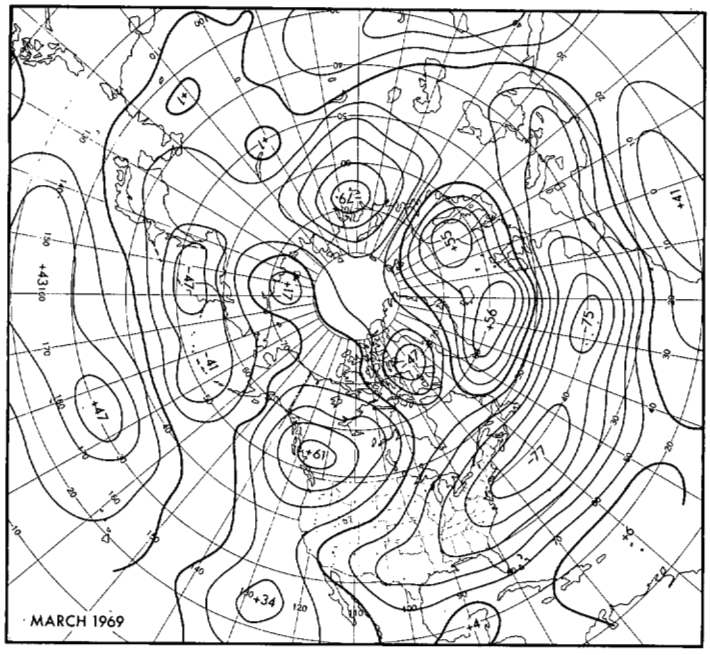

FIGURE 3.—Departure from the normal of the mean 700-mb height (in meters) for March 1969.

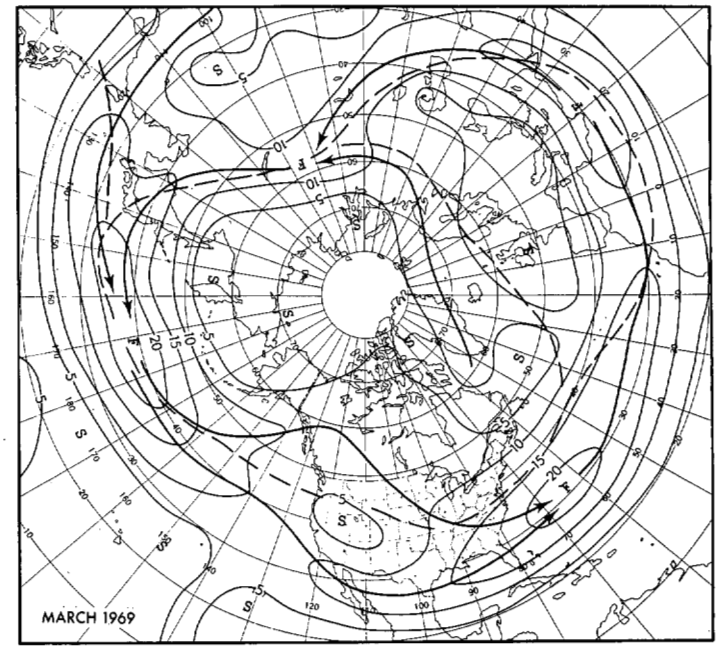

FIGURE 4.—Mean 700-mb isotachs (meters per second) for March 1969. Solid arrows indicate the observed axes of maximum wind speeds and dashed lines the normal axes.

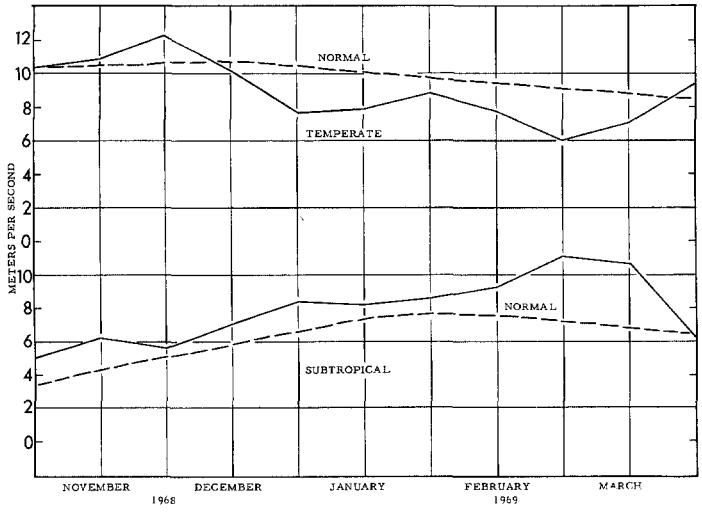

FIGURE 5.—Variations of the monthly average westerly wind speed for the western half of the Northern Hemisphere, 20°–35° N. and 35°–55° N. plotted every 15 days from Nov. 1, 1968, through March 1969.

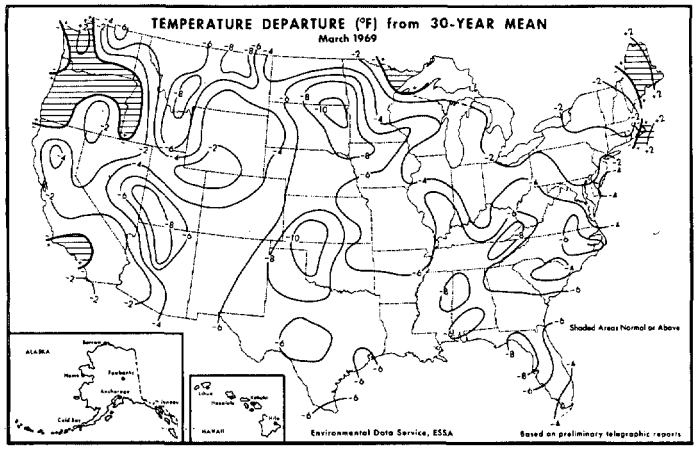

FIGURE 6.—Average sea-level pressure (in millibars) for March 1969.

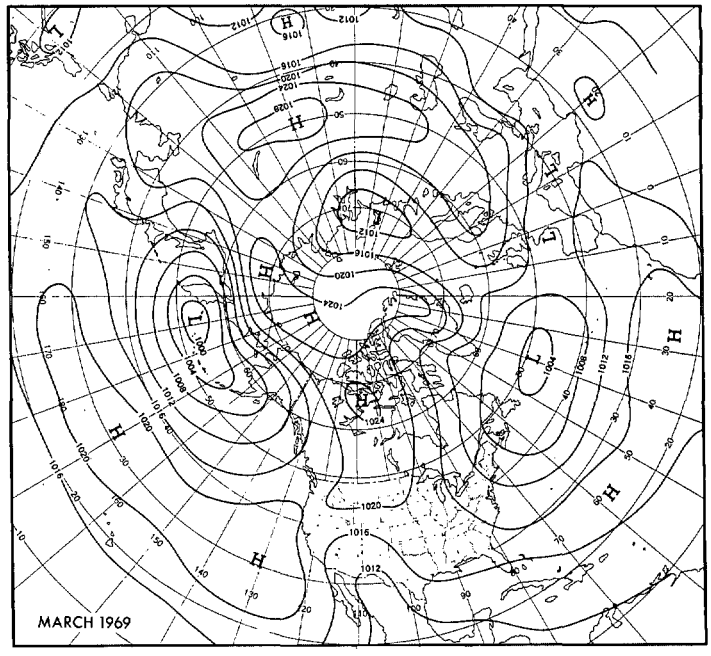

FIGURE 7.—Departure from normal of average surface temperature (°F) for March 1969 (from Environmental Data Service, 1969).

TABLE 1.—*Extremely low average temperatures recorded during March 1969*

Station	Temperature (°F)	Departure from normal	Remarks
Flagstaff, Ariz.	27.3	−8.3	Lowest in 70 yr
Pensacola, Fla.	53.7	−7.3	2d coldest March
Tallahassee, Fla.	53.4	−7.2	Coldest March
West Palm Beach, Fla.	64.7	−5.2	do.
Valentine, Nebr.	23.5	−7.8	2d coldest March
Concord, N.H.	28.3	−3.4	First time since 1884, coldest month of winter occurred in March.
Dodge City, Kans.	31.3	−10.5	2d coldest March
Roswell, N. Mex.	43.1	−6.4	do.
Corpus Christi, Tex.	57.8	−7.4	do.
El Paso, Tex.	49.4	−5.1	do.
Port Arthur, Tex.	54.7	−6.4	do.

pines to Baja California, except for an area of weak negative anomaly east of Hawaii. Negative height departures prevailed over all of the northern part of the Pacific except the Gulf of Alaska. The Pacific pattern resulted in a very strong wind "jet" that was close to the normal position (fig. 4). The associated mean sea level Low was considerably deeper than normal (fig. 5). In the Atlantic, frequent storminess well south of normal was reflected in a mean sea level Low approximately 10° south of normal.

The major bands of wind across Asia were near their usual locations for this month, with departures in speed being the main effect of the height anomaly pattern shown in figure 3 for that region. In southeast Asia, the 700-mb height pattern was almost identical to the normal.

3. MONTHLY TEMPERATURES

Most of the United States had below-normal temperatures during March (fig. 7), with record or near-record temperatures in many places (table 1). An extensive area of large negative departures was observed across the South from the east coast to Arizona. These lower temperatures were connected with below-normal 700-mb heights and northerly anomalous flow (fig. 3). Other areas of extremely low average temperatures included most of Nebraska and the Dakotas and parts of Montana, Idaho, Utah, and Nevada. Over the majority of the areas just mentioned, 700-mb heights were above normal; however, an extensive snow cover was present in these areas. This snow cover far exceeds the expected at this time of the year (Dickson and Posey, 1967), and the depth of snow in many sections that are ordinarily snow covered in March was considerably more than normal. The horizontal extent of snow, and to a lesser degree its depth, has an important effect upon the albedo (Posey and Clapp, 1964), which in turn affects the temperature.

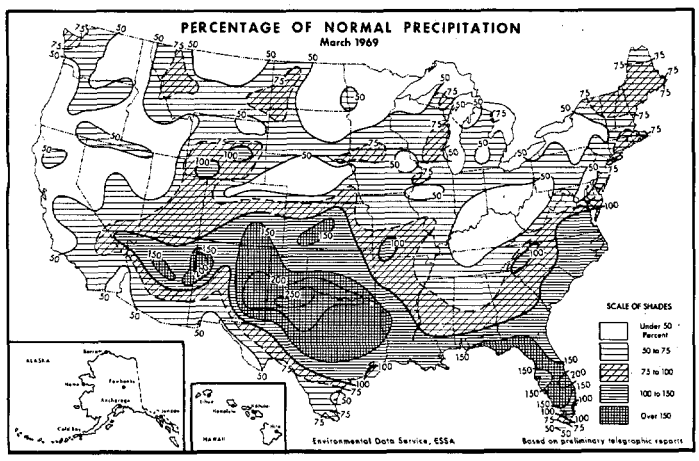

FIGURE 8.—Percentage of normal precipitation for March 1969 (from Environmental Data Service, 1969).

TABLE 2.—*Maximum and minimum temperature records established in March 1969*

Station	Temperature (°F)	Date	Type of record
Bakersfield, Calif.	92	29	Highest March maximum
Fresno, Calif.	87	29	Highest for date
Denver, Colo.	−2	8	Lowest for date
West Palm Beach, Fla.	44	12	do.
do.	51	28	do.
Cairo, Ill.	22	11	do.
Moline, Ill.	10	31	Lowest so late in season
Rockford, Ill.	12	29	Lowest for date
Springfield, Ill.	4	10	do.
Evansville, Ind.	19	15	do.
Sioux City, Iowa	5	29	Lowest so late in season
Minneapolis, Minn.	−5	29	do.
Rochester, Minn.	−7	29	do.
St. Cloud, Minn.	−8	29	do.
Kansas City, Mo.	18	29	Lowest for date
Omaha, Nebr.	10	29	do.
Bismarck, N. Dak.	−9	30	Lowest so late in season
Fargo, N. Dak.	−15	29	do.
Youngstown, Ohio	69	20	Highest for date
Eugene, Oreg.	75	27	Highest for March
Aberdeen, S. Dak.	−14	30	Lowest for date
Corpus Christi, Tex.	34	26	Lowest so late in season
Milford, Utah	76	30	Highest for date
Salt Lake City, Utah	73	30	do.
Lynchburg, Va.	18	28	Lowest so late in season
Olympia, Wash.	76	26	Highest for March
Madison, Wis.	2	30	Lowest so late in season
Milwaukee, Wis.	7	30	do.
Casper, Wyo.	6	8	Lowest for date

Along the Northwest coast the strength of the positive 700-mb height anomaly and easterly anomalous flow were related to above-normal temperatures. Elsewhere in the Far West, near-normal 700-mb heights were associated with temperatures of 1° to 2° below normal, except for an unusual 4° below normal at San Diego. Indications are that the West Coast would have had higher temperatures except for the effects of the below-normal sea-surface temperatures reported along the coast in March.

In northeastern United States and westward to the Great Lakes Region, temperatures generally ranged from about 2° below to 2° above normal. This section had 700-mb heights that were considerably below normal

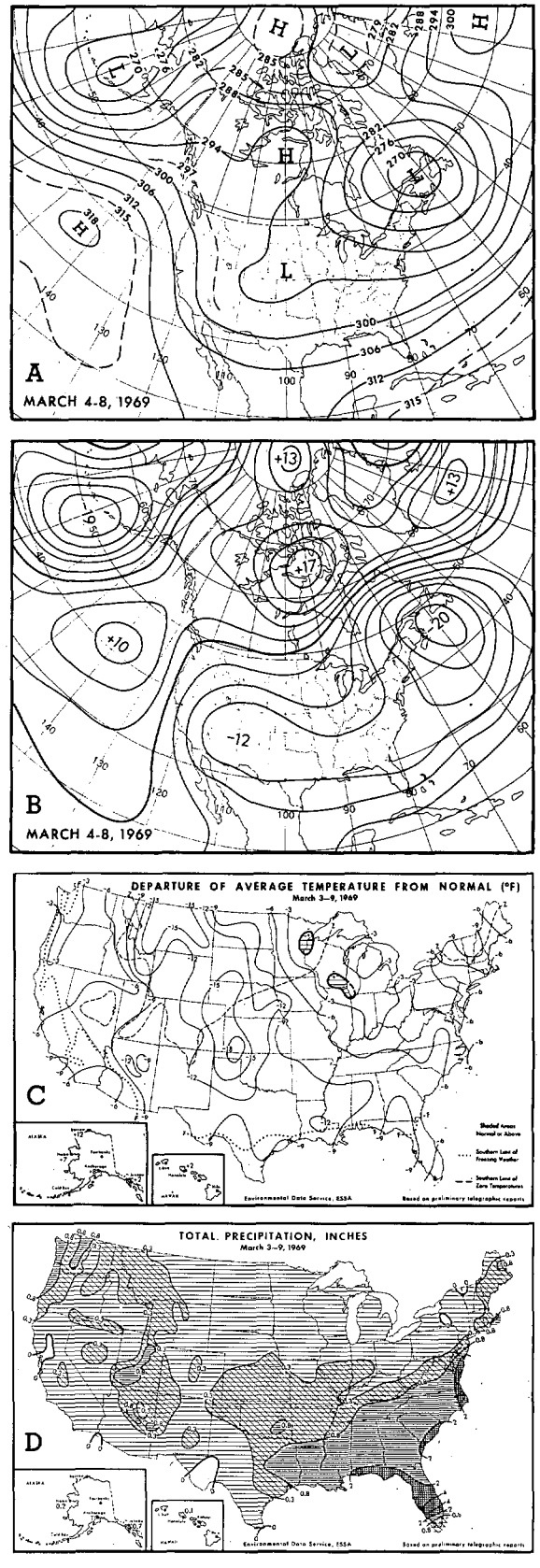

FIGURE 9.—(A) mean 700-mb contours and (B) departure from normal (both in decameters) for Mar. 4–8, 1969; (C) departure of average surface temperature from normal (°F) and (D) total precipitation (inches) for week of Mar. 3–9, 1969 (from Environmental Data Service, 1969).

(fig. 2), and New England had record-breaking snow depths; but the strong easterly anomalous flow at 700 mb

and sea-level flow from the Atlantic (figs. 3 and 6) resulted in frequent incursions of mild maritime air.

4. MONTHLY PRECIPITATION

The strong southern branch of the mean wind flow across the United States (fig. 4) was associated with migratory storms that remained quite far south in general, and the resulting precipitation pattern was generally wet across the South and dry to the north (fig. 8). The mean anomalous flow from the north and northeast (fig. 3) also contributed to the dryness in the North, since it assured less northerly penetration than normal of moisture-laden air from the Gulf of Mexico. Relatively few stations reported either extreme wetness or dryness, but some of the more northern areas did indicate some unusual dryness. Medford, Oreg., with only 0.29-in. precipitation had the second driest March of record. Reports from Cheyenne, Wyo., indicated that only once in a decade on the average did March precipitation remain as low as the reported 0.27 in. Sheridan, Wyo., and Williamsport, Pa., both indicated the continuation of a precipitation deficit which started in January. At Williamsport, 3.45 in. for the January through March period was the least for this season since 1900.

Most of southern California was relatively dry this month under the influence of a strong offshore upper level ridge. This contrasted to the heavy precipitation in other southern sections this month and to southern California's own extreme wetness and flooding in January and February (Stark, 1969; Wagner, 1969).

5. VARITIONS OF THE WEATHER AND CIRCULATION WITHIN THE MONTH

The westerlies over North America early in March were divided into two out-of-phase branches with an anomalously deep trough over the United States and a strong ridge to the north over central and western Canada (figs. 9A and B). This caused most of the United States to become quite cold (fig. 9C), following a relatively warm period over the North from the Rockies eastward and in the southern Plains for the week from February 24 to March 2 (Stark, 1969). Several daily minimum temperature records were set this week along the eastern slopes of the Rockies. These records are listed in table 2.

Three migratory storms contributed to the precipitation shown in figure 9D. Each of these storms moved southeastward from the Great Basin through the long-wave trough to the Southeast before moving northeastward over the Atlantic. Nearly all of the Country received precipitation from one or more of these storms, but amounts were light in the North. However, since temperatures were below freezing in most northern areas, the precipitation that fell in the heavy snowpack areas was in the form of snow and added slightly to the expected flood problem later on.

The major trough-ridge and height anomaly patterns changed very little over North America during the week

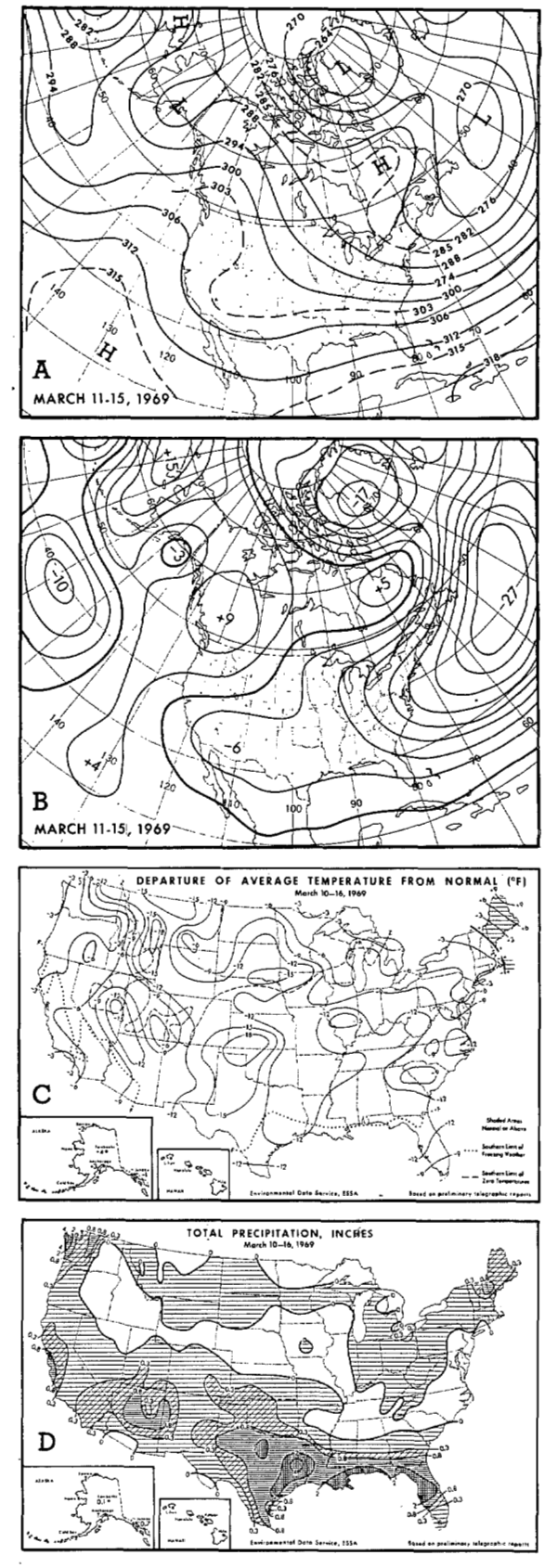

FIGURE 10.—Same as figure 9, (A) and (B) Mar. 11–15, 1968; (C) and (D) for week of Mar. 10–16, 1969 (from Environmental Data Service, 1969).

of March 10–16 (figs. 10A and B). Temperatures remained relatively low in all sections except Maine, where up to 9° above normal was observed (fig. 10C). Maritime air, borne on a northeasterly surface wind, caused the

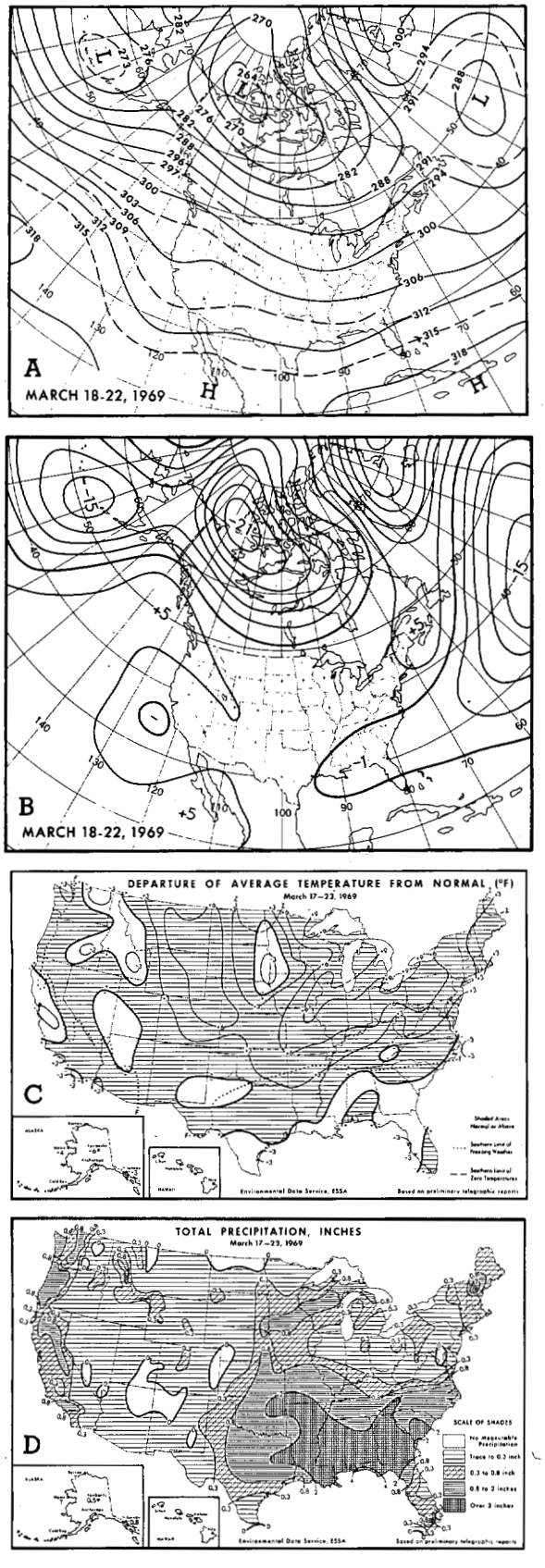

FIGURE 11.—Same as figure 9, (A) and (B) Mar. 18–22, 1969; (C) and (D) for week of Mar. 17–23, 1969 (from Environmental Data Service, 1969).

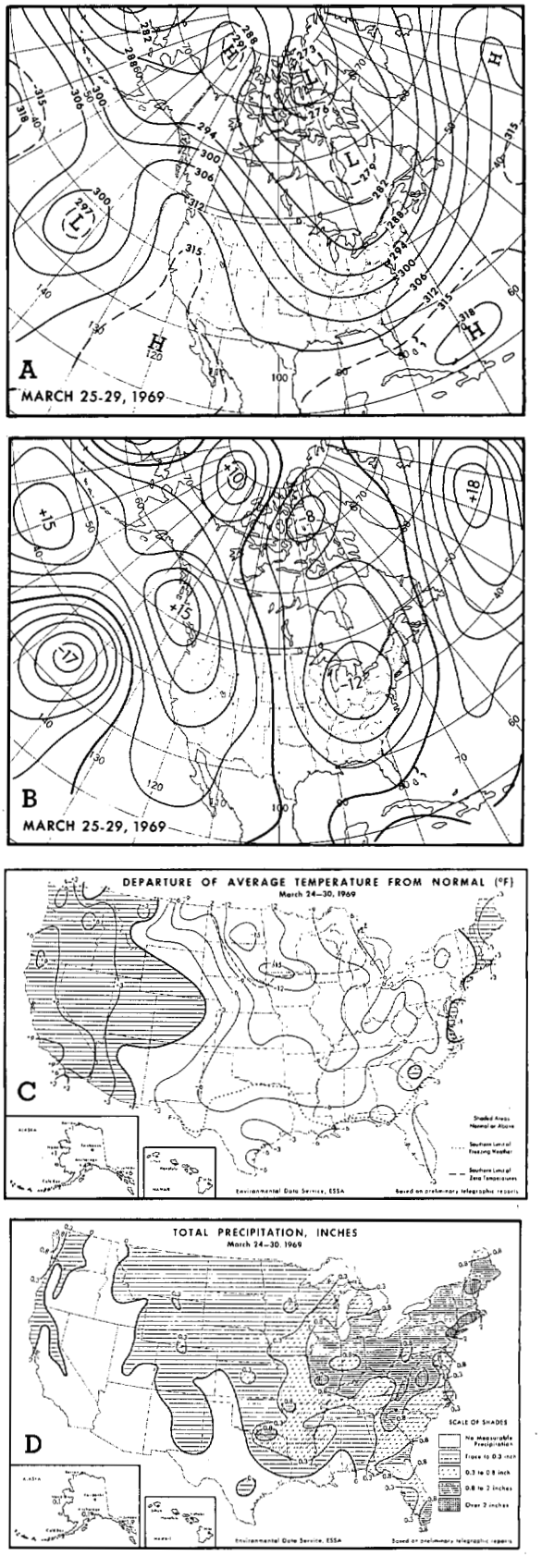

FIGURE 2.—Same as figure 9, (A) and (B) Mar. 25–29, 1969; (C) and (D) for week of Mar. 24–30, 1969 (from Environmental data Service, 1969).

above-normal temperatures in Maine, even though 700-mb heights were considerably below normal.

Again this week, the heavier precipitation was across the South (fig. 10D). The major difference was that a large area from the Middle Atlantic States to Idaho received no precipitation this week, because the Lows moved on a more southern track and were less intense than the storms of the previous week. The result was a

narrow band of heavy precipitation along the Gulf Coast and in the Southwest.

During the third week of March, temperatures rose rapidly across the Nation, as the circulation over North America rapidly deamplified, and 700-mb heights rose over the United States and fell over Canada (figs. 11A, B, C). Progression of the southwest trough in response to the increasing westerlies brought increased storminess and a large area of heavy precipitation to the Southeast (fig. 11D). One Low that moved along the more favored March storm track farther north brought significant precipitation to Iowa, southern Minnesota, and parts of Wisconsin and Michigan. The passage of migratory storms and trailing fronts brought precipitation to scattered areas of the Far West and some of the Rocky Mountain States.

The circulation around North America amplified as rapidly the final week of March as it had deamplified the previous week (fig. 12A). However, the pattern was different from the early March circulation with a full latitude ridge in the West and a deep north-south-oriented trough in the East. The large positive height anomalies and easterly anomalous flow (fig. 12B) in the ridge resulted in unseasonably warm temperatures in the West. Strong northerly flow between this ridge and the eastern trough deployed cold Polar and Arctic air over most of the eastern two-thirds of the Country (fig. 12C). Many daily minimum temperature records were broken the last few days of the month east of the Rockies (table 2). At the same time, some daily record maximum temperatures were observed to the west of the Rockies under the strong upper level ridge. Subsiding air associated with the western ridge resulted in little or no precipitation in much of the western half of the Nation this week, with most of the significant precipitation being confined to the immediate vicinity of the deep eastern trough (fig. 12D).

6. ALASKAN AND HAWAIIAN WEATHER

Under the effects of southerly anomalous as well as real flow and near-normal 700-mb heights (figs. 2 and 3), most of Alaska was less cold than normal during March. Some of the departures in temperature were quite large, being an average of 7° to 8°F in sections of southwest Alaska (not including the Aleutian Chain). A few localities, such as Yakutat and Shemya, had slightly below-normal temperatures. At Yakutat, 2°F below normal was associated with extremely heavy precipitation. The 14.40 in. of measured precipitation there was 5.7 in. above normal. However, most of Alaska received either near- or below-normal precipitation during the month.

Monthly average temperatures received from Hawaii ranged from 69.9°F at Lihue Airport to 73.6°F at Honolulu. Precipitation varied more than the temperature over the islands. Hilo reported 30.64 in., which was 15.94 in. above normal, while Lihue reported 1.75 in., which was 2.81 in. below normal. The majority of the Hawaiian precipitation reports received were above normal.

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