THE WEATHER AND CIRCULATION OF NOVEMBER 1951[1]

WILLIAM H. KLEIN

Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.

The month of November 1951 was notable for its early cold weather in most of the United States. Chart I-B shows that average temperatures for the month were below the long-period normal in all parts of the country except for the far West and portions of New England and the Rocky Mountain States. The greatest departures from normal (over 8° F.) occurred in Wisconsin and Minnesota, while the lowest temperatures in an absolute sense were found in northern Minnesota and North Dakota, where the temperature averaged 17° F. (Chart I-A). This was the coldest November on record at Green Bay, Wis., South Bend, Ind., and Dubuque, Iowa. November's temperature regime contrasts with the pattern observed during the preceding month, when the temperature averaged well above normal throughout most of the eastern and southern halves of the Nation [1]. Only in sections of the Southwest, Northern Plains, and Pacific Coast did October's temperature anomaly persist through November. In nearly all other regions large changes occurred. Such pronounced differences between the temperature anomalies of adjacent months have been more frequent from October to November than between any other pair of months during the past decade [2].

[1] See Charts I–XV following p. 214 for analyzed climatological data for the month.

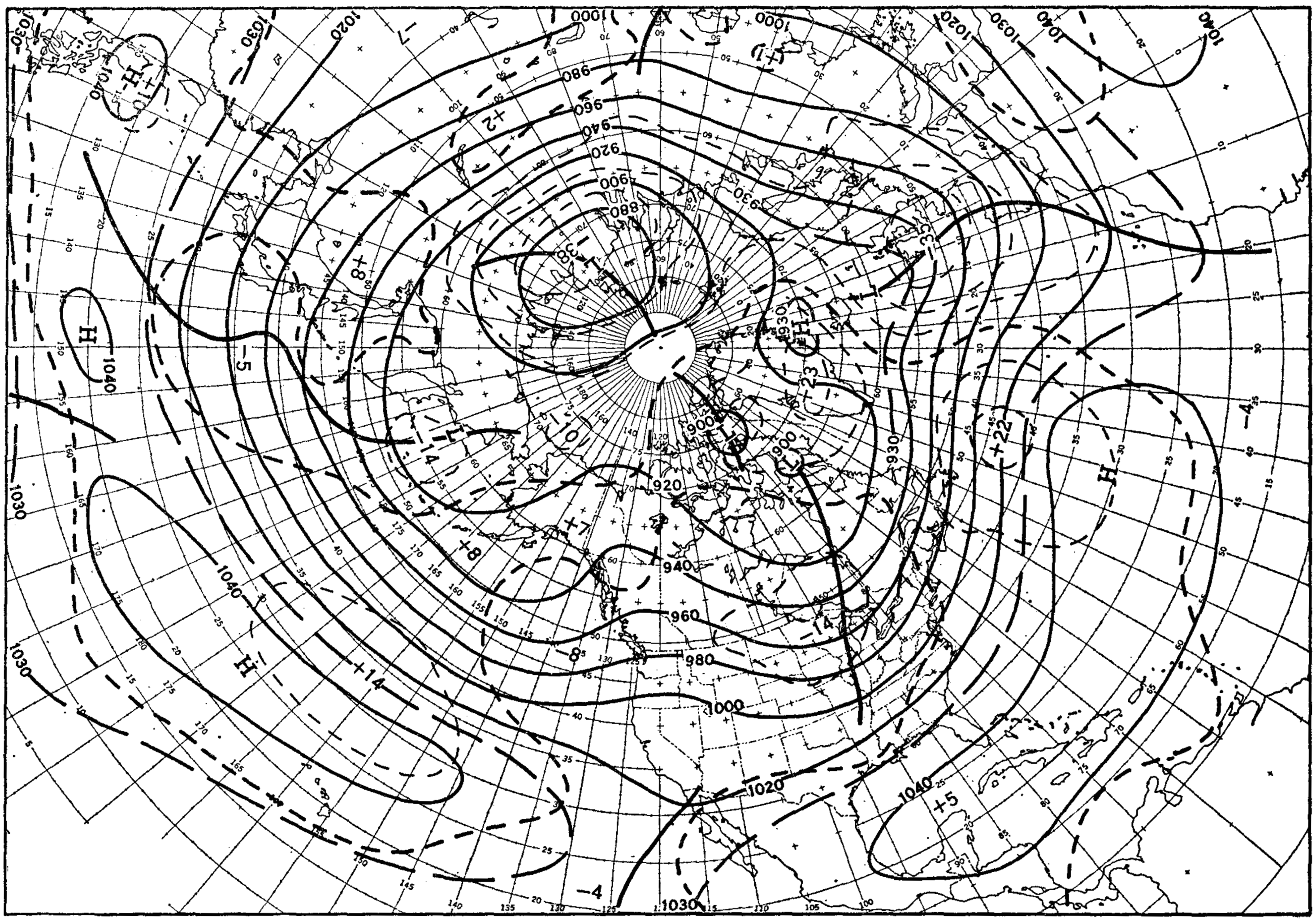


FIGURE 1.—Mean 700-mb. chart for the 30-day period October 31–November 29, 1951. Contours at 200-foot intervals are shown by solid lines, intermediate contours by lines with long dashes, and 700-mb. height departure from normal at 100-foot intervals by lines with short dashes with the zero isopleth heavier. Anomaly centers and contours are labeled in tens of feet. Minimum latitude trough locations are shown by heavy solid lines.

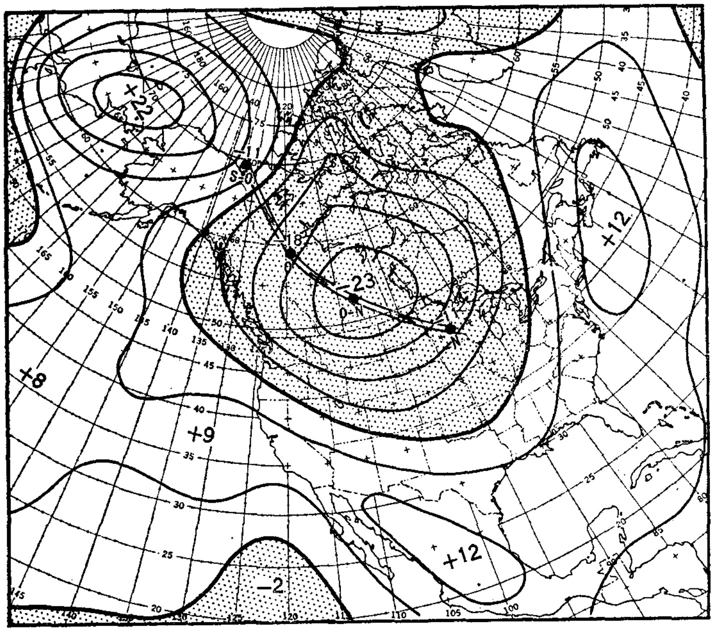


Figure 2.—Mean thickness anomaly for the layer between 1,000 and 700 mb. for the 30-day period October 15–November 14, 1951. Isopleths are drawn at 50-foot intervals with the zero isopleth heavier, and centers are labeled in tens of feet. Negative values are shaded. Arrows indicate track of principal negative anomaly center as determined from four consecutive 30-day mean charts. The intensity in tens of feet is plotted above each position of the center, and the 30-day period encompassed is plotted below (e. g., O stands for October, O-N for mid-October to mid-November, etc.).

November's cold weather was closely related to the presence of a monthly mean trough at all levels of the troposphere extending from the Mississippi Valley through James Bay to Baffin Island (Charts XII to XV). This trough was located west of its normal position along the Atlantic coast and was considerably deeper than normal over practically the entire United States, with greatest departures in Minnesota (fig. 1), where the weather was coldest. On the other hand, 700-mb. heights averaged above normal in Alaska and western Canada, where a ridge was located. Between this ridge and the trough in the Mississippi Valley currents of deep cold air flowed southeastward in repeated surges throughout the month. Each of these surges was accompanied by the movement of a polar anticyclone from its source region in northwestern Canada southeastward into the United States (Chart IX). The most severe and widespread cold wave of this type occurred during the first week of November, when new records for early season low temperatures were set in over a dozen states from the Great Basin to the Atlantic coast.[2]

It is probable that November's cold would not have been so extreme if temperatures in Canada had been near normal. Objective estimates of the temperatures in the United States based on the observed 700-mb. circulation pattern alone would call for near-normal temperatures in most of the country. The reason for this discrepancy is believed to be the recent temperature distribution in western and central Canada. In this region, the source for most of the polar continental air affecting the United States, temperatures were far below normal throughout the months of October and November. This condition was most pronounced during the 30-day period from mid-October to mid-November as illustrated in figure 2. As a result the Canadian air which invaded the United States at frequent intervals during the month was abnormally cold at its source, and temperatures in the United States were lower than would normally be expected from the observed circulation alone. It is pertinent that the center where the coldest air relative to normal was found appeared to move steadily southeastward on the monthly mean charts, from the Arctic coast of Canada in September–October to Minneapolis, Minn., in November, along the track indicated in figure 2. A study of the factors responsible for this remarkable migration and its relation to Canadian surface temperature, snow, and ice is planned.

The only State unaffected by the recurrent cold air outbreaks was California, where temperatures remained above normal during all but the last week of the month. This area, as well as portions of adjoining States, was dominated by mild Pacific air transported by stronger-than-normal southwesterly flow at both 700 mb. (fig. 1) and sea level (Chart XI). Temperatures also averaged above normal in eastern New England, as mean wind components from the south were much stronger than normal at both sea level and 700 mb. Near-record high temperatures occurred in this area on November 14. The only other part of the country with monthly mean temperatures above normal was the northern Rocky Mountain States, where some temperature departures were slightly positive under the influence of rather strong anticyclonic westerly flow at 700 mb.

The anticyclone and cyclone tracks presented in Charts IX and X present a rather chaotic appearance at first glance. The principal tracks have therefore been illustrated schematically in figure 3, where they are superimposed on the field of relative vorticity computed from the monthly mean 700-mb. contours (fig. 1). The schematic tracks were prepared on the basis of the daily Northern Hemisphere maps analyzed regularly in the Extended Forecast Section of the U. S. Weather Bureau, as well as Charts IX and X. As expected, the tracks largely follow the steering current of the mean 700-mb. flow. However there is also a marked tendency for many of these tracks to lie along the major axes of cyclonic and anticyclonic vorticity, as previously noted [3]. This relationship is indicative of the fact that the field of relative vorticity at 700-mb. is generally a good index of the monthly mean sea level pressure pattern. For example, centers of anticyclonic vorticity at 700 mb. in figure 3 are nearly superimposed on centers of high pressure at sea level (Chart XI) in the Great Basin, southwest Pacific, central Atlantic, northwest Canada, and northern Greenland. Likewise, centers of cyclonic vorticity and low pressure almost coincide in the vicinity of the Bering Sea, Gulf of Alaska, Davis

[2] Further details about the early November cold wave can be found in the following article by Carr and in the December 1951 issue of *Weatherwise* (pp. 131 and 141).

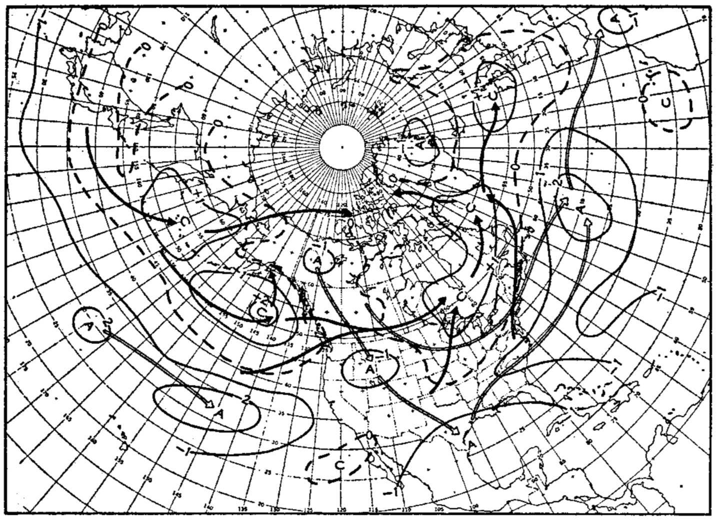


FIGURE 3.—Vertical component of mean relative geostrophic vorticity at 700 mb. for the 30-day period October 31–November 29, 1951, in units of 10^{-5} sec^{-1} with the zero lines dashed. Centers of anticyclonic vorticity are labeled "A" and centers of cyclonic vorticity are labeled "C". Idealized cyclone and anticyclone tracks are indicated by solid and open arrowhead curves respectively.

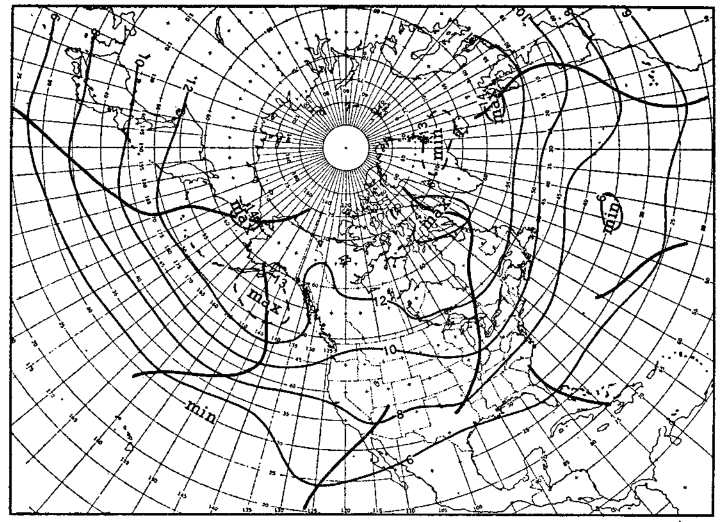


FIGURE 4.—Vertical component of mean absolute geostrophic vorticity at 700 mb. for the 30-day period October 31–November 29, 1951. Isopleths at intervals of 2×10^{-5} per second are shown by solid lines with intermediate isopleths dashed. Axes of maximum vorticity are given by heavy solid lines. Centers of maximum and minimum absolute vorticity are labeled MAX and MIN respectively.

Strait, and northwest British Isles. In these anticyclonic centers migratory high pressure areas on the daily map tended to cluster, intensify, and move in loops, while daily Lows behaved similarly in the cyclonic centers. Cyclonic activity was minimized in the anticyclonic centers, and anticyclonic activity was weak in the cyclonic centers. Thus, in a sense, these centers may be considered as centers of action observed during the month.

The cyclone and anticyclone tracks can be clarified further by reference to the monthly mean chart of absolute vorticity, figure 4. This map was prepared by simply adding the Coriolis parameter to values of the relative vorticity computed for figure 3. It is noteworthy that most of the daily cyclones moved toward regions of higher absolute vorticity, while the anticyclones generally moved toward lower vorticity, in agreement with the theory of vorticity transfer [4]. This principle is helpful in explaining some tracks which crossed the mean 700-mb. contours at rather large angles, such as the anticyclone track along the Rocky Mountains and the cyclone track in the central United States. It can also be applied to tracks which do not lie in the principal channels of relative vorticity, for example, the storm path along the east coast of North America and the anticyclone track through the lower Lakes. The last two tracks intersect in southern New England in a region of zero relative vorticity. This was a region of great interdiurnal pressure variability, where Highs and Lows followed each other in rapid succession, with neither predominating on the monthly mean. A similar condition prevailed along the northern border of the western United States. The anticyclones which traversed the Great Lakes, however, were primarily of the shallow cold type so that cyclonic vorticity prevailed in the mean at the 700-mb. level. It is also interesting to note that the gradients of both 700-mb. height and absolute vorticity were extremely strong to the south of the Gulf of Alaska and near Newfoundland. Within these regions migratory cyclones and anticyclones were numerous and active during the month. These disturbances were effective in transferring the vorticity required for maintenance of the zonal circulation according to Kuo's theory [4].

Since absolute vorticity generally increases in magnitude with increasing latitude, the isopleths in figure 4 are primarily sinusoidal in character. These isopleths tend to parallel the contours of 700-mb. height, which usually decrease with increasing latitude. Therefore axes drawn through points of maximum vorticity along latitude circles generally coincide with trough lines drawn through points of minimum height along latitude circles. Thus the principal troughs in figure 1, in the eastern Atlantic, western Pacific, southeast Pacific, and North America all appear in virtually the same location as axes of maximum vorticity in figure 4. However, the latter chart contains an additional axis of importance, extending from a vorticity maximum in the Gulf of Alaska southwestward to a position just north of the Hawaiian Islands. This feature was reflected in a mean trough at sea level (Chart XI), a weak center of negative height anomaly at 700 mb. (fig. 1), and an abundance of cyclonic activity (Chart X), all of which combined to help produce above normal precipitation in most of the West Coast and adjoining States (Chart III). This vorticity axis also helps explain the asymmetry in figure 1, where the ridge in western North America is much closer to its downstream trough, in North America, than to the first trough upstream, off the coast of Asia. Figure 4 contains a more uniform wave spacing and suggests that the axis of maximum 700-mb. vorticity in the eastern Pacific affected the wave pattern. This points up the limitations in using the somewhat arbitrary definition of a trough as a line connecting the *minimum latitude reached by contours.* Another significant axis of maximum vorticity appears off the south Atlantic coast of the United States. This corresponds to an area of maximum contour curvature in figure 1. This feature may have been responsible, in part at least, for the heavy precipitation observed in Florida and southern parts of Alabama and Georgia, as well as the fact that below-normal temperatures extended all the way to the east coast of the United States, well east of the 700-mb. trough in the Mississippi Valley.

Precipitation was in excess of normal in virtually all of the northeast quarter of the United States. Numerous cyclones traversed this area during the month, and its mean 700-mb. vorticity was mostly cyclonic. In fact, the line of zero relative vorticity in figure 3 coincides well with the line of normal (100 percent) precipitation in Chart III-B (except in the middle Atlantic States). It is also relevant to note the coincidence of the western limit of the excess precipitation with the axis of negative 700-mb. height anomaly, approximately along 95° W. In other words, where precipitation was above normal, 700-mb. wind components relative to normal were from the south; while precipitation was generally below normal in sections with 700-mb. flow from a northerly direction, relative to normal. More than twice the normal amount of precipitation fell along the north and middle Atlantic Coast and also in a narrow zonal band from Virginia to Missouri. The coastal precipitation occurred along a principal cyclone track (fig. 3), while the zonal band was located just north of a zone of marked confluence at 700 mb. [5] (fig. 1). Weather highlights associated with these conditions were gusts of 96 m.p.h. at Blue Hill, Mass. on the 3d, tornadoes in the Midwest on the 13th, and local floods in Arkansas on the 24th.

The combination of below-normal temperature and above-normal precipitation resulted in total snowfall well in excess of normal in most of the Northeast and Midwest, with greatest departure (over 16 times the normal amount) in parts of Missouri and adjacent States (Chart V-A). During the first week of the month some sections of the Southern States observed their earliest snowfall on record and many stations in the Midwest had record November 24-hour amounts. The 12.5-inch fall in St. Louis, Mo., on the 6th was the greatest 24-hour fall in that city in the past 39 years. Mild weather during the last week of November resulted in melting most of the month's snowfall, so that northern New England was the only area east of the Rocky Mountains with a deep snowcover on December 4 (Chart V-B).

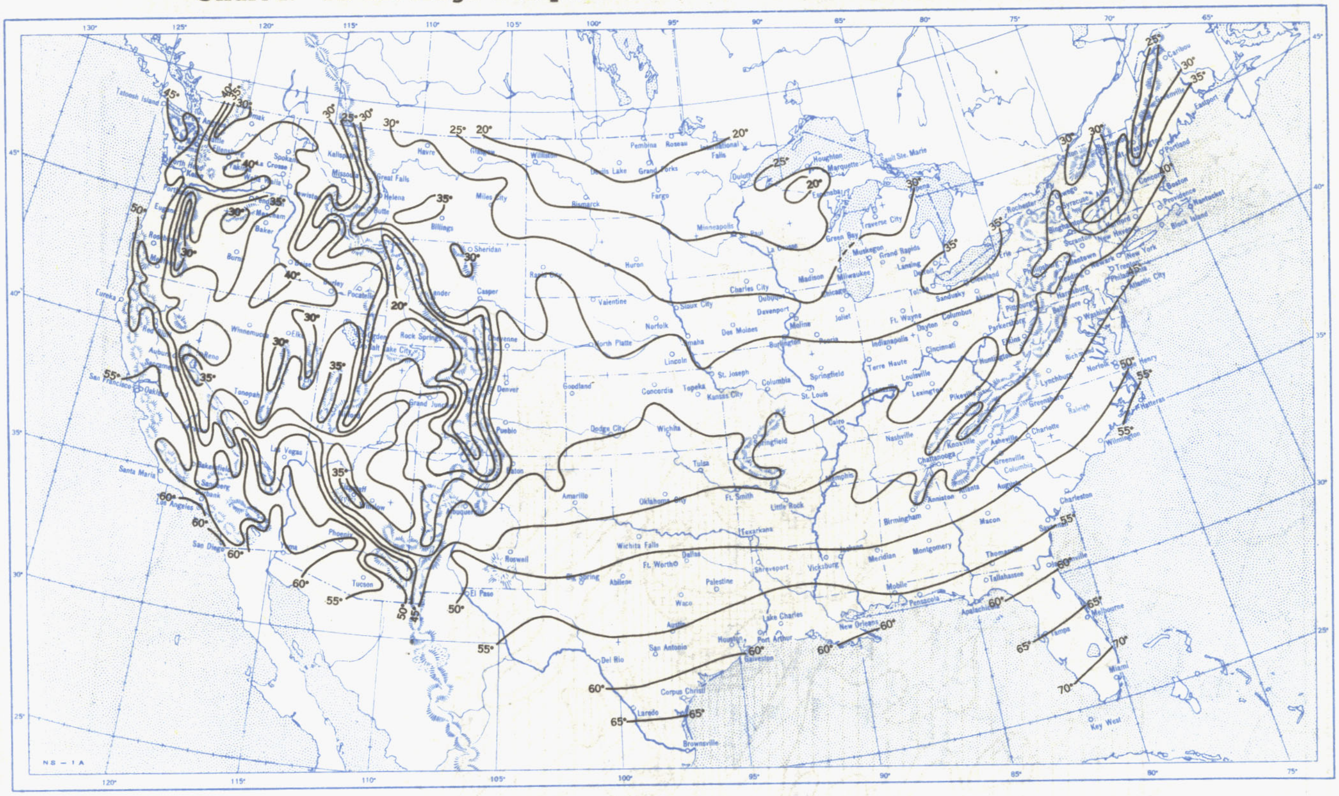
Except for Colorado, precipitation was generally deficient throughout the Plains and Rocky Mountain States. Dry weather in this area was associated with downslope (foehn) winds since the 700-mb. flow was stronger than normal from the northwest and the principal cyclone track was north of the United States border. Furthermore, this region was traversed by numerous anticyclones during the month, and the mean relative vorticity was strongly anticyclonic. Anticyclonic vorticity was also associated with subnormal precipitation in the West Gulf States and parts of the deep South.

From a hemispheric point of view perhaps the outstanding feature of November's weather was the heavy rainfall in the Po River Valley of Italy. This culminated in the worst flood in North Italy's modern history, with over 150 persons killed and nearly 200,000 made homeless. Some of the meteorological conditions associated with this disaster are illustrated in figure 1. North Italy was located in a region of stronger than normal southwesterly flow at 700 mb., about 800 miles east of a deep mean trough. Such a position has been found to provide the optimum combination of moisture and convergence for heavy precipitation due to cyclonic and frontal activity [5]. In addition, a portion of Italy's rainfall was orographic in nature. It is also important to note that the blocking regime over Europe during October diverted much cyclonic activity to the Mediterranean and produced a closed 700-mb. Low centered over northern Italy [1]. This circulation pattern was favorable for heavy rainfall, thus setting the stage for November's flood.

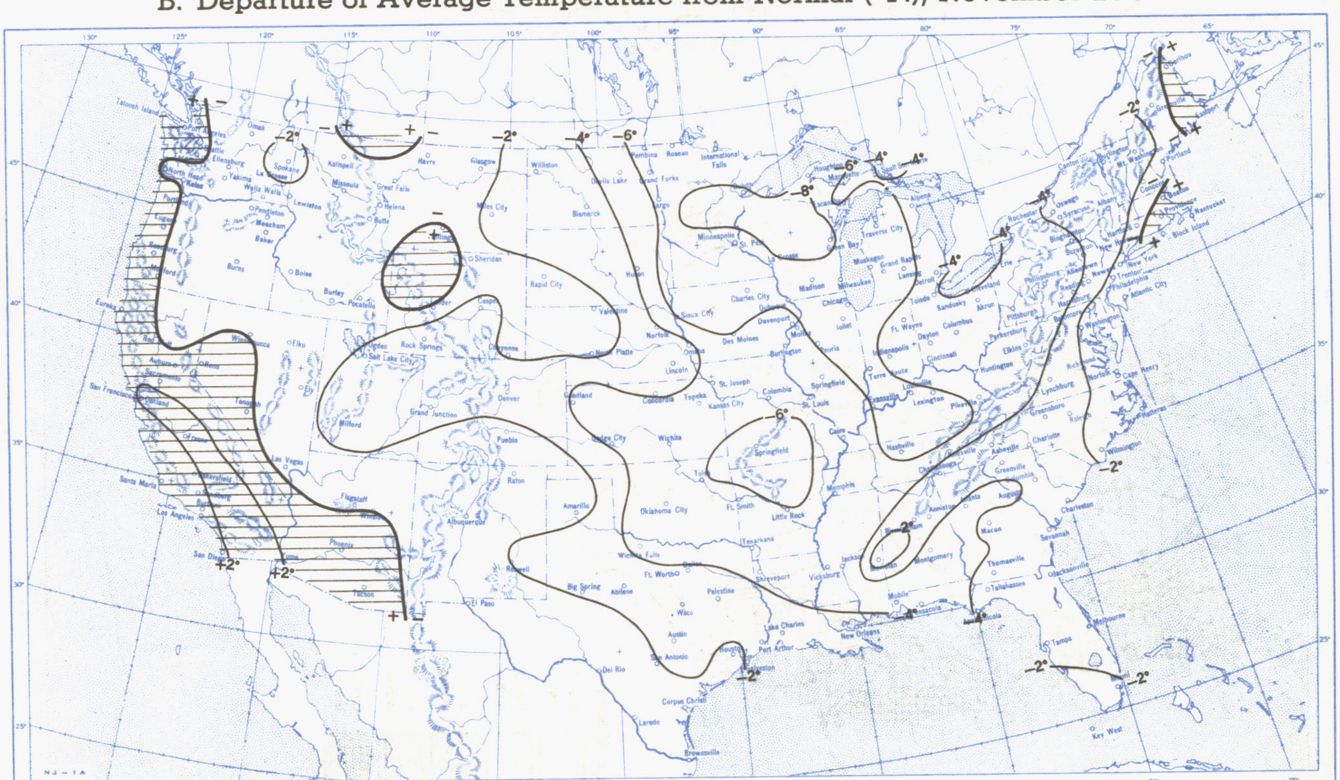
REFERENCES

1. H. F. Hawkins, Jr., "The Weather and Circulation of October 1951," *Monthly Weather Review*, vol. 79, No. 10, October 1951, pp. 196–199.
2. J. Namias, "The Annual Course of Month-to-Month Persistence in Climatic Anomalies" (to be published in the *Bulletin of the American Meteorological Society* during 1952).
3. W. H. Klein, "The Weather and Circulation of February 1951," *Monthly Weather Review*, vol. 79, No. 2, February 1951, pp. 35–38.
4. H-l. Kuo, "Vorticity Transfer as Related to the Development of the General Circulation," *Journal of Meteorology*, vol. 8, No. 5, October 1951, pp. 307–315.
5. W. H. Klein, "Winter Precipitation as Related to the 700 mb. Circulation," *Bulletin of the American Meteorological Society*, vol. 29, No. 9, November 1948, pp. 439–453.

Chart I. A. Average Temperature (°F.) at Surface, November 1951.

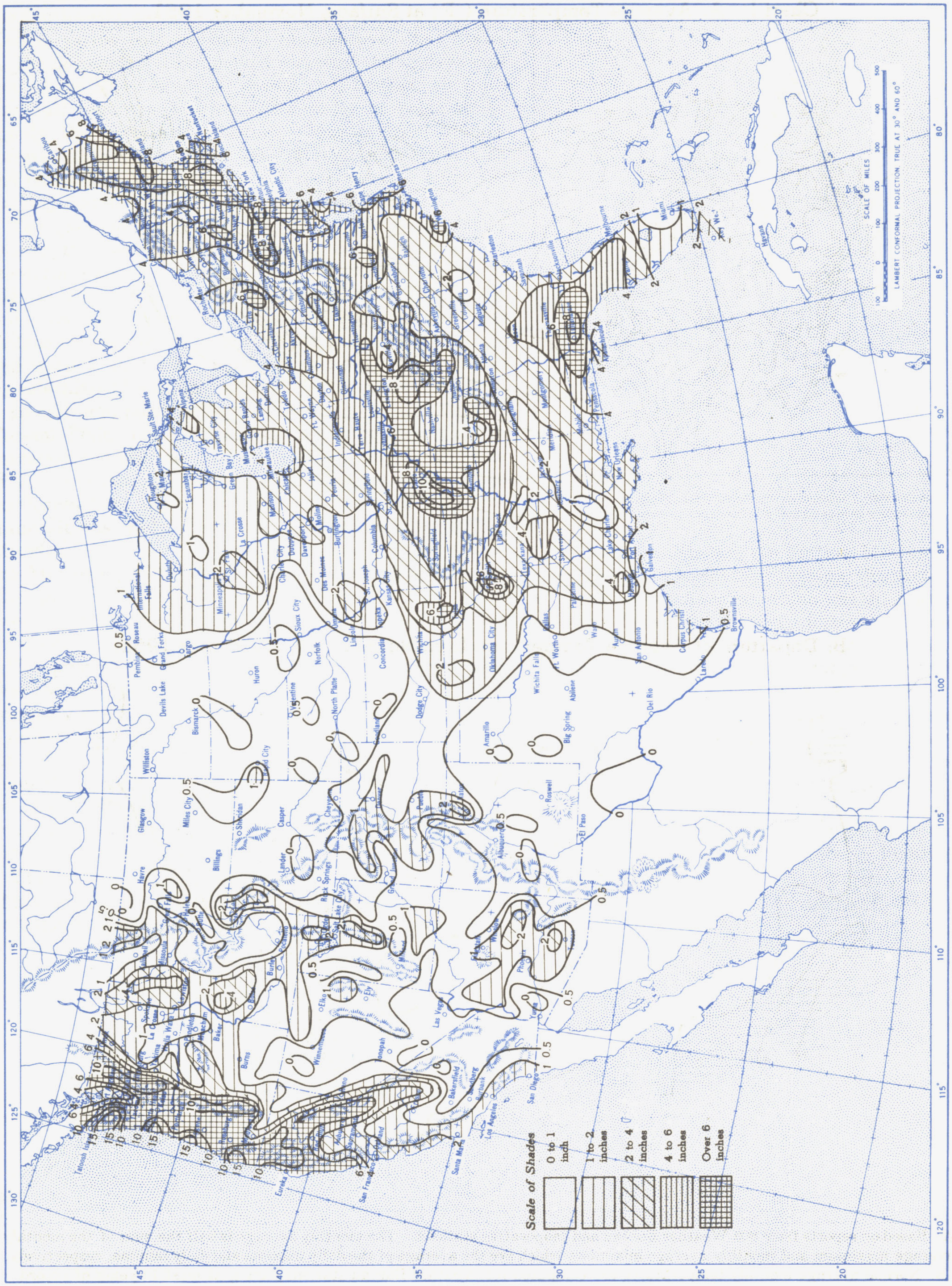


B. Departure of Average Temperature from Normal (°F.), November 1951.



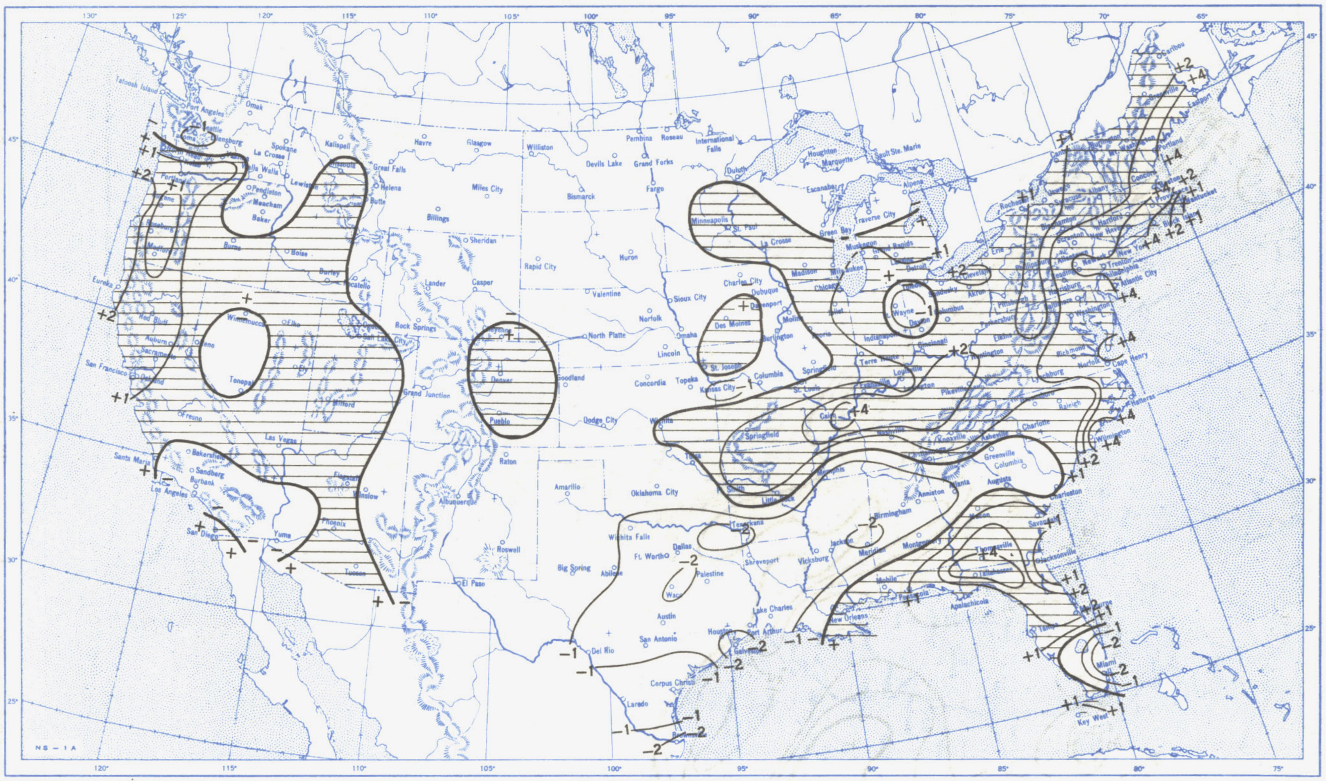
A. Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.
B. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

Chart II. Total Precipitation (Inches), November 1951.

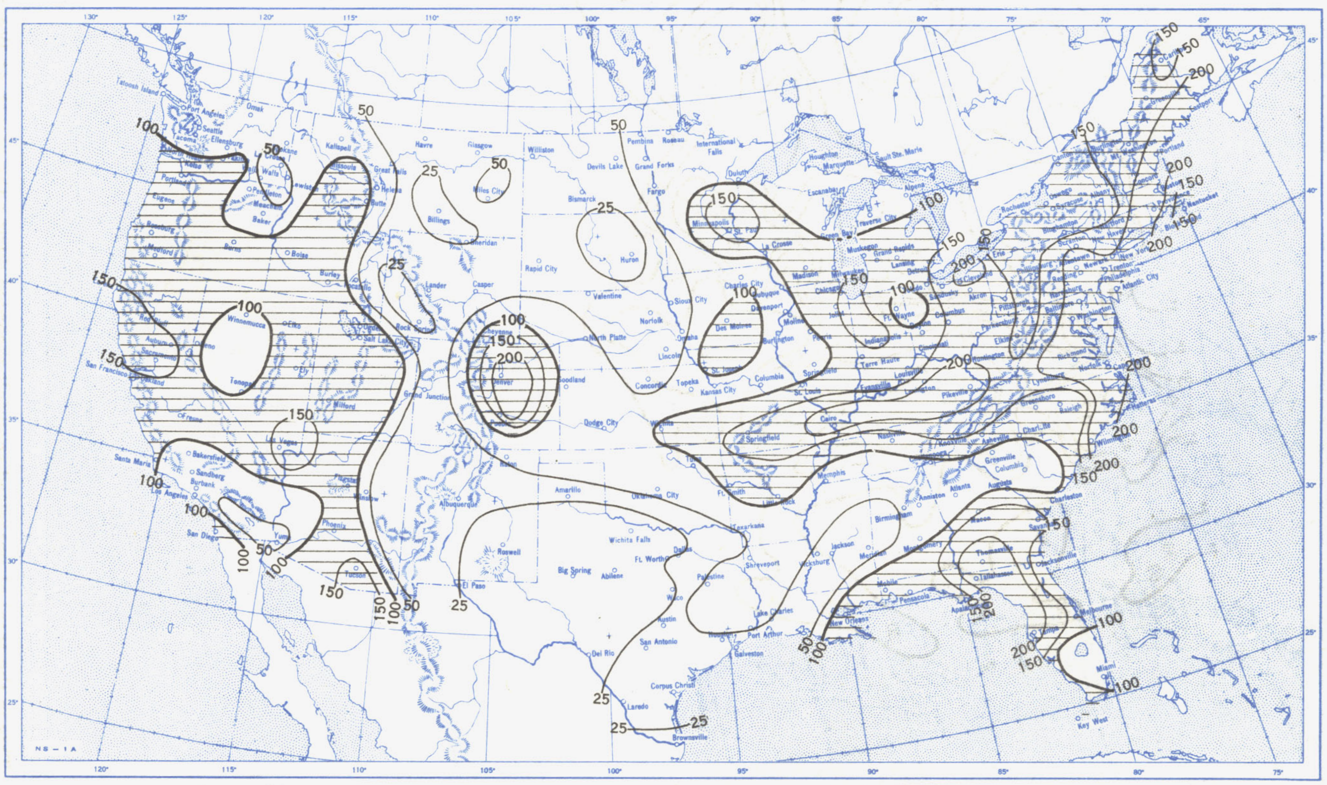


Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), November 1951.

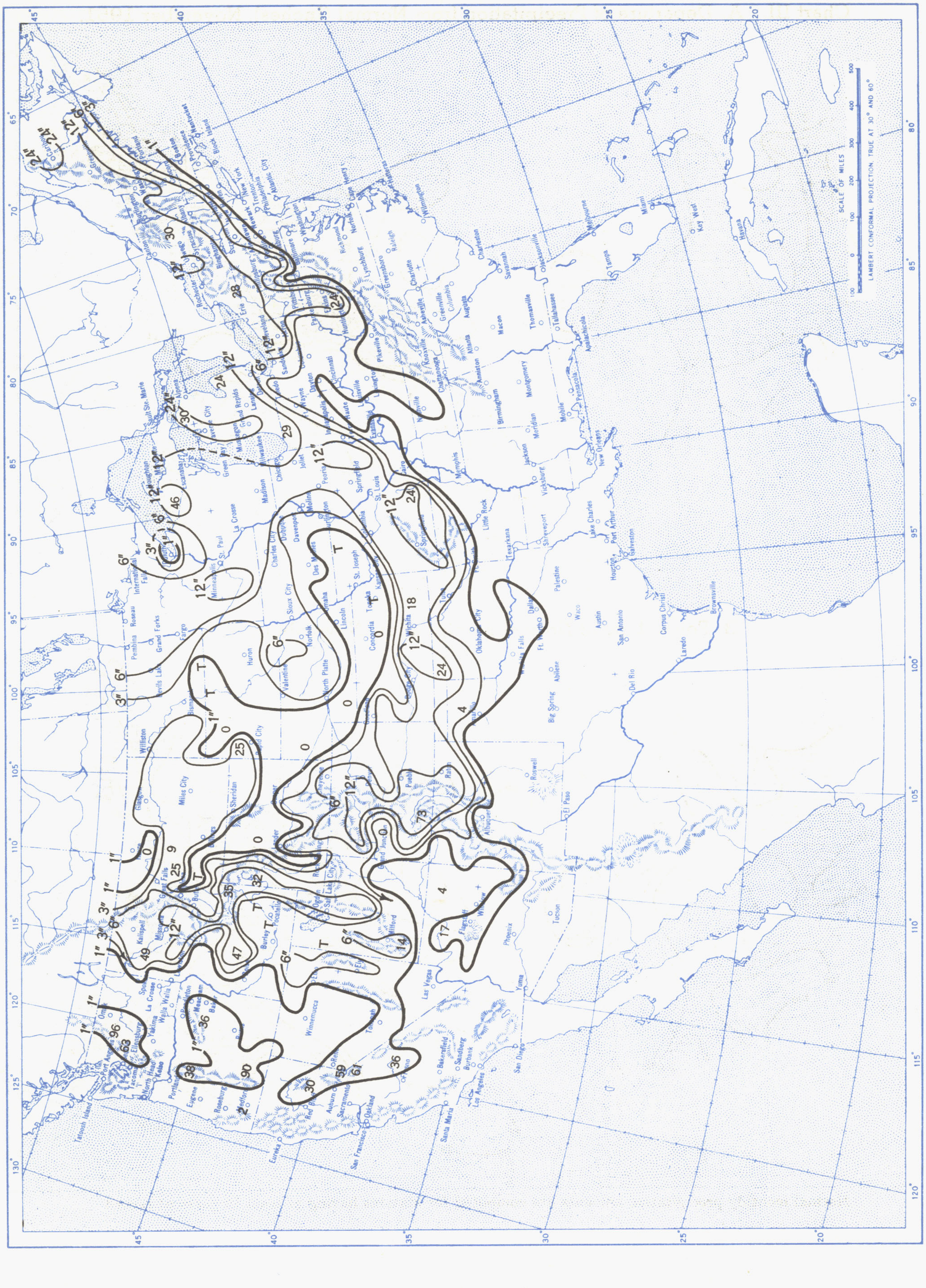


B. Percentage of Normal Precipitation, November 1951.



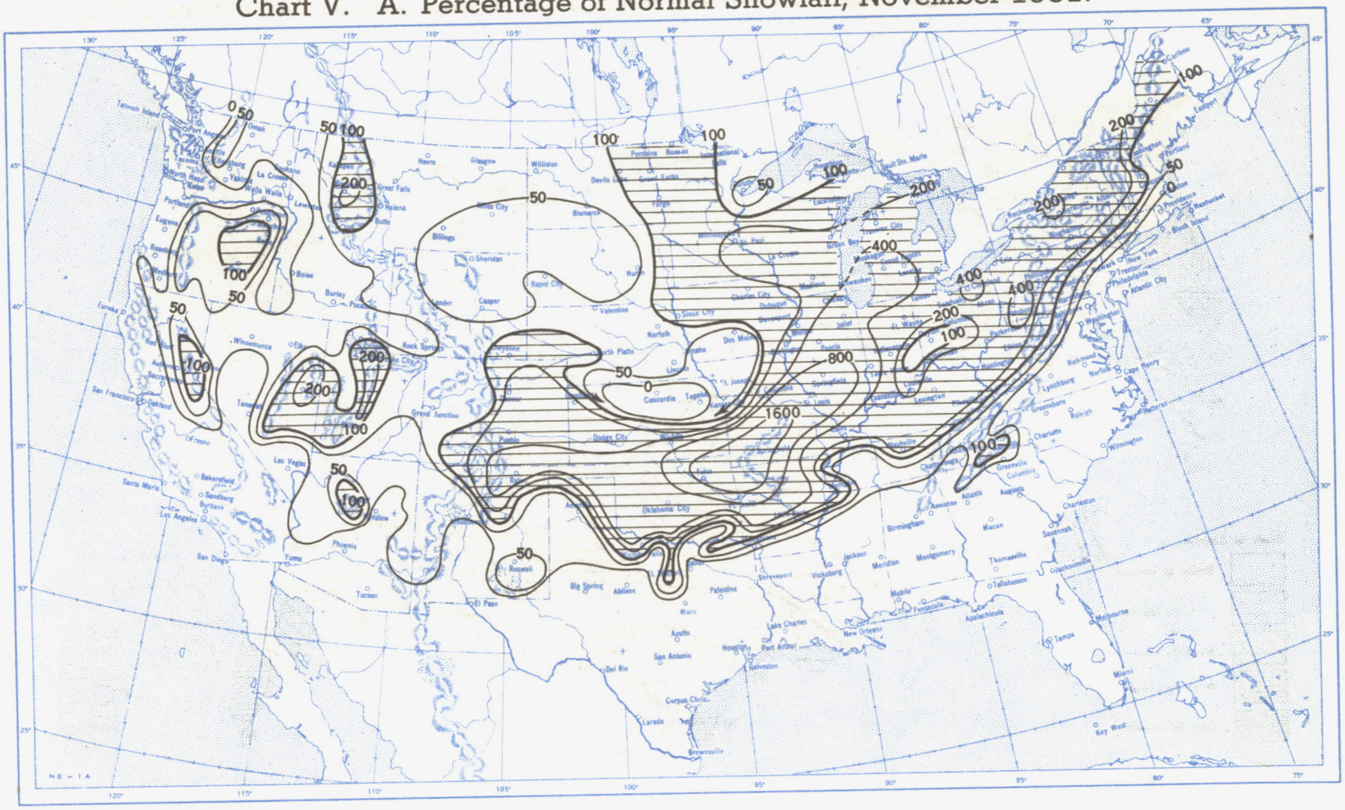
Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart IV. Total Snowfall (Inches), November 1951.

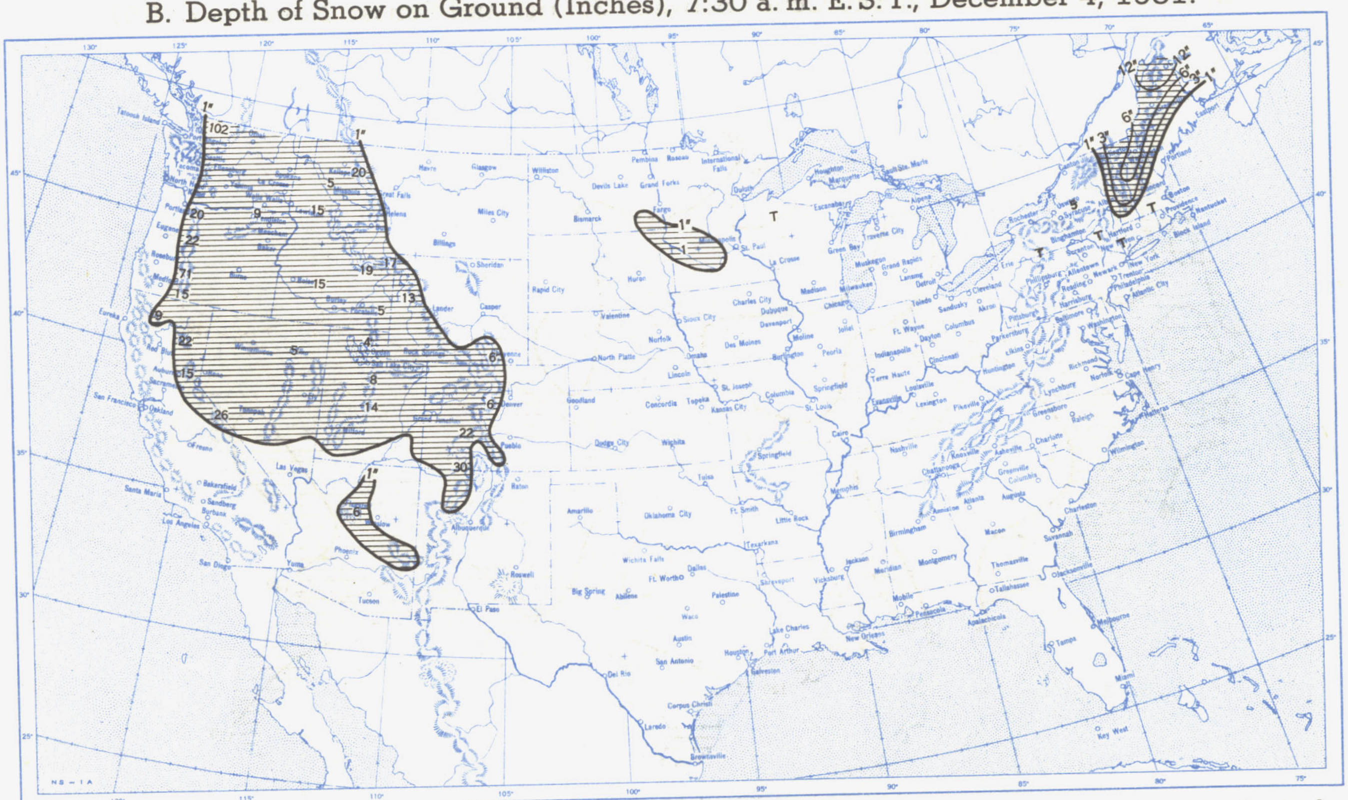


This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, November 1951.

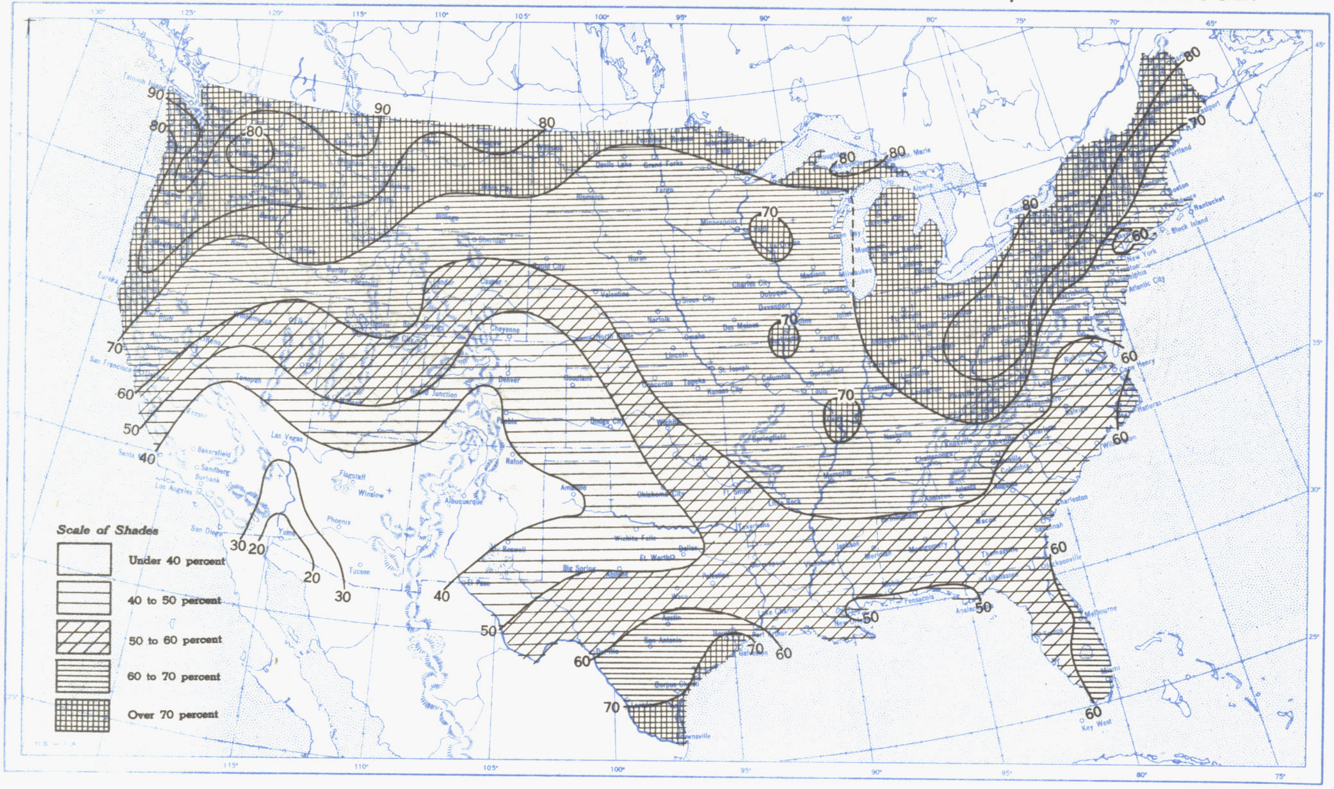


B. Depth of Snow on Ground (Inches), 7:30 a. m. E. S. T., December 4, 1951.

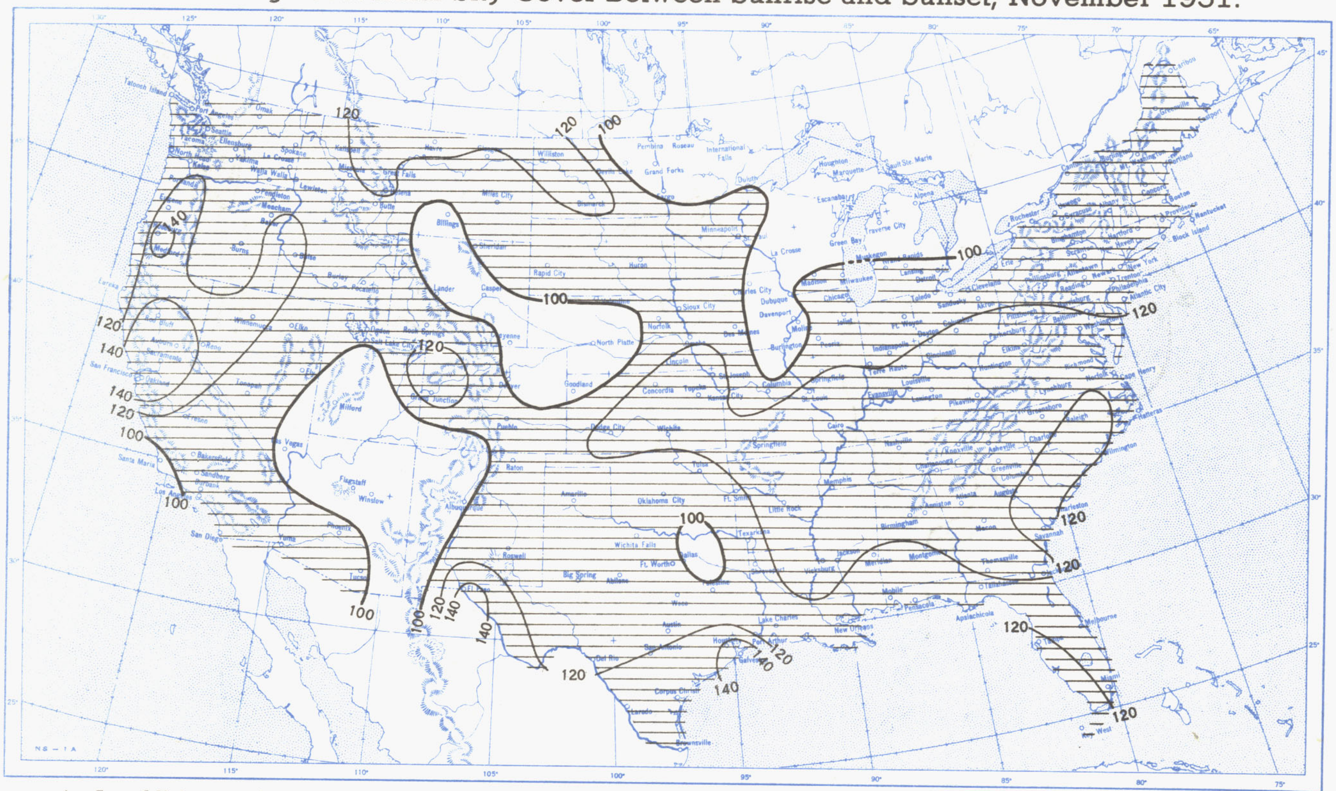


A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record.
B. Shows depth currently on ground at 7:30 a. m. E. S. T., of the Tuesday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, November 1951.

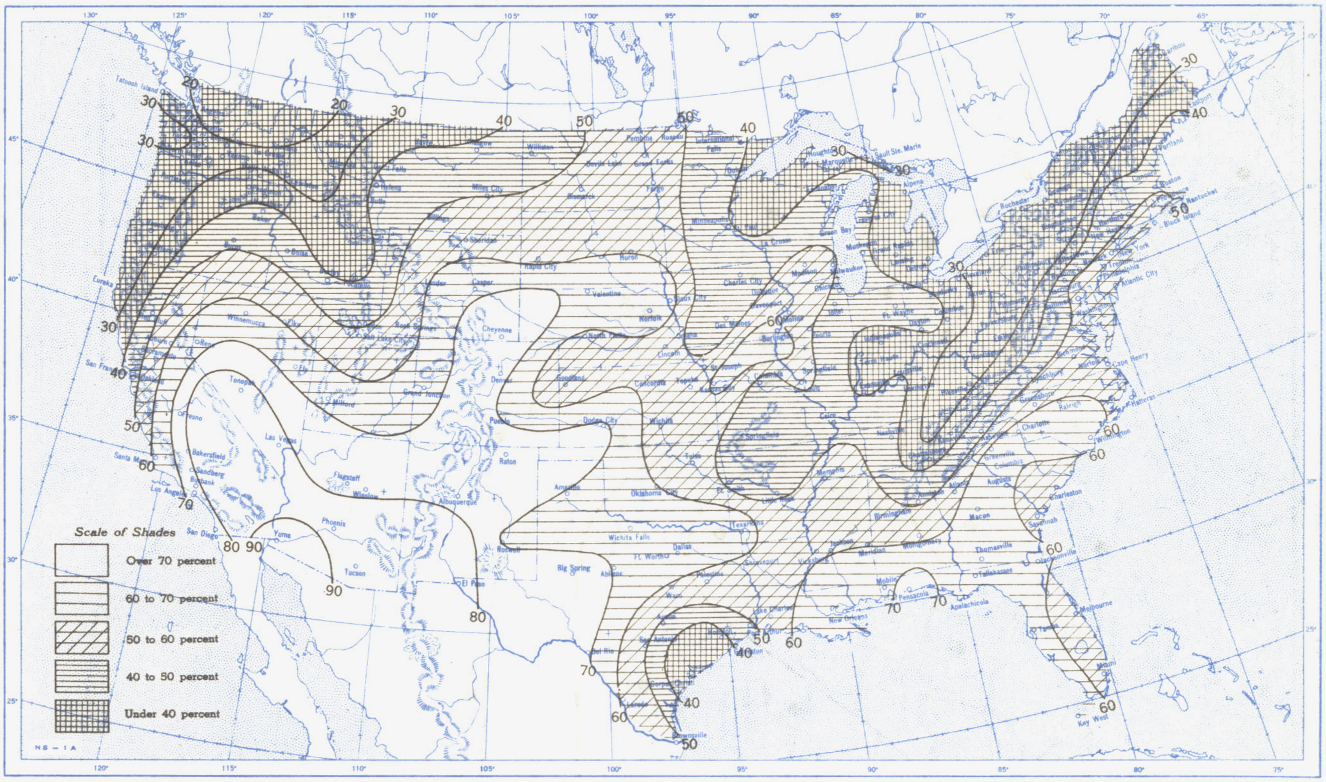


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, November 1951.

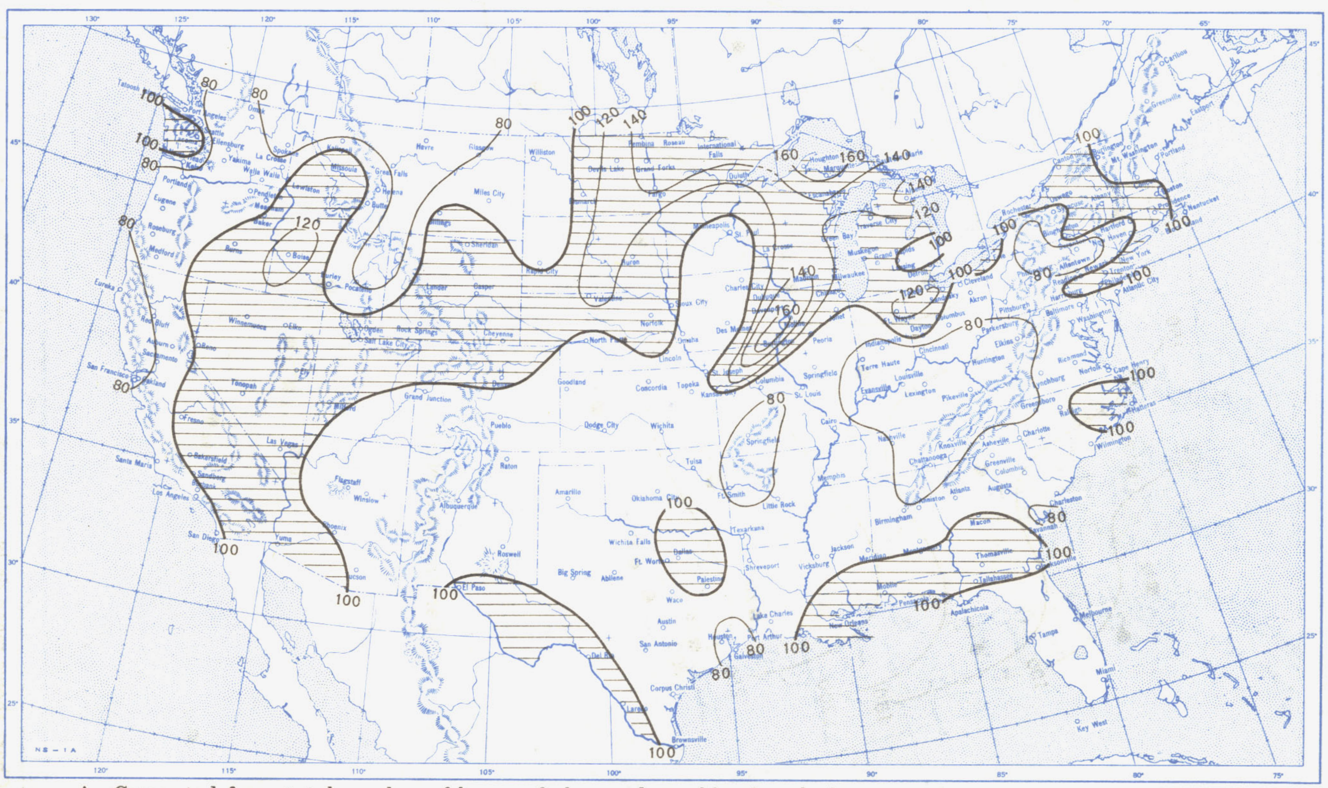


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, November 1951.



B. Percentage of Normal Sunshine, November 1951.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, November 1951. Inset: Percentage of Normal Average Daily Solar Radiation, November 1951.

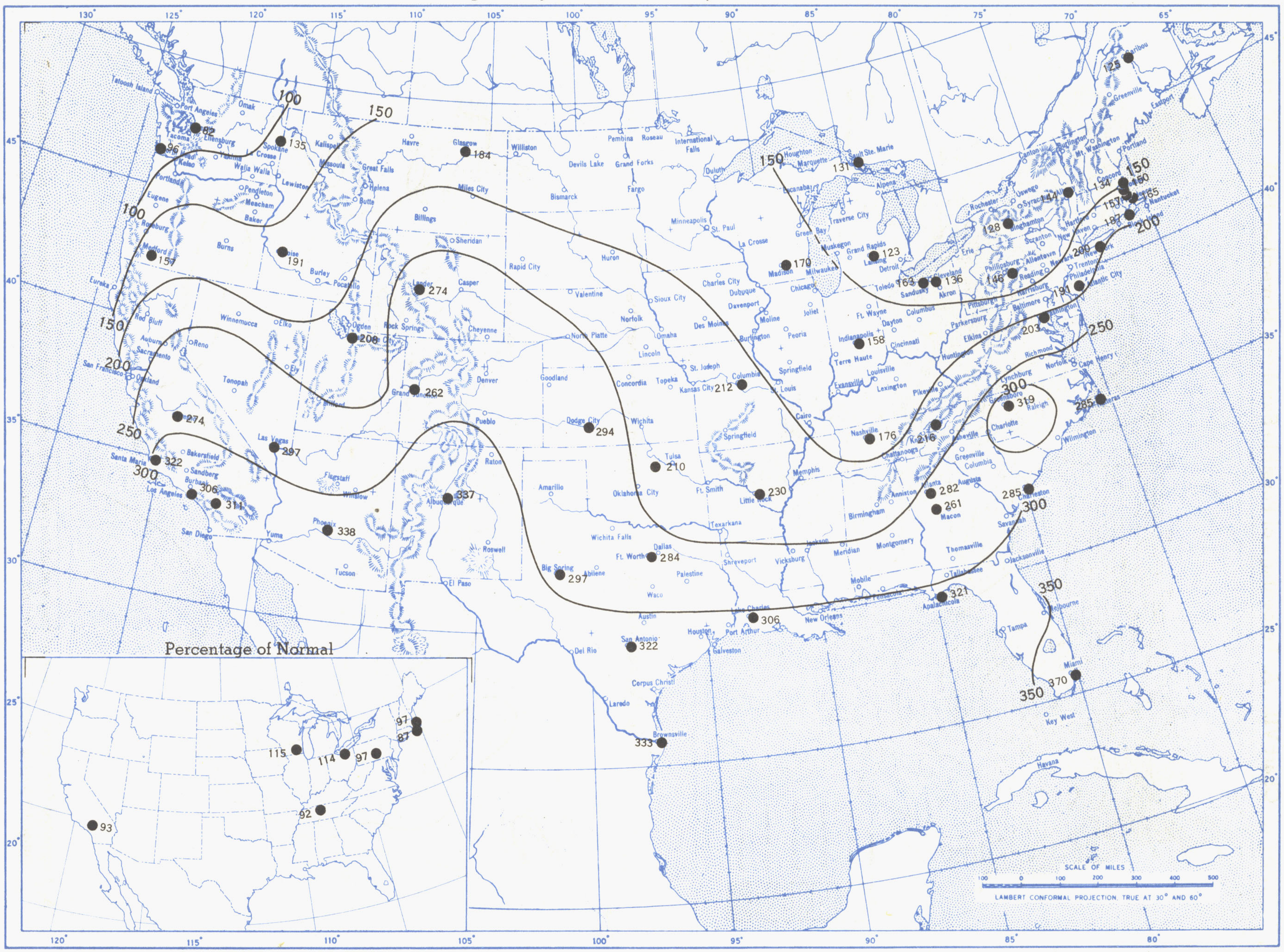
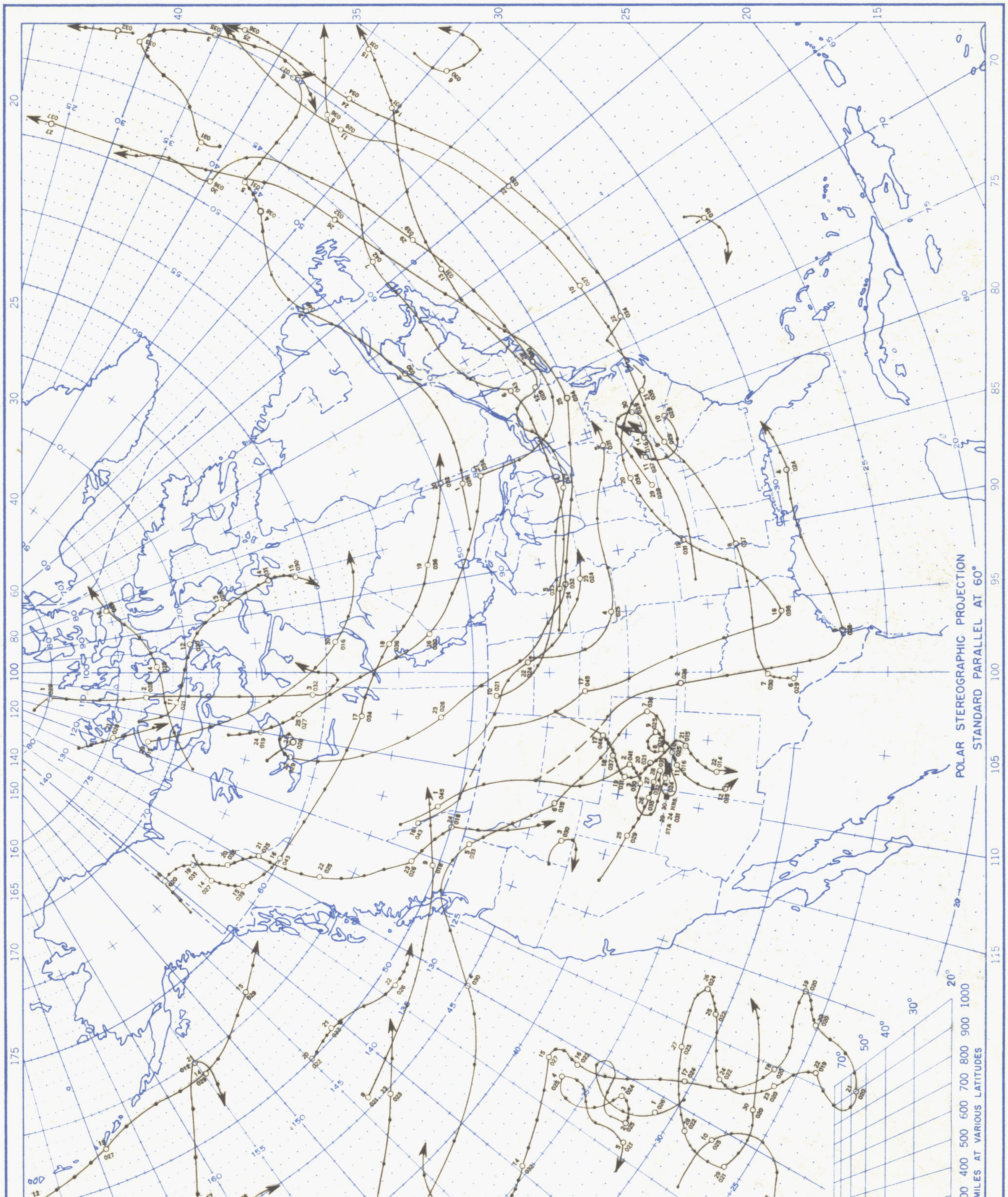


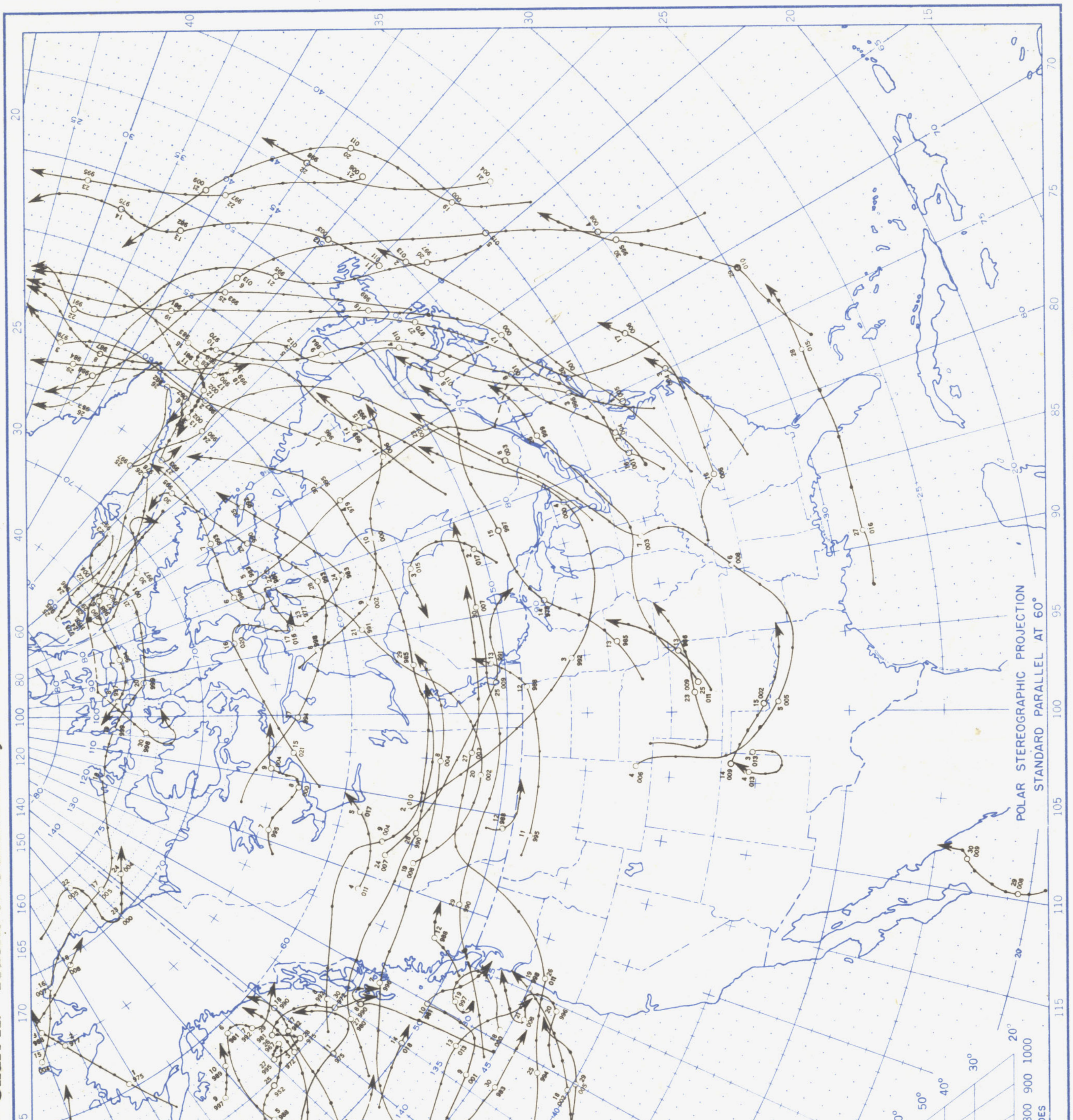
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm. $^{-2}$). Basic data for isolines are shown on chart. Further estimates obtained from supplementary data for which limits of accuracy are wider than for those data shown. Normals are computed for stations having at least 9 years of record.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, November 1951.



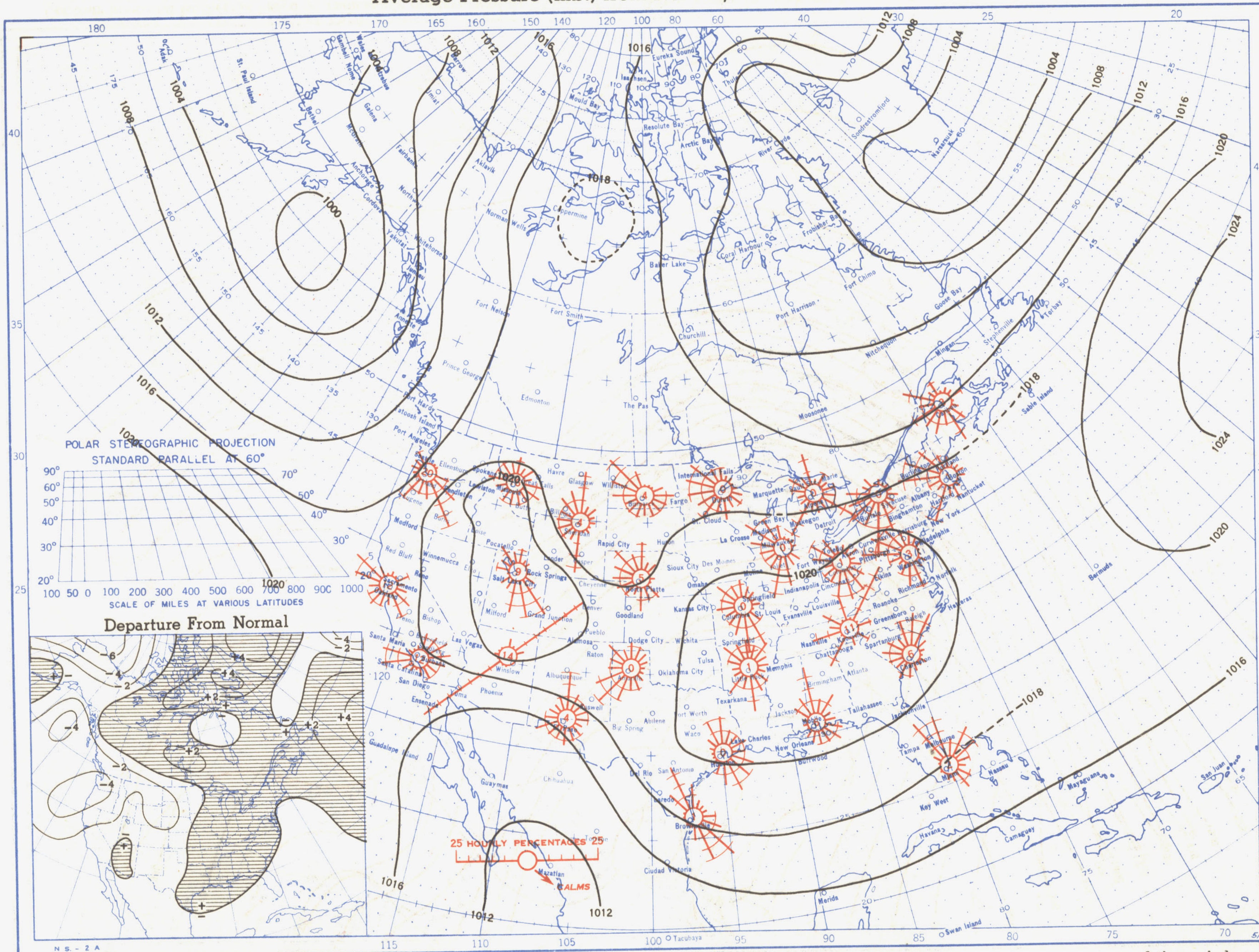
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, November 1951.



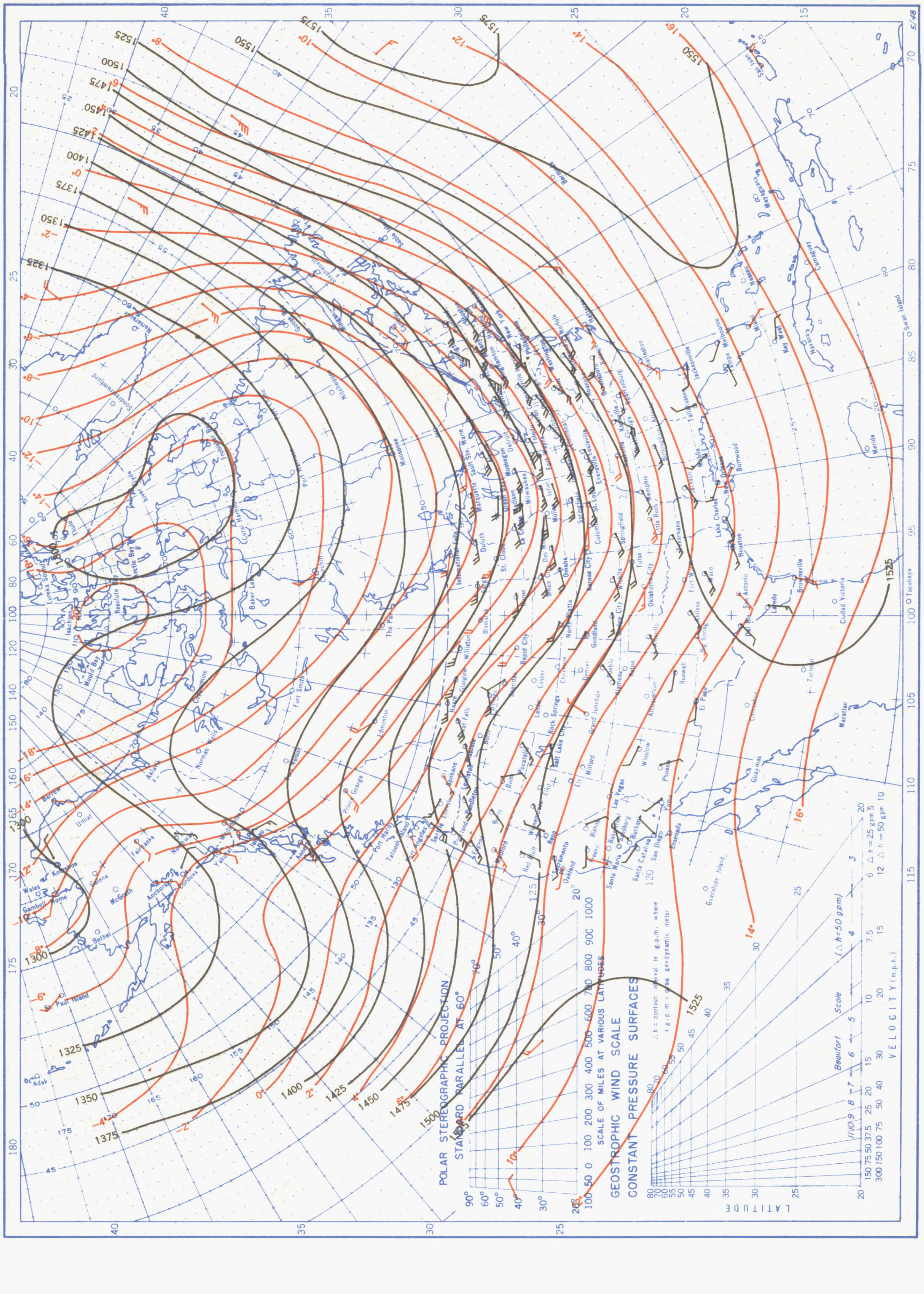
Circle indicates position of center at 7:30 a.m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, November 1951. Inset: Departure of Average Pressure (mb.) from Normal, November 1951.



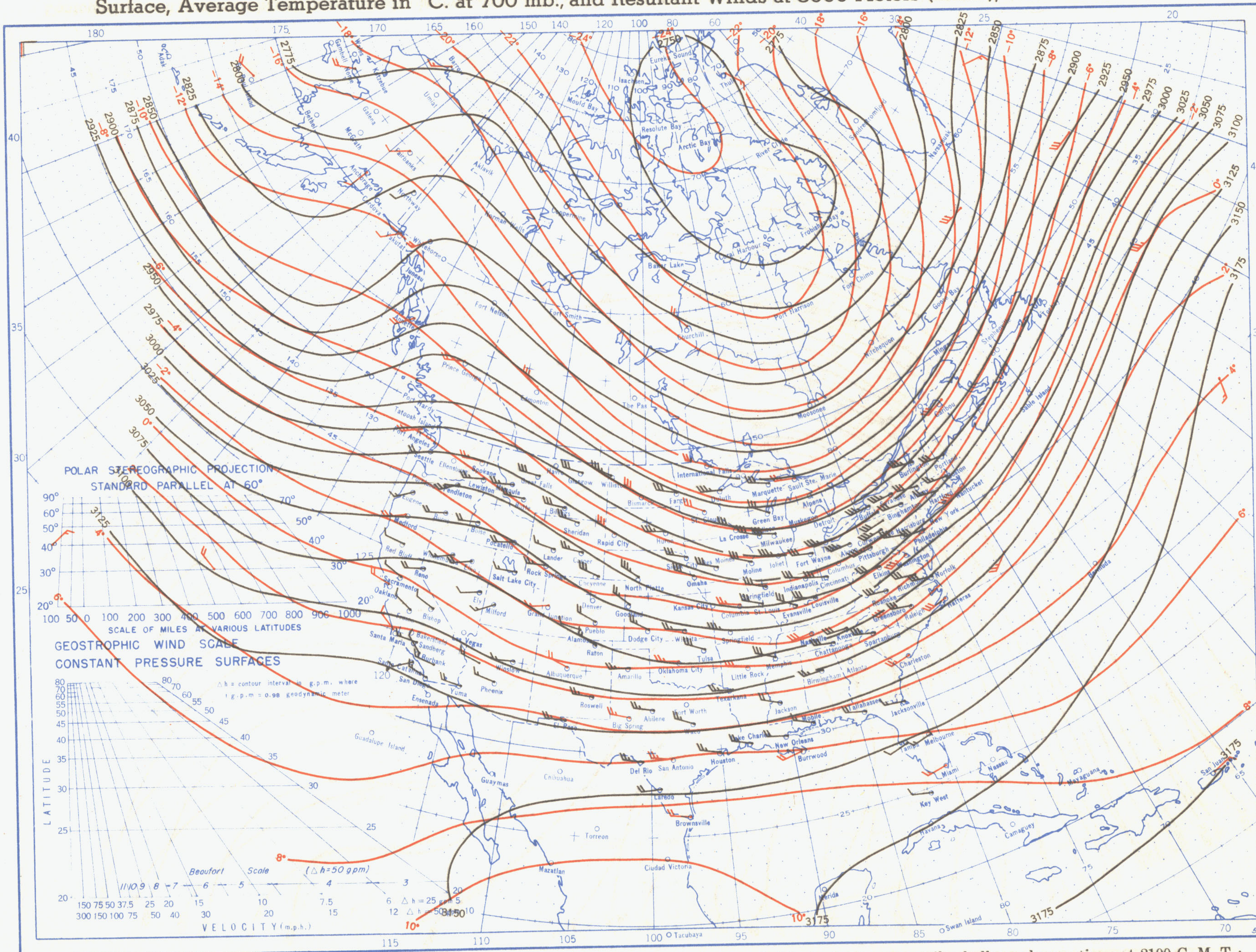
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid based on readings from the Historical Weather Maps (1899-1939) for the 20 years of most complete data coverage prior to 1940.

Chart XII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 850-mb. Pressure Surface, Average Temperature in °C. at 850 mb., and Resultant Winds at 1500 Meters (m.s.l.), November 1951.



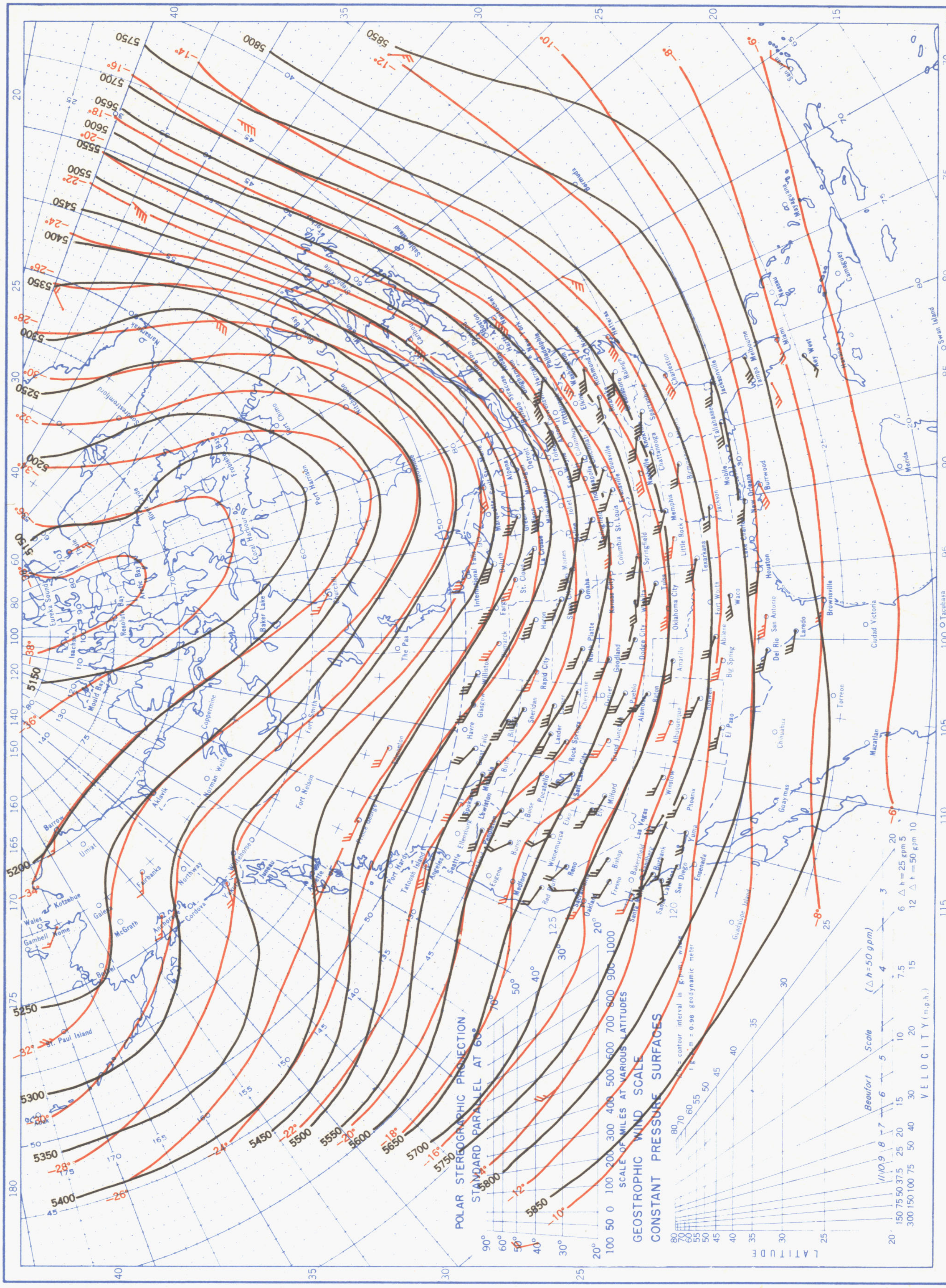
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIII. Average Dynamic Height in Geopotential Meters (1 g.p.m.. = 0.98 dynamic meters) of the 700-mb. Pressure Surface, Average Temperature in °C. at 700 mb., and Resultant Winds at 3000 Meters (m.s.l.), November 1951.



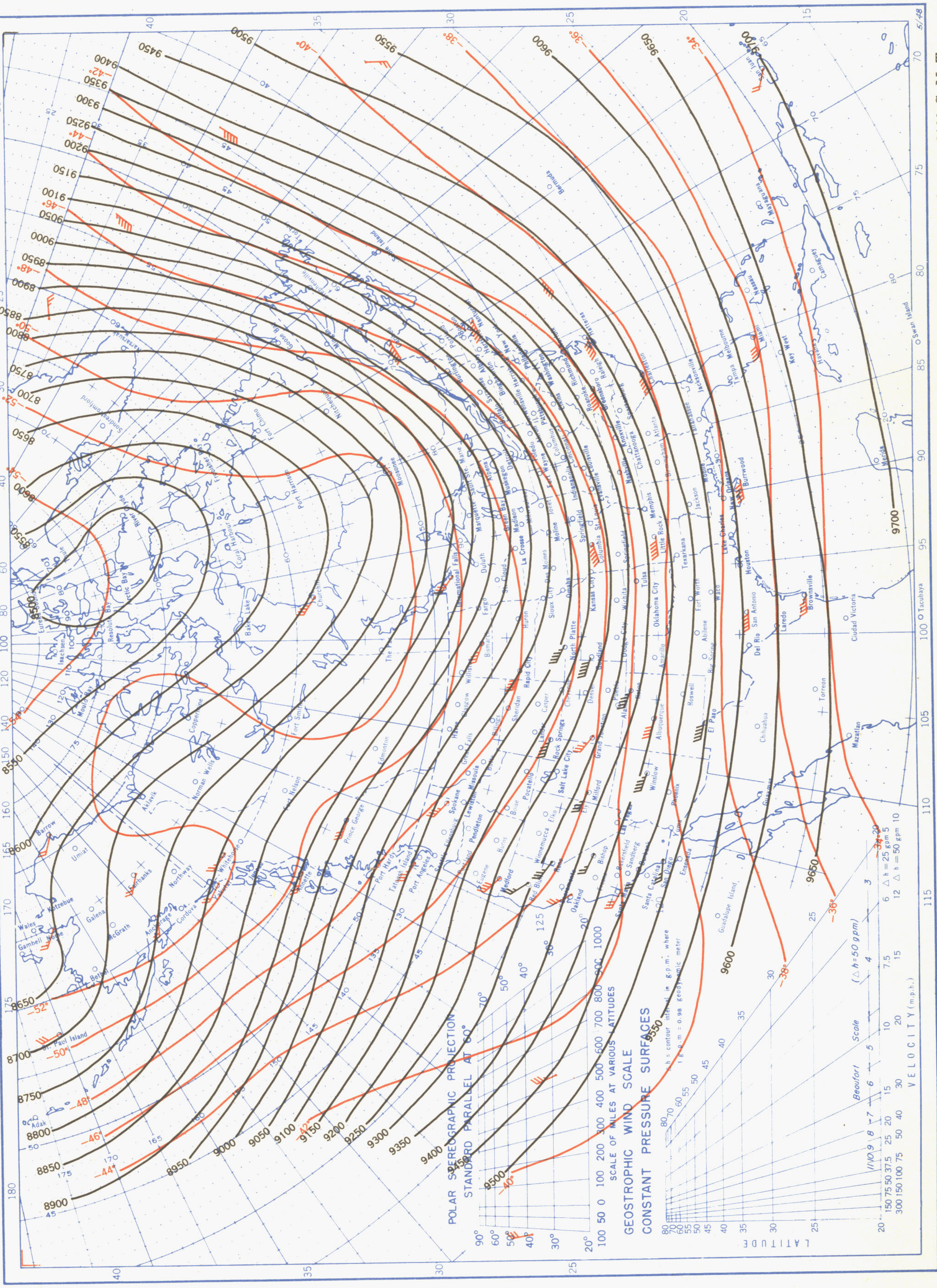
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 500-mb. Pressure Surface, Average Temperature in °C. at 500 mb., and Resultant Winds at 5000 Meters (m.s.l.), November 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.

Chart XV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 300-mb. Pressure Surface, Average Temperature in °C. at 300 mb., and Resultant Winds at 10,000 Meters (m.s.l.), November 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.