THE WEATHER AND CIRCULATION OF MAY 1957 [1]

A Month with Severe Floods and Devastating Tornadoes in the Southern Plains of the United States

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1. INTRODUCTION

More tornadoes were observed in the United States during May 1957 than in any other month of record. Furthermore, record numbers of tornadoes were reported for any one week and for any one day. Monthly rainfall was also abnormally high. Over 75 percent of the area of the United States received more than the normal amount of rainfall, and several regions received 300 to 500 percent of normal. Precipitation was not only heavy, but also unusually persistent, especially in portions of the Southern Plains where two or more inches of rainfall were reported in each of four out of five weeks. The recurrent heavy rains produced frequent and severe flooding in parts of Texas, Oklahoma, and neighboring areas to the east and northeast.

These severe weather anomalies were brought about by an atmospheric circulation which was favorable for such activity and unusually persistent. In the lower troposphere a prevailing southeasterly flow advected moist tropical air over most of southeastern and central United States. In the mid-troposphere cyclonic conditions prevailed over the western United States and anticyclonic circulation over the East. In the upper troposphere a strong jet stream flowed from an area of maximum winds over northwestern Mexico across the southern Plains to New England. Under this circulation pattern, cold maritime Pacific airmasses frequently occupied the West, while maritime tropical airmasses dominated the Southeast.

2. 30-DAY MEAN CIRCULATION

Namias [7, 8] found that for the United States area during the period 1942 to 1954 there was a minimum of persistence of certain climatic anomalies from April to May. For the longer period, 1893 to 1953, Enger [3] found no minimum of persistence from April to May. Most recently there has been a return toward the greater persistence which must have characterized the earlier years prior to 1942. This is indicated in table 1 which gives the number of stations out of 100 selected cities which remained in the same or adjacent temperature classes from April to May. Although the year 1956 [6] agreed with the 1942–54 average [7], the years 1955 [16] and 1957 produced much greater persistence in temperature. The average of 57 for the period 1942–54 was one of the lowest for any pair of months during the year.

TABLE 1.—*Measure of persistence of monthly mean temperature anomalies in the United States from April to May*

Period	Persistence (percent)
Average 1942–1954	57
1955	98
1956	52
1957	83

Other measures also indicate the high persistence of climatic anomalies this spring. Forty-eight stations (out of 100) remained in the same precipitation class, compared with an average of 33 for the 1942–50 period [7]. The correlation between patterns of 700-mb. height anomaly for April and May 1957 was 0.50, compared with 0.20 for the period 1942–50 [7].

The circulation of this May considered over the entire Northern Hemisphere exhibited several noteworthy features. The largest anomaly was a positive 360-ft. center associated with a pronounced blocking anticyclone in Russia (fig. 1). Positive anomalies of the blocking variety were also observed over the entire Arctic with extensions southward through Alaska and Greenland. Rex [9] found blocking to be common in May, and many previous authors in this series of articles have emphasized the predominance of blocking at this season [4, 5, 15, 16].

This May high-latitude blocking and accompanying easterlies in polar latitudes (55° N.–70° N.) (fig. 2) were strongest at mid-month. Early and late in May polar westerlies existed—a more normal situation. The subtropical westerlies (20° N.–35° N.) persisted above normal as a result of the expanded circumpolar westerlies associated with higher than normal 700-mb. heights in the Arctic. The subtropical and temperate index curves were in phase with each other but 180° out of phase with the polar westerlies. Temperate westerlies were subnormal early in May, then increased and remained above normal at an almost constant value during most of the month, before returning to subnormal values at the end of May. This lack of week-to-week variability was indicative of the persistent circulation that existed during most of May.

[1] See Charts I–XVII following p. 192 for analyzed climatological data for the month.

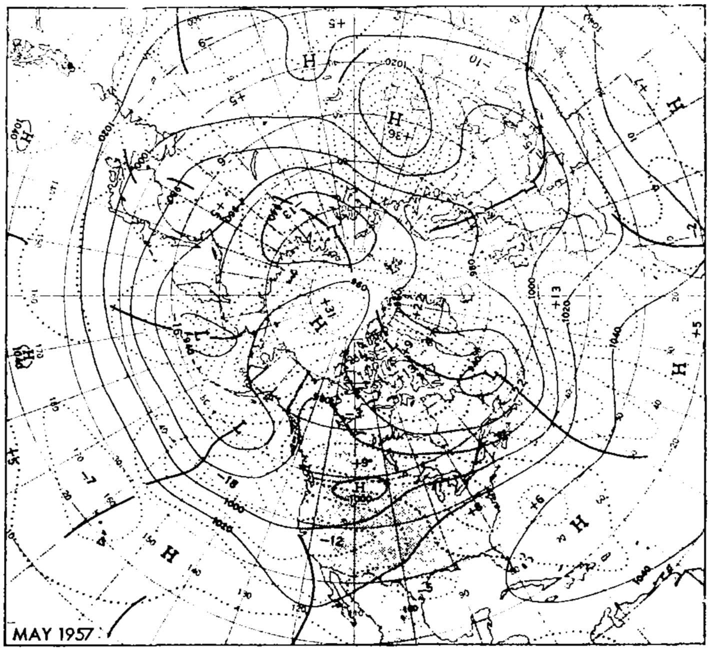

FIGURE 1.—Mean 700-mb. contours and height departures from monthly normal (both in tens of feet) for May 1957. Cyclonic conditions and subnormal heights in western United States and anticyclonic conditions and above normal heights in the East combined to produce widespread heavy precipitation and severe weather.

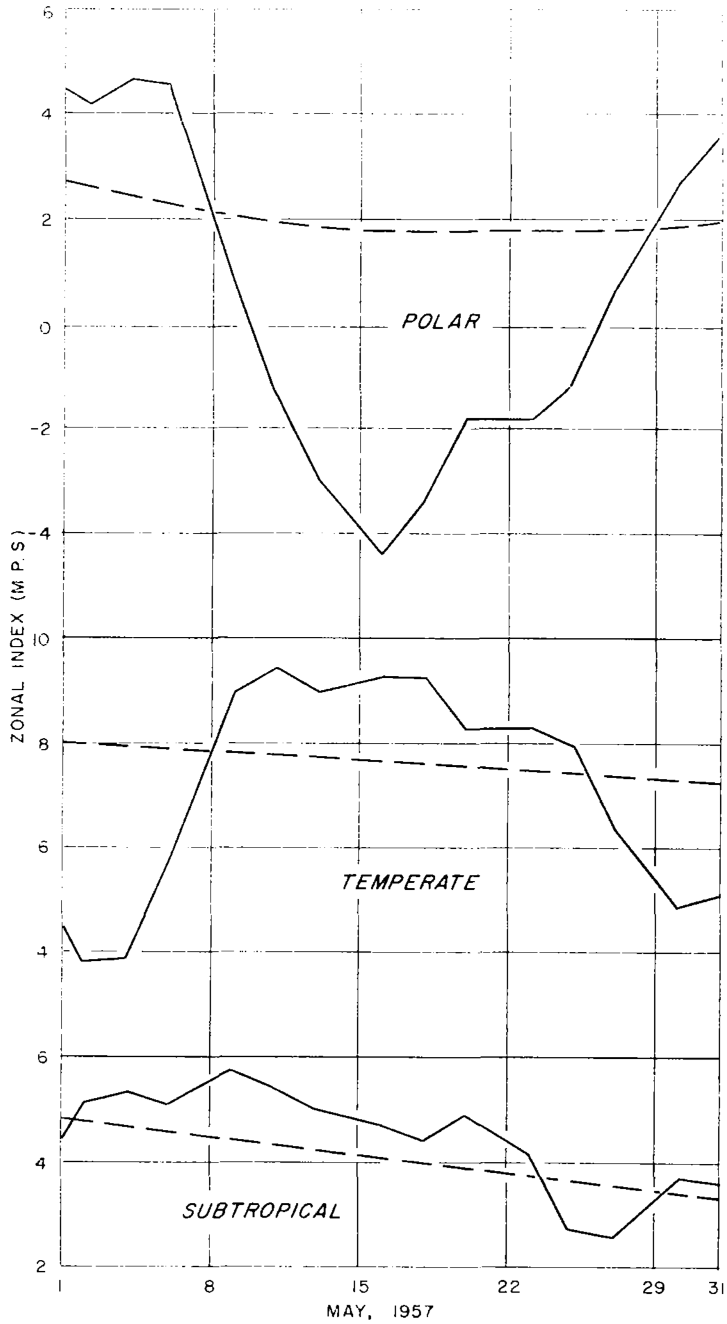

FIGURE 2.—Time variation of 700-mb. westerlies (in meters per second) over the Western Hemisphere for polar (55° N.–70° N.), temperate (35° N.–55° N.) and subtropical (20° N.–35° N.) belts. Solid lines connect 5-day mean index values (plotted at middle of 5-day period and computed three times weekly), and dashed lines show variation of corresponding normal indices. At mid-month easterlies prevailed in the polar region while above normal westerlies dominated other regions—a manifestation of the expanded circumpolar vortex.

The mean circulation over North America (fig. 1) had a confluent configuration which was similar to, but more pronounced than, that found on the normal chart [12]. In Canada a ridge was observed in the west and a trough in the east. The opposite was true in the United States, where there was a trough with subnormal heights along the west coast and a ridge with above normal heights in the East. The trough-to-trough wavelength across the United States was abnormally long (66° of longitude at 35° N. and 102° of longitude at 45° N.). The broad, eastward extent of cyclonic circulation gave rise to frequent periods of storminess in the Southern Plains. The below normal heights which extended eastward from the west coast to the Mississippi Valley were particularly significant in showing the eastward penetration of low-latitude disturbances, even though a mean trough was not observed over the continent.

The major features of the 700-mb. geostrophic wind field (fig. 3A), like those of the 700-mb. height pattern, were located near their normal positions, but the magnitude of the winds was quite anomalous (fig. 3B). For example, the two axes of maximum wind speed over North America averaged very close to the normal locations, although wind speeds along these axes were greater than normal (fig. 3B). One air stream flowed southeastward out of northwestern Canada and the other northeastward from northern Mexico to combine into a single jet stream near Nova Scotia. Wind speeds were above normal along the jet stream axes over the United States, especially in the Southwest. The major negative anomalies were subnormal wind speeds in the Northern Plains and Rocky Mountain States. The quasi-stationary position of the jet stream, in addition to its greater than normal strength, had a pronounced effect on the monthly weather (to be discussed later).

The jet stream was better delineated and wind speeds along its axis were stronger in the upper troposphere than at the lower levels. At 200 mb. the jet stream axis was

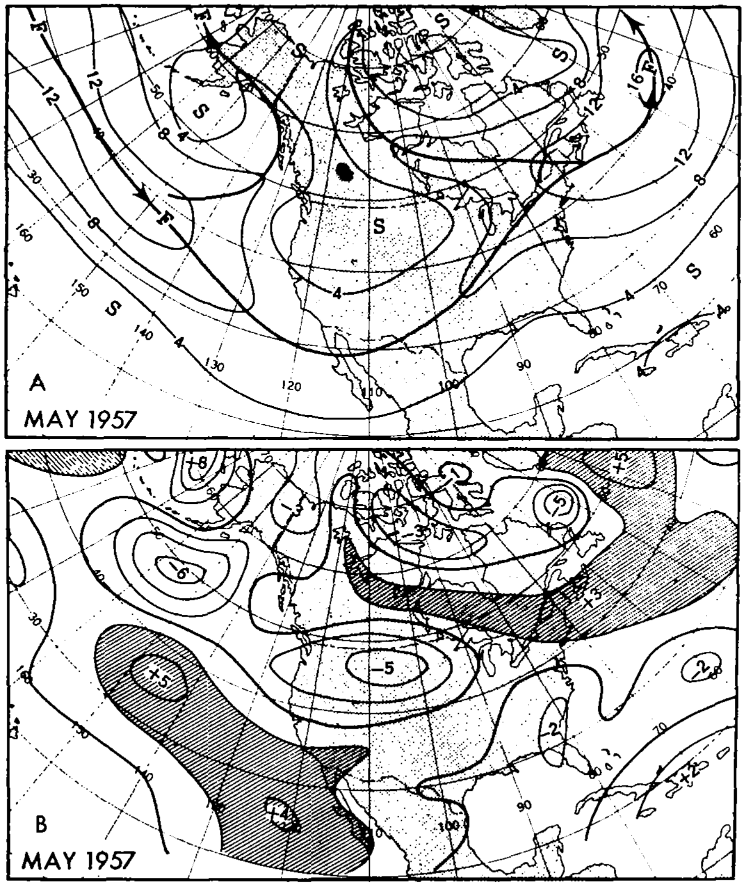

Figure 3.—(A) Mean 700-mb. isotachs and (B) departure from monthly normal wind speed (both in meters per second) for May 1957. Solid arrows in (A) indicate principal axes of maximum winds at 700 mb. Anomalies in (B) greater than +2 are hatched. A confluent pattern, similar to the normal, existed over North America, but wind speeds averaged greater than normal along the jet stream from northern Mexico to Maine.

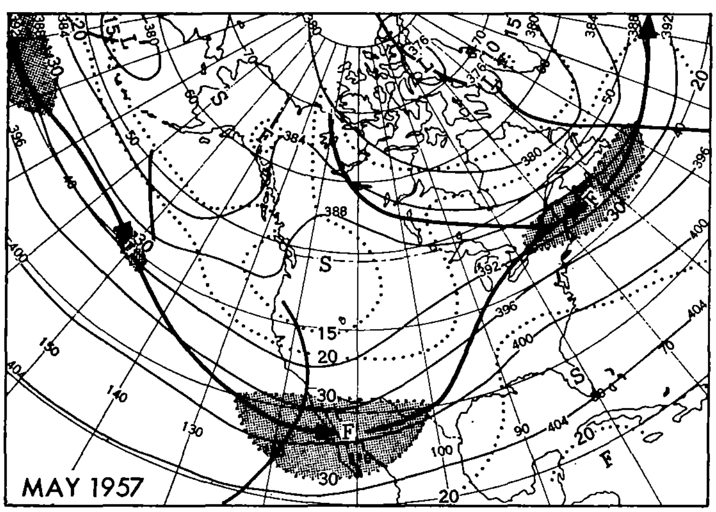

Figure 4.—Mean 200-mb. contours (solid, in hundreds of feet) and isotachs (dotted, in meters per second) for May 1957. Wind speeds greater than 30 m. p. s. are stippled. Solid arrows indicate the average position of the 200-mb. jet stream. Wind speed maximum observed over northern Mexico, so that regions of the Southwest were downstream from an area of maximum winds.

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located rather far south in the West, and the strongest winds were centered over Mexico (fig. 4). If this mean isotach pattern indicates the preferred daily wind field (and an examination of the daily weather maps revealed that it does), then southwestern United States was frequently located under the left front quadrant of the jet maximum (north of the jet axis and downstream from the maximum wind). This is the most likely area of high-level divergence and stormy weather according to Riehl [10] and Beebe and Bates [2].

The contour pattern at 200 mb., which resembled the one at 700 mb., had a deep trough with cyclonic vorticity in the Far Southwest and a flat ridge in the East. The confluent pattern was also discernible at this level, with broadscale northwesterly flow observed over Canada and southwesterly flow over the United States.

The monthly mean sea level chart (Chart XI) had some rather interesting and important features. Pressures averaged below normal over most of the United States and above normal over Canada and the Arctic. This configuration of anomalies was a reflection of the high-latitude blocking and expanded circumpolar vortex referred to previously. Another surface feature, especially noteworthy from the standpoint of precipitation, was the broadscale southeasterly flow over a large area of the United States. It was particularly strong in the central Plains where it had an upslope component.

In addition to the flow patterns, the associated thermal field was conducive to cyclonic activity. Cold maritime Pacific airmasses dominated the Southwest and kept the thickness (700–1000 mb.) below normal (fig. 5), but in the East maritime tropical airmasses dominated, and the thickness averaged above normal. The southern boundaries of the subnormal thickness corresponded approximately with the upper jet stream axes (fig. 4) and also with the band of high frequency of surface fronts (fig. 6). The cold-in-the-West, warm-in-the-East temperature pattern, with the frontal zone frequently in the Southern Plains, combined with the overlying jet stream and planetary wave to form an ideal set-up for heavy precipitation and severe weather in the central United States.

3. WEATHER OF THE MONTH AND ITS RELATION TO THE MEAN CIRCULATION

Precipitation was heavy and widespread during May and most areas reported more than normal amounts (Charts II, III). Several stations, including Prescott, Ariz., Blue Canyon and Santa Maria, Calif., Pueblo, Colo., Macon, Ga., Fort Worth and San Antonio, Tex., and Pocatello, Idaho reported the wettest May on record. Less significant rainfall statistics, such as, second wettest May, most precipitation in recent years, and record amounts for 24-hour periods, were noted by many stations. The largest amounts of precipitation for May (Chart II) were located along the band of high frequency of surface fronts (fig. 6) in Arkansas, Missouri, Oklahoma, and central Texas. Over 12 inches of precipitation were

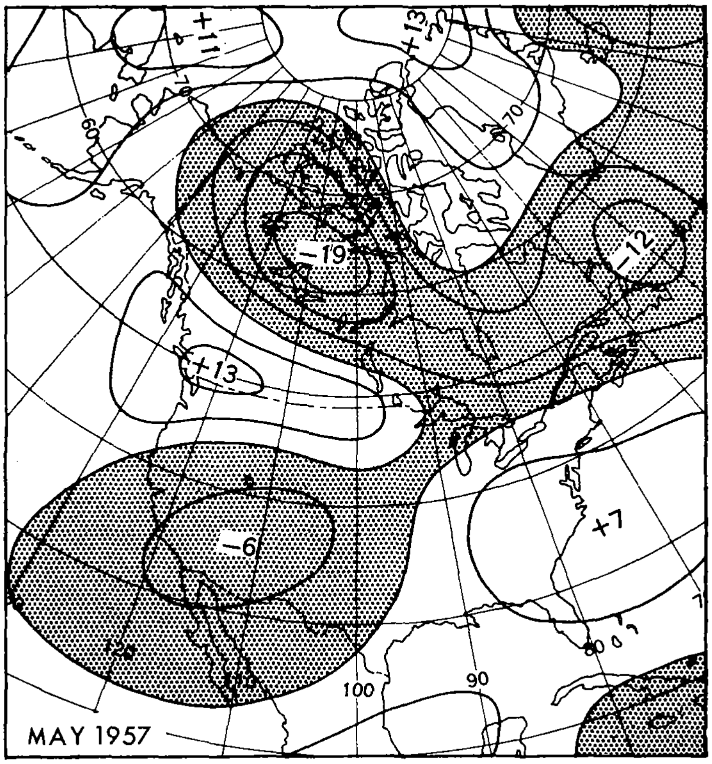

FIGURE 5.—Departure from normal of mean thickness (1000–700 mb.) for May 1957, with subnormal values stippled. Isoline interval is 50 feet and centers are labeled in tens of feet. Cold air dominated the Southwest and warm air the East, with their common boundary frequently located over the Great Plains.

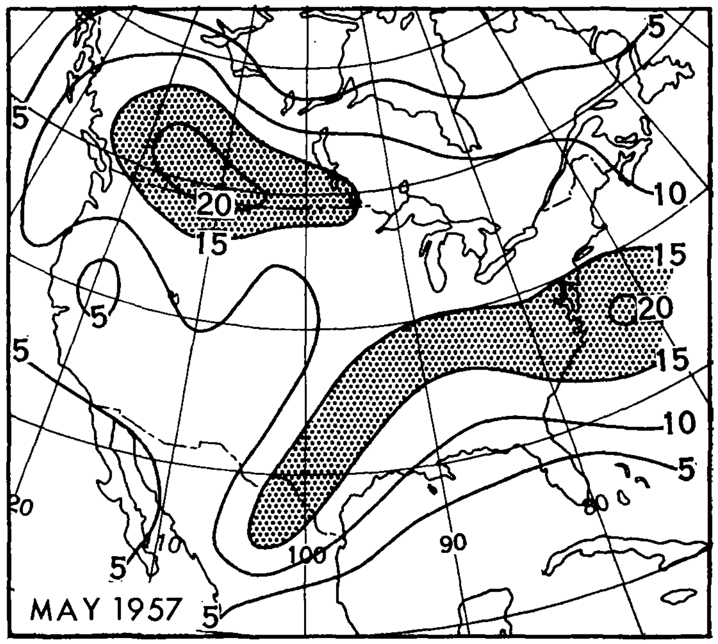

FIGURE 6.—Number of days in May 1957 with fronts of any type (within squares with sides approximately 430 nautical miles). Frontal positions taken from *Daily Weather Map,* 1:30 p. m., EST. Areas with 15 or more days with fronts are stippled. Note high frequency in southern Plains, where floods and severe local storms were prevalent.

reported by stations in Texas and Oklahoma, and as much as 10 inches in the Southeast around Georgia. This rainfall in the Southeast, which was as much as 300 percent of normal, occurred under subnormal monthly westerlies (fig. 3B), indicative of the fact that onshore flow at low levels was quite prevalent.

Over southern California stronger than normal westerly flow with cyclonic curvature (figs. 1 and 3B) enhanced orographic lifting, and 200 to 500 percent of normal rainfall was reported. Another contributing factor to the California rains was cyclonic activity at sea level at unusually low latitudes along and off the coast (Chart XI).

In general, precipitation this May was not only abnormally heavy but also very persistent in many regions of the United States. Rainfall was most persistent in a small area of Oklahoma which reported two or more inches in each of six out of seven weeks during the period April 15 to June 2, 1957 (fig. 7). A larger area composed of parts of Texas, Oklahoma, and Arkansas had two or more inches of rain in each of four weeks out of the same 7-week period. Some extremely large totals in inches for five weekly periods (mostly in May) are given in table 2.

Throughout the first half of May heavy rainfall was reported in the Southeast and southern Great Plains. During the fourth week (May 20–26) record-breaking rains continued in the southern Great Plains and extended into the middle Mississippi Valley. These excessive rainfalls produced widespread flooding of record proportions. The large, short-period (6 to 24 hours) precipitation amounts accompanying the violent convective activity resulted in numerous flash floods. The longer-period (1 to 7 weeks) almost continuously heavy amounts maintained many of the rivers in the southern Great Plains at flood or near flood stages during the entire month. A brief summary of weekly flood reports which appeared in the *Weekly Weather and Crop Bulletin, National Summary* [14] for the 5-week period April 29 to June 2, 1957 follows.

TABLE 2.—*Total precipitation for the indicated weeks in May at stations in the United States (preliminary report)*

Station	Total precipitation (inches)
April 29–May 5, 1957	
Miami, Fla	9.52
Montgomery, Ala	6.35
Wichita Falls, Tex	5.07
May 6–12, 1957	
Abilene, Tex	5.75
May 13–19, 1957	
Lakeland, Fla	5.84
May 20–26, 1957	
Fort Worth, Tex	8.49
Little Rock, Ark	8.90
Shawnee, Okla	6.56
Owensboro, Ky	7.07
Rapid City, S. Dak	4.35
May 27–June 2, 1957	
Madill, Okla	6.57
San Antonio, Tex	7.42

First week, April 29–May 5.—"Shower activity, continuing in Texas and Oklahoma during the past week, caused most streams in eastern and central Texas as well as in portions of Oklahoma and Arkansas to maintain very high flows. Flooding continued on major streams with moderate to severe lowland overflow resulting. Flash flooding also was reported on the Wichita River tributaries in vicinity of Wichita Falls, Tex.

"By the end of the period the lower Sabine and Red Rivers had still not crested and heavy inundation was reported on the Red River below Shreveport, La., at Grand Ecore and Alexandria, La., where flood crests 9 to 10 feet over flood stage were indicated from May 7 to 11. The Sabine River was nearing crest at Logansport, La., at a stage near 40 feet, 15 feet over flood stage. The forecast crests for the Red River are the second highest of record exceeded only by the record flood of 1945. At East Point, La., 250 families have been evacuated."

Second week, May 6–12.—Flood threats continued in Texas. A downpour of over 6 inches resulted in a devastating flash flood at Lampasas. Local flooding also was reported at Denver, Colo.

Third week, May 13–19.—Critical flooding developed during this week in Oklahoma. 13.07 inches of rain fell in 24 hours at Hennessey. The worst flood on record was reported on the Cimarron River. Flooding also occurred in Kansas, Montana, and California.

Fourth week, May 20–26.—This was an extremely bad week as record-breaking rainfall covered the southern Great Plains and extended into the Mississippi Valley. Floods reintensified in Texas and Oklahoma, and were now also reported in Arkansas, Kentucky, and Tennessee.

Fifth week, May 27–June 2.—Widespread flooding occurred in Arkansas and eastern portions of Texas and Oklahoma.

These heavy rains during May definitely alleviated, except for small regions in western Texas and New Mexico, the extended drought which has plagued the southern Great Plains for several years.

The heavy rainfall in the United States was logically related to the circulation, since the following observed conditions, which have been previously discussed, are well recognized as precipitation "producers": (1) mid-tropospheric trough in the western United States and ridge in the East with southwesterly flow over most of the country, (2) strong inflow of maritime tropical airmasses at low levels, (3) surface fronts and horizontal temperature gradients, in this case, cold in the West and warm in the East, and (4) overlying 200-mb. jet stream with maximum winds upstream from the storm area. The interaction of these meteorological parameters will be discussed further when the circulation for the week May 20–26 is examined in the following section.

Concomitant with the heavy rainfall in the southern and central Plains was record-breaking severe storm activity. During May 1957 approximately 231 tornadoes were reported, an all-time record (records start in 1916 [13]). The previous high for May is 219 tornadoes which

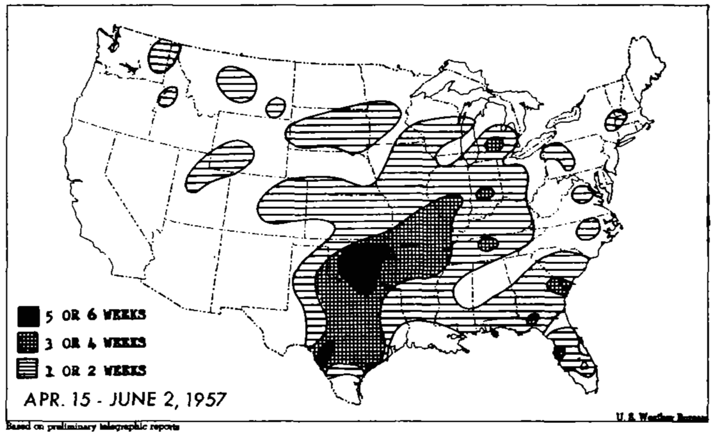

FIGURE 7.—Number of weeks during the 7-week period April 15–June 2, 1957 that the total weekly precipitation was two or more inches. Rainfall was abnormally persistent in the southern Plains, for some areas received two or more inches in as many as five or six weeks during this period.

was observed in 1955 when the circulation was quite similar to that of this May [16]. This month's circulation pattern with a ridge in the East and trough in the West is very similar to the circulation that existed during other Mays when tornadoes were common, namely in 1955, 1953, 1949, and 1933. After comparing monthly mean 700-mb. circulations with the tornado records from 1933 to 1957, the author is convinced that an extremely good relation exists between these large-scale averaged flow patterns and local severe storm activity measured over a similar time period.

There was considerable week-to-week variability in the number of tornadoes reported (table 3). The most severe weather occurred during the fourth period (May 20–26) when 124 tornadoes were observed. The majority of tornadoes this May occurred east of the Rocky Mountains and west of the Mississippi River, although there were a few widely scattered tornadoes over many other parts of the United States. The region of most dense incidence was Oklahoma, northern Texas, and Kansas. Neighboring States reported smaller but sizeable numbers of tornadoes.

Although tornadic activity and flooding in the Plains dominated the weather picture for seven consecutive weeks starting April 15, there were noteworthy reports early in May of minor droughts and forest fires in New England and the Middle Atlantic States. The first week of May the forest fire hazard intensified in New England and most forests were "closed." The period from April 9

TABLE 3.—*Number of tornadoes for the indicated weeks in May 1957 (preliminary reports)*

Week in 1957	Number of tornadoes
April 29–May 5	40
May 6–12	25
May 13–19	49
May 20–26	124
May 27–June 2	49

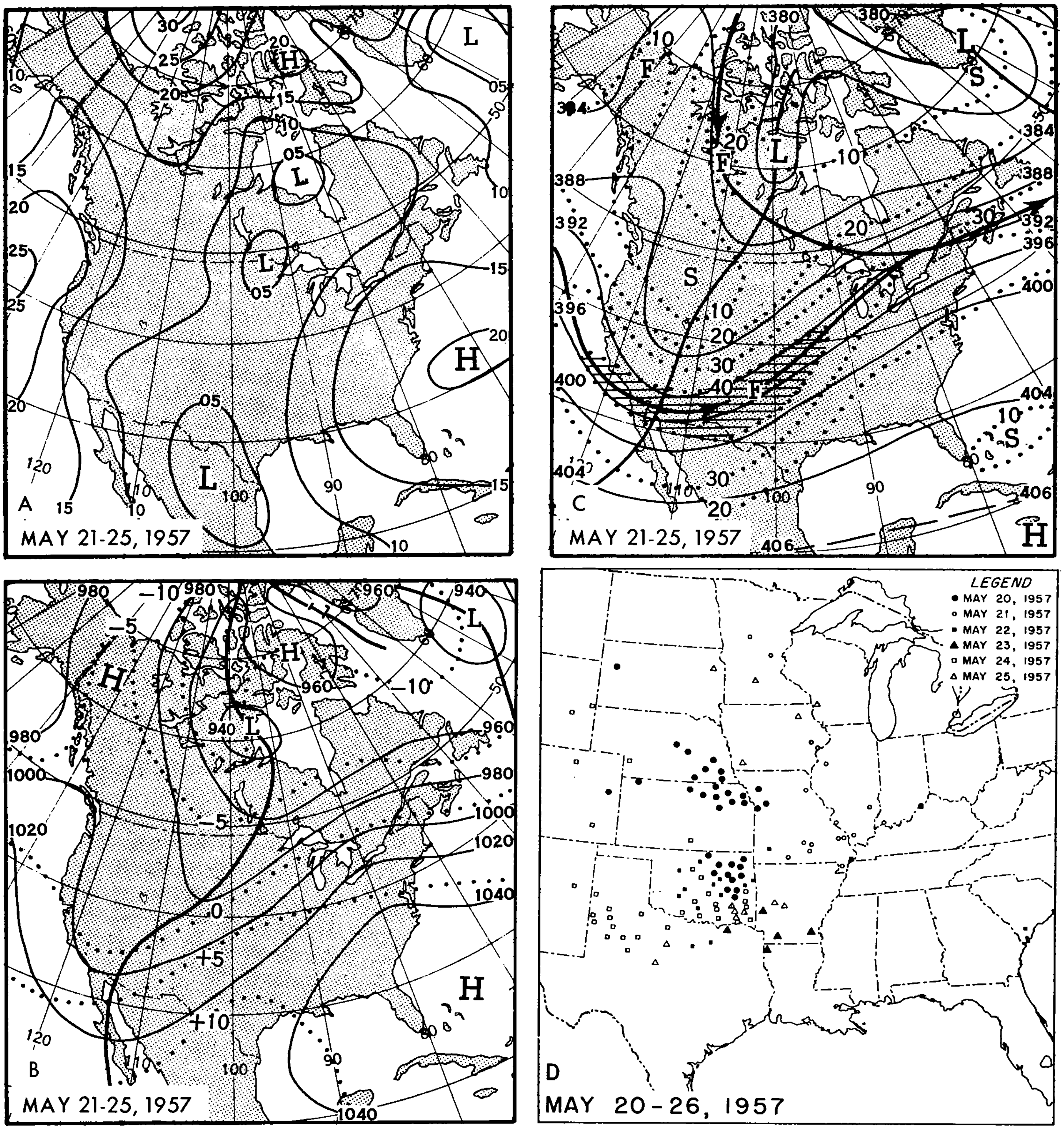

FIGURE 8.—(A) Five-day mean sea level isobars (in millibars with hundreds omitted). Sharp trough over Great Plains was flanked by pronounced ridges along both coasts of United States. (B) Mean 700-mb. contours (solid, in tens of feet) and isotherms (dotted, in ° C.). Configuration of both the contours and isotherms was favorable for heavy rain and severe weather in the southern Plains and central Mississippi Valley. (C) Mean 200-mb. contours (solid, in hundreds of feet) and isotachs (dotted, in meters per second). Wind speeds greater than 40 m. p. s. are hatched. Pronounced jet maximum over the Southwest was conducive to severe weather in the Plains. A, B, and C all for the period May 21-25, 1957. (D) Location of tornadoes reported over the United States during the week May 20-26, 1957, a record for any week. Symbols indicate the date of occurrence. Note the large numbers on May 20 and 24. None were reported on May 26. Data furnished by Office of Climatology, U. S. Weather Bureau. These are early reports and subject to minor change.

to May 10 was the driest 30-day period in April and May on record at the Blue Hill Meteorological Observatory (Milton, Mass.) [17]. During the second week, rains in New England relieved dry conditions and removed the forest fire problem, but little or no precipitation occurred in the Middle Atlantic States and fire hazard conditions mounted. However, during the third week widespread rains over most of the northeastern United States alleviated the drought in both regions.

In contrast to the interesting precipitation regime of May, the temperature picture contained few highlights. Average temperature anomalies for the month (Chart I-B) were small, and the weekly departures were not extreme, one of the largest being only $-12°$ F. in Utah the fourth period (May 20–26). The monthly anomalies correspond well with the mean 700-mb. height (fig. 1) and thickness (fig. 5) anomalies. Temperatures were above normal in the Northwest and Southeast and subnormal over the Southwest with an extension northeastward to the Great Lakes.

4. THE CIRCULATION ASSOCIATED WITH ONE OF THE WORST TORNADO WEEKS ON RECORD, MAY 20–26, 1957

In considering the month as a whole the extreme nature of the weather of this week was often referred to. Temperature anomalies were the largest for the month, critical flooding was widespread, and a record number of tornadoes was reported. We have also seen that the general circulation of May was conducive to severe weather anomalies in the Great Plains. In other words the weather regimes of shorter duration, about a week, were superimposed on, or "couched" in, a long-period or monthly flow pattern favorable for tornadoes. It will be further shown that during May 20–26 the daily perturbations were also "couched" in 5-day mean or long waves which encouraged severe storm activity.

Many areas in the Great Plains and Mississippi Valley were afflicted by tornadoes this week (fig. 8D). Destructive tornadoes were particularly prevalent in Oklahoma and northern Texas. Exceptionally bad days were May 20 and 24 when over 30 storms were reported. It is not surprising that a great many tornadoes occurred, because the atmospheric circulation was very favorable for severe local storms.

Beebe [1] published composite charts for conditions which accompanied severe local storms in selected areas of the Mid-West. The distribution of reported tornadoes for this week falls mainly in Beebe's area II. His composite charts for this area (fig. 3 in [1]) bear a striking resemblance to the 5-day mean charts centered on this period (fig. 8). At sea level a sharp trough over the Great Plains was flanked by pronounced ridges along each coast (fig. 8A). The importance of the eastern ridge for severe weather has long been recognized since it is the mechanism that advects moist tropical air over the continent. Apparently the presence of the western ridge serves two major purposes: (1) by flux of vorticity it helps to maintain the trough and ridge downstream, and (2) it deploys the cold maritime Pacific airmasses into the Southwest. In general, then, the surface flow pattern possessed a configuration which brought maritime Pacific and maritime tropical airmasses into juxtaposition over the Plains.

The 700-mb. chart (fig. 8B), which was similar to the sea level map, had a wave of large amplitude with a deep trough over the northern Plains and southern Rocky Mountains, which favored intensification of the daily perturbations as they moved through western United States. The contour pattern was remarkably similar to the corresponding composite (fig. 3 in [1]) and the absolute heights were approximately the same. The mean isotherms also had the same configuration as those of the composite map, and the no-change line (line of apparent zero advection) was located in the southwesterly flow well east of the 700-mb. trough line and quite close to the area of dense tornado reports (fig. 8D).

The indicated cold advection, east of the 700-mb. trough and over the low-level southerly flow, tended to increase the lapse rate in that area. Early studies emphasized the importance of differential advection in producing vertical instability prior to the incidence of severe local storms, but recent studies [11] suggest that it plays only a minor role, although it still may be significant. This period the flow at the mid-tropospheric level (fig. 8B) suggests both advection from the south of the relatively dry air that normally overlies the tropical air and advection from the west of cool Pacific air. The combination of advection of warm moist air surmounted by advection of cool dry air could produce the convectively unstable stratification of airmasses which commonly precedes severe local storms.

At 200 mb. the contour field (fig. 8C) was similar to that at the lower levels with the trough in the West even more pronounced. The associated wind field was also favorable for tornadoes in the southern Great Plains. The jet maximum in the Southwest was situated with its center over eastern New Mexico, so that there is a high probability that northern Texas, Oklahoma, and Kansas, and to a lesser degree central Texas, Missouri, and Iowa were under a favored area of upper divergence which could "trigger" severe local storms [2].

Summarizing, we see that a combination of mid- and low-tropospheric flow patterns prevailed which could produce the convectively unstable lapse rates that are known to precede severe local storms, and a high-tropospheric wind field existed that could lift these lower-level airmasses and "trigger" the tornadoes.

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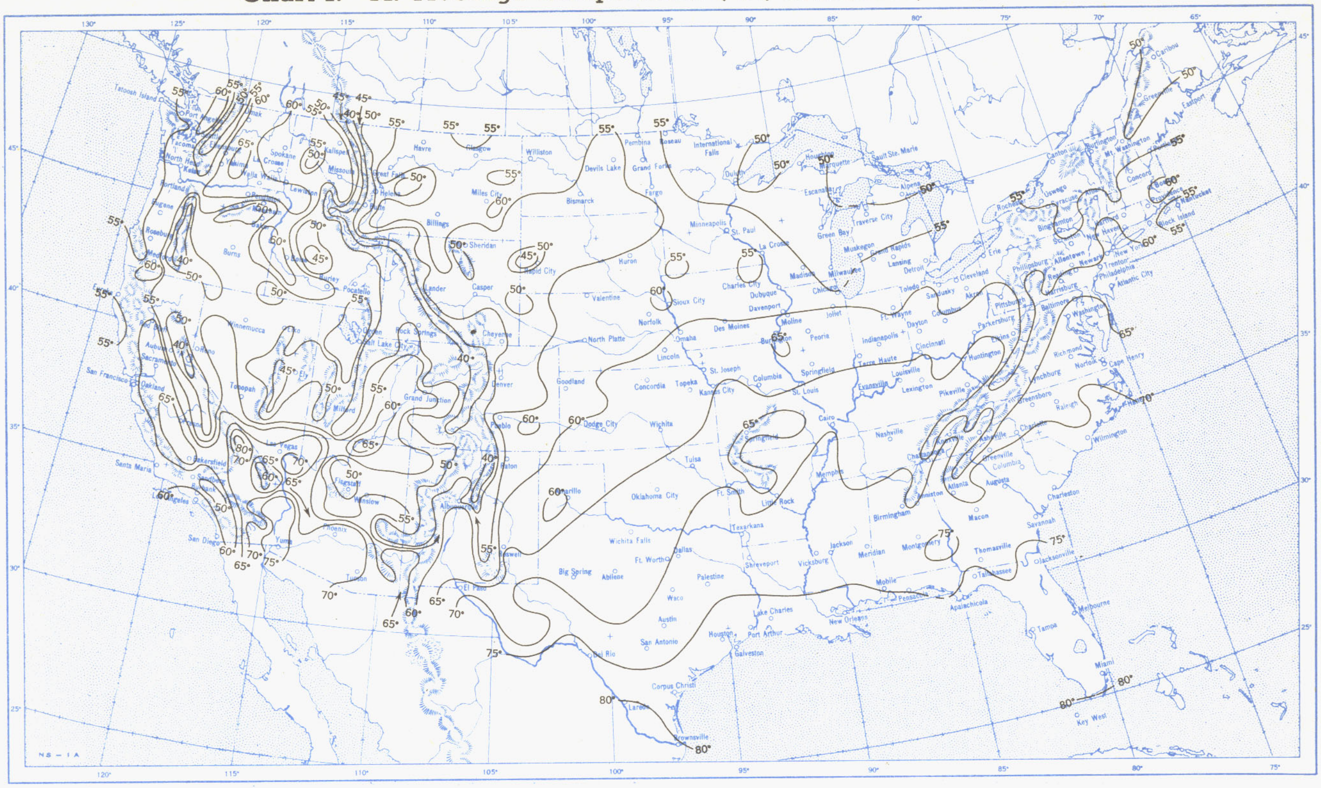
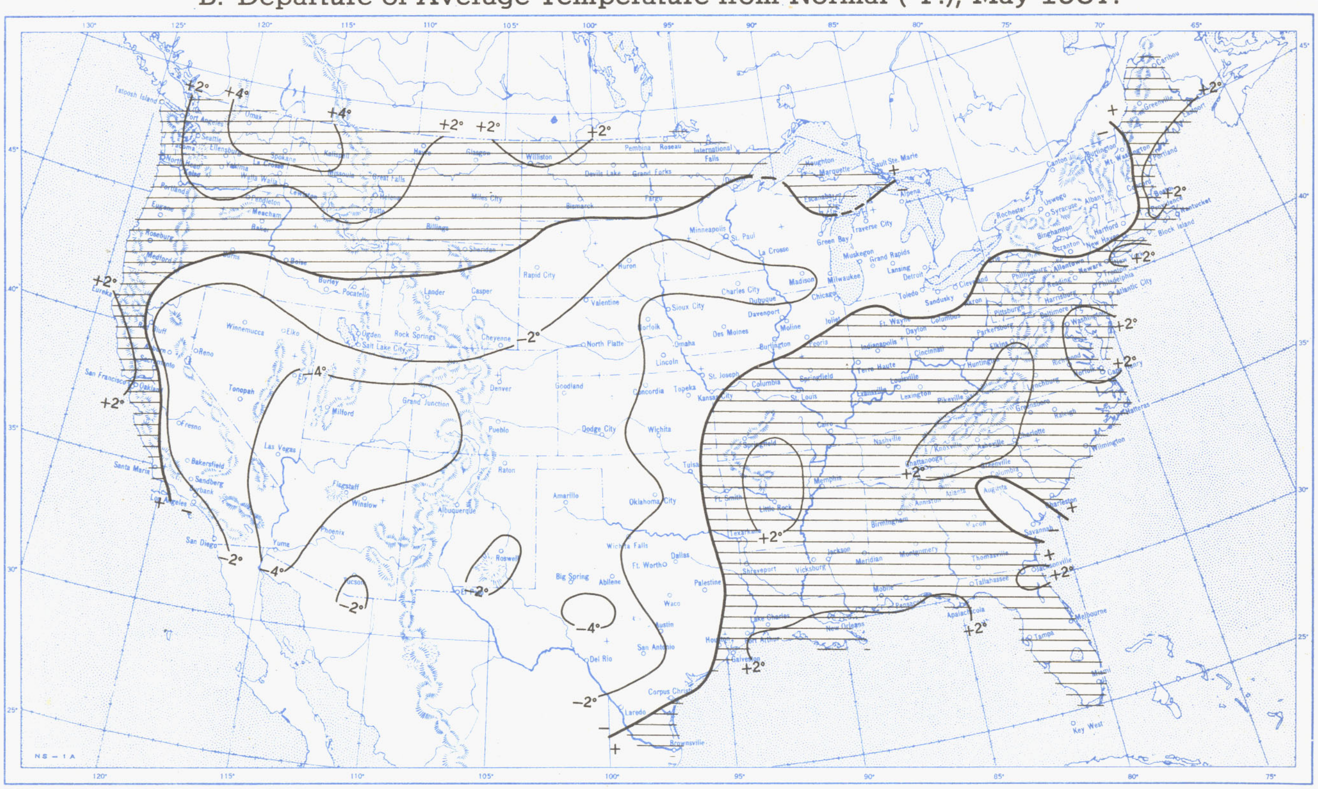
Chart I. A. Average Temperature (°F.) at Surface, May 1957.

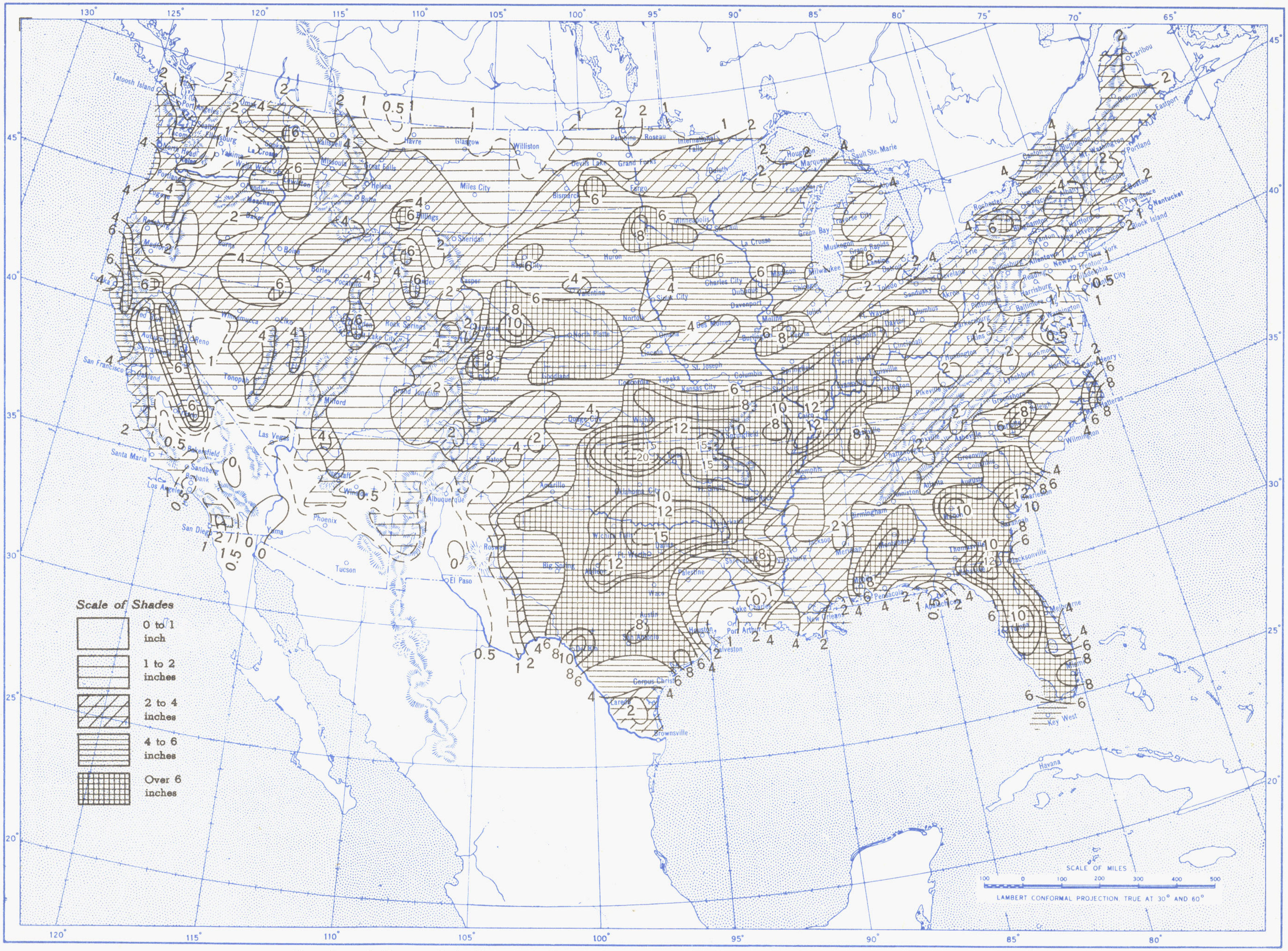


B. Departure of Average Temperature from Normal (°F.), May 1957.



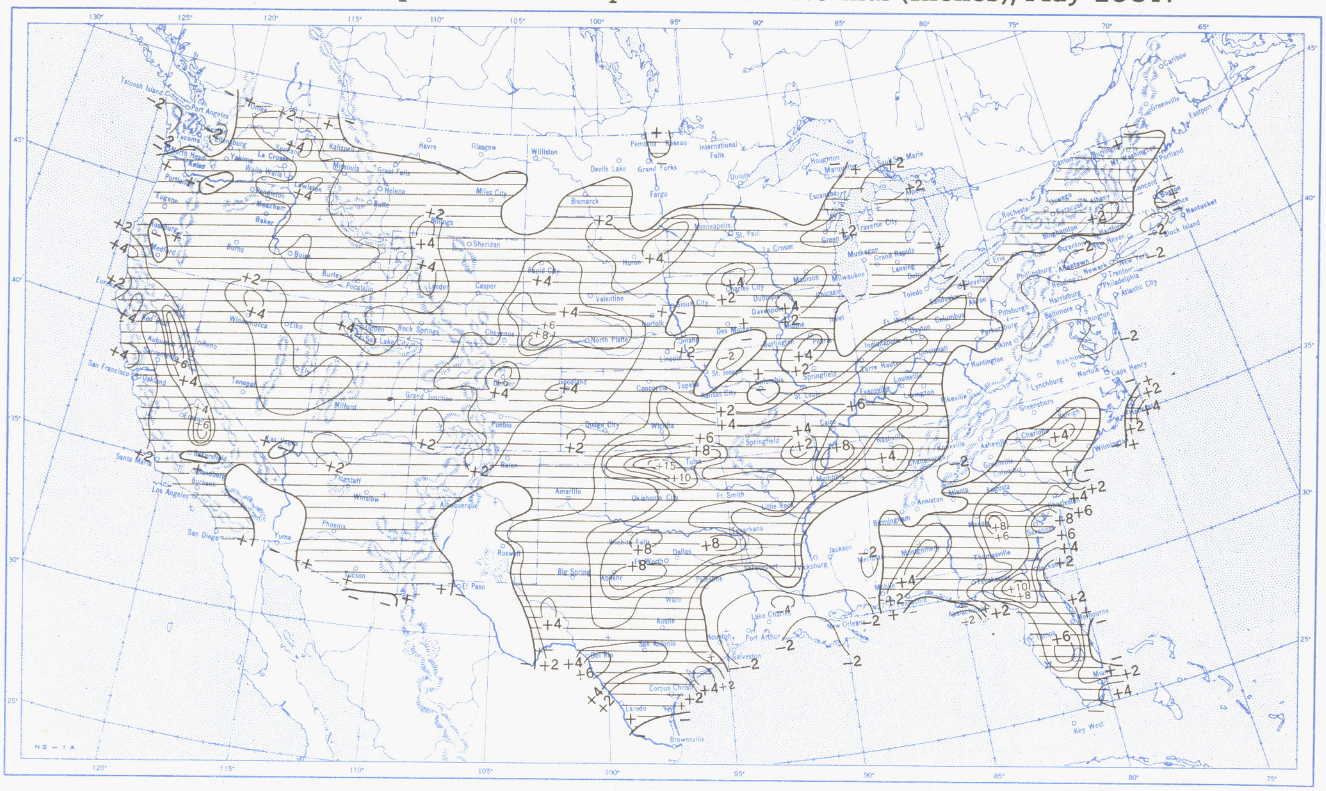
A. Based on reports from over 900 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.
B. Departures from normal are based on the 30-yr. normals (1921-50) for Weather Bureau stations and on means of 25 years or more (mostly 1931-55) for cooperative stations.

Chart II. Total Precipitation (Inches), May 1957.

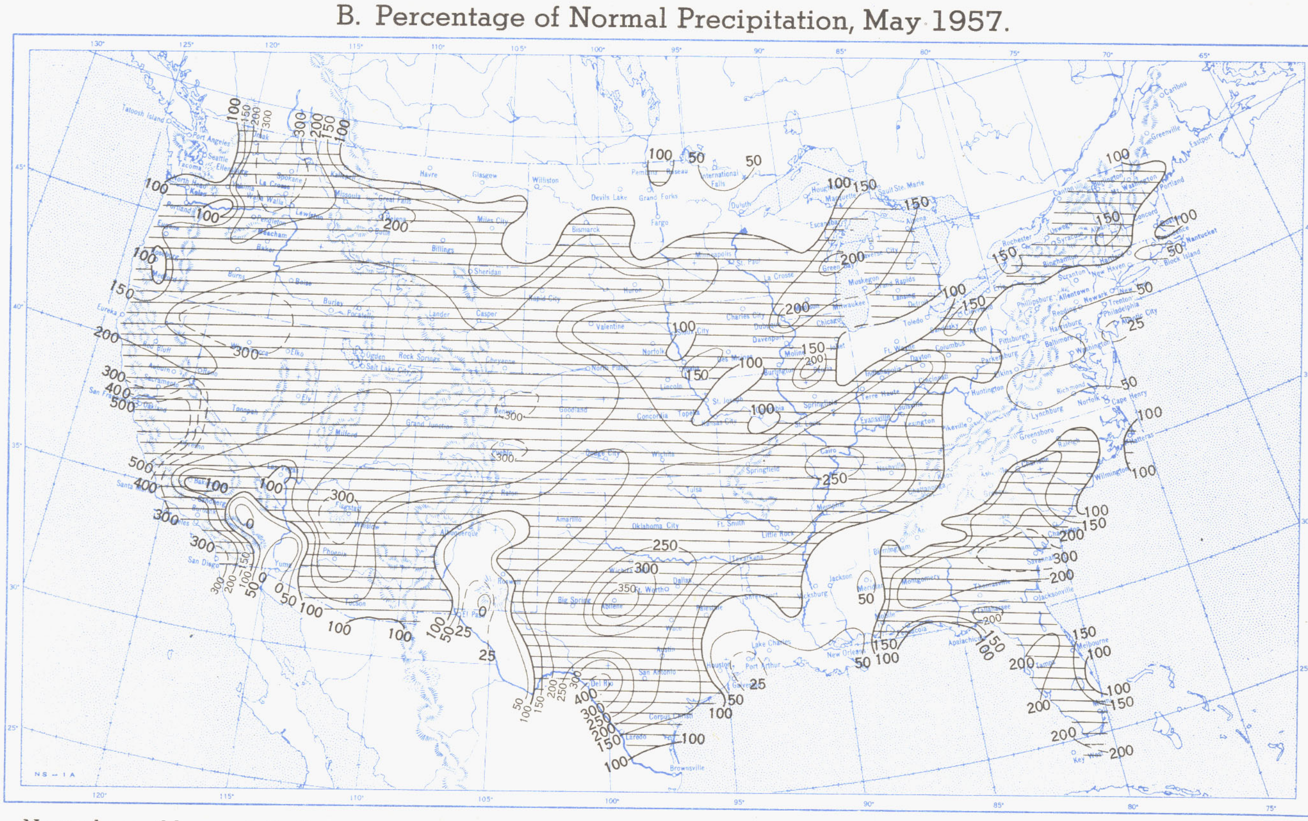


Based on daily precipitation records at about 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), May 1957.

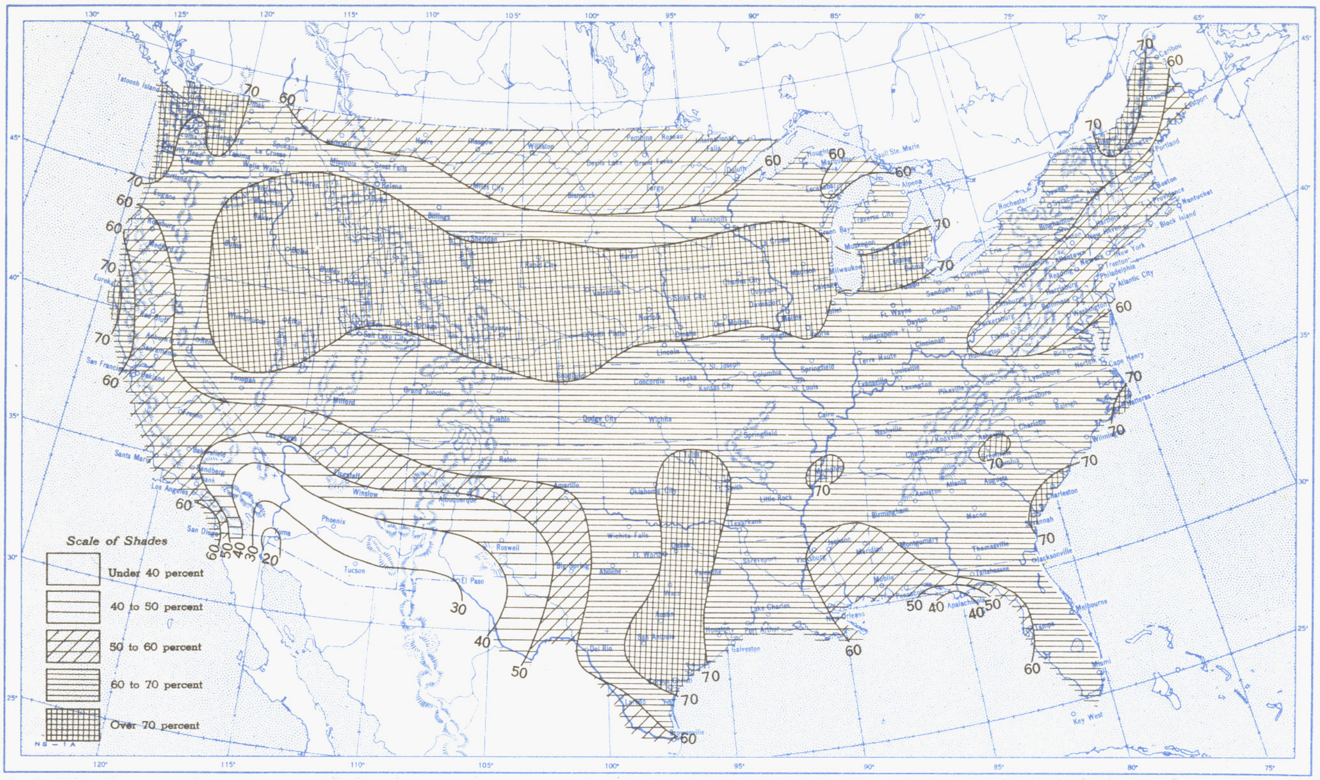


B. Percentage of Normal Precipitation, May 1957.

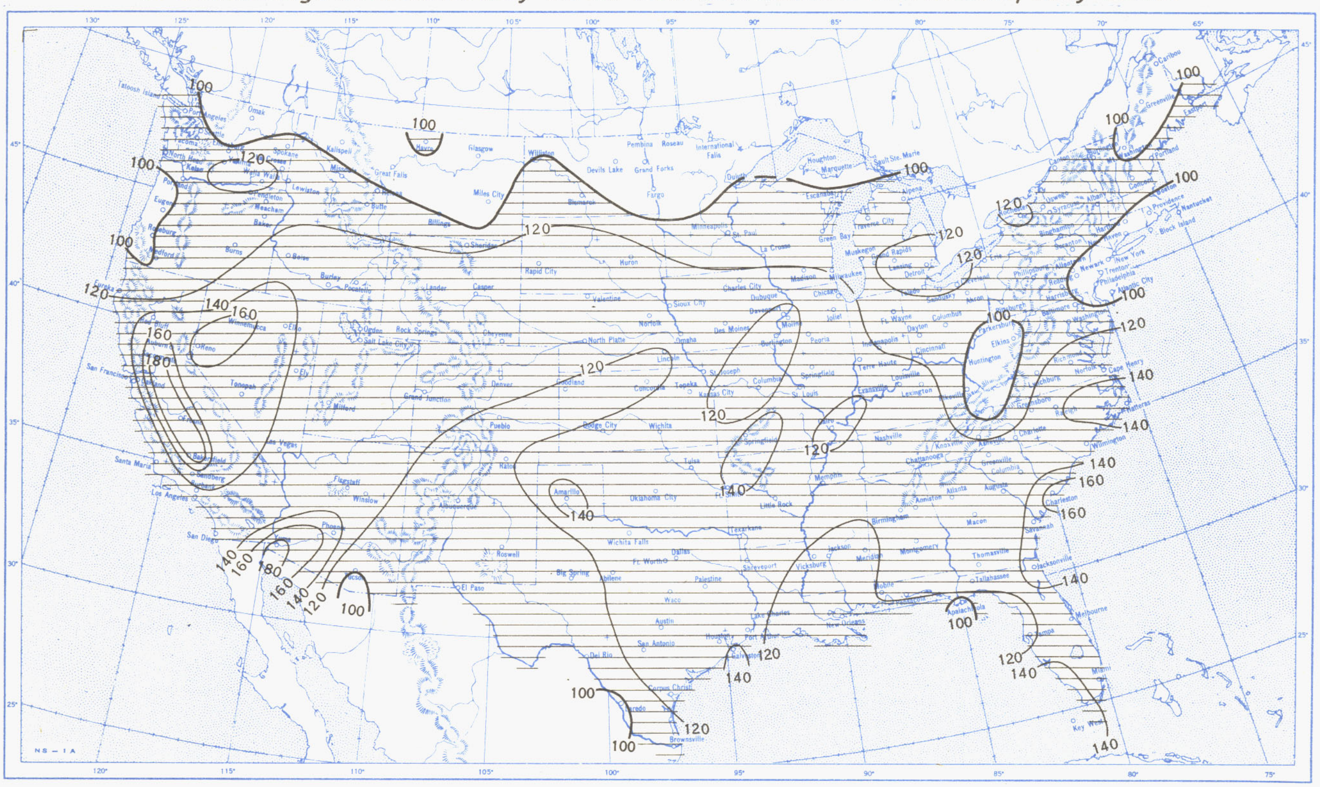


Normal monthly precipitation amounts are computed from the records for 1921-50 for Weather Bureau stations and from records of 25 years or more (mostly 1931-55) for cooperative stations.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, May 1957.

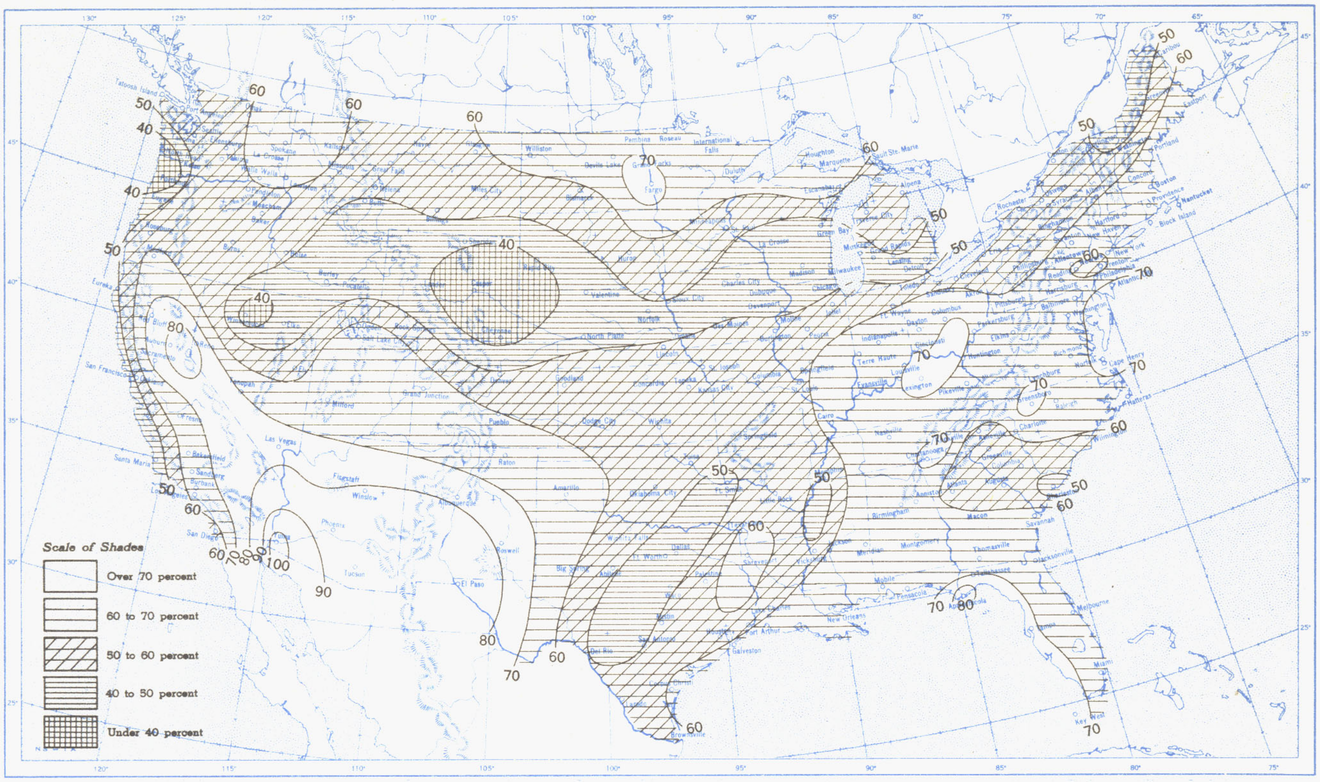


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, May 1957.

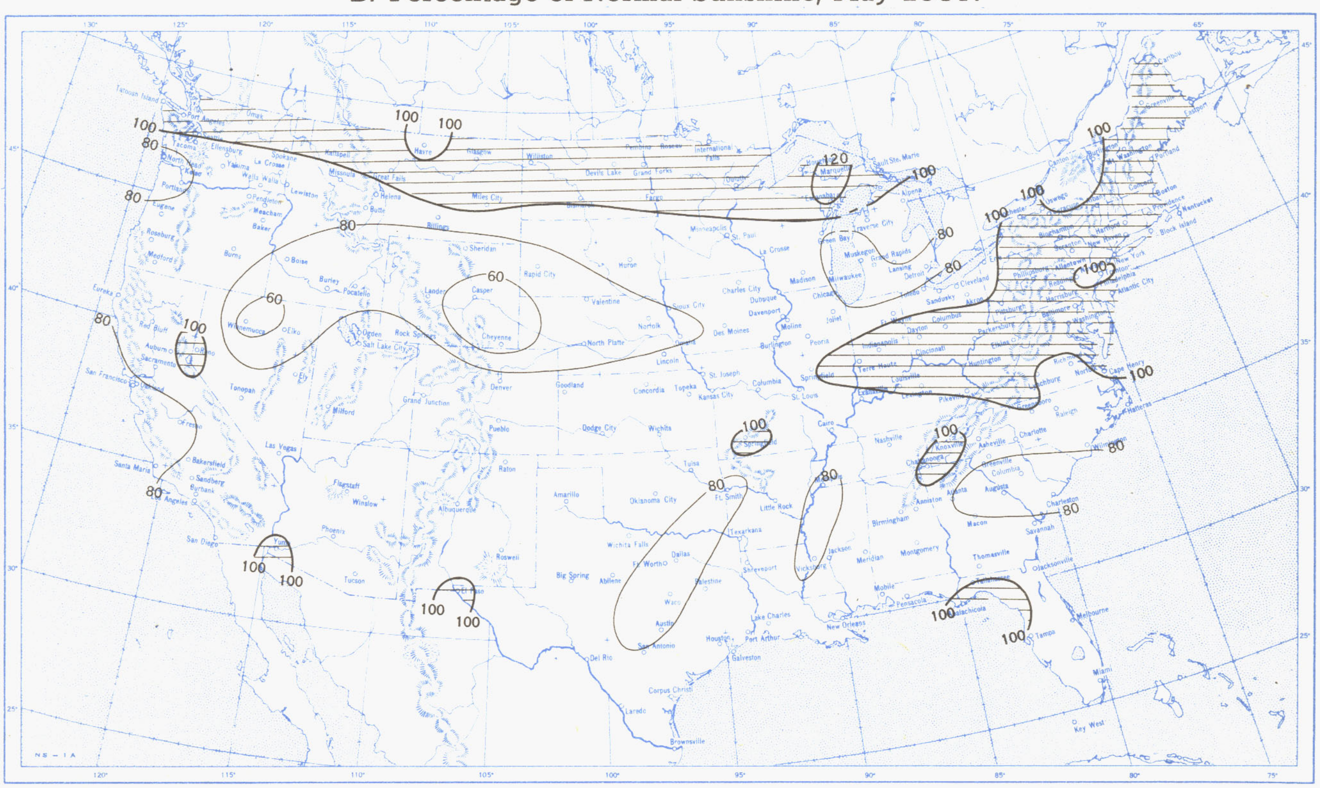


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, May 1957.



B. Percentage of Normal Sunshine, May 1957.



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, May 1957. Inset: Percentage of Mean Daily Solar Radiation, May 1957. (Mean based on period 1951-55.)

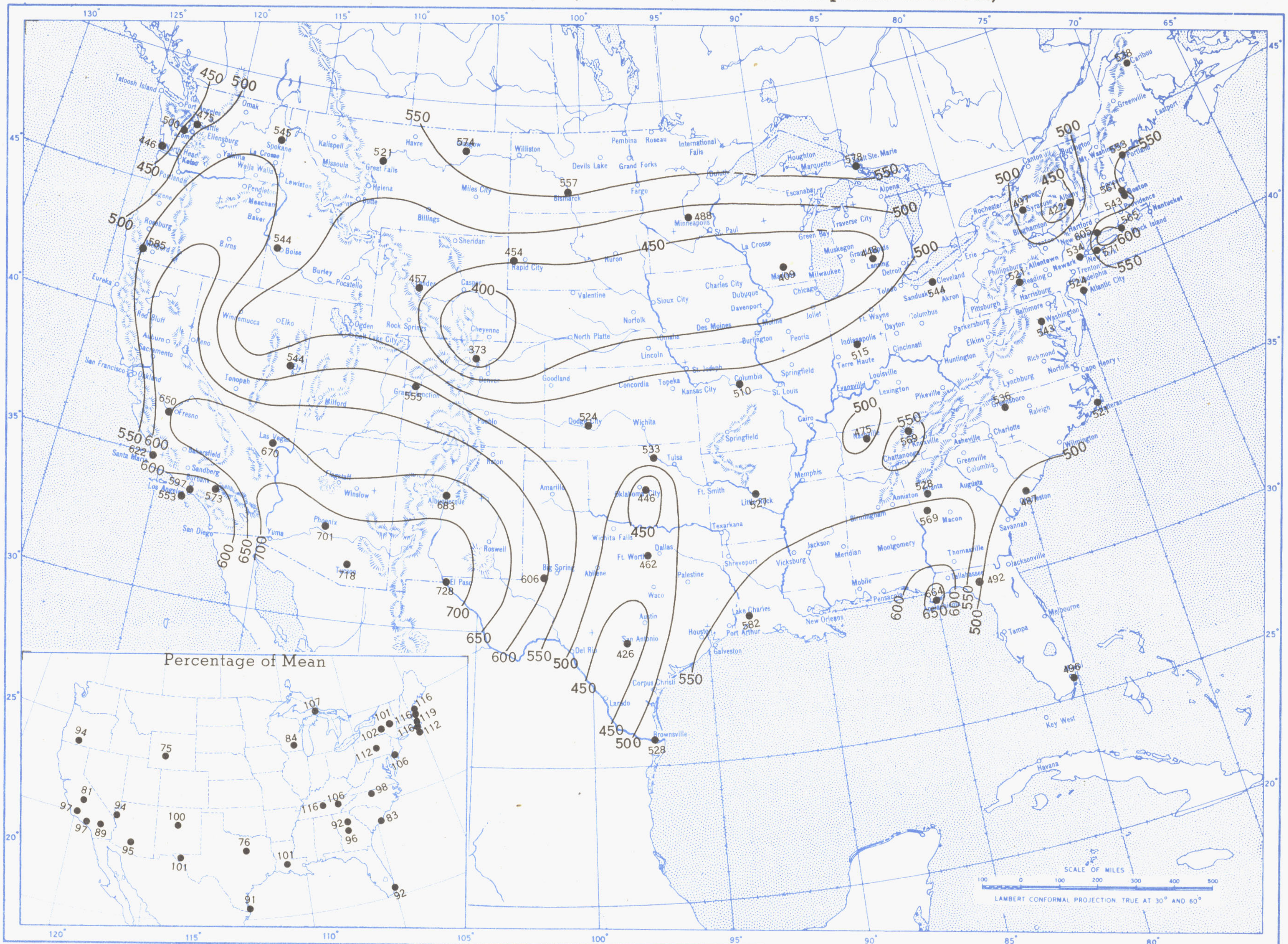
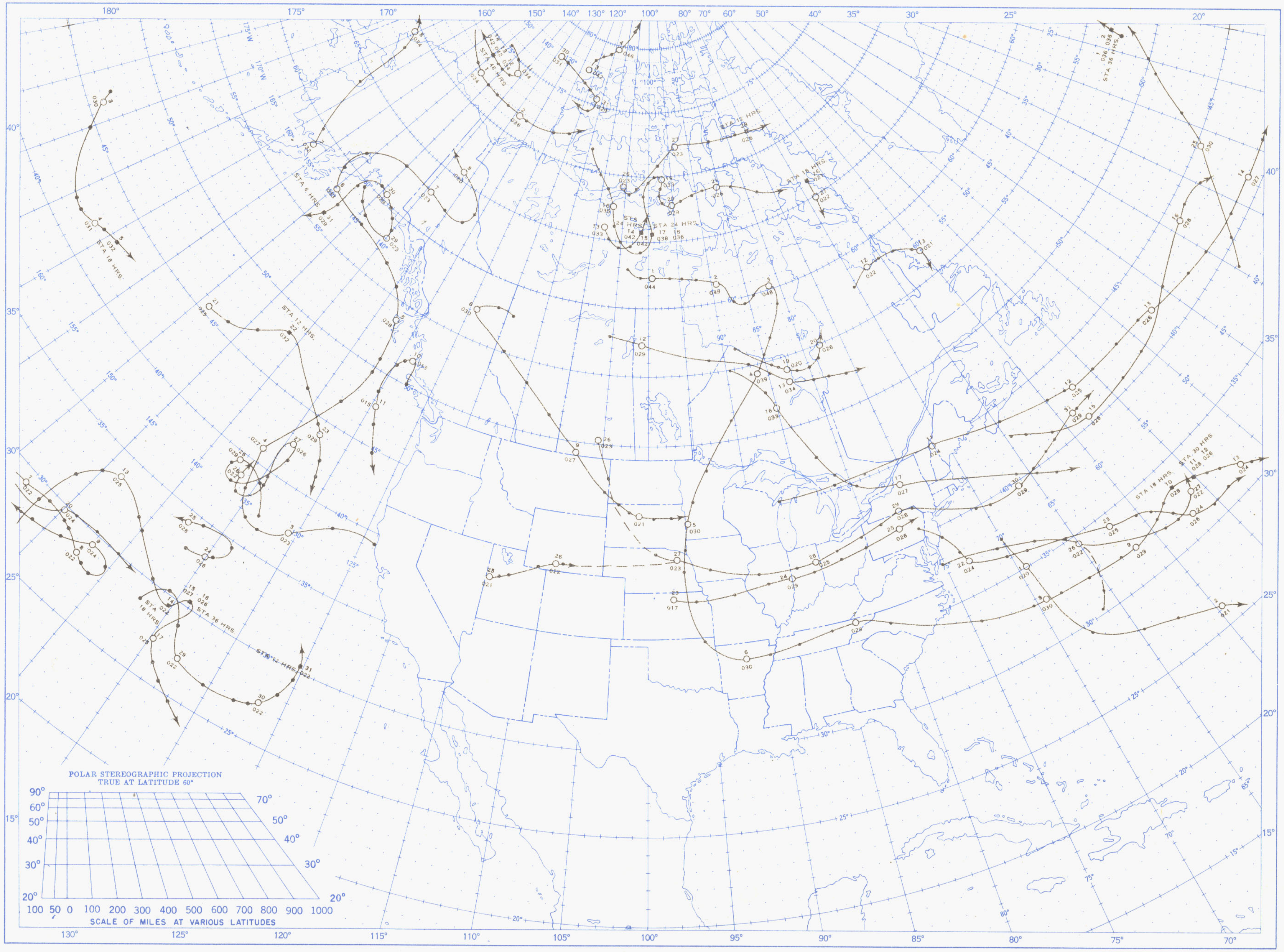


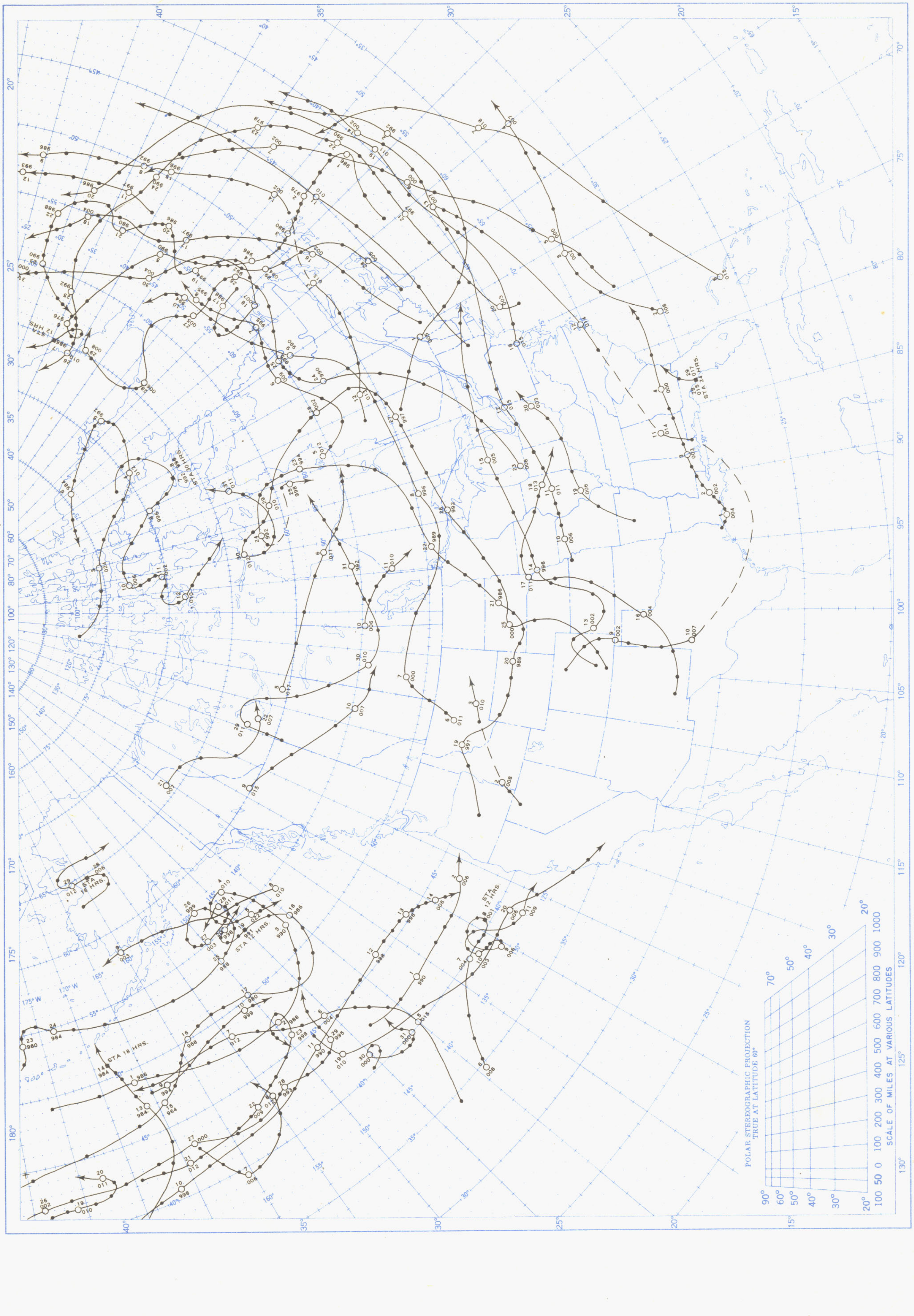
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm. $^{-2}$). Basic data for isolines are shown on chart. Further estimates are obtained from supplementary data for which limits of accuracy are wider than for those data shown. The inset shows the percentage of the mean based on the period 1951-55.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, May 1957.



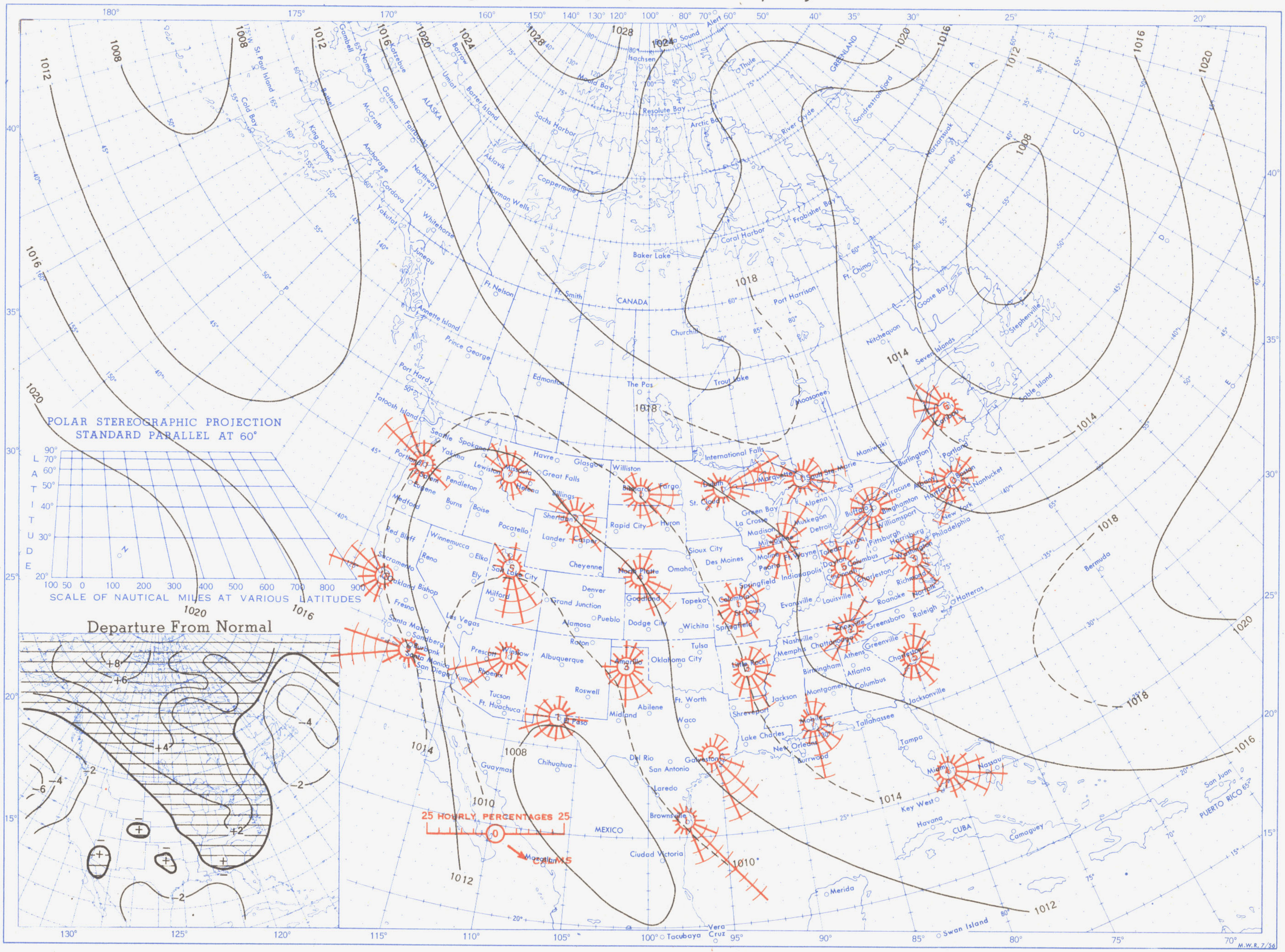
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position.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

Chart X. Tracks of Centers of Cyclones at Sea Level, May 1957.



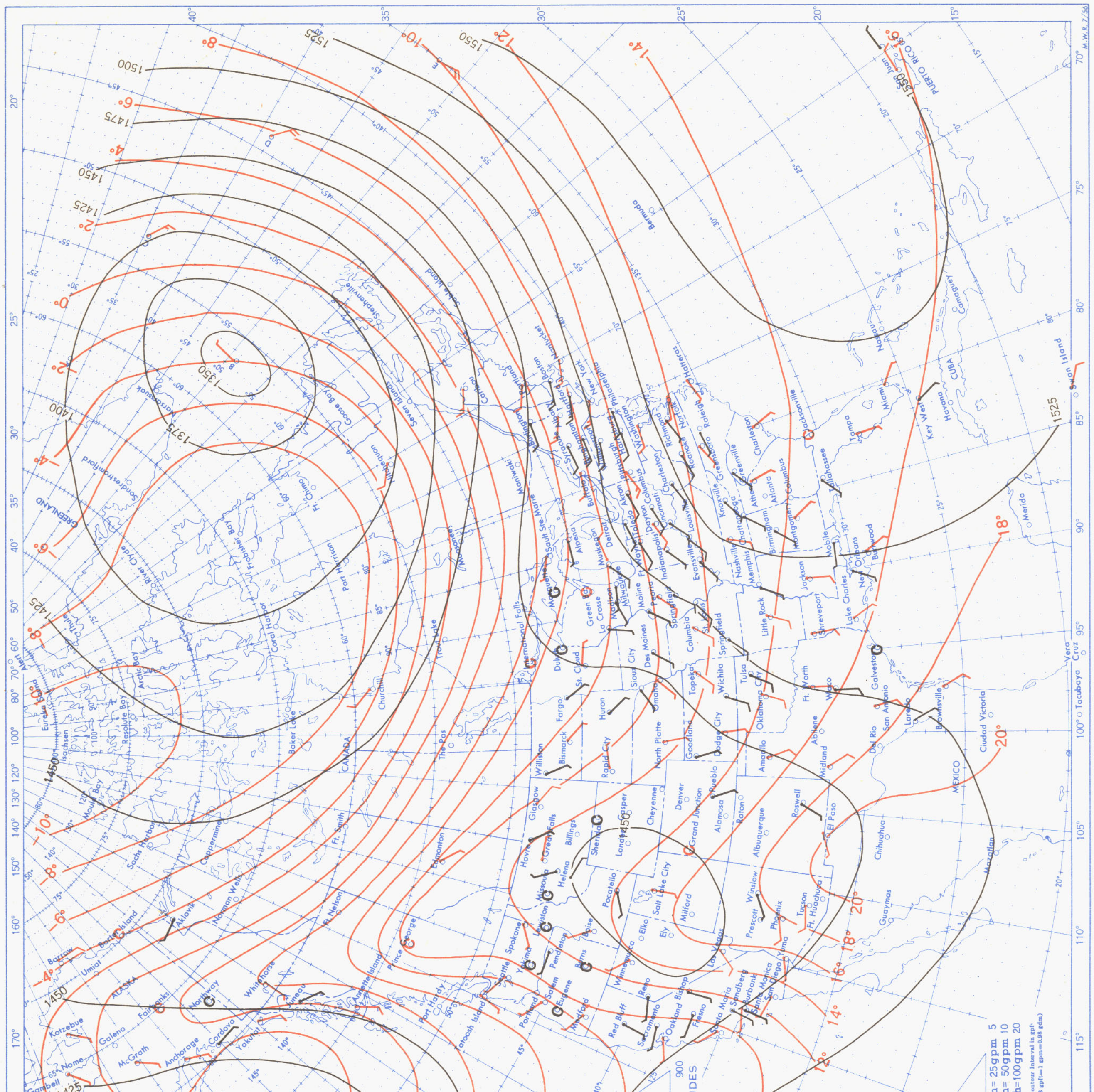
Circle indicates position of center at 7:30 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, May 1957. Inset: Departure of Average Pressure (mb.) from Normal, May 1957.



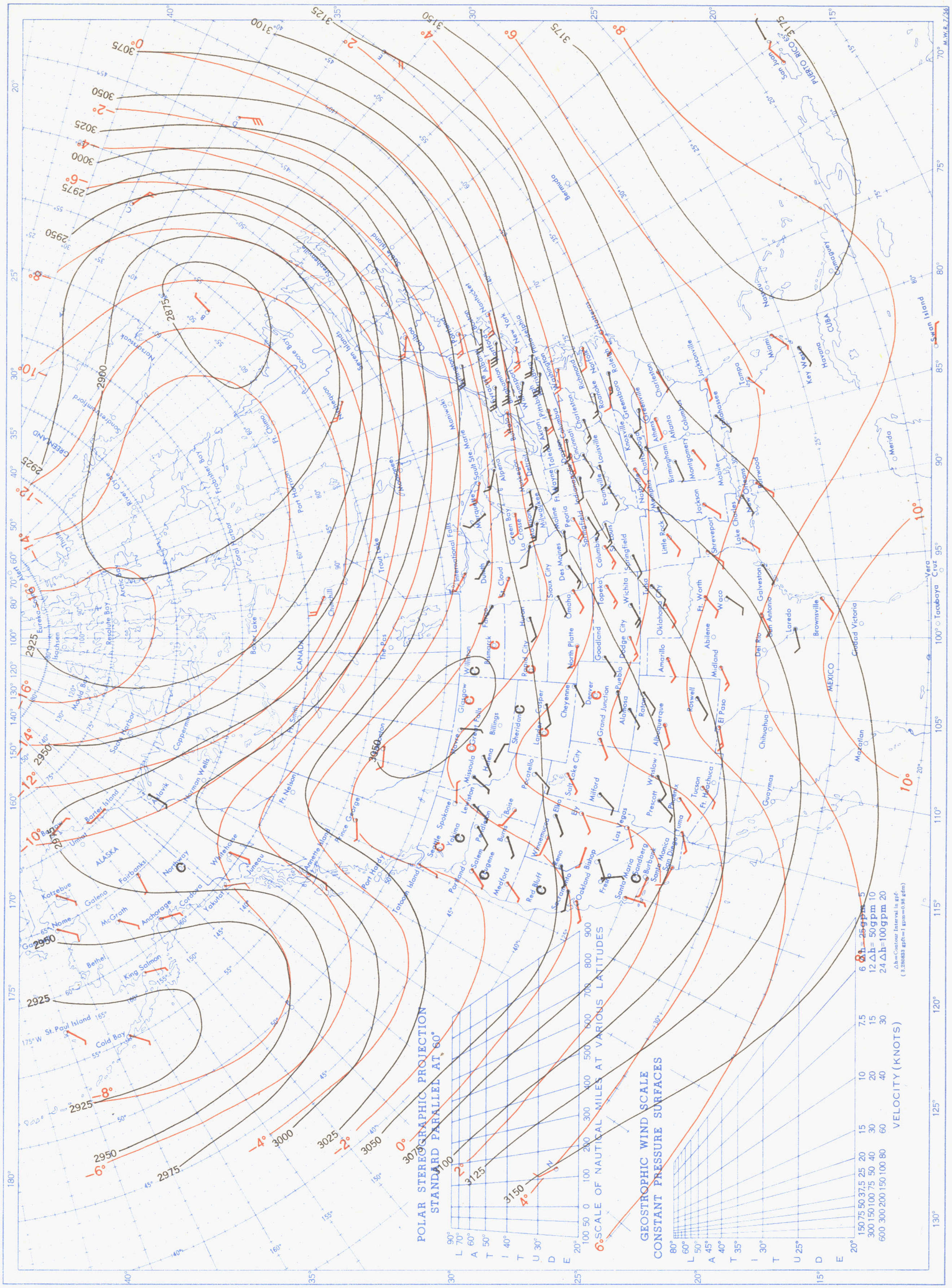
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections 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. 850-mb. Surface, 0300 GMT, May 1957. Average Height and Temperature, and Resultant Winds.



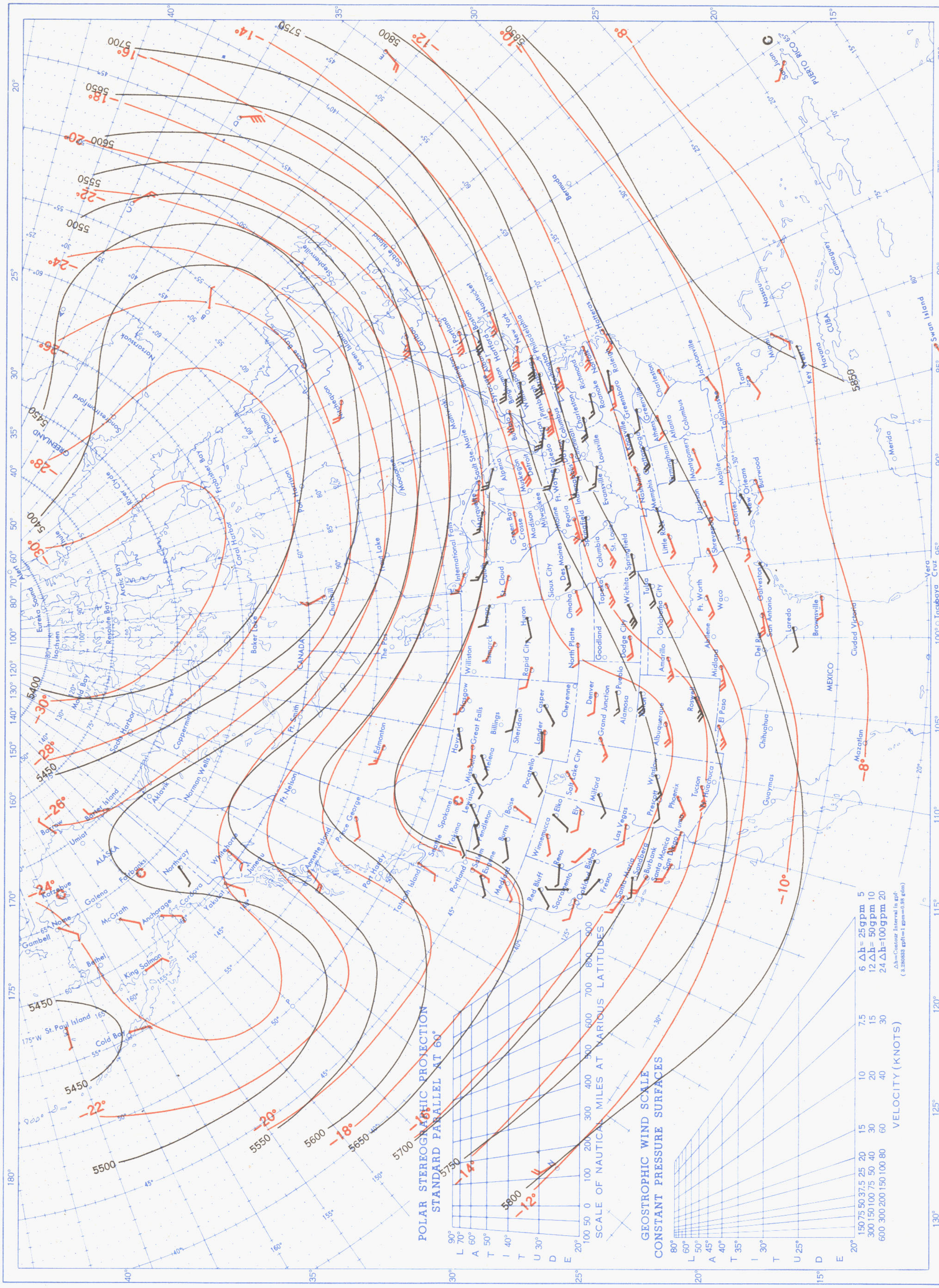
Height in geopotential meters (1 g.p.m. = 0.98 dynamic meters). Temperature in °C. Wind speed in knots; flag represents 50 knots, full feather 10 knots, and half feather 5 knots. Winds shown in red are based on rawins taken at the indicated pressure surface and time. Those in black are based on pibals taken at 2100 GMT and are for the nearest standard height level.

Chart XIII. 700-mb. Surface, 0300 GMT, May 1957. Average Height and Temperature, and Resultant Winds.



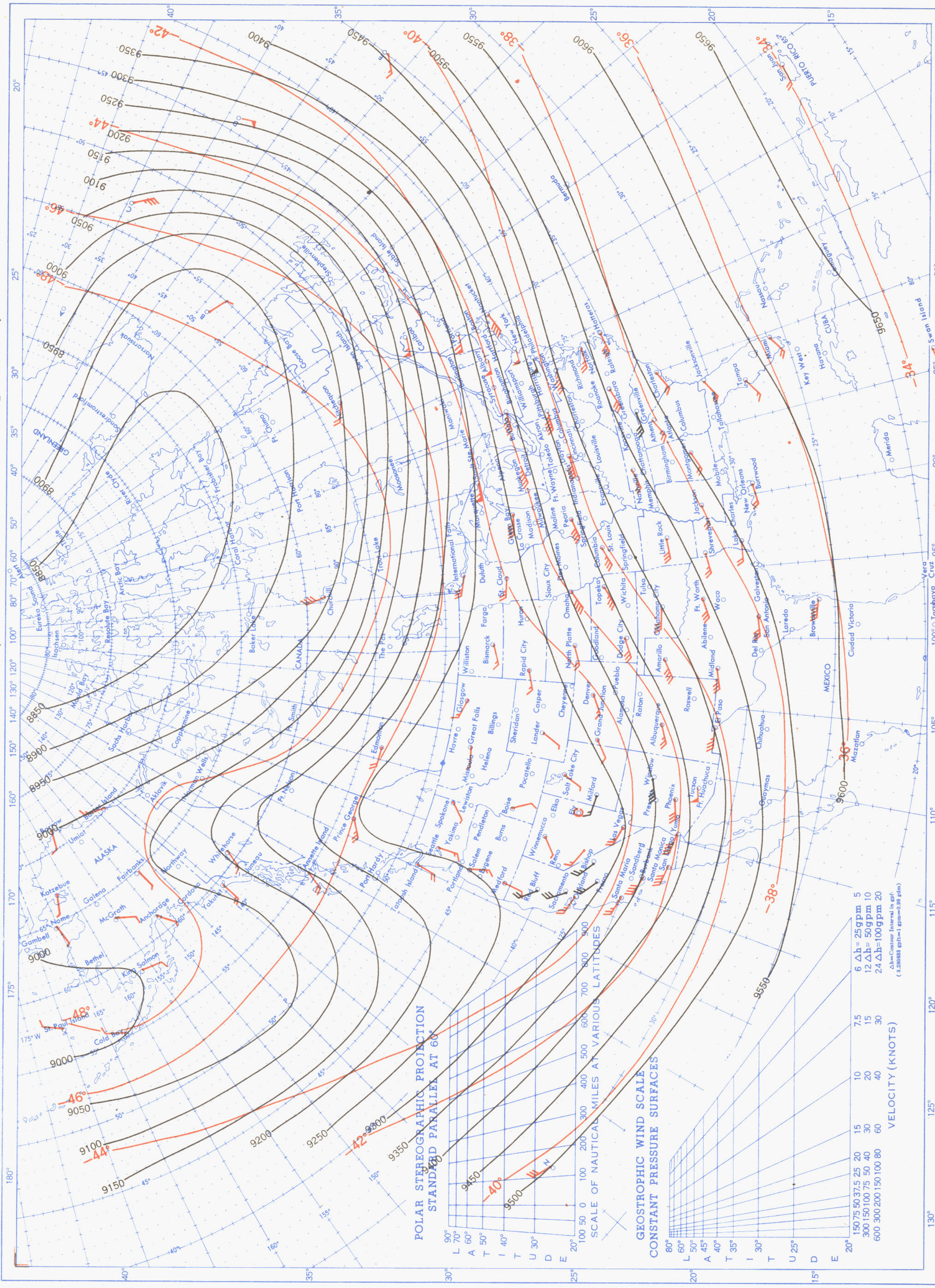
See Chart XII for explanation of map.

Chart XIV. 500-mb. Surface, 0300 GMT, May 1957. Average Height and Temperature, and Resultant Winds.



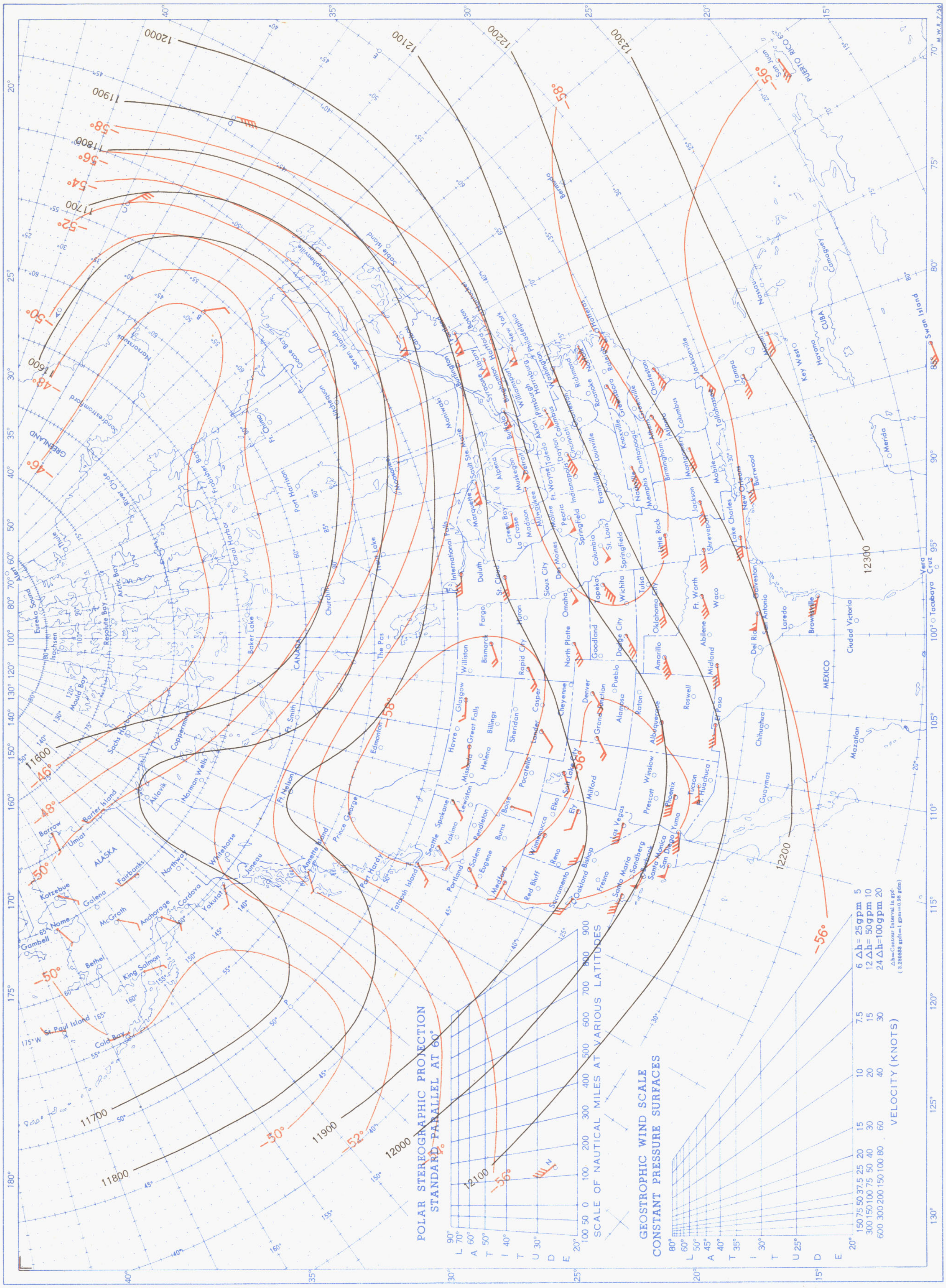
See Chart XII for explanation of map.

Chart XV. 300-mb. Surface, 0300 GMT, May 1957. Average Height and Temperature, and Resultant Winds.



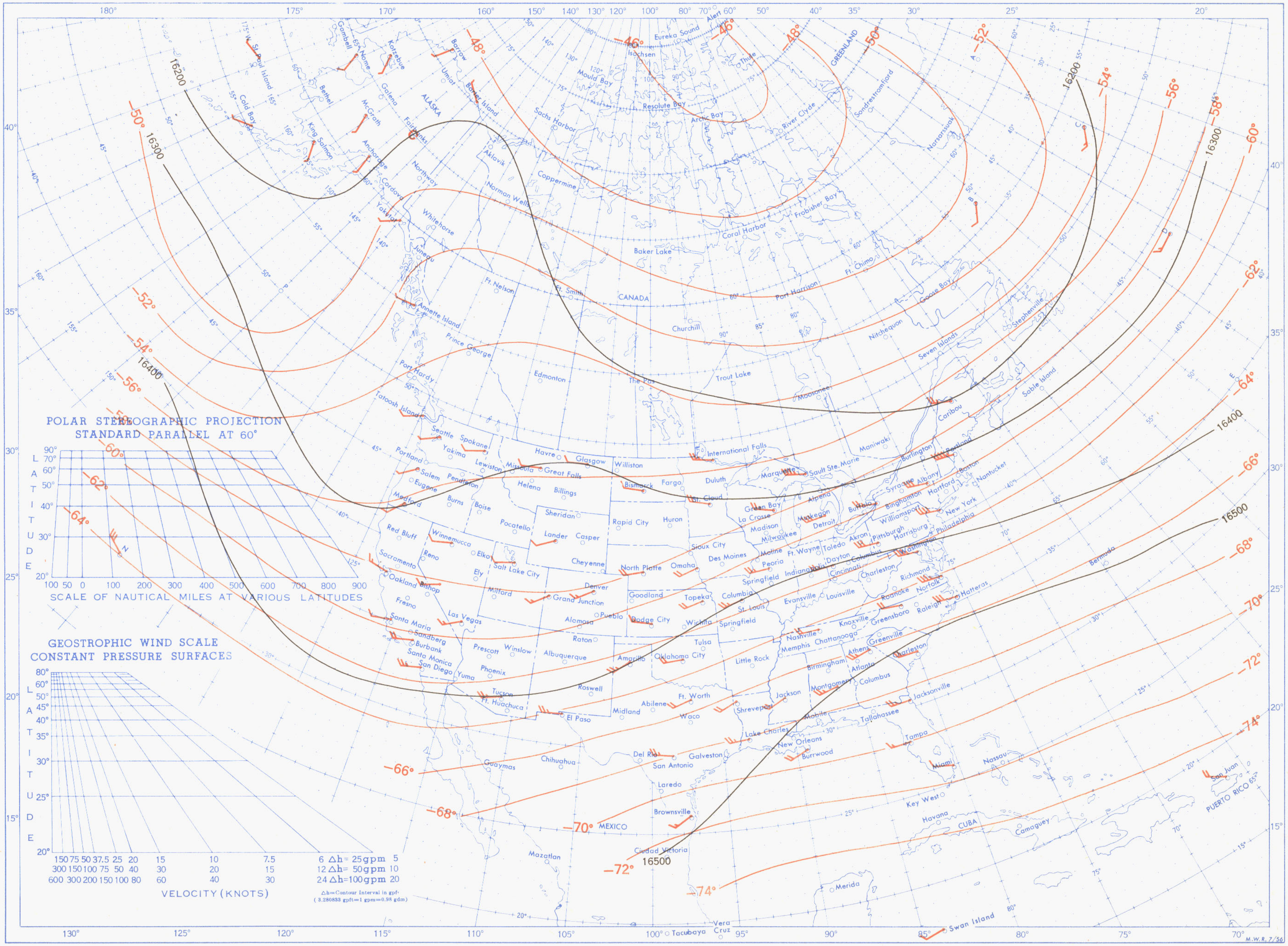
See Chart XII for explanation of map.

Chart XVI. 200-mb. Surface, 0300 GMT, May 1957. Average Height and Temperature, and Resultant Winds.



See Chart XII for explanation of map. All winds are from rawin reports.

Chart XVII. 100-mb. Surface, 0300 GMT, May 1957. Average Height and Temperature, and Resultant Winds.



See Chart XII for explanation of map. All winds are from rawin reports.