DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

MONTHLY WEATHER REVIEW

JAMES E. CASKEY, JR., Editor

Volume 84
Number 4

APRIL 1956

Closed June 15, 1956
Issued July 15, 1956

TORNADO COMPOSITE CHARTS

ROBERT G. BEEBE

Severe Local Storms Forecast Center, U. S. Weather Bureau, Kansas City, Mo.

[Manuscript received March 30, 1956; revised May 3, 1956]

ABSTRACT

Composite charts of height (or sea level pressure), temperature, and dew point were prepared for the surface, 850-, 700-, and 500-mb. levels for tornado occurrences in 6 different areas in the United States. Cases selected for inclusion in these composite charts were mostly based upon the occurrence of 3 or more tornadoes within any one of the 6 areas during a 12-hour period. The number of cases ranged from 17 to 66 in any one area with a total of 229 cases. These charts present a mean picture of synoptic conditions from 0 to 12 hours before the outbreak of tornadoes for each of the 6 areas. In spite of seasonal and geographical differences in data, the similarity of patterns is striking.

1. INTRODUCTION

The preparation of composite charts for selected weather situations provides one means for identifying larger-scale features which are common to these situations. Also, composite charts clearly depict anomalies or departures from normal. The primary purpose of this study was to determine the common characteristics of tornado situations with varying geographic locations as well as anomalies. It was expected that such a study would provide some basis for further research regarding the larger-scale weather features of the environment in which tornadoes develop. It was originally planned that these data would be analyzed in considerable detail and the findings discussed in the paper. However, time has not yet permitted such an analysis, and so it was decided to make the analyzed charts, and some tentative conclusions, more widely available.

2. SELECTION AND COMPILATION OF DATA

The work reported upon here represents an extension of a project initiated by the Short Range Forecasting Development Section of the Weather Bureau, the results of which were given limited distribution in manuscript form [1]. The present study includes composite charts for the continental United States of height (or sea level pressure), temperature, and dew point for the surface, 850-, 700-,

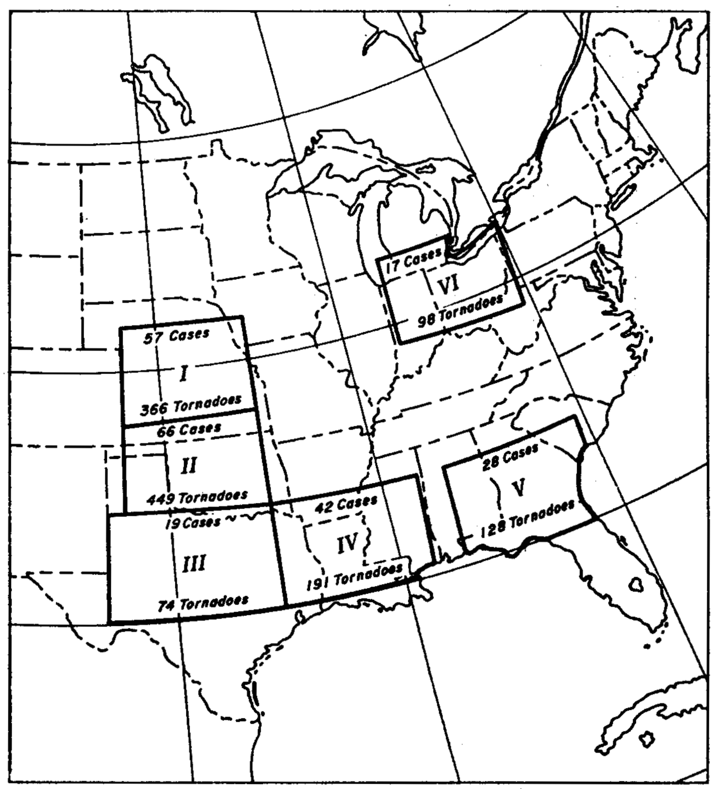


FIGURE 1.—Map showing areas in which tornadoes were reported for compilation of data for composite charts. Upper number shows number of cases, lower, number of tornadoes.

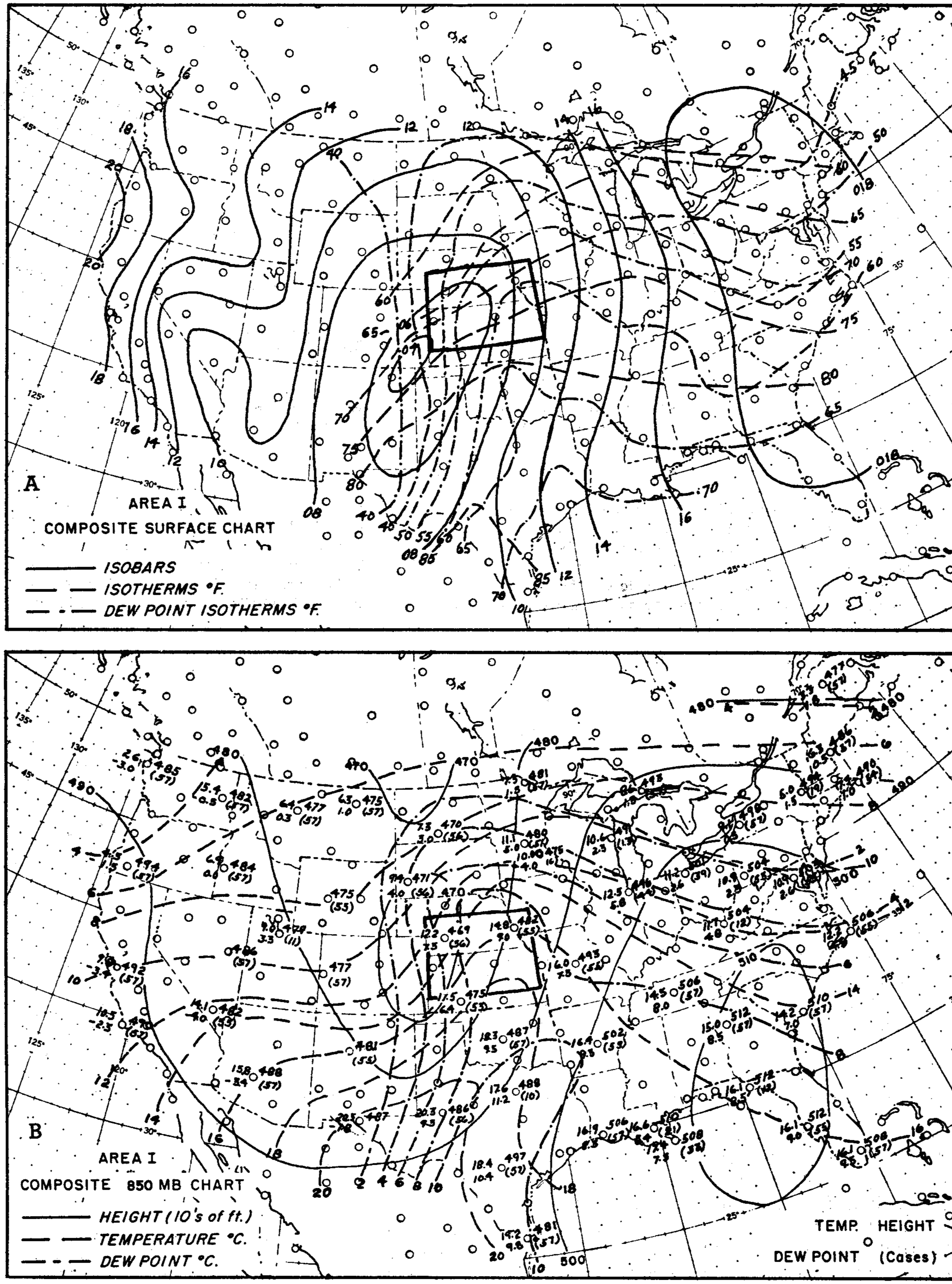
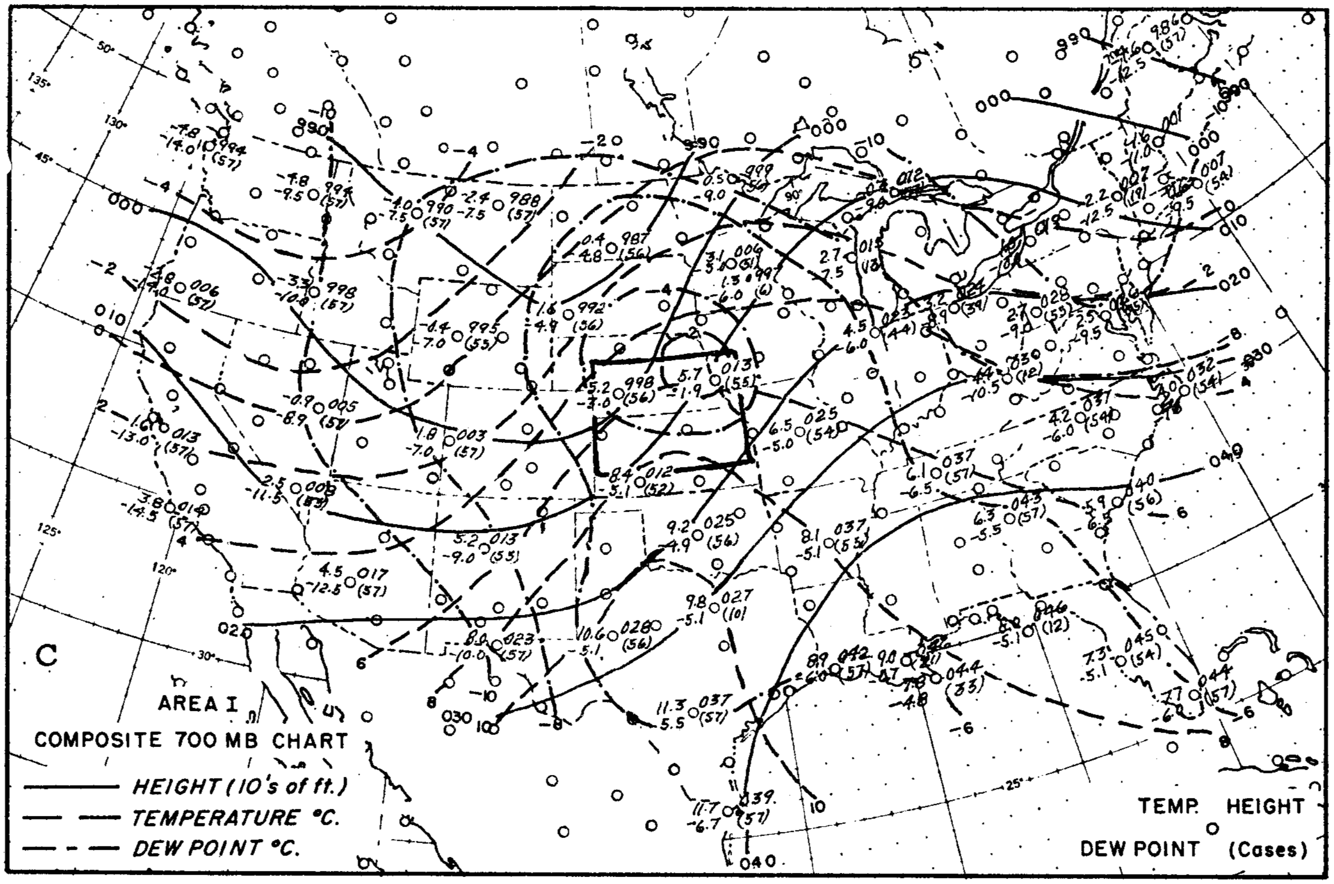


Figure 2.—Composite maps based upon data from 57 different tornado situations (366 tornadoes) that occurred in area I (outlined) from March through June, 1945 through 1953. (A) Surface, (B) 850 mb., (C) 700 mb., (D) 500 mb.



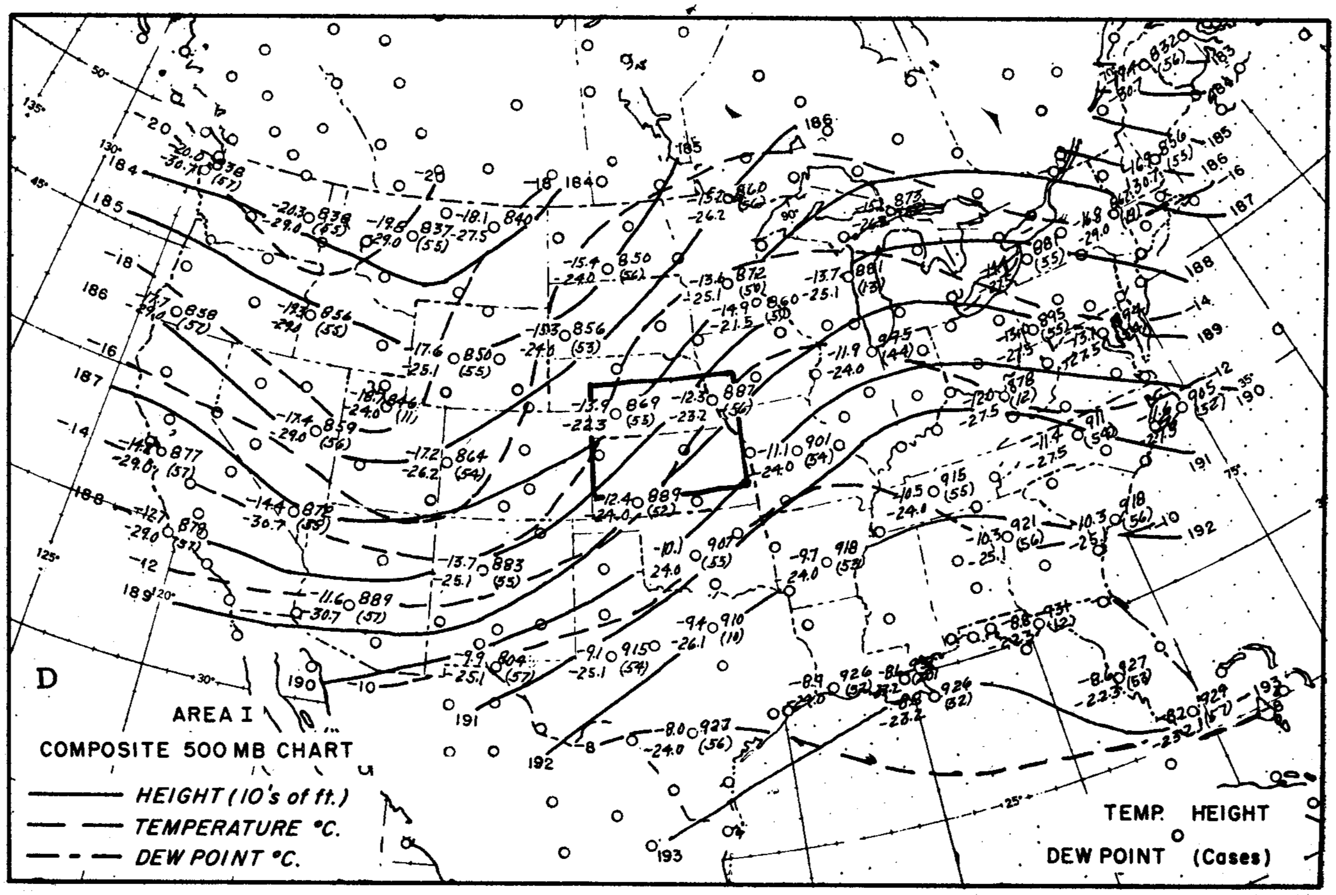


FIGURE 2—Continued.

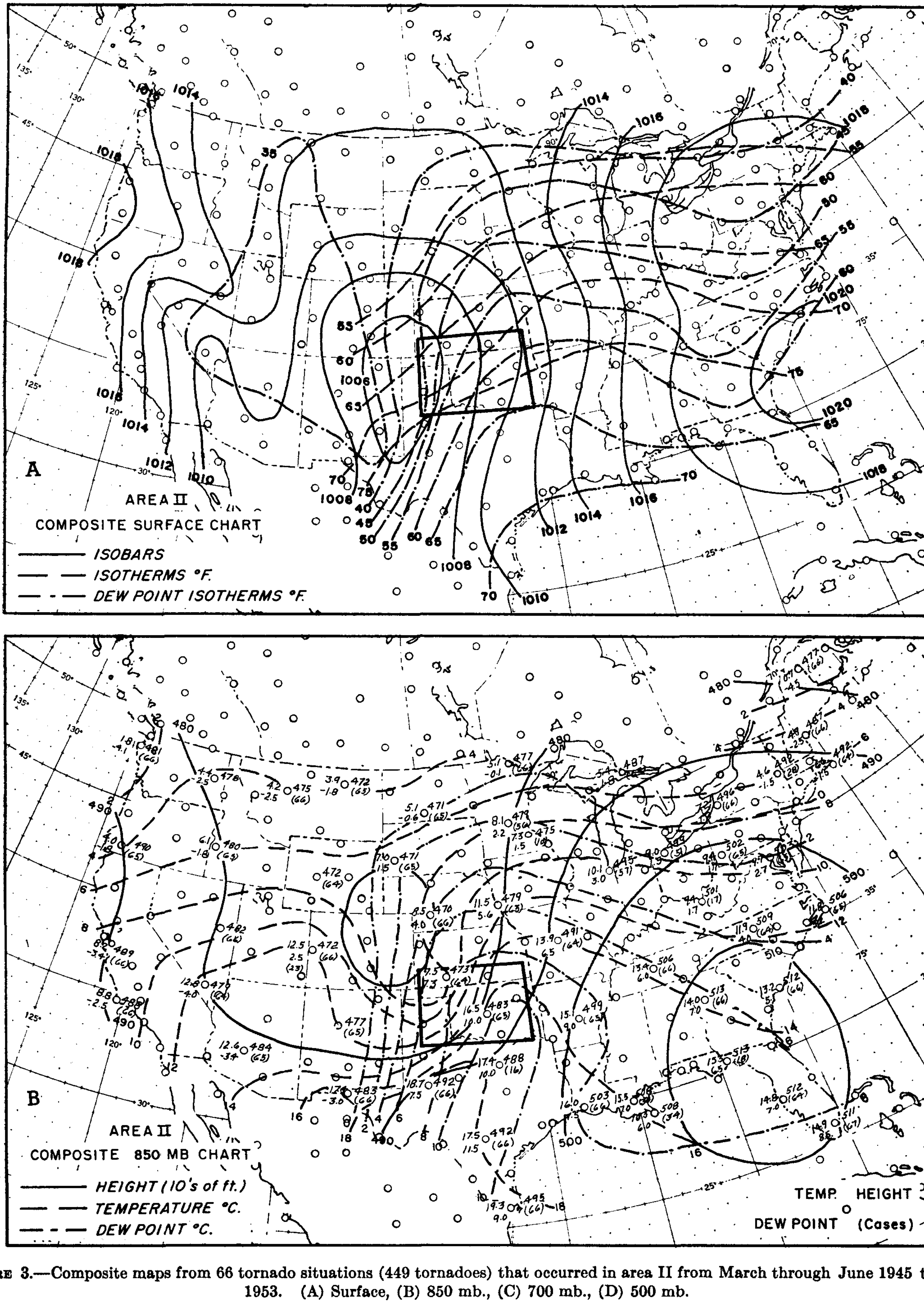


Figure 3.—Composite maps from 66 tornado situations (449 tornadoes) that occurred in area II from March through June 1945 through 1953. (A) Surface, (B) 850 mb., (C) 700 mb., (D) 500 mb.

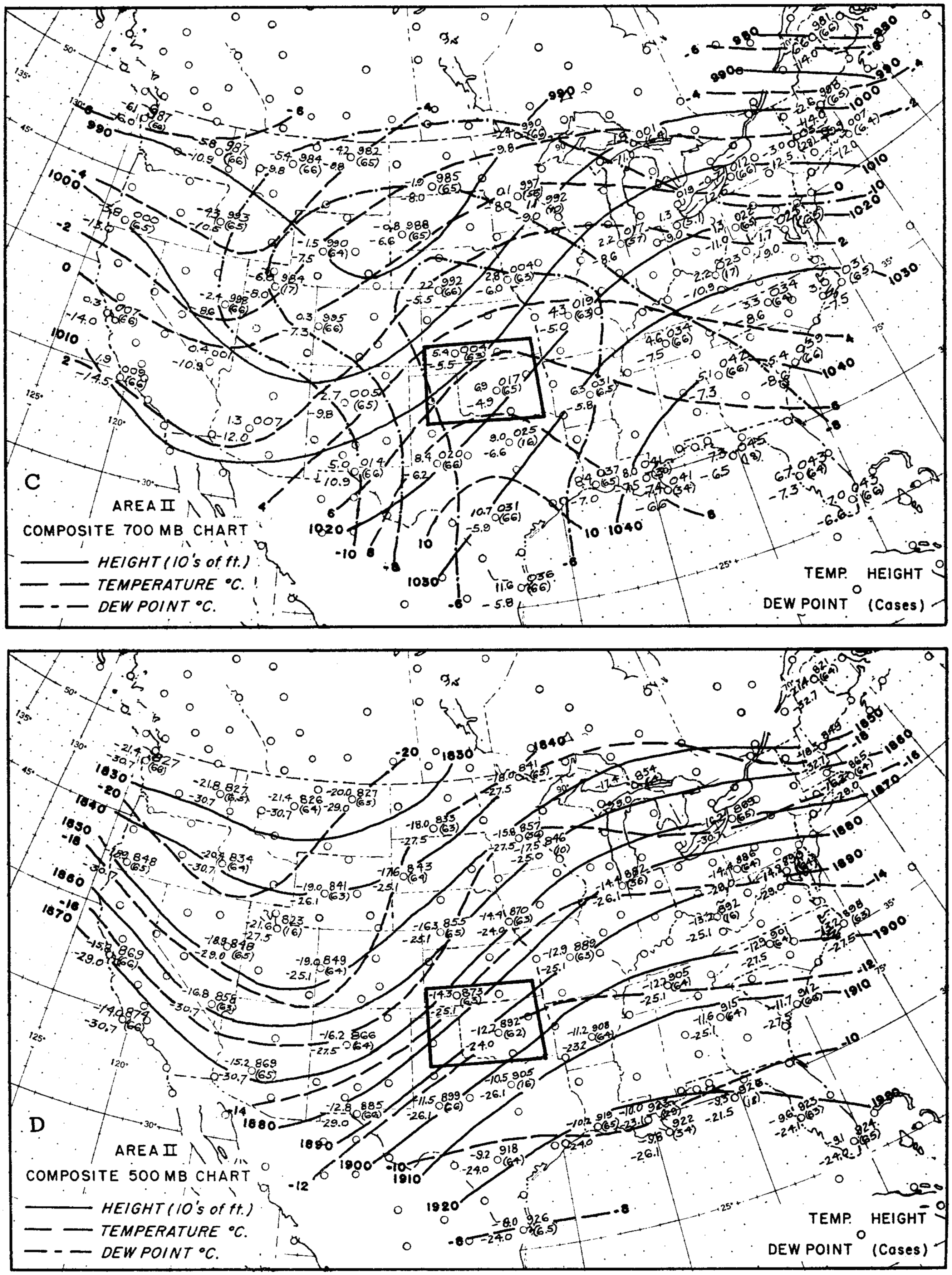


FIGURE 3—Continued.

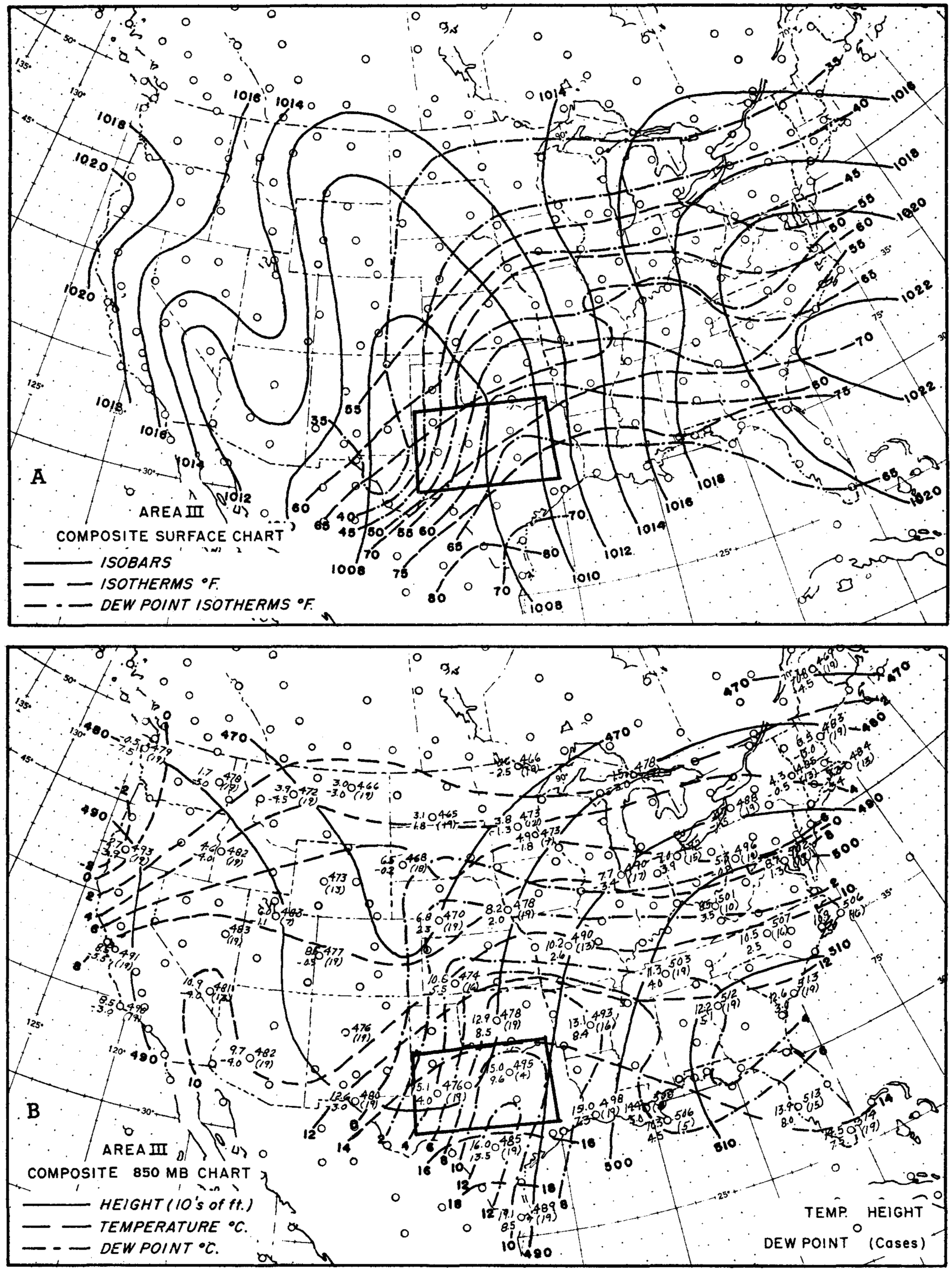
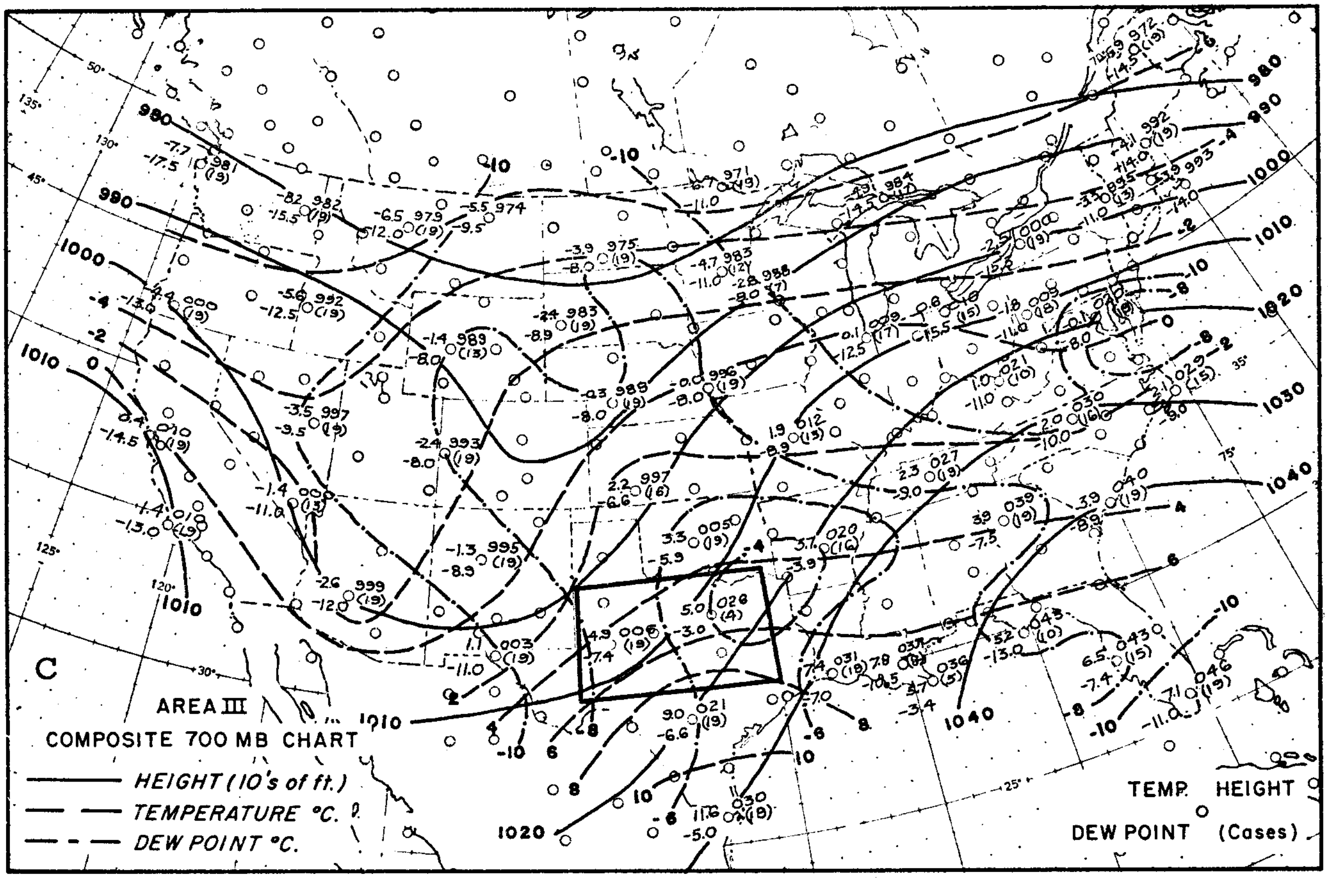


Figure 4.—Composite maps from 19 tornado situations (74 tornadoes) that occurred in area III from February through June 1945 through 1953. (A) Surface, (B) 850 mb., (C) 700 mb., (D) 500 mb.



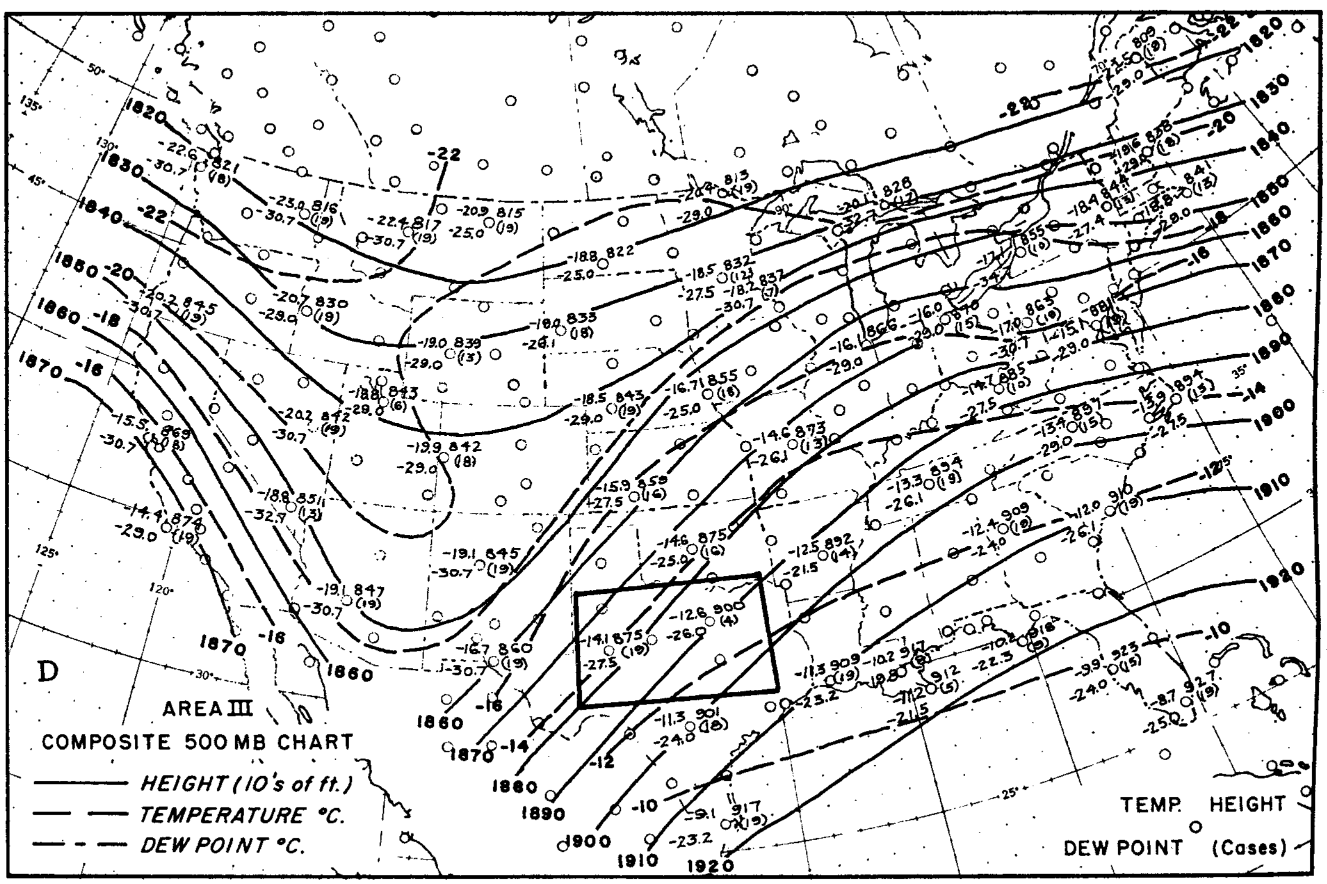


FIGURE 4—Continued.

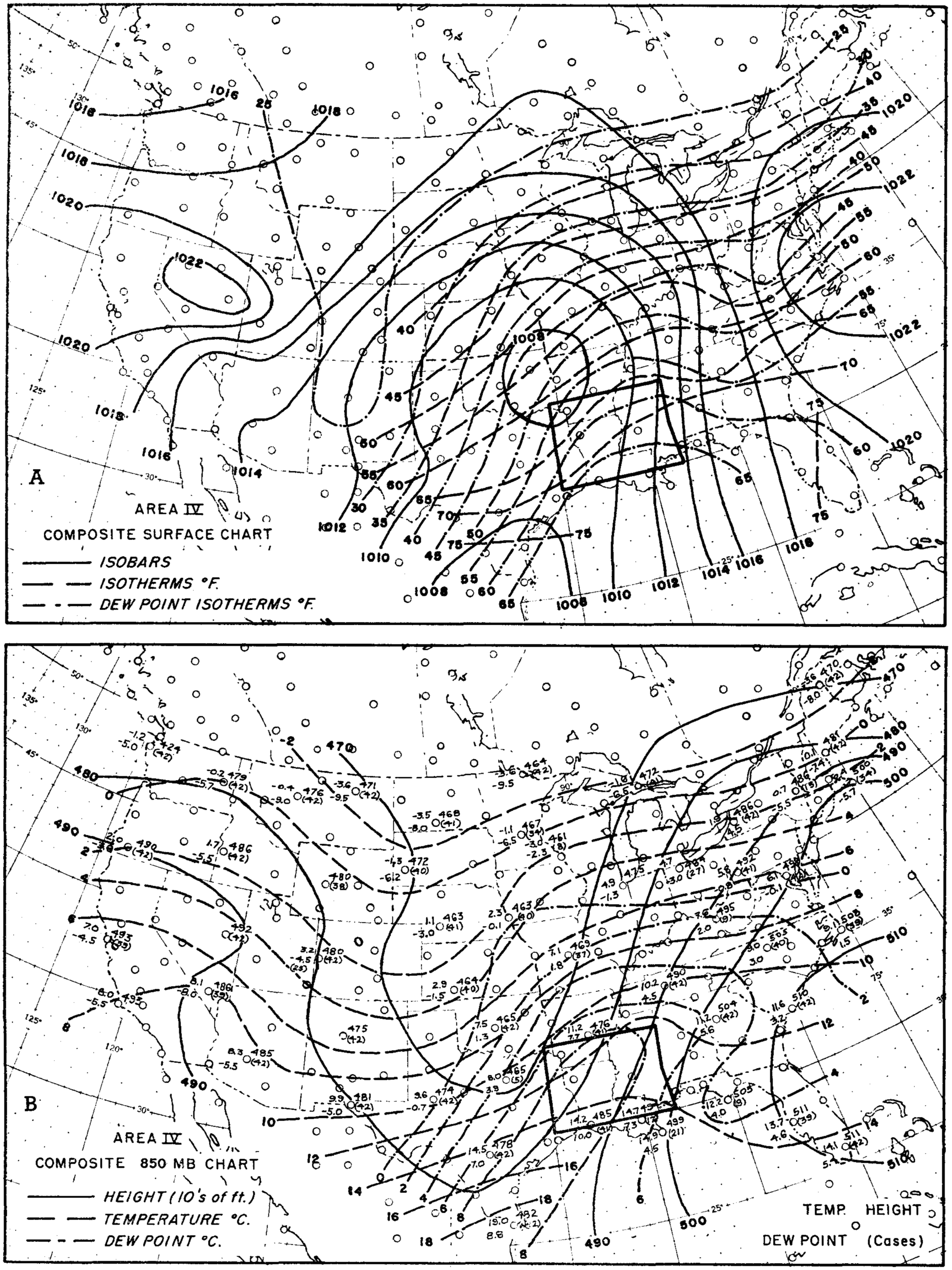
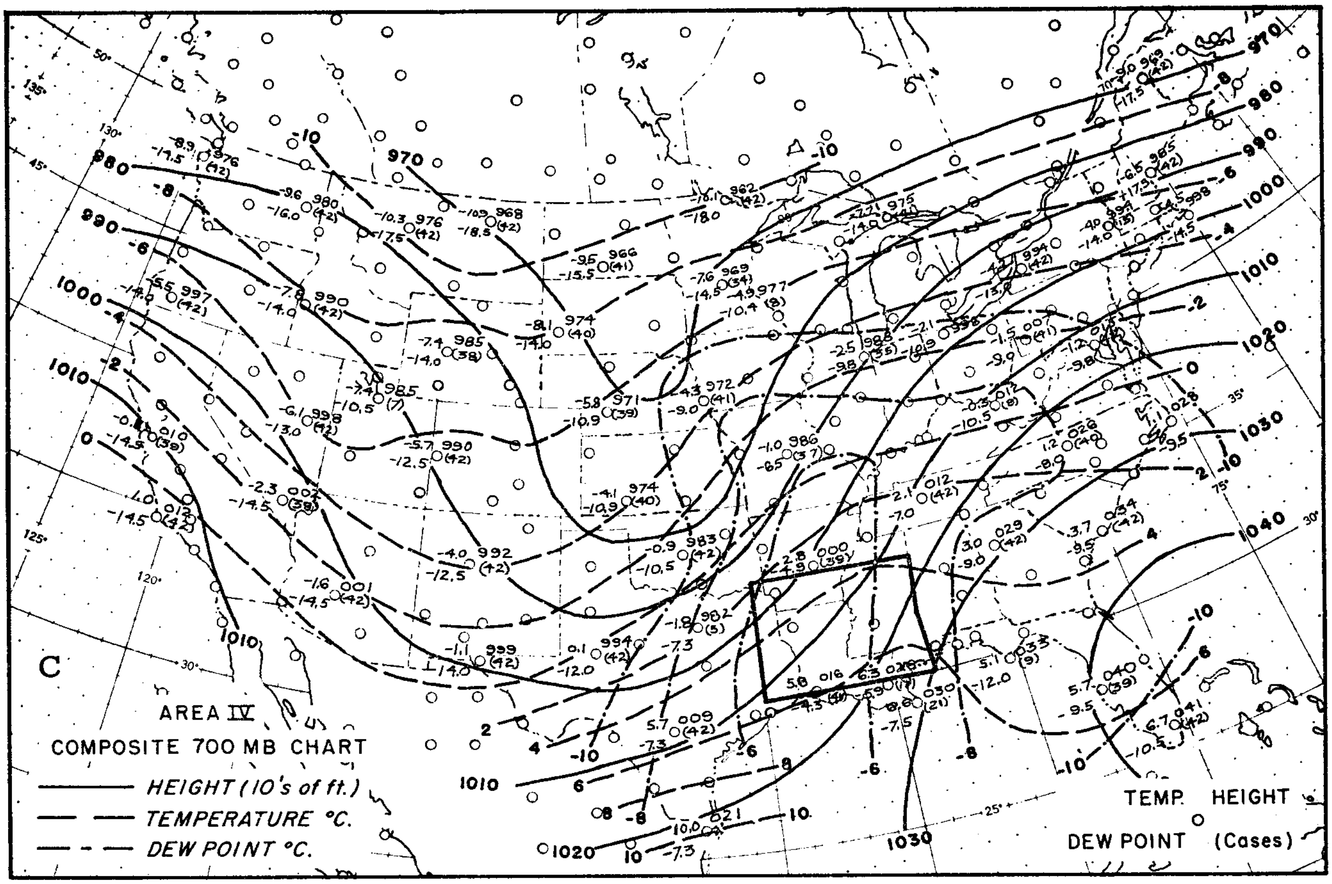


FIGURE 5.—Composite maps from 42 tornado situations (191 tornadoes) that occurred in area IV from January through May 1945 through 1953. (A) Surface, (B) 850 mb., (C) 700 mb., (D) 500 mb.



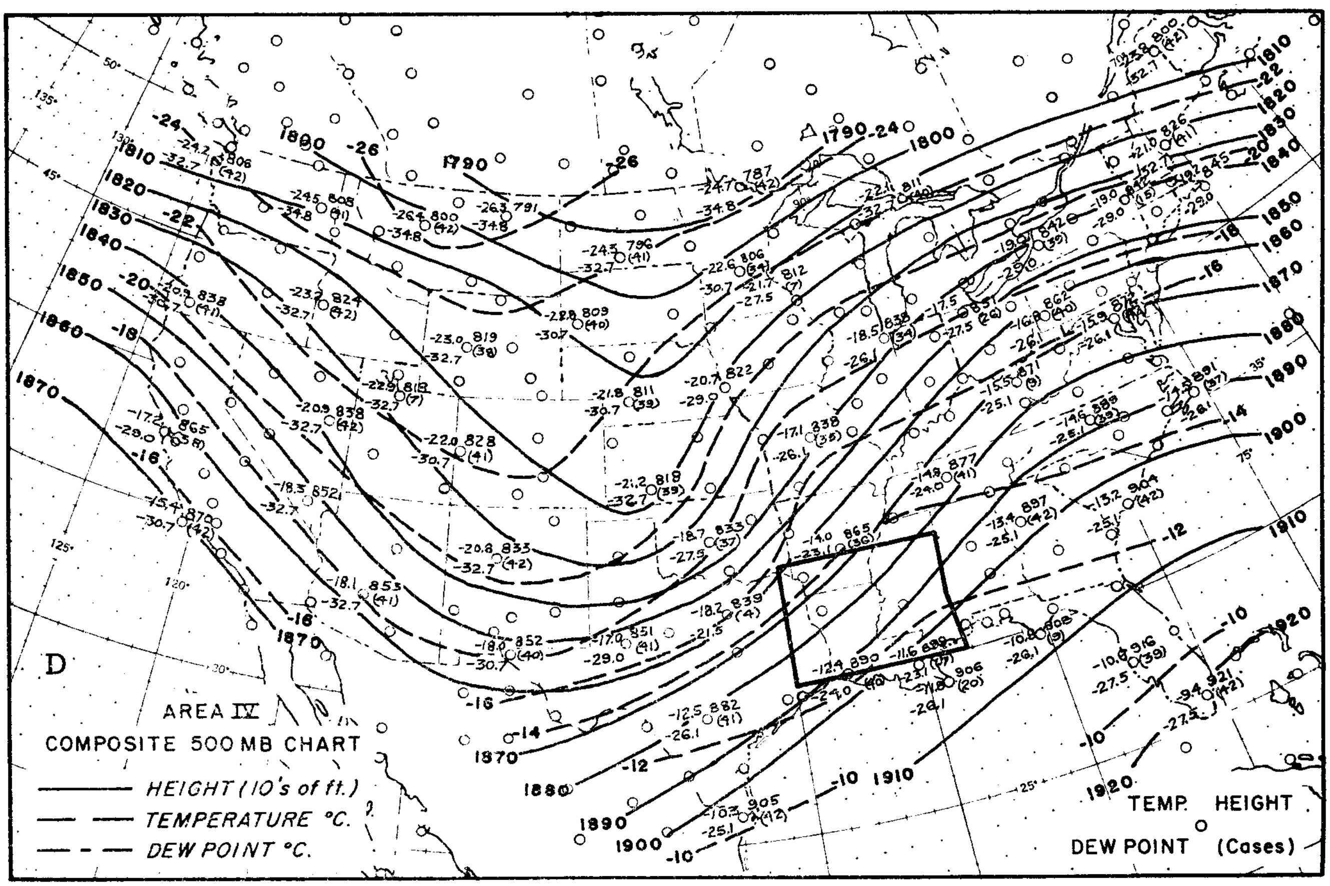


FIGURE 5—Continued.

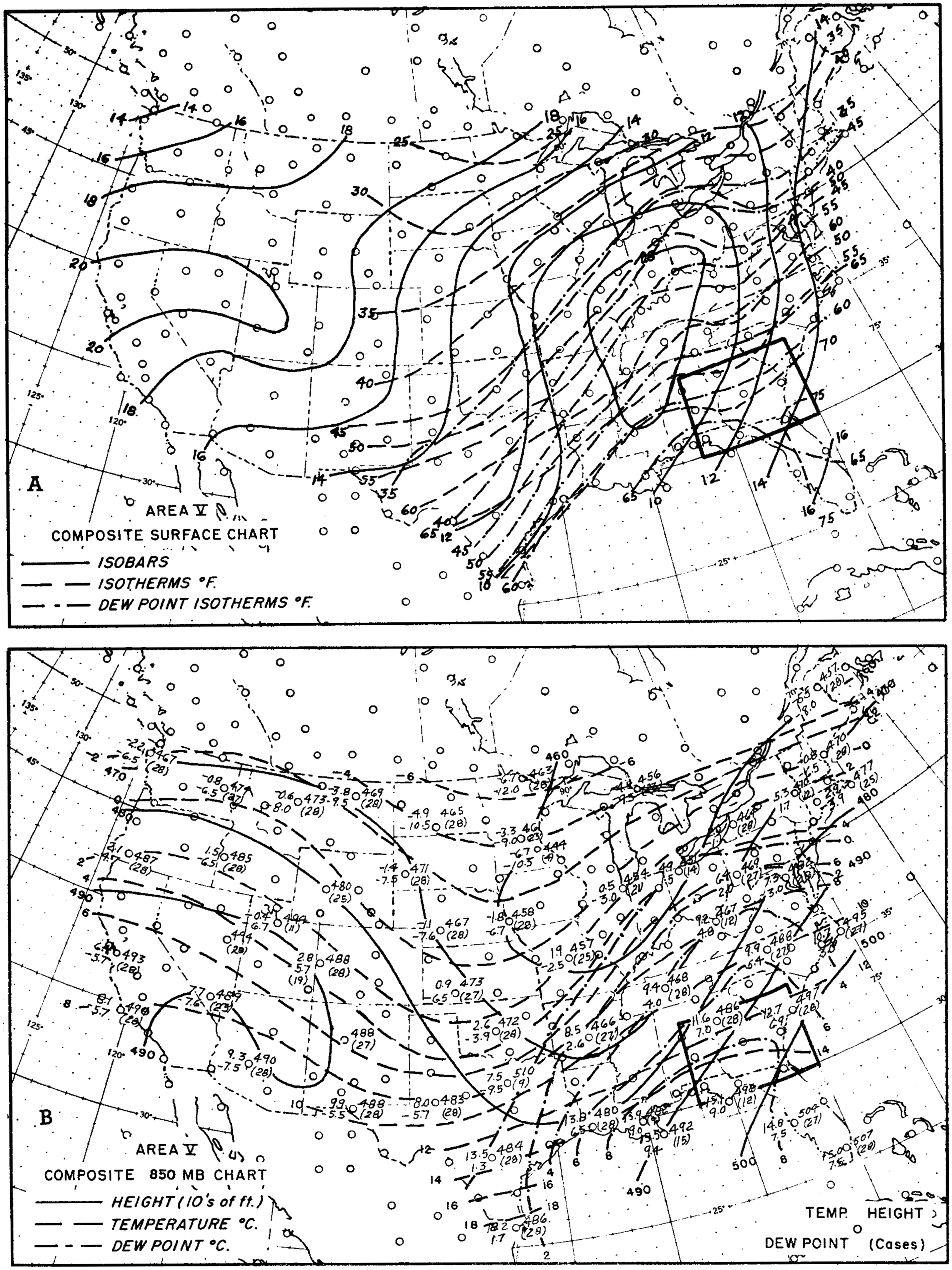
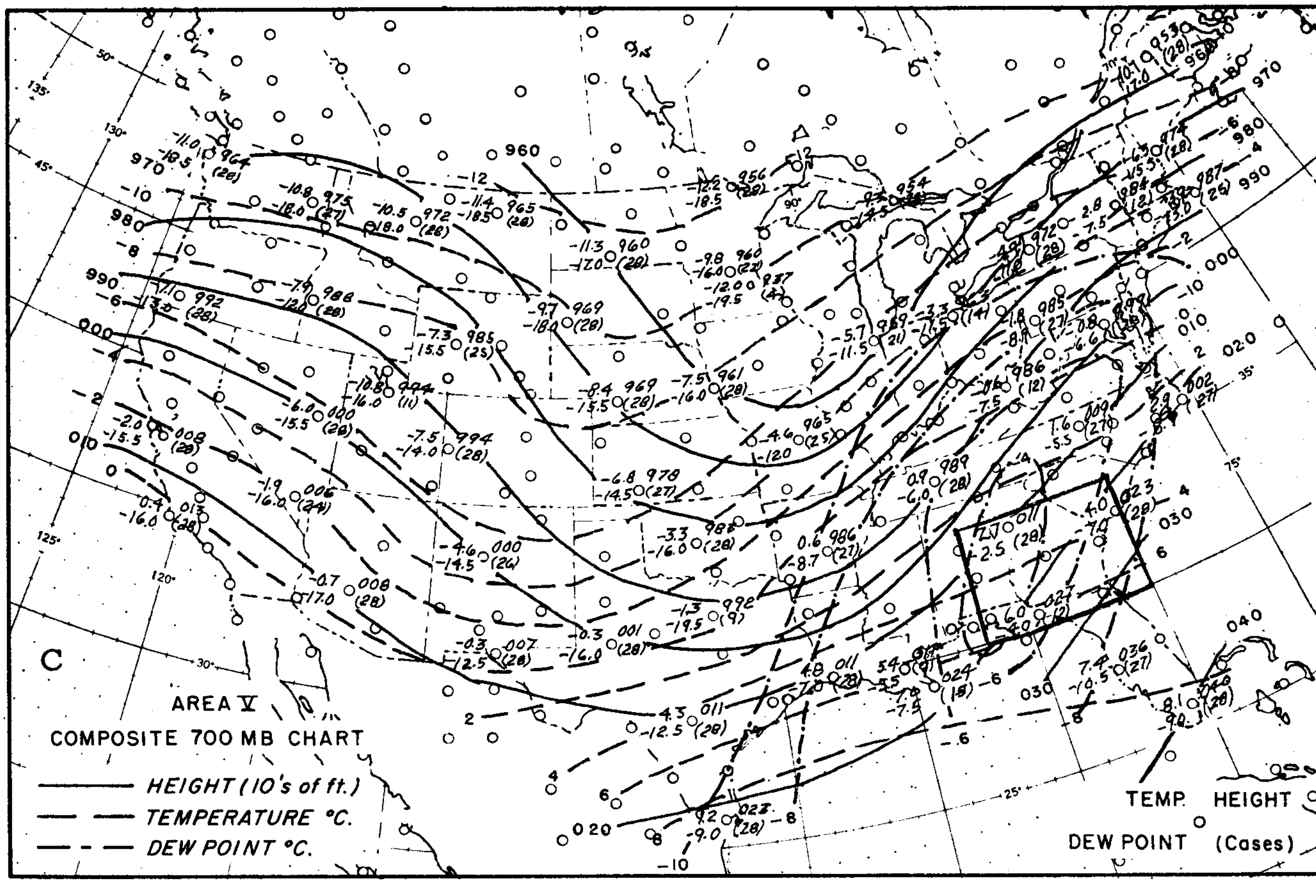


Figure 6.—Composite maps from 28 tornado situations (128 tornadoes) that occurred in area V from January through May 1945 through 1953. (A) Surface, (B) 850 mb., (C) 700 mb., (D) 500 mb.



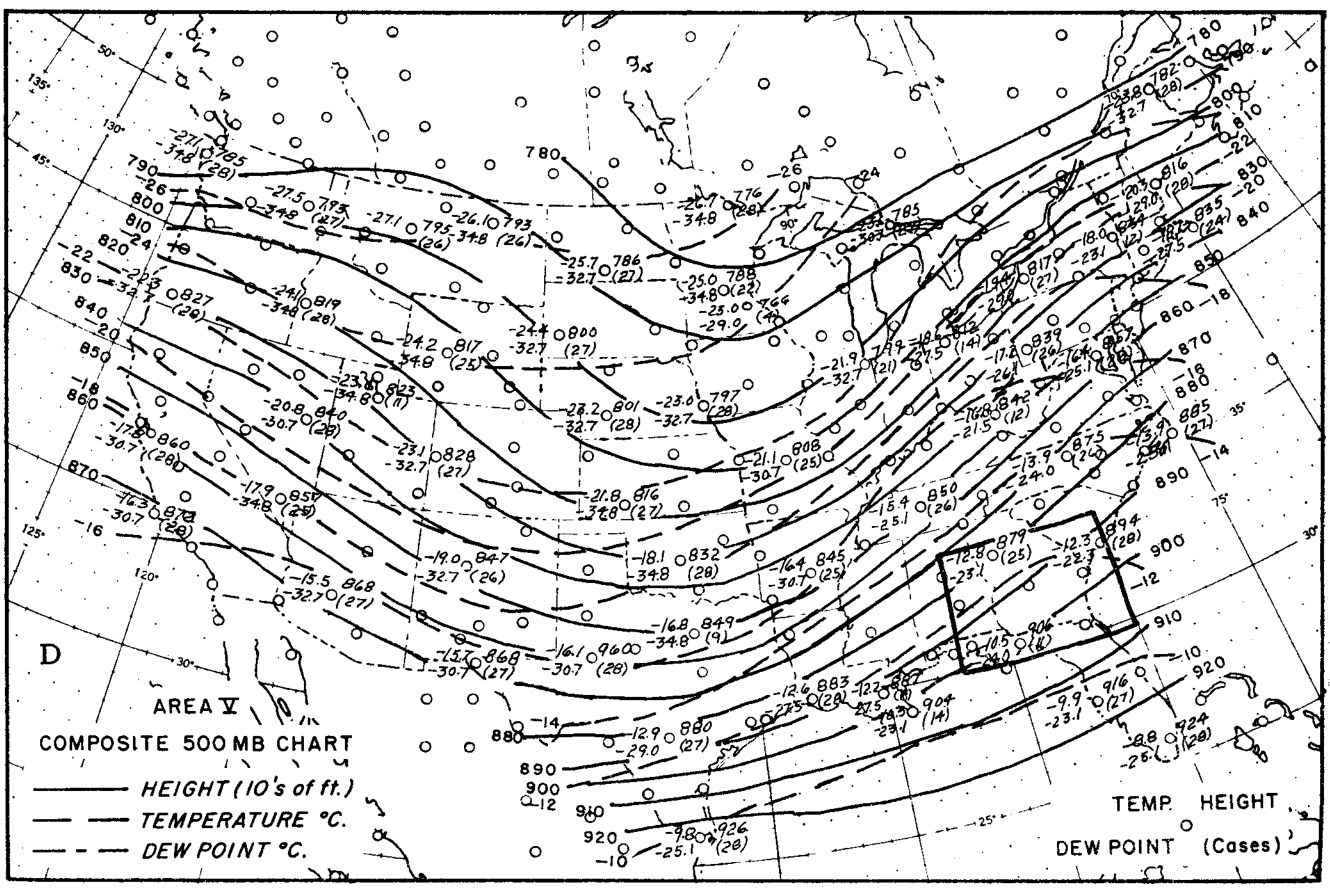


FIGURE 6—Continued.

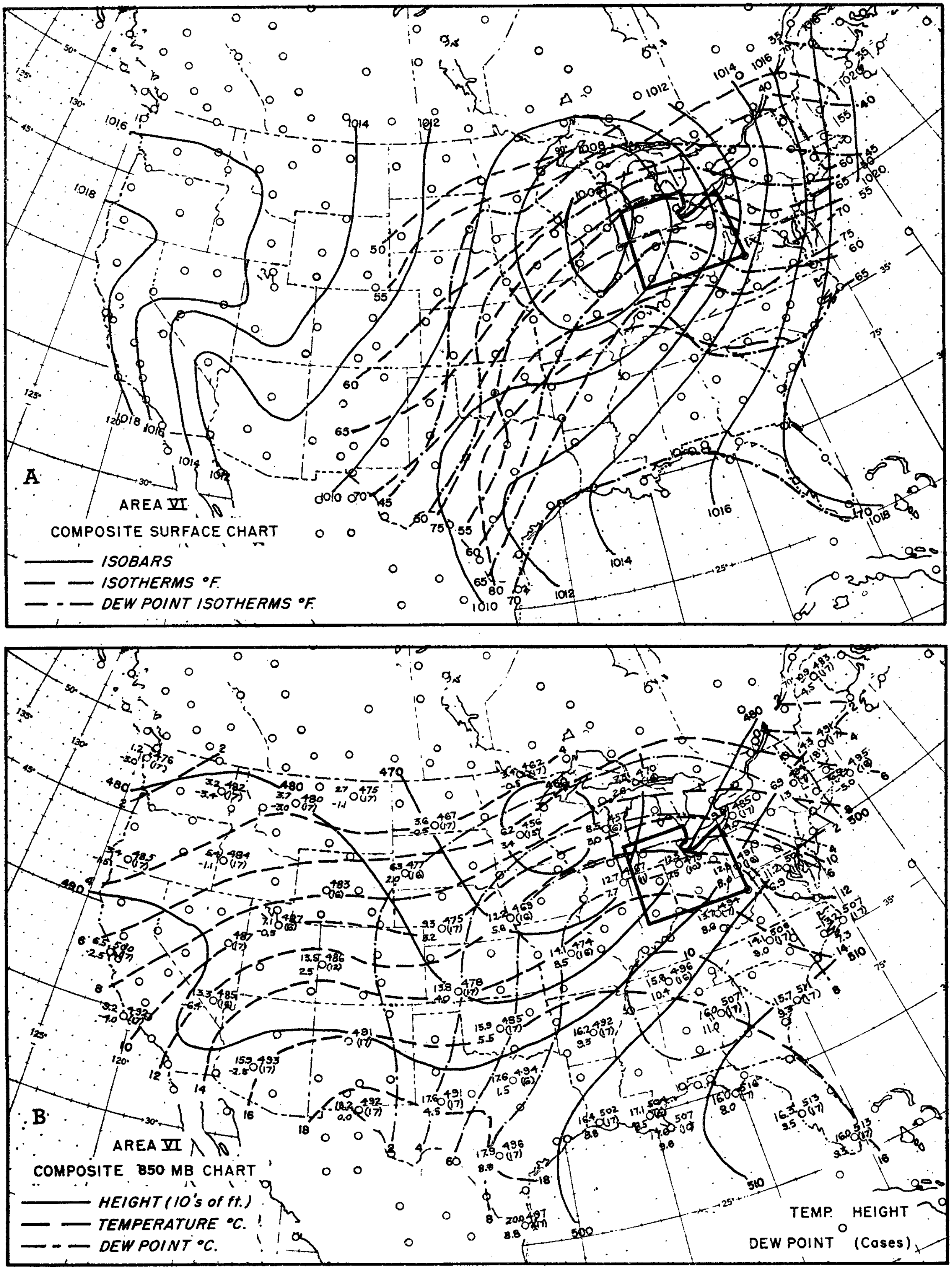
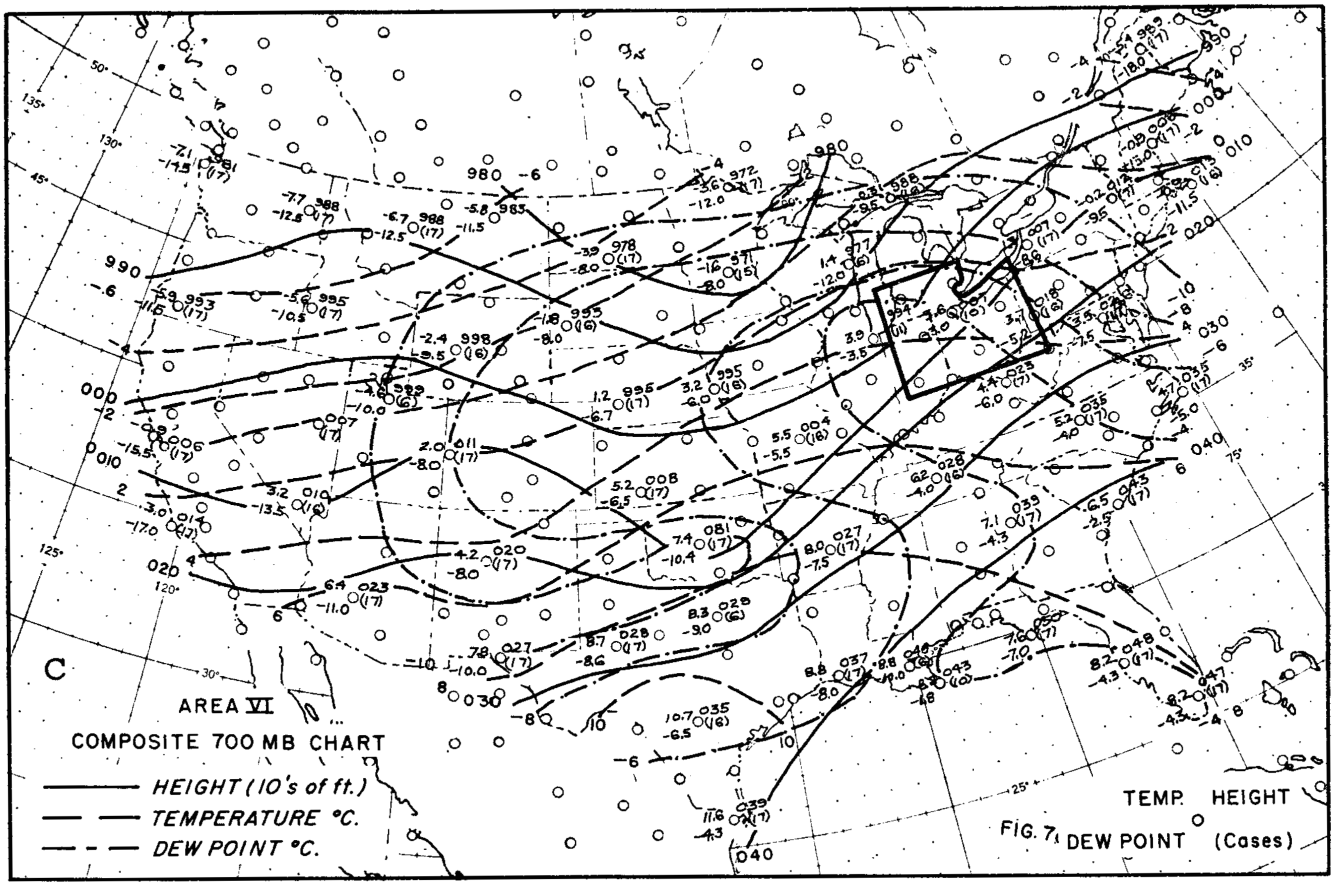


FIGURE 7.—Composite maps from 17 tornado situations (98 tornadoes) that occurred in area VI from March through June 1945 through 1953. (A) Surface, (B) 850 mb., (C) 700 mb., (D) 500 mb.



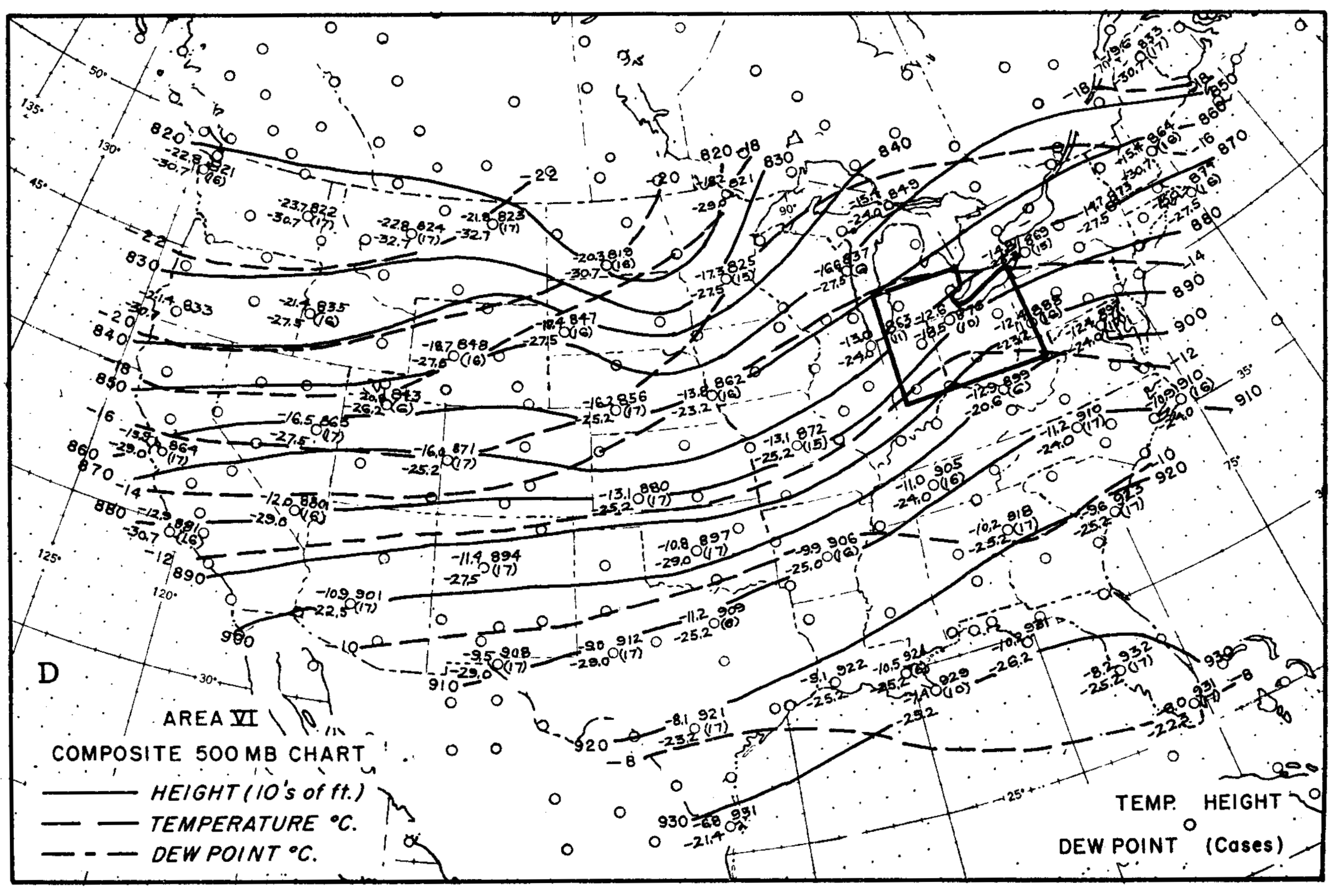


FIGURE 7—Continued.

and 500-mb. levels for tornado occurrences in 6 different areas (see fig. 1).

This study includes data from 229 cases, whereas the prior study was based upon only 72 cases (5 areas). The interest here was in family-type tornado outbreaks rather than isolated occurrences, so that the tornado situations were selected on the basis of the occurrence of several tornadoes. A tornado situation was originally defined as one in which 3 or more tornadoes occurred within a specific area and at least 2 of these tornadoes were separated by a distance of 100 miles or more. However, this objective definition was found to be too restrictive to include a large sample of situations for each area, particularly for those areas wherein the frequency of occurrence was small. The tornado situations used here were mostly as defined above, but with some exceptions, including cases with 2 tornadoes within the area plus one or more just outside, or 2 tornadoes within the area plus other severe local storms (large hail, damaging windstorms, etc.). A few cases were included in which a tornado situation occurred in two adjacent areas at the same time so that data in these cases were used twice.

Tornado situations were selected for study from occurrences during the tornado seasons of 1945 through 1953. The tornado season used here includes the months of January through May in areas IV and V, February through June in area III, and March through June in the other areas. The number of tornado situations upon which the composites are based varied from 17 in area VI to 66 in area II, with a total of 229 situations for the 6 areas. The selection of dates and times for the composite chart data was made such that the upper-air data used here were from either 0300 GMT or 1500 GMT observations, whichever time immediately preceded the time of the first reported tornado in the given area. Data from stations reporting only surface observations were taken from the synoptic 6-hourly maps preceding sounding time (3 hours before). These composites thus present a mean picture of upper-air conditions from 0 to 12 hours before the outbreak of tornadoes for each of these 6 areas, discounting the importance of diurnal variations. For 169 of the 229 cases, the composite charts are based upon 1500 GMT data while for the other 60 cases they are based upon soundings at 0300 GMT. Except for surface temperatures, the importance of diurnal pressure, temperature, and dew point variation is considered to be relatively unimportant here.

Following the selection of these 229 situations, a list of dates and times was prepared so that the Office of Climatology could compile data from their punched cards for each case. Of course, data for different areas were tabulated separately. Upper-air data were tabulated from every station in the continental United States (about 55) that made soundings during all, or part, of these periods. It was necessary to make some adjustments in the original tabulation of the upper-air data. Moisture values from the soundings were in terms of mixing ratio. These mixing ratio values for each level were converted into dew point values in degrees Celsius.

Surface data (pressure, temperature, and dew point) were tabulated for all available stations in or in the immediate vicinity of, each of the 6 areas (about 100 stations in each case). Some stations were duplicates in the cases where the areas are adjacent. For the remainder of the United States outside the vicinity of each area the surface data were obtained from the upper-air soundings. Surface temperatures and dew points were used as reported and are simple averages. Sea level pressure was obtained by reduction of the 1000-mb. surface to sea level. (Sea level pressures were not computed for the sounding stations that happened to fall within a given area.) While the sea level pressure distribution over the western part of the United States may not be representative, it is probably near the accuracy usually obtained in the determination of sea level pressures. Since the surface temperatures and dew points are dependent to a large extent on elevation, no attempt was made to analyze these values west of the Continental Divide. Actually, of course, the dew point values are not strictly representative of the moisture content of the air but it was felt that the additional work required would not be justified by the small difference likely to be obtained.

Thus, the surface analysis is based on data from about 100 stations in and around each area and on about 50 sounding stations over the remainder of the United States, and is therefore felt to be particularly reliable in each general area of tornado occurrences. The upper-air analyses are based on all available soundings.

3. ANALYZED CHARTS

Average station values of height (or sea level pressure), temperature, and dew point were computed for each of the 4 levels and for each of the 6 areas. These data were then plotted on charts and analyses made which are shown in figures 2 through 7. Upper-air data are shown for each station and the number of observations from which the average values were determined are shown in parentheses under the height value. Data are not shown on the surface analyses because of the space limitation. The locations of all reported tornadoes during the 12-hour periods used, by areas, are shown in figure 8. A tabulation of some of the interesting features of these analyses is shown in table 1.

4. SUMMARY

GENERAL

1. A veering of wind with height occurs over all areas.
2. The geostrophic wind, as measured by the contour spacing, increases with height over all areas.
3. The Showalter stability index [2] varies from −1 in area III to +2 in area V.

SURFACE CHARTS

1. The mean dew point over the center of the areas

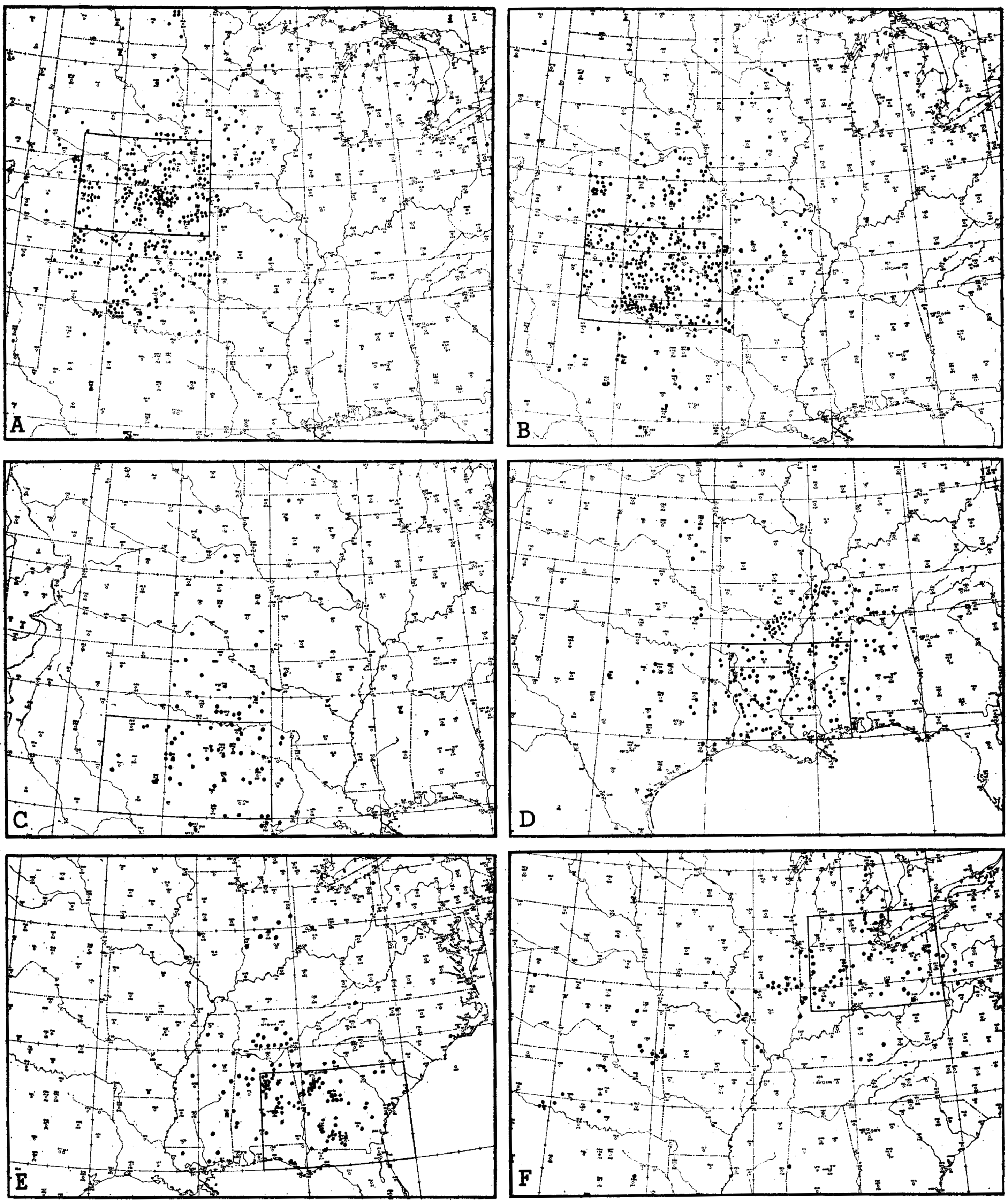


FIGURE 8.—Maps showing locations of all reported tornadoes during the time periods selected from each area (outlined). (A) Area I, (B) Area II, (C) Area III, (D) Area IV, (E) Area V, and (F) Area VI.

TABLE 1.—*Averages of meteorological elements centered on each area, with area size and number of tornadoes*

	Area					
	I	II	III	IV	V	VI
Square miles	95,000	100,000	124,000	103,000	95,000	95,000
Number tornado situations	57	66	19	42	28	17
0300 GMT data	8	17	7	16	11	1
1500 GMT data	49	49	12	26	17	16
Tornadoes in area	164	279	32	95	94	40
Tornadoes in and around area	366	449	74	191	128	98
Showalter stability index	0	0	−1	0	2	1
Surface data, center of area:						
Pressure (mb.)	1006	1008	1008	1010	1011	1008
Temperature (°F.)	72	72	70	70	70	70
Dew point (°F.)	58	60	60	63	63	60
Geostrophic wind direction (deg.)	200	200	180	210	230	220
Geostrophic wind speed (kt.)	30	24	20	32	28	20
850-mb. data, center of area:						
Height (tens of ft.)	476	479	480	485	493	481
Temperature (°C.)	16	15	15	14	14	13
Dew point (°C.)	9	9	10	10	8	8
Geostrophic wind direction (deg.)	205	215	230	220	230	230
Geostrophic wind speed (kt.)	32	30	25	35	30	35
Distance (miles) to trough to west	225	325	250	400	550	450
700-mb. data, center of area:						
Height (tens of ft.)	1010	1014	1011	1010	1018	1009
Temperature (°C.)	7	7	6	5	4	4
Dew point (°C.)	−3	−5	−6	−5	−4	−4
Geostrophic wind direction (deg.)	225	230	235	240	240	235
Geostrophic wind speed (kt.)	35	30	40	50	40	35
Distance (miles) to trough to west	400	650	500	540	750	600
500-mb. data, center of area:						
Height (tens of ft.)	1883	1887	1887	1884	1891	1880
Temperature (°C.)	−12	−13	−13	−13	−12	−13
Geostrophic wind direction (deg.)	230	235	235	240	245	245
Geostrophic wind speed (kt.)	55	55	60	75	70	60
Distance (miles) to trough to west	650	700	600	750	850	600

varies from 58° F. in the most northwesterly area (I) to 63° F. in the southeastern area (V) with an average near 60° F.

2. The pressure over the center of the areas varies from 1006 mb. in area I to 1011 mb. in area V.

3. A moisture ridge is observed in all cases and the axis is near the occurrences. While a strong gradient of moisture to the west of the moisture ridge is shown in all cases, it is most pronounced in the western areas (I, II, III). This effect is due, in part at least, to the normal westward decrease in surface dew points in this region.

4. Gradient winds are from a southerly direction in all cases with the average speed near 27 knots; the gradient is strong to the east of the occurrences and drops off rapidly to the west as a closed low center is approached.

850-MB. CHARTS

1. A pronounced moisture ridge is observed in all areas. However, the centers of the western areas (I, II, III) are just to the west of the moisture axis, that of area IV is near the center of the moisture axis, and those of the eastern areas (V, VI) are near the center of a broad moisture ridge.

2. The temperature ridge is near the occurrences in all areas but is much more pronounced in the western areas (I, II, III).

3. A trough of low pressure is observed to the west and the distance varies from 250 miles in areas I and III to near 500 miles in area V.

700-MB. CHARTS

1. A rather pronounced trough exists to the west of occurrences in all cases, although the amplitude is somewhat less than the average in area VI. It is interesting to note the rather uniform displacement of the trough some 500–600 miles west of the occurrence area. A normal 700-mb. chart [3] for this season (January through June) is characterized by a predominantly zonal flow, although a trough of small amplitude does exist near the Pacific Coast. Thus, the troughs shown here are a real feature of the selected situations and represent an important departure from normal.

2. The 700-mb. no-change line (zero temperature advection) [4] is observed to the west of all areas, averaging around 125 miles for areas I, II, III, and IV but near 400 miles in areas V and VI.

3. The temperature patterns in all cases, like the contour patterns, exhibit a considerable departure from normal. (The normal charts are characterized by a west-east orientation of the isotherms.)

4. Tornado occurrences are near the axis of a moisture ridge. However, the moisture gradient upstream from the center of the moisture ridge (toward less moist air) is generally more pronounced than downstream.

500-MB. CHARTS

1. The geostrophic wind averages near 65 knots over the center of the areas. Also, in all cases, the pressure gradient decreases markedly immediately to the southeast.

2. Contour and temperature patterns at this level exhibit about the same characteristics and departures from normal as at the 700-mb. level.

3. The contour-isotherm relationship in the vicinity of tornado occurrences shows no important temperature advection either over the areas or immediately upstream.

ACKNOWLEDGMENTS

The author gratefully acknowledges the help and cooperation of the Office of Climatology of the U. S. Weather Bureau for the compilation and summarization of many of the data used in the preparation of these charts, without which this study would not have been possible. Also, sincere appreciation is extended to Miss Georgina Neubrand for her assistance in the tabulation of many of the surface data and preparation of the charts.

REFERENCES

1. U. S. Weather Bureau, Tornado Composite Charts, Washington, D. C., February 1954 (unpublished manuscript).
2. A. K. Showalter, "A Stability Index for Thunderstorm Forecasting," *Bulletin of the American Meteorological Society*, vol. 34, No. 6, June 1953, pp. 250–252.
3. U. S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper* No. 21, Washington, D. C., October 1952, 72 charts.
4. C. F. Van Thullenar, Forecasting New Cyclone Developments, U. S. Weather Bureau, Boston, Mass., 1945 (unpublished).