Surface Parameters Associated with Tornadoes

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ABSTRACT

Surface parameters at the location of over 5000 tornadoes from January 1968 through 15 June 1974 were computed objectively at the National Severe Storms Forecast Center. This set of conditions 0–3 h prior to tornado occurrence provides a large sample and was used to determine a variety of tornado related averages. The mean conditions associated with tornadoes include: temperature 74°F, dew point 62°F, sea level pressure 1007 mb, and wind 175° at 7 kt. Significant seasonal and geographical variations from these averages were noted and illustrated.

1. Introduction

This study was conducted to provide a large set of surface data associated with tornado occurrences in the United States. Earlier studies of tornado related surface parameters by Whiting and Bailey (1957) and Beebe (1956) provided useful information using hand extracted data. However, neither study was intended to provide general information for all times of year and sections of the country. In this study, it was possible to obtain a large sample of objectively analyzed surface parameters 0–3 h prior to the tornado occurrence for all the United States from the Rocky Mountains eastward. The large sample size permitted the data to be broken down by individual months and states as well as regions and seasons.

2. Data and computation

The National Severe Storms Forecast Center (NSSFC) tornado data tapes provide the time and location for each reported tornado from 1950 to the present time. In addition, surface data have been archived at three-hourly intervals since 1968. Using these two sets of data, surface parameters 0–3 h before the occurrence of each of more than 5000 tornadoes were determined.

An objective analysis technique devised by Inman (1970) following a method described by Endlich and Mancuso (1968) was used on the NSSFC CDC 3100 computer. The method uses a first degree polynomial to fit data from the five surface observations nearest to the tornado location. Each parameter such as temperature or dew point was analyzed separately. Since surface data were available only at three-hourly intervals, the data nearest in time prior to the tornado touchdown was used. For example, for a tornado which occurred at 0127 GMT, the 0000 GMT surface data from the five nearest stations was used.

The tornado tape contained information on 5631 tornadoes from January 1968 through 15 June 1974, the period of this study. No computation was made west of approximately 110°W which eliminated 77 tornado cases. Occasional missing data on the surface history tape accounted for the loss of several hundred tornado occurrences. Thus, surface parameters were actually computed for a total of 5160 tornadoes.

As a comparison and a check on the objectively analyzed data, surface conditions for all tornadoes during 1973 were determined subjectively at NSSFC. The comparison, along with standard deviations for both man and machine, is shown in Table 1. The two methods are in good agreement. The most significant difference was in wind speed where the computer average was 7 kt and the manual average 13 kt. A similar comparison with results in the Whiting and Beebe studies shows general agreement when corresponding regions are considered.

3. Findings

a. Overall averages

The following average surface parameters for the 5160 tornado cases were determined: temperature 74°F, dew point 62°F, sea level pressure 1007.1 mb, wind direction 170°, and wind speed 7 kt. Figs. 1, 2 and 3 show the frequency distribution for temperature, dew point, and sea level pressure respectively.

Fig. 4 illustrates the frequency of tornado occurrences by hour of day. Over 30% of the tornadoes in this study occurred between 2100 and 0000 GMT. The limitation of surface history data to three-hourly intervals meant that all of these tornado cases made use of the 2100 GMT surface data. Also, it should be kept in mind that the averages presented here are weighted toward the small or "mini" tornado since the smaller storms make

TABLE 1. Comparison of man versus machine analysis. All tornadoes in 1973 (1098 cases). Standard deviations in parenthesis.

	Temperature (°F)	Dew point (°F)	Sea level pressure (mb)	Wind direction (deg)	Wind speed (kt)
Man	71 (8)	64 (6)	1006.0 (6.8)	175	13
Machine	71 (9)	62 (8)	1006.5 (6.3)	175	7

up the bulk of the 700 to 1000 tornadoes reported annually in the United States.

Fig. 1, showing distribution of precedent surface temperatures, illustrates the small percentage of tornadoes occurring in either very cool or very warm air. Seventy-five percent of all tornadoes occurred with temperatures in the 65 to 84°F range. Fig. 2 shows that over half of all cases occurred with dew points in the 60 to 69°F range.

While many of the more destructive tornadoes are associated with deep surface lows, the overall average sea level pressure was 1007.1 mb. Fig. 3 shows that only 11% of all tornadoes occurred with related pressures below 1000 mb. Sixty-six percent occurred with pressures between 1003 mb and 1015 mb.

b. *Monthly variation*

Monthly averages of each parameter were computed and shown in Table 2 along with the total number of cases for each month. The expected strong seasonal changes are evident. Average surface temperatures range from 62°F in December to 81°F in July and August.

Significant monthly variations from the overall average sea level pressure of 1007 mb are shown. The range is from 1003 mb in April to 1011 mb in August. Throughout the year 67% of the tornadoes were associated with pressure below 1012 mb. In the summer months, however, pressures are higher and in August 54% of the tornadoes occurred with pressures greater than or equal to 1012 mb.

Note that the January averages for temperature, dew point, and sea level pressure all show a rise from

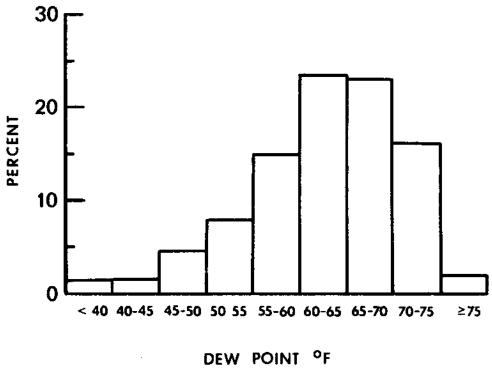

FIG. 2. Relative frequency of tornado-related surface dew points (°F).

the December values. This stands out as an interruption in generally falling values from fall to spring. An examination of the January tornadoes shows that in both January 1971 and January 1972 outbreaks in Alabama and Georgia occurred with relatively high pressures. This was most pronounced on 15 January 1971 when 10 tornadoes occurred in Georgia and Alabama with pressures generally between 1018 mb and 1020 mb. The tornadoes were small and short lived and occurred along a rapidly moving surface front. A strong 500 mb short wave accompanied the system but no significant surface development took place and pressures remained high. The concentration of January tornadoes in the Gulf Coast area where temperatures and dew points are normally higher also contributed to the January rise.

c. *Geographical averages*

State averages of each parameter were computed and the results shown in map form in Fig. 5. The small numbers at the right-hand side of each plot show the total number of tornado occurrences in each state. Averages are not plotted for states having fewer than 16 tornado cases. These are averages for the entire six and one-half year period for each state.

Mean tornado related pressures were generally highest in the east and lowest in a band from Kansas

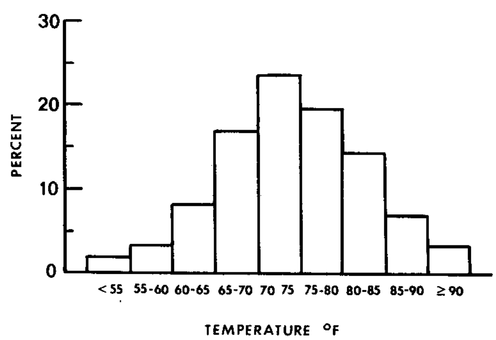

FIG. 1. Relative frequency of tornado-related surface temperatures (°F). Data for all months and areas.

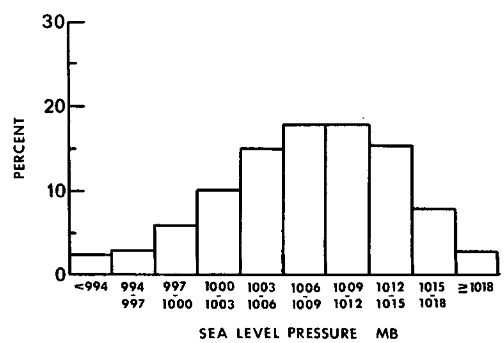

FIG. 3. Relative frequency of tornado-related sea level pressures (mb).

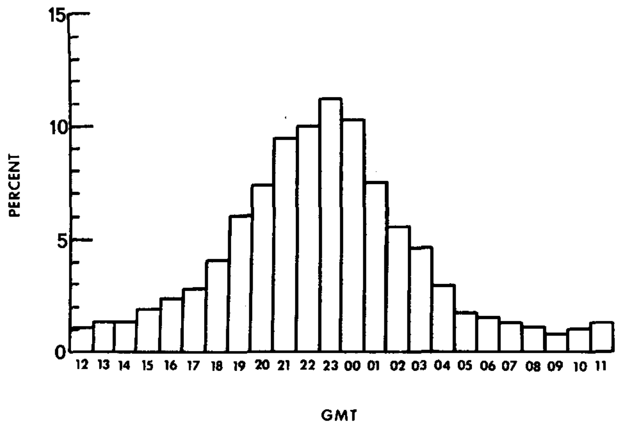

FIG. 4. Hourly percentage of tornado reports January 1968 through 15 June 1974. Graph indicates all tornadoes beginning during indicated hour (GMT).

TABLE 2. Monthly averages of surface parameters associated with tornadoes (1968–1974). Total, 5631 cases.

	Cases	Temperature (°F)	Dew point (°F)	Sea level pressure (mb)	Wind direction (deg)	Wind speed (kt)
Jan	124	65	60	1010.1	190	7
Feb	164	64	57	1005.5	180	10
Mar	329	67	58	1005.3	190	9
Apr	909	69	59	1003.8	170	12
May	1128	73	61	1006.8	170	7
Jun	1178	77	64	1007.1	170	7
Jul	595	81	66	1010.8	190	4
Aug	427	81	67	1011.1	190	3
Sep	288	76	65	1009.3	180	6
Oct	165	72	64	1007.9	160	8
Nov	177	68	61	1006.1	170	8
Dec	147	62	57	1004.8	180	12

and Oklahoma to Kentucky. The lowest state average was Oklahoma's 1004.3 mb, while the highest was 1011.1 mb in Florida. The large number of tornadoes on 3 and 4 April 1974 with pressures generally between 985 mb and 1005 mb influenced several of the state averages toward lower sea level pressures.

Examination of the state-mean winds shows a division generally following the Mississippi River. East of the Mississippi, most tornado related surface winds averaged from the south or south southwest, while west of the Mississippi south southeast winds were common. The influence of lee troughing in the west and the Bermuda high pressure cell in the east probably accounts for this distribution in state averages.

d. *Regional-seasonal variations*

The data were broken down into the five regions and four seasons shown in Figs. 6 through 9. The choice of regions was arbitrary and resulted in some dissimilar groupings. The seasons were made up of whole calendar months and did not follow the astronomical seasons.

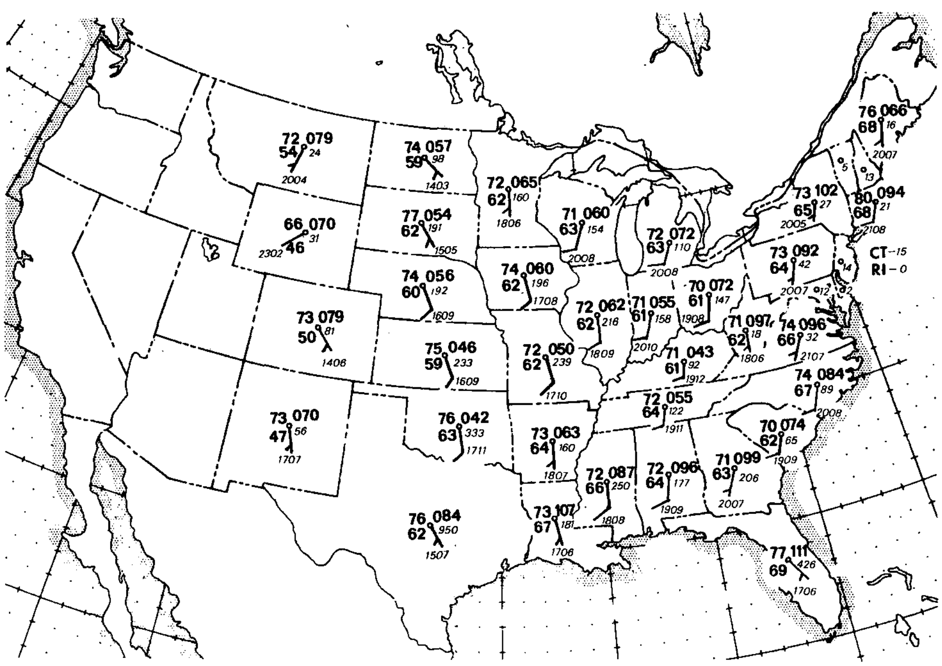

FIG. 5. State averages of surface parameters 0–3 h prior to tornado. Temperature and dew point at left of plot in °F. Sea level pressure in millibars and tenths, with the leading 10 omitted, at upper right hand position. Wind velocity shown in tens-of-degrees and knots. Number of tornado reports shown at right center position.

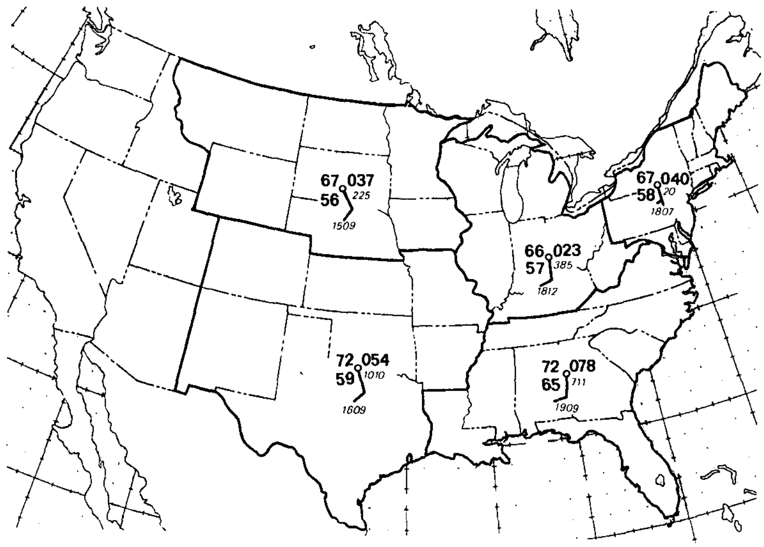

FIG. 6. Tornado related surface parameters by region for spring (March, April and May). Plot is same as Fig. 5. Total cases: 2366, including western tornadoes not indicated.

Again, the small figures at the right-hand side of each plot indicate the number of cases in each division.

In all seasons, temperatures were about 5°F warmer in the two southern regions when compared to the three northern regions. Significant variations were noted in average pressures in winter and spring. In the spring, pressures averaged 1008 mb in the Southeast, but only 1002 mb in the Ohio Valley-Great Lakes region. By summer, average values for pressure, temperature, and dew point were higher in all regions and pressures ranged from 1007 mb in the North Central states to 1013 mb in the Southeast. During September, October and November the parameters showed the smallest variations from region to region.

The limited number of tornado cases during the winter months was concentrated in the Southeast. During the six and one-half years of this study no tornadoes were reported in the North Central states during the winter months. Only five tornadoes were recorded in the Northeast and no averages were plotted due to the small sample.

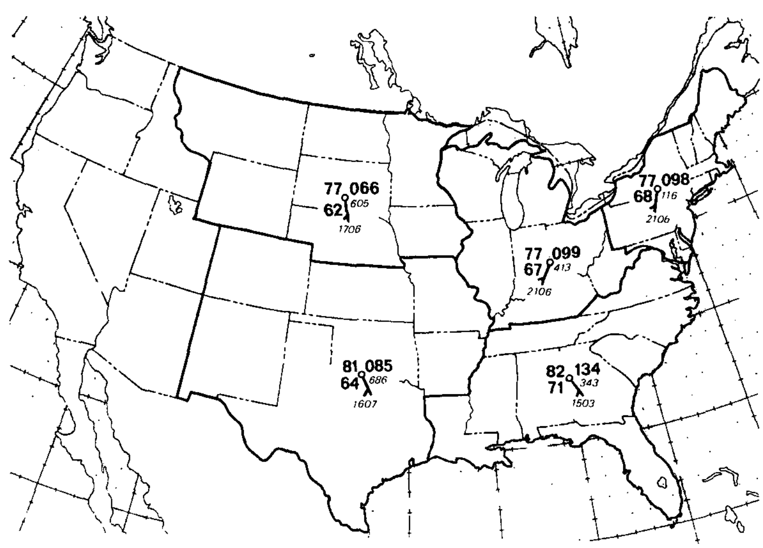

FIG. 7. Tornado related surface parameters. Summer (June, July and August). Total, 2200.

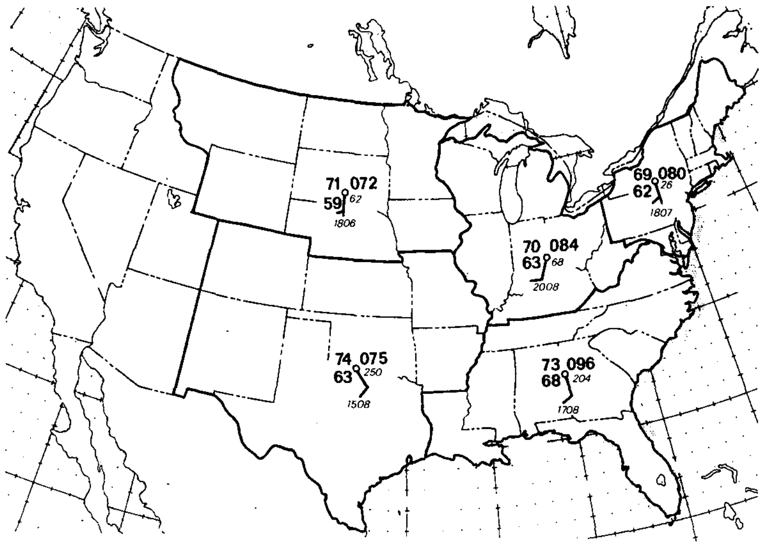

FIG. 8. Tornado related surface parameters. Fall (September, October and November). Total, 630.

4. Comparison with climatological normals

The tornado related surface parameters shown in Figs. 5–9 were compared with normals published in the *Climatic Atlas of the United States* (Environmental Science Services Administration, 1968). The state averages for pre-tornado sea level pressures shown in Fig. 5 are about 10 mb lower than the annual normals. When individual seasons are compared the tornado related pressures are significantly lower than the long term normals. For instance, in Fig. 9 the tornado related pressure for the Ohio Valley-Great Lakes area in December, January, and February is 999 mb. The climatological normal for the same three-month period over that area is about 1019 mb—a difference of 20 mb. This is not surprising since cold season tornadoes in the Ohio Valley would normally require a well developed surface low to pull Gulf moisture northward into the area.

The tornado related mean wind distribution mentioned earlier follows closely the annual distribution of prevailing winds shown in the *Climatic Atlas*. A detailed comparison with climatic normals would require a month and state breakdown of the tornado related parameters. In general, though, it can be said that tornadoes are preceded by lower than normal pressures and in the cold seasons, unusually high values

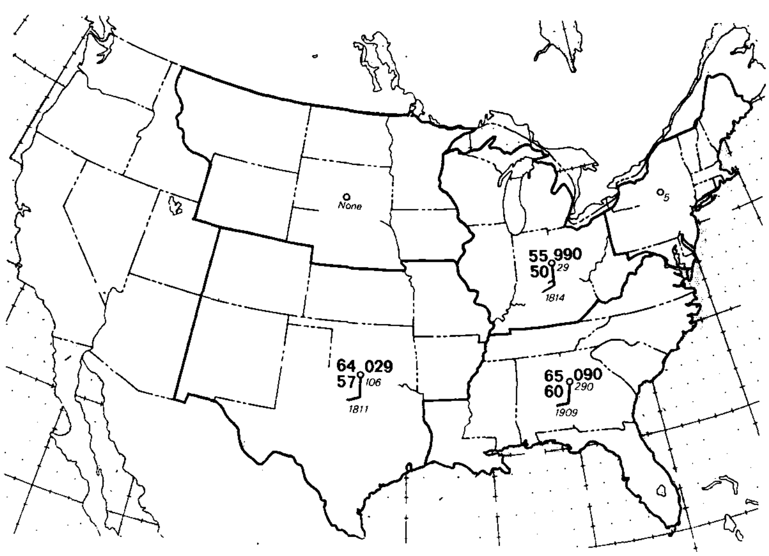

FIG. 9. Tornado related surface parameters. Winter (December, January and February). Total, 435.

of temperature and dew point. In the fall and winter dew point departures of 20 degrees above normal are common.

5. Conclusion

This study and the data now available at the National Severe Storms Forecast Center should provide a useful source of information for tornado forecasters and researchers. The averages presented here are not predictive in nature, but should be used as part of the climatology of tornadoes in the United States. They can provide information concerning the likelihood of tornadoes given certain surface parameters. The figures presented here are but a sample of the possible uses of these data.

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