Winter Tornado Outbreaks

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ABSTRACT

Winter tornado outbreaks comprise 9% of all major outbreaks since 1950. In four out of five cases, they are accompanied by widespread blizzard, heavy snow conditions, and/or extensive glazing on the cold side of the responsible weather system. Two mean storm tracks for these outbreaks have been established but one predominates. This track has its origin over the southern plains states and moves northeastward to the upper Great Lakes region. Owing to the location of its origin, it is associated with a stronger baroclinic zone than the typical winter storm of the Plains states, since the 500 mb trough is typically farther south and the southerly low-level (850 mb) air flow out of the Gulf of Mexico is significantly more moist. A comparable number of heavy snow/ice storm occurrences without major tornado outbreaks was investigated and it appears that the intensity of the baroclinic zone and the location of the low-level features with respect to the Gulf moisture are the determining factors in differentiating between outbreak and non-outbreak situations. While the intensity of winter outbreak tornadoes is comparable to spring outbreak tornadoes, long-track winter outbreak tornadoes account for a greater percentage of deaths than the long-track spring outbreak tornadoes. Possible reasons for this are presented.

1. Introduction

Major tornado outbreaks during the winter months of December, January and February are often accompanied by heavy snows (in some instances reaching blizzard proportions) on the cold side of the associated surface low pressure system. Thus, while severe storm forecasters at the National Severe Storms Forecast Center (NSSFC) are monitoring the developing weather situation for one element, forecasters at the National Weather Service Forecast Offices (WSFO's) on the cold air side are monitoring it for another.

Although weather patterns of this type have been recognized, the authors were unable to find any previous studies concerning the statistical properties of the joint phenomena. It is the purpose of this paper to present some of these properties in order to establish a more knowledgeable understanding of this winter event.

2. Data

During the winter months, tornado frequency is greatest in the states adjacent to the Gulf of Mexico, and on into Georgia and the Carolinas (Brown and Roberts, 1935). In this study tornado occurrences are taken from the NSSFC "filtered" log (Kelly *et al.*, 1978) for the years 1950–79. During this period, 68% of all the December through February tornadoes (1040 out of 1531 tornadoes) in the United States occurred in Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina and North Carolina. However, major tornado outbreaks, as defined by Galway (1977), which occurred in these months present an entirely different distribution. There were 23 major outbreaks in the winter months accounting for a total of 385 tornadoes. Clearly, while the wintertime tornado outbreak is a comparatively rare event, it is still significant. These 23 outbreaks represent 9% of all major outbreaks for the 30 years. The distribution of the individual tornadoes in the 23 outbreaks is shown in Fig. 1. The outbreak tornadoes were equally divided between the Gulf and southeastern states (192 occurrences) and in Oklahoma and the states through the Mississippi and Ohio River Valleys (193 occurrences). Nearly 18% of the wintertime tornadoes over the Gulf and southeastern states occur with outbreaks while 43% of the wintertime tornadoes in Oklahoma and the states through the Mississippi and Ohio River Valleys are in outbreaks.

The Environmental Data Information Service's (EDIS) *Storm Data, Weekly Weather and Crops Bulletin* and *Climatological Data* were used to determine whether heavy snow/ice storms occurred in connection with the tornado outbreaks. For this paper, heavy snow is simply defined as four or more

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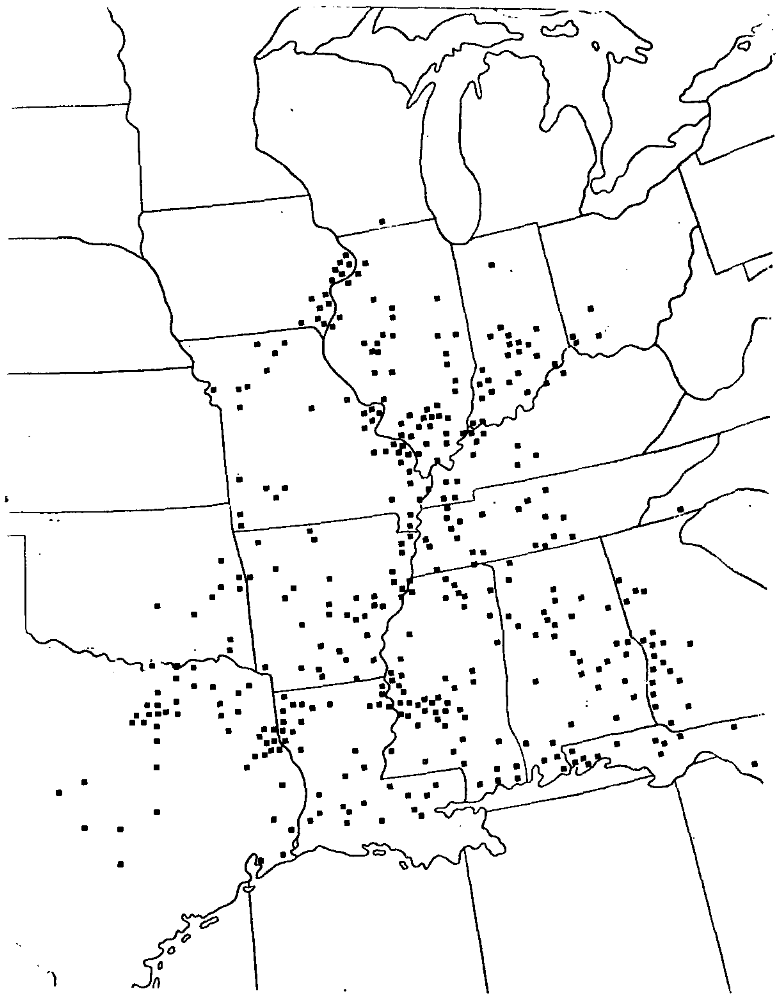

FIG. 1. Distribution of tornadoes with 23 winter (December–February) major tornado outbreaks, 1950–79.

inches (≥10 cm) per storm.[2] While major blizzards and very heavy snowstorms are well documented by *Storm Data*, this publication indicated that a few outbreak-related systems apparently did not produce 4 or more inches of snow (≥10 cm). However, examination of local climatological data and tables of snowfall and snow on the ground showed that many of these storms produced snowfalls of 4–10 inches (10–25 cm) in bands whose widths were on the order of 60 nautical miles (n mi) or less. These narrow bands of locally heavy snow occurred between regular observing points and were not included in *Storm Data*, even though reports from cooperative observers reveal that heavy snow did occur.

[2] This differs from the National Weather Service definition which requires 4 or more inches of accumulation in 12 hours or 6 or more inches (15 cm) accumulation in 24 hours.

Unlike tornado statistics, the determination of the exact time that snow/ice storms begin, reach a peak, and end is somewhat vague. The general notations of late afternoon, early morning, during the evening are often found. Nevertheless, they can be related to the beginning of the tornado outbreaks well enough to establish whether the heavy snow commenced before, during or after the onset of the tornado outbreak.

3. Statistical Results

Table 1 summarizes the winter tornado outbreaks used in this study. Of the 23 outbreaks, 19 were accompanied by heavy snow/ice storms. Snowfall totals ranged from 4 to 30 inches (10–76 cm) and four of the storms were classified as blizzards. Of the 19 cases, there are three in which the heavy snow

TABLE 1. 1950–79 major winter tornado outbreaks, tornadoes and deaths with outbreaks, total tornadoes and deaths from all winter tornadoes, and number of heavy snow/ice storms with outbreaks.

	December	January	February	Total
Outbreaks	8	7	8	23
Moderate (10–19)	6	5	7	18
Large (20)	2	2	1	5
Tornadoes (% of total)	141 (28.6)	134.(31.0)	110 (18.2)	385 (25.2)
Total tornadoes	493	432	606	1531
Deaths (% of total)	26 (26.3)	38 (41.8)	201 (81.4)	265 (60.6)
Total deaths	99	91	247	437
Heavy snow/ice cases	5	6	8	19
No heavy snow/ice cases	3	1	0	4

criterion was not met, but extensive glazing occurred over a large area. Eight of the 19 cases have both heavy snow and ice. Of the four outbreaks without heavy snow or ice, two had less than four inches of snow (<10 cm), leaving only two outbreaks that apparently were not accompanied by any frozen precipitation.

The 23 outbreaks produced 25% of all of the tornadoes during the 90 months studied and resulted in 265 fatalities (61% of all winter tornado deaths). The worst winter outbreak of the 30 year period was the Mississippi Delta outbreak of 21 February 1971 which resulted in 121 tornado-related fatalities.

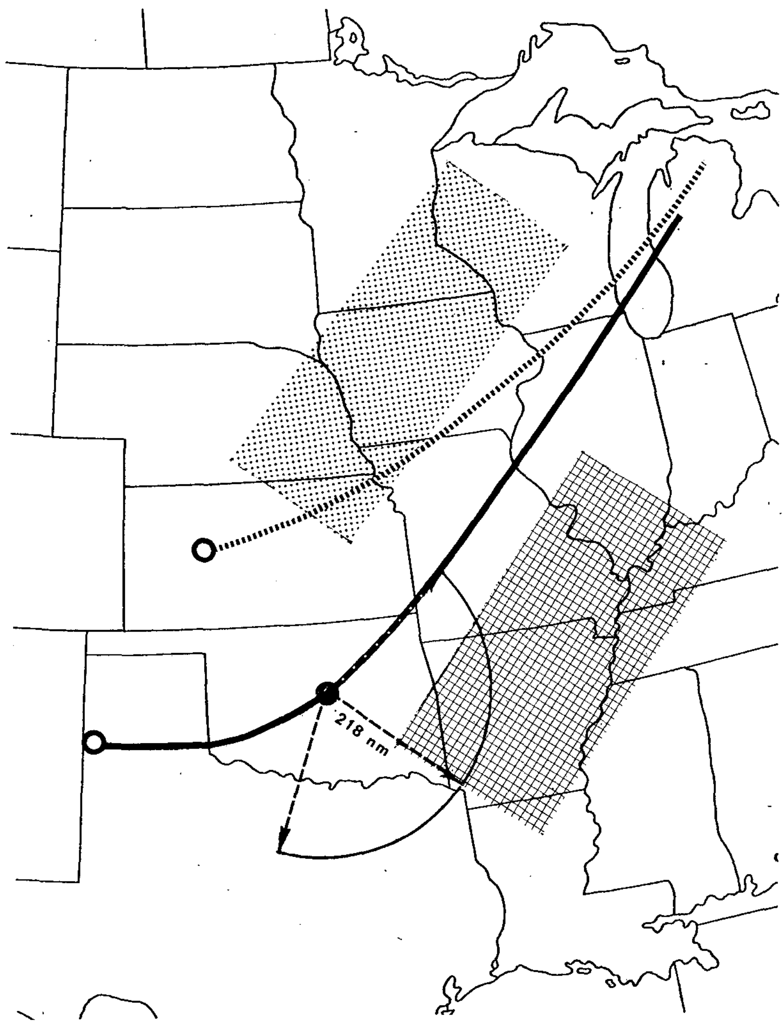

FIG. 2. Mean surface storm track (solid line) computed from 16 Great Plains cases. Dashed line indicates Klein's mean surface storm track for all Great Plains winter storms. Open circles are mean positions of surface low formation. Solid circle is mean location of surface low and distance from initial tornado activity. Arc references direction from surface low of initial tornado activity (NE through SSW). Cross-hatched area is the mean envelope of tornado activity. Stippled area is the mean envelope of heavy snow/ice storm.

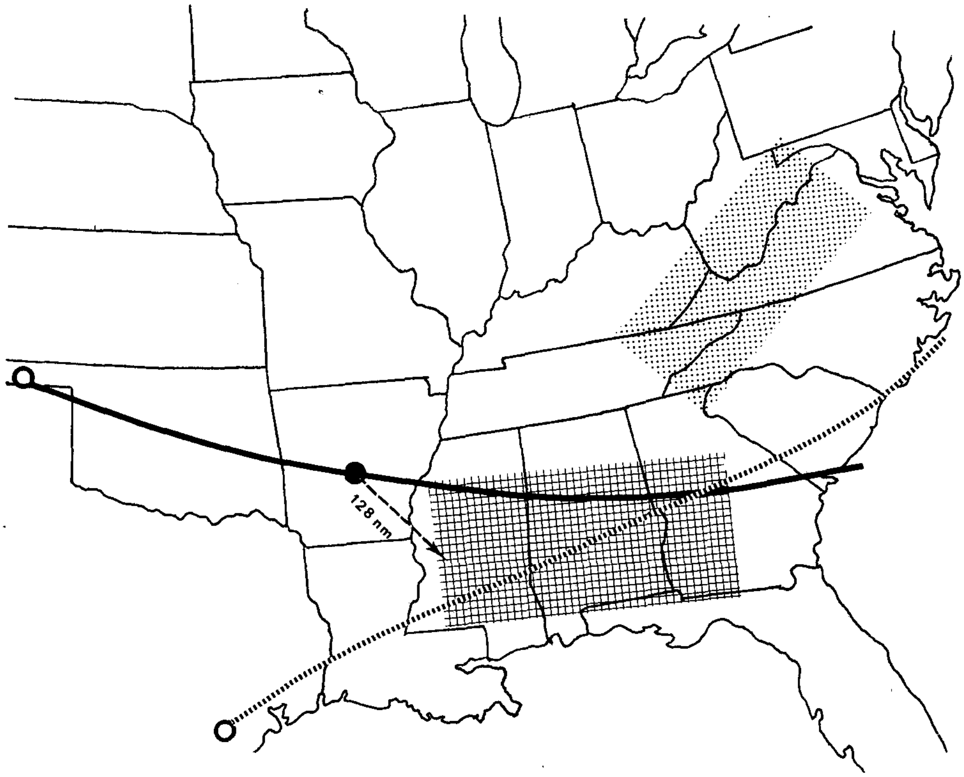

FIG. 3. Mean Southeast surface storm track (solid line) computed from the three cases. Dashed line is Klein's mean surface storm track for all Southeast winter storms. Open circles are mean positions of surface low formation. Solid circle is mean location of surface low and distance from initial tornado activity. Cross-hatched area is the mean envelope of tornado activity. Stippled area is the mean envelope of heavy snow/ice storm.

4. Storm tracks

The centers, six hourly positions, and tracks of the individual cyclone associated with each outbreak were obtained from "Track of Centers of Cyclones at Sea Level" published in the *Monthly Weather Review* (1950–58) and in *Climatological Data, National Summary* (1959–79). Two preferred tracks are apparent, here called the Great Plains Track and the Southeast Track, as the major portion of their trajectories is confined to these geographical areas. The Great Plains track (Fig. 2) accounts for 16 of the outbreaks and the Southeast track (Fig. 3) three. In all cases, the primary surface low center either formed or reorganized in the general area of southeast Colorado, northeast New Mexico, and the Texas–Oklahoma Panhandles.

The mean tracks can be compared with the primary tracks for all storms during the winter months over an 87-year period (Klein, 1957). Klein's tracks are shown as dashed lines in Figs. 2 and 3. His study indicated west central Kansas as the mean source for all winter Great Plains lows. The formation and movement of the Great Plains tornado/heavy snow/ice storm track to the south of the mean storm track suggests that the advection of low-level moisture from the Gulf of Mexico into the surface system may be one of the reasons why the 16 cases were so anomalous. There is less similarity between our Southeast track which originates in the Oklahoma Panhandle and Klein's track which originates in southeast Texas. A major conclusion cannot be drawn with only three cases, but it is suggested that

TABLE 2. Dimensions of tornado and snow/ice areas with respect to storm tracks. Centroid, width and length in n mi, area in n mi^2.

	Great Plains		Southeast	
	Tornado	Snow/ice	Tornado	Snow/ice
Centroid	200	230	93	300
Width	186	162	145	140
Length	412	476	295	360
Area	77×10^3	77×10^3	43×10^3	50×10^3

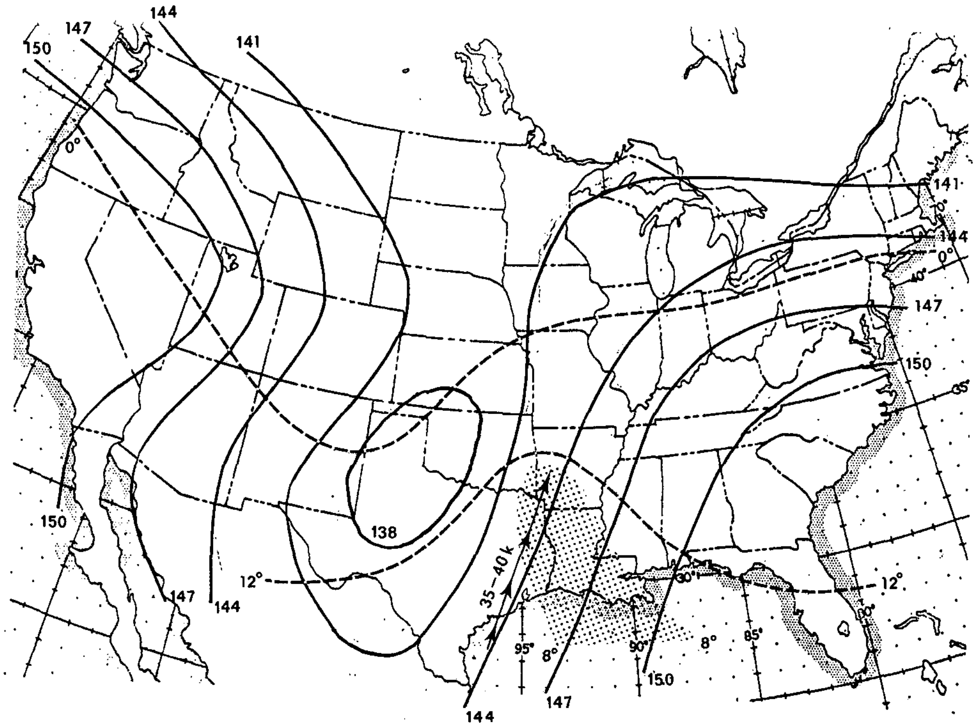

FIG. 4. Mean 850 mb chart for seven cases of the Great Plains track. Stippled area indicates 8°C or greater dew-point temperature. Solid lines indicate isohypes in dam. Dashed line indicates isotherm in °C. Maximum wind axis in kt.

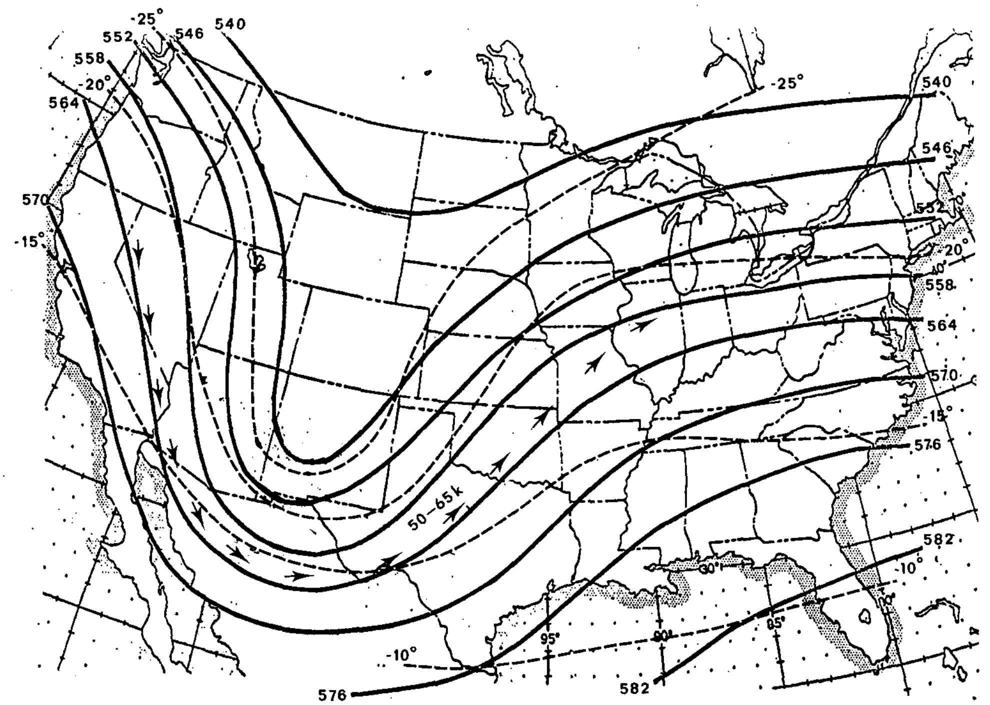

FIG. 5. Mean 500 mb chart for seven cases of the Great Plains track. Solid lines indicate isohypes in dam. Dashed lines indicate isotherm in °C. Maximum wind axis in kt.

the track is the result of a strong baroclinic zone oriented in an east-southeast/west-northwest direction and the access to Gulf moisture.

The envelopes of activity for both the tornado outbreaks and the heavy snow/ice storms have been determined with respect to the individual storm tracks. This includes the centroid of the envelopes as well as the width and length. These have been averaged and are depicted in Figs. 2 and 3, with the cross hatching denoting the mean area of tornado activity and the stippling indicating the mean area of heavy snow/ice. Table 2 presents the average dimensions of the activity areas. The Southeast areas are generally smaller than those of the Great Plains, but this may be biased by the small number of cases. The length of the heavy snow/ice area for the Great Plains, in reality, is longer than that presented, but the portions of Canada affected by these storms are not included. Also, the surface lows of the three Southeast cases began to fill as they approached the Atlantic Coast, in response to cyclogenesis taking place off the coast. This cyclogenesis accounts for the northward projection of the heavy snow/ice area into the mid-Atlantic states.

The heavy snow/ice began prior to the tornado activity in nine cases, and subsequent to it, in four cases. Figs. 2 and 3 indicate the mean position and distance from the surface low center (solid circle) when the tornado activity commenced. While the direction varied from northeast through south-southwest for the Great Plains track, the mean is southeast at 218 n mi. All three cases with the Southeast track began southeast of the surface low center at a mean distance of 128 n mi. No special significance is attached to the central pressure of the surface low (the range was from 978 to 1005 mb). How-

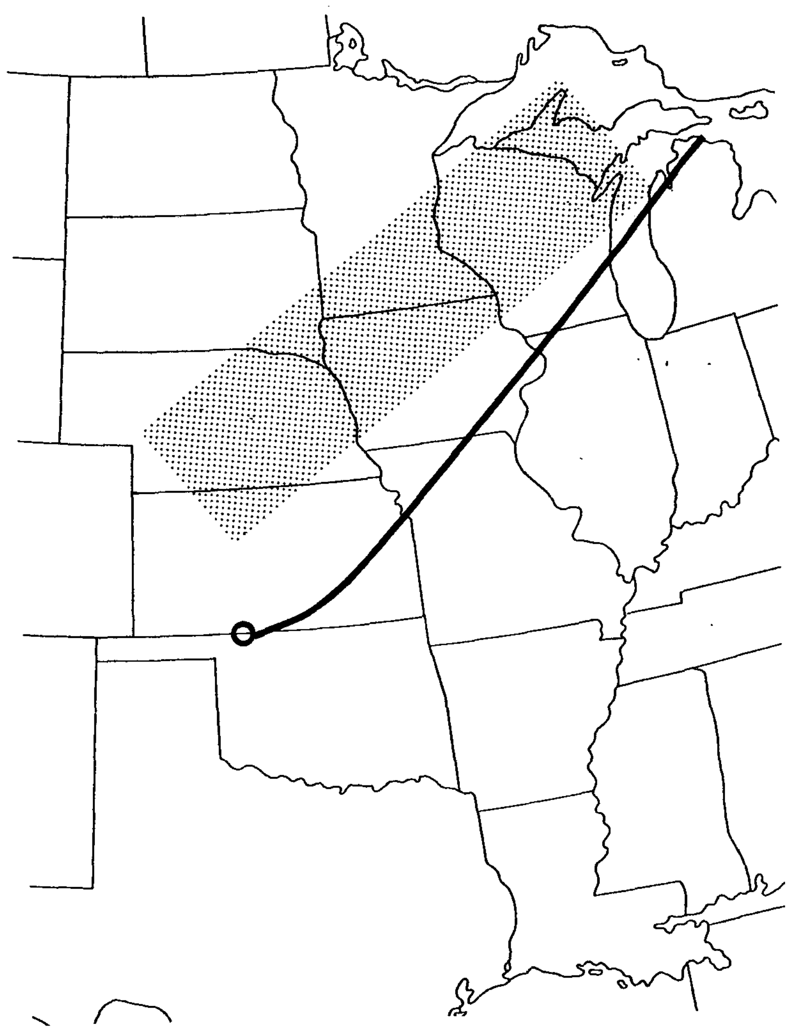

FIG. 6. Mean surface track for six cases of the Great Plains track without major tornado outbreaks. Mean envelope of heavy snow/ice storm is stippled.

ever, it is noted that in 10 cases the central pressure fell during the tornado activity, in six it remained the same, and in the three Southeast cases, it filled.

5. Upper air data

Radiosonde data area available in the NSSFC data bank for seven of the Great Plains cases and mean charts of the 850 and 500 mb levels were constructed from the observations nearest but prior to the time the outbreaks commenced. Since data were available for only one case of the Southeast track, no charts were constructed.

Mean maps, for the most part, tend to smooth significant but spatially limited details in the various meteorological fields. However, the 850 (Fig. 4) and 500 (Fig. 5) mb mean maps for the seven cases in the Great Plains track proved to be revealing. The height fields at both levels indicate a rather intense upper air system, with a strong baroclinic zone at 850 mb from the Texas Panhandle northeastward across Oklahoma into Missouri. A similar, but much weaker, zone appears at 500 mb. The 850 mb moisture axis from the central Gulf coast into southeast Oklahoma and western Arkansas as outlined by the stippling (8°C isodrosotherm) shows that the low-level moisture is well established prior to outbreak inception. The strength of the low-level jet is reflected by the 35–40 kt winds at 850 mb through eastern Texas into Arkansas. Mean maps in another tornado study (David, 1976) do not accentuate the low-level jet as prominently.

The occurrence of heavy snow/ice storms during the winter months not accompanied by major tornado outbreaks is quite common. In order to determine if there are any identifiable differences between the two situations, six such cases were selected at random. These are drawn from winter months in which the total number of tornadoes for the month was less than 10, and for which upper air data were available. The mean storm track, heavy snow area, and mean 850 and 500 mb charts for these cases are shown in Figs. 6, 7 and 8.

The mean storm track is similar to Klein's mean track for all Great Plains winter lows. The surface low center forms further north than it does for outbreak storms. The 850 mb chart for the non-outbreak cases places the closed low some 6° of latitude north of that with outbreaks. The influx of Gulf moisture is half that of the major outbreak cases and in a much narrower band. The baroclinic zone at 850 mb is weaker than shown in Fig. 4. The 500 mb trough in Fig. 8 is rather flat when compared to the trough with major outbreaks and, although the wind fields in both are comparable, the non-outbreak wind maximum is displaced northward. Again, the baroclinity of the non-outbreak cases is somewhat weaker. It appears that the intensity of the baroclinic

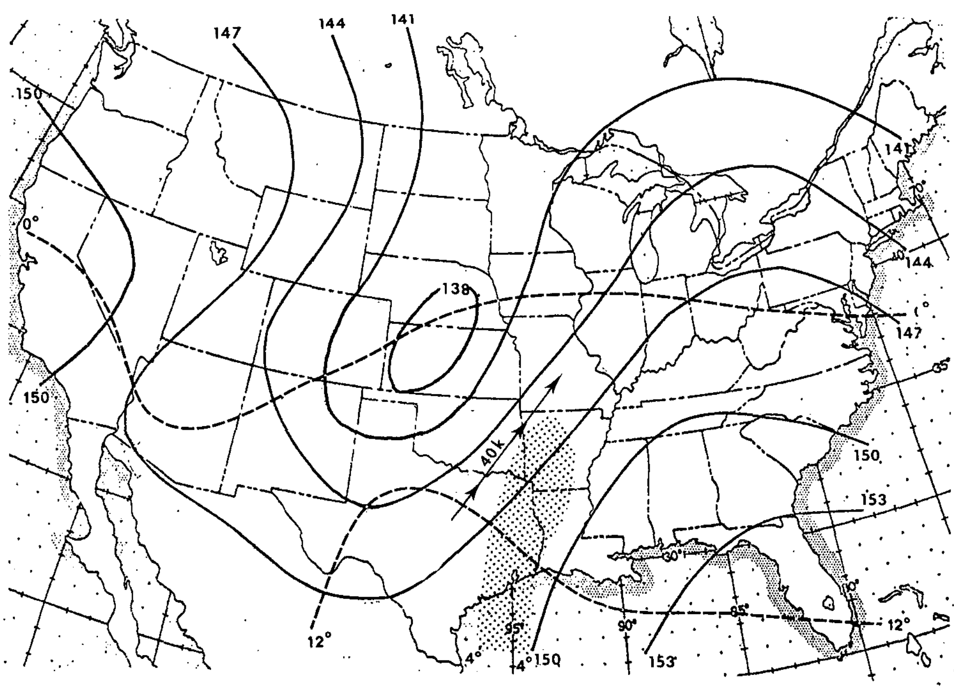

FIG. 7. Mean 850 mb chart for six cases of the Great Plains track without major tornado outbreaks. Stippled area indicates 4°C or greater dew-point temperature. Major features as in Fig. 4.

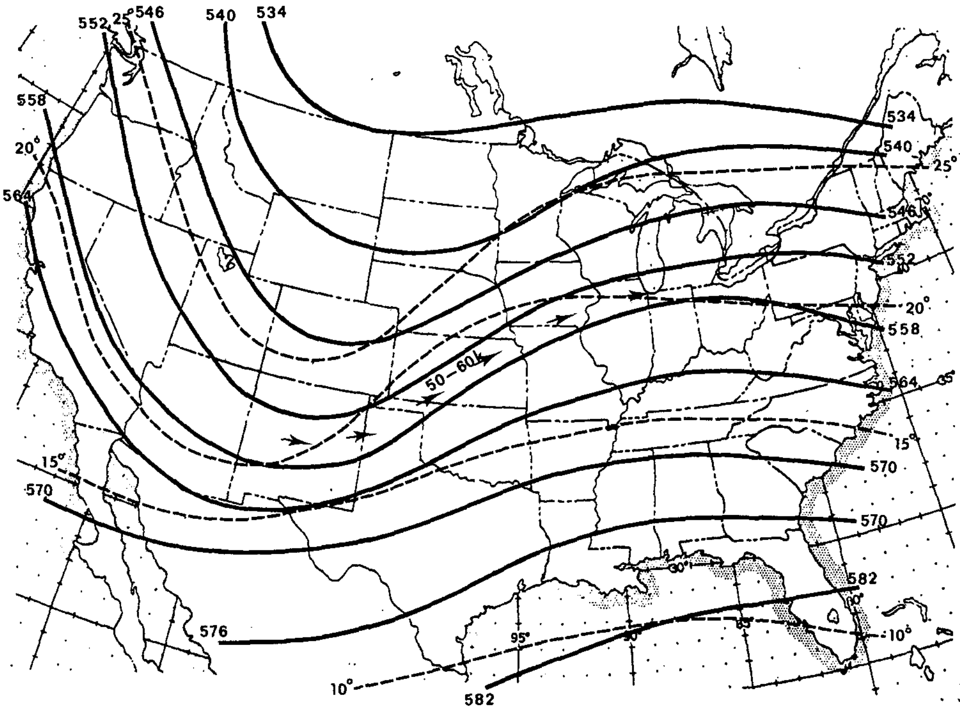

FIG. 8. Mean 500 mb chart for six cases of the Great Plains track without major tornado outbreaks. Major features as in Fig. 5.

zone and the location of the low level features with respect to the Gulf moisture are the determining factors differentiating between outbreak and non-outbreak situations.

6. Winter versus spring outbreaks: Implications

The intensity of the tornadoes in winter outbreaks was compared to those in spring outbreaks (March–May) via FPP indices (Fujita and Pearson, 1973). The distribution of tornados and tornado deaths by force and path length for each season has been determined. While there are seven times the number of major outbreaks in spring months as in winter, and about seven times the number of tornadoes, the distribution of weak, strong, and violent tornadoes and the distribution of short, intermediate, and long-track tornadoes between the two seasons are remarkably similar (Table 3).

Variations, both in force and path length of the tornado category, are evident but the magnitude of the differences suggests they are not statistically significant. This pattern continues in the death category when the F-scale is inspected, but the trend reverses when deaths with intermediate and long-track tornadoes are considered. In winter outbreaks, the majority of deaths occur with long track tornadoes (PL4-5) while the intermediate path length tornadoes (PL2-3) account for the majority of deaths in the spring outbreaks.

Some possible reasons for this reversal have been considered. One is that nighttime tornadoes were the cause. The hourly distribution of deaths for winter and spring outbreaks is shown in Fig. 9. Deaths from winter outbreak tornadoes peak at 1600 LST, one hour earlier than the peak of the spring outbreaks. So this cause can be discounted. A second possibility is that the majority of deaths in the long-track winter tornadoes took place early in their existence, prior to adequate warnings. However, the data reveal that most of the deaths occur during the middle or latter segments of the tracks, after warnings

TABLE 3. Intensity (F-scale) and path length (PL) of tornadoes and fatalities in percent for each with winter and spring outbreaks.

	Tornadoes		Deaths	
	Winter	Spring	Winter	Spring
F0-1	41.7	49.0	0.4	1.4
F2-3	53.6	44.6	28.8	31.4
F4-5	4.7	6.4	70.8	67.2
PL0-1	60.0	58.0	8.7	6.6
PL2-3	34.5	37.1	28.4	55.8
PL4-5	5.5	4.9	62.9	37.6

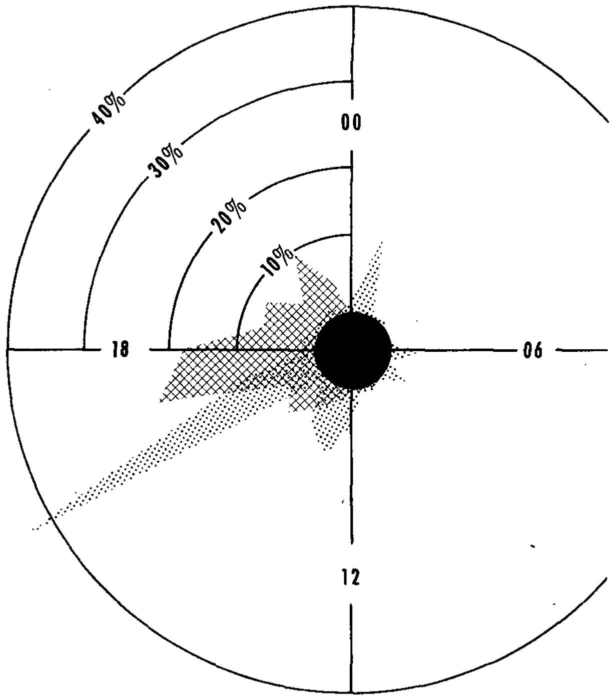

FIG. 9. Hourly distribution of deaths for winter (stippled area) and spring (cross-hatched area) outbreaks in percent.

had been distributed. A notable example of this is the Mississippi Delta Outbreak of 21 February 1971, in which four long-track tornadoes killed 118 people. In this case, the average minimum lead time of the watches for these tornadoes was over 3.5 h and the average minimum lead time for the warnings was nearly 1 h (NOAA, 1971).

Since neither time of day not apparent adequate lead time of the watches and warnings are conclusive, per se, to explain the anomalously high death rate associated with long track winter outbreak tornadoes, it is speculated the answer may be a psychological one. Psychological factors have been alluded to in the past in contributing to tornado-related deaths. Brouillette (1966) concluded that most people do not take precautionary measures on the basis of a single clue (warning). Sims and Baumann (1972) implied that fatalism and passivity are partially responsible for the high number of tornado deaths in the South. It may well be that a large number of the populace considers the winter months as an unlikely period of the year for tornadoes. Hence, less credence is given to the tornado watches and warnings.

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