The Tinker AFB Tornadoes of March 1948

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ABSTRACT

During March of 1948 Tinker Air Force Base was hit directly by two tornadoes during a period of only five days. The first tornado was the most destructive, to that point, ever to occur in Oklahoma. The second storm caused considerable additional damage and was remarkable in another, more significant, way. The first operational tornado forecast had been issued by Air Force Officers E. J. Fawbush and R. C. Miller a few hours before the tornado moved across the base. This extremely unusual meteorological situation, two tornadoes hitting the same location within five days, coupled with the fortuitous forecast of the event, had a profound impact on the evolution of operational severe weather forecasting in the United States. These events eventually stimulated the initiation of public severe thunderstorm forecasting by the Weather Bureau.

Miller often presented anecdotal accounts of the events leading up to the landmark forecast, for example, in seminars and interviews during a visit to the National Severe Storms Laboratory during March 1994. He often stressed that the remarkable similarity of the synoptic settings on 21 and 25 March 1948 helped give him and Fawbush the courage to issue the now famous forecast. In this paper the synoptic environments that led to the two tornado occurrences at Tinker are analyzed and discussed. There were indeed similarities; however, it is surprising how different many aspects of the storm settings actually were. Similarities and important differences are illustrated with a series of synoptic surface and upper-air charts. It is likely that development of a base severe weather plan following the tornado disaster of 20 March, in addition to the presence and exhortations of General F. S. Borum at the base weather station on 25 March, provided as great a motivation for the first tornado forecast as did the similarity of the synoptic settings.

1. Introduction

During March of 1948 two destructive tornadoes struck Tinker Air Force Base (AFB) within the course of only five days. The first tornado occurred shortly after 2200 CST the evening of 20 March (i.e., about 0400 UTC on 21 March). The damage was severe and there had been no forecasts or warnings indicating the potential severity of the day's weather and storms. This tornado produced more than $10 million in damage on the base (American Meteorological Society 1948), making it the most destructive tornado, from a property damage perspective, ever to strike in Oklahoma to that point in time. The infamous Woodward, Oklahoma, tornado of 6 April 1947 had caused 101 deaths, but only about $8 million in property damage in the state (Flora 1953).

Only five days later, on 25 March, the synoptic pattern again appeared to favor development of strong thunderstorms over Oklahoma. Two officers at the Tinker AFB Weather Detachment, Major E. J. Fawbush and Captain R. C. Miller, had been feverishly studying prior work related to tornadoes and storm forecasting (e.g., Lloyd 1942; Showalter and Fulks 1943) since the events of 20 March. They had also been studying the conditions that had produced the storms five days before.

They felt the situation on the morning of 25 March had many similarities to the conditions of 20 March, enough so that they alerted the base commander, General F. S. Borum. The general spent much of the day at the base weather station and during the afternoon Fawbush and Miller, with the general's support and even urging, issued severe thunderstorm and then tornado forecasts, triggering General Borum's newly developed base severe weather plan. This new plan required Tinker personnel to take damage mitigation actions (e.g., moving aircraft to hangars, tying down loose objects, etc.) if heavy thunderstorms were forecast to strike the base.

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The events of the afternoon of 25 March were described by Newton et al. (1978) as follows:

> On the morning of 25 March 1948, just five days after the Tinker storm, Fawbush and Miller noted a great similarity between the latest weather charts and those of 20 March. A prognostic chart, showing the expected positions of critical parameters at 1800 CST, led to the unsettling conclusion that central Oklahoma would be in the primary threat area by late afternoon. After General Borum was briefed on the current and forecast charts, the decision was made to issue a warning of 'Severe Local Thunderstorms with large hail and wind gusts to 65 mph,' valid from 1500 to 1800.

By 1430 CST a strong squall line was approaching Tinker from the southwest. The general came again to the weather station and soon asked:

> if the forecasters believed tornadoes were likely in the vicinity of the base. . . . When the general was informed that the probability was considered high enough to justify issuance of a warning, his only comment was: 'Do it!' At 1500 the first operational tornado forecast was issued, with a warning for Tinker Air Force Base valid from 1600 to 1800.

At about 1800 CST the second tornado in five days moved directly across Tinker AFB, verifying the now famous, first operational tornado forecast. Even though the severe weather plan had been activated, the tornado produced an additional $6 million in damage on the base. It is interesting to note that the damage inflicted at Tinker AFB was so severe because of the destruction of numerous, very expensive military aircraft. Indeed, many of the developments and much of the progress in severe weather forecasting and research that occurred in the decade following the Tinker tornadoes was motivated by the vulnerability of new military aircraft to severe weather.

This event and forecast were to have long-term impacts on the evolution and methodologies used in severe weather forecasting in this country [see Doswell et al. (1993) for a review of tornado forecasting]. Doswell et al. state that:

> Although tornado forecasting had its roots in the nineteenth century, stemming mostly from the work of J. P. Finley [see Galway (1985) for more on Finley], it was not until the early 1950s that serious tornado forecasting began. The successes of Fawbush and Miller clearly paved the way for a civilian tornado forecasting program.

Miller often talked of the similarity of the weather patterns that produced the tornadoes. However, there has never been a formal documentation of the large-scale weather conditions present on these two days. Sounding and surface data from 1948 have been used to analyze the synoptic settings present on 20 and 25 March. These analyses are presented in the following sections, along with assessments of similarities and important differences. The new analyses follow the conventions developed and used by Miller (1967) and those who worked with him in the Military Weather Warning Center.

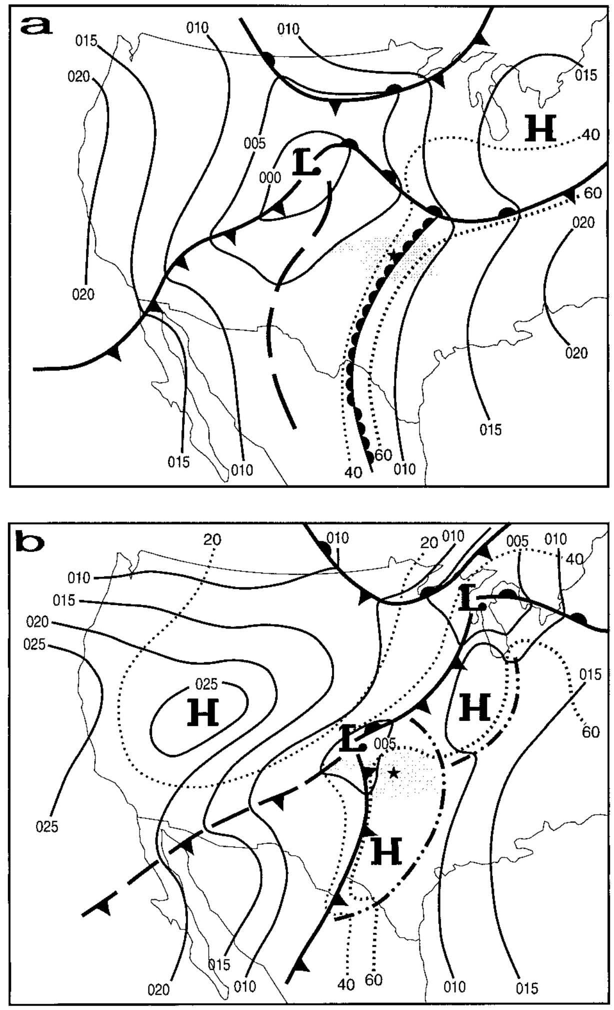

FIG. 1. Surface analyses for (a) 1230 UTC 20 Mar 1948 and (b) 1230 UTC 21 Mar 1948. Isobars are shown at 5-mb intervals. The dryline (continuous round blips); surface troughs (heavy dashed lines); 20°, 40°, and 60°F dewpoint isodrosotherms (dashed lines); squall lines (dash–double dot lines); and standard surface analysis features are shown. The location of Tinker AFB is indicated by the star.

2. Surface analyses

The surface analyses for 1230 UTC on 20 and 21 March 1948 are shown in Fig. 1. Several key features present at the surface on 20 March included the surface low (pressures lower than 1000 mb) over the west-central high plains and the dryline positioned over western Texas and central Oklahoma. The dewpoint at Tinker was quite low (in the 40°s F!) as this day began. During the day, the dryline retreated toward the west and north, allowing moist, low-level air from the Gulf of Mexico to spread over most of Oklahoma. By 1230 UTC the

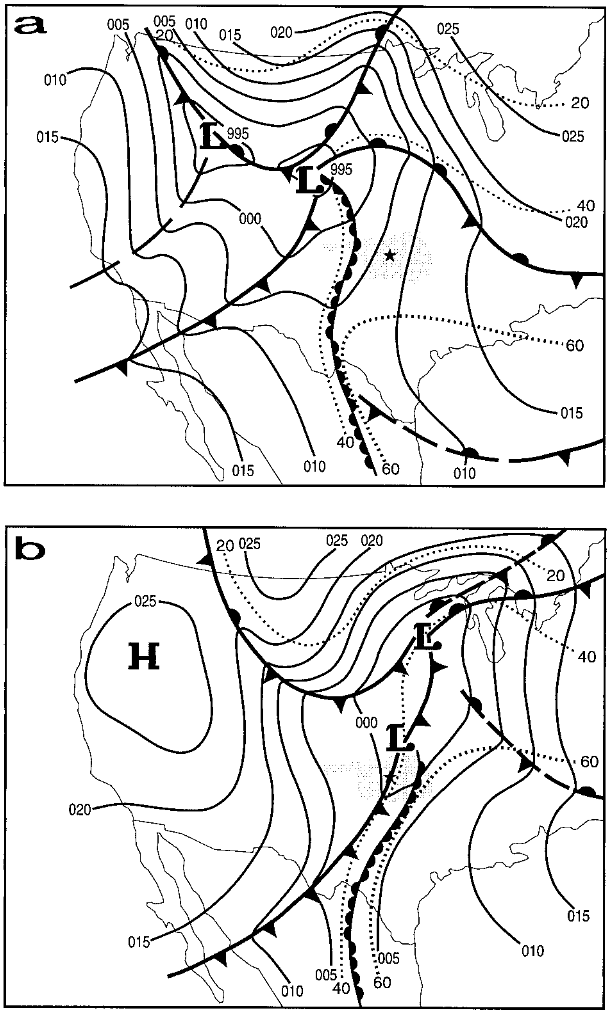

FIG. 2. Surface analyses as in Fig. 1 for (a) 1230 UTC 25 Mar 1948 and (b) 1230 UTC 26 Mar 1948.

next morning (Fig. 1b) there were two surface low pressure centers present, with one to the northwest of Tinker. The Pacific cold front had begun consolidating with, or overtaking, the dryline. There were two significant lines of thunderstorms affecting the area from the Great Lakes southward to Texas. The surface cyclones with this event were not particularly intense for spring storm systems over the plains.

Similar surface charts for 25–26 March are presented in Fig. 2. In a general sense the surface patterns were similar with a low, a bit more intense on 25 March, over the west-central plains. Polar fronts were present over the northern tier of states and Pacific cold fronts and drylines were affecting the southwest and southern plains. The return flow on 25 March, however, had a considerably different character than that of 20 March. A precursor front had penetrated into the Gulf of Mexico and the air flowing northward across the plains was the modified maritime polar air mass from the north side of this decaying front. With time the return flow on 25 March appeared to become a mix of modified maritime polar and tropical air masses. This is a fairly typical March situation as described by Crisp and Lewis (1992). This return flow had penetrated much farther north and west at 1230 UTC on 25 March than it had five days earlier, but dewpoints increased only gradually from the north-central plains southward to the Gulf.

Since the dryline usually does not retreat westward during the day nearly as frequently as it does at night (Schaefer 1974), the situation on 25 March was more favorable for thunderstorms. The Gulf air mass (albeit modified) was already in place across the state. On both afternoons, however, dewpoint temperatures recovered into the 60°s F at Tinker before the onset of the severe thunderstorms. In sum, both days appeared basically similar at the surface, with the exception of the very substantial westward retreat of the dryline on 20 March.

3. Upper-air analyses

The charts at 1500 and 0300 UTC for each tornado event are used, at 850 and 500 mb, to illustrate the upper-air settings associated with the tornadic storms. Upper-air data times were 3 h later in the day during 1948 than they are now. Analyses above 500 mb are not shown because many of the observations were missing above this level; indeed, many winds were missing even at 500 mb.

The 850-mb charts for 20–21 March are presented in Fig. 3. The maps are basically similar to the surface charts shown above. In the morning, high dewpoints were positioned far south and east of Tinker and very dry air from the Mexican Plateau had spread over most of Oklahoma. The 0300 UTC chart clearly illustrates that substantial north- and westward advection of the maritime tropical air mass from southeastern Texas had occurred across most of Oklahoma.

On 25–26 March (Fig. 4), the setting was generally similar except that in the morning the dryline at 850 mb was positioned just west of Tinker AFB. The dewpoints on 25 March within the air stream from the Gulf of Mexico were lower, probably due to the modified continental polar character of this flow. On both mornings the height gradients favored flow with a substantial westerly component over Oklahoma. The dryline had already passed Tinker, or was nearby, with the most moist air in lower levels positioned well to the south-southeast. Interestingly, on 25 March the evening data also indicate that the dryline had retreated slightly westward during the day.

An area forecast for the southern plains, given these morning surface and 850-mb charts, would likely indicate the western boundary of the area that would experience afternoon thunderstorms near or east of Tinker. This supposition follows because of the dryline positions and their likely remaining stationary, or translating eastward, during the late morning and afternoon as westerly winds at 850 mb were mixed toward the surface.

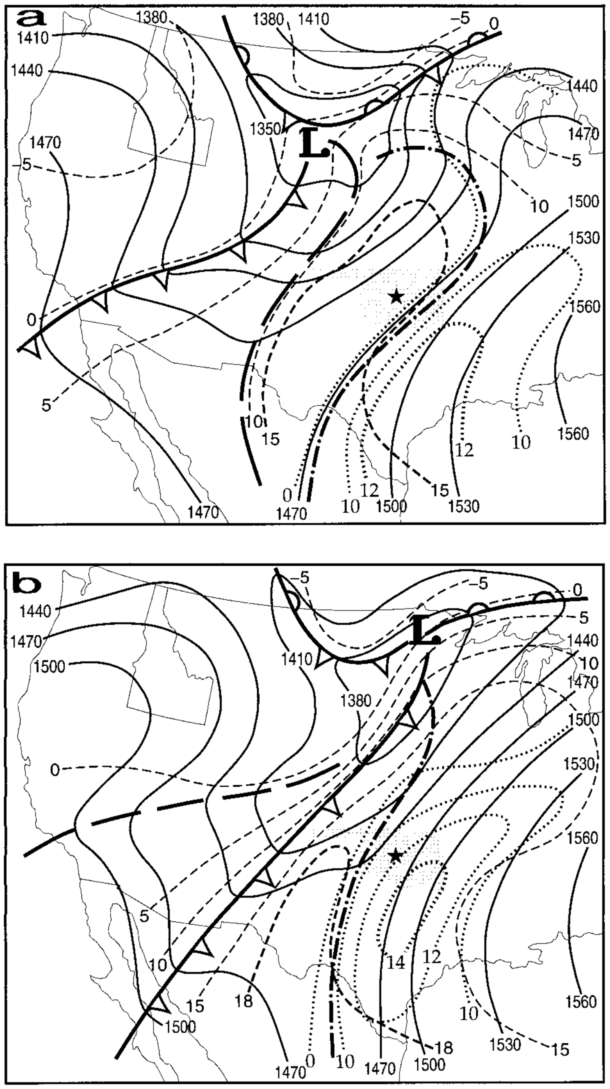

FIG. 3. The 850-mb analyses for (a) 1500 UTC 20 Mar 1948 and (b) 0300 UTC 21 Mar 1948. Symbology follows Miller (1967). Fronts are shown with open barbs. Height troughs are heavy dashed lines. Dryline positions are heavy dash–dot lines. Temperature (dewpoint) isotherms (isodrosotherms) are light, dashes (dots) in °C. Height contours are in m.

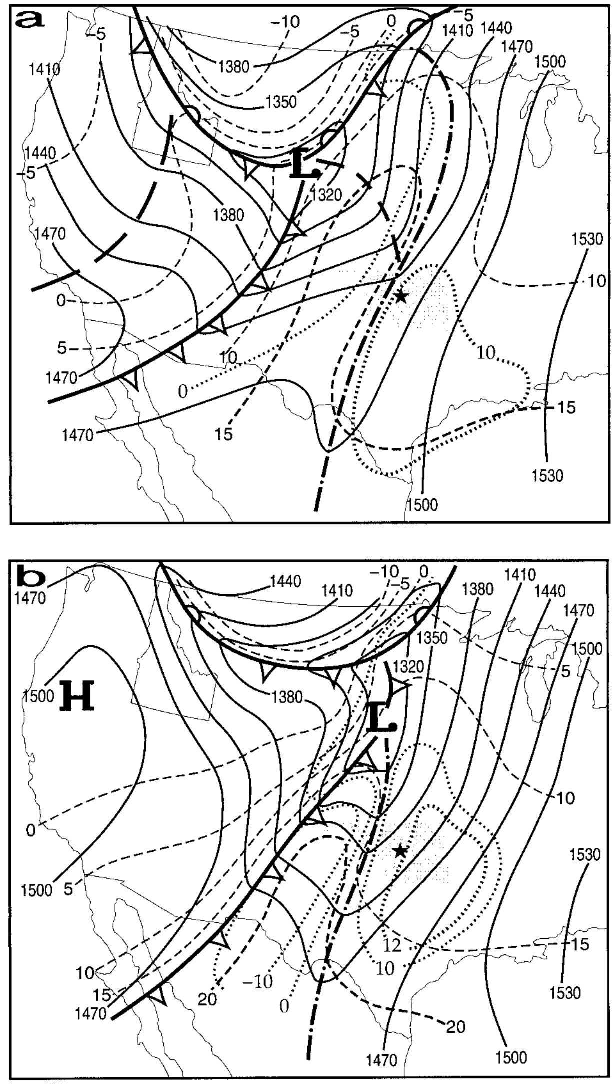

FIG. 4. The 850-mb analyses as in Fig. 3 for (a) 1500 UTC 25 Mar 1948 and (b) 0300 UTC 26 Mar 1948.

The 500-mb charts for 20–21 March (Fig. 5) show a full-latitude trough moving slowly across the western United States. Temperatures in the core of this trough were quite cold, less than −30°C, and strongest midlevel winds (inferred both from the height gradients and the observations that were available) were located over northwestern Oklahoma. There were several short waves rotating around the larger-scale trough. It appears that a weak wave moving northward from Mexico may have played a role in focusing the severe thunderstorms in central Oklahoma. However, we would need the modern tools of satellite imagery and model forecasts to evaluate this feature (plus of course observations from Mexico, which were not available in 1948).

The 500-mb charts for 25–26 March are presented in Fig. 6. These analyses indicate a much different setting on this second storm day of the week. A very pronounced, negatively tilted short-wave trough was moving across the Southwest toward Oklahoma. This wave was positioned over the Texas panhandle by 0300 UTC. The middle-level jet stream winds were more westerly on 25–26 March, and it appears that large-scale forcing for vertical motion was much more intense. From a forecaster's perspective, the most negative aspects of this day (regarding whether or not thunderstorms would be likely in the Tinker area) day are the lower moisture content of the return flow air mass and the leading, but weaker, short wave positioned over the plains north of Oklahoma at 1500 UTC. This leading trough could have led forecasters to anticipate continued eastward move-

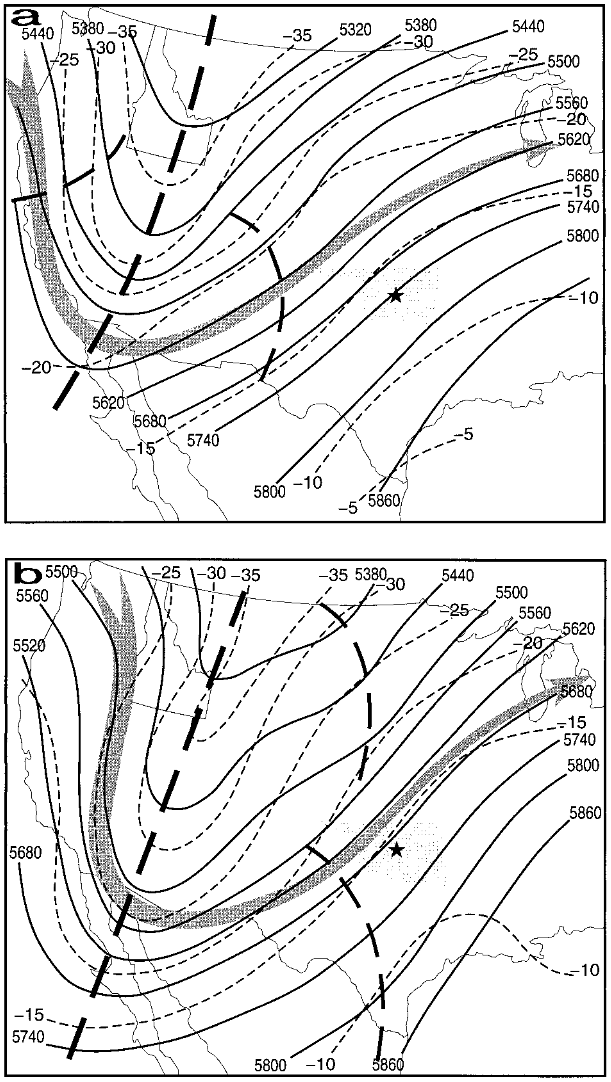

FIG. 5. The 500-mb analyses for (a) 1500 UTC 20 Mar 1948 and (b) 0300 UTC 21 Mar 1948. Height contours are in m. Major height trough positions are heavy dashed lines, and minor troughs are lighter dashed lines. Isotherms in °C are light dashed lines. The axis of strongest wind speeds is indicated by gray-shaded arrow.

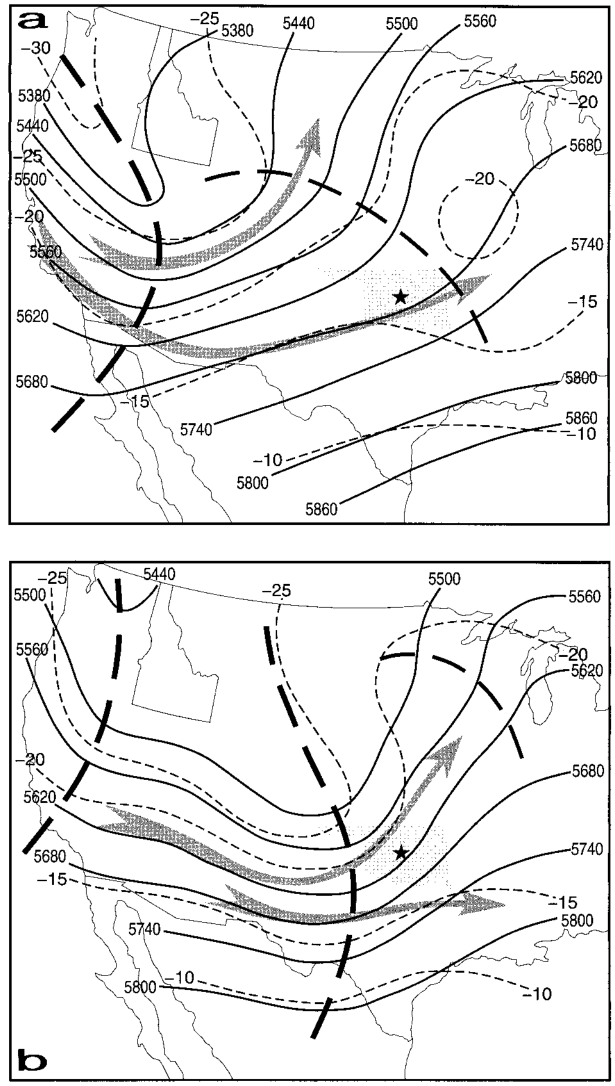

FIG. 6. The 500-mb analyses as in Fig. 5 for (a) 1500 UTC on 25 Mar 1948 and (b) 0300 UTC on 26 Mar 1948.

ment of the dryline, with the region of storm development occurring to the east and north of Tinker.

4. Composite charts and upper-air soundings

Drawing upon all data available, composite charts of the approximate conditions present close to the times of the two tornadoes were constructed. These charts follow the symbology and color coding presented by Miller (1967) and are shown in Fig. 7.

At 0600 UTC on 21 March the most important and key severe weather features and parameters appear to have been the juxtaposition of the surface and 850-mb dryline, the weak 500-mb short wave, and the middle- to upper-level jet stream over western Oklahoma. Note that many winds were missing at 500 mb, particularly over the central and northeastern United States, indicating that very strong winds were present at upper levels. The hottest air at 850 mb lay to the west over southwestern Texas and the Panhandle, while the low-level jet and low-level moisture axis appeared to be positioned well to the east of Tinker.

From today's severe weather forecasting perspective this situation does not appear to be exceptionally strong or threatening. For example, the primary vorticity maximum at 500 mb was most likely positioned far to the west of Oklahoma, and the strongest influx of lower-level moisture appeared to be advecting into the middle Mississippi Valley.

The composite chart for 0000 UTC on 26 March, however, illustrates a much stronger confluence of classic severe weather features and parameters over the

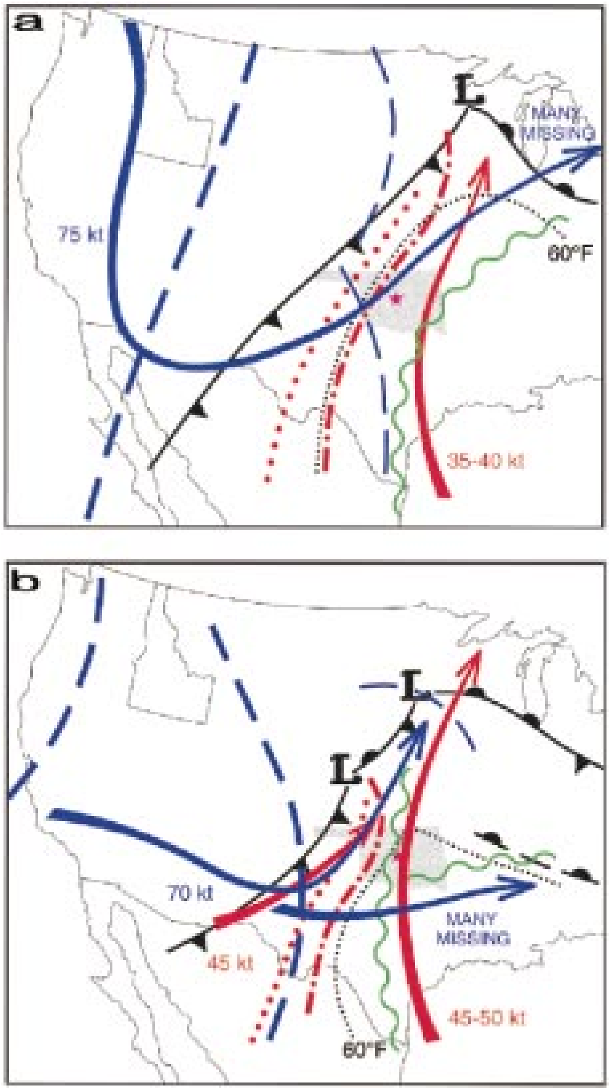

FIG. 7. Composite charts constructed for (a) 0600 UTC 21 Mar 1948 and (b) 0000 UTC 26 Mar 1948. Features are as on preceding charts with 500-mb features in blue, 850-mb features in red and green, and surface frontal analyses and 60°F dewpoint in black. The wavy green lines indicate moisture axes at 850 mb and the red dotted lines the axes of highest temperatures at 850 mb. Maximum observed wind speeds are indicated; many winds were missing at 500 mb.

southern plains. Key features illustrated in Fig. 7b include the likely positioning of the surface and 850-mb dryline over western Oklahoma, just to the west of the low-level jet and axis of highest moisture content, which lay very nearly over Tinker. A powerful vorticity maximum seemed to be positioned just to the west of Oklahoma, and it was moving rapidly eastward. Associated with this significant short-wave trough were strong and diffluent jet stream winds at and above 500 mb. Further, temperatures at 500 mb over the southern plains were considerably cooler on 25 March; for example, compare the positions of the $-10°$ and $-15°C$ isotherms in Figs. 5b and 6b. This setting was considerably different than that of five days earlier. It is quite ''classic'' from the severe weather forecasting perspective and is similar to many patterns that were to be highlighted a number of years later by Miller (1967) in his famous TR-200 forecasting guide.

The final observational data examined in this reanalysis were the upper-air soundings for the morning and evenings of both tornado days. The 1500 UTC morning soundings for Oklahoma City are shown in Fig. 8. The sounding for 20 March was remarkable in its dryness and complete lack of moist, convective potential instability. The mean mixing ratio below 850 mb was only on the order of 5 g kg^{-1}. However, the maximum afternoon temperature and dewpoint observed at the surface, plotted in the sounding, illustrate dramatically the extreme destabilization that occurred as the dryline retreated to the north and west.

The sounding for 25 March (Fig. 8b) shows much different conditions on the morning of the second tornado. Central Oklahoma was clearly within the moist return flow from the Gulf and there was convective available potential energy present, although a substantial lid or cap was indicated above about 850 mb. The maximum observed surface temperature and dewpoint indicate an extremely unstable environment developed by late afternoon. This was partly due to the higher dewpoints on 25 March but resulted mostly from the extremely cold temperatures aloft. For example, the sounding plots indicate that temperatures from 600 to 300 mb were 5°–9°C colder on the morning of 25 March, resulting in a much more volatile thermodynamic environment for deep convection. The winds were very strong below 500 mb on both mornings; there was considerably more veering of the winds aloft on 25 March; and the tropopause appeared much lower on 25 March.

The 0300 UTC sounding for 21 March is presented in Fig. 9. The key aspect of this sounding was that considerable instability had indeed developed (lifted index of $-5°$ to $-8°C$), and very little lifting was required to initiate deep convection. The winds aloft remain quite strong. The 0300 UTC sounding at Oklahoma City on 26 March was contaminated by storms that had already moved across the area and is not shown.

These soundings indicate very dramatic destabilization during the days of interest; thus a very difficult forecast situation was present for both events. For example, slightly more westerly flow in low levels would likely have kept the dryline over or east of the Tinker area, shifting the threat of severe thunderstorms into eastern Oklahoma.

5. Discussion

The meteorological analyses of the observational data available for the two, tornadic storm days at Tinker AFB provide a somewhat surprising picture. It is surprising because, based upon years of anecdotal accounts, we had expected to find synoptic settings that were con-

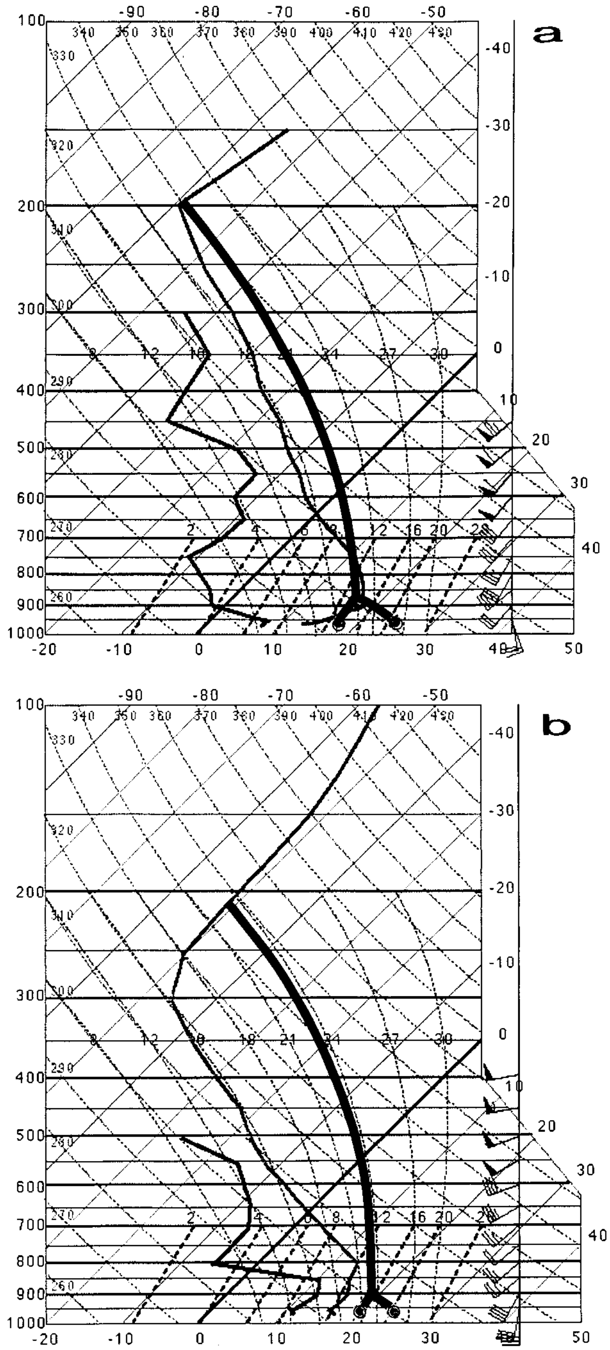

FIG. 8. Skew *T*–log*p* plots of the Oklahoma City soundings at 1500 UTC on (a) 20 Mar 1948 and (b) 25 Mar 1948. Winds are full barb for 10 kt (or 5 m s^{-1}) and flags for 50 kt (or 25 m s^{-1}). The surface parcel and its lifted characteristics are indicated for the maximum concurrent observed values of temperature and dewpoint prior to the tornadoes.

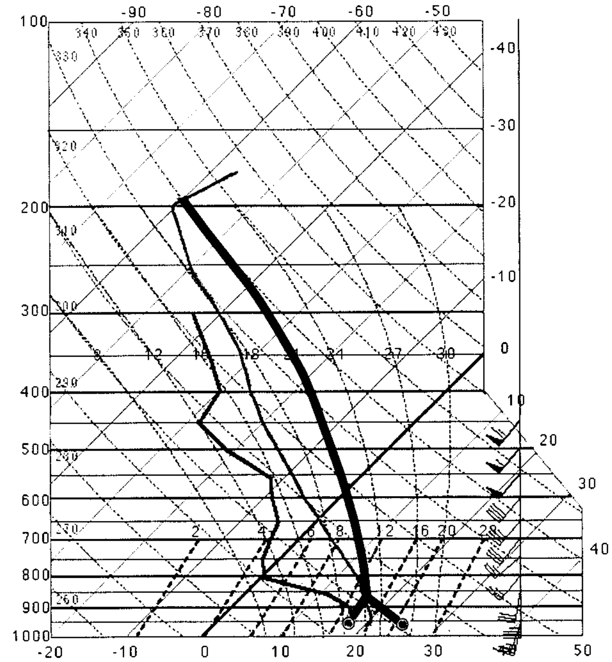

FIG. 9. Skew *T*–log*p* plot of the Oklahoma City sounding for 0300 UTC on 21 Mar 1948. Details as in Fig. 8.

siderably more similar. The surface patterns were most similar and conditions aloft were markedly different. The event of 25 March was characterized by a much stronger baroclinic environment and an intense, rapidly moving short-wave trough. The moist, potential convective instability was very great by late afternoon on 25 March, more so than on 20 March.

The mesoscale and storm-scale aspects of the environment over central Oklahoma on 20 March must have played a significant role in the development and evolution of the severe thunderstorm that struck Tinker AFB during the early nighttime hours. The synoptic setting on 25 March was markedly more favorable for severe thunderstorms, and even significant outbreaks of tornadic storms. Indeed, the pattern that affected the southern plains and Tinker AFB on the day of the famous first tornado forecast came to be recognized as a ''Miller type-B'' pattern and was highlighted in his TR-200 as being one of the two most potent of severe weather patterns.

It is interesting that no reference seems ever to have been made to the dramatically more favorable synoptic patterns present on 25 March 1948. Thus, it is not clear whether or not Fawbush and Miller recognized fully, at that early point in their forecasting research, the quite different character of the synoptic pattern on the day of the second tornado.

After studying these analyses and reaching the above conclusions, the March 1948 issue of the *Monthly Weather Review* (American Meteorological Society 1948) was reexamined. The ''Severe Local Storms for March 1948'' section reports the following two events for 20–21 March:

1) hail damage in and near Cloud Chief, Washita County, Oklahoma, around 2000 CST—this is about 130 km west-southwest of Tinker AFB, and

2) the first Tinker AFB tornado at 2200 CST.

However, for 25–26 March the following severe weather reports are listed: 1) the second Tinker AFB tornado at 1800 CST, and 2) tornado and hail in Noble County at 1830 CST—about 130 km north of Tinker.

In the east-central quarter of the state the following is noted:

1) tornado at Zena, Oklahoma, at 2100 CST;
2) tornado at Boyton, Oklahoma, at 2145 CST;
3) tornado (or tornadoes) in Hughes, McIntosh, Muskogee, and Sequoyah Counties from 2030 to 2330 along a path 102 mil long and 100 yards to 2 mil wide; these tornadic storms were accompanied by heavy rains and severe hail, continued intense as they moved into western Arkansas, and produced 13 deaths and 44 injuries; property damage is listed as less than a million dollars;
4) tornado in Crawford and Washington Counties in Arkansas near midnight;
5) severe thunderstorms in Logan County, Arkansas, near midnight.

Considering the quite limited severe thunderstorm reporting of the 1940s, compared say to that of the 1980s and 1990s, it appears that a very significant outbreak of severe and tornadic thunderstorms occurred on 25–26 March 1948. The severe events of five days earlier were far more isolated.

Given the above meteorological assessments, the question remains, ''What exactly did stimulate Fawbush and Miller to issue their famous forecast?'' The authors feel that development of a base severe weather plan following the tornado disaster of 20 March and the presence and exhortations of General Borum at the weather station on 25 March probably provided as great, or greater, motivation for the first tornado forecast as did the ''similarity'' of the synoptic settings.

It is amazing that this first forecast was so fortuitously successful, that is, two significant tornadoes occurring at the same precise location within five days. Regardless, the fact that the second tornado did—with unbelievable luck, both good and bad—strike Tinker AFB undoubtedly accelerated the development of severe storms forecasting. It appears that the amazing coincidence of multiple tornadoes hitting a military installation where, in retrospect, just the right players happened to be stationed is perhaps the preeminent and quintessential event of operational severe storm forecasting.

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