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WEST TEXAS MESONET OBSERVATIONS OF WAKE LOWS AND HEAT BURSTS ACROSS NORTHWEST TEXAS

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1. INTRODUCTION

Wake lows (WLs) and heat bursts (HBs) are mesoscale phenomena associated with thunderstorms that can result in strong and sometimes severe (>25.5 m $s^{-1)}$, near-surface winds. The operational detection of severe winds is problematic because the associated convection can appear quite innocuous via WSR-88D data. The thermodynamic environment that supports WL and HB development is similar, and is often compared to the classic "onion" sounding structure as described by Zipser (1977). Observational studies such as Johnson et al. (1989) show that nearly dry-adiabatic lapse rates are prevalent in the lower to mid-troposphere, with a shallow stable layer near ground level. This type of environment is most commonly observed in the high plains during the warm season. While documented heat bursts were infrequent in the past, the recent expansion of surface mesonetworks are increasing the likelihood that these events will be sampled. One such network is the West Texas Mesonet (WTXM), a collection of over 40 meteorological stations spread across the Panhandle and South Plains of northwest Texas. During the period 1 June 2004 to 30 August 2006, the authors have recorded 10 WL/HB events that have been sampled by stations of the WTXM. Some of the more extreme measurements include a 15 degrees Celsius increase in temperature at the Pampa and McClean WTXM sites in one event and 35 m s^{-1} wind gusts at sites in Brownfield and Jayton on separate occasions. Additionally, several of the events have caused considerable property damage.

This paper will survey the mesoscale environment of 10 WLs/HBs through analyses of the WTXM augmented by supporting radar and satellite data. Although only limited statistical analysis is provided, it is hoped that the collection of events in this study will help establish some of the typical surface characteristics of WLs/HBs and aid forecasters in recognizing their onset and evolution.

2. DATA AND ANALYSIS

The study area encompassed the current domain of WTXM stations (Fig. 1).

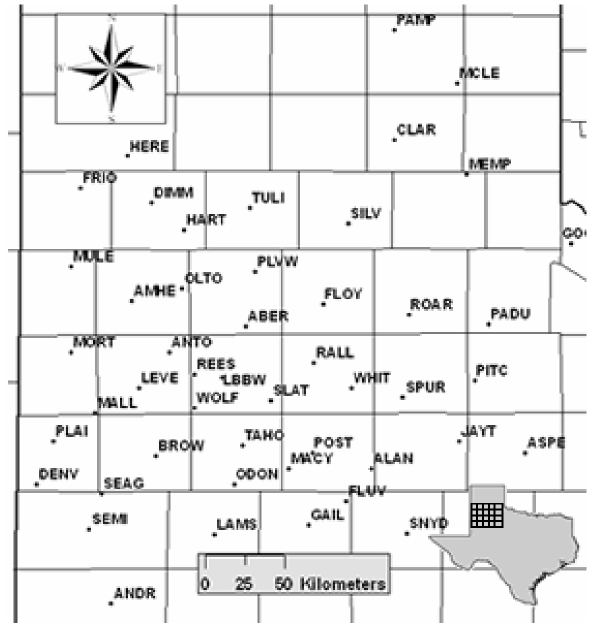

FIG. 1. The Study area including the WTXM station locations. Not all stations were available for every event.

Meteorological data from each WTXM station is recorded in 5-minute intervals, representing average values during that period plus the peak 3-second gust for the wind speed. Schroeder et al. (2005) provides further information on the WTXM. Objective analysis grids of temperature, dewpoint, pressure, pressure tendency (30-min and 60-min), and mass divergence were produced for each WL/HB event. Radar data from the Lubbock (KLBB) WSR-88D, satellite data from GOES East, and radiosonde data from Amarillo (KAMA) and Midland (KMAF) were also utilized.

3. WAKE LOWS

Previous studies (e.g. Johnson, 2001) have shown that WLs typically form during the decaying stage of a mesoscale convective system (MCS) near the back edge of the trailing stratiform precipitation region (TSR). In this area, parcel descent is aided by a dry subcloud layer where evaporative cooling is inadequate to maintain saturation or offset adiabatic warming; and the parcel continues to the surface despite being warmer than its environment. Additionally, rear-to-front flow aloft within the stratiform region, often in the form of a descending rear-inflow jet, may enhance subsidence warming. WLs are commonly associated with pressure

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falls of 4 mb hr^{-1} and can be tracked through the pattern of pressure falls or surface divergence (Johnson et al., 1989). The pressure difference between the WL and the mesohigh can also lead to a strong pressure gradient between the two regions. A surface pressure fall of 10 mb in 20 minutes was measured in one such case (Johnson et al., 1996). Table 1 shows the WL cases detected from the WTXM data for this study.

TABLE 1. Wake low cases in this study along with the maximum pressure drop and wind gust for each.

Date (UTC)	Maximum Pressure Drop	Maximum Wind Gust
7 July 2004	-1.7 mb	29.3 m s^{-1}
4 June 2005	-6.4 mb	28.8 m s^{-1}
6 June 2005	-4.4 mb	35.1 m s^{-1}
18 Sept 2005	-4.1 mb	25.6 m s^{-1}
27 May 2006	-3.7 mb	34.2 m s^{-1}
21 June 2006	-5.8 mb	28.4 m s^{-1}

4. THE WAKE LOW OF 7 JULY 2004

This WL resulted in two severe wind gusts reports of 30.2 m s^{-1} at MACY and 27.0 m s^{-1} at TAHO between 0500 and 0700 UTC. Radiosonde observations at 0000 and 1200 UTC from KAMA and KMAF (Fig. 2a and 2b) revealed nearly dry adiabatic lapse rates from 700 mb to 500 mb. The KAMA sounding also exhibited a substantial capping inversion at 0000 UTC. Scattered thunderstorms that developed during the evening hours across the western and central portions of the domain evolved into a squall line exhibiting a typical symmetric trailing stratiform MCS structure by 0400 UTC (not shown). By 0556 UTC, composite reflectivity showed several indications that the MCS had entered the dissipating stage, including a weak echo region extending from the southwest flank of the MCS into the center of the TSR and a shift to a more asymmetric appearance to the stratiform region, with greater areal coverage to the north of the MCS axis (Fig. 3). One to 2 mb hr^{-1} pressure falls began to develop in the vicinity of TAHO on the back edge of the TSR, behind an area of pressure rises associated with the mesohigh. The pressure fall center moved southeast during the period 0555 to 0625 UTC and weakened. About this time a secondary fall center developed near LAMS. The fall center extended east to near MACY, but weakened considerably by 0640 UTC. Meanwhile, the pressure rise center to the southeast strengthened to near 6 mb hr^{-1} in the vicinity of SNYD by 0640 UTC. The reflectivity minimum also continued to move southeast during this period and was located in the vicinity of MACY at 0625 UTC, the time of the peak wind gust. Despite the weak changes observed in the pressure tendency fields, the divergence fields (Fig. 4a and 4b) proved useful to track the mesolow/mesohigh couplet.

5. HEAT BURSTS

Numerous previous HB studies have resolved many of the properties of this phenomenon. While WLs can occur any time of day in conjunction with MCS evolution, the HB is primarily a nocturnal phenomenon. In one of the earliest works, Byers and Braham (1949) noted a relative humidity “dip” in their mesonet data during certain thunderstorm events. This dip was accompanied by a temperature rise of one to two degrees Celsius. The authors suggested that this was in part due to an insufficient rate of evaporation of the water droplets in the downdraft to maintain saturation during their descent to the surface. This hypothesis was supported by Fujita (1985) who also noted that a drop in dewpoint temperature could be caused by the entrainment of drier environmental air into the downdraft. Both of these studies examined downdrafts resulting from individual thunderstorm cells. In a similar manner as WLs, HBs may also result from downdrafts in the TSR of a MCS. Bernstein and Johnson (1994) concluded that HBs in their study were a result of strong, large-scale descent caused by rear inflow jets in the TSR. The speed of the downdraft and the depth of the stable layer will determine whether or not the downdraft is sufficient to deform the stable layer, allowing warm, dry air to reach the surface. Operational determination, however, of these two parameters is problematical due to the spatial and temporal resolutions involved.

Through examination of the WTXM data the onset of the HB was determined to occur when there was a simultaneous rise in temperature and decrease in dewpoint of any magnitude that preceded a HB event. The first 10-minute period (three observations) was examined to study the initial gradients associated with the HB while a 60-minute period was chosen in order to capture the full extent of each event. Interestingly, the majority of the HB events in this study occurred around 0600 and 1200 UTC. Table 2 highlights the extremes found from all the station data for each event.

TABLE 2. Heat burst cases in this study along with the maximum temperature and dewpoint changes and wind gust for each.

Date (UTC)	Max ΔT	Max ΔT_d	Max Wind Gust
23 May 2005	7.8 °C	-11.0 °C	19.9 m s^{-1}
4 June 2005	3.3 °C	-9.4 °C	28.5 m s^{-1}
6 June 2005	5.8 °C	-7.2 °C	35.1 m s^{-1}
18 Sept 2005	6.1 °C	-9.1 °C	25.6 m s^{-1}
27 May 2006	7.2 °C	-15.0 °C	34.20 m s^{-1}
21 June 2006	6.7 °C	-13.3 °C	28.35 m s^{-1}
12 July 2006	5.6 °C	-1.7 °C	28.80 m s^{-1}

6. THE HEAT BURST OF 18 SEPTEMBER 2005

This HB is of particular interest because it produced widespread winds in the range of 20 to 30 m s^{-1} and damage in the city of Lubbock. The evolution of this HB was representative of those found in previous studies (Johnson, 1983). In late afternoon, thunderstorms developed over the western and central portions of the study area. During the period 0000 to 0600 UTC on 18 September, several thunderstorms over the western area evolved into a small MCS which then gradually dissipated while moving northeast. The vertical profile of the atmosphere showed characteristics typical of the WL/HB environment. Manual interpolation from the 0000 and 1200 UTC radiosonde observations from KAMA and KMAF (Fig. 6a and 6b) showed a dry and warm mixed layer with nearly dry adiabatic lapse rates to 500 mb. Additionally, a shallow inversion developed approximately 100 mb (1000 m) deep. Objective analysis of the WTXM data showed an area of temperature maximum/dewpoint minimum located in the vicinity of the damaging wind gusts at 0510 UTC (Fig. 7). This area was also located within the TSR of the decaying MCS as indicated by the KLBB WSR-88D (not shown). The maximum temperature rise with the HB was 6.1 degrees Celsius while the maximum wind gust was 30.2 m s^{-1} as recorded at the National Weather Service (NWS) office in south Lubbock. Table 3 shows salient data from the WTXM stations that were primarily affected by the HB. During the first 10-minutes of the event, indicators of a HB were subtle at best. At the western stations, the HB signature was of shorter duration, lasting between 15 and 30 minutes, while the signature was discernable up to 70 minutes across the central stations. The meteogram from the WTXM site in west central Lubbock (LBBW) depicts a non-typical gradual change in the dry-bulb and dewpoint temperatures with the first surge of strong winds arriving approximately 15 minutes after the HB onset and the strongest winds 25 minutes later (Fig. 5).

7. SUMMARY AND CONCLUSIONS

WTXM observations of WL and HB events with associated strong/severe winds were compiled for this study. Despite these detailed observations, no completely reliable method of high wind prediction was discovered through the use of the surface data alone. Approximately 50 percent of the severe wind gusts were observed concurrently or slightly in advance of pressure falls in the case of WLs or with rises in temperature and decreases in dewpoint in the case of HBs. However, a real-time algorithm to detect the wind gusts using the five-minute WTXM data has the potential to provide some lead time in the other half of the cases. An algorithm currently being developed will be tested at the NWS Lubbock office to determine its viability. Additionally, given a suitable thermodynamic environment, radar and satellite data have the potential to show areas of subsidence warming associated with the development of WLs and possible HBs.

References and supplemental information will be available at the following address:

http:// www.srh.noaa.gov/lub/science/23sls

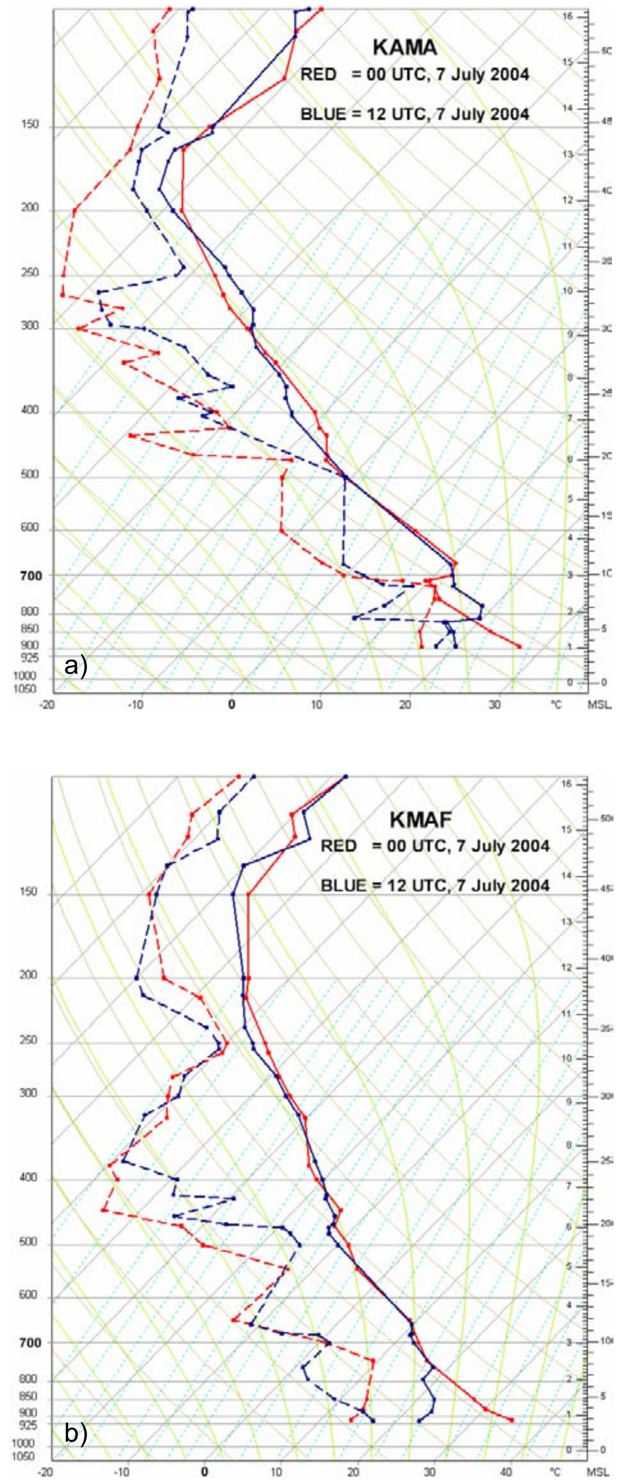


FIG. 2. Comparisons of the 0000 and 1200 UTC, 7 Jul 2004 skew-*T* plots for a) Amarillo, and b) Midland.

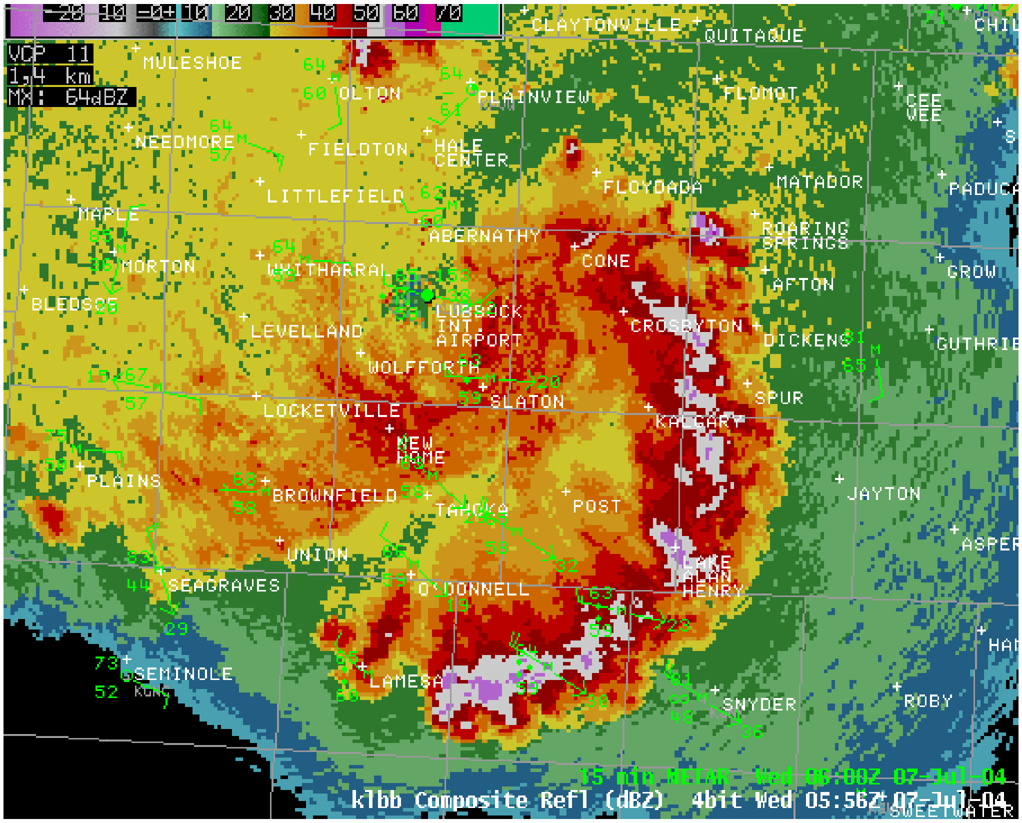
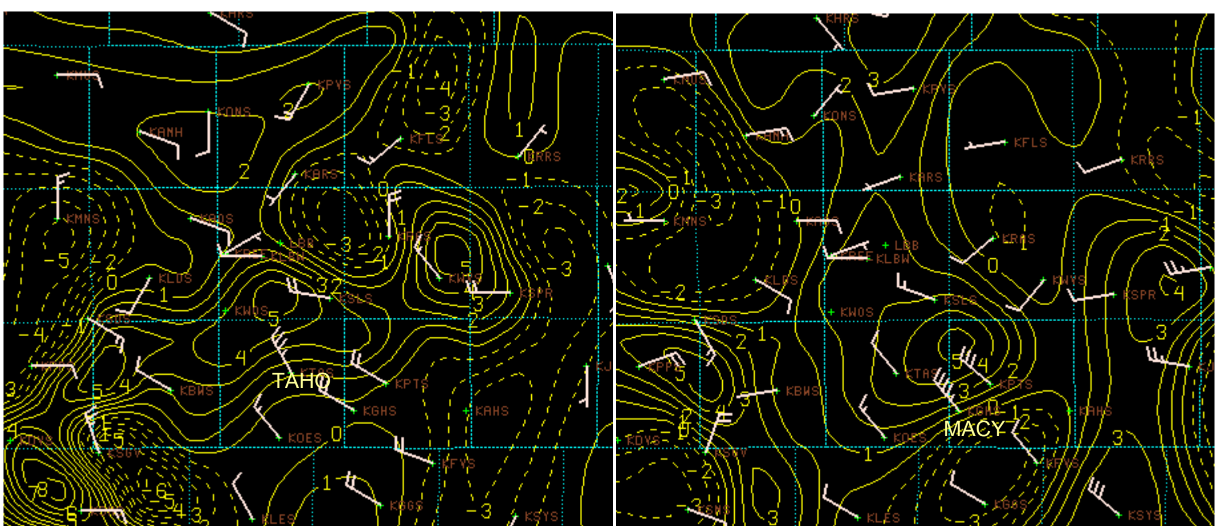


FIG. 3. KLBB WSR-88D 0556 UTC, 7 Jul 2004 composite reflectivity with overlay of surface observations. Note the wedge of lower reflectivity in the vicinity of Tahoka around the time of maximum wind gust.



a) b)

FIG. 4. Divergence of the wind objective analysis plots at times of maximum observed wind at TAHO and MACY for a) 0555 UTC, and b) 0625 UTC, 7 Jul 2004. Divergence contours are in units of 10^{-4} s^{-1}.

TABLE 3. Summary of West Texas Mesonet Station data for 17 Sep 2005. Stations are listed in order of west to east. **ΔT** and **ΔT$_d$** refer to the difference between the initial temperatures and the highest (in the case of **ΔT**) or the lowest (in the case of **ΔT$_d$**) values in the subsequent 10 or 60-minute period. **ΔWS** refers to the difference between the 5-minute average wind speed at the HB onset time and the peak 5-minute average wind speed recorded in the 10 or 60 minute period. **Gust** refers to the peak 3-second gust recorded during the 10 or 60-minute period.

Station *(refer to Figure 1)*	**Time of HB Onset (UTC)**	**10 minute maximum values**				**60 minute maximum values**			
		ΔT (°C)	**ΔT$_d$** (°C)	**ΔWS** m s^{-1}	**Gust** m s^{-1}	**ΔT** (°C)	**ΔT$_d$** (°C)	**ΔWS** m s^{-1}	**Gust** m s^{-1}
LEVE	03:40	3.2	-3.2	5.0	12.9	3.4	-3.2	11.8	19.8
REES	03:55	1.4	-3.4	1.9	10.7	4.3	-8.5	6.8	14.0
LBBW	04:20	1.8	-4.0	-1.0	7.5	5.4	-8.8	11.7	23.6
ANTO	04:30	0.8	-1.0	2.4	8.0	6.1	-7.7	12.7	18.9
ABER	04:30	2.4	-3.9	3.9	9.4	3.0	-5.2	3.9	9.4
SLAT	04:30	5.0	-8.3	10.5	17.0	5.2	-9.1	15.6	25.0
RALL	05:40	1.9	-3.9	6.3	18.5	4.4	-7.1	14.5	25.6
WHIT	05:45	0.7	-1.3	2.4	12.2	3.2	-7.4	5.4	16.7

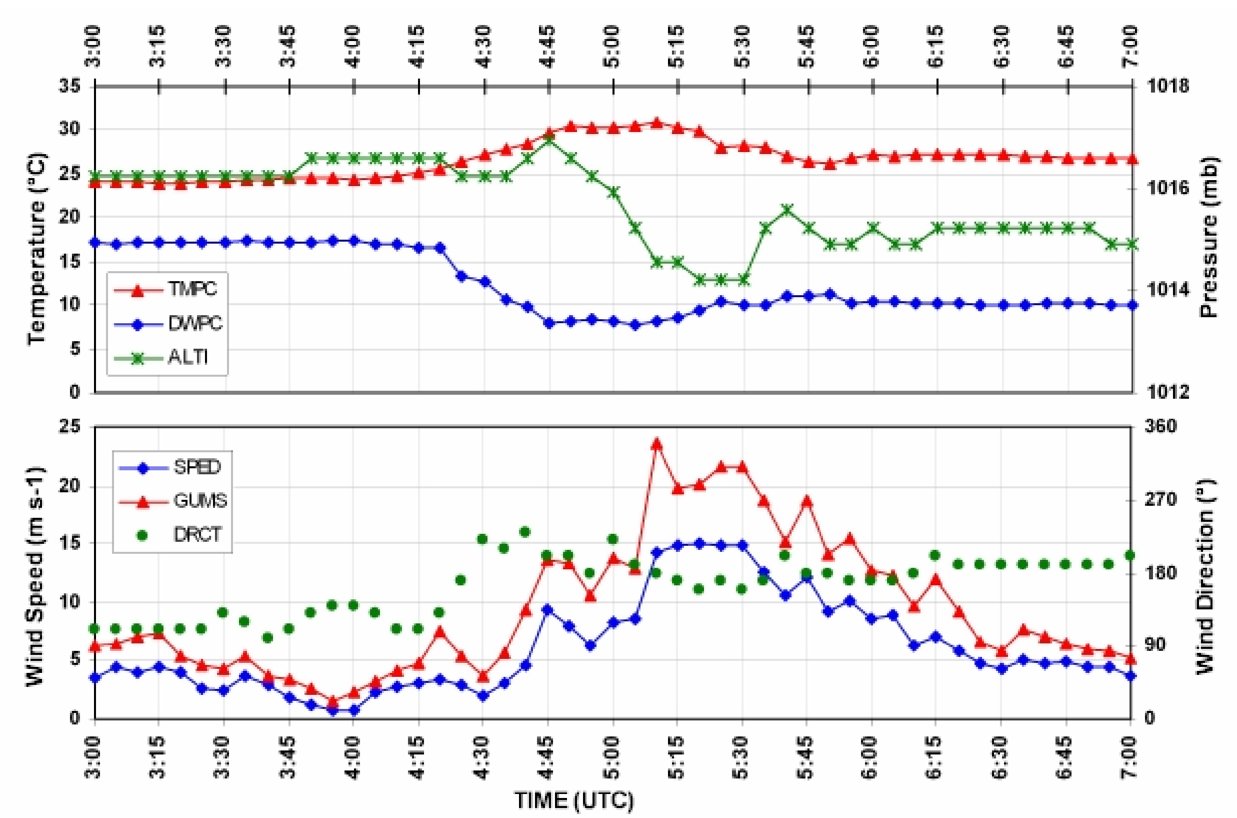


FIG. 5. Time series of five-minute observations from the WTXM LBBW station for 0300 to 0700 UTC, 18 Sep 2005 (10 p.m. to 2 a.m. local time). All variables are 5-minute averages except for "GUMS", which is the peak 3-second gust in each 5-minute period.

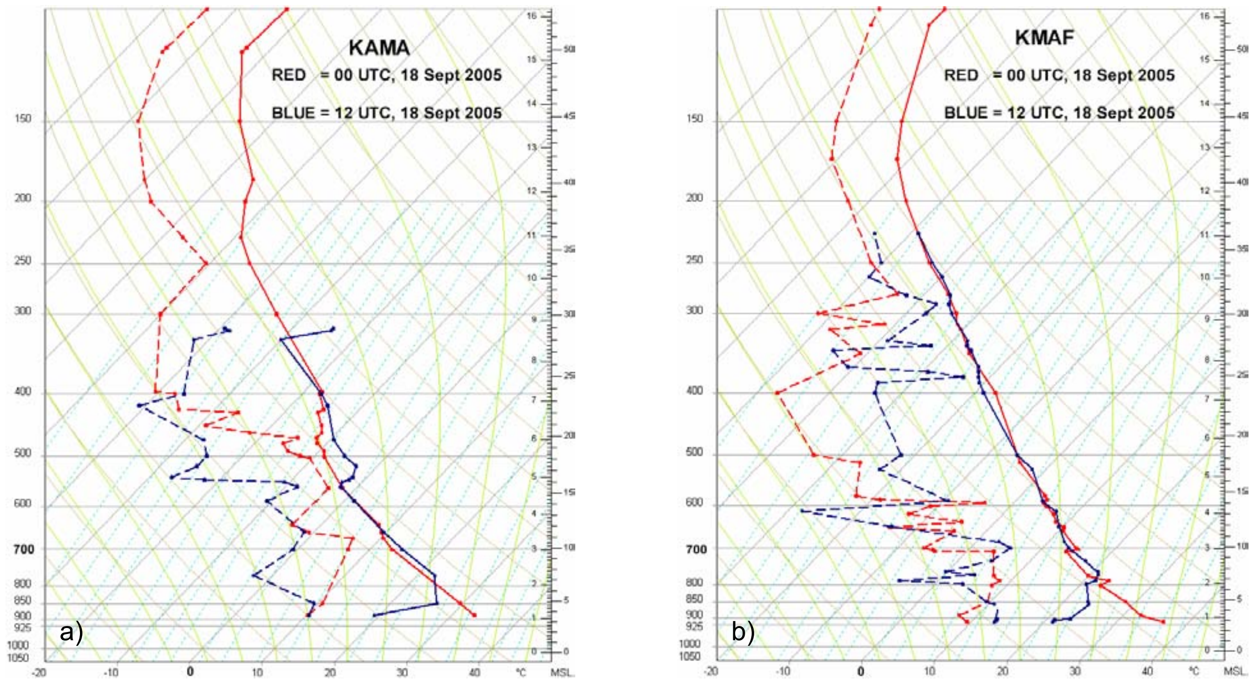


FIG. 6. Comparisons of the 0000 UTC and 1200 UTC, 18 Sep 2005 skew-*T* plots for a) Amarillo, and b) Midland.

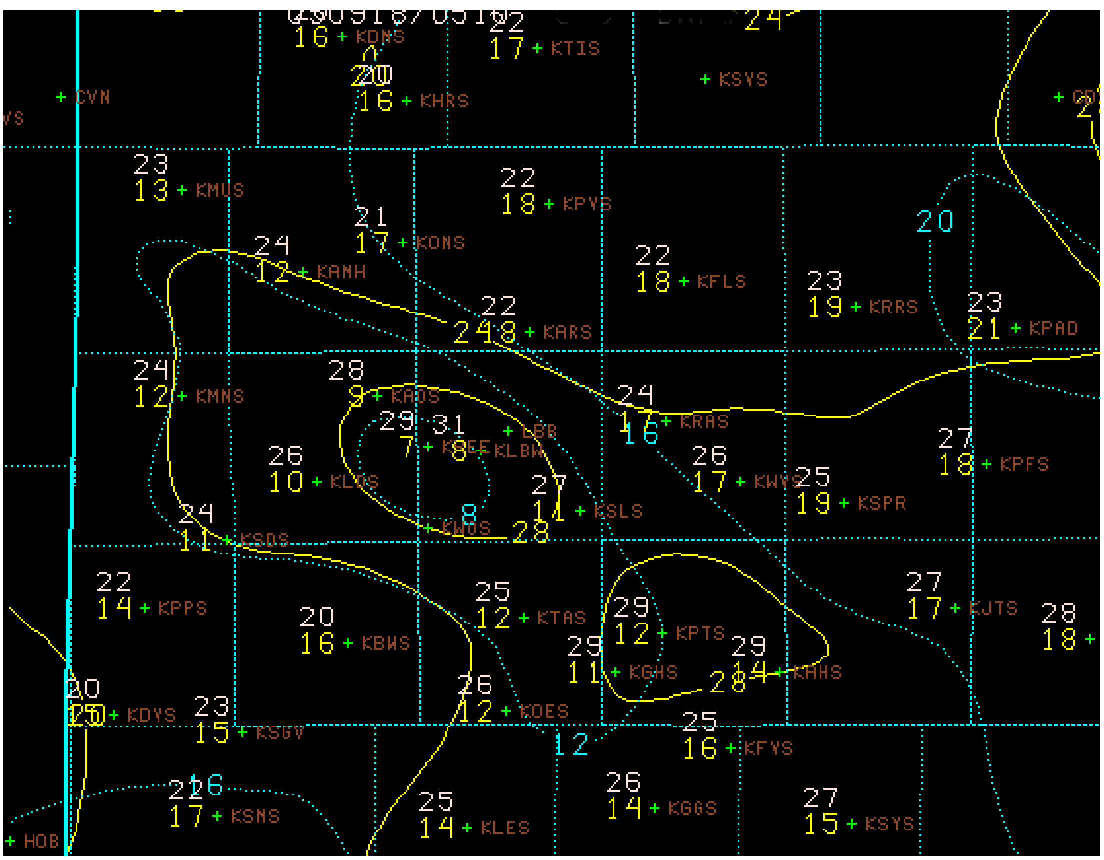


FIG. 7. Objective analysis of temperature (°C, solid yellow contours) and dewpoint (°C, dashed blue contours) for 0510 UTC, 18 Sep 2005.