1.4 A CLIMATOLOGY OF HEATBURSTS AS DETECTED BY THE OKLAHOMA MESONET

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1. INTRODUCTION

Decaying nocturnal thunderstorms can produce hot, dry, and gusty surface winds called "heatbursts" (e.g., Lane 2000). Though rare in the meteorological literature, most of the documented heatbursts occurred in the Great Plains of the United States during the warm season, typically between 0000 and 1200 UTC, and were associated with weak or dissipating radar echoes.

Heatbursts are characterized by a sudden and highly localized increase in air temperature, a simultaneous decrease in relative humidity and dewpoint temperature, and strong gusty winds. Air pressure typically decreases during the event. Heatbursts have occurred on time scales that range from several minutes to several hours, with sudden temperature increases as high as 13˚C (Cunningham 1989), relative humidity decreases as large as 83% (Cunningham 1989), and wind gusts as strong as 47 m s^{-1} (MacKeen et al. 1998).

For the purposes of this study, a "heatburst event" was defined as either (1) a single heatburst or (2) a series of heatbursts that affected one or more surface-observing stations during a single day and demonstrated temporal or spatial continuity. Heatbursts that affected multiple stations during the same day but lacked temporal or spatial continuity with one another were treated as separate events.

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Using data from the Oklahoma Mesonet (Brock et al. 1995; McPherson et al. 2007), Lane (2000) documented 51 heatburst events across Oklahoma from October 1993 through September 1998. Many affected only one observing site and lasted only several minutes; some affected as many as 12 stations and persisted for several hours. For example, a prolonged heatburst event on 23 May 1996 caused severe winds that resulted in ~$18 million in damage across southwest and central Oklahoma. Although such events are rare, this episode revealed that heatbursts could significantly affect public safety and property, especially private and commercial aviation.

This paper updates the climatology of the heatburst events across Oklahoma to cover the period from 1 January 1994 to 30 June 2008.

2. METHODOLOGY

The data set for this study included all archived Mesonet data from 1 January 1994 through 30 June 2008. Criteria chosen to search the archives for potential heatbursts were as follows:

(1) an increase in air temperature of 2.7˚C during a 10-min period,

(2) a simultaneous decrease in dewpoint temperature of 2.7˚C, and

(3) a maximum wind gust of at least 10 m s^{-1} five minutes prior to, during, or 5 min after the thermodynamic perturbations.

Using archived data, the search detected 330 potential "heatburst days" during the

14.5-year period. These 330 days were days when heatburst criteria were met at least once at one or more stations within the network.

Upon manual inspection, 174 of the 330 potential event days were determined to be instances of dryline passage, frontal passage, or a thermodynamic change in response to either a rapid increase in solar radiation during the morning hours or the passage of a daytime precipitation system.

The remaining 156 event days could not be attributed to these well-known phenomena. Accordingly, they were identified as heatburst days, defined as one or more individual heatbursts detected at one or more stations during a 24-hour period. On 61 of these 156 heatburst days, multiple Mesonet sites were affected by heatbursts. Further analysis of Mesonet data indicated that on 34 of these 61 “multiple site” days, heatbursts occurred at two or more Mesonet sites with a lack of temporal or spatial continuity between bursts. Thus, from the 156 heatburst days, 203 individual heatburst events were identified.

4. CLIMATOLOGY OF OKLAHOMA HEATBURSTS

Almost all of the heatbursts detected by the Oklahoma Mesonet were underneath or adjacent to weak radar echoes (generally less than 30 dBz) at the time of the event. Four basic radar patterns were associated with the events: (1) radar echoes associated with rapidly weakening convection, (2) weak reflectivity not produced by or associated with deep moist convection, (3) weak radar echoes to the rear of a dissipating mesoscale convective system (MCS), and (4) weak reflectivity along the periphery of intense convection that did not appear to be weakening.

4.1. Spatial distribution

Figure 1 displays number of heatbursts detected at each Mesonet site during the 14.5-year period. Heatbursts were practically non-existent in the southeast quarter of the state; yet, they were relatively frequent in the northwest quarter and Panhandle sections.

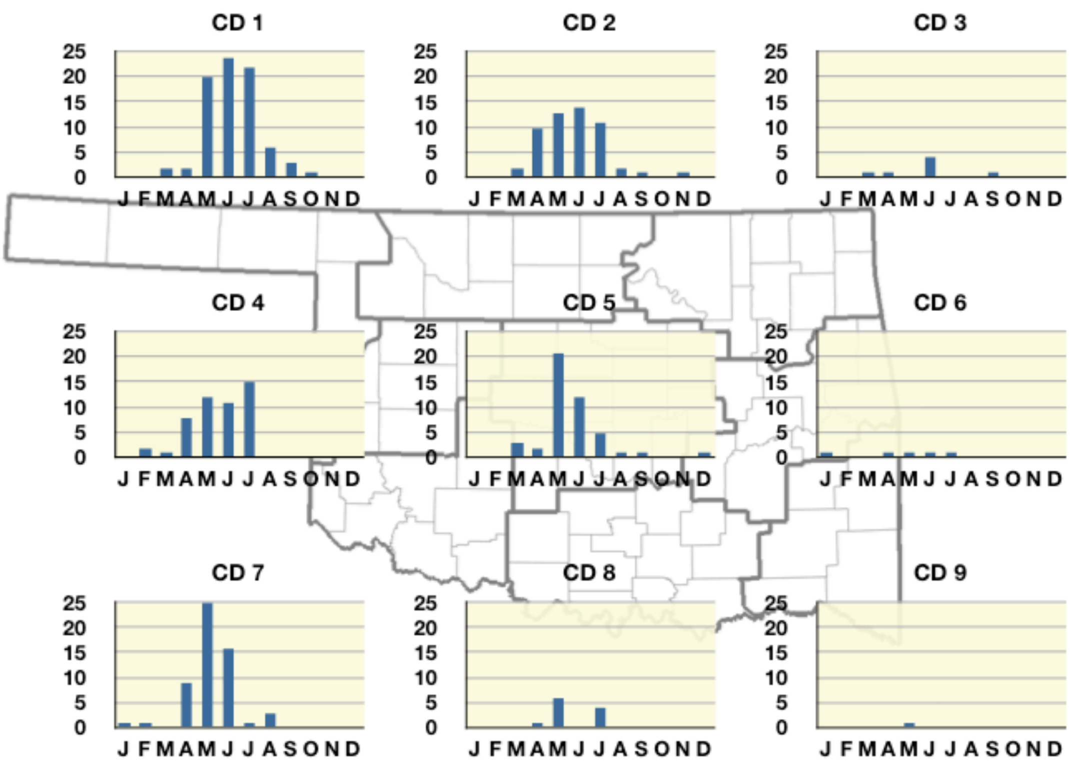

Figure 1. *Geographical distribution of heatburst detections by climate division (CD) across Oklahoma and by month (J, F, M, ... for January, February, March,...) for 14.5 years. If a heatburst event was measured at 10 Mesonet sites, then it was counted as 10 detections.*

This geographical distribution of heatburst detections corresponds to the climatological gradient in atmospheric moisture between southeast and northwest Oklahoma (e.g., as represented by annual precipitation; Fig. 2). Normally, the boundary layer is drier across northwest Oklahoma than across southeast Oklahoma. During late spring and summer over the high plains, when a shortwave trough (or other mid-atmosphere lifting mechanism) interacts with an elevated moist layer, convection may develop above the boundary layer. As convective rain descends through a dry boundary layer (e.g., across western Oklahoma), it evaporates and the adjacent air cools. If the environmental lapse rate is nearly dry adiabatic in the sub-cloud layer, all of the rain may evaporate and the descending air will begin to heat by compression, possibly resulting in a heatburst at the ground.

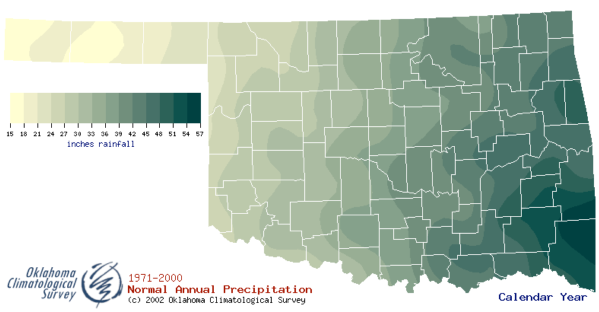

Figure 2. *Normal annual precipitation for Oklahoma from 1971 to 2000. Darker greens represent higher values of precipitation.*

4.2. Monthly distribution

Figures 1 and 3 depict heatburst events by month for Oklahoma's nine climate divisions (Fig. 1) and for the entire state (Fig. 3). Seventy-four percent of heatburst events occurred during May, June, and July. With 58 of the 203 events, June was the most active month for heatbursts. At the other extreme, only one event per month occurred during October, November, and December. This monthly distribution is similar to that of the annual frequency of occurrence for convection across Oklahoma.

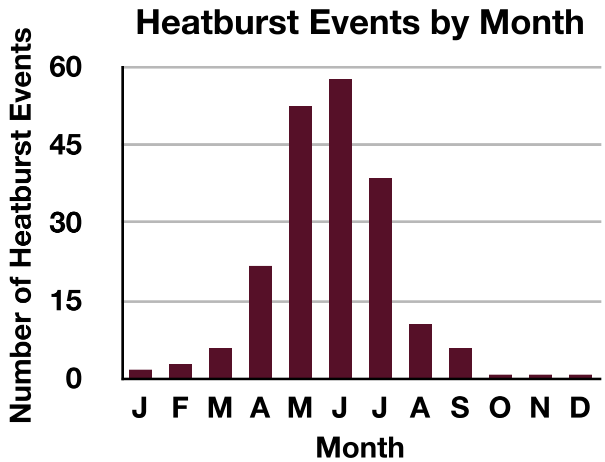

Figure 3. *Number of heatburst events by month, as measured by the Oklahoma Mesonet, for all climate divisions of Oklahoma from 1 January 1994 through 30 June 2008.*

Figure 4 displays the heatburst detections at each station by month (i.e., if a heatburst event were measured at 10 Mesonet sites, then it was counted as 10 detections). Although individual heatburst events are more common in June (Fig. 3), they tended to be spatially larger when they occurred during May, as represented in Fig. 4.

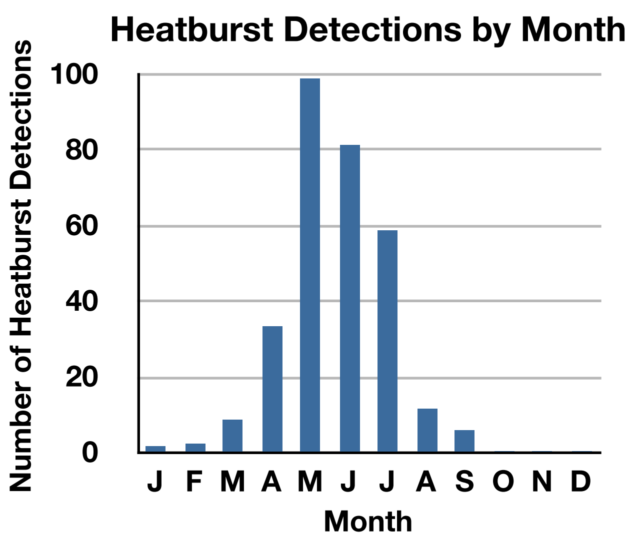

Figure 4. *Number of detections of heatbursts at individual Oklahoma Mesonet sites by month for all climate divisions (CDs) of Oklahoma from 1 January 1994 through 30 June 2008. If a heatburst event were measured at 10 Mesonet sites, then it was counted as 10 detections.*

4.3. Frequency by time of day

Figure 5 shows the heatburst detections in Oklahoma by time of day, revealing a peak of activity between 0200 and 0400 UTC. Seventy-three percent of the events occurred between 0000 and 0800 UTC.

Heatbursts were once thought to be exclusively nocturnal in nature, possibly because surface-based inversions were not observed during the daylight hours. As indicated in Fig. 5, however, heatbursts did occur in Oklahoma during the peak of solar activity. In these rare afternoon (1600 to 2400 UTC) events, persistent cloud cover could have resulted in a weak stable layer that prevented deep convective mixing in the boundary layer. During any time of the day, thunderstorms could dissipate rapidly if they move into a more stable environment.

The peak of heatburst activity during early evening corresponded to the timing of dissipation of convection during spring and summer across Oklahoma. During the warm season, especially when synoptic forcing and vertical wind shear are weak, deep, moist convection often forms during the afternoon. As the sun sets and surface temperatures cool, instability weakens and convection rapidly dissipates. Eventually a weak near-surface stable layer may exist with dry adiabatic lapse rates between the inversion and the retreating cloud base. In this scenario, air that descends from the dissipating thunderstorm with sufficient negative buoyancy to penetrate the stable layer could produce a localized downdraft of warm, dry air.

This diurnal cycle of convective dissipation would be most pronounced at and shortly after sunset. In addition, the decrease in heatburst activity into the night also could be attributed to strengthening of the nocturnal inversion. As the inversion strengthens, the likelihood of subsiding air penetrating it decreases.

During the late spring, mesoscale convective systems (MCS) develop and move across Oklahoma, typically during the night. The circulations within a decaying MCS can create heatbursts in the vicinity of the wake depression.

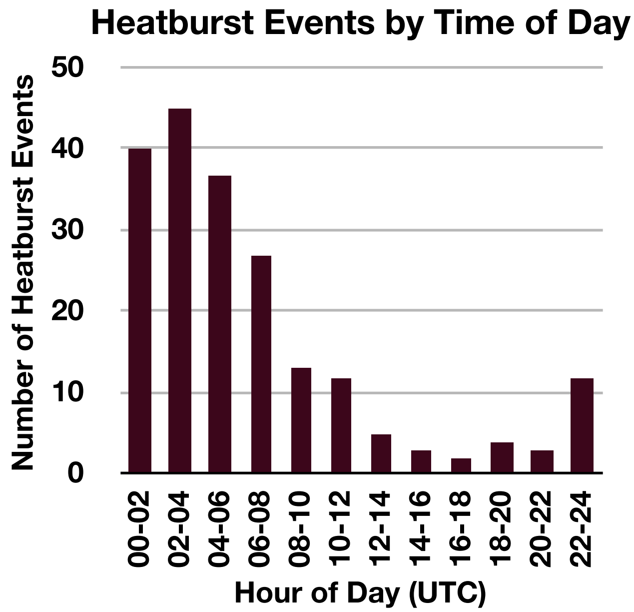

Figure 5. *Number of heatburst events by time of day (e.g., 01 = 0100 UTC), as measured by the Oklahoma Mesonet, for all climate divisions of Oklahoma from 1 January 1994 through 30 June 2008.*

5. SUMMARY

Though rarely captured by synoptic-scale, hourly observing networks, heatbursts appear to be somewhat common in semi-arid western Oklahoma, as measured by the Oklahoma Mesonet and its 5-min observation interval. Most events were associated with collapsing thunderstorms or subsidence behind convective complexes. Typically, these events occurred during the evening or night from May through July.

6. ACKNOWLEDGEMENTS

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