The Severe Convective Storm Climatology of the Texas and Oklahoma Panhandles

Introduction

The intention of this paper is to serve as a reference source and to make the reader aware of the spatial and temporal threat of severe local storms in the Texas and Oklahoma Panhandles and to serve as a reference source. The Amarillo County Warning Area (CWA) has forecast and warning responsibilities for 23 counties, including 20 counties in the Texas Panhandle and three counties in the Oklahoma Panhandle (Figure 1). The terrain is quite variable across the area. In fact, the elevation ranges from just over 0.54 km (1,800 ft) above sea level in Collingsworth County in the southeastern Texas Panhandle to almost 1.46 km (4,800 ft) above seal level in Cimarron County in the western Oklahoma Panhandle. The most prominent geologic feature in the Panhandles is the Caprock, which begins in Gray County and stretches south southwest for over 321 km (200 mi). The Caprock divides the lower, rolling plains in the eastern Texas Panhandle from the flat, higher plains in the western and central Texas Panhandle. The Caprock has been shown to influence convection (Marshall and Peterson, 1980) and possibly enhance the potential for tornadoes. Other geologic features, such as the Canadian River Valley extends from Oldham County in the southwestern Texas Panhandle to Hemphill County in the northeastern Texas Panhandle. Lindley (1997) proposed that the Canadian River Valley may also play a role in possibly increasing the number of tornadoes.

As is the case with any severe local storm climatology, inherent limitations arise (Kelley et al, 1985), particularly when severe weather occurs over sparsely populated areas such as the Panhandles. Nonetheless, this study does show that some generalities of the temporal and spatial distribution of severe weather can be inferred.

Data and Methodology

The data for this study were collected from the National Climatic Data Center's Storm Data (NOAA 1950-2010) and the Storm Prediction Center's SVRGIS (Smith, 2005). The severe hail and severe convective wind data used in SVRGIS are derived directly from Storm Data. However, tornado data used by SVRGIS and Storm Data are different. SVRGIS uses segmented tornado paths as opposed to the individual tornado segments used in Storm Data. For the purposes of this study, Storm Data was chosen to represent the tornado data. The severe hail and severe convective wind data covered the period from 1955 to 2009 while the tornado data covered the period from 1950 to 2009. It should be mentioned that severe hail constitutes a hail diameter of 19.05 mm (0.75 in.) and severe convective wind gusts must be 50 kts (58 mph) or greater. Tornado data between 1950 and February 1, 2007 were rated according to the Fujita Scale (Fujita, 1971), which was developed in 1971. Before the scale was developed, tornadoes were retroactively rated. Since February 1, 2007, the Enhanced Fujita Scale has been used to rate tornadoes.

Once the data were extracted and entered into spreadsheets, basic statistical analyses were performed. In addition, all of the spreadsheets were converted to Database IV (DBIV) files and imported into ArcMap to create the maps used in this study. Spatial analyses were then performed on the data using ArcMap.

Severe Weather Climatology

A total of 8,594 severe weather reports occurred in the Amarillo CWA during the study period, 1950-2009. Of this, 1,018 tornadoes were reported, 1,727 severe convective wind events were reported, and 5,849 severe hail events were reported. Clearly, hail was the most frequently reported severe weather phenomena and accounted for just over 68 percent of the total number of severe weather reports. On the other hand, severe wind and tornadoes were less commonly reported, but severe convective winds and tornadoes accounted for 20 percent and nearly 12 percent, respectively, of the severe weather reports. Excluding tornadoes, the yearly trend (Figure 2) in severe weather reports has greatly increased since the late 1980s. This trend is likely an artifact of increased populations, increased public severe weather awareness due to NWS outreach programs, and the development of trained spotter networks.

The five most active severe weather years in terms of severe weather events in the current CWA structure were:

- 2007 – 673 events
- 2009 – 624 events
- 2008 – 608 events
- 2002 – 492 events
- 2004 – 431 events

It can be clearly seen that the years with the most severe weather events have come within the last decade. An enormous increase in the number of storm chasers and an increase in the number of information outlets are the most likely explanation behind the recent increase in severe weather reports. However, it should not be implied that the years listed above are the most active severe weather years that the Panhandles have experienced since 1950. As the number of storm chasers continues to grow and technology continues to evolve, there will be greater numbers of severe weather reports in the future.

Tornado Climatology

This paper will present a brief updated tornado climatology across the Texas and Oklahoma Panhandles, but the reader is encouraged to refer to Lindley (1997) and Garner (1991) for a more comprehensive tornado climatology. Tornadoes are no strangers to the CWA, and in fact, the area averages 21.1 tornadoes per year based on a 30-year climatology from 1980-2009. The five most active tornado years in the current CWA structure were:

- 2007 – 65 tornadoes

- 1995 – 43 tornadoes
- 1982 – 41 tornadoes
- 1979 – 39 tornadoes
- 1990 – 38 tornadoes

All of the tornadoes occurred between February and November, but the large majority (over 83 percent) occurred between April and June (Figure 3). This seems physically reasonable since these months typically possess a favorable combination of buoyancy, vertical deep layer shear, high boundary layer moisture, low-level shear, and an active dry line. There was not a tornado reported during the 60-year period during December and January. Over 81 percent of the tornadoes reported during the study period were classified as weak tornadoes (F0/EF-0 and F1/EF-1) (Figure 4). This number is higher than the national average of 61.7 percent (Kelley et al., 1978). It is worth mentioning that many Panhandle tornadoes occur over open land and fail to impact any structures. Therefore, it is nearly impossible to accurately rate a tornado that produces no damage.

Tornado reports increased substantially in the early afternoon hours and peaked in the early evening around 1800 LST (Figure 5). The thermodynamic and dynamic environments are likely most supportive of tornadoes during these times because of the favorable combination of buoyancy, vertical deep layer shear, and a marked increase in low-level shear caused by the onset of the low-level jet. Although the time range for tornadoes occurs when the dew point depressions are typically at a maximum, this may be offset when low-level moisture has some degree of depth, storms interact with boundaries, and/or upslope flow produces enough cloud cover to inhibit deep vertical mixing. Nocturnal tornadoes are quite uncommon across the CWA, most likely because parcels become rooted above the boundary layer when the surface temperature cools.

Tornadoes exhibited less political bias than severe convective wind events and severe hail events, but an increase in reports near cities and along transportation lines were still clearly evident (Figure 6). Nonetheless, a greater number of tornadoes occurred across the southeastern half of the CWA as opposed to the northwestern half of the CWA. It is interesting to note that significant tornadoes (F2 or greater) exhibited a greater east to west variability. In fact, a higher quantity of significant tornadoes appeared to occur off the Caprock. It is more difficult for moisture to be transported up the Caprock and sustained for a considerable period of time, particularly from April through June when the dry line tends to be active. Therefore, low-level moisture is more readily sustained off the Caprock and less prone to getting mixed out by the dry line until the late afternoon or early evening hours. Consequently, lower dew point depressions lead to lower cloud bases, which limit the amount of evaporational cooling beneath the sub-cloud layer. Provided that a favorable combination of buoyancy, vertical deep layer shear, and low-level shear, the potential for tornadoes is typically higher off of the Caprock. Tornadoes that occur across the higher terrain of the western Panhandles tend to be weaker, possibly since they originate from higher based convection. No F5 occurred in the Texas or Oklahoma Panhandles during the study period, but 24 F4 tornadoes have been documented. The last F4 tornado to affect the CWA occurred during a prolific tornado outbreak on June 8, 1995. Four F4 tornadoes occurred that day, including 1.6 km (1 mi) north of McLean, 8 km (5 mi) southwest of Kellerville, 12.8 km (8 mi) southwest of Allison, and 4.8 km (3 mi) northwest of Allison.

Severe Convective Wind Climatology

Although severe convective winds have occurred in all but one month of the year across the Amarillo CWA, they are most commonly a warm season phenomenon (Figure 7). In fact, an overwhelming majority of nearly 80 percent of all severe convective wind events occurred between May and August with June being the most active. This is remarkably similar to the results of Kelly et al. (1985), and it is not surprising since these months coincide with the period of maximum solar heating and highest buoyancy. The polar jet stream typically begins its poleward retreat in late May and June, but convection associated with upper level northwest flow and mountain convection still occurs during July and August. Another possible factor that drives the high number of severe convective wind reports during the warm season is the nocturnal low-level jet. Occasionally, the low-level jet will sustain and even strengthen convective complexes that propagate across the western High Plains through the advection of high theta-e air. A relative minimum of severe convective wind events was observed between September and March, owing to the fact that atmospheric buoyancy is extremely limited during these months.

Similar to tornado reports, convective wind reports ramped up early in the afternoon (after 1400 LST) and peaked in the evening hours (1800 LST) (Figure 8). Furthermore, over 96 percent of severe convective wind reports occurred between 1400 and 200 LST. Analyzing Figures 7 and 8, it can be clearly seen that severe convective wind events occur most prominently during the warm season and during peak heating. It can be argued that solar heating during this temporal scale results in the largest dew point depressions observed in a daily period. As a result, this increases the cloud base and produces a dry sub-cloud layer. Therefore, thunderstorms possess a greater potential to develop downdrafts capable of producing damaging winds. Although severe convective wind reports begin to decrease in the late evening hours, thunderstorms during this time period may be temporarily sustained by the nocturnal low-level jet before it propagates eastward. On the contrary, severe convective wind events were not commonly reported between the early morning hours and just after noon.

The spatial distribution of severe convective wind events seemed to follow along political boundaries (e.g. cities and roads), which was especially evident near the city of Amarillo (Figure 9). However, a general zonal gradient of severe wind events was noted with more events off of the Caprock and less events on the Caprock. Significant convective wind (65 knots or greater) reports followed similar political boundaries, but no spatial continuity pattern was evident. The fastest convective wind speed recorded in the CWA was 108 knots and occurred 16 km (10 mi east southeast of Borger on April 6, 2001.

Severe Hail Climatology

Severe hail is also primarily a warm season phenomenon in the CWA as more than 93 percent of all events occurred between May and September (Figure 10). However, a small threat for hail even existed in March and October. Similar to the peak for severe convective winds, June was also the peak for severe hail events. This may be attributed to the existence of a favorable combination of buoyancy, shear, and instability aloft (i.e. steep lapse rates). The CWA is typically under the influence of deep southwest flow aloft in May and June, which contributes to the development of an elevated mixed layer (EML). Although the polar jet shifts poleward during these months, sufficient deep layer shear remains present for hail generation. After June, however, the strongest belt of westerlies has retreated well north of the area. As a result, deep layer shear becomes more anemic, which lessens the potential for hail and especially significant hail. Not surprisingly, severe hail reports are extremely rare from November through February due to limited buoyancy.

Once again, similar to severe convective wind events, severe hail events ramped up considerably in the early afternoon hours, but the peak was an hour earlier around 1700 LST (Figure 11). This time period is physically reasonable since solar heating is at a maximum and buoyancy typically peaks during the late afternoon and early evening hours. Severe hail events were much less common between 0000 and 1200 LST, which is not surprisingly due to a less favorable thermodynamic environment.

Hail reports seemed to follow political boundaries more so than tornado and severe convective wind reports (Figure 12). A greater number of severe hail reports occurred across the southeastern half of the CWA as opposed to the northwestern half of the CWA. Additionally, significant hail (50.8 mm or 2 in or greater in diameter) reports also exhibited a pattern to occur more frequently over the southeastern half of the CWA. The high frequency in this area may be explained by the fact that the dry line typically encounters a deeper layer of moisture and begins to slow its eastward progression. The largest hail stone size recorded in the CWA during this study's time period was 120.65 mm (4.75 in), which occurred 1.6 km (1 mi) southeast of Canyon on May 24, 1996. It is worth mentioning that beyond this study period, a hail stone diameter of 152.4 mm (6 in) was measured 9.6 km (6 mi) south of Sunray on June 12, 2010. This is believed to be the largest hail stone ever documented in the Texas and Oklahoma Panhandles.

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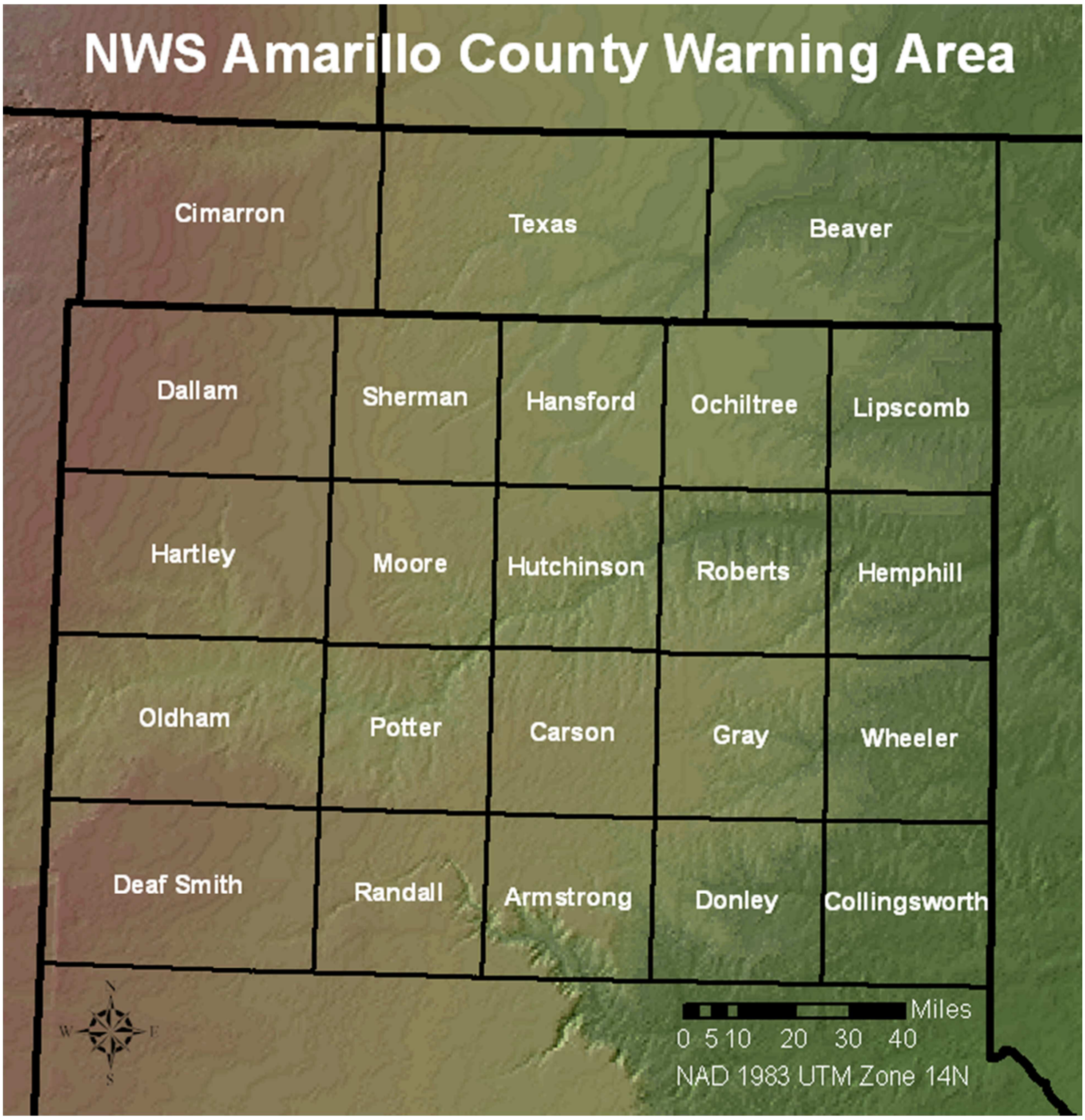

Figure 1. Topographical map of the Amarillo County Warning Area (CWA).

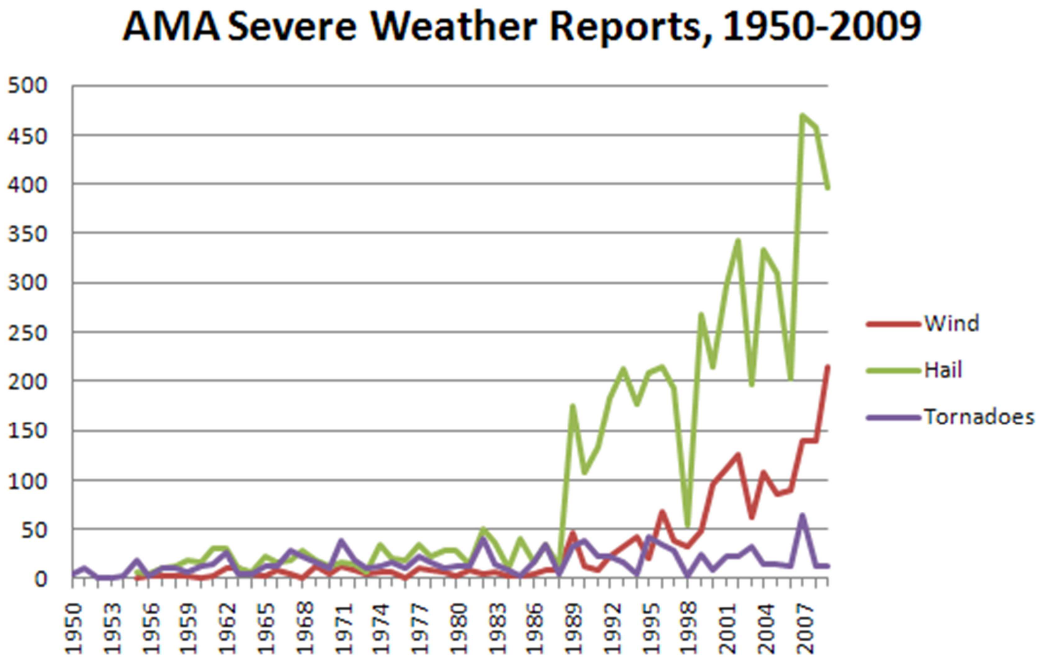

Figure 2. Severe weather reports in the Amarillo CWA, 1950-2009.

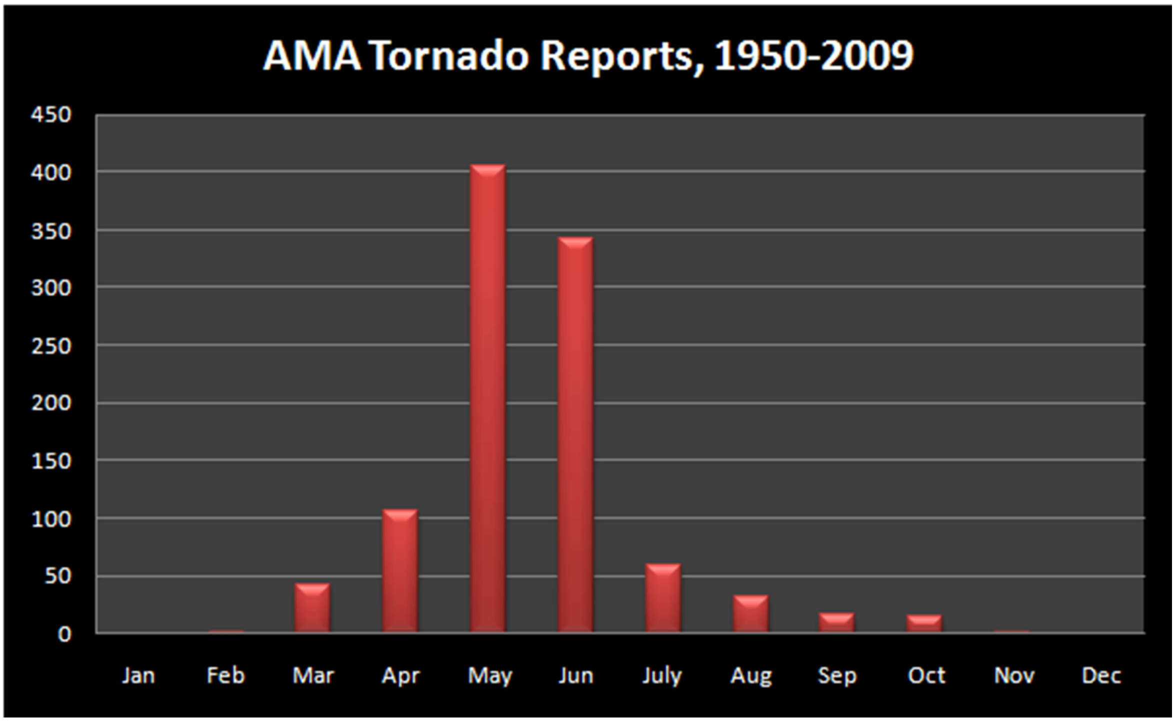

Figure 3. Monthly distribution of tornado reports in the Amarillo CWA, 1950-2009.

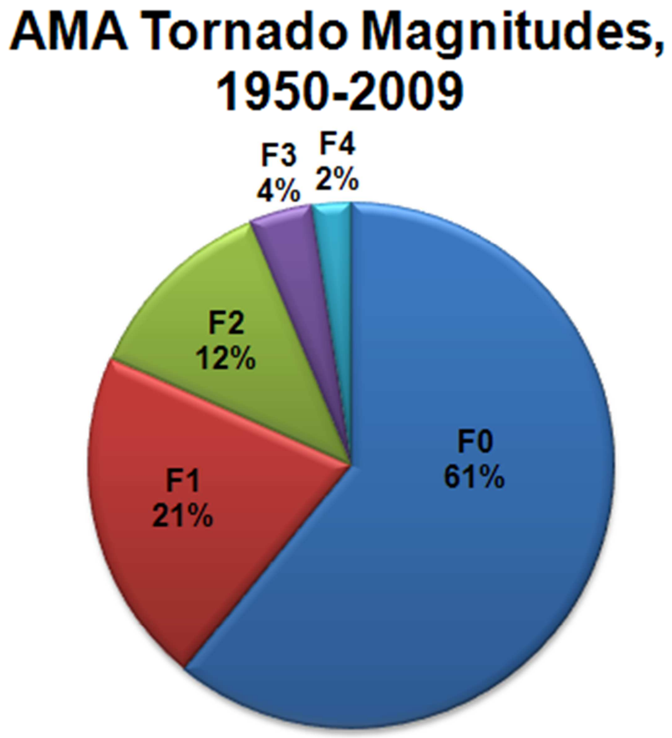

Figure 4. Percentage of tornado ratings in the Amarillo CWA, 1950-2009.

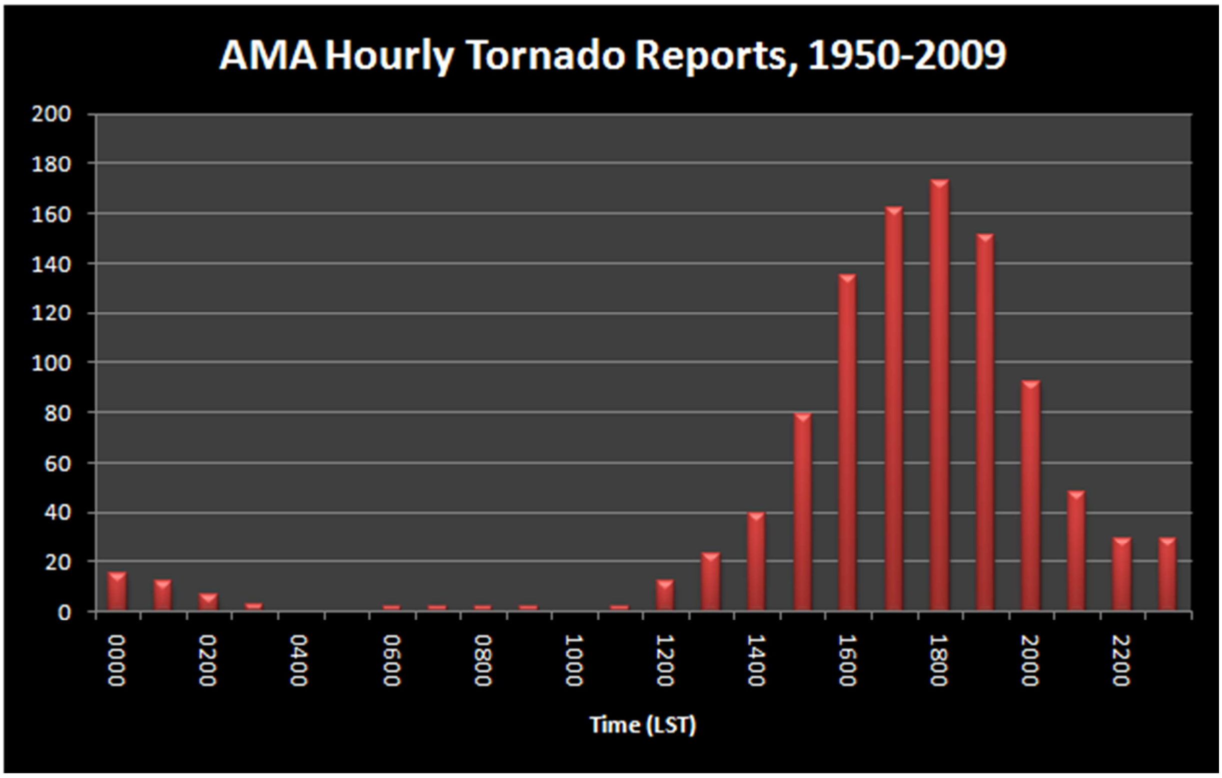

Figure 5. Hourly distribution of tornado reports in the Amarillo CWA, 1950-2009.

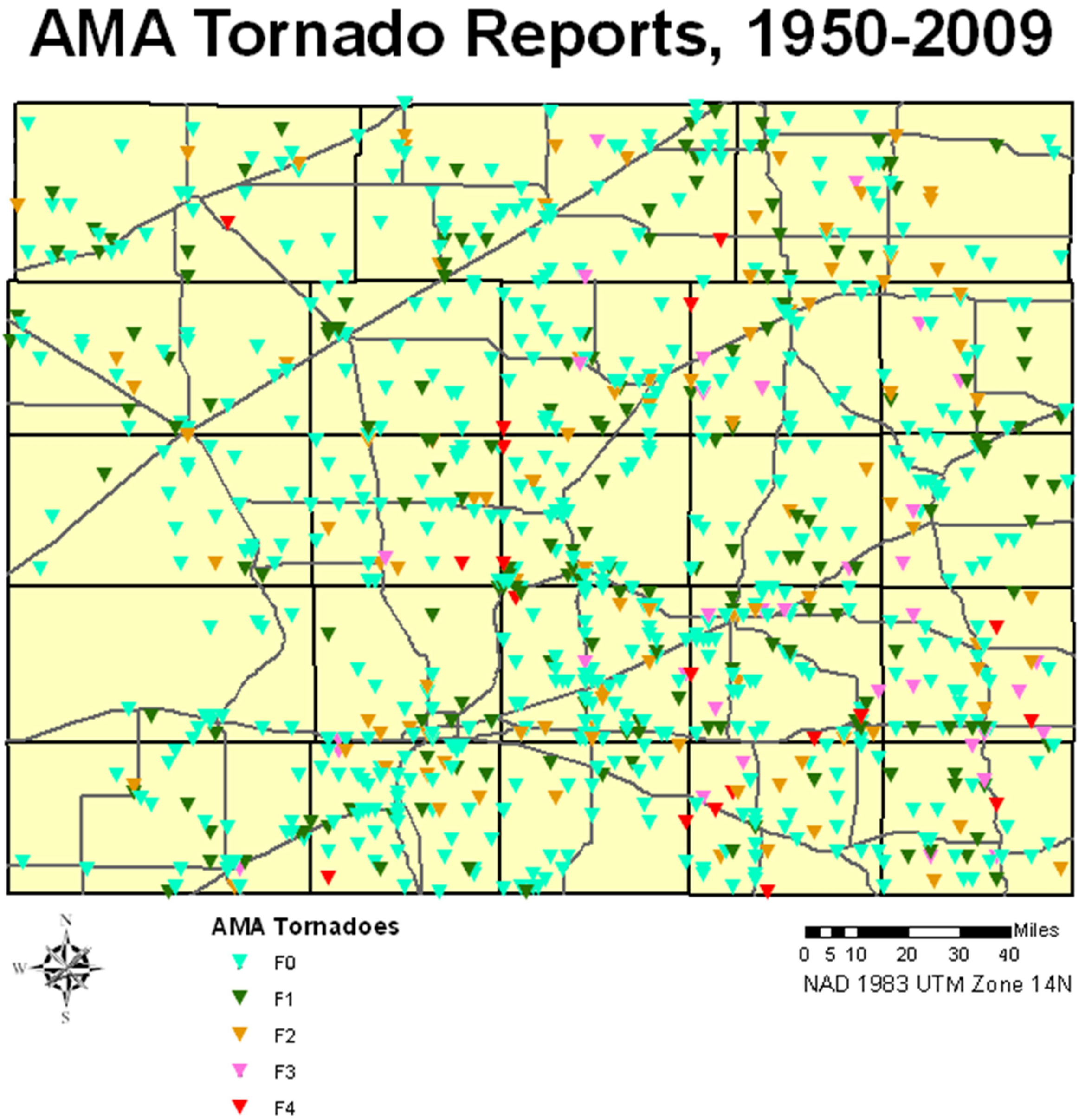

Figure 6. Spatial distribution of tornado reports and magnitudes in the Amarillo CWA, 1950-2009.

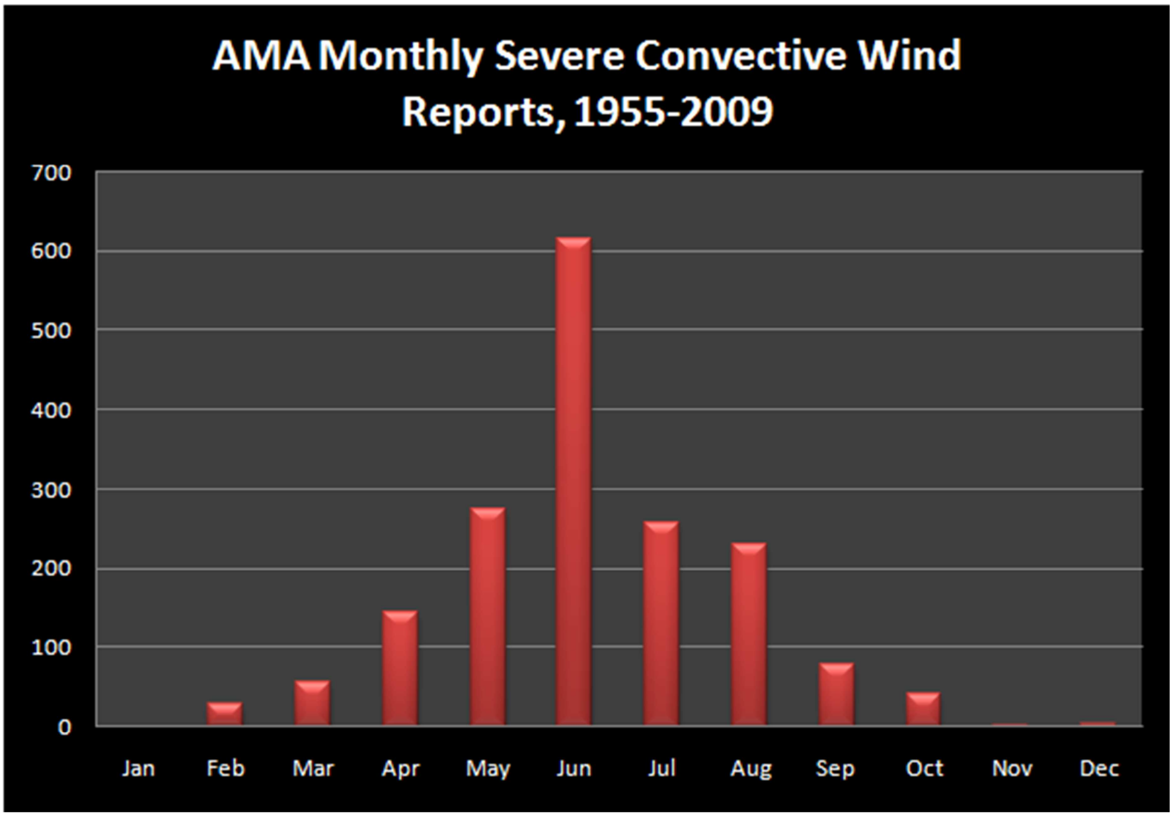

Figure 7. Monthly distribution of severe convective wind reports in the Amarillo CWA, 1955-2009.

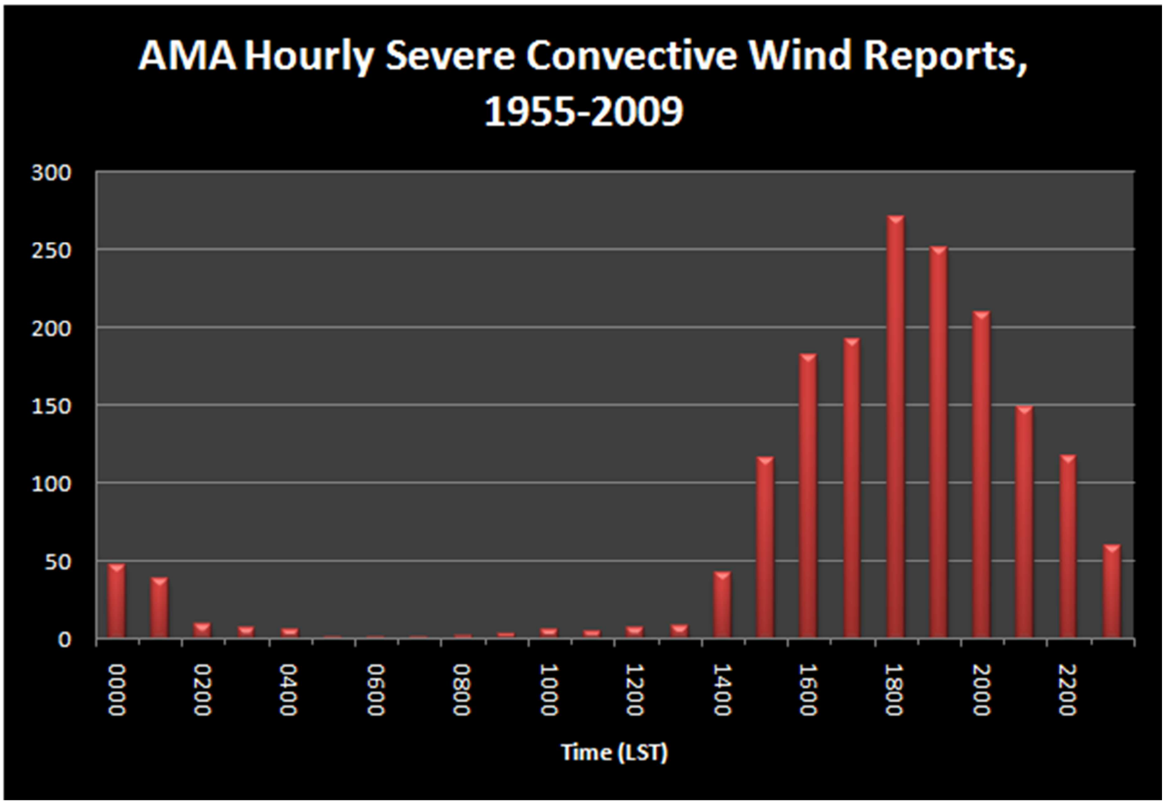

Figure 8. Hourly distribution of severe convective wind reports in the Amarillo CWA, 1955-2009.

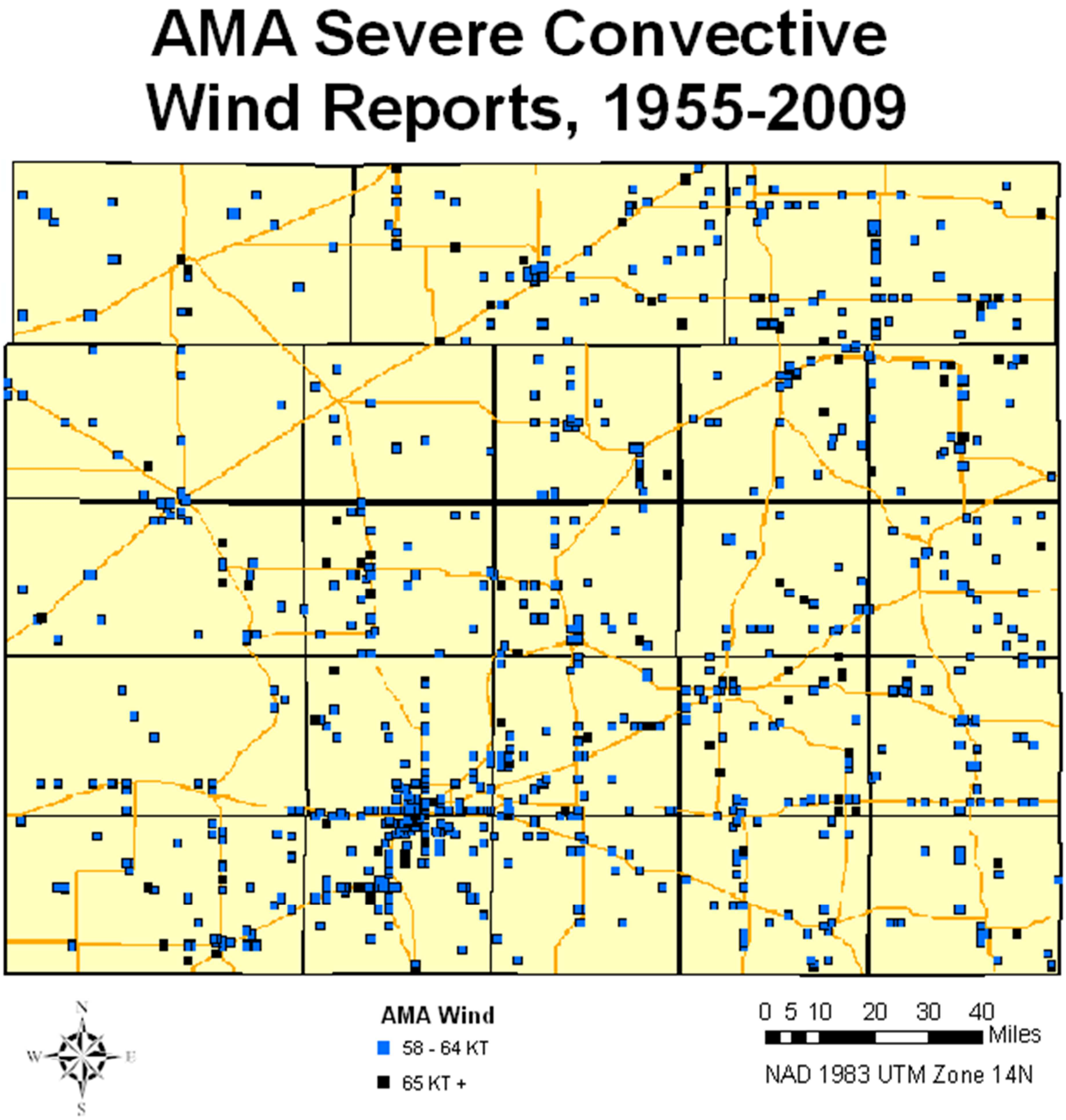

Figure 9. Spatial distribution of severe convective wind reports, including significant convective wind reports, in the Amarillo CWA, 1955-2009.

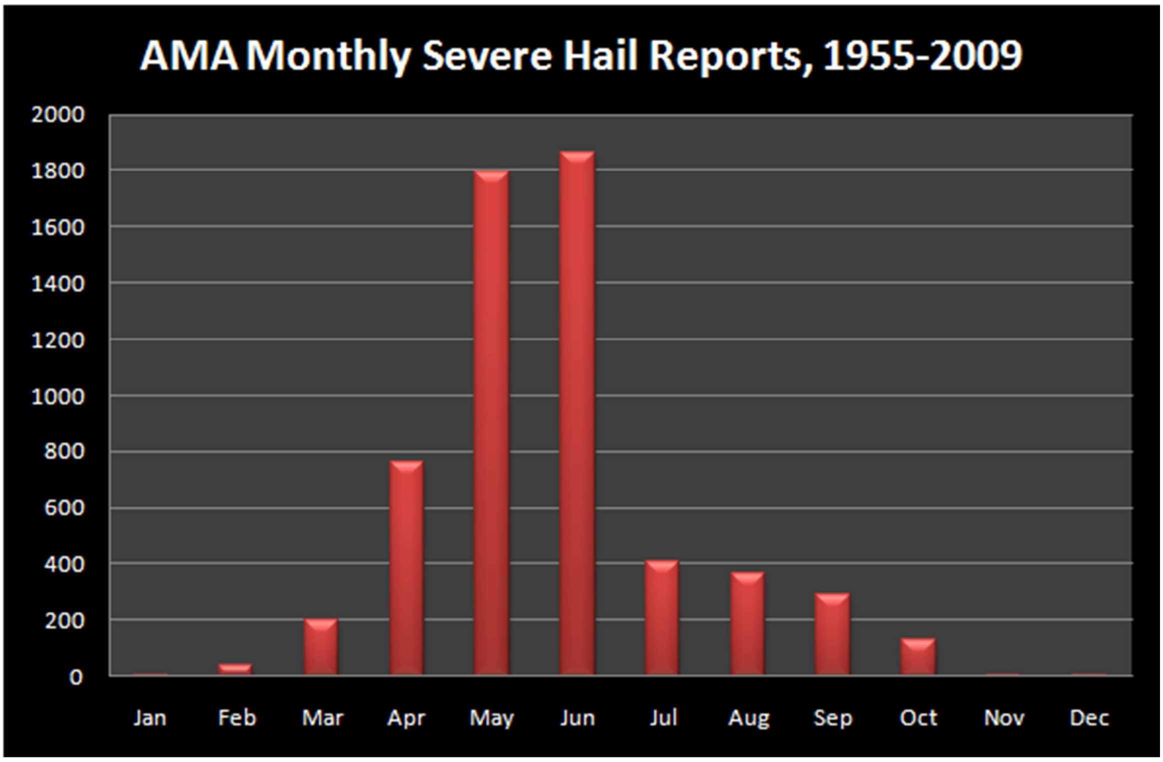

Figure 10. Monthly distribution of severe hail reports in the Amarillo CWA, 1955-2009.

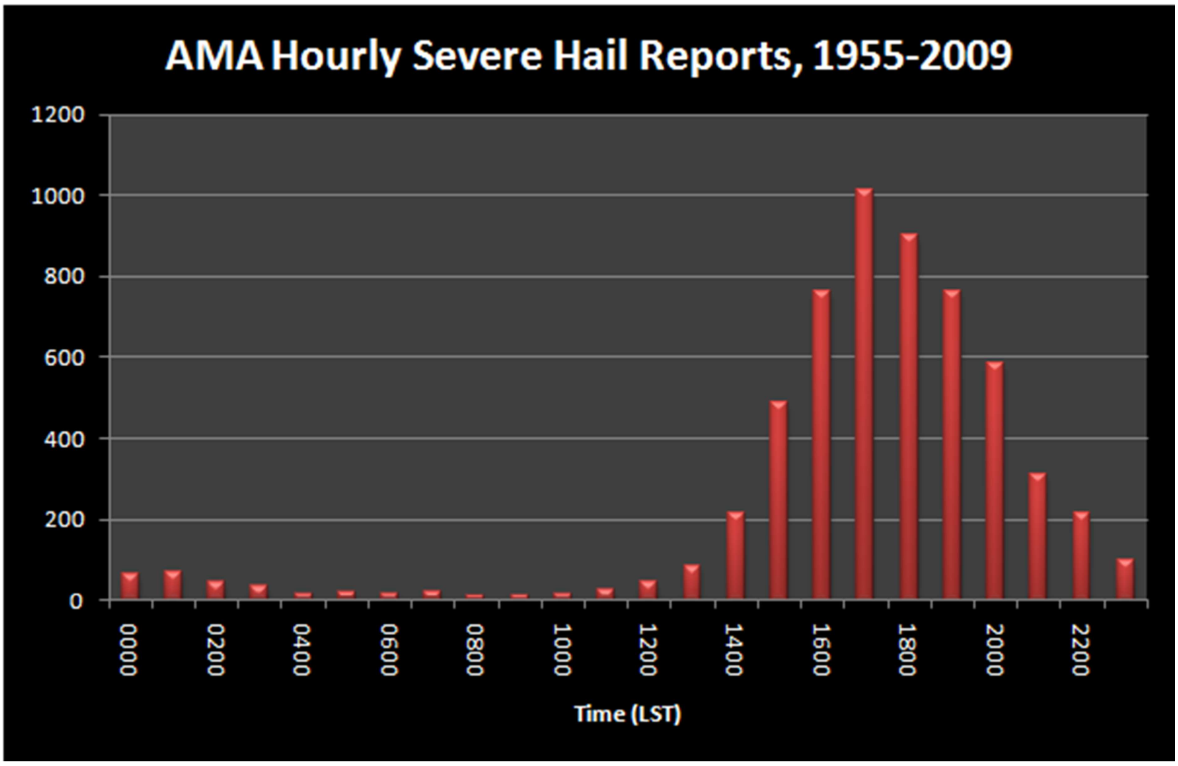

Figure 11. Hourly distribution of hail reports in the Amarillo CWA, 1955-2009.

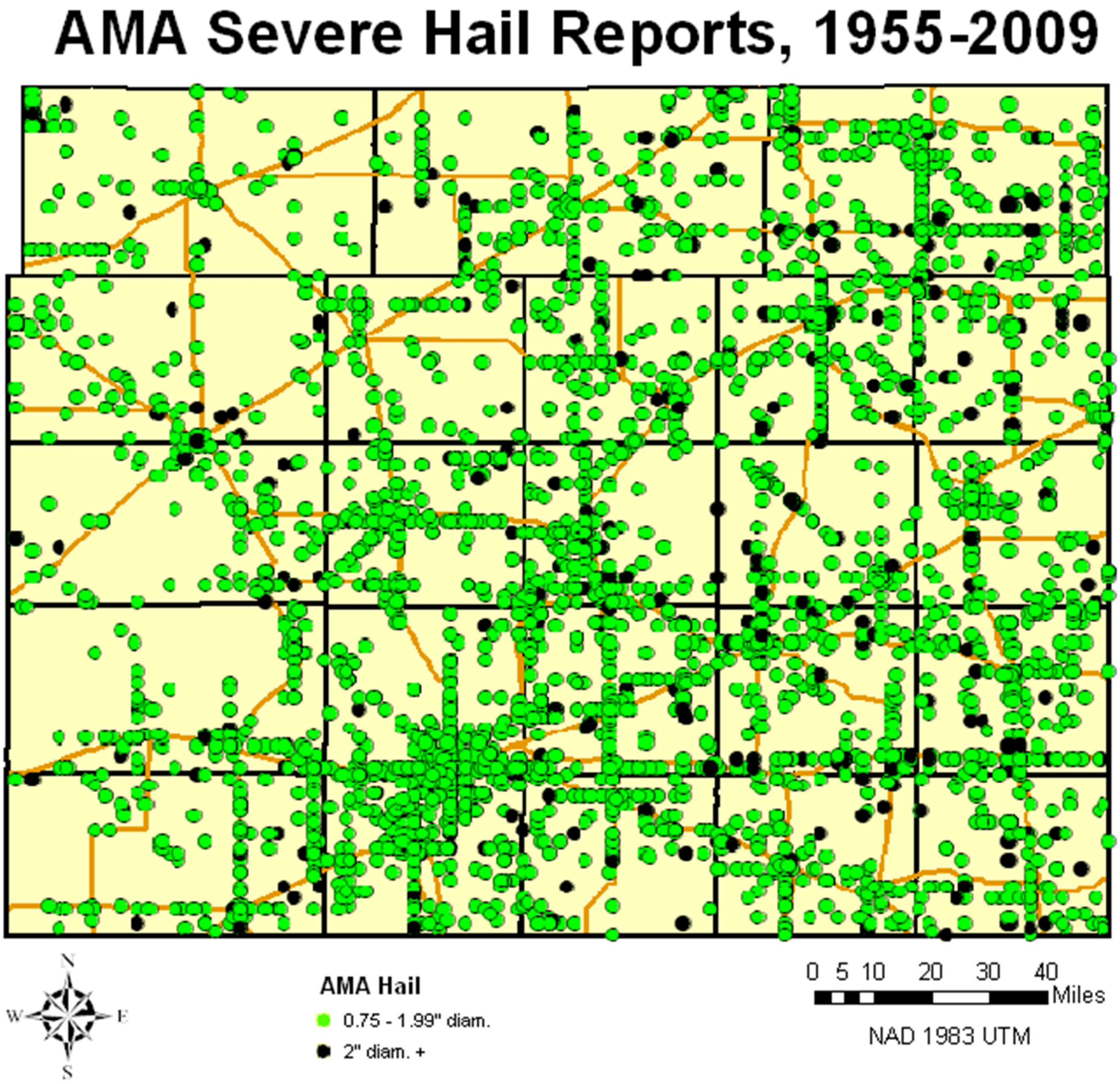

Figure 12. Spatial distribution of severe hail reports, including significant hail reports, in the Amarillo CWA, 1955-2009.