

# AN ANALYSIS OF SOUTHERN U.S. ICE STORM FREQUENCY FROM 2000-2009

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## ABSTRACT

The Southern Climate Impacts Planning Program (SCIPP) is a climate research program that focuses on helping the public improve planning for weather and climate-related disasters. SCIPP focuses on the high frequency of hazardous weather events, including extremes in precipitation. Over the past several years, SCIPP has speculated that there has been an increase in the number of ice storms within the region each winter. This paper analyzes trends in ice storm frequency and intensity for the years 2000-2009 using data from the National Climatic Data Center's Storm Events and Storm Data datasets. For this period of study, it was found that an ice storm maximum stretches from southwestern Texas through Oklahoma, northwestern Arkansas, southeastern Kansas and central Missouri. It was also found that there is no consistent trend associated with the number of ice storms, the ice thickness values of recorded ice storms, or the number of ice storm catastrophes over the last ten years. Ice storm frequency was also briefly compared to atmospheric signals and El Nino-Southern Oscillation (ENSO) events. This project also identified discrepancies in ice storm reporting across National Weather Service office boundaries as evidenced through Geographic Information Systems mapping. This project provides preliminary results that can be incorporated into more extensive studies to create national criteria for documenting ice storms.

## 1. INTRODUCTION

Ice storms in the Southern Plains region have had a detrimental impact on both life and property, usually resulting in millions of dollars in property damage, week-long power outages, and fatalities (Robbins and Cortinas 2002). Although ice storms that do occur in the Southern United States are less frequent than in other regions of the United States, they often carry greater amounts of precipitation, which results in higher ice accumulations and damage costs (Call 2010). Understanding the changes in the frequency and the severity of ice storms within this region remains a critical task in better preparing for future catastrophes. Researchers have examined case studies to develop general theories regarding ice storm frequency and intensity, however longer term climatological analyses have been difficult to undertake due to a lack of a common definition for this phenomenon. The purpose of this project was

to document all known ice storm events during the past decade across the Southern Plains region to detect potential trends in both frequency and intensity. The topics of focus included: the number of ice storms that have occurred between the years 2000-2009, any spatial trends within the Southern Plains, ice thickness and damage estimates, and the longevity of each storm system. In addition to quantifying any trends in ice storm occurrence during the past decade, this project also briefly investigated potential atmospheric signals that can contribute to a changing long-term trend in ice storms.

The next section of this paper is a review that relates the ice storms of 1998 and 2000 to the importance of preventing catastrophes. It also presents results from previous studies to introduce current knowledge on both ice storm impacts and potential changes. Section 3 presents a description of the datasets and the methodology used during this project. The results of this study are provided in Section 4. Section 5 provides a thorough discussion of the results. It also provides several North American Regional Reanalysis (NARR) plots that display anomalies of particular atmospheric variables that may be responsible for changes in ice storm frequency and severity within the Southern Plains. Finally, Section 6 concludes the paper by summarizing the major results and

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the unanswered questions that were discovered during this project.

## 2. REVIEW

There have been several recent ice storms that have had a crippling effect over different regions of the United States. The Ice Storm of 1998 that began on January 5 and lasted through January 9 impacted over 3 million people in Northern New York, New England, and Canada and caused extensive property damage, power outages, transportation delays, and fatalities. Ice accumulations from the storm measured over 3 inches in some areas (Gyakum and Roebber 2001). According to Risk Management Solutions Inc. (2008), if this ice storm were to recur in 2008 the damage cost would be between 1 and 3 billion dollars (as compared to the estimated 1.04 billion dollars in damage in 1998). Similarly, the poorly forecasted St. Valentine Ice Storm (Illinois) that lasted from January 14 through January 15 of 2000 resulted in ice accumulations around 2 inches, millions of dollars in damage, and week-long power outages. The region affected by the storm was declared a disaster area (Rauber et al. 1994). Each of these events underscores the importance of continuing to understand ice storms and their changing long-term frequency and intensity.

There have been significant changes in ice storm impacts over the past few decades. Power outages are suggested to be the longest lasting impact of ice storms. Extensive outages lead to carbon monoxide poisoning (from the use of generators), fires, and the loss of heating sources. According to Call (2010), power outages during recent storms (since 1990) have been more widespread and tend to last longer than ice storms that have occurred before 1990. Recent ice storms have resulted in power outages that last, on average, for several weeks, whereas ice storms that occurred before 1990 usually resulted in power outages that lasted around a week. This may be related to the increase in electrical use over time, an increase in the frequency or intensity of ice storms, or a combination of both (Call 2010).

Charles Bennett has suggested that a "glaze belt" exists from northwestern Texas through New England (cited in Cortinas et al. 2004). This has captured the interest of many scientists, including John Cortinas and Stanley Changnon. Cortinas et al. (2004) suggests that this entire area is likely to experience storms with ice accumulations between .25 and .5 inches once every three years. Case studies following this have focused on a

particular region in North America and a specific type of frozen precipitation to verify Bennett's suggestion. The results have generally correlated with Bennett's research, but have also extended focus on other aspects of climatology such as the duration of each event, the proportion of freezing to frozen precipitation, and the average meteorological conditions during each event. These studies have found that freezing precipitation is most common in the United States from November through March and is usually short-lived (Robbins and Cortinas 1996; Cortinas 2000; Cortinas et al. 2004). These studies have also suggested that the greatest frequency in freezing precipitation occurs in the western portion of the Central Plains (Bernstein and Brown 1997; Bernstein 2000; Cortinas et al. 2004). Despite these results, there is no extensive information on freezing precipitation across the entire area of the contiguous United States (Cortinas et al. 2004).

This paper will generally follow the same procedure as the case studies to further examine Bennett's ice storm climatology by focusing strictly on the Southern Plains region as well as focusing exclusively on freezing rain. This will establish a 10-year climatological analysis for this specific region of the United States which can serve as a solid starting point for future extensions of the study. This paper will also focus on storm duration and time of year but will not focus on the proportion of freezing to frozen precipitation or the meteorological conditions associated with the storms.

In addition to Charles Bennett, Stanley Changnon has also done extensive research on ice storms that has served as additional motivation for this project. Changnon (2003) compared radial ice thickness values in different regions within the United States from 1928-1937, which included the Southern Plains. The highest recorded radial ice thickness in the Southern Plains region was 1.97 inches, which was slightly lower than the highest United States recording in the Deep South (2.13 inches). Changnon found that the average radial thickness during this time period was .512 inches, which was among the highest averages in the United States. In addition, based on Changnon's dataset, the number of catastrophic ice events within a ten-year period in the Southern United States was between five and six. Although this is low in comparison with other regions, Changnon states that the storm-producing conditions last longer and result in larger ice deposits. Changnon (2003) also states that, in the Southern United States, the number of days with freezing rain is low but the frequency of catastrophes is relatively

high. This indicates that ice storms are more severe and result in higher amounts of damage in the South compared to other regions in the United States. This study focused on similar aspects of ice storms that Changnon analyzed, including average ice thickness values, the number of catastrophes, and the frequency of events. The results of this project were compared to Changnon's results to some extent. This project did not compare the Southern Plains to any other region in the United States. Since the definition of "catastrophe" changes every several years, the number of catastrophes recorded in this project was not compared to Changnon's results.

### 3. DATA AND METHODOLOGY

Unlike weather events, such as hurricanes or severe storms, there is no historical event archive of ice storms. There are a number of factors that have contributed to this problem in the past including, but not limited to, a lack of a national standard definition of ice storms, fewer meteorological observation sites and technology for recording events, and fewer communication capabilities for reporting impacts. In addition, winter storms that produce substantial ice accumulation at the surface are extremely complex weather events that typically produce multiple modes of winter precipitation (i.e., freezing rain, sleet, and snow) that can vary significantly over short distances and also change in time. All of these factors make documentation of ice storms and therefore climatological analyses of these events a challenging task.

For this particular study, the National Climatic Data Center's (NCDC) Storm Events and Storm Data datasets were used as the primary source for examining and quantifying past ice storm events. NCDC uses data resulting from hourly freezing rain values that are extracted from raw station records and are quality controlled and digitalized (Changnon and Bigley 2004). The datasets are not without their limitation, however, as the storm details recorded in Storm Events and Storm Data may be provided by untrained observers and highly qualitative in some cases (Changnon 2003). However, because this project was concerned with ice storms that have occurred during the most recent decade, the records are improved over the past decade and were sufficient for this research. The data gathered for this study was not compared to any NCDC data prior to 2000. The first step of the project was to determine the criteria for an ice storm. For this study, any event that was listed in NCDC's Storm Events database

as an "Ice Storm" was considered, regardless of the thickness measurements provided. The next step of the project was to determine a specific region of focus within the Southern Plains. Due to the relevance of this issue to the Southern Climate Impacts Planning Program (SCIPP) Regional Integrated Sciences and Assessment Program, which covers the states of Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas, the SCIPP region was established as the initial domain for this project. The domain was subsequently expanded to include the bordering regions of Kansas and Missouri.



Figure 1. The states included in the SCIPP region.

The annual number of events was stratified by the El Niño and Southern Oscillation data (ENSO) index. Monthly index values were obtained from the Climate Prediction Center (CPC). Using the CPC definition of El Niño and La Niña each winter season (December-February) was classified as either experiencing an El Niño, La Niña, or neutral event and was color-coded on a chart.

Using NCDC's Storm Events database, the year, the dates (beginning and end) and the duration (time in days or hours) of each ice storm event listed were recorded in a spreadsheet. After every event had been recorded for each state within the SCIPP region, NCDC's Storm Data was used to record each county that was affected by each ice storm event. NCDC's Storm Data was also used to generate a brief synopsis of each ice storm which included ice thickness and estimated property damage. The synopsis was generated to identify trends in ice storm intensity, whereas the information on counties affected, year, duration, and dates were collected to identify changes in ice storm frequency. The total number of ice storm events were tabulated for each county, sorted, and subsequently input into Geographic Information Systems software (ArcGIS) for display using each county's unique Federal Information Processing Standards (FIPS) code.

In addition to the GIS data, a composite list of all ice storm events to occur between the years 2000 and 2009 was created. The composite list consisted of the year the storm occurred, the date of each storm, the duration, the states within the SCIPP region that were affected, the counties within the SCIPP region that were affected, and the synopsis that was previously generated. The composite list was produced using the information from both Storm Events and Storm Data. Events were also further examined using NEXRAD National Mosaic Reflectivity Images from the NEXRAD radar archive of NCDC. In some cases surface, upper air, and radar data were viewed in the Oklahoma Climatological Survey's WeatherScope software to further investigate questionable events (i.e., sleet vs. freezing rain). This resulted in the elimination of several events not associated with freezing temperatures at the surface.

Once each storm had been verified by NEXRAD images, the number of recorded storms was plotted in Excel against each year and month, the number of ice storms recorded in each state was plotted, the average ice thickness measurements were plotted against each year, and the number of catastrophes was plotted against each year. For these plots, average ice thickness was calculated by taking the highest and lowest values recorded during the given year and dividing by two. Using the definition given in Changnon (2003), a "catastrophe" was categorized as an ice storm resulting in over \$25 million dollars in damage. The composite list was created to reinforce both changes in ice storm frequency and intensity and can be found in the Appendix.

#### 4. RESULTS

The following results illustrate the regional occurrence of ice storm events as well as changes in both ice storm frequency and severity throughout the last decade as found from the NCDC datasets. Figure 2 depicts the number of ice storm events found for the last decade (2000-2009). The map indicates ice storms within the SCIPP region were generally prevalent across the northern half of the region although some events were recorded as far south as southeastern Texas while northern areas of west Texas and Tennessee recorded few events. Overall, the data indicated that there is a regional maximum within the SCIPP region that extends from southwest Texas (near San Angelo), northeastward through Oklahoma, and northwestern Arkansas. This result raised the question regarding the possible continuation of this maximum to locations further north and east. To examine this issue, the domain was extended north and east to also include Kansas and Missouri.

##### **Arkansas:**

Statewide, Arkansas experienced fairly equal numbers of ice storms during the past decade with the heaviest activity occurring in the northwestern region. Figure 2 indicates that Benton, Carroll, Washington, and Madison Counties have experienced the most ice storms from the years 2000-2009. The in-state maximum of ice storms in northwestern Arkansas also appears to have corresponded well to the regional maxima present across Oklahoma to the west.

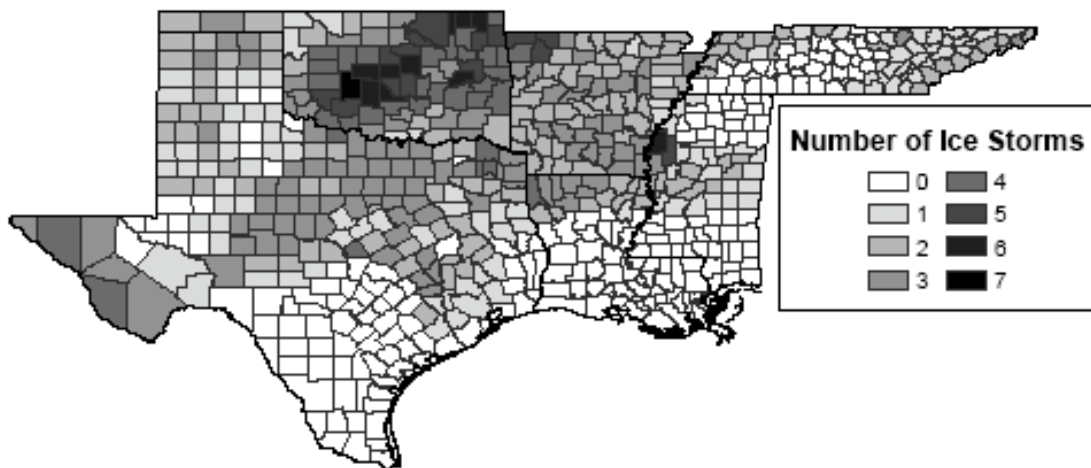


Figure 2. The number of ice storms recorded in each county within the SCIPP region. The highest frequency is located across Oklahoma. There is a noticeable maximum that extends from Texas through Oklahoma and into Northwestern Arkansas.

**Louisiana:**

The northern section of Louisiana has been affected the most by ice storms over the past decade with Caddo Parish experiencing the highest number of ice storms within the state. Parishes in central and southern Louisiana did not record any ice storms over the past decade. Overall the spatial occurrence of ice storms in Louisiana appeared to match up fairly well with the surrounding states and region.

**Mississippi:**

The central part of Mississippi was the area within the state affected most often by ice storms over the past decade with Bolivar and Sunflower Counties recording the most events. The presence of a strong gradient in ice storm frequencies between these counties and surrounding ones is immediately evident and raised questions regarding their validity. While the overall spatial trend in Mississippi appears to fit with the region, the local maximum is questionable.

**Oklahoma:**

The state of Oklahoma was affected more by ice storms than any other state in the SCIPP region during the past decade. There was a maximum in the central part of the state with Caddo, Canadian, and Oklahoma Counties recording the most ice storm events. The spatial analysis reveals a distinct maximum in ice storm events stretching from southwest, through central Oklahoma, northeastward to Kansas and Arkansas. Lower frequencies of ice storms were

observed in far northwestern Oklahoma, including the Oklahoma Panhandle, as well as far southern and southeastern Oklahoma. Overall, the spatial frequency of ice storms appears to correlate fairly well with the larger regional pattern observed during the past 10 years.

**Texas:**

Most of the ice storms observed in Texas occurred in the east central, west central, and the western (Big Bend) portions of the state. Southern portions of Texas, including the coastal region and south central did not experience any ice storm events. Western Texas experienced fewer ice storms than locations further to the east, and in some counties no ice storm events were observed during the 10-year period. Perhaps most notable is the relative maximum of ice storm events that stretches from southwest Texas (near San Angelo) towards the north and east into Oklahoma.

**Tennessee:**

The data gathered for Tennessee displayed a unique pattern. Most ice storms have been recorded in either the western or eastern region of the state, leaving the central region fairly untouched. Due to increasing terrain effects in eastern Tennessee, it is likely that the mechanism that causes ice storms is significantly different across eastern and western Tennessee. These results match up quite well with previous research that has identified a relative minimum across central Tennessee.

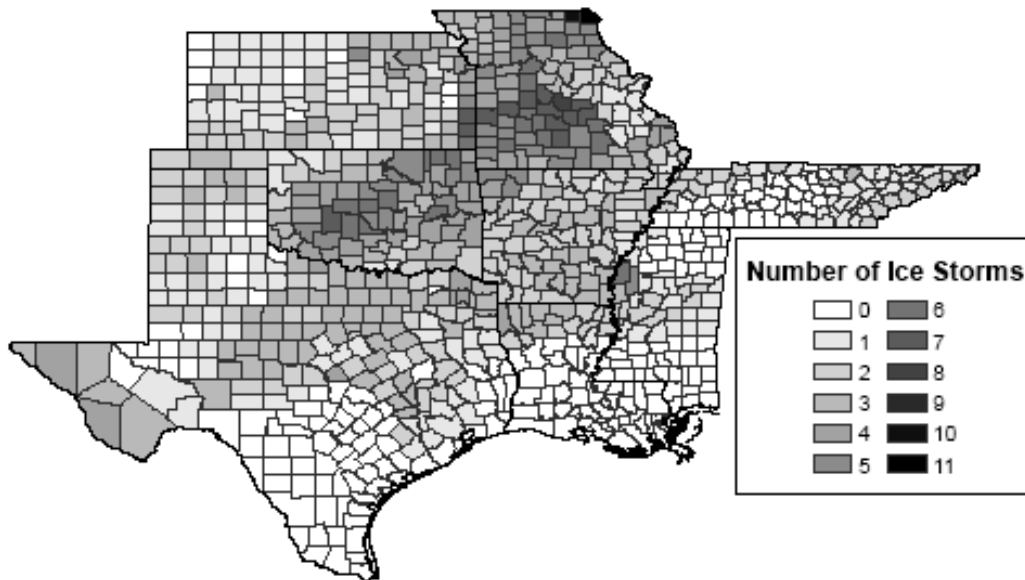


Figure 3. The number of ice storms recorded in each county with the addition of Kansas and Missouri. The ice storm maximum becomes more distinct as it extends into central Missouri.

**Kansas:**

The extreme southeastern counties in Kansas were most affected by ice storms during the past decade with Bourbon, Cherokee, Crawford, and Linn counties recording the most ice storms. In general, the ice storm event maximum present in Oklahoma appears to extend into this portion of Kansas, although border discrepancies are evident. The western half of Kansas had fewer ice storms over this period and in some cases no events at all. A second maximum was evident in northeastern Kansas near the Kansas City area.

**Missouri:**

Missouri recorded the most ice storms of all of the states analyzed. The highest number of ice storms was found to occur in the far northeastern section of the state (Clark and Scotland Counties). A relative maximum in ice storms is also evident in the southern and southwest portions of that state which appear to be a continuation of the maximum observed in Oklahoma. The results also reveal a discrepancy in ice storm reporting as the general region surrounding the St. Louis area has fewer ice storms than regions to the north, west, and south. This issue will be examined later in this paper.

**Composite List of Ice Storms:**

There were a total of 56 events recorded from January of 2000 to December of 2009 (See Appendix).

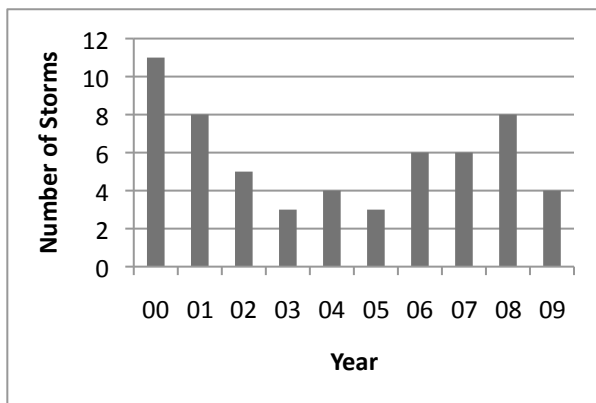


Figure 4. The number of ice storms recorded in each year over the past decade. The year 2000 was the most active.

The year 2000 experienced the greatest number of ice storms during the past decade (11 storms) and the years 2003 and 2005 recorded the fewest number of events (3 storms).

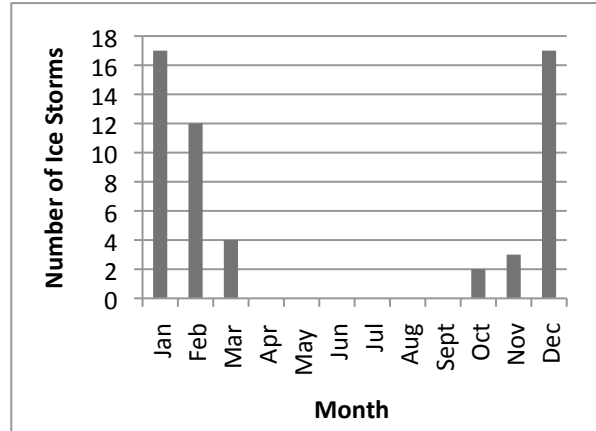


Figure 5. The number of ice storms recorded for each month over the past decade. December and January were found to be the most active months.

Regarding the seasonality of ice storms (Fig. 5), the highest number of events over this past decade was found to occur in January and December with 17 each. The period most favorable for ice storms ranges from December through February (82% of the events from this past decade ranged between these months). October and November had several events (1 and 2, respectively), while March had a slightly higher frequency with 3 events.

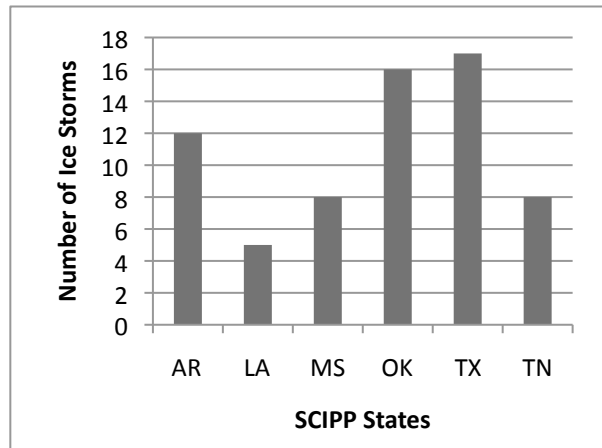


Figure 6. The number of ice storms recorded in each SCIPP state over the last decade. Texas and Oklahoma experienced the most ice storms.

It was found that Texas experienced the most ice storms this past decade (Fig. 6), which is largely a function of its size. The southern and eastern states including Louisiana, Mississippi, and Tennessee experienced the least amount of storms.

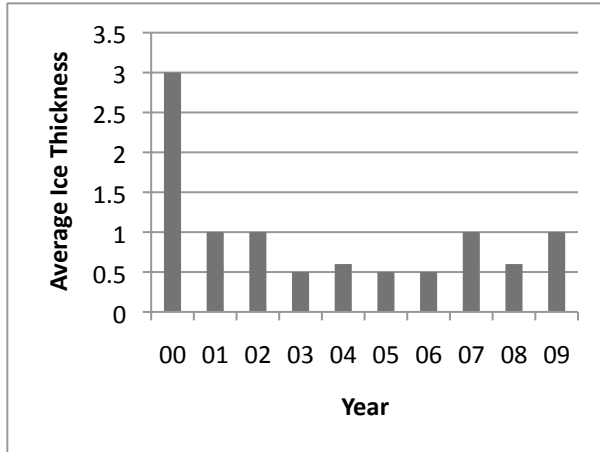


Figure 7. The average ice thickness of storms over the last 10 years. The year 2000 averaged the highest thickness values.

Average ice thickness was also plotted for the past decade (Fig. 7). The year 2000 averaged the highest ice thickness with three inches, while the remainder of the years were tightly clustered near 1 and 0.5 inches.

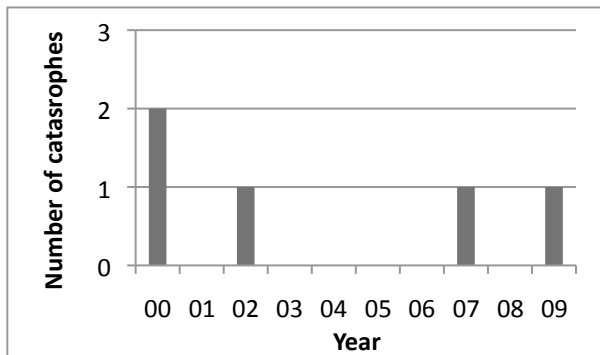


Figure 8. The number of catastrophic ice storm events during the past decade. There was an average of one catastrophic event every two years.

Figure 8 shows the number of catastrophes that occurred each year within the past decade. The year 2000 recorded the most catastrophes of any year (2) while the other years experienced 1 or no catastrophes throughout the region. Overall, the region has averaged 1 catastrophic event every 2 years during the past decade. Catastrophic ice storms during this period include:

- December 12-13, 2000 ice storm
- December 24-27, 2000 ice storm
- January 29-31, 2002 ice storm
- December 8-12, 2007 ice storm
- January 5-6, 2009 ice storm

Figure 9 indicates that ENSO may affect ice storm frequency. Two of the three most active

seasons were associated with La Nina (white); two of the three seasons experiencing El Nino were among the least active seasons (black). The neutral phase events (gray) were associated with an average number of ice storm events for the period. Interestingly, aside from the '00-'01 winter season, there seems to be a general upward trend in the number of events per year. However, a longer analysis is needed to more thoroughly investigate annual trends and ENSO relationships.

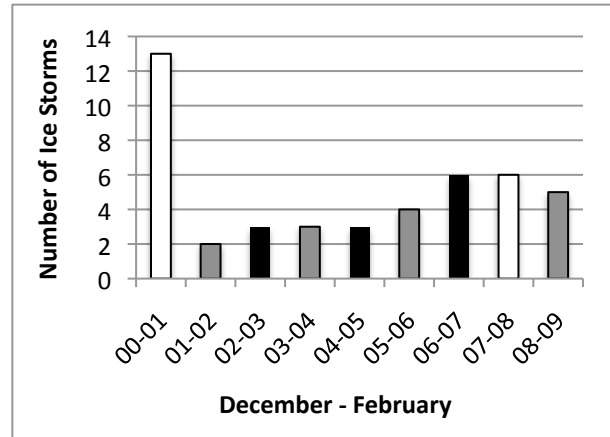


Figure 9. Ice storm frequency in relation to ENSO phase. La Nina (white bars), El Nino (black bars), and Neutral (gray bars) phases were identified for the December to February period using historical Climate Prediction Center data (available at: [http://www.cpc.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml)).

## 5. DISCUSSION

### Composite List:

Over the past decade, there have been irregular fluctuations in the frequency of ice storms. Although there was a general increase from 2005 to 2008, there has not been a year as active as 2000. Recently, there has been a decrease in the frequency of ice storms (2008-2009). The fluctuations in ice storm frequency may be linked to ENSO. La Nina winters in the SCIPP region typically result in higher amounts of precipitation which may lead to an increase in ice storms, whereas El Nino typically results in drier winters for most of the region, possibly resulting in fewer ice storms events. In addition, La Nina events produce colder conditions in most of the SCIPP region, which may lead to more cold air intrusions and more ice storms. Although it is difficult to separate El Nino events from neutral events, the results suggest that La Nina events are associated with a higher frequency of ice storms. Studying this potential trend over a longer period of time in greater detail would reveal a better conclusion.



Ice storms were recorded to be most prevalent from October through March, with January and December having the highest frequencies. This is in general agreement with Changnon's (2003) claim that ice storms are most frequent between November and March. Seasonally, ice storm frequency has remained unchanged with time.

It was also concluded that the average ice thickness values measured for each storm and the number of catastrophes have had irregular fluctuations over the past decade. The average ice thickness measurements have increased from .512 inches recorded between 1928 and 1937 to 1.5 inches from 2000 to 2009. This suggests an increase in average ice thickness over time, but recordings from 1928-1937 may not have been as accurate as those from this past decade. In addition to this, the definition of "ice storm" in this project was not based off of any thickness parameters, allowing very low values to be used when calculating the average value. When comparing this project's results to the ice accumulation claim in Cortinas et al. (2004) it is clear that maximum ice accumulations have exceeded .5 inches every year in the past decade (Appendix). However, due to large errors in ice thickness measurements, it is inconclusive whether or not average ice thickness measurements in ice storms are increasing over time. The number of catastrophes may have decreased due to improvements in forecasting or a decrease ice storm frequency and intensity. However, these results are an estimate because Storm Events and Storm Data contain many missing damage reports. If damage reports improve in the future, a better conclusion can be made. In addition, the definition of catastrophe is likely to change with time and is a difficult variable to interpret.

**SCIPP analysis:**

The output generated by ArcGIS for the SCIPP data indicated the existence of a maximum that extended through portions of Texas, Oklahoma, Arkansas, and Missouri. The most significant part of the maximum was located in Oklahoma. It was determined that counties in Central Oklahoma have experienced the greatest number of ice storms within the past decade. Because this study did not analyze meteorological conditions, there are still questions regarding the causes of the location of the relative ice storm maximum, and how the most recent decade compares to previous decades.

As an exploratory exercise to briefly examine longer-term changes in atmospheric conditions,

North American Regional Reanalysis (NARR) data were employed. For instance, warming near the 850 millibar (mb) level may result in a warmer melting layer, which would increase the amount of freezing rain reaching the surface as compared to ice pellets or sleet. Figure 10 shows NARR data of 850 mb air temperature during December through February for the years 2000-2009 as compared to a base-line of 1979-2001. There is a clear indication of warming in this layer of the atmosphere, which may play a role in these events. Along with this, the changes in air temperature at 925mb were also plotted to account for elevation differences within the region. Figure 11 provides the anomaly data for 925mb comparing the years 2000-2009 to the years 1979-2001. This figure again shows a similar area of increase in the Southern Plains. While Figures 10 and 11 depict winter anomalies (December through February), during the past 10 years as compared to 1979-2001 and thus do not represent atmospheric conditions for any individual ice storm event, the plots do capture the envelope of the winter season and the general trends observed.

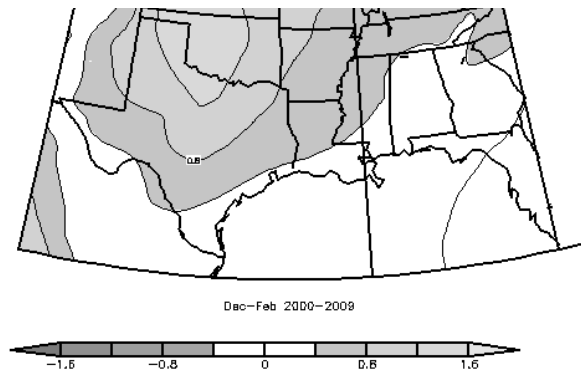


Figure 10. The 850 mb temperature anomaly comparing 2000-2009 with 1979-2001. A warming signal is present in the Southern U.S. during the past decade.

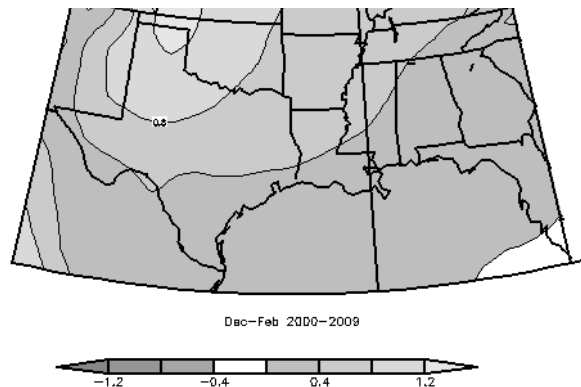


Figure 11. 925 mb anomaly data comparing 2000-2009 to 1979-2001. A clear warming signal is evident in the Southern U.S.



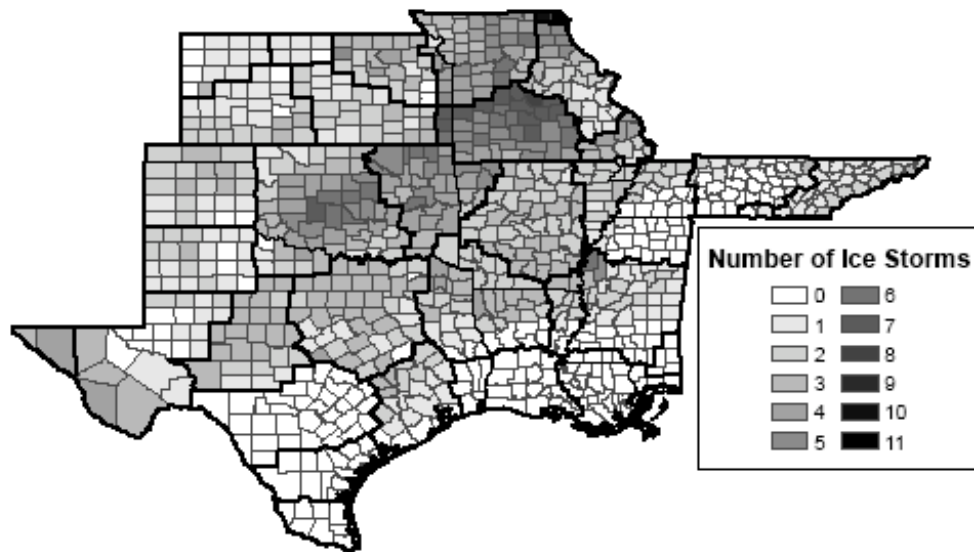


Figure 12. The boundaries of each NWS office within the Southern Plains region plotted on top of the ice storm recordings. There are clear changes in recorded ice storms among several boundaries, indicating the variety of office standards for reporting ice storms.

**Data Issues:**

When analyzing the ice storm maxima, it is important to note the abrupt change in ice storm frequency in Central Missouri. This was determined to be caused by the boundaries of the National Weather Service (NWS) offices across the state. Figure 12 shows the borders of each NWS office within the region and it is clear that the boundaries of the St. Louis NWS office in northeastern Missouri coincide with areas of ice storm frequency change. This was also noticed in other areas of the region as well, particularly in south Texas and eastern Tennessee. The NWS office in Springfield, Missouri, located in the southwestern part of the state has recorded more ice storms than surrounding offices. This may be because the ice storm maximum contributes to a higher frequency of storms in this region, or the criteria of an ice storm for this office differ significantly from surrounding offices. Regardless of the reason, this finding highlights a limitation with the NCDC dataset. There appears to be no consistent definition of an ice storm that is followed by the entire United States. Each NWS office has its own criteria for determining different weather phenomena. The criteria for an ice storm needs to be redefined and nationally followed for more accurate research. Because of this, the results of this study may be over- or under-represented in some locations.

It should also be noted that the date and duration of the events recorded in Storm Events and Storm Data are, to some extent, subjective. Start and end dates may be interpreted differently among observers, making it difficult to record a true timeframe of an event. The ice storm that occurred in mid January of 2007 was the best example (See appendix). In this particular case, there were several ice storms between January 12 and January 21 generated from the same synoptic system. The events were divided into three separate events based on the Storm Data synopses, NEXRAD reflectivity images, and WeatherScope data. The organization of the events for this project may be interpreted differently by other researchers, suggesting that it is difficult to analyze multi-day ice storm events and sometimes the date and duration of an ice storm. This problem was encountered several times throughout this project and some interpretation beyond the methodology was required.

**6. CONCLUSIONS**

This demonstration study aimed to quantify the occurrence of ice storms throughout the Southern U.S. over the past decade to examine spatial patterns and changes in ice storm frequency and extent. The study found a distinct maximum in ice storm occurrence that stretches from southwestern Texas northeastward through

Oklahoma, northwest Arkansas, southeast Kansas, and southwestern Missouri. In general, the results are consistent with previous spatial analyses of ice storms conducted previously. The study also briefly examined potential larger changes in atmospheric conditions through NARR analyses which found a warming signal throughout the layer of the atmosphere most commonly associated with the melting layer. This research study also identified a myriad of issues relating to the NCDC ice storm datasets and definitions. There were also many missing damage reports that made the catastrophe analysis incomplete, and furthermore, there were several noticeable changes in ice storm frequency located along NWS office boundaries. These factors make it incredibly difficult to interpret spatial results and determine whether or not the observed ice storm maximum is significant or the result of NWS office practices.

Perhaps one of the most important conclusions resulting from this study is the recommendation for the establishment of a consistent nationwide definition for “ice storm” to improve the documentation of these complex winter storm events. This research effort represents the first step in a substantial, new research effort underway at the Oklahoma Climatological Survey to better understand ice storms, their occurrence, impacts, and possible future.

## 7. ACKNOWLEDGEMENTS

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## APPENDIX:

### Ice storm Composite List:

Data from NCDC's Storm Events and Storm Data

<http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms>

<http://www7.ncdc.noaa.gov/IPS/sd/sd.html;jsessionid=277C8116A5D92E2FD8852C2839054D9F>

#### Event 1:

January 26-28, 2000 Louisiana: 2pm on the 26-1130pm on the 28, at least \$7,370,000 property, 1-4 inches  
**Bienville, Bossier, Caddo, Claiborne, De Soto, Jackson, Lincoln, Ouachita, Red River, Union, Webster, East Carroll, Madison, Morehouse, Richland, West Carroll**

Texas: 12pm on the 26-11pm on the 28, no damage report, 1-4 inches

**Bowie, Camp, Cass, Franklin, Gregg, Harrison, Marion, Morris, Red River, Smith, Titus, Upshur, Wood**

Mississippi: 6am on 27-6am on 28, at least \$285k property, 1-2 inches

**Hinds, Issaquena, Kemper, Lauderdale, Leake, Madison, Neshoba, Newton, Rankin, Scott, Sharkey, Warren, Yazoo**

**Summary:** 1-4 inches, 12pm on January 26 through 1130pm on January 28, at least \$7,655,000 property

#### Event 2:

March 16, 2000 Oklahoma: 2-4 inches of mixed freezing rain and sleet, 8am on the 16-11pm on the 16, no damage report  
**Alfalfa, Beckham, Blaine, Custer, Dewey, Grant, Greer, Harmon, Major, Roger Mills, Washita**

#### Event 3:

October 8-9, 2000 Texas: 8am on the 8-10am on the 9, up to .5 inches, no damage report

**Big Bend Area, Pecos, Presidio Valley**

#### Event 4:

November 8-9, 2000 Kansas: 1pm on the 8-7am on the 9, no ice thickness given, no damage report

**Johnson, Linn, Miami**

Missouri: 12pm on the 8-9am on the 9, no damage report, up to an inch of ice

**Bates, Carroll, Cass, Henry, Jackson, Johnson, Lafayette, Pettis, Ray, Saline**

**Summary:** 12pm on the 8-9am on the 9, no damage report, around an inch of ice accumulation

#### Event 5:

Dec 7, 2000 Arkansas: 2am on the 7-3pm on the 7, at least \$10.0k property damage-no ice report

**Mississippi**

#### Event 6:

December 10-11, 2000 Oklahoma: 6am on the 11-6pm on the 11, no thickness or damage reports

**Adair, Cherokee, Craig, Creek, Delaware, Haskell, Latimer, Le Flore, Mayes, McIntosh, Muskogee, Nowata, Okfuskee, Okmulgee, Osage, Ottawa, Pawnee, Rogers, Sequoyah, Tulsa, Wagoner, Washington**

Missouri: 4am on the 10-4pm on the 11, .25-.5 inches, no damage report

**Knox, Lewis, Marion, Pike, Ralls, Shelby, Cooper, Howard, Pettis, Saline**

**Summary:** 4am on the 10-6pm on the 11, no damage report, .25-.5 inches

#### Event 7:

Dec 12-13, 2000 Arkansas: ice from .25 to 4 inches, at least \$360,015,000 property, 8am on the 12-4pm on the 13

**Columbia, Hempstead, Howard, Lafayette, Little River, Miller, Nevada, Sevier, Union, Crawford, Franklin, Sebastian, Ashley, Chicot**

Louisiana: 10pm on the 12-4pm on the 13, at least \$27.0M property, average 1 inch

**Bienville, Bossier, Caddo, Claiborne, De Soto, Lincoln, Red River, Union, Webster, Caddo**

Texas: 4pm on the 12-4pm on the 13, .25-6in, \$124.0M property,

**Brazos, Burleson, Colorado, Grimes, Houston, Madison, Trinity, Walker, Washington, Bowie, Camp, Cass, Cherokee, Franklin, Gregg, Harrison, Marion, Morris, Nacogdoches, Panola, Red River, Rusk, Shelby, Smith, Titus, Upshur, Wood, Callahan, Fisher, Haskell, Jones, Nolan, Taylor, Throckmorton**

Oklahoma: 3pm on the 12-4pm on the 13, 1-4 in, at least \$140.0k property damage

**Atoka, Bryan, Choctaw, Haskell, Latimer, Le Flore, McIntosh, Muskogee, Pittsburg, Pushmataha, Sequoyah, Mccurtain**

Mississippi: 3am on the 13-5pm on the 13, at least \$43.0k property damage, .125-.25in

**Bolivar, Sunflower, Washington, Coahoma, De Soto, Tunica**

**Summary:** .125-6 inches, 8am on Dec. 12 through 5pm on Dec 13, \$511,198,000 property damage

#### Event 8:

December 15-16, 2000 Missouri: 9am on the 15-5am on the 16, at least \$10k in property damage, .25- .5 inches

**Clark, Scotland, Bollinger, Butler, Cape Girardeau, Carter, Perry, Ripley, Wayne, Camden, Dent, Douglas, Howell, Laclede, Maries, Miller, Morgan, Oregon, Ozark, Phelps, Pulaski, Shannon, Texas, Wright**

#### Event 9:

December 21, 2000 Mississippi: 130am on the 21-4am on the 21, no thickness details, at least \$12.0k property damage

**Choctaw, Clay, Grenada, Lowndes, Montgomery, Noxubee, Oktibbeha, Webster, Winston**

Event 10:

December 24-27, 2000 Arkansas: \$165M property, 11pm on the 24-2am on the 27, .25-6 inches  
**Columbia, Hempstead, Howard, Lafayette, Little River, Miller, Nevada, Sevier, Union, Arkansas, Baxter, Boone, Bradley, Calhoun, Clark, Cleburne, Cleveland, Conway, Dallas, Desha, Drew, Faulkner, Fulton, Garland, Grant, Hot Spring, Independence, Izard, Jackson, Jefferson, Johnson, Lincoln, Logan, Lonoke, Marion, Monroe, Montgomery, Newton, Ouachita, Perry, Pike, Polk, Pope, Prairie, Pulaski, Saline, Scott, Searcy, Sharp, Stone, Van Buren, White, Woodruff, Yell, Benton, Carroll, Crawford, Franklin, Madison, Sebastian, Washington**

Louisiana: 11pm on the 24-955pm on the 26, \$106.0M property, .25-1 inches

**Bienville, Bossier, Caddo, Claiborne, Jackson, Lincoln, Ouachita, Union, Webster**

Texas: .25-3 inches, 11pm on the 24-12am on the 27, at least \$32,175,000 property

**Bowie, Camp, Cass, Franklin, Marion, Morris, Red River, Titus, Brown, Callahan, Coke, Coleman, Concho, Crockett, Fisher, Haskell, Irion, Jones, Nolan, Runnels, Schleicher, Shackelford, Sterling, Taylor, Throckmorton, Tom Green, Archer, Baylor, Clay, Foard, Knox, Wichita, Wilbarger**

Oklahoma: .25-3 inches, 11pm on the 24-2pm on the 27, around \$170M property damage

**Adair, Cherokee, Choctaw, Craig, Creek, Delaware, Haskell, Latimer, Le Flore, Mayes, McIntosh, Muskogee, Nowata, Okfuskee, Osage, Ottawa, Pawnee, Pittsburg, Pushmataha, Rogers, Sequoyah, Tulsa, Wagoner, Washington, Mccurtain, Atoka, Bryan, Caddo, Canadian, Carter, Cleveland, Coal, Comanche, Cotton, Garvin, Grady, Hughes, Jefferson, Johnston, Lincoln, Love, Marshall, McClain, Murray, Oklahoma, Pontotoc, Pottawatomie, Seminole, Stephens, Tillman**

Missouri: 3pm on the 26 10pm on the 26, no damage report, no ice thickness given

**Bollinger, Butler, Cape Girardeau, Carter, Mississippi, New Madrid, Perry, Ripley, Scott, Stoddard, Wayne**

**Summary:** 11pm on the 24-2pm on the 27, .25-6inches, at least \$473,175,000 property damage

Event 11:

December 28, 2000 Arkansas: average of .25 inches, no damage report, 2am on the 28-9am on the 28

**Bradley, Calhoun, Clark, Cleveland, Dallas, Desha, Drew, Grant, Jefferson, Ouachita, Pike**

Event 12:

January 13-14, 2001 Missouri: 7pm on the 13-4am on the 14, no damage report, up to .125 inches

**Clark, Scotland**

Event 13:

January 27-29, 2001 Oklahoma: 10am on the 28-3pm on the 28, no damage report, .25-1 inches

**Alfalfa, Beckham, Blaine, Caddo, Canadian, Custer, Dewey, Garfield, Grant, Greer, Harmon, Jackson, Kay, Kingfisher, Kiowa, Logan, Major, Noble, Payne, Washita**

Kansas: 9pm on the 27-3am on the 29, no damage report, .25-.75 inches

**Butler, Cowley, Greenwood, Harper, Harvey, Kingman, Marion, Reno, Sedgwick, Sumner, Bourbon, Crawford**

Missouri: 4am on the 28-3pm on the 29, .25-.5 inches, no damage report

**Clark, Scotland, Barton, Benton, St. Clair, Vernon**

**Summary:** 9pm on the 27-3pm on the 29, .25-1 inches, no damage report

Event 14:

February 8-9, 2001 Kansas: 6am on the 8-6am on the 9, .25 inches, no damage report

**Barber, Clark, Comanche, Kiowa, Pratt, Stafford**

Missouri: no correct start time (recorded as the 7)- 2am on the 8, no ice thickness given, no damage report

**Clark, Scotland**

**Summary:** no correct start time (recorded as the 7)-6am on the 9, .25 inches, no damage report

Event 15:

February 14-16, 2001 Texas: 1030am on the 15-9am on the 16, .1-.2 inches, no damage report

**Archer, Baylor, Clay, Wichita, Wilbarger**

Oklahoma: 9pm on the 14-9am on the 16, no damage report, .1-.2 inches

**Caddo, Canadian, Carter, Cleveland, Coal, Comanche, Cotton, Garvin, Grady, Hughes, Jefferson, Johnston, Lincoln, McClain, Murray, Oklahoma, Pontotoc, Pottawatomie, Seminole, Stephens, Tillman**

**Summary:** 9pm on the 14-9am on the 16, .1-.2 inches, no damage report

Event 16:

February 21, 2001 Kansas: 330pm on the 21-10pm on the 21, .25 inches, no damage report

**Bourbon, Cherokee, Crawford**

Missouri: 330pm on the 21-11pm on the 21, at least \$25k property damage, .25-2 inches

**Crawford, Iron, Madison, Reynolds, St. Francois, Ste. Genevieve, Washington, Barton, Benton, Camden, Cedar, Christian, Dade, Dallas, Dent, Douglas, Greene, Hickory, Howell, Jasper, Laclede, Lawrence, Maries, Mcdonald, Miller, Morgan, Newton, Oregon, Ozark, Phelps, Polk, Pulaski, Shannon, St. Clair, Texas, Vernon, Webster, Wright**

**Summary:** 330 pm on the 21- 11pm on the 21, .25-2 inches, at least \$25k property damage

Event 17:

February 27, 2001 Kansas: 1145am on the 27, no damage report, no ice thickness given

**Osage**

Event 18:

March 1, 2001 Kansas: 720am on the 1-725am on the 1, no damage report, no thickness given

**Geary, Pottawatomie**

Event 19:

November 27-29, 2001 Arkansas: 2am on the 28- 12pm on the 29, at least \$1.8M property, .5-1 inches

**Benton, Carroll, Madison, Washington**

Texas: 1230pm on the 27-6pm on the 29, no damage report, no ice thickness given

**Bell, Bosque, Collin, Comanche, Cooke, Coryell, Dallas, Denton, Eastland, Ellis, Erath, Falls, Fannin, Freestone, Grayson, Hamilton, Hill, Hood, Hopkins, Hunt, Jack, Johnson, Kaufman, Lamar, Lampasas, Limestone, McLennan, Mills, Montague, Navarro, Palo Pinto, Parker, Rains, Robertson, Rockwall, Somervell, Stephens, Tarrant, Van Zandt, Wise, Young**

Oklahoma: 1am on the 28-12pm on the 29, at least \$1.0M property, .5-1 inches

**Adair**

**Summary:** 1230pm on the 27-6pm on the 29, .5-1 inches, at least \$1.9M property

Event 20:

January 5, 2002 Kansas: 845am on the 5-1114am on the 5, no damage report, no ice thickness given

**Brown, Dickinson, Geary, Lyon, Morris, Nemaha, Pottawatomie, Riley, Wabaunsee**

Event 21:

January 29-31, 2002 Texas: 6pm on the 29-6am on the 30, no damage report, .25 inches or more

**Hansford, Hemphill, Lipscomb, Ochiltree, Roberts**

Oklahoma: 6pm on the 29-12pm on the 31, \$302.0M property, .25-2 inches

**Alfalfa, Beckham, Blaine, Caddo, Canadian, Cleveland, Comanche, Custer, Dewey, Ellis, Garfield, Grady, Grant, Greer, Harmon, Harper, Kay, Kingfisher, Kiowa, Lincoln, Logan, Major, McClain, Noble, Oklahoma, Payne, Roger Mills, Washita, Woods, Woodward, Cimarron, Texas, Beaver, Nowata, Osage, Pawnee, Washington**

Kansas: 9pm on the 29-3pm on the 31, 1-2 inches, at least \$38M property damage

**Barber, Clark, Comanche, Kiowa, Pratt, Stafford, Johnson, Leavenworth, Linn, Miami, Wyandotte, Bourbon, Crawford, Allen, Chautauqua, Elk, Greenwood, Labette, Montgomery, Neosho, Wilson, Woodson**

Missouri: 10 pm on the 29-10pm on the 31, .25->1 inches, at least \$32,475,000M property damage

**Audrain, Boone, Knox, Lewis, Marion, Moniteau, Monroe, Ralls, Shelby, Bates, Carroll, Cass, Chariton, Clay, Cooper, Henry, Howard, Jackson, Johnson, Lafayette, Macon, Pettis, Platte, Randolph, Ray, Saline, Benton, Morgan, St. Clair, Vernon**

**Summary:** 6pm on the 29-10pm on the 31, .25-2 inches, at least \$372,475,000 property damage

Event 22:

March 1-2, 2002 Texas: 11pm on the 1-6am on the 2, less than .1 inches, no damage report

**Clay, Wichita**

Oklahoma: 8pm on the 1- 6am on the 2, .1 inches, no damage report

**Blaine, Caddo, Canadian, Carter, Cleveland, Comanche, Cotton, Custer, Dewey, Garvin, Grady, Hughes, Jefferson, Kingfisher, Kiowa, Lincoln, Logan, McClain, Murray, Oklahoma, Payne, Pontotoc, Pottawatomie, Roger Mills, Seminole, Stephens, Tillman, Washita'**

**Summary:** 8pm on the 1-6am on the 2, no damage report, around .1 inches

Event 23:

October 23-24, 2002 Kansas: 7am on the 23'12am on the 24, .125-.5 inches, no damage report

**Cloud, Marshall, Republic, Washington, Grant, Haskell, Meade, Morton, Seward, Stafford, Stanton, Stevens**

Event 24:

December 3-4, 2002 Arkansas: 8pm on the 3-7am on the 4, at least \$10.1 M property, no ice thickness given

**Clay, Craighead, Greene, Lawrence, Mississippi, Poinsett, Randolph, Benton, Carroll, Madison, Washington**

Tennessee: 1am on the 4-11am on the 4, at least \$35.0k property, no ice thickness given

**Dyer, Gibson, Henry, Lake, Lauderdale, Obion, Weakley**

Oklahoma: 4pm on the 3-430am on the 4, trace to .5 inches, no damage report

**Craig, Creek, Delaware, Mayes, Nowata, Osage, Pawnee, Rogers, Tulsa, Washington, Caddo, Canadian, Cleveland, Comanche, Grady, Greer, Harmon, Jackson, Kiowa, Lincoln, Logan, McClain, Oklahoma, Payne, Pottawatomie**

Missouri: 10pm on the 3-7am on the 4, at least \$10k property damage, no ice thickness given

**Dunklin, Pemiscot**

**Summary:** 4pm on the 3-11am on the 4, trace to .5 inches, at least \$10,045,000 property damage

Event 25:

January 16, 2003 Kansas: 425pm on the 16- 525 on the 16, no damage report, no ice thickness

**Ottawa, Cloud**

Event 26:

February 25-26, 2003 Arkansas: 230am on the 25-9am on the 26, .25-.67 inches, at least \$100k property damage

**Ashley, Chicot, Arkansas, Bradley, Calhoun, Clark, Cleveland, Conway, Dallas, Desha, Drew, Faulkner, Garland, Grant, Hot Spring, Jackson, Jefferson, Lincoln, Lonoke, Monroe, Montgomery, Ouachita, Perry, Pike, Prairie, Pulaski, Saline, White, Woodruff, Yell**

Mississippi: 240am on the 25-5am on the 26, at least \$145k property damage, .25-.5 inches

**Bolivar, Washington, Sunflower**

**Summary:** 230am on the 25-9am on the 26, .25-.67 inches, at least \$245k property damage

**Event 27:**

January 3-4, 2004 Missouri: 1130pm on the 3-12pm on the 4, no damage report, no ice thickness given

**Marion, Monroe, Ralls**

**Event 28:**

January 25-26, 2004 Tennessee: 8am on the 25- 8pm on the 25, no damage report, .125-.25 inches

**Johnson, Southeast Carter, Unicoi, Washington**

Kansas: 1255am on the 25-1115pm on the 26, no thickness given, at least \$5k in damage

**Wabaunsee, Cloud, Douglas, Geary**

Missouri: 2am on the 25-1pm on the 25, <.25-1 inches, no damage report

**Bollinger, Cape Girardeau, Perry, Wayne, Benton, Camden, Dallas, Dent, Hickory, Laclede, Maries, Miller, Morgan, Phelps, Polk, Pulaski, Shannon, St. Clair, Texas, Webster, Wright**

**Summary:** 1225am on the 25-1115 pm on the 26, .125-1 inches, at least \$5k damage

**Event 29:**

February 4-5, 2004 Arkansas: 7pm on the 4-2am on the 5, no damage report, .25 inches

**Carroll, Madison**

**Event 30:**

December 22-23, 2004 Mississippi: 5pm on the 22 12am on the 23, no ice thickness given, at least \$400k property damage

**Bolivar, Sunflower**

**Event 31:**

January 4-5 2005 Texas: 6am on the 4-6am on the 5, .25-.5 inches, no damage report

**Hansford, Lipscomb, Ochiltree, Dallam, Gray, Hartley, Hemphill, Hutchinson, Moore, Roberts, Sherman, Wheeler**

Oklahoma: 6am on the 4-6am on the 5, .25-.5 inches, no damage report

**Cimarron, Beaver, Texas**

Kansas: 6pm on the 4-6am on the 5, .25-1 inches, no damage report

**Atchison, Johnson, Leavenworth, Linn, Miami, Wyandotte**

Missouri: 6pm on the 4-6pm on the 5, .25-1 inches, at least \$20k property damage

**Jackson, Platte, Buchanan, Clay, Grundy, Clark, Scotland, Cass, Carroll, Livingston, Putnam, Chariton, Mercer, Pettis, Saline, Linn, Macon, Randolph, Knox, Lewis, Shelby**

**Summary:** 6am on the 4-6pm on the 5, .25-1 inches, at least \$20k property damage

**Event 32:**

January 29, 2005 Tennessee: 12am on the 29-8pm on the 29, at least \$5.0k property damage, .25-.5 inches

**Cumberland, Fentress, Grundy, Van Buren, Anderson, Bledsoe, Blount / Smoky Mountains, Bradley, Campbell, Claiborne, Coker / Smoky Mountains, East Polk, Grainger, Hamblen, Hamilton, Hancock, Hawkins, Jefferson, Johnson, Knox, Loudon, Marion, McMinn, Meigs, Morgan, North Sevier, Northwest Blount, Northwest Carter, Northwest Coker, Northwest Greene, Northwest Monroe, Rhea, Roane, Scott, Sequatchie, Sevier / Smoky Mountains, Southeast Carter, Southeast Greene, Southeast Monroe, Sullivan, Unicoi, Union, Washington, West Polk**

**Event 33:**

December 7-8, 2005 Texas: 3am on the 7-4am on the 8, \$70.0k property, .1-.2 inches

**Franklin, Red River, Titus, Brazos, Burleson, Washington**

**Event 34:**

January 20, 2006 Missouri: 4pm on the 20-8pm on the 20, at least \$10k property damage, .25 inches

**Clark, Scotland**

**Event 35:**

February 18, 2006 Tennessee: 5am on the 18-1212pm on the 18, no damage report, .25-.5 inches

**Franklin**

Mississippi: 12pm on the 18-3pm on the 18, .25 inches, at least \$60k property damage

**Bolivar, Sunflower**

**Summary:** 5am on the 18 -3pm on the 18, .25-.5 inches, at least \$60k property damage

**Event 36:**

February 20, 2006 Mississippi: 8am on the 20-2pm on the 20, at least \$1.3M property damage, .25-.6 inches

**Attala, Choctaw, Holmes, Leake, Madison, Oktibbeha, Winston, Yazoo,**

Louisiana: 6am on the 20 10am on the 20, at least \$250.0k property, .25-.5 inches

**Franklin, Madison, Richland**

**Summary:** 6am on the 20-2pm on the 20, .25-.6 inches, at least \$1,250,000 property damage

**Event 37:**

November 29, 2006 Kansas: 6am on the 29- 8pm on the 29, at least \$10k in damage, .25-.5 inches

**Atchison, Leavenworth, Linn, Miami**

Missouri: 6am on the 29- 10pm on the 29, no damage report, .25-.5 inches  
**Adair, Bates, Buchanan, Caldwell, Carroll, Cass, Chariton, Clay, Clinton, Daviess, De Kalb, Grundy, Harrison, Jackson, Johnson, Lafayette, Linn, Livingston, Macon, Mercer, Pettis, Platte, Putnam, Ray, Saline, Schuyler, Sullivan**  
**Summary:** 6am on the 29-10pm on the 29, at least \$10k in damage, .25-.5 inches

Event 38:

December 18-20, 2006 Texas: 12am on the 19-12pm on the 20, no damage report, .25-.75 inches  
**Carson, Dallam, Deaf Smith, Hansford, Hartley, Hutchinson, Moore, Ochiltree, Oldham, Potter, Roberts, Sherman, Bailey, Castro, Hale, Lamb, Lubbock, Parmer, Swisher**  
Oklahoma: 12am on the 19-12pm on the 20 at least \$900k property, .25- $<$ .5 inches,  
**Cimarron, Texas**  
Kansas: 4pm on the 18-morning of the 21, no damage report, no ice thickness given  
**Finney, Grant, Gray, Hamilton, Haskell, Hodgeman, Kearny, Lane, Morton, Ness, Scott, Stanton, Trego**  
**Summary:** 4pm on the 18-morning of the 21, .25-.75 inches, at least \$900k property damage

Event 39:

December 28-31, 2006 Texas: 6pm on the 29-6am on the 31, at least \$68k property, .38 inches  
**Moore, Potter, Randall**  
Oklahoma: 6pm on the 28-6pm on the 30, no damage report, .25 inches  
**Cimarron, Texas**  
Kansas: 12 am on the 30-12am on the 31, at least \$500k in damage, .5 inches  
**Jewell, Phillips, Rooks, Smith**  
**Summary:** 6pm on the 28-6am on the 31, .25-.5 inches, at least \$568k property damage

Event 40:

January 12-15, 2007 Texas: 2am on the 12-6pm on the 15, .1-2 inches, at least \$862000 property  
**Dawson, Glasscock, Scurry, Borden, Mitchell, Howard, Reagan, Midland, Haskell, Throckmorton, Bailey, Briscoe, Castro, Childress, Cochran, Cottle, Crosby, Dickens, Floyd, Garza, Hale, Hall, Hockley, King, Lamb, Lubbock, Lynn, Motley, Parmer, Swisher, Terry, Yoakum, Gaines, Callahan, Fisher, Jones, Nolan, Taylor, Ector, Cooke, Montague, Coke, Coleman, Runnels, Sterling, Concho, Irion, Mcculloch, Tom Green, Grayson, Collin, Denton, Jack, Palo Pinto, Wise, Young, Eastland, Ellis, Hood, Johnson, Somervell, Erath, Hill, Crockett, Menard, Schleicher, Sutton, Lampasas, McLennan, Anderson, Bell, Henderson, Hopkins, Hunt, Kaufman, Navarro, Rains**  
Oklahoma- no start and end time, over 3 inches, no damage report  
**Pittsburg, Muskogee, Atoka, Delaware, Mcintosh, Wagoner, Cherokee, Mayes, Craig**  
Kansas: 3pm on the 12-6pm on the 14, no ice thickness, no damage report  
**Bourbon, Cherokee**  
Missouri: 645am on the 12-4pm on the 15, .25-2.5 inches, at least \$1837M property damage  
**Clark, Scotland, Jasper, Barton, Mcdonald, Newton, Vernon, Barry, Cedar, Dade, Benton, Christian, Dallas, Greene, Lawrence, Polk, St. Clair, Stone, Wright, Laclede, Morgan, Webster, Camden, Maries, Audrain, Boone, Callaway, Cole, Crawford, Franklin, Gasconade, Jefferson, Knox, Lincoln, Marion, Moniteau, Monroe, Montgomery, Osage, Pike, Ralls, Shelby, St. Charles, St. Louis, St. Louis (c), Warren**  
**Summary:** 2am on the 12-6pm on the 15, .1-2.5 inches, at least \$2,874,000 damage

Event 41:

January 15-18, 2007 Texas: 4am on the 15-217pm on the 18, .125-1 inches, at least \$101,000 property  
**Smith, Milam, Robertson, Big Bend Area, Marfa Plateau, Presidio Valley, Terrell, Gaines, Comal, Kerr, Lee, Milam, Robertson, Austin, Brazos, Burleson, Colorado, Grimes, Harris, Houston, Liberty, Madison, Montgomery, Polk, San Jacinto, Walker, Waller, Washington, Wharton, Anderson, Bosque, Comanche, Ellis, Fannin, Hill, Lampasas, Navarro, Palo Pinto, Wise, Young, Bell, Falls**

Event 42:

January 18-21,2007 Texas: 218pm on the 18-12am on the 21, .25-1 inches, at least \$280,000 property  
**Big Bend Area, Guadalupe Mountains Of Culbers, Scurry, Dawson, Bailey, Briscoe, Castro, Childress, Cochran, Cottle, Crosby, Dickens, Floyd, Garza, Hale, Hall, Hockley, Kent, King, Lamb, Lubbock, Lynn, Motley, Parmer, Swisher, Terry, Yoakum, Hudspeth**  
Arkansas: 854 pm on the 20-12am on the 21,  $>$ .25 inches, no damage report  
**Boone**  
Kansas: 7pm on the 20-11pm on the 20, no damage report, .25-1 inches  
**Bourbon, Cherokee, Crawford**  
**Summary:** 218pm on the 18-12am on the 21, .25-1inches, at least \$280,000 property damage

Event 43:

February 24, 2007 Missouri: 6am on the 24-6pm on the 24, no damage report, 1- near 2 inches  
**Clark**

Event 44:

December 1, 2007 Kansas: 1 am on the 1-6am on the 1, .25-.5 inches, no damage report  
**Brown, Clay, Marshall, Nemaha, Republic, Washington, Cloud**  
Missouri: 435am on the 1-215pm on the 1, .25-.75 inches, no damage report



**Adair, Atchison, Daviess, Gentry, Grundy, Harrison, Livingston, Mercer, Nodaway, Putnam, Schuyler, Sullivan, Worth, Scotland, Clark**

**Summary:** 1am on the 1-215pm on the 1, .25-.75 inches, no damage report

Event 45:

December 8-12, 2007 Arkansas: 4am on the 9-3pm on the 10, no damage report, .25 inches

**Benton**

Texas: 11am on the 9-6pm on the 10, no ice thickness report, at least \$25,000 property

**Wilbarger, Wichita**

Oklahoma: 10pm on the 8-6am on the 11, 1-2 inches, at least \$310M property

**Craig, Creek, Mayes, Nowata, Osage, Ottawa, Pawnee, Rogers, Tulsa, Washington, Blaine, Canadian, Kay, Logan, Major, Payne, Delaware, Wagoner, Muskogee, Okfuskee, Comanche, Noble, Cherokee, McIntosh, Woodward, Custer, Beckham, Cotton, Garvin, Seminole, Stephens, Dewey, Jackson, Kingfisher, Kiowa, Washita, Caddo, Tillman, Pontotoc**

Kansas: 1am on the 9-10pm on the 11, .25-2 inches, at least \$133,450,000 property damage

**Bourbon, Cherokee, Crawford, Neosho, Wilson, Montgomery, Woodson, Allen, Labette, Atchison, Doniphan, Linn, Coffey, Lyon, Gray, Hodgeman, Meade, Decatur, Gove, Sheridan, Clark, Edwards, Lane, Stafford, Trego, Dickinson, Geary, Morris, Osage, Ottawa, Kiowa, Morton, Pawnee, Rush, Logan, Norton, Rawlins, Thomas, Wichita, Clay, Cloud, Pottawatomie, Riley, Wabaunsee, Jackson, Jefferson, Marshall, Nemaha, Republic, Washington, Brown, Mcpherson, Lincoln, Russell, Ellsworth, Barton, Kingman, Rice, Marion, Chase, Saline, Reno, Harvey, Butler, Sedgwick, Cowley, Greenwood**

Missouri: 11pm on the 8- 12pm on the 12, .25-1.5 inches, at least \$8,145,000 property damage

**Audrain, Boone, Callaway, Cole, Gasconade, Knox, Lincoln, Marion, Moniteau, Monroe, Montgomery, Osage, Pike, Ralls, Shelby, Bates, Chariton, Cooper, Howard, Johnson, Pettis, Saline, Jasper, Macon, Barton, Benton, Camden, Cedar, Dade, Dallas, Hickory, Lawrence, Maries, Miller, Morgan, Polk, St. Clair, Vernon, Mcdonald, Adair, Andrew, Atchison, Buchanan, Caldwell, Carroll, Clay, Clinton, Daviess, De Kalb, Gentry, Grundy, Harrison, Holt, Jackson, Linn, Livingston, Nodaway, Platte, Ray, Sullivan, Worth, Mercer, Putnam, Schuyler, Lawrence, Newton, Greene, Laclede, Pulaski, Dent, Texas, Clark, Scotland**

**Summary:** 10pm on the 8-7am on the 12, .25-2 inches, at least \$451,620,000 property damage

Event 46:

January 25,2008 Arkansas: 8am on the 25-10pm on the 25, at least \$200k property, .25 inches

**Ashley, Chicot**

Louisiana: 8am on the 25-10pm on the 25, at least \$300k property damage, .25 inches

**East Carroll, Morehouse, West Carroll**

Mississippi: 9am on the 25-10pm on the 25, at least \$300k property damage, .25 inches

**Bolivar, Carroll, Holmes, Humphreys, Issaquena, Leflore, Washington**

**Summary:** 8am on the 25 10pm on the 25, at least \$800,000 property damage, .25 inches

Event 47:

February 10-12, 2008 Oklahoma: 230am on the 11-8pm on the 11, no damage report, .25-.5 inches

**Craig, Nowata, Ottawa, Washington**

Kansas: 304pm on the 10-3pm on the 11, .25-1 inches, no damage report

**Cherokee, Crawford, Chautauqua, Elk, Neosho, Wilson**

Missouri:3am on the 11-2am on the 12, .25-.75 inches, no damage report

**Barry, Newton, Dade, Lawrence, Cedar, Dallas, Jasper, Polk, Stone, Webster, Camden, Christian, Greene, Hickory, Pulaski, Texas, Wright, Dent, Laclede, Vernon, Phelps, Shannon, Maries, Miller**

**Summary:** 304pm on the 10-2am on the 12, .25-1 inches, no damage report

Event 48:

February 15-16, 2008 Texas:10pm on the 15-8am on the 16, no damage report, .25 inches

**Hale**

Event 49:

February 21-22, 2008 Kansas: 5am on the 21-1pm on the 21, .25-1 inches, no damage report

**Bourbon, Crawford, Cherokee**

Missouri: 2am on the 21- 3am on the 22, .25-1 inches, no damage report

**Benton, Camden, Wright, Hickory, Morgan, Vernon, Howell, Jasper, Laclede, Lawrence, Maries, Newton, Ozark, Webster, Bollinger, Carter, Perry, Wayne, Barton, Douglas, Greene, Polk, Pulaski, St. Clair, Stone, Taney, Dent, Shannon, Barry, Cedar, Christian, Dallas, Oregon, Phelps**

**Summary:** 2am on the 21-3am on the 22, .25-1 inches, no damage report

Event 50:

December 15-16, 2008 Tennessee: 4pm on the 15-9am on the 16, no damage report, .25-.5 inches

**Benton, Robertson, Stewart**

Event 51:

December 18-19, 2008 Missouri: 3pm on the 18-9am on the 19, .25-1 inches, no damage report

**Clark, Scotland, Adair, Andrew, Atchison, Clinton, Daviess, De Kalb, Gentry, Grundy, Harrison, Holt, Mercer, Nodaway, Putnam, Schuyler, Sullivan, Worth**

Event 52:

December 27, 2008 Kansas: 345am on the 27-730am on the 27, no damage report, .25-.5inches  
**Osage, Jackson, Jefferson**

Event 53:

January 5-6, 2009 Arkansas: 2pm on the 5-9am on the 6, no damage report, .10-.5 inches

**Crittenden, Cross, Lee, Phillips, Poinsett, St. Francis**

Tennessee: 2pm on the 5-9am on the 6, no damage report, .10-.25 inches

**Dyer, Obion, Shelby, Tipton**

**Summary:** 2pm on the 5-9am on the 6, no damage report, .1-.5 inches

Event 54:

January 26-28, 2009: Arkansas: 1pm on the 26-5am on the 28, .25-2 inches, at least \$135,425,000 property damage

**Baxter, Boone, Garland, Marion, Benton, Crawford, Franklin, Madison, Sebastian, Washington, Fulton, Independence, Izard, Jackson, Newton, Pope, Searcy, Stone, Johnson, Perry, Saline, Van Buren, Conway, Faulkner, Logan, Montgomery, Polk, Pulaski, Scott, White, Woodruff, Yell, Craighead, Cross, Greene, Lawrence, Mississippi, Poinsett, Randolph**

Tennessee: 8pm on the 26-6am on the 28, .25-2.25 inches, no damage report

**Carroll, Crockett, Dyer, Gibson, Henry, Lake, Lauderdale, Obion, Tipton, Weakley, Benton, Montgomery, Robertson, Stewart, Sumner**

Texas: 4am on the 27-5am on the 28, .1-.75 inches, at least \$560,000 property damage

**Eastland, Erath, Freestone, Hood, Jack, Lampasas, Montague, Palo Pinto, Stephens, Wise, Young, Cooke, Fannin, Grayson, Collin, Parker, Ellis, Johnson, Navarro, Tarrant, Denton, Brown, Coke, Coleman, Concho, Crockett, Irion, Mcculloch, Menard, Runnels, San Saba, Sterling, Tom Green, Hopkins, Hunt, Lamar, McLennan**

Oklahoma: 11am on the 26-2am on the 28, 1-1.5 inches, no damage report

**Pittsburg, Adair, Cherokee, Creek, Delaware, Haskell, Mayes, Mcintosh, Muskogee, Okfuskee, Osage, Pawnee, Rogers, Sequoyah, Tulsa, Wagoner, Choctaw, Pushmataha**

Missouri: 2pm on the 26-6am on the 28, .25-2 inches, at least \$40k property damage

**Barton, Christian, Dade, Dallas, Greene, Jasper, Laclede, Lawrence, Mcdonald, Newton, Polk, Texas, Vernon, Webster, Wright, Benton, Camden, Cedar, Douglas, Hickory, St. Clair, Dent, Howell, Maries, Ozark, Phelps, Dunklin, Pemiscot**

**Summary:** 11am on the 26-6am on the 28, .1-2.25 inches, at least \$136,025,000 property damage

Event 55:

March 12-13, 2009 Tennessee: 643pm on the 12-250am on the 13, .3- 1inches, at least \$76,000 property damage

**Fentress, Dickson, Pickett, Putnam**

Event 56:

December 23-24, 2009 Kansas: 1am on the 23-10am on the 24, at least \$20k property damage, up to .25 inches

**Barton, Russell**