SIMPLE PLANNING TOOL
FOR OKLAHOMA CLIMATE HAZARDS

VERSION 1.5 (JANUARY 2019)


Back Cover Photo: Riley, R., 2008: Cloud-to-ground lightning during a thunderstorm in northwest Oklahoma.

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About the Simple Planning Tool

This tool is a compilation of relatively easy-to-use online interactive tools, maps, and graphs to assist planners and emergency managers in the state of Oklahoma who are assessing their long-term climate risks, both historically and in the future. It is primarily designed for decision-makers who serve small- to medium-sized communities, but may also be of interest to those who serve larger areas. This tool was developed with input from local and state emergency managers and planners. While it may not answer every question one has about hazard climatologies and future trends, it aims to cut through the internet clutter and point to relatively simple data tools that can be used during planning processes and in plans. The Simple Planning Tool for Oklahoma Climate Hazards was produced by the Southern Climate Impacts Planning Program (SCIPP, www.southernclimate.org).

The tool may be accessed online at http://www.southernclimate.org/documents/SPTOK.pdf
For tool assistance or questions, please contact scipp@southernclimate.org

About SCIPP

The Southern Climate Impacts Planning Program (SCIPP) is one of 11 National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Sciences and Assessments (RISA) teams. SCIPP is a climate hazards and research program for the south central United States and focuses on increasing the region’s resiliency and level of preparedness for weather extremes now and in the future. The area SCIPP serves includes the 6-state region of Oklahoma, Texas, Arkansas, Louisiana, Tennessee, and Mississippi.

About the Authors

Leah Kos: Leah is the Climate Assessment Specialist for SCIPP. Her work focuses on the assessment of stakeholder risk and vulnerability to extreme weather and climate events, and how the use of climate hazard data can better meet the needs of users in decision-making and adaptation efforts.

Rachel Riley: Rachel is SCIPP’s Associate Program Manager. She engages with decision-makers and conducts research using social science methods with the goal of understanding the contexts in which climate information is relevant to them and to determine realistic pathways for reducing disaster risk.
User Instructions

This document is alphabetically organized by climate hazard (p. 5-17) and three other hazards (p. 18-20). A table is included for each hazard and describes the data limitations, historical climatology tools, and projected future trends. See the example table below and corresponding descriptions to the left for more details on how each table is organized.

Table Components

1. This section describes known data limitations for the hazard. Knowing limitations can help one interpret data results more accurately.

2. The historical climatology rows show several tools that provide freely-available historical data relevant to each hazard.

3. For each individual tool, this column provides its name, period of record of the data used (some tools use multiple periods), and the source.

4. This column provides the information that can be obtained from the tool and instructions on how it can be found.

5. This row provides the website link to access the tool. (Note: In the event of a URL change, search the web using the accompanying information.)

6. This column shows an image of the tool’s final product (i.e. map, graph, table).

7. A concise summary of the state-of-the-science on whether the hazard is projected to be influenced by climate change, and if so, how.

Table: Drought

**U.S. Drought Risk Atlas**
(period by state)
National Drought Mitigation Center

This interactive tool provides historical drought indices at a local level and can identify drought periods at different levels of severity, duration, and frequency.

1. On the left side column (moving from top to bottom) choose Oklahoma -> Climate division of interest -> Annual -> Precipitation. 2. When the cursor is hovered over a point, the year and annual index will be displayed.

**Tool Link:** [http://droughtatlas.unl.edu/Data.aspx](http://droughtatlas.unl.edu/Data.aspx)

**Historical Climate Trends Tool**
(1895-present)
Southern Climate Impacts Planning Program

This interactive graphing tool shows precipitation trends, of which very dry periods are a drought indicator. It can also help estimate the probability of future precipitation and hence drought events.

1. On the left side column (moving from top to bottom) choose [Oklahoma](http://droughtatlas.unl.edu/Data.aspx) -> Climate division of interest -> Annual -> Precipitation. 2. When the cursor is hovered over a point, the year and annual index will be displayed.

**Tool Link:** [http://charts.src.iso.edu/trends/](http://charts.src.iso.edu/trends/)

**U.S. Drought Monitor Statistics Graph**
(2000-present)
National Drought Mitigation Center

This interactive graphing tool shows the frequency of drought conditions in Oklahoma along with each drought’s maximum intensity and duration (shown by color).

1. In the top banner, next to [Area](http://charts.src.iso.edu/trends/), choose Climate Division or County. 2. Next to Area, either type in OK to select climate division or enter your type of interest. 3. Next to [Index](http://charts.src.iso.edu/trends/), select [USDM]. 4. Zoom in by hovering inside graph area and then click on the time-period.

**Tool Link:** [http://droughtmonitor.unl.edu/Data/Timeseries.aspx](http://droughtmonitor.unl.edu/Data/Timeseries.aspx)

**Water Reservoir Visualization Tool**
(2004-present)
Southern Regional Climate Center & the Southern Climate Impacts Planning Program

This interactive tool displays recent and historical reservoir elevations, the relationship between current conditions and mood pool levels, and precipitation data from nearby stations all on one page. If connected to drought cycles and/or precipitation trends, this tool can be used to show the impacts of drought on water supplies which can affect drinking and irrigation water supplies.

1. In upper left, under State, select Oklahoma. 2. Select a reservoir from the map or drop-down list. 3. Scroll down and use select information provided.

**Tool Link:** [http://reservoir.src.iso.edu/](http://reservoir.src.iso.edu/)

**Future Trend**

Drought has always been part of Oklahoma’s climate because of highly variable precipitation patterns. However, droughts are projected to increase in severity and frequency due to climate change. Even if annual precipitation amounts do not change much, higher temperatures will increase evaporation from lakes, soils, and plants, stressing agricultural and natural systems. Models project that Oklahoma will experience a decrease in soil moisture across all seasons by the end of the century, with the greatest decreases occurring in summer (Wehner et al. 2017). Further, rising temperatures will lead to increased demand for water and energy, which could stress natural resources (Shafer et al. 2015).
A Note About Climate Data Availability.

Data availability differs among weather variables. Some variables are easier and less costly to observe than others. For example, temperature and liquid precipitation have longer and more complete periods of record than tornadoes and freezing rain. In addition, it is not scientifically appropriate to analyze long-term trends for some hazards due to reporting differences over time. For example, the long-term trends of tornadoes, severe wind, and hail reports are biased due to population increases and advances in the ability to detect and communicate information. Refer to the data limitations portion of each hazard section for more details.

In an ideal world, every city, county, or tribe in Oklahoma would have detailed, long-term climate records. However, even though modern science and technology have greatly advanced data collection, there are limitations which are noted above. Data products such as tables, graphs, and maps are commonly produced from single point observations, analyses that interpolate between data points (for those locations that do not have individual records), or by averaging (such as across climate divisions). Users should be aware that this document references tools that show observational points, some that show interpolation analyses, and some that show averages.

Although individual stations are often favored as they provide local data, it might not be the best choice to use a single station’s data for long-term risk analysis if it is of poor quality (i.e. has data gaps or has not been calibrated) or has a short period of record. For example, some stations have long-term temperature records that begin in 1895. Other stations, such as those run by the Oklahoma Mesonet for example, have only existed since 1994 but have a relatively high spatial density. Depending on user needs, it may be more appropriate to look at data from a station that is relatively close to the desired location (i.e. not in the exact city or county) if it has a longer period of record. In other words, if a user is looking to assess a location’s long-term risk, a nearby station with 60 or 100 years’ worth of data may be more valuable than a local station that only contains 15 years of data or has long periods of missing data. Furthermore, if a nearby station does not have a long-term record, it may be more valuable to focus on the tools with interpolated analyses or averages. These tools are acknowledged by atmospheric science professionals, including climatologists, to represent accurate and relevant data when locations are under-represented.

Using point data may also miss important events that pose a risk to the city. For example, if a strong tornado passed close to a city, using only historical tracks from within city limits would not include the event and therefore under-estimate risk. It is wise to consider nearby areas along with the particular location of interest when assessing hazard risk.

For more information on data limitations or questions regarding suspect data, contact the Oklahoma State Climatologist, Gary McManus, at ocs@ou.edu or 405-325-2541.
A Note About Climate Change.

The future trend portion accompanying each hazard section in this document provides concise summaries of the most up-to-date scientific knowledge regarding how climate change currently is or is expected to impact each hazard. The science is clear that the global climate is changing at a rate at which we have not experienced before in modern times, and increasing evidence shows that humans are a primary influence behind this rate of change. However, the changes we are experiencing and can expect to experience in Oklahoma are nuanced. In many cases, only descriptive information about likely changes can be given, as climate models are currently not capable of providing skillful magnitudes of the changes. For example, models may be able to examine changes in environmental conditions favorable to storms but lack the resolution to determine likely storm severity. For information that is more in-depth than that which accompanies each hazard section in this tool, please visit the resources listed in Appendix C.

A Note About Impact Data.

Understanding the detailed impacts of weather and climate on cities, counties, and tribes is an important and necessary step to be able to reduce risks and costs. Impacts of events are dependent upon characteristics of the location such as low-lying areas susceptible to flooding, soil types, housing construction, and resources available to respond and rebuild. Given disparate data sources, however, gathering comprehensive impact data and including it in the Simple Planning Tool was beyond the scope of this project and the expertise of the authors. If future resources support further research, additional versions of the Simple Planning Tool for Oklahoma Hazards may include impact data.
# Cold Extremes

**Data Limitations:** Oklahoma generally has good quality long-term data records for cold temperature values, however the consistency of cumulative years on record vary by station. The majority of stations consist of a large record dating back up to the 19th century, however some station locations include gaps in records that could be subject to technical issues or changes in monitoring location.

<table>
<thead>
<tr>
<th>Historical Climatology</th>
<th>Cold Extremes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freeze Dates</strong>&lt;br&gt;(1981-2010)&lt;br&gt;Oklahoma Climatological Survey</td>
<td>These static maps show the average dates of first freeze, average date of last freeze, earliest fall freeze, and latest spring freeze. Maps can be used to understand the times of the year in which you might experience temperatures below freezing for your area.&lt;br&gt;&lt;br&gt;1. Scroll to middle of page to view the maps. 2. Click on map of interest from the following: <em>average dates of first freeze, average date of last freeze, earliest fall freeze, or latest spring freeze.</em>&lt;br&gt;&lt;br&gt;Tool Link: <a href="http://climate.ok.gov/index.php/climate">http://climate.ok.gov/index.php/climate</a></td>
</tr>
<tr>
<td><strong>Highs and Lows Below 32°F</strong>&lt;br&gt;(1981-2010)&lt;br&gt;Oklahoma Climatological Survey</td>
<td>These static maps show the average number of days each year that the high temperature is less than 32°F and the average number of days each year that the low temperature is below 32°F. Maps can be used to understand the total number of days per year in which in which your area might experience high or low temperatures below freezing.&lt;br&gt;&lt;br&gt;1. Scroll to the middle of the page. 2. Click on map of interest from the following: <em>average number of days each year that the high temperature is less than 32°F</em> and <em>average number of days each year that the low temperature is below 32°F.</em>&lt;br&gt;&lt;br&gt;Tool Link: <a href="http://climate.ok.gov/index.php/climate">http://climate.ok.gov/index.php/climate</a></td>
</tr>
<tr>
<td><strong>Wind Chill Days and Hours</strong>&lt;br&gt;(1973-2017)&lt;br&gt;Midwest Regional Climate Center</td>
<td>This set of maps depict the average number of days, day with 3 or more hours, and average number of hours per year with wind chill values at or below a variety of thresholds (e.g., 15°F, 0°F, -10°F).&lt;br&gt;&lt;br&gt;1. Near the top of the page, click on the map link of interest out of the three options: <em>Average Number of Days</em>, <em>Days with 3 or More Hours</em>, or <em>Average Number of Hours</em>. 2. Right above the map, mouse over the wind chill temperature value of interest to view the corresponding data on the map. 3. To interpret the colors, see the legend on the right side of the map.&lt;br&gt;&lt;br&gt;Tool Link: <a href="https://mrcc.illinois.edu/clim/windChill/index.jsp">https://mrcc.illinois.edu/clim/windChill/index.jsp</a></td>
</tr>
<tr>
<td><strong>Average Annual Heating Degree Days</strong>&lt;br&gt;(1981-2010)&lt;br&gt;Oklahoma Climatological Survey</td>
<td>This static map shows the average annual heating degree days (HDD), a measurement used to quantify the demand for energy needed to heat buildings.&lt;br&gt;&lt;br&gt;1. Scroll to the middle of the page. 2. Click on <em>average annual heating degree days (HDD)</em> link.&lt;br&gt;&lt;br&gt;Tool Link: <a href="http://climate.ok.gov/index.php/climate">http://climate.ok.gov/index.php/climate</a></td>
</tr>
</tbody>
</table>

**Future Trend**<br>

Oklahoma has consistently observed a below average number of very cold winter nights since 1990. Historically unprecedented winter warming is projected by the end of the 21st century under a higher emissions scenario (Frankson et al. 2017). Extreme cold events will continue to impact Oklahoma; however, they will occur less frequently and with less intensity (Vose et al. 2017). Warmer winters signify that temperatures will remain warm for a longer amount of time, shortening the cold season which will subsequently lead to a longer frost-free period and growing season. By mid-century, models are projecting that Oklahoma will see 10 to 30 fewer days below 32°F, with the greater reduction being across the northern two-thirds of the state. Also, by mid-century, the coldest day of the year is projected to be 5°F warmer and the most intense cold wave is projected to be 10°F warmer (Vose et al. 2017).
# Drought

**Data Limitations:** Drought cannot be assessed by a single indicator. Unlike many other hazards where impacts are immediate and apparent, drought has a slow onset, sometimes go undetected, and affects different sectors on different timescales. Consequently, it is important to assess drought using a variety of indicators, some which respond better to short-term conditions, such as for agriculture, and others that respond to longer-term conditions, such as water resources. Many indicators are combined into the weekly U.S. Drought Monitor, however these only dates back to 2000.

<table>
<thead>
<tr>
<th>Historical Climatology</th>
<th></th>
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</table>
| **U.S. Drought Risk Atlas** | This interactive tool provides historical drought indices at a local level and can identify drought periods at different levels of severity, duration and frequency.  
1. On the left side, select Oklahoma to search by state or zoom in on the map, then search by location.  
2. Select a location from the Station List on the right → then click Update Station.  
3. Below, there are a variety of drought indicator tabs to explore. For example, the Heatmap option under the Drought Monitor tab shows monthly (or weekly) values of indicators. Oranges (reds) show periods of severe (extreme) drought.  
Tool Link: [http://droughtatlas.unl.edu/Data.aspx](http://droughtatlas.unl.edu/Data.aspx) |
| **Historical Climate Trends Tool** | This interactive graphing tool shows precipitation trends, of which very dry periods are a drought indicator. It can also be used to help estimate the probability of future precipitation and hence drought events.  
1. On the left side column (moving from top to bottom) choose Oklahoma → Climate Division of Interest → Season of Interest → Precipitation.  
2. Hovering the cursor over a point will display the year and total rainfall for the selected season.  
3. For more information on how to interpret the chart, click on Chart Info.  
Tool Link: [http://charts.srcc.lsu.edu/trends/](http://charts.srcc.lsu.edu/trends/) |
| **U.S. Drought Monitor Statistics Graph** | This interactive graphing tool shows the frequency of drought conditions since 2000, along with each drought’s maximum intensity and duration (shown by color scale). The U.S. Drought Monitor is the official source for aid decisions by the USDA and several other agencies and programs.  
1. In top banner, next to Area Type choose either Climate Division or County.  
2. Next to Area, either type in OK to select climate division of interest or type in county of interest.  
3. Next to Index, select USDM.  
4. Zoom in by clicking inside graph and dragging over a specific time-period.  
Tool Link: [http://droughtmonitor.unl.edu/Data/Timeseries.aspx](http://droughtmonitor.unl.edu/Data/Timeseries.aspx) |
| **Water Reservoir Visualization Tool** | This interactive tool displays recent and historical reservoir elevations, the relationship between current conservation and flood pool levels, and precipitation data from nearby stations all on one page. If correlated to drought cycles and/or precipitation trends, this tool can be used to show the impacts of drought on water supplies which can affect drinking and irrigation water supplies.  
1. In upper left, under State, select Oklahoma.  
2. Select a reservoir from the map or drop-down list.  
3. Scroll down and use select information provided.  
Tool Link: [http://reservoir.srcc.lsu.edu/](http://reservoir.srcc.lsu.edu/) |

## Future Trend

Drought has always been part of Oklahoma’s climate because of highly variable precipitation patterns. However, droughts are projected to increase in severity and frequency due to climate change. Even if annual precipitation amounts do not change much, higher temperatures will increase evaporation from lakes, soils, and plants, stressing agricultural and natural systems. Models project that Oklahoma will experience a decrease in soil moisture across all seasons by the end of the century, with the greatest decrease in the summer (Wehner et al. 2017). Further, rising temperatures will lead to increased demand for water and energy, which could stress natural resources (Shafer et al. 2014).
**Hail**

**Data Limitations:** Hail data are not of sufficient quality to robustly determine historical trends and is of poorer quality than even the tornado dataset. This can be attributed to the increases in non-meteorological factors such as population and storm spotter coverage over time, as well as the uncertainty in reported hail size. However, the recent acknowledgement to assess the number of hail days instead of individual hail reports has mitigated some of the biases.

<table>
<thead>
<tr>
<th>Historical Climatology</th>
<th></th>
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</thead>
</table>
| **Severe Hail Days Per Year** | (1986-2015) | This map shows the average number of days per year in which severe hail reports were received in your area during the period noted. The map gives you a sense of the approximate number of days each year that you can expect to see severe hail (1-inch or greater in diameter) in your area. The 2-inch or greater map is also available for viewing.  
1. Click on the link below to go to the website 2. Select 1.00-Inch Hail Days or 2.00-Inch Hail Days.  
| **Severe Hail Reports** | (1950-2014) | This interactive tool shows you the historical record for individual severe hail reports in your area. It can be used to determine hail events that have impacted your area or close to your area.  
1. On left side of screen, click on Search by Location. 2. Choose the diameter of the area of which you want to investigate (25 or 50 miles). 3. Select Hail (de-select Torn and Wind). 4. Pan, zoom, and then click on the map area of interest. 5. Reports are displayed on the map and in two tables below the map.  
Map: Mouse over individual storm reports for details.  
Tables: There are two tables, Real Time Reports, which does not include hail size, and Detailed Hazard Reports, which does. Click on column header to sort by column of interest. For example, to view the dates in which the largest hail occurred, click on the Scale column header to sort by the largest hail values.  
| Tool Link: [https://www.srcc.lsu.edu/storm_reports](https://www.srcc.lsu.edu/storm_reports) |
| **Storm Events Database** | (1950-2018) | This interactive tool shows you the historical record for individual severe hail reports by county. It can be used to determine hail events that have impacted your area or close to your area.  
1. On the bottom left, under Select State or Area, choose Oklahoma → then Search 2. From top to bottom, select a specific Begin and End Date, as well as County of interest. 3. Under Event Type(s), select Hail. 4. Under Advanced Search and Filter Options → Hail Event Type Filter, select hail size of interest. 5. Press Search. Summary results are presented in a table. **Note:** This tool can be used to analyze a variety of additional hazards.  
| Tool Link: [https://www.ncdc.noaa.gov/stormevents/](https://www.ncdc.noaa.gov/stormevents/) |

**Future Trend**  
Hail is commonly associated with severe thunderstorms. Climate models project an increase in the frequency and intensity of severe thunderstorms, and events with large hail are projected to increase (Kossin et al. 2017). At the same time, models project an overall decrease in the number of days with hail per year (Brimelow et al. 2017). Confidence in the projections is currently low, however, due to the isolated and sporadic nature of hail events and limited comprehensive datasets which make it difficult to track long-term trends (Wuebbles et al. 2017a).
## Heat Extremes

**Data Limitations:** Oklahoma generally has good quality long-term data records for temperature values, however the consistency of cumulative years on record vary by station. The majority of stations consist of a large record dating back up to the 19th century, however some station locations include gaps in records that could be subject to technical issues or changes in monitoring location.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
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</thead>
</table>
| **Historical Climate Trends Tool**<br>(1895-present)<br>Southern Climate Impacts Planning Program | This interactive graphing tool shows annual, seasonal and monthly temperature trends by state and climate division. It can be used to gain a general understanding of temperature trends and show previous periods of higher temperatures, as well as years of extreme temperature. It could also be used to help estimate the probability of future extreme temperature events.  
1. On left side of screen (from top to bottom) select **Oklahoma** → **Climate Division of Interest** → **Season of Interest** → **Temperature**.  
2. For more information on how to interpret the chart, click on Chart Info.  
Tool Link: [http://charts.srcc.lsu.edu/trends/](http://charts.srcc.lsu.edu/trends/) |
| **Climate Extremes Portal -Temperature**<br>(period of record varies by station)<br>Southern Regional Climate Center | This interactive tool shows temperature extremes at point locations. It can be used to show the severity of past events that have occurred in a region of interest. Highlighted below are two ways the tool can be used to analyze heat extremes:  
1. **High temperature records by month:** On left side of screen (from top to bottom) select **Records In A Month** → **High Max Temperature** → **Month of Interest** → **Go**.  
2. Mouse over icons for record details including station name, date of occurrence and station period of record.  
7. **All-time records:**  
    1. Select **All-Time Records** → **High Max Temperature** → **Go**.  
    2. Mouse over icons for record details including station name, date of occurrence and station period of record.  
Tool Link: [http://extremes2.srcc.lsu.edu/](http://extremes2.srcc.lsu.edu/) |
| **Observed Number of Extremely Warm Nights**<br>(1900-2014)<br>Cooperative Institute for Climate and Satellites – North Carolina & NOAA National Centers for Environmental Information | This is a static map inside of a scientific document displaying the number of observed extremely warm nights in Oklahoma from the period 1900 to 2010. Extremely warm nights are defined as days with a minimum temperature above 80°F, and this map averages these nights over 5-year periods. The values in this map are taken from averages of 9 long-term reporting stations throughout the state.  
1. Scroll down until you reach Figure 3B. Shows the observed number of extremely warm nights (above 80°F) per 5-year period.  
Figure 3B located at [https://statesummaries.ncics.org/ok](https://statesummaries.ncics.org/ok) |
## Heat Extremes (Continued)

| Historical Climatology | Heat Index Days and Hours (1973-2017) Midwest Regional Climate Center | This set of maps depict the average number of days, day with 3 or more hours, and average number of hours per year with heat index values at or above a variety of thresholds (e.g., 95°F, 110°F, 105°F).

1. Near the top of the page, click on the map link of interest out of the three options: Average Number of Days, Days with 3 or More Hours, or Average Number of Hours.
2. Right above the map, mouse over the heat index value of interest to view the corresponding data on the map.
3. To interpret the colors, see the legend on the right side of the map.

Took Link: [https://mrcc.illinois.edu/clim/heatIndex/index.jsp](https://mrcc.illinois.edu/clim/heatIndex/index.jsp) |
| --- | --- | --- |
| **Average Number of Days with Highs Above 90°F (1981-2010)** Oklahoma Climatological Survey |(205,722),(262,782)(262,714),(318,774)(318,706),(375,766)(375,698),(432,758) | This static map shows the average number of days per year (between 1981-2010) when the high temperature is 90°F or hotter.

1. Scroll to the second row of maps on the page.
2. Click on Average number of days with highs above 90°F.

| **Average Number of Days with Highs Above 100°F (1981-2010)** Oklahoma Climatological Survey | This static map shows the average number of days per year (between 1981-2010) when the high temperature is 100°F or hotter.

1. Scroll to the second row of maps on the page.
2. Click on Average number of days with highs above 100°F.

| **Average Annual Cooling Degree Days (1981-2010)** Oklahoma Climatological Survey | This static map shows the average annual cooling degree days (between 1981-2010) for a 30-year period.

1. Scroll to the second row of maps on the page.
2. Click on Average annual cooling degree days (CDD).

| Future Trend | The frequency and intensity of heatwaves and extreme heat events have increased across the United States since the mid-1960’s (Wuebbles et al. 2017b). Warming in Oklahoma has occurred mostly during the winter and spring seasons. As the global temperature continues to increase, the occurrence and intensity of extreme heat events are projected to increase (Wuebbles et al. 2017b). The historical top 2% of hot days per year (about 7 days per year) range between 95°F and 100°F across the state. By mid-century, there is a projected 20 to 27 day increase of days per year that exceed those temperatures. Additionally, the historical top 2% of warmest nights (about 7 days per year) for Oklahoma fall between 70°F to 75°F and by mid-century it is expected that an additional 35 nights per year will exceed those thresholds (Shafer et al. 2014). |
## Heavy Rainfall and Flooding

**Data Limitations:** There is a relatively long historical record of precipitation data. However, a lack of spatial density of stations combined with highly variable precipitation across the state means that some rainfall events, including high rainfall amounts, may not be adequately represented in the data. Also, flood risk depends on a precipitation event, preceding events, the built environment and flood mitigation techniques. Flooding can and does occur outside of the Federal Emergency Management Agency (FEMA) Special Flood Hazard Areas. Flood impacts are extremely localized, so the data listed below may not adequately represent a single community or neighborhood flood risk or history.

<table>
<thead>
<tr>
<th>Historical Climatology</th>
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<tbody>
<tr>
<td><strong>Climate Extremes Portal - Precipitation</strong></td>
</tr>
<tr>
<td>(period of record varies by station)</td>
</tr>
<tr>
<td>Southern Regional Climate Center</td>
</tr>
<tr>
<td>Interactive map shows precipitation extremes at airport weather stations, which can be used to show some previous heavy rainfall occurrences (i.e. the highest rainfall totals do not necessarily occur at airport weather stations). 1. Pan and zoom to location of interest. 2. To obtain <em>High precipitation records by month</em>: On left side of screen select <em>Records In A Month → High Precipitation → Month of interest → Go</em>. 3. Measurement unit is inches. Mouse over icon for record details (date of occurrence and station record). 4. To obtain <em>All-time records</em>: Select <em>All-Time Records → High Precipitation → Go</em>.</td>
</tr>
<tr>
<td>Tool Link: <a href="http://extremes2.srcc.lsu.edu/">http://extremes2.srcc.lsu.edu/</a></td>
</tr>
</tbody>
</table>

| **NOAA Atlas 14 Precipitation Frequency Data Server**  |
| (Last updated in 2013)  |
| NOAA Hydrometeorological Design Studies Center  |
| Interactive tool shows rainfall frequency estimates for select durations (e.g. 3-, 12- and 24 hours) and recurrence intervals (e.g. 100-, 500-, and 1000-years) with 90% confidence intervals. Probable maximum precipitation (PMP) values are not represented in this tool. Such values will be available through an additional tool in the near future. 1. Click on *Oklahoma* from the map. A new screen will open. 2. To select a location, either enter the desired location, station or address manually OR select a station from the interactive map. 3. Precipitation frequency estimates will be displayed in both table and graph forms below. 4. For additional help, select *FAQ* from the left-hand menu, then refer to the Section 5 link under section 1.1. |
| Tool Link: [https://hdsc.nws.noaa.gov/hdsc/pfds/index.html](https://hdsc.nws.noaa.gov/hdsc/pfds/index.html) |

| **Multi-Day Extreme Precipitation on xmACIS2**  |
| (period of record varies by station)  |
| NOAA Regional Climate Centers  |
| Interactive tool shows the highest multi-day (user chooses duration) rainfall totals for a station of interest in a table. It can be used determine the upper level thresholds of multiple day rainfall amounts that have occurred, and what one could expect to occur again. 1. On left side of screen, select *Single-Station*, then *Extremes*. 2. Next to *Variable*, select *Total Precipitation*. 3. Enter length of period of interest (e.g. 2 Days for 2-day rainfall totals). 4. Click on *Select station* tab. 5. Search for area or choose from List (AMA, OUN, & TSA cover Oklahoma). 6. Click *Go*. 7. Table will be displayed on screen. Note the period of record (POR) on the bottom of the table. Choose a station with longer POR if possible. |

<p>| <strong>Flood Impacts by River Crest Height</strong>  |
| National Weather Service Arkansas-Red Basin River Forecast Center  |
| Interactive tool shows a summary of flood impacts for location of interest. It can be used to show the extent of flood events. 1. On map, pan and zoom to area of interest. 2. Double-click on stream gauge of interest (small circle) on the map. 3. Click <em>River at a Glance</em> tab near top of page. 4. Left column: Select gauge of interest. Right column: At a minimum, select <em>Flood Impacts, Location Map, Record Crest History</em>. 5. Click <em>Make my River Page!</em> 6. Information you selected will be displayed on a new page. |
| Tool Link: <a href="https://www.weather.gov/abrfc/">https://www.weather.gov/abrfc/</a> |</p>
<table>
<thead>
<tr>
<th>Heavy Rainfall and Flooding (Continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEMA Flood Map Service Center</strong></td>
</tr>
<tr>
<td>Federal Emergency Management Agency</td>
</tr>
</tbody>
</table>
| Website can be used to locate and identify flood hazard zones in a jurisdiction and produce maps for inclusion in a hazard mitigation plan. When combined with other map layers it can provide a spatial relationship between flood hazard zones and critical facilities and infrastructure. Note that the 100-yr floodplain is an estimate used for insurance and regulatory purposes. Floods can and do occur outside of the areas depicted. *Note: This tool is a little more involved than some of the others and it is helpful to use a larger computer screen because of the amount of data shown.*
1. Enter an address, place, or coordinates in the search bar near the top of the page. 2. Click *Search*. 3. Click *Streets* view in upper right corner of the map. 4. The panel of land outlined in light blue is the one that will be mapped. If you need a different panel, click on the one of interest (Zoom out if needed. It may take a few seconds for it to be selected). 5. Zoom in to view details in map such as those shown at right. Note legend below map and effective date in bold above the map. 6. To download a black & white static image of full original FIRM panel, click on *Map Image* icon. 7. To access a colored map, click on Dynamic Map icon. You may need to disable your browser’s pop-up blocker.  

**Tool Link:** [https://msc.fema.gov/portal](https://msc.fema.gov/portal)

<table>
<thead>
<tr>
<th><strong>Historical Climatology</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Historical Climate Trends Tool</strong></td>
</tr>
<tr>
<td>(1895-present)</td>
</tr>
<tr>
<td>Southern Climate Impacts Planning Program</td>
</tr>
</tbody>
</table>
| Shows precipitation trends by state and climate division, annually, seasonally, and by month. Years, seasons, or months with high precipitation totals may be indicative as years with flood events during one or more parts of the year, however must be correlated with other data.  
1. On the left side of screen select *Oklahoma*. 2. Select climate division of interest or entire state. 3. Select annual, season, or month of interest. 4. Select *Precipitation*.  

**Tool Link:** [http://charts.srcc.lsu.edu/trends/](http://charts.srcc.lsu.edu/trends/)

<table>
<thead>
<tr>
<th><strong>Historical Flood Risk and Costs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1996-present)</td>
</tr>
<tr>
<td>Federal Emergency Management Agency</td>
</tr>
</tbody>
</table>
| Map visualization and graphs show state and county flood events that are documented in NOAA’s Storm Events Database. It shows the number of flood events by county and costs of flooding based on average National Flood Insurance Program and FEMA’s Individual and Household Program payments.  
1. Under *Choose a State*, select *Oklahoma*. 2. Oklahoma statistics will be displayed on the page. 3. If you wish to view statistics by county, click on a county on the map displayed on the page.  


<table>
<thead>
<tr>
<th><strong>Future Trend</strong></th>
</tr>
</thead>
</table>
| Heavy rainfall and flooding have always been part of Oklahoma’s climate. Annual precipitation has increased over the vast majority of Oklahoma, with the highest change occurring in winter. According to Easterling et al. (2017), heavy rainfall (top 1% of annual events) increased by 12% between 1958 and 2016. Seasonally, rainfall is projected to increase in winter and spring and decrease in summer and fall by the end of the 21st century, but projected changes are small compared to natural variations. There is strong confidence that there will continue to be an increase in the frequency and intensity of heavy rainfall events over the 21st century (Easterling et al. 2017), which increases the chance of flooding. However, flooding is a locally complex phenomenon and can be exacerbated by human action (or inaction) as much as it can be caused by atmospheric conditions.  


## Lightning

### Data Limitations:
Historically, most lightning data have been proprietary therefore climatological records of the hazard are limited. However, a new NOAA satellite became operational in late 2017 and contains a significant technological advancement called the Geostationary Lightning Mapper (GLM). The GLM can detect the presence of total lightning including in-cloud, cloud-to-cloud, and cloud-to-ground. While this advancement will not provide historical lightning data, it will add to the climatological record as time goes on.

### Historical Climatology

<table>
<thead>
<tr>
<th>Annual and Monthly Distributions of Cloud-to-Ground Lightning (1996-2016)</th>
<th>These static maps show the cloud to ground lightning density (strikes per km²) over Oklahoma, averaged over the years 1996-2016. There are five maps on the website that display annual and seasonal (winter, spring, summer, and fall) densities.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Click on the link to access the Oklahoma Climatological Survey's <em>Tornadoes &amp; Severe Storms</em> climatology page. 2. Select lightning map(s) of choice from the following: <em>Yearly Lighting Density, Winter Lightning Density, Spring Lighting Density, Summer Lightning Density, Fall Lightning Density</em>. 4. Analyze your lightning frequency based on county lines.</td>
<td>Tool Link: <a href="http://climate.ok.gov/index.php/climate/category/tornadoes_severe_storms">http://climate.ok.gov/index.php/climate/category/tornadoes_severe_storms</a></td>
</tr>
</tbody>
</table>

### Future Trend

Lightning is associated with thunderstorms, so as more favorable environments for thunderstorms are expected across the United States, increases in lightning are also projected. Studies have shown an increase in lightning associated with severe storms (Schultz et al. 2011). Climate models project an increase in the frequency and intensity of severe thunderstorms (Kossin et al. 2017), therefore lightning occurrences are likely to increase. Confidence in the projections is currently low, however, due to the isolated and sporadic nature of lightning events and limited comprehensive datasets which make it difficult to track long-term trends (Wuebbles et al. 2017a).
# Severe Thunderstorm Winds

**Data Limitations:** Population and temporal biases (i.e. greater number of reports in recent decades), a limited number of weather stations that record wind speed, and the fact that severe thunderstorm winds can be very localized, mean that data are not of sufficient quality to robustly determine whether there have been trends over a long period of time (e.g. 100+ years).

| Historical Climatology | **Severe T-Storm Wind Days Per Year** *(1986-2015)*  
NOAA/National Weather Service Storm Prediction Center | This map shows you the average number of days per year in which severe thunderstorm wind reports were received in your area. The map gives you a sense of the approximate number of days each year that you can expect to see severe thunderstorm winds (57 mph or greater) in your area.  
1. Click on the link to access the Oklahoma Climatological Survey's *Tornadoes & Severe Storms* climatology page.  
2. Select 50 Knot Wind Days or 65 Knot Wind Days.  
| | **Severe T-Storm Wind Reports** *(1950-present)*  
Southern Regional Climate Center | This interactive tool shows you the historical record for individual severe thunderstorm wind reports (gust of 57 mph or greater) in your area. It can be used to determine severe thunderstorm wind events that have impacted your area or close to your area.  
1. On left side of screen, click on *Search by Location*.  
2. Choose the diameter of the area of which you want to investigate (25 or 50 miles).  
3. Select *Wind* (de-select *Torn and Hail*).  
4. Pan, zoom, and then click on the map area of interest.  
5. Reports are displayed on the map and in two tables below the map.  
6. Map: Mouse over individual storm reports for details.  
7. Tables: There are two tables, *Real Time Reports*, which does not include wind speed, and *Detailed Hazard Reports*, which does. Click on column header to sort by column of interest. For example, to view the dates in which the highest wind occurred, click on the *Scale* column header to sort by the highest wind value.  
   Tool Link: [https://www.srcc.lsu.edu/storm_reports](https://www.srcc.lsu.edu/storm_reports) |
| | **Severe T-Storm Watch Climatology Map** *(1993-2012)*  
NOAA/National Weather Service Storm Prediction Center | This map shows you a 20-year climatology of severe thunderstorm watches. From this map you can get a sense of the approximate number of days each year you can expect to have a severe thunderstorm watch issued for your county(ies).  
1. Under the *Storm Prediction Center WCM Page* banner near the top of the page, click on the *Watch Frequency Maps* link.  
2. Scroll down a bit until you see *20y SPC Watch Climatology*.  
3. Click on the *average number of severe thunderstorm watches per year* image to view it in larger form.  
4. Note: this WCM page contains a lot of other statistics about the hail, severe thunderstorm and tornado products that come out of the NWS Storm Prediction Center if you are interested in digging deeper into data.  
   Tool Link: [http://www.spc.noaa.gov/wcm/](http://www.spc.noaa.gov/wcm/) |
| Future Trend | Damaging winds in Oklahoma are associated with severe thunderstorms. More favorable environments for severe thunderstorms are expected and increases in severe wind occurrences are projected. Climate models project an increase in the frequency and intensity of severe thunderstorms over the Southern Great Plains, especially during the peak storm season (March, April, May). Uncertainty remains, however, in the assumption that the favorable environments will reach their potential of producing damaging winds (Kossin et al. 2017). |
# Tornado

**Data Limitations:** Tornado reports prior to around 1980 were compiled from written records. Consequently, many tornadoes may have gone unreported or multiple tornadoes may have been listed as a single track. Tornado tracking is unique as occurrences are recorded either by damage assessments or visual accounts (Kossin et al. 2017). Advanced radar technology, increases in population in rural areas, usage of video and social media, emphasis on documentation, and improvements in communication have resulted in an increase in the number of reports, especially among weaker (EF0-EF1) tornadoes. As these systematic biases are present, use caution when using long term trends as they are based solely on the number of reports.

<table>
<thead>
<tr>
<th>Historical Climatology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tornado Tracks Tool</strong></td>
<td>This is an interactive tool that shows historical tornado track details by track location or county. Consider nearby storm tracks, even if they did not hit your location, because small changes in storm motion can bring a tornado into your town. 1. Select area of interest either by zooming or entering a location into the search box. 2. Use panel on left side of screen to select variables of interest. Options include by Magnitude, Year Range, Month, and Casualties. 3. For more information, select either Track or County and click on area of interest on the map.</td>
</tr>
<tr>
<td>(1950-2016) Midwestern Regional Climate Center</td>
<td></td>
</tr>
<tr>
<td><strong>Tornado Risk Assessment</strong></td>
<td>This site is a series of graphs that shows tornado occurrences and statistics based on a given point. Statistics include F/EF scale frequency and probabilities of strikes occurring per month and time of day. 1. Click on black bar at top of page (bar includes location, radius and time period information) and provide zip code of interest. 2. Click Run. 3. Details about tornadoes that have occurred within selected area are displayed on page.</td>
</tr>
<tr>
<td>(1950-2015) NOAA/National Weather Service Storm Prediction Center</td>
<td></td>
</tr>
<tr>
<td><strong>Tornado Days Maps</strong></td>
<td>These static maps show the average number of tornado days per year for all magnitudes (separate maps show EF1+, EF2+ and EF4+ days) within 25 miles of any point from 1986-2015. Tornado frequencies at a given location can be compared to nearby and regional locations. 1. Click on the link to access the Oklahoma Climatological Survey's Tornadoes &amp; Severe Storms climatology page. 2. Select from the following: Tornado Days, EF1+, EF2+, or EF4+ Tornado Days.</td>
</tr>
<tr>
<td>(1986-2015) NOAA/National Weather Service Storm Prediction Center</td>
<td></td>
</tr>
<tr>
<td><strong>Tornado Watch Climatology Map</strong></td>
<td>This map shows you a 20-year climatology of tornado watches. From this map you can get a sense of the approximate number of days each year you can expect to have a tornado watch issued for your county(ies). 1. Under the Storm Prediction Center WCM Page banner near the top of the page, click on the Watch Frequency Maps link. 2. Scroll down a bit until you see 20y SPC Watch Climatology. 3. Click on Average number of tornado watches per year image to view it in larger form. 4. Note: This WCM page contains a lot of other statistics about the hail, severe thunderstorm and tornado products that come out of the NWS Storm Prediction Center if you are interested in digging deeper into data.</td>
</tr>
<tr>
<td>NOAA/National Weather Service Storm Prediction Center</td>
<td></td>
</tr>
</tbody>
</table>

### Future Trend

Records over the past 40 years show that there has been an increase in the frequency of days with a large number of tornadoes (i.e. tornado outbreaks). However, there has also been a decrease in the frequency of days with tornadoes (Kossin et al. 2017). In other words, increasingly, when tornadoes occur, they are more likely to occur in conjunction with a tornado outbreak. It is currently difficult to account for tornadoes in climate models because they occur on a very small scale. Therefore, more research is needed to understand how climate change is influencing tornadoes (Walsh et al. 2014). Progress has recently been made, however, in understanding how the large-scale climate system relates to the conditions that support tornadoes. As such, climate models project an increase in the frequency and intensity of severe thunderstorms, which can include tornadoes, most commonly during the months of March, April, and May. However, confidence in the details of this projected increase remains low (Kossin et al. 2017).
## Data Limitations

A systematic, national collection of wildfire reports did not begin until the early 1990s. Many analyses are based on only a few years of data, which may not capture multi-year variability or trends. Further, fires accounted for by local jurisdictions may not always translate into national databases.

### Historical Climatology

**Wildfire Climatology**


K. C. Short/ U.S. Department of Agriculture Forest Service

This interactive tool can be used to show locations of reported fire occurrences between 1992-2015, in and near a county or city. Individual years can be viewed to determine relative risk. Many fires in urban areas are not reported to the U.S. Forest Service database, however, so it may under-represent fire risk in urban areas. *Note: There is a learning curve associated with this tool and it is helpful to use a larger computer screen because of the amount of data shown.*

1. Click on the *Map View* link below. 2. Next to *View In*, click *ArcGIS Online map viewer*. A new internet browser window will open. 3. On the left side of the screen, under *Contents*, expand *EDW FireOccurrence 01* by clicking the arrow to the left of the name. Make sure you click on the top *EDW FireOccurrence 01* with the triangle next to it, not the bottom one. 4. Select year(s) of interest or *All Years* (last in the list). 5. Zoom in on map if data are not shown. 6. To view Oklahoma fires only, hover mouse over year of choice and click on the flashlight (filter) icon. 7. Select *STATE* in left dropdown menu → In far-right box enter *OK* → Click *APPLY FILTER*. 8. A table containing the details of each fire can be viewed by clicking the table icon (two icons left of the flashlight icon). 9. The map symbols represent varying causes of wildfire occurrences. To view the legend, click on the legend button directly above and to the far right of *Contents*. 10. To view data on an individual fire, click on the fire symbol of interest, then in the top right-hand corner of the table, click on the three horizontally lined tab and select *Center on Selection*. Details of the selected fire will be displayed in the table. 11. Refer to the paper linked below for table column definitions. *Note: Additional filters can be applied by clicking on the flashlight icon again and choosing desired selections (e.g. The column STAT_CAUSE_DESCR describes the cause of the fire).*

**Map View:**

[https://apps.fs.usda.gov/arcx/rest/services/EDW/EDW_FireOccurrence_01/MapServer](https://apps.fs.usda.gov/arcx/rest/services/EDW/EDW_FireOccurrence_01/MapServer)


### Southern Wildfire Risk Assessment Portal

(period of record varies by product)

Southern Group of State Foresters

*Adobe Flash required; not compatible with mobile devices.*

This interactive tool can be used to identify areas within and/or near a city that are at greatest risk of wildfire. It is especially useful for identifying risk areas in the wildland-urban interface and to help prioritize areas where tactical analyses, community interaction, or mitigation treatments might be necessary to reduce risk. *Note: There is a learning curve associated with this tool and it requires Flash. Public Viewer accessible to anyone. Professional Viewer is also free but requires account request.*

1. Click on the link and select *Public Viewer* near the bottom of the screen. 2. Pan and zoom-in on the map to area of interest. 3. Click on *Map Themes* in the upper left-hand corner. 4. Under the *Wildfire Risk* section on the left side of the screen, select the layer you want to view. Details about each layer can be found by hovering over the circular “i” icon. 5. Pan and zoom-in or -out on map as needed. *Note: Data are displayed at a very fine (25-meter) resolution.*

**Tool Link:** [https://www.southernwildfirerisk.com/](https://www.southernwildfirerisk.com/)
### Wildfire (Continued)

| **Prescribed Fire Climatology** (1996-2015) | This tool is a series of static graphics and tables within a scientific report. It can be used to identify the best months to conduct prescribed burns as a wildfire management strategy. Coupled with tools such as SouthWRAP, one can target locations and timing for safe burning along the wildland-urban interface. The report describes the average, minimum and maximum number of days with a consecutive 4-hour period suitable for prescribed fire as a management tool to reduce vegetation fuel load and improve vegetation health.  
1. Click on the report link. 2. Tables and Figures relevant to Oklahoma: Tables 2 and 7, Figures, 7, 8, 13-17, 25. | ![Suitable Burn Conditions from 1997-2015 Under PBE Criteria](image)

1. Zoom into desired location(s) on map. 2. On left side of screen, select year → base map → and layer opacity of interest. **Note:** Oklahoma-specific data and map files (down to the county level) are available by scrolling down the page. | ![WUI Change](image)

| **Wind Rose Plots** (period of record varies by station) | View common and prominent wind speeds and directions for your area. Plots can be viewed either by month or by the full years on record. This tool can be used to describe general climate and the predominant direction in which air pollutants flow. It may also be useful for understanding how wildfire events may evolve or play out in a community.  
1. In the **Select By Network** section, choose Oklahoma ASOS then click **Switch Network**. 2. Select station of interest, either from list or map, then click **Select Station**. 3. You will be brought to a new page. Near the top of the page, click on the **Wind Roses** tab. 4. Yearly climatology is displayed at the top of the page, monthly climatologies are displayed below that. | ![Wind Rose Plots](image)

| **Future Trend** | Between 1984 and 2011, the number of large wildfires increased in the Southern Plains, which includes Oklahoma ([Wehner et al. 2017](#)). Wildfires in Oklahoma are dependent upon current weather conditions, seasonal climate patterns, vegetation conditions, and an available source for ignition (such as a spark, flame, or intentional). Given this complex relationship, little is known how climate change may affect wildfire conditions across Oklahoma. However, projected increases in temperatures that can dry fine fuels such as grasses and enhanced wet/dry cycles that promote vegetation growth and drying or dormancy, coupled with population growth along the wildland-urban interface, suggests the risks of wildfires is likely to continue to increase. | ![Future Trend](image)
### Data Limitations

Long term records are limited across the state, especially in southeast Oklahoma. Ice storm/freezing rain data are very limited due to the complexity of observational accounts (e.g. rain, freezing rain, and snow can occur at a single station during a single event).

### Historical Climatology

<table>
<thead>
<tr>
<th>Snowfall Climatology Tool (1960-present)</th>
<th>This interactive tool shows the annual average number of 1-, 2-, or 3-day periods with snow totals at certain thresholds. Stations are limited so use the one closest to your location as a proxy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Position map to area of interest. 2. On left side of screen, select Average → # of days of interest → threshold → all months (or month of your choice). 3. Click on an individual station to receive more information. This information request is highlighted in blue. Additional information is shown below it and can be expanded by clicking Table of All Values.</td>
<td></td>
</tr>
<tr>
<td>Tool Link: <a href="http://mrcc.isws.illinois.edu/gismaps/snowclimatology.htm">http://mrcc.isws.illinois.edu/gismaps/snowclimatology.htm</a></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Snowfall Extremes (period of record varies by location)</th>
<th>This interactive static map shows the 1-Day, 2-Day, and 3-Day snowfall maximums by county.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select the day(s) of interest on the top right side of the map. 2. Mouse over county of interest for information on the maximum snowfall event on record. 3. A table below the map shows location (by county and station), date of event, and snowfall total details.</td>
<td></td>
</tr>
<tr>
<td>Tool Link: <a href="https://www.ncdc.noaa.gov/snow-and-ice/snowfall-extremes/OK">https://www.ncdc.noaa.gov/snow-and-ice/snowfall-extremes/OK</a></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ice Storm Climatology (1948-2000)</th>
<th>These are static images within a scientific report. Shows the average annual number of days with freezing rain (Fig. 2) and month of highest average number of freezing rain days (Fig 9). For reference when viewing these figures, Oklahoma typically sees 2-3 freezing rain events per year, most commonly in January.</th>
</tr>
</thead>
<tbody>
<tr>
<td>To view, 1. Click on the Full Text tab and scroll to the bottom of the page. 2. View full sized images of Fig 2. and Fig. 9 by clicking on respective images.</td>
<td></td>
</tr>
</tbody>
</table>

### Future Trend

Years consisting of a large number of snowfall days declined significantly across the southern United States between 1930 and 2007. Models suggest that although the number of snowfall events will likely continue to decrease given overall atmospheric warming, when snow does occur, accumulations will be greater due to increases in atmospheric moisture (Krasting et al. 2013). There is significant uncertainty surrounding the future of ice storms in Oklahoma. Observational data limitations and the complexity of the events themselves make it difficult to determine with much specificity whether patterns have and/or will change. Models show that by mid-century there will generally be a northward shift of the rain, sleet and snow dividing line across the central United States. This shift will add to the complexity of determining precipitation type for winter events (rain, ice or snow) in Oklahoma, however, the increase in atmospheric moisture may bring an increase to the amount of precipitation that does fall (Easterling et al. 2017).
# Dam or Levee Failure

**Data Limitations:** The tools below do not provide dam or levee failure information but rather information on the locations of and pertinent details about dams and levees in Oklahoma. The dam inventory is limited to dams with a height of at least 25 feet and exceed 15 acre-feet in storage or at least 50 acre-feet of storage and exceed six feet in height unless the dam is classified as high hazard potential. The high hazard potential dam is a dam where failure will probably cause loss of human life regardless of the physical condition of the structure.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>National Inventory of Dams by State</strong>&lt;br&gt;(1900-2016)&lt;br&gt;U.S. Army Corps of Engineers</td>
<td>This tool provides you with an overview of the dams in Oklahoma, including the number by hazard potential, height, owner type, primary type, primary purpose, and completion date. 1. Near the middle of the page, select your organization type to enter the National Inventory of Dams. 2. Near the top of the next page, click on the <em>NID By State</em> tab. 3. Use the drop-down menu to select OK. 4. Run Adobe Flash if needed. 5. A summary map of dam locations across the state is viewable on the right side of your screen. Several bar charts that break down the number of dams by a variety of variables are viewable on the left side of your screen.</td>
<td><a href="http://nid.usace.army.mil/cm_apex/f?p=838:12:7691546328146">http://nid.usace.army.mil/cm_apex/f?p=838:12:7691546328146</a></td>
</tr>
<tr>
<td><strong>National Inventory of Dams Interactive Report</strong>&lt;br&gt;(1900-2016)&lt;br&gt;U.S. Army Corps of Engineers</td>
<td>This report allows you to view the details of individual dams within the state of Oklahoma. 1. Near the middle of the page, select your organization type to enter the National Inventory of Dams. 2. Near the top of the page, click on the <em>NID Interactive Report</em> tab. 3. On the top left part of the page, click on the arrow next to the magnifying glass, then select State. Enter OK in the box, then click Go. 4. You can choose which columns to display or not by clicking Actions → Select Columns, then move the column headers as needed. Then click Apply. 5. To sort by column, click on the column header. 6. Click the Help tab for additional instructions (red link) and legend information.</td>
<td><a href="http://nid.usace.army.mil/cm_apex/f?p=838:12:7691546328146">http://nid.usace.army.mil/cm_apex/f?p=838:12:7691546328146</a></td>
</tr>
<tr>
<td><strong>National Levee Database</strong>&lt;br&gt;(Levee Inventory: 1882-Present)&lt;br&gt;U.S. Army Corps of Engineers</td>
<td>This tool allows you to to explore levees in your area, including location, year constructed, length, number of people and structures at risk should failure occur, property values in the risk area, and more. 1. On the left side of the screen, click Oklahoma. 2. Explore the map as you see fit or click on the county of interest on the left side of the page. 3. To change the Basemap type, click on the Basemap drop-down menu on the upper-right corner of the map, and select map type of interest. 4. To view more details about each levee, scroll down and click Map in the Resources section. 5. You will see several layer options on the left side of the screen. 6. Click National Levee Database (or other layer of interest). 7. To view the details of each levee, zoom-in on the map and click on the levee of interest (red line). A box should pop up on the screen that contains clickable links. 8. Click on the levee link of interest to obtain details about the levee. 9. Browse the tool as needed. More data can be viewed by creating an account and signing in (permissions vary by organization type).</td>
<td><a href="https://levees.sec.usace.army.mil/#/">https://levees.sec.usace.army.mil/#/</a></td>
</tr>
</tbody>
</table>

**Future Trend**

Increases in extreme rainfall (Easterling et al. 2017) may increase the likelihood of dam failure, however this is highly dependent upon the quality of the structures. Most dams are at or near their 50 year design life, so the probability of failures increases with time. Dams that are not well maintained have an increased likelihood of failure. Washed out spillways, deteriorated primary spillway conduits, collapsed riser structures and slope instability can lead to a dam breach. New development downstream of existing dams increase the potential consequences that would occur if a dam were to fail. Major dam failures across Oklahoma are few since owners are required to perform routine inspections and maitenence (OWRB 2019).
# Earthquake

**Data Limitations:** Globally, scientific understanding of earthquake processes is somewhat limited, and the available history of seismicity is typically too short to establish reliable spatiotemporal patterns of large earthquake occurrences (Stein et al. 2012).

<table>
<thead>
<tr>
<th>Historical Data</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Earthquakes in Oklahoma Earthquake Map</strong> (1989-present)</td>
<td>Shows past earthquakes and location of Arbuckle waste water disposal wells on a zoomable map. Can be used to show previous occurrences since 1989. 1. Select period of interest below map. 2. Zoom in on map to location of interest. 3. Click on a single data point on the map to reveal the time, data, location, and magnitude of the earthquake. Tool Link: <a href="http://earthquakes.ok.gov/what-we-know/earthquake-map/">http://earthquakes.ok.gov/what-we-know/earthquake-map/</a></td>
</tr>
<tr>
<td>Oklahoma Geological Survey and Oklahoma Corporation Commission</td>
<td></td>
</tr>
<tr>
<td><strong>Oklahoma Area Seismicity Map, includes induced seismicity</strong> (1950-2015)</td>
<td>Shows the historical seismicity across the state (single points) along with the chance of damaging shaking in 2017 (contoured colors). Note: The 2017 Chance of Damage accounts for induced seismicity from wastewater disposal well injections associated with oil and gas plays. Can be used to help determine the risk of a damaging earthquake in your area. Tool Link: <a href="https://earthquake.usgs.gov/earthquakes/byregion/oklahoma/OKdamagemap_june2017.gif">earthquake.usgs.gov/earthquakes/byregion/oklahoma/OKdamagemap_june2017.gif</a></td>
</tr>
<tr>
<td>U.S. Geological Survey</td>
<td></td>
</tr>
<tr>
<td><strong>Oklahoma Earthquakes Bar Graph</strong> (1978-2018)</td>
<td>Shows the annual number of M3.0+ earthquakes in Oklahoma over time in a bar graph format. Can be used to show how the risk of earthquakes has increased in recent years. Tool Link: <a href="https://earthquake.usgs.gov/earthquakes/byregion/oklahoma/OK-M3-dec3-2018.pdf">https://earthquake.usgs.gov/earthquakes/byregion/oklahoma/OK-M3-dec3-2018.pdf</a></td>
</tr>
<tr>
<td>U.S. Geological Survey</td>
<td></td>
</tr>
<tr>
<td>U.S. Geological Survey</td>
<td></td>
</tr>
</tbody>
</table>

**Future Trend**

Prior to 2009, Oklahoma experienced 1-2 earthquakes per year that were magnitude 3.0 or greater. The rate of M3.0+ earthquakes increased to a peak of about 3 per day in 2015 concurrent with a statewide increase in wastewater injection into deep underground strata (Andrews and Holland 2015). As wastewater injection volumes have declined by over half, compared with 2015, the rate of M3.0+ earthquakes have decreased to about 1 per day in late 2017. Thus, the future seismic hazard is interlinked with wastewater disposal well activity but will likely remain elevated, compared to background tectonic rates, for at least the next decade (OGS 2017).
Poor Air Quality (Dust, Pollutants, Smoke)

Data Limitations: Geographical and spatial gaps exist, especially in rural areas. However, areas distant from monitoring stations typically experience consistently good air quality. Also, there is no single air pollutant relevant to every discussion, so there is no single way to express air quality (California Environmental Health Tracking Program 2015). Monitoring frequency varies by pollutant (e.g., carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead). Tools often display data for the five air pollutants that make up the Air Quality Index (AQI): carbon monoxide, nitrogen dioxide, ozone, particulate matter (PM10 and PM2.5) and sulfur dioxide.

<table>
<thead>
<tr>
<th><strong>Air Trends</strong></th>
<th>This static image displays the annual national and regional trends for the 5 AQI pollutants as well as for lead. 1. To obtain graphs, scroll down page slightly and click on pollutant link of interest in Air Quality Trends section. 2. When regional analysis exists, click on Regional Trends link at the top of the page. 3. Select South from the list. 4. Graph will display on the bottom of the page.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Compare</strong></td>
<td>This interactive map displays county-based trends for the five AQI air pollutants that may affect human health. For data limitations specific to this tool, including the pollutants that are accounted for in the analyses, click on the Basic Info tab at the top of the page, then Data Limitations on the right side of the page. Note: For information on the predominant directions in which air pollutants flow, refer to the Wind Rose Plots tool in the Wildfire section, p.17. 1. Scroll down until you see the U.S map. 2. In the upper left-hand corner of the map, click on Trends, then select group of interest. 3. Click county of interest to obtain graph of annual statistics. 4. For data broken down into months, click on Seasons in upper left-hand corner, then select group of interest.</td>
</tr>
<tr>
<td><strong>Ozone Exceedances</strong></td>
<td>This interactive graphing tool compares 8-hour ozone exceedances between two years or multi-year periods for a city or county. Comparisons are shown by day, month and year. The ozone exceedance level for this tool is 0.070ppm. 1. Under Geographic Area, select a City or County (Oklahoma cities listed: Ardmore, Lawton, McAlester, Miami, Oklahoma City, Ponca City, Tablequah and Tulsa) 2. Under Baseline Period, select either a single year or a multi-year period and the year(s) in which you are interested. 3. Under Comparison Period, select either a single year or a multi-year period and the year(s) in which you are interested in. 4. You may need to uncheck Use ALL Monitors when comparing time periods if data aren’t available for both periods. 5. Click Plot Data.</td>
</tr>
<tr>
<td><strong>Outdoor Air Quality Data</strong></td>
<td>This multiyear tile plotting tool shows the daily AQI pollutant values for a specific location or time period. Each tile represents one day of the year and is color-coded based on the AQI level for that day. 1. Under Pollutant, select pollutant of choice. (ex: Ozone, All AQI Pollutants) 2. Under Period, select a beginning and ending year 3. Under Geographical Area, select a city or county (Note: cities available are listed in the Ozone Exceedances tool above) 4. Click Plot Data.</td>
</tr>
<tr>
<td><strong>Future Trend</strong></td>
<td>Dramatic improvements in air quality have occurred over the past half-century due to technological innovations and federal regulations (ODEQ 2018). The projected increased frequency and intensity of droughts will make it easier for dry soil to become airborne, which will lower air quality and cause breathing and respiratory problems (EPA 2016a). Hotter temperatures can increase the formation of ground-level ozone, which has a variety of health effects including asthma and respiratory problems. Air quality will also worsen during wildfire periods (EPA 2016b). Continued technological innovation and enforcement of federal regulations should result in additional air quality improvement (ODEQ 2018).</td>
</tr>
</tbody>
</table>
Acknowledgements

The Simple Planning Tool for Oklahoma Climate Hazards is a result of SCIPP’s engagement with emergency managers and planners in Oklahoma and Arkansas since 2016. We thank Robert Hill (Emergency Management) and Paula Dennison (Development Services) from Stillwater, Oklahoma for providing the initial concept for this tool. We would also like to thank everyone who contributed to the development and completion of this tool, including James Cuellar (SCIPP Undergraduate Student Assistant).

A note of thanks is also extended to the individuals who assisted in reviewing sections of and/or provided additional information for the tool: Kristin Calhoun (Cooperative Institute for Mesoscale Meteorological Studies/National Severe Storms Laboratory), Patrick Marsh (NWS Storm Prediction Center), Jacob Petre (Oklahoma Department of Environmental Quality), Rick Smith (National Weather Service Norman Forecast Office), Yohanes Sugeng (Oklahoma Water Resources Board), and Jake Walter (Oklahoma Geological Survey).
References


ODEQ (Oklahoma Department of Environmental Quality), cited 2018: personal communication with Jacob Petre, Air Quality Division.


# Appendix A - Hazard Definitions

## Cold Extremes

**Definition:** A marked and unusual cold weather characterized by a sharp and significant drop of air temperatures near the surface (maximum, minimum, and daily average) over a large area and persisting below certain thresholds for at least two consecutive days during the cold season (WMO 2015).

*Note:* There is no universally-recognized metric for what constitutes a cold extreme. The World Meteorological Organization recommends characterizing a cold wave by its magnitude, duration, severity, and extent. Magnitude is defined as a temperature drop below certain threshold(s), either as an absolute value or percentiles. These values must be determined by the local climatology.

**Description:** Cold extremes occur when polar and arctic air is displaced from polar regions toward the equator. The lack of sunlight in polar regions during winter allows the buildup of cold, dense air. Wiggles in the jet stream allow equator-ward (southward in the Northern Hemisphere) transport of cold air into the continental United States. High-amplitude jet-stream patterns (a series of large troughs and ridges in the upper atmosphere around the globe) allow air masses to move from their source regions.

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## Drought

**Definition:** A deficiency of moisture that results in adverse impacts on people, animals, or vegetation over a sizeable area (NWS 2009).

**Description:** Drought impacts vary based on the duration and intensity of the event. A few dry weeks may affect crops and lawns, while droughts lasting months or years may significantly impact large water resources. At its extreme, nearly decade-long droughts may lead to farm and business foreclosures and mass migration. Some conditions that may lead to drought development include a large-scale, stationary high-pressure system which inhibits precipitation, feedback from dry soils accelerating warming of the air, La Nina which displaces jet streams, or large-scale ocean circulations in the Pacific and Atlantic Oceans. Droughts may happen in any location and at any time of year. Impacts often become severe more quickly for drought occurring during the summer, when evaporative loss is high; however slower-evolving droughts in the Fall and Winter can have tremendous economic impacts on winter crops and livestock. Droughts are more frequent in areas where annual evaporation may exceed annual precipitation.

Drought is rated by the weekly U.S. Drought Monitor (2018) on a scale from D0 (abnormally dry) to D4 (exceptional drought). D0 occurs, on average, in any given location about 21-30% of the time. D1, moderate drought, occurs on average 11-20% of the time, or roughly once every 5-10 years. D2, severe drought, occurs 6-10% of the time, or about every 10-20 years. D3, extreme drought, occurs 3-5% of the time and D4, exceptional drought, occurs 0-2% of the time, or about every 50 years. Severity is based upon a variety of drought indicators, impacts, and input from local experts.
<table>
<thead>
<tr>
<th><strong>Hail</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> Showery precipitation in the form of irregular pellets or balls of ice more than 5mm (0.2 inches) in diameter, falling from a cumulonimbus cloud (NWS 2009).</td>
</tr>
<tr>
<td><strong>Description:</strong> Hail forms by the collision of supercooled drops – raindrops that are still liquid even though the air around them is below freezing. The hailstone grows, supported by the updraft, until it is too heavy to remain aloft. Stronger updrafts generally produce larger hail size. Because obtaining large hail sizes requires a strong updraft, the timing of large hail is related to the lifecycle of large cumulonimbus clouds, which peak in intensity during late afternoon and evening hours. Updrafts may also be supported by vertical motion along a boundary, such as a front or mountains.</td>
</tr>
</tbody>
</table>
Hail severity is rated by the diameter of the largest hailstones in a storm. Hail of 1-inch diameter or greater is considered a severe storm. |

<table>
<thead>
<tr>
<th><strong>Heat Extremes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> A marked unusual hot weather (maximum, minimum and daily average) over a region persisting at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds (WMO 2015).</td>
</tr>
<tr>
<td><strong>Note:</strong> There is no universally-recognized metric for what constitutes a heat extreme. The World Meteorological Organization recommends characterizing a heat wave by its magnitude, duration, severity, and extent. Magnitude is defined as a thermal measurement such as maximum temperature, or combination of several measurements, exceeding certain threshold(s). These values must be determined by the local climatology. Other studies have used thresholds based on human physiological response to heat, such as consecutive days of maximum or minimum temperatures above a threshold.</td>
</tr>
<tr>
<td><strong>Description:</strong> Heat extremes in the central United States occur when a dominant large-scale high-pressure system prevents movement of other air masses into a region. The high-pressure contributes to intense heating from solar radiation, due to a lack of cloud cover, and light winds preventing the dispersion of heat, especially from urban areas. This results in both higher than average maximum and minimum temperatures.</td>
</tr>
</tbody>
</table>
### Heavy Rainfall and Flooding

**Definition:** Heavy rainfall is rain with a rate of accumulation exceeding a specific value that is geographically dependent (AMS 2012). Flooding is any high flow, overflow, or inundation by water which causes or threatens damage (NWS 2009).

**Description:** Heavy rainfall is a subjective term, but is rain falling at a rate more than the underlying surface can handle, causing runoff, inundation of low-lying areas, and flooding. This may include short-duration thunderstorms lasting a few hours or rainfall accumulating over several days. Flooding is the result of heavy rainfall but also the underlying surface. The rate of infiltration (how quickly it is absorbed by the soil), how quickly runoff reaches the creeks and rivers, if there had been prior rainfall, if the ground is frozen, and other local factors affect runoff and flooding. Consequently, a rainfall of a given rate and amount may cause flooding in one circumstance but not in another. Flooding is most likely in low-lying areas, along the edges of water bodies (ponds, lakes, rivers), and over impermeable surfaces (such as streets and parking lots). Primary causes include slow-moving thunderstorms and storms that track over a location in rapid succession, or tropical systems. Flash flooding may occur with intense thunderstorms while river flooding usually requires rainfall accumulated over a longer duration. Flooding may also be caused by breaches of dams or levees, where fast-moving water may be especially destructive.

Rainfall accumulations may be compared against previous occurrences through the concept of “return-period values”. This is a statistical assessment of the frequency with which similar amounts have been recorded in the past at a specific location. These return periods, such as 1 in 25 years (a 4% chance of occurring in any given year), are not predictive tools – a large event occurring in the recent record does not prevent another similar or larger event occurring shortly after. Also, if heavy rainfall has already occurred, stormwater retention systems may be filled to capacity allowing a smaller event to cause flooding impacts similar to a much larger event. Rainfall rates and accumulations are usually greatest during the spring, summer, and fall, when warm air can hold more water vapor to produce greater rain rates. River flooding is most likely in spring or fall, when fronts may stall giving a focus for thunderstorm development. Tropical systems, either from the Gulf of Mexico or from the Pacific Ocean, can produce among the highest rainfall rates in the state.

### Lightning

**Definition:** A visible electrical discharge produced by a thunderstorm. The discharge may occur within or between clouds, between the cloud and air, between a cloud and the ground or between the ground and a cloud. (NWS 2009)

**Description:** Lightning forms from charge separation within thunderstorms, usually cumulonimbus clouds. Lightning is essentially a large spark of static electricity, similar to touching a doorknob on a dry day (although much more powerful). Most lightning forms from streamers that work their way down from the charge centers of clouds toward the ground. When it gets close to the ground, a return stroke is initiated, which we see as a flash of light. Thunder is created by a shock wave from rapid heating of the air to 18,000 degrees – hotter than the surface of the sun.

Lightning is capable of striking as far as 10 miles away from a storm. Distance can be estimated by counting the seconds between the flash and the sound of thunder. It takes 5 seconds for the shockwave to travel one mile. Lightning severity is not rated, although new detection systems allow accurate identification of lightning strikes allowing analysis of lightning frequency.
### Tornado

**Definition:** A violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. (NWS 2009)

**Description:** Tornadoes generally form from severe thunderstorms, particularly supercell thunderstorms – those that are isolated with unimpeded inflow of moisture and enhanced by wind shear. Tornadoes may also form along squall lines or in bands of storms associated with hurricanes. Tornadoes require moist air, instability (warm air rising), a source of lift such as a front, dryline, or heating, and wind shear (change in wind direction and speed with height).

Tornadoes can occur at any time of the year in Oklahoma and at any time of the day, although they are most common in spring and summer and in late afternoon to early nighttime hours.

Tornado intensity is rated by the damage they produce, on a scale from EF0 (weak) to EF5 (violent). Strong (EF2-EF3) and Violent (EF4-EF5) tornadoes account for only about one-third of all tornadoes, but 97% of fatalities and the vast majority of economic impacts. Tornadoes along squall lines and hurricane bands are more likely to be weak, although widespread severe straight-line winds may accompany these types of storms.

### Wildfire

**Definition:** Any free burning uncontainable wildland fire not prescribed for the area which consumes the natural fuels and spreads in response to its environment (NWS 2009).

**Description:** Wildfires occur when weather conditions meet with sufficient fuel and an ignition source. Weather conditions include warm temperatures, low humidity, strong winds, and a period without precipitation allowing fuels to dry. Fuels are vegetation ranging from fine fuels such as grass and pine needles to large woody materials such as trees, dead and decaying logs, and organic material in the soil. Large woody materials are difficult to ignite; the presence of fine fuels allows fire to get started and become intense enough to ignite larger materials. Ignition sources may be natural such as lightning or human-caused such as sparks from equipment, power transformers, a chain dragging behind a vehicle, or heat sources such as discarded cigarettes.

There are two wildfire “seasons” in Oklahoma, although they can happen in any month. Fires are a common occurrence in late winter when dormant vegetation provides fine fuels and warm, windy, dry days provide weather conditions that allow ignition and spread. Summer has higher temperatures that can allow fires to become very intense, but there is typically less wind and consequently less spread. Fire spread may be increased on south-facing slopes, which are usually drier and warmer because of exposure to the sun, windy locations such as canyons, and along steep slopes. Very intense fires may become “crown fires” if they burn to the tops of trees, allowing embers to spread farther and create spot fires. Crown fires are almost impossible to extinguish without cooler, wetter weather conditions.

Fire danger is measured on a Burning Index scale, ranging from 0 to 110+. Values below 20 are considered low fire potential, 40-80 is high, and 110 or higher is extreme. The burning index combines potential energy release (fire intensity), flame length, and rate of spread. The National Weather Service issues Red Flag Warnings when weather conditions are favorable for ignition and spread of wildfires. Another popular index is the Keetch-Byrum Drought Index (KBDI) that considers weather and vegetation conditions. The scale ranges from 0 to 800; values below 200 indicate high fuel moisture making ignition unlikely; values above 600 are indicative of intense wildfire conditions with any that develop capable of downwind spotting (starting new fires).
### Winter Storm (Ice, Sleet, Snow)

**Definition:** A winter storm is a winter weather event that produces impactful accumulations of freezing rain (ice), sleet and/or snow. (NWS 2018)

**Description:** Winter storms may include heavy snowfall, blowing and drifting snow, high winds, extreme cold or ice storms. Among the greatest hazards associated with winter storms are traffic accidents. The most extreme instance is a blizzard, which is defined as winds greater than 35 mph, visibility less than ¼ mile, lasting at least 3 hours. New snowfall is not necessary for a blizzard; blowing snow can similarly obscure visibility.

Winter storms are measured by snowfall accumulation or ice thickness. Winter storms occur in Oklahoma between November and March and are usually created by large low-pressure systems moving rapidly across the country. In Oklahoma, ice storms are a greater threat than blizzards. Access to moisture from the Gulf of Mexico falling over shallow cold air near the surface can produce ice accumulations of two inches or greater with tremendous damage to power distribution.

### Dam or Levee Failure

**Definition:** Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water or the likelihood of such an uncontrolled release. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water is properly considered a failure. These lesser degrees of failure can progressively lead to or heighten the risk of a catastrophic failure. They are, however, normally amenable to corrective action (USSD 2018).

**Description:** Dams help address the complex challenge of controlling and distributing water. They have been recognized as a key water management practice dating back to early civilizations of the Americas, ancient Egypt and China. As water is a part of the hydrologic cycle, dams work to conserve water through reservoirs to prohibit flow back to the ocean. With the advancement of civilization and a growing population, water withheld in such reservoirs are an integral part of society and is a necessary source for energy, drinking water, irrigation practices, etc. Dams also protect areas of development and civilization from floods through flood control measures. Dam safety and maintenance standards have increased over time.
Earthquake

**Definition:** A sudden slip on a fault, with resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth. (USGS 2018)

**Description:** Earthquakes occur from the sudden release of stress in the Earth's crust. Stress is built up by the motion of tectonic plates. Stress may also be built up through the injection of fluids. During an earthquake, rocks on either side of a fault line move either horizontally or vertically. This movement creates three types of waves: Primary, Secondary and Rayleigh waves. Primary waves spread outward from the epicenter (source of the fracture) as compression, like a spring. Secondary waves vibrate at right angles to the direction of travel; these are the most damaging. Rayleigh, or surface, waves move vertically, giving an undulating motion.

The Meers fault, located in southwest Oklahoma, has the potential for producing a strong earthquake. Additionally, Oklahoma experienced a substantial increase in light (M4.0-4.9) and Moderate (M5.0-5.9) earthquakes in recent years caused by wastewater injection from oil production, although the number of earthquakes declined in 2016 and 2017. An earthquake caused by the New Madrid fault, situated in the Mississippi Valley, could also impact Oklahoma.

Earthquake intensity is measured on the Moment Magnitude Scale. Each point represents a 10-fold increase in the wave amplitude and a 32-times increase in energy release.

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Poor Air Quality (Dust, Pollutants, Smoke)

**Definition:** A measure of the monitored natural and man-made pollutants in an area.

**Description:** Air quality problems result from the accumulation of aerosols, such as dust, pollen, smoke, salt, or human-produced chemically-active compounds that build up in an area over time. Under normal conditions, winds disperse these aerosols and compounds, but sustained periods of light winds can allow buildup to unhealthy levels. Many aerosols are produced naturally but may have artificially elevated concentrations through burning (concentration of smoke and carbon monoxide) or agriculture. Industrial activities and urban environments add other sources of pollution, including photochemical smog which is produced from the interaction of sunlight with nitrous oxides (primarily from automobile engines) and volatile organic compounds. Ozone is a component of this smog.

Air quality problems occur when dispersion – the ability of the atmosphere to spread pollutants over a large area – is inhibited. Temperature inversions, where a warm layer of air aloft prevents upward motion, and light winds, such as a large high-pressure system, provide favorable conditions for air quality events. Some pollutants, such as ozone, occur in higher concentrations during higher temperatures and more intense sunlight while others, such as smoke or dust, can accumulate in high concentrations any time of the year. Local and regional landscapes, such as mountain valleys, can also “trap” pollutants. Warmer summertime temperatures are likely to increase the concentration of pollutants such as ozone.

Concentrations of pollutants are measured and averaged over time. A time-averaged concentration is used because exposure to a high concentration of pollutants during a short time might have an impact equivalent to an exposure to a lower concentration over a longer time (American Meteorological Society). When the average exceeds public health regulations over a defined period, such as several hours or a day or a number of days per year, the area is noted as being noncompliant. One way to assess air quality for your location is to look at the daily Air Quality Index (AQI) issued by the U.S Environmental Protection Agency. AQI is calculated for five major pollutants including ground-level ozone, particle pollution (particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide.
Appendix B - Historical FEMA/Presidential Disaster Declarations by State, County or Tribal Nation

The below data visualization interactive reference page displays statistics of disaster declarations for both states and tribal nations, dating back to 1953.

Disaster Declarations for States and Counties: https://www.fema.gov/data-visualization-disaster-declarations-states-and-counties

This page contains an interactive tool that allows the exploration of historic federal disaster declarations by state, county, hazard, and year. To access information from this page, first select a state or territory from the drop-down list. Information on federally declared disasters within the selected region will be displayed below, organized by natural hazard.

Clicking on a hazard will provide an in-depth analysis over the region including:

- Declarations based by county
- The months and years the hazard has occurred historically, and
- The complete list of federal disasters declarations for that hazard (declarations can be viewed by clicking on the title).

Disaster Declarations for Tribal Nations: https://www.fema.gov/data-visualization-disaster-declarations-tribal-nations

This page contains an interactive tool that allows the exploration of historic federal disaster declarations by tribal nation, hazard, and year. To access information from this page, first select a tribal nation from the drop-down list. Information on federally declared disasters within the selected region will be displayed below, organized by natural hazard. The in-depth analysis of a selected tribal nation will be similar to the information provided for disaster declarations of states and counties above.

Note: Oklahoma’s tribal nations are not currently represented in this tool because 1) they have not yet declared a disaster, 2) have not met FEMA’s financial threshold, or 3) have received assistance through the state instead of directly from FEMA. The amended 2013 Stafford Act allowing federally recognized tribes to directly declare disasters required a minimum threshold of $1 million in damages. This large amount made it difficult for tribes to independently qualify for declarations. Beginning in January 2017, however, FEMA released pilot guidance which reduces the disaster declaration eligibility threshold to $250,000. More information on this pilot guidance can be accessed here: https://www.fema.gov/media-library/assets/documents/128307.
Appendix C - Climate Change Science Resources

The *Simple Planning Tool* v.1.5 is geared towards providing Oklahomans with the most accurate and trustworthy data sources. The tool also identifies future climate trends for each hazard. As noted in the *A Note About Climate Change* (p. 5) section, below is a list of credible, up-to-date climate change science resources to consider for additional information beyond what the *Simple Planning Tool* provides.


The National Climate Assessment is the most accurate state-of-the-science agreed upon in the science community. This report was produced by a team of more than 300 experts guided by a Federal Advisory Committee, which was extensively reviewed by the public and experts including federal agencies and a panel of the National Academy of Sciences. Released in November 2018, it represents the second of two volumes of the Fourth National Climate Assessment (NCA4) and builds upon the work of the three previous assessments. Focusing on regional chapters, the NCA4 Volume II is a technical scientific assessment of climate change-related impacts, risks and adaptation on the United States, as described in the NCA4 Volume 1: Climate Change Special Report (CSSR).


This stand-alone report is an authoritative assessment of the science relating to climate change and its physical impacts, with a focus on the United States. Released in November 2017, it was led by NOAA, represents the first of two volumes of the NCA4, and is mandated by the Global Change Research Act of 1990. The CSSR is designed to serve as the foundation for efforts to assess climate-related risks and inform decision-making about responses. The report provides 1) an updated detailed analysis of the findings of how climate change is affecting weather and climate across the United States; 2) an executive summary and other materials that provides the basis for the discussion of climate science found in the second volume of the NCA4; and 3) foundational information and projections for climate change, including extremes, to improve "end-to-end" consistency in sectoral, regional and resilience analyses.

**Attribution of Extreme Weather Events in the Context of Climate Change (2016):**

(To access for free, report can be viewed online or a PDF can be downloaded by creating a free account.)

This National Academies of Sciences, Engineering and Medicine report examines the current state of science of extreme weather attribution and identifies ways to move the science forward to improve attributing capabilities. The following infographic provides an overview of the report and how climate change is affecting extreme weather:

[https://www.nap.edu/resource/21852/extremeweather-infographic.pdf](https://www.nap.edu/resource/21852/extremeweather-infographic.pdf)
Appendix D - Incentive and Action Programs for Hazard Risk Reduction

Below is a list of resources providing information on incentive and action programs intended to assist in reducing hazard risk for your community. The list is not necessarily comprehensive. Please reference the provided links for more information on each program.

All Hazards

*Integrating Hazards into the Comprehensive Plan - Webinar* ([https://www.planningforhazards.com/webinars](https://www.planningforhazards.com/webinars), scroll to bottom of page): This one-hour webinar focuses on how local governments and communities can reduce their risk and vulnerability by integrating hazard risk reduction strategies into their comprehensive plan. Colorado planners describe the processes, practices used and lessons they learned when integrating hazards into their comprehensive plans. This webinar was developed in consideration for Colorado, but concepts can be similarly applied and adapted for Oklahoma.

*Natural Hazard Mitigation Saves: 2017 Interim Report* ([http://www.nibs.org/page/mitigationsaves](http://www.nibs.org/page/mitigationsaves)): The National Institute of Building Sciences issued this interim report to highlight the benefit of two broad avenues for implementing mitigation strategies. (1) The Institute’s project team analyzed 23 years of federally funded mitigation grants and found that hazard mitigation funding can save the nation $6 in future disaster costs for every $1 spent. (2) The team looked at scenarios that focus on designing new buildings to exceed provisions of the 2015 model building codes, and the findings revealed that investing in exceeding these building codes can save the nation $4 for every $1 spent.

Flooding

*National Flood Insurance Program (NFIP)* ([https://www.fema.gov/national-flood-insurance-program](https://www.fema.gov/national-flood-insurance-program)): This program “aims to reduce the impact of flooding on private and public structures by providing affordable insurance and encouraging communities to adopt and enforce floodplain management regulations. These efforts help mitigate the effects of flooding on new and improved structures...and reduces the socio-economic impacts of disasters.”

*NFIP Community Rating System (CRS)* ([https://www.fema.gov/national-flood-insurance-program-community-rating-system#](https://www.fema.gov/national-flood-insurance-program-community-rating-system#)): CRS “is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements.” As a result, community participation reduces policy holder flood insurance rates and ultimately flood damage to insurable property.

Severe Thunderstorms: Wind (Tornadic and Straight-Line) and Hail

*Insurance Institute for Business and Home Safety (IBHS) Fortified Homes Program* ([https://disastersafety.org/fortified/resources/](https://disastersafety.org/fortified/resources/)): This program is a set of engineering and building standards designed to help strengthen new and existing homes through system-specific building upgrades to minimum building code requirements that will reduce damage from specific natural hazards. Relevant to Oklahoma hazards, their research includes standards for high winds and hail. Some insurance companies offer discounts for having wind-resistant construction and/or hail-resistant shingles. Contact local insurance providers for more information and applicability.

Wildfire

*Community Planning Assistance for Wildfire (CPAW)* ([https://planningforwildfire.org/resources/cpaw-training-materials/](https://planningforwildfire.org/resources/cpaw-training-materials/)): The CPAW program provides communities with training and technical resources to improve land use planning in the wildland-urban interface. Their list of provided materials includes webinars, presentations, handouts and posters. Note: As this is a national program, some of these materials may not be applicable to Oklahoma conditions.
Southern Climate Impacts Planning Program
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