

Finding Tornado Alley

Overview

In this lesson, students will work with 10 years of tornado data for the entire United States to explore Tornado Alley. They will use three different approaches—frequency, intensity, and density—to identify Tornado Alley, the part of the country where most tornadoes occur. Finally, students will examine and compare seasonal differences in tornado occurrences.

This lesson is taken from the ESRI EdCommunity website *Thinking Spatially Using GIS*, a free online resource. This website offers several lessons for use in classrooms about a variety of topics.

Estimated Time

120 minutes, split up among three class periods

Materials

Student Activity: Finding Tornado Alley

Worksheet 1: Tornado Alley

Worksheet 2: Map of the 48 States

Optional Breakout Lesson: Map Scale and Measurement

Optional Breakout Lesson: Symbols and Map Features

Optional Breakout Lesson: Calculating Averages

Computer and internet access (for teacher and each student/or groups)

Learning Objectives

After completing the lesson, students will be able to:

- Identify and compare four regions in the United States based upon tornado activity
- Identify spatial patterns on different map layers of geographic data
- Identify temporal patterns on different map layers of geographic data
- Analyze and compare the frequency, intensity, and density of tornadoes and learn about the differences between them
- Compare the geographic extent of different layers of information

Vocabulary

N/A

GIS Tools and Functions

Open a map file on ArcGIS Online

Zoom to the geographic extent of a layer

Add a data layer to a map

Identify to get information about a feature

Use a filter to select features and records in a layer

Open the attribute table for a layer

Turn layers on and off

Change map style (legend)

Sort fields in a table

Select records in a table

Create a graduated symbols style in the legend

Create a unique symbols style in the legend

Additional Resources

- Physical Geography: <http://www.physicalgeography.net>
- Physical Geography: <http://www.regentsprep.org/regents/ushisgov/themes/geography/physicalgeography.cfm>
- Article: <http://www.tornadochaser.net/tornalley.html>
- NOAA Article: <http://www.noaa.gov/resource-collections/tornadoes>
- NOAA Photo Library: <http://www.photolib.noaa.gov/nssl/tornado1.html>

Opening the Lesson

Begin this lesson by focusing on the following concepts.

1. The United States is made up of landforms and physiographic regions
2. Three different aspects of tornado occurrence: frequency, intensity, and density
3. Averages and how to calculate them
4. Studying natural disasters can help you learn about weather, climate, landforms, and other aspects of geography
5. Patterns of features on maps have spatial and temporal patterns

6. Tornado dynamics
7. Weather patterns change by season and by year

Next indicate to students that Tornado Alley is an area of the United States that has more tornadoes than any other place on Earth. Many people argue about which states are in Tornado Alley. In this lesson, you will learn how to find this area for yourself! By the time you finish this lesson, you will be able to list the states that have the most frequent tornadoes, the strongest tornadoes, and the greatest concentration of tornadoes. You will be able to identify states that are in Tornado Alley.

Go on to say that tornadoes are associated with certain weather patterns, and these patterns change with the seasons. In this lesson, you will learn which regions of the United States have tornadoes at different times of the year—winter, spring, summer, and fall.

“Let’s explore Tornado Alley.”

Developing the Lesson

Task 1: Open the map

8. Distribute a copy of **Student Activity: Finding Tornado Alley** to each student. Indicate that students will use this handout as a guide throughout this lesson, as they work with the ArcGIS online maps. It is identical in content to the lesson plan that follows. Also distribute copies of the **Tornado Alley** and the **Map of the 48 States** worksheets to each student.
9. a. Launch an Internet browser.
b. Go to this link: <http://arcg.is/1K6fM56>

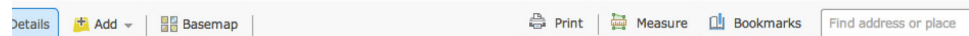
A map document has been created for you to use in this exercise. When the map document opens, you see a map of the United States. The ArcGIS Online Map Viewer title is in the top left corner of the window.



A map of the 48 states labeled with their abbreviations appears on your screen. On the left side of the map, you will see a column containing three buttons: About this map, Contents, and Legend.

Click on “Contents”. A list of layers appears. Layers are used to show geographic data on a GIS map. Each layer has a name and a legend. You can turn layers on and off. At the top of the map, you see menus and buttons that you will use during this activity.

10. Look at the ArcGIS Online map window and observe the following:
 - On the right side you see a map.
 - On the left side you see a column that displays the legend for the map.
 - In the top right corner you will see a “Modify Map” link.
11. Click on the Modify Map link in the top right corner of the map view.
12. Look at the top of the ArcGIS Online map viewer window and notice the different buttons. You will use some of these buttons as your progress through this lesson.



Task 2: Enlarge the ArcGIS Online window

If the ArcGIS Online Map Viewer window is small when the map document first opens, you may wish to enlarge it.

13. In the upper right corner (PC) or upper left corner (Mac) of your ArcGIS Online window there are three buttons. Click the middle button (PC) or the right green button (Mac).



Now the ArcGIS Online Map Viewer window fills your whole screen.

You can also change the size of your ArcGIS Online window by stretching it. Stretching the window instead of maximizing it allows you to organize other windows and dialog boxes as they appear.

14. Place the cursor on any corner of the ArcGIS Online window that is not at the edge of your screen. The cursor changes to a diagonal double-headed arrow. Click and drag the window outward until the ArcGIS Online window fills about two-thirds of the screen. Let go of the mouse button.

Task 3: Tornadoes of the United States

15. Hover over and click on Show Contents of Map button.



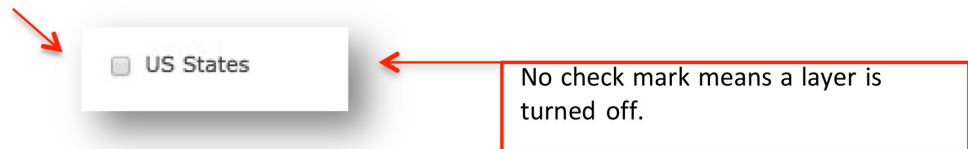
In ArcGIS Online Map Viewer, a map is made up of layers.

16. Look at the Contents area on the left of the map and observe the following:

- There are thirteen layers: Names, US States – Outlines, State Tornadoes, Winter Tornadoes, Spring Tornadoes, Summer Tornadoes, Fall Tornadoes, Strongest Tornadoes, Tornado Density, US States, All Tornadoes 1995-2004, Landforms, and Light Gray Canvas basemap.
- Each layer except the last layer (the Light Gray Canvas basemap) has a small box in front of it.
- The boxes for US States, US States – Outlines, and Landforms are checked.
- The other boxes in front of the layers are unchecked.

Next, you will learn how to turn layers on and off.

17. Turn off the US States layer by clicking the box next to the layer name.



18. Turn on the All Tornadoes 1995-2004 layer by clicking the box next to the layer name. Each dot represents a tornado that occurred from 1995-2004 (a period of 10 years).



This is called turning a layer on and off.

Q1: Look at your map. In what part of the country do most tornadoes occur?
(Circle the correct answer.)

- a. Eastern states
- b. Western states
- c. Central and eastern states

Q2: Do you see any states that don't have tornadoes?

- a. Yes
- b. No

19. Zoom out of the map until all 50 states are in view.

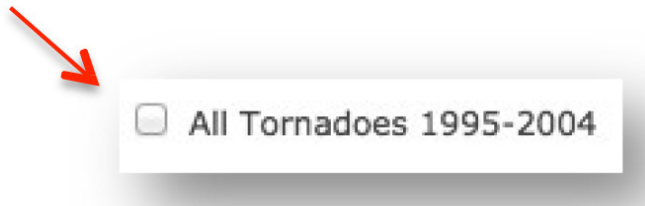
Q3: Do you see any states now that don't have tornadoes?

- a. Yes
- b. No

20. Zoom back in to the 48 states. Tornadoes are more common in some parts of the country than others. Let's look at a different view of the United States.
21. Turn off the **US States—Outlines** layer by clicking the check mark next to the layer name.



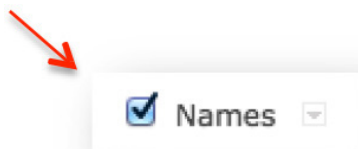
22. Turn off the **All Tornadoes 1995-2004** layer.



You are now looking at an image of the United States showing high areas (mountains) and low areas (plains and valleys). This is called a Physical Map of the United States.



23. Turn on the **Names** layer by clicking the box next to the layer name.



Now you see the names of some of the landforms of the United States.

24. Turn on the **All Tornadoes 1995-2004** layer again.



Q4: Look at your map. In what part of the country do most tornadoes occur?

- a. Rocky Mountains
- b. Great Plains
- c. Appalachian Mountains

The Great Plains has lots of thunderstorms, creating the kind of weather conditions that can cause tornadoes. Thunderstorms occur when warm, moist air meets cool, dry air.

25. Turn on the US States—Outlines layer



Warm, moist air that feeds these thunderstorms comes from the body of water south of the Great Plains.

Q5: Look at your map. What is the name of this body of water?

Cool, dry air comes from the land to the north of the Great Plains.

Q6: Look at your map. What is the name of this country?

26. Turn off the **Names** layer.

27. Turn off the **All Tornadoes 1995-2004** layer.

Task 4: States where tornadoes occur most often

While Tornado Alley is generally in the middle of the country, many people argue about the specific states that belong in this area. There are three different ways, or methods, to decide which states are in Tornado Alley:

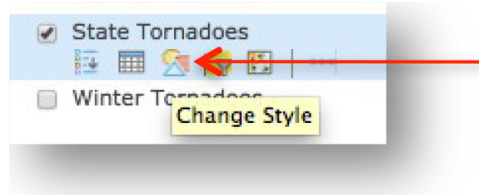
1. States where tornadoes occur most often (frequency)
2. States where the most dangerous tornadoes occur (intensity)
3. States where the greatest concentration of tornadoes occurs (density)

You will use GIS to analyze these three methods and decide on some of the states that are in Tornado Alley. You will start by finding out where tornadoes occur most often.

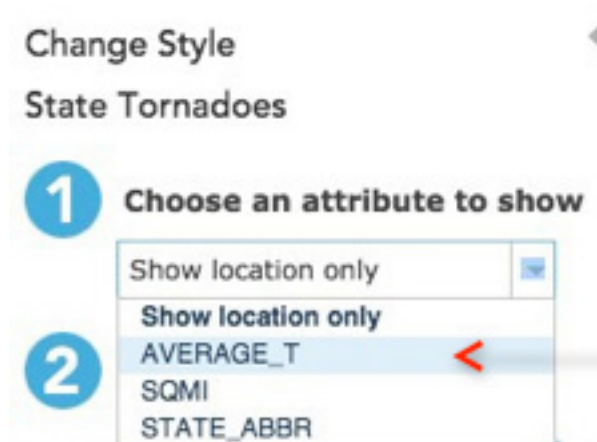
28. Turn on the **State Tornadoes** layer.

The **State Tornadoes** layer contains information about the tornadoes for each state. You will change its symbols.

29. Hover over the **State Tornadoes** layer and click on **Change Style**.



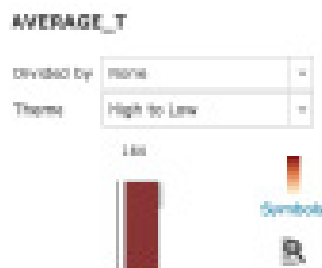
30. Click on the down arrow next to **Choose an attribute to show** and select **AVERAGE_T**.



31. Click on the **Counts and Amounts (Color)** SELECT box and click on **OPTIONS**.



32. Click on Symbols.

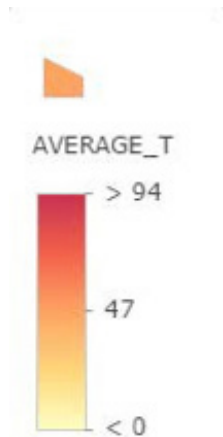


33. Choose the **Red to Yellow** color ramp.



34. Click Ok.

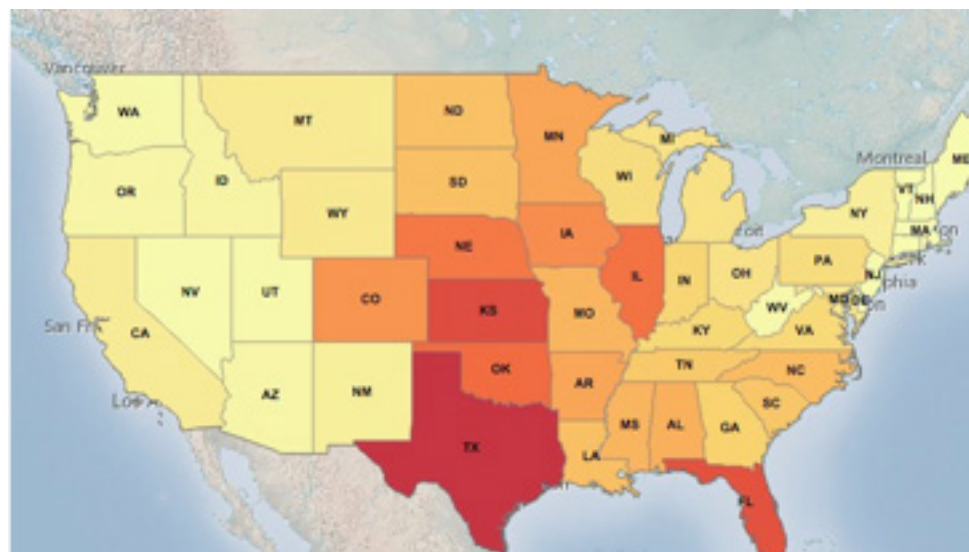
35. Drag the slider to the left of the color ramp to **94**.



36. Click Ok.

37. Click Done.

You see a map showing the average number of tornadoes per year in each state (from 1995 to 2004). The red color means there were a lot of tornadoes; the yellow means there were relatively few tornadoes



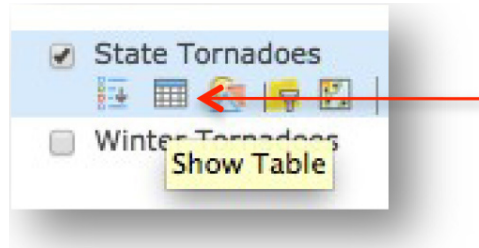
Q7: Look at your map and at the legend. In which state did tornadoes occur most often?

What does “average number of tornadoes per year” mean?

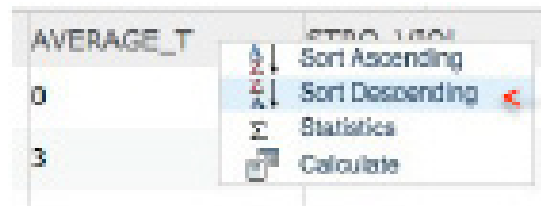
Suppose a state had 200 tornadoes from 1995 to 2004 (a period of 10 years). If you divide the total number of tornadoes (200) by the number of years (10), you will get the average number of tornadoes per year:

$$200 \div 10 = 20 \text{ tornadoes per year}$$

38. Hover over the **State Tornadoes** layer and click on the Show Table button.

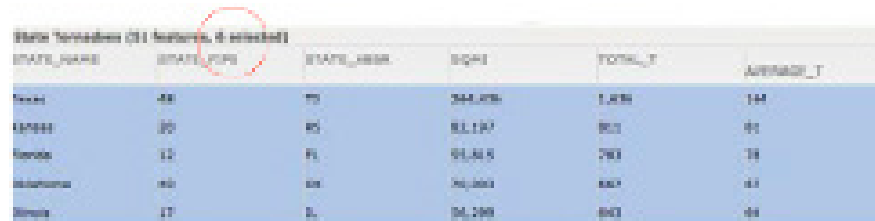


39. Click on the field name **AVERAGE_T** and choose Sort Descending. The states are listed in order from the highest number to the lowest number of tornadoes.



Let's look at the top six states.

40. Hold down your Shift key on the keyboard, and slowly click the first six records in the table (count them). They become highlighted in blue. They also become highlighted on your map. You may need to scroll down to see the sixth record in the table or drag your map up slightly to see all of the six states highlighted on your map.



STATE_NAME	STATE_POP	STATE_ABR	STATE	TOTAL_T	AVERAGE_T
Texas	28	TX	344,076	1,676	144
Arkansas	20	AR	81,197	80	80
Florida	12	FL	91,615	783	38
Mississippi	10	MS	30,000	887	88
Illinois	17	IL	24,298	843	88

Note: If you make a mistake, click the first record without holding down the CTRL key. Then hold down the CTRL key and click the next five records.

41. Look in the table for the STATE_NAME field. You see the names of six states highlighted in blue.

42. Take out the **Tornado Alley** worksheet that your teacher gave you.
43. Find Column 1: Highest average number of tornadoes.

Q8: Write the names of these six states in Column 1 of your worksheet.
(Some state names are filled in for you.)

44. Close the table of attributes.

Task 5: State where the strongest tornadoes happen.

Another way to decide which states are in Tornado Alley is to see where the strongest tornadoes happen. The strength of a tornado is measured by the speed of its winds and by how much damage it causes. You will look at which states had the strongest tornadoes between 1995 and 2004.

45. Turn off the **State Tornadoes** layer.



46. Turn on the **Strongest Tornadoes** layer.



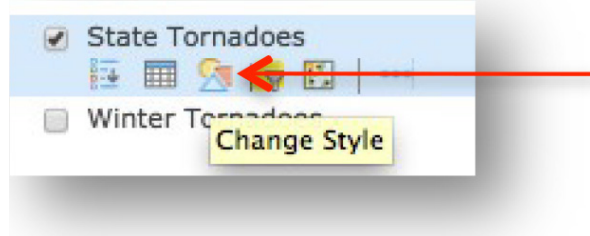
Each purple dot represents a single tornado. These tornadoes had winds that were stronger than 150 miles per hour and caused a lot of damage. Only a small portion of all tornadoes are really strong.

Q9: Look at the map. List two states that you think have a high number of strong tornadoes.

1. _____
2. _____

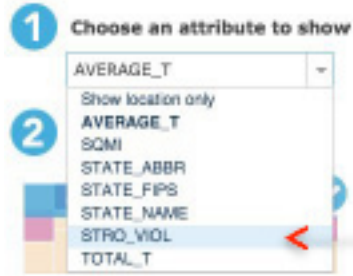
Now you will find out if you were right.

47. Turn off **Strongest Tornadoes**.
48. Turn on **State Tornadoes**.
49. Hover over the **State Tornadoes** layer and click on the **Change Style** button.



50. Click on the down arrow next to **Choose an attribute to show** and select **STRO_VIOL**.

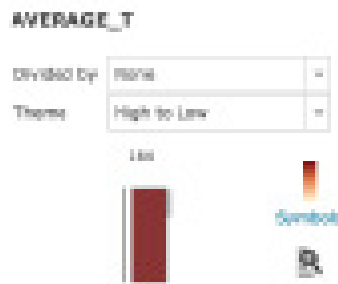
Change Style
State Tornadoes



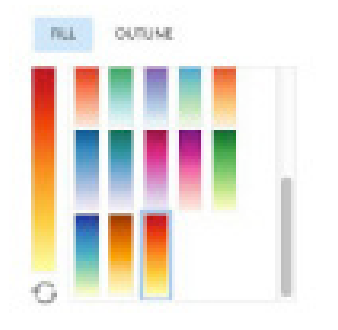
51. Click on the **Counts and Amounts (Color)** SELECT box and then the **OPTIONS** box.



52. Click on Symbols.

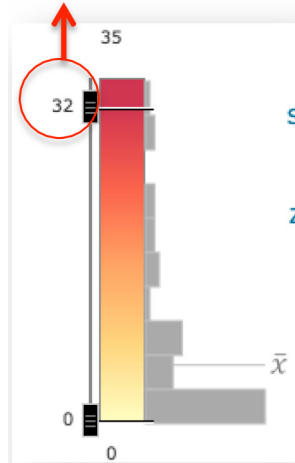


53. Choose the **Red to Yellow** color ramp.



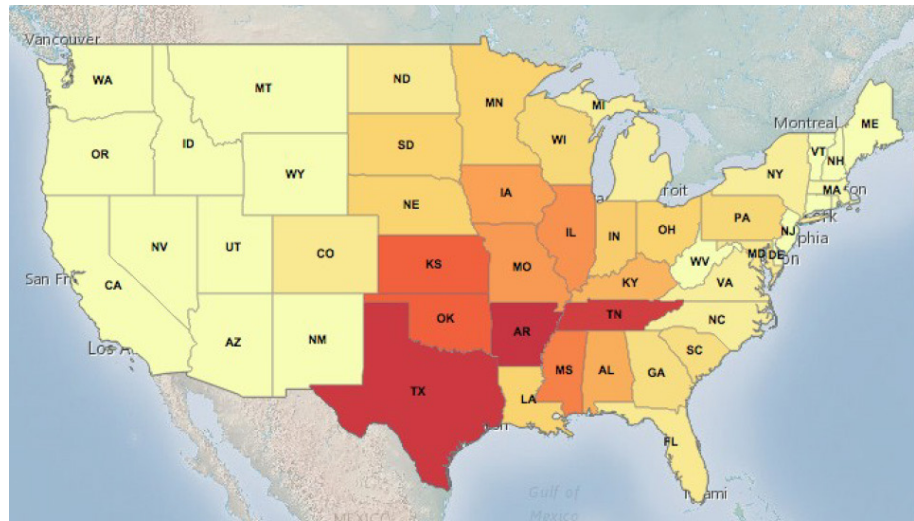
54. Click OK.

55. Drag the slider to the left of the color ramp to **32**.



56. Click OK.

57. Click Done.



58. Click one of the dark red states.

59. On the left side of the popup window you see the name of the field names.
On the right side you see the values.

60. Look at the value for the STRO_VIOL field. It tells you the number of strong and violent tornadoes that occurred in that state from 1995 to 2004.

Q10: What is the name of this state?

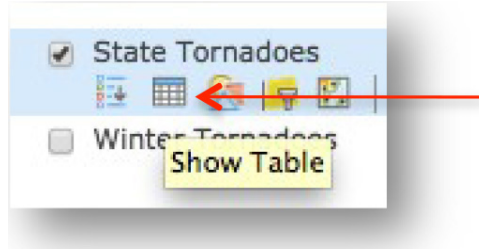
Q11: How many strong and violent tornadoes did it have from 1995 to 2004?

61. Click another dark red state on the map.

Q12: What is the name of this state?

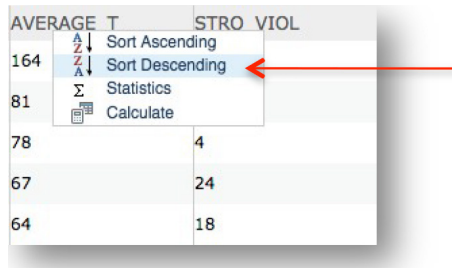
Q13: How many strong and violent tornadoes did it have from 1995 to 2004?

- 62. Close the popup window.
- 63. Hover over the **State Tornadoes** layer and click on the **Show Table** button.



State Tornadoes Layer Show Table

- 64. Click on the field name **STRO_VIOL** and choose Sort Descending.



The states are now listed in order from the highest number of strong and violent tornadoes to the lowest number.

Let's look at the top six states.

- 65. Hold down your Shift key on the keyboard, and slowly click the first six records in the table (count them). They become highlighted in blue. They also become highlighted on your map. You may need to scroll down to see the sixth record in the table or drag your map up slightly to see all of the six states highlighted on your map.

SQMI	TOTAL_T	AVERAGE_T	STRO_VIOL
52,913	454	45	35
264,436	1,636	164	31
42,092	278	28	30
70,003	667	67	24
82,197	811	81	24

- 66. Let go of the Shift key.
- 67. Look to the left in the table until you see **STATE_NAME**. You see the names of six states highlighted in blue.

68. Take out the **Tornado Alley** worksheet.
69. Find Column 2: Highest number of strong or violent tornadoes.

Q14: Write the names of these six states in Column 2 of your worksheet. (Some state names are filled in for you.)

70. Close the table of attributes.

Task 6: States with the highest concentration of tornadoes.

Looking at tornado density is a third way to decide which states are in Tornado Alley. This shows where the most tornadoes occurred within the smallest area of land (closest together). When you map how close together or far apart tornadoes are, you call this a tornado “density” map.

71. Turn off State Tornadoes.



72. Turn on the Tornado Density layer and the US States – Outlines layer.



The dark red areas show where tornadoes are most dense (close together). The light red (pink) areas show where tornadoes are least dense (spaced far apart).

73. Look at the map. The highlighted areas are where tornadoes are most dense (close together).

74. Take out the **Tornado Alley** worksheet.

75. Find Column 3: Highest tornado density.

Q15: Write the names of the states that have the most dense tornadoes in Column 3 of your “Tornado Alley” worksheet. (If you have turned off your US States–Outlines layer, turn it on to see the state name abbreviations.)

Q16: How many states contain dense tornado areas?

76. Turn off the Tornado Density layer.

You have defined Tornado Alley in three different ways:

1. States where tornadoes occur most often.
2. States where the strongest tornadoes occur
3. States where tornado density is highest

You listed these states on your **Tornado Alley** worksheet in Columns 1, 2, and 3.

77. Look at Columns 1, 2, and 3 now.

Q17: Which states appear in all three lists? Write the names of these states at the bottom of your “Tornado Alley” worksheet under “States in Tornado Alley.” (Two state names have already been filled in for you.)

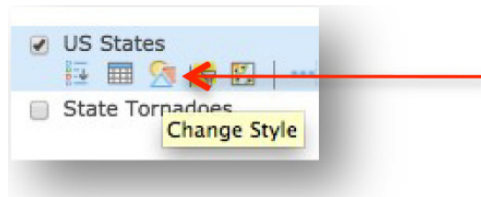
- 78. Take out your **Map of the 48 States** worksheet.
- 79. Color in these six states on the map.

Over 10 years, from 1995 to 2004, these states have been in Tornado Alley no matter what method you use to define this area.

Task 7: Where tornadoes occur during the seasons.

You have seen how tornadoes can occur close together over land. They can also occur close together over time. In this step you will look at where tornadoes occur during each season of the year and in each region of the United States.

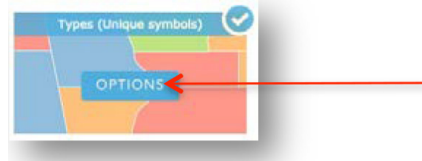
- 80. Turn on the US States layer.
- 81. Hover over the **US States** layer and choose **Change Style**.



- 82. Click on the down arrow next to **Choose an attribute to show** and select **REGION**.

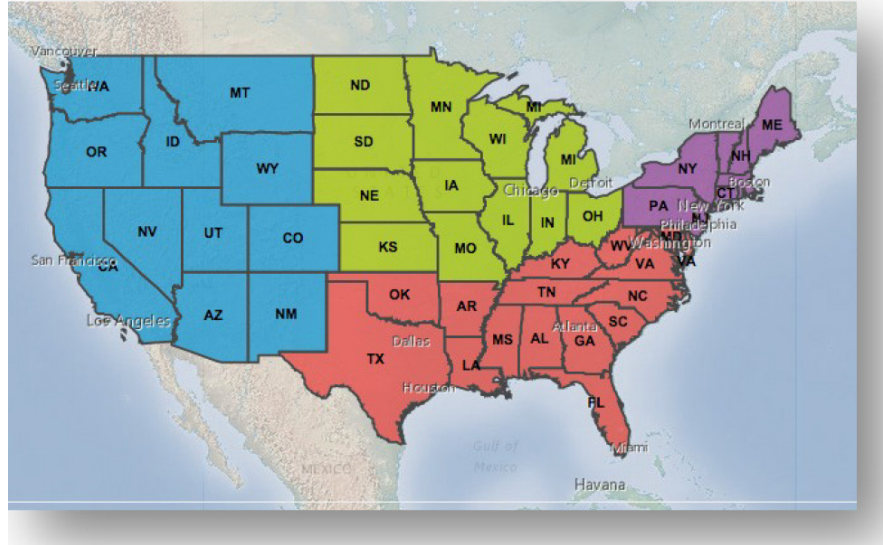


- 83. Click on the **Types (Unique symbols)** Options box.

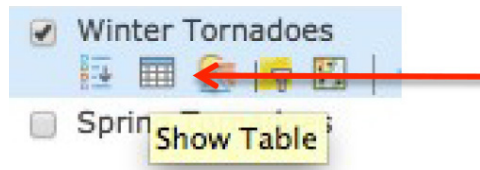


- 84. Click on OK to accept the automatic style change.
- 85. Click Done.

You see four United States regions, each with a different color, and you can see the state outlines.



86. Turn on the **Winter Tornadoes** layer.
87. Winter tornadoes from 1995 to 2004 appear as green dots on the map.
Q18: Look at the map. In what region of the country are most winter tornadoes? Hint: Look at the States legend to see the names and colors of the regions.
 - a. Midwest
 - b. Northeast
 - c. South
 - d. West
88. Hover over the **Winter Tornadoes** layer and click on the **Show Table** button.

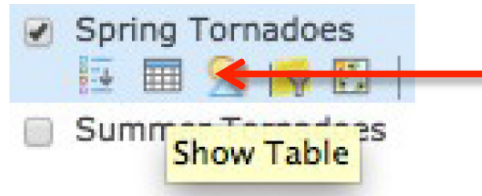


89. Look at the top title bar to see how many records (features) are in the table.
Q19: How many tornadoes occurred in winter between 1995 and 2004?
90. Close the table of attributes.
91. Turn off the **Winter Tornadoes** layer.
92. Turn on the **Spring Tornadoes** layer. (If you receive a “Layer did not draw completely” message, click on OK.)
Spring tornadoes from 1995 to 2004 appear as red dots on the map.

Q20: In what regions of the country are most spring tornadoes?

- a. Midwest
- b. Northeast
- c. South
- d. West

93. Hover on the **Spring Tornadoes** layer and click on the Show Table button



94. Look at the top title bar to see how many records (features) are in the table.

Q21: How many tornadoes occurred in spring between 1995 and 2004?

95. Close the table of attributes.

Q22: Look at the map. List two differences between winter tornadoes and spring tornadoes. (Hint: You can turn both layers on at the same time or turn them on and off to compare them.)

- a.
- b.

96. Turn off the **Spring Tornadoes** layer.

97. Turn on the **Summer Tornadoes** layer.

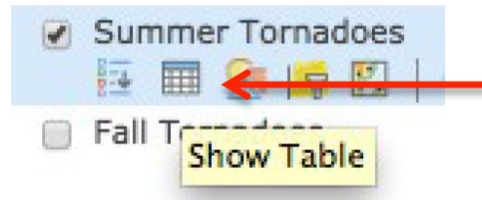
Summer tornadoes from 1995 to 2004 appear as yellow dots on the map.

Q23: In what region of the country are most summer tornadoes?

- a. Midwest
- b. Northeast
- c. South
- d. West

Q24: Look at the map. List one difference between summer tornadoes and spring tornadoes. (Hint: You can turn both layers on at the same time or turn them on and off to compare them.)

98. Hover on the **Summer Tornadoes** layer and click on the Show Table button.



Look at the top title bar to see how many records (features) are in the table.

Q25: How many tornadoes occurred in summer between 1995 and 2004?

99. Close the table of attributes.

100. Turn off the **Summer Tornadoes** layer.

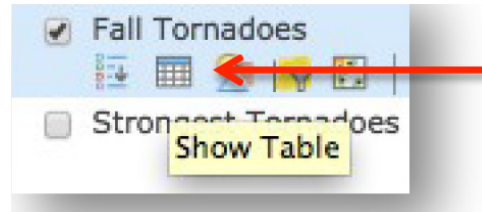
101. Turn on the **Fall Tornadoes** layer.

Fall tornadoes from 1995 to 2004 appear as blue dots on the map

Q26: In what region of the country are most fall tornadoes?

- a. Midwest
- b. Northeast
- c. South
- d. West

102. Hover on the **Fall Tornadoes** layer and click on the Show Table button.



Look at the top title bar to see how many records (features) are in the table.

Q27: How many tornadoes occurred in fall between 1995 and 2004?

Q28: Which season had the most tornadoes?

- a. Winter
- b. Spring
- c. Summer
- d. Fall

Q29: What is the peak season for the southern states (the season when the South has the most tornadoes)?

- a. Winter
- b. Spring

- c. Summer
- d. Fall

Q30: What is the peak season for the northern states (the season when they have the most tornadoes)?

- a. Winter
- b. Spring
- c. Summer
- d. Fall

Q31: Discuss with your classmates some possible reasons that the locations of tornadoes change with the season. Write down two possible reasons.

- a.
- b.

Task 8: Exit ArcGIS Online.

103. Close the ArcGIS Online browser tab.

Concluding the Lesson

Engage students in a discussion about the observations and discoveries they made during their exploration of US tornadoes and Tornado Alley.

“People who live in Tornado Alley are aware of the dangers of tornadoes and understand that they are part of life.

“GIS can help researchers and scientists map patterns that show where tornadoes touch down and study how tornadoes behave on the ground, including how far and fast they move and how wide an area they cover. Their research leads to better warning systems and better methods for predicting when a tornado might occur. These improvements make it safer for people who live in Tornado Alley.”

Have students turn in their **Student Activity: Finding Tornado Alley and Map of the 48 States** worksheet to be graded.

Extension of the Lesson

Give each student three copies of the **Map of the 48 States**. Have students color each map according to the three columns from the **Tornado Alley** worksheet: frequency, intensity, density. Students should title each map correctly. After the maps are colored, have students compare the maps and discuss differences among the three.

Then, have students compare their map of tornado frequency to this map of Tornado frequency from 1950–1995. Are there similarities? Differences?

<http://www.britannica.com/science/tornado/images-videos>

Answers

Q1: Central and eastern states

Q2: No

Q3: No

Q4: Great Plains

Q5: Gulf of Mexico

Q6: Canada

Q7: Texas

Q8: Texas, Kansas, Florida, Oklahoma, Illinois, Nebraska

Q9: Answers may vary but should include Texas, Kansas, Arkansas, Oklahoma, Tennessee

Q10 & 12: Texas, Arkansas, Tennessee

Q11 & 13: 31 (Texas), 35 (Arkansas), or 30 (Tennessee)

Q14: Arkansas, Texas, Tennessee, Kansas, Oklahoma, Mississippi

Q15: South Dakota, Iowa, Nebraska, Illinois, Colorado, Kansas, Oklahoma, North Carolina, Texas, Arkansas, Florida

Q16: 11

Q17: Texas, Kansas, Oklahoma, Illinois, Iowa, Arkansas

Q18: South

Q19: 784

Q20: South

Q21: 5,285

Q22: Answers may include the following:

There are many more tornadoes in the spring

Winter tornadoes occur mostly in the South, with very few in the Midwest or Northeast

Spring tornadoes extend much farther north and west

Spring tornadoes cover a much bigger area of the United States

Q23: Midwest

Q24: Answers may include the following:

Summer tornadoes are more concentrated in the northern states

Spring tornadoes are more concentrated in the southern states

Q25: 4,380

Q26: South

Q27: 2,173

Q28: Spring

Q29: Fall

Q30: Summer

Q31: Answers may include the following:

The temperature warms in the spring and summer

More thunderstorms occur in the spring and summer

The sun is farther north in the sky during spring and summer

The temperature difference between warm and cold air masses is greater during the spring and summer, producing more thunderstorms.

3. Look at the ArcGIS Online map window and observe the following:
 - On the right side you see a map.
 - On the left side you see a column that displays the legend for the map.
 - In the top right corner you will see a “Modify Map” link.
4. Click on the Modify Map link in the top right corner of the map view.
5. Look at the top of the ArcGIS Online map viewer window and notice the different buttons. You will use some of these buttons as you progress through this lesson.



Task 2: Enlarge the ArcGIS Online window

If the ArcGIS Online Map Viewer window is small when the map document first opens, you may wish to enlarge it.

6. In the upper right corner (PC) or upper left corner (Mac) of your ArcGIS Online window there are three buttons. Click the middle button (PC) or the right green button (Mac).



Now the ArcGIS Online Map Viewer window fills your whole screen.

You can also change the size of your ArcGIS Online window by stretching it. Stretching the window instead of maximizing it allows you to organize other windows and dialog boxes as they appear.

7. Place the cursor on any corner of the ArcGIS Online window that is not at the edge of your screen. The cursor changes to a diagonal double-headed arrow. Click and drag the window outward until the ArcGIS Online window fills about two-thirds of the screen. Let go of the mouse button.

Task 3: Tornadoes of the United States

8. Hover over and click on Show Contents of Map button.



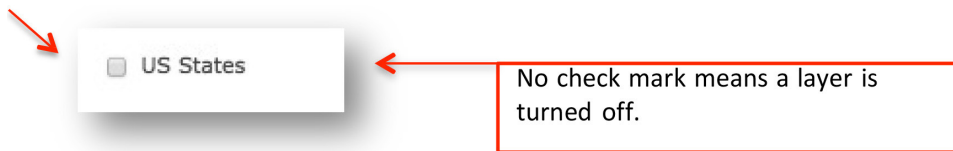
In ArcGIS Online Map Viewer, a map is made up of layers.

9. Look at the Contents area on the left of the map and observe the following:

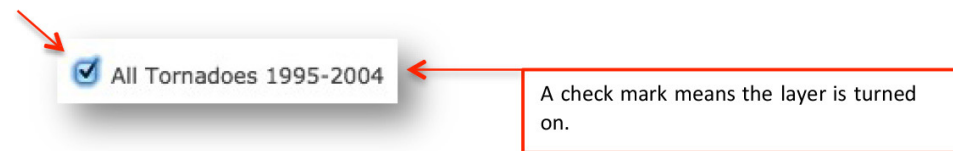
- There are thirteen layers: Names, US States–Outlines, State Tornadoes, Winter Tornadoes, Spring Tornadoes, Summer Tornadoes, Fall Tornadoes, Strongest Tornadoes, Tornado Density, US States, All Tornadoes 1995-2004, Landforms, and Light Gray Canvas basemap.
- Each layer except the last layer (the Light Gray Canvas basemap) has a small box in front of it.
- The boxes for US States, US States – Outlines, and Landforms are checked.
- The other boxes in front of the layers are unchecked.

Next you will learn how to turn layers on and off.

10. Turn off the US States layer by clicking the box next to the layer name.



11. Turn on the All Tornadoes 1995-2004 layer by clicking the box next to the layer name. Each dot represents a tornado that occurred from 1995-2004 (a period of 10 years).



This is called turning a layer on and off.

Q1: Look at your map. In what part of the country do most tornadoes occur?

- Eastern states
- Western states
- Central and eastern states

Q2: Do you see any states that don't have tornadoes?

- Yes
- No

12. Zoom out of the map until all 50 states are in view.

Q3: Do you see any states now that don't have tornadoes?

a. Yes

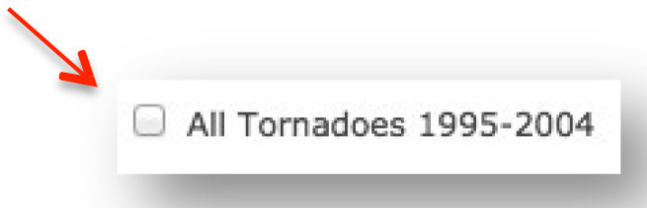
b. No

13. Zoom back in to the 48 states. Tornadoes are more common in some parts of the country than others. Let's look at a different view of the United States.

14. Turn off the US States — Outlines layer by clicking the check mark next to the layer name.



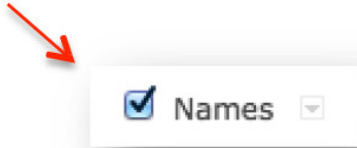
15. Turn off the All Tornadoes 1995-2004 layer.



You are now looking at an image of the United States showing high areas (mountains) and low areas (plains and valleys). This is called a Physical Map of the United States.



16. Turn on the Names layer by clicking the box next to the layer name.



Now you see the names of some of the landforms of the United States.

17. Turn on the All Tornadoes 1995-2004 layer again.

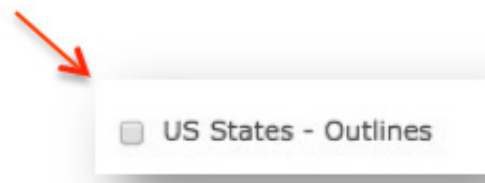


Q4: Look at your map. In what part of the country do most tornadoes occur?

- a. Rocky Mountains
- b. Great Plains
- c. Appalachian Mountains

The Great Plains has lots of thunderstorms, creating the kind of weather conditions that can cause tornadoes. Thunderstorms occur when warm, moist air meets cool, dry air.

18. Turn on the US States—Outlines layer.



Warm, moist air that feeds these thunderstorms comes from the body of water south of the Great Plains.

Q5: Look at your map. What is the name of this body of water?

Cool, dry air comes from the land to the north of the Great Plains.

Q6: Look at your map. What is the name of this country?

19. Turn off the Names layer.

20. Turn off the All Tornadoes 1995-2004 layer.

Task 4: States where tornadoes occur most often

While Tornado Alley is generally in the middle of the country, many people argue about the specific states that belong in this area. There are three different ways, or methods, to decide which states are in Tornado Alley:

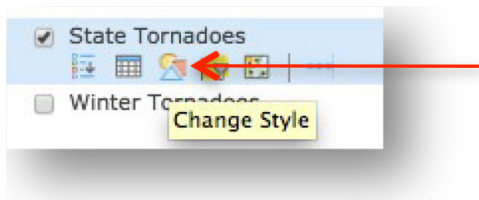
1. States where tornadoes occur most often (frequency)
2. States where the most dangerous tornadoes occur (intensity)
3. States where the greatest concentration of tornadoes occurs (density)

You will use GIS to analyze these three methods and decide on some of the states that are in Tornado Alley. You will start by finding out where tornadoes occur most often.

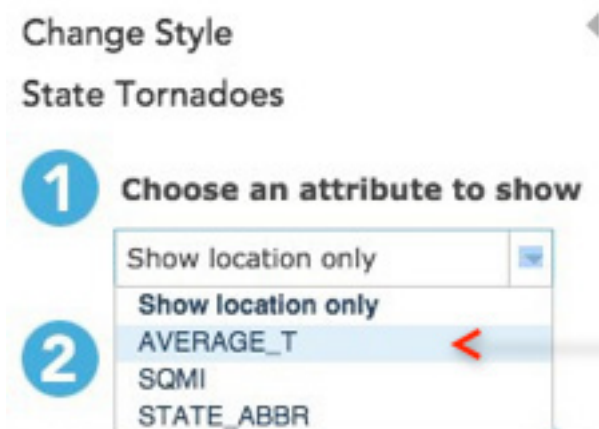
21. Turn on the State Tornadoes layer.

The State Tornadoes layer contains information about the tornadoes for each state. You will change its symbols.

22. Hover over the State Tornadoes layer and click on Change Style.



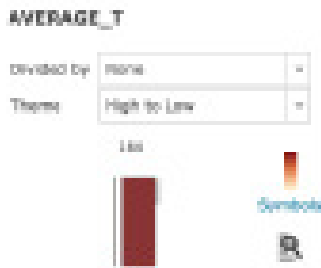
23. Click on the down arrow next to Choose an attribute to show and select AVERAGE_T.



24. Click on the Counts and Amounts (Color) SELECT box and click on OPTIONS.



25. Click on Symbols.

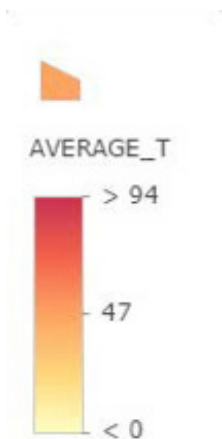


26. Choose the Red to Yellow color ramp.



27. Click OK.

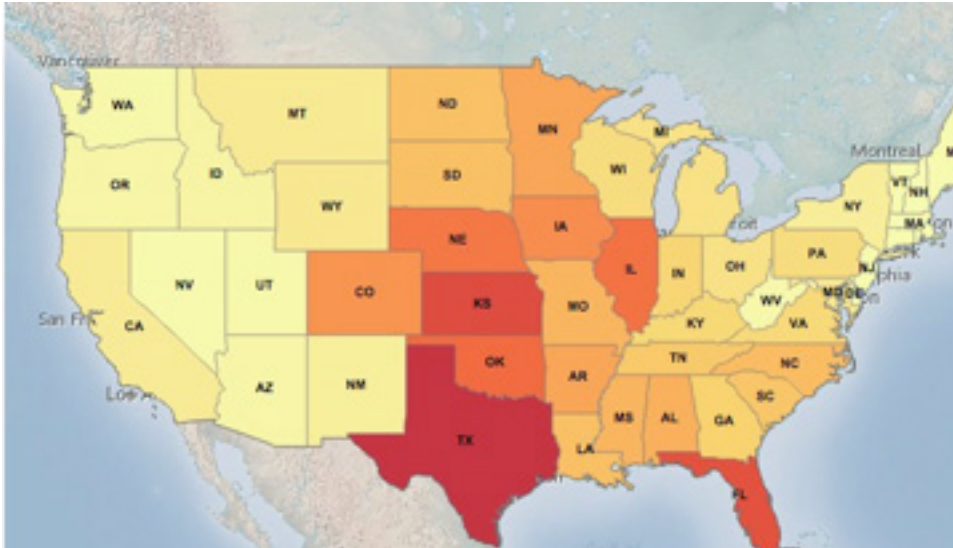
28. Drag the slider to the left of the color ramp to 94.



29. Click OK.

30. Click Done.

You see a map showing the average number of tornadoes per year in each state (from 1995 to 2004). The red color means there were a lot of tornadoes; the yellow means there were relatively few tornadoes.



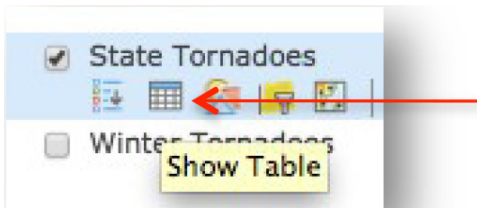
Q7: Look at your map and at the legend. In which state did tornadoes occur most often?

What does “average number of tornadoes per year” mean?

Suppose a state had 200 tornadoes from 1995 to 2004 (a period of 10 years). If you divide the total number of tornadoes (200) by the number of years (10), you will get the average number of tornadoes per year:

$$200 \div 10 = 20 \text{ tornadoes per year}$$

31. Hover over the State Tornadoes layer and click on the Show Table button. This brings up the table of state tornado data.



32. Click on the field name AVERAGE_T and choose Sort Descending. The states are listed in order from the highest number to the lowest number of tornadoes.



Let's look at the top six states.

33. Hold down your Shift key on the keyboard, and slowly click the first six records in the table (count them). They become highlighted in blue. They also become highlighted on your map. You may need to scroll down to see the sixth record in the table and also drag your map up slightly to see all of the six states highlighted on your map.

STATE_NAME	STATE_POP	STATE_AREAS	EQPT	TOTAL_T	AVERAGE_T
Texas	48	79	244,476	1,476	14
Illinois	30	65	81,197	911	9
Florida	12	71	71,445	793	14
Mississippi	66	68	70,000	667	6
Missouri	17	51	74,288	643	6

Note: If you make a mistake, click the first record without holding down the CTRL key. Then hold down the CTRL key and click the next five records.

34. Look in the table for the STATE_NAME field. You see the names of six states highlighted in blue.
35. Take out the **Tornado Alley** worksheet that your teacher gave you.
36. Find Column I: Highest average number of tornadoes.

Q8: Write the names of these six states in Column I of your worksheet. (Some state names are filled in for you.)

37. Close the table of attributes.

Task 5: State where the strongest tornadoes happen.

Another way to decide which states are in Tornado Alley is to see where the strongest tornadoes happen. The strength of a tornado is measured by the speed of its winds and by how much damage it causes. You will look at which states had the strongest tornadoes between 1995 and 2004.

38. Turn off the State Tornadoes layer.

State Tornadoes <

39. Turn on the **Strongest Tornadoes** layer.

Strongest Tornadoes <

Each purple dot represents a single tornado. These tornadoes had winds that were stronger than 150 miles per hour and caused a lot of damage. Only a small portion of all tornadoes, are really strong.

Q9: Look at the map. List two states that you think have a high number of strong tornadoes.

1. _____

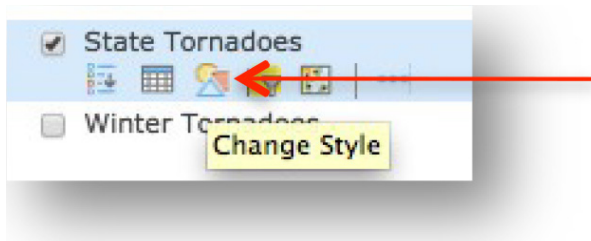
2. _____

Now you will find out if you were right.

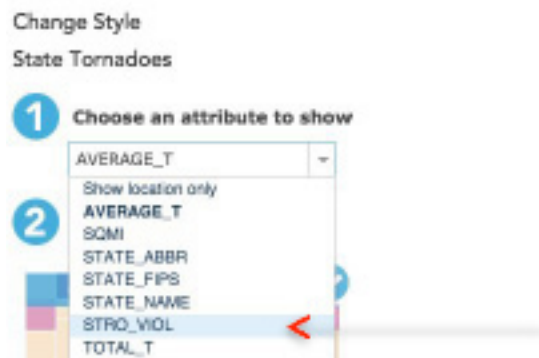
40. Turn off Strongest Tornadoes.

41. Turn on State Tornadoes.

42. Hover over the State Tornadoes layer and click on the Change Style button.



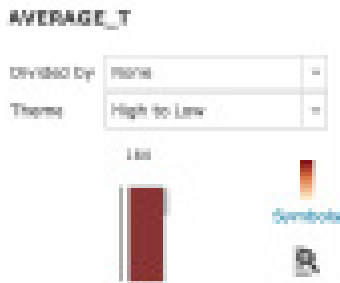
43. Click on the down arrow next to Choose an attribute to show and select STRO_VIOL.



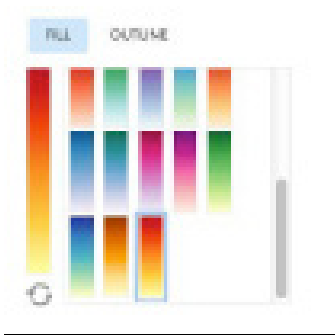
44. Click on the Counts and Amounts (Color) SELECT box and then the OPTIONS box.



45. Click on Symbols.

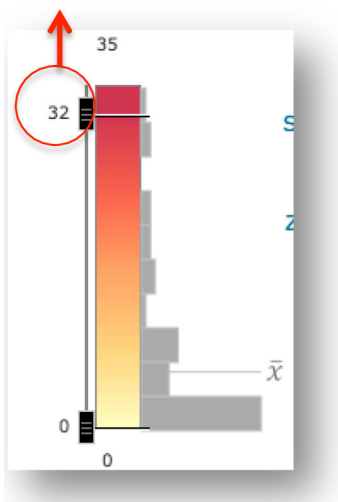


46. Choose the Red to Yellow color ramp.



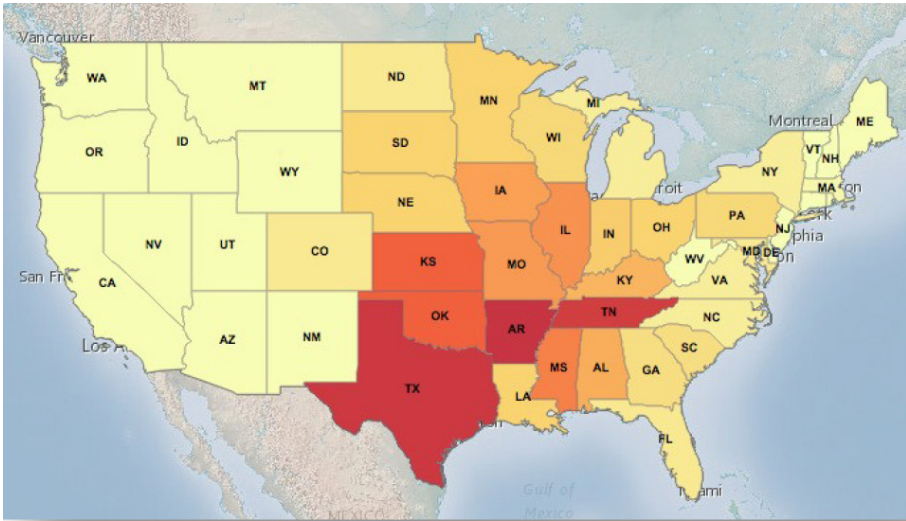
47. Click OK.

48. Drag the slider to the left of the color ramp to 32.



49. Click OK.

50. Click Done.



The red color means more strong and violent tornadoes the yellow color means less.

51. Click one of the dark red states.

52. On the left side of the popup window you see the name of the field names. On the right side you see the values.

53. Look at the value for the STRO_VIOL field. It tells you the number of strong and violent tornadoes that occurred in that state from 1995 to 2004.

Q10: What is the name of this state?

Q11: How many strong and violent tornadoes did it have from 1995 to 2004?

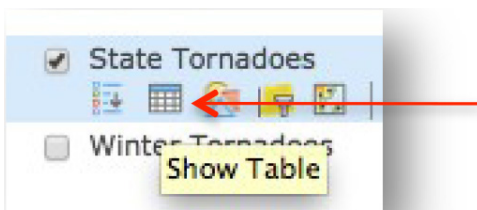
54. Click another dark red state on the map.

Q12: What is the name of this state?

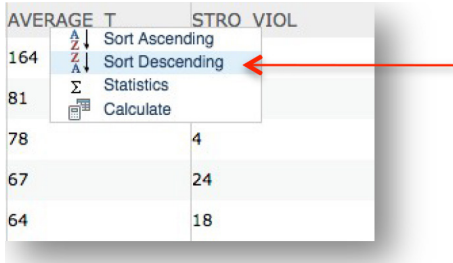
Q13: How many strong and violent tornadoes did it have from 1995 to 2004?

55. Close the popup window.

56. Hover over the State Tornadoes layer and click on the Show Table button.



57. Click on the field name STRO_VIOL and choose Sort Descending.



The states are now listed in order from the highest number of strong and violent tornadoes to the lowest number.

Let's look at the top six states.

58. Hold down your Shift key on the keyboard, and slowly click the first six records in the table (count them). They become highlighted in blue. They also become highlighted on your map.

You may need to scroll down to see the sixth record in the table and also drag your map up slightly to see all of the six states highlighted on your map.

SQMI	TOTAL_T	AVERAGE_T	STRO_VIOL
52,913	454	45	35
264,436	1,636	164	31
42,092	278	28	30
70,003	667	67	24
82,197	811	81	24

Note: If you make a mistake, click the first record without holding down the CTRL key. Then hold down the CTRL key and click the next five records.

59. Let go of the Shift key.

60. Look to the left in the table until you see STATE_NAME. You see the names of six states highlighted in blue.

61. Take out the Tornado Alley worksheet.

62. Find Column 2: Highest number of strong or violent tornadoes.

Q14: Write the names of these six states in Column 2 of your worksheet. (Some state names are filled in for you.)

63. Close the table of attributes.

Task 6: States with the highest concentration of tornadoes.

Looking at tornado density is a third way to decide which states are in Tornado Alley. This shows where the most tornadoes occurred within the smallest area of land (closest together). When you map how close together or far apart tornadoes are, you call this a tornado “density” map.

64. Turn off State Tornadoes.



65. Turn on the Tornado Density layer and the US States – Outlines layer.



The dark red areas show where tornadoes are most dense (close together). The light red (pink) areas show where tornadoes are least dense (spaced far apart).

66. Look at the map. The highlighted areas are where tornadoes are most dense (close together).

67. Take out the **Tornado Alley** worksheet.

68. Find Column 3: Highest tornado density.

Q15: Write the names of the states that have the most dense tornadoes in Column 3 of your “Tornado Alley” worksheet. (If you have turned off your US States–Outlines layer, turn it on to see the state name abbreviations.)

Q16: How many states contain dense tornado areas?

69. Turn off the Tornado Density layer.

You have defined Tornado Alley in three different ways:

1. States where tornadoes occur most often.
2. States where the strongest tornadoes occur
3. States where tornado density is highest

You listed these states on your **Tornado Alley** worksheet in Columns 1, 2, and 3.

70. Look at Columns 1, 2, and 3 now.

Q17: Which states appear in all three lists? Write the names of these states at the bottom of your “Tornado Alley” worksheet under “States in Tornado Alley.” (Two state names have already been filled in for you.)

71. Take out your **Map of the 48 states** worksheet.

72. Color in these six states on the map.

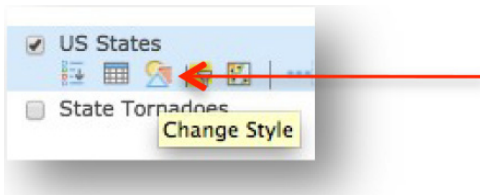
Over 10 years, from 1995 to 2004, these states have been in Tornado Alley no matter what method you use to define this area.

Task 7: Where tornadoes occur during the seasons.

You have seen how tornadoes can occur close together over land. They can also occur close together over time. In this step you will look at where tornadoes occur during each season of the year and in each region of the United States.

73. Turn on the US States layer.

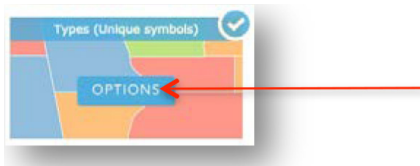
74. Hover over the US States layer and choose Change Style.



75. Click on the down arrow next to Choose an attribute to show and select REGION.



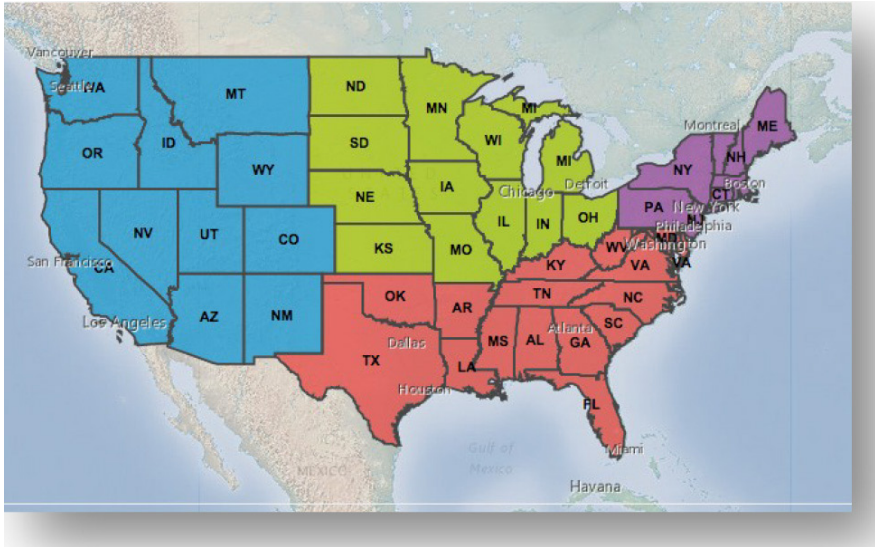
76. Click on the Types (Unique symbols) Options box.



77. Click on OK to accept the automatic style change.

78. Click Done.

You see four United States regions, each with a different color, and you can see the state outlines.



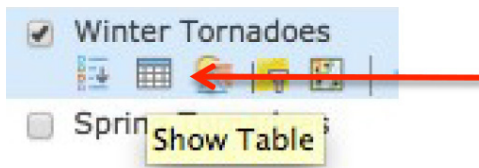
79. Turn on the Winter Tornadoes layer.

80. Winter tornadoes from 1995 to 2004 appear as green dots on the map.

Q18: Look at the map. In what region of the country are most winter tornadoes? Hint: Look at the States legend to see the names and colors of the regions.

- a. Midwest
- b. Northeast
- c. South
- d. West

81. Hover over the Winter Tornadoes layer and click on the Show Table button.



82. Look at the top title bar to see how many records (features) are in the table.

Q19: How many tornadoes occurred in winter between 1995 and 2004?

83. Close the table of attributes.

84. Turn off the Winter Tornadoes layer.

85. Turn on the Spring Tornadoes layer. (If you receive a “Layer did not draw completely” message, click on OK.)

Spring tornadoes from 1995 to 2004 appear as red dots on the map.

Q20: In what regions of the country are most spring tornadoes? (Circle the correct answers.)

- a. Midwest
- b. Northeast
- c. South
- d. West

86. Hover on the Spring Tornadoes layer and click on the Show Table button.



87. Look at the top title bar to see how many records (features) are in the table.

Q21: How many tornadoes occurred in spring between 1995 and 2004?

88. Close the table of attributes.

Q22: Look at the map. List two differences between winter tornadoes and spring tornadoes. (Hint: You can turn both layers on at the same time or turn them on and off to compare them.)

- a. _____
- b. _____

89. Turn off the Spring Tornadoes layer.

90. Turn on the Summer Tornadoes layer.

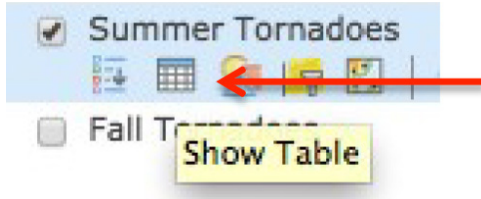
Summer tornadoes from 1995 to 2004 appear as yellow dots on the map.

Q23: In what region of the country are most summer tornadoes?

- a. Midwest
- b. Northeast
- c. South
- d. West

Q24: Look at the map. List one difference between summer tornadoes and spring tornadoes. (Hint: You can turn both layers on at the same time or turn them on and off to compare them.)

91. Hover on the Summer Tornadoes layer and click on the Show Table button.



Look at the top title bar to see how many records (features) are in the table.

Q25: How many tornadoes occurred in summer between 1995 and 2004?

92. Close the table of attributes.

93. Turn off the Summer Tornadoes layer.

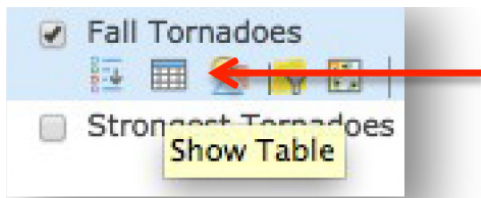
94. Turn on the Fall Tornadoes layer.

Fall tornadoes from 1995 to 2004 appear as blue dots on the map

Q26: In what region of the country are most fall tornadoes?

- a. Midwest
- b. Northeast
- c. South
- d. West

95. Hover on the Fall Tornadoes layer and click on the Show Table button.



Look at the top title bar to see how many records are in the table.

Q27: How many tornadoes occurred in fall between 1995 and 2004?

96. Close the table of attributes.

Q28: Which season had the most tornadoes?

- a. Winter
- b. Spring
- c. Summer
- d. Fall

Q29: What is the peak season for the southern states (the season when the South has the most tornadoes)?

- a. Winter
- b. Spring
- c. Summer
- d. Fall

Q30: What is the peak season for the northern states (the season when they have the most tornadoes)?

- a. Winter
- b. Spring
- c. Summer
- d. Fall

Q31: Discuss with your classmates some possible reasons that the locations of tornadoes change with the season. Write down two possible reasons.

- a. _____
- b. _____

Task 8: Exit ArcGIS Online.

97. Close the ArcGIS Online browser tab.

Conclusion

People who live in Tornado Alley are aware of the dangers of tornadoes and understand that they are part of life.

GIS can help researchers and scientists map patterns that show where tornadoes touch down and study how tornadoes behave on the ground, including how far and fast they move and how

wide an area they cover. Their research leads to better warning systems and better methods for predicting when a tornado might occur. These improvements make it safer for people who live in Tornado Alley.

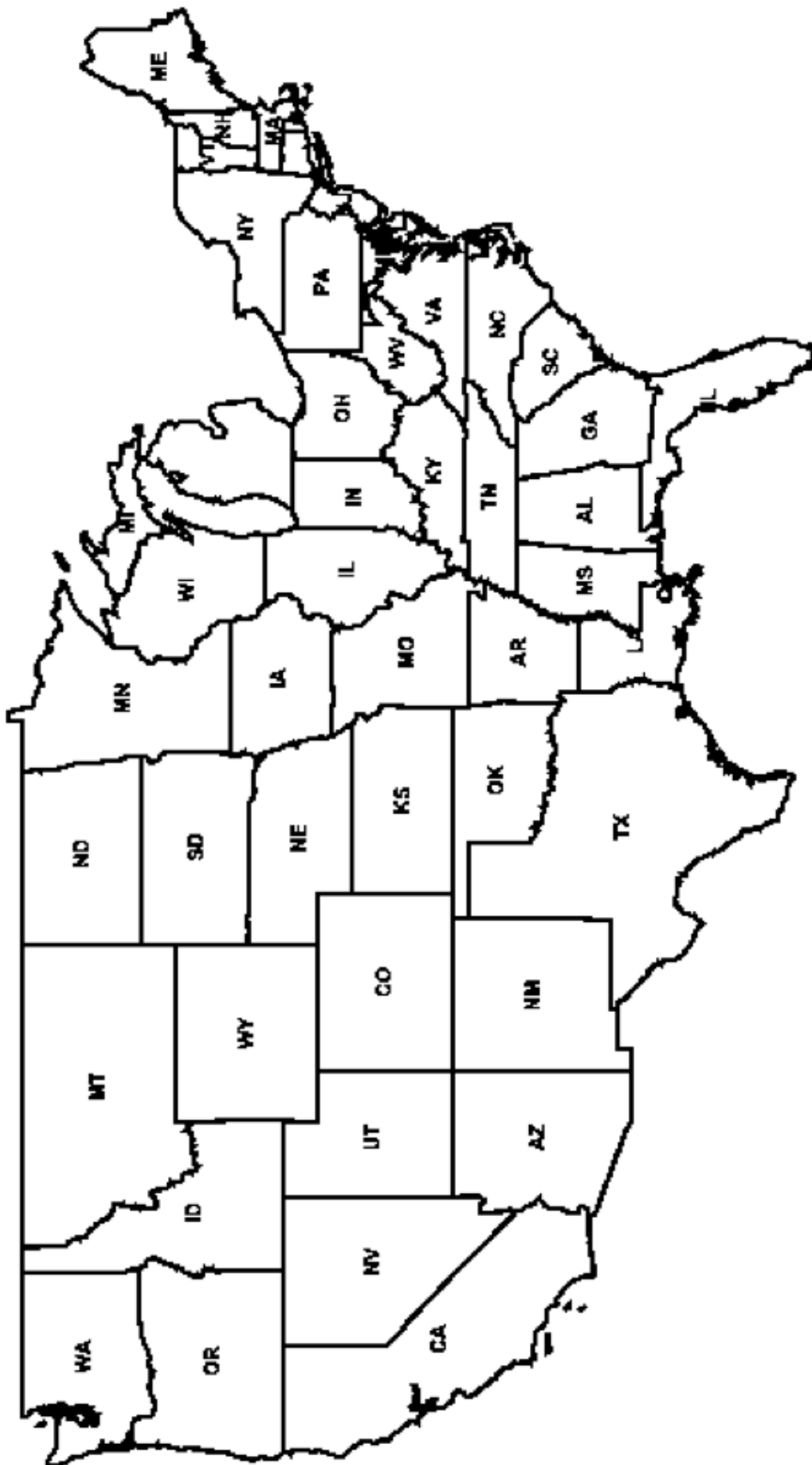
Worksheet I:
Tornado Alley

Column 1	Column 2	Column 3
Highest average number of tornadoes	Highest number of strong or violent tornadoes	Highest tornado density
1.	1.	1.
2.	2.	2.
3.	3.	3.
4.	4.	4.
5.	5.	5.
6.	6.	6.
7. Iowa	7. Illinois	7.
8. Colorado	8. Missouri	8.
9. Minnesota	9. Iowa	9.
10. Arkansas	10. Alabama	10.
11. Alabama	11. Kentucky	11.

States in Tornado Alley

1. Texas
- 2.
- 3.
- 4.
- 5.
6. Arkansas

Worksheet 2:
Map of the 48 States



Optional Breakout Lesson I: *Map Scale and Measurement*

Part I: Map Measurements: Use the map provided by your teacher.

You are planning a trip from _____ to _____ on Highway _____.
(city name) (city name) (Route)

You want to determine the distance between these cities by using the map. On the map, locate the legend showing the scale of miles and answer the following questions. Show your math.

1.

1 inch = _____ miles

1 inch = _____ kilometers

3 inches = _____ miles

2. How many inches are there between the two cities listed above? Show your work below and fill in the statement.

There are _____ inches between _____ and _____.
(city name) (city name)

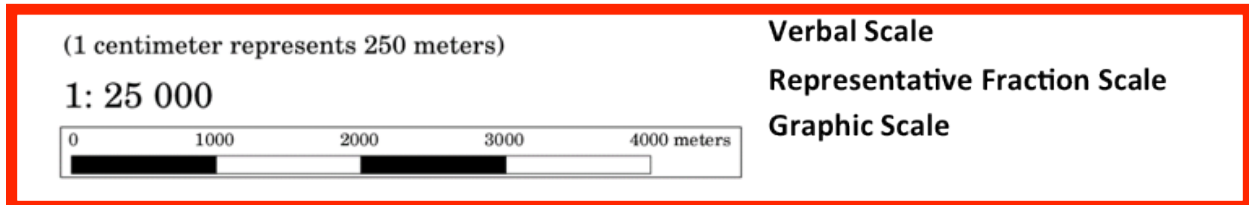
3. How many miles are there between these two cities?

There are _____ miles between _____ and _____.
(city name) (city name)

Lesson revised from: <http://illuminations.nctm.org/lesson.aspx?id=1675>



Three ways to express scale:

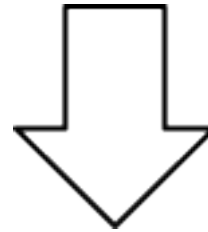


Source: https://docs.qgis.org/2.6/en/docs/gentle_gis_introduction/map_production.html

Part 2: Large Scale versus Small Scale



A LARGE SCALE map shows a smaller area in greater detail



A SMALL SCALE map shows a larger area in less detail

Identify the following map pairs as either LARGE-SCALE or SMALL-SCALE. Write large or small on the blank line.



a. _____



b. _____



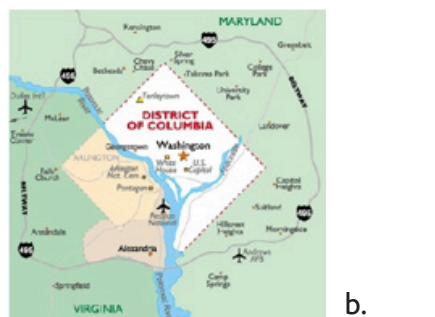
a. _____



b. _____



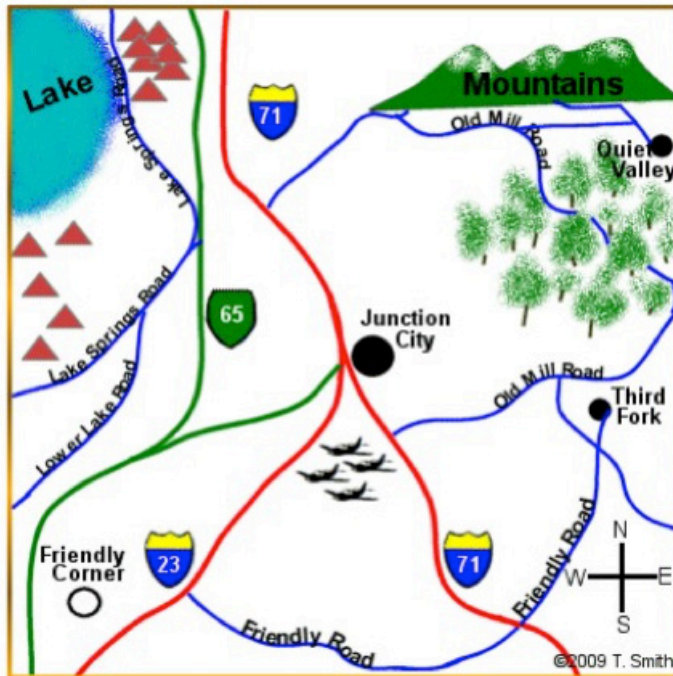
a. _____



b. _____

Optional Breakout Lesson 2: Symbols and Map Features

Maps are used to represent a variety of information. This information includes things such as roads, parks, cities, rivers, and buildings. These features are represented by symbols. A symbol is a picture on a map that represents something in the real world. Understanding what the symbols mean requires the use of a map key or legend. The map key explains what the symbols represent.



1. Circle the symbol that represents an airport?



2. The red triangle symbol represents what map feature? _____

3. Draw the symbol that you think represents a forest?

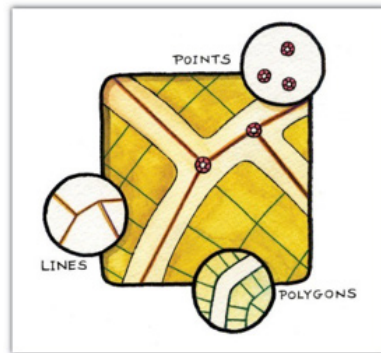
Symbols also represent a characteristic of a map feature which may influence the **size**, **color**, and shape of the symbol used.

4. What data do the three various circles  represent? Why would they use three different circles to represent this data?

5. Why are there three different colors of lines? What do the three colors represent?



In mapping, there are three types of features: point (hospital), line (roads) or polygons (park).



Identify the following features as either point, line or polygons



2.





4.





6.



Optional Breakout Lesson 3:

Calculating Averages

Suppose a state had 200 tornadoes from 1995 to 2004 (a period of 10 years). If you divide the total number of tornadoes (200) by the number of years (10), you will get the average number of tornadoes per year:

$$200 \div 10 = 20 \text{ tornadoes per year}$$

Let's figure out the average number of tornadoes per year for the following states. Round to the nearest ten. Show your math for each state.

1. Texas. Total number of tornadoes over ten years is 1,636. Average number of tornadoes per year
2. Louisiana. Total number of tornadoes over ten year is 333. Average number of tornadoes per year
3. Michigan. Total number of tornadoes over ten years is 157. Average number of tornadoes per year
4. Arizona. Total number of tornadoes over ten years is 40. Average number of tornadoes per year
5. New Jersey. Total number of tornadoes over ten years is 25. Average number of tornadoes per year