Investigation II:
Annual Precipitation in the United States

Purpose
The purpose of this activity is to study the distribution of annual precipitation around the US. Students analyze what regions receive high precipitation and what areas receive low precipitation. Students begin to look at data in various forms, starting with text data from media and scientific resources (Readings for Part 1), they generate predictive data based on their first findings (Paper Map of Annual Precipitation), then they look at geospatial data generated by computer models based on observed data (Annual Precipitation layer from the North American Regional Reanalysis in the GIS). Students are responsible for comparing the data they predicted to the scientific data across and drawing conclusions.

Overview
Students examine total annual precipitation patterns across the continental United States using their existing knowledge of annual precipitation to create a generalized annual precipitation map of the U.S., review a set of short readings and develop a revised total annual precipitation paper map based upon these readings, and begin to develop GIS (Geographic Information Systems) skills as they complete a detailed analysis of total annual precipitation patterns.

Student Outcomes
Part 1
- Develop a generalized knowledge of total annual precipitation patterns across the continental United States.
- Describe which areas of the continental US receive high, medium, and low amounts of total annual precipitation.
- Understand that multiple; interacting Earth systems influence patterns of precipitation.
- Understand the differences between weather and climate.

Part II
- Develop skills in the use of the GIS tool to analyze archived data sets.
- Categorize data

• Interpret data displayed on a map
• Reflect on, review, and revise prior predictions

Time
Part 1 - One 45-50 minute class periods
Part 2 - One 45-50 minute class periods

Level
Secondary

Materials and Tools
Part 1
- Student guide and student response sheets
- Paper copies of blank Map: Total Annual Precipitation Prediction (1 copy per student)
- Student Readings
- Paper copies of student response sheets
- Red & blue markers or colored pencils

Part II
- Computers (1 computer for each student preferred) with access to the Internet (access to url http://wd.fieldscope.us).

Preparation
- Part I - Make appropriate copies (blank maps, student readings, worksheets, etc)

Prerequisites
None; however it would be helpful for students to have gone through Investigation I: Introducing Natural Water Availability.
Review the following with Students:

**Background**

Part 1
- What is GIS?
- Earth system science terminology used in this activity:
  - Precipitation—water, in liquid or solid form, that is deposited on the surface of the Earth from the atmosphere. Forms of precipitation include rain, drizzle, sleet, snow, hail, and dew.
  - Total annual precipitation—the total amount of precipitation that occurs over a period of one year in any given place.
  - Contiguous United States—the continuous 48 states, excluding Alaska and Hawaii.

Part 2
- How to use the GIS analysis tool.
- Students learn to use the GIS (Geographic Information System) tool to see how complex precipitation data can be displayed on a map and analyzed.

**Teaching Notes**

Part 1: How Wet or Dry Is It Across the US?
- This activity asks students to read a short set of articles about precipitation patterns in different regions of the US. These readings do not cover every study city or region of the US. You could provide additional resources for students to investigate annual precipitation in more depth. These resources might include atlases, textbooks, wall maps, and climate web sites.

Part 2: Total Annual Precipitation
- Precipitation is expressed as centimeters of water throughout this investigation. Not all precipitation is in the form of rain. When the amount of snow, rain, sleet, hail, or any type of precipitation is measured, it is measured as the amount of melted, liquid water. Therefore the term “precipitation” is best thought of as “liquid water,” or just “water.”

**What is the “Annual Precipitation” layer?**

This GIS data layer contains seasonal as well as annual precipitation, evaporation, and water runoff data for the entire continental United States. These data are an average of the ten year long 1996-2005 time period. **NARR** (North American Regional Reanalysis) is a long-term, consistent, high-resolution climate dataset for North America. The NARR Water Data is produced by taking data from weather stations across the country and then using sophisticated computer models to calculate estimated values for those places where there are not any weather stations. The NARR Water Data displayed in each 32 kilometer square pixel (or cell) is a calculated value, not the actual weather station data.

The Annual Precipitation layer in Investigation III contains data on annual precipitation, evaporation and surface runoff (see figure 1). One way to view the list of variables associated with this data layer is by clicking on the down pointing triangle in the **Annual Precipitation** box within the layer list panel. This reveals a list of the variables contained in the Annual Precipitation layer.

**Geographic regions**

Throughout this module of Watershed Dynamics Investigations I-IV students will be exploring NARR Water data in a variety of ways. Some questions expect that students are familiar with standard region...
names such as Pacific Northwest, Rocky Mountain region and Southwest. It may be helpful to review these designations with students prior to beginning the investigations.

Why would we want to investigate the average of ten years (1996-2005) of water data rather than data for just one year?
Questions:

1. How are the maps from the groups similar? How are they different?

   Student answers will vary.

2. What do you think some of the errors, or problems, might be with these prediction maps?

   The data used to color in the maps does not cover the entire continental United States. Students will have to use personal knowledge to predict the gaps between data points, not actual data, thus causing inaccuracies. Students are expected to indicate high, medium, and low categories without a lot of data points to compare.

3. What amounts of total annual precipitation did you consider to be high? Medium? Low?

   Student answers will vary, though students should have attempted to define discrete ranges of total precipitation for each category.

4. What were your reasons for making these high, medium, and low total annual precipitation categories?

   Student answers will vary, though students should have attempted to define discrete ranges of total precipitation for each category.
Map: Total Annual Precipitation Prediction

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Total Annual Precipitation Value From Readings</th>
<th>Is that value High, Medium, or Low?</th>
<th>Total Annual Precipitation From the GIS-Annual Precipitation Layer (centimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, Georgia</td>
<td>127.5 cm</td>
<td>High</td>
<td>124 cm – 127 cm</td>
</tr>
<tr>
<td>Baltimore, Maryland</td>
<td>77.9 cm – 102 cm</td>
<td>Medium</td>
<td>106 cm – 113 cm</td>
</tr>
<tr>
<td>Denver, Colorado</td>
<td>27.9 cm – 45.7 cm</td>
<td>Low</td>
<td>38 cm – 51 cm</td>
</tr>
<tr>
<td>Las Vegas, Nevada</td>
<td>10.5 cm</td>
<td>Low</td>
<td>15 cm – 18 cm</td>
</tr>
<tr>
<td>Little Rock, Arkansas</td>
<td>127 cm</td>
<td>High</td>
<td>107 cm – 124 cm</td>
</tr>
<tr>
<td>Los Angeles, California</td>
<td>29.0 cm</td>
<td>Low</td>
<td>28 cm – 43 cm</td>
</tr>
<tr>
<td>Lubbock, Texas</td>
<td>66.1 cm</td>
<td>Medium</td>
<td>97 cm – 112 cm</td>
</tr>
<tr>
<td>Miami, Florida</td>
<td>204 cm</td>
<td>High</td>
<td>112 cm – 132 cm</td>
</tr>
<tr>
<td>Minnesota (Northwest)</td>
<td>46 cm</td>
<td>Low</td>
<td>46 cm – 58 cm</td>
</tr>
<tr>
<td>Minnesota (Southeast)</td>
<td>81 cm</td>
<td>Medium</td>
<td>74 cm – 91 cm</td>
</tr>
<tr>
<td>Montana</td>
<td>46 cm</td>
<td>Low</td>
<td>Best answer 30 cm, varies 23 cm – 120 cm</td>
</tr>
<tr>
<td>New York City, New York</td>
<td>126.2 cm</td>
<td>Medium</td>
<td>56-117 cm</td>
</tr>
<tr>
<td>Philadelphia, Pennsylvania</td>
<td>102 cm</td>
<td>Medium</td>
<td>114 cm – 122 cm</td>
</tr>
<tr>
<td>Portland, Oregon</td>
<td>91 cm</td>
<td>Medium</td>
<td>120 cm – 224 cm</td>
</tr>
<tr>
<td>Seattle, Washington</td>
<td>94.2 cm</td>
<td>High</td>
<td>104-158 cm</td>
</tr>
<tr>
<td>Tulsa, Oklahoma</td>
<td>103.3 cm</td>
<td>Medium</td>
<td>99 cm – 110 cm</td>
</tr>
<tr>
<td>Tucson, Arizona</td>
<td>30.5 cm</td>
<td>Low</td>
<td>24 cm – 33 cm</td>
</tr>
</tbody>
</table>
Questions:

1. How do the actual total annual precipitation values from the GIS data compare to the values that you found in the newspaper and journal readings?

   The statistics in the readings are similar to the ones found in the NARR data and should lead to a similar picture. Though, because the NARR data is based upon computer modeling, and because it only shows data at a 32 square kilometer resolution, NARR values will not be exactly like those found in the readings.

2. Is the high range of 150 cm on the legend the highest total annual precipitation of the map? What is the highest total annual precipitation value you can find on the map using the Pointer Tool? Where in the U.S. does this region of very high precipitation occur?

   Values reach 422 cm off the coast of Washington state. The values on the map go higher than the scale in the legend at the bottom of the screen, which reads from 0-152 cm. The highest values are in the Pacific Northwest and in the Southeast or the Gulf Coast region.

3. What is the lowest total annual precipitation value you can find using the Pointer Tool? Where in the U.S. does this region very low precipitation occur?

   Values do go as low as 3.5 cm in Southern California and Arizona. As a whole, the Southwest has the lowest precipitation.

4. What is the total annual precipitation value where you live?

   Students answers will vary based on region.

5. Mark the legend below with the ranges of high, medium and low total annual precipitation.

   Student answers should vary (within reason) as this question is written to elicit students’ ideas.

6. How did you decide the dividing points between each of the three precipitation categories? What information did you use to make your decision?

   Student answers will vary, but should justify the break points they chose. An example to justify the above answers: “I chose 76 cm to divide medium from low because it divided the red and blue landmasses into separate categories. The high could be above 127 cm to distinguish areas of extreme precipitation.”

7. Is there only one correct way to divide the range of data into categories? Suggest another range of total annual precipitation values that might be used to divide the data into high, medium, and low categories.

   No, there are multiple valid ways to break the data. The ranges could be equal intervals of 50 cm, or there could be more categories used. Students should elaborate on this question with their own ideas, recognizing that some science is subjective.
8. Compare your answer to question #2 above to the map with Very High Precipitation Areas (>= 125 cm) selected. What additional information is evident on the new map?

Data reported in question #2 is accurate. However, by using the map selection of very high precipitation the areas with extreme amounts of precipitation are clearly visible.

9. Compare your answer to question #3 above to the map with Very Low Precipitation Areas (<25 cm) selected. What additional information is evident on the new map?

Similarly, the areas with extremely low precipitation amounts are clearly evident on the map made using the analyze tool to select values displayed on the map.

10. Overall, how well do your paper map predictions agree with the actual precipitation data shown on the Map Table? In what areas did your predictions not agree? Are there any surprises?

Answers should accurately relate back to their map predictions. Surprises will vary based on their experience and prior knowledge of precipitation rates around the country.

11. How would you compare total annual precipitation east of the Mississippi River versus west of it?

The eastern half of the country receives more precipitation than the western half. Also, the east is more uniform in its wetness, while the west has areas of very high precipitation and areas of very little precipitation.

12. What two regions of the US receive the greatest amount of total annual precipitation?

The Pacific Northwest (parts of Washington, Oregon, and California) and the Southeast (Louisiana, Mississippi, Alabama, Florida, Tennessee, and parts of Georgia, Arkansas, Kentucky)

13. What region of the US receives the least amount of total annual precipitation?

The Desert Southwest (Nevada, Arizona, California, New Mexico, and Utah).

14. Can you tell from the NARR Water Data used thus far what part of the total annual precipitation comes from rain? From snow?

No. This data is only listed as precipitation and is measured in centimeters of liquid water.