GLOBE Watershed Dynamics
Module 1
(FieldScope)

Credit: www.drought.gov

Teacher's Guide

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Any opinions, findings, conclusions or recommendations expressed in this material are those of the developers and do not necessarily reflect the views of the National Science Foundation.

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The GLOBE Watershed Dynamics would like to extend a special appreciation to pilot teachers and evaluators involved in the development and review of these activities.

Welcome to Watershed Dynamics!

Thank you for participating in the Watershed Dynamics Earth System Science Project.

What is Watershed Dynamics?

Watershed Dynamics is a project within the GLOBE Program. Watershed Dynamics is designed to help students deepen their understanding of watersheds, where water is and where is goes over time through:

1. Understanding water availability and precipitation patterns in Module I; and
2. Using NetLogo software, understading hydrographs, gaining hands-on experience through conducting field work and experimenting with the GIS tool in Module II.

For more background on Watershed Dynamics, visit www.globe.gov/projects/watersheds or www.osep.northwestern.edu/projects/GLOBE

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Investigation I:
Introducing Natural Water Availability

Purpose

The purpose of this activity is to prime students to learn about earth systems and the water cycle. Students activate prior knowledge by discussing the questions included in the activity. They build connections and relationships by using the concept mapping tool to organize their thoughts. It is important that students share what they already know so the teacher can help build new knowledge around their existing frameworks and also address student misconceptions.

Overview

This introductory activity jump-starts students' thinking about water availability, water balance, and local area hydrology. Through a series of guided questions students consider some of the factors (precipitation, evaporation, runoff, infiltration, seasonality, etc) that influence local water availability. They finish the lesson by using a computer based concept map tool to develop a concept map that illustrates how multiple interacting processes affect local water availability. Consider breaking students into groups of 2-3 to answer questions and create concept map.

Student Outcomes

- Set the stage for multiple follow-up activities in this unit by getting students to think about the water budget of their local area.
- Generally understand the main Earth system components at play in water availability: precipitation, evaporation, infiltration, and surface runoff.
- Develop a concept map that describes water local availability.
- Depict Earth system inter-relationships on a concept map.

Time

One to two class periods depending on depth of student brainstorming and answers/research

Level

Secondary

Materials and Tools

- IHMC Cmap tools concept mapping software (or equivalent like Inspiration)
- 1 sheet of blank 11 x 17 paper (or larger) per group (optional)
- Pencils or markers (optional)

Preparation

Download CMap onto computers or for developing Concept maps on paper.

Prerequisites

None; although a basic introduction into the following terms and concepts would be beneficial:

- Earth system processes that influence local water availability
- Water cycle
- Watershed concept
- Water balance equation
- Concept mapping complex ideas and inter-relationships

Concept maps can be shaped over time. Since all the Investigations are designed to build on each other you might consider using this introductory Investigation to allow students to get their conceptions and misconceptions down without too much instruction. Review the maps before beginning the next Investigation to identify any major misconceptions or gaps in knowledge that may need more scaffolding. Consider revisiting the concept map throughout the investigation.

Teaching Notes

Prior to starting, explain to your students that the focus of this introductory activity is on natural Earth system processes that affect water availability in the area where they live. Guide students away from thinking about man-made water distribution systems as they answer the discussion questions. Explain that this activity examines the processes of natural water processes/balance in a given region and that it is not about water coming out of a faucet.

You may need to introduce your students to a simple concept map if they are not already familiar with the process of developing concept maps. Consider introducing students to the process of concept mapping on paper prior to using the software. Or demo the software and do a class concept map on a white or black board that is familiar to students.

Student Response Questions

Total Annual Precipitation

a. Where does the water in your area come from?

b. Approximately how much total annual precipitation does your area receive in an average year?

Seasonal Precipitation Patterns

c. Approximately what percentage of the precipitation in your region comes from rain? From snow?

d. What seasons or months of the year are the wettest? The driest?

e. Is there precipitation in your area during the hottest season? During the coldest season?

Surface Runoff

f. If there are rivers, streams, or creeks in your area—when do they flow with the most water? The least?

g. Does any of the water in rivers, streams, or creeks in your area come from melting snow?

h. Where in your area's water system does precipitation go other than runoff into rivers, streams, or creeks?

Infiltration

i. What happens to water in the top meter of the ground during hot, dry weather conditions? During cool, wet weather conditions?

j. What happens to water that seeps into the ground?

k. Are there water wells in your area? If there are wells, where does the water in these wells come from?

Weather and Climate Change

l. Has the amount of available water in your area changed over long periods of time (tens of years)?

m. What evidence have you seen that would indicate that there is sometimes too much water in your area?

n. What evidence have you seen that would indicate that there is sometimes too little water in your area?

Watersheds

o. Every local area is located within a watershed. What is a watershed? What rivers, streams, or creeks are there in your watershed? What are the physical boundaries of your watershed?

p. Does any water in your region come from other regions? If so, how?

Land-use Changes

q. How has human development changed water availability in your local area?

Water Cycle

r. What is the water cycle? What parts of the water cycle occur within your local area?

IHMC Cmap Tools concept mapping software

With Cmap there is no need for students to make multiple drafts of their concept map. Since Cmap is computer based it gives students the flexibility to edit, delete and add to their map right on the screen. Cmap allows students to work synchronously or asynchronously with others on a concept map. Concept maps created with Cmap can be saved, emailed, shared, printed out in a variety of formats, embedded in other documents or saved as a webpage. Cmap can be downloaded at no cost from the IHMC Cmap webpage. The link is: http://cmap.ihmc.us/

Simply click on “downloaded” (near the bottom of the concept map at this site) and a window will open asking you to choose platforms and download the tool. Follow the install wizard that will open when you access the program for the first time to set-up Cmap.

Note: You may also have access to other concept mapping tools such as Inspiration. Feel free to use another application if it’s available. The tool itself is not important – rather the creation, use and editing of the concept map.

Creating a concept map using Cmap

Step-by-step instructions for creating a concept map using Cmap are included in the student version of the lesson. They are repeated here to get you started:

Launch Cmap Tools program on your computer.

Note on Text Formatting Conventions Used in the Investigation Directions

Italicized – Commands executed by student or typing completed by the student in Cmap
Bold – Window, layer, or window names displayed by program
Underlined – A variable selected from pull-down menu
Shaded – Questions or sections to be answered or completed by the student.

Click on file and choose new Cmap.

A new window will open. Double click in the center to begin creating your concept map.

Follow the instructions on the screen to edit text and add new bubbles. Be sure to explore the Styles window to change the appearance of your concept map.

To get started, use the concept headers above each group of questions you answered with your group in part 1 of this lesson. These topic headers will form the basic structure for your concept map.

Save your concept map within Cmap or export it in a variety of formats. To save your concept map click file then click save Cmap. Choose a destination to save the concept map and name your Cmap.

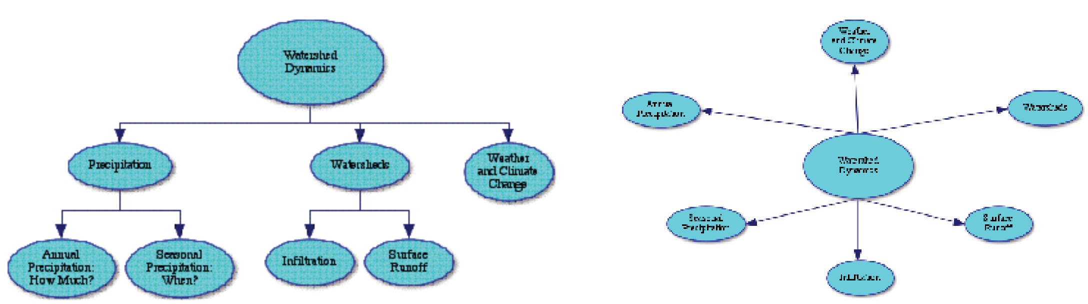


Figure 1, Foundational concept map examples

Notes on Technology (new)

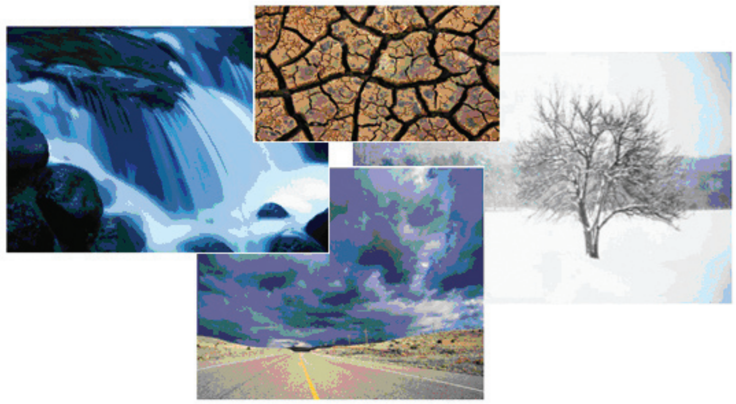
- IHMC Cmap Tools concept mapping software
- With Cmap there is no need for students to make multiple drafts of their concept map. Since Cmap is computer based it gives students the flexibility to edit, delete and add to their map right on the screen. Cmap allows students to work synchronously or asynchronously with others on a concept map. Concept maps created with Cmap can be saved, emailed, shared, printed out in a variety of formats, embedded in other documents or saved as a webpage. Cmap can be downloaded at no cost from the IHMC Cmap webpage. The link is:http://cmap.ihmc.us/

- Simply click on download and a window will open asking you to choose platforms and download the tool. Follow the install wizard that will open when you access the program for the first time to set-up Cmap.

- Note: You may also have access to other concept mapping tools such as Inspiration. Feel free to use another application if it's available. The tool itself if not important – rather the creation, use and editing of the concept map.

Investigation I:
Introducing Natural Water Availability

Part 1: Developing a Concept Map Describing Natural Local Water Availability



It is an early Monday morning and you are just waking up. You yawn, stretch and get out of bed and head to the bathroom. Without even thinking about it you turn on the faucet and out comes clean, clear water. Have you ever stopped to think about how that water gets to you? Humans have done an amazing job creating systems that capture, filter and move water around to meet our needs. However, humans aren't the only creative system engineers; nature has developed a pretty great water, or hydrologic, system itself.

In this investigation, we want you to think about all the ways that water, in all it's forms (liquid, solid and gas), moves through your local environment. You and your peers will work together to develop a picture of your ideas – this is called a Thinking or Concept Map. Using the Key Concepts below – write down words and phrases that you know relate to the concepts. Your teacher will give you more specific instructions depending on how you will build your concept map. Don't worry about knowing it all, not knowing it all or about being right. This is just the first step in a process of exploration and investigation. Throughout the coming investigations you will be building your knowledge and understanding of the watery (or not so watery) world around you.

In preparation to construct your concept map, first consider and answer the list of questions on the **Student Response Sheet** located at the end of the activity. The questions focus on natural water availability in the area where you live.

Note on Text Formatting Conventions Used in the Investigation Directions
Italicized – Commands executed by student or typing completed by the student in Cmap **Bold** – Window, layer, or window names displayed by program <u>Underlined</u> – A variable selected from pull-down menu Shaded – Questions or sections to be answered or completed by the student.

The goal of these questions is for you to think about the natural processes and features that affect natural water availability in your area. Your answers will be used later in this activity to help develop a water availability concept map for your local area. Take the time to seriously consider and answer each question. Answer the questions to the best of your ability with the knowledge you already have.

<u>Creating a concept map using Cmap Tools (or other concept mapping tool):</u>

1. You will be using Cmap to create a concept map to link answers and ideas about water availability your group had together. Cmap is a computer software tool that allows you to create, edit, delete, add, and share concept maps.
2. *Launch* Cmap Tools program on your computer.
3. *Click* on **file** and *choose* <u>new Cmap</u>.

4. A new window will open. *Double click* in the center to begin creating your concept map.

5. Follow the instructions on the screen to edit text and add new bubbles. Be sure to explore the Styles window to change the appearance of your concept map.

To get started, use the concept headers above each group of questions you answered with your group in part 1 of this lesson. These topic headers will form the basic structure for your concept map.

6. Save your concept map within Cmap or export it in a variety of formats. To save your concept map *click* **file** then *click* save Cmap. Choose a destination to save the concept map and name your Cmap.

7. As a group, make a 3-4 minute presentation to the class describing the key features and interrelations depicted on your concept map.

Part 2: Extension—Compare and Contrast Your Concept Map to a Classic Water Cycle Diagram

Compare your concept map to Figure 1 below depicting the Earth's water cycle.

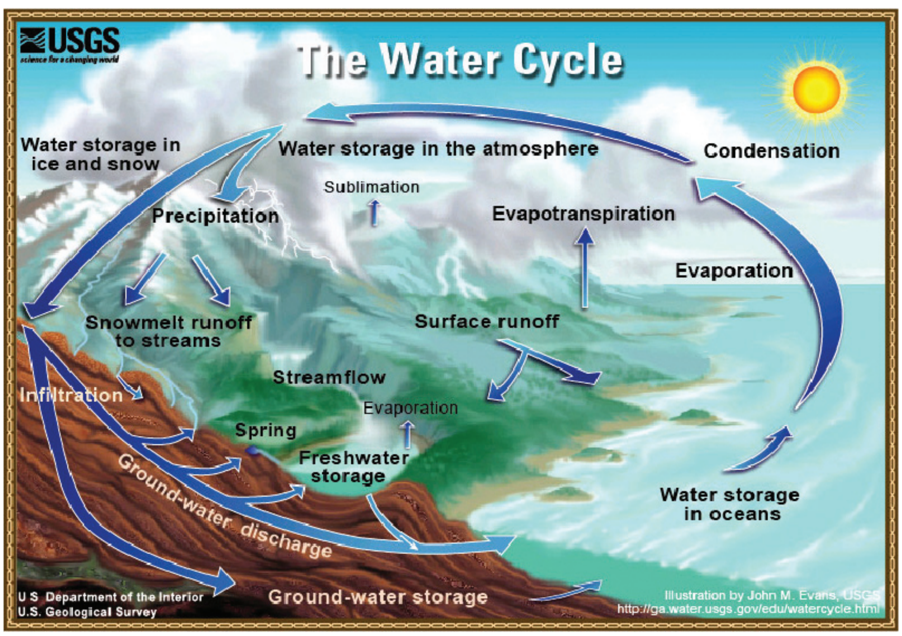


Figure 1, The Water Cycle, USGS

Questions:

1. Does your concept map depict all of the main components of the water cycle shown on the attached diagram? Identify and describe the water cycle processes that are not depicted on your concept map.

2. How does your concept map depict more detailed information about local water availability than this generalized water cycle map?

Name ____________________ Date__________ Class __________

Student Response Sheet
Investigation I: Concept Map Development Questions

Total Annual Precipitation

a. Where does the water in your area come from?

b. Approximately how much total annual precipitation does your area receive in an average year?

Seasonal Precipitation Patterns

c. Approximately what percentage of the precipitation in your region comes from rain? From snow?

d. What seasons or months of the year are the wettest? The driest?

e. Is there precipitation in your area during the hottest season? During the coldest season?

Surface Runoff

f. If there are rivers, streams or creeks in your area—when do they flow with the most water? The least water?

g. Does any of the water in rivers, streams or creeks in your area come from melting snow?

h. Where in your area's water system does precipitation go other than runoff into rivers, streams or creeks?

Infiltration

i. What happens to water in the top meter of the ground during hot, dry weather conditions? During cold, wet weather conditions?

j. What happens to water that seeps into the ground?

k. Are there water wells in your area? If yes, where does the water in these wells come from?

Weather and Climate Change

l. Has the amount of available water in your area changed over long periods of time (tens of years)?

m. What evidence have you seen that would indicate that there is sometimes too much water in your area?

n. What evidence have you seen that would indicate that there is sometimes too little water in your area?

Watersheds

o. Every local area is located within a watershed. What is a watershed? What rivers, streams or creeks are there in your watershed? What are the physical boundaries of your watershed?

p. Does any water in your region come from other regions? If so, how?

Land Use Changes

q. How has human development changed water availability in your local area?

Water Cycle

r. What is the water cycle? What parts of the water cycle occur within your local area?

Q1. Does your concept map depict all of the main components of the water cycle shown on the attached diagram? Identify and describe the water cycle processes that are not depicted on your concept map.

Q2. How does your concept map depict more detailed information about local water availability than this generalized water cycle map?

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 (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 - Two 45-50 minute class periods
Part 2 - Three 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).
- Map #2 Revised Total Annual Precipitation Prediction paper map (Created by students in Part 1).
- Blank Map #3 General Precipitation Zones paper map

Preparation

- Part I - Make appropriate copies (blank maps, student readings, worksheets, etc)
- Part II - Gather student-created maps from Part I, make copies of blank map #3

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?

- Section B 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 "NARR Water Data (1996-2005)"?

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 NARR Water Data (1996-2005) layer in Investigation II contains data *on annual precipitation, evaporation and surface runoff (see* tfigure 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 NARR Water Data (1996-2005) layer.

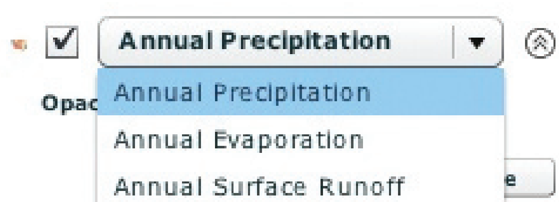


Figure 1, List of variables within MyWorld

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?

Name ____________________ Date __________ Class ________

Student Response Sheet
Investigation II Part 1: How Wet or Dry Is It Across the United States?

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.

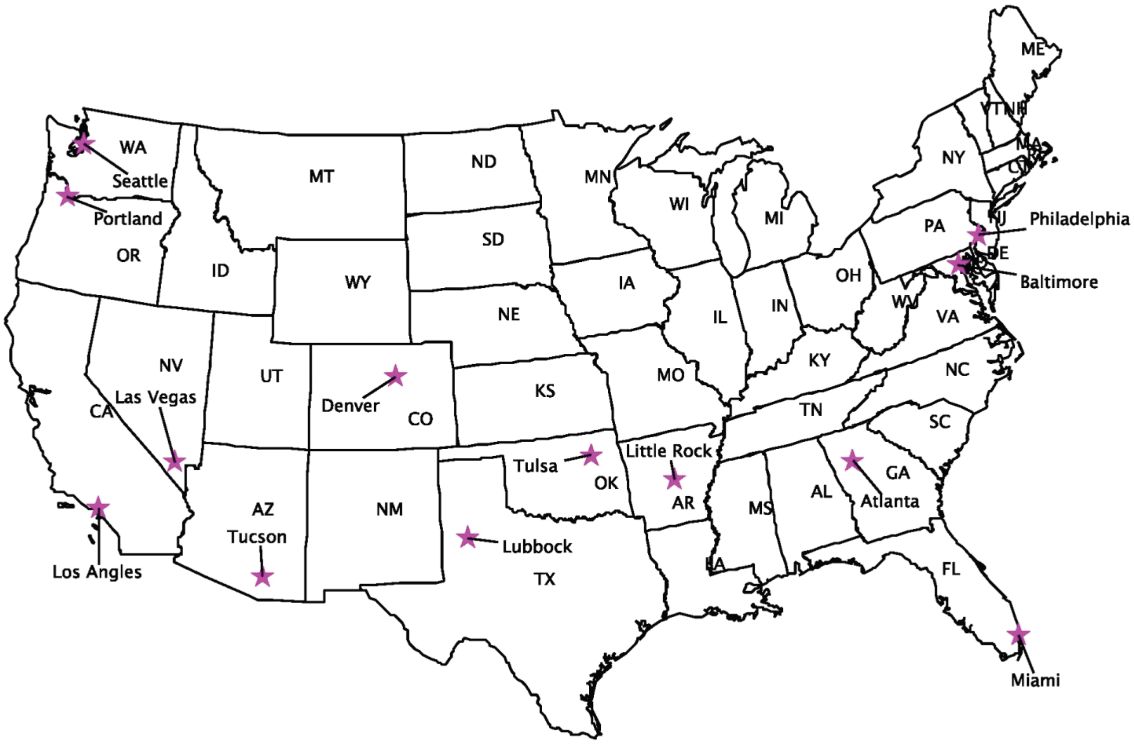
3. What were your reasons for making these high, medium, and low total annual precipitation categories?

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

4. Compare this "revised" map with the first total annual precipitation map that you created. Describe the differences and similarities between these two maps.

   Student answers will vary, though students should try to link their thinking back to some point of reference, probably the amount of precipitation in the place where they live.

Map: Total Annual Precipitation Prediction Name(s) ______________________



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

Name ______________________ Date __________ Class ________

Student Response Sheet
Investigation II Part 2: Total Annual Precipitation

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 with 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 with 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 (Map #2) 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. No. This data is only listed as precipitation and is measured in centimeters of liquid water.

Investigation II: Annual Precipitation in the United States

Does it seem to you like some parts of the United States always get more rain than other parts? The two contrasting images to the left seem to indicate that is the case.

Your task in this investigation will be to figure out just how much precipitation the United States receives in one year and to determine what areas get a lot, what areas just get some and what areas don't get much at all. Start by thinking about what you already know – where, when and how much precipitation (rain, sleet, snow, etc) does the U.S. get in a year? Review current articles and news stories about precipitation across the United States. You will use a GIS (Geographic Information System) program to look at patterns of precipitation based on data collected by researchers. By the end of this investigation you should be able to determine where you might need either an umbrella or sunscreen.

Investigation II Part 1: How Wet or Dry Is It Across the US?

In this section you will use your current knowledge, the knowledge of your classmates, and what you learn from scientific articles, to make a map that predicts precipitation patterns across the continental United States.

1. Break into groups of 3-4 students.
2. Read through the attached selection of news and scientific articles about water issues that various regions and cities face. **Note:** These readings do not cover every city or region of the United States.
    a. Record the name of the study city or region that the article is about in the table below the blank paper map titled, **"Map: Total Annual Precipitation Prediction"**.
    b. In the **Notes From Readings** column of the table write down the total annual precipitation amounts for each city or region, if stated in the article.
    c. After reading all of the articles decide which cities receive high, medium, or low amounts of total annual precipitation and record this in the data table.
    d. The last column, **Total Annual Precipitation**, will be filled in during Part 2 of this investigation.
    e. Use the extra lines on the data table to make predictions about the area you live in and other places you know about.
    f. Extension: Your teacher may ask you to search other resources for information about total annual precipitation patterns. These resources might include textbooks, atlases, web sites, wall maps, guest speakers, etc.

Images above from
http://news.nationalgeographic.com/news/2008/03/photogalleries/Midwest-pictures/ and
http://drought.unl.edu/gallery/2008/California/extreme.htm

7. Using the information gathered from the readings and summarized in the data table below the map, as well as what you know about the U.S., color the **Map: Total Annual Precipitation Prediction**.

   a. Color in those regions of the US that receive **high** amounts of precipitation with **blue**.

   b. Next color in regions that receive **low** amounts of precipitation with **red**.

   c. Regions receiving **medium** amounts of precipitation can be left uncolored (white).

4. Make a 3-4 minute presentation of your predictions to the class.

   Show the class your map and describe specific reasons why you decided each region was classified as receiving high, medium, or low amounts of total annual precipitation. Discuss any prior knowledge you had that helped you make these predictions like a trip to another part of the country.

<u>Analysis Questions</u>

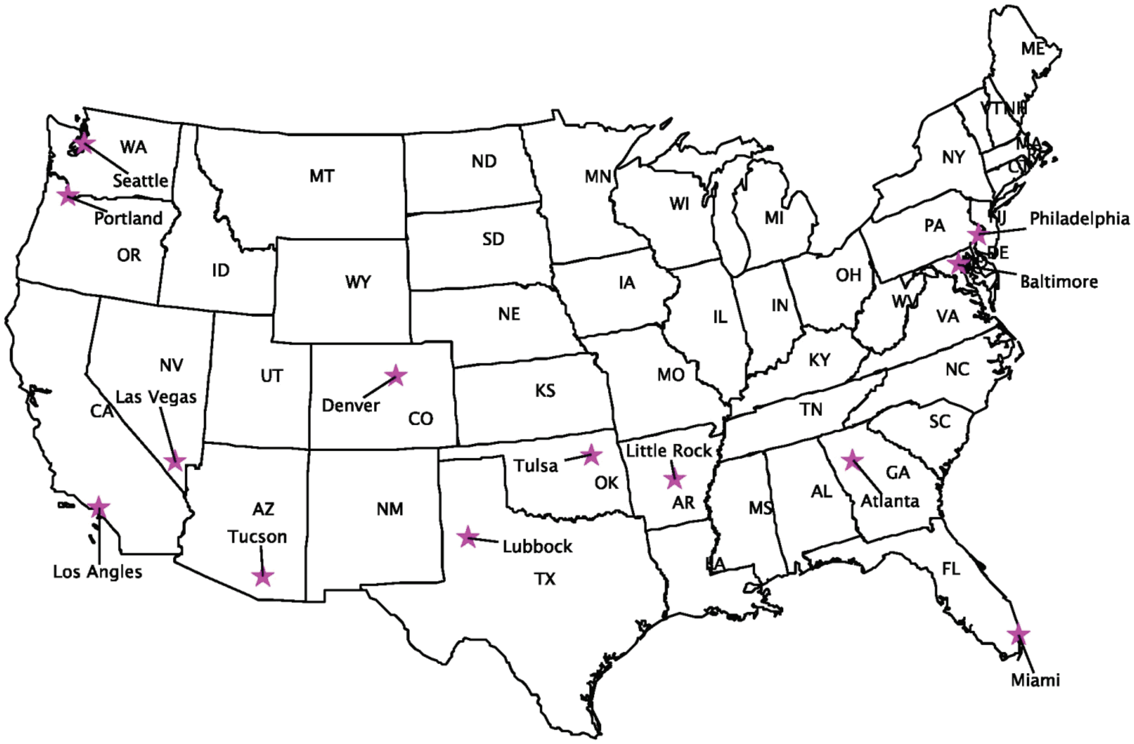
1. How are the maps from the groups similar? How are they different?

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

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

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

Map: Total Annual Precipitation Prediction Name(s) ______________________



CITY or REGION	Notes From Readings: Total Annual Precipitation	High, Medium or Low	Total Annual Precipitation *From the GIS-NARR Data Layer (centimeters)*

Readings for Investigation II Part 1: How Wet or Dry Is It Across the US?

These readings are to be used with Step 2b (above). The readings are clips taken from newspapers, magazines, and scientific articles.

Northeastern US

Baltimore, Maryland– In the next part of the study, we compared long-term trends in precipitation over the last 56 years between Baltimore County (BWI Weather Station) and Baltimore City (U.S. Customs House) (Figure 8). The BWI and Baltimore City weather stations received roughly 40 inches *(102 cm)* of rain per year until 1980. After 1980, BWI continued to receive the same amount of rain, while the Baltimore City station decreased to 30.29 inches *(77.9 cm)* per year between 1980 to the end of the record in 1995.

DiMaggio, A., Roberge, R. "A Study of Precipitation Trends in the Baltimore Metropolitan Region." 2005.
http://pages.towson.edu/mroberge/hydro/dimaggio2005.pdf

South/Southeastern US

Little Rock, Arkansas– Arkansas saw only 34 inches *(86 cm)* of rainfall during 2005 to maintain the state's natural beauty that it markets to attract tourists for fishing, boating, swimming and other recreation. Forecasters say Arkansas usually receives about 50 inches *(127 cm)* of rain each year. The subsequent droughts and warmer winter weather have prompted two-thirds of Arkansas counties to declare 52 burn bans and has farmers worried about their cattle and crops. Cattlemen had problems because their pasture grasses dried too early this season forcing them to buy hay to feed their animals at the last minute. Farmers are also considering if they should plant water-consuming rice this coming season.

"Burn bans, drought hit Arkansas." U.S. Water News Online. January 2006
www.uswaternews.com/archives/arcconserv/6burnbans1.html

Miami, Florida– Water levels in one of the United States' largest freshwater lakes dropped to a record low, after months of lower-than-normal rainfall levels have severely affected the main backup water supply for 5 million South Florida residents. The South Florida Water Management District reported a record low of 8.94 feet *(2.73 meters)* in Lake Okeechobee, the heart of the Everglades. The average water level should be around 13 feet *(3.96 meters)* this time of year. The region's drought is leading water managers to assess how to best protect drinking water supplies, meet needs of the important agriculture, fishing and tourism industries, and protect natural resources. South Florida is largely dependent on the 1890 square kilometer Lake Okeechobee during dry periods, when it can be used as a reservoir if water wells from groundwater aquifers get too low. Rainfall directly over the lake has been low enough to qualify the drought as a one-in-100-year event, the district said. Just 40 inches *(102 cm)* of rain have fallen on the region in the past 18 months, about half the average amount, water managers said.

"Florida's Lake Okeechobee hits record low due to drought." U.S. Water News Online. June 2007.
www.uswaternews.com/archives/arcsupply/7florlake6.html

Atlanta, Georgia– 2007 will be remembered as one of the driest years ever recorded for North Georgia. With a total of 31.85 inches *(80.9 cm)* of rain in Atlanta, or 18.35 inches *(46.6 cm)* below normal, 2007 was the second driest ever recorded. Every month except for June and December recorded less than normal rainfall.

Lawrenceville, Georgia Weather
www.lawrencevilleweather.com/about.htm

Lubbock, Texas– "We're going to have to start to sell cows if we don't get some rain," said Welch, who manages up to 10,000 head of cattle on Spade Ranches across West Texas…The first 11 months of 2006 rank as the 31st driest January-through-November stretch since 1895. Average rainfall for that period was 23 inches *(58 cm)*, down from the normal of 26.02 inches *(66.1cm)*, the National Weather Service said. Compounding the lack of rainfall is a statewide average temperature of 68.9 degrees *(20.5 degrees Celsius)*, the second warmest January through November on record.

"Texas drought took its toll in 2006, but next year could be wetter." U.S. Water News Online. January 2007.
www.uswaternews.com/archives/arcconserv/7texadrou1.html

Tulsa, Oklahoma– The most recent "30-year normal" annual precipitation for Tulsa is 40.69 inches *(103.3 cm)*, calculated for the period from 1961 through 1990. During the "Dust Bowl" era of the 1930s, Tulsa recorded a decadal mean of 35.82 inches *(90.9 cm)* of rain, which was actually greater than that for the 1950s.

"Temperature and Precipitation Trends During the 20th Century in Tulsa." National Weather Service, Tulsa OK.
www.srh.noaa.gov/tsa/science.html

Midwestern US

Minnesota– The average annual precipitation (rainfall plus the water equivalent found in snowfall) in Minnesota ranges from nearly 18 inches *(46 cm)* in the far northwest to more than 32 inches *(81 cm)* in the southeast. Precipitation patterns in Minnesota and across most of the eastern United States) are dictated by proximity to the Gulf of Mexico. Locations closer to the source of warm, moist air provided by the Gulf, receive more precipitation on average.

"What is the average annual precipitation in Minnesota?"
www.dnr.state.mn.us/climate/faqs.html

Western US

Denver, Colorado– Ever since Denver residents drilled the first Arapahoe well in 1883, withdrawal has exceeded recharge. But until the population began to explode, having enough water was not a daily concern. While Denver itself does not withdraw water from the underlying aquifers today (the city uses surface water, which is recharged with snowmelt from the Rockies and rain), the outlying areas rely mainly on the deep aquifers, especially the Arapahoe. And with only 11 to 18 inches *(27.9 to 45.7 cm)* of annual precipitation, natural recharge of the aquifer is not possible at the current rate of extraction, Moore says.

"Western Aquifers Under Stress." Geotimes. May 2004
www.geotimes.org/may04/feature_westernaq.html

Las Vegas, Nevada– Governor Guinn spoke about the present growth, saying the population doubled to 1.3 million between 1985 and 1995, and it is expected to double every 10 years into the future. In order to accommodate the growth, the citizens have voted for nearly $6.0 billion in bonds to build schools and $2.0 billion to convey and treat water from Lake Mead. Las Vegas receives a scant 4.13 inches *(10.5 cm)* of annual precipitation, making it one of the driest cities in the nation. Water is critical to its future. Las Vegas plans to take 300,000 acre-feet of water from Lake Mead, which is Nevada's total apportionment of Colorado River water under the 1922 seven-state compact. This is not enough water to meet the area's full growth potential, so there are efforts underway to acquire additional water supplies.

Desert Anomaly… Receiving a scant 4.13 inches of precipitation, Las Vegas is one of the driest cities in the United States, yet it's prospering.
www.ci.slc.ut.us/utilities/NewsEvents/news1999/news12231999.htm

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Tucson, Arizona– "Since the early 1980's the Tucson community has sought to reduce its dependence on a limited groundwater supply by encouraging water conservation. Located in the Sonoran desert in the Southwestern U.S. the Tucson basin receives an average rainfall of 12 inches *(30.5 cm)* per year, approximately half in winter and half in the summer "monsoon season" which runs from July to September. With summer temperatures regularly over 100 F *(37.7 C)* the need to reduce outdoor water use for landscape irrigation continues to be a focus of conservation efforts in the region."

"DROP YOUR WATER USE" PLANT TAGGING PROGRAM -TUCSON, ARIZONA.
www.azwater.gov/dwr/WaterManagement/Content/AMAs/TucsonAMA/TAMA_documents/DYWU_summary.pdf

West Coast/Pacific Northwest US

The root of the problem is easy to state: The semiarid West has too little water, spread too unevenly throughout the year. Most of **Montana** sees less than 46 centimeters *(18.4 in)* of precipitation a year. Even rainy **Portland, Oregon** receives only about one-tenth of its annual 91 centimeters *(36.4 in)* of precipitation during the summer. For most of California the fraction is even smaller. **Philadelphia, Pennsylvania** by contrast, typically receives 102 centimeters *(40.8 in)* of annual precipitation, 30% of which comes in the summer.

"Water Resources: As the West Goes Dry." Science, 20 February 2004. AAAS
www.sciencemag.org/cgi/content/full/303/5661/1124

Los Angles, California– With little moisture in usually wet February, meteorologists said Los Angeles is facing its driest year (2007) ever with less than 2½ inches *(6.4 cm)* of rain so far. Prolonged dry weather, which extended the wildfire season, comes just two years after the region was awash with a near-record 37 inches *(94 cm)* of rain. Eleven inches *(30 cm)* fell that February, usually the region's rainiest month. But more than eight months into the rain year starting July 1, 2006, and ending June 30, the downtown/University of Southern California rain gauge only measured 2.42 inches *(6.2 cm)* — 0.92 inch *(2.3 cm)* of it falling in February. Normal annual rainfall in Los Angeles is 11.43 inches *(29.0 cm)* and there's no rain in the forecast for the next 10 days, meteorologist Eric Boldt said from the National Weather Service regional office in Oxnard. The last time it was this dry was in 1923-1924 season when 2.50 inches *(6.4 cm)* of rain was recorded through March 22, 1924.

Los Angeles on pace for driest rain year ever. USA Today.
www.usatoday.com/weather/news/2007-03-07-dry-la_N.htm

Seattle, Washington– It was the kind of rain the Rain City had never seen. A daylong deluge on Monday demolished rainfall records, flooded streets and inundated cars. While Seattle began drying out Tuesday, residents of smaller towns elsewhere in Washington evacuated neighborhoods and anxiously waited for flooding rivers to crest. Seattle received 5.02 inches *(12.8 cm)* Monday. It was the most rainfall in a 24-hour period since Seattle began keeping records in 1891. The deluge beat the previous one-day record — 3.41 inches *(8.7 cm)* on Nov. 20, 1959 — by almost 50%....Seattle's rainy reputation has more to do with days-long stretches of gray clouds than actual precipitation. The city's average annual rainfall is 37.07 inches *(94.2 cm)*, less than **Atlanta, Georgia** *(50.20 inches/127.5 cm)* or **New York City, New York** *(49.69 inches/126.2 cm)*, according to the National Oceanic and Atmospheric Administration. Rain here often comes in small doses spread over many days. During December and January, sunny days occur about 50% of the time in New York and Chicago, compared with 15% in Seattle.

Flooding follows record rain. USA Today October 10, 2003
www.usatoday.com/news/nation/2003-10-21-seattle-rain-usat_x.htm

Name ______________________________ Date ____________ Class _________

Student Response Sheet
Investigation II Part 1: How Wet or Dry Is It Across the United States?

Questions:

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

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

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

4. Compare this “revised” map with the first total annual precipitation map that you created. Describe the differences and similarities between these two maps.

Investigation II Part 2: Total Annual Precipitation

> Note on Text Formatting Conventions Used in the Investigation Directions
>
> *Italicized* – Commands executed by student or typing completed by the student within the GIS tool
> **Bold** – Window, layer, or window names displayed by the GIS tool
> <u>Underlined</u> – A variable selected from pull-down menu
> Shaded – Questions or sections to be answered or completed by the student.

Opening the Activity

1. *Launch* your Web browser. Type in the following url:

- http://wd.fieldscope.us

In the top right corner of the screen are the tabs for the different activities (Figure 1,A). For this activity, you will use **Investigation II** (the default).

In Investigation II are two tabs (Figure 1,B), you will start in the **Map tab**.

Data layers are viewed in the Layers list portion of the window (Figure 1,C) and the resulting maps in the map panel (Figure 1,D).

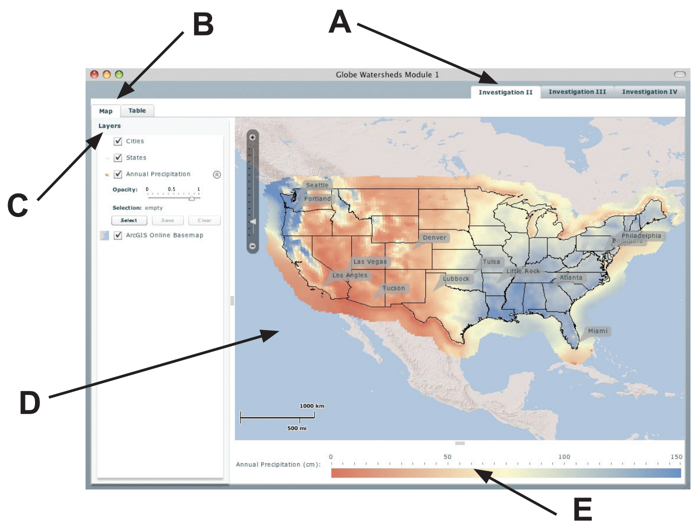


Figure 1, My World (Web-based)

All the layers are checked to be displayed, or shown, on your map. You can show and hide these layers by clicking on the check box.

At this point, four layers are being shown: **Cities**, **States**, **Annual Precipitation**, and **ArcGIS Online Basemap**.

Notice the legend below the map, which shows the name of the layer **Annual Precipitation** and units (**cm** of water). Also displayed is a color key legend with the units and range of values for the displayed variable.

> 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."

Exploring Total Annual Precipitation Data on a GIS Map

GIS maps are powerful, interactive data analysis tools. Now that you have created a map using real data, it is time to use GIS technology to explore the map in detail, and to compare this GIS data to the map-based predictions that you made in Part 1 of this investigation.

Place your cursor on the map and click on any cell to read the annual precipitation value for that location from the legend below the map. For example, clicking on Denver shows a triangle at approximately 39.79 cm of precipitation along the bottom legend.

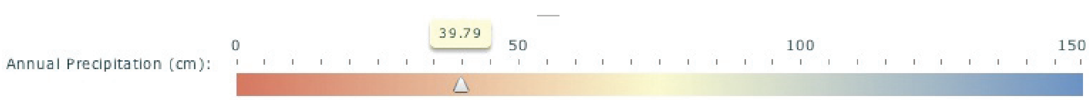


Figure 2, The GIS bottom legend showing precipitation in Denver

2. Use the Pointer Tool to *find* the actual total annual precipitation amounts for some of the listed cities/regions you read about in part 1. *Record* these data in the **Total Annual Precipitation** column located on the bottom of your colored "Map: Total Annual Precipitation Prediction" paper map.

Question:

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?

3. Use the Pointer Tool to explore the range of total annual precipitation values across the continental United States.

Questions:

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?

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?

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

In Part 1 of this investigation you created a "Total Annual Precipitation Prediction" map that showed areas of high precipitation in blue, medium amounts of precipitation in white, and low amounts of precipitation in red. You probably struggled to figure out what represented a high, medium, and low amount of total annual precipitation. Instead of guessing, you now have the information and technology tools available with which make decisions about how to group total annual precipitation into high, medium, and low categories.

Looking at the Investigation II project map displayed in the GIS, notice that the Annual Precipitation data layer uses the same blue, white, and red color scheme to indicate high, medium, and low amounts of total annual precipitation.

4. Using your pointer to gather data from the Annual Precipitation data layer, *mark* on the legend below what values you think best defines the range of high, medium and low total annual precipitation.

Question:

5. Mark on the legend in Figure 3 the ranges of high, medium and low total annual precipitation.

Figure 3, The GIS bottom legend, nothing selected

Questions:

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

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.

Making Selections and a Map Table

In the previous section of this investigation you explored the Annual Precipitation data and categorized ranges of total annual precipitation as being high, medium, or low. The GIS tool will allow you to make selections of different annual precipitation values.

In this section, you will use a powerful GIS feature to create maps that show areas that receive specific amounts of annual precipitation. Next, you will use another feature (**Map Tables**), which allows you to view a series of maps at the same time. Being able to view different maps at the same time makes it easy to compare the information shown on the maps, and to draw conclusions from the data

5. Select areas of different precipitation ranges by *clicking* on the **Select** button. (see Figure 4).

   This will open a box called **Select Annual Precipitation** which allows you to select different values of Annual Precipitation to view on the map.

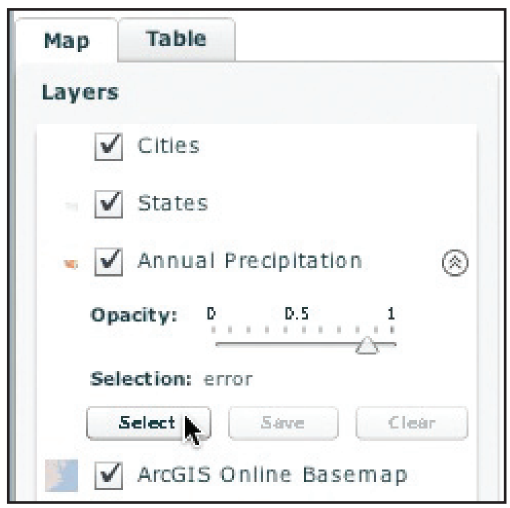


Figure 4, Select button for creating maps

6. First, make a selection that shows those areas with the highest precipitation values. Use the following settings for this selection (Figure 5).

   a. *Check* the box for **Greater than**

   b. *Type* **75** into the box.

   c. *Click* **Select**

   The GIS will change appearance. Now the map will have a selection of points highlighted.

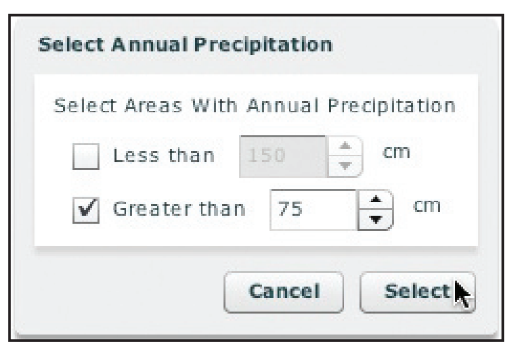


Figure 5, Select Annual Precipitation

7. You can change the Opacity of the Annual Precipitation layer by moving the Opacity slider (Figure 6).

    a. *Click and drag* the slider to **1**

    b. *Click and drag* the slider to **0**

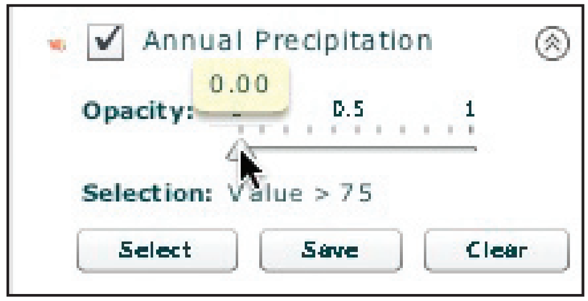


Figure 6, Opacity Slider

It is important to understand what information is being selected to create this map, so that you can be clear about what is being shown. This map uses the **Annual Precipitation** data, but only shows areas that receive **High Precipitation Areas (Greater than 75 cm)**.

Save this data into the Table.

8. In the Annual Precipitation Layer, *click* the **Save button (Figure 7)**.

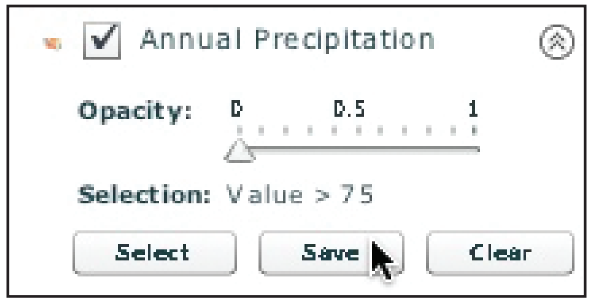


Figure 7, Save Opacity Selection

This will open a new window on your map. The four rectangles in this window represent the layout of the table (Figure 8).

    a. Choose where in the table this map selection will go.

    b. Check that the name represents the data.

    c. *Click* **Save**.

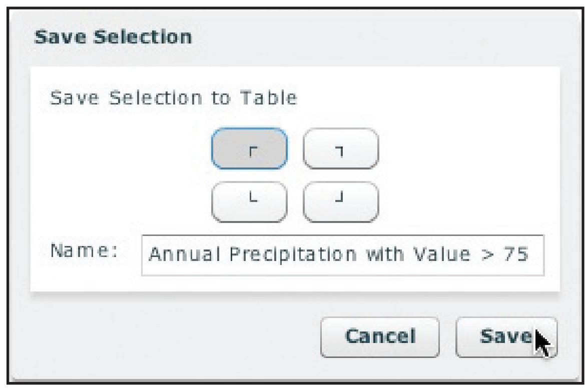


Figure 8, Save Selection to Table

When you saved the map selection to the table, you moved into the Table Tab. You can see where your other selections will go.

9. *Click* on the **Map tab** to return to the map.

10. Repeat the selection procedure for the following values of annual precipitation areas (Figure 9):

    a. Low Precipitation Areas (<75 cm)

    - Be sure to deselect the “Greater than” and select “Less than”

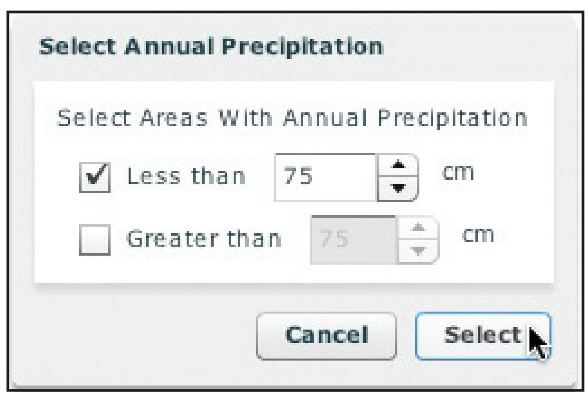


Figure 9, Select Annual Precipitation

11. Save this map selection to the top right corner of the Table (Figure 10).

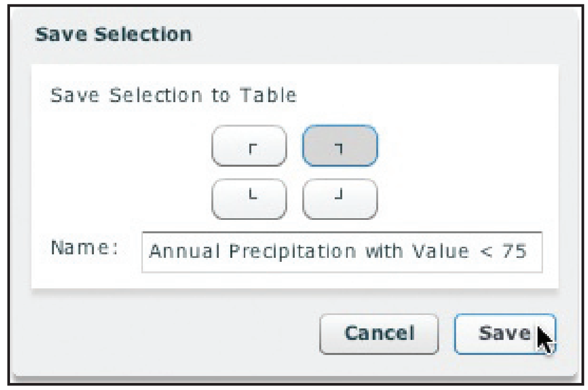


Figure 10, Save selected annual precipitation values

12. Repeat this selection and saving procedure for the following values:

    a. Very High Precipitation Areas: Greater than 125 cm
    b. Add the **Very High Precipitation Areas (>=125 centimeters)** selection to the lower left-hand box of the Map Table by using the same procedure as before.
    c. Very Low Precipitation Areas: Less than 25 cm
    d. Add the **Very Low Precipitation Areas (< 25 centimeters)** selection to the lower right-hand pane of the Map Table by using the same procedure outlined in Step 8 above.

Questions:

8. Compare your answer to question #2 above with the map with Very High Precipitation Areas (>= 125 cm) selected. What additional information is evident on the new map?

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

The table below summarizes the values of the four different selections from the **Annual Precipitation** layer, and the location of each selection in the **Annual Precipitation Map Table**.

Select Records from: (Field)	Whose: (Operation)	Value (cm)	Result Name: (Selection Title)	Location of Selection in Annual Precipitation Map Table
Annual Precipitation	Is greater than or equal to (>=)	75	High Precip	Upper left-hand cell
Annual Precipitation	Is less than (<)	75	Low Precip	Upper right-hand cell
Annual Precipitation	Is greater than or equal to (>=)	125	Very High Precip	Lower left-hand cell
Annual Precipitation	Is less than (<)	25	Very Low Precip	Lower right-hand cell

View and Analyze theAnnual Precipitation Map Table

13. *View* the completed **Annual Precipitation Map Table** by *selecting* the **Open** button in the **Map Tables** pane (See Figure 11).

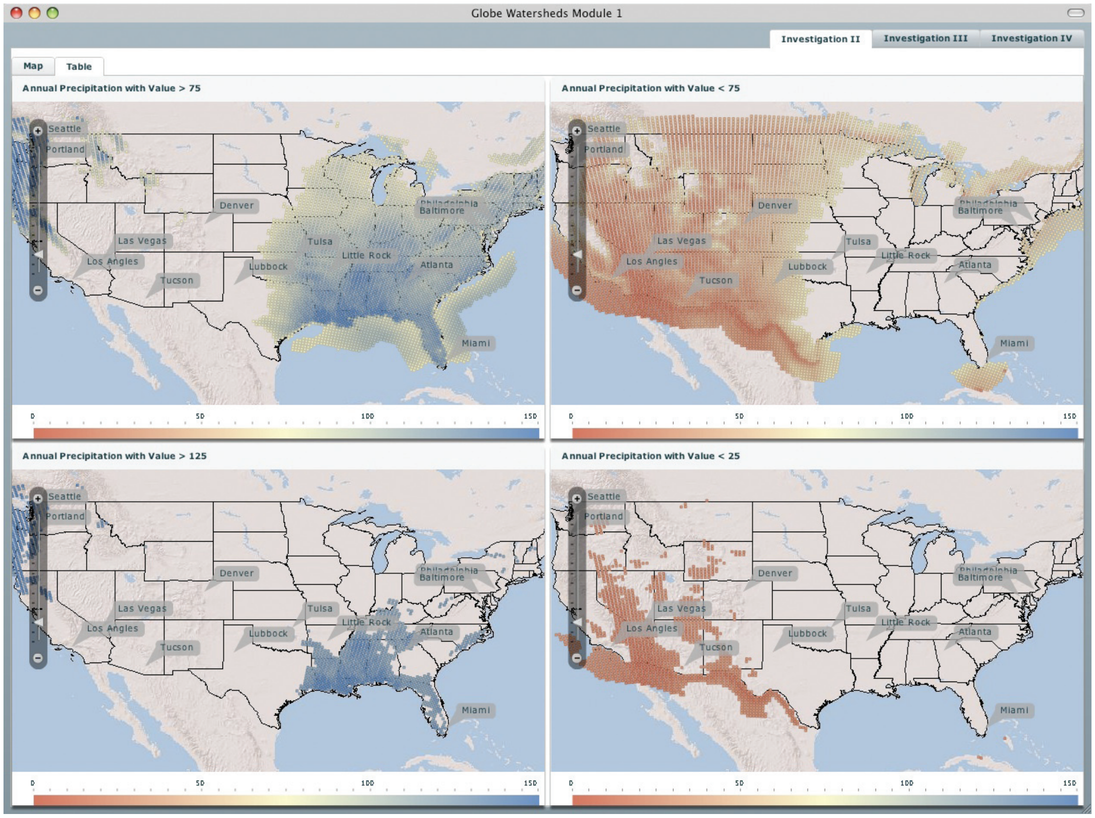


Figure 11, Annual Precipitation Map Table

The **Annual Precipitation Map Table** makes it easy to see which areas of the continental United States receive very high, high, low and very low amounts of total annual precipitation. This is much easier than trying to interpret all of the annual precipitation data, at the same time, on one map.

Note that the **Pointer Tool** can be used on Map Tables, like any map, to see the exact amount of precipitation for any point on the map. Clicking on any point on one map selects the same point on all of the maps in the Map Table.

14. Compare the data presented in the **Annual Precipitation Map Table** with the predictions you made on your *"Map: Total Annual Precipitation Prediction" paper map* created in the first part of this investigation.

Question:

10. Overall, how well do your paper map predictions (Map #2) agree with the actual precipitation data shown on the Map Table? In what areas did your predictions not agree? Are there any surprises?

Questions:

Close the Map Table window when finished.

EXTENSION: Try different values for very high, high, low and very low annual precipitation amounts. How do the patterns shown change across the country?

Synthesis

Now it is time to synthesize what you have learned about total annual precipitation patterns across the continental US.

Questions:

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

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

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

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

Extension: Examining Factors That Influence Patterns of Total Precipitation

Thus far, this investigation has focused only on examining the total amount of annual precipitation that the continental United States receives. As you worked through this investigation you may have wondered why different regions get different amounts of total annual precipitation.

Find out what factors influence precipitation patterns. Search Earth and environmental science books, and web sites, to find the answers to the following questions.

1. Identify seven climate control factors that influence precipitation patterns. Explain how each climate control factor influences precipitation patterns and provide a specific example of an area in the US that is affected by this factor.
2. Why is it significantly drier on the east side of the west coast mountain ranges of Washington, Oregon, and California than on the west side of these mountain ranges?
3. What factors cause the Pacific Northwest to receive so much precipitation?
4. What factors cause the Southeast to receive more precipitation than the rest of the eastern half of the country?

Name ______________________________ Date ___________ Class ________

Student Response Sheet
Investigation II Part 2: Total Annual Precipitation

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?

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?

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

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

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

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

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.

8. Compare your answer to question #2 above with the map with Very High Precipitation Areas (>= 125 cm) selected. What additional information is evident on the new map?

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

10. Overall, how well do your paper map predictions (Map #2) agree with the actual precipitation data shown on the Map Table? In what areas did your predictions not agree? Are there any surprises?

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

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

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

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

Investigation III: Annual Precipitation, Evaporation and Surface Runoff in the US

Purpose

The purpose of this activity is to analyze the relationships between precipitation, evaporation, and surface runoff in the earth system. Students compare three different but related sets of data to understand how these things are related. They look at comparative rates of each process across the US and draw conclusions about where they are similar, where they are different, and why this variability exists.

Overview

This investigation begins by exploring a new component of the water balance equation: ***evaporation***. In Part 1 of this investigation, students examine patterns of total annual evaporation across the U.S. and compare them to annual precipitation. They do this by using the same set of GIS analysis skills that they employed in the previous investigation—making selections and creating a Map Table. In this investigation students also begin to record quantitative data about precipitation and evaporation that will be used to support their answers to questions.

Part 2 of the investigation introduces a third component of the water cycle: ***surface runoff***. Surface runoff refers to the amount of water that flows down creeks, streams and rivers. Students examine patterns of annual surface runoff across the U.S. and compare them to patterns of precipitation and evaporation using the GIS tool.

Student Outcomes

- Understand the Earth system processes that influence the rate and timing of evaporation and surface runoff in a given area.
- Compare annual precipitation patterns to annual evaporation and surface runoff patterns.
- Gain skill and understanding in the use of the the GIS analysis tool.
- Collect and record quantitative data in a data table and use it to support responses to questions
- Analyze and interpret data displayed on maps.

Time

- Part 1—One 45-50 minute class period
- Part 2—One 45-50 minute class period

Level

Secondary

Materials and Tools

- Computers (1 computer for each student preferred) with access to the Internet (access to url http://wd.fieldscope.us).
- Student guide and response sheets (optional)

Preparation

Make copies of student pages as necessary

Prerequisites

Investigation II: Annual Precipitation in the United States.

Review the following with students before doing activity.

Background

Because precipitation and evaporation are components of the global water cycle the total amount of water is constant over time with equal rates of precipitation and evaporation world-wide, but depending on location and time of year (i.e. seasons) these two may not balance with evaporation actually being greater than the precipitation. Students will explore precipitation and evaporation amounts across the US. As they collect data for study cities, they should recognize that there is not always a balance between the two components at a specific location. Some of the imbalance is the result of seasonal factors. For example, when precipitation occurs as snow during the winter, it doesn't contribute to surface runoff and evaporation as readily as when it melts during the spring. But, some of the imbalance may be due to the fact that there are regional or global factors involved.

Part 1

Evaporation is a physical process by which a liquid or solid substance is transformed to the gaseous state. Evaporation represents the return of precipitation back into the atmosphere. Like precipitation, evaporation is not evenly distributed by location. The main sources of water vapor in the lower atmosphere are evaporation from the Earth's surface and transpiration by plants.

Consider a class brain-storming session or concept map.

Major factors influencing the rate of evaporation include atmospheric temperature, wind, atmospheric humidity, and the availability of water.

- The movement of water between Earth's surface and the atmosphere is partially controlled by atmospheric humidity.
- If there is little or no surface water, then the total amount of evaporation is low. In hot arid areas, such as the southwest, the total amount of evaporation is low because there is little water in the system to evaporate. However, the rate of evaporation (verses total amount of evaporation occurring over time) is high when water is available in hot arid areas. High evaporation is dependent on high precipitation, although there is sometimes a time lag in evaporation. For example evaporation rates are high in the Pacific Northwest and Rocky Mountains in the spring and summer when there is little precipitation.
- The type of land surface and vegetation influences evapotranspiration rates.
- The higher the wind speed, the greater the rate of evaporation.
- Evaporation rates increase with increasing temperature.
- During warmer months, plant transpiration rates increase.

Part 2

In this part of the investigation students will examine surface runoff. Surface runoff is the water that flows down creeks, streams and rivers. Precipitated water that has not evaporated back into the atmosphere or infiltrated into the ground runs off as surface water.

Major processes and factors influencing the timing and quantity of surface runoff include the amount of precipitation, rate of precipitation, form of precipitation (snow, rain, sleet, hail, etc), season the precipitation fell, infiltration rate, degree of ground saturation, land use and ground cover, and geology.

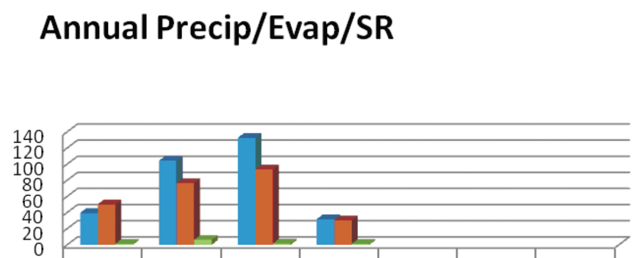
Teaching Notes

Before the students begin Part 1 of this investigation, ask them to develop a working hypothesis describing the relationship between total annual precipitation and total annual evaporation. Will areas with high precipitation have high evaporation rates? Will areas with low precipitation, such as the hot, arid west, also have high total annual evaporation? Write the various hypotheses down on the class white board so that students can refer back them as work through the My World analysis.

As part of this investigation students fill out a table of annual precipitation, evaporation and surface runoff for four pre-selected cities as well as three of their choice. One extension of this activity is to graph the data using Excel or other graphing/charting program. The chart can help students visualize the relationships of these different variables across the county. One important relationship for them to observe is how little surface runoff occurs compared to evaporation.

An Excel spreadsheet has been created for this purpose named Water Availability.xls and it available for download at http://www.globe.gov/projects/watersheds/h2oavailability. After downloading and opening, click on the Investigation III tab at the bottom of the sheet to open the appropriate table and chart. Blank cells are in the table to add the students selected cities (See Figure 1).

Another option is to have students create the chart on graph paper.



	Denver	Seattle	Miami	Tucson	Home	City 1	City 2
Annual Precipitation, cm	39.8	104.4	132.9	31.9			
Annual Evaporation, cm	50.4	76.7	93.8	30.6			
Annual Surface Runoff, cm	1.2	6.2	1.8	1.24			

Figure 1, Excel graph example

Name ______________________ Date __________ Class ________

Student Response Sheet
Investigation III: Annual Precipitation, Evaporation and Surface Runoff in the US

Questions:

1. Now that you are familiar with the annual precipitation patterns across the US and with the factors influencing rates of evaporation, make a prediction about the similarities and differences in the patterns of annual precipitation and annual evaporation. For example, for areas of high annual precipitation what do you expect the annual evaporation amounts to be? For areas of low annual precipitation?

   Student answers will vary.

2. Which color on the Annual Evaporation map represents the highest evaporation and which color represents the lowest?

   Highest evaporation is brown. Lowest evaporation is green.

3. Complete the column labeled "Annual Evaporation (cm)" in the data table below:

   Write in the name of your city in the first row of the data table. Choose two additional cities and complete the last two rows of the data table with the data for the cities you chose.

City	Annual Precipitation (cm)	Annual Evaporation (cm)	Annual Surface Runoff (cm)
Denver	39.8	50.4	1.2
Seattle	104.4	76.7	6.2
Miami	132.9	93.8	1.8
Tucson	31.9	30.6	1.24

4. Review the factors that influence evaporation rates from page 1 of this investigation. Which of these factors are evident in the annual evaporation map?

   The general patterns of precipitation and evaporation across the US are consistent. Many areas with high amounts of annual precipitation also have high amounts of evaporation. Many areas with low amounts of precipitation have low amounts of evaporation.

5. Complete the column labeled "Annual Precipitation (cm)" in the data table above in question #3

6. Earlier in this activity you made a prediction about the similarities and differences in annual precipitation and evaporation amounts. Use the map table to compare the data to the prediction you made in question #1. What are the differences? (Be sure to discuss the amount of evaporation in high and low precipitation areas.)

   Student responses will vary based on their predictions.

7. Now that you are familiar with the annual precipitation and evaporation patterns across the US, make a prediction about the similarities and differences in the patterns of annual precipitation and annual surface runoff. For example, for areas of high annual precipitation what do you expect the annual surface runoff amounts to be? For areas of low annual precipitation?

   Student responses will vary.

8. Which color on the Annual Surface Runoff map represents the highest surface runoff and which color represents the lowest?

   Highest surface runoff is purple. Lowest surface runoff is gold.

9. Complete the column labeled “Annual Surface Runoff, cm” in the data table above in question #3

10. Review the factors influencing surface runoff listed above. What evidence do you see that supports these factors in the annual surface runoff map? Can you explain high and low surface runoff areas using the factors listed above?

    High surface runoff occurs in areas where precipitation does not evaporate back into the atmosphere or infiltrate into the ground. The surface runoff map shows areas with high surface runoff are consistent with high precipitation areas in general and exception is the high surface runoff areas in the Rocky Mountain region where topography plays a role.

11. In general, what is the relationship between surface runoff and precipitation in regions that receive high amounts of annual precipitation? What is the relationship between surface runoff and precipitation in regions that receive low amounts of annual precipitation?

    In general, it appears that high runoff areas are also high precipitation areas, although there are exceptions. For example Florida receives high amounts of precipitation but has low total surface runoff. In general, areas with low annual precipitation also have low amounts of surface runoff.

12. Identify an area of the US where total annual surface runoff is high even though total annual precipitation is only medium. What are possible processes or factors that cause surface runoff to be high for this area?

    The Rocky Mountains have high amounts of surface water runoff even though they have moderate amounts of annual precipitation. Much of the precipitation in the Rocky Mountains falls as snow, which tends to runoff as surface water when it melts.

13. Identify an area of the US where the total annual surface runoff is low even though the annual precipitation is high. What are some possible processes or factors that cause surface runoff to be low for this area?

    Florida and parts of Georgia, South Carolina, Alabama and Mississippi have high annual precipitation amounts and low annual surface runoff amounts. Annual evaporation tends to be very high in these areas in part due to the high average temperatures in the southeastern US. The geology of the area also plays a role.

Investigation III: Annual Precipitation, Evaporation and Surface Runoff in the US

Floods in the Midwest! Drought in the Southeast and the West! Record snowfall in the East! All these statements could easily show up as headlines in most regional newspapers. But, think about this… the Midwest doesn't stay flooded, the Southeast and West does get some rain and the East doesn't stay buried in snow; why not? Where does all the precipitation go and how does it get there? These are the questions you will be working on answering in this next investigation.

If you have been participating in the all the Investigations in this unit you have had a busy time of it so far – good job! In Investigation I, you and your peers created a picture or concept map of what you know about nature's hydrologic (water) systems. In Investigation II, you made predictions about the amount of precipitation (rain, sleet, snow, etc.) that various parts of the US get on an annual basis. Now, it's time to figure out what happens to all that precipitation once it has reached the surface of the planet. In Investigation III we'll begin to think about the relationship between annual precipitation patterns across the continental United States and annual evaporation and surface runoff patterns. You will make a map table showing annual precipitation amounts and compare them to annual evaporation and annual surface runoff across the United States.

Because precipitation and evaporation are components of the global water cycle the total amount of water is constant over time with equal rates of precipitation and evaporation world-wide, but depending on location and time of year (i.e. seasons) these two may not always balance. In some cases evaporation rates might actually be greater than precipitation rates or precipitation rates could be greater than evaporation rates. Part 1 of this investigation explores evaporation, a new component of the water balance equation. In this investigation you will examine total annual evaporation. You will do this by using the same set of GIS analysis skills that were used in the previous investigation.

Investigation III Part 1:
Investigating patterns of annual evaporation and annual precipitation.

Note on Text Formatting Conventions Used in the Investigation Directions *Italicized* – Commands executed by student or typing completed by the student within the GIS tool **Bold** – Window, layer, or window names displayed by the GIS tool Underlined – A variable selected from pull-down menu Shaded – Questions or sections to be answered or completed by the student.

Question:

1. Now that you are familiar with the annual precipitation patterns across the US (from Investigation II) and with the factors influencing rates of evaporation (from the background reading above), make a prediction about the similarities and differences in the patterns of annual precipitation and annual evaporation. For example, for areas of high annual precipitation what do you expect the annual evaporation amounts to be? For areas of low annual precipitation?

Getting started – Navigating to the Project

1. *Launch* your web browser. Go to website: http://wd.fieldscope.us

2. *Click* on the tab for **Investigation III** (Circled in Figure 1).

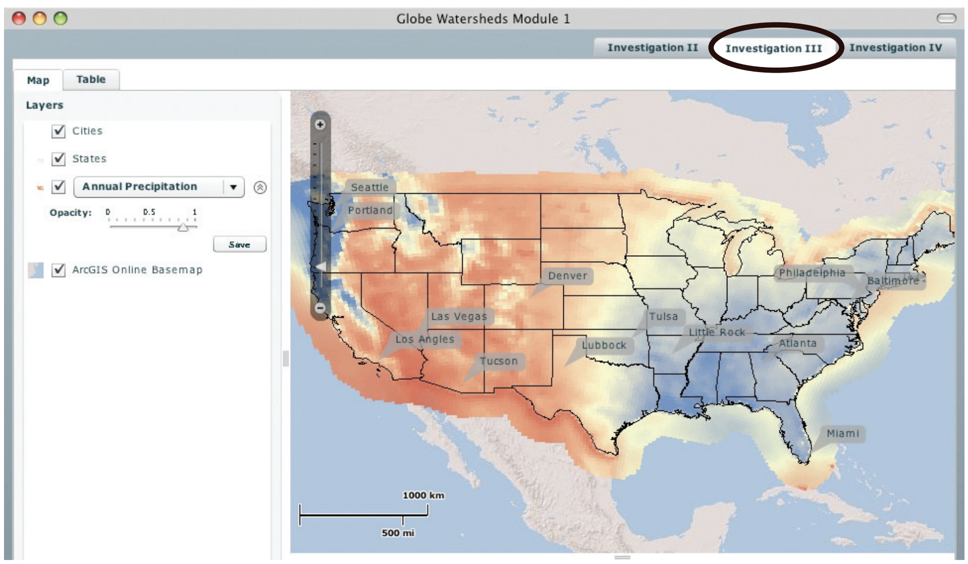


Figure 1, Opening Ivestigation III

Notice the legend below the map which shows the name of the layer Annual Precipitation and units (cm of water). Also displayed is a color key legend with the units and range of values for the displayed variable.

Exploring Total Annual Evaporation Data

3. *View* the **Evaporation** data by *changing the pull-down menu* in the layer list *from* **Annual Precipitation** *to* **Annual Evaporation** (Figure 2). The resulting map should look like Figure 3.

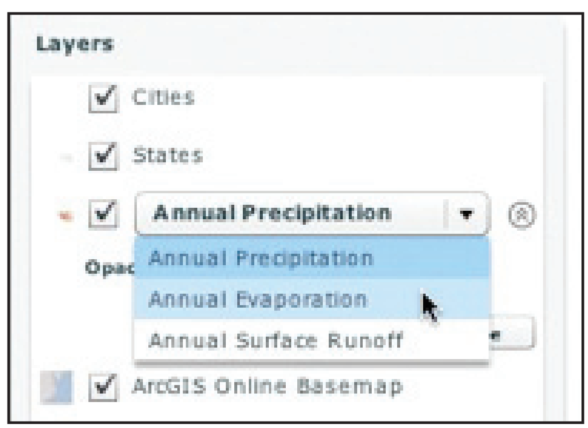


Figure 2, Viewing Evaporation Data

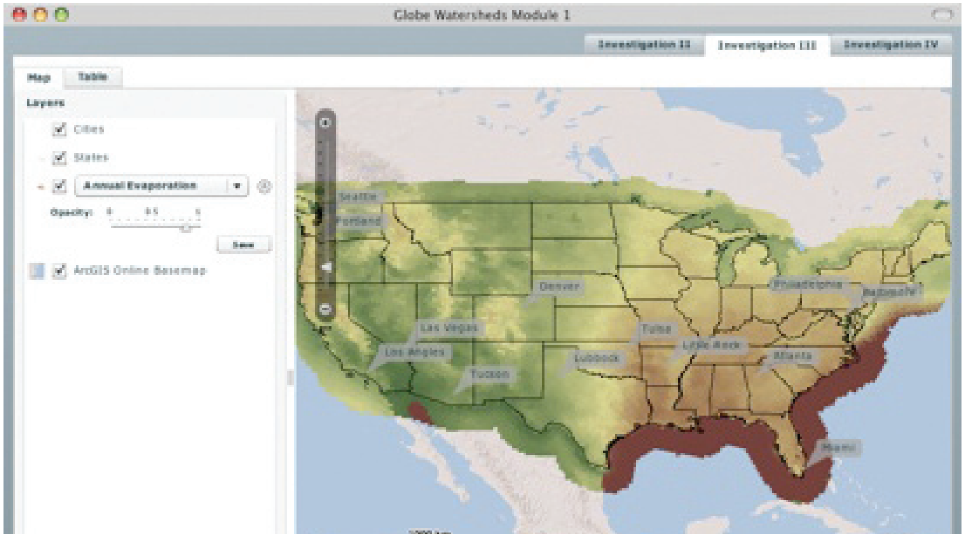


Figure 3, Annual Evaporation Map

Notice that the **Annual Evaporation** map appears and that the color of the map and its associated legend changes to reflect annual evaporation data.

Questions:

2. Which color on the Annual Evaporation map represents the highest evaporation and which color represents the lowest?

3. Complete the column labeled “Annual Evaporation, cm” in table 1 below.

Write in the name of your city in the first row of the data table. Choose two additional cities and complete the last two rows of the data table with the data for the cities you chose.

City	Annual Precipitation (cm)	Annual Evaporation (cm)	Annual Surface Runoff (cm)
Denver			
Seattle			
Miami			
Tucson			

Table 1, Annual Precipitation, Evaporation and Runoff

Question:

4. Review the factors that influence evaporation rates from page 1 of this investigation. Which of these factors are evident in the annual evaporation map?

Comparing Annual Evaporation to Annual Precipitation Using a Map Table

In the first section of this investigation you explored the NARR Annual Evaporation data and recorded annual evaporation amounts for your own city and several others. In this section we will begin making a map table to compare annual precipitation with annual evaporation.

4. With **Annual Evaporation** displayed on the map, click the save button.

   This will save your data into the Table tab. Where you place the data can make it easier to view later.

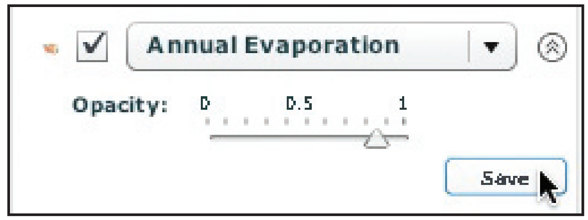


Figure 4, Save Annual Evaporation data into Table

5. *Place* the **Annual Evaporation map** in the top left corner (Figure 5).

   a. Make sure it is named **Annual Evaporation**.

   b. *Click* Save.

   This will move you into the **Table** tab. This is where you will be able to view multiple layers of data at the same time.

   c. Click on the **Map** tab to return to the map view (Figure 6).

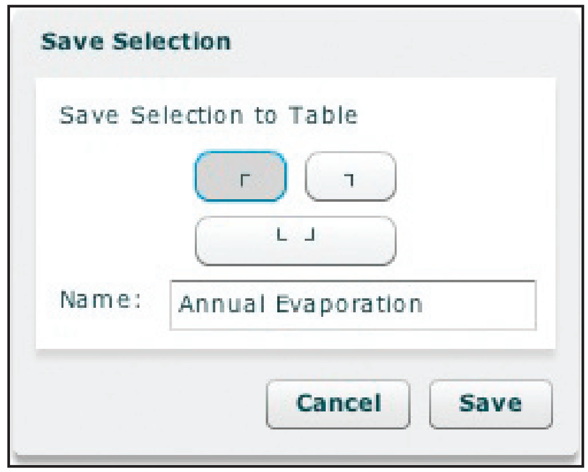


Figure 5, New Map Table

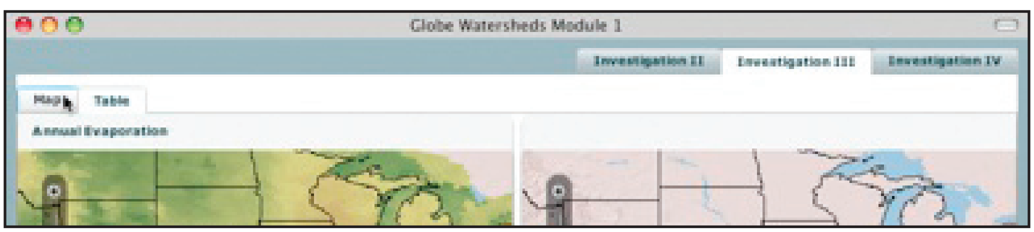


Figure 6, Map Tab button location

6. *View* the **Annual Precipitation** data layer by *changing the pull-down menu* from **Annual Evaporation** to **Annual Precipitation**. (Figure 7).

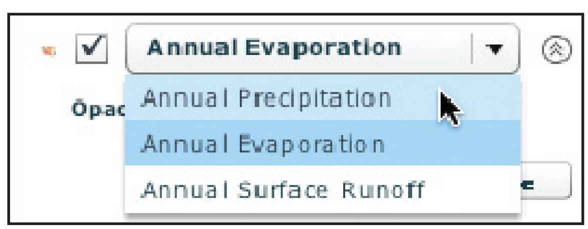


Figure 7, Viewing Annual Precipitation data layer

Question:

5. Complete the column labeled “Annual Precipitation (cm)” in table 1 (Below Question #3).

7. Insert the Annual Precipitation map into the bottom cell of the map table (Figure 8).

.   a. Make sure it is named Annual Precipitation.

    b. Click Save

8. You should have moved to the Table tab. If not, *view* the map table by *clicking* the **Table** tab.

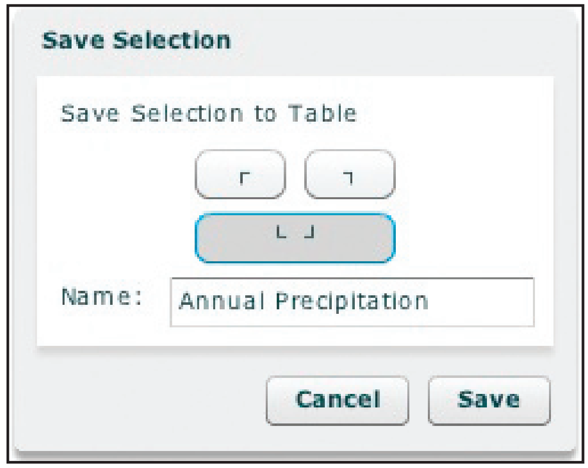


Figure 8, Adding Annual Precipitation to map table

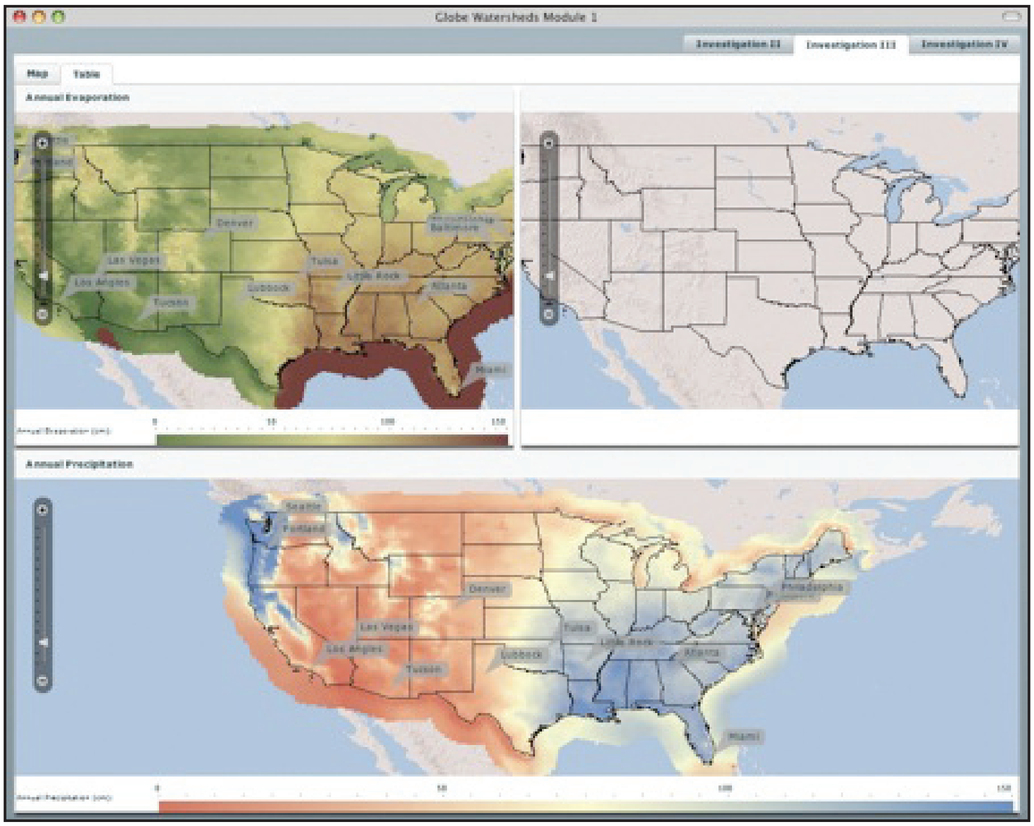


Figure 9, Map Table displaying Annual Evaporation and Annual Precipitation

Question:

6. Earlier in this activity you made a prediction about the similarities and differences in annual precipitation and evaporation amounts. Use the map table to compare the data to the prediction you made in question #1. What are the differences? (Be sure to discuss the amount of evaporation in high and low precipitation areas.)

9. Return to the **Map** tab when you are finished.

Investigation III Part 2: Investigating patterns of annual surface runoff and annual precipitation.

In this part of the investigation you will examine surface runoff. Surface runoff is the water that flows down creeks, streams and rivers. Precipitated water that has not evaporated back into the atmosphere or infiltrated into the ground runs off as surface water.

Major processes and factors influencing the timing and quantity of surface runoff include the amount of precipitation, rate of precipitation, form of precipitation (snow, rain, sleet, hail, etc), season the precipitation fell, infiltration rate, degree of ground saturation, land use and ground cover, and geology.

Question:

7. Now that you are familiar with the annual precipitation and evaporation patterns across the US, make a prediction about the similarities and differences in the patterns of annual precipitation and annual surface runoff. For example, for areas of high annual precipitation what do you expect the annual surface runoff amounts to be? For areas of low annual precipitation?

Exploring Total Annual Surface Runoff

10. *View* the **Annual Surface Runoff** data map by *changing* the layer *from* **Annual Precipitation** *to* **Annual Surface Runoff** *(Figure 10).*

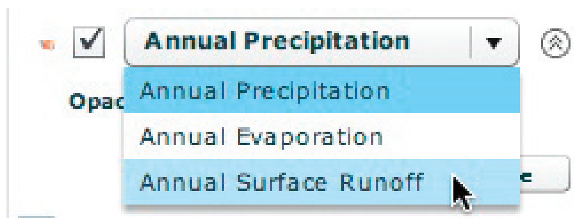


Figure 10, Selecting Annual Surface Runoff maps

Questions:

8. Which color on the Annual Surface Runoff map represents the highest surface runoff and which color represents the lowest?

9. Complete the column labeled “Annual Surface Runoff, cm” in Data Table 1 above in question #3.

10. Review the factors influencing surface runoff listed above. What evidence do you see that supports these factors in the annual surface runoff map? Can you explain high and low surface runoff areas using the factors listed above?

11. *Save* the **Annual Surface Runoff** into the top right map table (Figure 11).

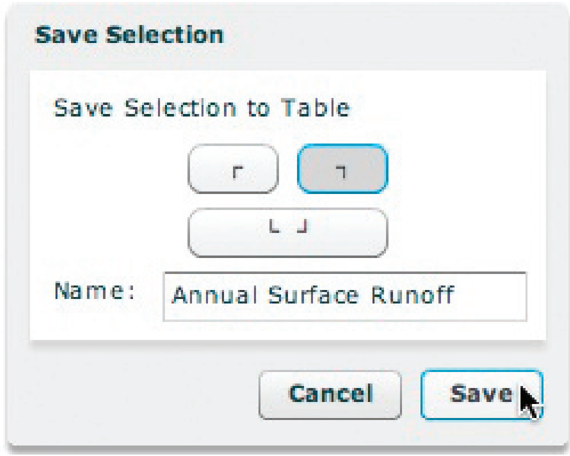


Figure 11, Saving Annual Surface Runoff to map tables

12. *This will take you to the Table tab. Look at the completed data.*(See Figure 12).

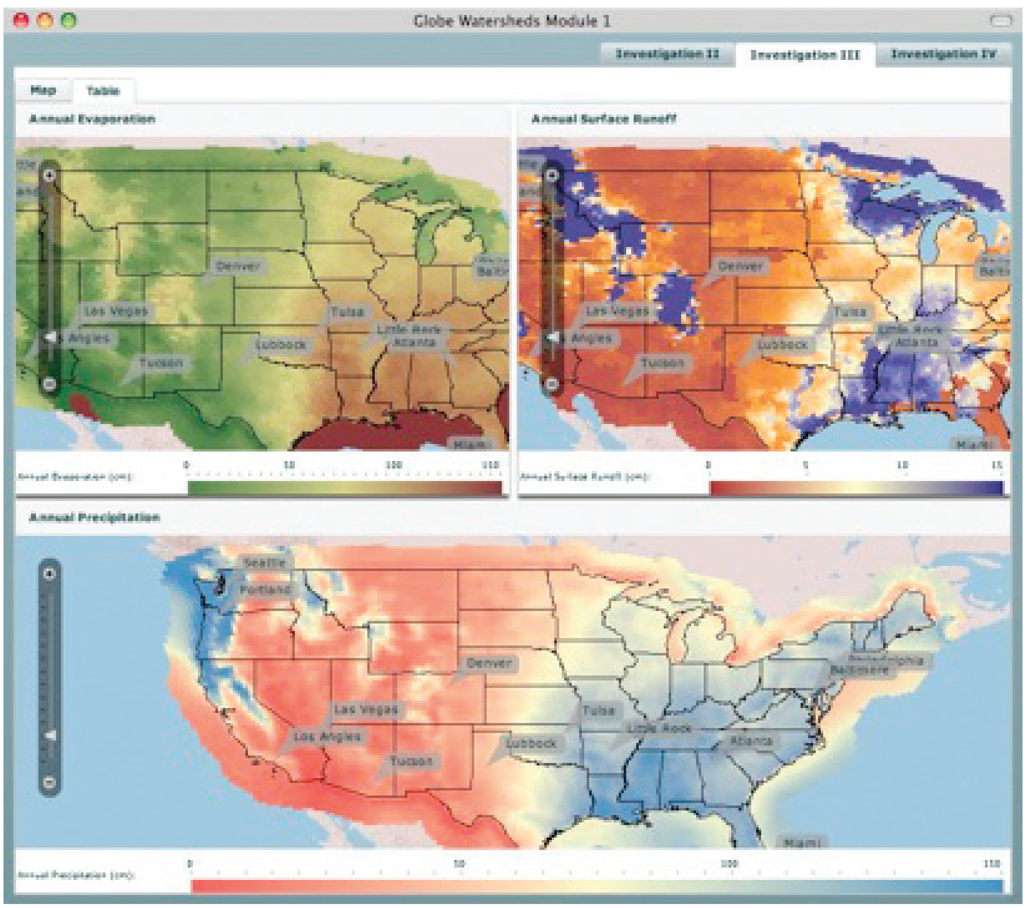


Figure 12, Completed Map Tables maps

Questions:

11. In general, what is the relationship between surface runoff and precipitation in regions that receive high amounts of annual precipitation? What is the relationship between surface runoff and precipitation in regions that receive low amounts of annual precipitation?

12. Identify an area of the US where total annual surface runoff is high even though total annual precipitation is only medium. What are possible processes or factors that cause surface runoff to be high for this area?

13. Identify an area of the US where the total annual surface runoff is low even though the annual precipitation is high. What are some possible processes or factors that cause surface runoff to be low for this area?

Name ________________________________ Date ____________ Class _________

Student Response Sheet
Investigation III: Annual Precipitation, Evaporation and Surface Runoff in the US

Questions:

1. Now that you are familiar with the annual precipitation patterns across the US and with the factors influencing rates of evaporation, make a prediction about the similarities and differences in the patterns of annual precipitation and annual evaporation. For example, for areas of high annual precipitation what do you expect the annual evaporation amounts to be? For areas of low annual precipitation?

2. Which color on the Annual Evaporation map represents the highest evaporation and which color represents the lowest?

3. Complete the column labeled "Annual Evaporation (cm)" in the data table below:

Write in the name of your city in the first row of the data table. Choose two additional cities and complete the last two rows of the data table with the data for the cities you chose.

City	Annual Precipitation (cm)	Annual Evaporation (cm)	Annual Surface Runoff (cm)
Denver			
Seattle			
Miami			
Tucson			

4. Review the factors that influence evaporation rates from page 1 of this investigation. Which of these factors are evident in the annual evaporation map?

5. Complete the column labeled "Annual Precipitation, cm" in the data table above in question #3.

6. Earlier in this activity you made a prediction about the similarities and differences in annual precipitation and evaporation amounts. Use the map table to compare the data to the prediction you made in question #1. What are the differences? (Be sure to discuss the amount of evaporation in high and low precipitation areas.)

7. Now that you are familiar with the annual precipitation and evaporation patterns across the US, make a prediction about the similarities and differences in the patterns of annual precipitation and annual surface runoff. For example, for areas of high annual precipitation what do you expect the annual surface runoff amounts to be? For areas of low annual precipitation?make a prediction about the similarities and differences in the patterns of annual precipitation and annual surface runoff. For example, for areas of high annual precipitation what do you expect the annual surface runoff amounts to be? For areas of low annual precipitation?

8. Which color on the Annual Surface Runoff map represents the highest surface runoff and which color represents the lowest?

9. Complete the column labeled "Annual Surface Runoff, cm" in the data table above in question #3

10. Review the factors influencing surface runoff listed above. What evidence do you see that supports these factors in the annual surface runoff map? Can you explain high and low surface runoff areas using the factors listed above?

11. In general, what is the relationship between surface runoff and precipitation in regions that receive high amounts of annual precipitation? What is the relationship between surface runoff and precipitation in regions that receive low amounts of annual precipitation?

12. Identify an area of the US where total annual surface runoff is high even though total annual precipitation is only medium. What are possible processes or factors that cause surface runoff to be high for this area?

13. Identify an area of the US where the total annual surface runoff is low even though the annual precipitation is high. What are some possible processes or factors that cause surface runoff to be low for this area?

Investigation IV: Seasonal Precipitation and Seasonal Surface Runoff in the US

Purpose

Students will consider the seasonality of precipitation and surface runoff and think about how the time of year can impact these variables. Students will observe the seasonal surface runoff and consider how this process changes through the seasons. They will compare the seasonal data across the different parameters and consider other variables that can influence the rates.

Overview

Students should be ready to consider the seasonality of precipitation and surface runoff, having made predictions about precipitation across the US and explored the patterns of annual precipitation, evaporation and surface runoff during the previous investigation. In this investigation, students will explore the seasonality of precipitation and surface runoff and then begin to consider some regions where the amounts of seasonal precipitation and surface runoff are not consistent. Students will be collecting quantitative data and recording it in a data table and using these data to support the answers they give to questions included in the activity. Students will begin to recognize the effect of factors such as type of precipitation, ground cover and topography on the patterns of seasonal precipitation and surface runoff.

Student Outcomes

- Discover how precipitation varies on a seasonal (winter, spring, summer, fall) basis in different regions of the US.
- Discover how surface runoff varies on a seasonal (winter, spring, summer, fall) basis in different regions of the US.
- Compare and analyze maps showing different subsets of data with Map Tables.

Time

One 45-50 minute class period

Level

Secondary

Materials and Tools

- Computers (1 computer for each student preferred) with access to the Internet (access to url http://wd.fieldscope.us).
- Student guide and student response sheets (optional)

Preparation

Make copies of student pages as necessary

Prerequisites

Investigation II: *Annual Precipitation in the United States* and Investigation III: *Annual Precipitation, Evaporation and Surface Runoff in the US*

Review the following with students before doing activity.

Background

Does the same amount of precipitation fall during winter, spring, summer, or fall where you live? In Investigation II students examined total annual precipitation. In this investigation students will look at how precipitation varies on a seasonal basis in different regions of the US.

In Investigation III students learned about the patterns of annual surface runoff. In this investigation students will examine patterns of seasonal surface runoff. We will try to understand the timing and quantity of surface runoff and compare it to seasonal precipitation patterns.

Seasons are defined by calendar months in this investigation rather than by solar dates.

- Winter—December, January, February
- Spring—March April, May
- Summer—June July, August
- Fall—September, October, November

Teaching Notes

As part of this investigation students fill out a table of seasonal precipitation and surface runoff for four pre-selected cities as well as three of their choice. As in Investigation III, an extension of this activity is to graph the data using Excel or other graphing/charting program. One important relationship for them to observe is how precipitation changes seasonally in the different cities as well as how seasonal surface runoff is affected by seasonal precipitation.

An Excel spreadsheet has been created for this purpose named Water Availability.xls and it available for download at http://www.globe.gov/projects/watersheds/h2oavailability. After downloading and opening, click on the Investigation IV tab at the bottom of the sheet to open the appropriate table and chart. Blank cells are in the table to add the students selected cities. Below is an example of the data from the four pre-selected cities in the Investigation. Because of the difference in scales, 0-60 cm for precipitation and 0-6 cm for surface runoff, it may be better to have students create two separate graphs (See figures 1 and 2).

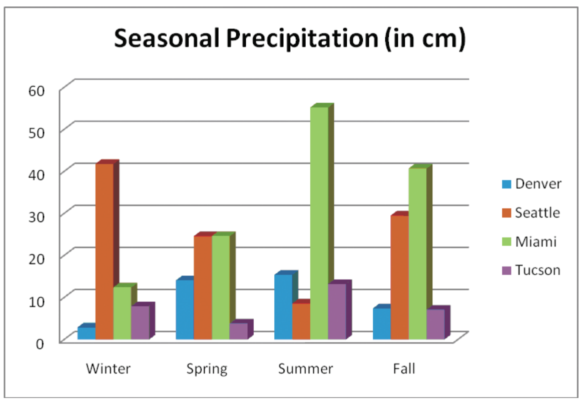


Figure 1, Seasonal Precipitation (cm)

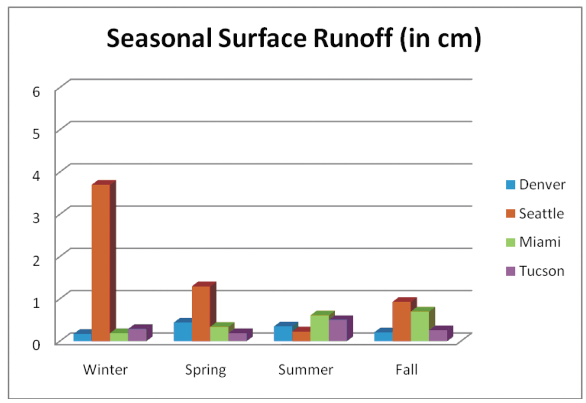


Figure 2, Seasonal Surface Runoff (cm)

Name ________________________ Date ____________ Class _________

Student Response Sheet
Investigation IV: Seasonal Precipitation and Seasonal Surface Runoff

Questions:

1. During which season does the place where you live receive the greatest amount of precipitation? The least amount?

Student answers will vary depending on location.

2. During which season do you think the Rocky Mountains in Colorado receive the greatest amount of precipitation? Which season do you think is the wettest for Orlando, Florida? Explain your reasoning for each answer.

Student answers will vary.

3. What is the range of values for Seasonal Precipitation shown on the scale bar at the bottom of each of the maps in the map table? Why do you think this range is different from the range of 0 to 150 cm used in Investigation II: Annual Precipitation?

Seasonal precipitation values range from 0-40 cm on the seasonal precipitation map table scale bar. The range is different from the range for annual precipitation because each pane of the map table considers one quarter of the year.

4. Record the amount of precipitation by season in the data table below. You should write in the name of your city in the first row of the data table and the names of the two cities you chose in Investigation III for the last two rows.

	Seasonal Precipitation (cm)				Seasonal Surface Runoff (cm)			
City	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Denver	2.9	14.1	15.4	7.4	0.17	0.44	0.35	0.21
Seattle	41.8	24.6	8.6	29.5	3.7	1.0	0.23	0.93
Miami	12.4	24.6	55.2	40.7	0.19	0.34	0.61	0.70
Tucson	7.9	3.8	13.2	7.1	0.29	0.19	0.50	0.26

5. Which regions of the country have the highest amounts of winter precipitation? The lowest amount?

The highest winter precipitation amounts are observed in the Pacific Northwest and the Northern Rocky Mountain regions. The lowest winter precipitation amounts are found in the Northern and Central Plains States. Examples of these extremes include Seattle with 30.5 cm of precipitation in the winter and Bismarck, ND with 3.3 cm of winter precipitation.

6. During which season(s) does the Pacific Northwest appear to get high amounts of precipitation?

The Pacific Northwest receives the highest amounts of precipitation during the winter with 30.5 cm, however it receives high amounts during all seasons with the exception of summer. (Spring 20.1 cm and fall 29.5 cm.)

7. Describe the seasonal precipitation patterns for the Southeast region.

Portions of the Southeast receive high amounts of rainfall all year, but fall appears to be the overall driest season. For example, Jackson, MS receives 36.7 cm in the winter, 37.0 cm in the spring, 32.4 cm in the summer and 27.6 cm in the fall. The Mississippi River portion of the region receives high precipitation during winter and spring. Florida and the Gulf Coast receive high precipitation primarily during the summer. Orlando receives 62.0 cm in the summer but only 22.0 cm in the spring.

8. Which regions receive high amounts of precipitation (>=20 cm) during the majority of the seasons throughout the year?

The Southeast receives a high amount of precipitation all year round as well as the Northeast. Most of the Midwest receives high precipitation in the spring and summer, but it decreases in the fall and winter.

9. Which regions receive low amounts (<20 cm) of precipitation year round?

The Desert Southwest receives low amounts of precipitation year-round. For example, students should note that from the data table that Phoenix receives a high of 6.1 cm in the winter and low of 3.0 cm in the spring.

10. Which regions have the highest surface runoff during the winter?

Areas with high winter surface runoff include the Southeast, the Pacific Northwest, the Rocky Mountain West, the upper part of the Northeast, and the region around the Great Lakes. Examples include: 3.7 cm in Seattle, around 6 cm in Maine, 5 cm in northern Wisconsin and over 10 cm in some areas of the Rocky Mountains.

11. Record the amount of surface runoff by season in the table in Question #4.

See data table

12. During which season is surface runoff lowest across the US? Highest?

As a whole, surface runoff is lowest during summer and fall. Surface runoff is highest during winter and spring.

13. Explain why you think the patterns of surface runoff you described in question 12 exist.

For many, though not all areas, high surface runoff occurs in the same time period when there is high precipitation. The high amounts of surface runoff are accentuated in the spring by snowmelt fed runoff.

14. How are the patterns of seasonal precipitation and season surface runoff similar across the US? How are they different?

There are some similarities; such as the Southeast has high precipitation and high surface *runoff, but in other places, like the Rocky Mountain West, there is high runoff when there is only moderate precipitation. So while there are some similarities, the relationship is not perfect, thus raising the issue that other factors must influence the amount of surface runoff.*

15. What factors and processes do you think account for the high surface runoff in the Rocky Mountains during the winter and spring?

Most of the precipitation that falls in the Rocky Mountains during winter and spring is snow, though rain does occur at lower elevations. Much of this precipitation apparently runs off as surface water, perhaps because of the steep terrain and other geologic factors. Also, water that infiltrates into the ground high up in the mountains reappears as surface water in the lower elevations of the mountains.

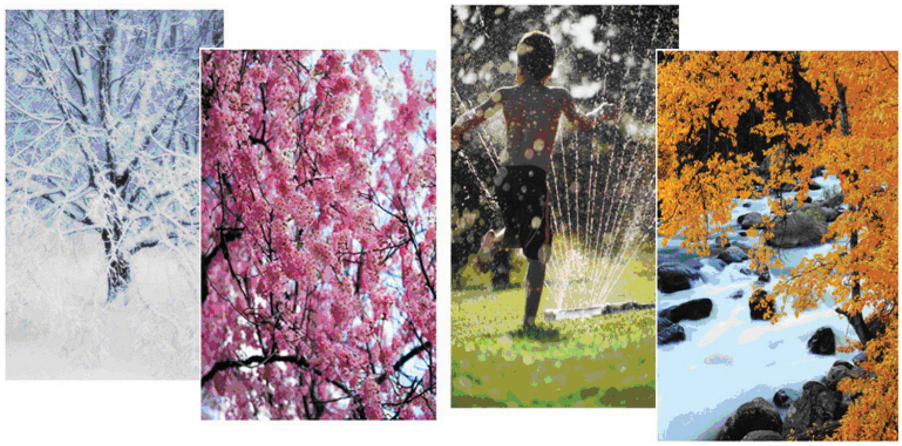
16. How are the patterns of summer / fall precipitation and summer / fall surface runoff similar across the US? How are they different? (Do high amounts of precipitation coincide with high amounts of surface runoff? Do low amounts of precipitation coincide with low amounts of surface runoff?)

In general, it appears that high runoff areas are also high precipitation areas, although there are exceptions. For example Florida receives high amounts of precipitation in the summer, but has low total surface runoff. The Rocky Mountain region has higher surface runoff in the summer months than fall in general. Areas with low annual precipitation tend to have low amounts of surface runoff.

17. How is the pattern of precipitation and surface runoff for the summer / fall seasons in the Rocky Mountains different than for the winter / spring seasons?

Most of the precipitation the Rocky Mountain region receives during the winter and spring is snow. The surface runoff is highest during the spring when the snow melts. Residual snowmelt and later spring storms contribute to the elevated amount of summer surface runoff for the region. Precipitation and surface runoff amounts decline again in the fall.

Investigation IV: Seasonal Precipitation and Seasonal Surface Runoff in the US



Winter, Spring, Summer, Fall – there are many changes that go on around us as we move through the seasons. Classes begin and end, holidays and birthdays are celebrated, the weather grows warmer and colder. Changes also occur in the rates and amounts of precipitation, evaporation and surface runoff. Do you notice the same amount of precipitation fall during winter, spring, summer, or fall where you live? In Investigations I, II and III you have been able to use your thinking skills, mapping skills and research skills to learn about local and regional patterns of precipitation, evaporation and surface runoff. In Investigation II you examined total annual precipitation. In this investigation you will look at how precipitation varies on a seasonal basis in different regions of the US. In Investigation III you learned about the patterns of annual surface runoff. In this investigation you will examine patterns of seasonal surface runoff. We will try to understand the timing and quantity of surface runoff and compare it to seasonal precipitation patterns.

Seasons are defined by calendar months in this investigation rather than by solar dates:

- Winter—December,January, February
- Spring—March, April, May
- Summer—June, July, August
- Fall—September, October, November

Note on Text Formatting Conventions Used in the Investigation Directions

Italicized – Commands executed by student or typing completed by the student within the GIS tool
Bold – Window, layer, or window names displayed by the GIS tool
Underlined – A variable selected from pull-down menu
Shaded – Questions or sections to be answered or completed by the student.

Investigation IV Part 1: Seasonal Precipitation in the US

In Investigation II you examined the total amount of precipitation that falls across the United States on an annual basis. Just as different parts of the US receive different amounts of precipitation, they also receive different amounts of precipitation during different seasons of the year. Knowing when a region will be wet, or dry, is important for many reasons. For example, farmers choose the type of crops and the time to plant based upon seasonal precipitation patterns. People traveling to different parts of the country for vacations like to know if they will be have wet or dry weather.

Questions:

1. During which season does the place where you live receive the greatest amount of precipitation? The least amount?

2. During which season do you think the Rocky Mountains in Colorado receive the greatest amount of precipitation? Which season do you think is the wettest for Orlando, Florida? Explain your reasoning for each answer.

Opening a project and exploring seasonal precipitation

In Investigations II and III, you created map tables to help you visualize, compare and analyze annual precipitation, evaporation and surface runoff patterns. In this activity, you will use map tables that are provided with the project file to visualize, compare and analyze seasonal precipitation and surface runoff patterns across the US.

1. *Launch* your web browser. *Go to* website: http://wd.fieldscope.us.

2. *Click on* the tab for **Investigation IV** (Circled in figure 1).

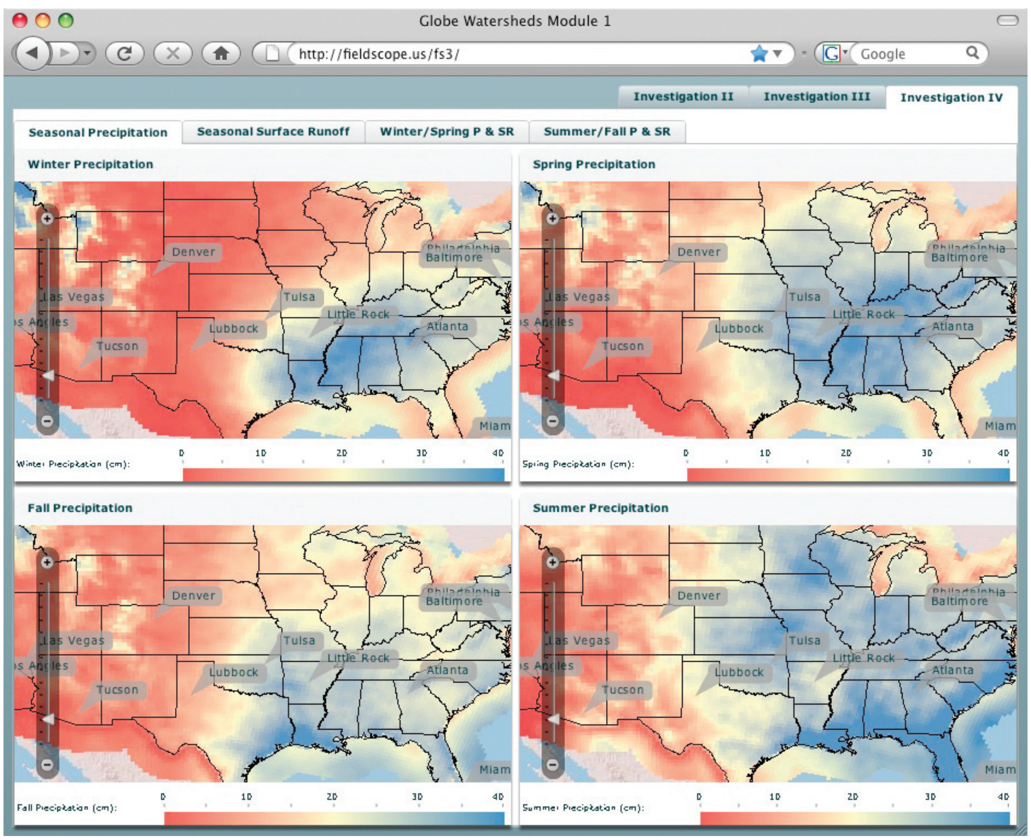


Figure 1, Investigation IV tab

Investigation IV has four map tables in it for you to look at different sets of data. The first table shows you precipitation patterns for the different seasons. Pay attention to which season is in which corner.

Questions:

3. What is the range of values for Seasonal Precipitation shown on the scale bar at the bottom of each of the maps in the map table? Why do you think this range is different from the range of 0 to 150 cm used in Investigation II: Annual Precipitation?

4. Record the amount of precipitation by season in table 1 (below) or on your Student Response Sheet. You should write in the name of your city in the first row of the table and the names of the two cities you chose in Investigation III for the last two rows.

(Remember that you can click on any one of the maps in the Seasonal Precipitation Map Table and the amount of precipitation for each season for that city will be displayed on the legend with a triangle next to it.)

	Seasonal Precipitation (cm)				Seasonal Surface Runoff (cm)			
City	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Denver								
Seattle								
Miami								
Tucson								

Table 1, Seasonal Precipitation and Runoff data

Questions:

5. Which regions of the country have the highest amounts of winter precipitation? The lowest amount?

6. During which season(s) does the Pacific Northwest appear to get high amounts of precipitation?

7. Describe the seasonal precipitation patterns for the Southeast region.

8. Which regions receive high amounts of precipitation (>=20 cm) during the majority of the seasons throughout the year?

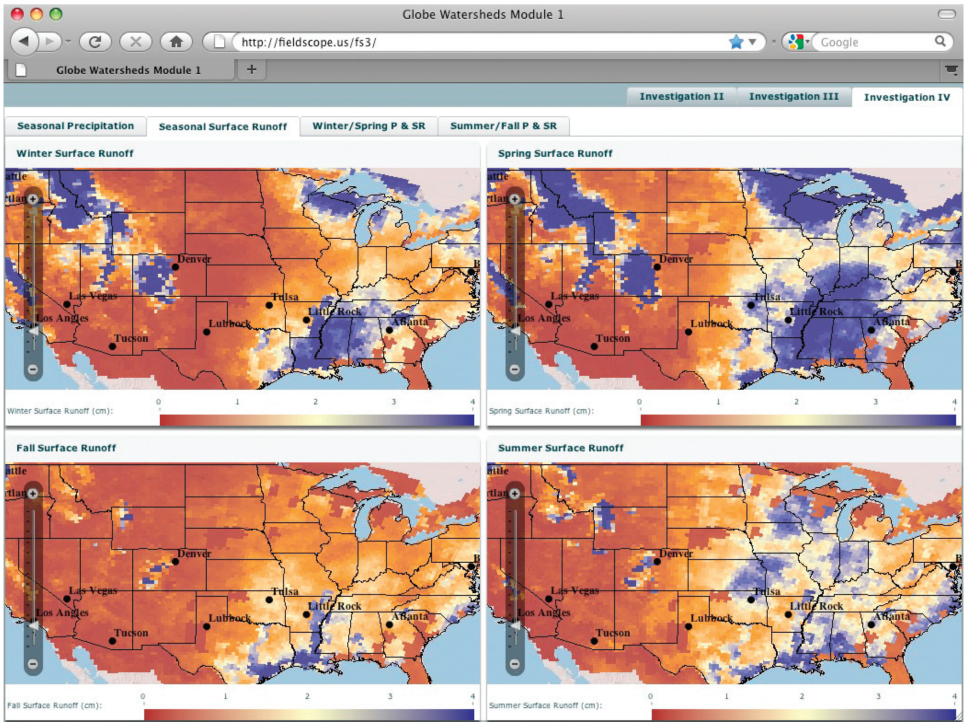
9. Which regions receive low amounts (<20 cm) of precipitation year round?

Investigation IV Part 2:
What Regions of the Country Have the Highest Surface Runoff On a Seasonal Basis?

3. *Click on* the map table tab **Seasonal Surface Runoff**.

Winter

Spring



Fall

Summer

Figure 2, Seasonal Surface Runoff maps

Questions:

10. Which regions have the highest surface runoff during the winter?

11. Record the amount of surface runoff by season in the Table 1.

12. During which season is surface runoff lowest across the US? Highest?

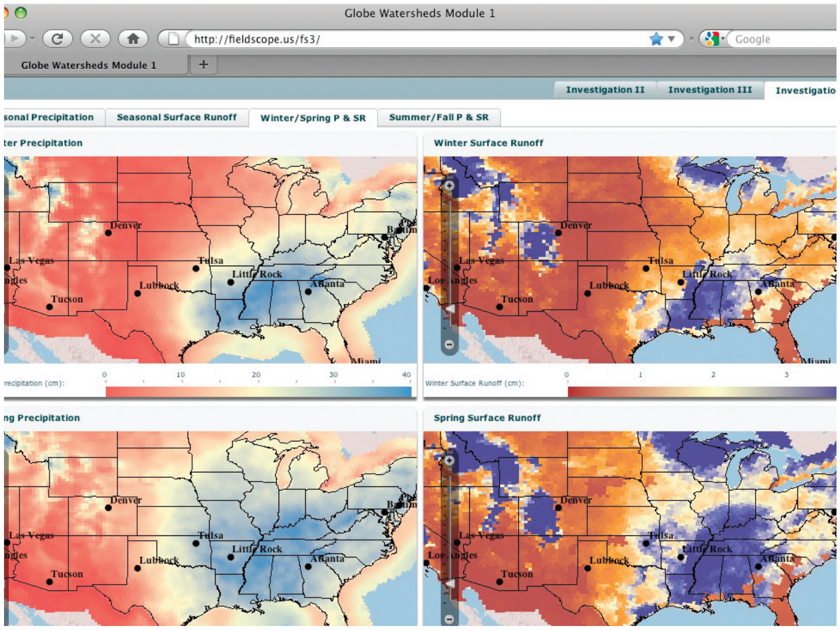
13. Explain why you think the patterns of surface runoff you described in question 12 exist.

Comparing Seasonal Precipitation and Seasonal Surface Runoff

4. *Click on* the map table tab **Winter/Spring P & SR**.

Winter

Spring



Winter

Spring

Figure 3, Winter/Spring Precipitation and Surface Runoff maps

Questions:

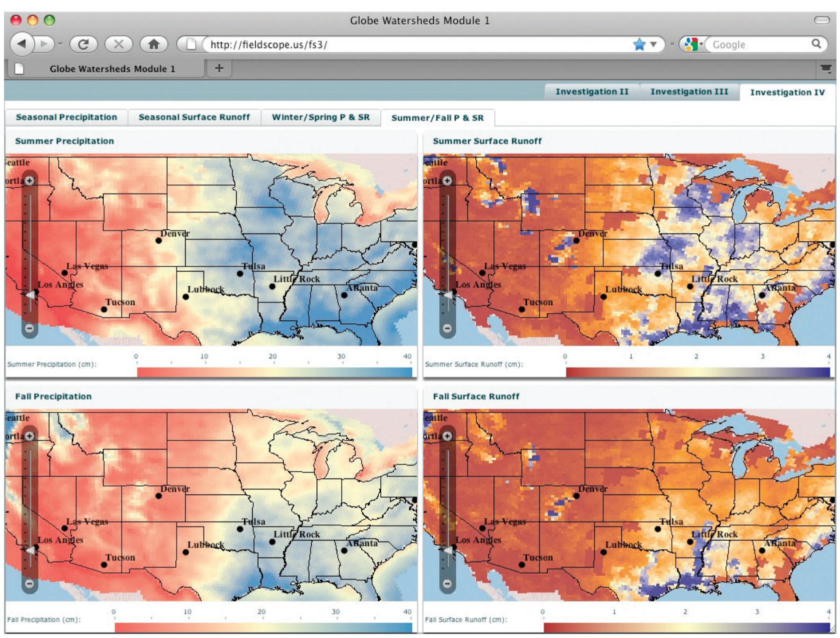
14. How are the patterns of winter / spring precipitation and winter / spring surface runoff similar across the US? How are they different? (Do high amounts of precipitation coincide with high amounts of surface runoff? Do low amounts of precipitation coincide with low amounts of surface runoff?)

15. What factors and processes do you think account for the high amounts of surface runoff in the Rocky Mountains during the spring (more so than during the winter)?

5. *Click on* the map table tab **Summer/Fall P & SR**.

Summer

Fall



Summer

Fall

Figure 4, Summer/Fall Precipitation and Surface Runoff maps

Questions:

16. How are the patterns of summer / fall precipitation and summer / fall surface runoff similar across the US? How are they different? (Do high amounts of precipitation coincide with high amounts of surface runoff? Do low amounts of precipitation coincide with low amounts of surface runoff?)

17. How is the pattern of precipitation and surface runoff for the summer / fall seasons in the Rocky Mountains different than for the winter / spring seasons?

Name ____________________ Date ________ Class ______

Student Response Sheet
Investigation IV: Seasonal Precipitation and Seasonal Surface Runoff

Questions:

1. During which season does the place where you live receive the greatest amount of precipitation? The least amount?

2. During which season do you think the Rocky Mountains in Colorado receive the greatest amount of precipitation? Which season do you think is the wettest for Orlando, Florida? Explain your reasoning for each answer.

3. What is the range of values for Seasonal Precipitation shown on the scale bar at the bottom of each of the maps in the map table? Why do you think this range is different from the range of 0 to 150 cm used in Investigation II: Annual Precipitation?

4. Record the amount of precipitation by season in the table below. You should write in the name of your city in the first row of the data table and the names of the two cities you chose in Investigation III for the last two rows.

	Seasonal Precipitation (cm)				Seasonal Surface Runoff (cm)			
City	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Denver								
Seattle								
Miami								
Tucson								

5. Which regions of the country have the highest amounts of winter precipitation? The lowest?

6. During which season(s) does the Pacific Northwest appear to get high amounts of precipitation?

7. Describe the seasonal precipitation patterns for the Southeast region.

8. Which regions receive high amounts of precipitation (>=20 cm) during the majority of the seasons throughout the year?

9. Which regions receive low amounts (<20 cm) of precipitation year round?

10. Which regions have the highest surface runoff during the winter?

11. Record the amount of surface runoff by season in the table in Question #4.

12. During which season is surface runoff lowest across the US? Highest?

13. Explain why you think the patterns of surface runoff you described in question 12 exist.

14. How are the patterns of seasonal precipitation and season surface runoff similar across the US? How are they different?

15. What factors and processes do you think account for the high surface runoff in the Rocky Mountains during the winter and spring?

16. How are the patterns of summer / fall precipitation and summer / fall surface runoff similar across the US? How are they different? (Do high amounts of precipitation coincide with high amounts of surface runoff? Do low amounts of precipitation coincide with low amounts of surface runoff?)

17. How is the pattern of precipitation and surface runoff for the summer / fall seasons in the Rocky Mountains different than for the winter / spring seasons?