GLOBE Watershed Dynamics

International Water Availability
(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.

Project Contributors:

Principal and Co-Investigators:

Kemi Jona [1]
Daniel Edelson [2]
David Maidment [3, 4]

Project Coordinator:

Colleen Buzby [1]

Evaluator/Additional Contributors:

Aida Awad [6]
Steve McGee [5]
Matthew Rossi [1]
Eric Russell [2]
Colin Sheaff [1]

GLOBE Program Team Lead:

Gary Randolph [7]
David Smith (former) [7]
Martos Hoffman (former) [7]

1. Northwestern University
2. National Geographic Society
3. University of Texas at Austin
4. CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science, Inc.)
5. The Learning Partnership
6. Maine East High School
7. The GLOBE Program Office

For more information contact the GLOBE Help Desk:
help@globe.gov

Contact the Watershed Dynamics Project directly at:
watersheds@globe.gov

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 it goes over time through guiding students in:

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 http://wd.northwestern.edu.

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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 45 minute 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 visit http://bubbl.us (an online concept mapping tool) or students can develop 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.

Click on file and choose new Cmap.

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

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.

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.

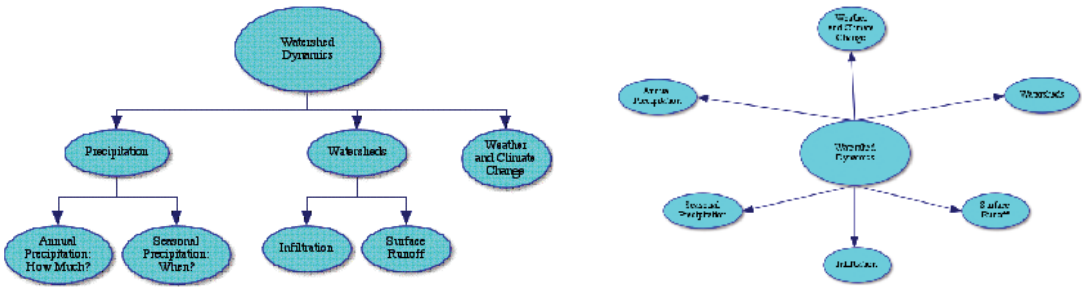


Figure 1, Foundational concept map examples

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

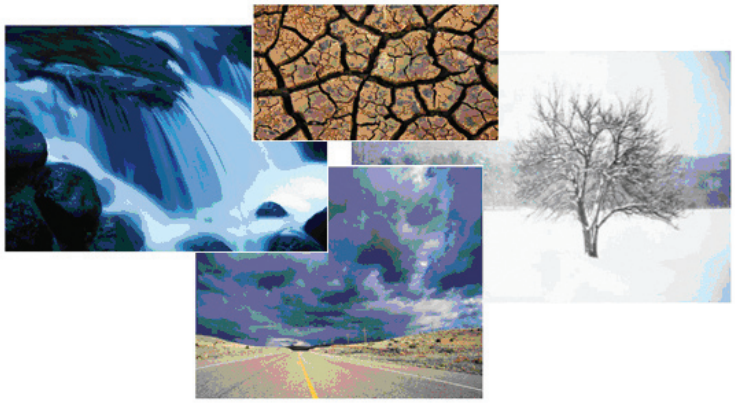
a concept map. Concept maps created with Cmap can be saved, emailed, shared, printed out in a variety of formats, embedded in other documents or saved as a webpage. Cmap can be downloaded at no cost from the IHMC Cmap webpage. The link is:http://cmap.ihmc.us/

- 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 or other on-line concept mapping tools where students can also create and edit concept maps synchronously or asynchronously. 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 Underlined – 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.

Creating a concept map using Cmap Tools (or other concept mapping tool):

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* new Cmap.

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.

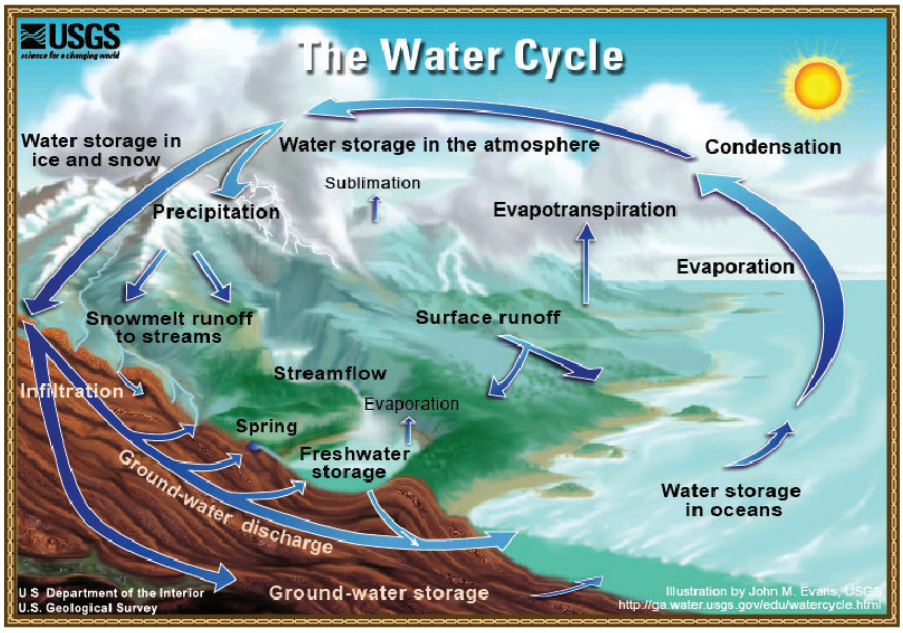


Figure 1, The Water Cycle, USGS

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

Purpose

The purpose of this activity is to study the distribution of annual precipitation around the world. Students analyze what regions receive high precipitation and what areas receive low precipitation. Students begin to look at data in various forms, starting with text data from media and scientific resources (Readings for Part 1), they generate predictive data based on their first findings (Paper Map of Annual Precipitation), then they look at geospatial data generated by computer models based on observed data (Annual Precipitation Layer in the GIS). Students will then compare their predictions to the scientific data in the GIS.

Overview

Students examine total annual precipitation patterns around the world using their existing knowledge of annual precipitation to create a generalized annual precipitation map of the world, 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 around the world.
- Describe which areas of the world receive high, medium, and low amounts of total annual precipitation.
- Understand that multiple; interacting Earth systems influence patterns of precipitation.
- Understand the differences between weather and climate.

Part II

- Develop skills in the use of the GIS tool to analyze archived data sets.
- Categorize data
- Interpret data displayed on a map
- Reflect on, review, and revise prior predictions

Time

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

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://wdi.fieldscope.us).

Preparation

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

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.

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 Around the World?

- This activity asks students to read a short set of articles about precipitation patterns in different regions of the world. These readings do not cover every study city or region. Additionally, most readings refer to precipitation in metric units while others refer to both metric and non-metric units. Students should use only the metric units in these investigations. 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 millimeters of water throughout this investigation. Not all precipitation is in the form of rain. When the amount of snow, rain, sleet, hail, or any type of precipitation is measured, it is measured as the amount of melted, liquid water. Therefore the term "precipitation" is best thought of as "liquid water," or just "water."

What is the "Annual Precipitation" layer?

This GIS data layer contains seasonal as well as annual precipitation, evaporation, and water runoff data for the entire world. These data are an average of the ten year long 1996-2005 time period. **NCEP** (National Centers for Environmental Prediction) Reanalysis is a long-term, consistent, high-resolution climate dataset.

The data is produced by taking data from weather stations around the world and then using sophisticated computer models to calculate estimated values for those places where there are not any weather stations. The data displayed in each pixel (or cell) is a calculated value, not the actual weather station data.

The Annual Precipitation layer in Investigation III contains data *on annual precipitation, evaporation and surface runoff (see* figure A). 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 layer.

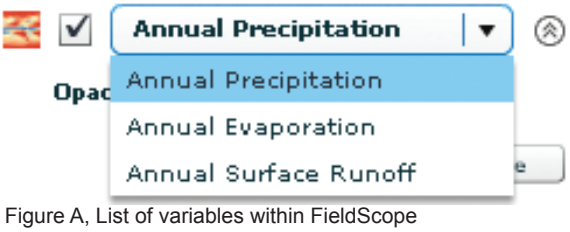


Figure A, List of variables within FieldScope

Geographic regions

Throughout this module of Watershed Dynamics Investigations I-IV students will be exploring data in a variety of ways. Some questions expect that students will be familiar with names of the continents as well as some countries. It may be helpful to review these designations with students prior to beginning the investigations. It may also be helpful to instil in students the importance of using atlases and maps

for the purposes of learning geography as well as for the successful use of these activities. Several resources are available on-line include Google Earth, ArcGIS Explorer, and Wikimapia.

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 Around the World?

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

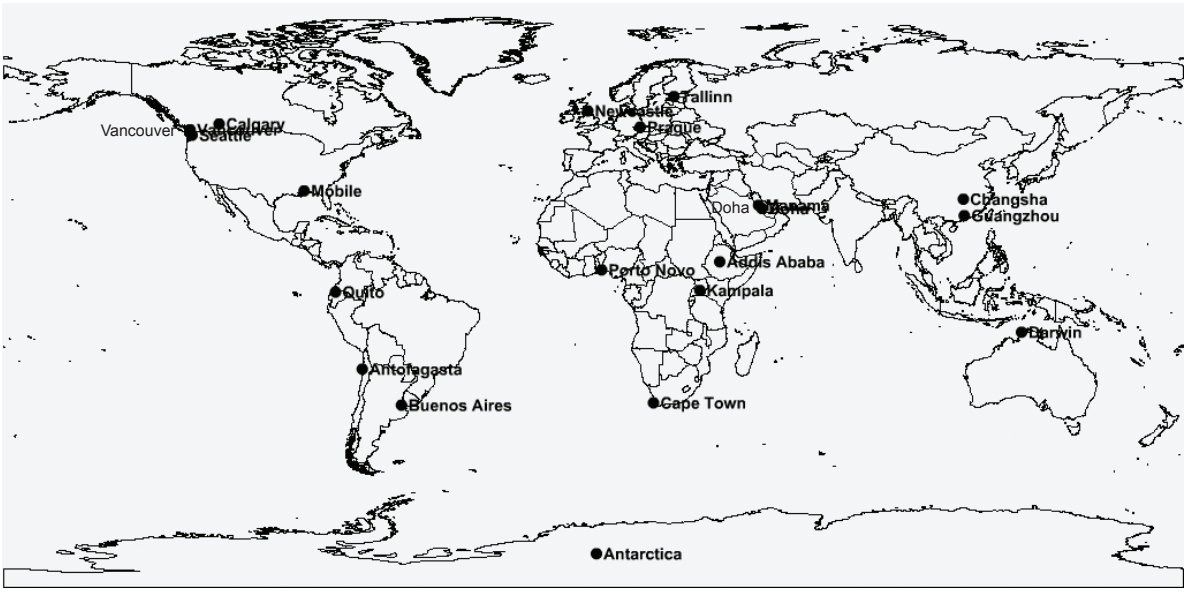
3. What amounts of total annual precipitation did you consider to be high? Medium? Low?

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

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

   Student answers will vary. They should justify why they separate values, it could be based on even splits, or they could have defined the 3 lowest the only low, and the 3 highest as the only high, but this answer should support the values they used in the previous question.

Map: Total Annual Precipitation Prediction Name(s) _____



LOCATION	Total Annual Precipitation Value From Readings	Is that value High, Medium, or Low?	Total Annual Precipitation *From the GIS-Annual Precipitation Layer (milimeters)*

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 Annual Precipitation data and should lead to a similar picture. Though, because the Annual Precipitation data is based upon computer modeling, and because it only shows data at a coarse resolution, Annual Precipitation values will not be exactly like those found in the readings.

2. Is the high range of 3000 mm on the legend the highest total annual precipitation of the map? What is the highest total annual precipitation value you can find by clicking on the map? Where in the world does this very high precipitation occur?

   Values in the blue can reach approximately 6000 mm. The values on the map go higher than the scale in the legend at the bottom of the screen, which reads from 0-3000 mm The highest values are near the Equator.

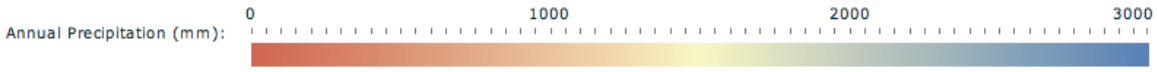
3. What is the lowest total annual precipitation value you can find by clicking on the map? Where in the world does this very low precipitation occur?

   There are very low values in Antarctica, central Asia, several areas over the oceans and in the Sahara region of Africa, where values are lower than 10 mm.

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 1500 mm to divide medium from low because it divided the red and blue landmasses into separate categories. The high could be above 2500 mm 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 500 mm, or there could be more categories used. Students should elaborate on this question with their own ideas, recognizing that some science is subjective.

8. Compare your answer to question #2 above to the map with Very High Precipitation Areas (>= 2000 mm) selected. What additional information is evident on the new map?

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

9. Compare your answer to question #3 above to the map with Very Low Precipitation Areas (<500 mm) selected. What additional information is evident on the new map?

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

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

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

11. What regions of the world received the greatest amount of total annual precipitation?

    The Equatorial region (parts of Latin America, Africa and Asia)

12. What regions of the world receive the least amount of total annual precipitation?

    Students should be able to identify the Sahara Desert (Northern Africa) as an area that receives very little precipitation.

13. How would you compare total annual precipitation near the Equator versus North or South of the Tropics? (note, while the Tropic of Cancer and Capricorn are not evident in the GIS, it should be possible to esitmate where these lines lie on the map)

    The Equatorial region experiences, on the whole, much more precipitation that either North or South of it. An exception might be the transition from Western Africa, near Sierra Leone (which receives a great amount of precipitation), to Central Africa, near Central African Republic (which receives moderate precipitation), to Eastern Africa, near Somalia (which receives very little preciptation).

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

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

Investigation II: Annual Precipitation

Does it seem to you like some parts of the world 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 different regions of the world receive 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) do certain cities and countries get in a year? Review current articles and news stories about precipitation from around the world. 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 Around the World?

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 around the world.

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 world.
   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 **Total Annual Precipitation Value 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 under ***Is that value High, Medium, or Low?***
   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

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

   a. Color in those regions of the world 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 world.

Analysis Questions

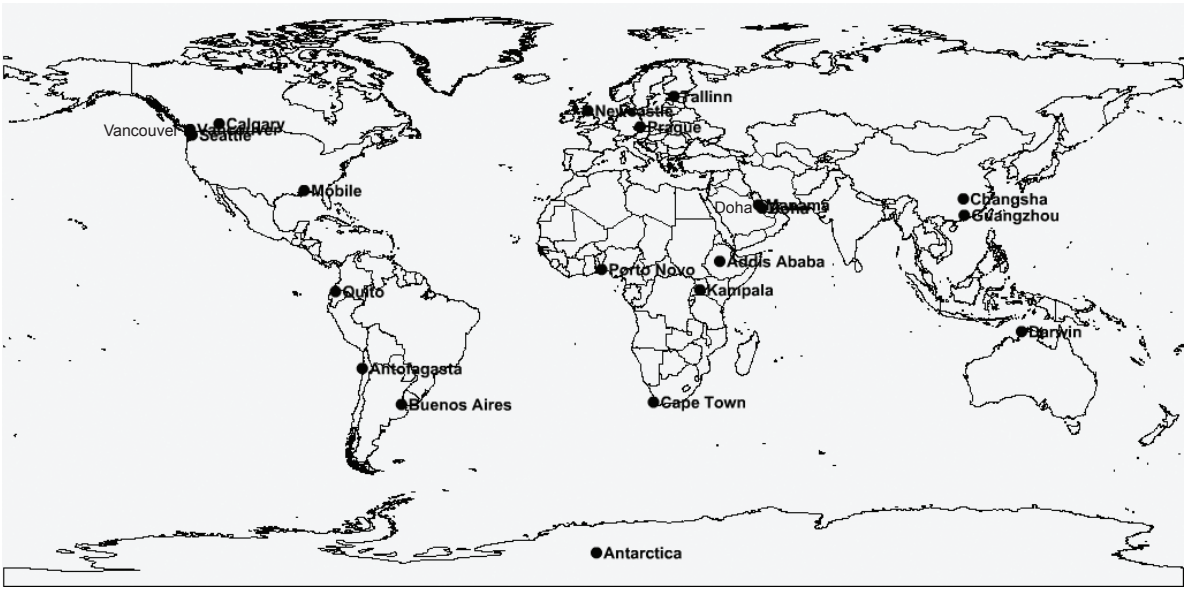
1. How are the maps from the groups similar? How are they different?

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



LOCATION	Total Annual Precipitation Value From Readings	Is that value High, Medium, or Low?	Total Annual Precipitation *From the GIS-Annual Precipitation Layer (milimeters)*

Readings for Investigation II Part 1: How Wet or Dry Is It Around the World?

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

AFRICA

In **Afar, Ethiopia** poor rains are reported to have sucked wells and rivers dry, forcing women to trek for up to seven hours a day to find water. Thousands of livestock - which are the main means of survival for Afari farmers - are also reportedly dying at an alarming rate.

Afar is a lowland region, constituting one-fifth of the territory of Ethiopia. On average, the region receives 300 mm of rainfall a year - a quantity which can fall in the capital, Addis Ababa, in a single month.

Agencies are warning that seven countries in Africa face a potentially catastrophic famine - with as many as 14 million people at risk of starvation.

Source: BBC News, World Edition "Ethiopia facing food crisis" 2005.
http://news.bbc.co.uk/2/hi/africa/2153837.stm

The climate in **South Africa** is typically warm and dry, with winter temperatures rarely falling below 0° C, and summer maxima frequently above 35° C. The average annual rainfall is approximately 500 mm (considerably less than the world average of 860 mm). Most of the central and eastern parts of the country enjoy summer rainfall, whilst the western side of the country is the winter rainfall region.

Source: South African Government Department of Environmental Affairs "Background to South Africa"
http://www.environment.gov.za/Enviro-Info/sote/nsoer/general/about.htm

ASIA

CHANGSHA, May 17, 2010 (Xinhua) -- The third round of heavy rain to pound central China's Hunan Province this month began late Sunday, and more rains are expected this week, the province's flood-control and drought relief headquarters said.

Downpours hit townships in north and northwest Hunan; about 3.7 million people were affected. According to the headquarters, the direct economic losses were estimated at 1.66 billion yuan (240 million U.S.dollars).

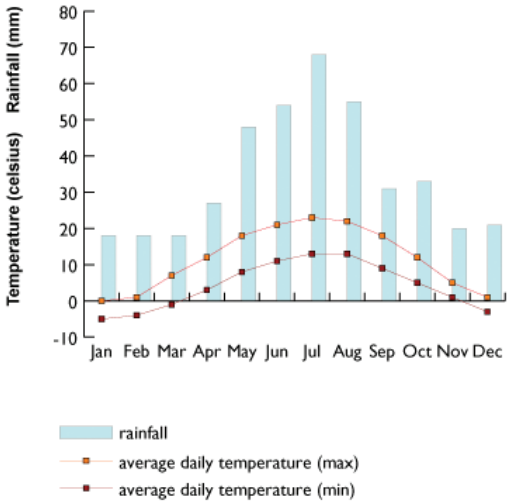
In southern province of Guangdong, three rainstorms pelted Guangzhou, the provincial capital, bringing the highest weekly rainfall, of up to 440 mm, in 25 years. The precipitation equalled a quarter of the city's annual rainfall, according to meteorological statistics.

People clear the rocks that blocked a river in Bajiaoshan Village of Xinhua County, central China's Hunan Province, May 15, 2010. A rainstorm hit the county again on May 12, causing geological accidents, including landslides and mud flows. (Xinhua/Guo Guoquan)

Source: Xinhua News "New round of torrential rains pound Chinese regions"
http://news.xinhuanet.com/english2010/china/2010-05/17/c_13299698.htm

EUROPE

The following bar chart for Prague, Czech Republic shows the year's average weather condition readings covering rain, average maximum daily temperature and average minimum temperature.



Source: BBC News "New round of torrential rains pound Chinese regions"
http://www.bbc.co.uk/weather/world/city_guides/results.shtml?tt=TT003480

Drought warnings have been issued across the UK as the country suffers its driest start to the year for 46 years.

Parts of the country are facing hosepipe bans and the government's environmental watchdog and water companies have been forced to activate their drought action plans. Figures from the Met Office show rainfall across the UK for the first five months of 2010 averaged 318.99 mm, compared to the long-term average of 424.1 mm. Drought fears: A lack of rainfall has caused the Haweswater reservoir in Cumbria to fall to 61 per cent capacity - nearly 20 per cent less than normal.

This made the start of 2010 the driest since 1964, when an average of 307.99 mm was recorded.

Drought fears: A lack of rainfall has caused the Haweswater reservoir in Cumbria to fall to 61 per cent capacity - nearly 20 per cent less than normal

Source: Daily Mail "Drought warning for UK as country suffers driest start to year for almost 50 years"
http://www.dailymail.co.uk/news/article-1287008/Drought-warning-UK-country-suffers-driest-start-year-50-years.html?ito=feeds-newsxml

LATIN AMERICA & CARIBBEAN


Elleanthus.(CHRIS KRAUL)

Mindo is an easy-access epicenter of biodiversity in northwestern Ecuador teeming with hundreds of orchid and bird species, all framed by spectacular Andean scenery in a cool, temperate climate.

Its surrounding cloud forest contains a specific variety of tropical or subtropical ecosystem that occurs at just the right mix of altitude -- Mindo's valley varies from 4,500 to 8,000 feet -- cloud cover, sunlight, mild temperatures and moisture. Rainfall averages 5 feet *[1524 mm]* or more per year.

It rains almost every day, but much of Mindo's wetness comes from condensed moisture from clouds that hover at canopy level, particularly after noon. Moss covers many of the trees. In this botanical caldron, orchids, bees, hummingbirds and the other pollinators they depend on thrive.

Source: Indystar "Step outside into Ecuador's floral factory and aviary"
http://www.indy.com/posts/step-outside-into-ecuador-s-floral-factory-and-aviary

BUENOS AIRES, (IPS) - The persistent drought affecting some 90 percent of Argentine territory has slain cattle in the hundreds of thousands and caused forest fires, drastic restrictions on water use and local disputes over water.

The area around Tostado, a town in the northeastern province of Santa Fe, is one of the worst hit. Over the last two years, heat and drought have silently killed off cattle and bankrupted farmers on small and medium sized ranches.

"This area normally gets between 800 and 900 mm of rainfall a year, but in 2008 it got 344 mm, and this year it has had less than 340," states veterinarian Felipe Brizuela, the head of the Regional Economic Council of Tostado.

Source: Inter Press Service News Agency "Desperately Dry"
http://ipsnews.net/news.asp?idnews=49238

The world's driest place, the Atacama Desert, receives only 0.04" of rain (0.2% of the 16.5" that Salt Lake City sees each year). It is located in northern Chile and covers about 40,600 square miles of land.

The reason it is so dry is due to the rain shadow created on the leeward side of the Chilean Coast Range as well as a coastal inversion layer created by the cold offshore Humboldt Current.

While the average amount of precipitation is 0.04" for that region, some weather stations in the Atacama Desert have never received rainfall. Evidence even suggests that the Atacama may not have had any significant rainfall from 1570 to 1971!

Source: ABC4.com, Salt Lake City, Utah "Weekly Weather Wonder - Driest Places on Earth"
http://www.abc4.com/content/news/state/story/Weekly-Weather-Wonder-Driest-Places-on-Earth/edsMLVlwg0KVm9LRFrLFew.cspx

NEAR EAST

Manama's climate essentially comprises two phases. In the first phase, a hot summer extends between April and October, when temperature may reach over 45 degrees Celsius and are very uncomfortable. The blowing of southerly hot winds called the qaws during these months carrying sand dunes make it further painful. However in the second phase, Manama's climate changes for the better between November and March, when the temperature ranges between 10 degrees and 20 degrees Celsius. During December to March, humid winds called Shammal blow damp air with 90% moisture. However Manama has hardly a seven centimeter rain fall annually.

Source: Bahrain Travel "Manama - A Cultural Oasis in the Middle–East"
http://www.bahrain.vg/manama.html

NORTH AMERICA

Do you think Seattle is the rainiest city in the United States? Well, think again.

Mobile, Ala., actually topped a new list of soggiest cities in the contiguous 48 states, with more than 5 feet *[1524 mm]* of rainfall annually, according to a study conducted by San Francisco-based WeatherBill, Inc.

The Southeast dominated the most rainy list, while the Pacific Northwest never enters the list until Olympia, Washington pops up at number 24.

Source: MSNBC "And the rainiest city in the U.S. is..."
http://www.msnbc.msn.com/id/18827213

Grain farmers in southern Alberta have started counting their losses along with the millimetres of water flooding their fields as rain continues to drench the region.

More than double the annual average rainfall has deluged some spots in both southern corners of the province since April 1, making fields -- as well as highways -- impassible.

And farmers who were able to seed their fields are watching the seedlings come up yellow and spindly as their roots rot or are oxygen-deprived.

Laurence Nicholson worked from 4 a.m. to 10 p.m. in the spring to get the crop in his 405 hectares before the rain, but without sun and heat, the Medicine Hat grain farmer stands to lose $150,000.

"It's a disaster, really," Nicholson said. "We got 3.2 inches of rain in 10 minutes three years ago, but the ground was dry and took a lot of rain."

Southeastern Alberta usually sees up to 400 mm of rain over a year, but this spring has received up to 500 mm of rain since April 1, said moisture expert Ralph Wright, with Alberta Agriculture.

Source: Calgary Herald "Farmers under gun as heavy rain drowns fields"
http://www.calgaryherald.com/news/Farmers+under+heavy+rain+drowns+fields/3184297/story.html?cid=megadrop_story

ANTARCTICA

One of the driest places on Earth may come as a surprise to you. Antarctica is the largest desert in the world. It only receives 8" *[203.2 mm]* of precipitation per year (that's drier than the driest year ever recorded at Salt Lake City).

In fact, Antarctica, on average, is the coldest, driest, and windiest continent. It also has the highest average elevation of all the continents.

Source: ABC4, Salt Lake City, Utah "Weekly Weather Wonder - Driest Places on Earth"
http://www.abc4.com/content/news/state/story/Weekly-Weather-Wonder-Driest-Places-on-Earth/edsMLVlwg0KVm9LRFrLFew.cspx

ARCTIC

Tundra is the coldest of all the biomes. Tundra comes from the Finnish word tunturi, meaning treeless plain. It is noted for its frost-molded landscapes, extremely low temperatures, little precipitation, poor nutrients, and short growing seasons. Dead organic material functions as a nutrient pool.

The arctic is known for its cold, desert-like conditions. The growing season ranges from 50 to 60 days. The average winter temperature is -34° C (-30° F), but the average summer temperature is 3-12° C (37-54° F) which enables this biome to sustain life. Rainfall may vary in different regions of the arctic. Yearly precipitation, including melting snow, is 15 to 25 cm (6 to 10 inches). When water saturates the upper surface, bogs and ponds may form, providing moisture for plants. There are no deep root systems in the vegetation of the arctic tundra, however, there are still a wide variety of plants that are able to resist the cold climate.

Source: University of California Museum of Paleontology "The Tundra Biome"
http://www.ucmp.berkeley.edu/exhibits/biomes/tundra.php

ATLANTIC OCEAN

Estimates of annual rainfall between the equator and 60°N, average 1034 mm and the annual volume is 3.93 × 104km3. Compared to the Pacific, the Atlantic is significantly drier and has less extreme values. Maps of amplitude and phase show that most of the North Atlantic cast of 60°W experiences a inter peak rainfall. The South Atlantic experiences its peak rainfall in the Southern Hemisphere summer.

Source: Dorman, C. E. and R. H. Bourke. 1981. Precipitation over the Atlantic Ocean, 30S to 70N. Monthly Weather Review 109:554-563.
http://journals.ametsoc.org/doi/abs/10.1175/1520-0493(1981)109%3C0554%3APOTAOT%3E2.0.CO%3B2

Name _____ Date _____ Class _____

Student Response Sheet
Investigation II Part 1: How Wet or Dry Is It Around the World?

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 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 3. categories.

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
Underlined – 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://wdi.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 there 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).

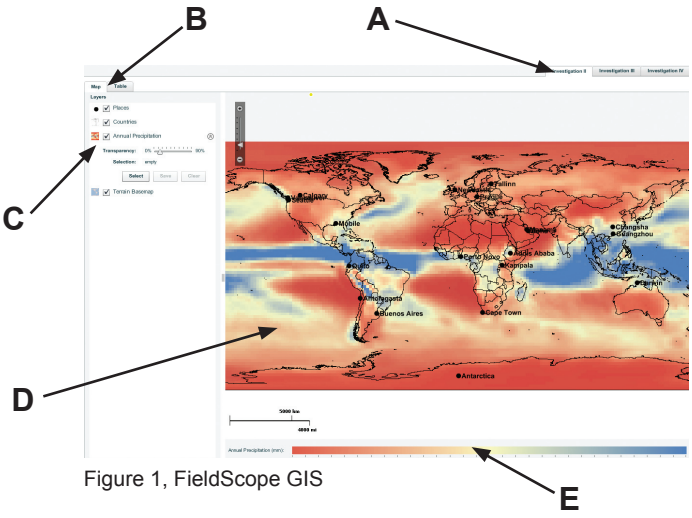


Figure 1, FieldScope GIS

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: **Places**, **Countries**, **Annual Precipitation**, and **Terrain Basemap**.

Notice the legend below the map (Figure 1,E), which shows the name of the layer **Annual Precipitation** and units (**mm**). 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 southern Sri Lanka shows a triangle at approximately 2140.95 mm of precipitation along the bottom legend.

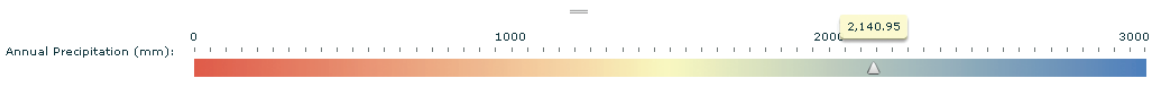


Figure 2, The GIS bottom legend showing annual precipitation in Sri Lanka.

2. Zoom in and click on the map 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. Click on the map to explore the range of total annual precipitation values around the world.

Questions:

2. Is the high range of 3000 mm on the legend the highest total annual precipitation of the map? What is the highest total annual precipitation value you can find by clicking on the map? Where in the world does this very high precipitation occur?

3. What is the lowest total annual precipitation value you can find by clicking on the map? Where in the world does this 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 to 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 cursor to click and 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 the legend below with 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.

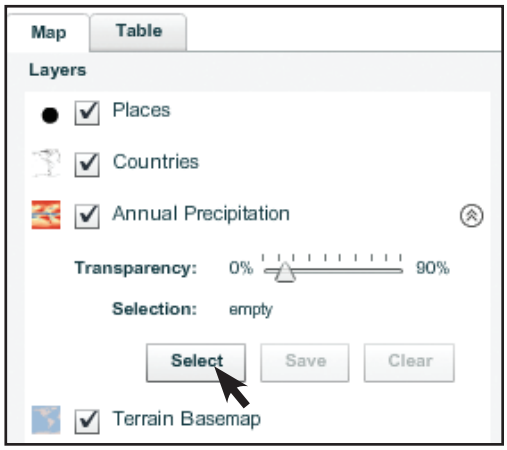


Figure 4, Select button for creating maps

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* **1500** into the box.

   c. *Click* **Select**

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

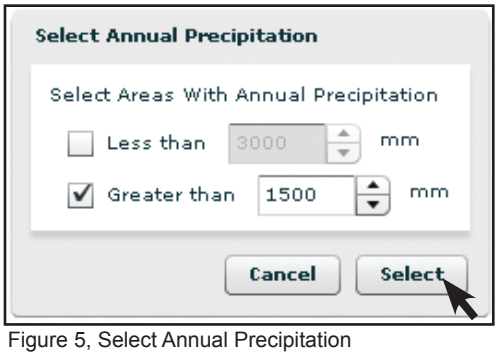


Figure 5, Select Annual Precipitation

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

   a. *Click and drag* the slider to **90%**

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

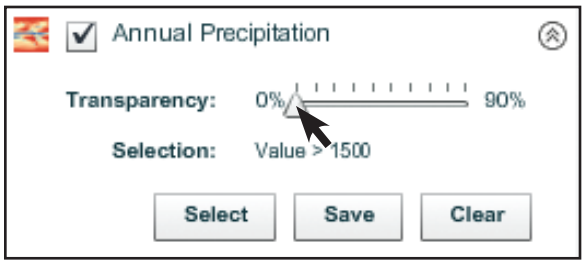


Figure 6, Transparency Slider

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 1500 mm)**.

Save this data into the Table.

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

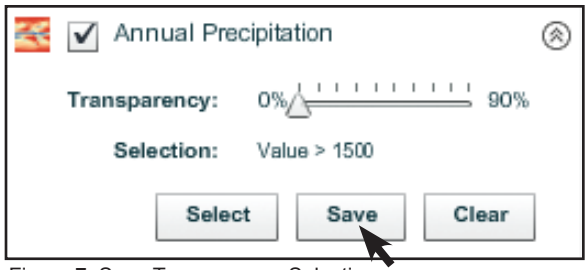


Figure 7, Save Transparency Selection

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**.

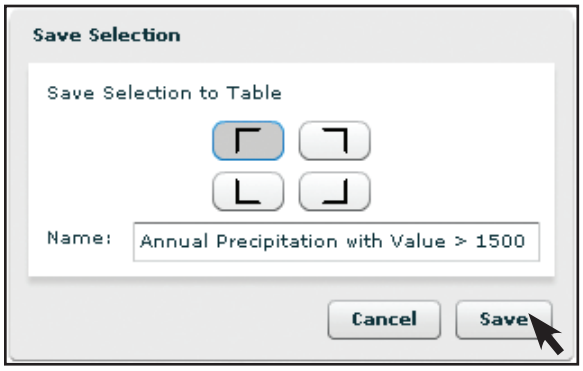


Figure 8, Save Selection to Table

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 (<1500 mm)

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

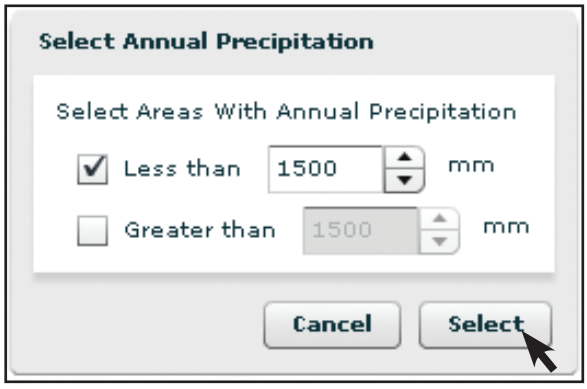


Figure 9, Select Annual Precipitation

11. Save the map selection (see Step 8); then save the selection to the top right corner of the Table (Figure 10).

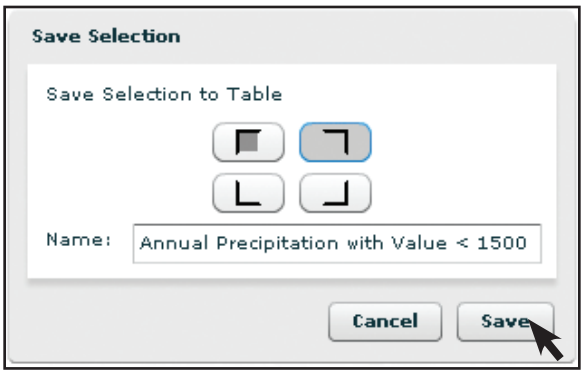


Figure 10, Save selected annual precipitation values

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

    a. Very High Precipitation Areas: Greater than 2500 mm

    b. Add the **Very High Precipitation Areas (>2500 millimeters)** 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 500 mm

    d. Add the **Very Low Precipitation Areas (< 500 millimeters)** selection to the lower right-hand box of the Map Table by using the same procedure outlined in Step 6 above.

Questions:

8. Compare your answer to question #2 above to the map with Very High Precipitation Areas (>= 2500 mm) selected. What additional information is evident on the new map?

9. Compare your answer to question #3 above to the map with Very Low Precipitation Areas (<500 mm) 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:	Whose: (Operation)	Value (mm)	Result Name:	Location of Selection in Annual Precipitation Map Table
Annual Precipitation	Is greater than or equal to (>)	1500	High Precip	Upper left-hand cell
Annual Precipitation	Is less than (<)	1500	Low Precip	Upper right-hand cell
Annual Precipitation	Is greater than or equal to (>)	2500	Very High Precip	Lower left-hand cell
Annual Precipitation	Is less than (<)	500	Very Low Precip	Lower right-hand cell

View and Analyze the Annual Precipitation Map Table

The **Annual Precipitation Map Table** makes it easy to see which areas of the world 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 you can use the cursor to click 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.

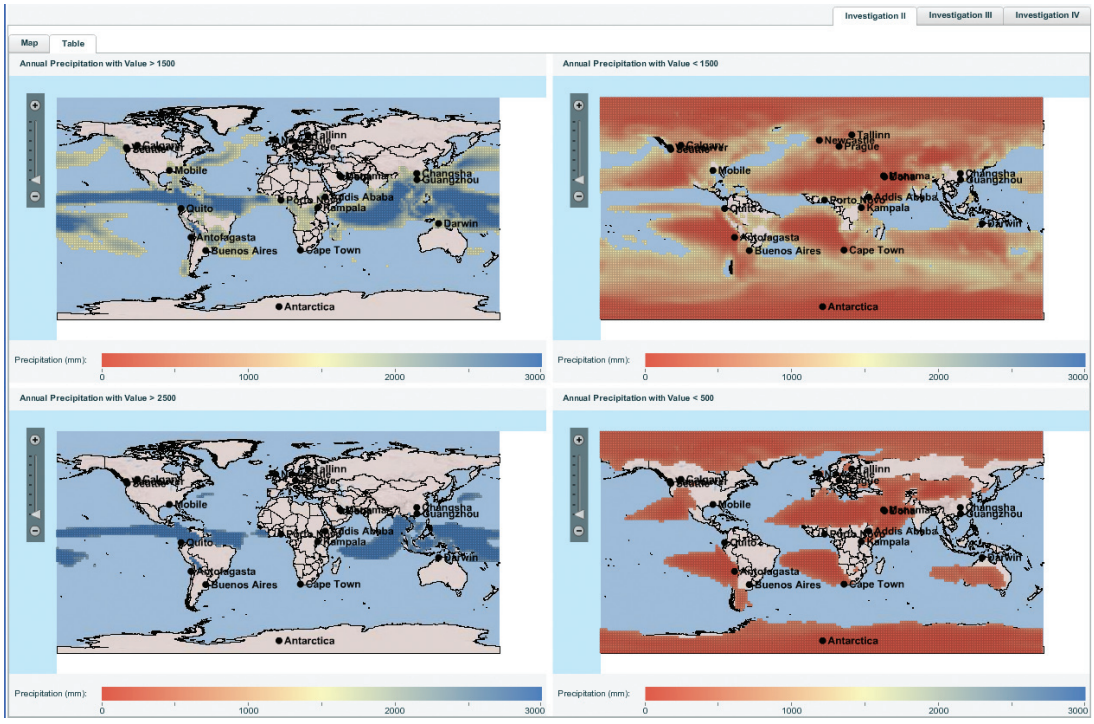


Figure 11, Annual Precipitation Map Table

13. 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 agree with the actual precipitation data shown on the Map Table? In what areas did your predictions not agree? Are there any surprises?

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

Synthesis

Now it is time to synthesize what you have learned about total annual precipitation patterns around the world.

Questions:

11. What regions of the world receive the greatest amount of total annual precipitation?

12. What regions of the world receive the least amount of total annual precipitation?

13. How would you compare total annual precipitation near the Equator versus North or South of the Tropics? (note, while the Tropic of Cancer and Capricorn are not evident in the GIS, it should be possible to esitmate where these lines lie on the map)

14. Can you tell from the Annual Precipitation 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 around the world. 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 world that is affected by this factor.
2. How do mountain ranges, such as the Andes in South America, influence the total precipitation in countires to the East?
3. What factors cause the Pacific Northwest region of North America (from the Gulf of Alaska down to Vancouver, Canada, and Oregon and Washington states of the United States) to receive so much precipitation? *See Apendix A, Image 1 for geographic assistance.*
4. What factors cause Madagascar to receive more precipitation than the Republic of Mozambique, to the west (on the east coast of Africa)? *See Apendix A, Image 2 for geographic assistance.*

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 3000 mm on the legend the highest total annual precipitation of the map? What is the highest total annual precipitation value you can find by clicking on the map? Where in the world does this very high precipitation occur?

3. What is the lowest total annual precipitation value you can find by clicking on the map? Where in the world does this 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 to the map with Very High Precipitation Areas (>= 2000 mm) selected. What additional information is evident on the new map?

9. Compare your answer to question #3 above to the map with Very Low Precipitation Areas (<500 mm) selected. What additional information is evident on the new map?

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

11. What regions of the world receives the greatest amount of total annual precipitation?

12. What regions of the world receives the least amount of total annual precipitation?

13. How would you compare total annual precipitation near the Equator versus North or South of the Tropics? (note, while the Tropic of Cancer and Capricorn are not evident in the GIS, it should be possible to esitmate where these lines lie on the map)

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

Investigation III: Annual Precipitation, Evaporation and Surface Runoff

Purpose

The purpose of this activity is to analyze the relationships between precipitation, evaporation, and surface runoff in the earth system.

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

Level

Secondary

Materials and Tools

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

Preparation

Make copies of student pages as necessary

Prerequisites

Investigation II: Annual Precipitation

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 (e.g. seasons) these two may not balance with evaporation actually being greater than the precipitation. Students will explore precipitation and evaporation amounts around the world. 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 deserts, 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 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.

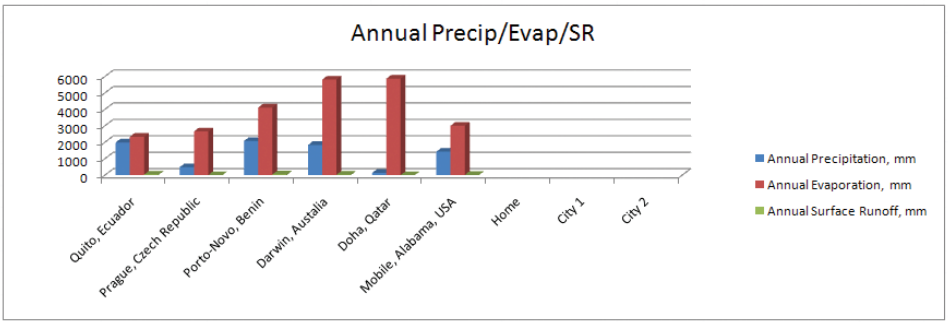
Teaching Notes

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 Sahara, also have high total annual evaporation? Write the various hypotheses down on the class white board so that students can refer back to them as they work through the analysis.

As part of this investigation students fill out a table of annual precipitation, evaporation and surface runoff for the 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 around the world. One important relationship for them to observe is how little surface runoff occurs compared to evaporation.

Both an Open Office Spreadsheet and an Excel spreadsheet have been created for this purpose named *WatershedDynamics-InternationalInvestigationIII-spreadsheet.odt* (for Open Office) and *WatershedDynamics-InternationalInvestigationIII-spreadsheet.xlsx* (for MicroSoft Excel) and are available for download at http://wd.northwestern.edu/curriculum/water-availability. After downloading and opening, click on the various tabs at the bottom of the sheet to open the appropriate table and chart. Blank cells are included in the table to add the students selected cities (See Figure A).

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



	Quito, Ecuador	Prague, Czech Republic	Porto-Novo, Benin	Darwin, Australia	Doha, Qatar	Mobile, Alabama, USA	Home	City 1	City 2
Annual Precipitation, mm	1981.74	485.28	2073.16	1836.71	134.65	1426.7			
Annual Evaporation, mm	2331.03	2659.64	4108.3	5813.69	5871.07	3004.98			
Annual Surface Runoff, mm	31.67	3.08	37.75	22.17	0.47	10.9			

Figure A, Excel graph example

Name _____ Date _____ Class _____

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

Questions:

1. Now that you are familiar with the annual precipitation patterns around the world 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 (mm)" in the data table below: (*See Appendix A, Image 3 - 6 for geographic assistance)*

   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.

Country/Region	Annual Precipitation (mm)	Annual Evaporation (mm)	Annual Surface Runoff (mm)
Quito, Ecuador	1981.74	2331.03.4	31.67
Prague, Czech Republic	485.28	2659.64	3.08
Porto-Novo, Benin	2073.16	4108.30	37.75
Darwin, Australia	1836.71	5813.69	22.17
Doha, Qatar	134.65	5871.07	0.47
Mobile, Alabama, USA	1426.70	3004.98	10.90

4. Review the factors that influence evaporation rates from page 1 of this investigation. Where do you see this evidence?

   The general patterns of precipitation and evaporation around the world 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 (mm)" 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 around the world, 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, mm" in the data table above in question #3

10. Review the factors influencing surface runoff listed above. Where do you see evidence 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 world 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?

    Northern Pakistan, Afganistan, and Tajikistan have low to moderate precipitation and high surface runoff, as do the areas surrounding the Himalayan Mountains. Much of the precipitation in tthese high mountain ranges falls as snow, which tends to runoff as surface water when it melts.

13. Identify an area of the world 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?

    Honduras and Nicaragua have moderate to high annual precipitation amounts and low annual surface runoff amounts. It's important to notice that annual evaporation tends to be very high in these areas.

Investigation III: Annual Precipitation, Evaporation and Surface Runoff

Floods, droughts, record snowfall! All these statements show up as headlines in many regional newspapers. But, think about this…areas that flood doen't stay flooded, areas that experience drought do get some rain at times and areas that experience record snowfalls don't remain 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 world 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 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.

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 (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://wdi.fieldscope.us

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

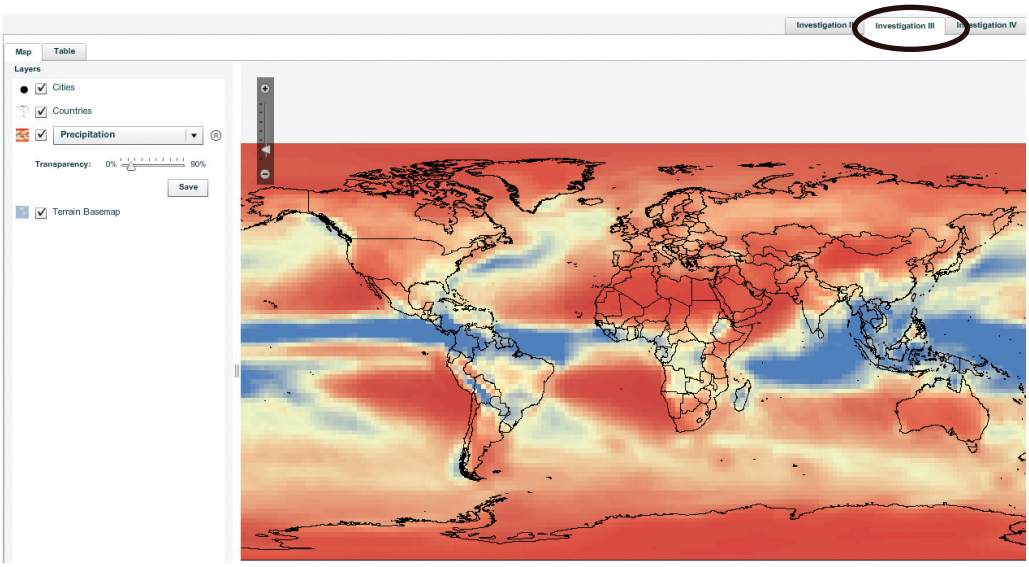


Figure 1, Opening Ivestigation III

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

Exploring Evaporation Data

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

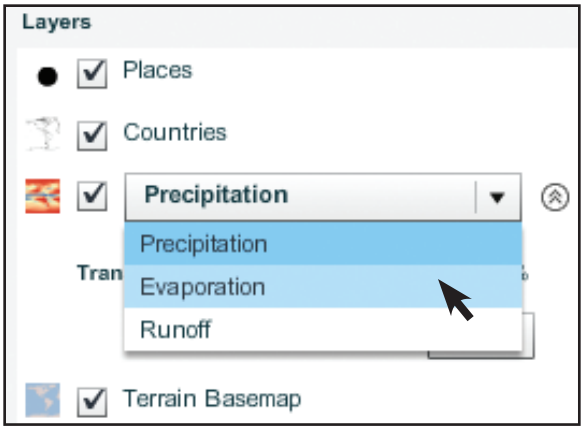


Figure 2, Viewing Evaporation Data

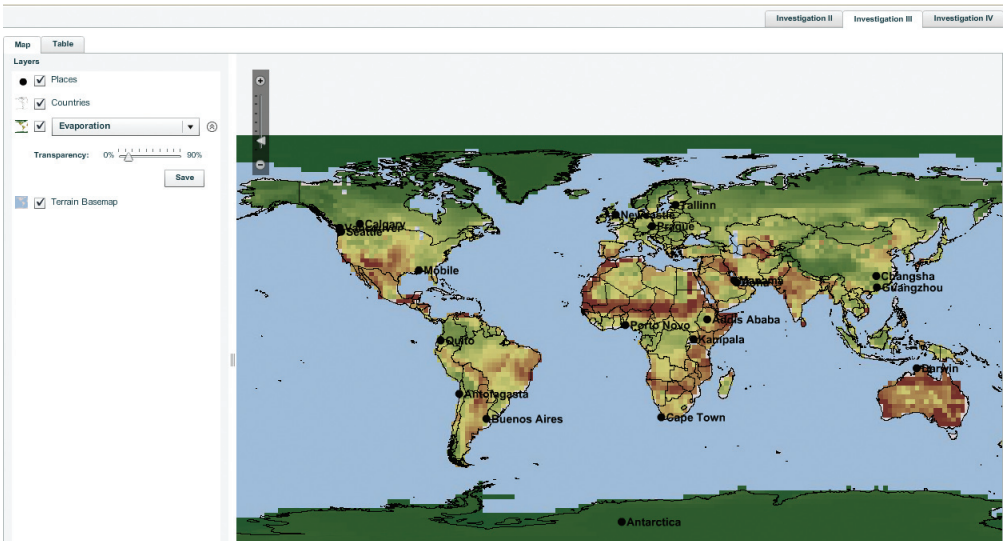


Figure 3, Evaporation Map

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

Questions:

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

3. Complete the column labeled "Evaporation, mm" in table 1 below. (*See Appendix A, Image 3 - 6 for geographic assistance)*

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.

Country/Region	Precipitation (mm)	Evaporation (mm)	Surface Runoff (mm)
Quito, Ecuador			
Prague, Czech Republic			
Porto-Novo, Benin			
Darwin, Australia			
Doha, Qatar			
Mobile, Alabama, USA			

Table 1, 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 evaporation map?

Comparing Evaporation to Precipitation Using a Map Table

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

4. With **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.

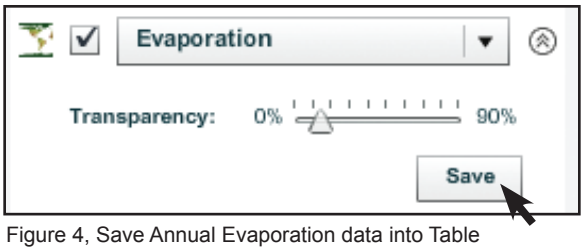


Figure 4, Save Annual Evaporation data into Table

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

   a. Make sure it is named **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).

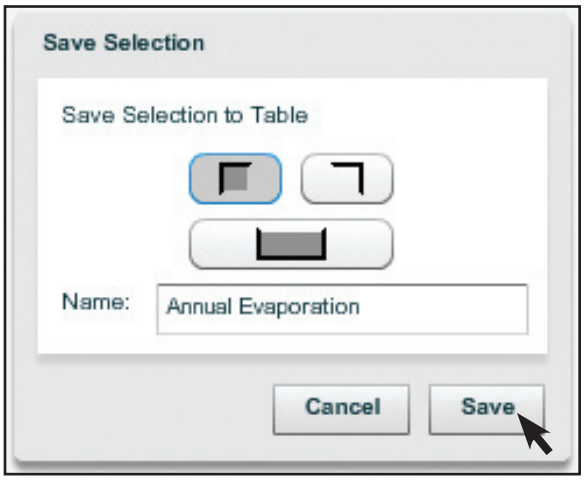


Figure 5, New Map Table

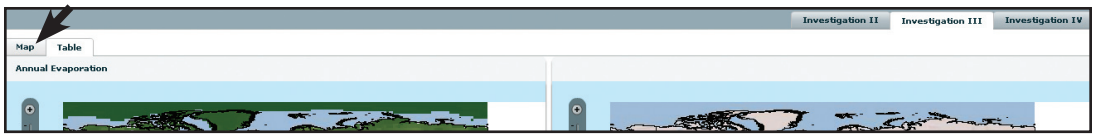


Figure 6, Map Tab location

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

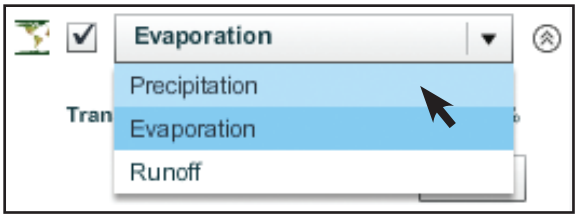


Figure 7, Viewing Annual Precipitation data layer

Question:

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

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

   a. Make sure it is named Precipitation.

   b. Click the save button.

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

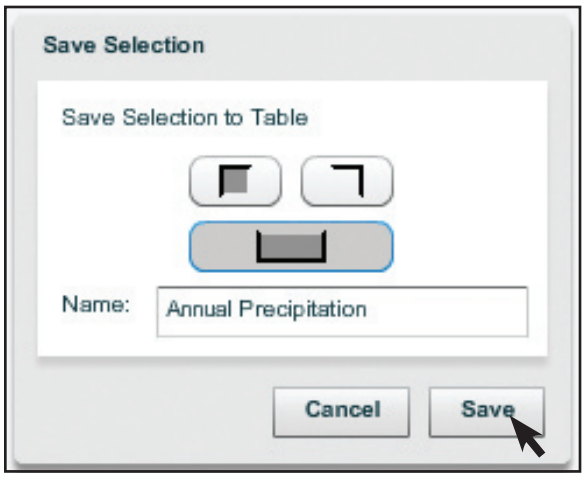


Figure 8, Adding Annual Precipitation to map table

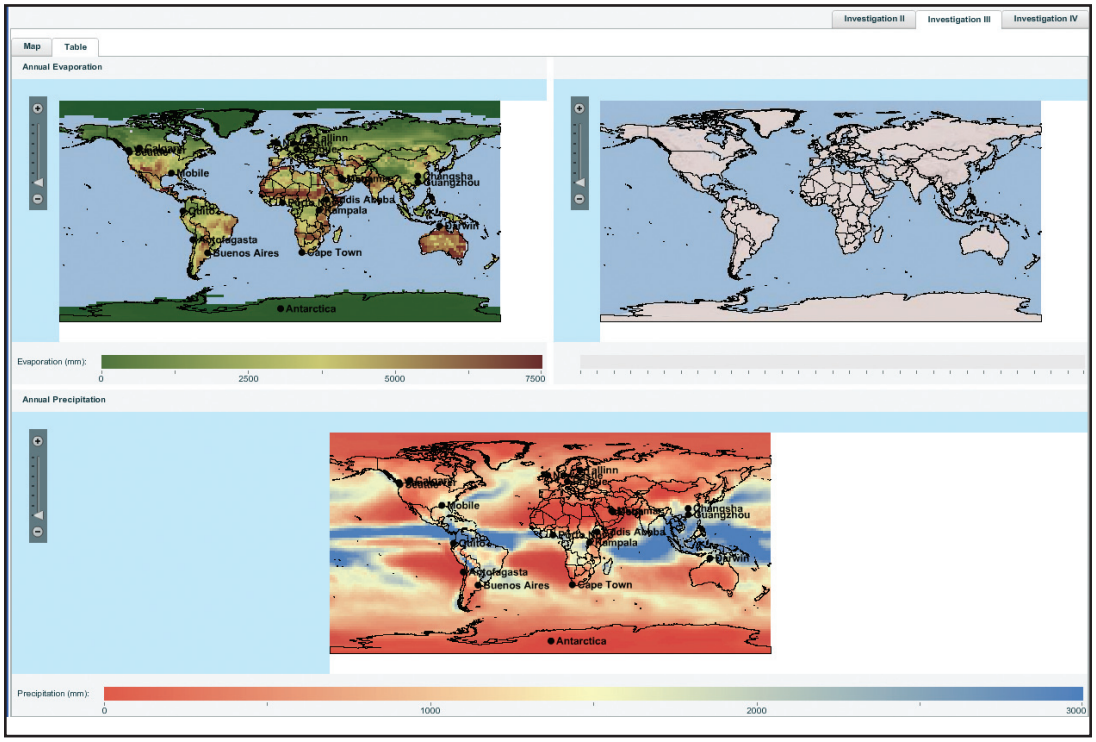


Figure 9, Map Table displaying Annual Evaporation and Annual Precipitation

Question:

6. Earlier in this activity you made a prediction about the similarities and differences in 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 surface runoff and 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 precipitation and evaporation patterns, make a prediction about the similarities and differences in the patterns of precipitation and surface runoff. For example, for areas of high precipitation what do you expect the surface runoff amounts to be? For areas of low precipitation?

Exploring Total Surface Runoff

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

Figure 10, Selecting Surface Runoff maps

Questions:

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

9. Complete the column labeled “Surface Runoff, mm” in Table 1 in question #3.

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

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

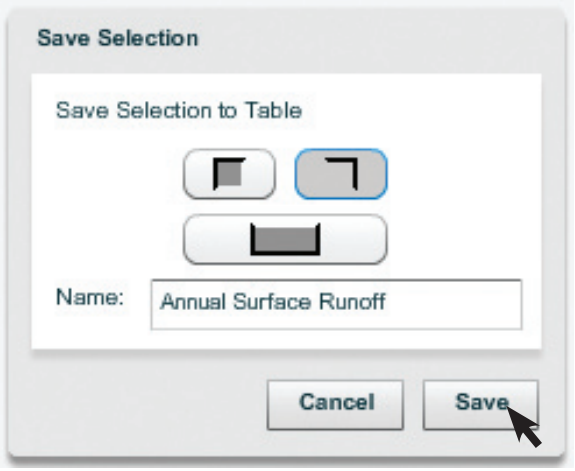


Figure 11, Saving Surface Runoff to map tables

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

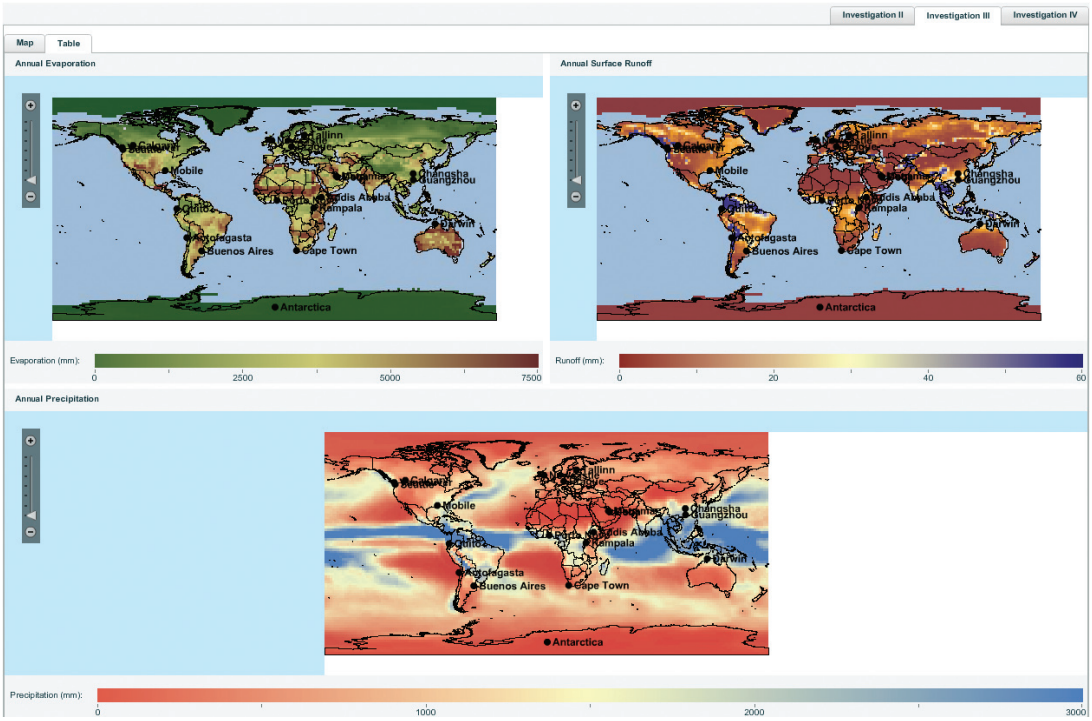


Figure 12, Completed Map Tables maps

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 precipitation?

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

13. Identify an area where the total surface runoff is low even though the 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: Precipitation, Evaporation and Surface Runoff

Questions:

1. Now that you are familiar with the annual precipitation patterns (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 precipitation and evaporation. For example, for areas of high precipitation what do you expect the evaporation amounts to be? For areas of low precipitation?

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

3. Complete the column labeled "Evaporation, mm" 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.

Country/Region	Precipitation (mm)	Evaporation (mm)	Surface Runoff (mm)
Quito, Ecuador			
Prague, Czech Republic			
Porto-Novo, Benin			
Darwin, Australia			
Doha, Qatar			
Mobile, Alabama, USA			

Table 1, Precipitation, Evaporation and Runoff

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

5. Complete the column labeled "Precipitation (mm)" in table 1 (Below Question #3).

6. Earlier in this activity you made a prediction about the similarities and differences in 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 precipitation and evaporation patterns, make a prediction about the similarities and differences in the patterns of precipitation and surface runoff. For example, for areas of high precipitation what do you expect the surface runoff amounts to be? For areas of low precipitation?

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

9. Complete the column labeled “Surface Runoff, mm” in Table 1 in question #3.

10. Review the factors influencing surface runoff listed above. What evidence do you see that supports these factors in the 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 precipitation? What is the relationship between surface runoff and precipitation in regions that receive low amounts of precipitation?

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

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

Investigation IV: Precipitation and Surface Runoff Throughout the Year

Purpose

Students will consider precipitation and surface runoff and think about how the time of year can impact these variables. Students will observe surface runoff during 4 groupings of months and consider how this process changes through the year. They will compare the data across the different parameters and consider other variables that can influence the rates.

Overview

Students should be ready to consider the temporal distribution of precipitation and surface runoff thoughout the year, having made predictions about precipitation and explored the patterns of annual precipitation, evaporation and surface runoff during the previous investigation. In this investigation, students will explore precipitation and surface runoff during four groupings of months and then begin to consider some regions where the amounts of 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 precipitation and surface runoff throughout the year.

Student Outcomes

- Discover how precipitation varies during different times of the year in different regions of the world.
- Discover how surface runoff varies during different times of the year in different regions of the world.
- Compare and analyze maps showing different subsets of data with Map Tables.

Time

One 45 minute class period

Level

Secondary

Materials and Tools

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

Preparation

Make copies of student pages as necessary

Prerequisites

Investigation II: *Annual Precipitation* and Investigation III: *Annual Precipitation, Evaporation and Surface Runoff*

Review the following with students before doing activity.

Background

Does the same amount of precipitation fall throughout the year 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 throughout the world.

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.

- December, January, February
- March April, May
- June July, August
- September, October, November

Teaching Notes

As part of this investigation students fill out a table of 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.

Both an Open Office Spreadsheet and an Excel spreadsheet have been created for this purpose named *WatershedDynamics-InternationalInvestigationIII-spreadsheet.odt* (for Open Office) and *WatershedDynamics-InternationalInvestigationIII-spreadsheet.xlsx* (for MicroSoft Excel) and are available for download at http://wd.northwestern.edu/curriculum/water-availability. After downloading and opening, click on the various tabs at the bottom of the sheet to open the appropriate table and chart. Because of the difference in scales, 0-850 mm for precipitation and 0-25 mm for surface runoff, it may be better to have students create two separate graphs (See figures B and C).

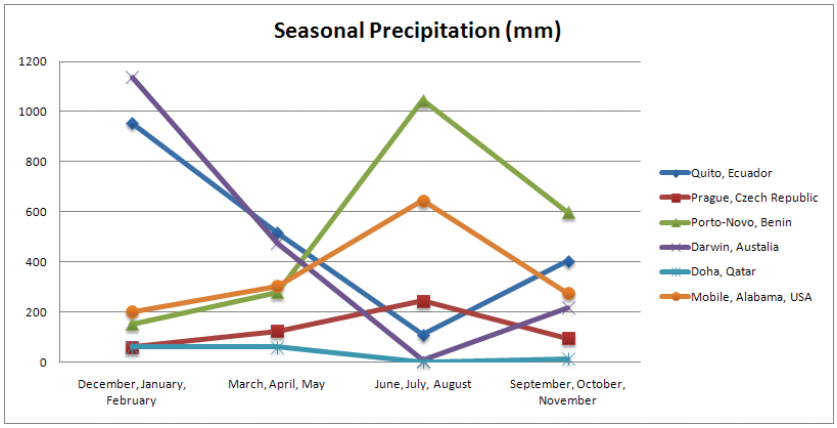


Figure A, Seasonal Precipitation (mm)

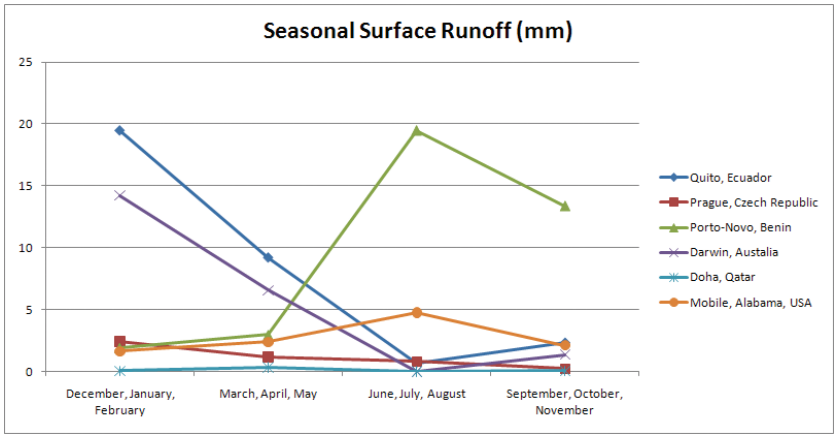


Figure B, Seasonal Surface Runoff (mm)

Name _____ Date _____ Class _____

Student Response Sheet
Investigation IV: Precipitation and Surface Runoff Throughout the Year

Questions:

1. During which month(s) 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 months do you think Thailand receives the greatest amount of precipitation? Which months do you think is the wettest for New Zealand? Explain your reasoning for each answer.

Student answers will vary.

3. What is the range of values for 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 3000 mm used in Investigation II: Annual Precipitation?

Precipitation values range from 0-850 mm on the 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 months 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, regions or coutries you chose in Investigation III for the last two rows.

	Precipitation (mm)				Surface Runoff (mm)			
City/ Country	December - February	March - May	June - August	September - November	December - February	March - May	June - August	September - November
Quito, Ecuador	954.45	515.20	108.11	403.97	19.47	9.19	0.69	2.30
Prague, Czech Republic	67.46	117.28	223.76	76.78	2.42	1.16	0.8	0.21
Porto-Novo, Benin	151.45	279.23	1045.21	597.25	1.92	2.96	19.47	13.38
Darwin, Austalia	1138.65	475.19	0.79	13.39	14.23	6.55	0.00	0.06
Doha, Qatar	60.48	59.98	0.79	13.39	0.06	0.34	0.00	0.06
Mobile. Alabama, USA	201.53	303.62	645.98	275.56	1.63	2.39	4.76	2.10

5. Which regions of the world have the highest amounts of precipitation during the months of December through February? The lowest amount?

The highest precipitation amounts during December through February are observed in western Madagascar (1389 mm). The lowest winter precipitation amounts are found in Niger and Chad, Northern Africa (0.77 mm).

6. During which months does Puerto Rico appear to get high amounts of precipitation?

Puerto Rico receives the highest amounts of precipitation (740.12 mm) during September, October, November time period.

7. Describe the annual precipitation pattern (based on these four monthly groupings) for Bangladesh.

Bangladesh receives low precipitation (7.26 mm) during December, January, February moderate precipitation (366.35 mm) during March, April, May; high precipitation (1161.53 mm) during June, July, August; and moderate precipitation (404.30 mm) during September, October, November.

8. Which region(s) receive high amounts of precipitation (>=500 mm) of precipitation year round?

Near Medan, the capital of the province of North Sumatra, Indonesia, receives a high amount of precipitation all year round: 619.29 mm during December, January, February; 872.65 mm during March, April, May; 700.76 mm during June, July, August; 1036.35 mm during September, October, November.

9. Which region(s) receive low amounts (<20 mm) of precipitation year round?

The Sahara Desert region receives low amounts of precipitation year-round. For example, students should note that many countries of the Sahara receive much less than 20 mm during all four monthly groupings. .

10. Which regions have the highest surface runoff during December, January, February?

Southern Chile experiences great surface runoff during all months of the year. During December, January, February the surface runoff value is 92.69 mm. Northern Chile and Southwest Bolivia also experience high surface runoff during this time period (however only near 35-40 mm)

11. Record the amount of surface runoff in the table in Question #4 (Table 1).

See data table

12. When is surface runoff lowest across most of the US? Highest?

As a whole, surface runoff is lowest during June, July, August and September October, November. Surface runoff is highest during December, January, February and March, April, May.

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 precipitation and surface runoff similar across the United States? 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 December, January, Februaryand March, April, May?

Most of the precipitation that falls in the Rocky Mountains during December, January, Februaryand March, April, May *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 (June - August/September - November) precipitation and Summer/Fall (June - August/September - November) surface runoff similar across Central and South America? 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. For example southern Venezuela and Northern Columbia receives high amounts of precipitation in the summer (June, July, August) and have high total surface runoff. There are also some exceptions though, such as Michoacán and México states of Mexico experience high preceipitation but lower surface runoff.

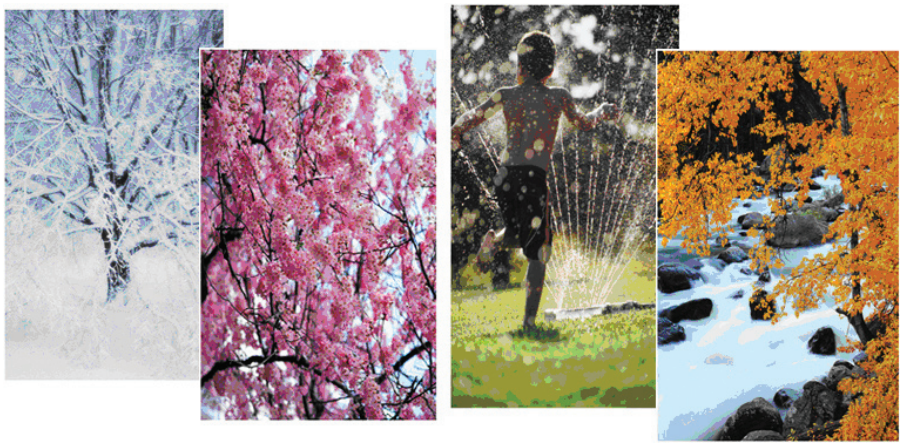
17. How is the pattern of precipitation and surface runoff for the Summer/Fall (June - August/September - November) months in Switzerland different than for the Winter/Spring (December - February/March - May) months?

Precipitation totals are as follows: December, January, February: 75.44 mm; March, April, May: 147.99 mm; June, July, August: 347.21 mm; September, October, November: 154.10 mm.

Surface Runoff totals are as follows: December, January, February: 9.91 mm; March, April, May: 36.65 mm; June, July, August: 6.36 mm; September, October, November: 9.78 mm.

Even though more precipitation falls during June, July, August (347.21 mm), more surface runoff is experienced during March, April, May (36.65 mm). Nearly the same amount of precipitation fell during September, October, November (154.10 mm) as during March, April, May (147.99 mm); however residual snowmelt adds to the surface runoff during March, April, May.

Investigation IV: Precipitation and Surface Runoff Throughout the Year



There are many changes that go on around us as we progress through the year - seasonal fluctuations. Classes begin and end, holidays and birthdays are celebrated, the weather changes from warmer to colder or from rainier to drier. Changes occuring in the rates and amounts of precipitation, evaporation and surface runoff vary throughout the world. Do you notice the same amount of precipitation throughout the year 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 in different regions of the world at different times of the year. In Investigation III you learned about the patterns of annual surface runoff. In this investigation you will examine patterns of surface runoff. We will try to understand the timing and quantity of surface runoff and compare it to precipitation patterns. We have grouped the months of the year into the following four groups:

- December,January, February
- March, April, May
- June, July, August
- 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: Precipitation Throughout the Year

In Investigation II you examined the total amount of precipitation that falls on an annual basis. Just as different parts of the world receive different amounts of precipitation, they also receive different amounts of precipitation during different months 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 precipitation patterns. People traveling to different parts of the world for vacations like to know if they will be have wet or dry weather.

Questions:

1. During which month(s) does the place where you live receive the greatest amount of precipitation? The least amount?

2. During which months do you think Thailand receives the greatest amount of precipitation? Which months do you think is the wettest for New Zealand? 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 around the world.

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

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

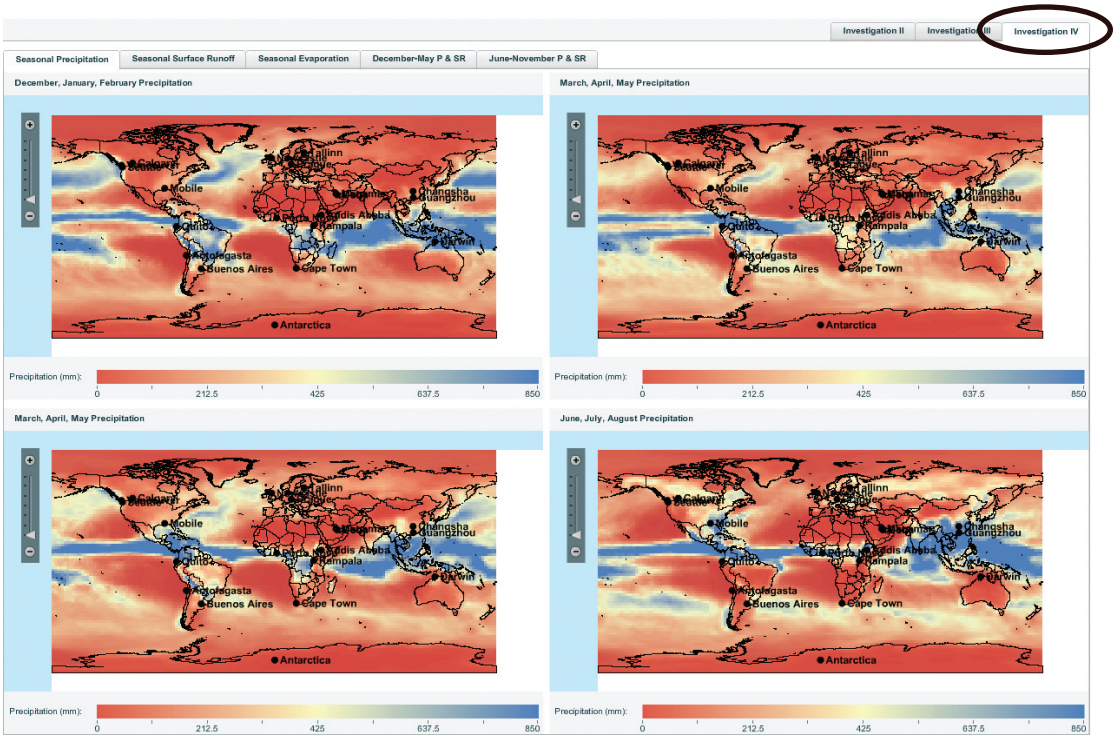


Figure 1, Investigation IV tab

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 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 3000 mm used in Investigation II: Annual Precipitation?

4. Record the amount of precipitation by seasons 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, regions or coutries you chose in Investigation III for the last two rows.

(Remember that you can click on any one of the maps in the 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.)

	Precipitation (mm)				Surface Runoff (mm)			
City/ Country	December - February	March - May	June - August	September - November	December - February	March - May	June - August	September - November
Quito, Ecuador								
Prague, Czech Republic								
Porto-Novo, Benin								
Darwin, Austalia								
Doha, Qatar								
Mobile. Alabama, USA								

Table 1, Seasonal Precipitation and Runoff data

Questions:

5. Which regions of the world have the highest amounts of precipitation during the months of December through February? The lowest amount?

6. During which months does Puerto Rico appear to get high amounts of precipitation?

7. Describe the annual precipitation pattern (based on these four monthly groupings) for Bangladesh.

8. Which region(s) receive high amounts of precipitation (>=500 mm) 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** (circled in Figure 2).

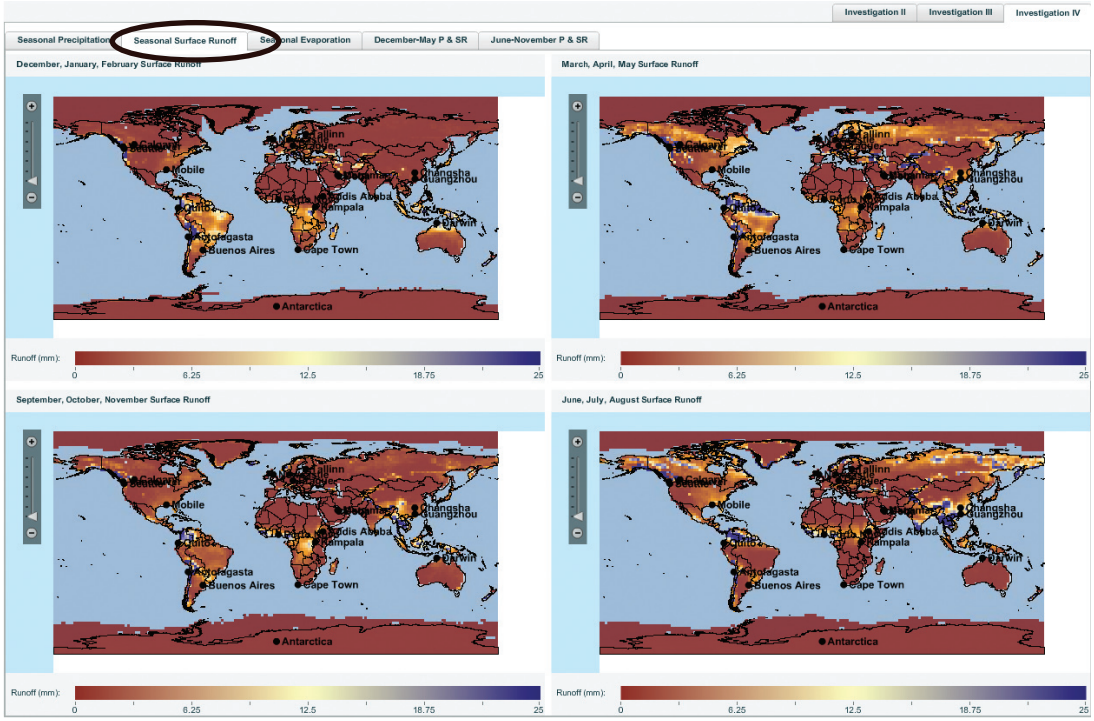


Figure 2, Surface Runoff maps

Questions:

9. Which region(s) receive low amounts (<20 mm) of precipitation year round?

10. Which regions have the highest surface runoff during December, January, February?

11. Record the amount of surface runoff in the table in Question #4 (Table 1).

12. When is surface runoff lowest across most of 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 **December-May P & SR**.

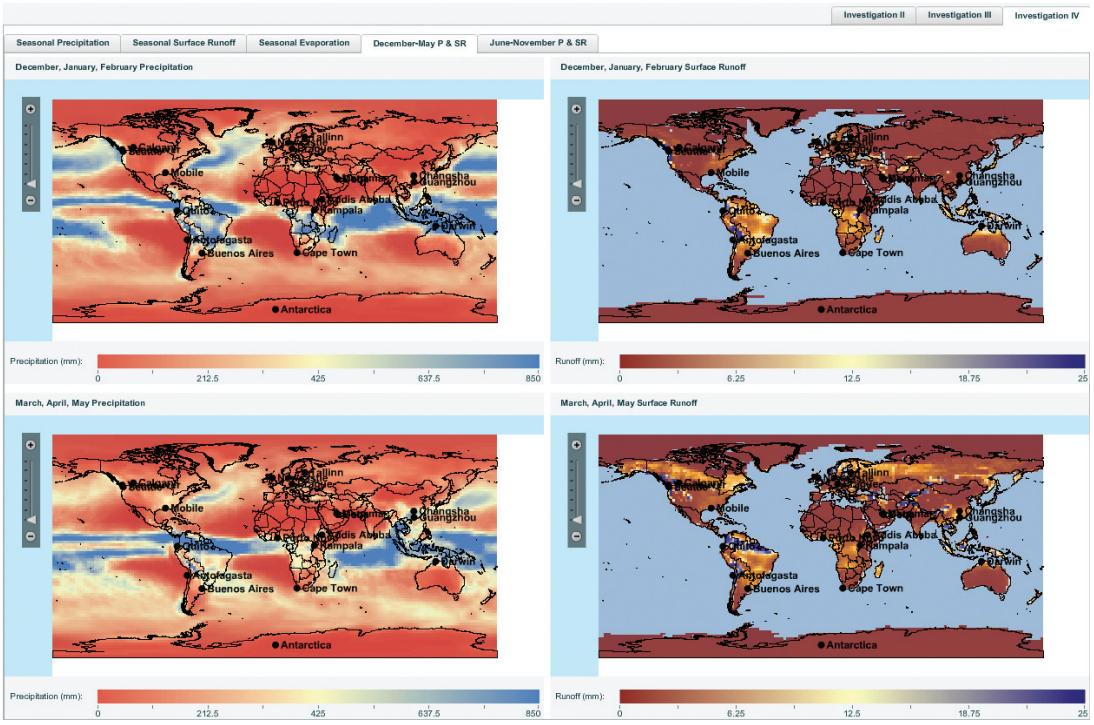


Figure 3, Annual Precipitation and Surface Runoff maps (December - February and March - May)

Questions:

14. How are the patterns of precipitation and surface runoff similar across the United States? How are they different?

15. What factors and processes do you think account for the high surface runoff in the Rocky Mountains during December, January, February and March, April, May?

5. *Click on* the map table tab **June-November P & SR**.

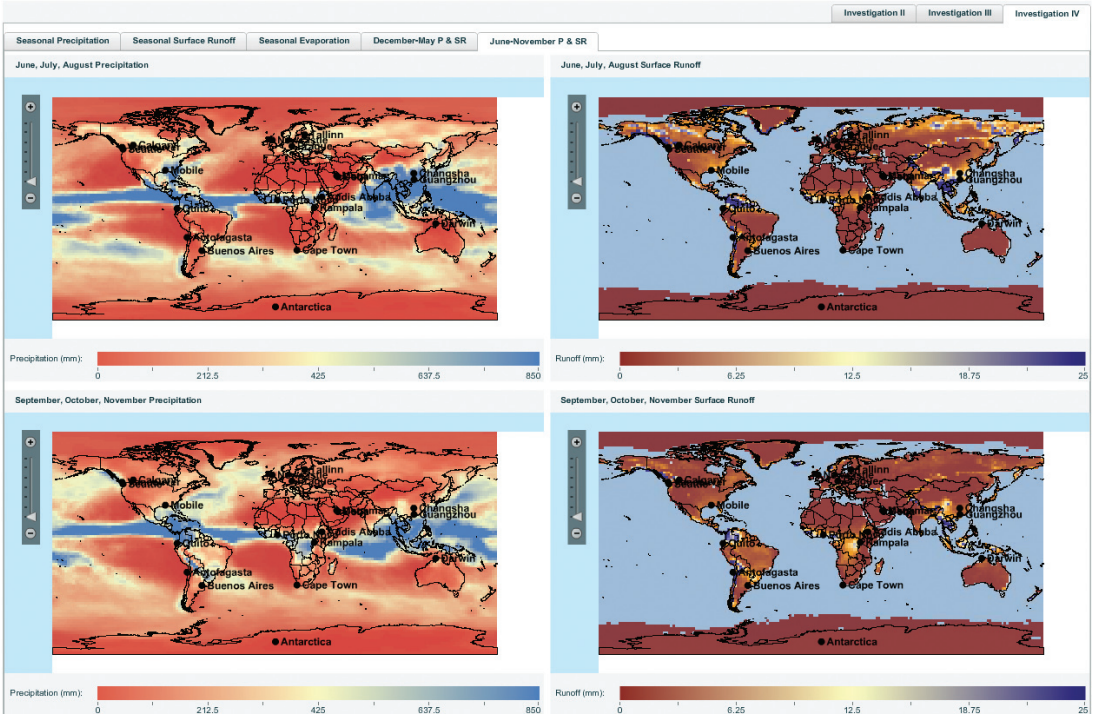


Figure 4, Precipitation and Surface Runoff maps (June - August and September - November)

Questions:

16. How are the patterns of June - August/September - November precipitation and June - August/September - November surface runoff similar across Central and South America? 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 June - August/September - November months in Switzerland different than for the December - February/March - May months?

Name _____ Date _____ Class _____

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

Questions:

1. During which month(s) does the place where you live receive the greatest amount of precipitation? The least amount?

2. During which months do you think Thailand receives the greatest amount of precipitation? Which months do you think is the wettest for New Zealand? Explain your reasoning for each answer.

3. What is the range of values for 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 3000 mm used in Investigation II: Annual Precipitation?

4. Record the amount of precipitation by months 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, regions or coutries you chose in Investigation III for the last two rows.

	Precipitation (mm)				Surface Runoff (mm)			
City/ Country	December - February	March - May	June - August	September - November	December - February	March - May	June - August	September - November
Quito, Ecuador								
Prague, Czech Republic								
Porto-Novo, Benin								
Darwin, Austalia								
Doha, Qatar								
Mobile. Alabama, USA								

5. Which regions of the world have the highest amounts of precipitation during the months of December through February? The lowest amount?

6. During which months does Puerto Rico appear to get high amounts of precipitation?

7. Describe the annual precipitation pattern (based on these four monthly groupings) for Bangladesh.

8. Which region(s) receive high amounts of precipitation (>=500 mm) of precipitation year round?

9. Which region(s) receive low amounts (<20 mm) of precipitation year round?

10. Which regions have the highest surface runoff during December, January, February?

11. Record the amount of surface runoff in the table in Question #4 (Table 1).

12. When is surface runoff lowest across most of 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 precipitation and surface runoff similar across the United States? How are they different?

15. What factors and processes do you think account for the high surface runoff in the Rocky Mountains during December, January, Februaryand March, April, May?

16. How are the patterns of precipitation for the time periods of June - August/September - November and the patterns of surface runoff for the time periods of June - August/September - November similar across Central and South America? 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 time periods of June - August/ September - November in Switzerland different than for the time periods of December - February/ March - May?

Appendix A: Images for Geographic Idenitification

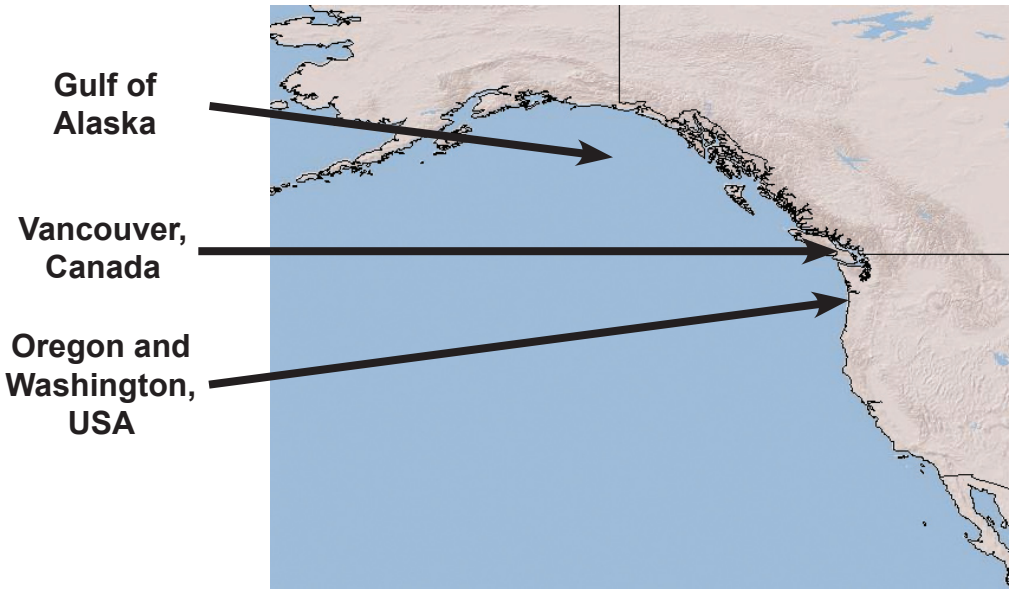


Image 1, Geographic location of Gulf of Alaska, Vancouvor, Canada, and Oregon and Washington, USA

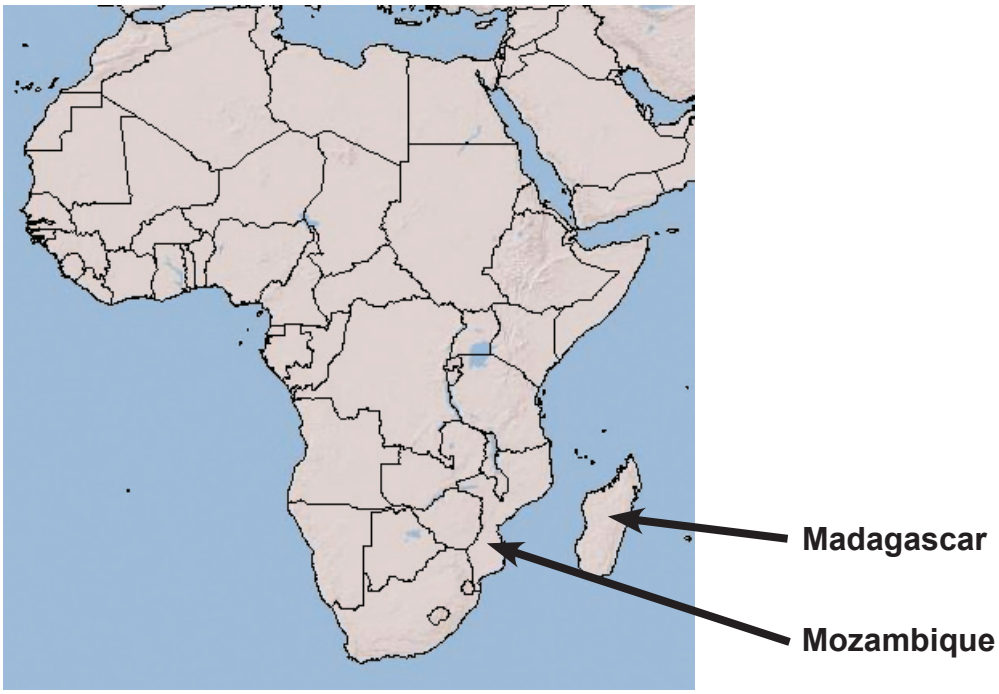


Image 2, Geographic location of Madagascar and Mozambique

Image 3, Geographic location of Quito, Ecuador

Image 4, Geographic location of Prague, Czech Republic

Image 5, Geographic location of Sri Lanka

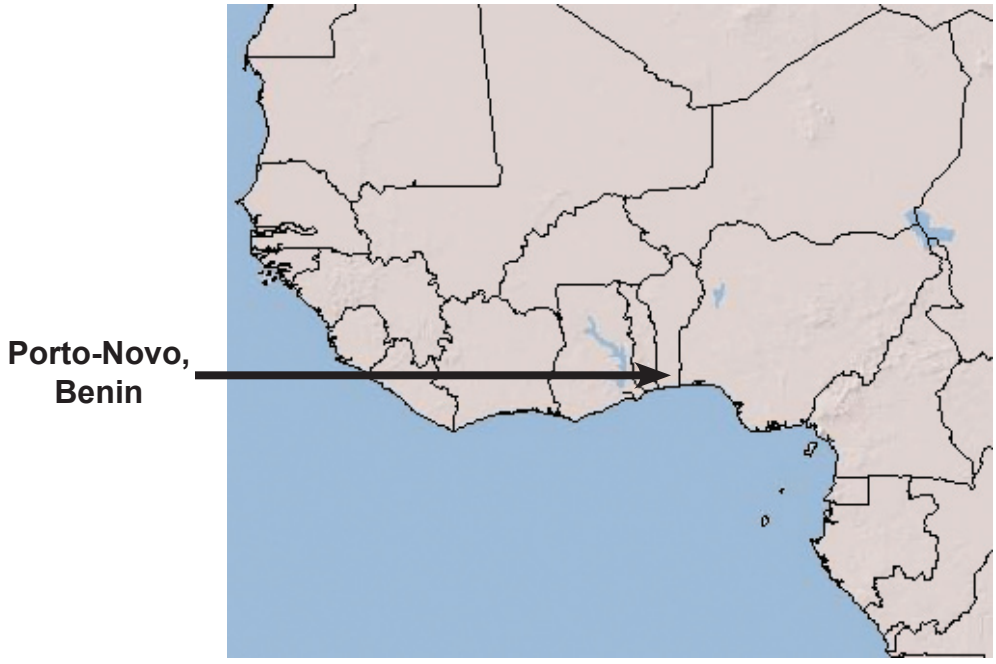


Image 6, Geographic location of Porto-Novo, Benin

Image 7, Geographic location of Buenos Aires, Argentina

Image 8, Geographic location of Darwin, Australia

Image 9, Geographic location for Tallinn, Estonia

Image 10, Geographic location for Kampala, Uganda

Image 11, Geographic location of Doha, Qatar