LC3: Using Graphs to Show Connections

Purpose

To show how graphs of GLOBE data over time show the interconnectedness of Earth's system components at the local level

Overview

The class explores interconnections among Earth system components by creating graphs of GLOBE student data on air and soil or water temperatures. More advanced students can create graphs with other connected variables, such as precipitation and soil moisture. The class analyzes and interprets these graphs, in response to guidance questions. Each student writes a description of the major interconnections and other variables they have detected in the graphs.

If the school has not yet collected 12 months of its own GLOBE data this study, the class works with data from Reynolds Jr. Sr. High School, a GLOBE school in Greenville, Pennsylvania, USA.

Student Outcomes

Students will be able to:

- Analyze and interpret a graph of GLOBE data that shows air and soil or water temperatures over a year;
- Explain how graphs of GLOBE data can show relationships among components of an Earth system.

Science Concepts

Physical Sciences

Heat is transferred by conduction, convection and radiation.

Heat moves from warmer to colder objects.

Sun is a major source of energy for changes on the Earth's surface.

Energy is conserved.

Chemical reactions take place in every part of the environment.

Earth and Space Sciences

Weather changes from day to day and over the seasons.

The sun is the major source of energy at Earth's surface.

Solar insolation drives atmospheric and ocean circulation

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Organisms' functions relate to their environment.

Organisms change the environment in which they live.

Humans can change natural environments.

Plants and animals have life cycles.

Ecosystems demonstrate the complementary nature of structure and function.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

All populations living together and the physical factors with which they interact constitute an ecosystem.

Populations of organisms can be categorized by the function they serve in the ecosystem.

Sunlight is the major source of energy for ecosystems.

The number of animals, plants and microorganisms an ecosystem can support depends on the available resources.

Atoms and molecules cycle among the living and non-living components of the ecosystem.

Scientific Inquiry Abilities

Making graphs on the Internet

Analyzing and interpreting graphs

Use appropriate tools and techniques.

Develop explanations and predictions using evidence.

Recognize and analyze alternative explanations.

Use appropriate mathematics to analyze data.

Communicate results and explanations.

Time

45 minutes

Level

Middle, Secondary

Materials and Tools

GLOBE Graphing Tool on the GLOBE Web site

Printer (to print graphs of GLOBE data)

Graph paper: 1-2 pieces for each student

Preparation

Make graphs in advance.

Make student copies.

Prerequisites

None

What To Do and How To Do It

Step 1. Preparation

Make the Graphs

It is recommended that you make the graphs suggested in this activity before making them with students. It is also recommended that you print and copy the graphs for student use, even if students will be making them on computers themselves. If you need to renew your familiarity with the GLOBE Graphing Tool, see *Using the GLOBE Graphing Tool* in the *Toolkit* section.

Four graphs with GLOBE student data from Reynolds Jr. Sr. High School are provided for you to copy if needed.

Make Student Copies

Analyzing and Interpreting Graphs Work Sheet

Assessment rubric for this activity (You may want to share with students.)

If you have conducted Activity LC2, go to Step 4.

Step 2. *(Begin here if you have not conducted both Activities LC1 and LC2.)* **Introduce the activity with a discussion of dramatic events or changes that have occurred in your local area.** Ask students to suggest events or changes, such as drought, flood, hurricane, fire, or loss of a particular habitat such as a wetland. Have students describe these events. What changed? What do people understand about it? What don't people understand? What do we still need to find out?

Explain that a new discipline of science – Earth system science has emerged, through which people attempt to understand changes like these by learning more about ways that parts of the Earth interact to make the whole. The discipline of Earth system science integrates all sciences that are concerned with the Earth: geology, hydrology, chemistry, botany and zoology, and meteorology.

People who study the Earth as a system are pioneers in this new discipline, and, as experts on their own local areas, GLOBE students can participate. Every area, every site is unique in certain ways. Ask students: How would you apply Earth system science to one of your study sites? How would you communicate the *system* aspect of your study site, its parts and how they interact, to another GLOBE school?

Explain that each one of the activities in the *Local Connections (LC)* series addresses aspects of this question.

Step 3: Introduce this activity.

Your students have explored their GLOBE study sites by making observations, gathering data, and conducting other investigations. For students who will be making graphs of the GLOBE data taken at Reynolds Jr. Sr. High School, photographs taken in the four cardinal directions from the hydrology study site are presented in Figure EA-LC3-1. These photographs will give students fuller knowledge of what that study site looks like. Let the students know that in this activity, they will explore the Earth as a system by graphing GLOBE data, looking for relationships between these components of their locality: air, and soil or water.

What are some relationships between air and soil or water? Conduct a brief discussion. If students do not mention the exchange of heat among those system components (also known as the energy cycle), suggest it to them.

They may have read about this exchange of heat, and of the relationships between air and soil or water, but have they seen supporting data? They can make graphs of GLOBE data and look for evidence of the relationships.

If you have not conducted the previous activity, Activity LC2, skip Step 4 and go directly to Step 5.

Step 4. Refresh your students' memories of the previous activity, in which they found that diagramming is a way to explore and understand a study site as a system.

Remind students that in that activity, they made diagrams to present and illustrate their ideas about interconnections among four major components of the study site: atmosphere, hydrosphere, pedosphere, and biosphere. As a refresher, ask them to briefly describe two or three of those interconnections. Tell them that in this activity, they will explore interconnections in another way: by making graphs of GLOBE student data on the computer.

Step 5. Explain what the graphs are to show.

Distribute the Student *Work Sheet Analyzing and Interpreting Graphs.* Explain that each graph is to show 12 months of data, or one annual cycle. Each data point on the graph will represent an individual measurement. Ask students:

- What would happen if you made graphs that showed the average for each month, rather than for each day that data were collected?

  (The graph would have many fewer data points and that you would not be able to see the day-to-day variations.)
- What would you be able to learn from a graph of monthly averages?

  (You would be able to learn general trends in temperatures throughout the year.)
- What would you *not* be able to learn?
  (You would not be able to learn about the effects of short-term events, such as storms, on temperatures, nor about the finer details of possible relationships among air and soil or water temperatures.)

It is recommended that students graph data from their own school. If the school has not collected a full year of GLOBE data on air and soil or water temperatures, students can graph data from Reynolds Jr. Sr. High School, a GLOBE school in Greenville, Pennsylvania, USA. See Figures EA-LC3-2 through EA-LC3-5.

Advanced students will be able to make more complex graphs, including different types of data such as in Figure EA-LC3-5, than middle students will, and they will be able to explore graphing GLOBE data in more sophisticated ways.

Step 6: Have the class use the GLOBE Visualization tool to make the first graph, Maximum Air Temperature Over a Year. Ask them questions to help them with analysis and interpretation of the graph. Note for teacher: The explanations given for why the system responds the way that it does at Reynolds Jr. Sr. High School in this and the following steps may not apply to your local study site. If your data show different relationships than those for Reynolds, have your students describe the differences and speculate why they might be different.

If computers are not available, use copies of printed versions of the graphs for students to study and interpret. See Figures EA-LC3-2 through EA-LC3-5.

Have students open the GLOBE Visualizations software on the GLOBE Web site, and go to GLOBE Graphs - Time Plots of Student Data. Have them make a graph of maximum air temperature over a year from their own school or from Reynolds Jr. Sr. High School's Atmosphere Study Site (also known as "ATM-02 Weather Station"). (Reynolds Jr. Sr. High School data for 1998 are shown in Figure EA-LC3-2.) Ask students to respond to the questions below about the graph, using their *Work Sheets*. Give students 5 minutes to write their responses, then discuss the questions as a class. At the end of the activity, there is an opportunity for students to revise their responses before you collect the *Work Sheets*.

Desired student responses appear in parentheses.

- What month has the highest maximum air temperatures? Why?

  (In the graph of Reynolds Jr. Sr. High School data, July and August have equally high surface air temperatures. While the summer solstice is in June, the Earth system takes some time to fully respond. As a result, maximum temperatures occur in July and August at Reynolds. In many places in the Northern Hemisphere , the maximum temperatures are in August. Warm air temperatures continue into some days of September and early October, but there are some days in those months with lower temperatures than any in July and August.)

- What month has the lowest maximum air temperatures? Why?

  (In the graph of Reynolds Jr. Sr. High School data, December has the lowest air temperature. There must have been an especially cold air mass that came through, because normally, the lowest temperatures are later in the winter, when the ground has become consistently cold.)

- What is the range of maximum air temperatures throughout the year (the difference between highest and lowest temperatures)?

  (In the graph of Reynolds Jr. Sr. High School data, the range is +32 C to –12 C, for a range of 44° C.)

Step 7. Have the class make a second graph of soil or water temperature over a year and discuss what it means.

Ask students to respond to the questions below about the graph (the surface water temperature over the year 1998 for Reynolds Jr. Sr. High School is shown in Figure EA-LC3-3), using their *Work Sheets*. Give students 10 minutes (adjust for class needs) to write their responses, then discuss the questions as a class.

- What month has the highest soil (or water) temperature? Why?

  (In the graph of Reynolds Jr. Sr. High School data, the highest water temperature of 24 degrees C is reached in August, with July a *very* close second. The surface air temperature takes some time to fully respond to the highest amount of solar radiation that occurs in June. As a result, the highest water temperatures at Reynolds Jr. Sr. High School occur in August).

- What month has the lowest soil (or water) temperature? Why?

  (In the graph of Reynolds Jr. Sr. High School data, the lowest water temperature is in March, but there are more days of low water temperatures in January and very early February, when the air is coldest. In considering why this happens, remember that the maximum air temperatures are taken every day, and the surface water temperatures are taken once a week. Then look back at the graph of maximum air temperatures at Reynolds Jr. Sr. High School, Figure EA-LC3-2. There are a number of days in March when there are very low maximum air temperature measurements. Since this cold period lasted more than a day, it seems to have affected the surface water temperatures, making one measurement very low also.)

- What is the range of soil (or water) temperatures throughout the year?

(In the graph of Reynolds Jr. Sr. High School data, the range of water temperatures is from 24 degrees Celsius to 1 degree Celsius, or 23 degrees Celsius.)

Step 8. Have the class make a third graph, of surface air temperature and soil or water temperature together, and discuss what it means.

Ask the class what this graph shows about the interconnection between air temperature and soil (or water) temperature , using the questions below. The graph of maximum air, surface water, and soil temperatures over the year 1998 for Reynolds Jr. Sr. High School is shown in Figure EA-LC3-4. Again, give students 5 minutes to write their responses on their *Work Sheets*, then discuss the questions and their responses as a class.

- Do air and soil (or water) temperatures reach their highest values during the same months? Why or why not?

  (Air, water, and soil reach their highest temperature values at different times, because they have different heat capacities. Air and soil absorb and release heat faster than water does. So air and soil will reach their highest temperature value earlier in the year than water will. In the graph of Reynolds Jr. Sr. High School maximum air and surface water temperature for 1998, the air approaches its maximum temperature through the spring faster than the surface water and attains high values a month before the water does. The times of consistently high temperatures for air occur in July and August and for surface water occur in mid July and August)
- Why are the peak values for air and soil (or water) temperatures different? What does this show about the differing characteristics of these two Earth system components?

  (The maximum (minimum) values of maximum air temperature are always greater (less) than the maximum (minimum) values of the surface water temperature. This is because the specific heat of air (the amount of energy needed to increase the temperature of air 1C) is less than the specific heat of water. Therefore, with the same amount of energy input (output) the temperature of the air increases (decreases) more than the temperature of water.)
- What does this graph show about the interconnection between air and soil (or water) temperatures?

  What patterns do you see, if any?

  (Air, water, and soil temperatures follow the same trends during the annual cycle, with water temperatures generally higher in the winter and lower in the summer, and soil temperatures generally lower in the winter and higher in the summer than air temperatures. This is a general pattern; it may vary from region to region.)

If you conducted Activity LC2, go to Step 9.

If you did not conduct Activity LC2, go directly to Step 10.

Step 9. If you conducted *Activity LC2,* **ask the class how the information on this graph is related to their diagrams.**

Did any students include the transfer of heat energy in their diagram of the study site during the previous activity? Explain that heat does move from air to soil, soil to air, air to water, and water to air. The direction of the transfer of heat depends on which is warmer. If the air is warmer, the heat transfer is from the air to the soil or water, and if the soil or water is warmer, the heat transfer is from the soil or water to the air .

Step 10. Give students a few minutes to complete their written responses to the questions on their *Work Sheets,* **including the** *Self-Reflection Log* **questions, then collect the** *Work Sheets.*

If there is not enough class time for this step, students can complete their *Work Sheets* as homework.

If you can review the *Work Sheets* before conducting the next activity, you will have an opportunity to shape your teaching of that activity in light of student responses to the self-reflection log questions.

Step 11. If you plan to conduct ***Activity LC 4,*** **prepare students for it.**

Let students know that in the next activity, they will develop a class diagram and description of their study site, to share with other GLOBE schools.

Student Assessment

The *Analyzing and Interpreting Graphs Work Sheet,* can be used for assessment. An assessment rubric is provided.

The last section of the *Work Sheet* is for student self-reflection, and student responses to those questions are not quantifiable.

If time permits, as an assessment task, you can ask students to make the same graphs as were required in this activity, using data from other GLOBE schools. The same rubrics on analysis and interpretation of graphs can be used for assessing this student work.

Further Investigations

Graphing More GLOBE Data

As an extension of step 8, have students speculate about other interconnections between Earth system components that one might explore by making graphs.

Have students retrieve their diagrams from *Activity LC2,* or use the sample diagram provided for that activity, and have them use the diagrams to help them generate ideas. Conduct a short class discussion about other interconnections they might explore in graphs.

For more advanced students, the teacher can suggest further investigations with GLOBE school data.

Some ideas for interconnections students may explore by graphing and analyzing the data:

- Air temperature, precipitation, and soil moisture (Figure EA-LC3-5)
- Air temperature and soil temperatures at 5 cm and 10 cm
- Air temperatures and soil moisture at various depths
- Precipitation pH, water pH, and soil pH
- Air temperature, rainfall and snowfall

Have the students examine the graphs they create to see where variables change with some consistent relationship to each other. For example, look at Figure EA-LL-56. This figure shows the monthly average maximum air temperature, precipitation, soil moisture at 10 cm, and soil moisture at 90 cm at Reynolds Jr. Sr. High School in Greenville, Pennsylvania, USA from April 1, 1998 through October 1, 1998. You can see that as the temperature rises from the spring to the summer the soil moisture decreases, with the soil moisture decreasing earlier and to a greater degree at 10 cm compared to at 90 cm. This occurs because as the temperature rises, evaporation increases, drying out the soil. The soil nearer the surface dries out sooner and more fully because it is closer to the warm atmosphere. This pattern can be seen as a consistent one if you look at how these variables vary over many years. In addition, you can see that after each precipitation event the soil moisture near the surface increases for a short time, then returns to its steady decrease from spring to summer as the temperatures rises. This is a consistent pattern over the period shown in the graph. Thus this graph shows interconnections between the atmosphere (temperature and precipitation) and soil (soil moisture).

As a follow-up to this activity, have your students graph data from other GLOBE schools to explore interconnections among components of the Earth system at those study sites.

Let your students know that ecological and physical characteristics of study sites at GLOBE schools around the Earth differ, and therefore, interactions among study site components can differ from site to site as well. The specific relationships for which your students find evidence at their site may not appear in data from another school. This does not mean your students should discount what they find in their graphs of other schools' data; rather, it should reflect to them the diversity and complexity of the Earth system in which we live.

Figure EA-LC3-1: Photographs of Reynolds study site in four cardinal directions from the Hydrology study site a) North, b) East, c) South, d) West. The photograph of the Reynolds Jr. Sr. High School study site appears in Figure EA-LC2-1.

a. North

b. East

c. South

d. West

Figure EA-LC3-2: Maximum Air Temperature at Reynolds Jr. Sr. High School 1/1/98-12/31/98

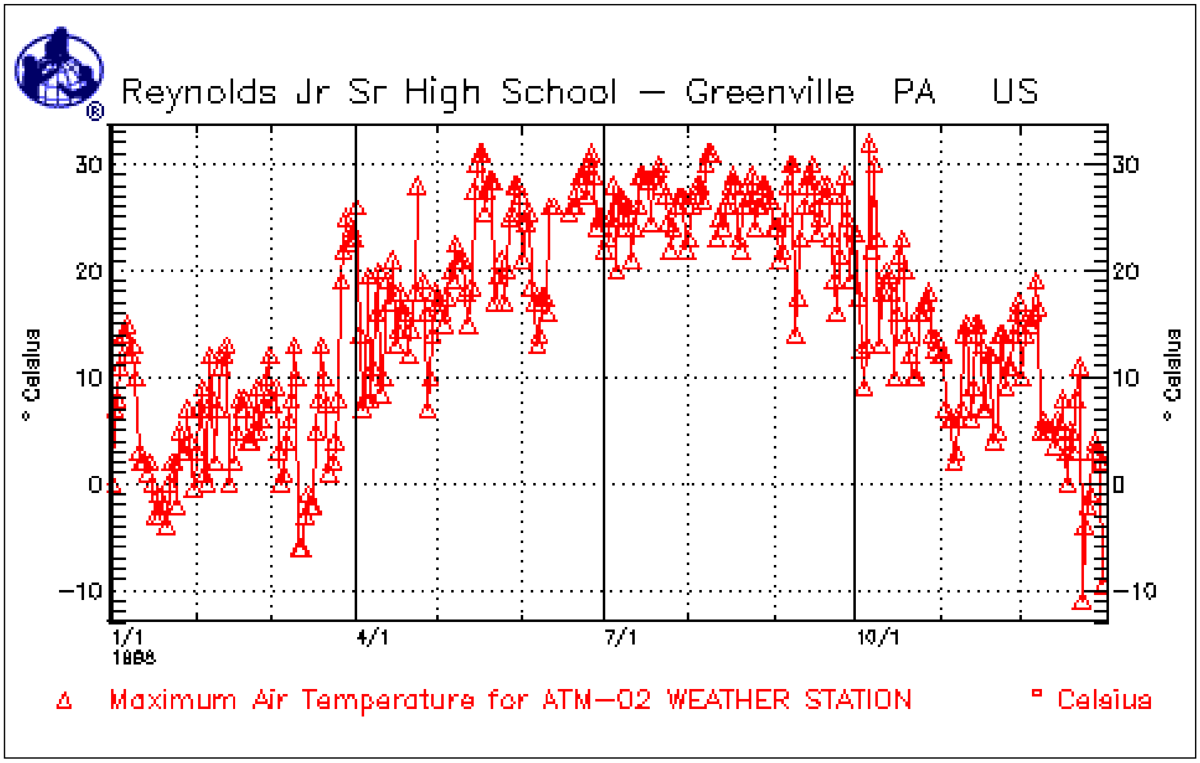


Figure EA-LC3-3: Surface Water Temperature at Reynolds Jr. Sr. High School 1/1/98-12/31/98

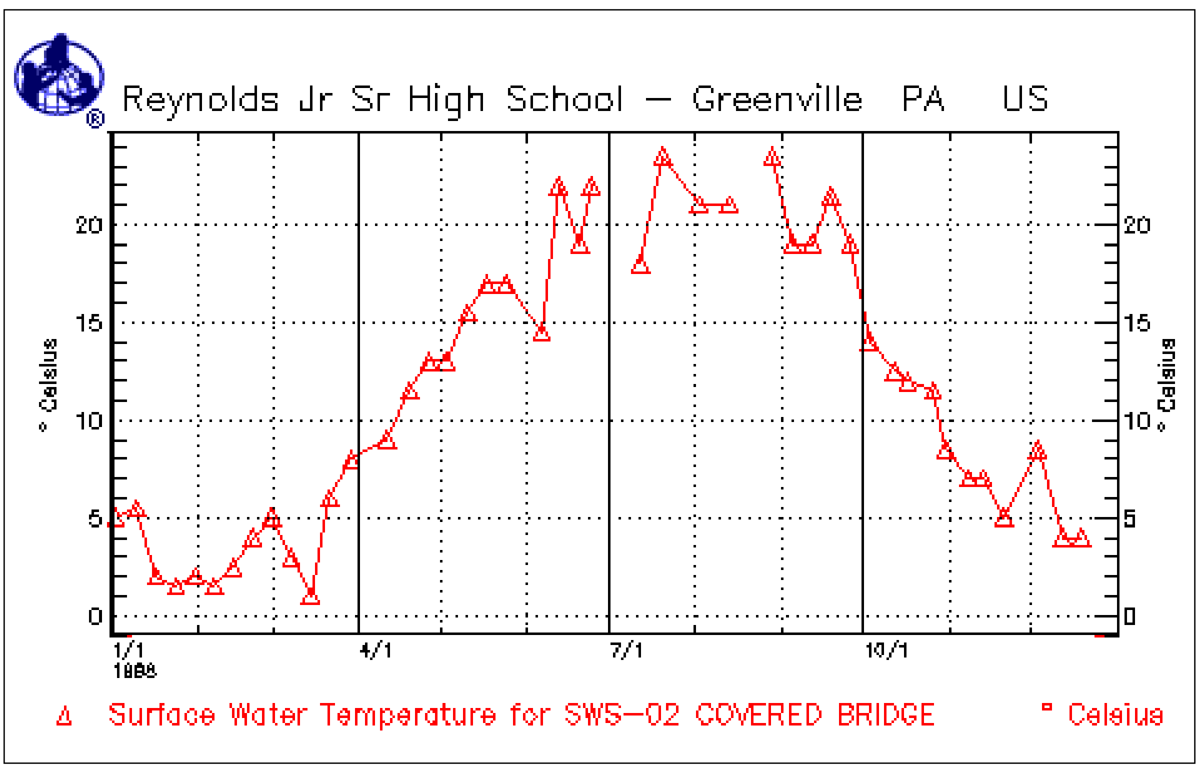


Figure EA-LC3-4: Surface Water, Maximum Air, and Soil Temperature at Reynolds Jr. Sr. High School 1/1/98-12/31/98

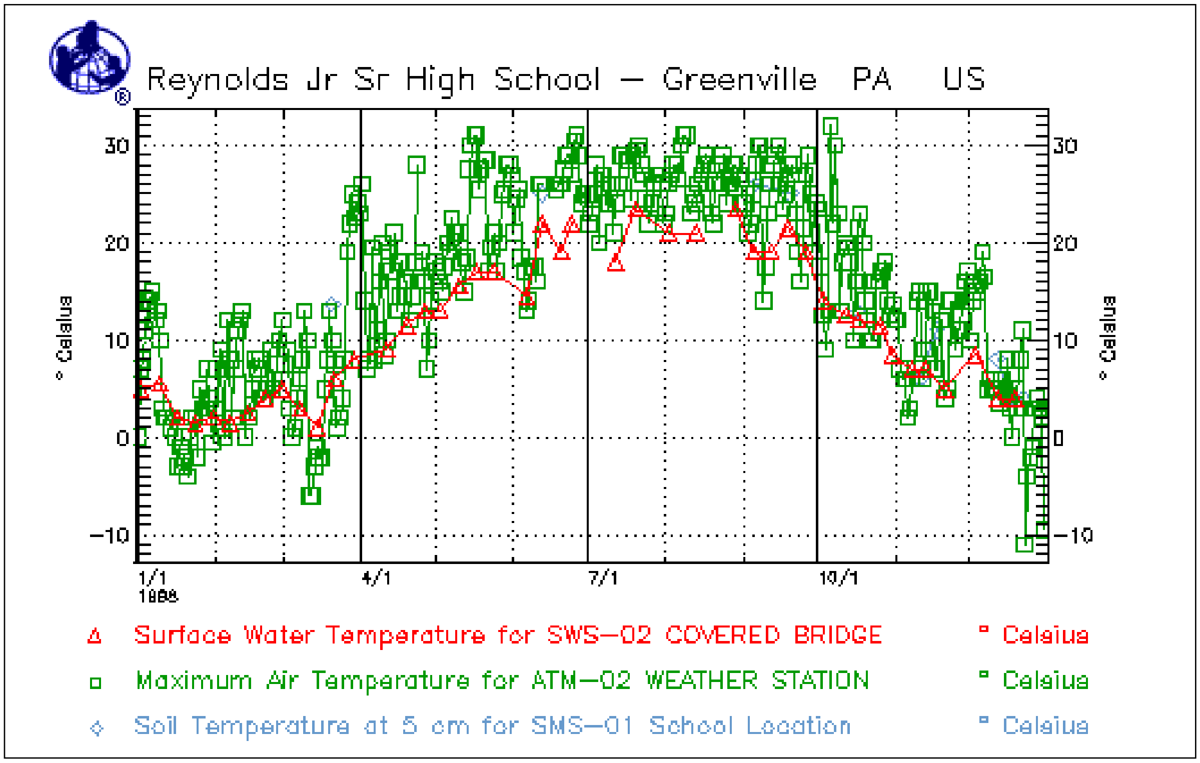
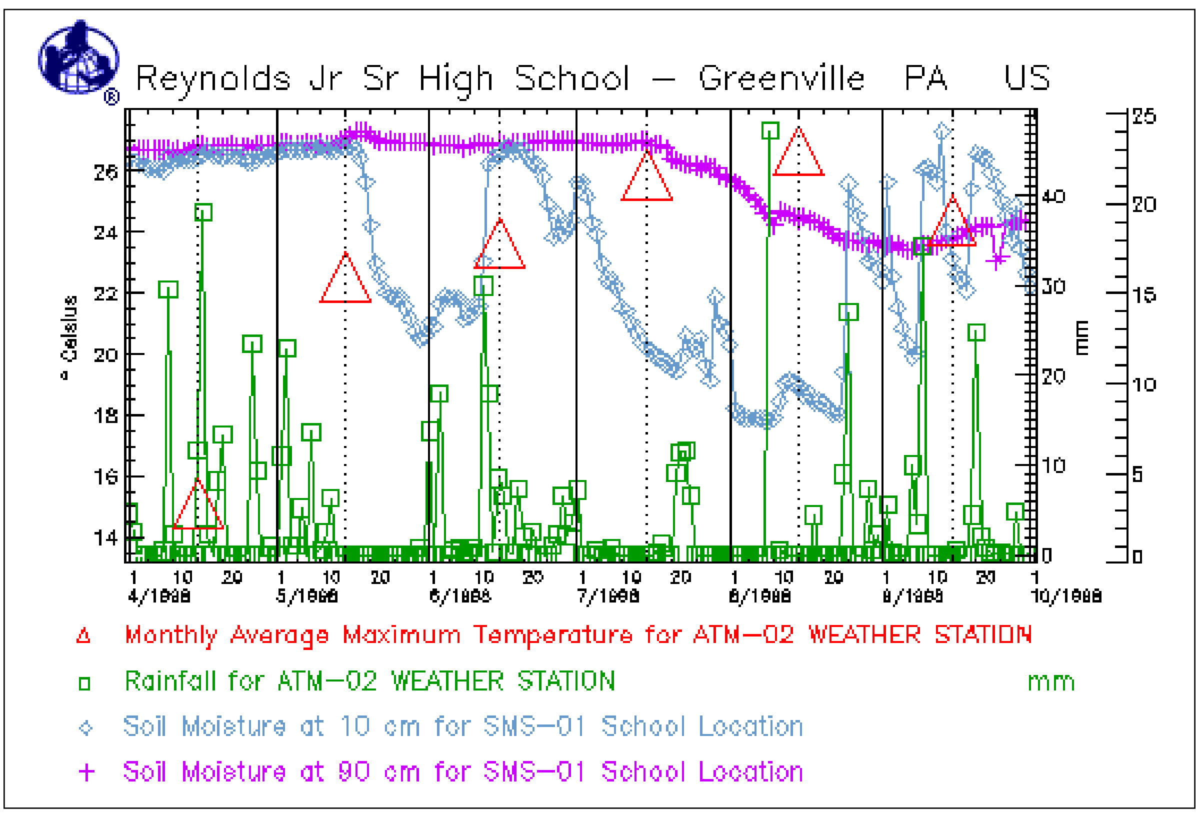


Figure EA-LC3-5: Monthly Average Maximum Temperature, Precipitation, Soil Moisture at 10 cm and Soil Moisture at 90 cm at Reynolds Jr. Sr. High School 1/1/98-12/31/98



Analyzing and Interpreting Graphs

Work Sheet

Name:____________________________ Class: ______________________Date:____________

1. First Graph: Maximum Air Temperature Over a Year

a. What month has the highest maximum air temperatures? Why?

b. What month has the lowest maximum air temperatures? Why?

c. What is the range of maximum air temperatures throughout the year (the difference between highest and lowest temperatures)?

2. Second Graph: Soil or Water Temperature Over a Year

a. What month has the highest soil (or water) temperature? Why?

b. What month has the lowest soil (or water) temperature? Why?

c. What is the range of soil (or water) temperatures throughout the year?

3. Third Graph: Maximum Air Temperature and Water or Soil Temperature

a. Do air and soil (or water) temperatures reach their highest values during the same months? Why or why not?

b. Why are the peak values for air and soil (water) temperatures different? What does this show about the differing characteristics of these two Earth system components?

c. What does this graph show about the interconnection between air temperature and soil (or water) temperatures? What patterns do you see, if any?

4. Other Earth System Relationships

What other relationships among study site system components do you think might be worth investigating, and what data would you need? Suggest only relationships that you think data could be obtained for. Think about all the interrelationships that you and other students may have listed and diagrammed.

(Did you list both the relationships to investigate *and* the data you would need?)

5. Self-reflection

Your responses to the questions below are intended to help your teacher become aware of what you're thinking and what you need help understanding. You will not be graded on these responses.

a. What have you learned in this activity that you feel confident about?

b. Which of the following areas, if any, are you having trouble understanding? Please check those
that apply, and describe what is giving you difficulty.

___ Making graphs from GLOBE Data Archive
___ Reading and interpreting graphs
___ Interpreting relationships among different components (air, soil, water)
___ Understanding the relationship of the graph to your own study site

c. What would you like to know more about?

Assessment Rubric: *LC3: Using Graphs to Show Connections*

Analyzing and Interpreting Graphs of GLOBE Data on Surface Air Temperatures and Soil or Water Temperatures

	4	3	2	1
Analysis of Graphs	Identifies highest and lowest values and ranges with no errors	Identifies highest and lowest values and ranges with few errors	Identifies highest and lowest values and ranges with some errors	Inaccurately identifies highest and lowest values
Interpretation of Graphs	Accurately and precisely identifies seasonal change patterns in data, and fully explains relationships among components	Accurately and generally identifies seasonal change patterns in data, and indicates relationships among components	Partially identifies seasonal change patterns in data and vaguely indicates relationships among components	Inaccurately identifies change patterns in data and neglects to explain relationships among components
Suggestions of Other Relationships	Suggests 3 or more other scientifically appropriate relationships to investigate; lists data needed	Suggests 2 other scientifically appropriate relationships to investigate; lists some data needed	Suggests 1 or 2 other scientifically appropriate relationships to investigate; lists little of the data needed	Suggests no other scientifically appropriate relationships to investigate