Earth System Science

An Activity Guide for the GLOBE Earth System Poster

Activity 1. Explore a Single Map

Activity 2. Explore Annual Changes (within a column)

Activity 3. Explore Relationships between Types of Data (across columns)

Activity 4. Global Patterns

Activity 5. Link with GLOBE Data

Activity Extensions

GLOBE™ Science and Education Program

TM

Global Patterns: Learning Activities for the GLOBE Earth System Poster

This booklet presents background information and learning activities to help you take advantage of the "GLOBE Earth System Poster," a science education poster developed by GLOBE. The poster can be a rich learning resource, and it can help your students understand the broader global context for your local GLOBE measurements.

This Activity Guide begins with information about the poster, the types of data displayed, the sources of the data and a few examples of global patterns that can be seen. The second part of the Activity Guide presents learning activities that you can do with your students, with an emphasis on helping your students explore the poster, search for patterns and make connections to the GLOBE student data.

The theme of this poster is patterns. Patterns can be found on many levels, from regional to global scales. Much of Earth science involves finding patterns and searching for the meanings of those patterns. Discovering, analyzing, and interpreting patterns as seen in a graphic display of data are essential skills for many scientific disciplines.

An Example to Help You Get Started

Before you read any further, please take a few moments to look more closely at the GLOBE Earth System poster. Look at the whole poster and look at some of the individual maps. Ask yourself "what patterns and connections do I see?"

Maybe your first impression is not patterns but beauty - with all those colorful graphic depictions of solar energy, global temperatures, soil moisture and so on. Or maybe it is confusion, with so many different types of data, changing in subtle and complex ways from one month to the next. However, the closer you look, the more you see, and the more the patterns emerge.

Extreme conditions are often the easiest patterns to perceive. For example, look at the map of Soil Moisture in July (Figure 1, the fifth column is Soil Moisture, the fourth row of maps is July). Look especially at Africa. (See Figure 2 and poster.) Notice how dry the Sahara Desert is and notice the moist band across equatorial Africa (on these maps on the poster, dry soil is yellow and moist soil is dark blue). (You could pick any month for this exercise, but July is a good example.)

Now shift your view to the column labeled Precipitation and look at the July Precipitation map. Notice how little precipitation falls on the Sahara and how much falls on the equatorial region. Now look at the July Cloud Amount map. Again you see the same pattern: cloudy over the equatorial region, clear over the desert.

In fact, if you look more closely at the Cloud Amount and Precipitation maps, you will see that this equatorial band of cloud cover and precipitation extends all the way around the globe. Scientists call this the Intertropical Convergence Zone, and it is one of the Earth's large-scale weather patterns.

If you now return to the Soil Moisture maps, you can see that the land in the equatorial region is moist all around the globe. And if you look at the Vegetation Index map (the last column on the right), you will see that land in the equatorial region also has lush vegetation.

In doing this example, you have discovered a basic global pattern, with connections among cloud amount, precipitation, soil moisture and vegetation. This process of exploration, analysis, and discovery of global patterns and connections is at the heart of the learning activities described here.

Figure 1 **GLOBE Earth System Poster** *Exploring connections in a typical year*

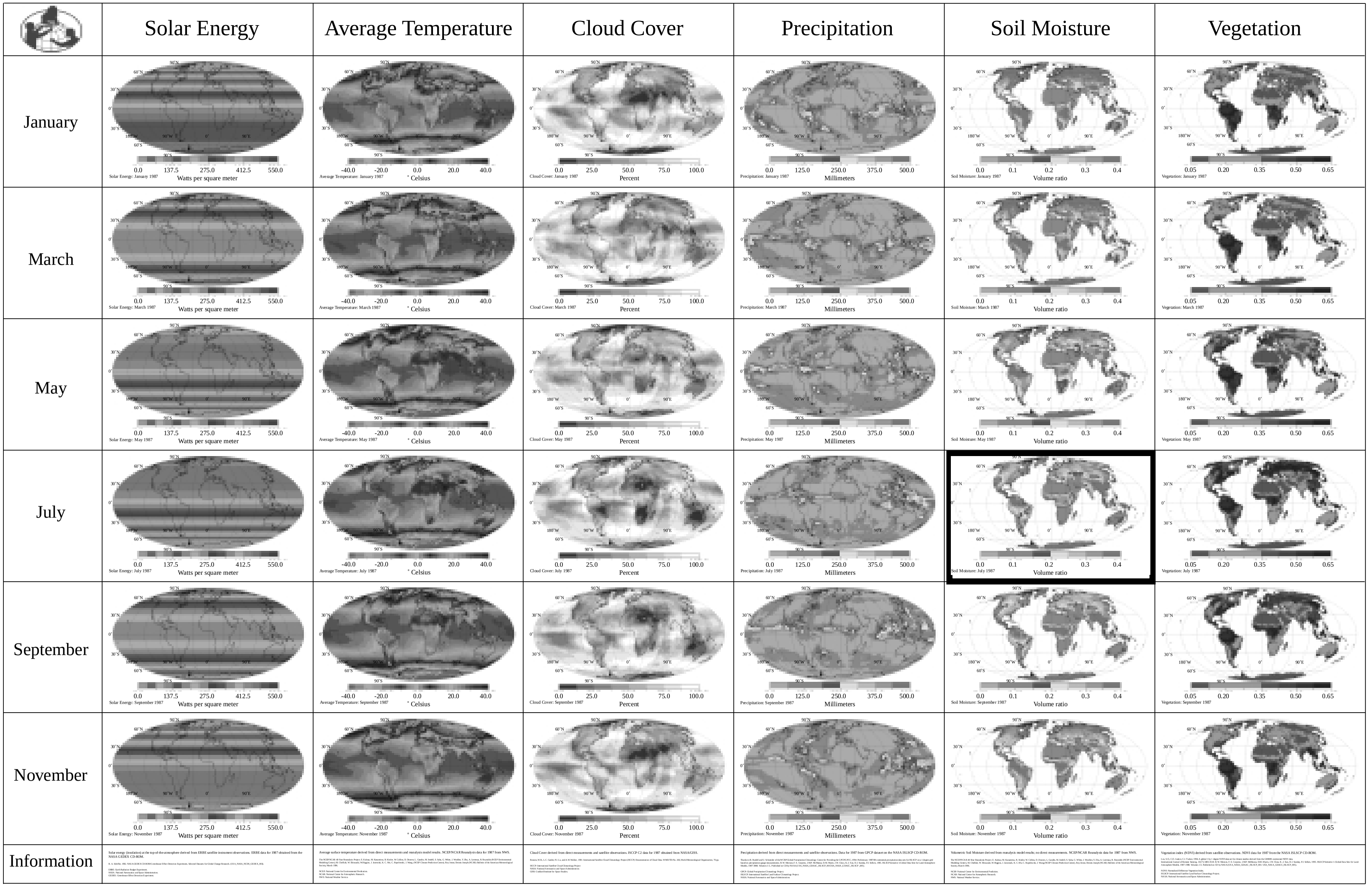
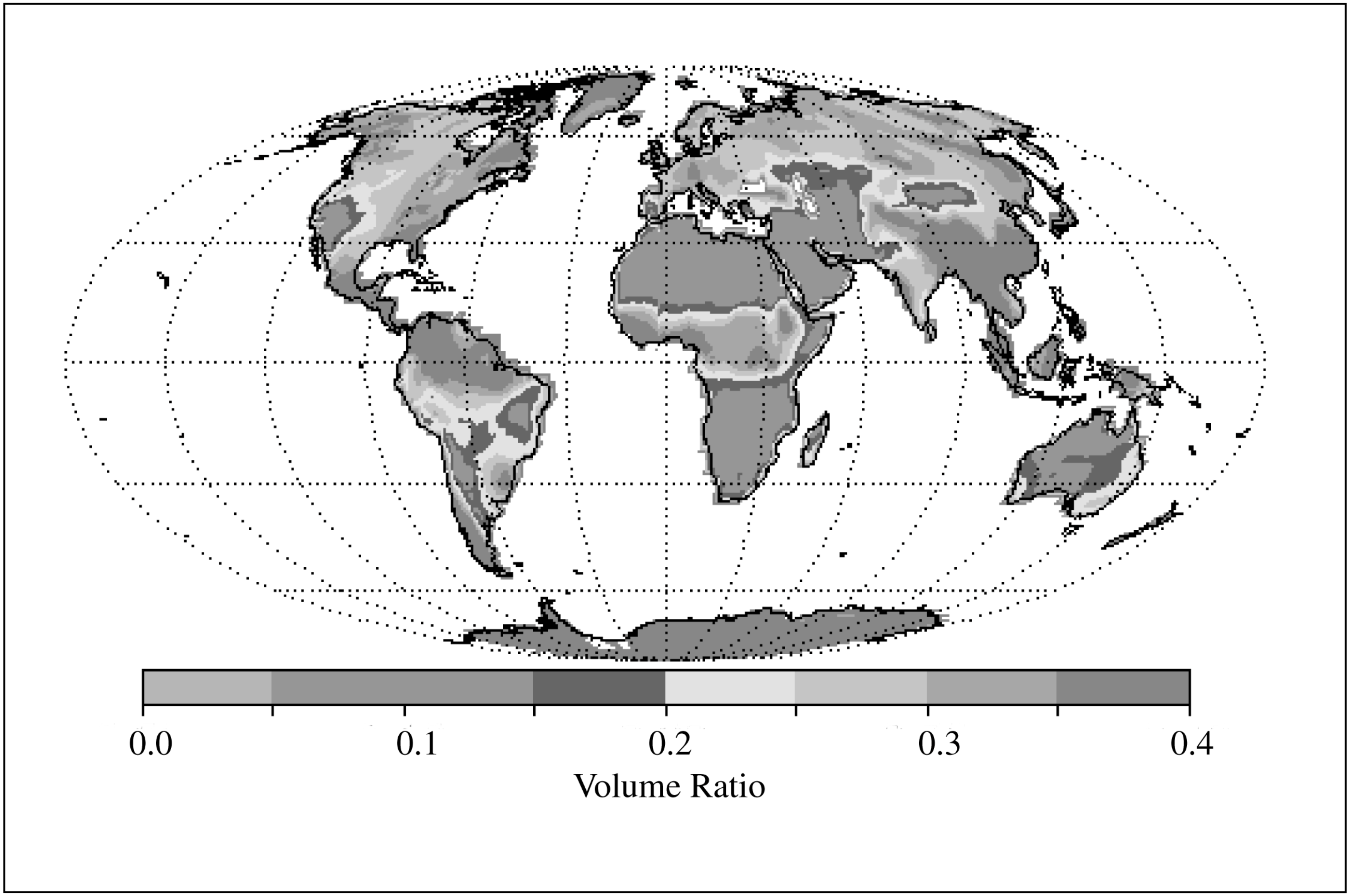


Figure 2 **_July Soil Moisture from the GLOBE Earth System Poster_**



A Guided Tour of the Global Patterns Poster

A. Each column shows a type of data

Each column in the poster shows a particular type of data:

1. Solar Energy – the amount of energy per square meter received by the Earth at the top of the atmosphere, before it is absorbed and scattered by air molecules, cloud, and aerosols (solid or liquid particles) in the atmosphere. These data are derived from Earth Radiation Budget Experiment (ERBE) satellite observations.

2. Average Surface Air Temperature – the monthly average temperature in degrees Celsius during every other month in 1987. These data are from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project and were derived from measurements and model simulations.

3. Cloud Amount – the amount of clouds in 1987 expressed as a percent, from 0% (cloud free) to 100% (totally cloud covered). These data are from the International Satellite Cloud Climatology Project (ISCCP) and were derived from ground-based and satellite observations.

4. Precipitation – the total accumulation of precipitation during every other month in 1987. These data are from the Global Precipitation Climatology Project (GPCP) and were derived from ground-based and satellite measurements.

5. Soil Moisture – the fraction of the volume of the soil that was water during each month in 1987. The scale goes from 0.0 (no water) to 0.4 (40% water). These data are from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) and were derived from model simulations. There were no direct observations.

6. Vegetation Index – a measure of the amount of vegetation based on data from NOAA satellites for every other month in 1987. To derive the vegetation index a special formula is used to compare two different colors or frequencies of light. Vegetation absorbs more light in one of these bands than the other. So by comparing the amount of radiation observed in these two bands we get a measure of how much vegetation there is. A high value indicates much vegetation and a low value indicates little vegetation. This index is called the Normalized Difference Vegetation Index (NDVI) from the International Satellite Land Surface Climatology Project (ISLSCP).

B. Scale bars show what the colors mean

Beneath each map is a scale bar, which shows what the colors on the map mean. For example, the Precipitation map scale bar shows a range from yellow (no precipitation) to dark blue (a lot of precipitation — 500 millimeters accumulation in the month). Although you can use the scale bar to determine actual values, it is more important in these activities to focus on patterns. The scale bar can be used as a guide to help you understand the range of values and which colors represent low and high values.

C. Each row is a different month

On the far left of the poster, you see the months of the year, in two-month increments: January, March, May, July, September, and November. This year-long view enables you to explore annual cycles. For example, the Average Temperature maps show the Northern Hemisphere warmest in July and coolest in January (and vice-versa for the Southern Hemisphere).

D. Why 1987?

The year 1987 was chosen for this poster for two reasons. First, the data from a typical year provide a useful case in point which enables students to see individual variability for that year. Thus students comparing their GLOBE data to this poster will find differences due to year-to-year natural variability. Second, there is a relatively large amount of data for 1987 because it was chosen for most of the Pathfinder dataset work done by NASA, NOAA and other agencies.

E. Computer-based Animations

If you have a computer and Internet connectivity, you can access and display an animation of these maps from the GLOBE Web page in the GLOBE Resource Room under Instructional Resources. You will download the same data as you see in the maps. However, with the animation, you will see the maps as in a movie, watching the data change from one month to the next.

The animations help you and your students discern annual patterns in the data. For example, if you watch the Average Temperature data animation, you will see a warming move north from January to July and south from July to January. Viewing the animations are optional, but can be a very powerful adjunct to the learning and exploration.

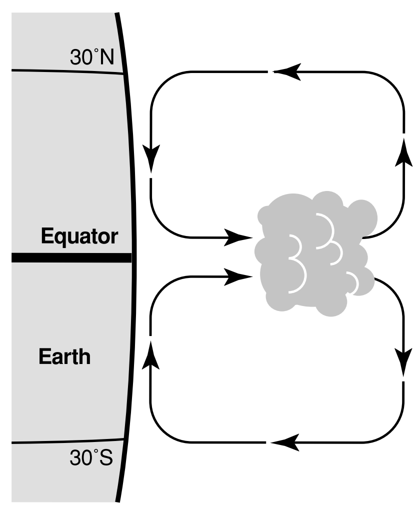
One difference between the animations and the poster: the poster shows data for every other month (6 total months), whereas the animation shows data for all months (12 total months). Hence, the animation enables you to see more information in the annual patterns (monthly instead of bi-monthly).

Global Patterns – a few examples

In using the poster, animations and related GLOBE student data, you and your students might see some of the following patterns:

1. The Seasonal Cycle: The seasonal cycle is clearly seen on the poster and in the animations of average temperature, with the average temperature at 60º N ranging from about –25 C to about +15 C. Such a range can be examined for many regions in both hemispheres. You can also see how the two hemispheres differ at a particular time of year.

2. The Intertropical Convergence Zone: Air generally moves toward the equator from about 30º N and 30º S. (See figure below.) The warm moist air that converges on the equator then begins to rise. As it rises, clouds form. The resulting clouds form a band that stretches around the equator and moves slightly north and south of it during the year. This is the Intertropical Convergence Zone, which can clearly be seen on the poster. You can also see enhanced precipitation in this region surrounding the globe.



3. Deserts: Once the air reaches high altitudes over the equator it spreads north and south and begins to descend toward the surface at about 30º N and 30º S. Descending air is dry and warm. As a result, this is a region of few clouds and many deserts, the most prominent of which on the poster is the Sahara Desert in Africa.

Earth Science Learning Activities

The learning activities described here exemplify an "inquiry-based" approach to student learning. Students examine the poster, look for patterns and connections, and pursue questions that intrigue them. Some students might focus on the patterns affecting Africa (as in the example above). Other students might be interested in seasonal changes in vegetation and the links to temperature and precipitation. And other students might want to compare their own GLOBE data measurements with the data shown in these maps for their own location.

Purpose

To discover patterns in global maps of environmental data, to interpret those patterns, and to draw conclusions and to make predictions based on them; to communicate those interpretations and predictions; to develop an understanding that the components of the Earth system interact.

Overview

A series of maps displaying global environmental data through the course of a year offers rich opportunities for enhancing our understanding of how the Earth works as a system.

Time

First four learning activities: two classroom periods

Fifth learning activity (link with GLOBE data): one classroom period

Extension activities: varied amounts of time

Key Concepts

Interacting systems of the Earth

Climate

Environmental changes in space and time

Skills

Discovering, analyzing, and *interpreting* patterns in a graphic display of data

Analysis of mapped data

Comparing

Using a key and *finding locations* on a map

Drawing conclusions

Level

Intermediate, Advanced

Materials and Tools

Student notebooks or paper pads with firm backs for taking notes while standing

World Atlas (book)

Computer with World Wide Web connection (to examine animations in Activity 2 and Activity 4).

Preparation

Familiarize yourself with the poster, and find the global patterns described in the section of this guide, "Global Patterns – A few examples," on page 6.

Tape or tack the poster to the classroom wall. Make sure the area in front of the poster is clear, so that students can stand close to the poster and study it. About eight students can study the map comfortably at one time.

Group the students into six teams.

Prerequisites

Students must have basic map reading skills; be able to identify latitude and longitude and to find the Equator; and know the names of the continents.

Methods to Explore the Poster

We present here five learning activities to help your students start working with the poster, and to help launch inquiry-based learning activities. Each of these activities uses a different method to explore the data (e.g. first look at a single map, then compare at least two maps at different times of year (down columns) or with different types of data (across columns).

1. Explore a Single Map — We begin by focusing on a single map in order to give students a manageable entry point. Students look at one map in the month of May, and interpret what they see for the rest of the class. They consider one region at a time. They present approximate numbers for the range of colors displayed in this region in May, showing their understanding of the scale bar.

2. Explore Annual Changes (within a column) — Students next compare maps within columns, looking up and down at different months within the column. They can also download and view the animation. They focus on how one kind of data pattern changes over the year. This helps students find annual and seasonal patterns.

3. Explore Relationships Between Types of Data (across columns) — Now students are ready to look across the poster and compare two types of data, across columns. For example, they may compare the Cloud Amount and Precipitation columns. At first, they may focus on just one region at a time. This helps them start exploring the linkages between two types of data.

4. Global Patterns — Students are now ready to point out global patterns, as they compare three or more columns at a time. They take patterns they've discovered in Activity 3, and look for them in other columns to determine whether those patterns hold for other kinds of data. One pattern that may emerge is the band of high cloud amount, precipitation, soil moisture, and vegetation around the region of the equator. Others are the bands of dry, low-vegetation, and low-precipitation at approximately 30 degrees north latitude and 30 degrees south latitude. This booklet provides the explanation for those patterns in Learning Activity 4 below.

This is a useful point at which to download and view the animations. Students can take a closer look at the seasonal changes and the connections among the data. Then can watch the full animation, step forward and backward and stop at particular months of interest.

5. Links with GLOBE data — Students compare their own local observations with the data shown in the poster. They also compare GLOBE student data maps and visualizations with the maps in the poster. They explain any differences they find.

From this point, students may pursue any of several investigations suggested in the booklet as Activity Extensions.

Note on Student Presentations

It is valuable to have your students present their interpretations of the maps to the rest of the class, as suggested below. Encourage your students to convey the core concepts clearly using appropriate maps, measurement units, and pattern analysis. This helps students consolidate learning and develop skills of scientific communication.

Activity 1. Explore a Single Map

Student teams study and interpret one selected map in the month of May, then present their interpretations to the class.

Assign one data type (in one column on the poster) to each student team. Explain that teams will begin by working with just one map of their assigned data, the map for May. Have them first consider one region of one continent within that map. They may study other regions and other continents as they become more comfortable with interpreting the data on the maps.

Students can make notes and confer with each other, then decide what they want to present to the class. Their presentations should include approximate numbers for the ranges of colors displayed in selected regions in May, showing their understanding of the scale bar. They may discover and point out striking characteristics of regions, such as in equatorial Africa, where a region with high amounts of solar energy, cloud amount, precipitation, and vegetation covers a wide expanse.

Guidance Questions for Students

You may want to copy and distribute these guidance questions to your student teams.

Student teams should each select one map of data to work with during this activity.

- First find the scale bar at the bottom of your map. What is the range of values shown there? Give your answer in the terms of the measurement units displayed on the map (watts per square meter, degrees Celsius, percent, millimeters, etc).

- Where in the world do you find the highest and lowest values of the data on your map? Where are the extremes? Why do you think the extremes are in these locations, and not somewhere else?

- Look for patterns. Describe them. Are they different on different continents or over water compared to over land? How do you explain these patterns?

Activity 2. Explore Annual Changes (within a column)

Student teams now consider and interpret whole columns, looking at data for the whole year. They discover seasonal changes leading to annual cycles.

Students expand their investigation started in Activity 1 by examining the maps of their data type in other months. They discover the annual cycle of that data type. For example, in the column for Average Temperature, they may find that areas of highest temperature around the equator appear to expand northward during the months of March, May, and July, and to contract during the months of September, November, and January. Students may perceive this as a kind of pulsing, particularly if they look at the animated displays on the Internet. (See "Computer-based Animations," on page 6.)

As in Activity 1, students present their discoveries of patterns, and their interpretations of those patterns to the rest of the class.

Teachers may choose to combine Activities 1 and 2 by having teams make one presentation to the class on both the single map and the single column.

Guidance Questions for Students

- What changes do you see through the year? What seasonal changes and annual cycles emerge? What explanations can you suggest for these patterns?
- Pick a location or area. During which months do the extreme highs and lows occur for each data type? What explanations can you suggest for the timing of those extremes?
- Which regions experience the extreme high's and low's for each data type? Which regions don't experience the extremes? Why do you think this is so?
- What differences, if any, do you find between the year's variations over the oceans versus the year's variations over the continents?
- Are there regions that remain unchanged over the year? Why do you think this is so?

Activity 3. Explore Relationships between Types of Data (across columns)

Student teams compare two or more types of data, looking across columns.

Have your students focus first on just the data for one month (in one row) as they look across columns. It may also help if they consider just one region at a time. Then they can put their global "picture" together.

Some relationships among data may be more easily perceived than others. For example, cloud amount and precipitation appear to be directly related in many regions. Relationships between solar energy and average temperature may be apparent. Relationships between cloud amount and temperature may not be apparent.

As in previous activities, student teams present their discoveries to the rest of the class.

Guidance Questions for Students

Different guidance questions will be helpful to different student teams, depending on the data they are studying.

- What relationship do you see between solar energy and average temperature? Remember that solar energy reaching the top of the atmosphere does not necessarily reach the Earth's surface, to affect the surface air temperatures shown on this poster represent.
- What relationships do you find between temperature and vegetation? What are the temperatures where the vegetation indices are highest?
- What amounts of solar energy, cloud amount, precipitation, and soil moisture characterize the world's most vegetated regions?
- What do you discover when you compare data for cloud amount and precipitation? Where there is usually cloud cover, is there much precipitation during the same month? Explain what you think is the reason for this.
- Consider the following: If cloud amount were reduced by 25%, what changes would you predict for the equatorial region of Africa? Why would you predict those changes?
- A friend has hired you as a consultant to tell her where she should establish a vegetable and fruit farm in another country. Where should she establish this farm? Why? Justify your recommendation to her using data from the poster.

  Now go to other sources and find out about your chosen location. Does this new information help to justify your decision? Did you give good advice to your friend?
- Where would you like to take a vacation during the month of November? Why?

  It may be interesting to notice what kind of data you choose to consider first: Is it solar energy or cloud amount? (Do you like it sunny?) Is it temperature? (Do you love the heat?) Is it vegetation?

Activity 4. Global Patterns

Students explore the poster for global patterns.

Students may begin with the regional relationships and patterns they discovered in Activity 3, to determine whether they apply to larger scales, and to what extent they are global. Students then present their findings to the class.

View the Computer-based Animations

If your students have not already viewed the computer-based animations, this is a good point at which to do that. (See, "Computer-based Animations," on page 6). Students can take a closer look at the seasonal changes and the connections among the data. If the animation is downloaded they can watch it, step forward and backward, and stop at particular months of interest.

Guidance Questions for Students

- How does the global pattern of solar energy relate to the other data on the poster?
- Compare conditions at the poles with conditions at the equator. What do you discover, and how can you explain it?
- Look at the equatorial region across the globe. What characterizes it?
- Look at the regions around 30 degrees N and 30 degrees S. What patterns do you find there?

One pattern that students may discover is the band of high cloud amount, precipitation, soil moisture, and vegetation around the region of the Equator. Another pattern they may discover lies in bands of dry, low-vegetation, low-precipitation at approximately 30º degrees N latitude and 30 degrees S latitude.

After students have discovered these patterns, you may want to explain how the two are related. These two regions are related through the circulation of air in a pair of large cells called Hadley Cells between 30º N and the equator and 30º S and the equator. As air reaches the equator near the surface, it warms and rises. As it rises, it cools. Since cool air can hold less moisture than warm air, clouds and precipitation form out of this rising air. Regions close to the equator receive rain. When the air reaches high altitudes it begins to move north and south. Then at about 30º N and 30º S, it begins to sink. This sinking air warms and is dry, so fewer clouds form and very little precipitation falls. The result is that there tend to be warm, dry desert climates at these latitudes.

Activity 5. Link with GLOBE Data

Students compare their own local observations – or those of another GLOBE school – with data shown in the poster. They also compare GLOBE student data maps and visualizations with the maps in the poster.

If you do not have GLOBE data on any particular measurement, you may use data from another school.

Ask students to explore and explain any differences they find between the data on the poster and the GLOBE data they have chosen to use. This exercise will help them to enhance their skills in reading and analyzing maps, and better prepare them to make predictions.

If the GLOBE data (or other data) have significantly different values from the data on the poster, help the students to determine why. Students should check their data carefully for errors. When students compare data from different sources, they should compare data for identical locations and for identical times of the year. Make sure also that the units of measurement being compared are the same.

Students may find data that appear extreme, well above or below the average for that time period. If so, those data could certainly be investigated. A certain amount of variation in temperature, cloud clover, precipitation, soil moisture, and vegetation is to be expected.

Activity Extensions

Students have learned to analyze and interpret the maps; now they must put their skills to work. They may pursue any of the "starter ideas" for investigations below.

- Consider ways in which the Earth systems data you have explored on the GLOBE poster have influenced the locations of human settlements. Where have people settled, and why? What are the conditions of solar energy, temperature, cloud amount, precipitation, soil moisture, and vegetation in the most populated areas of the globe? What are they in the least populated areas?
- One goal of working with global climate data is to develop the capability to understand how much the climate varies. Compare the data on the poster with reference climate data on the GLOBE Web site. How much does the climate data on the poster differ from the reference data you chose? How much different is the data on the poster from climate data from an El Niño or La Niña year?
- Compare data on the GLOBE Poster with data on maps that display other aspects of geography, such as population, agriculture, fisheries, and physical features. Fascinating comparisons with physical maps can be made, for example, because these maps will show mountains, deserts, ice sheets, sea ice, plains, and such features can be causes or effects of conditions shown on the GLOBE poster. One activity of interest may be for students to look at the western coasts of North and South America, on both the GLOBE poster and on physical maps of those regions.
- Select an issue or problem you think your class could investigate later this year or next year, either from the list below or from your own experience, and write a convincing proposal to your teacher or panel of reviewers (students may be included as reviewers.) The issue to be investigated should relate to the curriculum your teacher already plans to follow, and it should use at least some of the kinds of data displayed on the GLOBE poster. The issue you select may be a local issue of interest that is related to a global issue. The proposal should be structured so that the best proposal (as decided by a panel of teachers and possibly other impartial students) can be adopted as a class project.

  The research proposals might include the following:

  Clear description of the issue and why it is important to you;

  A focus question for the investigation;

  Kinds of data and other resources you may use;

  A strategic plan for the investigation (how you want to go about it);

  How long you think this investigation will take.

Possible Issues for Investigation

Availability of fresh water
Plant and animal species habitats
Desertification (expanding deserts) – Reforestation (expanding forests)
Famine in selected regions of the planet
Trade routes and patterns
Patterns of agriculture
Where do rivers flow and why

Kinds of Data that May Be Needed, Not on GLOBE Poster

Of course students may draw on any data or other resources.

- Agriculture
- Economic Activity
- Ocean boundaries, including changes over time (to show sea level rise and fall)
- Infrared radiation (indicates heat; from satellite images)
- Light from human sources at night
- Ocean currents
- Ozone levels
- Photosynthesis in the oceans
- Physical features of the globe
- Topography
- Trade Routes
- Volcanic eruptions
- Wind directions and speeds
- World population, distribution and density

Make sure students are aware that several years of measurements may be required to obtain the data needed to answer their questions.