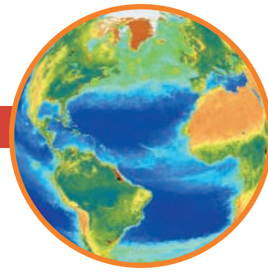
Educational Product	
Educators	Grades 9–12



Investigating the Climate System

ENERGY

A Balancing Act

PROBLEM-BASED CLASSROOM MODULES

Responding to National Education Standards in:

English Language Arts ◆ Geography ◆ Mathematics
Science ◆ Social Studies

Investigating the Climate System

ENERGY

A Balancing Act

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Give us your feedback:
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https://ehb2.gsfc.nasa.gov/edcats/educational_product
and click on "Investigating the Climate System."

NOTE: This module was developed as part of the series "Investigating the Climate System." The series includes five modules: **Clouds, Energy, Precipitation, Weather,** and **Winds.** While these materials were developed under one series title, they were designed so that each module could be used independently. They can be freely downloaded at:
http://www.strategies.org/CLASS.html

June 2003

CONTENTS

Investigating the Climate System

ENERGY

A Balancing Act

GRADE LEVELS

Grades 9–12

TIME REQUIRED

Five to seven class periods

OBJECTIVES

- Students will use and apply the scientific method.
- Students will research and explain how energy is absorbed at the Earth's surface.
- Students will research and explain how energy is reflected by the Earth's surface.
- Students will apply their research to define albedo and explain how it is determined, including the possible effects of the type of ground surface involved.
- Students will explain latent heat, and how it is associated with the phase changes of water.
- Students will apply their knowledge of latent heat to determine its role in governing surface temperatures.
- Students will apply what they have learned to determine the importance of energy absorption at the Earth's surface.
- Students will apply what they have learned to determine the importance of surface moisture, evaporation, melting, and sublimation in governing surface temperature.
- Students will research and determine the potential impacts a growing town will have on temperature.
- Students will research and explain why there are differences in summer temperatures for different locations at the same latitude. All points at the same latitude receive the same amount of incident solar radiation unless there are variations in the atmosphere (e.g., clouds, aerosols, water vapor).

DISCIPLINES ENCOMPASSED

Meteorology, climatology, geography, language arts, mathematics, and atmospheric science

KEY TERMS

active sensor, passive sensor
albedo
climate
convection
convective storm
Earth's energy budget
evaporation
greenhouse gases
hurricane
latent heat
latent heat transfer
latitude/longitude
lee side
radiate
scientific method
stabilization/destabilization of the atmosphere
sublimation
transpiration
urban heat island effect
water cycle/hydrological cycle

PREREQUISITE KNOWLEDGE

Water is a key element of the Earth's energy balance. The Sun's energy drives the **water cycle,** and in turn, water is a major factor in governing the surface temperature of the Earth. This unit is based on, first, gathering experimental data that demonstrates the importance of surface type in the absorption of solar energy, and the importance of surface moisture in the Earth's overall energy balance and, therefore, in determining temperature. Second, the experimental portion is followed by application of the information to solve real-world questions about land use and the connection between water and **climate.** The activities are also designed to: 1) strengthen students' development of the use of the **scientific method;** 2) strengthen students' abilities to solve problems and work with data; and 3) increase students' knowledge about energy in the Earth system through hands-on experimentation, problem solving using traditional observation data, and extension of this knowledge to a larger, more global view using satellite information.

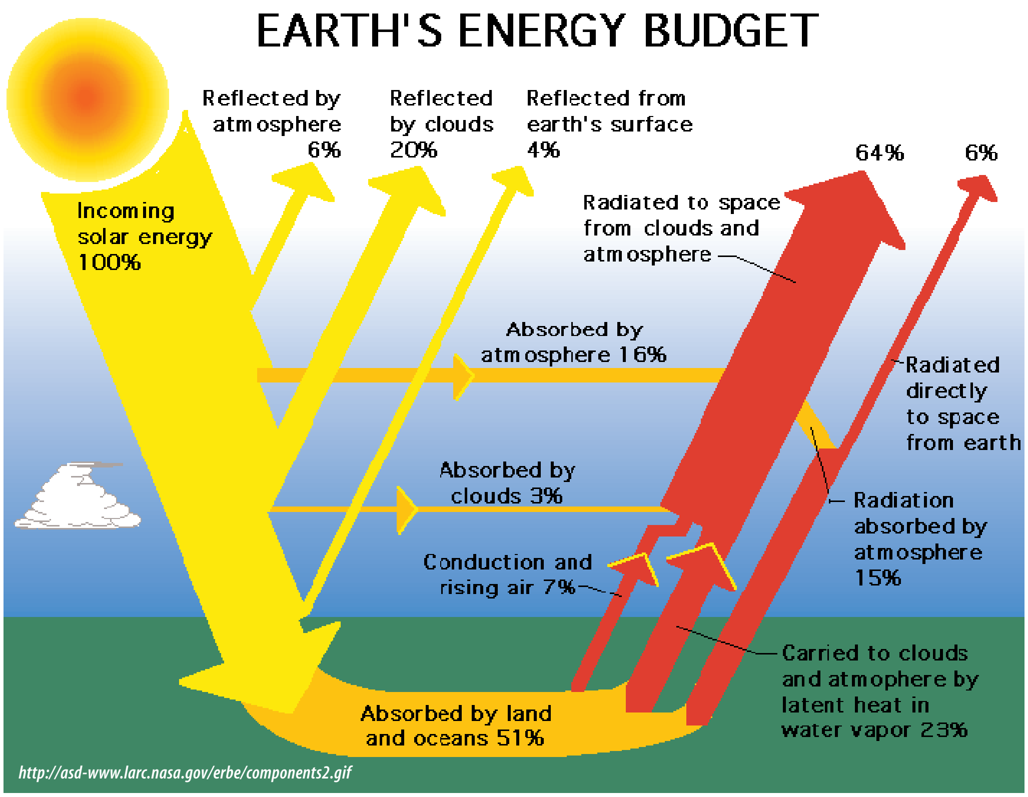


Figure 1

The **Earth's energy budget** (Figure 1) plays a major role in weather and climate around the world. Several key facts are evident if we follow the flow of energy from the Sun through the Earth system. Energy, like sound, travels as invisible waves of different sizes. We start by assigning an arbitrary measure of 100 units as the amount of solar energy received at the top of our atmosphere. The atmosphere and its elements (clouds, particles, molecules) reflect about 26 units back out to space and absorb another 19 units. The remainder of the energy passes through the atmosphere, with much of it (51 units) being absorbed by the Earth's surface. Essentially, the energy absorbed by the land and the oceans is what drives atmospheric and oceanic circulations. Finally, about 4 units of the energy are reflected by the surface. The **albedo,** or reflectivity, of a surface is the ratio of the reflected solar energy to the total incident solar energy—in other words, the measure of the fraction of solar energy reflected by a surface. The albedos of natural surfaces range from as low as .07 (93% of the energy is absorbed) in tropical forests and oceans with the Sun directly overhead, to .85 (only 15% of the energy is absorbed) for a fresh snow or ice surface at high **latitudes.**

Virtually all of the energy that heats the Earth's surface is then transferred to the atmosphere and to space by several different mechanisms. First, all surfaces **radiate** (give off) energy back through the atmosphere toward space. Also, heating from the Earth's surface causes upward motion of the air above **(convection)** and changes the state of water from liquid to vapor form **(evaporation)**. Convection, evaporation, and radiation from the surface exceed the total amount of energy that was absorbed by the surface to begin with! This is impossible unless there is a missing element of the energy budget. In fact, there is: the Earth's atmosphere contains water vapor, carbon dioxide, and other **greenhouse gases,** which absorb energy radiated toward space and then emit some to space and some back to the Earth's surface. Greenhouse gases are responsible for keeping the Earth's temperature warm enough to support life as we know it. The exercises presented in the following pages are intended to explore what governs the amount of energy absorbed by the Earth's surface and the important role of water in the Earth's energy budget.

Following is a brief summary of the water cycle, also called the **hydrological cycle** (Figure 2):

1. The heat energy required for **evaporation, sublimation,** or **transpiration** of water (the conversion of liquid water or ice on the Earth's surface to gaseous water vapor in the air) is stored in the vapor as **latent heat.** (A good example of latent heat is when someone comes out of a swimming pool. Energy is required to evaporate the water on the skin. This energy is taken from the surrounding skin, producing cooling, and stored in the water vapor.)
2. As the moisture-laden air cools, some of the water vapor condenses back into cloud droplets (water vapor changes to liquid water), releasing the latent heat.
3. When enough cloud droplets grow to precipitable size, they fall to the Earth's surface as rain/snow/sleet, etc.
4. Precipitation is absorbed by or accumulates on the Earth's surfaces, infiltrates into the ground, or runs off into lakes, streams, and rivers, and then back to the seas.
5. The cycle begins to repeat itself as moisture from the Earth's surfaces (oceans and land) evaporates, sublimates, or transpirates again. Note that when precipitation occurs, a convergence (coming together) of moisture is required to sustain the precipitation process, concentrating the latent heating in the column of precipitating atmosphere. The water cycle's redistribution of heat energy in the atmosphere not only cools the Earth's surfaces, it produces circulations in the atmosphere. These circulations are significantly different than those that result from the uneven heating of the Earth's surface by the Sun.

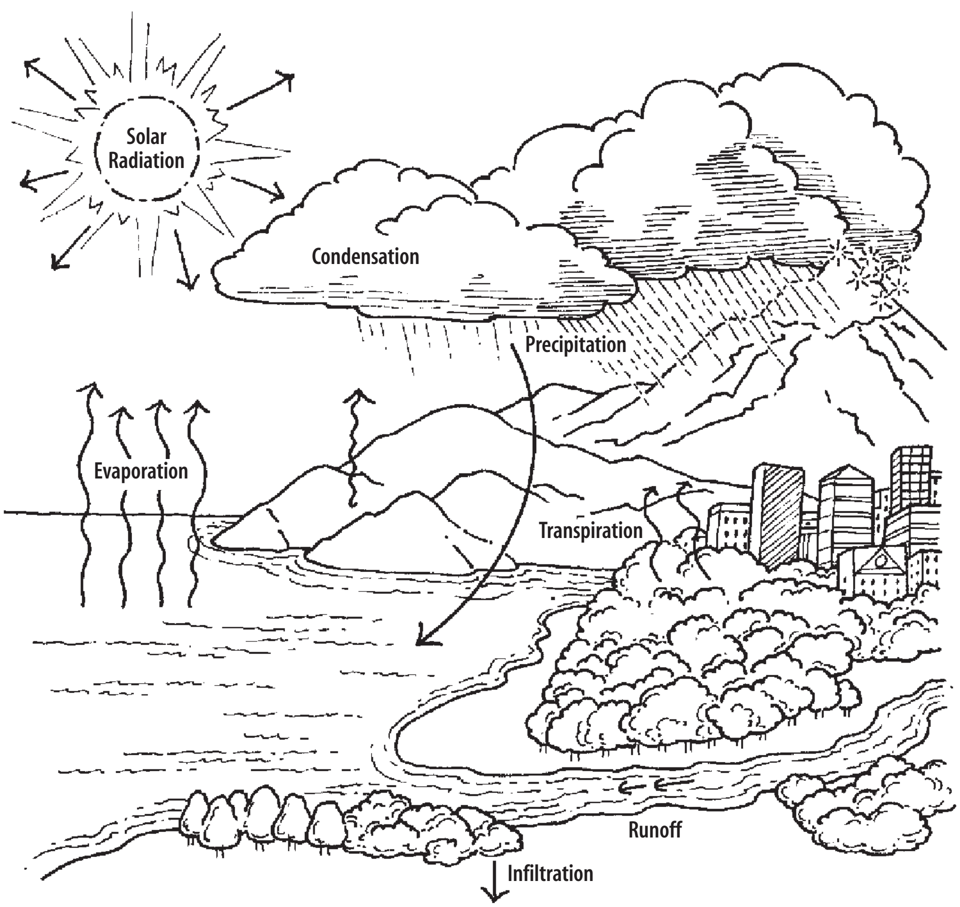


Figure 2: Water/Hydrological Cycle

SCENARIO *It's the end of the school year and you have been looking for a summer job. All the job openings you've found so far are the typical, boring positions that you were trying to avoid. One day, while complaining to a friend in class, your science teacher overhears your conversation. Your teacher pulls you aside after class and tells you about a great summer position that has opened in the lab of a friend, Dr. Jones. The job pays better than anything you've found and is definitely NOT typical. You'd get to work at the local laboratory with REAL scientists, helping with their research, as the Student Research Scientist. And, you'll even get your name published with the research! How many of your friends can say that? So, of course, you take the position.*

PART 1
Understanding the absorption of energy at the surface of the Earth.

Question: ***Does the type of the ground surface influence its temperature?***

BACKGROUND

The first key to understanding the absorption of energy at the surface of the Earth is to understand what governs how much energy is reflected. The albedo is the ratio of the reflected solar energy to the total incident solar energy—in other words, the fraction of solar energy reflected by a surface. The albedos of natural surfaces range from as low as .07 (93% of the energy is absorbed) in tropical forests and oceans with the Sun directly overhead, to .85 (only 15% of the energy is absorbed) for a fresh snow or ice surface at high latitudes. Students will directly relate to this concept by having noticed the difference between wearing a black or a white T-shirt on a sunny summer day, or the need to wear sunglasses on a sunny day after a major snowstorm. Each of these examples illustrates the effect of differences in albedos. This exercise is designed to demonstrate that the albedo of a land surface can have a measurable impact on the surface temperature.

MATERIALS

Thermometer; paper cups, each with a hole in the bottom; lab notebook; pencil; a nice sunny day

PROCEDURE

Your first assignment as Student Research Scientist is to familiarize yourself with the project. You have been given the question above, along with a list of materials, and you need to provide a scientific answer. It is up to you to determine how to conduct your research, although Dr. Jones has given you some guidelines:

- Think about the different types of surfaces that are outside, both natural and human-made. List them in your lab notebook. Do you think they will all be the same temperature? Why or why not?
- How would you test your hypothesis? Go ahead and do it. Be sure to record all your steps and your results.
- What comparisons can you make using the data collected? Explain the different methods of making comparisons.
- How does the data you have collected compare to data shown on weather maps?

ALTERNATE PROCEDURES

1. Cover a smaller area of the playground with large squares of different colors (e.g., construction paper) or of different textures (e.g., crumpled vs. flat paper) and follow the same procedure as above.

2. Have as many students as possible come to school wearing cotton T-shirts with pockets. The T-shirts should be different colors, including white and black. Or purchase two T-shirts, one white and one black, with pockets. Place the students outside in direct sunlight, or place two T-shirts on the ground, with thermometers in the pockets. After a set time, examine the temperature differences between the different colored shirts.

EXTENSION

What is the difference between the surface temperatures of Mars and Venus? Explain why/how this happens.

PART 2
How a change in water phase affects surface temperatures.

Question: ***How important is the evaporation of water in cooling a surface?***

BACKGROUND

The energy absorbed by the Earth's surface is transferred to the different components of the Earth system through multiple mechanisms (refer to energy diagram of Figure 1 on p. 3). Every surface radiates energy in the form of electromagnetic waves. Energy is also transferred through the interactions between air molecules and the land (conduction and convection). One of the most potent mechanisms of transferring energy involves the phase change of water. Most students recognize the importance of evaporation (e.g., of sweat) in the cooling of their bodies. This exercise and the ones that follow are designed to demonstrate just how different the surface temperatures would be of land that is dry, which means no evaporation could occur, and land that is wet. This demonstration can be directly related to real-world examples: for example, why summer temperatures in Texas become so extreme if it doesn't rain for a long period of time.

MATERIALS

Two aquariums, dry soil/sand, two heat lamps or other heat sources *(CAUTION: always be careful when using heat sources),* two thermometers, and water (the same experiment can be completed with only one of each of the items above, using one aquarium and a tank divider), lab notebook, pencil, graph paper.

PROCEDURE

Your next assignment is to study the same type of phenomena observed in Part 1, but this time in a controlled setting. Dr. Jones has again provided you with your research questions and the materials you will need. Your guidelines are:

- What are you trying to observe?
- What are the different ways you can set up the aquariums?
- What time frame are you planning to observe?
- Would you expect to find any differences in temperature between the different types of soils? Why or why not?
- Would you expect to find any differences in temperature between wet and dry soil? Why or why not?

After your experiment is completed, look back at your procedures. Was this the most effective method? Is there anything you would do different the next time around?

ALTERNATE PROCEDURE

Set up one aquarium with a layer of dry soil and sand, a thermometer, and a heat source directed at the bottom of the aquarium. Add moisture to the soil and then measure the temperature over time as the soil dries. Depending on how much water is added to the soil, this experiment may require several hours of observation time.

EXTENSIONS

- Simulate day and night by turning on and off the heat source and comparing the changes in temperature with time. This experiment can introduce the additional role of water in heat storage. Light and dark soils can also be substituted to introduce or reinforce and explore the relative importance of surface albedo versus moisture content in governing surface temperature. Which is more important? A change in albedo can also influence the rate at which energy is absorbed and, hence, the rate at which water evaporates, both of which affect the rate of change of temperature with time.
- To demonstrate how evaporative cooling influences temperature, compare the temperatures of wet and dry-bulb thermometers that are subjected to some form of artificial "breeze."
- Refer to the "Cloud in a Bottle" experiment with a temperature strip, in this series' *Clouds* module.

PART 3
Determining what controls the temperature of the land surface.

Question 1: *If my town grows, will it impact the area's temperature?*

BACKGROUND

The experimental data gathered under Parts 1 and 2 arms student scientists for exploring applications to the real world. The growth of cities and towns and the temperature of the desert regions of the Earth provide tangible and easily understood case studies for exploration.

As a city grows, the nature of the surface of the Earth changes, replacing forests or grasslands with concrete, asphalt, roofs, and other structures. Our experimental data suggest that these changes could influence at least two key variables that govern temperature—albedo and moisture. First, temperatures change as a city grows because the albedo for concrete and buildings is different than for forests or farmland. Second, unlike soil and vegetation, concrete and asphalt do not absorb and retain moisture, so latent heat flux, and therefore temperature, is likely to be very different. We can explore the relative importance of these two effects by examining two cities in very different regions of the United States: Pittsburgh and Phoenix. The first is surrounded by forests and farmland, while the latter is surrounded by desert.

MATERIALS

Meteorological observations for major urban areas and the surrounding countryside (Phoenix and Pittsburgh are provided in the Appendix F tables); or NOAA state-by-state ($3 per state) climate "normals" of the average maximum and minimum temperature data for all stations in the U.S. The "normal" is defined by a 30-year period of observations.

PROCEDURE

You are in the last phase of this research project. Dr. Jones has just told you that the final goal is to study the **urban heat island effect.** You will need to find out everything you can about the urban heat island effect and determine how the research you have already conducted relates to it. You will then need to compare temperature information from two cities to study this effect. What two cities would you choose? Why? If you want to see a dramatic difference, would you pick two cities in the same type of environment, or different? If you are unable to get the data you need, use the two tables in Appendix F.

Guidelines:

- For each city and surrounding countryside, explain what you see as far as the temperature pattern. What conclusions can you draw? Be sure to use the knowledge you have gained from Parts 1 and 2.
- Compare your findings for the two cities. Do they show the same thing? Why or why not?
- Which temperatures (maximum or minimum) show the trend better and why?
- What factors, other than what you have studied, could influence the temperatures of the two cities?

EXTENSION

Rather than provide data from two cities, have the students debate how to use this type of data from state records to solve the problem, with teacher guidance; or ask the students to pick a city and set up the problem. The idea would be to look at average monthly temperatures for major cities and then for data points just outside the cities. This could require the students to examine state atlases to find locations that are definitely non-urban to compare with the cities.

It can promote discussion about whether the adjacent sites should be at the same elevation and have similar topographic and surface features, whether coastal versus inland location makes a difference, and why. Humid areas usually serve as the best examples of the urban heat island effect, while the lack of moisture in arid regions, especially deserts, limits the temperature differences between cities and their surroundings.

Question 2: *Why are summer temperatures in the desert southwest so much higher than at the same latitude in the southeast?*

BACKGROUND

Latitude is the most important factor in governing surface temperature, since the amount of incident solar energy is highest at the equator (low latitudes) and lowest at the poles (high latitudes). Elevation and availability of moisture, among other variables, can cause temperatures to vary for different locations at the same latitude, even though all points along a latitude line receive the same amount of solar energy.

MATERIALS

Access to TRMM Web page educational resources: ***http://trmm.gsfc.nasa.gov,*** temperature information for different regions (see below).

PROCEDURE

Your final task is to determine how satellites can help scientists studying the urban heat island effect. Use NASA TRMM observations of precipitation to select a latitude band that has a large contrast in precipitation, and thus a large contrast in the amount of water available for evaporation. The TRMM 5-year climatology diagram (found on the TRMM Web site) can be used as a guide to exploring the relationship between surface temperatures and surface moisture. Use either an atlas, or data from the National Climate Data Center's Web site, to gather temperature information for different regions. This Web site provides point-and-click access to data and graphs for station locations across the country and even future model predictions for the entire continental U.S. An analysis of the data and graphs may promote questions about why the western desert regions exist (in part because they lie on the **lee side of mountains**). The key element is to consider why a dry desert has a higher temperature than a wetter land area. This analysis can be directly related to the aquarium tank experiments in Part 2.

The Tropical Rainfall Measuring Mission (TRMM) represents a significant advance in our ability to observe rainfall on a global scale. Even though TRMM's orbit covers only the latitudes between 35 degrees north and 35 degrees south, this is the region where most of the Earth's total precipitation occurs anyway. Although TRMM has limitations in sampling rainfall, it uses a variety of sensors that collect data over large areas. This provides a potential advantage for better global modeling of rainfall data than we have ever had before. By measuring not only how much rain occurs over both oceans and land, but also acquiring information on the vertical distribution of where the rain is forming, TRMM allows atmospheric scientists to determine whether latent heating is **stabilizing** or **destablizing the atmosphere.** Such information is very important as input for weather prediction models and global climate models.

EXTENSION

Can you show a correlation between warm temperatures and precipitation, by using either different years or different months in a single region? Can this relationship be extended into a forecast of future conditions? The National Climate Data Center has the advantage in that teachers may use actual data to discover correlations that are quantitative. This Web site may be used in other weather-related units as well.

APPENDIX A

Bibliography/Resources

The energy balance:

Kump, L., Kasting, J.F., and Crane, R.G. 1999. *The Earth System.* Prentice Hall: Upper Saddle River, New Jersey. (Chapter 3—"Global Energy Balance" contains an excellent description of the energy balance and includes a number of additional experimental or illustrative designs and models.)

The energy balance and the atmosphere/ocean circulation tied to the hydrologic cycle:

Henderson-Sellers, A., and Robinson, P.J. 1986. *Contemporary Climatology.* London: Longman Scientific and Technical, J. Wiley and Sons: New York. (A general reference for the topics of climate and the hydrologic cycle.)

Berner, E.K., and Berner, R.A. 1996. *Global Environment: Water, Air and Geochemical Cycles.* Prentice Hall: Upper Saddle River, New Jersey. (Chapter 1—"Introduction to the Global Environment: The Water Cycle and Atmospheric and Oceanic Circulation" ties the energy balance to the nature of the water cycle.)

White, I.D., Mottershead, D.N., and Harrison, S.J. 1989. *Environmental Systems.* Unwin Hyman, Ltd.: London, U.K. (Part III—"Global Systems" provides an overview linking energy and mass transfer and the water balance at the surface.)

Holland, H.D. and Petersen, U. 1995. *Living Dangerously: The Earth, Its Resources and the Environment.* Princeton University Press: Princeton, New Jersey. (Chapter 4—"The Hydrologic Cycle" provides a large-scale overview on the subject.)

Introductions to hydrologic sciences:

Bras, R.L. 1989. Hydrology: *Introduction to Hydrologic Science.* Addison-Wesley: Reading, Maine.

Viewsman, W., Lewis, G.L., and Knapp, S.W. 1989. *Introduction to Hydrology.* Harper and Row: New York.

The role of land surface character in governing the energy balance and water fluxes:

Dickinson, R.E. *Land surface processes and climate—surface albedos and energy balance.* In "Advances in Geophysics" V. 25. Academic Press, pp. 305-353. (Detailed.)

Journals:

AMS Newsletter, published by the American Meterological Society

The Earth Scientist, published by the National Earth Science Teachers Association

Geotimes, published by the American Geological Institute

GSA Today, published by the Geological Society of America

Journal of Geography, published by the National Council for Geographic Education

Journal of Geoscience Education, published by the National Association of Geoscience Teachers

Nature, Macmillan Publishers

Science, published by the American Association for the Advancement of Science

Scientific American

Weatherwise, Heldref Publications

Web Sites:

CERES: Clouds and the Earth's Radiant Energy System: ***http://asd-www.larc.nasa.gov/ceres/ASDceres.html***

The Earth's Global Energy Balance: ***http://www.iupui.edu/~geogdept/g107/martin/chap2p1.htm***

Earth's Radiation Budget Facts: ***http://eosweb.larc.nasa.gov/EDDOCS/radiation_facts.html***

For Kids Only: ***http://kids.earth.nasa.gov***

Global Climate Animations: ***http://geography.uoregon.edu/envchange/clim_animations/index.html***

Gulf of Maine Aquarium: ***http://octopus.gma.irg/surfing/weather/index.html***

NASA's Earth Observatory: ***http://earthobservatory.nasa.gov/Newsroom***

NASA Facts: Earth's Energy Balance: ***http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/terra/earths_energy_balance.htm***

National Climate Data Center: ***http://www.ncdc.nasa.gov/oa/ncdc.html***

NOAA Research: ***http://oar.noaa.gov/Education***

NWS Web Pages: ***http://www.nws.noaa.gov***
http://www.nws.noaa.gov/om

Ocean World: ***http://oceanworld.tamu.edu***

Radiation and Energy: ***http://itg1.meteor.wisc.edu/wxwise/museum/a2main.html***

What Is the Earth's Radiation Budget: ***http://eosweb.larc.nasa.gov/education/whatis.html***

APPENDIX B

Answer Keys

PART 1

Key Conclusion

The different albedos associated with human-made and natural surfaces affect how much solar energy is absorbed, and thus the surface temperature.

PART 2

Key Conclusion

The phase change of water is a very effective mechanism for transferring and storing energy in the atmosphere.

PART 3

Question 1

Pittsburgh exhibits a large difference in temperature in comparison with the surrounding countryside, while Phoenix does not. This should be used to promote a discussion about why this difference exists. Are the albedos of Pittsburgh and the countryside likely to be very different? How about Phoenix and the surrounding arid lands? What about moisture? Concrete and asphalt cannot retain moisture (rain runs off quickly, and the surface dries quickly); as a result, is there a moisture difference between Phoenix and the desert that surrounds it? Students should discuss other factors that might control temperatures (e.g., are all of the stations at the same elevation?) and which of those factors might impact their interpretations.

Key Conclusion

The nature of the surface, particularly the surface albedo and whether the ground is moist or dry, has an observable impact on the energy balance at the surface, and hence the temperature.

Question 2

Key Conclusion

Surface moisture and evaporation are of major importance in governing surface temperature.

APPENDIX C

National Education Standards

SCIENCE

Content Standard: K–12

Unifying Concepts and Processes

Standard: As a result of activities in grades K–12, all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement

Content Standards: 9–12

Science as Inquiry

Content Standard A: As a result of activities in grades 9–12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science

Content Standard B: As a result of activities in grades 9–12, all students should develop an understanding of:

- Interactions of energy and matter

Earth and Space Science

Content Standard D: As a result of activities in grades 9–12, all students should develop an understanding of:

- Energy in the Earth's system

Science and Technology

Content Standard E: As a result of activities in grades 9–12, all students should develop:

- Understandings about science and technology

Science in Personal and Social Perspectives

Content Standard F: As a result of activities in grades 9–12, all students should develop an understanding of:

- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

*National Research Council. 1996. **National Science Education Standards** p. 115, 143–171. Washington, DC: National Academy Press.*

MATH

Curriculum Standards for Grades 9–12

Standard 1: Mathematics as Problem Solving

Standard 2: Mathematics as Communication

Standard 3: Mathematics as Reasoning

Standard 4: Mathematical Connections

Standard 10: Statistics

*National Council of Teachers of Mathematics. 1989. **Curriculum and Evaluation Standards for School Mathematics** p. 63–119. Reston, VA: The National Council of Teachers of Mathematics, Inc.*

GEOGRAPHY

National Geography Standards for Grades 9–12

The World in Spatial Terms

Standard 1: How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.

Places and Regions

Standard 4: The physical and human characteristics of places.

Standard 5: That people create regions to interpret Earth's complexity.

Physical Systems

Standard 7: The physical processes that shape the patterns of Earth's surface.

Standard 8: The characteristics and spatial distribution of ecosystems on Earth's surface.

Human Systems

Standard 9: The characteristics, distribution, and migration of human populations on Earth's surface.

Standard 12: The process, patterns, and functions of human settlement.

Environment and Society

Standard 14: How human actions modify the physical environment.

*American Geographical Society, Association of American Geographers, National Council for Geographic Education, and National Geographic Society. 1994. **Geography for Life: National Geography Standards** p. 143–182. Washington, DC: National Geographic Research and Exploration.*

ENGLISH LANGUAGE ARTS

Standard 1: Students read a wide range of print and nonprint texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.

Standard 3: Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics).

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Council of Teachers of English and International Reading Association. 1996. ***Standards for the English Language Arts*** *p. 24–46. Urbana, Illinois and Newark, Delaware: National Council of Teachers of English and International Reading Association.*

SOCIAL STUDIES

Strand 3: *People, Places, and Environments.* Social Studies programs should include experiences that provide for the study of people, places, and environments.

Strand 8: *Science, Technology, and Society.* Social Studies programs should include experiences that provide for the study of relationships among science, technology, and society.

National Council for the Social Studies. 1994. ***Expectations of Excellence: Curriculum Standards for the Social Studies*** *p. 19–30. Washington, DC: National Council for the Social Studies.*

Problem-Based Learning

What is Problem-Based Learning?

The Problem-Based Learning (PBL) model of teaching is a lot like it sounds; students learn by solving a problem. While this occurs in all classrooms to a different extent, the PBL learning model causes a drastic shift in the roles of students and teachers. In traditional teaching methods, the teacher acts as director of student learning, which is commonly passive. With PBL, these roles shift. Students become active and responsible for their own learning, and the activity is student-centered; the teacher becomes more of a facilitator or guide, monitoring student progress.

By using this model, the students gain information through a series of self-directed activities in which the students need to solve a problem. These problems drive the learning process and are designed to help students develop the skills necessary for critical thinking and problem solving. Students learn that in the real world, problems, and their solutions, are not always cut and dried, and that there may be different possible answers to the same problem. They also learn that as they continue to gain information, they need to readjust their plan. In other words, they must perform self-assessment.

A PBL lesson starts with a problem posed directly to the students. These problems are poorly structured to reflect real-world situations. Students (most commonly in small, cooperative groups) are then left to determine what steps need to be taken in order to solve the problem. The teacher does not give the students the information needed prior to the activity. However, the teacher does need to make sure the students have enough prior knowledge to be able to interpret the problem and determine a plan of action.

A key component of PBL is constant feedback. While the students are constantly assessing their work, and in turn adjusting their plan, teachers also need to provide continual, immediate feedback. Without feedback, students may be uncomfortable with this type of activity, because they do not know what is expected of them. Teacher feedback provides reinforcement for student learning. Feedback should be an authentic, performance-based assessment. Students need to continually evaluate their contributions. Rubrics provide a good guide for both teachers and students, to ensure that the students are continually kept on the right track.

Why use PBL?

Traditional teaching methods focus on providing students with information and knowledge. The PBL model also adds "real-world" problem-solving skills to the classroom. It teaches students that there is sometimes more than one possible answer, and that they have to learn how to decide between/among these answers.

Students and PBL

Students are broken up into groups and are presented with a poorly structured, complex problem. Students should have enough background knowledge to understand the problem, but should not be experts. Any one, specific solution to the problem should not be evident. The students will need to determine what the problem is that they need to solve. Some organizational questions they may ask themselves are:

- What do we know about this problem?
- What do we need to know?
- How/where do we get the information needed to solve the problem?

The next step for the students is to determine a problem statement. From the information given to them in the problem, they should determine what they need to know and then plan a course of action to get the information they need to propose a solution. In implementing this plan, they will have to gather information to help them solve the problem. They will need to be sure that the resources they use are current, credible, accurate, and unbiased. As information is gathered and interpreted, they then apply their new knowledge, reevaluate what they know, and redetermine what they need to know to solve the problem. Once all the information is gathered, interpreted, and discussed, the group works together to propose a final solution.

Benefits of PBL

By using the Problem-Based Learning method, students gain more than just knowledge of facts. They develop critical thinking skills while working in collaborative groups to try to solve a problem. In doing this, they learn how to:

- interpret the question/problem,
- develop a problem statement,
- conduct research, reevaluating prior knowledge as new knowledge is gained,
- determine possible solutions, and
- pick the best possible solution based on the information they have gathered.

By providing immediate student feedback, the students can continually readjust their thinking, correcting any misconceptions or errors before moving on.

By using PBL, students become more familiar with "real-world" problems. They learn that there is not always only one correct answer, and that they need to work together to gather enough information to determine the best solution.

The PBL Classroom

When using the PBL model of instruction, it is best for students to work in small cooperative groups. The objective of this model is for students to work in a collaborative setting where they can learn social and ethical skills to determine how to answer the question presented. Students are expected to regulate themselves while in these working groups.

PBL Assessment

As the student groups work together to collect information, they will need to constantly assess their own progress and readjust their plan. As they do this, they will need continual, immediate feedback from the teacher. When they become more comfortable with this model, they will learn to rely less on the teacher and become more independent. By providing the students with the grading rubric, it will serve as a guide to ensure they are on the right track throughout the activity.

TRMM Introduction/Instruments

Introduction to the Tropical Rainfall Measuring Mission (TRMM)

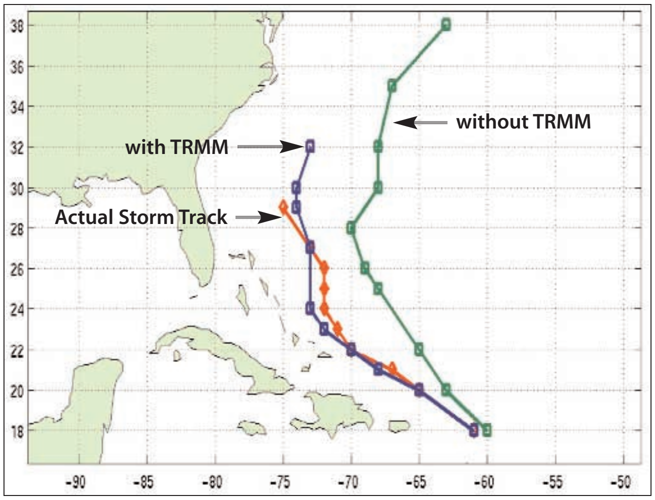
Rainfall is one of the most important weather and climate variables that determine whether mankind survives, thrives, or perishes. Water is so ubiquitous on planet Earth that we often take it for granted. Too much water results in devastating floods, and the famine caused by too little water (drought) is repsonsible for more human deaths than all other natural disasters combined. Water comprises more than 75 percent of our bodies and as much as 95 percent of some of the foods we eat.

Water is essential to life, as it nourishes our cells and removes the waste they generate. Water determines whether plants produce food, or whether they wither from drought or rot from dampness. Water is essential to our homes and factories, to our production of food, fiber, and manufactured goods, and to just about everything else we produce and consume. Although water covers more than 70 percent of the Earth's surface, only about 3 percent is fresh water—and about 75 percent of that is inaccessible because it is locked up in glaciers and icecaps.

Another important aspect of rainfall, or any other precipitation, is its role in redistributing the energy the Earth receives from the Sun. Evaporation of water from the Earth's surface, condensation of water vapor into cloud droplets or ice particles, precipitation, runoff of the precipitation, and melting of snow and ice constitute what is known as the water cycle, or the hydrological cycle. Evaporation, the process of changing water from liquid to gas form, absorbs 540 calories of energy per gram of water; while simply raising the temperature of a gram of water one degree Celsius—without changing its phase— requires only one calorie of energy. Thus, much of the Sun's energy that reaches the Earth's surface is used to evaporate water instead of raising the temperature of the surface. The resulting water vapor is carried upward by the atmosphere until it reaches a level where it is cooled to its condensation temperature. Then the water vapor releases the energy (540 calories per gram) it absorbed during the evaporation process. This "latent heat" release can occur thousands of kilometers from where the latent heat was originally absorbed.

Water plays an additional critical role in weather and climate: water vapor, it turns out, is the most abundant and most important greenhouse gas! Greenhouse gases trap some of the energy given off by the Earth's surface in the atmosphere. Therefore, the distribution and quantity of water vapor in the atmosphere are important in determining how well the Earth can emit the energy it absorbs from the Sun back into space. Unless the Earth loses as much energy as it receives, it will warm up. If the Earth loses more energy than it receives, it will cool down. The distribution of water vapor in the atmosphere also affects cloudiness; and clouds play an important role in determining how much solar energy reaches the Earth's surface, as well as how much heat can escape to space.

Perhaps it is now obvious that water, in all its forms, plays a critical role in determining what we call weather and climate. Our understanding of the complicated interactions involving water is insufficient to permit us to forecast, with much skill, weather beyond several days and climate beyond a few months. Because the occurrence of precipitation is highly variable in both time and space, and almost three-fourths of the Earth's surface has no rain gauges because it is covered by the oceans, we have never been able to adequately observe the global distribution of rain. Measurements from rain gauges on islands and satellite images of clouds have led to estimates of global precipitation. But TRMM—the first satellite to measure precipitation with the accuracy available from a radar in combination with other remote sensors—represents a breakthrough in our ability to monitor precipitation on a global scale. This is already leading to improved forecasts, as shown on the next page.



Hurricane Bonnie, August 1998:
5-Day Forecasts vs. Actual Storm Track
Improved forecasts can save money ($600K–$1M per mile of coast evacuated) and lives by more precisely predicting where the hurricane eye will be located at landfall. Source: Dr. A. Hou, NASA DAO

TRMM Instruments

TRMM Microwave Imager (TMI)

The TRMM Microwave Imager (TMI) is a passive microwave sensor that detects and images microwave radiation emitted by water droplets, ice particles, and the Earth's surface. TMI detects radiation at five different frequencies, which helps to distinguish between rainfall, bodies of water, and land. Data obtained from this instrument is used to quantify the water vapor, cloud water, and rainfall intensity in the atmosphere.

Precipitation Radar (PR)

The Precipitation Radar (PR), an **active sensor**, is the first space-based precipitation radar. PR emits radar pulses toward Earth, which are then reflected by precipitation particles back to the radar. By measuring the strength of the returned pulses, the radar is able to estimate rainfall rates. Among the three main instruments on TRMM, PR is the most innovative. Other instruments similar to TMI and the Visible and Infrared Scanner (VIRS) have operated in space before, but PR is the first radar launched into space for the purpose of measuring rainfall. Data obtained from this instrument:

- provides three-dimensional storm structures;
- helps to determine the intensity and three-dimensional distribution of rainfall over land and water, which can be used to infer the three-dimensional distribution of latent heat in the atmosphere;
- provides information on storm depth; and
- provides information on the height at which falling snow or ice particles melt into rain.

Visible Infrared Scanner (VIRS)

The Visible and Infrared Scanner (VIRS) measures radiance in five wavelength bands (from visible to infrared) emitted by clouds, water vapor, and the Earth's surface. The intensity of radiation from a cloud corresponds with the brightness or temperature of the cloud, which in turn indicates the height of the cloud—brighter (colder) clouds are higher in altitude, and darker (warmer) clouds are lower. In general, higher clouds are associated with heavier rain. By comparing VIRS observations with rainfall estimates from TMI and PR, scientists are able to better understand the relationship between cloud height and rainfall rate, and can apply this knowledge to radiation measurements made by other weather satellites.

Cloud and Earth's Radiant Energy System (CERES)

The Clouds and the Earth's Radiant Energy System (CERES) measures the amount of energy rising from the Earth's surface, atmosphere, and clouds. Clouds can have both a warming and cooling effect on the Earth, trapping energy emitted by the Earth's surface while blocking energy from the Sun. Similarly, water vapor also warms the Earth by trapping outgoing radiation, but also condenses to form clouds that sometimes have a cooling effect Data. from this instrument helps scientists learn more about how the Earth distributes the energy it receives from the Sun, as well as the effects of clouds and water vapor on the overall temperature and energy budget of the Earth. This information will help long-term climate models make more accurate predictions.

Lightning Imaging Sensor (LIS)

The Lightning Imaging Sensor (LIS) is a powerful instrument that can detect and locate cloud-to-ground, cloud-to-cloud, and intra-cloud lightning. The information gained from this instrument is used to classify cloud types and, together with other TRMM instruments, to correlate lightning flash rate with storm properties, including rainfall rate. It's also expected that the information provided from LIS will lead to future advances in lightning detection and forecasting.

APPENDIX F

Temperature Tables

PHOENIX AZ: Temperature Normals: Minimum

Seq #	Station #	Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
7	0498	Ashurst Hayden DAM													
9	0632	Bartlett DAM	39.7	42.1	45.0	51.2	59.0	67.7	74.9	73.7	68.7	58.6	47.4	40.9	55.7
17	1026	Buckeye	36.4	40.0	44.2	50.0	57.8	66.1	76.0	74.4	66.5	53.8	42.8	36.5	53.7
21	1306	Casa Grande	36.2	39.2	43.6	49.3	57.9	66.7	75.9	73.7	66.6	54.1	42.7	36.5	53.5
22	1314	Casa Grande Ruins N M	33.6	36.2	39.7	45.7	54.5	63.8	74.1	72.0	65.2	52.5	40.5	34.1	51.0
23	1353	Castle Hot Springs	39.5	42.4	45.2	50.9	58.7	68.0	75.5	73.4	68.1	58.1	47.0	40.4	55.6
24	1514	Chandler Heights	38.1	41.5	45.4	50.9	59.3	68.3	75.6	73.5	67.8	56.3	45.4	38.8	55.1
31	2109	Cordes	32.2	34.1	36.4	41.4	48.4	57.3	65.5	64.1	57.9	48.6	38.7	32.7	46.4
33	2329	Crown King	24.4	25.6	29.0	34.4	41.3	51.8	57.2	55.3	48.9	40.0	31.5	25.2	38.7
34	2462	Deer Valley	37.9	41.2	44.7	50.6	59.1	67.9	76.8	75.1	68.6	56.2	44.8	38.5	55.1
37	2807	Eloy 4 NE	37.0	40.5	45.5	51.3	59.2	67.8	75.1	73.4	67.0	55.7	44.6	37.6	54.6
39	3027	Florence	36.3	39.1	42.2	48.3	56.4	65.2	74.7	73.1	66.8	54.9	43.3	37.1	53.1
42	3393	Gila Bend	39.5	42.6	47.2	53.1	61.2	69.8	79.3	77.9	70.9	58.7	47.4	40.3	57.3
45	3702	Griggs 3 W													
49	4182	Horseshoe DAM													
59	4829	Laveen 3 SSE	37.7	41.2	44.9	51.4	59.6	69.0	77.3	75.1	68.2	56.0	44.7	38.1	55.3
61	4977	Litchfield Park	35.8	39.5	43.5	49.8	57.8	66.7	75.4	73.6	66.2	53.6	42.8	36.3	53.4
63	5270	Maricopa 4 N	33.6	37.3	42.0	47.9	56.4	66.0	75.9	73.5	65.5	52.4	40.4	33.8	52.1
66	5467	Mesa Experiment Farm	39.5	42.9	47.1	52.6	59.8	68.4	76.9	75.6	69.0	57.7	46.8	40.1	56.4
67	5512	Miami	32.1	34.9	39.4	46.3	54.7	63.7	70.0	67.7	61.9	50.9	39.8	33.0	49.5
69	5700	Mormon Flat	41.9	43.5	46.5	52.8	61.8	71.0	77.8	75.7	70.8	60.9	49.5	42.4	57.9
80	6481	Phoenix WSFO AP	41.2	44.7	48.8	55.3	63.9	72.9	81.0	79.2	72.8	60.8	48.9	41.8	59.3
86	6840	Punkin Center	29.1	32.1	36.5	41.7	51.2	59.1	69.8	67.6	58.7	46.5	35.1	28.2	46.3
88	7281	Roosevelt 1 WNW	36.9	39.7	44.0	50.9	59.9	68.9	74.6	72.6	67.3	56.6	45.5	38.1	54.6
91	7370	Sacaton	33.9	37.6	41.9	47.6	55.7	65.5	75.2	72.9	65.5	53.3	41.2	33.9	52.0
102	8112	South Phoenix	37.4	40.4	43.9	48.9	56.0	64.2	73.4	72.1	65.2	54.2	43.9	38.1	53.1
104	8214	Stewart Mountain	36.5	38.8	42.5	48.9	57.4	66.2	74.5	72.3	66.1	53.9	42.6	36.9	53.1
105	8273	Sunflower 3 NNW													
106	8348	Superior	42.0	44.8	47.5	53.5	61.5	71.3	75.4	73.8	70.2	61.3	50.9	43.6	58.0
107	8499	Tempe A S U	37.8	40.4	44.5	49.5	56.7	64.7	74.4	73.0	66.2	55.1	44.3	38.0	53.7
108	8598	Tolleson 1 E													
133	9634	Youngtown	38.2	41.6	45.5	51.5	59.8	68.6	77.0	74.9	67.8	56.2	45.0	38.3	55.4

PITTSBURGH PA: Temperature Normals: Minimum

Seq #	Station #	Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
1	0022	Acmetonia Lock 3													
4	0355	Bakerstown 3 WNW	16.6	18.6	27.8	37.3	46.8	55.0	60.0	58.3	51.7	40.5	32.5	22.7	39.0
7	0475	Beaver Falls 1 NE													
12	0861	Braddock Lock 2													
17	1033	Bruceton 1 S													
19	1105	Burgettstown 2 W	13.6	14.8	24.8	33.3	42.2	51.3	55.9	54.7	48.1	36.4	30.0	21.0	35.5
23	1377	Charleroi Lock 4													
33	1773	Coraopolis Neville IS													
41	2190	Donora 1 SW	19.7	21.8	30.6	38.8	48.6	57.3	61.6	60.9	54.7	42.9	34.9	25.2	41.4
48	2942	Ford City 4 S DAM	15.0	16.0	25.8	35.2	44.0	53.2	58.0	56.7	50.0	38.1	31.3	21.8	37.1
55	3343	Glenwillard Dash DAM													
74	4611	Kittanning Lock 7													
97	5902	Montgomery L and D	19.6	21.5	29.8	38.3	47.6	56.5	61.0	60.1	54.1	42.8	35.0	25.2	41.0
100	6151	Natrona Lock 4													
102	6233	New Castle 1 N	15.0	15.1	24.0	33.3	44.4	53.3	58.0	56.4	50.1	37.9	30.7	21.9	36.7
105	6310	New Stanton 1 SW													
115	6993	Pittsburgh WSCMO2 AP	18.5	20.3	29.8	38.8	48.4	56.9	61.6	60.2	53.5	42.3	34.1	24.4	40.7
117	7229	Putneyville 2 SE DAM	13.6	14.5	24.2	33.7	43.2	52.0	56.6	55.3	48.7	37.7	30.6	20.5	35.9
123	7782	Salina 3 W	14.6	15.4	25.3	33.8	44.7	53.3	58.1	56.9	49.8	38.7	30.8	21.8	36.9
125	7863	Schenley Lock 5													
130	8184	Slippery Rock 1 SSW	13.6	14.3	23.8	32.5	42.9	51.2	55.5	54.0	47.6	37.0	29.7	20.2	35.2
153	9655	Whitesburg													

APPENDIX G

Glossary

active sensor (active system)—A remote-sensing system (e.g., an instrument) that transmits its own radiation to detect an object or area for observation and receives the reflected or transmitted radiation. Radar is an example of an active system. [1] Compare with passive sensor.

albedo—The ratio of the amount of radiation reflected from an object's surface compared to the amount that strikes it. This varies according to the texture, color, and expanse of the object's surface and is reported in percentage. Surfaces with high albedo include sand and snow, while low albedo rates include forests and freshly turned earth. [2]

climate—The average weather conditions in an area determined over a period of years. [1]

convection—The rising of warm air and the sinking of cool air. Heat mixes and moves air. When a layer of air receives enough heat from the Earth's surface, it expands and moves upward. Colder, heavier air flows under it which is then warmed, expands, and rises. The warm rising air cools as it reaches higher, cooler regions of the atmosphere and begins to sink. Convection causes local breezes, winds, and thunderstorms. [3]

convective storm—A storm caused by convection. [3]

Earth's energy budget (radiant budget)—A measure of all the inputs and outputs of radiative energy to and from the Earth's system. [1]

evaporation—Change from a liquid (more dense) to a vapor or gas (less dense) form. When water is heated it becomes a vapor that increases humidity. Evaporation is the opposite of condensation. [1]

greenhouse gases—A gaseous component of the atmosphere contributing to the greenhouse effect. Greenhouse gases are transparent to certain wavelengths of the sun's radiant energy, allowing them to penetrate deep into the atmosphere or all the way into the Earth's surface. Greenhouse gases and clouds prevent some of the Earth's infrared radiation from escaping, trapping the heat near the Earth's surface where it warms the lower atmosphere. Altering this natural barrier of atmospheric gases can raise or lower the mean global temperature of the Earth. Greenhouse gases include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs), and water vapor. Carbon dioxide, methane, and nitrous oxide have significant natural and human sources while only industries produce chlorofluorocarbons. Water vapor has the largest greenhouse effect, but its concentration in the troposphere is determined within the climate system. Water vapor will increase in response to global warming, which in turn may enhance global warming. [1]

hurricane—Severe tropical storms whose winds exceed 74 mph. Hurricanes originate over the tropical and subtropical North Atlantic and North Pacific oceans, where there is high humidity and light wind. These conditions prevail mostly in the summer and early fall. Since hurricanes can take days and even weeks to form, time is usually available for preventative or protective measures. [1]

latent heat/latent heat transfer—The amount of heat given up or absorbed when a substance changes from one state to another, such as from a liquid to a solid. [4]

latitude/longitude—Latitude is the location north or south in reference to the equator, designated at zero (0) degrees—and represented by parallel lines that circle the globe both north and south of the equator. The poles are at 90° north and south latitude. Longitude is the location east or west in reference to the Prime Meridian, which is designated as zero (0) degrees longitude. The distance between lines of longitude are greater at the equator and smaller at the higher latitudes, intersecting at the Earth's North and South Poles. Time zones are correlated to longitude. [2]

lee side—The side of an object or obstacle, such as a ship's sail, a mountain, or a hill, furthest away from the wind, and therefore, protected from the direct force of the wind. The opposite of windward. [2]

passive sensor (passive system)—A system or instrument that uses only radiation emitted by the object being viewed, or reflected by the object from a source other than the system or instrument. [1] Compare with active sensor.

radiate/radiation—The process of giving off light, heat, or other radiant energy. [5]

scientific method—The scientific method is the way scientists get from asking a question to finding an answer. The general steps involved are:

- Defining the problem
- Stating a hypothesis
- Making observations
- Collecting data
- Analyzing data, making graphs
- Drawing conclusions based on the data
- Reflecting on your conclusions and determining what you would do differently next time. [6]

stabilization/destabilization of the atmosphere—Stabilization/stability occurs when a rising air parcel becomes denser than the surrounding air. It will then return to its original position. When the density of the air parcel remains the same as the surrounding air after being lifted, it is also considered stable, since it does not have the tendency to rise or sink further. Destabilization/instability is the state of equilibrium in which a parcel of air when displaced has a tendency to move further away from its original position. It is the condition of the atmosphere when spontaneous convection and severe weather can occur. Air parcels, when displaced vertically, will accelerate upward, often forming cumulus clouds and possibly thunderstorms. [2]

sublimation—The process whereby ice changes directly into water vapor without melting. [7]

transpiration—The process by which water in plants is transferred as water vapor to the atmosphere. [7]

urban heat island effect—The increased air temperatures in urban areas as contrasted to the cooler surroundings of rural areas. [7]

water cycle/hydrological cycle—The processes that cycle water through the Earth system. These include:

- Evaporation, changing from a liquid to a gas
- Condensation, changing from a gas to a liquid
- Sublimation, changing from a solid to a gas
- Precipitation, water molecules condensing to form drops heavy enough to fall to the Earth's surface
- Transpiration, moisture carried through plants from roots to leaves, where it changes to vapor and is released to the atmosphere
- Surface runoff, water flowing over land from higher to lower ground
- Infiltration, water filling the porous spaces of soil
- Percolation, groundwater moving in the saturated zone below the Earth's surface.

At ***http://watercycle.gsfc.nasa.gov*** you can download a water cycle movie. [9]

[1] *Looking at Earth From Space: Glossary of Terms,* 1993, NASA EP-302

[2] The Weather Channel Home Page: ***http://www.weather.com/glossary***

[3] The Earth Observatory Glossary: ***http://earthobservatory.nasa.gov/Library/glossary.php3***

[4] USGS Water Basics Glossary: ***http://sr6capp.er.usgs.gov/GIP/h2o_gloss***

[5] USGS Glossary: ***http://interactive2.usgs.gov/glossary***

[6] National Center for Ecological Analysis and Synthesis: ***http://www.nceas.ucsb.edu/fmt/doc?/frames.html***

[7] Ahrens, C. Donald. 1994. *Meteorology Today.* St. Paul, MN: West Publishing Company

[8] NASA Goddard Space Flight Center, Laboratory for Hydrospheric Processes: ***http://watercycle.gsfc.nasa.gov***

[9] University Corporation for Atmospheric Research, Introduction to the Atmosphere: Background, ***http://www.ucar.edu/learn/1_1_2_4t.htm***