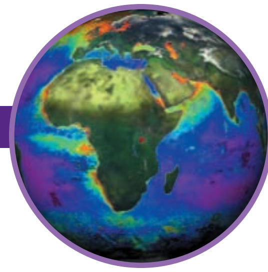
Educational Product	
Educators	Grades 5–8



Investigating the Climate System

WEATHER

Global Awareness Tour

PROBLEM-BASED CLASSROOM MODULES

Responding to National Education Standards in:

English Language Arts ◆ Geography ◆ Mathematics
Science ◆ Social Studies

Investigating the Climate System

WEATHER

Global Awareness Tour

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Give us your feedback:
To provide feedback on the modules online, go to:
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

WEATHER

Global Awareness Tour

GRADE LEVELS

Grades 5–8

TIME REQUIRED

Three+ periods, depending on whether done individually or by groups

OBJECTIVES

Through the scenario of planning concert locations for a "Global Awareness Tour" by the students' favorite musical group, the students will:

- Research, interpret, and be able to explain general characteristics of weather in tropical regions.
- Observe and compare tropical and mid-latitude weather patterns.
- Utilize TRMM observations of storms, droughts, floods, lightning, and other "extreme weather" situations.
- Develop Internet research skills.
- Enhance communication and presentation skills.

DISCIPLINES ENCOMPASSED

Earth science, physics, math, social studies, English/ language arts, technology

KEY TERMS & CONCEPTS

active TRMM sensor
air mass
anticyclone (high-pressure system)
cold front
complex (occluded) front
cyclone (low-pressure system)
Doppler radar
GOES satellite
latitude and longitude
passive TRMM sensor
radar
stationary front
TRMM instruments:
- Precipitation Radar (PR)
- TRMM Microwave Imager (TMI)
- Visible and Infrared Scanner (VIRS)

TRMM satellite
warm front

SUGGESTED READING/RESOURCES

basic Earth science textbook or review book

printed or online encyclopedia

The American Meteorological Society DataStream Project: ***http://www.ametsoc.org/dstreme***

GOES: ***http://www.ngdc.noaa.gov/stp/GOES/goes.html*** and ***http://www.sec.noaa.gov***

GPCP: ***http://precip.gsfc.nasa.gov***

National Climatic Data Center: ***http://www.ncdc.noaa.gov***

NOAA: ***http://www.noaa.gov***

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

Riverdeep: ***http://www.riverdeep.com***

TOPEX/Poseidon: ***http://topex-www.jpl.nasa.gov***

TRMM: ***http://trmm.gsfc.nasa.gov***

Tropical Prediction Center (formerly the National Hurricane Center): ***http://www.nhc.noaa.gov***

USA Today Weather Page: ***http://www.usatoday.com/weather.htm***

World Meteorological Organization: ***http://www.wmo.ch***

BACKGROUND INFORMATION

Investigating the Climate System: Weather is an activity designed to be used at the end of a unit on weather. Students are expected to understand the topics listed below before completing this activity:

- Weather variables such as temperature, pressure, precipitation, clouds, winds, and lightning.
- Mid-latitude weather patterns such as **air masses,** fronts, and pressure systems.
- Basic geography, including map reading and **latitude** and **longitude**.
- Geographical influences on weather patterns.
- The **TRMM satellite instruments,** and how they are used to observe surface and atmospheric conditions, information available in Appendix E.

GLOBAL AWARENESS TOUR

Plan a Concert Tour for your favorite music group!

MATERIALS

Most of this activity is based on the TRMM and other Internet sites.

World maps for each team and push pins/flags for each team's map

Post-it notes or index cards

INTRODUCTION

Congratulations! Your favorite music group is making an around-the-world "GLOBAL AWARENESS TOUR" and you have been selected to be the Event Manager!

The group has been chosen to perform a series of concerts in cities around the world to focus attention on such natural environmental hazards as:

- drought
- flooding
- wind and dust storms
- hurricanes
- lightning
- and, on a lighter note, wonderful daily weather.

You get to pick where the group will play, based on these guidelines:

- Use TRMM and other sources to select locations in the United States and elsewhere in the world where each of these conditions can be found.
- You need to give a reason why you selected each location.
- Thanks to the new technology invented by your group's road manager, you can even select examples that have already occurred and are saved in the TRMM Web site resources.
- If you are working with a group or in a class, you can select one or two of these guidelines and share your findings with other groups.

Ready to begin?

DAILY WEATHER

What causes the weather?

"What's the weather going to be?" Isn't this one of the most often-asked questions? Think of all the ways in which weather affects your daily activities. For most of us, all we want to know is, "Will it be hot or cold, wet or dry?" If you listen to television or radio weather reports, that's what you hear. Will you be able to get in your soccer game or practice? Will school be closed by a heavy snowfall? Is it a good day to go swimming? These and many other things that you do depend on the weather.

So what do we mean by "weather"? How do we measure and predict weather? Is weather the same in the tropics as in the mid-latitudes, where most of this country's population lives? These are some of the questions you'll have to answer in selecting the cities for your tour.

You may already know that here in the mid-latitudes, most of our weather results from the collision of differing air masses. Most of our storms form where warmer and cooler air masses collide. Such a boundary is called a **warm front** if warmer air is displacing cooler air, a **cold front** if cooler air is displacing warmer air, a **stationary front** if the differing air masses are not moving, and a **complex (occluded) front** if the differing air masses have become mixed with each other. **Anticyclones (high-pressure systems)** generally bring us fair weather while **cyclones (low-pressure systems)** are associated with stormy weather.

The National Weather Service (NWS)—at ***http://www.nws.noaa.gov***—is the government agency responsible for collecting official weather observations and issuing predictions. The NWS operates an extensive network of instruments stationed at airports and other land locations, on buoys in lakes and at sea, and carried upward by weather balloons, as well as **Doppler radar** and weather satellites. Most television, radio, and newspaper weather information originates from the NWS, even though many media outlets have their own meteorologists on staff.

Action Item DW1

For you to begin your research, you must first learn how to find, interpret, and describe weather data. To begin, find the current weather for your location (or a nearby location). Record the information below, being sure to include the source of your information. What does this information tell you? What images are provided? Do they help you to interpret the data? Why or why not? Describe what you see. Provide references.

WEATHER VARIABLE	CURRENT VALUE	SOURCE OF INFORMATION/IMAGES
Temperature		
Air pressure		
Wind direction		
Wind speed		
Sky cover		
Relative humidity		
Precipitation		
Other conditions		

Action Item DW2

Select some locations around the world where you might schedule your "Global Awareness Tour" and describe the present weather in those areas. (As a guide to what to look for, use the weather variable list from Action Item DW1.) Write this information on a "post-it" note or index card, then place it on the world map with a push pin or flag. What is the source of your information? What did you find out? Why did you select these locations?

Now it's time to choose some potential sites for your "Global Awareness Tour." For the start of the concert tour, you might want to choose locations that have great weather.

Action Item DW3 Using the knowledge you have gained in your research and information from the NASA TRMM satellite, identify three possible locations that would have the fine weather conditions you'd like for your concert. Be sure to provide supporting information for your selection.

LOCATION	REASON IT WOULD BE GOOD FOR THE TOUR

EXTENSION ACTIVITIES

1. Learn more about how satellites detect processes and events on our planet using ***http://www.noaa.gov/satellites.html.*** Compare and contrast polar-orbiting and geostationary satellites.
2. Compare TRMM data with TOPEX/Poseidon or JASON sea surface observations: ***http://topex-www.jpl.nasa.gov***
3. **"Think about ...."**
   What is one question that you thought of during this part of your "Global Awareness Tour" study that you might wish to investigate further? What resources do you need to carry out your investigation?

EXTREME WEATHER

"That's too much!" Has anyone ever said that to you? Or have you ever said that to someone else? When it comes to weather, how much is "too much?" What happens when there's too much or too little rain or snow, very strong winds, or severe conditions? How can TRMM be used to study such extreme weather events?

Remember that one of the main purposes of the "Global Awareness Tour" is to focus attention on how severe weather can have an impact on people. So this is your opportunity to find locations that will demonstrate fascinating aspects of our global environment.

Action item EW1 In trying to learn as much as you can about world weather patterns, a local meteorologist has provided you with some limited guidance. You have been told that data obtained from the TRMM satellite will be very helpful for your research. However, this is all you've been told. You'll need to learn more about this satellite, the type of information it provides, and why it is especially useful to you. The only guidance you've received on this satellite is its name. Where do you go to get information on the satellite? What have you found? Why is this satellite different from others? Remember, you were selected to organize this concert because of your reputation for detail.

Computers have been able to put together millions of TRMM observations into one map that shows precipitation over the first five-year period of this satellite's operation. Make sure you include this map in your research: ***http://trmm.gsfc.nasa.gov/images/5-year_TRMM_climo.gif***

Often, extreme weather events in distant parts of the world are related to each other. TRMM can help identify these connections. For example, did you know that flooding in South America and drought in Indonesia and Northern Australia almost always occur when there is an El Niño? You can read more about these connections at: ***http://trmm.gsfc.nasa.gov/overview_dir/variability_el_nino.html***

Drought can occur for several reasons. In some places, global climatic conditions cause permanent drought. One such example would be over the Sahara Desert in North Africa. Do the TRMM climatology images show this? Where else would you find such long-term drought conditions? In other locations, droughts may exist for shorter periods. What parts of the world are experiencing drought now? What might be causing these conditions?

Other important connections you might want to know about, so you can help others know more through the "Global Awareness Tour," are the well-established ones between extreme weather and certain diseases: ***http://trmm.gsfc.nasa.gov/overview_dir/climate_disease.html***

Action Item EW2 Use your TRMM satellite research and other sources to identify parts of the world that now or in the recent past have experienced:

- FLOODING
- DROUGHTS

Then, use the chart on this page to list your location selection for each of the listed categories, the reasons you selected those locations, and your supporting references.

	LOCATION	REASON FOR SELECTION	REFERENCES
FLOODING now			
FLOODING in the recent past			
DROUGHT now			
DROUGHT in the recent past			

Do any of the areas you identified seem to have flooding or drought during particular times of the year? What might explain these patterns? Are there any extreme events like this taking place now? If so, where? How do you know?

Action Item EW3

Use the information you gathered for the chart on p. 6 to identify one location in the United States and one location elsewhere in the world where flooding is taking place now. Be sure to include the source of your data. On another sheet of paper, write a summary of your observations and conclusions, using the knowledge you have gained from your research.

FLOODING

U.S. LOCATION	SOURCE
WORLD LOCATION	**SOURCE**

EXTENSION ACTIVITIES

1. How likely is flooding where you live? Try to determine what weather or climate conditions can cause this natural hazard.
2. How prepared are you for a flood? Design a safety campaign to help your family, schoolmates, and community get ready in case of a flood in your area.
   http://www.redcross.org/disaster/safety/floods.html
   http://www.nws.noaa.gov/om/brochures/ffbro.htm

Action Item EW4

Use the information you gathered for the chart on p. 6 to identify one location in the United States and one location elsewhere in the world where drought is taking place now. Be sure to include the source of your data. On another sheet of paper, write a summary of your observations and conclusions, using the knowledge you have gained from your research.

DROUGHT

U.S. LOCATION	SOURCE
WORLD LOCATION	**SOURCE**

EXTENSION ACTIVITY

Some of the locations where drought occurs are near the ocean. Can you find out why there is so little rainfall despite this proximity to water? Can the salty water be used as a source of freshwater for people in the drought-stricken areas? What are the constraints that limit such use?

Action Item EW5 Applying the same process you used for drought and floods, now research:

- WIND & DUST STORMS
- HURRICANES/TYPHOONS
- LIGHTNING

Based on that research, identify parts of the world that now or in the recent past have experienced wind and dust storms, now or in the recent past have had hurricanes/typhoons, and now or in the recent past have been affected by severe lightning. Then, use the chart below to list your location selection for each of the listed categories, the reasons you selected those locations, and your supporting references.

	LOCATION	REASON FOR SELECTION	REFERENCES
WIND & DUST STORMS now			
WIND & DUST STORMS in the recent past			
HURRICANES/ TYPHOONS now			
HURRICANES/ TYPHOONS in the recent past			
LIGHTNING now			
LIGHTNING in the recent past			

Do any of the areas you identified seem to have extreme weather during particular times of the year? What might explain these patterns? Are there any extreme events like this taking place now? If so, where? How do you know?

Action Item EW6 Use the information you gathered for the chart on p. 8 to identify one location in the United States and one elsewhere in the world where wind and dust storms are taking place now. Be sure to include the source of your data. On another sheet of paper, write a summary of your observations and conclusions, using the knowledge you have gained from your research.

WIND & DUST STORMS

U.S. LOCATION	SOURCE
WORLD LOCATION	**SOURCE**

EXTENSION ACTIVITIES

1. Another satellite that provides data about global winds is NASA's QuikSCAT: ***http://winds.jpl.nasa.gov/missions/quikscat/quikindex.html.*** Write a brief comparison between what TRMM can detect and what QuikSCAT does. How well do the two sets of data support each other's accuracy?
2. Can pollution particles carried by winds and dust storms reduce the amount of precipitation? Use TRMM resources to answer this question.

Action Item EW7 Use the information you gathered for the chart on p. 8 to identify one location in the United States and one location elsewhere in the world where hurricanes or typhoons are taking place now. Be sure to include the source of your data. If no storm is taking place now, you can go into the archives to make these selections. On another sheet of paper, write a summary of your observations and conclusions, using the knowledge you have gained from your research.

HURRICANES/TYPHOONS

U.S. LOCATION	SOURCE
WORLD LOCATION	**SOURCE**

EXTENSION ACTIVITIES

1. Examine current TRMM images to determine whether there are any active storms in tropical waters. Are there any at this time? (Be sure to check both hemispheres and all oceans.) If so, are they still tropical cyclones or tropical storms, or have they grown into hurricanes?

2. Look at some of the archived TRMM images and movies from previous hurricanes. Describe some of these that you find most interesting.

There are many other Web sites where you can learn more about hurricanes and typhoons. The Tropical Prediction Center (formerly the National Hurricane Center)—***http://www.nhc.noaa.gov***—is our country's official forecast and research authority on these powerful storms. They provide useful information about current and past storms.

Another Web site for interesting information is the USA Today Weather Page: ***http://www.usatoday.com/weather.*** They offer brief, but understandable descriptions about these storms, excellent graphics, and an easy-to-use archive.

3. What are two questions about hurricanes or typhoons that you might wish to investigate further, based on the images and other data available in the TRMM and other Web pages you have used?

4. Find out how likely it is that the area in which you live will be affected by a hurricane or typhoon. Design a plan for your school, community, and family to handle the approach of a hurricane.

TRMM also carries a Lightning Image Sensor (LIS). This instrument is the first satellite-borne system to observe the global extent of lightning strikes in the tropics. The data obtained by LIS provide important new information about the electrodynamic nature of our planet, connections between lightning and precipitation, and many other discoveries. Lightning is one of the most dangerous weather phenomena in the U.S. and around the world, killing hundreds and injuring thousands each year. So the more we know, the better we can design protection techniques.

At its simplest level, lightning is caused by the buildup of an electrical charge in large, vertically developing clouds. A cloud can build up an electrical charge through the rising and falling of air currents. Raindrops, hailstones, and ice pellets collide with smaller water droplets and ice in updrafts and downdrafts. Falling streams create a negative charge that accumulates in the lower parts of clouds, while rising streams create positive charges that accumulate in the upper parts. A lightning discharge neutralizes these differences.

Action Item EW8 Use the information you gathered for the chart on p. 8 to identify one location in the United States and one location elsewhere in the world where lightning is taking place now. Be sure to include the source of your data. If no storm is taking place now, you can go into the archives to make these selections. On another sheet of paper, write a summary of your observations and conclusions, using the knowledge you have gained from your research.

LIGHTNING

U.S. LOCATION	SOURCE
WORLD LOCATION	**SOURCE**

EXTENSION ACTIVITIES

1. Examine TRMM lightning images carefully. Answer the following questions:
- What parts of the world get a lot of lightning?
- What parts get none or very little lightning?
- Are there any parts of the world where it surprises you to see that lightning commonly occurs or doesn't occur?
- Do all locations along any given latitude experience the same amount of lightning? Along any given longitude?

2. Try these two simple experiments to demonstrate how electrical charges can build up:
- Take two balloons. First, just bring them together. What happens? Then rub them briefly. What happens now when they are brought together? Explain.
- With water running in a sink in a small thin stream, run a comb through your hair several times and place the comb near the water. Describe and explain what happens.

3. Where can you learn more about the dangers of lightning and what to do about it?

The National Severe Storms Laboratory (NSSL) of the National Oceanic and Atmospheric Administration (NOAA) leads our efforts in lightning research. You can find more interesting information about lightning and thunderstorms at:

http://www.nssl.noaa.gov/edu/ltg
http://www.nssl.noaa.gov/resources
http://www.nssl.noaa.gov/researchitems/thunderstorms.shtml
http://www.nssl.noaa.gov/hazard

4. How would it feel to be struck by lightning? You can read some survivor stories at:

http://www.science.nasa.gov/newhome/headlines/essd18jun99_1.htm

THUNDER MATH EXTENSION ACTIVITY

You probably already know that you see lightning before you hear its thunder because light travels faster than sound. You may also know that you can tell how far away you are from the lightning by using a simple "rule of thumb": If you count how many seconds it takes to hear thunder after you see a lightning stroke, every five seconds equals a distance of one mile (or 1.6 kilometers). So, for example, if you see lightning and then count ten seconds before you hear the thunder, then the lightning was two miles (3.2 kilometers) away (ten divided by five.) Here's a simple math activity to understand more about this:

During a storm, six students at locations A, B, C, D, E, and F saw the lightning stroke at point L at the same moment. The scale on this map is: one centimeter equals one mile. As mentioned above, every five-second difference between when you see lightning and when you hear thunder means a distance of one mile (or 1.6 kilometers) between you and the storm. Use this information to answer the following questions.

1. Which student heard the thunder first? ________

How long after seeing the lightning?

_____________ seconds.

2. Which student heard the thunder last? ________

How long after seeing the lightning?

_____________ seconds.

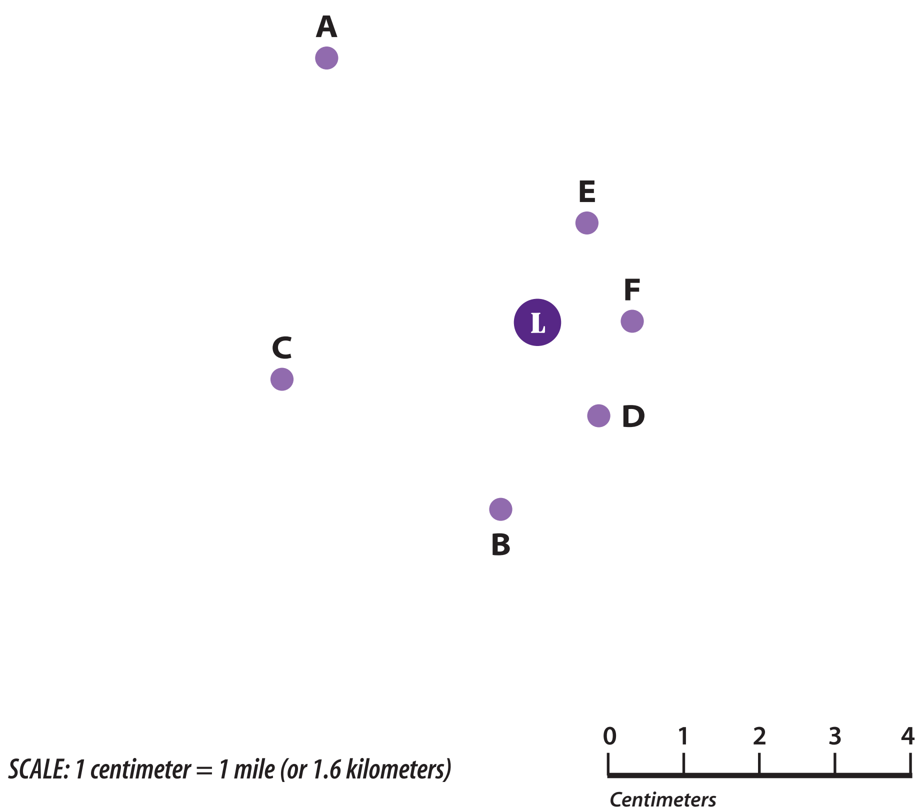
3. Which two students heard the thunder at the same time? ________ and ________ .

4. How far away from the storm was student B?

_____________ miles.

5. If the storm moved to directly above where student E is and another lightning stroke occurred, how long would it take before student C heard it?

_____________ seconds.



THIS IS IT!

It is now time to make your final decision. In the table below, summarize your choices for locations in your "Global Awareness Tour." Then plot these on your world map with push pins or flags.

TYPE OF EVENT	2 POSSIBLE LOCATIONS	TRMM /OTHER DATA THAT HELPED YOU LOCATE THEM	WHY DID YOU CHOOSE THESE SITES?
Fine weather			
Flooding			
Drought			
Wind or dust storm			
Hurricane or typhoon			
Lightning			

EXTENSION ACTIVITY: What songs would your favorite group perform at each location? Why?

APPENDIX A

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Nature, Macmillan Publishers

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

Scientific American

Weatherwise, Heldref Publications

Assessment Rubric & Answer Keys

RUBRIC: Action Items DW1–DW3 and EW1–EW8

SKILL	Extensively	Frequently	Sometimes	Rarely
Demonstrates ability to locate relevant information through appropriate Internet sites				
Collects and utilizes suitable data				
Clearly presents findings in tables and other formats				
Participates in class activities/discussions				
Makes appropriate connections between topics investigated and weather/climate standards				

ANSWER KEYS

DAILY WEATHER

Action Item DW1

- Student obtains current local weather using Internet or other sources (e.g., television, radio).
- Student records data correctly, including citation of sources.
- Student attempts to describe/interpret data and images.

Action Item DW2

- Student obtains weather from international locations using Internet or other sources (e.g., television, radio).
- Student records data correctly, including citation of sources.
- Student identified location on world map.
- Student attempts to describe/interpret data and images.

Action Item DW3

Student identifies three locations to exemplify "fine weather" and provides supporting reasons.

Extension Activities

1a. Student locates appropriate information about environmental satellites.

b. Student provides a suitable comparison/contrast of polar-orbiting and geostationary satellites. This could be done through an essay, a poster, a PowerPoint presentation, or other format.

2. Student provides a suitable comparison/contrast of TRMM and TOPEX/Poseidon or JASON satellites. This could be done through a format described above.

3. Student provides suitable answers for the "Think about...." questions.

EXTREME WEATHER

Action Item EW1

- Student accesses TRMM Web site and explores information and images available there.
- Student describes examples of what makes TRMM special for studying world weather.

Action Item EW2

- Student utilizes TRMM or other resources to identify locations experiencing flooding, currently or in the past, and cites source(s).
- Student utilizes TRMM or other resources to identify locations experiencing drought, currently or in the past, and cites source(s).
- Student identifies suitable locations for "global tour," provides appropriate reason for selection, and marks them on world map.
- Student answers questions concerning seasonal patterns with appropriate supporting data.

Action Item EW3

- Student utilizes TRMM or other resources to identify locations in the U. S. currently experiencing flooding, and cites source(s).
- Student utilizes TRMM or other resources to identify locations somewhere in the world currently experiencing flooding, and cites source(s).

Extension Activities (Flooding)

1. Student identifies likelihood of local flooding, including conditions under which it is most likely.
2. Student designs appropriate safety campaign concerning flooding. This might include presentation to a class or community group.

Action Item EW4

- Student utilizes TRMM or other resources to identify locations in the U. S. currently experiencing drought, and cites source(s).
- Student utilizes TRMM or other resources to identify locations somewhere in the world currently experiencing drought, and cites source(s).

Extension Activity (Drought)

- Student provides appropriate answer to question concerning why areas of drought may occur in proximity of oceans.
- Student describes possibilities of utilizing desalination to provide potable water, and also discusses constraints on such methods.

Action Item EW5

- Student utilizes TRMM or other resources to identify locations experiencing wind and dust storms, currently or in the past, and cites source(s).
- Student utilizes TRMM or other resources to identify locations experiencing hurricanes/typhoons, currently or in the past, and cites source(s).
- Student identifies suitable locations for "global tour," provides appropriate reason for selection, and marks them on world map.
- Student answers questions concerning seasonal patterns with appropriate supporting data.

Action Item EW6

- Student utilizes TRMM or other resources to identify locations in the U. S. currently experiencing wind and dust storms, and cites source(s).
- Student utilizes TRMM or other resources to identify locations somewhere in the world currently experiencing wind and dust storms, and cites source(s).

Extension Activities (Wind & Dust Storms)

1. Student provides suitable comparison/contrast between TRMM and QuikSCAT.
2. Student explains how pollution particles can reduce precipitation amounts, providing appropriate support from TRMM and other resources.

Action Item EW7

- Student utilizes TRMM or other resources to identify locations in the U. S. currently experiencing hurricanes/typhoons, and cites source(s).
- Student utilizes TRMM or other resources to identify locations somewhere in the world currently experiencing hurricanes/typhoons, and cites source(s).

Extension Activities (Hurricanes/Typhoons)

1. Student uses TRMM images and other resources to identify current active storms.
2. Student accesses archived TRMM images and movies, then provides description of which are of greatest interest.
3. Student identifies two suitable questions for additional investigation.

4a. Student identifies the likelihood of a hurricane/typhoon in their home area.

b. Student designs a safety plan to handle hurricane/typhoon conditions.

Action Item EW8

- Student utilizes TRMM or other resources to identify locations in the U. S. currently experiencing lightning, and cites source(s).
- Student utilizes TRMM or other resources to identify locations somewhere in the world currently experiencing lightning, and cites source(s).

Extension Activities (Lightning)

1. Student uses TRMM and other resources to answer the questions asked.
2. Student performs both experiments and answers the questions asked:

   Take two balloons. First, just bring them together. What happens? Nothing.

   Then rub them briefly. What happens now when they are brought together? They stick together. *Explain.* By rubbing the balloons, electrons are lost and therefore they attract each other.

   With water running in a sink, run a comb through your hair several times and place the comb near the water. Describe and explain what happens. The thin stream of water bends toward the comb. The comb becomes charged by running it through hair, causing the water to be attracted to it.
3. Student accesses suggested URLs and writes a suitable description of what is provided there.
4. Student accesses suggested URLs and writes a suitable "reaction" to what is provided there.

Thunder Math Extension Activity (Lightning)

1. *Which student heard the thunder first?* — F
   How long after seeing the lightning? — 4 seconds
2. *Which student heard the thunder last?* — A
   How long after seeing the lightning? — 15 seconds
3. *Which two students heard the thunder at the same time?* — E and D
4. *How far away was student B away from the storm?* — 2 miles (or 3.2 kilometers)
5. *If the storm moved to directly above where student E is and another lightning stroke occurred, how long would it take before student C heard it?* — 20 seconds

"THIS IS IT!"

- Student identifies two locations for each type of event.

APPENDIX C

National Education Standards

MATH

Curriculum Standards for Grades 5–8

Standard 1: Mathematics as Problem Solving
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 5–8

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.

Standard 3: How to analyze the spatial organization of people, places, and environments on Earth's surface.

Places and Regions

Standard 4: The physical and human characteristics of places.

Physical Systems

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

Human Systems

Standard 11: The patterns and networks of economic interdependence on Earth's surface.

Environment and Society

Standard 15: How physical systems affect human systems.

*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 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 6: Students apply knowledge of language structure, language conventions (e.g., spelling and punctuation), media techniques, figurative language, and genre to create, critique, and discuss print and nonprint texts.

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.

Strand 9: *Global Connections.* Social Studies programs should include experiences that provide for the study of global connections and interdependence.

*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.*

APPENDIX D

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)

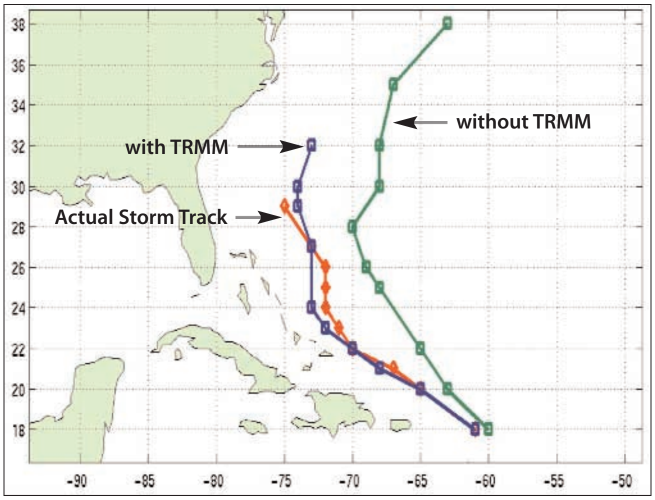
Rainfall is one of the most important weather and climate variables that determine whether mankind survives, thrives, or perishes. Water is so ubiquitous on planet Earth that we often take it for granted. Too much water results in devastating floods, and the famine caused by too little water (drought) 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.

Glossary

active TRMM sensors—A remote-sensing system 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] The TRMM Precipitation Radar (PR) is an active sensor.[2]

air masses—Large bodies of air, often hundreds or thousands of miles across, containing air of a similar temperature and humidity. Sometimes the difference between air masses are hardly noticeable, but if colliding air masses have very different temperatures and humidity values, storms can erupt.[1]

anticyclone (high pressure system)—A high pressure area where winds blow clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere.[1]

cold front—The leading edge of an advancing cold air mass that runs under and displaces the warmer air in its path. Generally, with the passage of a cold front, the temperature and humidity decrease, the pressure rises, and the wind shifts (usually from the southwest to the northwest in the northern hemisphere). Precipitation is generally at and/or behind the front, and with a fast-moving system, a squall line may develop ahead of the front.[3]

complex (occluded) front—A composite of two fronts formed as a cold front overtakes a warm front. A cold occlusion results when the coldest air is behind the cold front. The cold front undercuts the warm front and, at the Earth's surface, coldest air replaces less-cold air.[1]

cyclones (low pressure systems)—An area of low pressure where winds blow counterclockwise in the northern hemisphere and clockwise in the southern hemisphere.[1]

Doppler radar—A radar that determines the velocity of falling precipitation either toward or away from the radar unit by taking into account the Doppler shift (The change in wave frequency that occurs when the emitter or the observer is moving toward or away from the other).[4]

GOES satellite (Geostationary Operational Environmental Satellite)—NASA-developed, NOAA-operated series of satellites that:
- provide continuous day and night weather observations;
- monitor severe weather events such as hurricanes, thunderstorms, and flash floods;
- relay environmental data from surface collecting platforms to a processing center;
- perform facsimile transmissions of processed weather data to low-cost receiving stations;
- monitor the Earth's magnetic field, the energetic particle flux in the satellite's vicinity, and x-ray emissions from the Sun;
- detect distress signals from downed aircraft and ships.[1]

See also: ***http://www.oso.noaa.gov/goes*** and ***http://rsd.gsfc.nasa.gov/goes***

latitude/longitude—Latitude (aka geodetic latitude) is the angle between a perpendicular at a location, and the equitorial plane of the Earth. Longitude is the angular distance from the Greenwich meridian (0°), along the equator. This can be measured either east or west to the 180th meridian (180°) or 0° to 360° W.[1]

passive TRMM sensors—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] The TRMM Microwave Imager (TMI), Visible Infrared Radiometer (VIR), Cloud and Earth Radiant Energy Sensor (CERES), and Lightning Imaging Sensor (LIS) are all passive sensors.[2]

radar—Acronym for RAdio Detection And Ranging. An electronic instrument used to detect distant objects and measure their range by how they scatter or reflect radio energy. Precipitation and clouds are detected by measuring the strength of the electromagnetic signal reflected back.[3]

stationary front—A front which is nearly stationary or moves very little. May be known as a quasi-stationary front.[3]

TRMM instruments—See Appendix E.

TRMM satellite—Greenhouse gases and global warming continue to be one of the major environmental concerns in the U.S. and around the world. But the scientists still disagree on such big questions as: how much warming will there be? what other quantities, such as rainfall, might be affected? where will the changes occur?

To predict climate changes that might occur due to greenhouse gases, scientist use very sophisticated computer models. They try to use all the data they can possibly find to describe climate as it is today—and then they introduce changes into the models, such as the introduction of greenhouse gases, and see what happens. Before they can do this with confidence, however, they have to be sure that the models are properly describing the climate as it is today. Otherwise, the critics will ask: if the models don't even represent the current climate accurately, why should we believe predictions made with them? Why cut down on greenhouse gases if they really aren't a clear-cut problem?

The Tropical Rainfall Measuring Mission (TRMM) is a NASA satellite that's going to lend a hand by giving more information both to test and to improve the models. TRMM is particularly devoted to determining rainfall in the tropics and subtropics of the Earth. These regions make up about two thirds of the total rainfall on Earth and are responsible for driving our weather and climate system. TRMM will contribute to a better understanding of where and how much the winds blow, where the clouds form and rain occurs, where floods and droughts will occur, and how the winds drive the ocean currents. TRMM will do this not just by providing rainfall data but, more importantly, by providing information on heat released into the atmosphere as part of the process that leads to rain.

Most of the heat energy that drives the atmospheric circulation comes as the result of evaporation of water from the ocean surface. (Only about one-fourth of the energy comes directly from the Sun.) Energy from the Sun passes through the atmosphere to the ocean surface where much of it is absorbed and causes the liquid water there to become the gas we call water vapor. The amount of heat required to turn the liquid water into gas is called latent heat of evaporation. It is called latent because it is hidden away in the water vapor molecules, but can be released later on as the water vapor rises into the atmosphere and condenses back into liquid water droplets in the clouds or falls back to Earth as rain. In the tropics, huge equatorial cloud clusters and hurricanes involving lots of violent convective thunderstorms are the visible evidence of latent heat release.

By using TRMM measurements, scientists hope to better understand what the climate system is today and how the energy associated with rainfall interacts with other aspects of the global climate. [2]

warm fronts—The leading edge of an advancing warm air mass that is replacing a retreating relatively colder air mass. Generally, as a warm front passes, the temperature and humidity increase, the pressure rises, and although the wind shifts (usually from the southwest to the northwest in the northern hemisphere), it is not as pronounced as with a cold frontal passage. Precipitation, in the form of rain, snow, or drizzle, is generally found ahead of the surface front, as well as convective showers and thunderstorms. Fog is common in the cold air ahead of the front. Although fog usually clears after the front passes, some conditions may produce fog in the warm air. [3]

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

[2] NASA TRMM Home Page: ***http://trmm.gsfc.nasa.gov***

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

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