Science Lab Teacher's Guide: Exploring Precipitation and Floods

Standards

This science lab is designed for high school or advanced middle school students. It may be used to support national science education standards NS 9-12.6, personal and social perspectives. The lab will help students should develop understanding of:

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Because the lab is designed to be used nationally and not all school districts use the same lesson plan format, the lessons are formatted according to the commonly used constructivist model of learning called the ”Five Es." Each E describes a process that the students undergo rather than what the teacher does: Engage, Explore, Explain, Extend, and Evaluate. The students build their knowledge and skills from what they already know and can do. First, the students Engage in the lesson by being exposed to information that is meaningful to them and excites them to learn more. They then Explore more about the topic by participating in teacher-led and student-directed activities. The students are then asked to Explain what they have learned to solidify their new understanding of the concepts. The students then elaborate or Extend their learning by applying what they have learned to new situations, to broaden their perspective and deepen their understanding. Last, they are asked to assess their own learning and allow the teacher to Evaluate their performance.

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Background Information

Spring and early summer are typically rainy in the Midwestern United States. These warm rains that help the early season crops get started, are vital to agriculture, but in the spring of 2008, the rains were well beyond the normal amount. From Wisconsin to Kansas and across to Indiana, deluge after deluge pounded the region. All through the spring season, extreme rain events stacked up like airplanes at a busy airport and this week brought yet another cycle of heavy rains to the already waterlogged farmlands of Central Indiana. This rain pattern, driven by an area of low pressure over the Central Plains combined with high pressure anchored off the

Southeast coast of the U.S. to channel moisture up from the Gulf of Mexico into the mid-section of the country.

On the night of June 6, 2008, an intense rainstorm arrived and continued until the early hours of June 7. In the course of one night, Central Indiana received nearly 11 inches (280 mm) of rain, resulting in widespread flooding throughout the region. Many areas were evacuated. On June 8, the Wabash Valley between Lafayette and Terre Haute, Indiana, was placed under flood alert; all residents near the Wabash River were urged to evacuate their homes. On June 9th, President George W. Bush declared 29 counties in central Indiana a major disaster area. In all, the extreme rain event lasted approximately 10 days, caused numerous fatalities and caused $126 million in damages.

As a result of better forecasting and flood prediction, the damage and human suffering caused by such floods is now less than it would have been as little as 50 years ago. The advent of modern weather radar and satellite monitoring of precipitation, combined with sophisticated modeling of river flooding patterns, has allowed local officials to be able to prevent large losses of life and property. However, even more accurate predictions are possible as the science and understanding of precipitation patterns continues to improve. Through their contributions of rain gauge data, citizen scientists can play a role in increasing the understanding of precipitation patterns.

Precipitation

Earth has often been called the "just right" planet. What makes Earth "just right" for life? – our weather and climate. Our unique weather and climate, in other words, temperature combined with the quantity of rainfall and other precipitation, determines where life will flourish or perish on Earth. Too much rainfall, and rivers flood, too little, and soils dry out, making it difficult for plants and animals to survive, resulting in drought and famine.

Water is essential to all life. It comprises 75% of our bodies. We get water from drinking water and from the foods we eat. Water is used for everything. Not only do we use water to grow our crops, it is essential in the manufacturing and transport of our goods and in the processing of our waste. And yet very little fresh water is available for our use. Most of Earth's water is either too salty (the ocean) or frozen in glaciers.

Additionally, water and precipitation are critical in the redistribution of heat energy around the globe. This movement of water around the Earth is what is known as the water, or hydrological, cycle. Some of the Sun's energy that reaches the Earth's surface is used to evaporate and transport the water vapor from one place to another around the Earth. As this water vapor cools it condenses, forming clouds and precipitation.

Throughout history, humans have strived to understand and even control these patterns of weather and climate. By developing an understanding of the patterns of precipitation, scientists are making possible increasingly accurate weather, flood and drought forecasts. In the case of drought, these forecasts allow water managers to decide how to allocate precious water resources. Conversely, in the case of flood events, careful precipitation monitoring and forecasting can improve strategies intended to prevent damage and suffering.

Monitoring Precipitation with Satellites

Scientists use computer models to learn about precipitation patterns and the conditions, both on the land and in the atmosphere, that control them. Models not only allow forecasters to tell you how much rain to expect in tomorrow's storm, but they also allow scientists to understand how precipitation changes over time.

To check on the models' accuracy, scientists compare model results to rainfall measurements from ground-based weather stations and satellite measurements. The measurements reveal large- and moderate-scale precipitation patterns such as the anomalies that occur during El Niño or La Niña, when changes in ocean temperatures cause droughts and floods throughout the world.

Models, combined with satellite and ground measurements, have revealed interesting new understandings of precipitation patterns. For example, more rain falls downwind of large cities, and the timing of rainfall can be influenced by weekly commuter cycles (see “Urban Rain”, a feature article on the Earth Observatory website: http://earthobservatory.nasa.gov/Features/UrbanRain/urbanrain.php).

The more information scientists have to both observe patterns and refine the models, the better they understand the processes that control rain. Ground-based measurements provide the most accurate record of rainfall, but ground stations only record rain at a single location, leaving a gap between stations. Since rainfall totals can vary within a small area, these data gaps make it difficult for scientists to learn about the mechanisms that cause small-scale variations in rainfall.

Satellites, on the other hand, provide a "snapshot" of rainfall over a wide area at a given point in time. Satellites don't have the spatial data gaps that ground stations have, but they do have a time gap—they only see rainfall when they fly over it. Because satellites pass a region only once every 15 – 30 minutes, precipitation that is light or short-lived is hard to catch accurately. In fact the best rain measuring satellite, which uses radar, passes over every 2-4 hours.

Satellites also have limitations in their monitoring ability over certain geophysical regions. Over land, errors in estimates are generally higher near coastal areas and in regions covered in snow and ice. Precipitation that occurs in relatively shallow clouds, such as ones that occur due to wind flow over hills, valleys and mountains are also likely to have more errors in estimation.

Finally, satellites record the average rainfall in a very wide area—at best, four kilometers across. This means that the satellites can easily miss small patterns such as the influence of local topography (cities, land cover, etc.) on rain.

Comparing Ground and Satellite Data

To compensate for weaknesses in both types of observations, scientists match ground measurements to satellite data and use the relationship between the two to reveal patterns. Ground measurements, such as those collected by citizen scientists, including students, will increase scientists' ability to understand patterns of rainfall and changes in rainfall.

Student citizen scientists can contribute much to the understanding of rainfall patterns by reporting precipitation totals at their location. The Community Collaborative Rain, Hail and Snow Network, or CoCoRaHS, collects reports of daily rain, hail and snow events from citizen scientists that are used by a variety of organizations and individuals ranging from the National

Weather Service to insurance adjusters and water resources managers. Citizen scientists can join the CoCoRaHs network and contribute data or simply examine the data archives to inquire about local rainfall patterns. CoCoRaHS originated in 1998 at the Colorado Climate Center at Colorado State University. It now has over 12,000 observers in thirty-nine states (http://www.cocorahs.org).

Additional Resources

- Tropical Rainfall Measuring Mission (TRMM) satellite web site: http://trmm.gsfc.nasa.gov
- Weather basics from TRMM educational materials: http://trmm.gsfc.nasa.gov/education_dir/education.html
- Global Precipitation Analysis: http://precip.gsfc.nasa.gov
- Earth Observatory: http://earthobservatory.nasa.gov
- U.S. Drought Portal: http://drought.gov

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. J. Hydrometeor. 8(1), 38-55. Available at: ftp://meso.gsfc.nasa.gov/agnes/huffman/papers/TMPA_jhm_07.pdf.gz

General Student Learning Objectives

- Students will design, analyze, or carry out simple investigations and formulate appropriate conclusions based on data obtained or provided.
- Students will recognize and explain how human activities can accelerate or magnify many naturally occurring changes.
- The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.

Materials

- Rain Gauge: CoCoRaHS Website has a list of suppliers, approximately $20 – 25
- Wooden 4” x4” Post with a beveled top for mounting gauge
- Tools for placing the post into the ground such as a shovel, drill, screwdriver, hammer, nails/screws and level to attach gauge to post.
- Detailed map of your location
- Internet access to satellite data
- Google Earth (to identify the latitude and longitude of your test site)
- Data sampling sheet (Appendix A: CoCoRaHS Precipitation and Snow Measurement Form)

Lessons

Engage

Recent Floods

Flooding occurs naturally and serves a purpose, however it can be out of balance or occur where people have developed the area and thus cause great damage. For example, in the United States, there are frequent floods in the Mississippi watershed (like the spring and summer of 2011). In other parts of the world, such as China, flooding has been quite devastating (e.g., China flood of June 2010).

Engage students' interest in precipitation by reading articles about flooding in the United States and in other parts of the world. Current floods are tracked on the Earth Observatory at http://earthobservatory.nasa.gov/NaturalHazards/category.php?cat_id=9&m=01&y=2012
You can find news articles about current flood events on ReliefWeb: http://reliefweb.int/

You may also share videos from YouTube that show dramatic flooding and the associated human drama. Has this sort of event occurred where they live? Do they know anyone who lives in an area that has been flooded? What happened to the land and to the people? Could the flooding have been prevented?

Understanding precipitation, when and where it occurs, helps scientists understand when and where flooding may occur. Precipitation can be monitored by satellites, but more detailed data can be collected by volunteer scientists using rain gauges.

Collecting Local Precipitation Data
Students will put up a rain gauge in the schoolyard. Teams of students will be responsible for daily data collection and recording. Remind students that zero inches of rain is as important a reading as 3 inches of rain.

<u>Sampling Procedure:</u>
Warning: Do not take measurements during a severe storm, flood or lightning event.

Locate a sampling site:

1. For accurate measurements, your rain gauge should be placed away from any permanent structures such as fences or buildings; 2-5' above the ground; away from sprinkler systems, dogs and vandals and be easily accessible so that you can check it on a daily basis. You may be able to place the gauge in your yard, but you may wish to identify other locations within your community as well, particularly if you are interested in studying regional variability in rainfall patterns.
2. Using the map, identify possible rain gauge locations at various places in your region. Choose potential locations that are publicly accessible or where you have permission from the land owner to access the location on a daily basis.
3. Locate the site(s) in Google Earth. Place the cursor over the sampling site(s) and note the latitude and longitude that appears in the bottom left corner of the Google Earth window. Record this information on the data sampling sheet.
4. Select a sample location at the site. Look for objects that might adversely affect your collection of precipitation, as outlined in step one. Use the CoCoRaHS Training Slide Show (Appendix B) for more detailed specifications: http://www.cocorahs.org/media/docs/CoCoRaHS_Training_6.5.pdf
5. Place the post in the ground with the beveled end on top. Using the level, make sure the post does not lean in one direction or another.
6. Secure the post to make sure it does not wobble.

7. Mount your rain gauge on the post, with the gauge top a few inches above the top of the post. Place a level on the gauge to make sure the rain collector is level when you attach it to the post.
8. On your data sheet, note the condition of your rain gauge. Describe the surroundings (distance from trees and buildings).
9. If you wish to report your data to the CoCoRaHS network, complete the appropriate paper work to register your location with CoCoRaHS.

Testing Procedure:
Check your rain gauge daily at 7 am (in your local time zone). The hours of 5-9 am (in your local time zone) are acceptable. Record the amount of rain in the gauge on your data sheet (Appendix C) and report your rainfall to the CoCoRaHS Website. For more details review the information on the CoCoRaHS Website.

Use the CoCoRaHS directions in Appendix B to learn how to read the gauge.

There are a variety of training options on the CoCoRaHS site. From the home page or resources link, one can download additional training slide shows files. Alternately, go to the Indiana page to listen to a web cast of how to use your rain gauge.
http://www.cocorahs.org/state.aspx?state=in

Explore

How successfully do rain gauges catch rainfall patterns? Do the satellites record the same patterns of data as the ground-based gauges? How many gauges are required in order to observe regional patterns in rainfall? Scientists compare measurements from rain gauges with satellite measurements to answer these and other related questions. Using the June 2008 Midwest flood event, this section illustrates how to explore satellite data and rain gauge data together to answer questions about regional rainfall.

The Tropical Rainfall Measuring Mission (TRMM, pronounced “trim”) satellite is the most accurate rainfall observing satellite to orbit the Earth. It carries a suite of five instruments that, when combined, allow scientists to gather a very detailed three-dimensional view of rainfall patterns. However, these instruments do not directly measure precipitation. Instead they use a combination of active radar and passive measurements to record the energy and water vapor flowing through the atmosphere. This data allows scientist to estimate precipitation patterns on large scales across the Earth. One instrument is "passive," observing the intensity of radiant energy that the atmosphere, land, and ocean emit into space at microwave frequencies. The other instrument is the first weather radar in space, recording vertical profiles of rain, similar to surface-based radar systems.

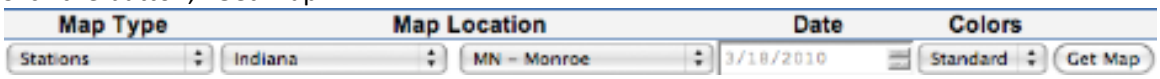
Together, these data sets allow scientists to build a 3-D picture of rainfall patterns in space and time. These estimates are calibrated by comparing the results to ground based observations, such as rain gauges and radars, with the satellite data.

For this example, we are going to use a station in Monroe County, in south-central Indiana. The station, near Indianapolis, Indiana, received a record-breaking period of rainfall from June 2 –12,

2008. This extreme rainfall event subsequently caused intense flooding in the Ohio and Lower Mississippi watersheds.

1. Launch the CoCoRaHS website http://www.CoCoRaHS.org/
2. Once the site has loaded, click on the word, “maps”.

3. Once the daily maps page loads, select the “Station Number Maps” link from the list of map types. (last one in the list)
4. Under map location title, use the pull down menu to select “stations,” choose your state of interest. In this case, choose Indiana.
5. Next choose the “county,” Monroe. Leave the dates and map colors in their default settings.
6. Click the button, “Get Map”.



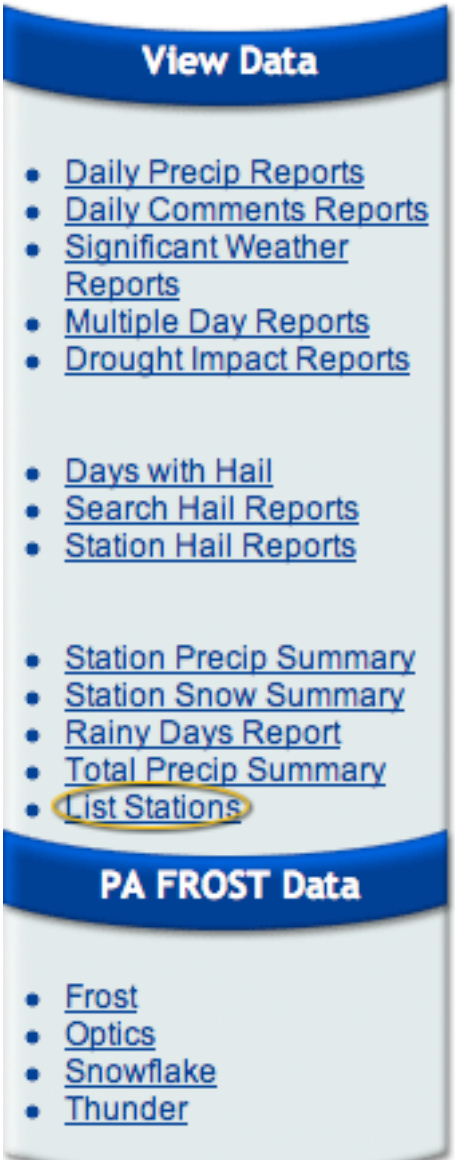
7. A map window will open with stations shown as little dots with their ID numbers next to them. We will use this station location map for reference later, so save it in the background or on your desktop.

When did it rain the most? Looking at rain gauge data

First you will get precipitation data from CoCoRaHS, a collection of observations made on the ground by citizen scientists using rain gauges. You will then look at satellite data collected over the same period of time and compare that to what was collected on the ground.

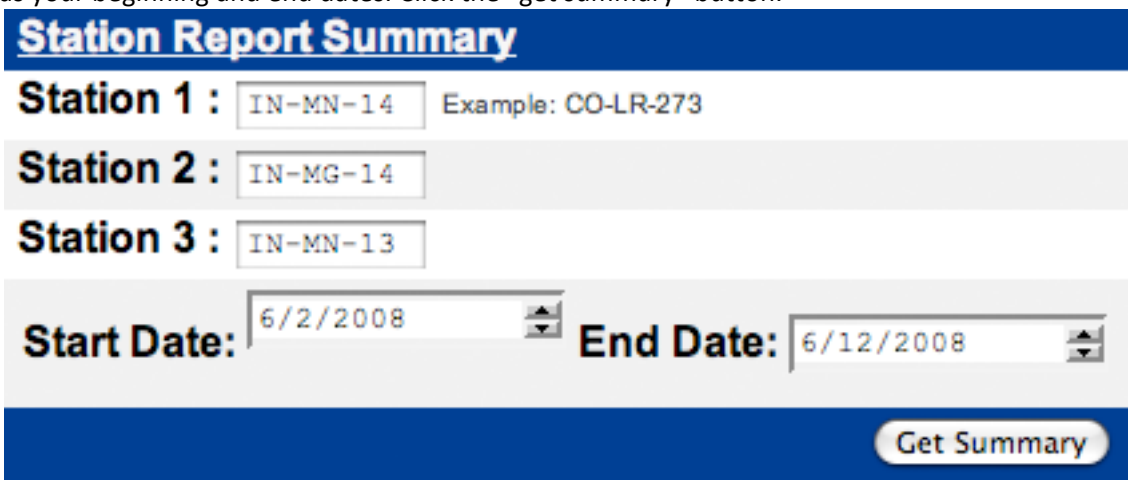
To graph rain gauge precipitation data:

1. Open a new window in your browser with the CoCoRaHS home page again.
2. This time on the top tab bar, click on, “view data”.
3. A new page will load. On this page there will be a list of station types. Scroll most of the way down the list to the link “List Stations”. This is a list of stations by state and county. Click on this link.
4. On the next page, choose the state and county you are interested in. For this example choose, Indiana and Monroe County. There are many stations in Indiana, this will select only the 15 stations that are in Monroe County. The stations are listed by; state, county and ID number. In the table of stations, under the “view” heading, click on the magnifying glass in the row with “IN-MN-14” to learn more about



this station's detailed location, including its latitude and longitude.

5. Record this station's latitude and longitude to use later in the comparison with satellite data. (Record the following: Station IN-MN-14, Latitude 39.265964, Longitude -86.521293.) Optional: click view the station in Google Maps.
6. On the side bar, under the heading View Data, click on the link "station precip summary". To access the data from this site http://www.CoCoRaHS.org/ViewData/StationPrecipSummary.aspx
7. In the next page that loads, you can type in the station ID numbers of any three stations that are of interest. Use the saved map of stations from step 3 of part 1 to view the station locations.
8. Type in IN-MN-14, IN-MG-14, and IN-MN-3. Choose the dates 6-02-2008 and 6-12-2008 as your beginning and end dates. Click the "get summary" button.



9. You will get a table of data. Check the data to see that it makes sense – is it what you asked for? Look for any days of intense precipitation. In this case, there was a rainy period from approximately June 1 -15, 2008. What date did the rainfall amount peak? How do the stations vary?
10. Once you have checked the data, copy and paste the station's data from the CoCoRaHS site into a spreadsheet program such as excel.
11. Since satellites report rain rate in millimeters per hour it will be easier to compare results if you use excel to convert the data from inches to millimeters by multiplying the total by 25.4. (1 inch =25.4 mm)
12. Produce a graph of rainfall rate in millimeters per 24 hours (y axis) versus date (x axis). Save your graph for comparison with the graph of satellite data that you will produce in the part 2.

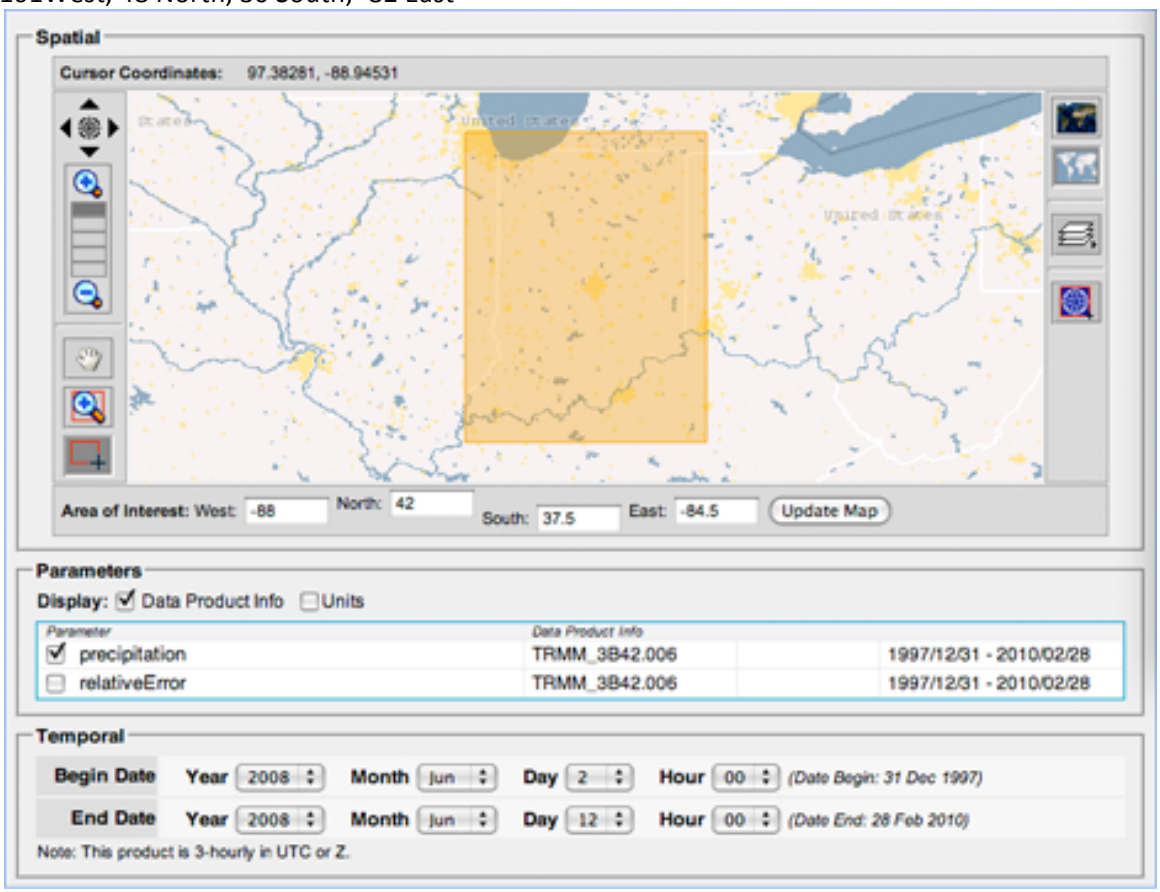
When did it rain the most? Looking at satellite data

To graph satellite precipitation data:

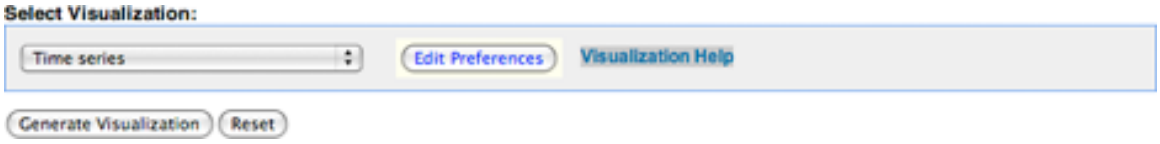
1. Use the dates, and location of your the selected CoCoRaHS stations as a starting point for a comparison of satellite and observer data.
2. Open a new window in your browser. Launch the Giovanni TRMM Online Visualization and Analysis System.
3. When this page loads, you will see a map of the world. Use your cursor to draw a box around your area of interest, Indiana. Note what latitudes and longitudes are

automatically input into the boxes below the map. Optional: Try drawing several boxes on the map in order to better understand the latitude and longitude numbers.

4. Alternately, use the coordinates that you recorded in part 1 step 3, from the Monroe, Indiana CoCoRaHS observers site as a starting point. They were Station IN-MN-14 Latitude 39.265964, Longitude -86.521293
5. In Giovanni choose coordinates that will give you a tight box around this area such as:- 101West, 48 North, 30 South, -82 East

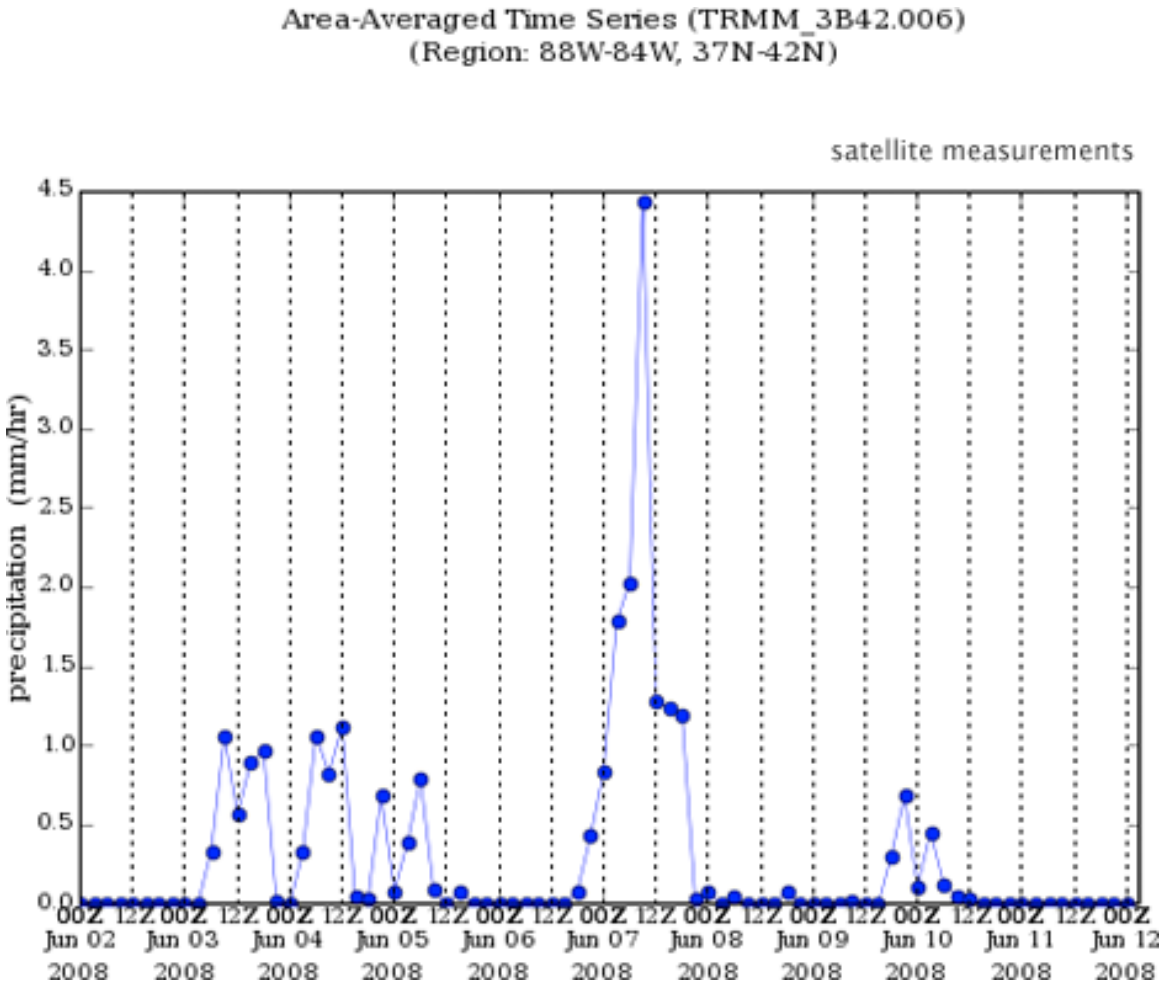


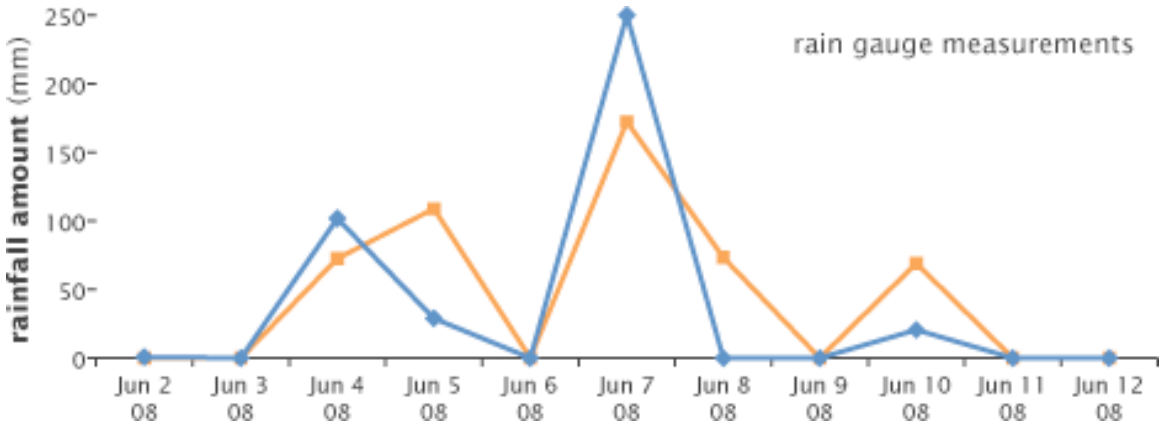
6. Choose “precipitation” as the parameter, set the temporal dates to begin June 2, 2008, and end June 12, 2008, and the visualization as “time series”.
7. Click the “generate visualization” button at the bottom of the page.



8. A new page will appear, showing you the steps the program is executing to generate the results. After a few seconds, when the processing is complete, you will see a graph.
9. NOTE: the graph will show you rain rates as observed by the satellite. A rain rate is a measurement of how hard it was raining. By contrast, your gauge measures rainfall totals, the amount of rain that fell in a 24-hour period. In theory, the rain rate multiplied by 24 should match the 24-hour rainfall total. In practice, however, this is seldom true because rain does not fall at the same rate over 24 hours.

10. Compare the graph of the satellite data to a graph of the CoCoRaHS data from Stations IN-MN-14 and IN-MG-14 during the same time period. Note that the gauges both recorded a large amount of rain on the same date that the satellites recorded a heavy rainfall rate.



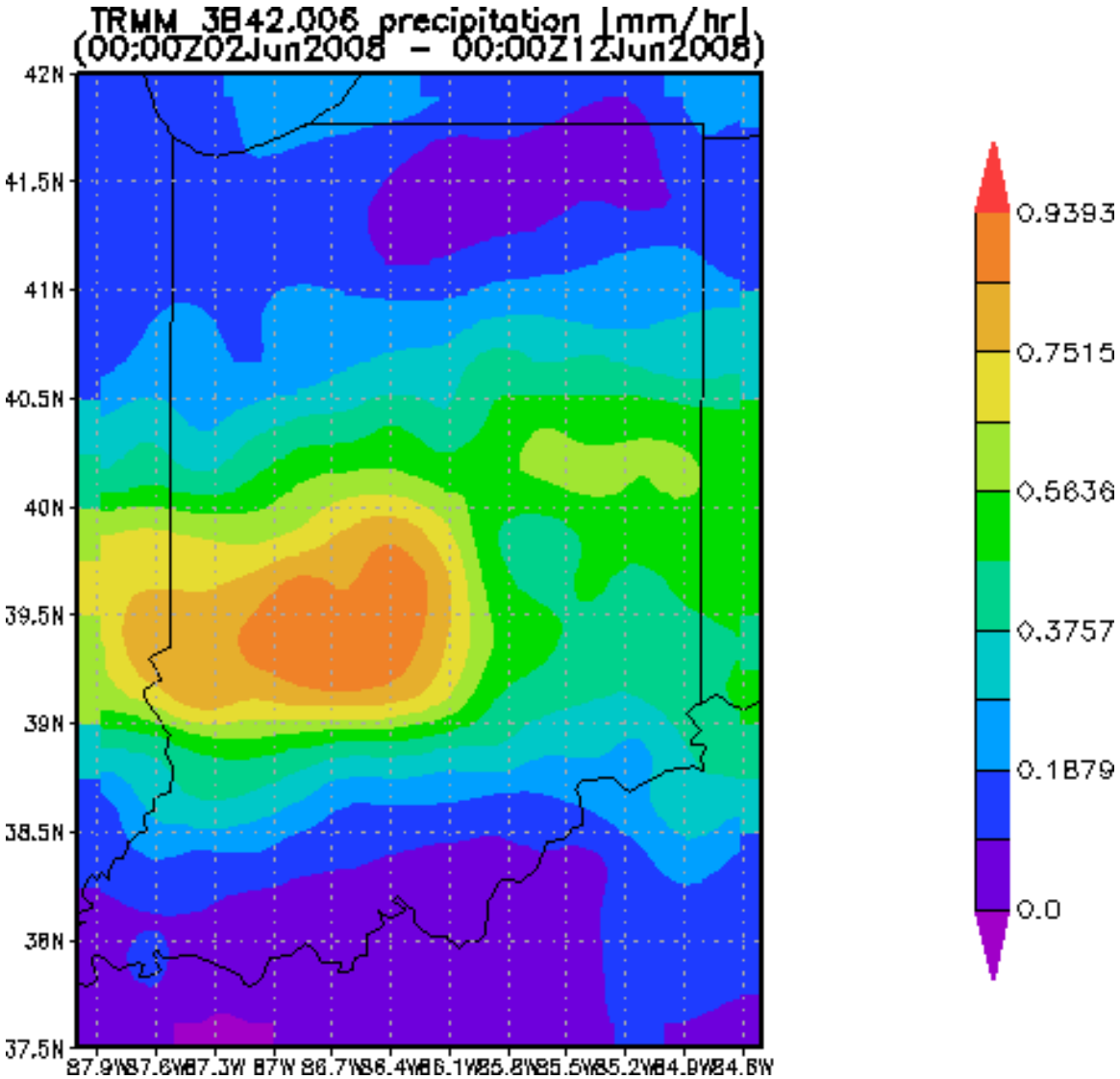


Where did it rain the most? Looking at satellite data

While rate versus time is one way to analyze data for several gauges, a broader way to look at rainfall rates across a larger area is on a map. In this example you will plot rainfall rates for this time period on a map for the area. The resulting map will help you to understand where the rainfall was the greatest, allowing you to relate this information to other geographic information such as topographic features and urban areas. In this example, we are going use TOVAS satellite data for the state of Indiana.

To view a map of satellite data:

1. Return to the Giovanni TRMM TOVAS site by clicking the back button from your results window.
2. Use the same coordinates as in the previous example. Choose the time period June 2-12, 2008.
3. This time change the parameter, setting to generate a map. Choose "Lat-Lon map, time-averaged" as your visualization.
4. Click the "generate visualization" button.
5. The computer will generate a map of the precipitation over the area and time that you have specified. This will appear as an image.



6. You can also choose “animation” to see the amount of rain each day for the period linked together in a quick time movie.

You can also download this map to view in Google Earth.

1. Click on the “download results” tab at the top of the page.
2. Scroll down to the button of the page.
3. Under the heading “Output Files”, click the radio button next to the KMZ icon to select this option.
4. Then click the KMZ icon. It will download to your computer and, depending on your settings, launch Google Earth.
5. Once Google Earth has loaded, the file you will be able to see the precipitation pattern over the region that you selected.
6. In Google Earth, observe the map of rainfall intensity for the state of Indiana. In Google Earth, add other features such as rivers, roads and cities to your map.
7. In the summer of 2008 there were major floods in this region. Add the USGS EDNA watersheds layer from http://edna.usgs.gov/watersheds/kml_index.htm

8. Use the map to predict in which watersheds the floods would have occurred. How might you, as a local weather personality or hydrologist have advised the citizens living this region? Would you have encouraged citizens living downstream of Indianapolis to evacuate?

Explain

Now that the students know how to look at rain gauge and satellite precipitation data, ask them work in groups to pick another location during another time period and repeat the process. They could pick an area/time where they knew it had a significant rain event. Or they might want to pick a place close to home to investigate rain events.

Ask the groups to do brief presentations showing their graphs. Were the rain gauge and satellite data showing the same rain events in the same way? Where did it rain the most in that area? Based on the land topography and human land uses in the area, do you think flooding would occur downstream from this site? Why or why not?

Extend

Try these ideas for extending students' understanding of precipitation:

1. See if you can predict the rain amounts better than the local weather person. Hold a competition to see who can guess the average rain fall over a week, as measured by your rain gauge.
2. Explore how El Nino and El Nina happen and how they correlate with rainfall patterns.
3. Monitor local rainfall and submit your data to the CoCoRaHS website. Be a part of the citizen science community!
4. When it was raining hard in your area, what was the weather like where your friend lives in another state? If the weather was sunny and rain-free, why was there that difference? What causes precipitation in one area, but not in another? Why do rainfall amounts change with the seasons?
5. Explore extreme precipitation events in around the world such as rain associated with tropical cyclones or extreme lack of rain, such as droughts.
6. Some people think that dramatic weather events affect the stock market. Can you find evidence to support that theory?
7. What is the difference between seasonal and emergency flooding? Look at graphs of each.
8. What types of careers involve understanding precipitation?

Evaluate

Evaluation of student comprehension is an ongoing process throughout the learning activities. Here are a few ideas for creating distinct evaluation activities:

1. Have students comment on their peers' presentations.
2. Provide the students with new precipitation graphs and ask them to describe the type of precipitation that occurred. Compare graphs of rain gauge data to those of satellite data.
3. Ask the students to create a public service announcement or one-page flyer to explain the connection between precipitation and flooding.

Appendix A: CoCoRaHS Precipitation and Snow Measurement Form

Appendix B: How to Read Your Rain Gauge by CoCoRaHS

Appendix C: How to Read Your Rain Gauge by CoCoRaHS