National Aeronautics and Space Administration

NASA eClips™

Educator Guide

NASA's REAL WORLD:
Measuring Raindrops

Educational Product	
Educators & Students	Grades 6-8

EG-2010-005-LaRC

Measuring Raindrops

National Standards:
National Science Education Standards (NSES)

Science as Inquiry
Abilities necessary to do scientific inquiry

Earth and Space
Structure of the earth system

National Council of Teachers of Mathematics (NCTM)

Representation
Use representations to model and interpret physical, social, and mathematical phenomena

Measurement
Apply appropriate techniques, tools, and formulas to determine measurements

Understand measurable attributes of objects and the units, systems, and processes of measurement

Geometry
Use visualization, spatial reasoning, and geometric modeling to solve problems

International Society for Technology in Education: National Educational Technology Standards (ISTE/NETS)

Research and Information Fluency
Students apply digital tools to gather, evaluate, and use information.

Grade Level:
6 - 8

Subjects:
Earth and Space Science, General Mathematics

Teacher Preparation Time:
20 minutes

Lesson Duration:
One 55-minute class meetings

Time Management:
This activity is designed to be conducted on a rainy day. Virtual data sets found in the Technology Tools section of the NASA eClips™ Teacher Toolbox may be substituted for actual rain data. As a class project, ask students to follow the weather forecast for several days to see when the activity can be conducted.

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Lesson Overview:

In this lesson, students look at NASA technology and how the study of clouds provides scientists with information about the global environment, weather patterns, and climate changes. Students then collect and analyze data about the size and shapes of raindrops. Students have the opportunity to compare a 2-D representation to a 3-D representation to understand why scientists use multiple sources of data to study Earth Systems. Students may also build a simple cloud chamber. This lesson is developed using the 5E model of learning.

Icons flag five areas of interest or opportunities for teachers.

- **Technology Icon** highlights opportunities to use technology to enhance the lesson.
- **Modification Icon** denotes opportunities to differentiate the lesson.
- **Resources Icon** relates this lesson to other NASA educator resources that may supplement or extend the lesson.
- **Connections Icon** identifies opportunities to relate the lesson to historical references and other topics or disciplines.
- **Check for Understanding Icon** suggests quick, formative assessment opportunities.

Essential Questions

- What is the water cycle and what roles does it play in Earth's systems?
- Why do scientists use multiple sources of data to study Earth Systems?

Instructional Objectives

Students will:

- explain what scientists learn from studying clouds;
- explore the changes of state occurring within the water cycle;
- explain how clouds and precipitation form;
- measure the size of raindrops using metric units;
- compare a real world and virtual experience; and
- create a color-keyed graph to summarize collected raindrop data.

Materials List

ENGAGE

Per class

- large empty metal can
- enough ice to fill the can
- clear pitcher or beaker
- water
- food coloring
- white paper towel or napkin

EXPLORE

Per class

- shallow pan
- enough flour to create a smooth layer on the bottom of the pan approximately 0.5 cm deep

Per student

- Student Guide
- letter size piece of light-colored card stock (White copy paper can be substituted. Do not use fibrous paper such as construction paper.)
- pencil
- metric rulers
- Virtual Rainstorm - Students can compare a real world rain collection experience to a virtual experience. You may do this by downloading Measuring Raindrops: A Virtual Rainstorm Microsoft PowerPoint file from the Technology Tools from the NASA eClips™ Teacher Toolbox.
- Sample Raindrops (optional) - Students can measure raindrops from the Sample Raindrops PDF file located in the Technology Tools section of the NASA eClips™ Teacher Toolbox.

EXPLAIN

Per group

- set of colored pencils or fine point markers
- fine point black marker

EXTEND

Per class

- sieve

5E INQUIRY LESSON DEVELOPMENT

ENGAGE (10 minutes)

In this ENGAGE activity, students learn that air contains water vapor and that water vapor can condense to form clouds and precipitation.

1. Before class, gather the following materials for the demonstration:
   - large empty metal can
   - enough ice to fill the can
   - clear pitcher or beaker
   - water
   - food coloring
   - white paper towel or napkin

2. Fill the metal can with the ice.

3. Fill the pitcher with water and add a few drops of food coloring. Stir the contents to evenly distribute the food coloring.

4. Students should predict what will happen when the colored water is poured into the can of ice.

5. Pour the colored water into the can of ice and allow it to stand for a few minutes.

6. After a few minutes, students should make observations of the can and share them with the class. They should notice moisture on the outside of the can.

7. **(CHECK FOR UNDERSTANDING)** Lead a class discussion on the source of water on the outside of the can. Ask students to suggest ways to test their hypotheses and support their results with evidence. *(Students might suggest wiping the outside of the can with a white cloth or paper towel. No food coloring will appear on the cloth so students may infer that no water came from the inside of the can.)*

8. **(TECHNOLOGY)** Show the NASA eClips™ video segment Real World: Global Cloud Observation Day (5:31). This segment can be found on the NASA eClips™ page of the NASA website:
   http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms="Global%20Cloud%20Observation%20Day"&category=0100
   The video may be streamed or downloaded from the nasa.gov website. A captioned version is also available at the nasa.gov site.

   (MODIFICATION) This video may be streamed from the NASA eClips You Tube™ channel:
   http://www.youtube.com/watch?v=B7m2a7EhRzc&feature=PlayList&p=887C1C3BAAD53F17&index=13

9. **(CHECK FOR UNDERSTANDING)** After watching the video segment, students should explain how the water ended up on the outside of the can. *(The can is cooler than the surrounding air. The surrounding air cools and the water condenses out of the air onto the side of the can.)*

10. **(CONNECTIONS)** Lead students in a discussion of the water cycle by asking the following questions:
    a. If the can were left out for several days, what would happen to the water? *(It may evaporate and return to the air.)*
    b. What happens to this water once it evaporates? *(It may eventually condense as part of a cloud.)*
    c. What happens to water in clouds? *(It may fall as precipitation.)*

11. **(RESOURCES)** For more information about the importance of clouds, visit http://www.nasa.gov/pdf/135641main_clouds_trifold21.pdf. A cloud chart can be downloaded at http://science-edu.larc.nasa.gov/cloud_chart/

EXPLORE (15 minutes)

Raindrops vary in size but are typically no more than 5 millimeters (mm) in diameter with the largest recorded raindrops 8 to 10 mm in diameter. Drops of water less than 0.5 millimeters in diameter are classified as mist or drizzle. One factor that influences the size of raindrops is what happens to them when they fall.

As raindrops fall, they do not have the teardrop shape normally associated with them in popular culture. Instead, they are shaped more like a parachute or a jellyfish with most of the water around the rim of the drop, while the upper part of the drop is a very thin film of water. When air blows through the thin film at the top, large drops break up into many smaller drops. Under laboratory conditions, breakup usually happens when the drops reach about 5 mm in diameter. When drops in clouds reach that size, they generally collide and break up. Large drops can also break up when they collide with other drops.

A second factor in drop size seems to be the number and types of particles in the air. Large drops often form in clean marine air because there are fewer particles on which the water can collect. Small raindrops often form in smoky air because of the large number of particles in the air. Small drops may collide to produce larger drops much as a drip does as it slides down a windowpane.

Resource:

Some of the Biggest Raindrops Found in Clean and Dirty Air
http://earthobservatory.nasa.gov/Newsroom/view.php?id=25068

In this **EXPLORE** activity, students measure and record the size of raindrops and graph their data.

1. Before class, determine the location of an easily accessible outside area in close proximity to the classroom. If the classroom has windows, students might be able to catch a sample by holding their paper and reaching outside the window for a few seconds. If the classroom is a long distance from the exit door, students may not have time to trace all the drop patterns before they dry. In this case, locate space in a hallway where students can trace the patterns before returning to the classroom.

2. Distribute the following materials to each student:
   - light-colored card stock
   - pencil
   - metric ruler

3. **(MODIFICATION)** Students with spatial awareness difficulties can use graph paper and count the number of squares or partial squares that the raindrops covered.

4. Emphasize to students that they need to hold their card stock flat when collecting the rain sample. Have extra card stock available for students who need to collect another sample.

5. Students should collect 20-50 raindrops on their paper, return to a dry area, and outline the drops immediately in pencil before they dry. If too many raindrops are collected, the individual shapes cannot be observed.

   In preparation for the **EXTEND** activity, teachers should collect raindrops from the same rainfall in a shallow pan containing a smooth layer of flour. Hold the pan in the rain for a second or two - just long enough for several raindrops to land in the pan and form little lumps in the flour. Do not discuss the results nor share these samples with students until the **EXTEND** activity.

6. **(MODIFICATION)** – If there is no rain in the forecast, students can measure raindrops from the Sample Raindrops PDF file located in the Technology Tools section of the NASA eClips™ Teacher Toolbox.
   http://www.nasa.gov/audience/foreducators/nasaeclips/toolbox/techtools.html

7. **(TECHNOLOGY)** Students can compare a real world rain collection experience to a virtual experience. You may do this by downloading Measuring Raindrops: A Virtual Rainstorm from the Technology Tools from the NASA eClips™ Teacher Toolbox. Discuss similarities and differences between the simulated and actual events. *(Answers may vary, but may include both events enable students to observe, record, measure and analyze data.)*

EXPLAIN (20 minutes)

In this EXPLAIN activity, students will analyze their collected raindrops.

1. Distribute a set of colored pencils or fine point colored markers to each group.

2. Students should measure the diameter of their smallest and largest raindrops in millimeters. Because not all of the outlines will be perfectly round, tell students to measure across the widest part of the raindrops.

3. Poll students to find the smallest and largest raindrops from class data. These measurements will determine the range for the color key. Based on this information, students devise a five-color key. Attempt to keep the intervals equal. For example, if the smallest raindrop is 1 mm and the largest is 14 mm, the color key would be:

1 – 3 mm	red
4 – 6 mm	orange
7 – 9 mm	purple
10 – 12 mm	green
>12 mm	blue

4. **(CHECK FOR UNDERSTANDING)** Ask students to share the intervals they have selected. Students may measure raindrops that are larger than scientifically recorded sizes (8 – 10 mm). Discuss what might be responsible for the differences. *(Answers may include flattening of the raindrop as it hits a hard surface, or the capillary action of water absorbing into the fibers of the card stock.)*

5. Students should color their raindrops according to the key. Record the total number for each size in Table 1 on page 4 of the Student Guide.

6. Students should construct a graph using the data from Table 1 on page 4 of the Student Guide. Discuss as a class which type of graph best suits this data. *(Bar graphs are appropriate for grouped raindrop frequency data.)*

7. **(TECHNOLOGY)** Students may use the Measuring Raindrops Interactive Spreadsheet Microsoft Excel file which can be downloaded from the Technology Tools section of the NASA eClips™ Teacher Toolbox.
   http://www.nasa.gov/audience/foreducators/nasaeclips/toolbox/index.html

8. Collect the data from each group to create a class graph. Ask students to compare their individual graphs to the class graph and discuss any differences between the two graphs.

9. **(TECHNOLOGY)** Teachers may use the Measuring Raindrops Interactive Spreadsheet to quickly aggregate and display class data.
http://www.nasa.gov/audience/foreducators/nasaeclips/toolbox/index.html

10. **(CHECK FOR UNDERSTANDING)** Ask students to discuss which graph best represents the actual distribution of raindrop sizes. *(The class graph is a better representation. With a larger data set, variations due to temporary conditions such as a gust of wind are minimized.)*

EXTEND (5 minutes; activities 2 - 4 are optional)

1. Show students the raindrops collected in the pan of flour from the Explore activity. Ask a student to pour the flour through a sieve to separate the lumps. Compare the 3-D raindrops to the drawings students created when they collected raindrop data. What are the benefits of collecting data in multiple ways? *(Answers may vary, but the lumps of flour represent 3-D raindrop data compared to 2-D data. The 3-D images provide more information about the shape of the raindrop and the amount of water contained in the drop. The 2-D representation is easier to measure and quantify.)*

2. **(CONNECTIONS)** Ask students to think and act like meteorologists by joining other students to collect ground truth cloud observations through NASA S'COOL. For more information about the S'COOL Project visit:
http://science-edu.larc.nasa.gov/SCOOL/index.php.
   a. To find out more about careers in the field of meteorology, visit
   http://kids.earth.nasa.gov/archive/career/meteorologist.html

3. To extend students' understanding of how clouds form, ask them to construct a cloud chamber. Directions may be found in NASA Meteorology: An Educator's Resource for Inquiry-Based Learning, Lesson 12, "How Clouds Form," pages 51 – 54. This guide can be found at
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Meteorology_Guide.html

4. Challenge students to design and conduct an experiment to test how temperature affects cloud formation. *(Answers will vary. Students could use water of varying temperatures to run this experiment.)*

EVALUATE (5 minutes)

1. Use questions, discussions and the responses in the Student Guide to assess the students' understanding of the objectives.

2. Arrange and hang raindrop collection sheets for display purposes.

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Measuring Raindrops

Essential Questions

- What is the water cycle and what roles does it play in Earth's systems?
- Why do scientists use multiple sources of data to study Earth Systems?

Background

Clouds and the Earth's Radiant Energy System or CERES, is a data- collecting sensor flown on satellites as part of Earth Observing Systems program. Scientists use the data collected to study how clouds may affect Earth's climate.

A number of CERES instruments are flown in different orbits to obtain measurements over the entire globe. Tropical Rainfall Measuring Mission, or TRMM, carries one CERES instrument. Other CERES instruments are found on the Terra spacecraft. Terra is the flagship of the Earth Observing System, or EOS. This major international program will monitor climate and environmental change on Earth over the next 15 years. Terra will enable new research into the ways that Earth's lands, oceans, air, ice, and life function as a total environmental system.

More CERES instruments are aboard another EOS spacecraft, Aqua. Aqua studies water in the Earth System.

NASA gives students opportunities to be involved in real world science. S'COOL, or Students' Cloud Observations On-Line, is a project where students record cloud observations at the same time specific satellites pass overhead. By comparing student observations to satellite data, scientists are able to validate the satellite data. Scientists call the data collected by observers ground truth data. The process of validating satellite data is referred to as ground truthing. This information is used to learn more about clouds and climate.

Earth is a system of individual parts that work together as a complex whole. The water cycle is one cycle within the Earth System. The movement of water between the atmosphere and Earth's surface is called the water cycle. Water evaporates from oceans and other bodies of water, entering the air.

Evaporation is the process by which water molecules in liquid water escape into the air as water vapor, a gas. As part of the water cycle, some of the water vapor in the air begins to condense and form clouds. Condensation occurs when molecules of water vapor in the air are cooled and change from a gas to a liquid. The liquid drops of water begin to collect within the clouds until they are heavy enough to fall as precipitation.

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Precipitation is any form of water that falls from clouds and reaches Earth's surface. Precipitation may fall as rain, sleet, snow, hail or freezing rain, depending on the conditions in the atmosphere at that moment in time. Regardless of its form, the water runs off the surface and moves back into oceans, lakes and streams.

Clouds of all kinds form when water vapor in the air condenses and becomes liquid water or ice crystals. As the air cools, the amount of water vapor it can hold decreases. Tiny particles must be present in the air so the water vapor has a surface on which to condense. These particles may be dust, salt crystals, or smoke. Atmospheric conditions determine what types of clouds will form.

Precipitation always comes from clouds, but not all clouds produce precipitation. For precipitation to occur, cloud droplets must grow heavy enough to fall through the air. One way the droplets grow is by colliding or combining with other cloud droplets. As collisions occur the droplets grow larger, causing them to fall faster and collide with each other more frequently. Eventually, the droplets fall out of the clouds as some type of precipitation.

Resources

CERES and the S'COOL project
http://science-edu.larc.nasa.gov/SCOOL/FindOutMore-whatceres.html
http://science.larc.nasa.gov/ceres/index.html

Animation of some early results from CERES on TRMM
http://asd-www.larc.nasa.gov/ceres/trmm/1st_earth_img/19971228_1b.htm

Information about Terra
http://terra.nasa.gov/

How Does Precipitation Form in a Cloud?
http://gpm.gsfc.nasa.gov/Newsletter/february03/science.htm

Vocabulary

cloud - A **cloud** is a large collection of very tiny droplets of water or ice crystals in the atmosphere.

Clouds and the Earth's Radiant Energy System, or CERES – CERES is a sensor flown on satellites to collect data about Earth's systems.

condensation – Condensation is the process of a gas changing to a liquid.

Earth System – The **Earth system** is a complex balance of individual parts that work together as a whole.

evaporation – Evaporation is the process of changing from a liquid to gas.

ground truth – Ground truthing is a validation process where a person on the ground (or sometimes in an airplane) makes a measurement of the same phenomenon a satellite is measuring, at the same time the satellite is measuring it. The two answers are compared to evaluate how well the satellite instrument is performing. The actual measurements taken on Earth are called "ground truth."

precipitation – Precipitation is water in the atmosphere that falls to Earth as rain, snow, hail, sleet, or freezing rain.

water cycle – The **water cycle** is one part of the Earth system. It involves the movement of water from Earth's surface to the atmosphere and back through the processes of evaporation, condensation, and precipitation.

A. EXPLORE

1. Gather the following materials from your teacher:
   - light-colored cardstock
   - pencil
   - metric rulers

2. You will also need a hard, flat surface, such as a three ring binder, to support your paper while collecting your raindrop sample.

3. When directed by your teacher, place the light-colored card stock on a flat surface. Go outside during a light rain. Allow the rain to strike your card stock. This should take only a few seconds. You should be able to distinguish individual drops on your paper.

4. Move to cover, continuing to hold your card stock flat. Quickly outline the EXACT shape of each raindrop with a pencil. You must finish outlining all the drops before the raindrops are no longer visible.

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B. EXPLAIN

1. Measure in millimeters the smallest and largest raindrop in your sample. Because the raindrops may not be round, measure the shape at its widest point. Report your measurements to your teacher.

2. As a class, find the range of raindrop sizes. Divide the range into intervals to create a five-color key. Enter the intervals into the Size of Raindrop Intervals column in Table 1.

3. Measure each raindrop on your card stock in millimeters.

4. Color the raindrops following the color key.

5. Once all raindrops have been colored, make a tally mark to indicate each time a raindrop of each color appears on the card stock. For example, if you colored 7 raindrops red, put 7 tally marks in Table 1 (卌 ||).

6. Complete the Frequency column in Table 1, then answer the questions.

Table 1: Raindrop Data

Size of Raindrop Intervalls in mm	*Color*	*Tally the number of Raindrops*	*Frequency*
Smallest Range	Red		
	Orange		
	Purple		
	Green		
Largest Range	Blue		

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1. Explain how the class determined the size of the intervals for the color coding.

2. What can you infer about raindrops from this activity?

3. How would your analysis of the data change if you organized the data into two intervals rather than five?

4. Describe another way to measure raindrops.

5. Can you think of any other data you could collect using a similar technique?

C. EXTEND

To learn more about precipitation and clouds, try one or more of these activities at home:

1. Think and act like a meteorologist by joining other students to collect ground truth cloud observations through NASA S'COOL Rover Project. For more information, visit http://science-edu.larc.nasa.gov/SCOOL/Rover/
   a. To find out more about careers in the field of meteorology, visit http://kids.earth.nasa.gov/archive/career/meteorologist.html

2. Construct a cloud chamber. Directions may be found in NASA Meteorology: An Educator's Resource for Inquiry-Based Learning, Lesson 12, "How Clouds Form," pages 51 – 54. This guide can be found at http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Meteorology_Guide.html

3. Design and conduct an experiment to test how temperature affects cloud formation.

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B. EXPLAIN

Table 1: Raindrop Data

Size of Raindrop Intervalls in mm	Color	Tally the number of Raindrops	Frequency
Smallest Range *1-3 mm*	Red	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 III	*58*
4-6 mm	Orange	卌 卌 卌 卌 III	*23*
7-9 mm	Purple	IIII	*4*
10-12 mm	Green	II	*2*
Largest Range *13 or larger mm*	Blue		*0*

1. Explain how the class determined the size of the intervals for the color coding.
   Answers may vary, but one way to determine the size of the intervals is to:
   - *Subtract the smallest value from the largest value*
     14 – 1 = 13
   - *Divide the answer by 5 and round up to the next whole number*
     13/5 = 2.6 so round to 3
   - *Each interval should be 3 mm*

2. What can you infer about raindrops from this activity?
   Answers will vary but may include that all raindrops came from the same rain event and may have been formed under similar atmospheric conditions.
   Students will likely infer that most raindrops will be the size of the category above that has the greatest occurrence/highest frequency. They are also likely to comment on the shape of the raindrops (round or oval).

3. How would your analysis of the data change if you organized the data into two intervals rather than five? *Answers will vary but should include noting changes in the frequency and intervals.*

4. Describe another way to measure raindrops. *Answers will vary. For instance, student might suggest counting drops and dividing by the number of drops in a shallow pan to get an "average" raindrop size. Students might use a paper that changes color where it is wet. Students might use a graphing calculator with a sensor hooked that can continuously measure mass. Each new raindrop adds to the mass. Constant mass means no raindrop is added at that time. Mass could be used to calculate the size of a raindrop. If students don't suggest something about mass, the teacher could prompt "How might the mass of a rain sample be used to measure raindrops?"*

5. Can you think of any other data you could collect using a similar technique? *Answers will vary, but this method would also work for measuring sleet and snowflakes.*

answerkey