Precipitation Protocols

Purpose

To determine the amount of moisture input to the local environment by measuring rain and snowfall and to measure the pH of precipitation

Overview

Students use a rain gauge and a snowboard to measure the daily amount of precipitation that has occurred. Students measure the depth and rain equivalent of each day's snow and of the total snowpack. Special pH measuring techniques for precipitation are used to determine the pH of rain and melted snow.

Student Outcomes

Students will understand that precipitation is measured in depth and this depth is assumed to apply to a large area, that precipitation has a pH that can vary, and that snow is an input of water to the surface just like rain and each snowfall is equivalent to some amount of rainfall.

Science Concepts

Earth and Space Science

Weather can be described by quantitative measurements.

Weather changes from day to day and over the seasons.

Weather varies on local, regional, and global spatial scales.

Precipitation forms by condensation of water vapor in the atmosphere.

Physical Science

Materials exist in different states.

Geography

The nature and extent of precipitation affects the characteristics of the physical geographic system.

Scientific Inquiry Abilities

Use a rain gauge to measure rainfall and rain equivalent of snow.

Use pH paper, pen, or meter to measure pH.

Use meter sticks to measure snow depth.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

In the field: 5 minutes for rain,
10-15 minutes for snow

In the lab: 5 minutes for snow rain equivalent
5 minutes for pH

Maintenance: 10 minutes weekly for cleaning the rain gauge

Level

All

Frequency

Daily within one hour of local solar noon

Materials and Tools

Installed rain gauge

Snowboard

Clean containers for pH samples 100 mL or larger

Two or three containers for snow samples

Carpenter's level

Meter stick

pH paper OR meter and pH buffers

Salt and salt card or tweezers

Sampling jar with lid

300 mL beakers or cups

Tweezers

Stirring rods or spoon

Latex gloves

Atmosphere Investigation Data Sheet

Distilled water for cleaning rain gauge

Welcome | Introduction | Protocols | Learning Activities | Appendix

Preparation	**Prerequisites**
Install the rain gauge. Construct a snowboard. Read and be familiar with the *Hydrology Investigation pH Protocol.*	None

Precipitation Protocols – Introduction

Earth is the only planet in our solar system where significant amounts of liquid water flow on the surface. All life depends on water. The water in the atmosphere, which plays an essential role in determining the weather, is part of the larger hydrologic cycle. In this cycle, water evaporates from the oceans and land into the atmosphere, falls back to the surface as precipitation, and returns to the sea on the surface in rivers and streams, and underground. Through this process, energy and chemicals are transported from place to place shaping our climate, giving us storms, and putting salt in our oceans and seas.

Precipitation refers to all forms of liquid or solid water that fall from the atmosphere and reach Earth's surface. Liquid precipitation includes rainfall and drizzle; solid precipitation includes snow, ice pellets, and hail. How much precipitation falls in a region, when it falls within the year, whether it falls as rain or snow, and the amount that falls in individual events helps define the climate of that region. When water is scarce, deserts occur. When there is plenty of water, there may be an abundance of plant growth. Winter rains are associated with Mediterranean climates. The water supply for many great rivers is the melting of the snow pack high in the mountains. Knowing how much precipitation falls and how much and when snow melts is key to understanding local and global climate.

When we study the history of Earth's climate, we notice that precipitation in all regions changes over time. For example, satellite images show that great rivers used to run through the Sahara Desert. There is scientific evidence that a shallow sea once covered much of the United States. All of these changes happened long before people lived in these regions. What changes are happening now?

Scientists do not have a very good idea of how much of the water cycle is made up of snowfall. Although the depth of snowfall can be measured using a relatively simple instrument (a meter stick), making accurate measurements is somewhat difficult because of the tendency of snow to blow around. In addition, not all snowfalls of the same depth contain the same amount of water. If you have ever lived in a place where there is snow, then you know that some snowfalls are light and fluffy (and don't make very good snowballs!), and some are heavy and wet (and are great for making snow people). In order to get an accurate idea of how much water is tied up in snowfall we need to measure both the depth and the rain equivalent of snow.

The atmosphere contains small amounts of many different chemicals. Some are in the form of gases but others are small particles suspended in the air called aerosols. These gases and particles are picked up in raindrops and snowflakes and we can't measure them all, but many of them change precipitation pH, which can be measured easily. The pH of the precipitation helps determine the effect of rainfall and snowfall on soil, vegetation, lakes, and streams.

Some rainstorms and snowstorms are big, covering whole regions, while others may be only 10 km across or even smaller. Within a storm, the amount of precipitation that falls and its pH vary from one place to another and may change during the course of the storm. It is not practical to catch and measure every raindrop or snowflake. We have to be content with samples collected in different places, but with more samples, our overall data on precipitation becomes more accurate. Every GLOBE school improves the knowledge of precipitation in its surrounding area!

Teacher Support

Precipitation Measurements and Sampling

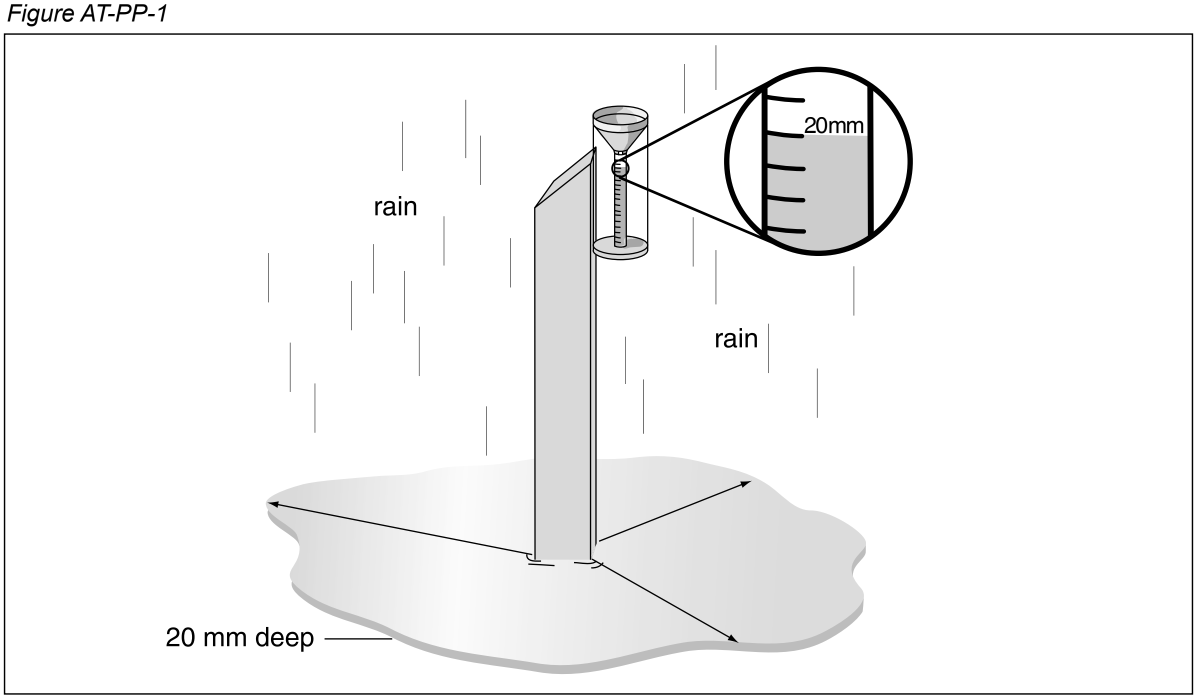
Scientists who model the hydrologic cycle need to know the total amount or volume of water that falls from the atmosphere to Earth's surface. When meteorologists and others measure precipitation they measure the depth of rain or snow that has fallen in a given amount of time. Rain gauge measurements, such as those done by GLOBE students, sample the amount of precipitation that falls. To get the total amount, you assume that the same depth of water fell over the area surrounding the rain gauge. See Figure AT-PP-1. If there is only one rain gauge in a region, this area can be quite large; the larger the area, the poorer the assumption. As more schools and others measure precipitation depth, the area represented by each measurement gets smaller and our knowledge of this part of the hydrologic cycle improves.

Measuring just the depth of snowfall isn't enough to enable you to know how much water is falling on the surface. Anyone who is experienced with snow knows that some snowfalls are light, powdery and relatively dry. Other snowfalls are heavy and wet. To determine the rain equivalent of a given snowfall, we need to collect a known quantity of snow and melt it.

Just as we can't just put a big bucket outside and then use a meter stick to measure the depth of rainfall; We can't just go out, collect a bucketful of snow and melt it. We need to collect snow to melt in a container of known size. The best way to determine the liquid water equivalent of snow is to use the outer cylinder of your rain gauge as your collection devise. By pushing the large cylinder straight down through the snow you will collect snow with an instrument of a known size.

Water moves through every living plant and animal. Chemicals in rainwater can have important effects on the land and water ecosystems. As water condenses into raindrops, some chemicals in the atmosphere dissolve in them and are carried to the surface with the rain. Aerosols (particles suspended in the air) also become attached to both raindrops and snowflakes and are washed out of the atmosphere by precipitation. Scientists call these processes wet deposition because through these processes precipitation deposits chemicals on Earth's surface.

Figure AT-PP-1



Scientists want to know how much of every possible chemical is deposited; GLOBE students can provide some help by measuring the most important chemical property of the precipitation, pH. The pH of water is altered as it moves through the environment. When water first condenses in the atmosphere, its pH is very close to neutral (7.0). Then, gases and particles from the atmosphere dissolve in the water droplets. This usually lowers the pH, making the droplets more acidic, but in regions where soil pH is high (8.0 or higher), the pH may increase as soil particles blown into the air are incorporated in raindrops. Normal precipitation in clear air is slightly acidic, having a pH of about 5.6. This is due to carbon dioxide (CO_2) and nitrogen in Earth's atmosphere. As water flows over the land surface or though the soil, the pH is changed by dissolving chemicals from the surface or soil.

Burning of some fuels releases gases (generally nitrogen or sulfur oxides) into the atmosphere that dissolve in water droplets and make precipitation more acidic. If the pH of rainfall is below 5.6 it is regarded as acid precipitation, and over a long period of time, it can directly harm plants. The most serious effect of acid precipitation, however, is weakening plants so that they become more susceptible to stresses such as cold, disease, insects, and drought. Acidic precipitation also leaches nutrients out of the soil and can release soluble aluminum ions from the soil, which can damage tree roots. If these aluminum ions are washed into lakes and streams they can harm many kinds of fish. In addition to being harmful to life forms, acid precipitation can damage structures. Acid precipitation is known to increase corrosion of metals and contributes to the destruction of stone structures and statues. In many regions of the world famous buildings and sculptures are deteriorating at increased rates.

The changes that can be studied using GLOBE precipitation data are those happening on shorter time scales of days to years. What is the seasonal variation in precipitation? When and how fast does snow melt and make its water available to the environment? Is this year particularly wet or dry for our location? What is the pH of precipitation and how does it vary? These are some of the questions that interest scientists and can be researched by GLOBE students.

Measurement Issues

Daily measurement of rain is desired. This provides a full picture of the pattern of rainfall and precipitation pH at your school and also ensures that the rain gauge is checked daily for debris, bird droppings, etc. GLOBE permits reporting of rain accumulations for up to 7 days, but as the number of days increases, the accuracy of the measurement decreases. Some of the water may evaporate from the rain gauge, especially when it's warm, samples may become contaminated, and the amount and pH readings may be for a combination of storms and weather systems. Despite these issues, there is considerable value in knowing the total input of water to your local environment over time, and so, reports of the total rainfall over several days are important when your students are unable to take daily readings.

It is important to report zero when there is no rain. If a school only reports rain when there is rain in the gauge, users of the data don't know what happened on the other days and this may make the data useless. Sometimes rain is spilled from the gauge before a reading is taken. In this case, always report "M" (missing) as the amount. This indicates to scientists using GLOBE data that there was rainfall for this day (or period of days) but an accurate reading was not obtained. If less than half a millimeter of rain is in the gauge, report "T" (trace) as the amount. See Table AT-PP-1.

It is important to take daily readings of snowfall. However, if this is not possible then the number of days since the last reading must be reported to GLOBE, along with the next reading. For example, say that you cleared the snowboard on Friday, but missed measurements on Saturday and Sunday. If you then measure snowfall on the board on Monday, you would report the total amount of new snow on the board, and enter "3" for the number of days that the snow accumulated. Even if you think you know that all of the snow fell on Sunday night, you must still report that your measurement on Monday

Table AT-PP-1: Reporting Precipitation

Type of Event	Report to GLOBE the # of days since your last measurement AND……
No rainfall	0
Rainfall > 0.5 mm with no problems reading the gauge	The rainfall amount in your rain gauge
Very small amount of rain < 0.5 mm	T (for Trace)
Spilled rain gauge before measurement could be made; gauge post fell over; etc	M (for Missing)

is the accumulation of 3 days. As with the rain gauge, accidents do happen and there may be a day when the snowboard has blown away or has been cleared before a measurement can be taken. In this case you should enter the letter "M" (for missing) for the daily snowfall amount. It is important that you record a missing value in these cases rather than a zero. Although it is a common mistake to substitute zero for missing values, this can lead to erroneous analyses of the data later on. However, only enter the letter "M" if the snowfall measurement is truly lost. That is, don't enter "M" for days when snow was accumulating on the snowboard. For example, when snowfall was read on Friday and Monday, but allowed to accumulate on Saturday and Sunday. DO NOT report "M" for the snowfall values for Saturday and Sunday. These values are not missing; they are included in the total snowfall reported on Monday.

Even if no new snow has fallen on your snowboard in the past 24 hours, you should take a daily measurement of the total depth of snow on the ground. This observation can give scientists information about how quickly snow is melting or sublimating (going from a solid form to a gas without first turning into a liquid).

In addition to measuring the amount of rainfall (and the rain equivalent for snow) you should measure the pH of the rain or melted snow using either pH paper or a pH meter. Special considerations must be made because most precipitation has low conductivity and both pH paper and pH meters do not perform well for low conductivity samples. Adding salt crystals to the rain or melted snow will increase the conductivity to an appropriate level. You can use either large salt crystals (0.5 mm to 2.0 mm in diameter) or finely ground "table" salt (with crystals less than 0.5 mm in diameter), as shown in Figure AT-PP-2. If you choose to use "table" salt you will use a *salt card* to measure the proper amount of salt. A *salt card* is an index card or clean piece of paper that contains two circles, one with a diameter of 4 mm and another with a diameter of 5 mm. You can create a *salt card* by either drawing two such circles on an index card or clean piece of paper or tracing or photocopying Figure AT-PP-3 onto a clean piece of paper. Large salt crystals are added using tweezers.

Figure AT-PP-2: Two Sizes of Salt Crystals

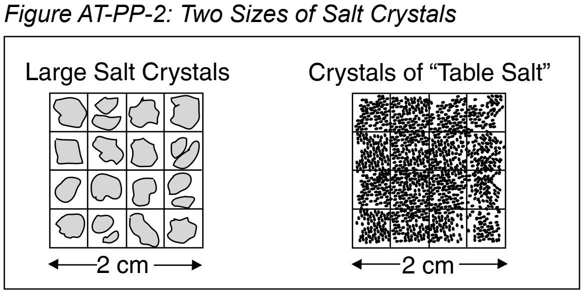
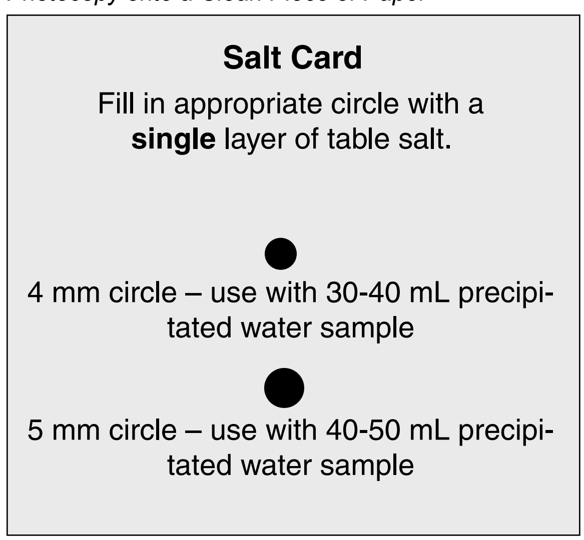


Figure AT-PP-3: Example Salt Card to Trace or Photocopy onto a Clean Piece of Paper



Student Preparation

Liquid Precipitation

Prior to the actual placement of the rain gauge, take a walk with students around the school grounds to locate the best places to put the gauge. Good questions to help get students started determining the best places to set up the rain gauge would be:

- Where would you put a rain gauge to catch the most rain? Why? (A clever student may answer that the place to catch the most rain would be under a downspout where the gauge could collect the rain running off of the roof of a building!)
- Is the place where you would catch the most rain the best place for the rain gauge? Why? (Remember that your data should be representative of the surrounding area.)

As you walk around the school grounds, have the students draw a map of the area. Younger students can just sketch the main features, such as the school building(s), parking lots, playgrounds, etc. Older students should fill in more details such as what the playground surface is (e.g. paved, grassy, or bare ground). The goal is to have a drawing of the school grounds so that when a decision is made on where to locate the weather instruments, students can locate them on their map. This will allow the students to give a good physical description of the area surrounding their instruments. In subsequent years, new classes of students can repeat this mapping exercise to note any changes in the school grounds and to understand why a specific location was chosen.

Observing and making a map of the area around the rain gauge contributes to four key elements of good scientific practice. First, the maps should be included in the student's individual Science Logs as part of students' documentation of their personal observations and notes. Second, a consensus map should be included in the school's Data Book along with the *Data Sheets*. Data about the conditions under which measurements are made is important metadata – data about data – and should be retained in each school's records. Third, GLOBE site definition sheets and data entry forms provide space for metadata to be entered as comments. Scientists must communicate all information about their observations that is needed for others to use their data. Fourth, all scientists should approach any measurement with some skepticism and ask themselves questions such as, "What could be influencing my observations and giving me inaccurate or unrepresentative data?"

Solid Precipitation

Prior to the first snowfall in your area, take a walk with students around the school grounds to locate the best places to measure the depth of snow. They should find an area away from buildings, trees, and other objects that may affect the depth of snow. Of course, like rainfall, there are small-scale variations in snowfall depth. A few questions to ask students to help them decide on the best place to measure snow are:

- Is the area of the rain gauge a good place to measure snowfall? Why or why not?
- Do you think different kinds of surfaces (e.g. grass, concrete, etc.) affect how much snow will accumulate in a particular place?
- What differences do you think you would see in snowfall depth over a large flat area compared to a very hilly area?
- How likely is it that someone will disturb the snow in this area by walking through it or by shoveling snow? Will salt or sand from nearby walkways or streets contaminate this location?

The water equivalent measurements of new snow and snow pack tie the rain and snow data together as elements of the hydrologic cycle. Discuss with students the concepts that there is a rain equivalent of snow, that snow is water stored on Earth's surface, and the reasons why the samples of snow must be taken in the careful manner required by the protocols. Students who understand the concepts of sampling rain and how snow measurements relate to rain measurements should be more careful and confident in taking data.

Questions for Further Investigation

When does your area get precipitation? Why?

What would happen if you got only half the normal amount of precipitation in a given year? How would the effects vary depending on when within the year there was less precipitation?

What would happen if you got double the normal amount of precipitation in a given year? How would the effects vary depending on when within the year there was more precipitation?

Is the amount of precipitation you get at your school the same or different from the amount measured at the five nearest GLOBE schools? What causes these differences or similarities?

Where do snow storms and rain storms come from before reaching your area?

Does precipitation pH vary from storm to storm? Why?

How do the amount and timing of precipitation relate to budburst and other phenology measurements?

How do the amount and timing of precipitation in your area relate to land cover?

How does the pH of precipitation relate to soil pH and the pH of nearby water bodies?

Instrument Maintenance and Calibration

Maintenance

Even if it has not rained, you should check your rain gauge daily to make sure that it is free of debris (windblown leaves, twigs, papers, etc.). Some birds seem to like sitting on the edge of the rain gauge and may leave droppings behind! Approximately once each month the rain gauge should be thoroughly cleaned with water and a bottle brush (or equivalent). This is to clean out any mold, mildew, or other things that may start to grow in the gauge. In very humid regions the gauge may need scrubbing more often; in dry areas you may only need to scrub the gauge once every two or three months (although dry debris should still be removed daily). Never use soap or detergent when cleaning the rain gauge because the residue will contaminate your precipitation pH measurements.

Bring the rain gauge indoors when the temperature falls below freezing. This will prevent the measuring tube from cracking. However, if you are in a transition season where temperatures can range from below freezing to above freezing during a 24-hour measurement period and both rain and snow are possible, you can leave the large overflow tube outside without the small measuring tube and funnel. This part of the rain gauge is less likely to crack. Any precipitation that falls into the large overflow tube can be brought indoors and poured into the small tube for accurate measurement.

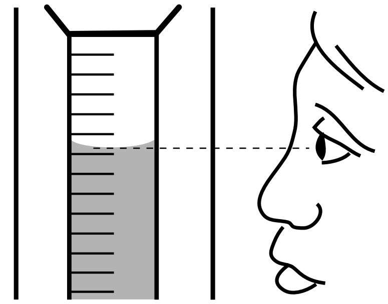
Little maintenance is needed for the snowboard. The main things are to make sure the snowboard is cleared off after each measurement, and to check the board occasionally to make sure it has not warped.

Calibration

To ensure that your rain gauge is level, you simply need to put a carpenter's level across the top of the funnel of the gauge in two directions. A carpenter's level is a straight piece of board that has small glass tubes running in one or more directions. Each glass tube has markings on it, and an air bubble inside.

Rainfall Protocol

Field Guide



Task

Measure the amount of rain that has collected in your rain gauge.

Measure the pH of the rain.

Prepare the rain gauge to collect more rain.

What You Need

- ❑ A properly sited and mounted rain gauge
- ❑ Clean sampling jar with cover for pH measurement samples
- ❑ *Atmosphere Investigation Data Sheet*
- ❑ Appropriate *Precipitation pH Lab Guide*
- ❑ Pen or pencil

In the Field

1. Read the level of the water in your rain gauge; be sure your eyes are level with the water in the measuring tube. Read the level at the bottom of the meniscus.
2. Record the rainfall amount to the nearest one-tenth of a millimeter.

   If there is no water in the rain gauge report 0.0 mm.

   If there is less than 0.5 mm, record "T" for trace.

   If you spill any water before measuring the amount of rain, record "M" for missing as the amount. (If you have only spilled a little, record the amount not spilled as metadata.)
3. Pour the water into the sampling jar and cover it for the pH measurement.
4. If there is water in the overflow tube:

   a. Remove the measuring tube from the overflow tube.

   b. Read the level of water in the measuring tube holding it so that your eyes are level with the meniscus.

   c. Record the amount to the nearest one-tenth of a millimeter.

   d. Pour the water from the measuring tube into the container for the pH measurement.

   e. Pour water from the overflow tube into the measuring tube.

   f. Repeat steps b through e until the overflow tube is empty.

   g. Add your measurements and record the sum as the rainfall amount.
5. Record the number of days rain has accumulated in the gauge. (The number of days since the rain gauge was last checked and emptied.)
6. Perform the appropriate *Precipitation pH Lab Guide* (depending on which type of pH measuring device and salt you are using).
7. Dry the rain gauge and remount it on its post.

Solid Precipitation Protocol
Field Guide

Task

Measure the amount of new snow that has collected on your snowboard.

Measure the total depth of snow on the ground.

Obtain samples of new snow and snowpack for pH measurement.

Obtain samples of new snow and snowpack to determine the water equivalent.

Prepare the snowboard to collect more snow.

What You Need

- ❑ A meter stick (or a longer measurement pole if snow accumulates to more than a meter in depth
- ❑ Snowboard
- ❑ A straight-sided container
- ❑ The overflow tube from your rain gauge
- ❑ Two clean sampling jars with covers for the pH samples
- ❑ A container for the snowpack rain equivalent sample
- ❑ Something flat and clean to slide under inverted containers
- ❑ *Atmosphere Investigation Data Sheet*
- ❑ Pen or pencil
- ❑ Labels for snow samples

In the Field

1. Insert the measuring stick vertically into the snow until it rests on the ground. Be careful not to mistake an ice layer or crusted snow for the ground. Read and record the depth of the snowpack.
2. Repeat the measurement in at least two more places where the snow is least affected by drifting.
3. Report all three of these numbers as the total snowfall. If the snowpack is so small that a depth cannot be read, record the letter "T" (for trace) for total snowpack.
4. After a new snow has fallen on earlier snow, gently insert the measuring stick vertically into the snow until it touches the snowboard. Read and record the depth of new snow. If no new snow has fallen, record 0.0 as the depth of new snow.
5. If there is new snow, take at least two more measurements at different spots on the snowboard.
6. Report these numbers as the depth of new snow. If the snowfall is so small that a depth cannot be read, record the letter "T" (for trace) for new snow. If the snow on the snowboard has been disturbed before you can take an accurate measurement, report "M" for missing.
7. Record the number of days since the last reading of snow on the snowboard.

Taking Samples for the Lab

8. After you have measured the depth of new snow on the snowboard and of the snowpack, take a straight-sided container (such as the overflow tube from the rain gauge), and hold it straight up and down over the snowpack, well away from the snowboard. Choose a place where the snow has not been disturbed. Push the container down until it almost touches the ground.
9. Slide something flat and clean under the container just above the ground and turn the container right side up. Be sure not to lose any snow.
10. Save this sample in a clean container, cover it, label it “snowpack pH”.
11. Take the overflow tube from the rain gauge, and hold it straight up and down over the snow away from the snowboard. Choose a place where the snow has not been disturbed. Push the tube down until it touches the ground.
12. Save this sample in your tube or another container, cover it, label it “snowpack rain equivalent”.
13. Hold a straight-sided container straight up and down over the snowboard. Push the container down until it almost touches the board’s surface.
14. Slide something flat and clean under the container just above the board and turn the container right side up.
15. Save this sample in a clean container, cover it, label it “new snow pH”.
16. Hold the overflow tube from your rain gauge straight up and down over the snowboard. Push the tube down until it touches the board’s surface. Slip something flat under the tube and turn it right side up OR hold the tube to the board and flip the board and tube over. Be sure not to lose any snow.
17. Save this sample in your overflow tube or another container, cover it, label it “new snow rain equivalent”, and take it inside with you.
18. Once you have taken your samples, place the snowboard on top of existing undisturbed snow. Push the snowboard gently into the snow so that its surface is even with the surface of the snow. Place a flag or other marker nearby to help you locate the snowboard after the next snowfall.
19. Take your labeled samples inside to melt and measure.

Solid Precipitation Protocol
Lab Guide

Task

Determine the liquid water equivalent of new snow fall and total snowpack.

Determine the pH of the new snow and the snowpack.

What You Need

- ❑ Samples from the field (pH and rain equivalent for new snow and snowpack)
- ❑ The small measuring tube from your rain gauge
- ❑ Appropriate *Precipitation pH Lab Guide*
- ❑ *Atmosphere Investigation Data Sheet*

In the Lab

1. Once your snow samples are indoors, allow them to melt. Be sure they are covered to prevent evaporation.
2. Pour the melt water from the "new snow" sample into the measuring tube of the rain gauge (you may want to use the rain gauge funnel to help).
3. Read and record the rain equivalent in millimeters to the nearest 10th of a millimeter.
4. If there is more water than can fit into the measuring tube, empty the tube and repeat steps 2 and 3 and add the amounts.
5. Record this as the rain equivalent on your *Data Sheet.*
6. Pour melted snow water back into the sample jar.
7. Perform the appropriate *Precipitation pH Lab Guide* (depending on which type of pH measuring device and salt you are using) on the pH sample.
8. Repeat steps 2-7 for the "snowpack" sample.

Precipitation pH Using pH Paper and Large Salt Crystals

Lab Guide

Task

Measure the pH of your precipitation using pH paper and large salt crystals.

What You Need

- ❑ *Atmosphere Investigation Data Sheet*
- ❑ Large salt crystals (0.5 mm to 2.0 mm in diameter)
- ❑ Tweezers
- ❑ Stirring rod or spoon
- ❑ pH paper
- ❑ 3 Clean 100 mL beakers or cups
- ❑ Covered sample jar containing at least 30 mL of rain or melted snow
- ❑ Latex gloves
- ❑ Pen or pencil
- ❑ Distilled water in wash bottle

In the Field

1. Pour a 50 mL (or less if you do not have 50 mL) sample of rain or melted snow from your sample jar into a clean beaker. You must have at least 30 mL of sample to measure pH.
2. Put on latex gloves.
3. Use tweezers to add one salt crystal into the beaker.
4. Stir the beaker's contents thoroughly with stirring rod or spoon until salt is dissolved.
5. Follow the instructions that came with the pH paper to measure the pH of the sample. Record the pH value on your *Data Sheet*.
6. If you have at least 30 mL of rain or snow left in your sample jar then repeat steps 1-5. Otherwise, repeat step 5. Continue until you have collected a total of 3 pH measurements.
7. Calculate the average of the 3 pH measurements and record on your *Data Sheet*.
8. Check to make sure that each measurement is within 1.0 pH unit of the average. If they are not within 1.0 unit of the average, then repeat the measurements. If your measurements are still not within 1.0 pH units of the average, discuss possible problems with your teacher.
9. Discard used pH paper in a waste container and rinse the beakers and sample jar three times with distilled water.

Precipitation pH Using pH Paper and "Table" Salt

Lab Guide

Task

Measure the pH of your precipitation using pH paper and "table" salt.

What You Need

- ❑ *Atmosphere Investigation Data Sheet*
- ❑ Finely ground "table" salt (crystals less than 0.5 mm in diameter)
- ❑ *Salt card* consisting of 4 mm and 5 mm circles drawn on a card or piece of paper
- ❑ Stirring rod or spoon
- ❑ pH paper
- ❑ 3 clean 100 mL beakers or cups
- ❑ Covered sample jar containing at least 30 mL of rain or melted snow
- ❑ Latex gloves
- ❑ Pen or pencil
- ❑ Distilled water in wash bottle

In the Field

1. Pour a 50 mL (or less if you do not have 50 mL) sample of rain or melted snow from your sample jar into a clean beaker. You must have at least 30 mL of sample to measure pH.
2. Put on latex gloves.
3. Sprinkle salt onto the appropriate circle on your *salt card*. If your rain or melted snow sample is 40-50 mL, use the large 5 mm circle on the *salt card*. If your rain or melted snow sample is 30-40 mL, use the small 4 mm circle.
4. Fill the appropriate circle with a **single** layer of salt. Remove any excess salt from the *salt card*.
5. Pour the salt covering the circle on your *salt card* into the beaker.
6. Stir the beaker's contents thoroughly with stirring rod or spoon until salt is dissolved.
7. Follow the instructions that came with the pH paper to measure the pH of the sample. Record the pH value on your *Data Sheet*.
8. If you have at least 30 mL of rain or snow left in your sample jar then repeat steps 1-7. Otherwise, repeat step 7. Continue until you have collected a total of 3 pH measurements.
9. Calculate the average of the 3 pH measurements and record on your *Data Sheet*.
10. Check to make sure that each measurement is within 1.0 pH unit of the average. If they are not within 1.0 unit of the average, then repeat the measurements. If your measurements are still not within 1.0 pH units of the average, discuss possible problems with your teacher.
11. Discard used pH paper in a waste container and rinse the beakers and sample jar three times with distilled water.

Precipitation pH Using pH Meter and Large Salt Crystals
Lab Guide

Task
Measure the pH of your precipitation using a pH meter and large salt crystals.

What You Need
- ❑ *Atmosphere Investigation Data Sheet*
- ❑ Tweezers
- ❑ Large salt crystals
- ❑ Pen or pencil
- ❑ pH meter
- ❑ pH buffers 4, 7, and 10
- ❑ 3 Clean 100 mL beakers or cups (0.5 mm to 2.0 mm in diameter)
- ❑ Covered sample jar containing at least 30 mL of rain or melted snow
- ❑ Latex gloves
- ❑ Distilled water in wash bottle

In the Field
1. Put on latex gloves.
2. Calibrate your pH meter according to the instrument instructions, using the pH buffers. Be sure to use enough standard to completely cover the tip of the electrode.
3. Rinse electrode *thoroughly* with distilled water. Any remaining standard can contaminate your sample.
4. Pour a 50 mL (or less if you do not have 50 mL) sample of rain or melted snow from your sample jar into a clean beaker. You must have at least 30 mL of sample to measure pH.
5. Use tweezers to add one salt crystal to the beaker.
6. Stir the beaker's contents thoroughly with stirring rod or spoon until salt is dissolved.
7. Follow the instructions that came with the pH meter to measure the pH of the sample and record the measurement on your *Data Sheet*. (**Note**: the electrode must be completely covered with sample water).
8. If you have at least 30 mL of rain or snow left in your sample jar then repeat steps 4-7. Otherwise, repeat step 7. Continue until you have collected a total of 3 pH measurements.
9. Calculate the average of the 3 pH measurements and record on your *Data Sheet*.
10. Check to make sure that each measurement is within 0.2 pH units of the average. If they are not with 0.2 units of the average, repeat the measurements. If your measurements are still not within 0.2 pH units of the average, discuss possible problems with your teacher.
11. Rinse the beakers and sample jar three times with distilled water.

Precipitation pH Using pH Meter and “Table” Salt

Lab Guide

Task

Measure the pH of your precipitation using a pH meter and “table” salt.

What You Need

- ❑ *Atmosphere Investigation Data Sheet*
- ❑ Finely ground “table” salt (crystals less than 0.5 mm in diameter)
- ❑ Salt card consisting of 4 mm and 5 mm circles drawn on a card or piece of paper
- ❑ Stirring rod or spoon
- ❑ pH meter
- ❑ pH buffers 4, 7, and 10
- ❑ 3 clean 100 mL beakers or cups
- ❑ Covered sample jar containing at least 30 mL of rain or melted snow
- ❑ Latex gloves
- ❑ Pen or pencil
- ❑ Distilled water in wash bottle

In the Field

1. Put on latex gloves.
2. Calibrate your pH meter according to the instrument instructions, using the pH buffers. Be sure to use enough standard to completely cover the tip of the electrode.
3. Rinse electrode *thoroughly* with distilled water. Any remaining standard can contaminate your sample.
4. Pour a 50 mL (or less if you do not have 50 mL) sample of rain or melted snow from your sample jar into a clean beaker. You must have at least 30 mL of sample to measure pH.
5. Sprinkle salt onto the appropriate circle on your *salt card*. If your rain or melted snow sample is 40-50 mL, use the large 5 mm circle of the *salt card*. If your rain or melted snow sample is 30-40 mL, use the small 4 mm circle.
6. Fill the appropriate circle with a **single** layer of salt. Remove any excess salt from the *salt card*.
7. Pour the salt covering the circle on your *salt card* into the beaker.
8. Stir the beaker’s contents thoroughly with stirring rod or spoon until salt is dissolved.
9. Follow the instructions that came with the pH meter to measure the pH of the sample and record the measurement on your *Data Sheet*. (**Note:** the electrode must be completely covered with sample water)
10. If you have at least 30 mL of rain or snow left in your sample jar then repeat steps 4-9. Otherwise, repeat step 9. Continue until you have collected a total of 3 pH measurements.
11. Calculate the average of the 3 pH measurements and record on your *Data Sheet*.
12. Check to make sure that each measurement is within 0.2 pH units of the average. If they are not with 0.2 units of the average, repeat the measurements. If your measurements are still not within 0.2 pH units of the average, discuss possible problems with your teacher.
13. Rinse the beakers and sample jar three times with distilled water.

Frequently Asked Questions

1. Why do we have to check the rain gauge every day, even if we know it hasn't rained?

The problem with containers like a rain gauge is that they tend to collect more than just rain. Leaves, dirt, and other debris can quickly spoil the rain gauge as a scientific instrument. This debris can block the funnel, causing rainwater to flow out of the gauge. Even if the debris isn't large enough to block the funnel, it may become mixed in with the rainwater and affect the level of precipitation you read or the pH reading. Therefore, it is important that you check the gauge daily to make sure it is free of dust and debris.

2. What is solar noon, and how do we figure out when it is in our area?

Local solar noon is a term used by scientists to indicate the time of day when the sun has reached its highest point in the sky in your particular location. The easiest way to determine local solar noon is to find out the exact times of sunrise and sunset in your area, calculate the total number of hours of daylight between those times, divide the number of daylight hours by two, and add that number to the time of sunrise. See the examples in *Solar Noon* in the section on *Measurement Logistics*.

3. When should we put our snowboard down?

The nice thing about the snowboard is that you don't have to anticipate the first snowfall. The snowboard doesn't have to go out until you already have snow on the ground. The purpose of the snowboard is to provide a barrier between old snow and new snow, so that you can measure the depth, liquid water equivalent, and pH of new snowfall.

4. Can we leave the overflow tube of our rain gauge out as a snow catcher?

Unfortunately, this won't work. Snow blows around too much to get an accurate measure of its depth using a rain gauge. Plus, we need to get several measurements of snow depth and average them to get a more accurate measure of the depth of snow in a region. However, on days where the temperature will be both above and below freezing, leave the overflow tube out to catch both rain and snow. The snow on these days is usually wet and heavy and doesn't blow as much and melts before local solar noon. You can measure the water in the overflow tube to get the rain equivalent of the snow plus any rainfall.

5. What do we do if the depth of new snow or snowpack is greater than the depth of our container?

Compact the snow in the container. If there is too much snow to fit in the container, push the container as far down as it will go and then pull it out.

If the snow stays in the container, empty it into a separate container which can be of any shape; or

If the snow does not come up with the container, use a small shovel or similar tool to dig the snow out of the column made by the container. Put all the snow in a separate container which can be of any shape.

Then push your straight-sided container further down in the snow continuing the hole where your first sample was taken, and repeat these steps until you have a sample that goes from the surface of the snow to the ground or the snowboard.

6. The snow protocol asks for up to four samples to be taken for pH measurements, and we only have one overflow tube; what can we do?

The pH samples do not need to be taken using the overflow tube. Any straight-sided container will do provided it is clean and will not contaminate the pH reading of the snow. Sometimes pH changes during a rain or snow storm and GLOBE wants the pH of the total precipitation that has fallen in the past day. The important points in sampling are:

1. avoid collecting snow that could be contaminated by contact with the snowboard or another surface and
2. collect a uniform column of snow that will represent the snow from the entire snowfall.

The overflow tube from the rain gauge is used in collecting the "new snow" and "snowpack" samples so that you can measure the rain equivalent using the measuring tube from the rain gauge. If you only have one rain gauge, first collect the snowpack sample and empty the contents of the overflow tube into another container and label it. Then reuse the overflow tube to collect the sample from the snowboard. If you do not wish to use the rain gauge, then you should do the following.

1. Use straight-sided containers instead of the overflow tube.
2. Take the samples and melt them in the same way.
3. Using your 100 mL or 500 mL graduated cylinders, pour the sample into the graduated cylinder and measure the volume as accurately as possible (± 1 mL in the 100 mL cylinder and ± 5 mL in the 500 mL cylinder).
4. Determine the area of the opening of the straight-sided container. If it is round, measure the diameter and calculate the area as follows:

$$\text{Radius} = \frac{\text{Diameter}}{2}$$

$$\text{Area (cm}^2) = \Pi \times (\text{radius})^2$$

Or if it is rectangular, measure the width and length of the opening and calculate the area as follows:

$$\text{Area (cm}^2) = \text{Width (cm)} \times \text{Length (cm)}$$

5. Calculate the rain equivalent depth of the melt water as follows:

$$\text{Depth (mm)} = \frac{\text{Volume of melt water (mL = cm}^3)}{\text{Area (cm}^2)} \times 10 \text{ (mm/cm)}$$

Note that milliliters are equivalent to cubic centimeters. Calculate the depth to the nearest 0.1 mm.

7. What should we do if we are likely to get both rain and snow during certain times of year?

There are many places where transition times (from Autumn to Winter, and then from Winter to Spring) mean that temperature can fluctuate above and below freezing over relatively short times. Once there is a chance that overnight temperatures will be below freezing, bring the funnel top and measuring tube of the rain gauge indoors. Leave the overflow tube in place at your Atmosphere Study Site. The narrow measuring tube is much more likely to crack if ice forms in it after a rainfall than is the larger overflow tube. The overflow tube will be able to catch any rain or snow that falls.

In some cases, you may get a snowfall that melts before your usual measurement time. If this happens, you can't report a new snow depth, but you can report as metadata that there was snow on the ground but it melted before a measurement was made.

Bring the measuring tube outside with you and use it to measure the amount of rain plus melted snow present in your overflow tube. If the water in your overflow tube all fell as rain, report it as rain. If the water in your overflow tube is all from snow which has melted, report it as the water equivalent of new snow, and report the new snow depth as "M" for missing and the snowpack depth on the ground as whatever value you measure (including 0.0 in many cases). If the water in your overflow tube is a mix of rain and melted snow or you don't know which it is, report it as rain and include in your comments that the sample included or may have included melted snow.

8. Snow fell overnight, but it melted before it was time to take the GLOBE Atmosphere measurements. What should we report as our data?

It is possible that an overnight snowfall may melt before the daily precipitation measurement is made. If you have left the overflow tube of your rain gauge outside, you can still report the liquid water equivalent of your snowfall. Note in your comments that your sample for liquid equivalent of new snow was collected in this way. Enter "M" for Daily Depth of New Snow and explain the circumstance in your comments.

9. New snow has fallen in the last day, but a significant amount of it blew away before we could measure it. What should we report as our data?

Report "M" for Daily Depth of New Snow and explain the circumstance in your comments. You should still report the total depth, rain equivalent, and pH of the snowpack if there is still any snow on the ground.

9. What is the best way to mark the location of our snowboard so we can find it after a new snowfall?

There are many ways in which you can do this. For example, you can place a flag in the ground next to the snowboard to help you locate the board. Or you could even attach a flag to the board itself (although you need to do this in such a way that it won't be unstable and tilt the board over on its side). Some ski resorts mount a pipe in a snowboard. The pipe can be marked with a permanent marking pen in millimeters and centimeters so that it not only helps you find the board, but also acts as a measuring stick to determine the depth of new snow.

10. If we know a new snowfall will melt before it is time to take our GLOBE measurements, should we try to take a measurement earlier in the day (for example, as soon as we get to school)?

If you have the time, it would be great to take a new snowfall measurement early in the day, particularly if warmer temperatures or high winds are forecast for later in the day and you think the snow may melt before solar noon. However, for consistency in the GLOBE archives, you still need to take snow measurements at solar noon. Record as metadata the time you took the earlier snowfall measurement, and the depth of the snow at that time. If you take snow measurements in the morning, make sure not to clear off the snowboard so that you can come back later in the day and take your solar noon measurements.

Precipitation Protocols – Looking At the Data

Are the data reasonable?

Precipitation can vary widely, even over short distances. So, in judging whether precipitation data are reasonable, common sense must be your guide. For example, if you lived in the state of Hawaii, it would be helpful to know that the record amount of rainfall received in the state in a 24-hour time period is about 965 mm. Figure AT-PP-4 from the National Climatic Data Center (NCDC) in Asheville, North Carolina in the U.S.A., shows you the maximum amount of precipitation received in each state of the U.S. in a 24 hour time period. In many areas, the maximum amount of precipitation was the result of a tropical storm or hurricane that hit that region

We can also find the total yearly precipitation for the wettest places in the world from the U.S. National Climatic Data Center, as shown in Table AT-PP-4.

*Figure AT-PP-4: Record Maximum 24-hour Precipitation (mm) through 1998 (*estimated)*

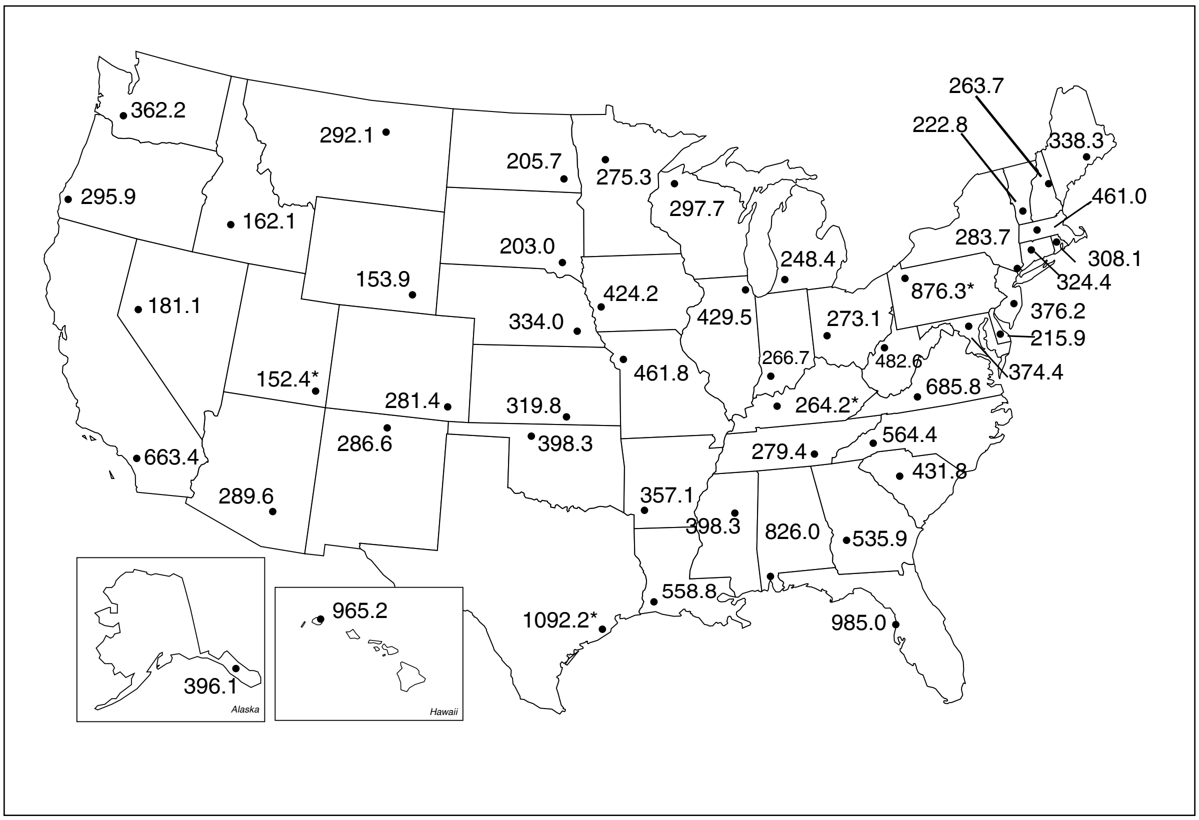


Table AT-PP-2

Continent	Highest Average (mm)		Place	Elevation (Meters)	Years of Record	
South America	13299	*+	Lloro, Colombia	158.5	#	29
Asia	11872	*	Mawsynram, India	1401.2	38	
Oceania	11684	*	Mt. Waialeale, Kauai, Hawaii, USA	1569.1	30	
Africa	10287		Debundscha, Cameroon	9.1	32	
South America	8992	+	Quibdo, Colombia	36.6	16	
Australia	8636		Bellenden Ker, Queensland	1555.1	9	
North America	6502		Henderson Lake, British Colombia, Canada	3.7	14	
Europe	4648		Crkvica, Bosnia-Hercegovina	1017.1	22	

**The value given is the continents's highest and possibly the world's highest depending on measurement practices, procedures, and period of record variations.*

+ The official greatest average annual precipitation for South America is 899.2 cm at Quibdo, Columbia. The 1329.9 cm average at Lloro, Columbia is an estimated amount.

 # Approximate elevation

A possible check on the reasonableness of data for an area is to compare with data from other nearby GLOBE schools or other sources of precipitation data. Figure AT-PP-5 shows 18 months of data for two schools in Croatia that are reasonably close to one another. Although you expect to see some variations in day-to-day precipitation, the overall patterns and amount of precipitation over time are similar.

In order to determine if precipitation pH data are reasonable, it helps to understand a little about the natural variability of the pH of normal precipitation. Because of naturally occurring carbon dioxide, sulfur dioxide and nitrogen oxides in the atmosphere, normal precipitation is somewhat acidic. Even in regions where there is little human activity, normal rainfall has a pH of about 5.6. However, some human activities can release much larger quantities of these and other gases into the atmosphere than would occur naturally. Once released into the atmosphere, these gases can react with other constituents of the air to form chemical compounds such as nitric acid and sulfuric acid that dissolve easily in water. The resulting water droplets will have pH values less than 5.6. These droplets can be carried long distances by prevailing winds, returning to Earth's surface as acid rain, snow, or fog. Sea spray, soil particles, and other substances can be swept up into the air and incorporated in water droplets. Many of these substances also change the pH of precipitation.

Figure AT-PP-6 shows the variation in average precipitation pH across the U.S.A. during 1999. This map shows us that average precipitation pH across the U.S.A. varies between about 4.2 and 5.6. The pH of individual precipitation events may be well outside this range, but it gives an indication of the approximate range of the average precipitation pH for this part of the world.

Figure AT-PP-7 is a graph of precipitation pH measurements from a GLOBE school in California, U.S.A. over a 5-month period of time, and shows that most of the measurements are between a pH of 6 and 7, but there is one data point with a pH of 9. If the pH was measured using pH paper, the variation of 1 pH unit is the same as the accuracy of the measurement method.

There are at least two possible explanations for an unusually high or low measurement of precipitation pH. One is that there was something different in the air that resulted in this unusual pH – for example, a dust storm, a forest fire, or some other phenomenon. A second explanation is that the pH pen or meter was not properly

Figure AT-PP-5

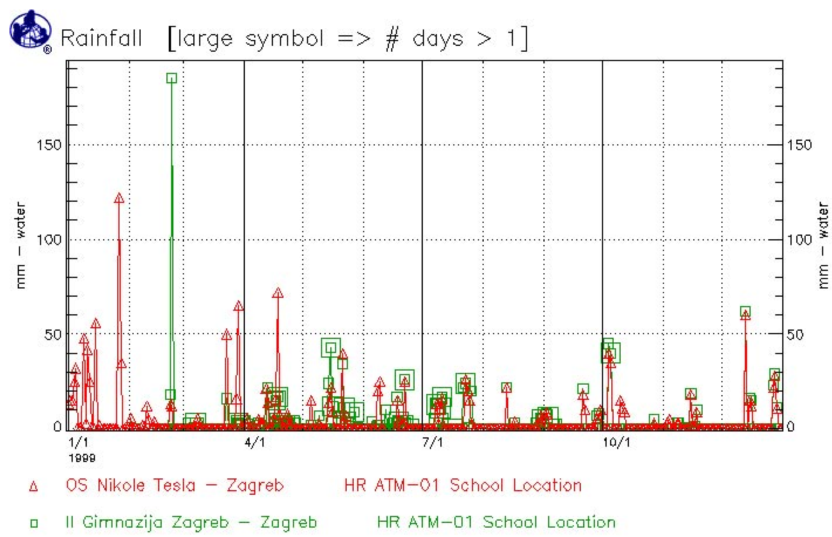


Figure AT-PP-6

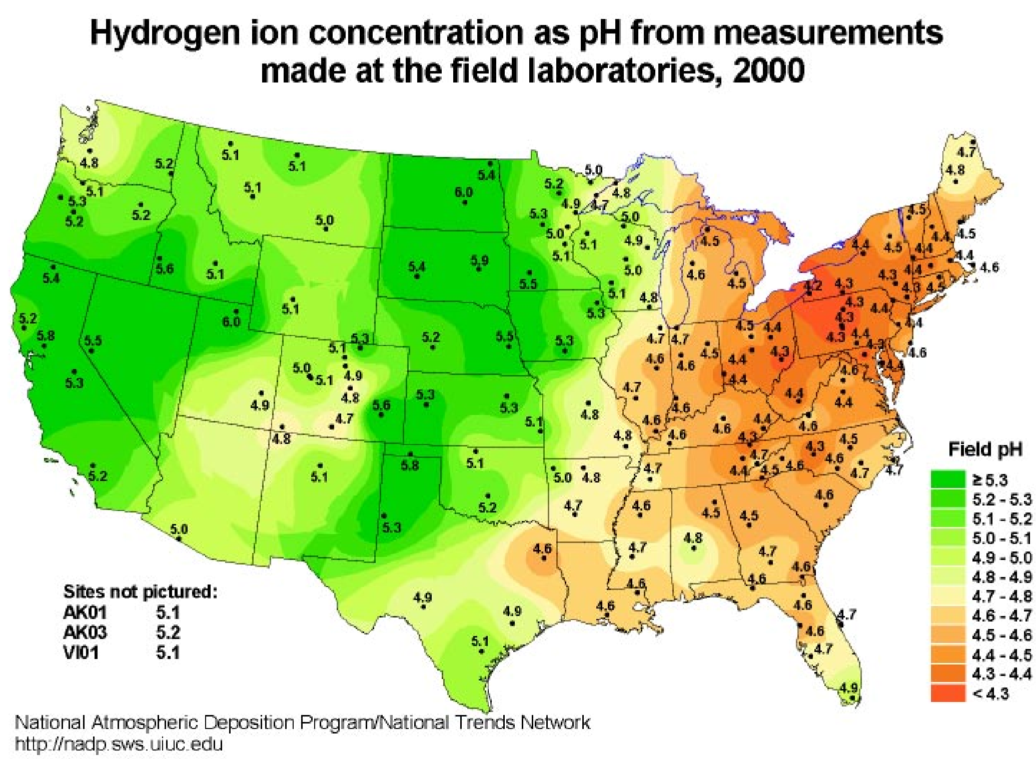


Figure AT-PP-7

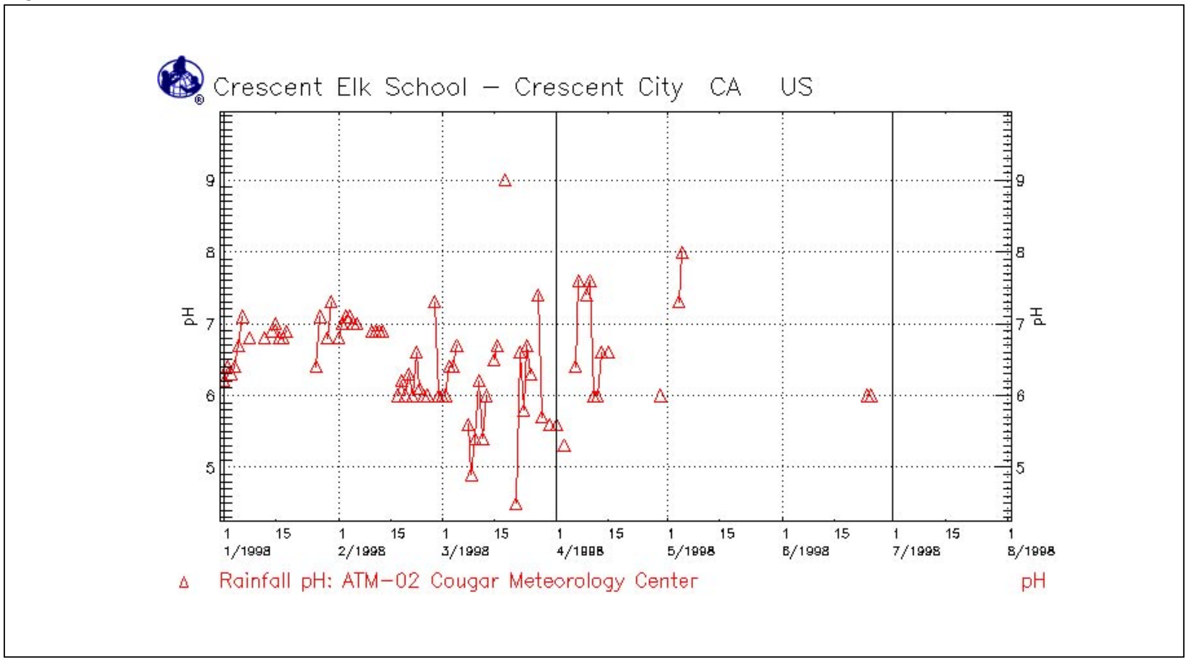
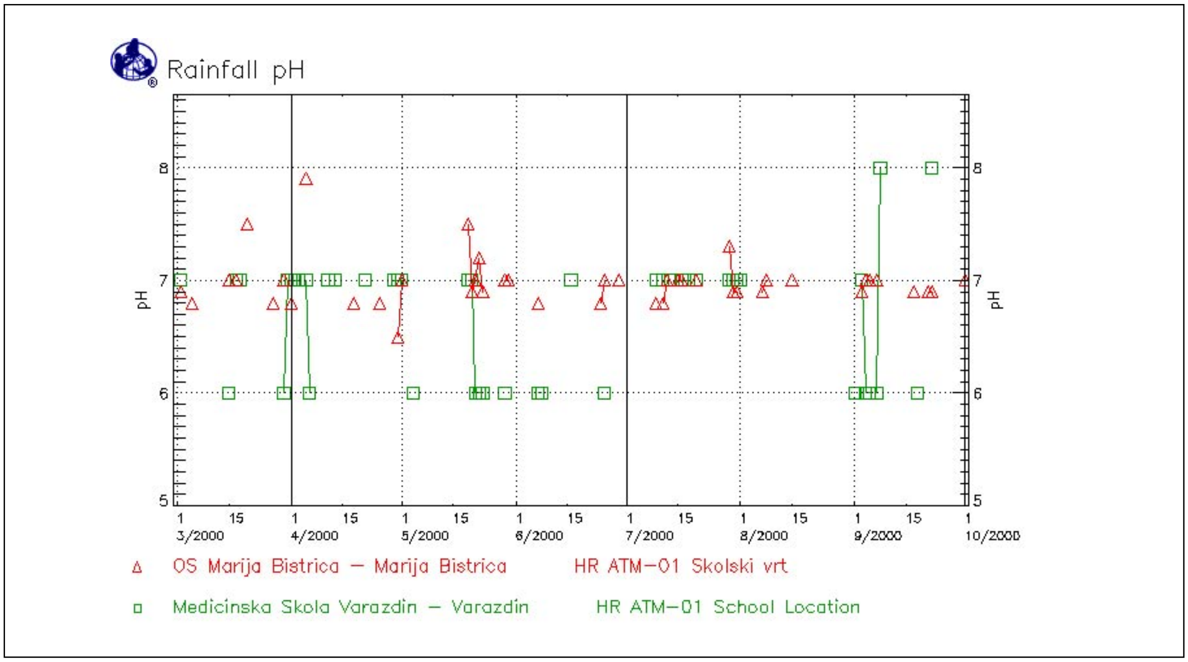


Figure AT-PP-8



calibrated or the pH paper had gone bad and the measurement is in error. The jump to 9.0 above is unusual and one should look at the comments reported by the school to better assess what was happening.

Comparison of data from schools that are reasonably close to one another shows variations of approximately 1 pH unit between these two schools. See Figure AT-PP-8. Given that all the data from Madecinska Skola are 6.0, 7.0, or 8.0, they were probably taken using pH paper, and this difference is reasonable. Both schools have occasionally higher pH readings that may be due to localized events affecting their rainfall. See Figures AT-PP-7 and AT-PP-8.

What do scientists look for in these data?

Scientists use precipitation data in their investigations of weather, climate, and atmospheric composition. In studying weather and climate, scientists may focus on individual rain events, patterns and average totals for precipitation over the year. Those concerned with atmospheric composition will look for how often there is enough rain or snow to wash trace gases and aerosols out of the air. Precipitation data are also useful for practical applications involving irrigation and water management.

In studies of weather, scientists may look at how much rain fell as part of a tropical storm or hurricane. They might also look at how much rain was associated with a particular level of flooding. This study could easily include data from many GLOBE schools in a region in combination with precipitation data from official weather stations.

Scientists trying to improve techniques for measuring average rainfall over large areas would compare data for specific days with the values they calculate from satellite or weather radar data. Each technique – rain gauge, satellite sensor, and radar – measures something different about the rain and has different limitations. So, comparing the different types of data can help improve techniques or provide a more accurate determination of how much precipitation actually occurred over an area.

Climate scientists look for different patterns in the data. What regions are the wettest? How little rain falls in deserts? What are the patterns of rainfall during the year? Climate scientists are particularly interested in how the total amounts and patterns of precipitation change over the years. Are rain events becoming more numerous? Are storms producing larger amounts of precipitation on average? Is the timing of rain during the year shifting?

As students, you can also learn about your climate by examining GLOBE precipitation data. For example, a student at Kingsburg High School in California, USA may hypothesize that the rainy season in northern California occurs at a different time of year than the rainy season in Benin, West Africa. To test this hypothesis, the student could search the GLOBE database for schools in Benin, and then compare the rainfall patterns from measurements made at their school in California to measurements made at one or more schools in Benin. Figure AT-PP-9 is an example of a comparison of two schools' rainfall records.

An initial look at this graph indicates that the rainy seasons in California and Benin do occur at different times of year. During this time period Benin received most of its rain between April and November, where as Kingsburg, California received most of its rainfall between January and April. To have more confidence in this conclusion we would need many more years of data.

As another example, students at Juuan Lukio/ Poikolan Koulu in Finland, in looking at a graph of rainfall and liquid water equivalent of snowfall may determine that their school receives most of its precipitation as snowfall. See Figure AT-PP-10.

Some simple calculations can be done with precipitation data. One of the most useful quantities that scientists use in looking at precipitation patterns is to look at the total amount of precipitation a given location receives in a certain time period (e.g., a week, a month, a season). To calculate these totals, students simply sum the precipitation data for a site for the time period desired

Figure AT-PP-11 is a comparison of rainfall over 11 days in March of 1999 between Ecopolis Center Junior Eco Club in Tokyo, Japan and Konigliches Athenaum Eupen in Eupen, Belgium.

We can obtain the actual numerical data for this time period for these two locations from the GLOBE archive:

GLOBE Data from Ecopolis Center Junior Eco Club, Tokyo, Japan from 03/05/1999 - 03/15/1999

Precipitation Rain

YYYYMMDD	LATITUDE	LONGITUDE	ELEVATN	SCHOOL	SITEID	RAINAMT	PH_RA	M
19990315	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.0	-99.0	0
19990314	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.0	-99.0	0
19990313	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.0	-99.0	0
19990312	35.4100	139.4000	10.0	RHG2H7U	ATM-01	3.0	4.7	3
19990311	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.0	-99.0	0
19990310	35.4100	139.4000	10.0	RHG2H7U	ATM-01	7.7	4.1	3
19990309	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.2	-99.0	0
19990308	35.4100	139.4000	10.0	RHG2H7U	ATM-01	12.0	5.1	3
19990307	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.0	-99.0	0
19990306	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.0	-99.0	0
19990305	35.4100	139.4000	10.0	RHG2H7U	ATM-01	0.8	6.1	3

GLOBE Data from Konigliches Athenaum Eupen, Eupen, Belgium from 03/05/1999 - 03/15/1999

Precipitation Rain

YYYYMMDD	LATITUDE	LONGITUDE	ELEVATN	SCHOOL	SITEID	RAINAMT	PH_RA	M
19990315	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.0	-99.0	0
19990314	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.0	-99.0	0
19990313	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.0	-99.0	0
19990312	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.0	-99.0	0
19990311	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.2	-99.0	0
19990310	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.0	-99.0	0
19990309	50.6292	6.0262	290.0	Tec1tGH	ATM-01	1.2	-99.0	0
19990308	50.6292	6.0262	290.0	Tec1tGH	ATM-01	1.6	-99.0	0
19990307	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.4	-99.0	0
19990306	50.6292	6.0262	290.0	Tec1tGH	ATM-01	4.2	-99.0	0
19990305	50.6292	6.0262	290.0	Tec1tGH	ATM-01	0.4	-99.0	0

We can calculate the total amount of rainfall each location received between 5 March and 15 March by adding up the rainfall each day (including those days that received zero rainfall)

For Ecopolis Center Junior Eco Club, Tokyo, Japan

0 + 0 + 0 + 3.0 + 0 + 7.7 + 0.2 + 12.0 + 0 + 0 + 0.8 = 23.7 mm

For Konigliches Athenaum Eupen, Eupen, Belgium

0 + 0 + 0 + 0 + 0.2 + 0 + 1.2 + 1.6 + 0.4 = 3.4 mm

We have now confirmed with calculations what we suspected by looking at the graph, the school in Japan received much more rainfall during this time period than did the school in Belgium. This large difference in the amount of rainfall between the school in Japan and the school in Belgium leads to many questions, for example: What is the total yearly rainfall at these two locations? What kinds of plants grow in these two locations? What kind of springtime weather do these places experience?

Student researchers should consider comparing precipitation totals, averages, and extremes between different schools or locations. You can compare monthly total precipitation from one year to another and look at the pattern in these totals over the year.

Precipitation data are important in understanding patterns of plant growth and the cycling of water in the environment. See *Green-Up Protocol Looking At the Data*. In some places, knowing the amount of precipitation is important for managing scarce water supplies. For instance, operators of dams may release more or less water through their dams depending on rainfall or snowmelt.

The actual input of water to the ground and water bodies (streams, rivers, lakes, etc.) is important for use in both plant growth and water resources studies. With rain this input is immediate, but with snow the amount of water produced when the snow melts is more crucial to know than the amount of snow that falls. If a location receives enough snow to build up a snow pack, a series of GLOBE measurements of the rain equivalent of new snow and snow pack can be taken to help with these studies.

For example, a school collects the data shown in the Table AT-PP-3.

Table AT-PP-3

Date	Days of Accumulation	New Snow (mm)	Rain Equivalent (mm) R_{NEW}	Snow Pack (mm)	Rain Equivalent (mm) R_{PACK}
12/10/99	1	0	0.0	0	0.0
12/12/99	1	0	0.0	0	0.0
12/13/99	1	0	0.0	0	0.0
12/14/99	1	10	1.5	10	1.5
12/15/99	1	110	5.5	120	7.0
12/16/99	1	5	1.0	110	7.5
12/17/99	1	0	0.0	110	7.5
12/18/99	1	75	8.7	180	16.0
12/19/99	1	30	M	200	M
12/20/99	1	30	3.0	200	18.0
12/21/99	1	0	M	185	M
12/22/99	1	0	M	185	M
12/23/99	1	0	0.0	180	17.0
12/24/99	1	—	M	180	M
12/25/99	1	—	M	190	M
12/26/99	1	—	M	200	M
12/27/99	1	178	22.4	335	39.5
12/28/99	1	—	M	320	39.0
12/29/99	1	8	0.5	320	39.0
12/30/99	1	33	M	350	M
12/31/99	1	28	5.5	360	48.0

From these data, these students can calculate the amount of water released into the environment. This calculation is:

Release amount (mm) = R_{NEW}(today) + R_{PACK} (yesterday) - R_{PACK} (today)

So for December 18, the release amount, stated as the equivalent depth of rain, was:

$$8.7 + 7.5 - 16.0 = 0.2 \text{ mm}$$

If there is no new snow between two dates, the release amount is simply the difference of the rain equivalent of the snow pack on the two days.

Some scientists studying climate investigate the interaction of sunlight with Earth's surface. For these investigations the presence or absence of snow on the ground is important. In their analyses, these scientists examine where and when there is snow on Earth's surface and often relate this information to satellite data. Students may ask how many days a year is there snow on the ground? What are the first and last days of the year when there is snow the ground?

Precipitation is a major way in which trace gases and aerosols are removed from the air. Most of this removal happens at the beginning of a storm; the first few millimeters of rain or centimeters of snow cleans the air. Scientists investigating atmospheric composition are interested in how often precipitation events occur that are large enough to remove trace gases and aerosols. Scientists are also interested in how much of an area experienced rain or snow because a localized storm only affects a small area, leaving the composition of the surrounding air largely unchanged. For this, they may look at cloud data (nimbostratus versus cumulonimbus clouds precipitation) or data from nearby GLOBE schools.

When looking at precipitation pH data, most interest is in the short-term average of precipitation pH and the trend of precipitation pH over time. A single reading of a very high or very low precipitation pH may not be significant, however, if over a period of time the precipitation pH continues to be either very high or very low, scientists begin to worry about the effects on local ecosystems.

Effects of very high pH precipitation on ecosystems have not been studied as much as the effects of low pH precipitation ("acid rain"). Some plants and animals can tolerate relatively high levels of acidity, where others may be very sensitive to even small decreases in pH. The effects of acid precipitation are usually seen the most in water bodies such as streams and lakes, or in wetlands such as marshes. The land cover and soils surrounding them also affect the pH of water flowing into these habitats. As water with low pH flows through soils, aluminum is released from the soils and this can cause additional stress in the environment. Thus, when scientists examine data on precipitation pH, they particularly look for values that are low over a long period of time. Scientists studying watersheds will look at precipitation pH along with soil pH and prevalent types of vegetation and land cover in their efforts to understand what is controlling or influencing the pH of water bodies.

Figure AT-PP-12 shows the precipitation pH for two schools in the Czech Republic from January 1998 through July 2001. The first thing we note from this graph is that neither school received precipitation that is very acidic. The lowest precipitation pH that either school reports is about 4, and this value is not common. The second thing we notice is that there doesn't appear to be an overall trend in precipitation pH over time at either school. That is, it doesn't appear that from early 1998 until the middle of 2001 there has been a steady increase or decrease in the pH of precipitation at these two locations. The next thing that scientists would want to explore after looking at the data from these two schools is to try to understand the differences in precipitation pH at these locations. Why is the precipitation pH at Gymnazium Dr. A. Hrdlicky systematically higher than at Zalkadni, and what does that mean for the ecosystems in these areas?

Two Examples of Student Research Investigations – Example 1: Rainfall Amount

Forming a Hypothesis

A student from CEG Adjohoun School in Adjohoun, Benin has been comparing GLOBE temperature measurements made at his school with other schools around Benin. He notices that during the time period from May through June of 2001 the average temperature measured at his school is typically somewhat greater than it is at another GLOBE school in Avrankou, Benin. See Figure AT-PP-13.

Looking at this graph makes the student wonder if this type of pattern is true for other GLOBE measurements. To begin his research, the student hypothesizes that;

Average rainfall in Adjohoun is greater than in Avrankou during the period of May through June of 2001.

Collecting and Analyzing Data

Data for rainfall have already been collected at both of these schools, so the first thing this student does is to graph the data. See Figure AT-PP-14.

After looking at the graph, the student decides that he really needs to create a data table with the values from this graph in order to determine if the average amount of rainfall received at Adjohoun really is greater than the rainfall received at Avrankou. He can easily retrieve the data from the GLOBE archives for each school, then save the information in one of several ways: by printing the table from the computer; by cutting and pasting the data into a spreadsheet; or by copying the data down on a sheet of paper by hand.

Next, the student needs to decide on a timescale to look at the rainfall data. He knows that daily rainfall varies a lot and in some cases he doesn't have daily values of rainfall, but has accumulated rainfall. He initially decides to calculate the total rainfall for this two-month period for both sites. To do this he adds up all the precipitation amounts for a given site.

He creates a table of the data:

Month	Rainfall Adjohoun (mm)	Rainfall at at Avrankou (mm)
April	124.4	162.0
May	118.2	282.7
June	161.3	193.8

The student finds that for Adjohoun, the rainfall for May and June of 2001 is 279.5 mm. His calculations show that during this same time period Avrankou received 476.5 mm of rain. Based on these sums the student concludes that, at least for these two months, Adjohoun received less rainfall than Avrankou, and his original hypothesis is not supported by these data.

Communicating Results

The student then presents an oral report to his teacher and class on his research. He explains to them his hypothesis and how he carried out his research. He shows them the data he has used and the calculations he has made. In addition, he discusses with the class what further research might be done, such as looking at a longer data record (perhaps for several years).

Example 2: Precipitation pH

Forming a Hypothesis

Students from Zakladni Skola – Ekolog, Praktikum in Jicin, Czech Republic have been taking measurements of precipitation and precipitation pH for a number of years. Several students decide to analyze these two data sets to see if there is a connection between the amount of rainfall received and the pH of the rainfall.

The students' first task is to choose a time period for their study, and then graph the data. The graph of rainfall amount and rainfall pH for two and a half years is shown in Figure AT-PP-15. Based on their examination of this graph, the students formulate the hypothesis that; As the amount of precipitation increases, the pH of the precipitation decreases.

Collecting and Analyzing Data

The first step in testing this hypothesis is to gather the data from the GLOBE archives. The data can be saved by printing the table from the computer, cutting and pasting the table into a spreadsheet, or copying down the values by hand. The students only need the data for those days where both rainfall and rainfall pH are reported.

The students then must decide how to analyze the data. In this case, they decide to group rainfall amounts and calculate the average pH for each group. They put the rainfall data into groups from 0.1 - 4.9 mm of rainfall, 5.0 - 9.9 mm, 10.0 - 14.9 mm, and so on. Then they calculate the average pH for each of these groups, and look for any trend in pH values as rainfall amounts increase. The following table gives their results:

Rainfall amount (mm)	Number of data points	Average pH
0.1 – 4.9	202	4.59
5.0 – 9.9	56	4.53
10.0 – 14.9	29	4.44
15.0 – 19.9	3	4.50
20.0 – 24.5	6	4.55
25.0 – 29.9	4	4.40
30.0 – 34.9	1	4.00
40.0 – 44.9	2	4.65
95.0 – 99.9	1	4.30

Notice that the students have started their rainfall amount with 0.1 mm instead of 0.0. This is because if the rainfall amount is zero, there can't be any pH value of rainfall. Also notice that the table of rainfall amounts isn't continuous (that is, some categories are missing) because there were no rainfall amounts in the data archive between those values.

The students decide from their calculations that there are too few data points in the rainfall categories above 14.9 mm for those calculations to be reliable. They focus instead only on the first 3 categories from their table.

Rainfall amount (mm)	Number of data points	Average pH
0.1 – 4.9	202	4.59
5.0 – 9.9	56	4.53
10.0 – 14.9	29	4.44

From these three points, there does seem to be some trend – there is an indication that the pH of the rainfall is slightly more acidic when more rain falls. This is an interesting result, and appears to support the students' hypothesis.

Communicating Results

The students decide to submit their research to a science fair. They create a poster that contains information about their hypothesis, the steps they took in doing their research, their data, calculations, and results. On their poster the students note that before they could positively conclude that rainfall pH decreases as the amount of rainfall increases, they would want to do some further calculations.

Future Research

The students would like to have a longer data record so that perhaps they would have more data at higher values of rainfall. They would also break the data up into smaller groupings, perhaps from 0.1-1.0 mm, 1.1-2.0 mm, and so on. If they find that their hypothesis is confirmed, the students could explore other variables, such as wind direction, length of rainfall event, or other parameters they think might be important, to determine why the pH decreases with increasing rainfall amounts.

The students also wonder if the pH value of rainfall changes during a single rain event. They propose that further study could be carried out by an experiment using the techniques they learned in the GLOBE protocols. In this case, however, the students propose that rather than collecting rainfall for 24 hours and then measuring the pH, they would set up an experiment on a rainy school day. The students would collect samples once every hour throughout the school day, and measure the pH of the rain for each hour of the rainfall event. They would then plot their data and see if there is a change in the pH of the rain as the storm goes on.

Figure AT-PP-9

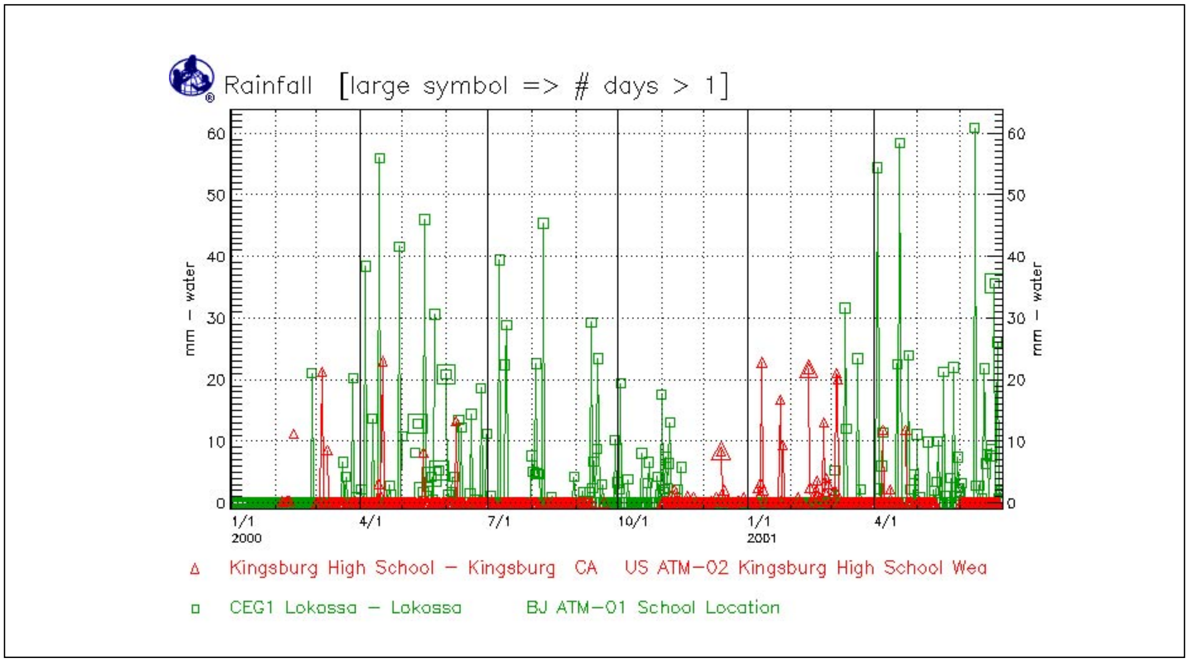


Figure AT-PP-10

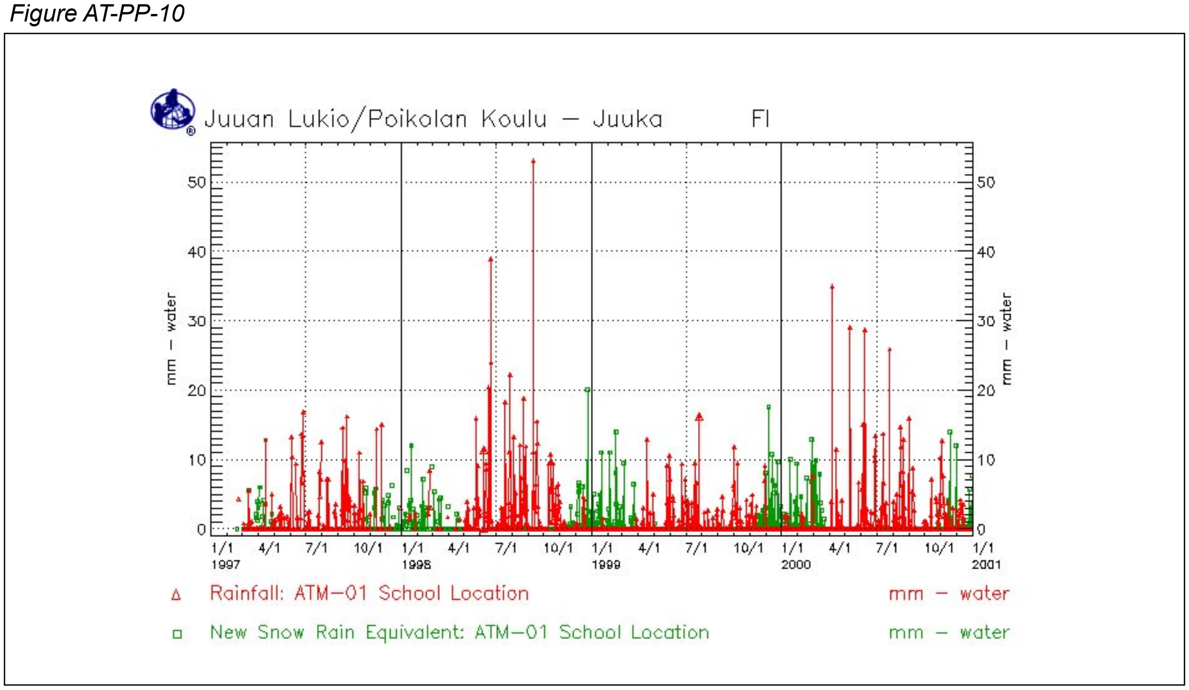


Figure AT-PP-11

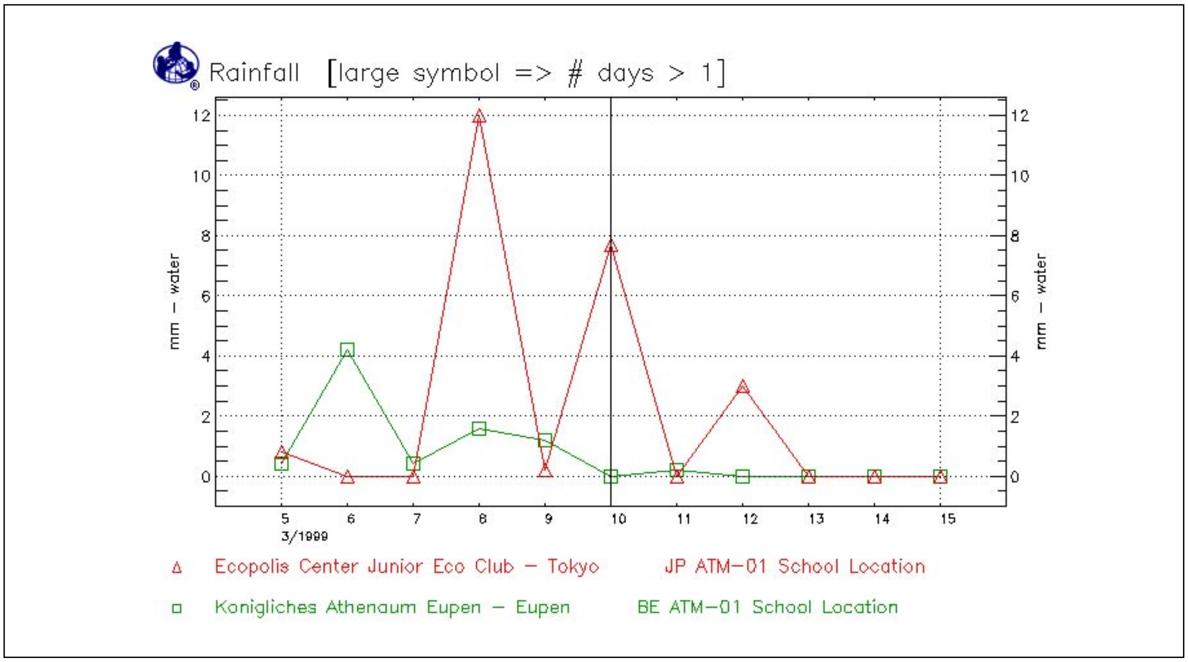


Figure AT-PP-12

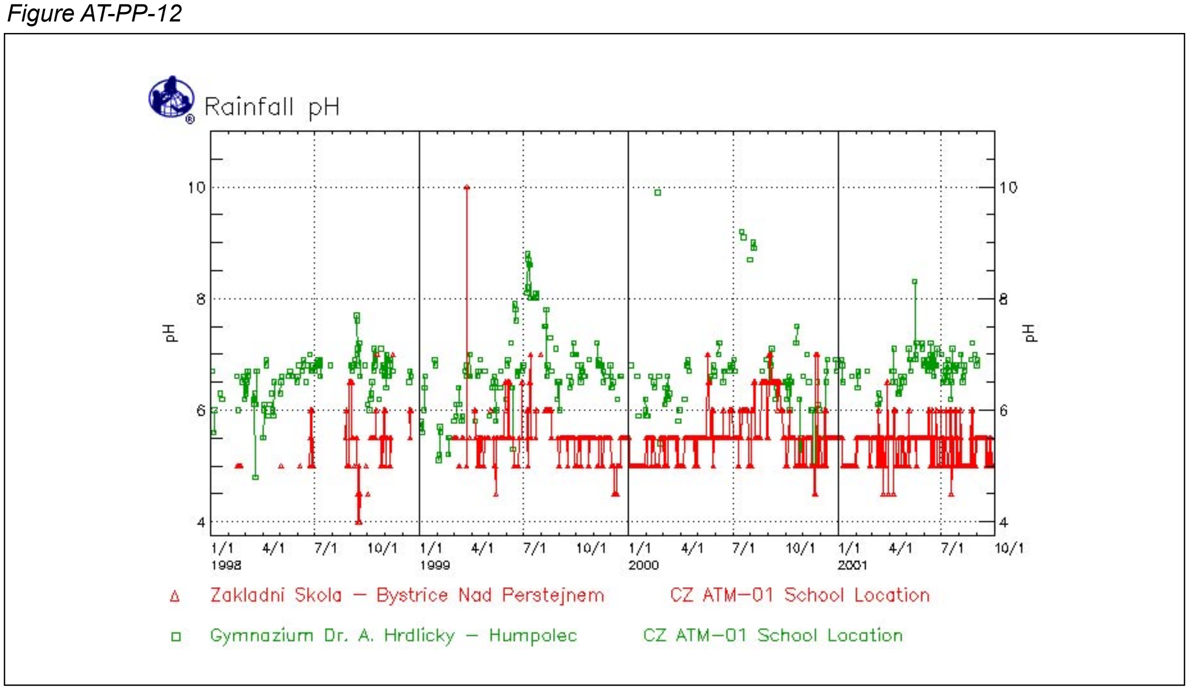


Figure AT-PP-13

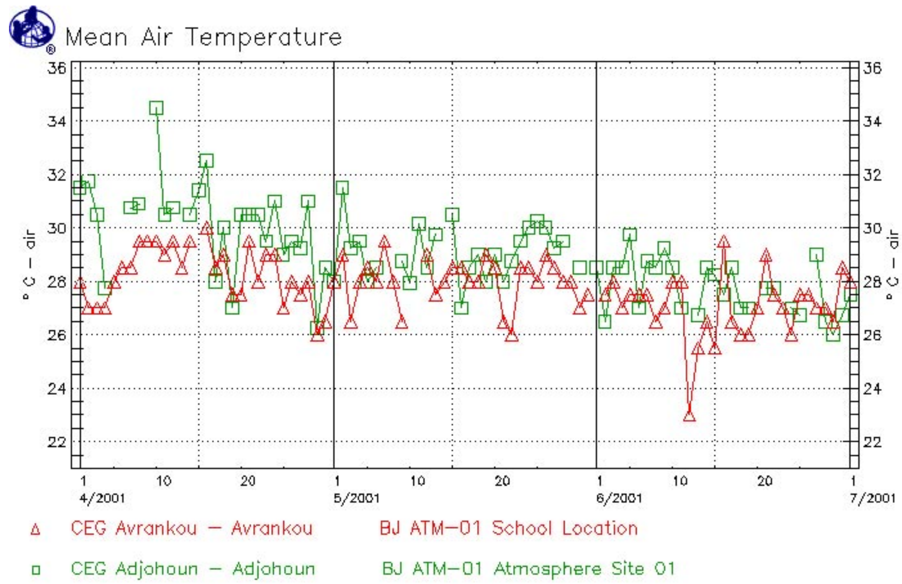


Figure AT-PP-14

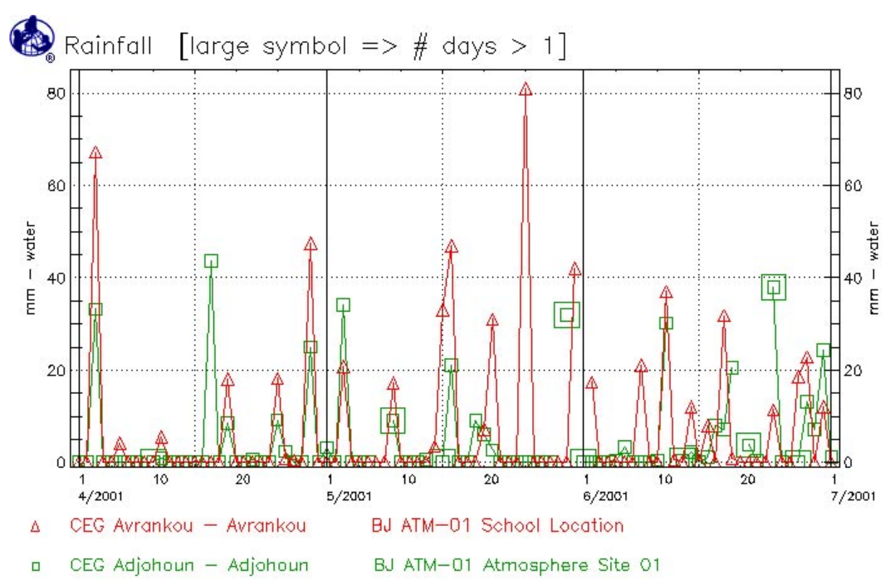


Figure AT-PP-15