# Letter

Welcome to TAHMO and S2S!

This document is meant for teachers who maintain TAHMO weather stations or who want to use TAHMO data in their classes. Most of this volume consists of lesson plans incorporating TAHMO weather data. There is also information about maintaining your observation equipment. When you have questions or comments about the program, equipment, data, or lesson plans, look at the section entitled “My Important Information and Contacts” to see who might best respond. TAHMO is glad to have you as a participant and we are here to help you!

# TAHMO SCHOOL-2-SCHOOL GUIDE

## Version 1

## Table of Contents

# My Important Information and Contacts

Station Name: ____________________________________________________________________

Station ID Number: ________________________________________________________________

My TAHMO representative's name and contact information: ________________________________

The School-2-School representative's email: ***s2s@tahmo.org***

S2S web site: ***School2School.net***

TAHMO web site: ***http://tahmo.org/***

Stepwise cleaning demonstration on YouTube: ***https://youtube/n9KGaUHkUP0***

## What is TAHMO?

“TAHMO” stands for Trans-African Hydro-Meteorological Observatory. It is network of automated weather stations across Africa. Stations are strategically placed to facilitate comprehensive weather monitoring over the entire continent. There are currently about 500 stations in operation, and the goal is to have a total of 20,000 by 2030.

TAHMO is a cooperative and cost-effective way to advance scientific knowledge about African weather and hydrology. Support for station equipment is provided by the weather station manufacturer, Meter Group, and station maintenance is performed by TAHMO’s local technical engineers. Generally, stations are installed at schools or on farms where volunteer operators commit to regular maintenance and sharing data collected at their station with the entire network.

Information collected from each TAHMO station is automatically transmitted by cell phone to a central server. Once on the server, data are processed for quality control and saved in a standard and easily used format. Schools and research institutions have free access to all TAHMO data for scientific research, educational purposes, and governmental applications. Having an integrated network of automatic weather stations across Africa provides local weather information and supports regional and continental efforts that benefit weather forecasting and modeling, agricultural productivity, flood control, emergency preparation, range and wildlife management, and environmental stewardship.

Specifically, the TAHMO project aims to:

- greatly increase the number of weather-monitoring sites in Africa
- place weather stations so that no large geographic areas are without monitoring
- create a geographically comprehensive network for long-term weather sampling
- develop an extensive network of the historical record of African weather conditions
- manage data for quality and historical security
- provide ready access to weather data in an open process and standardized format
- encourage schools to participate in station operation and data collection and analysis

## What is the School-2-School Program?

Simply collecting weather data is not enough. There must be bright minds to make use of the data. TAHMO has created the School-2-School (S2S) program to stimulate hands-on learning using data to which students can immediately relate. Weather stations placed at schools provide local, contemporary data that can be readily integrated into the curriculum. The lesson plans in this book are specifically designed to introduce students at all levels to working with relevant quantitative information. They will develop skills in calculation, graphing, computer applications, scientific inquiry, and technical writing. Students are encouraged to use their skills in pursuit of advanced training and professional practice in agriculture, meteorology, climatology, hydrology, ecology and environmental management.

Schools provide an ideal location for TAHMO stations for several reasons. Schools are established locations where long-term monitoring can be maintained well into the future. Generally, school sites offer some security that minimizes tampering with the instruments. Having a weather station on site instills curiosity and pride of ownership in students, teachers, and the community. This creates a natural opportunity for schools to incorporate weather data into their curriculum. Leaning activities directly relate to students' everyday life.

The S2S program encourages schools in Africa to share data, ideas, and educational resources with each other. Even schools that do not host a weather station or are not located in Africa can participate in S2S. A S2S representative can help any school find a partner in Africa, Europe, or the United States for sharing weather data, lesson plans, or other mutually beneficial materials.

### What is required for a school to host a TAHMO station?

Schools with TAHMO stations are responsible for general maintenance. This includes:

- inspecting the instruments for any damage or potential problems
- wiping off the solar sensor
- removing any debris from the rain gauge
- promptly reporting any issues to a S2S representative or the TAHMO country representative.

Maintenance instructions are provided in a later section titled "Cleaning your TAHMO station".

### The School-2-School web site

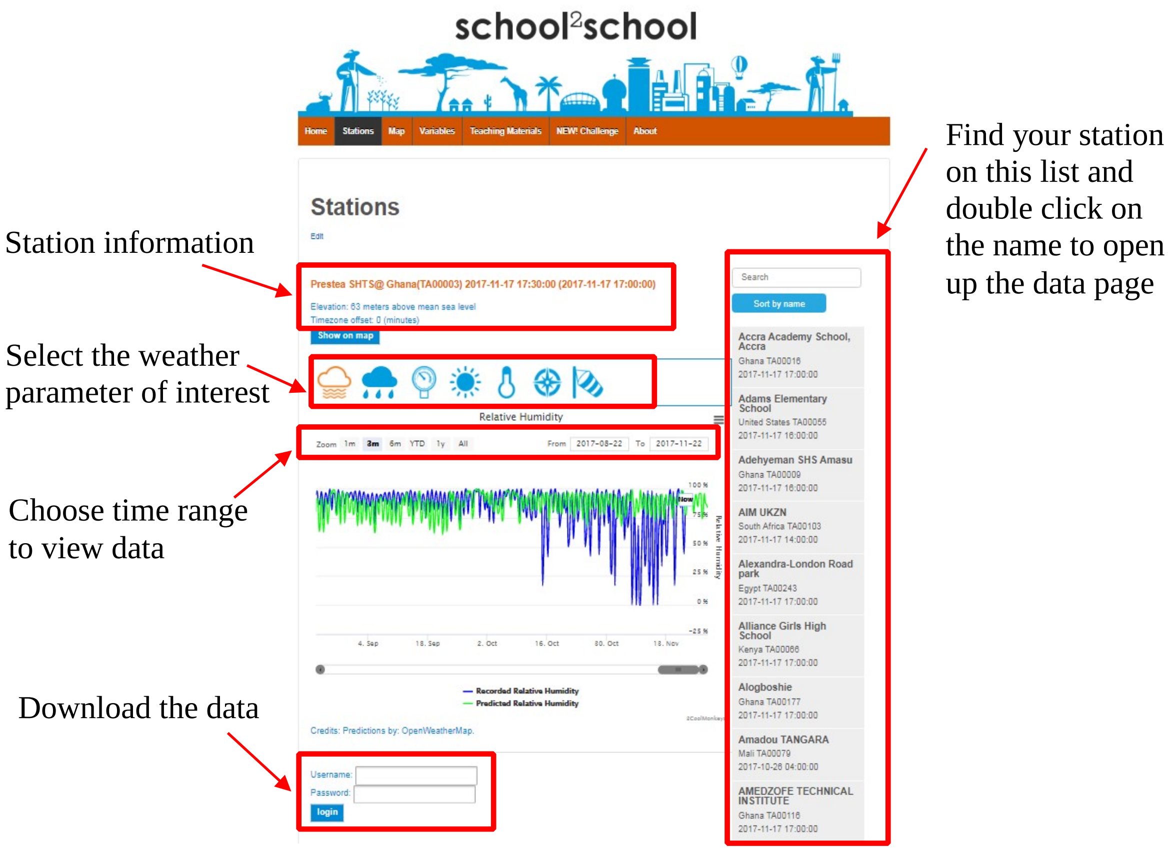
S2S maintains a website at School2School.net for participants and guests. Resources that are available there include lesson plans using weather data in the classroom, video tutorials about the instrumentation, weather data, and help with downloading. There is a form there that lets you easily send email messages to School-2-School staff. This is also the place to learn about the monthly classroom challenges that stimulate conversations among schools across the globe. The main menu on the top of the web page contains tabs to help you navigate the site. The website material is also available in French- if you wish to change the language, use the toggle on the top right menu bar showing the flag and language name.

### Here are the steps to view selected data collected at your school (see figure, below):

1. Click on the "Stations" tab: school2school.net/stations/
2. Search for your school name in the list on the right side of the page; double-click on the name to get specific information for that station.
3. The page will reload and now your station name should be written in orange text on the top of the page. Other station information displayed includes station ID, elevation of the station, and time zone offset.
4. Select the weather parameter of interest to graphically view its data. The measured parameters generally available relative humidity, rainfall amount, barometric pressure, solar radiation, air temperature, wind direction, and wind speed, listed in that order.

5. Click on the icon of the parameter you want to view. The icon is highlighted orange, and the values are plotted over time.

6. Choose the time range of interest to display a more detailed graph.




## How to download the entire data series for your station:

You must log in at the S2S web site to download data for your station. After your station is installed, your TAHMO representative can give you user name and password. Schools that do not have TAHMO stations can access a nearby station's data by requesting login information from a School-2-School representative. You can also download station data for a select number of stations in various countries using the username "guest" and password "guest".

1. Scroll down past your graph and fill in the two boxes with your user name and password then click on the "login" button.

2. Scroll further down the page and click on the button labeled "download."

3. The downloaded data are in a simple "csv" file consisting of columns (measured values) and rows (dates and times). The file can be opened with common spreadsheet programs such Microsoft Excel and Google Sheets.

4. You may need to format the data in your spreadsheet before use. For more information on downloading and formatting downloaded data in Excel, watch two tutorial videos under the “Teaching Materials” tab at school2school.net.

### How to use data in your classroom:

An integral part of the School-2-School program is incorporating the weather data into classroom work. TAHMO aims to engage students and increase interest in sciences with S2S activities such as taking readings from the weather station, creating graphs and interpreting data to identify trends, making weather predictions, comparing weather and climates diverse regions, and understanding how the weather sensors work.

Activities described in this book make use of real-time weather data collected from TAHMO stations at schools like yours. Schools without their own weather station can also be part of the S2S program; simply email the S2S representative to request log-in credentials for a nearby station.

The lesson plans are listed in an introductory table indicating their topics, suggested class levels, computer needs and other features to help you select activities suitable for your class. Each plan provides versions for both students and teachers.

Lesson plans are periodically updated and added on the S2S web site. Look for the tab labeled “Teaching Materials” at school2school.net, or directly at school2school.net/teaching-materials/. They are described on the web site as well by activity level, subject, duration, type, and required materials. Clicking on its name will open a lesson plan in your browser.

### The S2S Challenge Series

TAHMO’s School-2-School program invites you to collaborate with teachers and students around the globe. To stimulate sharing, TAHMO is hosting the School-2-School Challenge Series which is open to teachers and students at any grade level, even if they are not currently part of S2S program.

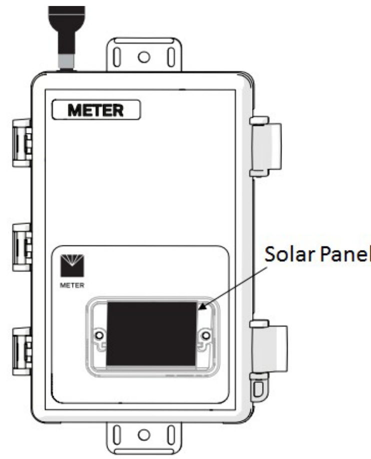
Challenges will occur ~6x per year, and should take less than one hour to complete. Challenges will range from classroom discussions, cleaning the school’s weather station, or completing a pre-made TAHMO lesson plan with your classroom. To complete the challenge, you will provide a photo of your classroom completing the challenge and submit it to a S2S representative via Facebook, WhatsApp, or email. Please submit one entry per class. Each challenge is announced in the monthly S2S email (The same information will be available on the School-2-School website under the “Challenge” tab: https://school2school.net/challenge/). Winning entries will be featured in the next month’s newsletter and receive a certificate of outstanding performance. Any school participating in all challenges in a year will be featured as our winning school on the TAHMO web page and in the TAHMO newsletter.

# Cleaning your TAHMO Station

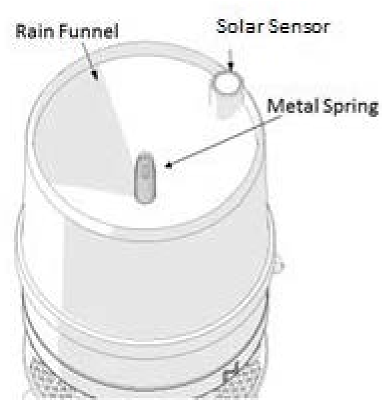
The TAHMO station needs to be checked every month to verify there are no obstructions and all instruments are clean. When you clean the station, you will need to bring a chair/stool to reach the station, a damp cloth, and paperclip or stick.

Go to the location of your TAHMO weather station. Enter the fenced area, closing the gate after you, and set up the chair or stool securely so you can reach the top of the weather station. To clean the weather station, complete the following three tasks:

1. Wipe off the solar panel on the data logger box using the cloth.
2. Wipe off any dust from the solar sensor using the cloth. The solar sensor is located on the side of the rain funnel and is a small circle.
3. Remove any leaves, bugs, or bird droppings from the rain funnel using the cloth. The rain funnel is located on the top of the weather station. You can use a paperclip or stick to remove any twigs from the spring.




Only remove the rain funnel if is very dirty and needs more extensive cleaning. You can remove the top of the rain funnel by pressing down and twisting it off counterclockwise. Use caution when opening the device to be careful not to break the wires connecting the solar sensor to the main body of the TAHMO station. Carefully disconnect the wire and continue cleaning. You can remove the metal spring in the center of the rain funnel in order to remove any pieces blocking the funnel. Re-secure the metal spring by gently pressing and turning the spring into the funnel hole. When you replace the funnel onto the weather station, plug back in the wires then align the funnel by pressing down and twisting clockwise.




Remember to close and lock the gate when you leave. Thank you for helping to keep the station running and producing quality data for use in agriculture, disaster management, and climate adaptation!

If you have concerns about your station or are having problems cleaning your station including finding the rain funnel, solar sensor, or solar panel on your station, please email your TAHMO country representative for help or email info@tahmo.org or S2S@tahmo.org. Additionally, please contact us if you have any other concerns about your station.

The next page provides a checklist and a cleaning schedule that should be filled out each month to ensure regular cleaning. Please place the day of the cleaning and a check or remark in each box when the function is performed.

**Monthly Checklist**

1. Wipe the solar panel
2. Wipe the solar sensor
3. Wipe the rain gauge
4. Check whether the data for all the parameters: school2school.net
5. Clean the weather station site

| | **Jan**<br>Day: | **Feb**<br>Day: | **Mar**<br>Day: | **April**<br>Day: |
|---|---|---|---|---|
| Wipe Solar Panel | | | | |
| Wipe Rain Gauge | | | | |
| Sonic Mirror | | | | |
| Does the station show data for all parameters? | | | | |
| REMARKS: | | | | |

| | **May**<br>Day: | **June**<br>Day: | **July**<br>Day: | **August**<br>Day: |
|---|---|---|---|---|
| Wipe Solar Panel | | | | |
| Wipe Rain Gauge | | | | |
| Sonic Mirror | | | | |
| Does the station show data for all parameters? | | | | |
| REMARKS: | | | | |

| | **September**<br>Day: | **October**<br>Day: | **November**<br>Day: | **December**<br>Day: |
|---|---|---|---|---|
| Wipe Solar Panel | | | | |
| Wipe Rain Gauge | | | | |
| Sonic Mirror | | | | |
| Does the station show data for all parameters? | | | | |
| REMARKS: | | | | |

If any sensor is not working, or your school require assistance, please contact your country coordinator, or send an email to s2s@tahmo.org

# Table of Contents

# Water Cycle: Teacher Guide

**Level:** Beginning

**Subject:** Geography

**Duration:** 30 minutes

**Type:** Classroom discussion

**Learning Goals:**

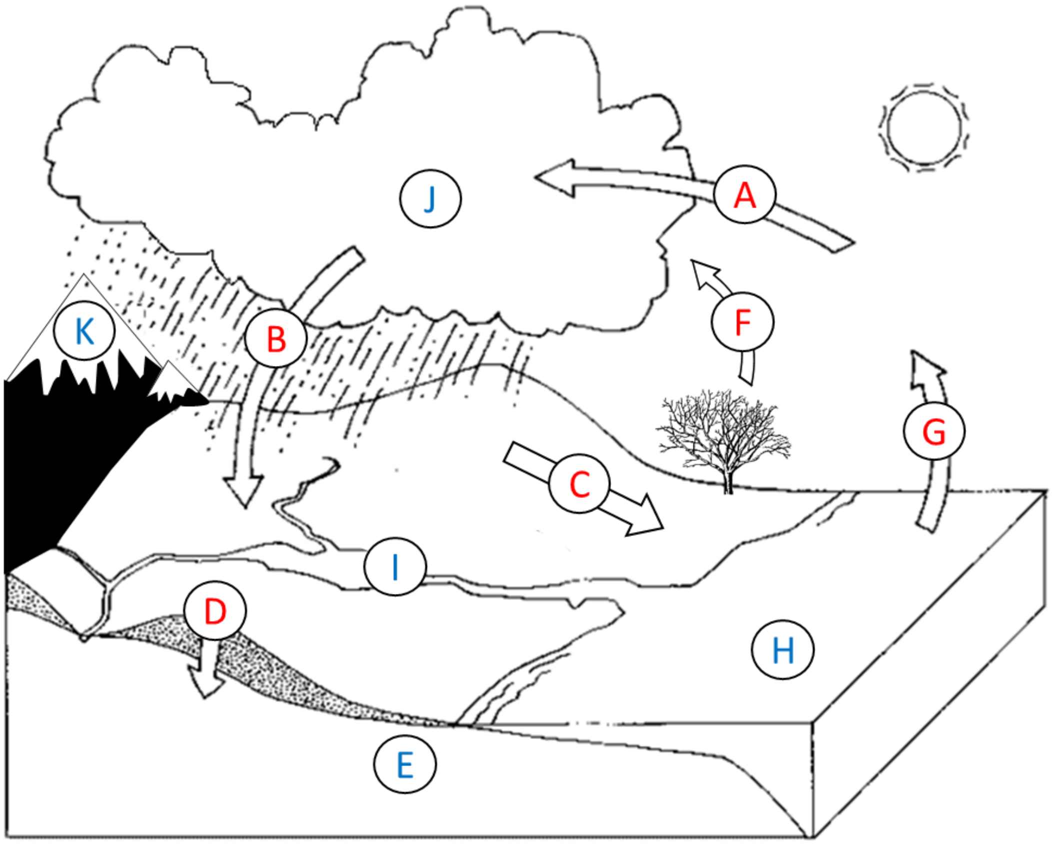
- Define each component of the water cycle
- Investigate the movement of water through the different stages of the water cycle
- Be able to explain the driving forces of the water cycle

**Background:**

- Water is found almost everywhere on Earth, from high in the atmosphere (as water vapor) to low in the atmosphere (precipitation, droplets in clouds) to mountain snowcaps and glaciers (solid) to running liquid water on the land, ocean, and underground. Sunlight causes evaporation and propels oceanic and atmospheric circulation, which transports water around the globe. Gravity causes precipitation to fall from clouds and water to flow downward on the land through watersheds.
- Energy from the sun and the force of gravity drive the continual cycling of water among these reservoirs. As the water is heated, it changes state from a liquid to a gas. This process is called evaporation. As more energy is added to the water, the water molecules move faster and farther apart. When water vapor is warmer and less dense than the surrounding air, it rises.
  Transpiration is the process that a plant takes up water through its roots and then gives off unused water from their leaves.
- As water vapor cools it condenses. This process changes the water's state from vapor to liquid. When a cloud's droplets join together and get too big to overcome gravity, they fall from the clouds as either rain or snow. When excess water falls on the land it will flow downhill as runoff.
- Infiltration occurs when water seeps into the land surface. The water fills pockets of air in the soil and rock. Water infiltrates because of the force of gravity. When the water reaches an impermeable layer, it creates an aquifer.

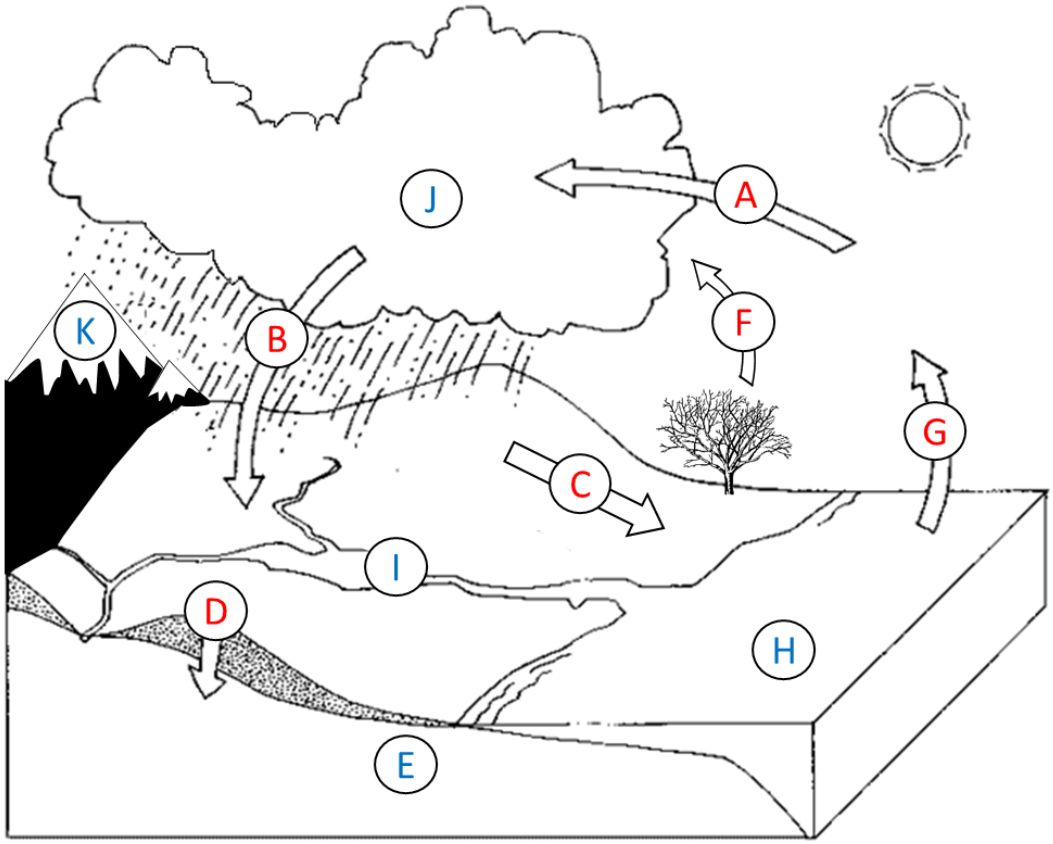
*Optional Follow-up Lesson Plan* the "Water Cycle Game" lesson plan that more deeply looks into the complexities of the water cycle. Look for it on the S2S website under Teaching Materials.

**Discussion:**




- Start by asking the class what the water cycle is, be sure to let multiple students give their interpretations. [Answer: The water cycle, also known as the hydrological cycle or the hydrologic cycle, describes the continuous movement of water on, above and below the surface of the Earth.]
- In small groups, ask students to come up with a list of places that we find water on the Earth. You may want to mention that water can be in the form of a gas (water vapor), a liquid (water), and a solid (ice) and that students should include all of the forms of water. [Answer: Clouds and atmosphere (liquid water and water vapor), river and lakes (liquid water), oceans (liquid water), glaciers and icebergs (ice), and groundwater (liquid water).]
- Identify the water sources on the water cycle plot. [Answer: H is Ocean, J is atmospheric water, I is surface water, K is snowpack, E is groundwater]
- Of these sources of water, which do you think there is the most of? [Answer: 96.5% Ocean, 1.7% glaciers/icebergs, 1.7% groundwater, 0.1% rivers/lakes, 0.01% clouds/atmosphere]
- What are the processes that move water between the different sources of water? These processes are shown with arrows in the water cycle diagram, ask the class think about each of these arrows and decide what sort of things are happening at each arrow. [Answer: at G the water is evaporating from the oceans and changing state from liquid to gas; at A the water is condensing and changing state from gas to liquid; in B the water is falling from the cloud to the land surface as precipitation; at C the excess water is flowing on the surface as runoff; at D the precipitation is being infiltrated into the soil and groundwater]

# The Water Cycle: Student Worksheet




Match the letters in the diagram above to the correct term in the list below:

1. Condensation _____
2. Groundwater _____
3. Infiltration _____
4. Evaporation _____
5. Transpiration _____
6. Rivers and Lakes _____
7. Precipitation _____
8. Snow and Glaciers _____
9. Clouds _____
10. Runoff _____
11. Ocean _____

Which stages of the water cycle require solar radiation?

______________________________________________________________________________

Which stages of the water cycle are driven by the force of gravity?

______________________________________________________________________________

Describe at least two different paths that water can take in the water cycle using the figure above. Start in the ocean.

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

V.1

# Temperature Cycles: Teacher Guide

**Level:** Beginning

**Subject:** Geography

**Duration:** 1 hour

**Type:** Small group activity

**Learning Goals:**

- Explain how temperature affects our daily life
- Create a table and a graph of local daily temperature
- Describe the general cycle of temperature changes including maximums and minimums, average, period and amplitude

**Materials:**

- Access to the School2School.net website

**Background:**

- Our bodies are constantly sensing the environment around us. One of the conditions that we are keenly aware of is temperature. Are you warm or cool right now? Temperature influences all plants and animals and controls many processes in our weather. We want to pay attention to temperature so we know how much to water crops, how much water livestock will need to drink, whether new fruit might freeze, and so on. That is why temperature sensors are important components in our weather stations.
- The familiar thermometer pictured above is a reliable temperature sensor. It works because the colored liquid in the thin tube expands as it gets warmer. The higher the temperature, the greater the expansion. The amount of expansion is measured by a ruler next to the tube. The units on the ruler are degrees instead of mm. Other thermometers have expanding metal springs that rotate a pointer over a round dial. The temperature sensors in the TAHMO station are based on the very high sensitivity of electronic circuits to small changes in temperature.
- Let's look at what our station tells us about temperature in our location.

**Discussion:**

Our weather station makes several measurements of temperature, pressure, and other parameters every hour. All of the values are recorded along with the date and time on a computer. This process produces lots of information that we call data. We need methods to organize and analyze so much information. One of these methods involves putting data of interest into a table of rows and columns. Usually each column contains a different kind of information or observation. Each row presents all of the actual values of the measurements or observations at one sampling time. Below is an example of Table 1 that can be used:

Table 1. Temperatures that I "feel" at different times of the day

| **Column A: Some of my daily activities** | **Column B: Time of Day** | **Column C: My sensation of Temperature** | **Column D: Recorded Temperature** |
|---|---|---|---|
| Getting up in the Morning | | | |
| Lunch time (noon) | | | |
| Going home from School | | | |
| Dinner time | | | |
| Going to bed at Night | | | |

Students should look at the table and answer these questions about its structure on their student worksheet:

a. What are the column names? [Answer: Daily Activity, Time of Day, Sensation of Temperature, Recorded Temperature]

b. Will each column contain words or numbers? [Answer: Column B will contain number/times; Column C will contain words; Column D will contain numbers/temperatures and should include the units of Celsius]

c. What are the row names? [Answer: The row names are the list of your activities, answers may vary based on the student's individual activities]

d. What does the caption that goes with the table name tell you about the purpose of this table? [Answer: the caption tells you a summary about what the table is about and what information will be included in the table]

Table 1 is not yet very informative because most if its cells are empty. But can you see that it will be helpful in organizing some specific data about you? Let's start filling in the table.

a. Add in Column A two additional activities you have during a typical day.

b. Put the usual time of each activity into Column B.

c. In Column C, use words like "warm" and "cold" and several others to describe the "feel" of the air on your skin at each time.

Now the table says a lot about you and your evaluation of one aspect of your surroundings. Use the nicely organized information to explain it to a classmate. How does your information compare to his or hers? Write a few sentences that summarize your comparison.

We can easily get data from other sources to make Table 1 more complete. For instance, what are some actual temperature values during your daily activities? Look at the S2S website for your TAHMO station and identify the outside air temperature recently recorded by your TAHMO weather station for one day.

Make a new column, Column D, in Table 1 by first giving it a proper heading and then inserting actual temperature values from at the times of your listed activities.

Examine your expanded Table 1 and write brief answers to these questions:

a. What word might you use to describe how your body will feel when the thermometer reports a temperature of 35C? Why? [Answer: answers may vary, examples may include words like warm, hot, sweaty, sunny or other descriptions that indicate that the temperature is very close to the normal range of body temperatures]

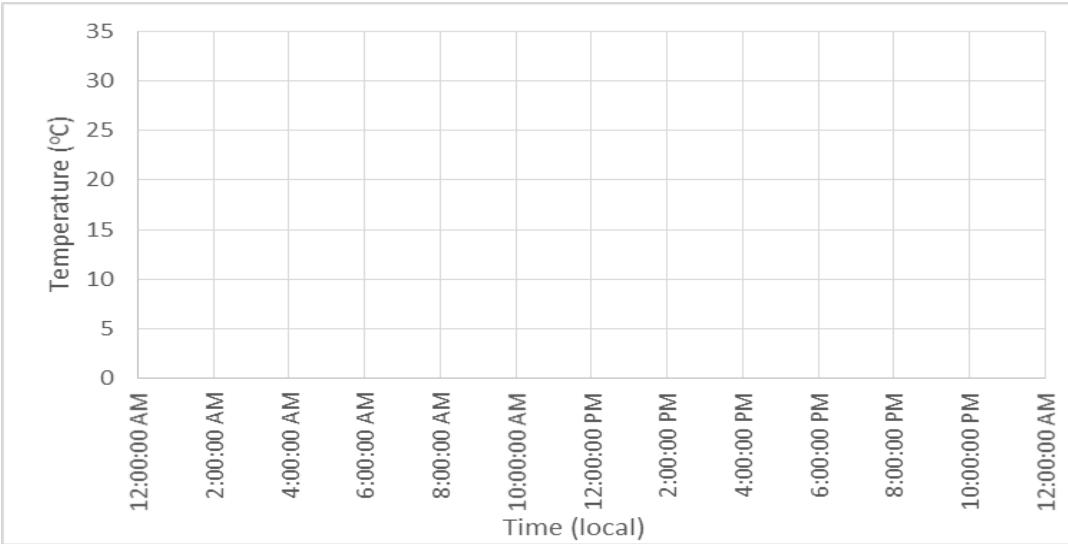
a. Give an example of a thermometer reading you would expect if you felt very cold. [Answer: answers may vary based on region, typical answer may range between 0 and 15 Celsius]

b. So, generally, how do the numerical values in Column D compare to your sensory descriptions in Column B? [Answer: answers may vary, examples: yes the sensory description accurately matches the actual temperature, or no because the student feels that the temperature is actually much warmer than they expected]

c. Consult with your classmates. Is there general agreement on the range of 'comfortable' temperatures? When do most of you feel cold? Hot? [Answer: answers may vary, comfortable room temperature is generally considered to be between 20 and 30 degrees Celsius]

A table is a good way to organize related data because it allows you to quickly look up specific values. A table is not a good way to represent data if you are trying to summarize information of display patterns in the data. A better way to detect trends in the data is by graphing them: if "a picture is worth a thousand words" then a graph is the picture of a table. So, let's make a picture of the information from Table 1. Figure 1 should have simple axis of time and temperature. Note that the graph, like a table, has a unique name and a brief description of its contents. Have the students place points on the graph for their activities (between 3 and 6 points is most appropriate). The time values from Column B of Table 1 will be shown on the horizontal axis of the graph. Temperatures from Column D are indicated on the vertical axis. Transfer the time and temperature information from Table 1 to Figure 1. Put a bold dot on the graph to indicate air temperature at each time listed in your table. You are not changing the data in any way, just presenting it differently, as a picture.

Figure 1. Air temperatures at the times of some of my daily activities




When you finish your graph, compare it to one that a classmate plotted. How are they similar? Write a few sentences that describe each of the following:

a. Your "picture" of temperature over time [Answer: answers may vary]

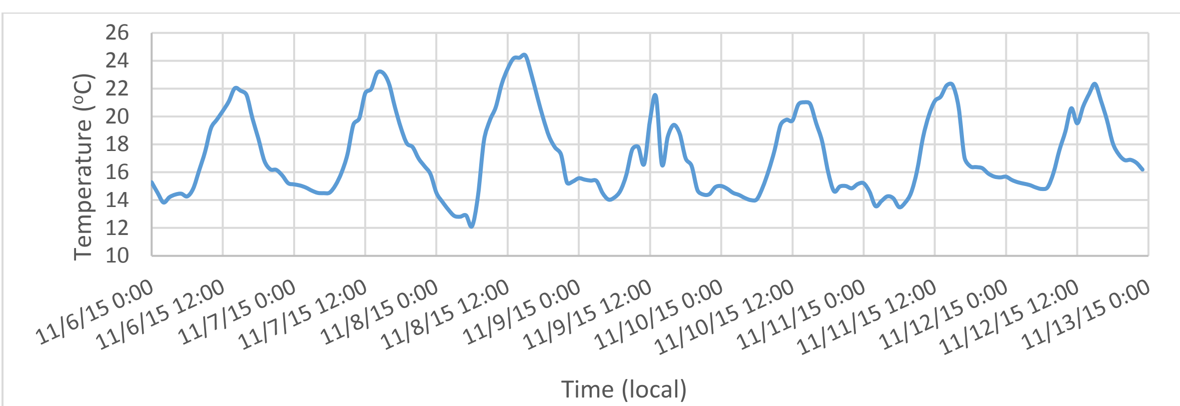
b. Your ideas about when a table should be used [Answer: answers may vary]

c. What a graph tells you that is not apparent in a table [Answer: it is generally easier to identify trends or patterns in graphs than in tables]

If you want a precise estimate of temperature, all you have to do is read a thermometer. But that may not always be convenient, e.g. when you are sleeping. As long as they are properly cared for, the instruments of a weather station like ours will make their readings, on schedule day or night, rain or shine. And when those data are recorded over a long period of time we can learn so much more than if we have just occasional readings.

Now you will start to look at multiple days of temperature data. It is preferred that you as the teacher download a week of temperature data from the TAHMO S2S website for your own station, but an example dataset is shown in Figure 2.

Figure 2. Hourly temperature measurements for St. Scholastica in Nairobi, Kenya for 11/6-13/2015



Using the week of temperature data, ask the students to look at the graph and examine is closely. Have the students write down, in their own words, their first impressions of this new graph, Figure 2:

a. What does the caption tell you? [Answer: the caption tells you about the axis (both x and y) and the location that the data is taken]

b. Next, look at the axes to determine what exactly is plotted. What is represented by the horizontal axis? What are the units and range of values? The vertical axis? [Answer: the horizontal axis, x-axis, is the local time and the axis displays both the data and the time in 12 hour increments; the vertical axis, y-axis, is the outside air temperature recorded in the units of degrees Celsius with a range from 10-26 degrees.]

c. How often was temperature recorded? For how many days? [Answer: the data is hourly data and it plotted for 7 days]

d. Did the temperature vary during a typical day? Is the variation similar to what you have observed in your Figure 1? [Answer: Yes, the temperature did vary during the day- the temperature starts lower in the morning and warms up during the beginning of the day, and then in the second half of the day the temperature beings to lower again]

Compare your first impressions with those of a classmate. Together, develop a question about temperature that can be answered by looking at this graph. Write down your question and give it to your teacher. [Teacher collects the questions and presents some to the class to practice interpreting the graph.]

Using the student questions about Figure 2, start a discussion with the class about the observations. Did any students notice that a similar temperature cycle happened every day? If no students brought up this topic, that is okay, simply start transitioning the topic to temperature cycles.

The regular up-and-down changes in temperature that occur almost every day are a cycle. There is a pattern that repeats itself – it goes round and round – every day. We can describe a cycle in specific ways. For instance, the time required for a single cycle is called its period. The range between the largest and smallest temperature values during a period is called the amplitude of the cycle.

Choose just one period of the several that appear on Figure 2. Draw and label vertical lines on the graph that mark the starting and ending times of the period. Write down your answers to these questions about that one period:

a. How did you decide where the period begins and ends? [Answer: The beginning of the period starts at midnight when the day starts and it ends at midnight. It is easy to choose this as the period because it divides the days based on date]

b. What are the highest and lowest temperatures during the period? So what is the amplitude of the period? [Answer: Generally the highest temperatures occur right after noon, and the lowest temperatures occur in the very early morning hours. During the first day (11/06/2015) the highest temperature is 22 degrees Celsius at 3pm, and the lowest temperature is 14 degrees Celsius and occurs at 2am]

c. How would describe the general cycle of temperature change for this period? [Answer: The lowest temperature occurs after midnight and increases through the day until the highest temperature, occurring right after noon, and then the temperature decreases until midnight]

Look at the graphs of some of your classmates to see how they decided to mark the start and end of a period. Does everyone agree? Is there a single "right" way to do it? Explain to the students that there is no right way to create a period. Some students may have chosen to start and stop at noon, other at midnight, maybe some at 6am when the sun rises. All are appropriate responses as long as the period remains constant for their graph.

Get ready to compare all of the periods that appear in Figure 2. Write down what you predict to observe in the following comparisons:

a. Will all the periods be the same length of time? Why? [Answer: Yes, all periods should be 24 hours in duration because that coincides with the number of hours in a day]

b. Will all the periods have the same amplitude? Why? [Answer: no the amplitudes of each period will not be the same because the temperature changes each day]

c. Does the maximum temperature occur at the same time in each period? [Answer: Yes, generally the maximum temperature should occur at solar noon which is roughly 1-3 pm but this may vary according to latitude, season, etc.]

d. Is the "average" temperature for each period the same? [Answer: answers may vary; in general the average temperature will be similar in a series of a few day, but this may change with the weather, season, etc.]

e. Will you be able to see if the weather is getting warmer or cooler overall during the time reported by the graph? How? [Answer: You can see if the weather is getting warmer or cooler overall by finding the daily average temperatures and seeing if those change over the week. If the first day is significantly cooler than the last day (18 vs 22 degrees Celsius for example) this may indicate that the weather is getting warmer.] Draw a horizontal line through the period to indicate the "average" temperature for that period. You can estimate what you think the average temperature for the entire week is or estimate the daily average.

Conclude this lesson by asking the class to describe how temperatures change during the day. Were the predictions that they made in the beginning of the activity correct? Why or why not? Did they learn more by confirming a correct prediction or by rethinking a prediction that turned out not to be as they expected? Is making an incorrect prediction a "mistake?"

# Temperature Cycles: Student Worksheet

Write down what temperature means to you and how temperature changes during the day. ______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Table 1. Temperatures that I "feel" at different times of the day

| Column A: Some of my daily activities | Column B: Time of Day | Column C: My sensation of Temperature | Column D: Recorded Temperature |
|---|---|---|---|
| Getting up in the Morning | | | |
| Lunch time (noon) | | | |
| Going home from School | | | |
| Dinner time | | | |
| Going to bed at Night | | | |

Look at the table and answer these questions about its structure:

a. What are the column names? ________________________________________________

b. Will each column contain words or numbers? _______________________________

c. What are the row names? __________________________________________________

d. What does the table's caption name tell you about the purpose of this table?

______________________________________________________________________

______________________________________________________________________

Fill in Table 1. Put the usual time of each activity into Column B. In Column C, use words like "warm" or "cold" to describe the "feel" of the air on your skin at each time.

Examine your expanded Table 1 and write brief answers to these questions:

b. What word might you use to describe how your body will feel when the thermometer reports a temperature of 35C? Why?

______________________________________________________________________

______________________________________________________________________

d. Give an example of a thermometer reading you would expect if you felt very cold.

______________________________________________________________________

e. So, generally, how do the numerical values in Column D compare to your sensory descriptions in Column B?

________________________________________________________________________

________________________________________________________________________

f. Consult with your classmates. Is there general agreement on the range of 'comfortable' temperatures? When do most of you feel cold? Hot?

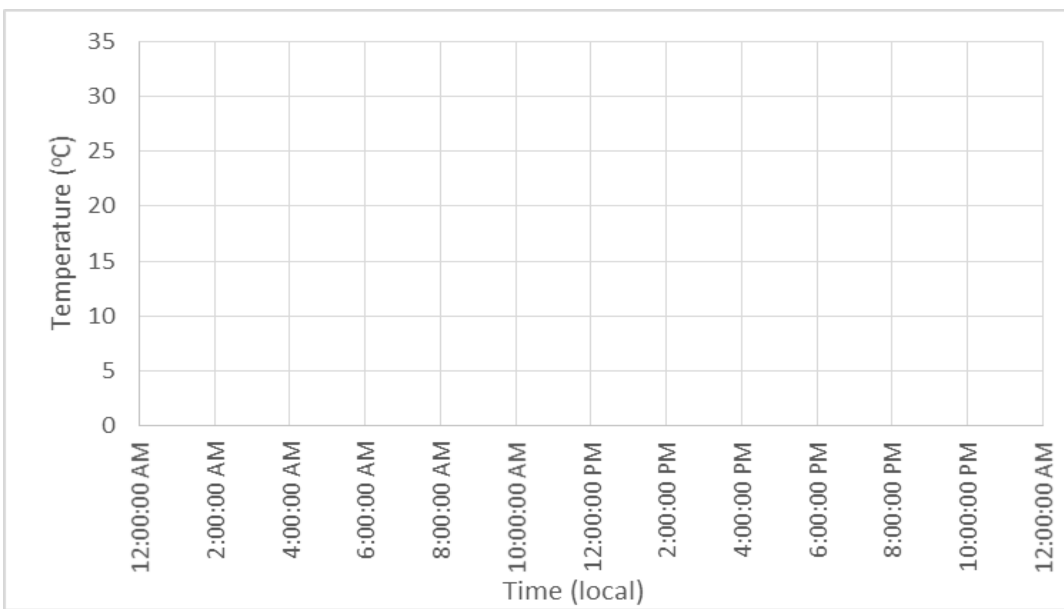
________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

A table is a good way to organize related data because it allows you to quickly look up specific values. A table is not a good way to represent data if you are trying to summarize information of display patterns in the data. So, let's make a picture of the information from Table 1. The time values from Column B of Table 1 will be shown on the horizontal axis of the graph. Temperatures from Column D are indicated on the vertical axis. Transfer the time and temperature information from Table 1 to Figure 1. Put a bold dot on the graph to indicate air temperature at each time listed in your table. You are not changing the data in any way, just presenting it differently, as a picture.

Figure 1. Air temperatures at the times of some of my daily activities




When you finish your graph, compare it to one that a classmate plotted. How are they similar? Write a few sentences that describe each of the following:

a. Your "picture" of temperature over time:

________________________________________________________________________

________________________________________________________________________

b. Your ideas about when a table should be used:

________________________________________________________________________

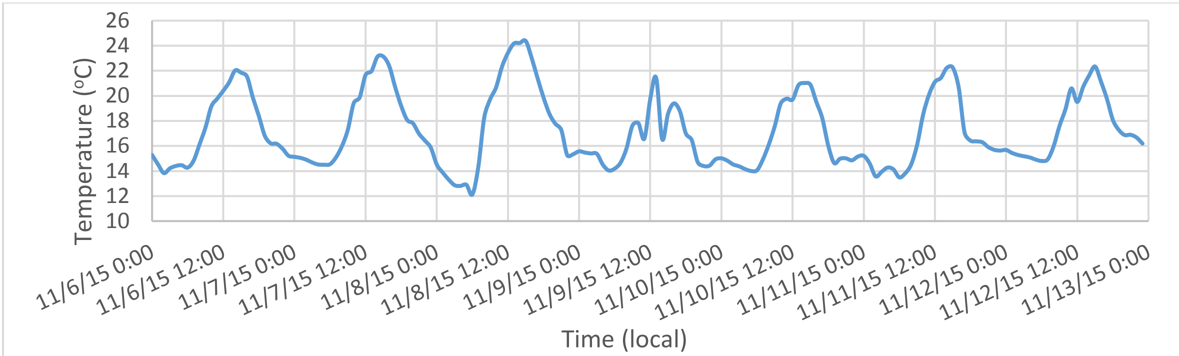
________________________________________________________________________

c. What a graph tells you that is not apparent in a table:

____________________________________________________________

____________________________________________________________

Figure 2. Hourly temperature measurements for St. Scholastica in Nairobi, Kenya for 11/6-13/2015




Refer to Figure 2 for the follow questions. Write down, in your own words, your first impressions of this new graph, Figure 2:

a. What does the caption tell you?

____________________________________________________________

____________________________________________________________

b. How often was temperature recorded? For how many days?

____________________________________________________________

____________________________________________________________

c. Did the temperature vary during a typical day? Is the variation similar to what you have observed in your Figure 1?

____________________________________________________________

____________________________________________________________

Compare your first impressions with those of a classmate. Together, develop a question about temperature that can be answered by looking at this graph. Write down your question below:

____________________________________________________________

____________________________________________________________

____________________________________________________________

Choose just one period of the several that appear on Figure 2. Draw and label vertical lines on the graph that mark the starting and ending times of the period. Write down your answers to these questions about that one period:

a. How would describe the general cycle of temperature change for this period?

____________________________________________________________

b. What are the highest and lowest temperatures during the period? What is the amplitude?

____________________________________________________________

# Solar radiation versus latitude: Teacher Guide

**Level:** Beginning

**Subject:** Geography

**Duration:** 40 minutes

**Type:** hands-on classroom activity

**Learning goals:**

- Define; Solar radiation, Latitudes and Equator.
- To find out the amount of solar radiation received near the poles as compared to the equator.
- To find out how latitudes affect the amount of solar radiation received at a point.

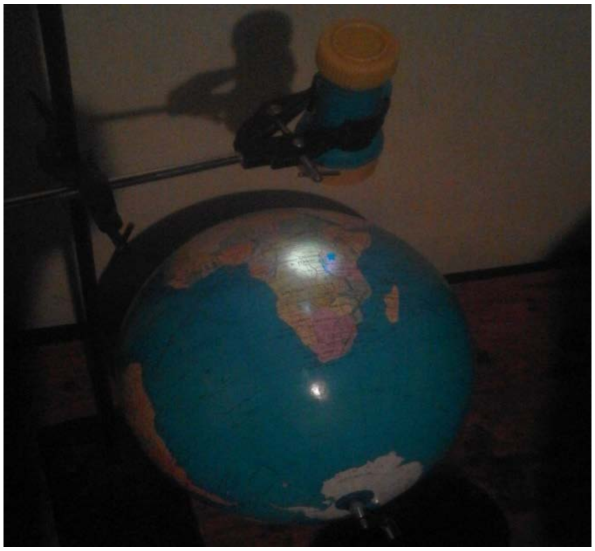
**Materials:**

- Globe
- Torch
- Tape Measure or Ruler
- Pencil
- Flat platform
- Stand

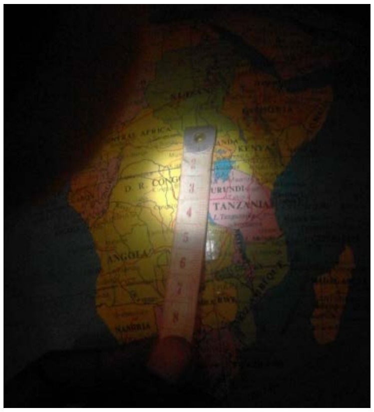
**Methods:**

Detailed step-by-step directions with pictures are also included in this power points for further instructions:

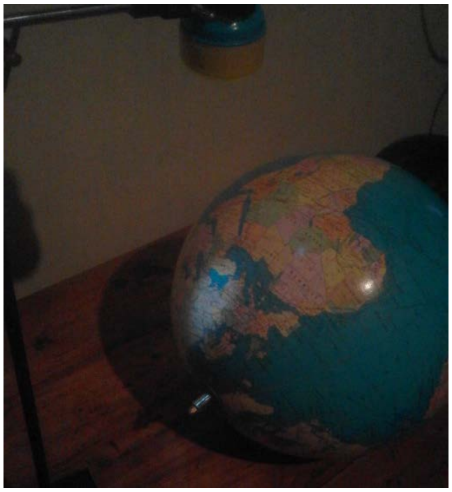
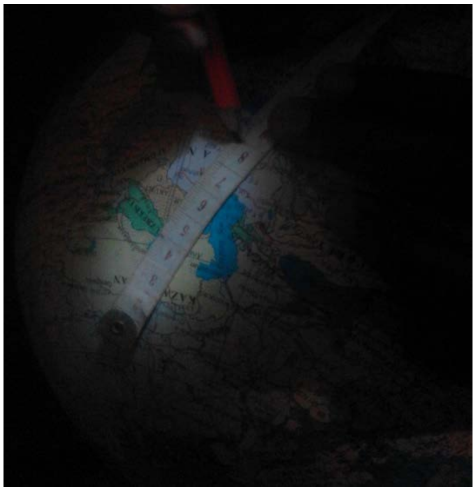
- Place the globe on a flat platform, preferably a table. Be sure to locate the position of the equator and the Polar Regions.
- With the help of the stand, light the torch and direct the beam of light so that it is at right angle to any point of equator.



- Notice that the light on the globe is circle. Measure the width of the beam of light and write it down (this is the same as the diameter of the circle of light).




- Now, direct the beam of light to any point near the North Pole. Notice that the shape of the light area is now an ellipsoid instead of a circle. Measure the width of light in both directions (the short direction and the long direction)

**Calculations:**

We measure the width of the beam of light near both the equator and the poles. To calculate the amount of light received per area, we divide the amount of light from the torch by the area the beam covers on the surface of the globe. Since it is hard to get the amount of light produced by the torch, it is preferred to use 100% as the amount produced by the torch. The area of the light can be calculated using the formula for either a circle (at the equator) or an ellipse (at the poles). The formula for the area of a circle is $A=\pi*(D/2)^2=3.14*(D/2)^2$ where D is the length/diameter of the beam of light. For an ellipse, the area is found using the formula $A=\pi*(D_1*D_2)$ where $D_1$ is the length of the beam of light in the long direction and $D_2$ is the length of light in the short direction.

Amount of light per area = amount of light produced by the torch / (area light on the surface of the globe). Assume that the amount of light produced by the torch is 100%.

$$L=T/A$$

- L is the amount of light per unit area
- T is light produced by the torch (100%)
- A is the width of the beam of light produced by the torch

**Results:**

At the Equator, the diameter of light measured was ____________ cm. The shape of the light was a (circle one: circle or ellipse) so to find the area of the light on the globe we used the formula $A=\pi*(D/2)^2$. Using the formula to calculate the light per unit area available, we found that the equator received _________ % of the light coming from the flashlight per unit area.

At the Poles, the length of light measured was ____________ cm in the long direction and ____________ cm in the short direction. The shape of the light was an (circle one: circle or ellipse) so to find the area of the light on the globe we used the formula $A=\pi*(D_1*D_2)/4$. Using the formula to calculate the light per unit area available, we found that the equator received _________ % of the light coming from the flashlight per unit area.

In this exercise, we found out that the equator receives about ______ times more sunlight per unit area than the poles.

[Answer from the example photos in this lesson plan: At the Equator, the diameter of light measured was 8 cm. The shape of the light was a circle so to find the area of the light on the globe we used the formula $A=\pi*(D/2)^2$. Using the formula to calculate the light per unit area available, we found that per unit area that the equator received 2% of the light coming from the flashlight.

At the Poles, the length of light measured was 8 cm in the long direction and 4 cm in the short direction. The shape of the light was an ellipse so to find the area of the light on the globe we used the formula $A=\pi*(D_1/2*D_2/2)$. Using the formula to calculate the light per unit area available, we found that per unit area the equator received 1% of the light coming from the flashlight.

In this exercise, we found out that the equator receives about 2 times more sunlight per unit area than the poles. ]

## Solar Radiation vs. Latitude: Student Worksheet

Define solar radiation:

______________________________________________________________________________

______________________________________________________________________________

What are the units for solar radiation?

______________________________________________________________________________

______________________________________________________________________________

Describe latitude:

______________________________________________________________________________

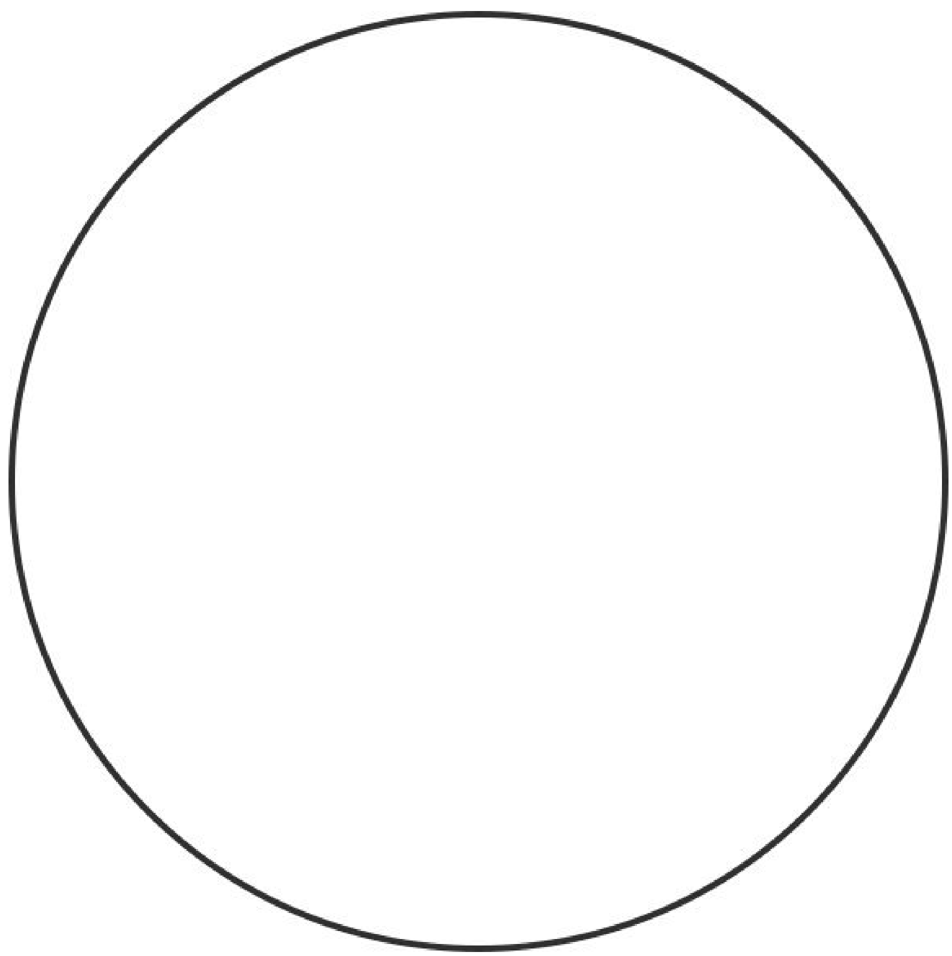
______________________________________________________________________________

What latitude is the equator?

__________________________________________________________

With the help of a pencil and a ruler, draw and label the following on the globe provided below.

- Equator
- Tropic of cancer
- Tropic of Capricorn
- North Pole
- South Pole



V.1

**Calculations:**

Calculate the amount of light received at both the equator and the poles per unit area covered by the light as follows;

$$L=T/A$$

Where,

L is the amount of light per unit length

T is the light produced by the torch (100%)

A is the width of the beam of light produced by the torch

**Results:**

At the Equator, the diameter of light measured was _____________ cm. The shape of the light was a (circle one: circle or ellipse) so to find the area of the light on the globe we used the formula $A=\pi*(D/2)^2$. Using the formula to calculate the light per unit area available, we found that the equator received _________ % of the light coming from the flashlight per unit area.

At the Poles, the length of light measured was _____________ cm in the long direction and _____________ cm in the short direction. The shape of the light was an (circle one: circle or ellipse) so to find the area of the light on the globe we used the formula $A=\pi*(D_1*D_2)/4$. Using the formula to calculate the light per unit area available, we found that the equator received _________ % of the light coming from the flashlight per unit area.

In this exercise, we found out that the equator receives about ______ times more sunlight per unit area than the poles.

Based on the results in the table above, which part of the globe receives a high amount of solar radiation?

_____________________________________________________________________________________

_____________________________________________________________________________________

Does knowing the amount of solar radiation that a latitude receives help us understand the climate in different regions? Why is it cold and snowy at the poles but hot at the equator?

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

_____________________________________________________________________________________

# Earth-sun distance versus solar radiation: Teacher Worksheet

**Level:** Beginning

**Subject:** Geography

**Duration:** 40 minutes

**Type:** Classroom Activity

**Learning goals:**

- Define: Solar radiation, revolution, aphelion, perihelion
- To find out how revolution affects the Earth-Sun distance
- Understand how Earth-sun distance affects the amount of solar radiation the Earth receives

**Materials:**

- Globe
- Torch/Flashlight
- Tape Measure or Ruler
- Blackboard compass
- Flat platform (preferably a round table)
- Marker or chalk

**Introduction:**

This lesson plan is designed to be a classroom activity and discussion. There is no student worksheet because students are encouraged to be actively involved by watching, observing, and asking questions throughout the activity. Students should make sure they can see the demonstration, this may require standing around the table where the activity takes place. Throughout the methods, be sure to ask students clarifying questions or to encourage them to contribute their observations. Depending on the background knowledge of the class, it may be necessary to provide them with background information on the Earth's orbit around the sun.

**Background:**

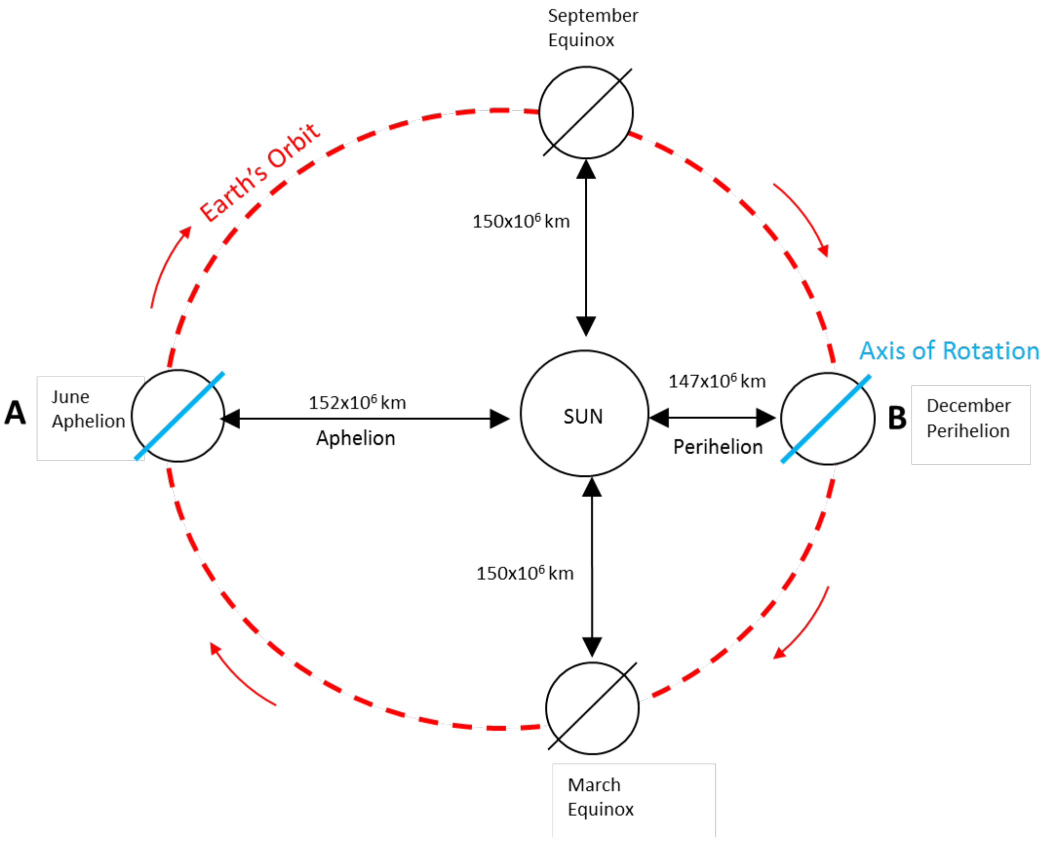
The Earth orbits the Sun at a speed of 108,000 km/hr. The length of the Earth's orbit is 940 million km. One orbit of the Earth around the Sun is called one revolution. The Earth completes one revolution every 365.25 mean solar days, which is why we observe a leap year (a year with an extra calendar day in February) every 4 years (so that 4 years is exactly 1461 days). In addition to the Earth orbiting around the Sun, the Earth rotates on its axis. One rotation of the Earth takes 24 hours, one day, which is why we have day and night. The Earth's rotates on an axis at an angle of 23 degrees, the axis of rotation is what causes seasonal changes of weather throughout the year. So, one revolution is one year and one rotation is one day.

The average distance from the Earth to the Sun is $149.6\text{x}10^6$ km, but the Earth's distance from the sun varies during its orbits. When the Earth is closest to the Sun, it is said to be at perihelion and occurs in December of each year at a distance of approximately $147\text{x}10^6$ km. When the Earth is farthest from the Sun, it is said to be at aphelion and occurs in June of each year at a distance of approximately $152\text{x}10^6$ km. The average distance of the Earth from the Sun is about 149.6 million km, which is also referred to as one astronomical unit (AU). During the Equinoxes the distance between the Sun and the Earth is $149.6\text{x}10^6$ km and the night is the same length as the day all over the world. The Perihelion and the Aphelion are both Solstices, meaning that they are the longest and shortest days of the year. The Perihelion occurs in the winter and is the shortest day of the year and is also called the Winter Solstice. The Aphelion occurs in the summer, also called the Summer Solstice, and is the longest day of the year.

**Methods:**

1. Locate the center of the flat platform (round table).
2. With the help of a construction compass, draw a round circle on the table using the marker. You may want to lay down a large paper on the table to avoid drawing on the table surface. (The circle represent the path followed by the earth as it revolves round the sun, shown in the figure by the red dotted line).
3. Place the torch/flashlight near the center of the table, be sure to offset it slightly to account for the Aphelion and the Perihelion. Ask the students what the torch/flashlight represents. [Answer: The sun revolved around the sun, the torch/flashlight represents the sun]
4. Choose two points A and B on one of the drawn circle to represent the aphelion and the perihelion respectively. Use the figure below as a reference. Note that, The earth's revolution (orbit of the earth around the sun) brings it close to the sun and far from it,

alternately, being nearest during the Perihelion in December and furthest during the aphelion in June.




5. Place the globe at point A, direct the torch light towards the globe. Using the tape measure the distance covered by the light from the torch to the globe in position A (note that the distance from the torch/flashlight to point A should be longer than the torch/flashlight to point B).
6. Now place the globe at point B and measure the distance covered by light again. It might be useful to create a table, like the one given below, on the blackboard to write down the results. This would be a good time to ask the students about their observations of the strength of the light that reaches the globe when it is in position A compared to position B. Did they notice that the light seems brighter when the globe is at position B compared to position A?

| Point # | Distance from point to torch/flashlight | Amount of light reaching the point |
|---|---|---|
| A (Aphelion) | | |
| B (Perihelion) | | |

**Calculations:**

For meteorological purposes, the sun is assumed to be a point source, which means that its size is small compared to the distance the radiation goes. The intensity of the radiation at a point (E) is inversely proportional to the square of the distance (d) of the point from the source i.e

$$E \propto \frac{1}{d^2},$$

Note: This formula may also be written as $E=k/d^2$. The quantity of the sun's radiation reaching the earth's surface is known as the solar constant (k). The solar constant, $S_o$, has a mean value of 1360 J $m^{-2}$ $s^{-1}$ and fluctuates by about 1 to 2% per year. Therefore k is the solar constant. For this demonstration, k will be the amount of light produced by the torch. Since we are using the same light source (torch/flashlight) for the entire exercise we can use to original equation of $E \propto 1/d^2$.

**Discussion:**

Ask the students to summarize what was performed during the lesson plan. Opened ended questions like this should encourage students to contribute in the discussion. [Possible Answer: we started by drawing the Earth's orbit around the sun on the paper, we placed the torch/flashlight in the center and the globe along the Earth's orbit. Then we compared the amount of light that reaches the globe at different locations around the orbit.]

Follow up the previous question by asking students what they learned during the demonstration. You may want to allow multiple students to answer this question as their answers may vary.

Ask the students to explain what is important about the Earth's orbit around the sun. How long is one revolution? [Answer: A revolution is when the Earth makes a complete orbit around the Sun. This is important because the distribution of daylight and nighttime hours depends on where the Earth is in its orbit.]

Ask the students to explain what is important about the Earth's rotation. How long is one rotation? [Answer: The Earth rotates around an imaginary axis that runs from the North Pole to the South Pole. This axis is tilted 23 degrees and is the reason that we experience season and other variations in weather each year. One rotation is 24 hours, or one day.]

Finally, ask the students based on their observations and calculations which point (A or B) did more energy from the Sun reach the Earth? [Answer: when the Earth is farther from the Sun, like at point A of the Aphelion, the energy from the Sun that reaches the Earth is less than when the Earth is closer, like point B of the Perihelion.]

# Water Cycle Game: Teacher Guide

**Level:** Intermediate

**Subject:** Geography

**Duration:** 30 minutes

**Type:** Small group activity

**Learning Goals:**

- Define each component of the water cycle
- Investigate the movement of water through the different stages of the water cycle
- Be able to explain the driving forces of the water cycle

**Materials:**

- Dice (printed template provided)
- 6 Printed activity sheets provided below

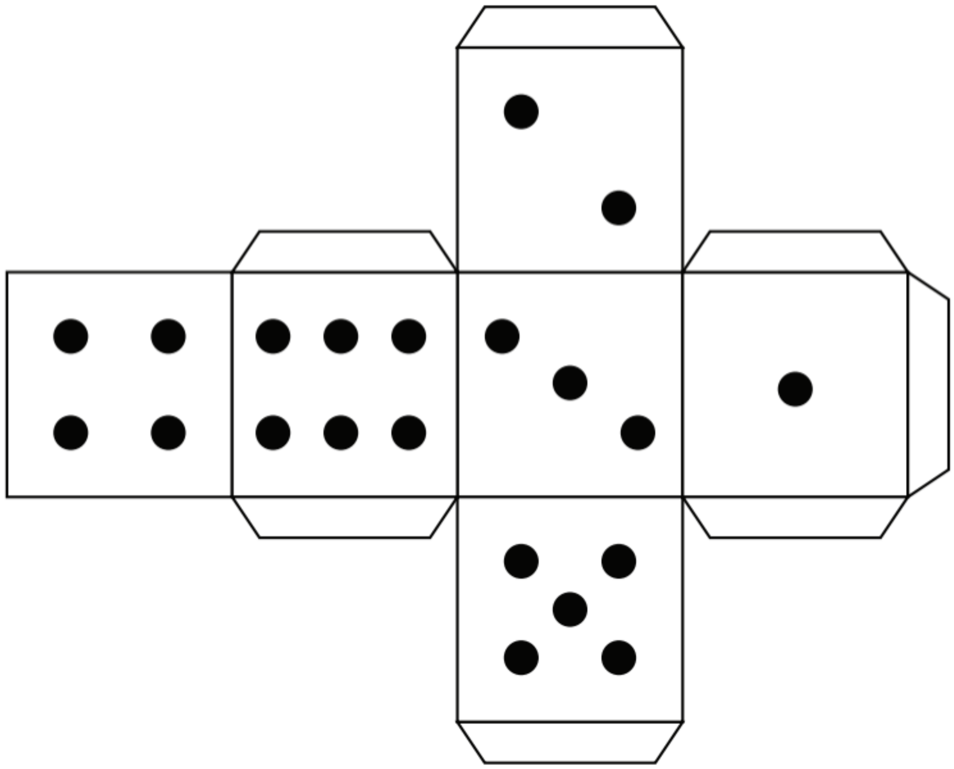
**Background:**

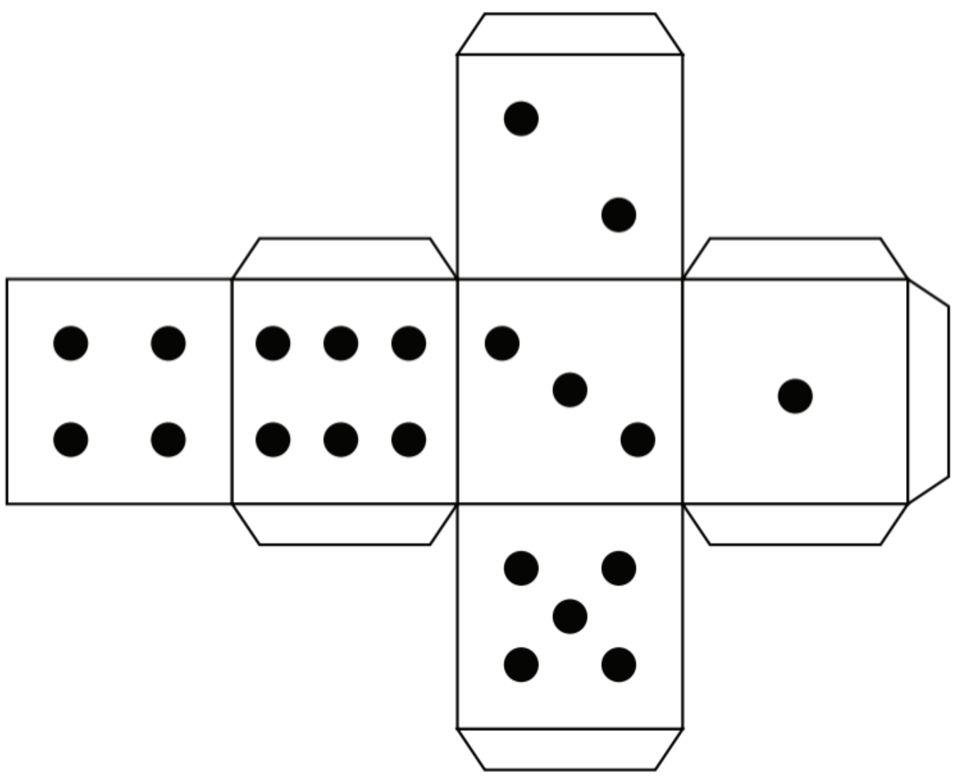
This lesson plan is intended for classes that want to continue to explore the complexities of the water cycle. To successfully complete this activity, students should already have a basic understanding of the water cycle including the ability to define the components of the water cycle and explain the driving forces between each stage. Background information for the water cycle is available on the School-2-School website under the Teaching Materials Tab with the “Water Cycle” lesson plan. Allow 30 minutes for this activity: 5 minutes to introduce the activity, 15 minutes to play the game (10 rounds of 1 minute each), and 5 minutes for class discussion.

Explain that students will play a game; they will role-play water as it moves throughout Earth. Start the conversation about the hydrologic cycle by asking students where water exists on Earth and how it gets there. By the end of the activity, the students would understand the processes by which water moves from one location to another including the multiple paths that water can take. This is activity is modified from the UAF Geophysical Institute.

If needed, reintroduce the term “water cycle.” Explain that a cycle is something that repeats over and over. For example, the year is a cycle. The twelve months of the year repeat over and over every year. Water moves on Earth in a cycle as well. Even though water moves in a variety of ways, it always returns to its original position.

The materials required for this activity are the printed 6 pages of student information sheets and 6 six-sided dice. If you do not have a six-sided dice, you can print out a dice template and glue together the cube. A template is provided below for 2 dice: print, cut out, and glue tabs to assemble.





V.1

Before the activity the teacher should arrange the classroom into 6 stations. Student should work in small groups, there should be one dice per group. Have one group start at each station. Each station represents the different places that water exists: oceans, rivers & lakes, groundwater, ice & glaciers, clouds, and plants. Each station will have a dice and an information sheet. The dice will move around with the group but the station information sheet will remain at the station for the duration of the activity.

Explain that when the signal is given, each group will roll the die. Students should read the number on the die and match it to the chart on the sheet on the table. The chart will indicate where to go next. For example, if a student rolls a 3 at the Soil Surface Station, he or she will move to the Ground Water station next. If confusion in the activity directions exists, it may be helpful to play a mock round to make sure students understand the rules.

At the next station, the student should roll the die and move according to the chart at the new station. Each station will have a different chart. As students move from station to station, they should chart their paths on their advanced topics student worksheets. For round 1, student should mark a #1 on the correct place on the water cycle map. For the following rounds, students should show their path using an arrow and placing the round number.  At the end of the game, students will share paths with each other.

**Discussion:**

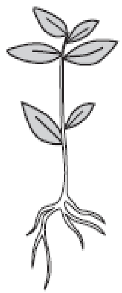
After the first round, have the students stop at their current station. Now is a good time to check in to check their understanding. Ask one student from each station to describe which station they started at, what number on the dice they rolled and the corresponding process of movement, concluding with their next station. Use this as an opportunity to help any groups that still have questions or are confused. Once each group has had the opportunity to share and all questions have been answered, you can instruct the class to continue with the remaining 9 rounds.

After the 10 rounds have been completed, instruct the students to find a seat and complete their student handout. Ask students to share the path that their water droplet took. Was this path more complicated than the students expected? How often did the group stay at the same station for more than one round?

Ask students to answer the following questions based on the paths that were taken during the water cycle game. List student ideas on the board and discuss as a class. Where can water from a plant go? How does water get to a river? Where can water go from a glacier? How does water get to a cloud?

Below is a summary of the 6 student information cards for the teacher's use, following by the 6 station information cards for student use during the activity.

| Starting Station | Dice Roll | Process of Movement | Moves To |
|---|---|---|---|
| Ocean | 1,2 | With heating from the sun you change from a liquid to a gas by the process of evaporation | Clouds |
| | 3,4,5,6 | You float in the ocean | Ocean |
| Rivers & Lakes | 1,2 | You percolate into the groundwater | Groundwater |
| | 3 | You flow into the ocean | Ocean |
| | 4 | A dry air mass combined with heating from the sun causes evaporation | Clouds |
| | 5,6 | You continue to flow from lakes to rivers | Rivers & Lakes |
| Groundwater | 1,2 | You pop up as an underground spring and supply water to a river or a lake | Rivers & Lakes |
| | 3 | After a long time you seep into the ocean | Ocean |
| | 4 | A root absorbs you up to be used by a plant | Plants |
| | 5,6 | You remain in the aquifer | Groundwater |
| Snow & Glaciers | 1 | You change from a solid to a gas through the process of sublimation | Clouds |
| | 2 | You break off (calve) from the glacier and become an iceberg in the ocean. You melt. | Ocean |
| | 3 | You melt and become runoff, entering a river or lake | Rivers & Lakes |
| | 4,5 | You melt and percolate into the underground water | Groundwater |
| | 6 | You remain a solid and stay where you are. | Snow & Glaciers |
| Plants | 1,2,3,4 | You move to the leaves of the plant and evaporate into the clouds in the process of transpiration | Clouds |
| | 5,6 | You are used by the plant to move necessary minerals to the parts of the plants that require them for photosynthesis. You remain in the plant | Plants |
| Clouds | 1 | You freeze into an ice crystal and combine with other ice crystals to form a snow flake. As the snow flake grows it becomes too heavy to be supported by the rising air and you fall to the earth. | Snow & Glaciers |
| | 2 | You combine with other droplets and grow larger and larger. You reach a size that cannot be supported by rising air and therefore fall as rain over a river or lake or enter a river or lake by runoff | Rivers & Lakes |
| | 3 | You combine with other droplets and grow larger. You reach a size that cannot be supported by rising air and therefore fall as rain over the ocean | Ocean |
| | 4,5,6 | You float in the atmosphere and remain as a cloud | Clouds |

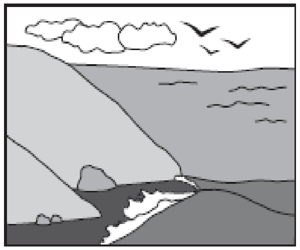


## PLANT

| | |
|---|---|
| 1 | Clouds |
| 2 | Clouds |
| 3 | Clouds |
| 4 | Clouds |
| 5 | Plant |
| 6 | Plant |

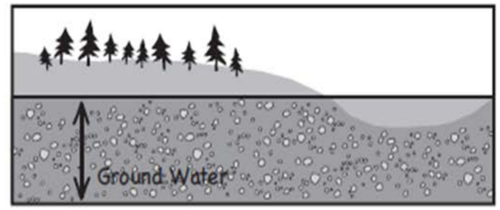
## CLOUDS

| | |
|---|---|
| 1 | Ocean |
| 2 | Ocean |
| 3 | Ocean |
| 4 | Clouds |
| 5 | Clouds |
| 6 | Clouds |



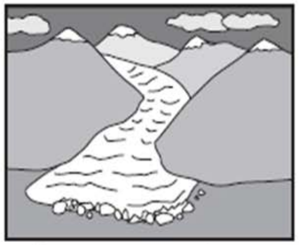
# OCEAN

| | |
|---|---|
| 1 | Clouds |
| 2 | Clouds |
| 3 | Ocean |
| 4 | Ocean |
| 5 | Ocean |
| 6 | Ocean |

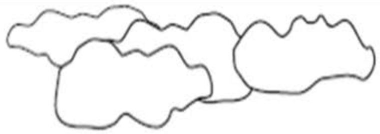
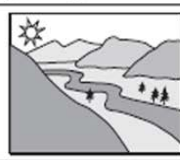
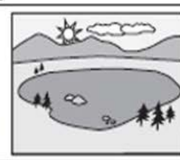
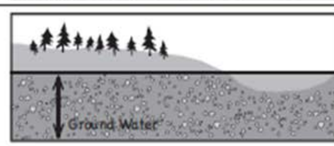
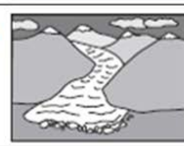


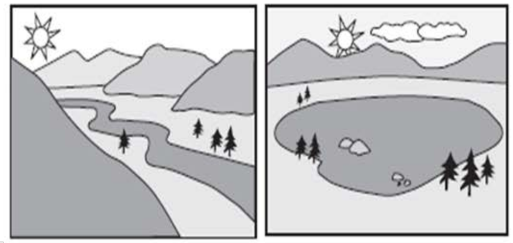

# GROUND WATER

| | |
|---|---|
| 1 | Rivers & Lakes |
| 2 | Rivers & Lakes |
| 3 | Ocean |
| 4 | Plant |
| 5 | Ground Water |
| 6 | Ground Water |

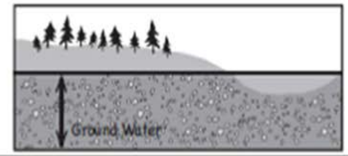
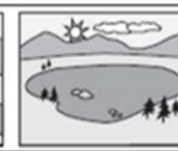
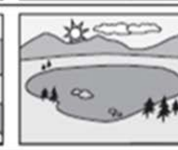


## Snow & Glaciers

| | | |
|---|---|---|
| 1 | ⚀ | Clouds  |
| 2 | ⚁ | Ocean  |
| 3 | ⚂ | Rivers & Lakes   |
| 4 | ⚃ | Ground Water   |
| 5 | ⚄ | Ground Water   |
| 6 | ⚅ | Snow & Glaciers  |



## RIVERS & LAKES

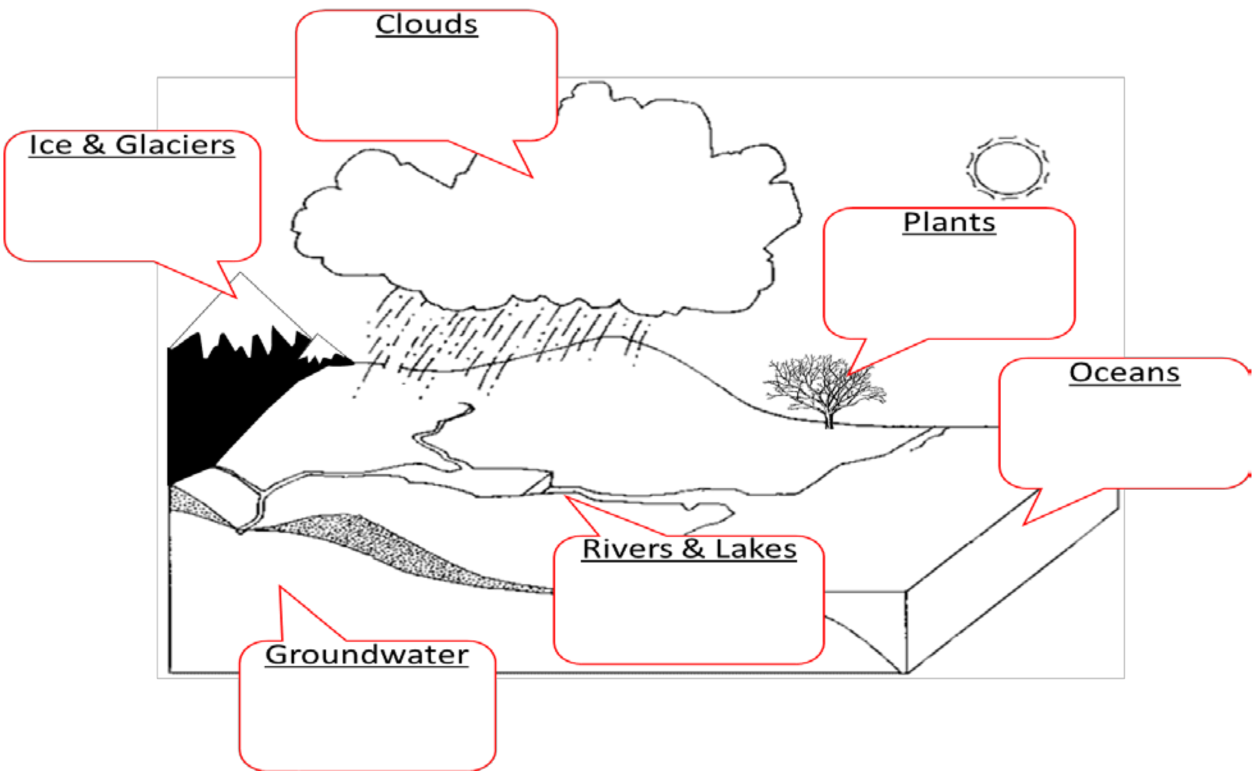
| | | |
|---|---|---|
| 1 | ⚀ | Ground Water   |
| 2 | ⚁ | Ground Water   |
| 3 | ⚂ | Ocean  |
| 4 | ⚃ | Clouds  |
| 5 | ⚄ | Rivers & Lakes   |
| 6 | ⚅ | Rivers & Lakes   |

# Water Cycle Game: Student Worksheet

Fill out the following table documenting the movement of your water droplet. For each round describe the process that moved your water droplet from one location to another (example: precipitation, runoff, infiltration, evaporation, root absorption, transpiration, or stays in place).

| Round | Starting Location | Process Description | Ending Location |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

On the Figure below, place the round number in the corresponding box. Draw arrows between the boxes to show the movement of the water droplet over the 10 rounds.

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## Wind Anemometer Activity: Teacher Worksheet

**Level:** Intermediate

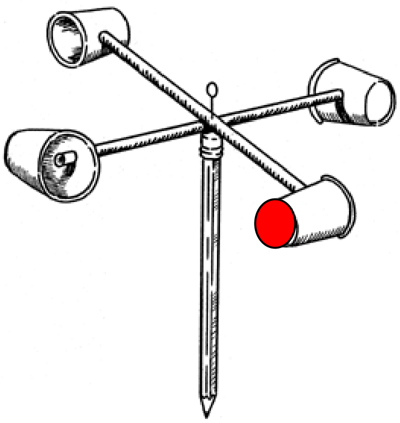
**Subject:** Geography and Mathematics

**Duration:** 1 hour

**Type:** Group hands-on activity

**Learning Goals:**

- Define an anemometer as an instrument used to measure wind speed
- Calculate the wind speed outside using the cup anemometer
- Compare the calculated wind speed to wind speed from the TAHMO station



**Materials per Group:**

- (1) pencil with eraser**,** (1) push pin**,** (2) Flexible straws**,** tape or stapler**,** (4) small paper or plastic cups (4)
- (1) timer or clock

**Methods:**

1. Working in teams of two, build a cup anemometer. Be sure that all of the cups face the same direction when assembled. You may need to tape or staple the straws together to keep them fixed at right angles. Fix the straws to the pencil eraser using the push pin, but make sure the straws can still rotate when the pencil is held still.
2. Mark one cup with a red dot or other mark, you can use this cup as a reference point when counting the rotations in the next step.
3. Go outside in a clear spot, preferably close to the TAHMO weather station. Holding your anemometer in the air, start the timer and count the number of revolutions. Record the time and number of anemometer rotations. Repeat for a total of 3 trials. Determine which direction the wind is coming from (N,E,S,W).
4. Perform the calculations below to compare the velocity from the anemometer to the velocity from the weather station.

**Calculations:**

We measured the number of revolutions of our anemometer. To calculate the angular velocity, we divide the number of rotations by the time. The angular velocity describes the speed at which a circle is spinning.

| | | | | |
|---|---|---|---|---|
| # Rotations | / | Time (seconds) | = | Angular velocity (rotations/second) |

Now that we have angular velocity, we want to convert it into linear velocities. The speed we drive our cars or walk are both linear velocities. To convert from angular velocity (revolutions per second) to linear velocity (radians per second) we need to use to conversion 1 revolution = 2*π radian ≈ 6.28 radians. A revolution is when the cup completes a circle, traveling 360 degrees, or 2π radians. We now have the angular velocity in rad/sec, to calculate linear velocity we multiply the radius of the wind anemometer by the angular velocity. The radius of our anemometer should be measured from the center of the pencil to the center of cup (shown right), there is a ruler provided on page 1 of the student worksheet.

| | | | | | | |
|---|---|---|---|---|---|---|
| Angular velocity (rotations/second) | * | Conversion from (rev/s) to (rad/s) | * | Anemometer radius (meters) | = | Linear velocity (meters/second) |

Students should fill out the results table on their worksheet with the # of revolutions

To find the average linear velocity of the wind using the cup anemometer, simply add the three calculated linear velocities and divide by 3.

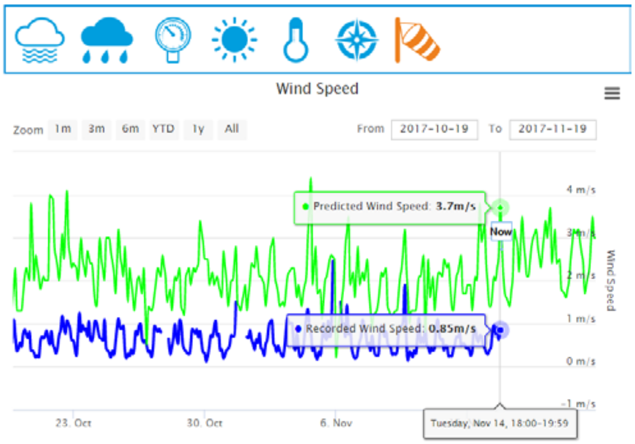
**Discussion:**

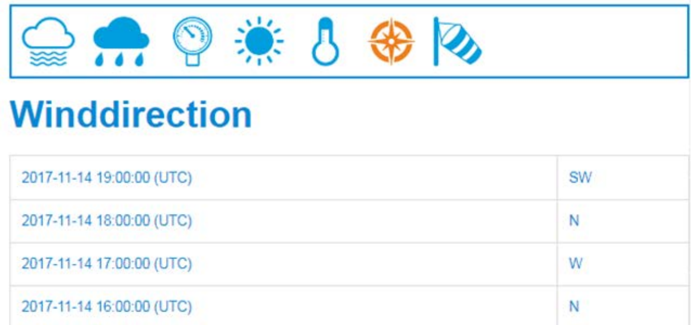
In a weather station, which meteorological variable does an anemometer measure and what are the units?

[Answer: the anemometer measures wind speed which has units of meters per second (m/s)]

What is the recorded wind speed and direction from the TAHMO weather station from the same time that the cup anemometers were tested outside?

[Answer: Answers will vary. Go to https://school2school.net/stations/ and select your TAHMO weather station. Select the wind speed variable and read the most recent wind speed measurement (this can be done by zooming to the 1 month view and then hovering your mouse over the most recent data point on the observed blue line shown in the picture below. Be sure the time of the data is the same as time that the students were taking data). Next choose the wind direction icon and record the most recent wind direction measurement- be sure the time corresponds to the time that the students were outside taking their measurements.]




What was your estimated wind direction from step 3? How does this compare with the recorded wind direction from the TAHMO station?

[Answer: Wind direction changes frequently and since the data from the School-2-School website records hourly averages it may be different than the estimated wind direction from step 3.]

How does the TAHMO wind speed value compare to the calculated linear velocity from the wind anemometer? What is the percent error between the two values? To calculate percent error subtract the calculated average linear velocity from the TAHMO wind speed then divide by the TAHMO wind speed.

[Answer: Our anemometer measured wind using a physical instrument that turned in the wind, while the TAHMO weather station uses a sonic anemometer to measure wind speed. A sonic anemometer operates by measuring the time it takes for a pulse of sound to travel between two transducers, and comparing that to the speed of sound, thus making sonic anemometers extremely accurate. While answers to this question will vary, it is likely that the calculated velocity is not the same as the TAHMO recorded wind speed.]

What errors are involved with measuring velocity with an anemometer?

[Answer: There are multiple sources of error when measuring wind velocity from an anemometer, here are a few: Cup anemometers are affected by friction, so at very low wind speeds they might not rotate. Because of the design, cup anemometers won't rotate if the wind direction isn't blowing directly into one of the cups. There are also small errors associated with converting an angular velocity into a linear velocity.]

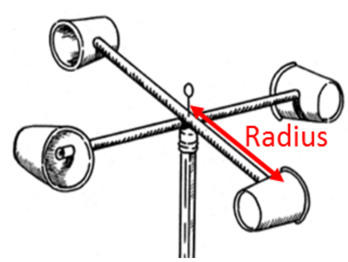
# Wind Anemometer Activity: Student Worksheet

1. Working in teams of two, build a cup anemometer. Be sure that all of the cups face the same direction when assembled. You may need to tape or staple the straws together to keep them fixed at right angles. Fix the straws to the pencil eraser using the push pin, but make sure the straws can still rotate when the pencil is held still.
2. Mark one cup with a red dot or other mark, you can use this cup as a reference point when counting the rotations in the next step.
3. Go outside in a clear spot, preferably close to the TAHMO weather station. Holding your anemometer in the air, start the timer and count the number of revolutions. Record the time and number of anemometer rotations. After you have completed a total of three trails, determine which direction the wind is coming from (North, East, South, or West).
4. Perform the calculations below to compare the velocity from the anemometer to the velocity from the weather station.
5. Answer the 4 discussion questions at the end of the worksheet.

We measured the number of revolutions of our anemometer. To calculate the angular velocity, we divide the number of rotations by the time. The angular velocity describes the speed at which a circle is spinning.

| # Rotations | / | Time (seconds) | = | Angular velocity (rotations/second) |
|---|---|---|---|---|
| _________ | / | _________ | = | ______________ |

Now that we have angular velocity, we want to convert it into linear velocities. The speed we drive our cars or walk are both linear velocities. To convert from angular velocity (revolutions per second) to linear velocity (radians per second) we need to use to conversion 1 revolution = 2*π radian ≈ 6.28 radians. A revolution is when the cup completes a circle, traveling 360 degrees, or 2π radians. We now have the angular velocity in rad/sec, to calculate linear velocity we multiply the radius of the wind anemometer by the angular velocity. The radius of our anemometer should be measured from the center of the pencil to the center of cup (shown right), be sure to record your measurement in meters. You may use the ruler provided at the bottom of this page or use your own.




| Angular velocity (rotations/second) | * | Conversion from (rev/s) to (rad/s) | * | Anemometer radius (meters) | = | Linear velocity (meters/second) |
|---|---|---|---|---|---|---|
| ______________ | * | 2 * π | * | ___________ | = | _____________ |

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**Results:**

To find the average linear velocity of the wind using the cup anemometer, simply add the three calculated linear velocities and divide by 3.

| Trial # | Time (s) | Revolutions | Linear velocity (m/s) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| Average | ------------ | ---------------- | |

**Discussion:**

In a weather station, which meteorological variable does an anemometer measure and what are the units?

______________________________________________________________________________

______________________________________________________________________________

What is the recorded wind speed and direction from the TAHMO weather station from the same time that the cup anemometers were tested outside?

______________________________________________________________________________

______________________________________________________________________________

What was your estimated wind direction from step 3? How does this compare with the recorded wind direction from the TAHMO station?

______________________________________________________________________________

______________________________________________________________________________

How does this value compare to the calculated linear velocity from the wind anemometer? What is the percent error between the two values? Hint: % error= (TAHMO wind speed - average linear velocity from the table above)/(TAHMO wind speed).

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

What errors are involved with measuring velocity with an anemometer?

______________________________________________________________________________

______________________________________________________________________________

# Solar Radiation vs Latitude: Teacher Guide

**Level:** Intermediate

**Subject:** Geography

**Duration:** 40 minutes

**Type:** Classroom discussions

**Learning Goals:**

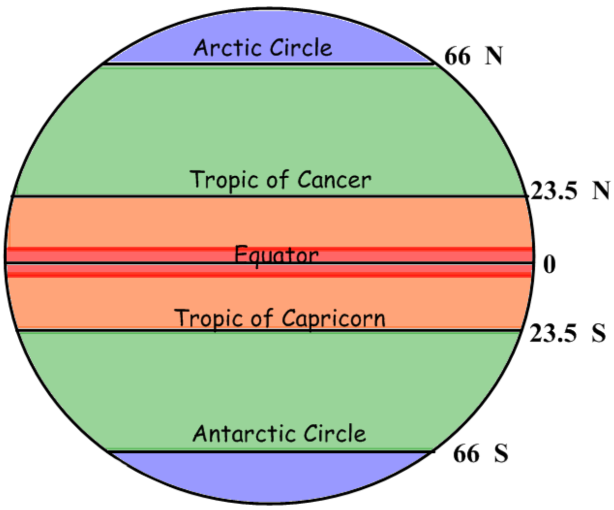
- Define the lines of latitude
- Understand how the sun shines on different parts of the globe based on the shape of Earth
- Make calculations on potential solar panel energy for different locations

**Materials:**

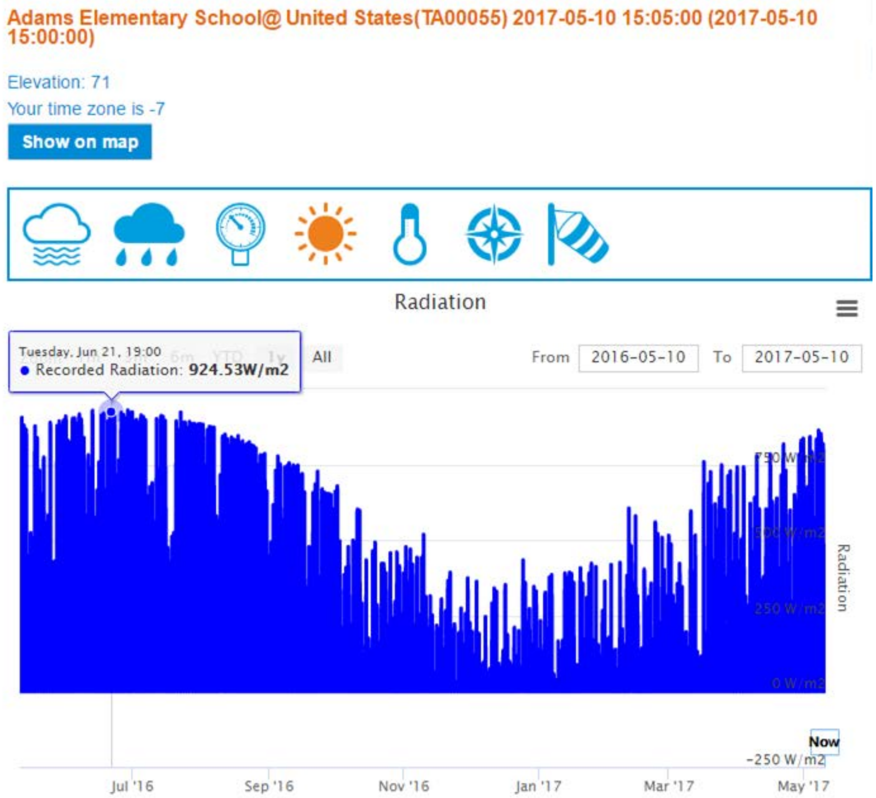
- Internet access- navigation to the School-2-School website
- Optional visualizations at http://profhorn.meteor.wisc.edu/wxwise/radiation/sunangle.htm

**Methods:**

- Ask the students what latitude is the equator? Tropic of Cancer? Tropic of Capricorn? Arctic Circle? Antarctic Circle?
  (Figure from http://msblaszak.cmswiki.wikispaces.net/Climate+Latitude)



- With the class, discuss the climate zones on Earth and at what latitudes are they found? [Answer: The tropics are between the Tropic of Cancer and the Tropic of Capricorn, which includes the Equator. The temperate zone is between the Tropic of Cancer and the Arctic Circle, and also between the Tropic of Capricorn and the Antarctic Circle. The polar zone is between the Arctic Circle and the North Pole, and between the Antarctic Circle and the South Pole.]
- Compare maximum solar radiations for multiple different stations. On the graph, zoom to view different dates of data to identify the maximum solar radiation. Use the “show on map” button to view the location of the station. Either estimate the latitude based on the map or use google maps to find the exact latitude. [Example viewing the 1 year time range : Adams Elementary school is in Corvallis, Oregon USA at a latitude of 44.6° N and the approximate maximum solar radiation is 920 $W/m^2$. St. Scholastica Catholic School is located in Nairobi, Kenya at a latitude of 1.3°S and the approximate solar radiation of 1,030 $W/m^2$]




- Make observations about the trends of maximum solar radiation at different latitudes. Do stations with higher maximum solar radiations tend to be closer to the equator or closer to the poles?
- Considering the Earth is a globe, how would this affect the incoming solar radiation? (Figure from https://www.nature.com/scitable/knowledge/library/introduction-to-the-basic-drivers-of-climate-13368032). [Answer: At the equator the sun is perpendicular to the surface, allowing maximum solar radiation to be distributed over a small surface area. Closer to the poles, the incoming solar radiation is the same but the light is spread over a larger surface area so the intensity is lower at a particular location.]


**Calculations:**

Compare the energy potential for solar panels in two latitudes. If a school installs 5 $m^2$ solar panels on their roof, how many lightbulbs can that solar panel power?

$$E = A * H * PR$$

**E** = Energy (W)

**A** = Total solar panel Area ($m^2$)

**H** = Annual average solar radiation panels ($W/m^2$)

**PR** = Performance ratio of solar panel, coefficient for losses (default value = 0.22)

With this solar panel, we can then calculate how many lightbulbs can be powered by this solar panel. If we are using a lightbulb with a 100 watt rating for ½ of the day, we can calculate how many lightbulbs can be sustained.

**# lightbulbs = E / 100 watts**

Adams Elementary at 44.6° N : E = 5 $m^2$ * (920 $W/m^2$) * 0.22 = 1012 Wh

Adams Elementary : E = 1012 W / 100 W = 10 light bulbs

St. Scholastica at 1.3°S : E = 5 $m^2$ * (1030 $W/m^2$)* 0.22 = 1133 Wh

St. Scholastica : E = 1133 W / 100 W = 11 light bulbs

**Results:**

| **Station** | **Max Solar Radiation ($W/m^2$)** | **Latitude** | **Solar Panel Energy Potential (Watts)** | **# lightbulbs that can be powered** |
|---|---|---|---|---|
| | | | | |
| | | | | |

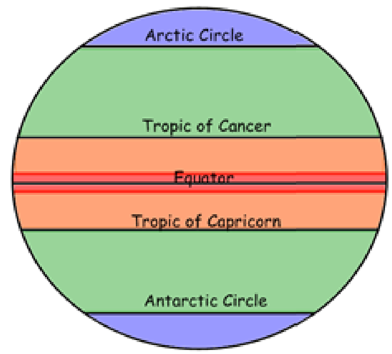
**Discussion:**

Why do the maximum and minimum solar radiation change throughout the year? [Hint: Select different months from the dropdown menu on the webpage and take note of the axis of rotation - http://profhorn.meteor.wisc.edu/wxwise/radiation/sunangle.html. The Earth is on an axis that is 23.5$^{o}$ from vertical which causes the seasons.]

Based on what you have learned about solar radiation at different latitudes, where are the best places to locate solar panel farms? What angles do you think will give the greatest energy for panels located at the equator? What about panels located near 45 degrees latitude, like Corvallis, Oregon? [Answer: Think about the fact that the bigger the shadow the solar panel makes, the greater the energy it is receiving from the sun. So the panel should face the sun. At the equator the sun should point directly up, in the northern hemisphere the solar panel should face south, in the southern hemisphere the sun should point north]

If electricity is 0.20 USD per kWh, how much money can each solar panel produce? [Answer for Adams Elementary : 1.012 kWh * 0.20 USD/kWh = 0.20 USD per day = 73.88 USD per year]

# Solar Radiation vs Latitude: Student Worksheet



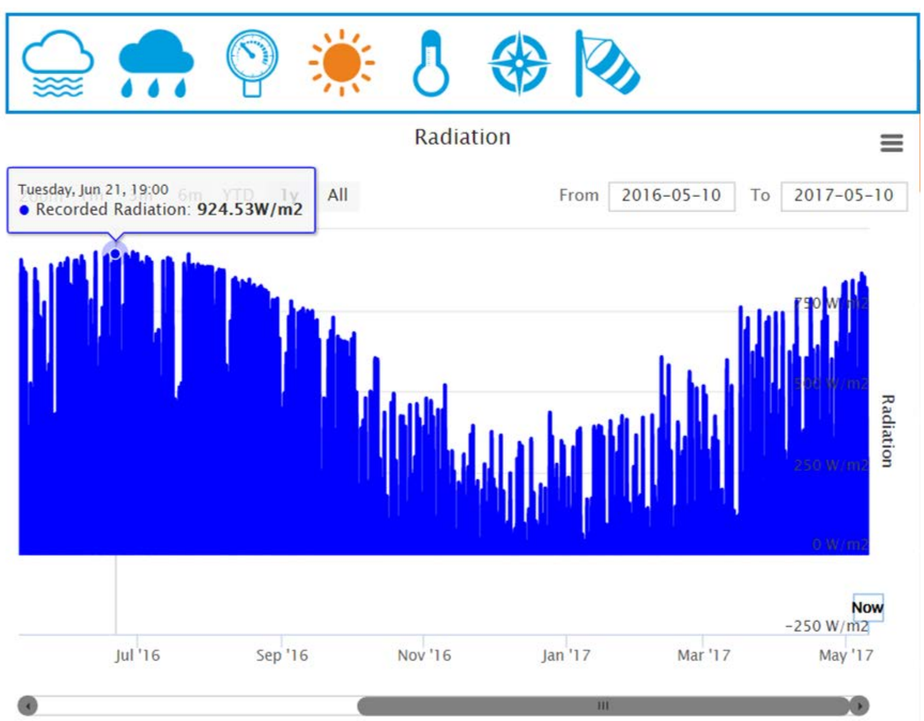

What latitude is the:

- Equator? ____________
- Tropic of Cancer? ____________
- Tropic of Capricorn? ____________
- Arctic Circle? ____________
- Antarctic Circle? ____________

What are the climate zones on Earth and at what latitudes are they found?

- Tropics:__________________________________________________
- Temperate:_______________________________________________
- Polar:_____________________________________________________

On the School2School.net website, look at the Map tab to view all stations across the globe. Choose two stations, one near the equator and one far from the equator. For each station view the solar radiation (the sun icon) and choose the zoom option to view 1 year of data (See Figure below). Use your cursor to float over the data, estimating the maximum value of solar radiation and recording it in the table.




If a school installs 5 $m^2$ solar panels on their roof, how many lightbulbs can that solar panel power?

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To find this out use the following equations to find out how much energy the solar panel can produce, and how many lightbulbs can be powered by that energy.

$$E = A * H * PR$$

$$\#\ lightbulbs = E / 100\ watts$$

**E** = Energy (W)

**A** = Total solar panel Area ($m^2$)

**H** = Annual average solar radiation panels ($W/m^2$)

**PR** = Performance ratio of solar panel, coefficient for losses (default value = 0.22)

| Station | Max Solar Radiation ($W/m^2$) | Latitude | Solar Panel Energy Potential (Watts) | # lightbulbs that can be powered |
|---|---|---|---|---|
| | | | | |
| | | | | |

Based on what you have learned about solar radiation at different latitudes, where are the best places to locate solar panel farms?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

What direction should the solar panel face? What angles do you think will give the greatest energy for panels located at the equator? What about panels located near 45 degrees latitude, like Corvallis, Oregon?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

# Advanced Topics: Calculating the required solar panel size to power the TAHMO station

This advanced topic is intended for classes that want to continue to explore real-world applications of solar panels. This advanced topic is option and should be determined based on the skill level of the classroom. This activity is designed to be done after the main lesson plan is completed, and does use values obtained earlier. Allow an additional 20 minutes for this activity.

In the TAHMO ATMOS 41 station, the solar panel captures the solar radiation which is stored as energy in six 1.5 Volt batteries in series. The batteries are used to power the instruments and data logger on the weather station. By design the batteries will power the weather station for 3 months. This safeguard is to ensure the station continues to collect data even in the case that the solar panel breaks, the weather is cloudy, or any other malfunction with the solar panel. How big of a solar panel does the TAHMO station need to meet this power demand?

First we need to calculate the rate of discharge of the station. The current that the instruments draw energy and discharge from the battery can be calculated by knowing the rating of the battery and the total discharge time. The AA batteries are rated for 2.85 Amp-hours, and battery should power the station for 3 months, or 2160 hours.

Current = Rating/time = 2.85 Amp-hours/ 2160 hours = 0.001 Amp= 1 milliAmp

If the power draw is 1 milliAmp, then the power charge needs to be 2 milliAmp, assuming sun shines on the solar panel for 12 hours per day and the system uses power for 24 hours per day. The total voltage of the batteries is 1.5 Volts * 6 batteries = 9 Volts. With this information, we can calculate power requirement for the solar panel.

Power = Current * Voltage = 0.002 Amp * 9 Volts = 0.018 Watts

Finally we can calculate the size of solar panel required to meet the power requirement. Knowing the maximum incoming solar radiation, we can calculate the size of the solar panel required.

Solar Panel Size = Power / SR = 0.018 W / (920 W/$m^2$) = 1.96 * $10^{-5}$ m2 [Adams Elementary]

Solar Panel Size = Power / SR = 0.018 W / (1030 W/$m^2$) = 1.75 * $10^{-5}$ $m^2$ [For St. Scholastica]

The actual size of the solar panel is 3cm x 7cm= 2.1 * $10^{-3}$ $m^2$, which is two orders of magnitude larger than the required size. Why do you think it was designed this way? [Answer: Engineers design products with a safety of factor to ensure that the design will not fail. Often, there are uncertainties in some of the values used in the calculations that lead to uncertainties in the calculations for design. There are also assumptions used in the calculations that have associated uncertainties.]

What are the assumptions associated with our calculations? [Answer: our calculations make assumptions that the maximum solar radiation is present for 12 hours a day, which is an overestimate because of the effects of seasons and diurnal solar radiation. It also assumes that all 365 days a year the sun is shining on the solar panel, which does not account for cloudy days. We also are assuming that this system is 100% efficient and that no losses occur.]

# Diurnal variation of solar radiation: Teacher Guide

**Level:** Intermediate

**Subject:** Mathematics and Statistics

**Duration:** 40 Min

**Type:** Small Group Exercise

**Learning Goals:**

- To understand how solar radiation varies in a day
- To understand what time of the day solar radiation reaches its maximum value
- To gain basic skills of plotting graphs using MS Excel

**Material:**

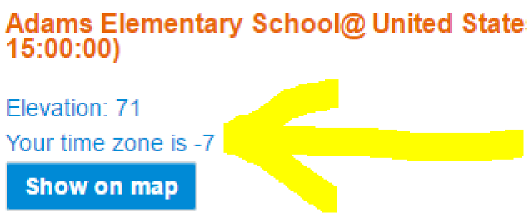
- Working computer and strong and stable internet and MS Excel. The computer will be shared in groups depending on the available computers

**Introduction**

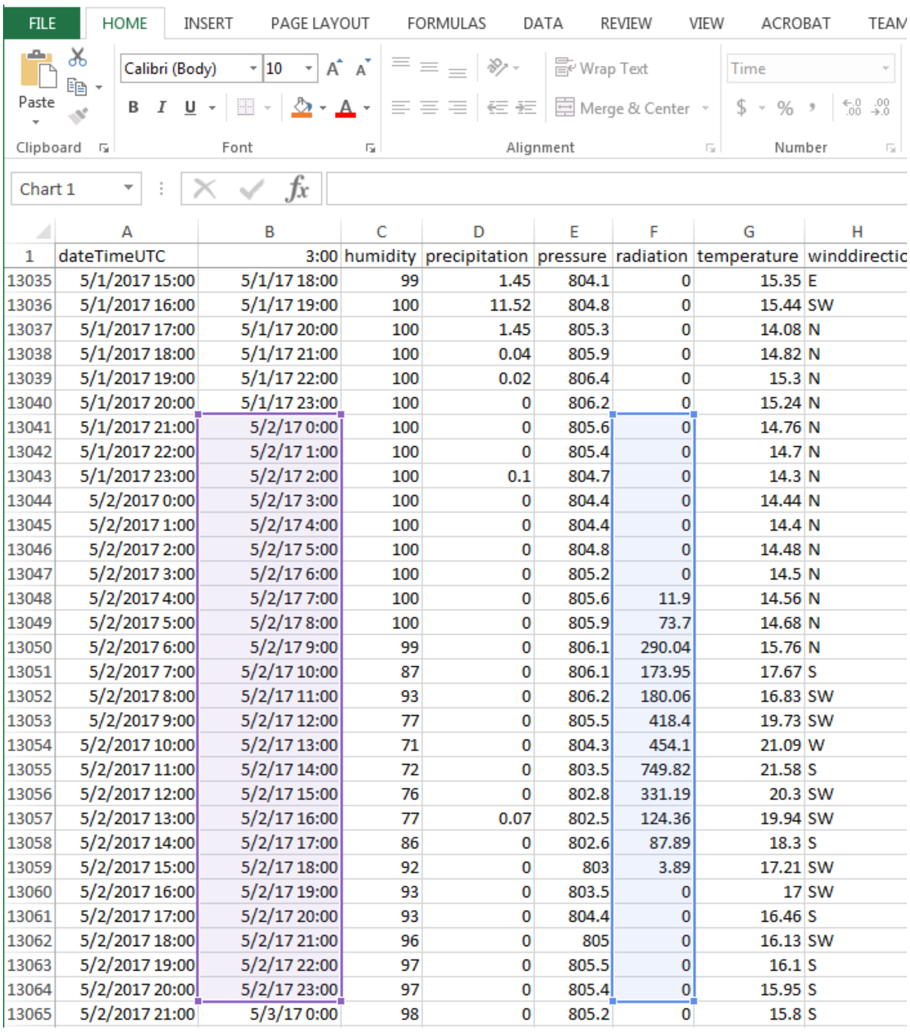
Solar ultraviolet (UV) radiation is an important environmental factor that affects human health. Moderate UV radiation triggers vitamin D synthesis in the skin which contributes to protection against breast cancer, prostate cancer and non-Hodgkin's lymphoma etc. However, excessive solar UV radiation has various direct and indirect effects on human health, which may lead to skin cancer, cataracts, immune suppression, photo-aging, and other ailments.

**Methodology**

Access the TAHMO school to school website and download daily solar radiation data for a particular station. Sort and analyse the data for plotting using Ms Excel. Please note that the time in the downloaded file is given in Coordinated Universal Time (UTC) and not local time. To convert from UTC to local time, use the time zone to either add or subtract from the UTC time. The time zone can be found on the School2School.net website for each station under the name of the school.

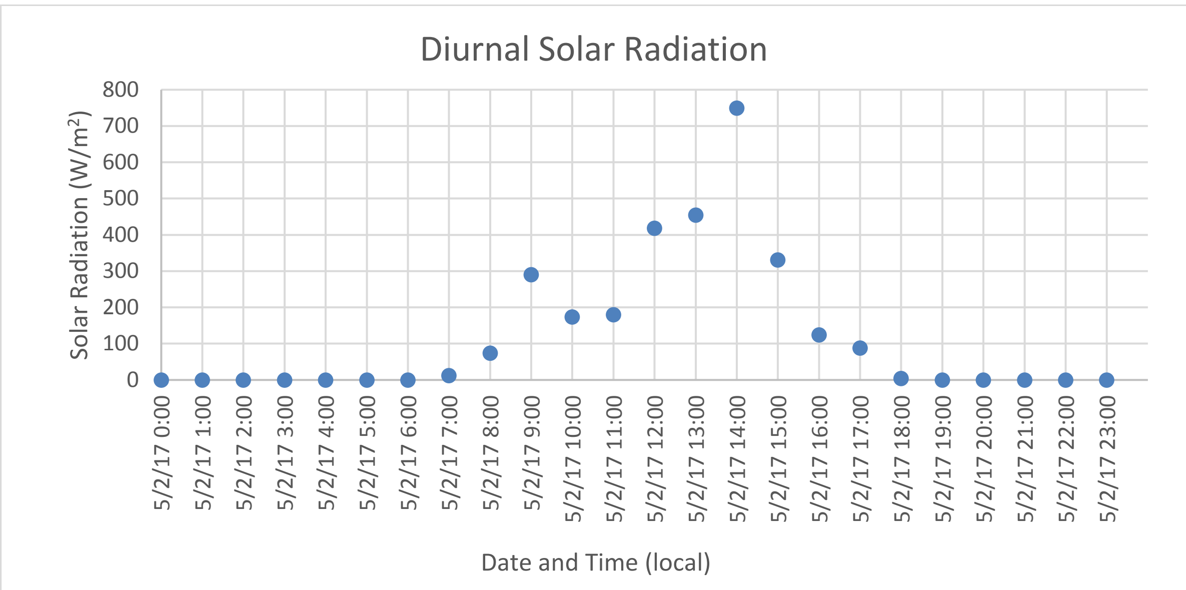


Select one day of data, from 12am to 11pm local time. The figure below is an example of solar radiation data selected for date 02 May 2017 from 0:00 to 23:00 (12am to 11pm local time).



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | dateTimeUTC | 3:00 | humidity | precipitation | pressure | radiation | temperature | winddirectic |
| 13035 | 5/1/2017 15:00 | 5/1/17 18:00 | 99 | 1.45 | 804.1 | 0 | 15.35 | E |
| 13036 | 5/1/2017 16:00 | 5/1/17 19:00 | 100 | 11.52 | 804.8 | 0 | 15.44 | SW |
| 13037 | 5/1/2017 17:00 | 5/1/17 20:00 | 100 | 1.45 | 805.3 | 0 | 14.08 | N |
| 13038 | 5/1/2017 18:00 | 5/1/17 21:00 | 100 | 0.04 | 805.9 | 0 | 14.82 | N |
| 13039 | 5/1/2017 19:00 | 5/1/17 22:00 | 100 | 0.02 | 806.4 | 0 | 15.3 | N |
| 13040 | 5/1/2017 20:00 | 5/1/17 23:00 | 100 | 0 | 806.2 | 0 | 15.24 | N |
| 13041 | 5/1/2017 21:00 | 5/2/17 0:00 | 100 | 0 | 805.6 | 0 | 14.76 | N |
| 13042 | 5/1/2017 22:00 | 5/2/17 1:00 | 100 | 0 | 805.4 | 0 | 14.7 | N |
| 13043 | 5/1/2017 23:00 | 5/2/17 2:00 | 100 | 0.1 | 804.7 | 0 | 14.3 | N |
| 13044 | 5/2/2017 0:00 | 5/2/17 3:00 | 100 | 0 | 804.4 | 0 | 14.44 | N |
| 13045 | 5/2/2017 1:00 | 5/2/17 4:00 | 100 | 0 | 804.4 | 0 | 14.4 | N |
| 13046 | 5/2/2017 2:00 | 5/2/17 5:00 | 100 | 0 | 804.8 | 0 | 14.48 | N |
| 13047 | 5/2/2017 3:00 | 5/2/17 6:00 | 100 | 0 | 805.2 | 0 | 14.5 | N |
| 13048 | 5/2/2017 4:00 | 5/2/17 7:00 | 100 | 0 | 805.6 | 11.9 | 14.56 | N |
| 13049 | 5/2/2017 5:00 | 5/2/17 8:00 | 100 | 0 | 805.9 | 73.7 | 14.68 | N |
| 13050 | 5/2/2017 6:00 | 5/2/17 9:00 | 99 | 0 | 806.1 | 290.04 | 15.76 | N |
| 13051 | 5/2/2017 7:00 | 5/2/17 10:00 | 87 | 0 | 806.1 | 173.95 | 17.67 | S |
| 13052 | 5/2/2017 8:00 | 5/2/17 11:00 | 93 | 0 | 806.2 | 180.06 | 16.83 | SW |
| 13053 | 5/2/2017 9:00 | 5/2/17 12:00 | 77 | 0 | 805.5 | 418.4 | 19.73 | SW |
| 13054 | 5/2/2017 10:00 | 5/2/17 13:00 | 71 | 0 | 804.3 | 454.1 | 21.09 | W |
| 13055 | 5/2/2017 11:00 | 5/2/17 14:00 | 72 | 0 | 803.5 | 749.82 | 21.58 | S |
| 13056 | 5/2/2017 12:00 | 5/2/17 15:00 | 76 | 0 | 802.8 | 331.19 | 20.3 | SW |
| 13057 | 5/2/2017 13:00 | 5/2/17 16:00 | 77 | 0.07 | 802.5 | 124.36 | 19.94 | SW |
| 13058 | 5/2/2017 14:00 | 5/2/17 17:00 | 86 | 0 | 802.6 | 87.89 | 18.3 | S |
| 13059 | 5/2/2017 15:00 | 5/2/17 18:00 | 92 | 0 | 803 | 3.89 | 17.21 | SW |
| 13060 | 5/2/2017 16:00 | 5/2/17 19:00 | 93 | 0 | 803.5 | 0 | 17 | SW |
| 13061 | 5/2/2017 17:00 | 5/2/17 20:00 | 93 | 0 | 804.4 | 0 | 16.46 | S |
| 13062 | 5/2/2017 18:00 | 5/2/17 21:00 | 96 | 0 | 805 | 0 | 16.13 | SW |
| 13063 | 5/2/2017 19:00 | 5/2/17 22:00 | 97 | 0 | 805.5 | 0 | 16.1 | S |
| 13064 | 5/2/2017 20:00 | 5/2/17 23:00 | 97 | 0 | 805.4 | 0 | 15.95 | S |
| 13065 | 5/2/2017 21:00 | 5/3/17 0:00 | 98 | 0 | 805.2 | 0 | 15.8 | S |

Using MS Excel, plot a line graph of solar radiation for period of twenty-four hours. This plot will show you the diurnal variation in solar radiation. The figure below is a graph showing diurnal variation of solar radiation at station TA00066 on 02 May 2017.



**Questions**

These questions will assist in discussing the graph plotted

1) What do the units of solar radiation ($W/m^2$) mean?
2) Describe the variation of solar radiation for the whole day
3) What time of the day shows the maximum solar radiation? Why?
4) What time of the day shows the minimum solar radiation? Why?
5) From the graph, what time does the sun rise and sun set?
6) How is the solar radiation information important for our daily activities?

**Discussion**

Discuss some of the factors affecting the amount of solar radiation reaching the earth surface and thus the weather station

Possible Answers:

- The amount of solar radiation reaching the earth's surface varies greatly because of changing atmospheric conditions and the changing position of the sun, both during the day and throughout the year.
- Clouds are also atmospheric condition that determines the amount of solar radiation that reaches the earth. Regions of the nation with cloudy climates receive less solar radiation than the cloud-free desert climates. Therefore, the solar radiation reaching the earth's surface decreases with increasing cloud cover.
- The amount of solar radiation also varies depending on the time of day and the season. More solar radiation is present during midday than during either the early morning or late afternoon. At midday, the sun is positioned high in the sky and the path of the sun's rays through the earth's atmosphere is shortened.

In which period of the year do you experience maximum solar radiation in your region? [Answer: This depends on the location of the country and the period of the year in which sun is close to the given latitude i.e. when the sun is over Equator, Tropic of Cancer or Tropic of Capricorn]

In which period of the year is the sun over the Equator, Tropic of Cancer and Tropic of Capricorn? [Answer: Over equator: the period is 21st – 22nd March and 22nd – 23rd September; Over Tropic of Cancer: the period is 20th – 22nd June; Over Tropic of Capricorn: the period is 21st – 22nd December]

# Diurnal variation of solar radiation: Student Worksheet

What do the units of solar radiation ($W/m^2$) mean?

_______________________________________________________________________________

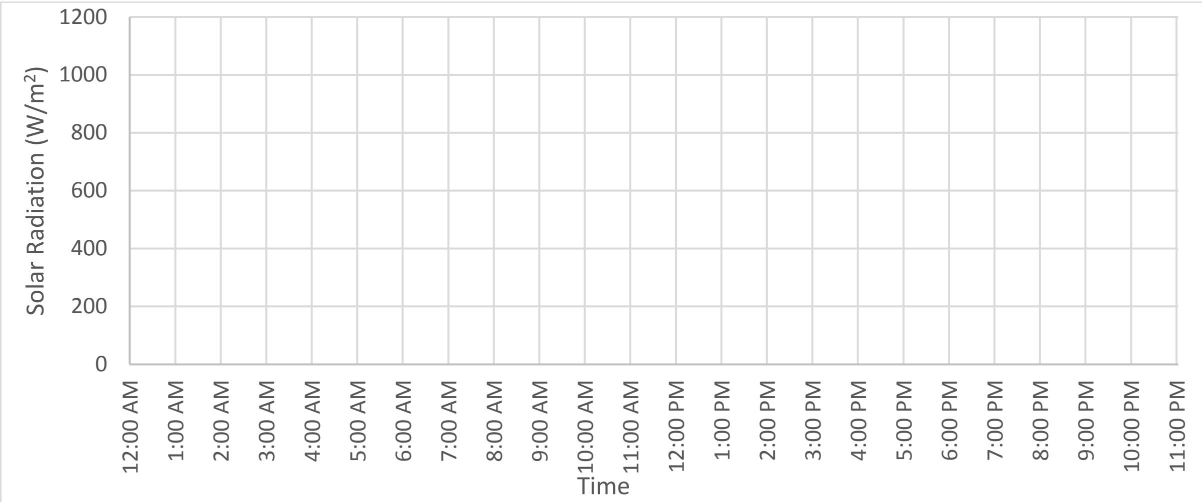
_______________________________________________________________________________

How is the solar radiation information important for our daily activities?

_______________________________________________________________________________

_______________________________________________________________________________

Access the School2School.net website and download solar radiation data. Sort and analyse the data using MS Excel. Make sure to convert the downloaded time in UTC to local time using the time zone. Select the column of solar radiation and choose one day of data from 12 am to 11pm local time. Create a line graph of Solar Radiation in Excel, draw the plot on the graph below.




Describe the variation of solar radiation for the whole day.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

What time of the day shows the maximum solar radiation? Why?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

What time of the day shows the minimum solar radiation? Why?

_______________________________________________________________________________

_______________________________________________________________________________

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From the graph what time does the sun rise and sun set?

_______________________________________________________________________________

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**Questions**

Discuss some of the factors affecting the amount of solar radiation reaching the earth surface and thus the weather station.

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In which period of the year do you experience maximum solar radiation in your region?

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In which period of the year is the sun over the Equator, Tropic of Cancer and Tropic of Capricorn?

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# Dew Point Temperature: Teacher Guide

**Level:** Intermediate

**Subject:** Geography

**Duration:** 50 Min

**Type:** Individual or Small Group Exercise

**Learning Goals:**

- To understand how humidity varies during high temperature and low temperature
- To know how temperature varies during high humidity and low humidity
- What time of the day do we have high and low humidity and temperature? This may vary for different regions
- To gain basic skills in computer i.e. using MS Excel

**Materials:**

- Computer and internet
- Daily and weekly temperature and humidity data from TAHMO station

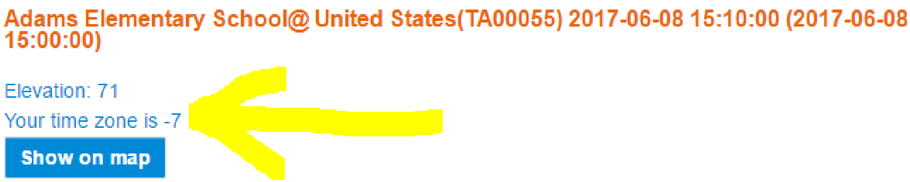
**Introduction**

You should realize that moisture in the atmosphere can appear in three states--solid, liquid, and a gaseous vapor. It is very rare when the air does not contain some water vapor. When the air is cooled to its saturation point, condensation occurs in the form of clouds and perhaps precipitation. At very high altitudes where the air is very cold, clouds consist of tiny ice crystals. And, of course, precipitation can occur in the form of snow and hail.

- It is possible in the atmosphere for ice crystals to go directly into water vapor, or water vapor directly to ice crystals. This process is called sublimation. The amount of heat involved in sublimation equals the sum of the heat of fusion plus the latent heat of vaporization.
- **Relative Humidity:** The ratio of the actual amount of water vapor in each volume of air to the amount which could be present if the air was saturated at the same temperature. It's commonly expressed as a percentage.
- **Dew Point:** The temperature to which a parcel of air must be cooled to reach its saturation point. It is important to understand that the temperature of the air influences the amount of water vapor that can be bound to the molecules of air. Water vapor capacity increases with temperature increase.

**Methods:**

1) Each team or group will switch on their laptop and connect to internet.
2) Go to TAHMO S2S program website and download temperature and humidity data for your school
3) Sort and analyse the data for plotting
    i. After downloading the data, filter the solar radiation data for a given specific date.
    ii. Please note that the time in the downloaded file is given in Coordinated Universal Time (UTC) and not local time. To convert from UTC to local time, use the time zone to either add or subtract from the UTC time. The time zone can be found on the School2School.net website for each station under the name of the school.




    iii. Select the solar radiation data for the filtered date from 12am to 11pm local time
    iv. Right click and copy the data. Open another sheet and paste

**Calculations:**

Calculate dew point temperature using the following formula?

$$Td = T - ((100 - RH)/5)$$

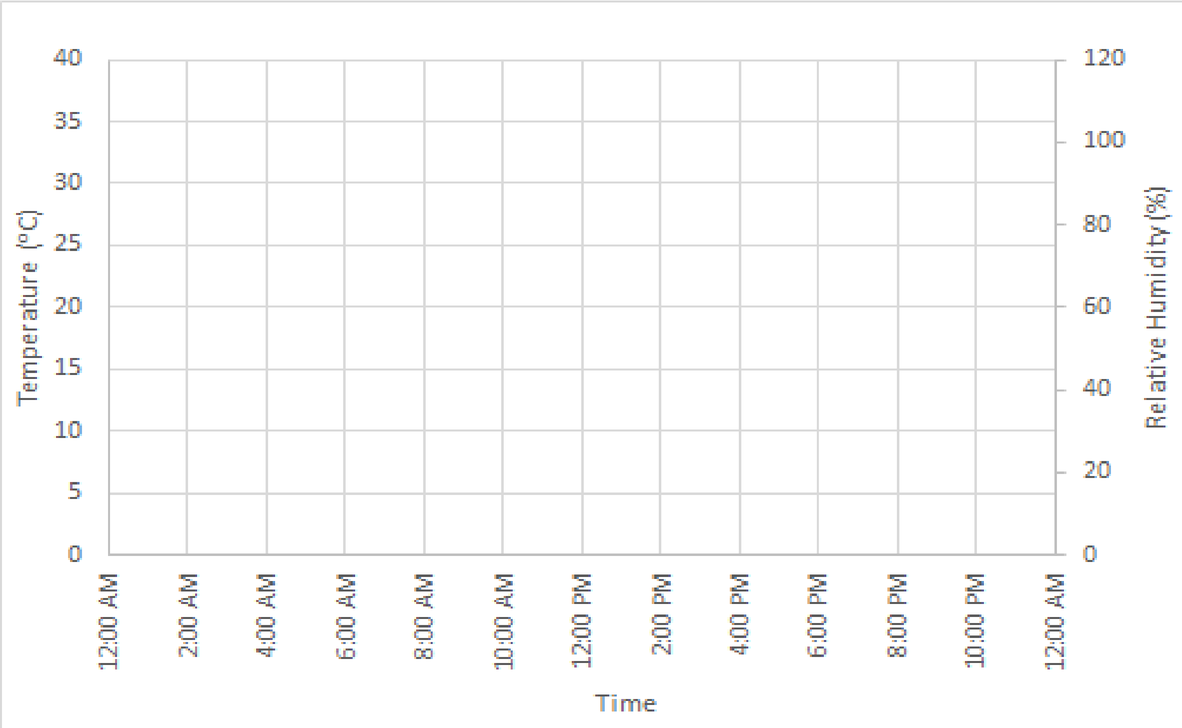
Where; RH = Relative Humidity (in percent)

Td = Dew point temperature (in degree Celsius)

T = Observed air temperature (in degree Celsius)

**Results**

Plot your results for temperature, relative humidity, and dew point temperature on the graph below. Use the left y-axis as the scale for both temperature and dew point temperature; use the right y-axis as the scale for the relative humidity data points.




**Discussion:**

How is the weekly trend of temperature and humidity? Can we make analogue weather prediction from the trend? (Answer: The teacher will guide the students in plotting graphs for weekly trends of temperature and humidity. From the trend graphs, analogue prediction can be done by looking at continuous similar trends of the temperature and humidity.)

How is the relationship between humidity and temperature? (Answer: Relative humidity is the ratio (expressed as a percentage) of the amount of moisture in the air to the maximum amount that can be present at that temperature. ... Because warm air can hold more water vapor than cool air, relative humidity falls when the temperature rises if no moisture is added to the air.)

Why does the relative humidity go up as the temperature goes down? (Answer: Relative humidity is the ratio of partial pressure (P1) of the water vapor in the current air to the saturation pressure (P2) of the water vapor air at constant temperature. If the temperature decreases then the amount of water vapor which the air can hold decreases, thus saturation vapor pressure (P2) decreases. Thus, Relative Humidity increases.)

Why do we experience lower temperatures when the air is humid? (Answer: If the water vapor content stays the same and the temperature drops, the relative humidity increases. If the water vapor content stays the same and the temperature rises, the relative humidity decreases. This is because colder air doesn't require as much moisture to become saturated as warmer air.)

# Temperature vs relative humidity: Student Worksheet

Define the following:

Relative Humidity: ___________________________________________________________________

Dew Point: ________________________________________________________________________

**Methods:**

1) Each team or group will switch on their laptop and connect to internet.
2) Go to TAHMO S2S program website and download temperature and humidity data for your school
3) Sort and analyse the data for plotting. To achieve the following will be done
   i. After downloading the data, filter the solar radiation data for a given specific date.
   ii. The downloaded data is given in UTC, change the time to local time using the time zone information from the School2School.net website
   iii. Select the solar radiation data for the filtered date from 12am to 11pm
   iv. Right click and copy the data. Open another sheet and paste

**Calculations:**

Calculate dew point temperature for one day using the following formula:

$$Td = T - ((100 - RH)/5)$$

Where; RH = Relative Humidity (in percent)

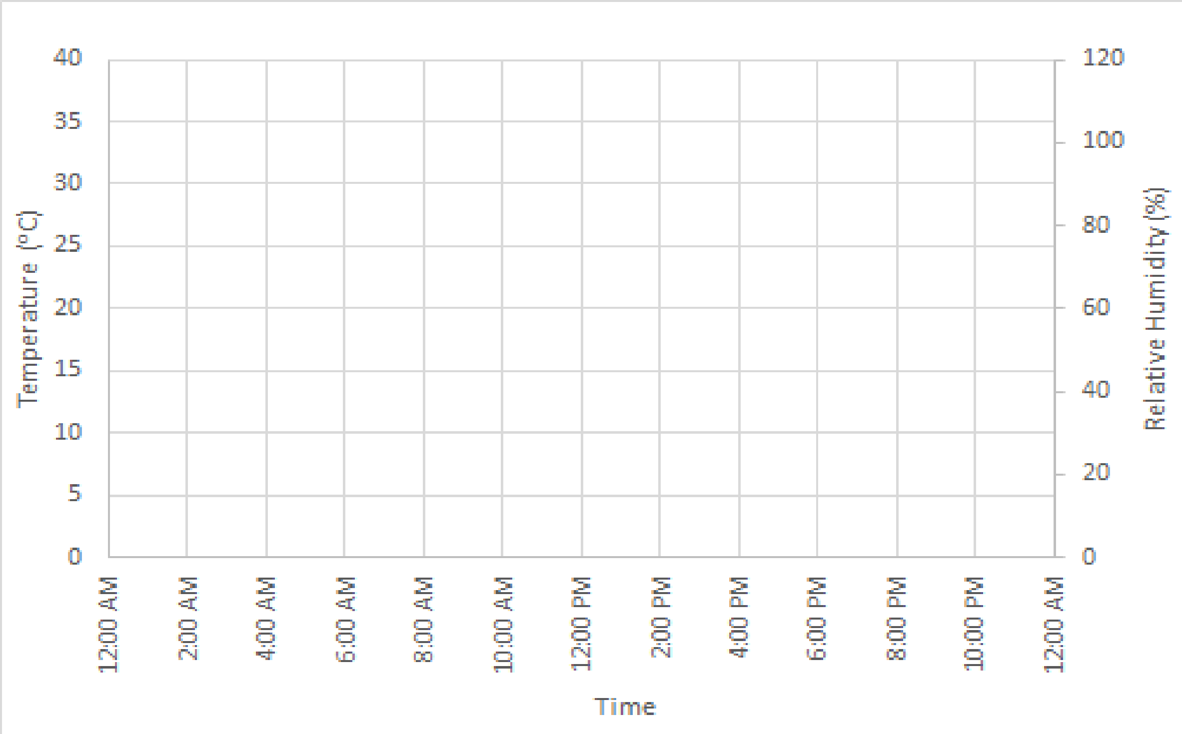
Td = Dew point temperature (in degree Celsius)

T = Observed air temperature (in degree Celsius)

Fill out the results table with the temperature, relative humidity, and dew point temperature. Then, plot your results for temperature, relative humidity, and dew point temperature on the graph in the results section. Use the left y-axis as the scale for both temperature and dew point temperature; use the right y-axis as the scale for the relative humidity data points.

**Results:**

| Time | Temperature ($^oC$) | Relative Humidity (%) | Dew point temperature ($^o$Celsius) |
|---|---|---|---|
| 12 am | | | |
| 1 am | | | |
| 2 am | | | |
| 3 am | | | |
| 4 am | | | |
| 5 am | | | |
| 6 am | | | |
| 7 am | | | |
| 8 am | | | |
| 9 am | | | |
| 10 am | | | |
| 11 am | | | |
| 12 pm | | | |
| 1 pm | | | |
| 2 pm | | | |
| 3pm | | | |
| 4pm | | | |
| 5 pm | | | |
| 6 pm | | | |
| 7 pm | | | |
| 8 pm | | | |
| 9 pm | | | |
| 10 pm | | | |
| 11 pm | | | |




Verify your hand drawn plots with MS Excel plots.

**Discussion:**

How is the weekly trend of temperature and humidity? Can we make analogue weather prediction from the trend?

______________________________________________________________________________

______________________________________________________________________________

How is the relationship between humidity and temperature?

______________________________________________________________________________

______________________________________________________________________________

Why does the relative humidity go up as the temperature goes down?

______________________________________________________________________________

______________________________________________________________________________

Why do we experience lower temperatures when the air is humid?

______________________________________________________________________________

______________________________________________________________________________

# Temperature vs Relative Humidity: Teacher Guide

**Level:** Intermediate

**Subject:** Geography and Mathematics

**Duration:** 50 mins

**Type:** class room activity

**Learning goal:**

- To determine the relationship between temperature and humidity using statistical analysis functions of TAHMO weather stations in MS Excel spreadsheets

**Materials:**

- A computer with access to internet and MS Excel
- Access to school2school.net to download hourly humidity and temperature data

**Methods:**

PART 1:

Go to the school2school website and select one of the stations you prefer, or use data from your local station if applicable. Click on temperature and humidity icons to open the data. Check at several temperature and relative humidity values measured at different times. Ask the class what they notice? Are the humidity values the same or different at different temperatures? These questions forms the base of our activity. Our activity will be trying to answer these questions.

Now that you have noted that the humidity changes with the temperature tell the students to give reasons as to what might be the cause of this scenario. The good thing about asking your students to give these reasons is to challenge them to think harder about this particular topic and also you are able to know their level of awareness in this area. Their answers will create the hypothesis to our activity. The correct hypothesis is that humidity is inversely proportional to the temperature. That is, as temperature increases humidity decreases and the inverse is also true.

Throughout the activity, the classroom will be testing the hypothesis they developed. To test the hypothesis you need the humidity and temperature data and therefore tell your students to collect and record several values of the two parameters and I would recommend that you to record the data in an excel spreadsheet. Record the data in two different columns and name them.

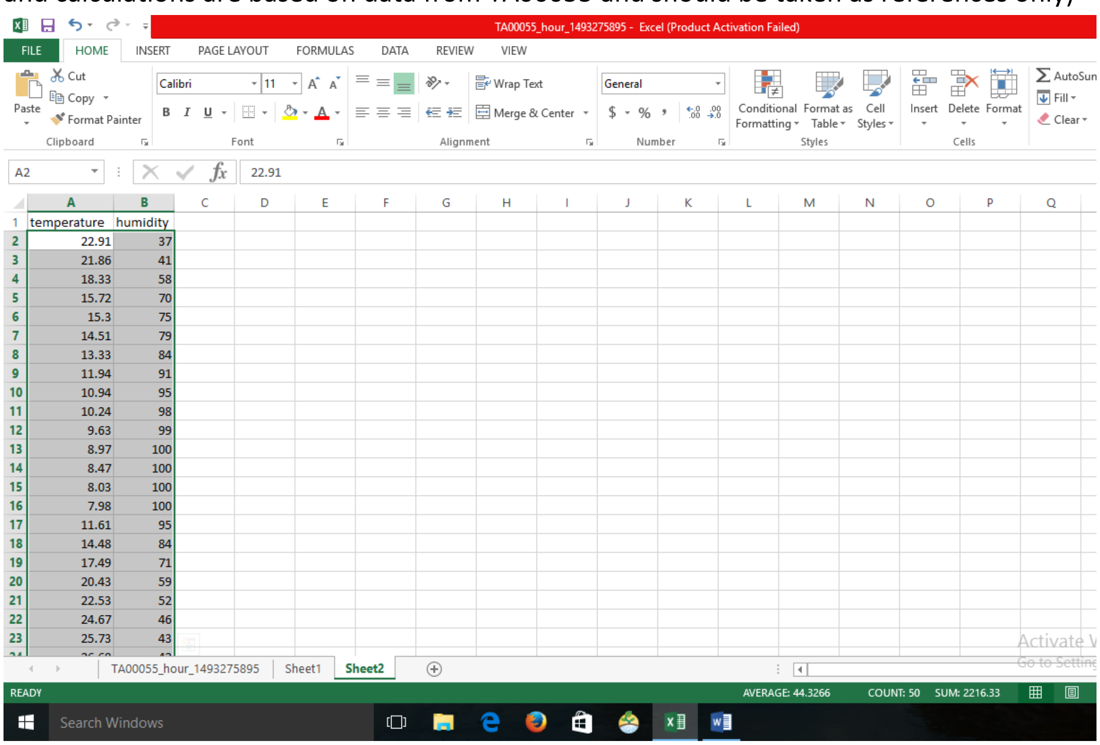
As this point the students should start working on their student handout. In the student handout, instructions are given for creating a table of data, plotting the data by hand, and calculating the correlation coefficient by hand (use of calculator are encouraged). These hand plots will be verified and compared with Excel plots in the following steps. Before moving onto the Excel portion, a few discussion questions might be useful:

- In our hand calculations, we only included 10 data points. When we plot all of the data points using Excel, do we expect it to show similar trends? (Answer: Yes, because the 10 data points we used are a subset of the total data we do expect the trends to be similar but not exact)
- What are some advantages of making the plots and calculation by hand first before using Excel? (Answer: we can better understand the process if we do the plots and calculations ourselves, that way when Excel gives us an answer we can understand and interpret it correctly)

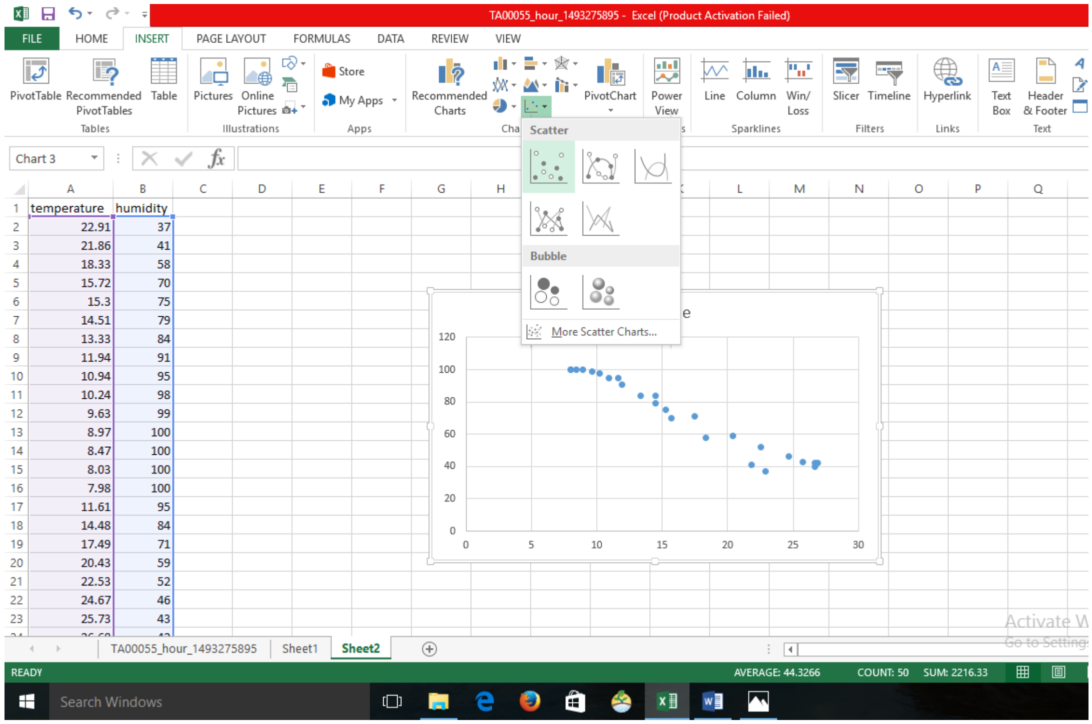
PART 2:

Now that the students have a better understanding of the correlation coefficient and know how to calculate it, we will duplicate this process using Excel. Using excel, plot the values you have on a chart (scatter plot). This chart makes it easier to see how one variable is affected as the other one changes. To accomplish this follow these steps:

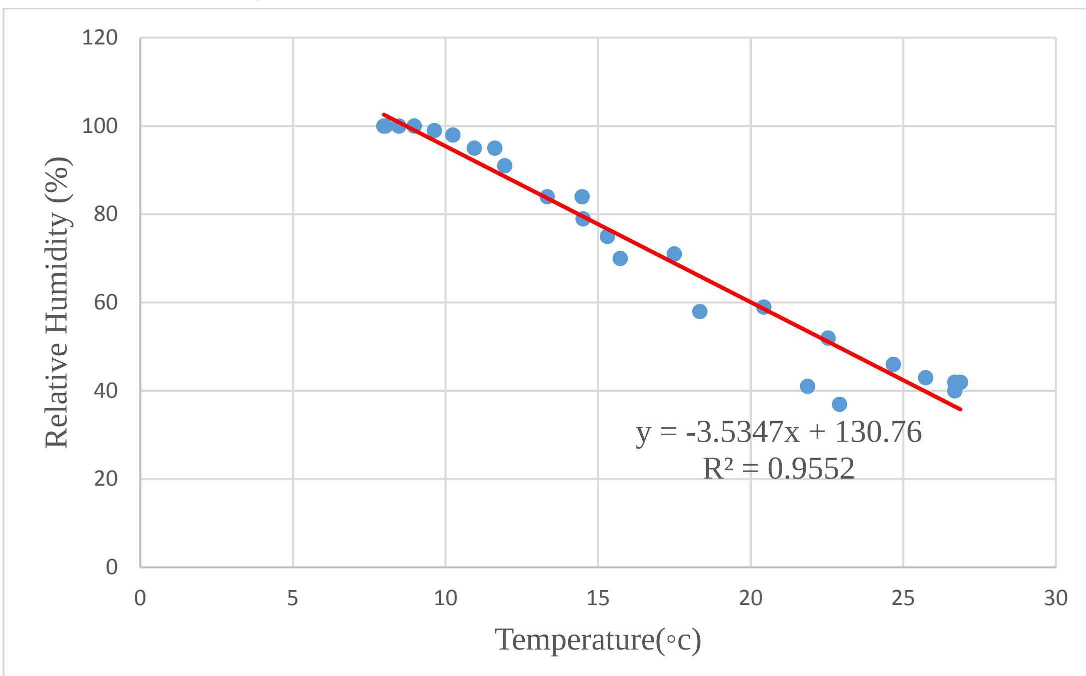
1. Highlight both columns containing temperature and humidity. (The following screenshots and calculations are based on data from TA00055 and should be taken as references only)




2. Open the insert tab on the main menu. Navigate to charts and select the scatter plots. A graph of the plotted data will be displayed.

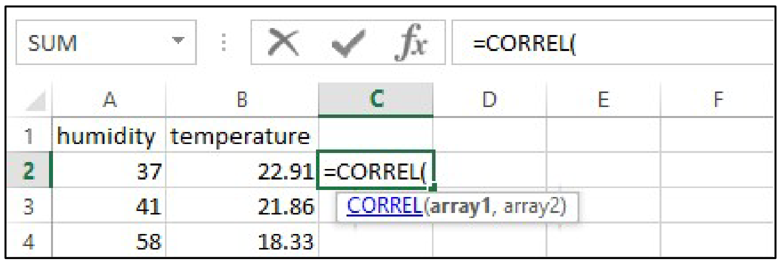


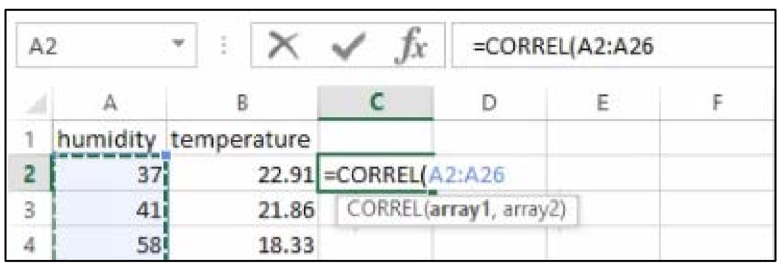

3. To see the trend, click an icon with a shape of a plus sign on the top right side of the chart and scroll down to trend line and select. A line will appear on the charts slanting on the direction of the change.

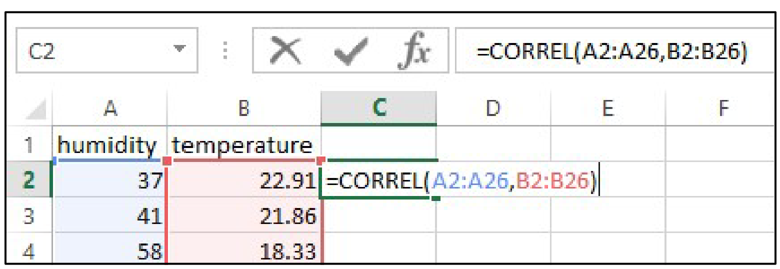


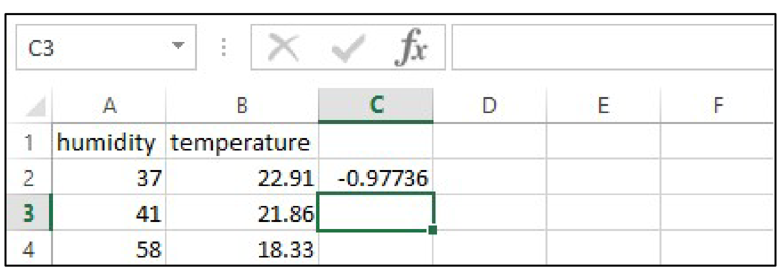

To calculate the strength of the relationship between your two parameters commonly referred to as correlation coefficient. The correlation coefficient determines the strength of the relationship between the two parameters. To accomplish this in Excel, follow these steps:

1. Click on any cell in your sheet. Enter an equals'=' sign. Immediately behind the equals sign type the word 'corr', excel will immediately below bring an icon with the word 'correl' Double click on it. It will inside your working cell write "correl" (and just below it 'CORREL (array 1, array2). Array is the data sets you want to perform the correlation. The number 1 and 2 indicates that you have two data sets that you want to perform the correlation.
2. So to perform the correlation click on "correl" (inside your working cell, highlight your first column and insert a comma "," then highlight the second column and close the bracket, then press enter. A correlation value should appear. That tells you the strength of the relationship between the parameters. Correlation coefficient for this dataset is calculated to be -0.97736114. A correlative coefficient above 0.80 is said to be strong, a value below 0.5 is said to be very weak. The following pictures shows the procedure described above:



**Discussion**

From the hand drawn plot and the Excel plots you created, what is the direction of the slope (Positive slope = / or negative slope + \)? [Answer: The slope is negative]

What does the slope direction tell you about the relationship between relative humidity and temperature? [Answer: A negative slope tells you that the two parameters are inversely proportional. This means that an increase in one parameter leads to a decrease of the other, and vice versa]

We have identified a relationship from the above. The question you should ask now is, how did we mathematically measure the relationship? [Answer: Correlation coefficient. Using our spreadsheet we are able to define how strongly our parameters are related by use of the correlation coefficient (it is a term mostly used in statistics to show the strength of relationship between variables). From the analysis correlation coefficient is-0.97736114, which means they are strongly related but in the opposite direction, that is as one changes the other one also changes but in the opposite direction. The R-squared value is 0.9552 or 96% which indicates that 96% of humidity in the air is controlled by temperature.]

Why is humidity inversely proportional to temperature? [Answer: If the water vapor content stays the same and the temperature drops, the relative humidity increases. If the water vapor content stays the same and the temperature rises, the relative humidity decreases. This is because colder air doesn't require as much moisture to become saturated as warmer air.]

# Temperature vs Relative Humidity: Student Worksheet

**Materials:**

- Pen
- Calculator
- Computer with MS Excel and internet access

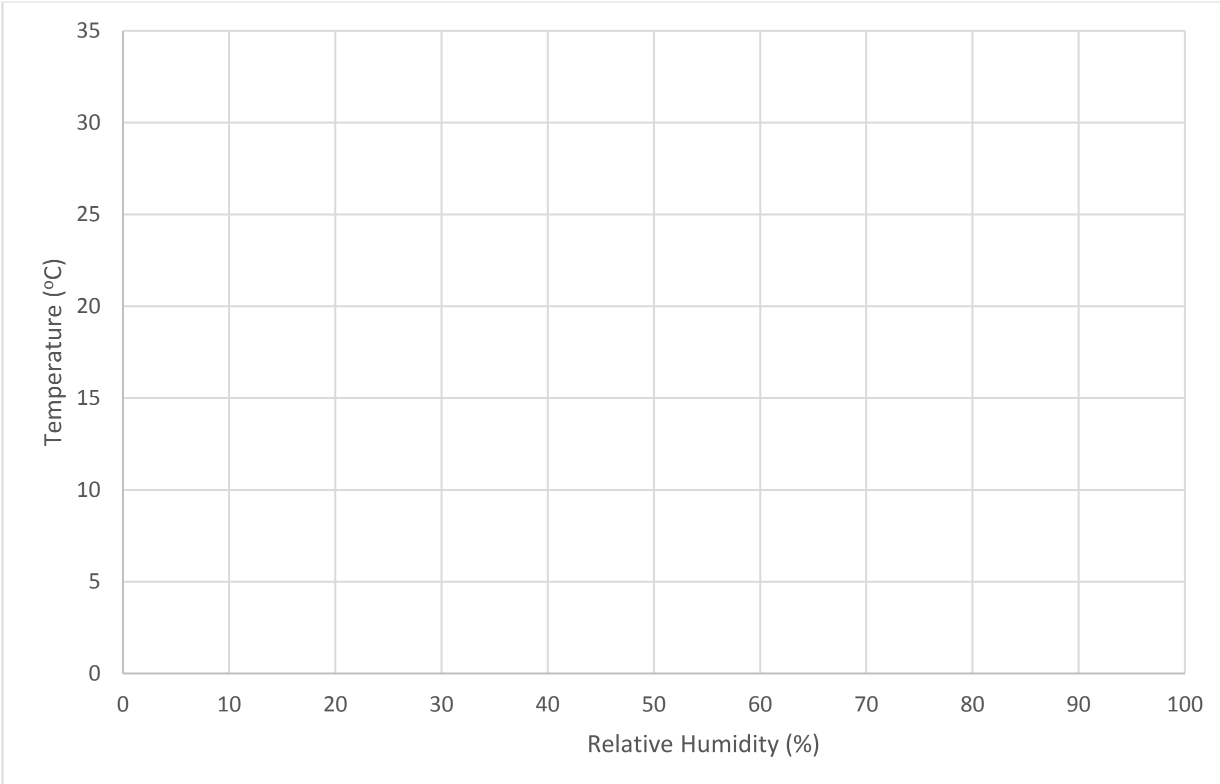
**Methods:**

Download the data from your local TAHMO weather stations from the School2School.net website. Open the hourly data in an Excel spreadsheet. Please note that the time in the downloaded file is given in Coordinated Universal Time (UTC) and not local time. In the table below, record the first ten hourly data for temperature and their corresponding relative humidity data from the Excel.

| Time | Temperature(◦c) | Relative Humidity (%) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Using the completed table above, by hand make a plot with temperature as the y-axis and humidity as the x-axis. Draw a line of best fit.

V.1




Calculation of correlation coefficient:

| X(temperature) | Y(humidity) | $x^2$ | $y^2$ | x*y |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Total= | Total = | Total = | Total = | Total = |

Use the following formulae to determine the strength of the relationship between temperature and humidity:

Where n= total number of variables in our case (20) and $\sum$ is the summation.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

Correlation coefficient = ___________________________________

**Discussion:**

What are the units for relative humidity? What is the range of possible values (minimum and maximum)?

_______________________________________________________________________________

_______________________________________________________________________________

From your graph what is the direction of the slope (Positive slope = / or negative slope + \)? Using the words temperature and relative humidity, explain the significance of a slope in that direction.

_______________________________________________________________________________

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# Diurnal Temperature Variation vs. Latitude: Teacher Guide

**Level:** Intermediate

**Subject:** Geography and Math

**Duration:** 50 Minutes

**Type:** Classroom Activity

**Learning Goals:**

- Define the spatial and temporal limits of the data
- Arrange the data for plotting using Excel
- Compare diurnal temperature variations for two locations at different latitudes
- Represent data using line graphs and carry out simple analysis

**Materials**

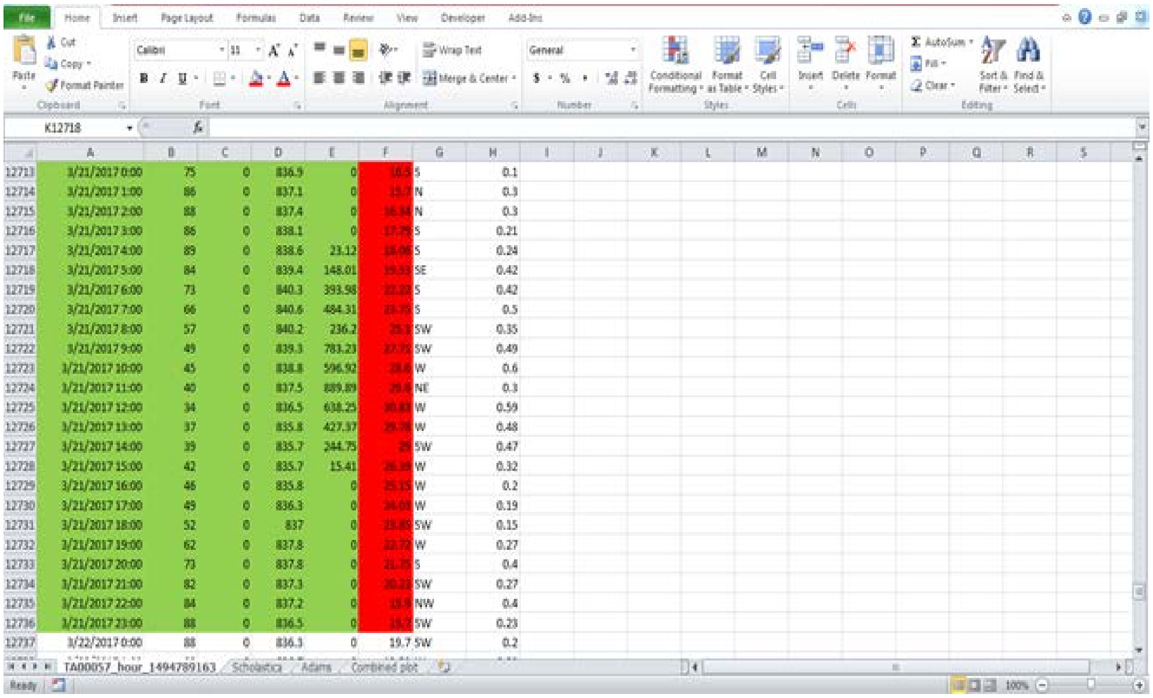
- Access weather data from the S2S TAHMO Website. http://school2school.net
- Spreadsheet program like Microsoft Excel

**Introduction**

Temperature is cyclical, meaning that each day it goes in a cycle with generally warmer temperatures during the day and cooler temperatures during the night. For more information on daily temperature cycles- see the temperature cycle lesson plan at https://school2school.net/wp-content/uploads/2017/11/temp-cycle.pdf. This lesson plan focuses on the diurnal temperature variation at different latitudes, comparing the high and low temperatures that occur during the same day. St Scholastica is in a tropical climate while Adams Elementary is a mid-latitude climate, thus these two stations are suggested for comparisons.

**Methods:**

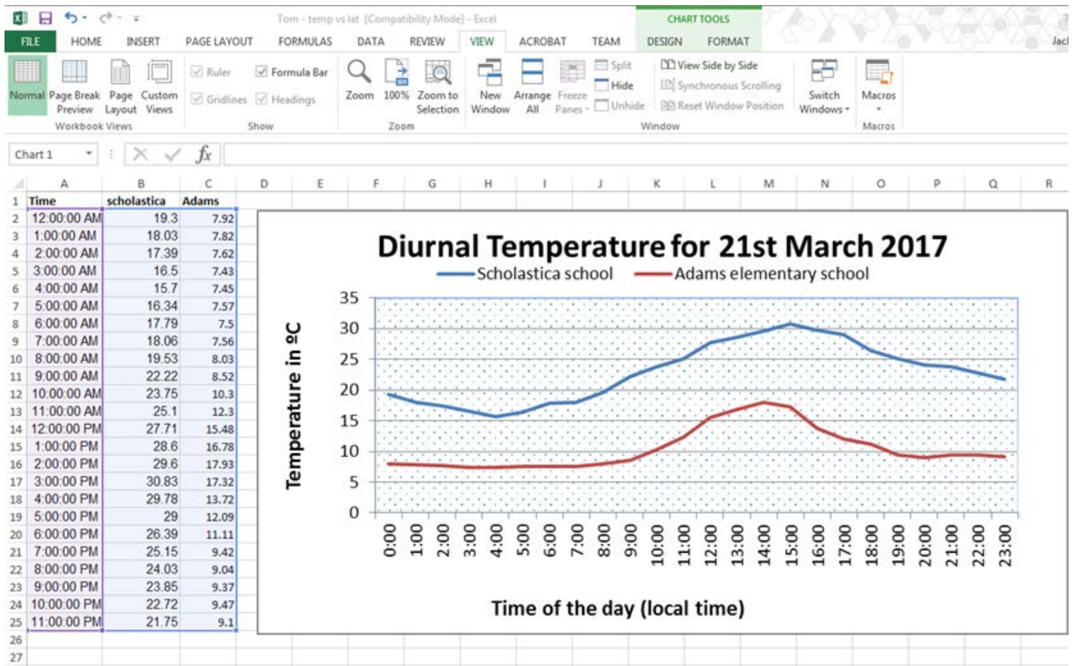
- Before class, the teacher can download and arrange the temperature data for both Scholastica and Adams Elementary school in advance to save on time. However, take a few minutes to practically guide the students on how you accessed, downloaded and arranged the data you are presenting to them. There is a video tutorial on the School-2-School website with more information on how to download the TAHMO data. The TAHMO data are saved in a CSV file format, a format is compatible with several analysis programs including Microsoft Excel, Open Access, and Google Sheets.
- The students can be divided to work in groups if the computer access is limited. The teacher should decide on the criteria knowing the composition and capabilities of the students. The choice of stations can be changed depending on the preference of the teacher and the students.
- The TAHMO data from the school2school website will have several columns. The first column has the date and time of the data record in Universal Time Coordinates. Please note that the time in the downloaded file is given in Coordinated Universal Time (UTC) and not local time. To convert from UTC to local time, use the time zone to either add or subtract from the UTC time. The time zone can be found on the School2School.net website for each station under the name of the school. You will need to convert the time for each station to the local time for the following analysis. When your students look at the data, ask for them to get familiar with the data by asking questions like what the time frequency is and what variables are recorded. [Answer: stations record humidity, precipitation, air pressure, solar radiation, air temperatures, wind directions and wind speed in hourly interval]
- Extract the temperature data for the specific date of choice for the 24hours. This should be done for the two stations. In Excel, plot the combined lined graph for both stations for the same day i. e 21$^{st}$ March 2017. As a geography student, what's unique with the 21$^{st}$ March and 23$^{rd}$ September dates of the year? [Answer: The times of the year when the sun is overhead the equator is normally referred to as the Equinox dates. The Equinox dates are usually around 21$^{st}$ March and 23$^{rd}$ September every year. During Equinox, the length of the day and night are usually equal. During the other times of the year, the sun is either on the Southern or Northern hemispheres.]




- In a new worksheet on the same spreadsheet, arrange your temperature data for the selected date to have three columns for time of the day, Temperature for Adams and temperature for Scholastica. Arrange your data in the spreadsheet as follows.

| **Time** | **St Scholastica** | **Adams** |
|---|---|---|
| 12:00:00 AM | | |
| 1:00:00 AM | | |
| 2:00:00 AM | | |
| …. | | |
| 8:00:00 PM | | |
| 9:00:00 PM | | |
| 10:00:00 PM | | |
| 11:00:00 PM | | |

- Next, plot a line graph for the 24 hour air temperature data for the two stations. The data should be arranged and plotted as shown below. Click on the insert button on the menu tool bar. A new bar opens and under the charts, select line and select further the type of line graph you want. The graphs must have temperature measurements in the Y-axis in any measurement unit and time in hours labeled in the X- axis. The interval for the time must be one hour. To be able to analyze and interpret the graphical data, the teacher can ask the students to answer the questions in the student worksheet and discuss the data from the graphs and compare for the two stations.



| Time | scholastica | Adams |
|---|---|---|
| 12:00:00 AM | 19.3 | 7.92 |
| 1:00:00 AM | 18.03 | 7.82 |
| 2:00:00 AM | 17.39 | 7.62 |
| 3:00:00 AM | 16.5 | 7.43 |
| 4:00:00 AM | 15.7 | 7.45 |
| 5:00:00 AM | 16.34 | 7.57 |
| 6:00:00 AM | 17.79 | 7.5 |
| 7:00:00 AM | 18.06 | 7.56 |
| 8:00:00 AM | 19.53 | 8.03 |
| 9:00:00 AM | 22.22 | 8.52 |
| 10:00:00 AM | 23.75 | 10.3 |
| 11:00:00 AM | 25.1 | 12.3 |
| 12:00:00 PM | 27.71 | 15.48 |
| 1:00:00 PM | 28.6 | 16.78 |
| 2:00:00 PM | 29.6 | 17.93 |
| 3:00:00 PM | 30.83 | 17.32 |
| 4:00:00 PM | 29.78 | 13.72 |
| 5:00:00 PM | 29 | 12.09 |
| 6:00:00 PM | 26.39 | 11.11 |
| 7:00:00 PM | 25.15 | 9.42 |
| 8:00:00 PM | 24.03 | 9.04 |
| 9:00:00 PM | 23.85 | 9.37 |
| 10:00:00 PM | 22.72 | 9.47 |
| 11:00:00 PM | 21.75 | 9.1 |



**Discussions**

- How is weather information useful in our daily lives at the local level? [Answer: Weather information is helpful in our social lives as it help us plan our social activities such as sports, weddings and parties among other things. In addition, the weather information is useful in our agriculture, aviation, disaster management, security and transport in general. Farmers need to know when the rains begin and when it ceases; flood forecasts can be helpful in averting disasters. Weather information is therefore useful in our lives]
- We know that the earth revolves around the sun and rotates about its own axis. Which of the two (revolution around the sun or rotation on own axis) causes day and night? [Answer: The earth rotation about its own axis causes day and night. When it is day on one side of the globe, it is night on the other side of the globe. Therefore, we can see from the above graph that when it's 12.00PM universal time, the temperatures are very low in Adams and very high in Scholastica. The revolution of the earth around the sun causes the four major seasons of winter, summer, spring and autumn.]

- What do you expect the plot of diurnal temperature look like? When is temperature at a minimum? When is the temperature at the highest? Use to plot below to draw a sketch of what you predict the daily temperature graph to look like. [Answer: we expect the temperature rises steadily from midnight to reach the peak at midday then falls gradually as the night approaches. The minimum temperature occurs at night, the maximum temperature occurs during midday]
- As a class, use Excel to plot the Temperature vs time for the schools that you looked at. Is the plot similar to what you sketched? Why or why not? [Answers may vary: in general locations that are closer to the equator will have higher maximum temperatures than locations that are farther from the equator]
- Considering the general temperatures from the two stations, what dressing codes would you recommend for someone visiting the two areas? [Answers may vary: Considering the observed temperature variation for the day in Scholastica, I would recommend generally light clothing during the day. Since the temperatures steadily rises, it would be advisable to dress in light cloths. However, the clothing choice is further dependent on one's health, preference and other weather elements. Outdoor activities are highly recommended. The temperature at Adams steadily falls before rising gradually later in the day. The general dressing code here should be warm cloths and maybe heavy for some times. Everyone should keep warm and indoor activities are encouraged.]

# Diurnal Temperature Vs Latitude: Student Worksheet

Match the weather elements to the instrument used to measure it by drawing a line between them.

| **Weather element** | **Instrument** |
|---|---|
| Air pressure | Anemometer |
| Rainfall | Wind sock |
| Wind speed | Solarimeter |
| Solar radiation | Rain gauge |
| Wind direction | Barometer |

How is weather information useful in our daily lives at the local level?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

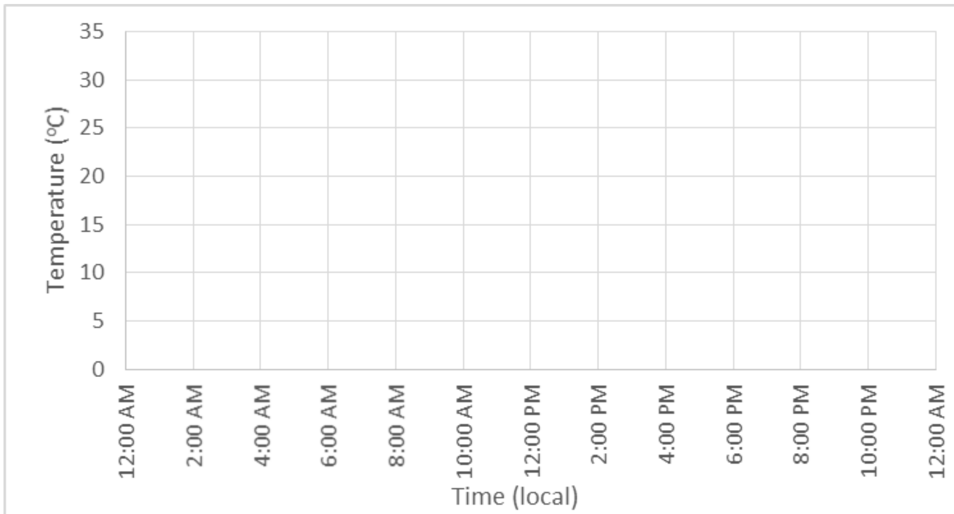
We know that the earth revolves around the sun and rotates about its own axis. Which of the two (revolution around the sun or rotation on own axis) causes day and night?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

What do you expect the plot of diurnal temperature look like? When is temperature at a minimum? When is the temperature at the highest? Use to plot below to draw a sketch of what you predict the daily temperature graph to look like.




As a class, use Excel to plot the Temperature vs time for the schools that you looked at. Is the plot similar to what you sketched? Why or why not?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

Describe the temperature variation for the whole day for the two stations. How are they similar, how are they different?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

Considering the general temperatures from the two stations, what dressing codes would you recommend for someone visiting the two areas?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

# Barometric Pressure Activity: Teacher Guide

**Level:** Intermediate

**Subject:** Geography and Mathematics

**Duration:** 1 hour

**Type:** Guided classroom activity

**Learning Goals:**

- Use the scientific process to find a relationship between barometric pressure and altitude
- Use data from the School2School.net website
- Use statistics to verify the relationship between barometric pressure and altitude

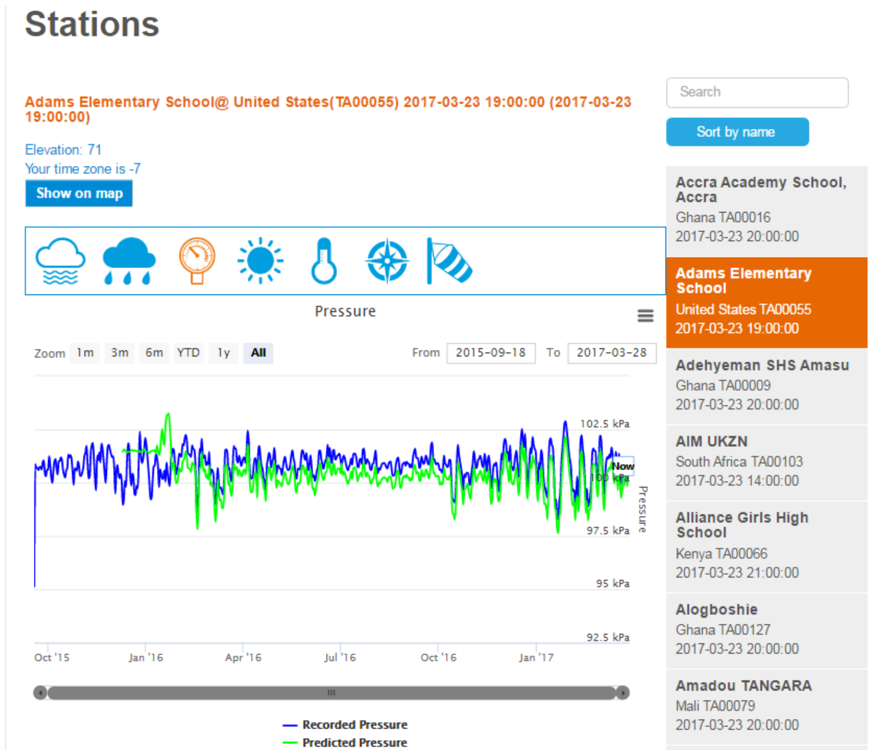
**Materials:**

- Access to the School2School.net website
- Barometric Pressure Powerpoint - https://docs.google.com/presentation/d/1G8R3GJ9aHg2me2-z3OdZV4ke-arQ_ualpZ_AgEE1ycE/edit?usp=sharing
- Pressure and Elevation Spreadsheet - https://drive.google.com/file/d/0BxNcyc_sE4pPcnZya1FIb3BaRlE/view?usp=sharing

**Methods:**

As a class work though the Barometric Pressure Powerpoint using the scientific process

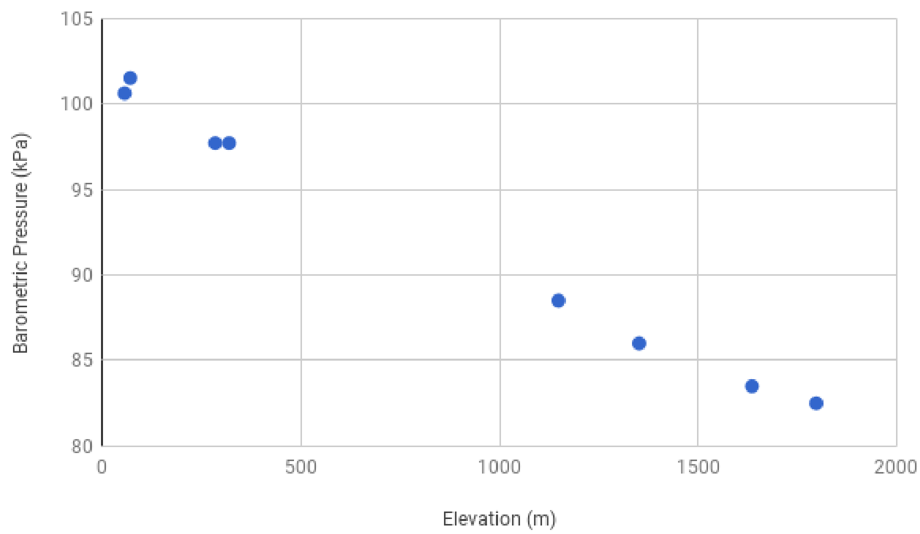
1. The first step of the scientific process is to ask a question. In this case, the question is: is barometric pressure different between stations? Start making observations by going to School2School.net, and clicking on the "Stations" tab. Navigate to your school's station if you have your own TAHMO station, or else just choose a close station. Pick the Barometric Pressure icon (third from the left) to display the graph of the recorded pressures (See image below). Note the maximum, minimum, and average pressure values (using estimations is okay- just a rough guess by eye is appropriate). Choose another station and compare your results, do you see a difference in the range of pressures for different stations? [Answer: the maximum pressure recorded is different for different stations, it doesn't seems like the variable is bounded]



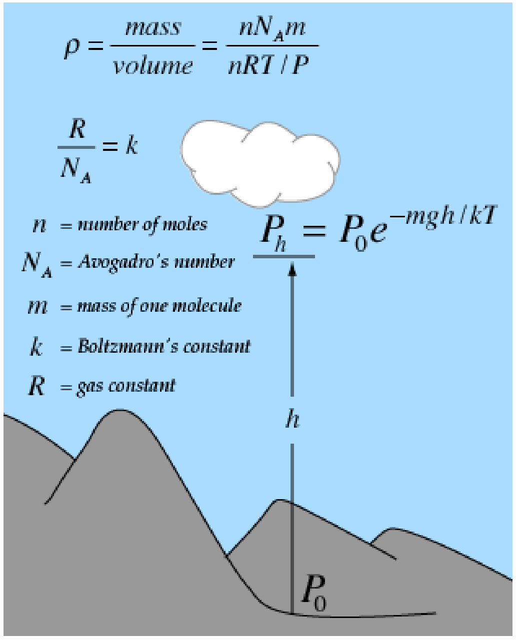

2. The second step of the scientific process is to develop a hypothesis. Now that you have seen that there are different pressure ranges for different stations, ask the class why they think barometric pressure is different for different stations? Have students develop multiple hypothesis for explaining the different barometric pressure ranges, remember that all hypotheses should be considered, this step is all exploring a wide variety of different explanations. What information from the School2School site can help formulate these hypotheses? Another piece of information given for each station is the elevation (in meters) and is located just under the station name. Once the concept of a relationship between pressure and altitude is suggested by a student, suggest that you use this as your primary hypothesis for the remainder of the activity. [Answer: A good working hypothesis might be that barometric pressure is controlled by elevation, or that barometric pressure and elevation and inversely related]
3. The third step of the scientific process is to test the hypothesis. Brainstorm with the class how you might test the hypothesis. A great way to start testing the hypothesis is to start collecting data for the two variables of interest: barometric pressure and elevation. Which variable is the explanatory variable and which one is the response variable? [Answer: Elevation is the explanatory variable because it is independent. The pressure is the response variable because it is dependent on the elevation]
4. The fourth step of the scientific process is to record the data, so create a spreadsheet with barometric pressure vs altitude for numerous stations (columns A-E in Sheet 1). A good question to ask the class is how many stations they think should be compared. [Answer: As a general rule, more than 7 data points is best]. Record the estimated average pressure for each station and record in the Excel sheet. You can you a rough eye-ball estimate the average pressure for each station- you do not need to calculate an exact average. [Note: Below is an example table of 7 stations with a wide range of elevations that is used in the following analysis in the calculations section, but any stations can be used for the analysis]

| Station Name | Location | Station # | Elevation (m) | Pressure (kPa) |
|---|---|---|---|---|
| Réseau MARP | Burkina Faso | TA00082 | 320 | |
| St. Scholastica Catholic School | Kenya | TA00057 | 1636 | |
| Accra Academy School | Ghana | TA00016 | 57 | |
| Bol Matafo2 | Chad | TA00084 | 285 | |
| Gashora Girls Academy | Rwanda | TA00075 | 1352 | |
| Entebbe WME | Uganda | TA00033 | 1149 | |
| Kenya Met. Dept | Kenya | TA00025 | 1798 | |
| Adams Elementary School | United States | TA00055 | 71 | |

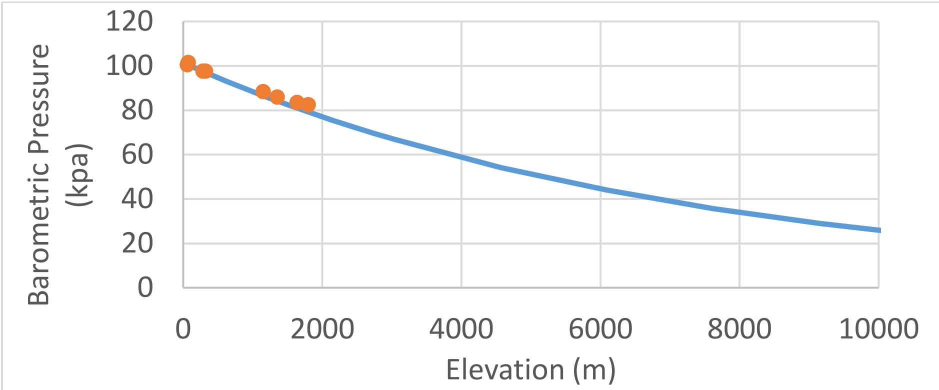
5. The fifth step of the scientific process is making conclusions. Once the data has been recorded, creating a plot is useful for seeing the relationship between the two variables (see image below). What kind of relationship do the data points show? [Answer: The trend that can be identified from the plot is that for lower elevations there is a higher pressure, and for higher elevations the pressure is lower- this is an inversely proportional relationship




6. Now that the relationship has been identified as inversely proportional, can it be validated using meteorology and mathematics. Ask the class, how can we look for a mathematical relationship barometric pressure and elevation? [Answer: Based on the idea gas law, there is a known mathematical relationship between pressure and elevation based on the barometric formula assuming the standard temperature lapse rate equals zero: Pressure = 101.325 * exp(-1.37*10-4*elevation). This formula is given in the spreadsheet on Sheet2 in columns L-M. Figure from http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/barfor.html]




7. Does our data follow this formula? Try plotting our 7 data points on the same graph as the barometric formula relationship. [Answer: Yes, our data does seem to follow the barometric formula relationship. The data points only cover a small ranges of elevation but it does seem to correctly represent the relationship.] Can this model be used to extrapolate the barometric pressure for elevations much higher than we have data for? [Answer: generally extrapolate outside of the collected range of values for the explanatory variable is not recommended. Even though we do have a mathematical relationship between elevation and barometric pressure, we should not extrapolate to calculate pressure for very high elevations.]




**Discussion**

Have the class summarize the activity by asking questions such as:

- What is the relationship between pressure and elevation? [Answer: they are inversely proportional]
- What are other factors that affect pressure besides elevation? [Answer: local weather such as temperature and wind speed also affect air pressure and air density]
- How did we use the scientific theory to reach our conclusions?

# Barometric Pressure Activity: Student Worksheet

Navigate to the School2School.net website, explore the barometric pressure trends for numerous stations for this activity. Using the 5 main steps of the scientific method, describe how each step was used in this activity.

1. Ask a question

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

2. Make a hypothesis

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

3. Develop a method to test your predictions

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

4. Collect data to test your hypothesis

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

5. Analyze data and draw conclusions

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

# Advanced Topics: Barometric Pressure

This advanced topic is intended for classes that want to continue to explore the barometric formula for pressure and elevation. As a general rule, the pressure drops approximately by 11.3 Pascals per meter in first 1000 meters above sea level. This following exercise will use Excel and mathematical principals to quantify how well our data fits the barometric formula.

The following calculations are based on the preselected 7 stations and the estimated average pressures. Your results may be slightly different based on stations chosen, estimated pressures, or dates chosen. The following calculations are for reference and to be used as a guide for the analysis only.

In mathematics, what strategies are there for determining the relationship between two variables? [Answer: sum of the square error (SSE), total sum of the square (SSTO), correlation coefficient (R), coefficient of determination ($R^2$)].

We can use statistics and the sum of the square error to determine how well our data fits the known relationship (Sheet2 columns G-H).] We will be using Excel's capabilities to calculate these variables. Start by setting up the spreadsheet with three additional columns titled: "Calculated Pressure", "y-yhat)^2", and "SSTO".

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Station Name** | **Location** | **Station #** | **Elevation** | **Pressure (kpa)** | **Calculated Pressure** | **(y-yhat)^2** | **SSTO** |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | | | |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | | | |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | | | |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | | | |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | | | |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | | | |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | | | |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | | | |

In column F we are calculating the theoretic pressure given the recorded elevation from the mathematical relationship. Type into the formula bar an equals sign (=) followed by 101.325 * EXP (-1.37 * 10-4 * D2. Use the cell reference of D2 instead of typing in the number. Push enter.

SUM | =101.325*EXP(-0.000137*D2)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Station Name** | **Location** | **Station #** | **Elevation** | **Pressure (kpa)** | **Calculated Pressure** | **(y-yhat)^2** | **SSTO** |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | =101.325*EXP(-0.000 | | |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | | | |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | | | |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | | | |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | | | |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | | | |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | | | |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | | | |

Hover your curser over the bottom right corner of the F2 cell until your curser shows a small black plus sign (this is the fill command). Click and drag the curser down to F9, this action will fill each of the cells with the same formula.

F2 | =101.325*EXP(-0.000137*D2)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Station Name | Location | Station # | Elevation | Pressure (kpa) | Calculated Pressure | (y-yhat)^2 | SSTO |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | 96.97887512 | | |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | 80.97991594 | | |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | 100.5368345 | | |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | 97.44500548 | | |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | 84.19278027 | | |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | 86.56712915 | | |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | 79.20244523 | | |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | 100.3441896 | | |

Column G will be used to calculate the sum of the square error (SSE). In the column you will calculate the square error between the calculated pressure and the recorded pressure, which will later be summed to give you the SSE. Type into the formula bar an equals sign "=" followed by a set of parenthesis and subtract column F from column E, after the end parenthesis raise your unit to the 2$^{nd}$ power. Push enter after adding the formula. Use the fill command to drag the formula in the rest of the stations in that column. In the cell G10 use the SUM function in excel to add all up all the values in column G. [Note: there is also an excel function to directly calculate SSE. In an empty cell type the following formula: =SUMXMY2(E2:E9,F2:F9)]

SUM | =(E2-F2)^2

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Station Name | Location | Station # | Elevation | Pressure (kpa) | Calculated Pressu | (y-yhat)^2 | SSTO |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | 96.97887512 | =(E2-F2)^2 | |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | 80.97991594 | | |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | 100.5368345 | | |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | 97.44500548 | | |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | 84.19278027 | | |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | 86.56712915 | | |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | 79.20244523 | | |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | 100.3441896 | | |

SUM | =SUM(G2:G9)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Station Name | Location | Station # | Elevation | Pressure (kpa) | Calculated Pressu | (y-yhat)^2 | SSTO |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | 96.97887512 | 0.520021093 | |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | 80.97991594 | 6.350823692 | |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | 100.5368345 | 0.003989884 | |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | 97.44500548 | 0.065022205 | |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | 84.19278027 | 3.266043166 | |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | 86.56712915 | 3.735989717 | |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | 79.20244523 | 10.87386743 | |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | 100.3441896 | 1.335897613 | |
| 10 | | | | | | | =SUM(G2:G9) | |

In column H you will calculate the total sum of the squares (SSTO). The SSTO is calculated by the difference between the sample and the sample average, this quantity is square. To calculate the sample mean, use the Excel AVERAGE command. The formula for column H uses the following formula structure: =(E2-Average(E2:E9))^2. Sum the column in cell H11 representing the SSTO.

SUM | =(E2-AVERAGE($E$2:$E$9))^2

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Station Name** | **Location** | **Station #** | **Elevation** | **Pressure (kpa)** | **Calculated Pressu** | **(y-yhat)^2** | **SSTO** |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | 96.97887512 | 0.520021093 | =(E2-AVER |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | 80.97991594 | 6.350823692 | 76.5625 |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | 100.5368345 | 0.003989884 | 69.7225 |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | 97.44500548 | 0.065022205 | 29.7025 |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | 84.19278027 | 3.266043166 | 39.0625 |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | 86.56712915 | 3.735989717 | 14.0625 |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | 79.20244523 | 10.87386743 | 95.0625 |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | 100.3441896 | 1.335897613 | 85.5625 |
| 10 | | | | | | SSE | 26.1516548 | |

SUM | =SUM(H2:H9)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Station Name** | **Location** | **Station #** | **Elevation** | **Pressure (kpa)** | **Calculated Pressu** | **(y-yhat)^2** | **SSTO** |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | 96.97887512 | 0.520021093 | 29.7025 |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | 80.97991594 | 6.350823692 | 76.5625 |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | 100.5368345 | 0.003989884 | 69.7225 |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | 97.44500548 | 0.065022205 | 29.7025 |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | 84.19278027 | 3.266043166 | 39.0625 |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | 86.56712915 | 3.735989717 | 14.0625 |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | 79.20244523 | 10.87386743 | 95.0625 |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | 100.3441896 | 1.335897613 | 85.5625 |
| 10 | | | | | | SSE | 26.1516548 | |
| 11 | | | | | | SSTO | | =SUM(H2: |

At this time, we have all the information necessary to calculate the coefficient of determination ($R^2$). The coefficient of determination indicates that the model explains a certain percent of the variability of the response data. In the example spreadsheet, the $R^2$ is in cell H13 of Sheet2, with a value of 0.94.

SUM | =1-G10/H11

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **Station Name** | **Location** | **Station #** | **Elevation** | **Pressure (kpa)** | **Calculated Pressu** | **(y-yhat)^2** | **SSTO** |
| 2 | Réseau MARP | Burkina Faso | TA00082 | 320 | 97.7 | 96.97887512 | 0.520021093 | 29.7025 |
| 3 | St. Scholastica Catholic School | Kenya | TA00057 | 1636 | 83.5 | 80.97991594 | 6.350823692 | 76.5625 |
| 4 | Accra Academy School, Accra | Ghana | TA00016 | 57 | 100.6 | 100.5368345 | 0.003989884 | 69.7225 |
| 5 | Bol Matafo2 | Chad | TA00084 | 285 | 97.7 | 97.44500548 | 0.065022205 | 29.7025 |
| 6 | Gashora Girls Academy | Rwanda | TA00075 | 1352 | 86 | 84.19278027 | 3.266043166 | 39.0625 |
| 7 | Entebbe WME | Uganda | TA00033 | 1149 | 88.5 | 86.56712915 | 3.735989717 | 14.0625 |
| 8 | Kenya Meteorological Department | Kenya | TA00025 | 1798 | 82.5 | 79.20244523 | 10.87386743 | 95.0625 |
| 9 | Adams Elementary School | United States | TA00055 | 71 | 101.5 | 100.3441896 | 1.335897613 | 85.5625 |
| 10 | | | | | | SSE | 26.1516548 | |
| 11 | | | | | | SSTO | | 439.44 |
| 12 | | | | | | R^2 | | =1-G10/H1 |

What does the coefficient of determination mean? [Answer: The correct interpretation of this value is that 94% of the variability in pressure is explained by the elevation.]

Ask the class, does this value mean that we have a good agreement between our data and the mathematical model? [Answer: Generally, a value for $R^2$ greater than 0.75 indicated good agreement between the data and the model. We got a value of 0.94 for the relationship between elevation and pressure, so yes there is a strong relationship between these two variables.]

Does the statistical analysis confirm our hypothesis?

# Wind Speed vs Temperature: Teacher Guide

**Level:** Intermediate

**Subject:** Geography and Mathematics

**Duration:** 1 hour

**Type:** Classroom activity

**Learning goal:**

- Use of statistical tool (MS Excel) and real time data to find the nature of the relationship between the two parameters

**Materials:**

- A computer with access to internet and MS Excel
- Access to school2school.net to download hourly humidity and temperature data

**Introduction:**

Temperature is the intensity of heat in a substance while the wind speed is the air in motion from. A gradient in temperature occurs when two locations are at different temperatures, causing the differences in air pressure between the two spots. The atmosphere tries to equalize the air pressure at these two spots, forming wind. Generally, the larger the temperature difference, the stronger the resulting winds will be. Temperature gradients between water and land can also cause local atmospheric circulations which affect winds. During the day in summer when the land heats up more quickly than water, heat-related low pressure causes rising air over land which moves over the water and cools, then returns to land as a cooling "sea breeze". At night, the water is often warmer than the land and the reverse circulation, which includes a breeze from land to sea called a "land breeze", takes its place.

**Methods:**

Open the school2-school website and choose one station that you would like to use for your analysis. If you have a TAHMO station in your school then it is the best to use. Open the wind speed and temperature data by clicking the icons labeled temperature and wind speed. Tell your students to compare the values of the two parameters. How do the data compare? Is there any notable relationship?

You notice that there is a relationship between the wind speed and temperature. Can you explain the relationship? Let the students give the answers. Since the class has not completed the analysis don't ignore any answer given by the students. At this point all answers are neither right nor wrong .The accepted hypothesis is that there is a direct relationship between the temperature and wind speed or the wind speed increases with temperature.

Now you have the hypothesis. At this step your students will now be proving or disproving that hypothesis i.e. testing the hypothesis. So tell your students to record several wind speed data values on two separate columns but in the same excel sheet and name them.

As this point the students should start working on their student handout. In the student handout, instructions are given for creating a table of data, plotting the data by hand, and calculating the correlation coefficient by hand (use of calculator are encouraged). These hand plots will be verified and compared with Excel plots in the following steps. Before moving onto the Excel portion, a few discussion questions might be useful:

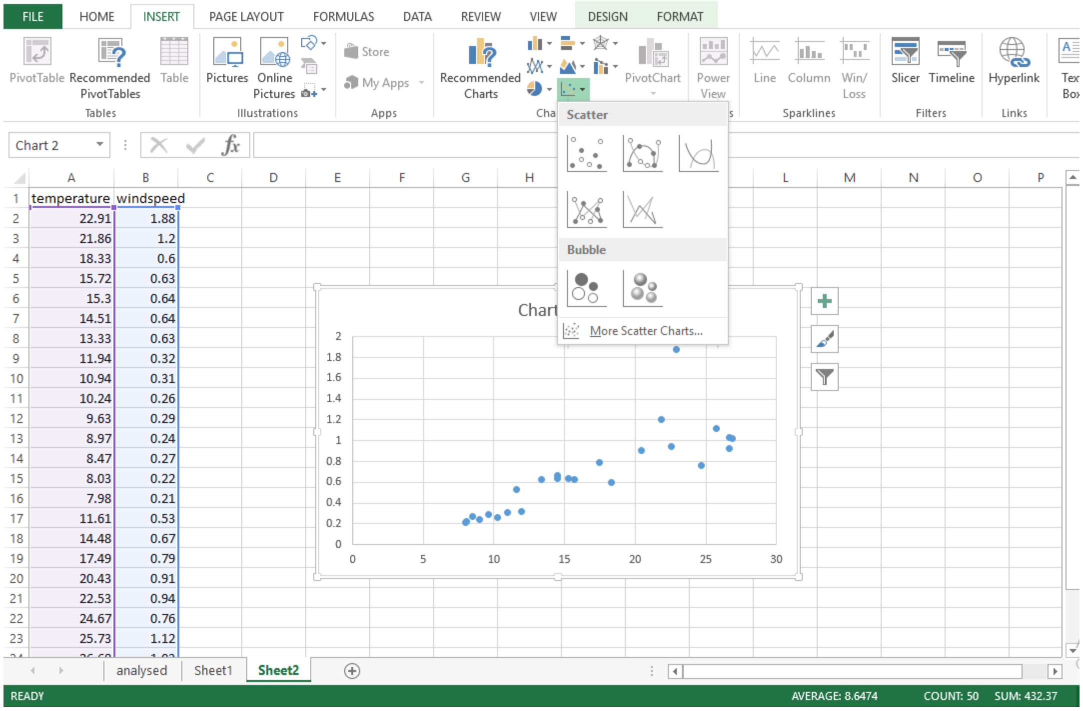
- In our hand calculations, we only included 10 data points. When we plot all of the data points using Excel, do we expect it to show similar trends? (Answer: Yes, because the 10 data points we used are a subset of the total data we do expect the trends to be similar but not exact)
- What are some advantages of making the plots and calculation by hand first before using Excel? (Answer: we can better understand the process if we do the plots and calculations ourselves, that way when Excel gives us an answer we can understand and interpret it correctly)

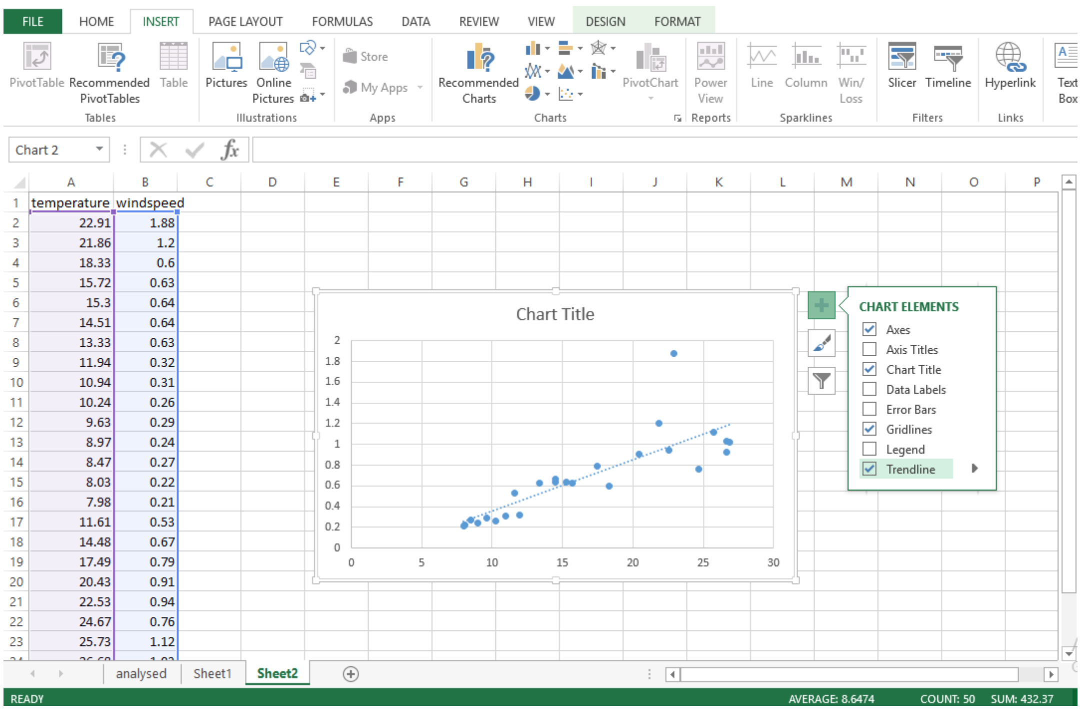
Using excel, plot the values you have on a chart (scatter plot). This chart makes it easier to see how one is affected as the other one changes. This is how to go about it:

1. Highlight both column containing temperature and wind speed. Then, navigate to charts and select the scatter plots. A graph of the plotted data will be displayed. To see the trend, click

an icon with a shape of a plus sign at the top right side of the chart and scroll down to trend line and select. A straight line will appear on the charts slanting to the direction of the change. From your graph what is the direction of the slope (Positive slope = / or negative slope = \)?

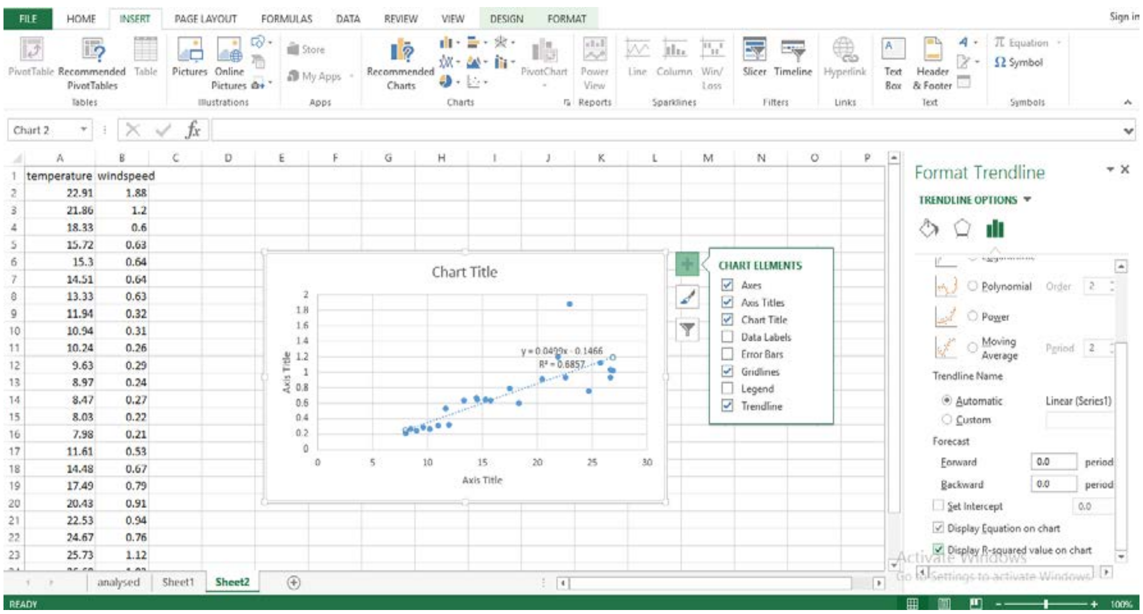
[Answer: it is a positive slope, which means temperature and wind speed are proportional]





2. You may find it interesting to label the axis and to give your chart a title actually it is important to do so. To do this click on your chart. On the same plus sign icon you used when adding the trend line, you will see an 'axis title' click on that option. Two boxes will appear on both axis of the chart with the name 'axis title'. Click inside those boxes and delete whatever is in them and type your titles including the units.

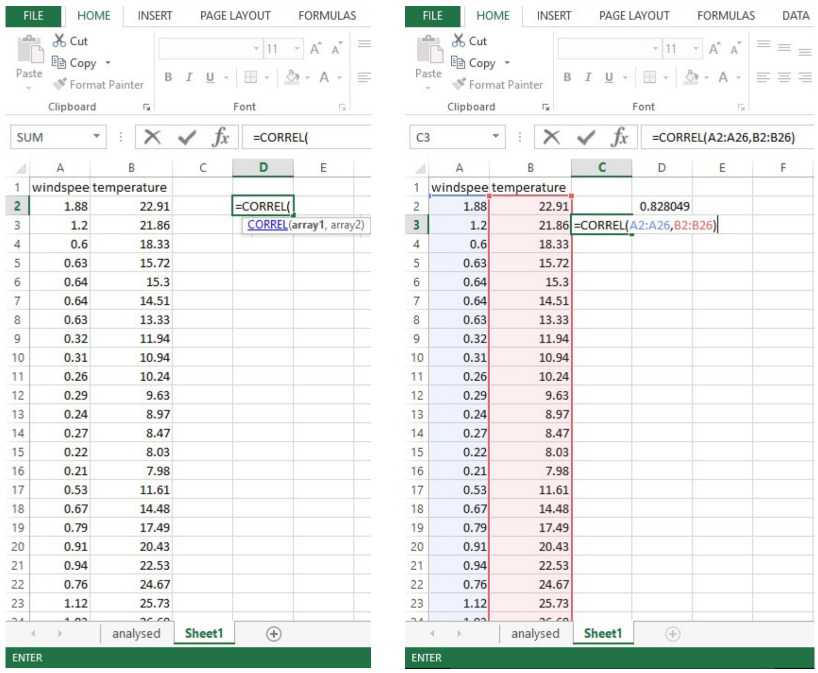
3. To add the equation of the trend line and the $r^2$ value, click on the trend line to highlight it. When you select the trend line a panel on the right hand side of the screen will open. Then right click and when you will be prompted to options pane scroll down to format trend line and then go to trend line options. Scroll down and tick both 'display Equation on the chart' and' display R-squared value on the chart'




4. To calculate the strength of the relationship between your two parameters commonly referred to as correlation coefficient. In Excel, click on any cell in your sheet. Enter an equals'=' sign. Immediately behind the equals sign type the word 'corr', excel will immediately below bring an icon with the word' correl' Double click on it. It will inside your working cell write "correl ("and just below it 'CORREL (array 1, array2). Array is the data sets you want to perform the correlation. The number 1 and 2 indicates that you have two data sets that you want to perform the correlation.

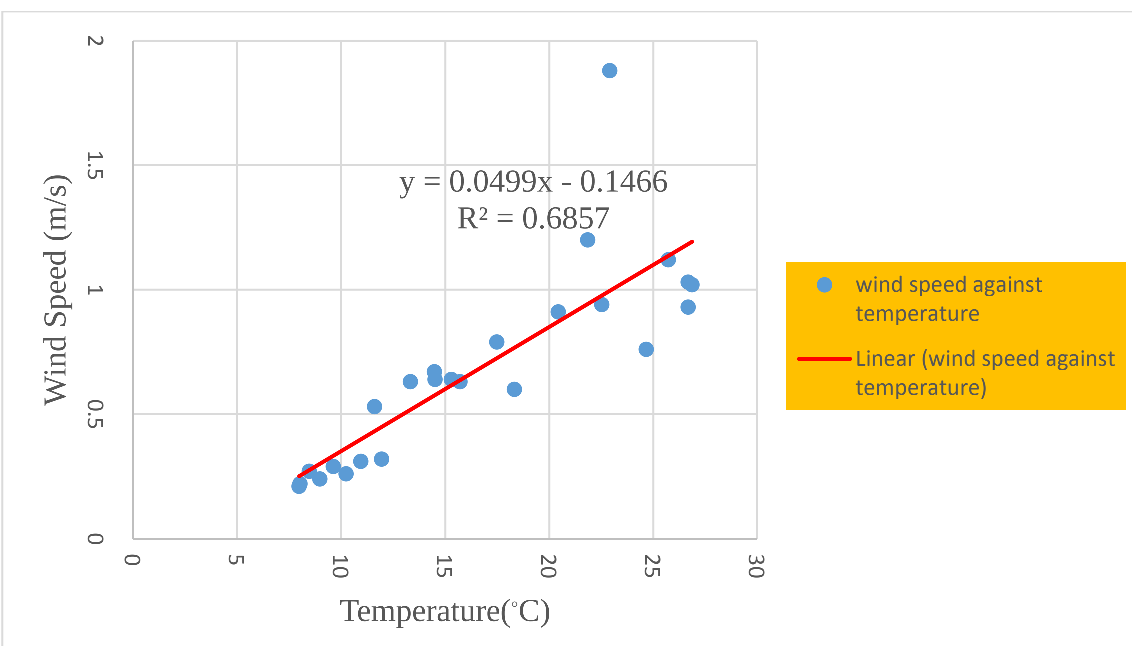
5. So to perform the correlation click on "correl (" inside your working cell, highlight your first column and insert a comma"," then highlight the second column and close the bracket, then press enter. A correlation value should appear. That tells you the strength of the relationship

between the parameters. In our case the correlation coefficient is 0.828049. The following pictures shows the steps described in this step 2 respectively.




**Results:**

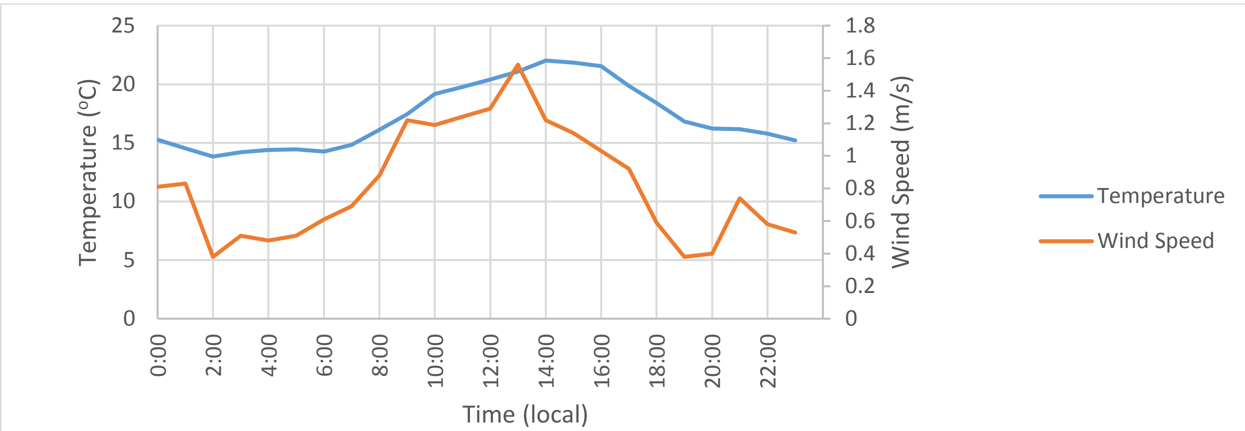
Have a look at our chart below. Ask the students what conclusion they can make from the chart. Can they now see clearly the relationship between our two parameters? What type of relationship? Does the chart have the answer to our correct hypothesis?



**Discussion**

What is the relationship between the correlation coefficient that we calculated and the R-squared that the Excel trend line gives us? What do each mean? [Answer: The correlation coefficient is "R" and if you square that values you get the "R-squared". From our correlation analysis our relationship strength is 0.828049. Our correlation coefficient is positive meaning that as temperature increase wind speed increase and the opposite is true. This is also supported by the fact that the trend line (the red line in our chart) has a positive gradient. Our R- squared value is 0.6857 which means that 69% of wind speed depends on temperature.]

Why is wind speed directly proportional to temperature? [Answer: Wind is caused by temperature difference between two layers of the atmosphere. Warm air rises and becomes less dense. As the warm and light air rises it starts to cool down it will become denser and start to sink. The maximum speed of the motion is at the maximum temperature as you can see in the chart below both occur at mid-day]




What time of the day when wind speed is at its peak? [Answer: Wind speed is at its peak when the temperature is maximum and this is normally at noon]

Where is the wind speed higher between ocean and land surface and why? [Answer: Land .Temperature gradient over the land is greater the over the ocean and therefore making wind speed over the land higher than over the ocean]

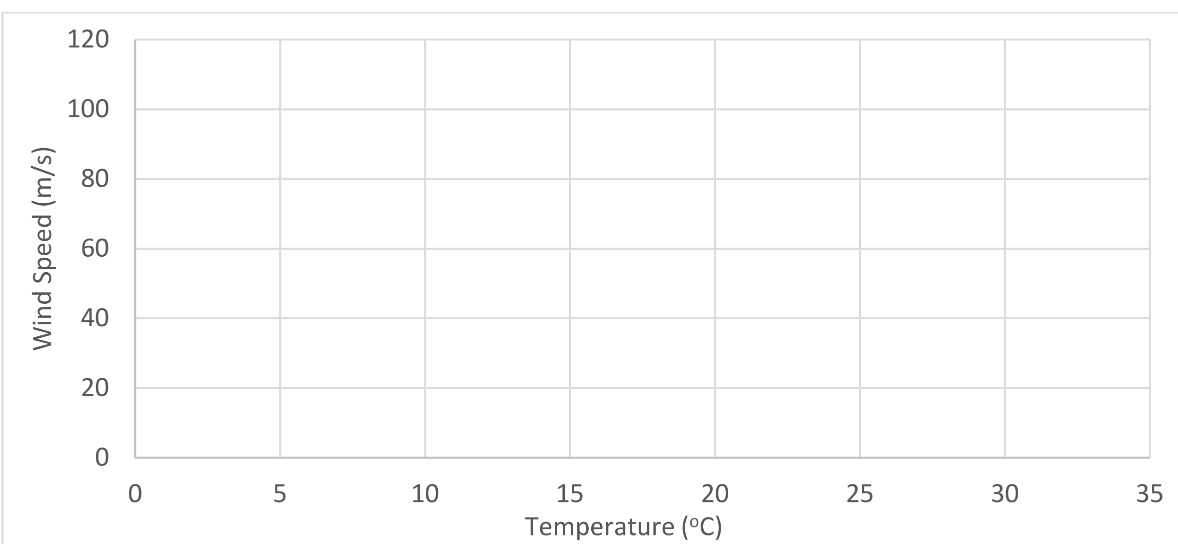
What are some of the natural phenomenon caused by the wind- temperature relationship? [Answer: Some of the phenomenon caused by the wind-temperature relationship are like katabatic and anabatic wind (winds that move down and upslope of a valley due to temperature difference between the floor and ridge of the valley), land and sea breeze (wind caused by temperature difference between land and ocean).]

# Wind speed: Student Worksheet

Download the data from your local TAHMO weather stations from the School2School.net website. Open the hourly data in an Excel spreadsheet. Record the first ten data points onto the table below, writing down the hourly data for time, temperature, and wind speed for now (keep the last three columns empty).

| Time | Temperature(°C) | Wind speed (m/s) | $x^2$ | $y^2$ | x*y |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| Sum= | | | | | |

Using the completed table above, by hand make a plot with temperature as the y-axis and wind speed as the x-axis. Draw a line of best fit.




V.1

Use the following formulae to determine the strength of the relationship between temperature and wind speed using the correlation coefficient:

Where n= total number of variables in our case (20) and $\sum$ is the summation.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

Correlation coefficient = ___________________________________

**Discussion:**

From your graph what is the direction of the slope (Positive slope = / or negative slope = \)? Explain what that means about the relationship between temperature and wind speed.

_______________________________________________________________________________

_______________________________________________________________________________

Where is the wind speed higher between ocean and land surface and why?

_______________________________________________________________________________

_______________________________________________________________________________

What are some of the natural phenomenon caused by the wind- temperature relationship?

_______________________________________________________________________________

_______________________________________________________________________________

# Data Timescales: Teacher Guide

**Level:** Intermediate

**Subject:** Mathematics

**Duration:** 1 hour

**Type:** Guided Classroom Activity

**Learning Goals:**

- Summarize daily or monthly weather data in Excel using Pivot Tables
- Define a timescale to view data for different research questions

**Materials:**

- Internet access to download a dataset at School2School.net
- Computer access with Excel or comparable spreadsheet program

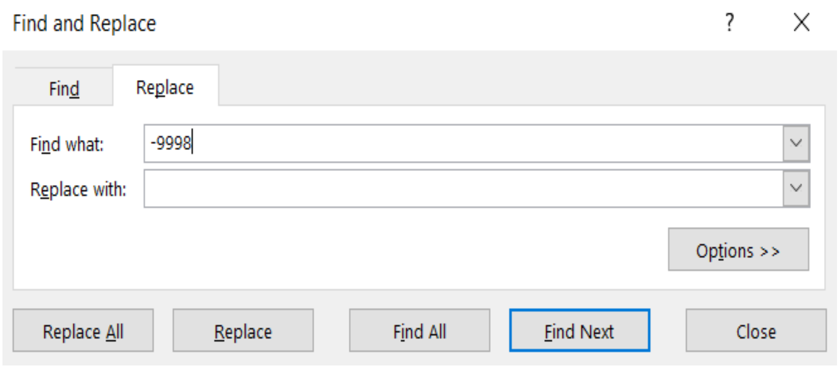
**Background:**

When the TAHMO data is downloaded, hourly data is available. Discuss with the class some advantages and disadvantages of having high temporal resolution data. While hourly data is useful for looking at daily trends, having such a large quantity of data entries can make it difficult to find trends across days, weeks, months, or years. In contrast, using daily averages can reduce the amount of information about the variable of interest. For example, looking only at average daily temperature you will miss the time of the maximum temperature for that day, but looking only at maximum daily temperature will mean you miss the average daily temperature trend. There are different circumstances and questions for which different timescales (hourly, daily, weekly, monthly, and yearly, etc.) are best. The Pivot Table tool in Excel is a convenient way to change the timescale that your data is presented in. This lesson plan will introduce using Pivot Tables to view data at different timescales. By the end of this activity the students should be able to define the best timescale to look at different research questions.

**Preparation:**

Before class, you may want to download the data and format it so that it is ready to use. You may also do this with the class as an exercise. Below are instructions on how to prepare the data for analysis in this lesson plan. First, navigate to the School2School.net website. In the stations tab choose the school that you would like to analyze. Directly below the plots there is a section to fill out the username and password associated with that site. The login information is site specific, so if you were given login information it will only work for your one station. After typing your username and password and clicking the “login” button, the page will reload and a new button to download the hourly data will appear. Choose that button and the hourly data for the station will download in a CSV format. This format is compatible with spreadsheet programs like Excel. Open the downloaded data in your spreadsheet program. [Note: There is an instructional video with step-by-step directions on how to download the TAHMO station data on the S2S website].

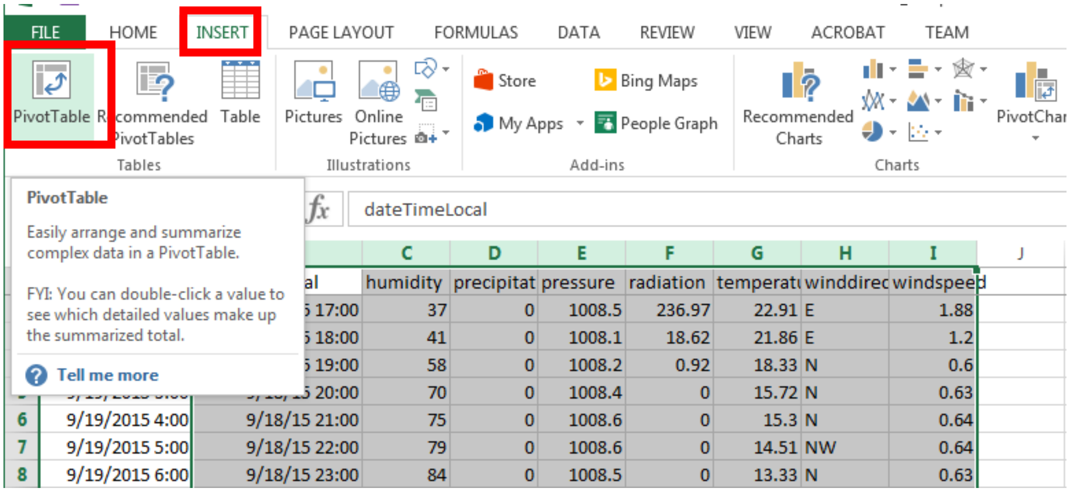

For TAHMO stations, any measurement with a value of -9998 is an error message. It is common for instruments to only be able to log numerical values, so when there is an error in the sensor it assigns a default error value. Any cell containing a value of -9998 should not be considered in analysis. In order to exclude -9998 error value from the analysis, we can delete all cells with this value and replace them with blank cells, signifying no data (replacing the value with a 0 would indicate the measured value was actually 0 and we don’t want that). To do this, type Control + H while your cursor is on your Excel sheet. This will bring up the replace command in Excel, type -9998 into the find bar and leave the replace bar blank, click replace all.



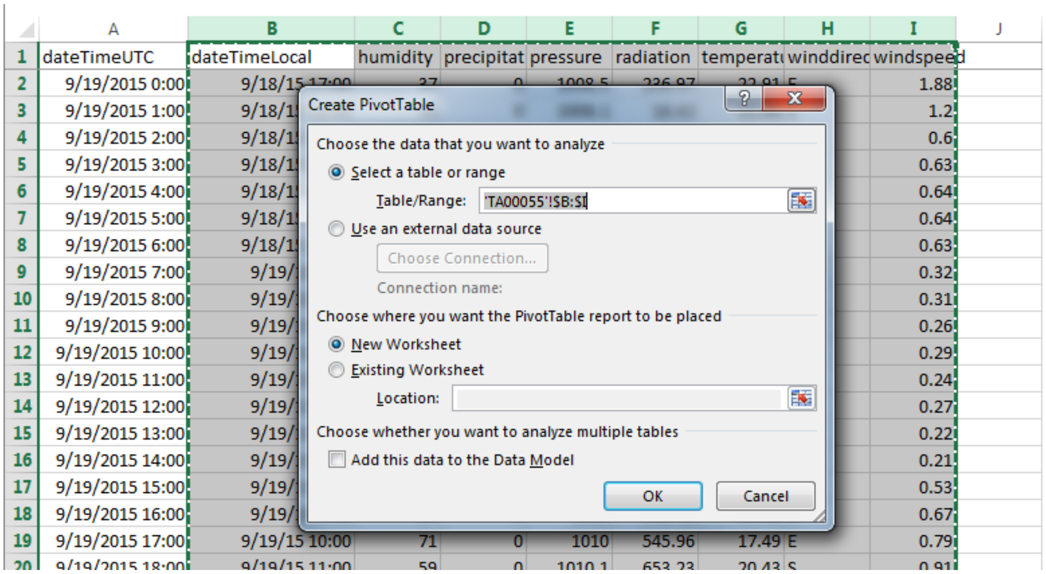

Next you will want to change the date from UTC to local time. The first column in the spreadsheet has the date and time of the data record in Universal Time Coordinates. Please note that the time in the downloaded file is given in Coordinated Universal Time (UTC) and not local time. To convert from UTC to local time, use the time zone to either add or subtract from the UTC time. The time zone can be found on the School2School.net website for each station under the name of the school. You will need to convert UTC to local time for each station for the following analysis. A video tutorial showing how to convert from UTC to local time is available on the S2S website under Teaching Materials, or at this link: https://youtu.be/5G5nRsej77A.

**Methods:**

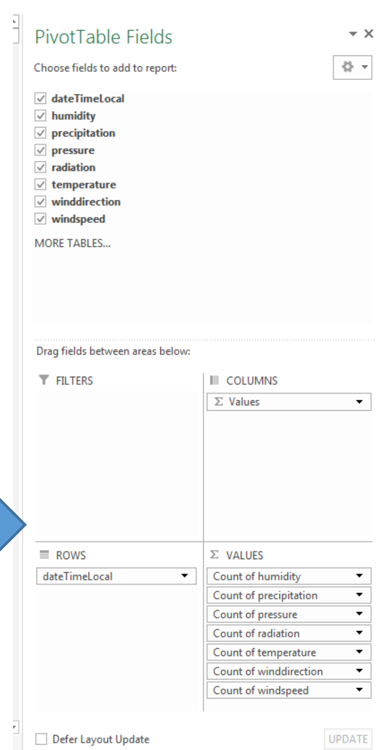
Select the columns B-I to include the Local Time Column and all of the weather variables. Under the INSERT tab, select the PivotTable option.

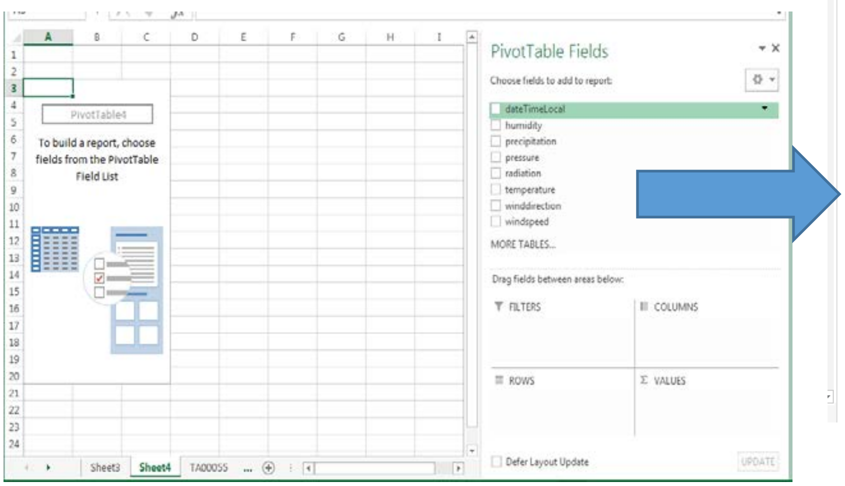



A new dialog box will open, press okay. A new worksheet will open with the pivot table.

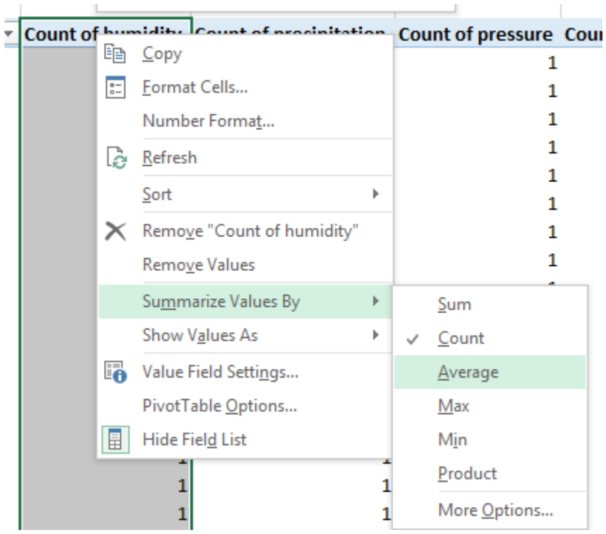



In the new worksheet, the PivotTable menu bar will appear. Here you will select the variables of interest for your table. Use your curser to check the boxes next to the variables, once the variable has been added to the grid below you can drag them between fields. You will want to use the Local Time as the Rows and the other variables under values. As you add the variables to the Pivot Table Fields you will notice the table start to populate in the spreadsheet page.



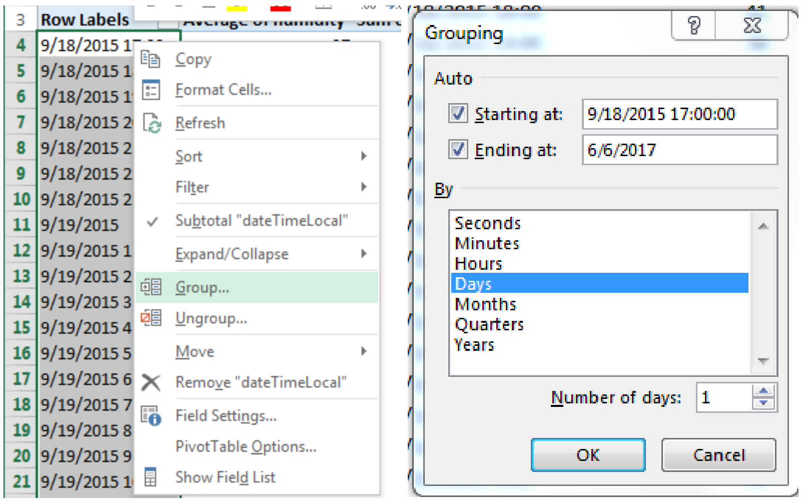




As the table is now, there is not a lot of information we can gain. Instead of having the count of each variable, which simply reports a 1 if there is data recorded and a 0 if the field is empty, we can assign a more meaningful summary for each column variable. Right click on the column header and select “Summarize Values By” and then “Average”.

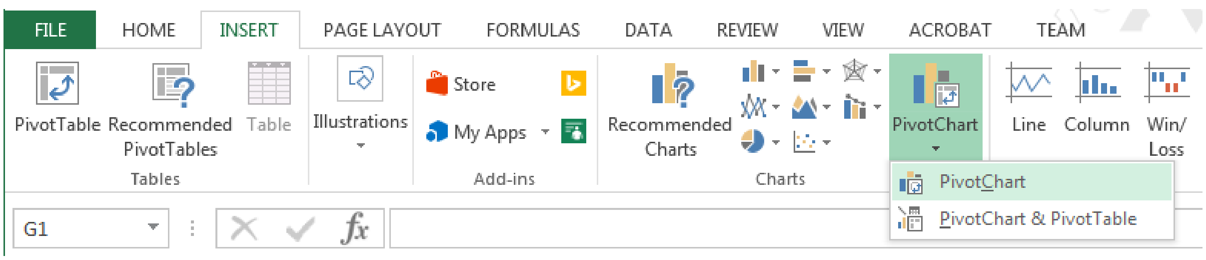



Discuss with your class different scenarios that we would want to summarize by a different metric such as the summation, maximum, or minimum. Ask the class what is an example where we might want to look at the minimum for each time? [Answers vary: example could be that we would want to know the minimum for each time step if we wanted the low temperature at night, or the least windy time.] When might you want to use the maximum for each time? [Answers vary: example could be that we would want to know the maximum for each time step if we wanted the hottest temperature reached or the windiest gusts.] When might you want to use the average for each time? [Answers vary: example could be that we would want to know the averages for each time step if we wanted to know the general trends over a long period of time.] For this example, we will use the average to gain a general understanding of the trends. Do the same for all of the columns. You may notice that there are two columns that don't make a lot of sense: Precipitation and Wind Direction. For precipitation, the total precipitation is more meaningful than the average precipitation so instead of summarizing by average, choose summarize values by "Sum". Wind direction is recorded in North, East, South, and West which are not numeric and thus can't be averages or summed. If you would like, you may deselect the wind direction variable from the Field List values.

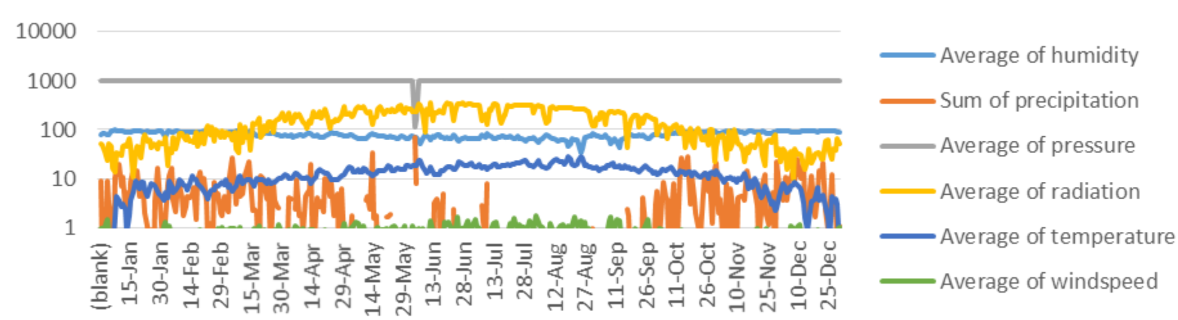
Now we are ready to change the timescale for which the data is presented. Right click on the time column and select "Group". A new dialog box will appear allowing you to choose the time range you wish to apply this grouping to and by what timescale. Choose "Days" as the grouping type.



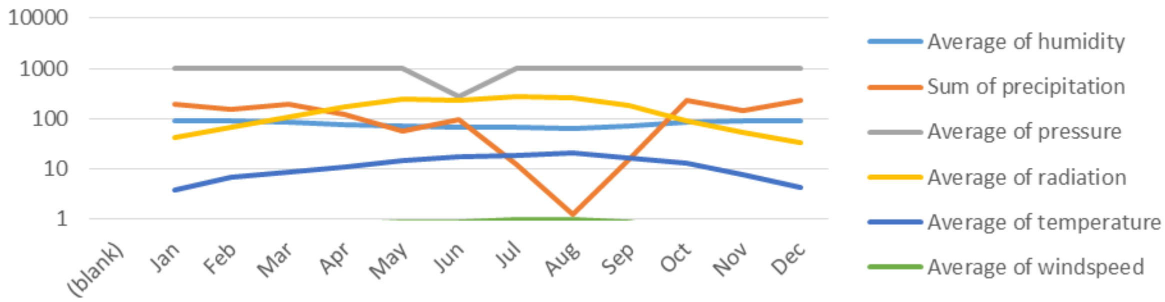

You will notice that your hourly data has now been condensed into daily data. For this daily data, the average daily temperature is averaged for all of the years of record. You can Insert a Pivot Chart to visualized the data.



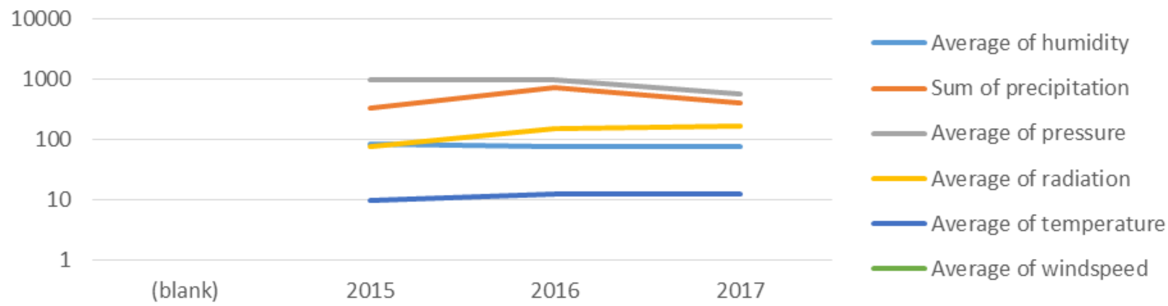

Discuss with the class what trends you can see. Answers will vary on location, but use observational skills to analyze the graph and make geralizations about the weather variable throught the year. How does pressure change thought the year? [Answers vary: example could be that pressure remains almost constant thought the year.] How does precipitation change though the year? [Answers vary: example could be that you can tell when there is a rainy season or a dry season based on the total precipitation.] How to humidity change? [Answers vary: example could be that relative humidity is fairly constant but decreases slightly during the dry season.] How to solar radiation change? [Answers vary: example could be that solar radiation tends to be higher during the dry season which corresponds to times of less clouds.] How does average temperature change? [Answers vary: example could be that temperature has a similar trend to solar radiation] How to windspeed change? [Answers vary: example could be that average wind speed is very low, but we do see large increases during storm events.]



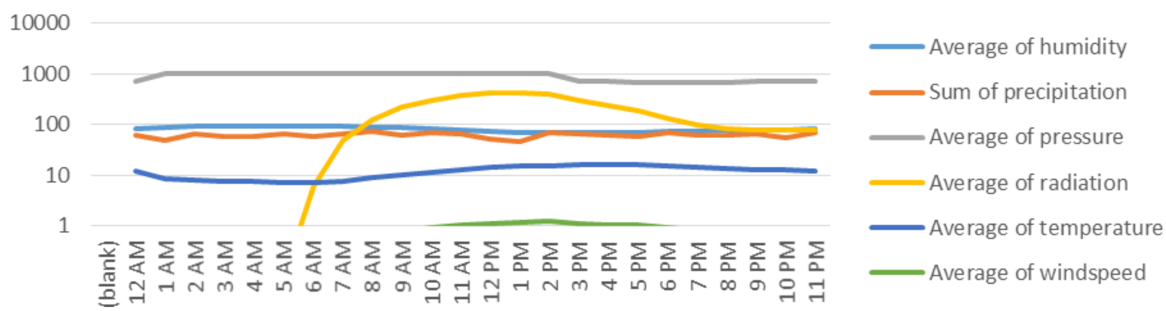
Next regroup the time data by “month” and observe how the graph changes. Can you see the same trends in the monthly data compared to the daily data? [Answer: The same trends will be visible in the monthly averaged data but they will be a lot less noise with less variation]




Next regroup the time data by “days” and observe how the graph changes. What trends to you see across the years? Do some variables seem to be increasing, staying the same, or decreasing? As a class discuss some possible reasons for these changes over the years. [Answers vary: Some examples include was it an El Nino or La Nina year? Can you see the effects of climate change?]




How else could you group the data by time? One example could be looking at hourly averages acrross the year. Regroup the data by hour and observe the plot. Ask the students to interpret the plot and what is means. One interpretation could be that this plot shows you the average value for each weather variable at a particular time of the the day, averaged across each day and year.



**Discussion:**

Discuss with the class why it is important to look at data on different timescales. Are there difficult conclusions you can make based on different timescales of data? [Answer: Yes] Ask the students to turn their attention to their student worksheet. Discuss the questions below in order to determine the correct timescale and metric that should be used to analyze the data based on the research question.

1. Suppose you want to know if your local climate is getting warmer or colder on average from the year you were born compared to this current year.

[Answer: The keywords of "warmer or colder" which refers to temperature, "on average" with refers to the average summary metric, and "year to year" which is the timescale. Thus the Average Yearly Temperature should be analyzed for this research question.]

What if you wanted to understand which months receive the least sunshine intensity each year?

[Answer: The keyword of "months" which refers to the monthly timescale, "least" with refers to the minimum summary metric, and "sunshine intensity" is the weather variable of solar radiation. Thus the Minimum Monthly Solar Radiation should be analyzed for this research question.]

Image you want to learn about the amount of precipitation that falls each day and compare the daily trend across the entire year.

[Answer: The keywords of "the amount" refers to the total or sum metric, "precipitation" refers to the weather variable of interest, and "each day" is the daily timescale of interest. Thus the Total (sum) Daily Precipitation should be analyzed for this research question.]

Image you want to understand how the maximum wind speed changes at different hours of the day, what timescale and metric would you use to analyze this question?

[Answer: The keywords of "the maximum" refers to the maximum summary metric, "wind speed" refers to the weather variable of interest, and "different hours of the day" is the hourly timescale of interest. Thus the Maximum Hourly Wind Speed should be analyzed for this research question.]

# Data Timescales: Student Worksheet

Suppose you want to know if your local climate is getting warmer or colder on average from the year you were born compared to this current year. What timescale and metric would you use to analyze this question? Check the correct box

- ☐ Average daily temperature
- ☐ Maximum yearly temperature
- ☐ Average yearly temperature
- ☐ Maximum daily temperature

What if you wanted to understand which months receive the least sunshine intensity each year? What timescale and metric would you use to analyze this question? Check the correct box

- ☐ Minimum monthly solar radiation
- ☐ Maximum daily solar radiation
- ☐ average monthly solar radiation
- ☐ maximum monthly solar radiation

Image you want to learn about how much precipitation falls each day and compare the daily trend across the entire year. What timescale and metric would you use to analyze this question? Check the correct box

- ☐ Average daily precipitation
- ☐ Maximum yearly precipitation
- ☐ Average yearly precipitation
- ☐ Total (sum of) daily precipitation

Image you want to understand how the maximum wind speed changes at different hours of the day, what timescale and metric would you use to analyze this question? Check the correct box

- ☐ Minimum hourly wind speed
- ☐ Maximum hourly wind speed
- ☐ Average daily wind speed
- ☐ Total daily wind speed

Create your own research question. Explain what timescale of data you would use to analyze your question.

______________________________________________________________________________

______________________________________________________________________________

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# Wind Energy: Teacher Worksheet

**Level:** Advanced

**Subject:** Physics, Engineering

**Duration:** 40-60 minutes

**Type:** Guided Classroom Activity

**Learning Goals:**

- Understand and apply the physics of energy
- Calculate how much energy a windmill could produce given wind speeds recorded at your local weather station

**Materials:**

- paper
- glue
- wooden stick
- pin
- scissors
- TA00055 data (downloaded)
- computer with MS Excel and internet

**Methods:**

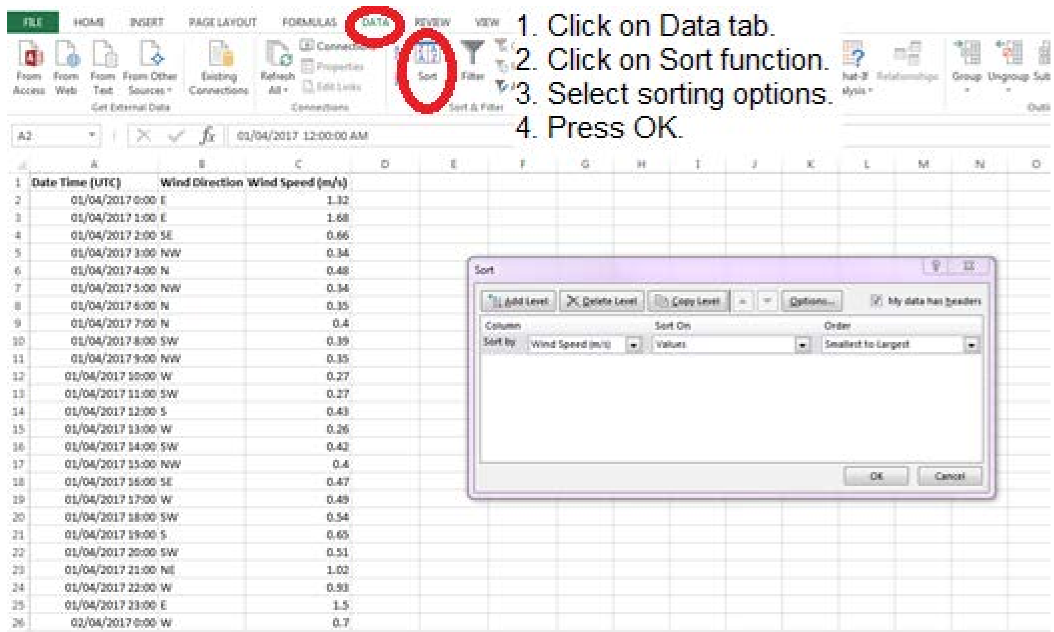
*PART I:* Fundamental Principles of Wind Energy [20 minutes]

1. Ask the students to make their own windmills. You can certainly skip this activity if you feel it is too young for your class, or you do not have time. It is intended to have a bit of fun and interaction (and think about the physical processes) before the students complete the worksheet. If you need to describe to the students how to create their own windmill, here is a step-by-step guide: www.theguardian.com/lifeandstyle/gallery/2009/jun/23/making-windmill-guide
2. Encourage them to experiment with their windmills. Tell the students to try to make the blades spin by blowing on them. Note how little or how much energy you need. What happens when you just breathe on the blades? What happens when you blow from different directions? Students should try to explain your observations and write down their answers on their student worksheet.

*PART II:* Wind speed data [10 minutes]

3. Ask the students to download the wind speed data for the past month from your local weather station. Weather data can be found on the School-2-School website at [https://school2school.net/teaching-materials/](https://school2school.net/teaching-materials/), here you can login information to download weather data from the website or a pre-formatted weather data as an Excel file.
4. Allow the students to format and filter the data. For this exercise, your students will need to use the Data → Sort option to find the windiest and least windy hours, and the AVERAGE function to calculate the average speed for each day. See screenshots below for more information.

*Sorting Data:*




*SUM function:*

| | | | | |
|---|---|---|---|---|
| 02/04/2017 0:00 | W | 0.7 | 0.016567568 | |
| 02/04/2017 1:00 | SE | 0.58 | 0.009424289 | |
| 02/04/2017 2:00 | SW | 0.34 | 0.00189846 | |
| 02/04/2017 3:00 | S | 0.2 | 0.000386416 | |
| 02/04/2017 4:00 | N | 0.63 | 0.012077757 | |
| 02/04/2017 5:00 | N | 0.5 | 0.006037743 | |
| 02/04/2017 6:00 | NE | 0.65 | 0.013264922 | |
| 02/04/2017 7:00 | NE | 0.73 | 0.018790278 | |
| 02/04/2017 8:00 | E | 0.9 | 0.035212119 | |
| 02/04/2017 9:00 | E | 1.06 | 0.057528391 | |
| 02/04/2017 10:00 | N | 0.55 | 0.008036236 | |
| 02/04/2017 11:00 | N | 0.4 | 0.003091325 | |
| 02/04/2017 12:00 | N | 0.39 | 0.002865223 | |
| 02/04/2017 13:00 | N | 0.5 | 0.006037743 | |
| 02/04/2017 14:00 | N | 0.49 | 0.005682676 | |
| 02/04/2017 15:00 | NE | 0.63 | 0.012077757 | |
| 02/04/2017 16:00 | NW | 1.18 | 0.079361643 | |
| 02/04/2017 17:00 | W | 0.84 | 0.028628757 | |
| 02/04/2017 18:00 | SW | 0.82 | 0.026632147 | |
| 02/04/2017 19:00 | SE | 1.09 | 0.062552421 | |
| 02/04/2017 20:00 | S | 1.19 | 0.081396459 | |
| 02/04/2017 21:00 | S | 1.01 | 0.049765544 | |
| 02/04/2017 22:00 | S | 0.74 | 0.019573108 | |
| 02/04/2017 23:00 | W | 0.5 | 0.006037743 | =sum(D26:D49) |

*AVERAGE function:*

| | | | |
|---|---|---|---|
| 02/04/2017 0:00 | W | 0.7 | |
| 02/04/2017 1:00 | SE | 0.58 | |
| 02/04/2017 2:00 | SW | 0.34 | |
| 02/04/2017 3:00 | S | 0.2 | |
| 02/04/2017 4:00 | N | 0.63 | |
| 02/04/2017 5:00 | N | 0.5 | |
| 02/04/2017 6:00 | NE | 0.65 | |
| 02/04/2017 7:00 | NE | 0.73 | |
| 02/04/2017 8:00 | E | 0.9 | |
| 02/04/2017 9:00 | E | 1.06 | |
| 02/04/2017 10:00 | N | 0.55 | |
| 02/04/2017 11:00 | N | 0.4 | |
| 02/04/2017 12:00 | N | 0.39 | |
| 02/04/2017 13:00 | N | 0.5 | |
| 02/04/2017 14:00 | N | 0.49 | |
| 02/04/2017 15:00 | NE | 0.63 | |
| 02/04/2017 16:00 | NW | 1.18 | |
| 02/04/2017 17:00 | W | 0.84 | |
| 02/04/2017 18:00 | SW | 0.82 | |
| 02/04/2017 19:00 | SE | 1.09 | |
| 02/04/2017 20:00 | S | 1.19 | |
| 02/04/2017 21:00 | S | 1.01 | |
| 02/04/2017 22:00 | S | 0.74 | |
| 02/04/2017 23:00 | W | 0.5 | =average(C26:C49) |

*PART III:* Calculations [20 minutes]

5. Introduce the formula on the *Student Worksheet*, relating it to kinetic energy and basic principles. It would be best to derive the formula on a blackboard for the students, so they understand where it comes from. If you as a teacher are unfamiliar with the context of the equation, this link could be useful to review as it provides a breakdown of how the equation provided in the student sheet is derived from basic physics principles (Newton's laws, kinetic energy, etc.): http://www.raeng.org.uk/publications/other/23-wind-turbine

$$P = \frac{1}{2} C_p \rho A v^3$$

   Where:

   $P$ = power output, W

   $C_p$ = maximum power coefficient

   $\rho$ = air density, kg/m$^3$

   $A$ = rotor swept area = $\pi r^2$ (r is the rotor radius in m), m$^2$

   $v$ = wind speed, m/s

   Assume that the windmill has a blade length (radius) of 10 m, the windmill captures 25% of the wind's kinetic energy (maximum power coefficient), and air density is 1.23 kg/m$^3$. Other helpful information on wind turbines can be found at: www.windpowerengineering.com/construction/calculate-wind-power-output/

6. Allow the students to complete the calculations on the Student Worksheet. Ask them to show their calculations. Encourage them to complete the discussion questions as well. Next, calculate the total energy the same windmill could have generated on the two days of the windiest and least windy hours above. Use hourly wind speeds, not a daily average.

7. Compute the average wind speed for the two days (windiest and least windy), and the amount energy that the windmill would have generated had the wind been steady at this speed.

# Wind Energy: Answer Key

**NOTE: This answer key uses the TA00055 April 2017 data.

**Results:**

1. Maximum wind speed (hour): **4.6 m/s** on (date and time): **07/04/2017 3:00**
   Minimum wind speed (hour): **0.2 m/s** on (date and time): **02/04/2017 3:00**
2. Energy for windiest hour: **4.7 kWh**

   $A = \pi r^2 = \pi * 10^2 = 314.159$

   $P = \frac{1}{2} C_p \rho A v^3 = 0.5 * 0.25 * 1.23 * 314.159 * 4.6^3 = 4701.518\, W$

   $E = Pt = 4701.518 * 1 = 4701.518\, Wh = 4.7\, kWh$

3. Energy for least windy hour: **0.0004 kWh**
   See sample calculation above.
4. Total energy for windiest day: **295.9 kWh**
   See spreadsheet in *Supplementary Materials* for calculations.
5. Total energy for least windy day: **13.5 kWh**
   See spreadsheet in *Supplementary Materials* for calculations.
6. Average wind speed on windiest day: **1.7 m/s**
   See spreadsheet in *Supplementary Materials* for calculations.
7. Average wind speed on least windy day: **0.7 m/s**
   See spreadsheet in *Supplementary Materials* for calculations.
8. Total energy for windiest day (average): **5.7 kWh**
   See spreadsheet in *Supplementary Materials* for calculations.
9. Total energy for least windy day (average): **0.4 kWh**
   See spreadsheet in *Supplementary Materials* for calculations.

**Discussion:**

*PART I:* Fundamental Principles of Wind Energy
What happens when you just breathe on the blades? What happens when you blow from different directions? Try to explain your observations.

**The students should be able to observe the effect of wind speed (their blowing) on windmill motion, and relate it to physics principles.**

*PART III:* Calculations
Why is the energy calculated differently when using hourly versus average daily wind speeds? [Hint: kinetic energy is proportional to the square of velocity.]

**The average velocities are lower than the maximum velocities per day, and this difference is amplified by the factor of three applied to velocity in the equation.**

# Wind Energy: Student Worksheet

**Methods:**

*PART I:* Fundamental Principles of Wind Energy

1. Make your own windmill with the paper, glue, stick, pin, and scissors. If you do not know how ask your teacher.
2. Try to make the blades spin by blowing on them. Note how little or much energy you need. What happens when you just breathe on the blades? What happens when you blow from different directions? Try to explain your observations.

*PART II:* Wind speed data

3. Download the wind speed data for the past month from your local weather station (or use TA00055 data).
4. Open it in MS Excel.
5. Format the data, and filter it to find the maximum and minimum wind speed hours.

*PART III:* Calculations (use space below and show all calculations)

6. Calculate the amount of energy (in kilowatt-hours, kWh) that a windmill could have generated in the windiest and least windy hours last month. Use the formula:

$$P = \frac{1}{2} C_p \rho A v^3$$

   where
   $P$ = power output, W
   $C_p$ = maximum power coefficient
   $\rho$ = air density, kg/m$^3$
   $A$ = rotor swept area = $\pi r^2$ (r is the rotor radius in m), m$^2$
   $v$ = wind speed, m/s
7. Assume that
   a. the windmill has a blade length (radius) of 10 m,
   b. the windmill captures 25% of the wind's kinetic energy, and
   c. air density is 1.23 kg/m$^3$.
8. Now calculate the total energy the same windmill could have generated on the two days of the windiest and least windy hours above. Use hourly wind speeds, not a daily average.
9. Compute the average wind speed for the two days (windiest and least windy), and the amount energy that the windmill would have generated had the wind been steady at this speed.

**Results:**

1. Maximum wind speed (hour): ______on (date and time): ____________________
   Minimum wind speed (hour): ______on (date and time): ____________________
2. Energy for windiest hour: ______

3. Energy for least windy hour: ______

4. Total energy for windiest day: ______

5. Total energy for least windy day: ______

6. Average wind speed on windiest day: ______

7. Average wind speed on least windy day: ______

8. Total energy for windiest day (average): ______

9. Total energy for least windy day (average): ______

**Discussion:**

*PART I:* Fundamental Principles of Wind Energy
What happens when you just breathe on the blades? What happens when you blow from different directions? Try to explain your observations.

*PART III:* Calculations
Why is the energy calculated different when using hourly versus average daily wind speeds? [Hint: kinetic energy is proportional to the square of velocity.]

# Data Statistics: Teacher Guide

**Level:** Advanced

**Subject:** Mathematics

**Duration:** 1 hour

**Type:** Guided Classroom Activity

**Learning Goals:**

- Reinforce prior knowledge of statistics
- Calculate statistics on large data sets in Excel

**Materials:**

- Internet access to download a dataset at School2School.net
- Computer access with Excel or comparable spreadsheet program

**Background:**

Discuss with the class why it is useful to mathematically describe our datasets. Descriptive statistics are used to quantitatively describe and summarize and identify trends in the data, particularly for very large datasets where hand calculations are difficult. Some measures that are commonly used to describe a data set are measures of central tendency and measures of variability. Measures of central tendency include the mean, median and mode, while measures of variability include the standard deviation, the minimum and maximum values, and skewness of the variables. Students should already be familiar with these measures of statistics (minimum, maximum, average, median, mode, and standard deviation) as this lesson plan does not include definitions and hand calculations.

- minimum- the lowest value in the dataset
- maximum- the largest value in the dataset
- mean- the average value of the dataset
- median- the middle number in the dataset
- mode- the value that is repeated the most times in the dataset
- standard deviation- the measures of the spread of the data
- skewness - the measure of the asymmetry of a probability distribution

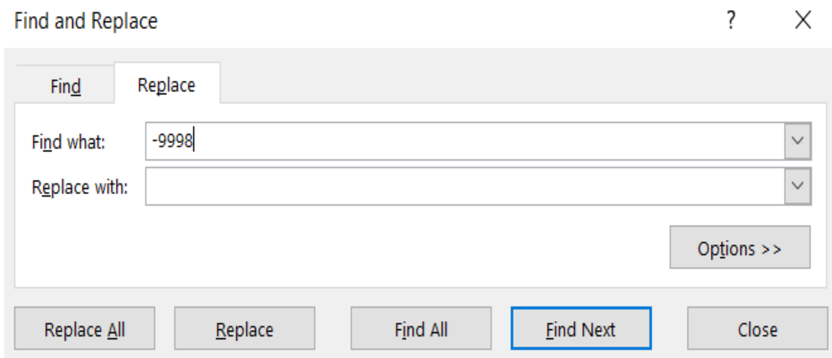
**Methods:**

Navigate to the School2School.net website. In the stations tab choose the school that you would like to analyze. Directly below the plots there is a section to fill out the username and password associated with that site. The login information is site specific, so if you were given login information it will only work for your one station. After typing your username and password and clicking the “login” button, the page will reload and a new button to download the hourly data will appear. Choose that button and the hourly data for the station will download in a CSV format. This format is compatible with spreadsheet programs like Excel. Open the downloaded data in your spreadsheet program. [Note: There is an instructional video with step-by-step directions on how to download the TAHMO station data on the S2S website].


Look through the data, are there any values that seems wrong? Try plotting a histogram of one of the variables, do you notice any values that aren’t realistic? Take relative humidity for example, was are the bounds for this variable? Can there be negative relative humidity? [Answer: No, relative humidity is expressed as a percent as is bound from 0 to 100, therefore any values outside of this range are suspicious.]

For TAHMO stations, any measurement with a value of -9998 is an error message. It is common for instruments to only be able to log numerical values, so when there is an error in the sensor it assigns a default error value. Any cell containing a value of -9998 should not be considered in analysis. Ask the students why do you think that the TAHMO engineers chose a number like -9998 to be the default error value? [Answer: A very large negative number like -9998 is easy to find in this dataset, and will not be mistaken for a measured value because it is outside of the range of possible measured values; that is why it was chosen]

In order to exclude -9998 error value from the analysis, we can delete all cells with this value and replace them with blank cells, signifying no data (replacing the value with a 0 would indicate the measured value was actually 0 and we don't want that). To do this, type Control + H while your cursor is on your Excel sheet. This will bring up the replace command in Excel, type -9998 into the find bar and leave the replace bar blank, click replace all.




Now our data is ready to use. Start by creating a table in your spreadsheet with the following headings, students will have a similar table on their student worksheet to fill in as you do the spreadsheet calculations.

| | **Relative Humidity (%)** | **Precipitation (mm/hr)** | **Pressure (kPa)** | **Solar Radiation ($W/m^2/hr$)** | **Temperature (°C)** | **Wind Speed (m/s)** |
|---|---|---|---|---|---|---|
| **min** | | | | | | |
| **max** | | | | | | |
| **mean** | | | | | | |
| **median** | | | | | | |
| **mode** | | | | | | |
| **standard deviation** | | | | | | |

While descriptive statistics can all be computed by hand, but since our dataset is so large it is convenient to use Excel's built in functions instead. The minimum function in Excel is "min"; to implement this in Excel click on an empty cell and type "=min(datarange)" but instead of datarange choose all of the data for one variable. Below is an example of each of the statistical Excel functions calculated for humidity. Calculate the statistics for each variable. Note: Wind direction entries are not numeric, therefore the statistics don't work for this variable. Repeat the process to calculate the statistics for each variable and fill in the table shown above.

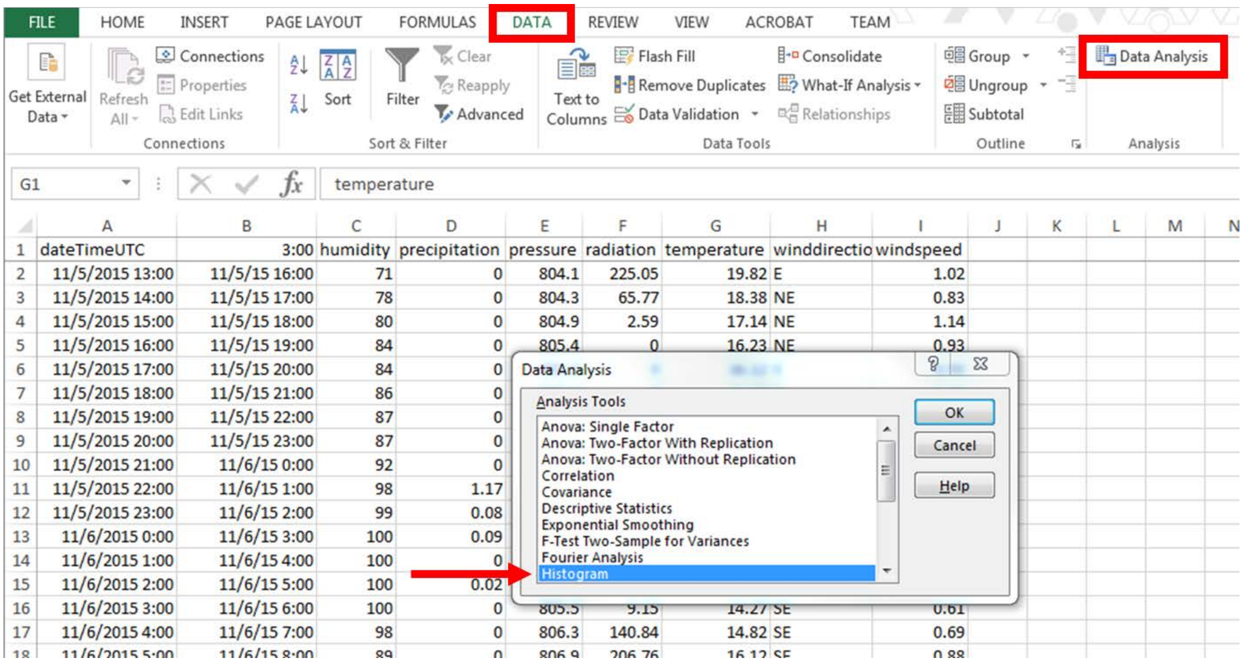
| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | dateTimeUTC | humidity | precipitation | pressure | radiation | temperature | winddirection | windspeed | | | humidity |
| 2 | 11/5/2015 13:00 | 71 | 0 | 804.1 | 225.05 | 19.82 | E | 1.02 | | min | =MIN(B2:B13073) |
| 3 | 11/5/2015 14:00 | 78 | 0 | 804.3 | 65.77 | 18.38 | NE | 0.83 | | max | =MAX(B2:B13073) |
| 4 | 11/5/2015 15:00 | 80 | 0 | 804.9 | 2.59 | 17.14 | NE | 1.14 | | mean | =AVERAGE(B2:B13073) |
| 5 | 11/5/2015 16:00 | 84 | 0 | 805.4 | 0 | 16.23 | NE | 0.93 | | median | =MEDIAN((B2:B13073)) |
| 6 | 11/5/2015 17:00 | 84 | 0 | 805.8 | 0 | 16.12 | E | 0.93 | | mode | =MODE.SNGL(B2:B13073) |
| 7 | 11/5/2015 18:00 | 86 | 0 | 806.3 | 0 | 15.69 | E | 0.63 | | std | =STDEV.P(B2:B13073) |
| 8 | 11/5/2015 19:00 | 87 | 0 | 806.5 | 0 | 15.42 | SE | 0.62 | | skew | =SKEW(B2:B13073) |
| 9 | 11/5/2015 20:00 | 87 | 0 | 806.5 | 0 | 15.83 | E | 0.66 | | | |

Once the students have filled in their table, take a look at the different values and discuss with the class what they notice. Which measure of statistics is used to describe variability? [Answer: standard deviation is the measure that describes the amount of variation in the data, with low standard deviations indicating data points that are close to the mean while high standard deviation values indicate the data points are spread out]. Which parameter had the most variability? )? [Answer: Solar Radiation has a large range and the most variability]. Discuss with the class why they think solar radiation has such a large range of values. Ask them to think about the nature of the variable, what values can be expect on different timescales (hourly, daily, monthly, yearly, or other). [Answer: Solar Radiation has diurnal (daily) variation, with values of zero at night and large values during the day]

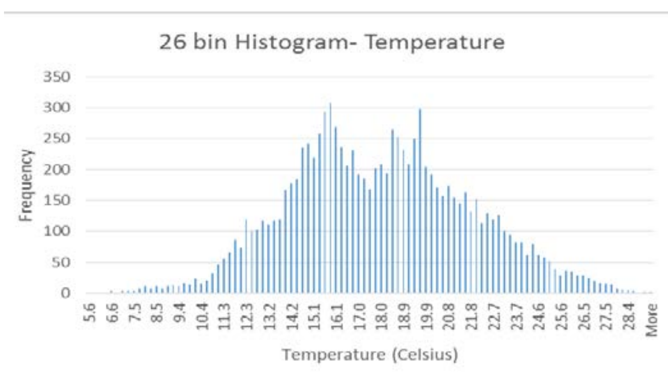
Brainstorm as a class which variable they think would have the least variability, be sure to explain this in context. For example, a student might say that they expect precipitation to have the least variability because most days in the dry season it doesn't rain and most days in the wet season it does rain OR they expect pressure to have the least variability because the altitude stays constant. This is only a brainstorming question, there is not correct answer. Compare the student predictions with the tables, do the numbers support your hypothesis or is it hard to tell? Many students might find it difficult to make find information to prove or disprove their hypothesis based on a table. What other ways of visualizing data might be more helpful than a table? Why is it useful to graphically describe our dataset? [Answer: Figures like a histograms are useful to represent data if you are trying to summarize information of display patterns in the data]. Compare and contrast different reasons to describe your data in a table to a graph. Identify and describe one data statistic that is easier to identify in the table than in the histogram. [Answers may vary: example could be the shape of the distribution is easier to see in a graph than in a table.] Identify and describe one data statistic that is easier to identify in the histogram than in the table. [Answers vary: example could be tables show an exact number as the mean but with the histogram you can only estimate.]

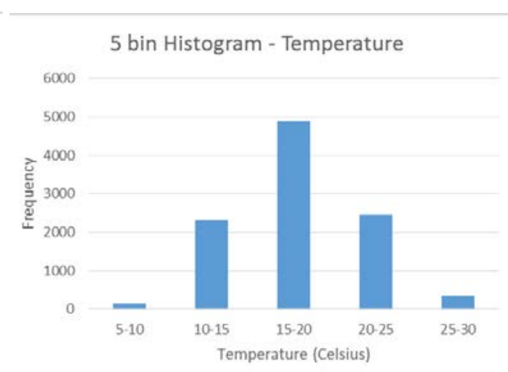
Next we are going to create a histogram for a weather variable of our choosing. You can repeat this process for as many weather variables as your class has time for. A histogram is a column chart that displays the frequency of different values. If you are using Microsoft Excel, you will need to install the Analysis ToolPak. To do this, on the File menu, click Options. When the Excel Options window pops up, select Add-Ins from the menu on the left hand side. Next click on the Manage list, select Excel Add-ins, and then click Go. In the Add-ins dialog box, click the box next to the row that says Analysis ToolPak and then click OK. Once you have installed the Analysis ToolPak, you will be ready to plot histograms. In other program such as Google Sheets, you have the ability to directly create histograms.

After you have the Analysis ToolPak installed, under the Data tab, choose the Data Analysis button. When the Data Analysis dialog box opens, choose the row Histogram and click OK. In the Histogram dialog box, select the data range of the variable you want to look at and click OK (you can also choose how many columns (bins) you want and where you would like the output results). A new sheet will open up with the Bin and Frequency headings.

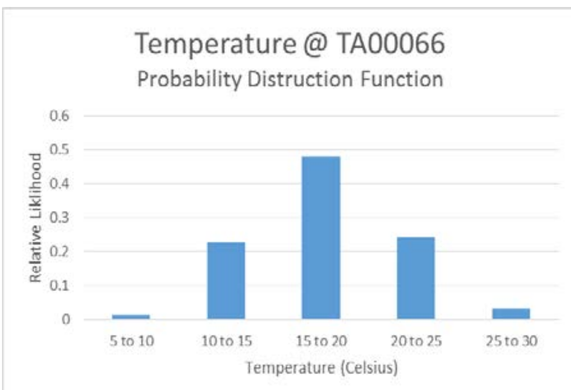


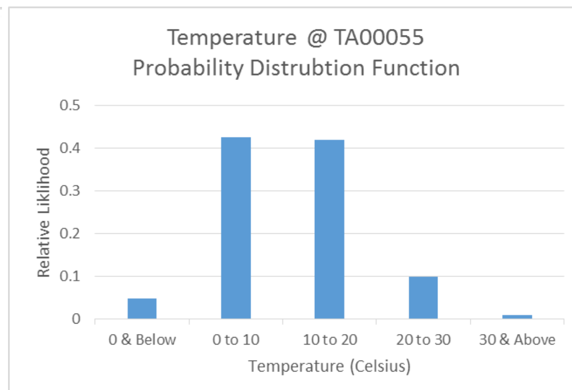

Open the new worksheet and select both rows, in the Insert tab select a column chart. In the new histogram created, label the axis appropriately. Below are two examples of a histogram for Temperature with different bin values (one with 26 bins and one with 7 bins) [Please note that these graphs may different for different weather stations based on local climate and weather- the graphs below are for reference only and use TA00066]. The number of bins dictates how detailed the distribution is. The advantage of having many bins is very details distributions, while the advantage of having only a few bins is that you can easily identify the overall trend and expected value.




A histogram is a convenient way to summarize the data to identify statistical descriptors like minimum and maximum, while also allowing you to see the type of distribution of the data (uniform, binary, single peak, two peaks, normally distributed, etc). The histogram gives you an idea of the long term expectation of the expected values for that variable. We can redraw a histogram by changing the y-axis from total frequency to relative frequency by dividing the frequency for each bar by the total number of samples. The benefit of using a histogram with the relative frequency is that we can compare graphs quickly even if they have different sample sizes. A histogram with the relative frequencies, also called relative likelihood, is commonly known as a probability distribution function (PDF). The area under the PDF curve is equal to one, representing that the graph shows all the given values for that variable. Create a PDF for one of the weather variables that you already have a histogram for. As a class think about how you interpret a PDF. Using the example PDF for TA00066 of temperature below, a correct interpretation could be that about 48% of the time the temperature is between 15 and 20 degrees Celsius OR less than 5% of the time the temperature is below 10 degrees Celsius or above 25 degrees Celsius. Ask the class, if they didn't know the weather forecast for tomorrow but they did have a PDF of past values, how would they make their predictions for tomorrow's temperature? [Answer: for station TA00066 students might guess that the temperature will likely be between 15 and 20 degrees Celsius but it could be as low as 5 or as high as 30, for station TA00055 stations might guess that the temperature is 80% likely to be between 0 and 20 degree Celsius]




What are other ways we might use to describe the data that we didn't already use? [Answer: There are many answers to this question. Some examples are: using plots like histograms and boxplots, variance, range, number of samples, skewness, five number summary, etc]

We looked at the entire dataset for our analysis, but we could have only looked at a subset of the data. What would be one useful reason to only look at a subset of the data? [Answers may vary: you could look at only day/night/seasonal temperatures, pressure, wind speed, or humidity to understand variations on a smaller scale like: what is the average temperature for a summer/winter, day/night?]

# Data Statistics: Student Worksheet

Match each statistical measure with its definition by drawing a line between them:

| | |
|---|---|
| Minimum | The middle number in the dataset |
| Maximum | The largest value in the dataset |
| Mean | The lowest value in the dataset |
| Median | The average value of the dataset |
| Mode | The measures of the spread/variability of the data |
| Standard deviation | The value that is repeated the most times in the dataset |

Download hourly data for a TAHMO weather station. Using Excel functions, fill out the table below.

| | **Relative Humidity (%)** | **Precipitation (mm/hr)** | **Pressure (kPa)** | **Solar Radiation ($W/m^2/hr$)** | **Temperature ($^oC$)** | **Wind Speed (m/s)** |
|---|---|---|---|---|---|---|
| **min** | | | | | | |
| **max** | | | | | | |
| **mean** | | | | | | |
| **median** | | | | | | |
| **mode** | | | | | | |
| **standard deviation** | | | | | | |

Which parameter had the most variability? What is the timescale of the variability (hourly, daily, monthly, yearly, or other)?

______________________________________________________________________________

______________________________________________________________________________

What are other ways might we use to describe the data that we didn't already use?

______________________________________________________________________________

______________________________________________________________________________

Why is it useful to mathematically describe our datasets?

______________________________________________________________________________

______________________________________________________________________________

V.1

Sketch a histogram of one of the parameters that you looked at. Be sure to create a title for your graph and label you axis. Label features on your graph including minimum, maximum, and mode.

Why is it useful to graphically describe our dataset?

_______________________________________________________________________________

_______________________________________________________________________________

Identify and describe one data statistic that is easier to identify in the table than in the histogram.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

Identify and describe one data statistic that is easier to identify in the histogram than in the table.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

We looked at the entire dataset for our analysis, but we could have only looked at a subset of the data. What would be one useful reason to only look at a subset of the data?

_______________________________________________________________________________

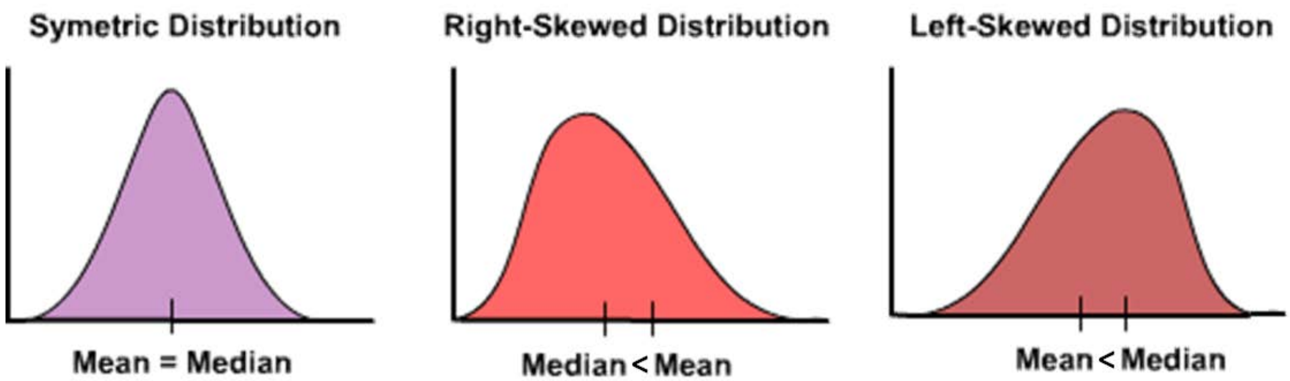
_______________________________________________________________________________

_______________________________________________________________________________

# Advanced Topics: Skewness of Data

This advanced topic is intended for classes that want to continue to explore statistical descriptions of datasets. This advanced topic is option and should be determined based on the skill level of the classroom. This activity is designed to be done after the main lesson plan is completed, and does use values obtained earlier. Allow an additional 20 minutes for this activity.

How can you use the mean and median to predict the shape of the distribution of the dataset? If the mean is smaller than the median, the data is said to be skewed to the left. Skewness is a measure of the symmetry of a probability distribution. If the median is smaller than the mean, the data is said to be skewed to the right. If the mean and the median are equal, the data is said to be symmetrical.




Based on the mean and the median, describe the shape of the distribution for each variable. Creation of a histogram plot (value is the independent variable, frequency is the dependent variable) to verify your predictions.

| Variable | Mean (=,<,>) Median | Predicted Skewness | Excel's Skew (+,-) | Plot |
|---|---|---|---|---|
| Relative Humidity | | | | |
| Precipitation | | | | |
| Pressure | | | | |
| Solar Radiation | | | | |
| Temperature | | | | |
| Wind Speed | | | | |

V.1

# Example Answer Key: Alliance Girls School TA00066

The plots and tables represented in this example answer key are only valid for the TAHMO station TA0006. The data used was downloaded on 2 May 2017, and can be accessed here: https://drive.google.com/file/d/0BxNcyc_sE4pPUzlOdVRVTl9uYnc/view?usp=sharing. Analysis for other stations may not display the same trends, so this example answer key should be used as a guide.

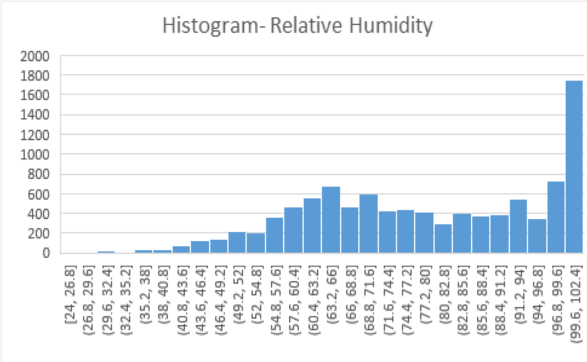
Answer Key: Data Statistics

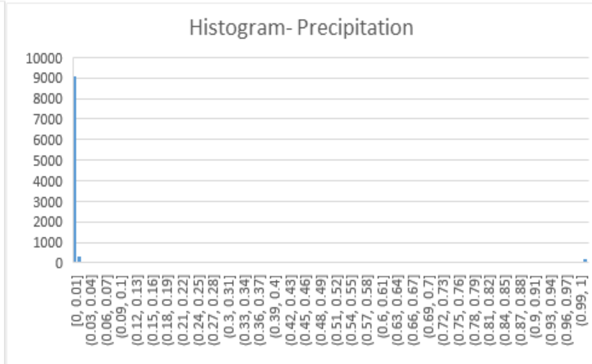
| | Relative Humidity (%) | Precipitation (mm/hr) | Pressure (kPa) | Solar Radiation ($W/m^2/hr$) | Temperature ($^oC$) | Wind Speed (m/s) |
|---|---|---|---|---|---|---|
| **min** | 24 | 0 | 781 | 0 | 5.61 | 0 |
| **max** | 100 | 35.5 | 809.3 | 1031 | 29.4 | 2.5 |
| **mean** | 78.18 | 0.12 | 804.99 | 132.50 | 17.91 | 0.51 |
| **median** | 79 | 0 | 805 | 0 | 17.73 | 0.49 |
| **mode** | 100 | 0 | 804.5 | 0 | 19.4 | 0 |
| **std** | 17.65 | 1.13 | 1.52 | 243.96 | 3.80 | 0.39 |

Answer Key: Advanced Topics and Skewness

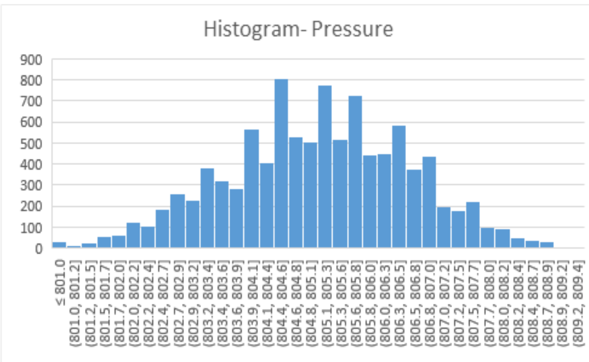
| Variable | Mean (=,<,>) Median | Predicted Skewness | Excel's Skew (+,-) | Plot |
|---|---|---|---|---|
| Relative Humidity | < | left | - 0.31 | left/- |
| Precipitation | > | right | + 17.21 | right/+ |
| Pressure | = | symmetrical | - 0.45 | left/- |
| Solar Radiation | > | right | + 1.83 | right/+ |
| Temperature | = | symmetrical | + 0.18 | symmetrical |
| Wind Speed | > | right | + 0.55 | right/+ |

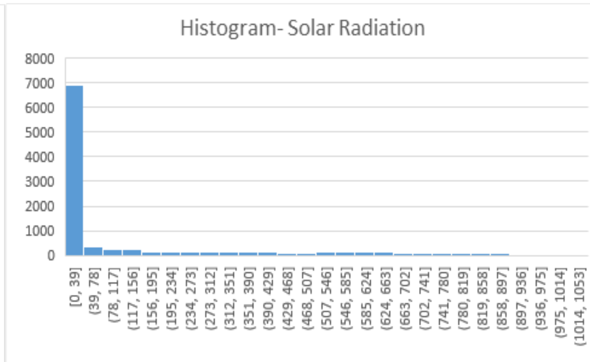
Predictions of skewness based on the mean and median are given as left, right, or symmetrical. When talking about skewness, we describe the direction of the tail: If a probability function is described as skewed right then you can imagine that the hump of the data is on the left and the tail end of the data is on the right. In Excel, the skewness function gives you a quantitative degree of skewness. A value greater than +1 means that there is a high degree of skewness to the right. A value less than -1 means that the data is very skewed to the left. A value between -0.25 and +0.25 is approximately symmetrical. A value between +0.25 and 1 is slightly skewed to the right. A value between -1 and -0.25 is slightly skewed left. Plotting a histogram (data values on the x-axis and frequency on the y-axis) is visually helpful to confirm the skewness trends.



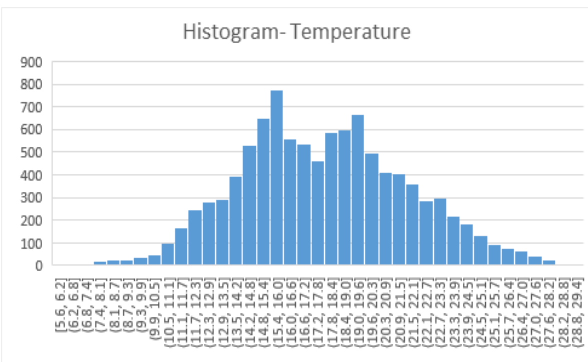



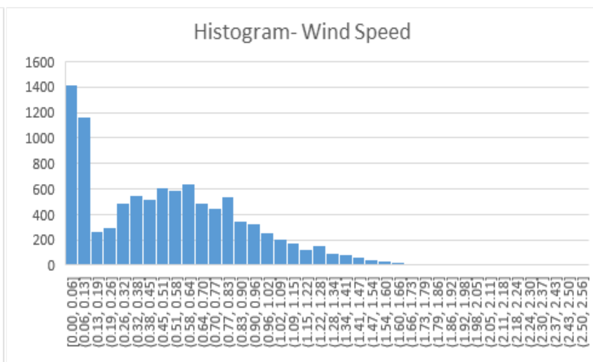

Relative Humidity looks to be skewed left, with the mode of the data on the right. Most precipitation values are 0 when it is not raining but there are values with heavy rain, thus the graph looks to be skewed right.




Pressure appears to be approximately symmetrical but it is hard to determine. Solar Radiation is strongly skewed right: half of the data is 0 and this represents the nighttime value.




Temperature looks to be approximately symmetrical, there are two peaks in this graph so we would call is a bimodal symmetrical distribution. Wind Speed is strongly skewed right, with a lot of data points at low wind speeds.