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Weather & Climate

Teacher Resource Guide

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WEATHER AND CLIMATE

<u>Students can measure and track five basic components of weather</u>:

1. Temperature

   Temperature is a measure of how fast particles are moving in a substance. When heat transfers from one substance to another, energy is gained or lost. Generally speaking, heat is a form of energy, and temperature measures heat energy.

   Students can measure temperature with thermometers. If you measure high temperatures, be sure the thermometers are designed to withstand the heat – ordinary weather thermometers may break in hot water.

   The alcohol (or mercury in older instruments) in a thermometer will expand when heated because the particles move apart from each other. When the alcohol cools, it contracts. By reading the number next to the top of the alcohol column, students can find the temperature.

   The two most common scales are Celsius and Fahrenheit. In the US, Fahrenheit is usually used for weather and household applications. Scientists and people in many other countries use Celsius.

2. Precipitation

   Precipitation is the term for water in either liquid or frozen form that has condensed in the atmosphere and fallen to Earth. A rain gauge may be placed in an open area to capture and measure precipitation. Students should experiment and observe the relationship between snowfall and rainfall amounts. Because water expands as it freezes, the level of snow in a rain gauge will decrease as it melts. The relationship is not a constant ratio but varies depending on the atmospheric temperature and the water content of the snow.

3. Humidity

   Water vapor (gas) is always present in the air. When it condenses, we can see clouds, fog, or precipitation. Even though it's invisible, we can measure water vapor or at least recognize its presence. Humidity is the term for the amount of water vapor in the air, but we are more often concerned with the *relative humidity*. The relative humidity is a measure of how much water vapor is in the air compared to how much **could** be in the air at that temperature. That's why the relative humidity is expressed as a percentage – for example, 50% relative humidity means that the air is holding half its maximum capacity of water vapor.

   Students can see an example of relative humidity by comparing two thermometer readings. Wrap the bulb of one thermometer with a cloth or towel soaked in room-temperature water and compare that reading to a dry thermometer. Unless the conditions are very humid, the wet bulb temperature will drop as water evaporates from the cloth. Since heat energy is necessary to evaporate water, the temperature around the wet bulb drops. The more evaporation that occurs, the faster and farther the wet bulb temperature will drop. More evaporation indicates that the air is drier.

So, the bigger the difference is between the two temperatures, the lower the relative humidity.

4. Air Pressure

   The air in the atmosphere is always pushing down on the Earth but the force it exerts changes. Scientists measure the force against a specific area (like a square inch) using instruments called barometers. Air pressure is another element of weather that we cannot see but can demonstrate that it's there.

   A helpful analogy for students to consider is water pressure since they can see water and it's much more dense than air. When they swim underwater, the weight of the water above them presses down and they probably feel it against their ears. If a container of liquid springs a leak, drops (or worse) will escape. Although we don't see it, air presses against us as if we're at the bottom of a pool, and things we inflate will lose air if they get punctured.

5. Wind

   When air moves, we feel the wind. As it affects objects in its path, we can observe its direction and strength. Wind is caused by differences in pressure and temperature in the atmosphere, and by the rotation of the Earth. Using their simple anemometers, students can compare the speed of the wind at different times.

<u>Comparing weather and climate</u>:

Weather gives a description of the state of the atmosphere at a given place and time. The conditions include temperature, precipitation, humidity, air pressure, wind speed and direction, and the type and amount of cloud cover.

Climate also describes the atmosphere but considers conditions over time. Therefore, climate can be thought of as average weather conditions.

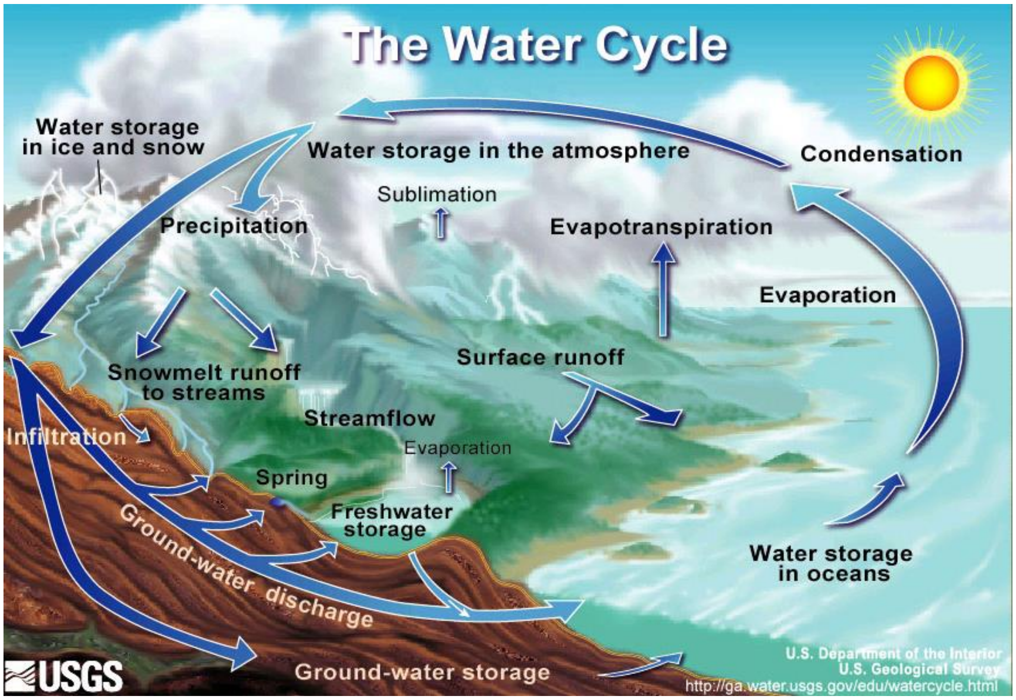
<u>The water cycle</u>:

The movement of water throughout the Earth and its atmosphere is called the *water cycle*. The amount of water circulating on earth is essentially constant. We can trace the paths water can take as it circulates above, on, and below the Earth's surface, and as water changes among three forms.

Liquid water is easily visible in rivers, streams, lakes, oceans, puddles, and other formations on the land. Drops may condense and form on objects on Earth when temperature differences occur, such as those that produce morning dew. Water travels underground also, infiltrating the Earth to pool under the surface. Droplets of liquid water in the air fall as rain or fog.

In areas of low temperature, water will freeze, or become a crystallized *solid*. Some places on Earth are covered with ice year round. Ice crystals form in clouds when the temperature is low enough, and several forms of precipitation are solid, such as snow and hail.

Water also exists as a *gas*, or vapor. Students can learn about this form of water by experimenting and observing. The noun *evaporation*, which contains the root word vapor, describes the process of liquid water changing to a gas. When the reverse process, gas to liquid, occurs, that's called *condensation*. Along with *precipitation*, the scientific word for moisture falling to Earth from the atmosphere, students will learn the three most important words to describe the water cycle.



Applying systems thinking to weather and climate:

Systems are groups of elements that form complex wholes. The elements in a system are interrelated. They interact with each other and are often interdependent. Although students and adults are surrounded by and are part of many systems, we often overlook the many complicated connections that drive behavior. Weather and climate are complex systems we encounter every day and provide fascinating opportunities for thinking systemically.

Weather and climate systems are so complex that we may think students can't understand how the relationships among the parts create a functioning whole. But systems thinking can become a habit, and the earlier students begin to think systemically and practice looking at the "big picture" view, the more adept they'll become at looking beyond simplistic explanations.

Here are some suggestions and techniques to use in class:

Behavior over time:

Systems tend to be dynamic, meaning they change over time. The best and most accessible way for students to become familiar with systems thinking is by considering the dynamic nature of a system, rather than looking at "snapshots." Drawing and reading graphs should be an integral part of most areas of study, and especially weather. Behavior over time graphs (BOTGs) can be full of information and insight. Once students learn to read a thermometer, have them record the outside temperature at the same time each day and track the change of seasons.

Teachers can use the weather chart from the New York Times attached to this guide to help students understand several principles about weather and system dynamics. Point out that are several BOTGs on the chart; actual daily temperature, average daily temperature, record high and low temperatures for each day, and precipitation.

One effective strategy is to have teams of students each study a copy of the chart and make up a set of questions. Make copies and have the teams answer each other's questions.

<u>Feedback</u>:

Simply stated, feedback refers to cases where output affects the input that created it. Cycles or loops result. Think about two common uses of the word feedback: Most people are familiar with the situation where a microphone (input) is placed too close to a speaker(output). The sound is amplified and travels back through the microphone to the speaker, where it is amplified and picked up again by the microphone. A feedback cycle is created with the noise becoming uncomfortably loud and distorted.

Another use of the word feedback describes how a person performing an action (output) receives information (input) about its effectiveness and modifies the action accordingly. If the process is successful, we might call it "constructive criticism."

Weather and climate systems contain feedback systems too. Hurricanes build up strength as they travel over warm ocean waters. The evaporated water rises, then condenses as it cools. Energy is released which leads to higher wind speeds. The strong winds cause more evaporation, and that vapor rises and eventually condenses.   Hurricanes begin to weaken when they encounter land or cooler water.

Another feedback system may be causing Earth's temperature to rise. When solar energy strikes the Earth's surface, heat radiates back toward space. Gases and clouds in the atmosphere contain and reflect back some of the heat, creating a "greenhouse effect." This is fortunate for us as it keeps our environment warm enough for us to survive. However, too much gas in the atmosphere can trap too much heat, kind of like putting on an extra blanket when we're already warm enough. Here's where the feedback comes in; the warmer the atmosphere, the more water vapor it can hold. The more water vapor, the more heat can be trapped. The more heat, the more vapor.

Surface ice can contribute to feedback loops also. Ice tends to reflect sunlight, so during periods when the Earth is cooling, ice accelerates the process. The more ice, the more reflection and less heat energy reaches Earth's surface. The less heat, potentially more ice and therefore more reflection and even less heat. The opposite process speeds up warming on Earth; when ice melts, more heat can be absorbed by the underlying land and water. Less ice forms on a warmer Earth so there is increased heating of the surface. More heat means less ice, and so on.

Feedback loops in a complex system like Earth's climate are very difficult to predict and model. But progress is being made, especially in the accuracy of short term forecasting. Help students find access to weather and climate data and they'll be able to follow the important investigations going on in modern science.

Delays:

Systems can be complicated, especially something as vast as weather and climate on Earth. The connections among elements of the system may be separated from each other by distance, time, and other connecting elements. Ocean storms passing by offshore can cause waves on the continental coastline days later. A rise or fall in water temperature in the Pacific Ocean can determine the winter weather in New England.

A good way to demonstrate a delay is to have students compare two graphs on the same background. Build a graph of the length of daylight in your area each day for a year. Exact numbers are not crucial – draw a smooth curve with the high point around June 21, the low point around December 21, and equal values (about 12 hours) on September 21 and March 21. Then find a graph of average daily temperatures. You'll find that the lowest average temperatures are in January and the highest in July. The curves will look about the same with the temperature graph following the length of daylight graph by about one month.

Ask the students what they think causes the delays between the shortest day and the coldest temperatures, and between the longest day and the highest temperatures. The sun heats the Earth, and heat radiates from the land and water to heat the air. It takes time for the heat stored up from the sun to radiate into the atmosphere, and after winter it takes time to warm up the Earth again.

Summary:

We naturally have difficulty understanding interconnected systems, and the weather and climate of Earth is one of the most complex. Introducing students to some of the tools of systems thinking will help them understand how the many elements of our meteorological system affect each other and what their role as citizens may be in the future.

Appendix

1. The New York Times chart of Boston weather for 2010 presents many opportunities for students to learn about weather and climate data while practicing important math skills. Point out that are several BOTGs on the chart; actual daily temperature, average daily temperature, record high and low temperatures for each day, and precipitation. One effective strategy is to have teams of students each study a copy of the chart and make up a set of questions. Make copies and have the teams answer each other's questions.

2. Map of sea ice around the North Polar region. Some of the most striking examples of climate change have occurred in the areas in the higher latitudes (The equator is latitude 0^0 and the poles are latitude 90^0.) The map is an example of change over time expressed graphically in a different way from a BOTG.

3. US temperature and precipitation maps for 2010 – these maps compare the actual weather to the average climatic conditions using colors to represent percentages.