The Water Cycle, Clouds, and Rainbows

Background Information

This section focuses on three interesting components of the atmosphere: the water cycle, clouds, and rainbows.

The Water Cycle

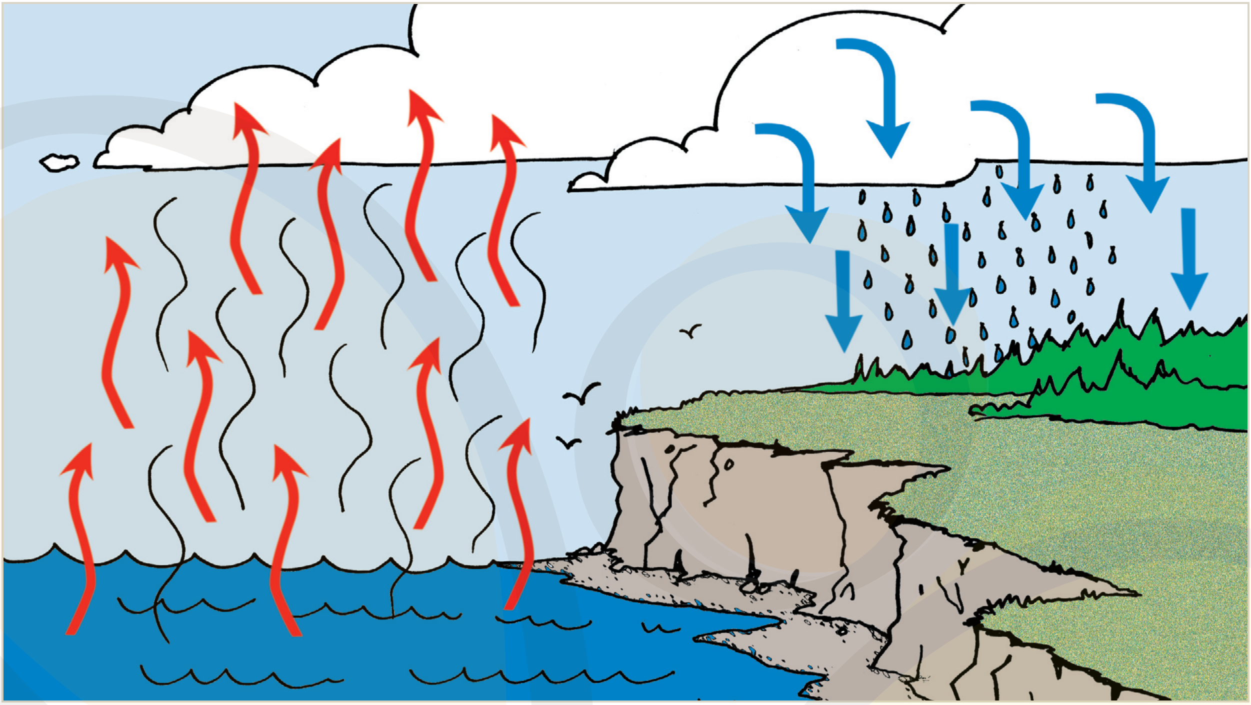
Most Montessori students will have been introduced at the lower elementary level to the basic concepts involved with the **water cycle**, the ongoing process of the earth's water being cycled from the atmosphere to the earth's surface and back again. The upper elementary level takes students to a more global view, focusing more on the fact that moisture moves with the air in convection cells of various sizes, from global cells such as the Hadley cell, to large weather systems, to isolated thunderstorms and showers.

While water is the focus of the water cycle, water is in fact like a passenger hitching a ride on air currents of various sizes. In each case, however, the underlying process is the same:

- Moisture **evaporates**, rising from bodies of water and the ground as water vapor, and plants **transpire**, releasing water vapor through tiny holes in their leaves.
- Warm air absorbs the moisture from the environment.
- **Humid** (moisture-laden) **air** rises into higher, cooler regions of the atmosphere.
- Humid air cools and the moisture condenses into larger droplets.
- Water droplets collect and fall as precipitation. If it is warm, they fall as raindrops. If it is cold enough, they fall as snow.
- The rain or snow falls into bodies of water such as **lakes**, bodies of pooled salt water or fresh water that are **landlocked**, surrounded by land, or the rain and snow lands on the earth and is absorbed by the ground and plants, becoming available once again for the water cycle.

The warmer the water and land, the more they warm the air above them and the more moisture evaporates from them. The warmer the air above the water and land, the more moisture the air can absorb. It is therefore the warming of the oceans and land by the sun that is at the root of the water cycle and the global weather patterns that result as that moisture moves around the atmosphere.

This water cycle manifests in many forms, each depending on the type of air movement that is driving it. On the largest scale, global convection cells cause global patterns of rainfall. For example, the great amount of warming that takes place at the equator causes the Hadley convection cell discussed in the previous section on global weather patterns. Much of the moisture carried in the Hadley cell falls at the equator in the form of thundershowers. However, weather systems embedded in the Hadley



The water cycle

cell also carry great amounts of moisture onto the continents, as occurs with hurricanes.

A hurricane is a perfect example of the water cycle operating at the scale of weather systems. Hurricanes form in low-pressure areas at the equator, where the warm ocean water evaporates easily and the warm air can carry a lot of moisture. As they develop, the air drawn toward the low-pressure center flows over the surface of the water, where it picks up more moisture, feeding the hurricane still more. The hurricane then continues to develop as long as it is over warm water. Hurricanes begin to lose power only when they drift over cooler water or over land.

Some meteorologists believe that global warming, an increase in the earth's overall temperature caused by the accumulation of gases in the atmosphere, may be causing more severe hurricanes as well as other climate disturbances. Hurricanes form and grow in warm air over warm water, and the warmer the air and water because of global warming, the more powerful hurricanes become.

A more regional version of the water cycle occurs because of the differences in how land and water retain heat. Because large bodies of land warm and cool faster than large bodies of water, seasonal convection cells form between the two. This is a version of a land-sea breeze on a very large scale, such as occurs in the monsoon, a pattern of tropical air and moisture flow that reverses each year.

At certain times of the year, a monsoon produces rain, and at others, dry weather. For example, in the Asian summer monsoon, the warm summer air over India rises, creating a low-pressure area which draws in moist air from the Indian Ocean. As it passes over the Himalayan Mountains, a mountain range across northern India, the moist air rises, cools, and rains on the region, producing the highest recorded rainfalls in the world, sometimes as much as 450 inches (1,140 cm) in a year. This pattern reverses in winter, with the warmer ocean drawing dry air from the interior of the continent, producing a dry season in India.

The Asian summer monsoon

On a still smaller scale, local warming within a low-pressure area can produce a convection cell that leads to a thunderstorm or a summer rain shower. In this case, evaporation from local bodies of water and the ground, in addition to transpiration from plants, contribute to the humidity level of the air at the surface. With daytime heating, the air warms and rises, and then cools as it reaches higher levels of the atmosphere. This leads to rain showers and thunderstorms, processes that recycle the water back into the lakes, ground, and plants.

Each version of the water cycle in different convection cells causes characteristic types of clouds. Clouds are visible evidence of the water cycle because they are collections of tiny water droplets being carried on the air currents. Clouds are classified into two main types: layered and convective. Each type is then classified according to the altitude at which it occurs in the atmosphere:

- **Low altitude** refers to the area from sea level or land up to 6,500 ft (2,000 m).
- **Middle altitude** refers to the area from 6,500–16,500 ft (2,000–5,000 m).
- **High altitude** refers to the area above 16,500 ft (5,000 m).

Clouds

Six basic types of clouds are produced: low, middle, and high layered cloud, and low, middle, and high convective cloud. Each of these types has many sub-types, but these six categories provide a basic system of **classifying**, which refers to arranging items into groups based on the characteristics they share (a summary sheet in NAMC's Curriculum Support Material also summarizes this information):

Layered Types of Cloud

- Low altitude (nimbo) up to 6,500 ft (2000 m) — **Nimbostratus**: a uniform, dense cloud close to the ground; often produces rain; becomes fog at ground level
- Middle altitude (alto) 6,500–16,500 ft (2,000–5,000 m) — **Altostratus**: mid-level cloud of varying thickness; often produces rain
- High altitude (cirro) above 16,500 ft (5,000 m) — **Cirrostratus**: wispy clouds formed mostly of ice crystals; also known as "mares' tails"

Cumulus clouds

Convective Types of Cloud

- Low altitude (nimbo) up to 6,500 ft (2,000 m) — **Cumulus**: small, puffy, white clouds associated with fair weather
- Middle altitude (alto) 6,500–16,500 ft (2,000–5,000 m) — **Cumulus congestus**: cumulus cloud growing in height, with a characteristic “cauliflower” appearance; often with rain showers beneath
- High altitude (cirro) above 16,500 ft (5,000 m) — **Cumulonimbus**: a thunderstorm cloud; often with heavy showers, high winds, thunder, and lightning; also known as an “anvil head” cloud

Each of the six major types of cloud tends to be associated with a particular type of weather system. Large areas of nimbostratus cloud are associated with cold low-pressure systems because the cold air condenses all of the moisture near the surface into low cloud. Altostratus clouds are often associated with warm fronts, as the warm, moist air climbs gently over the cold air, forming clouds at middle altitudes. Cirrostratus clouds are associated with fair weather because they are only visible when the lower levels of the atmosphere are clear of cloud.

Cumulus clouds are also associated with fair weather. They often occur when neither high- nor low-pressure dominates, allowing the moisture to rise and condense, but only at very low levels. As more heating occurs, and if the pressure is not too high, more vertical development of cumulus occurs, producing cumulus congestus clouds. These clouds are growing toward being thunderstorms if not prevented by high pressure at higher levels.

Finally, if there is sufficient heat and moisture available, and if high pressure does not prevent it or if a cold front moves through, cumulonimbus clouds form. Cumulonimbus clouds are thunderstorms that can reach to the top of the troposphere, the lowest layer of the atmosphere. At that point, they level off, producing a characteristically flat top, or “anvil head.” Their tremendous height allows large raindrops to form. Because they reach into the cold upper layers of the atmosphere, the droplets may freeze and form hail.

Rainbows

A **rainbow** is a giant arc of colored light that appears on the horizon. Rainbows require a particular alignment of sunlight, rain, and observer to be seen. Thus it is often thunderstorms or rain showers that produce rainbows. The creation of a rainbow requires that sunlight shines on a rain shower, and that the observer stand between the sun and the shower while facing the shower. These conditions do not occur by chance very often, making rainbows relatively rare.

For the sun to shine on the shower requires that the cloud not cover the whole sky, or that the sun be low enough on the horizon to shine underneath the cloud. The rain is necessary because each raindrop acts like a little prism, which is a transparent object — often glass — with a surface cut in shapes that allow light to split into its various colors. The observer must be standing between the sun and the shower because the light that creates a rainbow reflects back from the inside surface of the drop toward the observer's eye.

As the light passes into and out of the raindrop, it is refracted, which means that its direction is altered at the surface of the drop by the water in the drop. Because the colors that make up sunlight are bent different amounts at the surface of the drop, the light emerges as different colors. Only one color of light from each drop reaches the eye of the observer, so it takes millions of drops to create the rainbow.

Soap bubbles refract light in a similar way to raindrops

Note to the Teacher

The first activity in this section uses a terrarium, a small enclosed glass or plastic container which, when soil, moisture, and vegetation are placed inside, can be used to simulate a land environment for plants or animals. A terrarium can be used to simulate humid or dry conditions, depending on the amount of water, vegetation, and light and the type of soil used.

The activity uses a terrarium to study the water cycle on a small scale. Before this activity is presented, students can be invited to set up a simple terrarium producing humid conditions. The terrarium requires these basic components: a bowl of water representing a body of water (to suit the activity, place the bowl at one end of the terrarium), soil representing the earth's surface, a light source representing sunlight, and vegetation of various types, which can include small ornamental house plants, grass, and moss. Ideally, the terrarium will have a lid. If there is no lid, plastic wrap can be used to cover the top of the terrarium.

ACTIVITY 1

Observing the Water Cycle on a Small Scale

Purpose

To observe the water cycle on a small scale in the classroom.

Material

Illustration, The water cycle (see NAMC's CSM).

Terrarium prepared in advance with lid, soil, plants, and light source. Before the activity, remove the water from the bowl inside the terrarium.

Pitcher of hot water (hot enough to steam).

Adhesive tape.

Large bag of ice cubes or large frozen ice pack.

Physical Geography journals and pencils.

Presentation

- Most Montessori teachers present this concept in Years 4 and 5. This activity can be done in parts.
- Announce that the students will have an opportunity to observe a water cycle inside a terrarium.

Introduction and Review of Terms

- Demonstrate the illustration, The water cycle. Review what is meant by a water cycle, defining and discussing such terms as evaporation, transpiration, humidity, and condensation.

Examination of the Terrarium

- Demonstrate the terrarium and explain that it represents humid conditions on earth. Point out the terrarium's components and discuss what each represents: soil (earth's surface), light (sunlight), vegetation (plants).
- Demonstrate the pitcher of hot water (reheating if needed). Explain that this hot water represents water that has been warmed by the sun for several hours. Ask a student to fill the bowl in the terrarium with hot water. Invite the students to describe what they see (steam rises from

the bowl). Point out that just as steam rises from the hot water, so the water in lakes and oceans warmed by sunlight evaporates and rises.

- Point to the moist soil. Explain that even if it is not visible like the steam rising from the bowl, water also evaporates from the soil as it is exposed to heat and light. Review that evaporation from the soil is one reason why plants need to be watered regularly.

- Point to the plants and review the process of transpiration.

- Explain that with the ongoing evaporation and transpiration, the air in the terrarium is filling with water vapor.

Demonstration of the Water Cycle

- Cover the top of the terrarium with its lid (or plastic wrap). Explain that this represents the top of the first layer of the atmosphere, the troposphere, the layer in which weather occurs. Put some adhesive tape around the outside, if necessary, to seal air inside the terrarium.

- Place the ice cubes or ice pack on top of the lid — at the end opposite the bowl. Explain that you are doing this to simulate the air high up in the troposphere, which is very cold.

- Explain that you will leave the ice on the lid for about 10 minutes. Invite the students to observe the terrarium closely during this time and to note any changes they see (the water vapor will condense underneath the coldest part of the lid, and then drip back down into the terrarium). Ask the students to describe what they think is happening (water vapor is cooling and condensing, forming water droplets).

Discussion

- Explain that condensation like this takes place on a larger scale in the atmosphere and that the water cycle manifests in many forms, each depending on the type of air movement driving it. Discuss how global convection cells cause global patterns of rainfall such as hurricanes and how regional convection cells can cause monsoons, thunderstorms, and summer showers.

- Define and discuss global warming and how it could affect global water cycles.

- Ask the students to use their journals to draw and label the parts of the terrarium involved in the water cycle, using arrows and labels to show the path that water follows in its various forms.