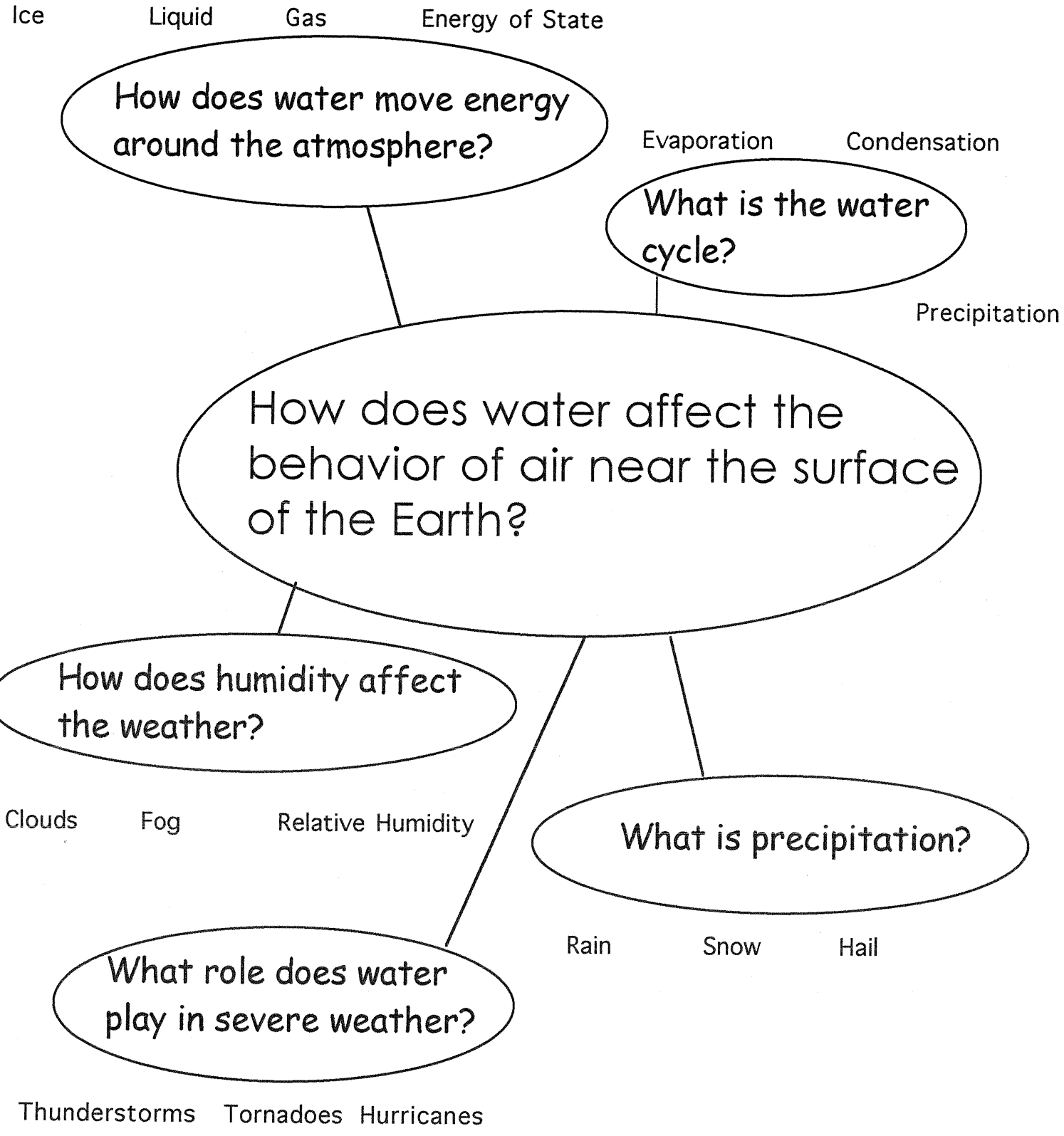
Water and Weather



Water on the Surface of Earth

The substance of water is so important in meteorology it is worth reviewing some of the things we learned in elementary school about water. The water cycle is something worth knowing as we enter this unit. We will construct some understanding of the relationship between energy and water. Without this most amazing substance covering much of our planet, the Earth's temperature would be much warmer. The role of water in the atmosphere is crucial to the thermal regulation of our planet and the pleasant temperatures we experience on our planet.

The Distribution of Water on the Surface of Earth

Oceans:

A quick glance at a globe will clearly show why the earth is often called the water planet. About 70% of the earth's surface is covered by the oceans. Except for minor differences in temperature and salinity, the oceans are pretty consistent around the globe. The water in the oceans represents most of the water on our planet, leaving a small part as fresh water flowing on the continents.

The salt water we see in the ocean can also be found in some large lakes. The Great Salt Lake in Utah is an excellent example of an inland salt-water sea. The salt in these lakes and the oceans comes from rocks weathering on the surface of the continents. As the rocks decompose and break into sediment, they release salts into the water that erode the landscape. The water eventually flows into the ocean where the salt remains. So what makes the oceans different from large fresh water lakes? The oceans and salt lakes have no outlet. When water flows into the ocean, it can't flow anywhere else, so the only way the water can leave an ocean is by evaporating from the surface. When water evaporates it leaves all salts and dissolved minerals behind. So we can now see why an ocean or lake with no water running out of it will eventually become salt water. The process of evaporation creates fresh water for the atmosphere while leaving the dissolved minerals and salts in the ocean.

Ice:

Outside of the oceans a small fraction of the earth's water supply exists as fresh water. All fresh water must be evaporated from the oceans and fall from the sky as precipitation. This is the earth's built-in water purification system. Most of this fresh water on earth is frozen in the ice caps that cover the polar regions of our planet.

The ice that we see on earth occurs in two regions. Near either pole where the surface receives less sunlight and temperatures are cold, winter snow accumulates over many years to form glacial ice. This causes the formation of ice caps. These vast regions of ice are two miles thick in some places. The second place we find large amounts of ice are in the higher elevations of mountains. These glaciers are referred to as alpine glaciers.

They are small compared to the polar ice caps but still store large amounts of fresh water. Alpine glaciers have carved many of the valleys we see in the mountains west of Denver. A few thousand years ago alpine glaciers covered a large portion of the Rocky Mountains.

During the Ice Ages the earth's climates cooled, causing more water to be stored in ice. During the Ice Ages sea levels dropped around the world as water from the oceans moved into the glaciers. Water that evaporated from the oceans fell on the land as snow. The cool temperatures in summer failed to melt the snow that fell each winter. Over time the

snow would be buried by more snow, causing it to turn into glacial ice. At present the earth is in a period of less ice. The last major ice age occurred about 10,000 years ago.

Surface Liquid Water:

On land, water plays a critical role in supplying food and cooling the atmosphere. Water is evaporated from the ocean into the air where it moves inland in the atmosphere. As the precipitation falls, it provides fresh water for plants and animals. The fresh water is stored in rivers and lakes as it constantly moves over the land. The fresh water on the surface of the earth is only a tiny fraction of the planet's total water, but it plays a critical role in promoting life on land.

The rivers and lakes on the continents of the earth are really the same. Lakes are really just very wide parts of rivers where the water is flowing slowly. All fresh water must be moving over the land. Once the water stops moving, it becomes salt water in a lake or the ocean.

Hidden Water:

Once we have recognized all the obvious sources of water on our planet we can now look at the "hidden" water. Hidden water is not easy to see because it is not flowing on the surface of the planet. Ground water and aquifers are an excellent example of hidden water. Water can be found underground in many places. Some of the larger aquifers are the size of an entire state. Most of the ground water we find today is left from the recent ice age. As the ice caps melted they formed large lakes on the surface. Water ultimately found its way downward into pockets beneath the surface.

Another hidden source of water is the water stored in life forms. Plants and animals continually recycle water for their metabolic needs. The water stored in a large tree and a small insect share one thing in common. The water in each case is just temporarily passing through the living organism. It is hard for us to imagine that the water in our bodies was part of a rain cloud just a few days before. The water in any single plant or animal does not add up to much compared to the fresh water that flows on the earth. If we look at a tropical rain forest, however, the amount of water stored in this complex ecosystem is quite impressive.

The last "hidden" source of water is in the earth's atmosphere. When liquid water evaporates, it turns to water vapor that cannot be seen. We feel this water as humidity in the atmosphere. The water vapor forms when energy in the form of heat is added to liquid water. The water evaporates and turns to water vapor in the air. This vapor eventually will lose its heat energy in the atmosphere and turn back into liquid that will fall as precipitation.

In this section we have seen that water occurs in various states on the surface of the earth. We recognized that fresh water is constantly moving on the surface of the earth. It is worth mentioning that water really cannot be destroyed. It can be polluted but not destroyed. In this way the water we see and drink today may be very old. Indeed the water you drink today could have once been part of a dinosaur some 70 million years ago. The movement of water around the surface of the earth leads us to the second section of this reading which describes the water cycle.

The Water Cycle

When humans think of water, they generally are referring to the 1% of the earth's water that is fresh and in liquid form. The fresh water that means so much to us land dwellers is just a small fraction of the total water on earth. The process which creates fresh water is described in the water cycle. The **Water Cycle** is simply defined as the movement of water on or near the surface of the earth. This includes water flowing underground near the surface and water moving aloft in the atmosphere.

The water cycle is driven by the energy of the sun. Sunlight hitting the surface of the earth warms the surface, causing liquid water to **evaporate**. The water eventually cools in the atmosphere and **condenses** into clouds which produces **precipitation**. The precipitation falls to the surface and creates **runoff** which flows downhill back into the oceans to be evaporated again.

The water cycle creates the fresh water on earth. The process of evaporation turns salt water into fresh water as the salt remains behind when the water evaporates. The fresh water which falls from the clouds then moves over the surface of the land. An interesting way to look at the difference between fresh and salt water is to look at the elevation of the water. Most water above sea level is fresh water because it has been moved there by the process of evaporation. All water below sea level is, of course, salt water because it lies in the ocean.

The water cycle operates in a "closed system" near the surface of the earth. This means that water is not created or destroyed. In other words, the system never gains or loses water. The fixed amount of water simply moves around the surface and lower atmosphere of the earth when energy is added to the water.

The Physical States of Water and Energy Transfer in the Atmosphere

Water is a critical component of the atmosphere and makes the earth unique in its ability to support life. The air temperature near the surface of the earth rarely varies more than 80° C at any given location. Water is one of the main reasons the earth's temperature range is so small. Water moves energy around the lower atmosphere by changing from solid to liquid to vapor and storing energy. In this reading we will examine the role of water and energy transfer near the surface of the earth.

Physical States of Water

Water is the only substance on earth that commonly occurs in all three physical states on the earth's surface. A **physical state** is defined as the form of the substance. Water can exist as a solid (ice), a liquid (liquid water), and a gas (water vapor) on the surface of the earth. What is the difference then between liquid water and ice? They are both made of the same substance, so why does water change form? To answer this question, we need to examine why water changes from one state to another. How then do we make ice change to water? Obviously, we add heat and melt the ice. So the difference between ice and water has something to do with energy. When we add or remove heat from water, it changes from one state to another.

Ice

The solid form of water occurs in regions with cold temperatures. Ice requires large amounts of energy to change it from solid to liquid form. One reason is the albedo of water changes dramatically when it changes from liquid to solid form. Ice has a very high albedo reflecting a large amount of the sun's energy off its surface. Liquid water absorbs a lot more solar energy as it changes temperature. Ice plays an important role in cooling the water in the oceans which generates currents. Ice is commonly found in the polar regions and at higher altitudes. Ice in polar regions is the result of low solar insulation. Ice at higher altitudes is due to decreased air pressure that results in lower temperatures.

Liquid Water

Water in its liquid state is by far the most abundant on the earth's surface. This is due to the temperature range of our planet. This relatively small temperature range is due to the large amount of water covering the earth's surface. The presence of large amounts of liquid water on the surface of our planet prevents the temperature from getting too high by absorbing large amounts of the sun's energy. Water can store vast amounts of solar energy by changing temperature or physical state.

Ocean currents move water from the equator, where it absorbs large amounts of solar energy and becomes very warm. When warm water moves into the cooler polar regions that do not receive much sunlight, the energy stored in the warm water is released, heating the air near the surface of the water. In this way water distributes solar energy around the globe by changing temperature.

Water Vapor

The gaseous state of water is most difficult to understand because it is invisible to humans. We can often feel the presence of water vapor in the atmosphere, but we never see it and, therefore, it is hard to understand the role of water vapor in the atmosphere. People often mistake steam for water vapor but it is not. Steam is condensed water or small drops of liquid water floating in the air. When water is in vapor form it cannot be seen. As water evaporates the vapor molecules mix with air. Warm air holds more water vapor than cold air because it expands. As the molecules get further apart there is more room for water vapor.

The Changing States of Water

As water changes from one physical state to another, it consumes and releases large amounts of energy. Just as liquid water can move energy by changing temperature, water in the atmosphere can store and transfer energy by changing states. As water changes from a liquid to a gas, it consumes huge amounts of energy. The water vapor then rises with the air it has evaporated into. As it goes up in the atmosphere the air cools, causing the water vapor to change back into liquid form we see as clouds. The difference between ice and water vapor is simply the amount of energy stored in the state of the matter. Ice is a low energy state, while water vapor is a high energy state. The amount of energy stored in the state of matter is referred to as latent heat. The energy needed to melt a piece of ice into water would be the latent heat between the two states of matter.

There are a number of terms used to describe the changes of state in water.

1. When ice changes to liquid water, it is referred to as melting.
2. Sometimes ice changes from solid state directly to gaseous state. This is called sublimation.
3. When water turns from liquid to vapor form, the process is called evaporation.
4. When liquid water freezes, it becomes ice.
5. When water vapor changes back into liquid water, it is referred to as condensation.

All the underlined words above are used to describe the changing states of water. We can now identify which processes consume energy and which release energy. Melting is a process that consumes energy because we apply heat to ice to melt it. Freezing is the opposite, where we must remove heat energy from water to cause it to freeze.

A simple chart shows how water consumes and releases energy to change physical states.