TEACHER BACKGROUND INFORMATION
Water Cycle

INTRODUCTION:

The **water cycle** transports water from oceans to the atmosphere, the land, and back to the ocean through the physical processes of evaporation, condensation, and precipitation. Without this cycle, the land would be so dry that nothing would grow. The water cycle can be considered to have four main events: (1) evaporation of water from the oceans, (2) transport of water vapor through the atmosphere, (3) condensation and precipitation of water onto the land and, (4) the return of water to the oceans by rivers and streams.

This description of the water cycle involves both the oceans and the land, but water vapor may evaporate from the land (lakes, rivers, plants, etc...) before it returns to the ocean and water vapor may condense and precipitate back to the ocean without ever touching the land. These can be considered small sub-cycles within the overall water cycle. The ocean-land exchange is the major-cycle, but there are many sub-cycles (Fig. 1).

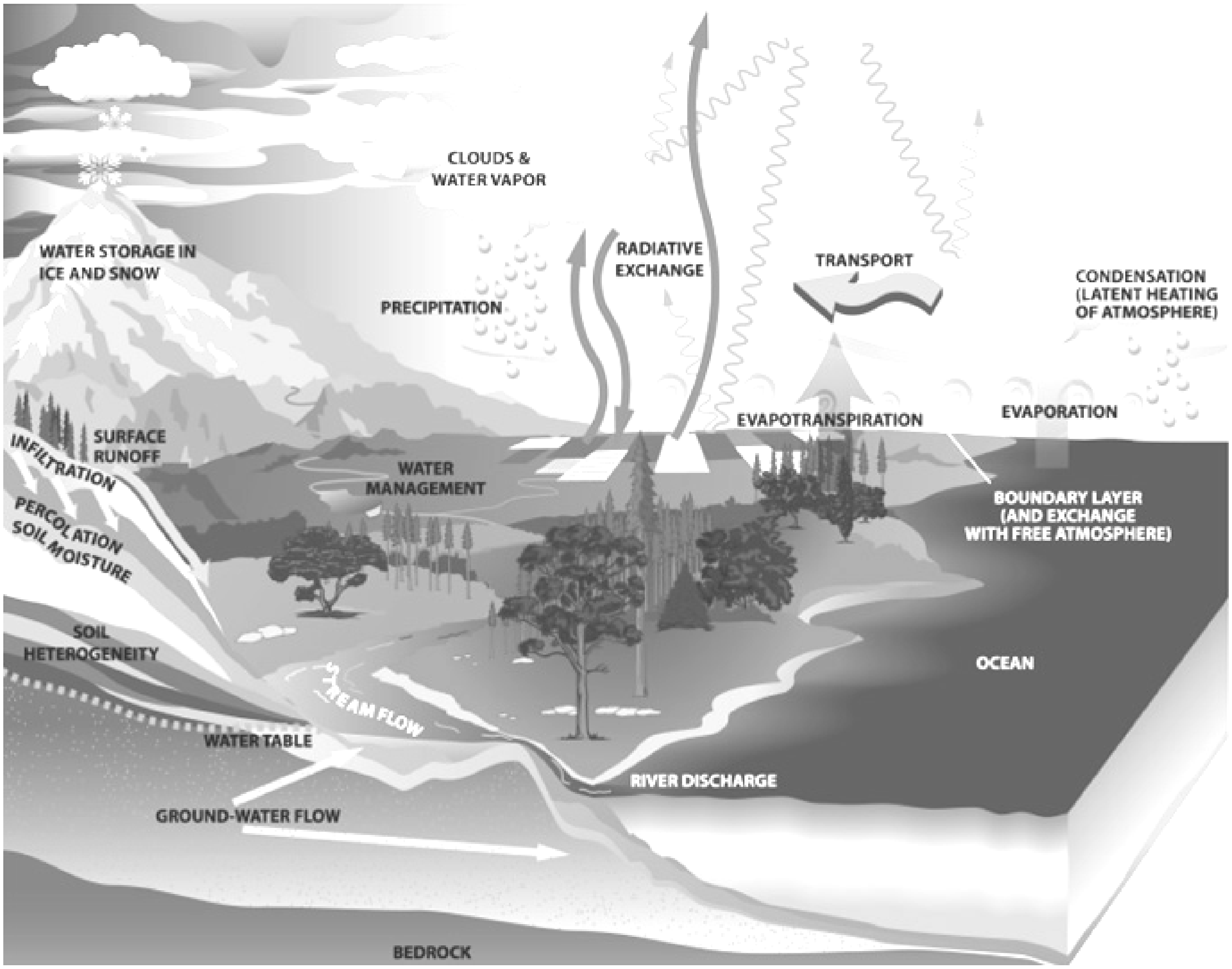

Figure 1 – The water cycle, including major-cycle and sub-cycles.
(http://watercycle.gsfc.nasa.gov/)

EVAPORATION:

We are going to start our study of the water cycle at the surface of the ocean. Here the water evaporates – it goes from the liquid phase to the gas phase (physical change). When water evaporates, individual water molecules leave the liquid and enter the atmosphere as the gas called water vapor (recall from the matter binder: a vapor is the gas form of a substance which is liquid at room temperature ~25^{o}C). While in the liquid state, water molecules are held together by cohesive (electromagnetic) forces. Water molecules have a wide range of kinetic energies. At the surface, water molecules are moving around rapidly, but the gas molecules just above the surface have even more kinetic energy. When these gas molecules strike the surface liquid molecules, they transfer some of their energy to the latter (conservation of momentum and energy). These water molecules then gain enough energy to overcome the cohesive (electromagnetic) forces holding them to the other water molecules and leave the water as a gas. Water vapor molecules take energy with them; therefore evaporation is a cooling process. If incoming solar radiation did not supply energy to the ocean water, the surface of the ocean would become cooler and cooler from the continuous evaporation that takes place. The sun supplies the energy that maintains the surface temperature, which allows the continual evaporation of water. Thus, it is the sun that supplies all the energy required to evaporate water.

Water evaporates faster at higher temperatures. If the water is hotter (warm currents), the molecules move faster. So they fly off into the air at a faster rate. If the water is cold (cold currents), evaporation still takes place but at a much slower rate. Remember, when water evaporates, it goes from a liquid to a gas and water will evaporate faster at higher temperatures.

Another important fact about the water cycle is that colder air cannot hold as much water vapor as hotter air. An air mass at 90^{o}F (such as what is found near the equator) can hold much more water than an air mass at only 40^{0}F (such as what is found closer to the poles).

CONDENSATION:

When water vapor condenses, it goes from a gas to a liquid. This is the opposite of evaporation. During condensation, water molecules in the air loose energy (cool). This energy loss can be caused by a number of different factors. One reason for this is when air rises, it moves further away from the heat source (Earths surface). Rising air is moving further from the surface of the earth that is heated by the sun. A second reason for this energy loss is that air looses its heat to cooler air through conduction. Another reason for air cooling when it rises is the decrease in static pressure as it moves away from the earth’s surface. The greatest static pressure is at the bottom of the atmosphere, near the earth’s surface. As the air rises, there is less static pressure which results in a lower temperature.

As a result of this energy loss, air cools as it rises. An important concept to connect to this is that colder air can hold less water vapor. So as air rises and cools, the colder air can no longer hold all the water vapor that is in it. This means that the water vapor in the colder air begins to condense.

As the air cools, the water vapor molecules have less energy. When they bump into each other instead of bouncing off, they stick together. The water vapor molecules do not have enough energy to overcome the cohesive forces between them. When enough water molecules stick together, a water drop is formed. On a hot day we can see this happen on the outside of a glass of cold water. The water molecules close to the glass slow down, bump together, and stick forming water drops on the side of the glass.

HOW THE WATER CYCLE WORKS:

The energy for the water cycle comes from the sun. The sun heats the surface of the earth (land and water/oceans). Water evaporates into the air. The air near the surface is also heated, so it expands. When it expands it becomes less dense and it rises. As the warm air with water vapor rises, it cools. Colder air cannot hold all the water vapor that is in it. The water vapor condenses and forms tiny drops. Millions of tiny drops in the air make up clouds. When the water vapor in the clouds cools even more, the drops get bigger and finally fall as rain. After the rain falls, it collects in streams and underground waterways. As the water returns to the oceans, it picks up salts and other minerals from the rocks and carries them to the ocean. This process has been going on for millions of years and that is why the oceans are salty.

RELATIVE HUMIDITY:

Recall that hotter air can hold more water vapor than colder air. If an air mass is holding all the water vapor it can hold, the relative humidity is 100%. But air does not always hold all the water vapor it can. If it is holding only half the water vapor it can hold, the relative humidity is 50%. Sometimes the air is holding only 1/10 of the water vapor it can hold – so the relative humidity is 10%. Basically, air at a given temperature can only hold a certain amount of water vapor (hot air: more water vapor; cold air: less water vapor). Just think about the distribution of hot air molecules, they are spread out thereby allowing water vapor molecules to fit in between them. In contrast, cold air is denser, with air molecules close together so less water vapor molecules can fit in between.

Relative humidity of air at a given temperature is the percentage of water vapor the air can hold. Remember the containers from the videodisc; hot air has a larger container and cold air has a smaller container. Again, the size of the container shows how much water vapor the air can hold. The percentage number tells how full the container (air) is which tells the relative humidity of air at a given temperature.

TEMPERATURE AND RELATIVE HUMIDITY:

Recall that hotter air can hold more water vapor than cold air and when an air mass is holding all the water vapor it can, the relative humidity is 100%. If the air is holding only half the water vapor it can hold, the relative humidity is 50%.

Relative humidity goes up when air cools. For example, take hot air that has 30% relative humidity. When that air cools, the amount of water vapor the air can hold goes down (the container gets smaller). But the amount of water vapor in the air does not change. Both air masses have the same amount of water vapor. In the hotter air, that amount of water vapor makes the relative humidity 30%, but in the colder air the same amount of water vapor makes the relative humidity 90%. The relative humidity went up as the air got colder.

When the air get colder, the amount of water vapor the air can hold will get even smaller. But the relative humidity cannot go above 100%. The extra water vapor cannot stay in the air, so it condenses and forms drops. Remember, relative humidity goes up when air cools.

RELATIVE HUMIDITY AND THE WATER CYCLE:

Relative humidity and the water cycle can now be combined and can be illustrated by the following example. Take an air mass at 70^0F over the ocean. Water evaporates until the air has a relative humidity of 70%. As the warm air mass rises, the temperature will go down.

As the temperature goes down, the amount of water vapor the air can hold goes down (container gets smaller). But the amount of water vapor in the air does not change. The relative humidity of the air mass goes up as the air cools.

As the air continues to cool, the relative humidity keeps going up until it reaches 100%. When the air can no longer hold all of the water vapor, some of the water condenses into drops – clouds form. As the air mass continues to cool, the relative humidity stays at 100% but more and more water vapor condenses. When enough water vapor condenses, the drops get big enough that rain falls.

DEW AND FOG:

When air cools and contains more water vapor than it can hold at that temperature, water vapor condenses. Tiny drops form and a cloud is made. The same thing happens close to the ground to form fog and dew.

During the day, the air is hotter than it is at night. So during the day, the air can hold more water vapor. At night, the air cools and it cannot hold as much water vapor. The water vapor condenses. If it condenses in a cloud close to the ground, fog is formed. If it condenses on the ground, dew or frost is formed.

Dew usually forms at night when the ground is much colder than the air. Air that comes in contact with the cold ground cools and droplets are formed. This is like the drops that from on a glass of cold water. In freezing weather, frost will form instead of dew.

Fog can form during the day or during the night. When fog forms, the ground is usually just a little cooler than the air. When the air cools enough, condensation occurs and a cloud forms. If this cloud stays close to the ground, it is called fog.

ACCUMULATION OF WATER ON LAND:

After precipitation forms and falls to the surface of the earth, the final step in the water cycle occurs. This is where the many different sub-cycles of the water cycle are found. Some precipitation falls directly into the ocean and becomes a part of the major cycle. Some precipitation falls on the land, collects in lakes and rivers, and flows back into the ocean where again it is part of the major cycle. Some of that water, however, may evaporate before it returns to the ocean, thus forming a sub-cycle of the water cycle. Some of the water seeps into the ground and is taken up into plants. What isn't used by the plant can be returned to the atmosphere through the process of evapotranspiration – where in water evaporating from plant exits through the stomata (tiny openings on the underside of the leaf that allow gases and water to enter/exit). Some of the water that seeps into the ground infiltrates into the water table and may become part of the ground water flow to the oceans. Also, some precipitation falls as snow or forms ice on the ground. In this instance, the water is stored in the snow and ice until it melts. At that point, it becomes part of the surface run-off which either makes it to the ocean by way of rivers, streams, or ground-water flow, or evaporates from the ground or plants before it reaches the ocean (refer to Figure 1).