Earth's Water – It Freezes, It Flows, and It Floats

Water Water Everywhere

Writing Topic: Describe and graph water in the Earth's oceans, lakes, rivers, glaciers, ground water, polar ice caps, and atmosphere. (Not required: Did you know that water has special properties? Most solids on Earth are denser than their liquid form. What would happen if solid water sunk in our oceans?)

VOCABULARY WORDS

1. Reservoir: a supply or source of water.
2. Water cycle: the cycle of processes by which water moves between the Earth's oceans, atmosphere, and land.
3. Evaporation: the process by which liquid water changes to water vapor.
4. Transpiration: the release of water from plant leaves.
5. Condensation: the process by which water vapor changes into liquid water and forms clouds.
6. Precipitation: the falling of water, either liquid (rain) or solid (snow or hail), out of the atmosphere.
7. Density: mass per unit volume. Density provides a measure of how tightly matter is crammed together in an object.

FOUNDATIONAL CONCEPTS

Water is essential for life on Earth. A person can last roughly three weeks without food but on average only three days without water. Conveniently, water is all around us on Earth with 71% of the Earth's surface covered by water. However, over 95% of all water on Earth is contained in the oceans where it is salty and undrinkable. Where is the rest of the water found? And where do we get fresh drinking water from?

Figure 1: *Image of Earth illustrating that the majority of Earth's surface is covered by water.*

Fresh water is found in many places. The majority of fresh water is locked in ice sheets in Antarctica and Greenland, which are not a useful source of drinking water. A more useful **reservoir,** or supply, of fresh water is ground water. Ground water is water stored underground in the cracks and space in soil, sand and rock. Ground water is accessed by drilling wells into the ground and pumping the water out. In the United States ground water supplies half of the drinking water. Ground water is also used for irrigation to help grow crops.

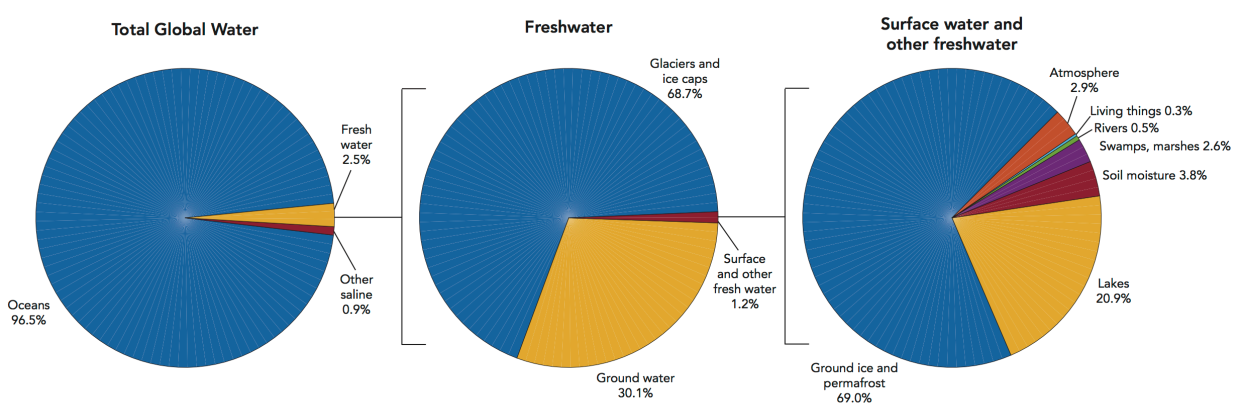

Figure 2: *Pie charts showing distribution of water amongst the various reservoirs on Earth*.

You are likely more familiar with surface water reservoirs such as the lakes and rivers that you can swim in. These are important sources of drinking water. However, they are only a tiny component of the whole system. Out of every five hundred thousand droplets of water on Earth thirty-five are found in lakes around the planet while only is found in a river! The atmosphere; clouds, rain and moisture in the air, is another small but important reservoir.

Water is not stationary. The **water cycle** is the process by which water circulates between the different reservoirs discussed above. The sun drives the water cycle. Heat from the sun causes liquid water to **evaporate,** changing from liquid to gas or vapor, from the oceans, lakes and rivers as well as from plants. **Transpiration** is the process by which water is carried through plants from the roots to the leaves and evapotranspiration is when this water evaporates into the atmosphere.

The water vapor rises into the atmosphere, cools, and **condenses** into clouds. The water falls out of the clouds in a process called **precipitation**. Precipitation often occurs when clouds are blown into mountains and need to lose mass in order to rise over the mountains. This is why it rains much more on the side of the mountains where the wind is blowing from. This is seen in the West Coast of America where the prevailing winds are from the west and the western side of the mountains is much wetter with far more vegetation than the eastern side. This is called orographic rainfall.

Precipitation can build up ice caps and glaciers. It can fall as rain that immediately flows downhill in streams flowing towards the ocean. In wintertime, it can form large snow packs that last until warmer temperatures arrive in the spring and summer at which point the snow melts and the water flows into rivers and lakes, and resupplies ground water aquifers where it can be stored for thousands of years.

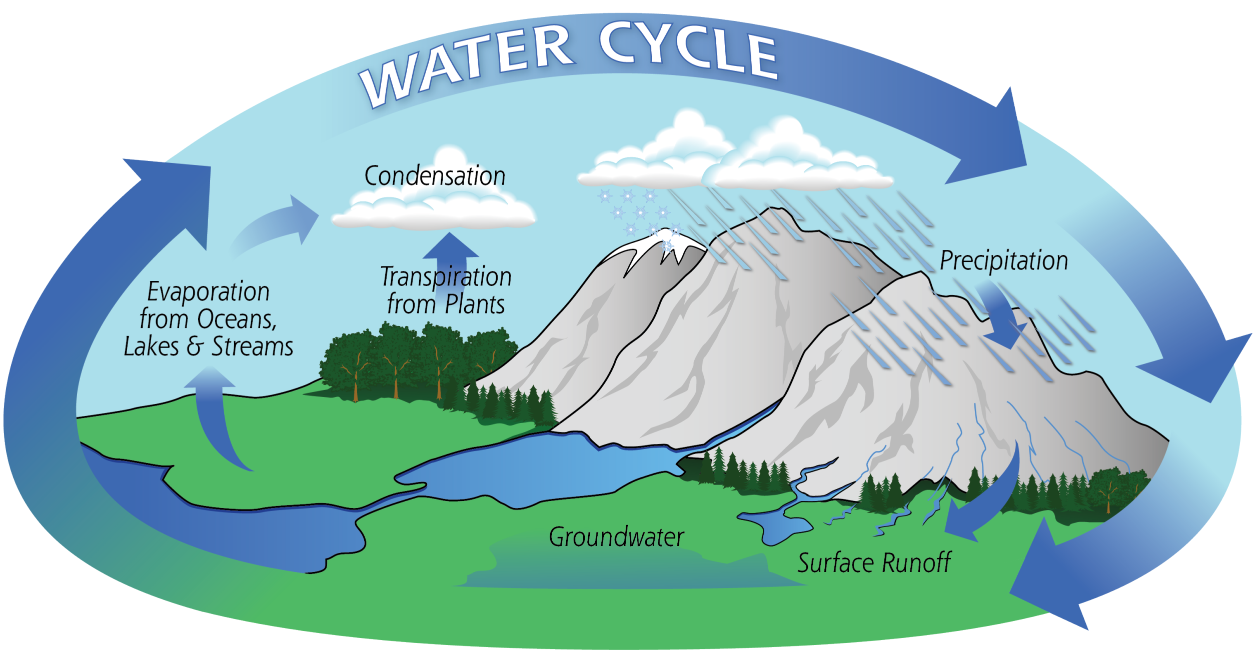

Figure 3: *The water cycle.*

Remember that it is called the water cycle. It has no beginning or end. Instead, water keeps moving. Once water has precipitated out it flows through rivers and surface runoff back to the oceans and lakes where it is evaporated and the cycle repeats.

EXPLORING DEEPER

Water has a curious property in that ice, the solid form of water, is less **dense** than liquid water. This is why ice cubes float in a drink and why icebergs float in the ocean. But before we explore this further, what exactly is density? Density is a measure of mass per unit volume or how tightly matter is crammed together in an object. Consider two boxes of the same size, one full of rocks and the other one full of feathers. Which box is heavier? The box of rocks because rocks are denser than feathers. Other examples are wood floating in water because it has a lower density, a rock sinking when you throw it into a river, and helium balloons rising in the air. Similarly, icebergs float because they are less dense than the water in which they float.

Why is ice less dense than water? When water freezes the molecules rearrange into a nice ordered structure with lots of space in between the molecules. In liquid water the molecules are less ordered with more molecules crammed into less space. This makes liquid water denser than ice because it has more molecules per unit volume.

Figure 4: *A polar bear on sea ice in the Artic.*

The fact that ice is less dense than water is extremely important for life on Earth. It allows for sea ice to float on top of the water in the Artic providing habitats for animals such as polar bears. It means that lakes freeze from the top down. The layer of frozen water at the surface of the lake insulates the lake from the cold air and prevents the rest of the lake freezing. This enables fish and other life to survive in the lakes throughout the winter.

BREAKOUT SECTION

Historical Connection: WHY ARE THE OCEANS SALTY?

The oceans are salty. In fact, they are so salty that humans cannot drink seawater. Human kidneys can only make urine that is less salty than seawater. In order to get rid of the excess salt taken in by drinking seawater, you have to urinate more water than you drink. Therefore, if you only drink seawater you will, eventually, die of dehydration. But why are the oceans salty? Where does the salt come from? Rainwater erodes rocks, breaks them down, and transports the material to the ocean. Two of the ions, or electrically charged atomic particles, which are transported into the ocean, are sodium and chloride. Together, these ions make salt, sodium chloride, and are responsible for making seawater salty and hence undrinkable.

Various people, such as John Joly in 1899, have tried to use the salt content of the oceans to determine the age of the Earth. If you can measure the current amount of salt in the ocean and you know how much salt is deposited in the ocean each year then, by assuming the oceans initially had no salt in them and that once salt is deposit in the ocean it remains there forever, you can calculate the age of the oceans.

$$\text{age of oceans} = \frac{\text{current amount of salt in oceans}}{\text{amount of salt deposited in oceans each year}}$$

Joly's calculations suggested that the oceans were 100 million years old, far less than the currently agreed upon age of 4.5 billion years. This is because the salt clock method has several important flaws. The amount of salt transported into the oceans depends upon erosion, rainfall and runoff and varies over millions of years. More importantly, salt does not remain in the ocean forever. It is removed from the ocean by plate tectonics lifting seabeds out of the ocean or subducting them deeper into the Earth. In fact, the ocean is roughly in a state of equilibrium; the amount of salt lost from the ocean and the amount it gains each year are about the same.

Despite these flaws, the salt clock method to determine the age of the oceans was an important stepping-stone towards the more developed methods we use now. It illustrates how logic and critical thinking can be used to attempt to understand the world around us.

<u>Real World Math:</u> CLIMATE CHANGE AND SEA LEVEL RISE

The Earth's climate is warming causing glaciers to retreat and ice caps to melt. In this section we will consider how much the level of the oceans would rise in the worst-case scenario of the complete melting of the Antarctica ice sheet. How could you go about calculating this?

You are given:

- A_{Earth}= surface area of the Earth = 510 million km^2
- P = percentage of the Earth's surface that is covered in water = 71%
- V = volume of ice on Antarctica = 26.5 million km^2

One way to go about this is to first calculate the surface area of the Earth that is covered by water:

$$\begin{aligned} A_{water} &= A_{Earth} \times P/100 \\ &= 510 \text{ million km}^2 \times 71/100 \\ &= 362 \text{ million km}^2 \end{aligned}$$

The next step is to divide the surface area of the Earth by the volume of water in Antarctica to obtain the height of the sea level rise:

$$\begin{aligned} h &= V/A_{water} \\ &= 26.5 \text{ million km}^2 / \ 362 \text{ million km}^2 \\ &= 0.07 \text{ km} \\ &= 70 \text{ m} \end{aligned}$$

This shows that if all of the ice in Antarctica were to melt the sea level would rise by 70m! This is a simplified calculation that illustrates the huge amount of water stored in Antarctica. There are several other factors that are not taken into account in this calculation. Firstly, water is denser than ice. Therefore, when the ice melts the water generated will take up less space than the ice that produced it. Secondly, the large mass of ice on the Antarctica continent can be viewed as a person standing on a trampoline. When the person is standing on the trampoline the trampoline bends down under the weight of the person. When they get off it bounces back up. Continents behave in the same way, except over thousands of years instead of seconds. This is called post-glacial rebound. North America is still bouncing back up after the melting of the huge ice sheet that covered all of Canada and the northern states of the USA during the last ice age some 20,000 years ago. Can you think about these effects and how the answer would change if you included them in your calculation? Would you expect more or less sea level rise? Are there any other processes that would change the amount of sea level rise that we have not discussed?

Figure 5: *NASA image of Antarctica and the southern portion of Africa from space.*

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PHOTOS, FIGURES, CHARTS CITED

Figure 1: *Image of Earth illustrating that the majority of Earth's surface is covered by water.*

NASA Earth Observatory images by Robert Simmon, using Suomi NPP VIIRS data from Chris Elvidge (NOAA National Geophysical Data Center). Suomi NPP is the result of a partnership between NASA, NOAA, and the Department of Defense.

https://earthobservatory.nasa.gov/blogs/elegantfigures/2013/04/22/earth-day-and-night/comment-page-1/

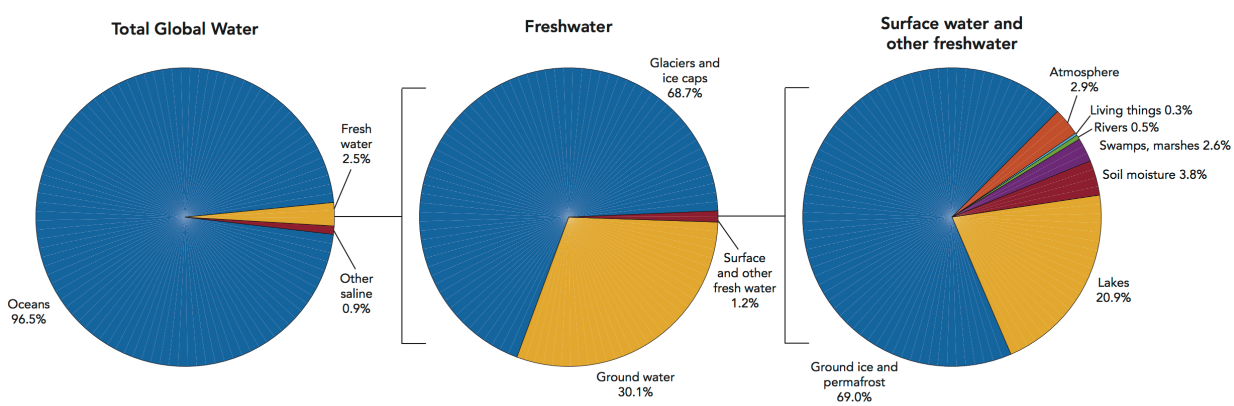

Figure 2: *Pie charts showing distribution of water amongst the various reservoirs on Earth*.

Adapted from USGS Water Science School by Leighton M. Watson. Data from Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York). Permission is granted for STEMTaught to use the image for their education mission.

https://water.usgs.gov/edu/earthwherewater.html

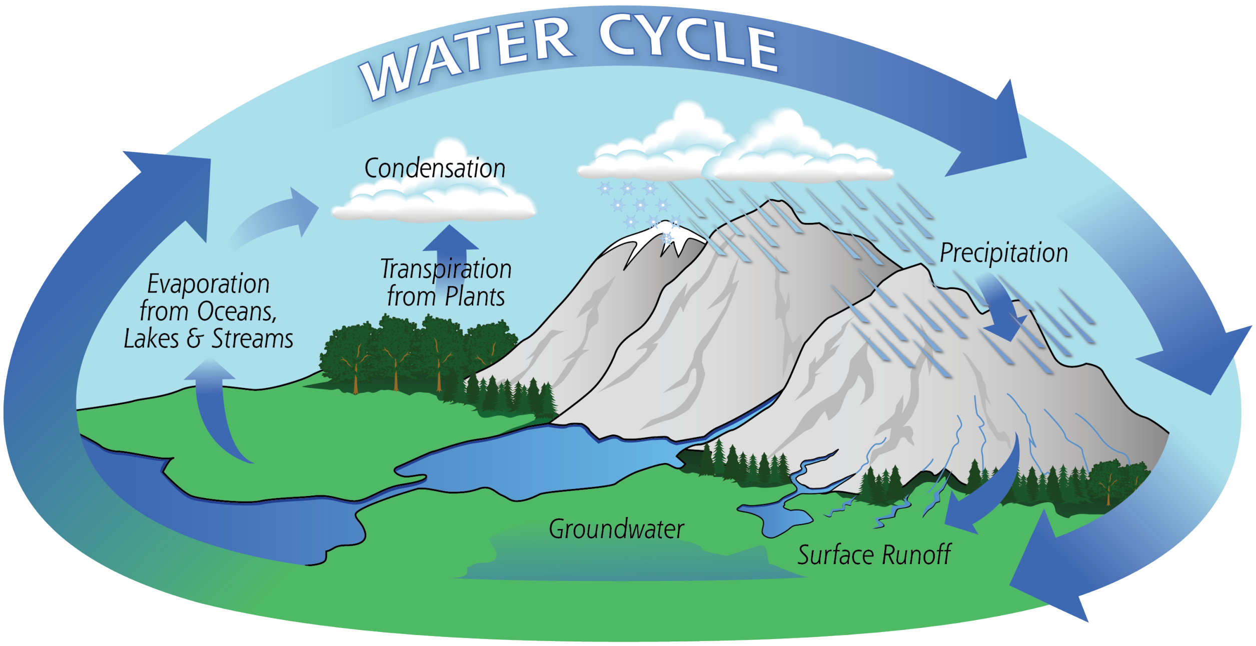

Figure 3: *The water cycle.*

NASA Global Precipitation Measurement (GPM) mission.

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Figure 4: *A polar bear on sea ice in the Artic.*

NASA

https://www.nasa.gov/feature/goddard/2016/polar-bears-across-the-arctic-face-shorter-sea-ice-season

Figure 5: *NASA image of Antarctica and the southern portion of Africa from space.*
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