AQUARIUS

Education & Public Outreach

# PROPERTIES OF FRESH WATER AND SEAWATER

**Unit:** *Salinity Patterns & the Water Cycle* **I Grade Level:** *Middle* **I Time Required:** *Up to three 45-min. periods* **I Content Standard:** *NSES Physical Science, properties and changes of properties in matter*. **I Ocean Literacy Principle 1e:** *Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic.*

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**Big Idea:** *Water has unique properties. About 97 percent of all water is in the oceans. Salt water or seawater has characteristics similar to fresh water with some noticeable differences because of the salts that are dissolved in water.*

**Key Concepts:**

- Life on Earth is possible because of water's unique properties.
- Water is the only natural substance that is found in all three states -- liquid, solid (ice), and gas (steam) -- at the temperatures normally found on Earth.
- Water can absorb a tremendous amount of heat acting like a heat buffer for the Earth.

**Essential Questions:**

- How do we use water every day?
- What properties of water make our daily life easier?
- How is salt water different from fresh water?
- Would the Earth be different if the oceans contained freshwater?

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**Knowledge and Skills:**

- Describe all three states of matter – solid, liquid, and gas – within the normal temperature range at Earth's surface for fresh water and for saline water.
- Explain how the high heat capacity & abundance of liquid water makes life on Earth possible.
- Demonstrate through experimentation, that water containing salts and minerals has different properties than fresh water.
- Graph data to analyze and articulate results/conclusions.

**Prior Knowledge:**

- The salt in seawater comes from the weathering of earth's land surface.
- Water can be a liquid or a solid and can go back and forth from one form to the other.
- When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point.

**Common Preconceptions:**

- Students generally do not regard freezing as taking place at a specific temperature.
- Students consider heat and temperature to be the same thing, often arguing that if you increase the amount of heat you will increase the temperature.
- Boiling is the maximum temperature a substance can reach.

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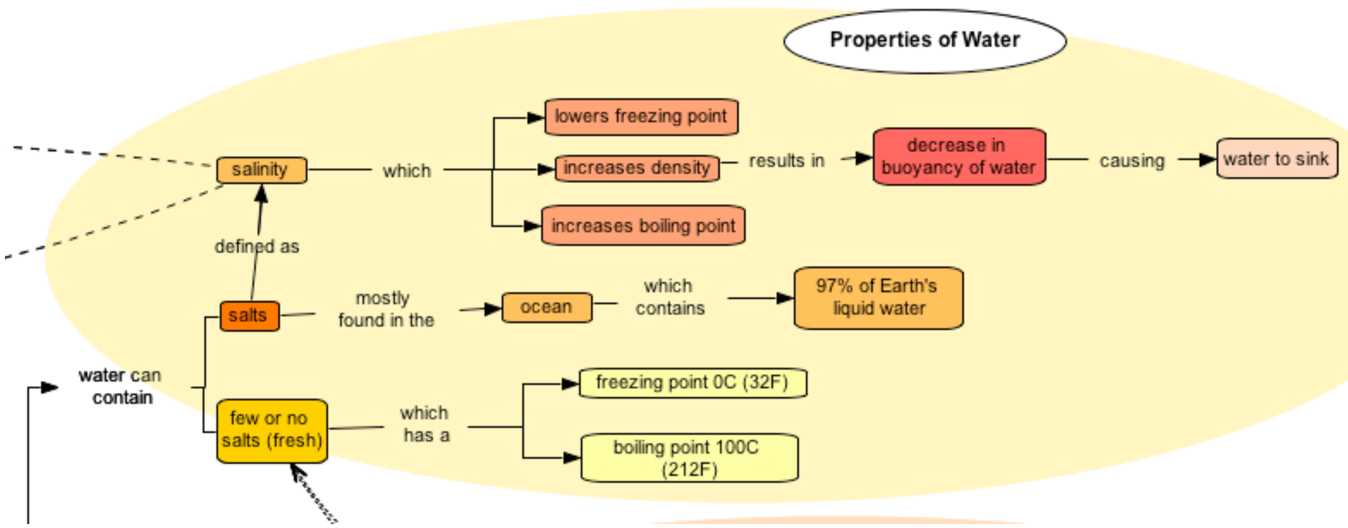
**Concept Map-** Create a preliminary concept map with the class, to determine the level of student knowledge. See Wrap Up below to revisit the concept map as a form of evaluation. This lesson and activity relates to the branch "Properties of Water" from the comprehensive Aquarius Concept Map – *Water & its patterns on Earth's surface*




**Background**
Liquid water ($H^2O$) is often perceived to be pretty ordinary as it is transparent, odorless, tasteless and ubiquitous. Water is unique in that it is the only natural substance that is found in all three states -- liquid, solid (ice), and gas (steam) - at the temperatures normally found on Earth. Earth's water is constantly interacting, changing, and in movement. Water freezes at 32° Fahrenheit (F) and boils at 212° F (at sea level). In fact, water's freezing and boiling points are the baseline with which temperature is measured: 0° on the Celsius scale is water's freezing point, and 100° is water's boiling point. Water is unusual in that the solid form, ice, is less dense than the liquid form, which is why ice floats. Water has a high specific heat index or capacity. This means that water can absorb a lot of heat before it begins to get hot. This is why water is valuable to industries and in your car's radiator as a coolant. The high specific heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans. *(Adapted from USGS Water Science http://ga.water.usgs.gov/edu/mwater.html )*

**Materials:**
***Station 1 (Boiling Point) –*** *distilled water, seawater (or "Instant Ocean" mix from a pet store that sells salt water fish), isopropyl alcohol (optional), hot plate, 3 flasks with rubber stoppers that hold a thermometer, 3 thermometers that can measure from -10°C to 110°C, graph paper;*
***Station 2 (Freezing Point) –*** *distilled water, seawater (or "Instant Ocean" mix), isopropyl alcohol, 3 thermometers that can measure from -10°C to 110°C, 3 large test tubes with a one hole fitted stoppers, 3 Pyrex beakers, dry ice chunks, gloves, graph paper;*
***Station 3 (Heat Capacity) –*** *hot plate, 2 flasks (same size), 2 thermometers, bucket of ice water, stop watch*

**Preparation:** *All activities work best as small group activities but can also be done as demonstrations (e.g., for younger students). If done as demonstrations, use an overhead projector to record data for the class.* ****Review Safety Procedures**** **(**Found at the end of this document.*)*
***Station 1 (Boiling Point) –*** *Fill one flask with distilled water, one flask with seawater, and – if desired – the third flask with alcohol (Caution: alcohol is flammable). Insert the thermometers through the stoppers and cap the flasks. Make sure the thermometers are suspended in the liquids. Set all three samples aside for half an hour so that they are all at room temperature. If alcohol is used in the experiment, make it is in a closed container and do not let it splash.*
***Station 2 (Freezing Point) –*** *Isopropyl alcohol works nicely because it contains water. When the water in the alcohol freezes, it should sink. There are numerous stores that sell dry ice as either chunks or cubes. Always use sturdy gloves and / or tongs to handle dry ice. If you do not wish to use dry ice, use a salt-ice mixture instead.*

***Station 3 (Heat Capacity) –*** *hot plate, 2 flasks (same size), 2 thermometers, bucket of ice water, stop watch*

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**Activity – Station 1 (Boiling Point)**

- In this procedure, students will explore the boiling point of water, including the differences between salt water and fresh water. Ask students to hypothesize: "Which will boil first: salt water or fresh water? Why?"
- Record the temperature of the distilled water, seawater and alcohol in the flasks. Turn on the hot plate. ****STOP Review Safety Procedures** Alcohol is flammable.**
- Begin with the distilled water. Check and record the temperature every 30 seconds. When the water begins bubbling and the temperature levels off, the water is boiling. Keep recording the temperature for 3 minutes after you see bubbles. Plot and graph your data. What is the boiling point of distilled water? How long did it take the distilled water to reach the boiling point?
- Repeat the experiment with seawater. Record the thermometer reading every 30 seconds. Plot and graph your data. What is the boiling point of seawater? How long did it take the sea water to reach the boiling point?
- Optional: Repeat the experiment with alcohol. Record the thermometer reading every 30 seconds. Plot and graph your data. What is the boiling point of alcohol? How long did it take the alcohol to reach the boiling point?
- Compare the results of the three experiments. Use your graphs. Are there any differences in the boiling points? How do you explain these differences?

**Activity – Station 2 (Freezing Point)**

- In this procedure, students will explore the freezing point of water, including the differences between salt water and fresh water. Ask the students the following questions: "For pure water, the freezing point is defined as 0°C, but have you ever measured it? How can we measure it? Can we put the thermometer in a solid chunk of ice or in chopped ice? What is the temperature of ice? Which will freeze more slowly, salt or fresh water? Why?"
- Fill one test tube with distilled water, the second with seawater, and the third with alcohol. Insert the thermometer through each rubber stopper and cap the test tubes. Make sure that the thermometer is suspended in the water. Record the temperature of each test tube.
- Using tongs or heavy gloves, fill the bottom of three Pyrex beakers with chunks of dry ice. ****STOP Review Safety Procedures**** WARN STUDENTS: "DO NOT TOUCH THE DRY ICE WITH YOUR BARE HANDS!" Place each test tube in a beaker of dry ice.
- Record the temperatures every 30 seconds until they level off. Observe the test tube of alcohol. What happens to the water that is in the alcohol? Compare it to the freezing point of the salt water and of the fresh water. Does the ice float or sink?
- Plot and graph your data. Compare the information on the three graphs. What is the freezing point of fresh water? Seawater?

**Activity – Station 3 (Heat Capacity)**

- In this procedure, students will examine water's ability to store heat. Water has a higher heat capacity than almost any other liquid. This means that it takes a lot of heat to change water's temperature significantly. We can measure and compare the heat capacities of water and air. Ask the students: "Based on your experience, which will heat and cool more slowly: water or air? Why?"
- Fill one flask with water and leave one flask empty. This flask is filled with air. Insert thermometers through rubber stoppers so that they are suspended in the flask and insert the stoppers into the flask. Thermometers should not be touching the inside of the flask.
- Record the temperature in each flask at room temperature. Place both flasks on top of the hot plate and start the stopwatch. ****STOP-Review Safety Procedures**** Record the time it takes for the water to reach 33°C. Also record the temperature of the empty flask at that instant. Ask the students: "Is the temperature in the flask of air higher or lower than the temperature of the flask of water?"
- Remove both flasks from the heat and place them in ice water. Record the time it takes for each flask to reach its original room temperature. Ask the students: "Which flask took longer to reach its

original room temperature?”

**Wrap-up:** If there is enough equipment set up several of each station, break the students into small groups. When activity for each station is complete do a gallery walk through the groups and have them explain their findings. Each group should present their findings not only to the teacher but also to the rest of the class. Engage the entire class in discussion after the gallery walk to reflect on the results.

**Assessment Questions – Station 1 (Boiling Point)**

- The boiling point of a liquid is the temperature at which it turns to gas. Water, when heated, evaporates and boils slowly compared to other liquids. This means that the heat of vaporization is high—the highest of all common liquids. Because of the high heat of vaporization, water evaporates slowly and absorbs a lot of heat. Water’s high heat of vaporization gives it a high boiling point (100°C). This is why much of Earth’s water is in liquid form.
- Have students consider differences between evaporation at the ocean surface versus a fresh water lake. Ask: “How would these processes differ? Which would evaporate more readily?"
- Look at the maps below. At top is sea surface salinity (SSS) based on computer models. Computer models are needed because SSS has only been sparsely measured over the past 100 years (as shown in the middle map). Ask: "Are SSS patterns consistent with how much sunlight reaches different parts of the earth?" Look at the bottom map of Sea Surface Temperature (SST). Ask: "Do SSS patterns coincide with SST? If not, what other factors might affect SSS?”

**Assessment Questions – Station 2 (Freezing Point)**

- The temperature at which a liquid becomes a solid is called the freezing point. The solid becomes a liquid at its melting point. The freezing point and melting point of water (or any other liquid) are the same. Water also has a high latent heat of fusion. Latent heat of fusion refers to the amount of heat gained or lost when a substance changes from a solid to a liquid, or a liquid to a solid. When ice is formed, large quantities of heat are given off. Most liquids become denser as they cool. If cooled until they become solid, the solid phase is denser than the liquid phase; however, this is <u>not</u> true of water. Pure water becomes denser as it cools until it reaches 4°C and further cooling decreases the density. Thus, water ice (0°C) is lighter than liquid water and floats on it.
- The fact that water ice is lighter than liquid water has key implications for Earth, including life in our oceans, lakes, and rivers. Considering these issues, ask the students: “Why this property is so important?” Another interesting property to consider is that when ice is formed it gives off heat. Ask the students: “How might this affect our oceans, lakes, and rivers? Can they think of other ways this helps humankind? For example, how might farmers use this knowledge when protecting their crops from freezing air temperatures?”

**Assessment Questions – Station 3 (Heat Capacity)**

- Water, when heated, evaporates slowly in comparison to other liquids. This means that the heat of vaporization is high – the highest of all common liquids. Water also has a high latent heat of fusion. Latent heat of fusion refers to the amount of heat gained or lost when a substance changes from a solid to a liquid, or a liquid to a solid. When ice is formed, large quantities of heat are given off. Liquid water also has an extremely high heat capacity – i.e., the amount of heat required to raise its temperature from the freezing point to the boiling point. The high values of the heat capacity, heat of vaporization, and latent heat of fusion mean that it takes more heat to cause a change in temperature in water than in most other substances. This makes water a strong buffer against both rising and falling temperatures.
- Water covers about 71% of Earth’s surface. Thus its ability to store heat strongly affects our climate. Ask the students: “About how much does the ocean change temperature from day to night? Do land areas experience greater or lesser differences in temperature from day to night? How does this affect the climate of coastal regions? What would happen if our oceans only covered 25% of Earth’s surface? Would the day to night temperature difference on landmasses be more or less extreme? Why?”

**Assessment Activities:** Revisit the concept map and have students add to the preliminary map that was created prior to the stations. This could be done as an individual assessment or as a class.

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**Vocabulary**

- **evaporation:** The physical process of converting a liquid to a gas. Commonly considered to occur at a temperature below the boiling point of the liquid. Opposite of condensation.
- **heat capacity:** The amount of heat required to raise the temperature of one gram of a substance by one degree Celsius without change of phase.
- **heat of vaporization:** The thermal energy absorbed by a liquid at its boiling point as it changes to a gas.
- **latent heat of fusion:** The heat released when water changes phase from liquid to solid.
- **salinity:** Of, relating to, or containing salt; salty; a measure of the amount of salt in a solution
- **states of matter:** A classification of substance according to its structural characteristics. Four states of matter are generally recognized: solid, liquid, gas and plasma.

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**Original source:** *Adapted from Orange County Marine Institute Curriculum Series and NASA's "Visit to an Ocean Planet" CD-ROM. Based on Phleger, Charles F. and Wallace, William J. Field Guide and Laboratory Manual for Oceanography: An Introduction. p. 30 - 31.*

***Aquarius* Education & Public Outreach URL:** http://aquarius.nasa.gov/

****Lab Safety Reminders****

**General Thermometer Use**

- If glass thermometers that are alcohol filled are recommended. If mercury thermometers must be used for purposes of higher accuracy, Teflon® coated are recommended.
- Resistance thermometers, or temperature probes, should be considered as alternatives to glass
- Never use a thermometer as a stirring device or swing or shake down a thermometer.
- Make sure you choose a thermometer with an appropriate temperature range. Overheating a thermometer can cause breakage of its reservoir.
- Never use an open flame on a thermometer bulb.
- Use extreme care when inserting or removing a thermometer from a rubber stopper.

**Safety Guidelines for Using Electric Hot Plates**

- Use a hot plate with a smooth, clean surface.
- Hot plates appear exactly the same whether hot or at room temperature. Always assume they are hot and act accordingly.
- Keep the electrical cord of a hot plate away from water and the heating surface.
- The cord of the hot plate should be checked periodically for frays and faults. Any hot plate with faulty wiring should not be used. Repair or replaced immediately.

**Safety Rules for All Heating Processes**

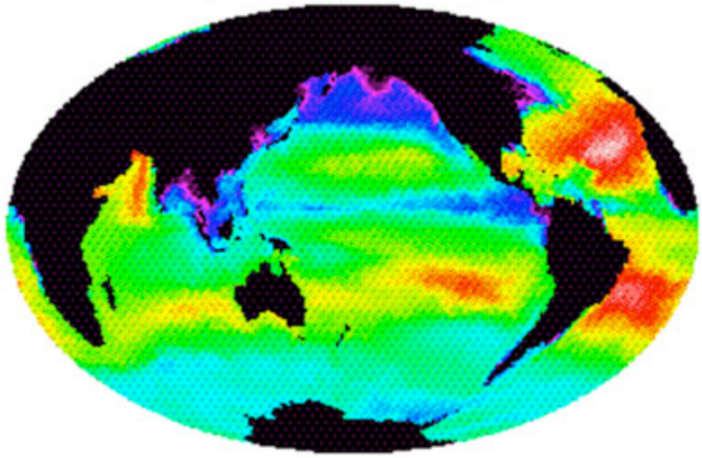
- When heating glassware, make sure to use only glassware made of borosilicate glass (Pyrex® brand or Kimax® brand). Common glass can break, explode or shatter very easily when subjected to heat shock.
- Never set hot glassware on cold surfaces or in any way change its temperature suddenly. Even a Pyrex® or Kimax® beaker will break if cold water is poured into a hot beaker.
- Use care when working with hot glass. Hot glass looks exactly the same as room temperature glass.
- Do not leave hot glassware unattended, and allow ample time for the glass to cool before touching.
- Check the temperature of the glassware by placing your hand near, but not touching, the potentially hot glass.
- Have hot pads, thick gloves, or beaker tongs available for grasping hot glassware.
- Never heat a closed container.
- Any set-up should be designed to allow for fast removal of the heat source.

**Cryogenics Guidelines**

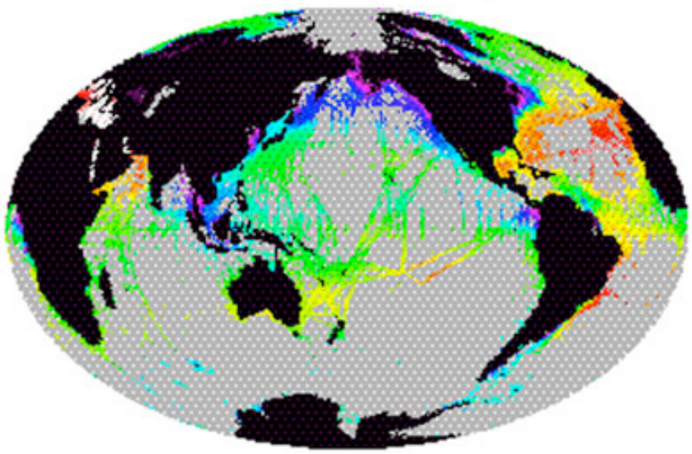
- Nonflammable cryogenics (e.g., liquid nitrogen and dry ice) can be educational but are dangerous and should be handled only by the teacher. Use chemical splash safety goggles at a minimum (complete face shield is better), thick gloves and long sleeves when working with either of these substances. It is important that students observing demonstrations wear eye protection and be seated at a safe distance from the demonstration.

## Sea Surface Salinity patterns based on computer models

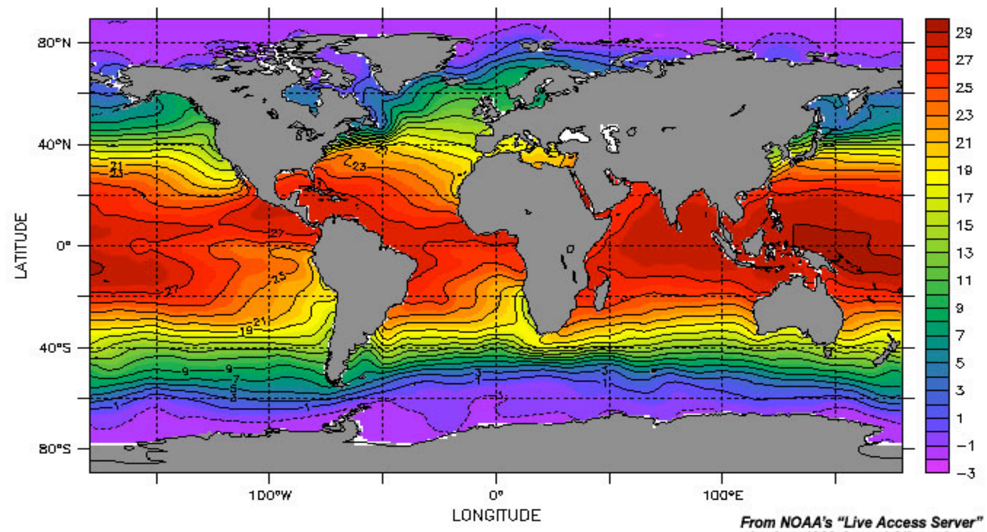
*(Red = high; Purple = low)*



## Sea Surface Salinity patterns based on data collected over the past 100 years



## Average Sea Surface Temperature (°C)




***From NOAA's "Live Access Server"***
***Levitus 1982 Annual Climatology***