Ocean Investigation

(HHMI/PWSSC Marine Science class, 9-12)

Objectives

After participating in Ocean Investigation, students will be better able to:

- discuss the general properties of sea water that affect life within and near it, particularly density, salinity, waves, currents and temperature.
- recognize the connectedness of water's properties, including how salinity and temperature affect density, temperature's influence on currents, etc.
- conduct a scientific investigation by utilizing their skills of observation, questioning, experimenting, reporting and synthesizing information.

Materials

* A classroom with a sink would be advantageous for this activity.

Ocean model kits (2/4)	thermometer	food coloring (3)
Salt/salt solution	stirring rods (2)	beaker
Rulers (3)	graduated cylinder (large)	Dixie cups
Orange juice	cranberry juice	soda water (blue)
Pitcher (drinking)	mixing bowl	corn meal
Large square trays (3)	ice pack	ice
Tea kettle	ruler	rubber duck
Mooring posters	various pitchers	Lab sheets
Place mats (6)	spatula	Lab Instruction sheets
Dump bucket	Lab sheet poster	dry erase markers
Tape	Example edible moorings	Vaseline
Hot gloves		

Edible mooring bags (candy galore, toothpicks, dental floss, one cookie, direction sheet)

Before the Class

This class involves several investigations for students to work through on their own in groups. (Depending on class size, groups should be no more than 5 students each – there can be four or six groups.) The first investigation will be done as a class. You will need to have the orange and cranberry juices, soda water, graduated cylinder, beaker, pitcher and Dixie cups handy for you to use. Organize the activities by station. The investigations require lots of water, ice, a couple of ice packs and hot water. The discussion of moorings and the assembly of the models will take place at the end of the class, have the posters, mooring examples and candy mooring bags accessible. The set up of each station will be discussed in the description of activities section.

Outline

I. Introduction – why study the ocean
   a. Welcome and preview of class
   b. Discuss with students what they know about the ocean (this can include components, sea life, tides, etc.)
   c. Discuss why it is important to study the ocean (industry, recreation, inclusion in local ecosystem)

II. Basic Ocean Factors via Lab Investigations
   a. Density Drink - will be done as a class; will be relevant to some other investigations. Work through a sheet together as a class.
   b. Currents (2)
   c. Salinity (1)
   d. Waves (2)
   e. Temperature (1)

III. Investigation Report
   a. Discuss the process and results of groups at each station. Encourage student sharing here, particularly as not all groups will be able to do each investigation.
   b. Discuss real life applications of each concept.

IV. Moorings and Review
   a. Introduce ways in which scientists study the ocean
   b. Moorings – go over parts, their jobs and assembly instructions
   c. Touch on reasons why it is important to know about the ocean, understand how different factors affect its behavior, etc

Modifications

Based on the size of the class, the number of groups can vary. There are enough activities to have six groups. If there are microscopes available at the school, we can investigate salinity with plant cells. If time is a factor, students can work through one or two investigations only. The edible moorings can be skipped or passed out for the kids to do with as they please.

Description of Activities can be found on the following pages.

Density Drink – DENSITY STRATIFICATION: CLASS COCKTAIL OF FRUIT PUNCH

Purpose: To demonstrate density layering of common fluids due to compositional differences that is analogous to layering of different salinity ocean water bodies.

Background:

Density is defined as mass per unit volume. In fluid systems, one fluid floats on top of another if it has a density which is less than the other. Density differences can be caused by differences in temperature, composition, or pressure.

In this experiment, the differences are based primarily on the composition of the fluid. Even though all layers are fluids, they do not mix rapidly, if handled gently, and will stay separate for a class period or more. Masses of subtly distinctive ocean water (having different temperatures or salinities) can persist for months and over hundreds of kilometers of distance. With these properties, scientists can identify and track water masses to learn about the speed and path of various water masses around the world.

Materials:

- 500- ml graduated cylinder
- 200-ml beaker
- Pint, cranberry juice
- Pint, orange juice (no pulp)
- Pint, soda water
- Blue food coloring
- Dixie cups for everyone
- Wide-mouth bottle or pitcher

Procedure:

1) Pour 150 ml of cranberry juice into the graduated cylinder. MAKE SURE ALL LIQUIDS ARE AT THE SAME TEMPERATURE.
2) Fill the beaker with 150 ml of orange juice. Tilt the graduated cylinder to 20 degrees from the horizontal; EXTREMELY SLOWLY pour the orange juice down the inner wall of the cylinder. GO SLOWLY AND THERE WILL BE A DISTINCT DENSITY SEPARATION, the OJ will stay on top of the cranberry juice.
3) Add blue food coloring to the soda water to dye it. Rinse the beaker, then repeat step 2 with 150-ml of blue soda water.
4) After a discussion of the observed fluid behavior (see below), decant the solution into the pitcher, distribute Dixie cups to all who are willing, and imbibe a fruit cocktail in class!

Discussion:

Though the solution looks atrocious, it's pretty tasty and this is that rare instance in which students are encouraged to drink the experiment!

The cranberry juice pigment and sugar content must be denser than that of the orange juice solids. The soda water is least dense not only because of sugar deficiency, but also due to its CO_2 gas content (the carbonation).

Jiggling the cylinder, one can notice an undulating wave between the fluid surfaces. This is an internal wave. The displacement here is greater than the jiggling of the upper liquid surface exposed to the air.

As an extension, take a plug and press down on top of the solution. Notice the ring of orange juice that is expelled up into the cranberry juice.

As you work through the density column, work through the poster Lab Sheet as to model what the groups should do in their own investigations.

Temperature and Density –

Purpose: To demonstrate the influence of temperature on the density of water.

Background:

The waters of the ocean are constantly moving. Deep currents are mainly caused by differences in the density of water. These currents can be quite large – up to several thousand kilometers long. The density is affected by temperature and salinity. Cold water is denser than warm water. When water cools, it contracts. This squeezes the water molecules more tightly, and as a result, increases the density of the water. Most deep currents flow in the opposite direction from surface currents. The coldest, most dense ocean water on earth is found off the coast of Antarctica. Because of its density, the cold Antarctic water sinks to the bottom of the ocean floor and flows north through the world's oceans. At the same time, warm surface currents near the equator flow south toward Antarctica.

These deep water currents travel very slowly in comparison to surface currents. In some cases, it may take up to 1000 years for one water molecule to travel from the polar regions to the equator. Despite their slow movement, these currents are essential to deep sea life, since they carry oxygen along with the temperature, salinity and density characteristics they acquired at the surface. As these deep ocean currents come close to land, the ocean floor rises, forcing the currents upward. This uprising of the cold current to the surface is called "upwelling." Upwelling is an important process for ocean life near the surface, since the rising currents carry along with them rich nutrients that have drifted to the ocean floor. Where upwelling occurs, there is an abundance of ocean life and rich fishing grounds.

Materials:

- Food coloring solutions (red and blue)
- Hot water (not hotter than 80C)
- Ice cubes
- Thermometer
- Ocean circulation model
- Hot gloves
- Stirring rods (2)

Procedure:

1) Fill the Ocean Circulation Model's vertical and cross tubes with tap water at room temperature. Make sure that the water level is equal in both tubes and that there aren't any leaks in the attached cross tubes.
2) Fill one of the cube-shaped containers with ice and the other with hot water (80C, though not hotter). Wear heat protective goggles.
3) Wait five minutes to allow the water in the vertical tubes to equilibrate with the temperature of the hot water and the ice placed in the cube-shaped containers.
4) Add 10 drops of blue food coloring to the vertical tube with ice and 10 drops of red food coloring to the vertical tube with the hot water. Quickly stir the food coloring in both tubes.
5) Observe what happens to the surface ocean currents (i.e. upper cross tube) and to the deep ocean currents (lower cross tube).

Discussion:

This demonstration's geometry relates equally well to an example close to home. The cold, dense summer water of the northern Gulf of Alaska builds up on to the shallower continental shelf and eventually flows north at depth through Hinchinbrook Entrance into the deeper Prince William Sound basin. Surface currents don't match what we think is happening at depth.

Salinity and Density –

Purpose: To demonstrate the influence of salinity on the density of water.

Background: Physical oceanographers examine the ways ocean water mixes. It's important because this jumbling helps seawater move around or circulate. This flow in the seas contributes to weather and climate, which in turn affect plants and animals in the sea, in the air above it, and on the nearby land. By churning up the sea at depth and sideways, nutrients can be brought to the sea plants, and then to the animals that graze on them, so that all the living things in this marine environment can continue to live. A fundamental way to move water is to change its density by how much salt it has in it. The more salt it has, the greater its density.

Materials:

- Saturated salt solution (blue)
- Ocean circulation model

Procedure:

1) Fill the Ocean Circulation Model's vertical tubes with tap water at room temperature ¾ full.
2) Fill the remaining portion of the tubes with the colored, saturated salt water by pouring it through the vertical tube on the left. (To make more saturated salt solution, dissolve 100g of salt in 300mL of tap water. Stir thoroughly to mix. Once the salt is in solution, add 10 drops of blue food coloring solution. Stir thoroughly for the dye to fully dissolve.)
3) Observe what happens to the salt water initially. Watch what happens after a period of five minutes.

Discussion:

Like temperature, salinity changes affect the way sea water moves. Changes in salinity can be a result of rain, runoff and melting of glacial ice. Extreme heat can increase salinity. In addition to sea movement, salinity also affects marine life.

Currents, Coriolis –

Purpose: To investigate the Coriolis effect

Background:

Just as rivers flow on land, similar huge streams of water called currents travel through the ocean. Like expressways, they loop around in some places, stretch straight ahead in others, and even cross over and under one another. Currents that flow near the surface act like a giant combination furnace/air conditioner. Driven by the wind, these uppermost currents form huge circles that shuttle sun-warmed water from the tropics to both poles and cooler water from the poles back toward the equator.

When hot air around the earth's equator rises, cold air from the poles rushes in to take its place, pushing the upper layer of ocean water with it. Then the earth, rotating on its axis, gets into the act, putting its own spin on things. With all this circling around, surface currents continually blend icy water and very warm water.

Materials:

Cornmeal shaker
Bowl

Procedure:

1) Fill a bowl almost to the top with water.
2) Sprinkle on a pinch of cornmeal.
3) Blow steadily and easily across the water surface and watch the way the cornmeal is carried by the currents.

Discussion:

The same thing that happened in the bowl happens when wind blows across the surface of our spinning planet: Ocean waters are swept around by circling currents, steered clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. This is called the Coriolis effects.

Take this counterclockwise rotation in the Northern Hemisphere which apparently deflects moving objects to the right, which is called the Coriolis Effect, and apply it to storm winds. Consider a big low pressure system. The air moves into this low pressure center because fluids (including air) flow from high to low pressure areas. Looking in the direction this air gets "sucked," the Coriolis Effect deflects it to the right. This rightward movement makes a cell whose winds blow around in a CCW orientation. Hence, we get an Aleutian low tracking from west to east whose winds end to "back" or deflect in a CCW manner. This Coriolis Effect is important since it explains why these winds behave the way they do. ("Backing" winds shift CCW; "veering" winds shift clockwise.)

Similarly, storm winds blow the surface waters of the sea. How will the Coriolis Effect affect the seas pushed by an east wind (blowing from east o west) along the north coast of the Prince William Sound? It will cause the seas to track to the right of the winds pushing it along. This deflection will steer the seas from westward movement to a northward direction. This rightward deflection of water is called Ekman transport. If the seas are headed north, they'll pile up on the north shore of Prince William Sound! In a big storm with high winds, it will cause a great surge of waters to pile up along the coastline. The Coriolis Effect is necessary to understand why the seas do what they do in these circumstances. [*This pileup or convergence of waters is occurring in a column of fluids. If they're not held in a container, and he seas aren't, they're free to flow outwards from beneath the pileup. This they do; it's called a downwelling. But that's another topic.*]

Currents, temperature –

Purpose: To investigate the difference between surface and deep water currents.

Background: Deep currents are caused when extra-cold, saltier water – particularly water near Freezing ice – sinks to the ocean floor and pushes warmer, less salty water out of the Way. Compared with surface currents, the deep currents are like very slow traffic lanes - it takes about 275 years for deep current cold water from the poles to cross the Atlantic and 500 years for deep currents to cross the Pacific.

Materials:

Food coloring
Container
Ice pack

Procedure:

1. Fill the container with about 3 cm of room temperature tap water.
2. Set the ice pack in the water against one end of the pan.
3. Squeeze a drop of food coloring in the water just in front of the ice and another single drop at the opposite end corner.
4. Watch carefully and compare what happens to the two drops.

Discussion:

Before long, the color from the drop nearest the ice will begin to move steadily forward, forming a long streak. That's because cold water from the melting ice pack pushes the warmer water, including the food coloring, toward the opposite end of the pan. The drop of coloring that is already at the far end has no place to go because the advancing cold water prevents it from spreading.

Waves, ocean depth – SHALLOW WAVES: Race

Purpose: To show the effect of water depth upon the speed of shallow-water surface waves.

Background: As ocean surface waves approach land they change from deep-water to shallow-water waves. Shallow-water waves are affected by the sea bottom causing changes in the wave's length, height and speed (but not its frequency). This exercise concentrates on changing the water depth to see its effect upon wave speed.

Materials:

- 2 small clear plastic pans
- metric ruler
- food coloring
- Optional: stopwatch

Procedure:

1. Place one tub level on the table. Fill the tub with water to 1 cm depth as measured with the metric ruler. Add several drops of food coloring (just to distinguish it from the second tub's water).
2. Lift one end about 2 cm above the table and watch the wave motion.
3. Place the second tub alongside and parallel to the first, both level.
4. Fill this tub to 2 cm depth.
5. Slide the pair of tubs so that they overhang the table. Use the ruler to lift up the overhanging edges about 2 cm above the table.
6. After the water surfaces have become still again, gently drop the tubs to the platform and observe their wave motions.
7. Add 1 cm of water to the second, clear tub.
8. Repeat steps 5 and 6.
9. Optional: Measure the wave speed by counting the number of tub lengths the wave travels and recording the time it takes to do so. Multiply the number of lengths by the tub's length in cm., which gives you the distance traveled, then divide this result by the time in seconds to travel that distance and you'll get the wave speed in cm/sec.

Discussion: The wave crest, or highest part of the wave, moves back and forth and is darker than the rest. The waves bounce off or reflect from the tub ends about 5 or 6 times before the energy is dissipated and the waves are no longer recognizable. Equal water depths should produce equal wave speeds in this setup. The wave speed should be reduced in the shallower water due to more bottom interference.

Waves, energy transfer –

Purpose: To investigate the transfer of a wave's energy to an object in the water.

Background: When you see a wave out at sea, it may seem like the water is being carried along to another part of the ocean, but it is not. The water just moves up and down in place as the wave, which is actually energy, passes through. The surface of the water changes shape but it stays in the same place.

Materials:

Pan
Rubber duck

Procedure:

1. Practice making waves in the pan by raising one end several centimeters off of the desk.
2. Determine the motion of the wave.
3. Add the rubber duck to the pan and repeat making waves.
4. Observe the duck's position in the water to determine in what way energy is moving in the pan.
5. Try to move the duck from one spot in the pan to another.

Build a Mooring

Provide students with bags and start them on the creative path by explaining the process. Use the poster and picture to describe what particular instruments measure. Have examples handy to share possible moorings. After students build their mooring models, they should share with the group (explain what their mooring will measure, how, and why) before eating the moorings!

BACKGROUND: The mooring parts are lowered off the stern of the ship starting with the top. After all the components are floating in the water (and all connected on the mooring line), the anchor weight is lowered into the water and then released, allowing the mooring to vertically extend.

Syntactic Foam Buoy is a 4 ft diameter non-compressible, high-density plastic float with a hard outer body attached to the mooring cable to keep it upright in the ocean.

The mooring cable may be 5/8 in diameter VLS or “very low stretch “braided nylon or airplane cable, chains, or 3/8 in diameter Kevlar cable. Usually the links are zinc so that they undergo preferential corrosion. Most other components are plastic so that they won’t corrode.

The Seacat CTD (conductivity/temperature/depth) probe is a multi-purpose instrument one of whose functions is to measure how easily electrical current flows in the seawater. This aspect is directly dependent upon the quantity of dissolved salts in the water: the saltier it is, the easier it passes electricity. Indirectly, it measures how much of a specific salt type there is in the water, namely dissolved sodium chloride, NaCl. It does this by emitting a known electric current through a fixed surface area “donut” for a set length of time and measuring how much current is passed through. The temperature is measured in a water flow-through channel in which electrical resistances between two metals are converted into temperature measurements by a temperature thermistor since resistance (the inverse of conductivity) varies with temperature. Finally, the depth is measured with a pressure cell. The more pressure, the greater the depth; it is calibrated for seawater. These CTDs are placed at different depths to measure and record how these different factors vary with depth of water.

The nitrate sensor measures concentrations of nitrogen and oxygen bonded together (NO_3) in the water. It does so by collecting a little of the seawater in a box. The seawater is then mixed with another chemical and a colorimeter measures the color change. The color change tells how much nitrate there is. Nitrate concentrations are generally low in the offshore regions of Gulf of Alaska and are higher in coastal waters. Nitrate is a requirement for plant (phytoplankton) growth.

The vinyl floats are smaller diameter buoys helping to stabilize and keep the mooring cable upright.

The Microcat CTD is another type of conductivity-temperature-depth sensor. It has a vane or arm attached to it so that it keeps the instrument oriented in the direction that the water is flowing

The sediment trap is a device that captures particles of debris falling down through the seawater. It opens from time to time to catch them. They may be inorganic particles of minerals from river runoff or stirred up from the seafloor, or they may be organic debris, all the parts and bodies of plants and animals.

The acoustic release is a mechanical coupling device that holds the mooring cable to the anchor, but then releases it when it receives a special sound signal from the research vessel. When released from the anchor, the mooring floats to the surface. Once sighted, the mooring is slowly approached by the research vessel and then the top mooring part is snagged with a gaff hook. Its line is attached to the winch hook and dragged in, beginning the retrieval process for all of the mooring.

The train wheel anchors are just that- heavy, strong, available pieces of metal suitable for anchoring the entire system.

The above sensors were on a bio-physical mooring. Other moorings measure just physical characteristics, such as temperature, conductivity, depth and currents. These are physical moorings.

The RDI or Research Design Instruments ADCP is an acoustic Doppler current profiler. It is a device that measures the speed and direction of currents at many different depths above it. It does so by sending out a vibrational (sound or acoustic) wave that is reflected off of particles that are about the size of your pinky finger and smaller in the water. The wave shifts its frequency according to whether it is going with the direction of flow of the water or against it. This shift is the Doppler Effect and it explains the phenomenon of a siren gaining a higher pitch or tone as the fire engine speeds towards you, or lowering tone as it speeds away from you.

Some other sensors not shown are:

PAR- standing for **Photosynthetically-Active Radiation**, measuring how much sunlight is available for plants to grow at depth.

A fluorometer estimates how much chlorophyll there is in the water. Remember chlorophyll is the green pigment which captures the sun's energy and converts it into plant energy through photosynthesis. When chorophyll is hit with certain light, it absorbs it and gives back light of a different type. This new type of light is fluorescence. Thus, the amount of fluorescence is also a measure of how much chlorophyll there is in the water.

A transmissometer measures how much light from a beam passes through a given volume of water. Light can be lost by absorption or scattering by the particles in the water. The transmissometer is corrected for absorption and measures scattering primarily. In effect it is like an electronic Secchi disk.

A ULS for "upward-looking sonar," is another type of underwater radar that can measure ice thickness.