FRESHWATER & SEAWATER DENSITY

OCEAN NETWORKS CANADA

Duration
2 class periods (1 for activity and questions, 1 for observatory extension)

Theme
Exploring how changes in salinity and temperature affect the density of water.

Objectives
Students will:

- Alter the salt content and temperature of water to explore how layers of water of different densities form in the water column.
- Use the Ocean Networks Canada Data Plotting Utility to investigate the relationships between temperature and salinity at different locations using data collected from CTDs mounted on two community observatories.

Vocabulary
- **Density**: The mass per unit volume of a substance.

Curriculum connections (Activity + Extensions)

	Grade 7	Grade 8	Grade 9	Grade 10
Big Ideas	The Earth and its climate have changed over geological time.	The kinetic molecular theory and the theory of the atom explain the behavior of matter.	The biosphere, geosphere, hydrosphere, and atmosphere are interconnected, as matter cycles and energy flows through them.	Energy is conserved and its transformation can affect living things and the environment.
Supported Inquiry	How do people and their practices impact Earth and its climate?	How does the kinetic molecular theory work? What are its applications?	How do Earth's major spheres interact?	*Not yet available in draft curriculum.*
Content	Chemical changes. Evidence of climate change over geological time and the recent impacts of humans.	Kinetic molecular theory.	Effects of solar radiation on the cycling of mater and energy.	Chemical processes and their uses, including practical applications and implications including Aboriginal perspectives. The law of conservation of energy, thermal energy transformations.
Curricular Competencies	**Questioning and predicting** • Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest. • Make observations aimed at identifying their own questions	**Questioning and predicting** • Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest. • Make observations aimed at identifying their own questions	**Questioning and predicting** • Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest. • Make observations aimed at identifying their own questions, including increasingly	**Questioning and predicting** • Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest. • Make observations aimed at identifying their own questions, including increasingly

	about the natural world. • Identify a question to answer or a problem to solve through scientific inquiry. • Formulate alternative "If…then…" hypotheses based on their questions. • Make predictions about the findings of their inquiry. **Planning and conducting** • Measure and control variables through fair tests. • Observe, measure, and record data (qualitative and quantitative) using equipment, including digital technologies, with accuracy appropriate to the task. **Processing and analyzing data and information** • Construct and use a range of methods to represent patterns or relationships in data, including tables, graphs, keys, scale models, and digital technologies as appropriate. • Use scientific understandings to identify relationships and draw conclusions. **Evaluating** • Reflect on their investigation methods, including the adequacy of controls on variables and the quality of the data collected. • Identify possible sources of error and suggest improvements to their investigation methods. • Demonstrate an awareness of assumptions, question information given, and identify bias in their own	about the natural world. • Formulate alternative "If…then…" hypotheses based on their questions • Make predictions about the findings of their inquiry. **Planning and conducting** • Measure and control variables through fair tests. • Observe, measure, and record data (qualitative and quantitative) using equipment, including digital technologies, with accuracy appropriate to the task. **Processing and analyzing data and information** • Construct and use a range of methods to represent patterns or relationships in data, including tables, graphs, keys, scale models, and digital technologies as appropriate. • Use scientific understandings to identify relationships and draw conclusions. **Evaluating** • Reflect on their investigation methods, including the adequacy of controls on variables and the quality of the data collected. • Identify possible sources of error and suggest improvements to their investigation methods. • Demonstrate an awareness of assumptions, question information given, and identify bias in their own work and secondary sources. • Demonstrate an understanding and appreciation of	abstract ones, about the natural world. • Formulate multiple hypotheses and predict multiple outcomes. **Planning and conducting** • Collaboratively and personally plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative). **Processing and analyzing data and information** • Seek and analyze patterns, trends, and connections in data, including describing relationships between variables and identifying inconsistencies. • Use knowledge of scientific concepts to draw conclusions that are consistent with evidence. • Analyze cause-and-effect relationships. **Evaluating** • Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions. • Describe specific ways to improve their investigation methods and the quality of the data. • Evaluate the validity of and limitations of a model or analogy in relation to the phenomenon modeled. • Demonstrate an awareness of assumptions, question information given, and identify	abstract ones, about the natural world. • Formulate multiple hypotheses and predict multiple outcomes. **Planning and conducting** • Collaboratively and personally plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative). **Processing and analyzing data and information** • Seek and analyze patterns, trends, and connections in data, including describing relationships between variables and identifying inconsistencies. • Use knowledge of scientific concepts to draw conclusions that are consistent with evidence. • Analyze cause-and-effect relationships. **Evaluating** • Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions. • Describe specific ways to improve their investigation methods and the quality of the data. • Evaluate the validity of and limitations of a model or analogy in relation to the phenomenon modeled. • Demonstrate an awareness of assumptions, question information given, and identify

	work and secondary sources. • Demonstrate an understanding and appreciation of evidence (qualitative and quantitative). • Exercise a healthy, informed skepticism and use scientific knowledge and findings for their own investigations to evaluate claims in secondary sources. • Consider social, ethical, and environmental implications of the findings from their own and others' investigations. **Applying and innovating** • Transfer and apply learning to new situations. • Generate and introduce new or refined ideas when problem solving. **Communicating** • Communicate ideas, findings, and solutions to problems, using scientific language, representations, and digital technologies as appropriate.	evidence (qualitative and quantitative). • Exercise a healthy, informed skepticism and use scientific knowledge and findings for their own investigations to evaluate claims in secondary sources. **Applying and innovating** • Transfer learning to new situations. • Generate and introduce new or refined ideas when problem solving. **Communicating** • Communicate ideas, findings, and solutions to problems, using scientific language, representations, and digital technologies as appropriate.	bias in their own work and secondary sources. • Consider social, ethical, and environmental implications of the findings from their own and others' investigations. **Applying and innovating** • Generate and introduce new or refined ideas when problem solving. • Transfer and apply learning to new situations. **Communicating** • Formulate physical or mental theoretical models to describe a phenomenon. • Communicate scientific ideas, information, and perhaps a suggested course of action for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations.	bias in their own work and secondary sources. • Consider social, ethical, and environmental implications of the findings from their own and others' investigations. **Applying and innovating** • Contribute to care for self, others, community, and the world through individual or collaborative approaches. • Co-operatively design projects with local and/or global connections and applications. • Transfer and apply learning to new situations. **Communicating** • Formulate physical or mental theoretical models to describe a phenomenon • Communicate scientific ideas, information, and perhaps a suggested course of action for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations.

Background

Density is a measure of mass per unit of volume (D=m/V). Seawater is denser than freshwater because seawater has a higher concentration of dissolved salts, i.e. a higher salinity. As these dissolved salts have mass, a given volume of seawater is more dense than the same volume of freshwater. Adding dissolved salts also causes the water to contract slightly, further increasing the density.

As temperature increases, volume increases due to thermal expansion. Therefore, for a given mass of particles (Grade 9, 10: atoms, molecules), an increase in volume results in a decrease in density (D=m/V).

These activities explore how changes in both salinity and temperature affect the density of water.

Materials

- 2 x ice cube trays
- 2 x small aquaria (~3 litres volume) or other transparent containers
- 2 x vials of food colouring (each different dark colours, e.g. red, green)
- Cold seawater* (1 litre + enough to fill 1 ice cube tray)
- Cold freshwater (2 litres + enough to fill 1 ice cube tray)
- 1 x kettle of hot freshwater + enough kettles to share between student groups of 4–5
- 1 x alcohol thermometer
- 1 x box of salt
- 1 x electronic scale
- 1 x scoop
- 1 small sponge
- Enough (plastic) graduated cylinders (at least 500 ml), or Mason jars, for 1 per student group of 4–5
- Enough plastic funnels for 1 per student group of 4–5

**If you can't easily access the ocean to collect seawater, you can approximate your own by dissolving 30 g of salt per litre of water.*

Preparation (day before class activity)

1. Freeze an ice cube tray of seawater with food colouring added.
2. Freeze an ice cube tray of fresh water with a different colour added.
3. Wait until just before the activity before taking out the ice cubes so that they stay frozen.

Preamble to activities

Discuss water density in terms of temperature and salinity with the students.

Activity 1

1. Ensure the following demonstration is visible to all students.
2. Start with 2 aquaria, each filled with 1 L of cold *freshwater*.
3. Announce to the students that you will place a coloured *seawater* ice cube into 1 of the aquaria. Have students make predictions about what they think will happen.
4. Place a coloured *seawater* ice cube into the first aquarium. Record what happens using words and photos/video. Have the students draw a picture to compare their prediction to what was observed. [*As the ice cube melts, the coloured water should remain on the bottom of the aquarium, underneath the less dense freshwater*.]
5. Announce to the students that you will place a coloured *freshwater* ice cube into the second aquarium. Have students make predictions about what will happen when the next ice cube is added.
6. Place a coloured *freshwater* ice cube into the second aquarium. Record what happens using words and photos/video. Have the students draw a picture to

compare their prediction to what was observed. [*As the ice cube melts, the coloured water should slowly diffuse throughout the freshwater of the aquarium as they have the same density*.]

Activity 2

1. Ensure the following demonstration is visible to all students.
2. Start with 1 aquarium containing of 1 L of cold, clear *seawater*.
3. Add 10 g of salt to the seawater and stir to dissolve. If we assume the seawater has a salinity of 30 ppt (parts per thousand), adding 10 g of salt to 1 L (1000 ml) of water will increase the salinity by 10 ppt. The final salinity will be 40 ppt.
4. Add a few drops of food colouring and stir to mix.
5. From the kettle, gently and slowly pour hot *freshwater* onto the sponge floating in the coloured seawater. A freshwater layer should sit on top of the seawater.
6. Challenge groups of students to try to create three layers of different coloured water in each of their graduated cylinders (or Mason jars) by changing the temperature and salinity of water and by designing different techniques to prevent the water layers from mixing too quickly. For example: cold, green seawater on the bottom; cold, clear freshwater in the next layer; hot red freshwater on the surface.

Questions:

- Explain where the different coloured water from the ice cubes ended up and why.
    - *Seawater is denser than freshwater and therefore sinks. Freshwater is less dense than seawater and therefore floats on the surface. Hot freshwater is less dense still.*
- How does salinity affect density? Why?
    - *Water with a higher salinity has a higher concentration of dissolved salts. As these dissolved salts have mass, a given volume of seawater is more dense than the same volume of freshwater (D=m/V).*
- How does temperature affect density? Why?
    - *As temperature increases, volume increases due to thermal expansion. Therefore, for a given mass of particles (Grade 9, 10: atoms, molecules), an increase in volume results in a decrease in density (D=m/V).*
- Why will the layers of coloured water become less distinct over time?
    - *Over time, dissolved salts will diffuse from the seawater into the freshwater causing the layer to break down. Also, the cold seawater and hot freshwater will slowly reach room temperature, again causing the layer to break down.*

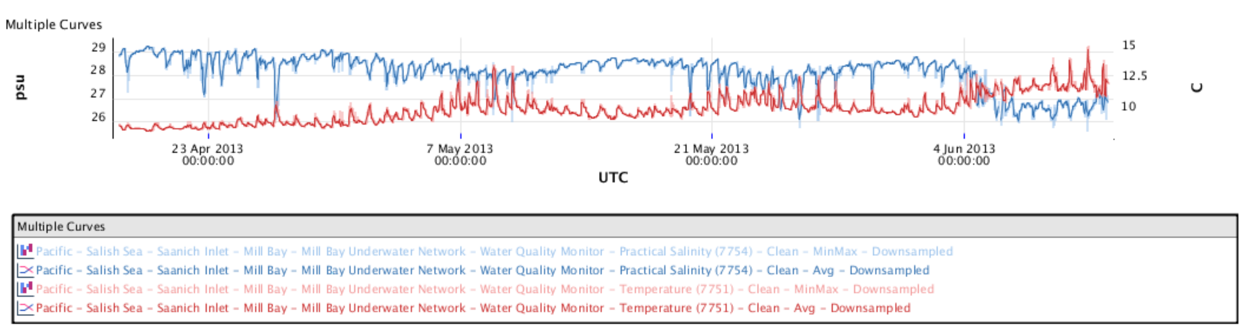
Classroom Safety

- Remind students to be careful when using glassware, aquaria, and hot water.
- Make sure there is a broken glass container nearby.
- Avoid crowding around aquaria.
- Have towels, a 'wet floor' sign, and a mop at the ready!

Activity 3

<u>Part 1</u>

1. Open the Ocean Networks Canada [Data Plotting Utility](http://dmas.uvic.ca/PlottingUtility) by entering the following into your browser address bar: **http://dmas.uvic.ca/PlottingUtility**
2. Towards the top of the screen, underneath the gray menu options, find the section titled, **Time Period Selection**. In the **Date From (UTC)** box, enter *18-Apr-2013*; in the **Date To (UTC)** box, enter *12-Jun-2013*.
3. Click the **Plot** button under **Refresh Plot(s)**. You'll now see this date range listed in the **Time Range History** box on the right.
4. Next, select the Mill Bay Community Observatory in the left-had sidebar by clicking the "+" next to each of following in sequence: **Pacific** > **Salish Sea** > **Saanich Inlet**.
5. Next, click the "+" next to **Mill Bay** to expand the menu, click the "+" next to **Mill Bay Underwater Network**, then the "+" next to **Water Quality Monitor**.
6. From the list of water quality parameters measured by the various sensors onboard the observatory, click on **Practical Salinity** and then **Temperature**. Two graphs should now display on screen for the date range you selected in Step 2.
7. Overlay the plots by ***right***-clicking on one of the plotted parameters in the sidebar (e.g. Temperature) and selecting **Add to Plot 1 Right Y Axis**, where Plot 1 is Practical Salinity and Plot 2 is Temperature. You should now see a graph that looks like the one below (Practical Salinity in blue, Temperature in red):

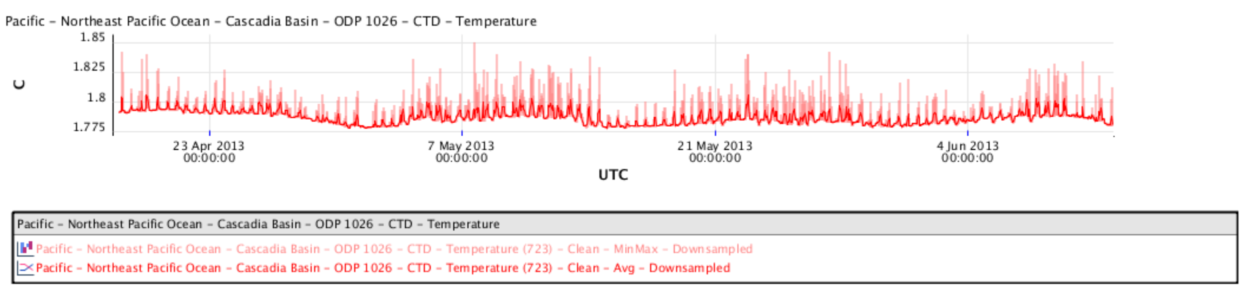


Questions:

- How do ocean temperature and salinity vary during the time period you have selected? Is there a general increase or decrease in values? Is the data highly variable or fairly consistent? (Hint: if you wish to investigate individual data values, hover your mouse pointer over the plotted data to reveal more information).

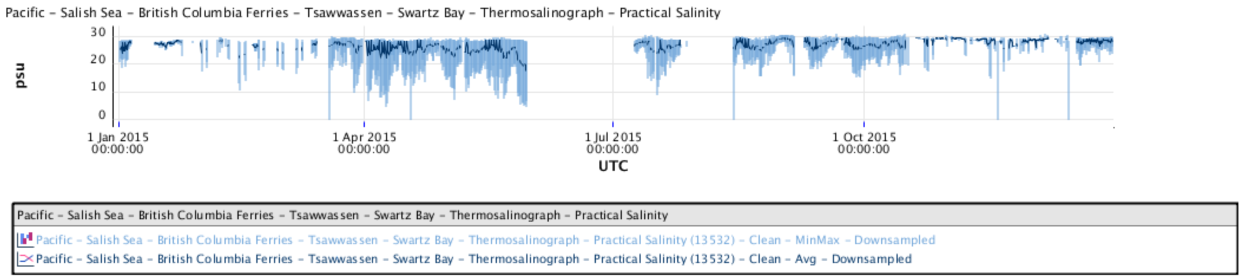
  - *Ocean temperature gradually rises while salinity gradually drops. These changes are more rapid after June 4.*
  - *Ocean temperature is more variable over the period most likely due to day/night differences in solar radiation. (Students can confirm this by plotting temperature and solar radiation on the same graph.)*

- Why does the ocean temperature change from April to June? What is causing this? The observatory is located at 6 m depth—would you expect to see the same temperature changes in the deep ocean? Why?
  - *Ocean temperature gradually rises due to increased solar radiation from spring into summer.*
  - *The shallow surface waters of the ocean are greatly influenced by the weather and seasons, being heated by the sun and cooled by wind and rain. Deep ocean waters are more insulated from these changes, therefore their temperatures are generally quite stable. See this plot (reproduced below) from Cascadia Basin as an example. The temperature of this deep (2660 m) site off the west coast of Vancouver Island varies by less than 0.1 of a degree for the same time period (18 April – 12 June, 2013).*



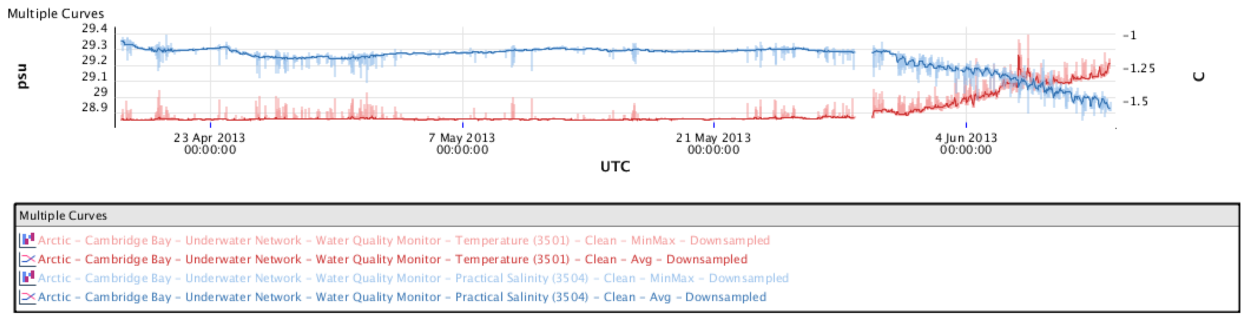
- During the summer months you would expect to see an increase in salinity in shallow marine waters due to increased evaporation and decreased precipitation (and upwelling, depending on location). Is this what the sensor has recorded for June at Mill Bay? What do you think could be responsible for the change in salinity at this time? (Hint: Consider major freshwater inputs. Where might these be coming from and why?)
  - *From June 4, the salinity of the seawater noticeably decreases.*
  - *Major freshwater systems—such as the Fraser River watershed—experience floods and high flows at this time of year, introducing high volumes of less dense freshwater into coastal waters, diluting them and lowering their salinity. See the effects of this freshwater input on the salinity of coastal waters by viewing this plot (reproduced below) of data collected over a 1-year period by ONC sensors on the BC Ferry between Tsawwassen (BC mainland) and Swartz Bay (east coast of Vancouver Island). The path travelled every day by this ferry passes through the*

plume of water entering the Salish Sea from the Fraser River. Freshwater flows are higher in mid-spring into early summer due to the seasonal melt of snow packs at higher elevations in the watershed. Gaps in the data are due to the sensors being out of the water for maintenance purposes.



Part 2

8. Now we will choose a community observatory in a different location to compare with Mill Bay. To do this, open a new tab in your browser—don't close the existing Mill Bay tab—and enter **http://dmas.uvic.ca/PlottingUtility** in the address bar.
9. Towards the top of the screen, underneath the gray menu options, find the section titled, **Time Period Selection**. In the **Date From (UTC)** box, enter *18-Apr-2013*; in the **Date To (UTC)** box, enter *12-Jun-2013* —the same time period you used when looking at the Mill Bay data.
10. Click the **Plot** button under **Refresh Plot(s)**. You'll now see this date range listed in the **Time Range History** box on the right.
11. Next, select the Cambridge Bay Community Observatory in the left-had sidebar by clicking the "+" next to each of following in sequence: **Arctic** > **Cambridge Bay**.
12. Next, click the "+" next to **Cambridge Bay** to expand the menu, click the "+" next to **Underwater Network**, then the "+" next to **Water Quality Monitor**.
13. Just as you did for Mill Bay, on the sidebar on the left, click on **Practical Salinity** and then **Temperature**. Two graphs should now display on screen for the date range you selected in Step 9.
14. Overlay the plots by ***right***-clicking on one of the plotted parameters in the sidebar (e.g. Temperature) and selecting **Add to Plot 1 Right Y Axis**, where Plot 1 is Practical Salinity and Plot 2 is Temperature. You should now see a graph that looks like the one below (Practical Salinity in blue, Temperature in red):



Questions:

- How do the data for Cambridge Bay compare to those for Mill Bay? Are the trends in salinity and temperature similar or different for the same time period? Are the actual values similar? (Compare the range values on the y-axes.)
    - *The overall trends are similar between the two locations, with a rapid rise in temperature and fall in salinity beginning in late May/early June.*
    - *The actual values are different: a change from 28.9–26.3 psu for Mill Bay vs. 29.4–28.9 psu for Cambridge Bay; and a change from 8.9–13.5 °C for Mill Bay vs. -1.6–-1.2 °C for Cambridge Bay.*
- Is the decrease in salinity in June related to the increase in temperature during this month? Why? What process is responsible for the measured drop in salinity?
    - *Yes, the decrease in salinity in June is likely related to the increase in temperature during this month.*
    - *Although the changes in both salinity and temperature are small, late May/early June sees the beginning of seasonal summer warming which breaks up and melts the ice cover, lowering the salinity of the surrounding water.*
    - *To see the trend continue throughout the summer, and the effects of freezing in the winter, the students can modify the date in the* ***Date To (UTC)*** *box to* 31-Dec-2013 *and refresh the plot*.

Extensions

Grade 8

- Is seawater just freshwater with salt in it?
- Why does saltwater freeze at a lower temperature than freshwater?
- Does the density of water affect the buoyancy of an object? How might you test this?
- How might changes in water temperature and density affect the movement of water in the oceans?
- Where in your community is fresh and salt water mixing? Or, if you are from an inland community, choose a coastal environment that is known for fresh and salt water mixing and describe the two bodies of water (names of rivers, bays, estuaries) and how and where they meet.

Grade 9

- Draw a molecule of water and a molecule of sodium chloride showing the correct number of atoms arranged with the correct number of bonds for each molecule.
- Draw a Bohr diagram for each of the following atoms: hydrogen, oxygen, sodium, chlorine.
- Is salt dissolving in water a physical or chemical change? (See this website for an animation of salt dissolving in water.)
- Where in your community is fresh and salt water mixing? Investigate this ecosystem further: e.g., what are the seasonal changes that occur in this area and how do they influence density?

Grade 10

- Consider the molecules H_2O and NaCl: Would you classify the molecules as ionic or covalent? Why?
- Draw Lewis diagrams for H_2O and NaCl.
- Is NaCl classified as an acid, a base, or a salt? Why? (Consider chemical formula and properties.) What other salts are present in seawater?
- Create a list of organic and inorganic compounds commonly found in seawater. How do these compounds end up in the oceans?
- Where in your community is fresh and salt water mixing? What type of environment is this? Investigate this ecosystem further: e.g., how does the mixing of fresh and salt water contribute to the productivity of an ecosystem? How and why do you think this area is used by Indigenous Peoples? Interview a local elder or community knowledge holder to learn about this specific area and its importance in harvesting different marine species.

Additional Activities

- Ocean News article (see sidebar on webpage for additional information) and lesson plan on climate change and its impact on the world's oceans.

Resources

- Exploring the link between seawater density and ocean currents: the thermohaline circulation. http://scied.ucar.edu/ocean-move-thermohaline-circulation [Retrieved April 20, 2016]
- Understanding the possible effects of climate change on ocean currents: might the thermohaline circulation "turn off"? http://www.ucsusa.org/global_warming/science_and_impacts/impacts/abrupt-climate-change.html#bf-toc-7 [Retrieved April 20, 2016]