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This series of lessons was developed by the Maine Mathematics & Science Alliance and a group of Maine, Massachusetts, and New Hampshire middle school science teachers with funding from NOAA Environmental Literacy Grant NA07SEC4690002. For more information about the *Earth as a System is Essential: Seasons and the Seas* (EaSiE) project, visit www.mmsa.org/easie



The guiding questions for this lesson are adapted from the EaSiE Project Summer Institute's presentation by Amy Cline, University of New Hampshire, 2008.



Seasons in the Gulf of Maine

Thermoclines

Overview

The overarching goal of *Earth as a System is Essential: Seasons and the Seas* (EaSiE) is to transform the traditional middle school study of terrestrial seasons and weather into an exploration of the dynamic interactions between Earth's land, water, atmosphere, and the living world. A previous Seasons in the Gulf of Maine lesson applied the understandings of weather and climate to investigate seasonality in the Gulf of Maine (lesson available at mmsa.org/easie). Monthly sea surface temperature (SST) climatologies were examined for patterns and trends over the course of a year. Monthly chlorophyll climatologies were then analyzed, and relationships between the SST and chlorophyll patterns were explored.

This lesson extends patterns related to seasonal changes observed in the sea surface temperature satellite images to explore a third dimension: seasonal changes with depth in the Gulf of Maine region.

This lesson supports the big idea: Just as on land, there are seasonal changes in the Gulf of Maine.



NOTE: *This lesson series is intended to serve as a relevant context for the teaching and learning of seasons-related ideas in middle school. It is not designed to replace a comprehensive curriculum, but rather enrich and integrate authentic Earth systems science content into instructional units using NOAA resources. It is suggested that teachers use the materials to supplement existing lessons aligned with the learning goal:*

Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in intensity of sunlight and the resulting warming of the earth's surface produces the seasonal variations in temperature (*Benchmarks for Science Literacy*).

This systems perspective provides a foundation for developing an understanding of the *Ocean Literacy Essential Principles and Fundamental Concepts (2006)*:

- The Earth has one big ocean with many features.
- The ocean is a major influence on weather and climate.

This lesson also sets the stage for developing an understanding of the *Essential Principles of Climate Science (2009)*: <http://www.noaa.gov/climate.html>

Background Information:

What causes variations in climate and seasons on planet Earth?

The motion of the earth and its position with regard to the sun have noticeable effects. The earth's one-year revolution around the sun, because of the tilt of the earth's axis, changes how directly sunlight falls on one part or another of the earth. It is this difference in heating different parts of the earth's surface – not proximity to the sun - that produces variations in climate and seasons.

Because the earth turns daily on an axis that is tilted 23.5 degrees relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in intensity of sunlight and the resulting warming of the earth's surface land and water produces the seasonal variations in temperature. This combination also changes the length of each day throughout the year.

From: Science for All Americans <http://www.project2061.org/publications/sfaa/online>
Benchmarks for Science Literacy <http://www.project2061.org/publications/bsl/online/>

Thermocline

A thermocline is the transition layer between the mixed upper water layer and deep water layer. The definitions of these layers are based on temperature.

The mixed layer is near the surface where the temperature is roughly that of surface water. In the thermocline, the temperature decreases rapidly from the mixed layer temperature to the much colder deep water temperature.

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The mixed upper layer and the deep water layer are relatively uniform in temperature, while the thermocline represents the transition zone between the two.

Thermoclines have seasonal variation. The images in Appendix A represent typical thermoclines found in the Gulf of Maine:

Winter

With the sun's rays weakened, the cold winds and ocean circulation mix ocean layers, bringing rich nutrient stores to the surface water. Though nutrients are available, the low light and strong mixing deter phytoplankton growth.

Spring

The spring image shows a thin layer at the top of the ocean that is warmer than the rest of the water column below. Comparing this spring thermocline with other seasons illustrates how much the water column changes throughout the year.

Summer

The summer image shows the top layers of the ocean continuing to warm down to about 20 meters. The change in colors and the bend in the line indicates a drastic

change in temperature from approximately 15 degrees Celsius, (49 degrees Fahrenheit) at the surface to 5 degrees Celsius, (41 degrees Fahrenheit) at the bottom.

Fall

The fall image shows that there is still a defined separation between the top, warmer layers of the gulf and those below the surface. Comparing the fall to the summer thermocline illustrates that the surface waters have a much thinner warm layer although more mixing has taken place and caused the warm summer surface waters to be mixed with the cold deep waters. This creates a more gradual change in temperature.

For more information about seasonal water temperature profiles in the Gulf of Maine, visit: http://www.gomoos.org/datatypes/WATER_TEMPERATURE.html

Essential Question:

Do bodies of water have seasons?

Knowledge and skills:

1. Interpret thermocline images.
2. Analyze data provided by thermocline representations.
3. Apply thermocline data to understand the idea of seasonality in the Gulf of Maine.



Preparation:

Prepare copies of seasonal thermocline images; 1 set for each team of four students.

Time Required:

1 class period.




Teaching the Lesson

ELICIT:

1. Remind students of the prior lesson where they examined sea surface temperature (SST) monthly climatology maps of the Gulf of Maine.
2. Revisit the list of trends and patterns they observed:
 - What were the 'hottest months' in the Gulf of Maine – as indicated by sea surface temperature?
 - Why might it be that some of the 'hottest weather months' (air temperature) were not the 'hottest SST months' (June), and some of the 'cooler months' were not the 'cooler SST months' (Sept)?

EXPLORATION OF SEASONS IN THE GULF OF MAINE:

3. Today we will be continuing to explore the question, "Are there seasons in the Gulf of Maine?" We'll shift from a two-dimensional question – looking at the water surface temperature – to a three-dimensional investigation – looking at water temperature with depth. 
4. Establish teams of four. Each team should have a 'winter', 'spring', 'summer', and 'fall' member. Students will now conduct a "Thermocline jigsaw".
5. Have all the 'winter' students gather in a group. The 'spring', 'summer', and 'fall' students also group with their same-season classmates.
6. Distribute copies of the corresponding seasonal thermocline graph to the 'winter'- 'spring'- 'summer'- 'fall' groups (Appendix A).
 - Explain how the data is collected using temperature sensors on buoys, averaged to represent a seasonal condition, and then translated into a computer image.
 - Review the color key and axes that accompany the image. It is likely that students will be able to understand the vertical depth axis, but the horizontal temperature axis may be interpreted as distance rather than temperature.
 - Remind students that this was computer-generated, to help us 'see' the data. These colors are not the true colors, and represent temperature zones.

7. Conduct a “Think/Pair/Share”:

- Each student will individually examine their map and write a description of what the data is telling them.
- Students will then pair up with a partner from the same ‘season’, and describe to each other what they see: What is the water temperature at the surface? Does it change as you go deeper? In what way – is this change the same throughout, or are some changes more pronounced at different depths? How do you know?
- All students from the same ‘season’ now share their findings with each other as a ‘season-alike’ group, and prepare a description that they will bring back to their ‘winter’-‘spring’-‘summer’-‘fall’ team.

8. Reconvene in ‘four seasons’ teams. Starting with winter, what is the surface water temperature? What happens to water temperature as you go deeper? Continue with spring, summer, and fall. How does the story change as you go through seasons? How are the patterns in each season similar or different to the season before and the season after?

Students should examine and compare changes in temperature at particular depths, as well as how quickly temperatures change with depth (rates of change). Have students write down what similarities and differences they see in this series of four images.



EXPLANATION:

9. Review findings as a large group. Ask the whole group to share their ideas. Make a list on the board about what trends and patterns they see throughout the entire year. (Refer to Background Information in Teacher Notes for a summary of the patterns.)

See the *Seasons in the Gulf of Maine Sea Surface Temperature and Chlorophyll* lesson for additional discussion that might take place (available at mmsa.org/easie):

- Thermal energy stored in bodies of water/heat transfer
- Role of the ocean in shaping Earth’s climate and weather patterns
- Impact of seasonal temperature and thermocline changes on biological components of bodies of water (e.g. phytoplankton, fish)

ELABORATION:

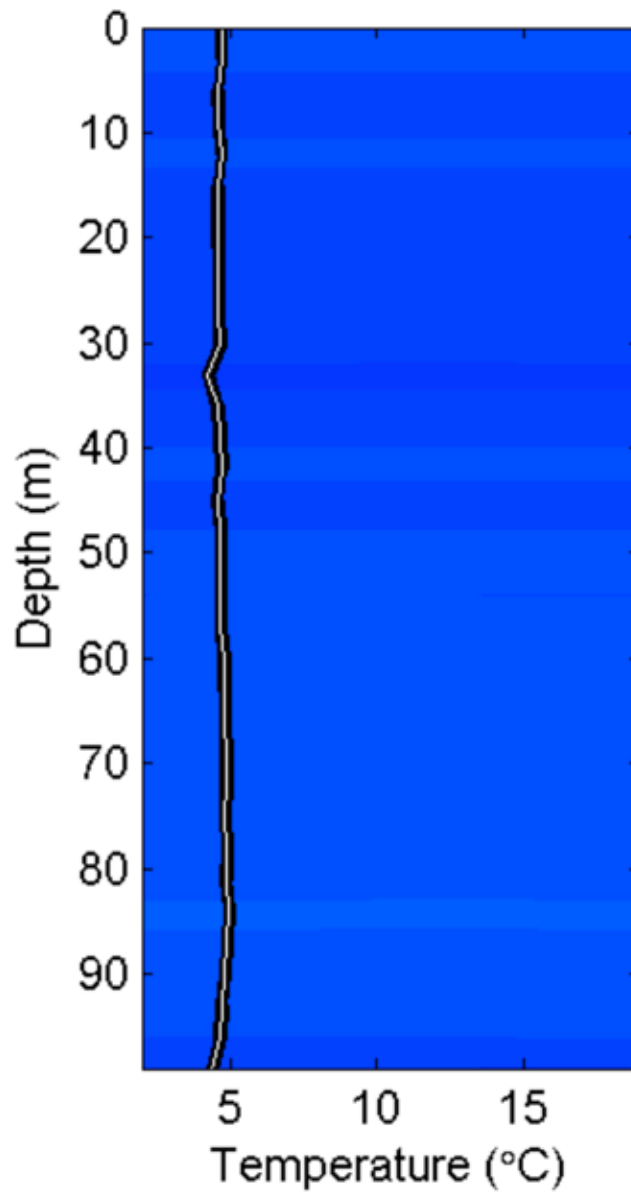
10. Revisit the question, "Are there seasons in the Gulf of Maine?" If students have been building their operational definitions of weather, climate, and seasons and describing the patterns from sea surface temperature climatology and thermocline representations in their science notebooks, use these resources to continue to guide this discussion. The discussion should now be based upon the evidence provided by the thermocline data (Steps 7 – 9).



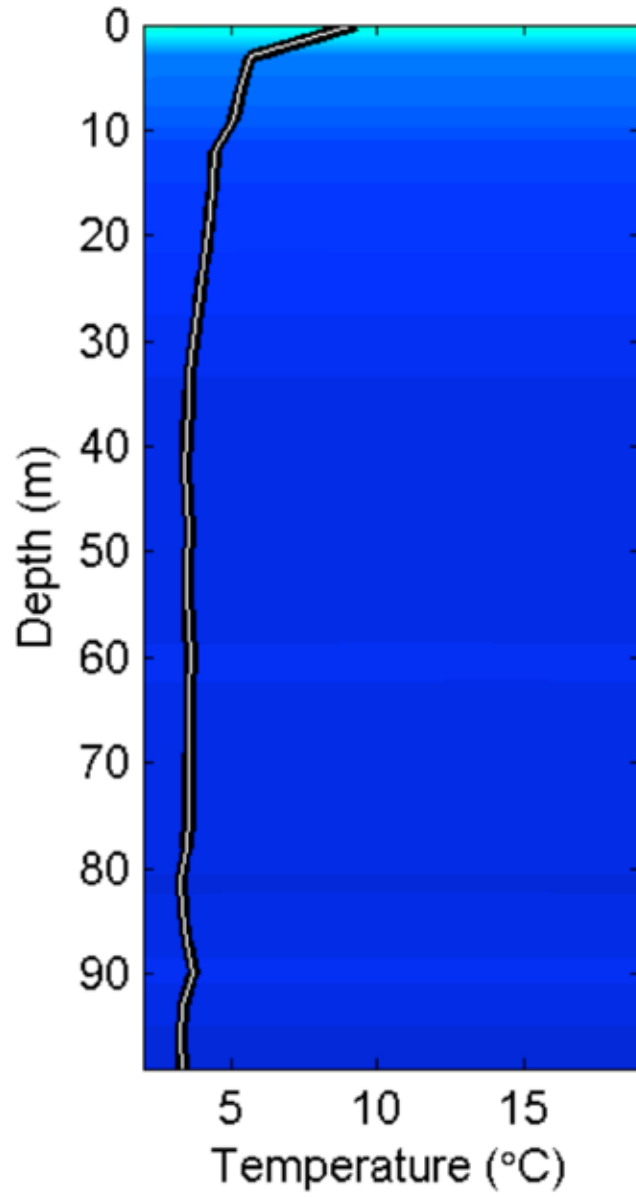


Appendix A

Winter Thermocline

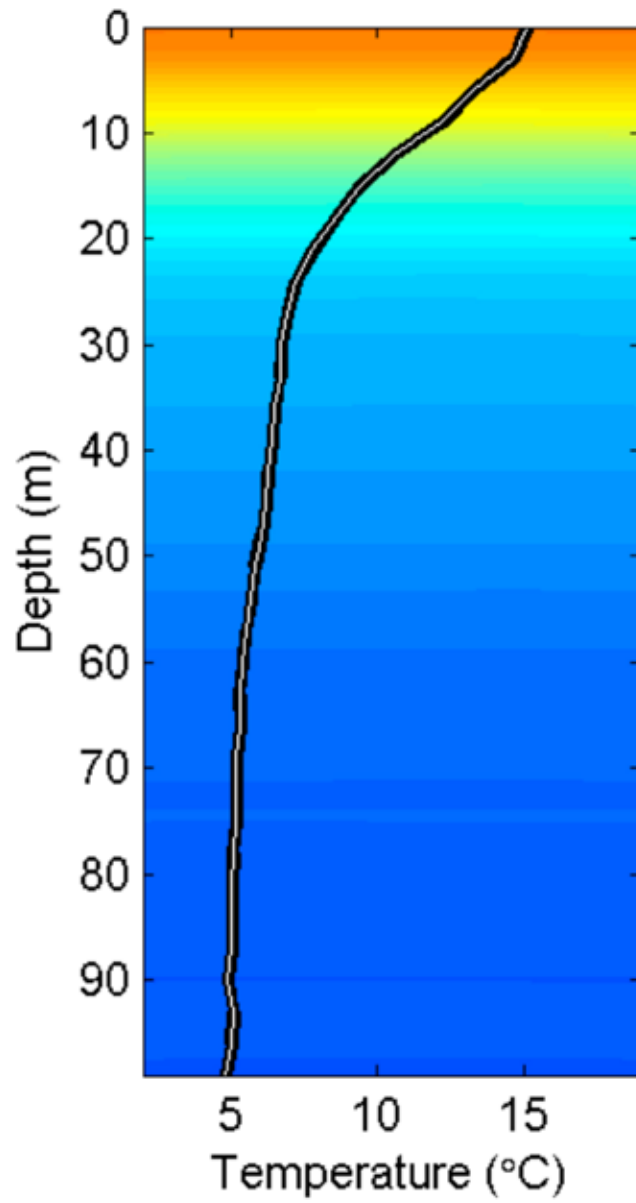


Spring Thermocline



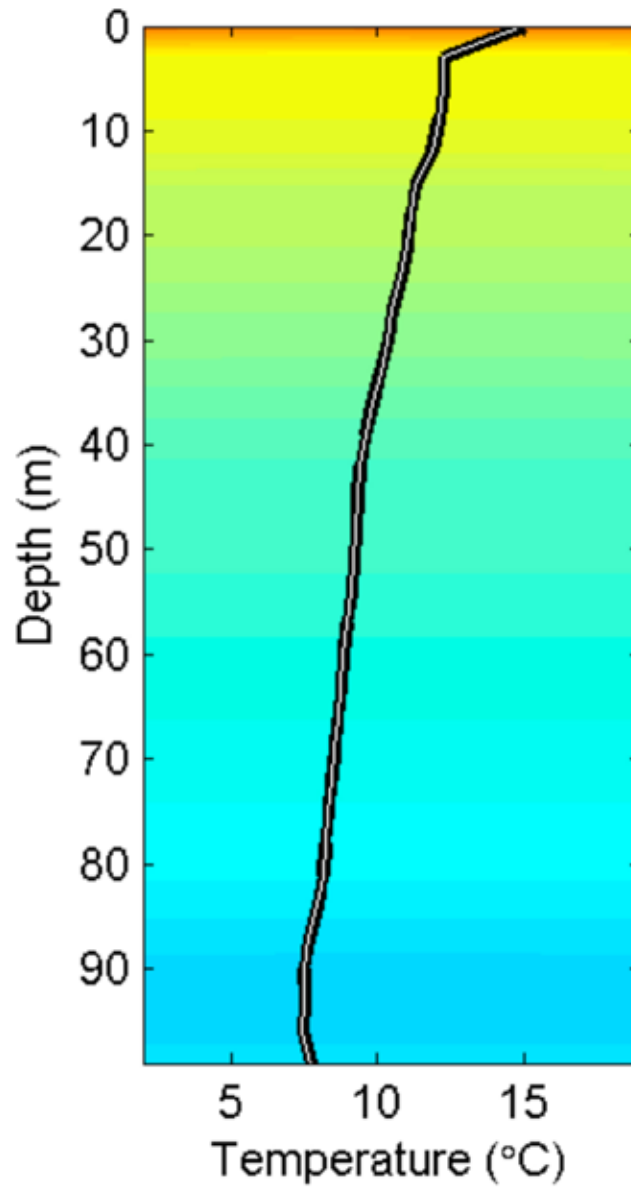
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Summer Thermocline



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Fall Thermocline



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