



Arctic Ocean Exploration

Current Events

FOCUS

Currents and water circulation in the Arctic Ocean

GRADE LEVEL

9-12 (Earth Science)

FOCUS QUESTION

What factors drive water circulation in the Arctic Ocean?

LEARNING OBJECTIVES

Students will be able to identify the primary driving forces for ocean currents.

Students will be able to infer the type of water circulation to be expected in the Arctic Ocean, given information on temperature, salinity, and bathymetry.

ADDITIONAL INFORMATION FOR TEACHERS OF DEAF STUDENTS

In addition to the words listed as key words, the following words should be part of the vocabulary list.

Continental shelf
Chukchi Sea
Atlantic Ocean
Greenland Sea
Submarine ridges
Alpha Ridge
Lomonosov Ridge
Arctic Mid-Oceanic Ridge
Canadian Basin
Biological communities
Sea-ice realm
Diatoms
Algae

Photosynthesis
Bacteria
Viruses
Fungi
Energy source
Flatworms
Crustaceans
Jellyfishes
Squids
Detritus
Sponges
Polychaete worms
Sea anemones
Tunicates
Ascidians
Organism
Grabs
Dredges
Cores
ROPOS
ROV
Manipulator
Sampling
Relative abundance
Microscopic algae
Hydrothermal vents
Chemosynthesis
Silt
Biomass
Sediment
Carnivorous species
Shallow
Circulation
Inferences
Salinity

Vertical circulation
Vertical mixing
Topography

The key words are integral to the unit but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. This list of vocabulary is quite long and may increase the time required for the lesson. The students should work in teams of two for the "Influence of Salinity on Density" and "Influence of Temperature on Density" activities. Copy the entire Background Information section and provide it as a handout for Step 3 of the Learning Procedure.

MATERIALS

- "Influence of Salinity on Density" and "Influence of Temperature on Density" activity sheets, one for each student group
- Maps of the "Arctic Region" download from http://www.lib.utexas.edu/maps/islands_oceans_poles/arctic_ref802647_1999.jpg) and "Arctic Ocean Bathymetry" download from http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/current_map.html
- Diagram of "Arctic Ocean Water Structure" download from <http://www.grida.no/db/maps/arctic/pages/arcticwaterstructure.htm>
- Data sheet sets of "Arctic Ocean Salinity" and "Arctic Ocean Temperature," one set for each student group download these sheets as follows:
 1. Point your web browser to http://www.nmic.noaa.gov/atlas/html/clim/clim_tsd.htm#d0;
 2. In the table labeled "Depth 0 m", click on the cell in the "Means" row of the "Temperature" column.
 3. Save the image.
 4. Repeat Steps 2 and 3 for the cell in the "Means" row of the "Salinity" column.
 5. Repeat Steps 2 through 4 for the tables labeled "Depth 100m" and Depth 2000 m.

You should end up with six maps: three for salinity at 0, 100 m, and 2,000 m; and three for temperature at these depths.)

- Table salt, about 4 tablespoons per student group
- Plastic squeeze bottles, two per student group
- Red and blue food coloring
- 100 ml graduated cylinder, one per student group
- Glass pan, about 9" x 13" x 3", one per student group
- Plastic zip-lock bags, 1-quart size, two per student group
- Binder clips, medium size, two per student group
- Ice cubes, about 500 ml per student group
- Hot tap water, about 800 ml per student group

AUDIO/VISUAL MATERIALS

None, unless you want overhead transparencies of maps and diagrams for group discussions

TEACHING TIME

One or two 45-minute periods

SEATING ARRANGEMENT

Groups of four students

MAXIMUM NUMBER OF STUDENTS

32

KEY WORDS

Pelagic
Benthic
Sympagic
Salinity
Density
Canadian Basin

BACKGROUND INFORMATION

The Arctic Ocean is the smallest of the world's four ocean basins with a total area of about 5.4 million square miles or 14 million square kilometers (roughly 1.5 times the size of the United States). It is bordered by Greenland, Canada, Alaska, Norway, and Russia. The Arctic Ocean has the widest continental shelf of any ocean, extending

750 mi (1,210 km) from the coast of Siberia, but also has areas that are quite deep. The average depth is 12,000 ft (3,658 m) and the maximum depth is 17,850 ft (5,441 m). The Chukchi Sea provides a connection with the Pacific Ocean via the Bering Strait, but this connection is very narrow and shallow, so most water exchange is with the Atlantic Ocean via the Greenland Sea. The Arctic Ocean is almost entirely covered with ice for eight months of the year, and a drifting polar ice pack covers the central and western portions year-round. Sea temperatures over much of the Arctic seldom rise above 0°C.

At this point, we know that there are at least three distinct biological communities in the Arctic Ocean. The Sea-Ice Realm includes plants and animals that live on, in, and just under the ice that floats on the ocean's surface. Because only 50% of this ice melts in the summer, ice flows can exist for many years and can reach a thickness of more than six ft (2 m). Sea ice is not usually solid like an ice cube, but is riddled with a network of tunnels called brine channels that range in size from microscopic (a few thousandths of a millimeter) to more than an inch in diameter. Diatoms and algae inhabit these channels and obtain energy from sunlight to produce biological material through photosynthesis. Bacteria, viruses, and fungi also inhabit the channels, and together with diatoms and algae provide an energy source (food) for flatworms, crustaceans, and other animals. This community of organisms is called sympagic, which means "ice-associated." Partial melting of sea ice during the summer months produces ponds on the ice surface that contain their own communities of organisms. Melting ice also releases organisms and nutrients that interact with the ocean water below the ice.

The Pelagic Realm includes organisms that live in the water column between the ocean surface and the bottom. Melting sea ice allows more light to enter the sea, and algae grow rapidly since the sun shines for 24 hours a day during the summer. These algae provide energy for a variety of floating animals

(zooplankton) that include crustaceans and jellyfishes. Zooplankton, in turn, is the energy source for larger pelagic animals including fishes, squids, seals, and whales.

When pelagic organisms die, they settle to the ocean bottom, and become the energy source for inhabitants of the Benthic Realm. Sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans, tunicates, and ascidians are common members of Arctic benthic communities. These animals provide energy for bottom-feeding fishes, whales, and seals.

The floor of the Arctic Ocean is divided by three submarine ridges (Alpha Ridge, Lomonosov Ridge, and the Arctic Mid-Oceanic Ridge), one of which (the Lomonosov Ridge) creates a relatively isolated area known as the Canadian Basin. This area is particularly interesting to scientists because its isolation could mean that it contains unique life forms that are found nowhere else on Earth. This activity focuses on water circulation in the Arctic Ocean, and on how the processes that drive ocean circulation contribute to this isolation.

Ocean currents are caused by winds and changes in seawater density. Density can be changed by evaporation or freshwater input (which raise or lower the salinity), as well as by temperature changes. Near the equator, for example, evaporation causes seawater salinity and temperature to increase. The density of seawater increases as salinity rises, and decreases as temperature rises. So even though the water is saltier, the higher temperature keeps the surface water from sinking. But as the water flows toward the poles (driven by wind), it becomes cooler and sinks due to increased density.

In this activity, students will make observations about the relationships between temperature, salinity, and density. These observations will provide the basis for drawing inferences about circulation in the Arctic Ocean, given information about temperature, salinity, and topography of the Arctic Ocean basin.

LEARNING PROCEDURE

1. Have students follow instructions for “Influence of Salinity on Density” and “Influence of Temperature on Density” activities. You may wish to have each group do both activities, or divide the activities among the groups to save time.
2. Have each group present their results, and draw inferences about the effects of salinity and temperature on water density. Students should have observed that water with added salt (higher salinity) tends to settle beneath water without salt (lower salinity), and infer that increasing salinity increases the density of water. They should also have observed that when water is cooled it tends to sink, while increasing temperature causes water to rise, and infer that increasing temperature reduces the density of water (note that this is not strictly true when water is near freezing; pure water reaches its maximum density at a temperature of 4°C, while the maximum density of seawater is below freezing).
3. Show the class a copy of the “Arctic Region” and “Arctic Ocean Bathymetry” maps. Have students identify countries that border the Arctic Ocean, and places where circulation might take place with other oceans. Students should realize that there are relatively few places where such circulation can occur, and that the largest of these is off the eastern coast of Greenland.
4. Distribute copies of “Arctic Ocean Salinity” and “Arctic Ocean Temperature” data sheets. Be sure students realize that each set of data sheets contains information about temperature or salinity at the ocean surface and at depths of 100 m and 2000 m.
5. Have each group examine and discuss both sets of data sheets, and prepare a brief written statement about water circulation in the Arctic Ocean.
6. Lead a discussion based on students’ inferences about circulation in the Arctic Ocean. Students

should identify areas of low salinity along the coast of Russia, and attribute these to large rivers (Lena, Yenisei, and Ob) that flow into the Arctic. The Mackenzie River has a similar effect on the Canadian coast. Students should infer that these areas of low salinity will also have a lower density than other portions of the ocean, and this would contribute to stratification of the ocean (i.e., reduce vertical circulation and mixing). In deeper waters, salinity is much more uniform, so there would be little circulation caused by density differences. At first glance, temperature data might seem to suggest that there could be some vertical mixing due to temperature effects on density, since temperatures of surface waters are colder than deeper water. These differences are relatively small, however, and are offset by the effect of salinity on density. Moreover, density of deeper waters is increased by a third factor: water pressure, which causes an increase in density with increasing pressure. Students should recognize that very deep (2000 m) portions of the Arctic Ocean are almost entirely isolated by topography. Only a very small area near the east coast of Greenland has a connection to the North Atlantic Ocean. Ocean ridges further divide and isolate the deeper portions of the Arctic Ocean basin.

When students have completed their inferences, show the “Arctic Water Structure” diagram, which shows the general patterns of surface circulation, and confirms the relative isolation of deeper waters by topography and density conditions.

THE BRIDGE CONNECTION

www.vims.edu/BRIDGE/polar.html

THE “ME” CONNECTION

Have students described how ocean currents affect their own lives. They should recognize the influence that oceanic heat transfer has on global and regional weather, and may also mention other interactions such as fisheries or ocean pollution.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Biology, Chemistry, Physics

EVALUATION

Written statements prepared in Step 5 provide a means for evaluating the performance of each student group. Oral participation in discussions provides a supplemental means of evaluating individual student performance.

EXTENSIONS

1. Visit <http://topex-www.jpl.nasa.gov/education/activities.html> for numerous lesson plans and ideas on ocean-related activities, particularly on aspects related to physical oceanography.
2. Have students investigate water circulation systems in other oceans, and determine which forces are the primary drivers of these systems.

RESOURCES

<http://oceanexplorer.noaa.gov> – Find out more about the Arctic Ocean Expedition and read daily documentaries and reports of discoveries posted for your classroom use.

<http://www.arctic.noaa.gov/> – NOAA's Arctic theme page with numerous links to other relevant sites.

<http://maps.grida.no/arctic/> – Thematic maps of the Arctic region showing populations, ecoregions, etc.

<http://www.cru.uea.ac.uk/cru/info/thc/> – Explanation of thermohaline ocean circulation and discussion of the potential effects of climate change

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Geochemical cycles

FOR MORE INFORMATION

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<http://oceanexplorer.noaa.gov>

Student Handout

Influence of Salinity on Density

Activity Guide

1. Prepare a concentrated salt solution by dissolving 4 tablespoons of table salt in approximately 250 ml tap water. Color the solution with red food coloring (about 4 drops). Pour the solution into a plastic squeeze bottle.
2. Prepare a second squeeze bottle with tapwater only.
3. Squeeze about 50 ml of the tapwater into a 100 ml graduated cylinder.
4. Holding the tip of the squeeze bottle against the inside of the graduated cylinder near the top, slowly squeeze about 25 ml of the concentrated salt solution into the cylinder. Record your observations. Empty and rinse the graduated cylinder.
5. Squeeze about 50 ml of the concentrated salt solution into the 100 ml graduated cylinder.
6. Holding the tip of the squeeze bottle against the inside of the graduated cylinder near the top, slowly squeeze about 25 ml of the tap water into the cylinder. Record your observations.
7. What do you infer about the effect of dissolved salt on the density of water?

Student Handout

Influence of Temperature on Density

Activity Guide

1. Fill a glass pan with tap water.
2. Put ice cubes into a 1-quart size plastic zip-lock bag so that the bag is half full. Attach the bag to one end of the glass pan with a medium binder clip.
3. Half-fill another 1-quart size plastic zip-lock bag with hot tap water. Attach this bag to the opposite end of the glass pan with another medium binder clip.
4. Add four drops of red food coloring to the water next to the plastic bag containing the hot water. Add four drops of blue food coloring to the water next to the plastic bag containing the ice cubes. Observe the motion of the food coloring for several minutes, and record your observations.