TEMPERATURE AND DEEP OCEAN CIRCULATION

OVERVIEW

Ocean *currents* arise in several ways. For example, wind pushes the water along the surface to form wind-driven currents. Over larger areas, circular wind patterns create hills and valleys on the ocean surface. In these areas, the balance between gravity and Earth's spin causes *geostrophic* currents to flow.

Deep ocean currents are caused by differences in water *temperature* and *salinity* (*density*). In this experiment, the students will *hypothesize* the cause of ocean currents and then develop a *model* to help explain the role that temperature plays in deep ocean currents.

CONCEPTS

- Cold water is more dense than warm water, and is therefore heavier.
- In some regions of the ocean, circulation is based upon the sinking of cold water and the subsequent *displacement* of warm water.

MATERIALS

- Approximately 9 x 13 x 3 inch glass dish
- Tap water
- Hot tap water
- Small waterproof ziplock bags
- 2 Clothes pins (or small clamps)
- 2 Different colors of food coloring
- 2 Eye droppers
- Rock
- Ice cubes, or a chemical cold pack
- Map of deep ocean currents
- Map of sea surface temperature

PREPARATION

Gather the supplies or send a supply list home with the students. Make sure that the students mark their names on anything they bring to class that will be returned home.

Set up one activity station for each group of four students. Provide each group with a check list of supplies and a copy of the setup procedures.

Divide the class into groups of four. This allows for the participation of all members. You may wish to assign each student in the group a job. One student could be responsible for making sure that all the supplies are available and that the activity is set up correctly. Another could be responsible for compiling the results for the group and for making the final drawing. The third student could act as the group runner, making sure that the water is hot and that the ice is not melting too rapidly. The last person in the group could be responsible for making sure that the activity is cleaned up and the material returned to the proper place and person.

Procedure

Engagement

Display the maps of wind-driven ocean currents and sea surface temperature [Figs. 1 and 2]. Have the students note the difference between warm and cold currents. Ask the students to write a hypothesis that explains the cause of these surface currents.

Conduct the following experiment to learn more about the relationship between temperature and deep ocean currents.

Activity

1. Fill the glass pan with tap water. Let the pan rest for a few minutes while the water settles.
2. Place a rock in a plastic bag and fill the bag with hot water. Seal the bag, and use the clothes pin to clip it to one corner of the glass pan.
3. Fill another bag with ice cubes or the chemical cold pack, and clip the bag to the opposite corner of the pan.
4. Use one of the droppers to add four drops of food coloring to the water next to the ice cube. Use the other dropper to add four drops of a different color of food coloring next to the bag of hot water. Observe the food coloring for several minutes. Where did the water sink? In what direction did the current flow along the bottom? Where did the water rise? Make drawing of what you observed.
5. Make a hypothesis about what happened. How does this hypothesis compare your earlier hypothesis about ocean circulation?
6. Discuss and answer these questions with your group. Be prepared to discuss your answers with the entire class. Do you think that the direction of deep-water currents could be reversed? Compare your model to Earth's oceans by looking at an image of global sea surface temperature. Where are the oceans coldest? Where are they the warmest?

Explanation

Thermohaline circulation is the name for currents that occur when colder, saltier water sinks and displaces water that is warmer and less dense. In this activity, you examined the relationship between temperature and deep ocean currents without changing the water's salinity.

In Earth's equatorial regions, surface ocean water becomes saltier as the water, but not the salt, evaporates. However, the water is still warm enough to keep it from sinking. Water that flows towards the poles begins to cool. In a few regions, especially in the North Atlantic, cold salty water can sink to the sea floor. It travels in the deep ocean back towards the equatorial regions and rises to replace water which is moving away at the surface. This whole cycle, called the *global conveyor belt*, is very important in regulating climate as it transports heat from the equatorial regions to polar regions of Earth. The full cycle can take a thousand years to complete.

Extension

This activity demonstrates both horizontal and vertical ocean circulation associated with temperature changes. Satellites, however, are able to "see" only the ocean surface and thus can map near surface currents. For example, the TOPEX/Poseidon satellite uses a *radar altimeter* to measure the sea surface height over 95% of the world's ice-free oceans. The data collected by this satellite are used to make maps

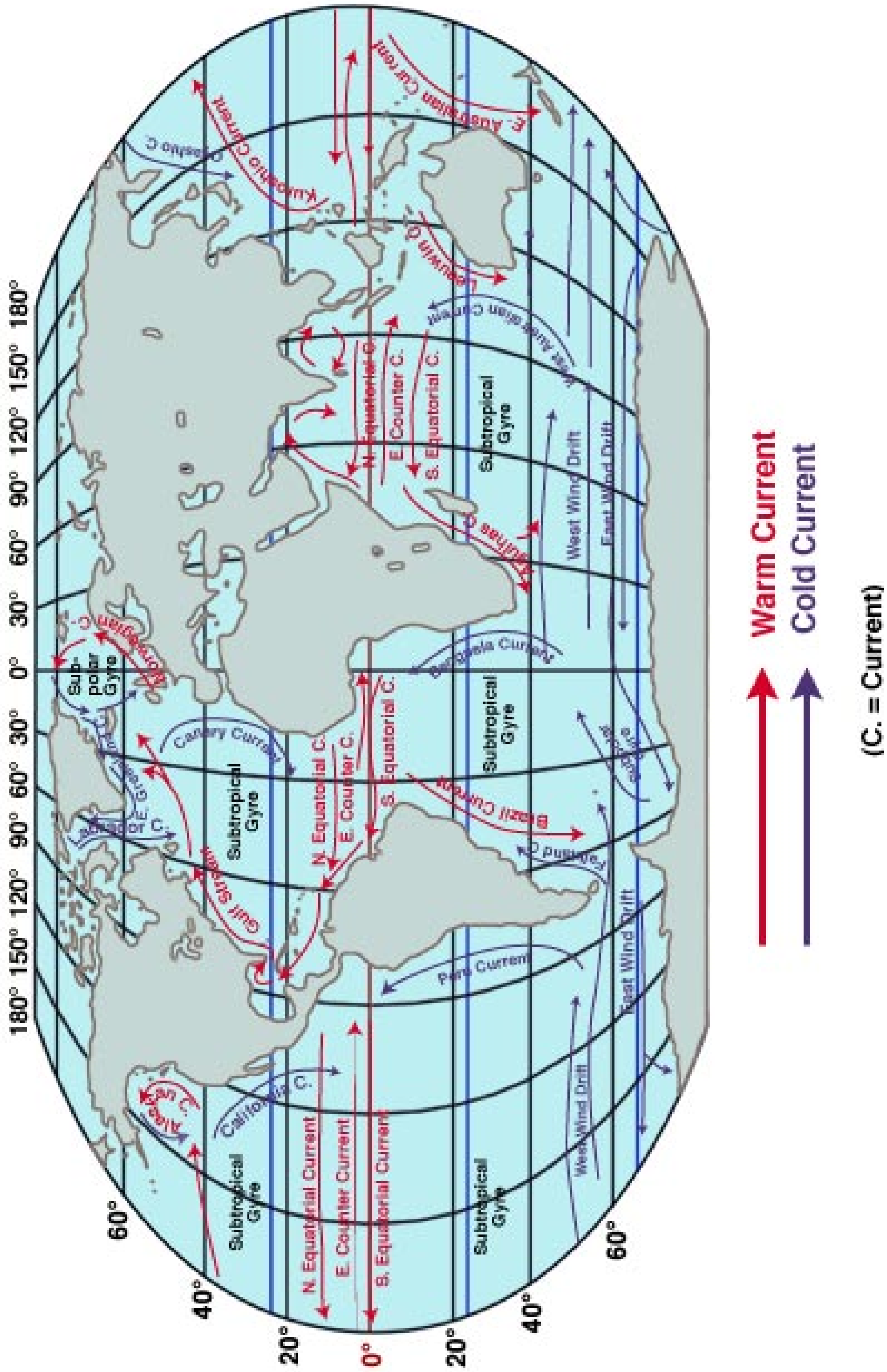

Figure 1. Wind-driven surface current.

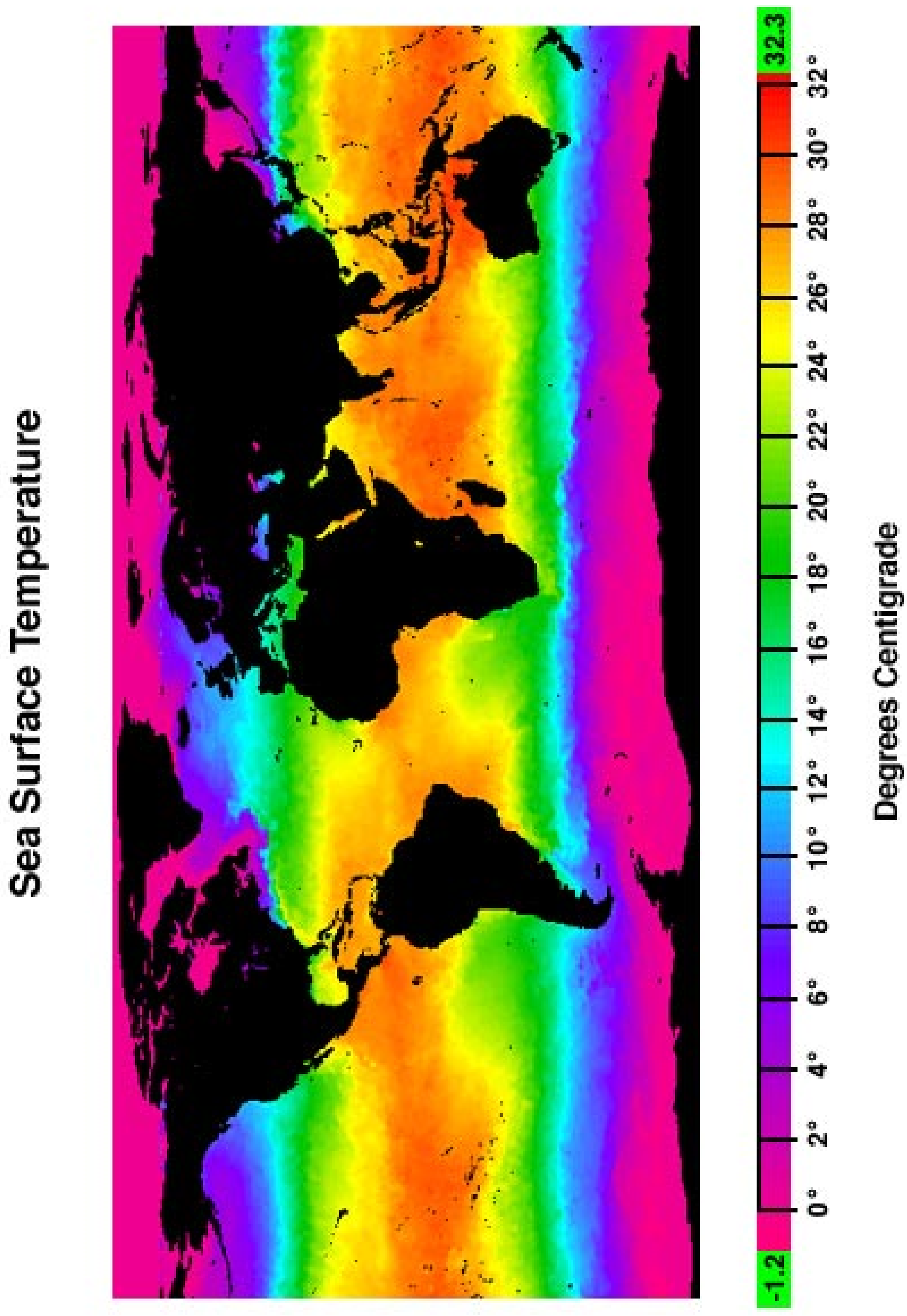
Sea Surface Temperature
-1.2
0°
2°
4°
6°
8°
10°
12°
14°
16°
18°
20°
22°
24°
26°
28°
30°
32°
32.3
Degrees Centigrade

Figure 2.

of dynamic *ocean topography* [Fig. 3]. From these, scientists can monitor the speed and direction of geostrophic ocean currents [Fig. 4].

Have students look at the world maps of geostrophic ocean currents and dynamic ocean topography at the same time [Figs. 3 and 4]. By studying these maps together, they should develop an understanding of how currents move around highs and lows of dynamic ocean topography. After they have compared these maps, can they see a difference between current flow direction and ocean topography in the northern versus southern hemisphere? Can they explain why this difference might exist?

Students can also complete the *Salinity and Deep Ocean Circulation* Activity. This will help them to understand that deep ocean currents are caused by both density and temperature.

Links to Related CD Activities, Images, and Movies

Map of *Wind-driven ocean currents*

Map of *Sea surface temperature*

Image of *Global conveyor belt*

Animation of *Global conveyor belt*

Map of *Geostrophic currents*

Image of *TOPEX/Poseidon dynamic ocean topography*

Animation of *Effect of Coriolis force on wind and ocean currents*

Activity *Salinity and Deep Ocean Circulation*

Vocabulary

current	*density*	*displacement*
geostrophic	*global conveyor belt*	*hypothesis*
model	*ocean topography*	*radar altimeter*
salinity	*temperature*	*thermohaline circulation*

Source

Adapted from Macmillan/McGraw-Hill School Publishing Company, *Oceans in Motion.* p. 50 - 51.
Adapted from Orange County Marine Institute, *Sea Adventure Camp.*

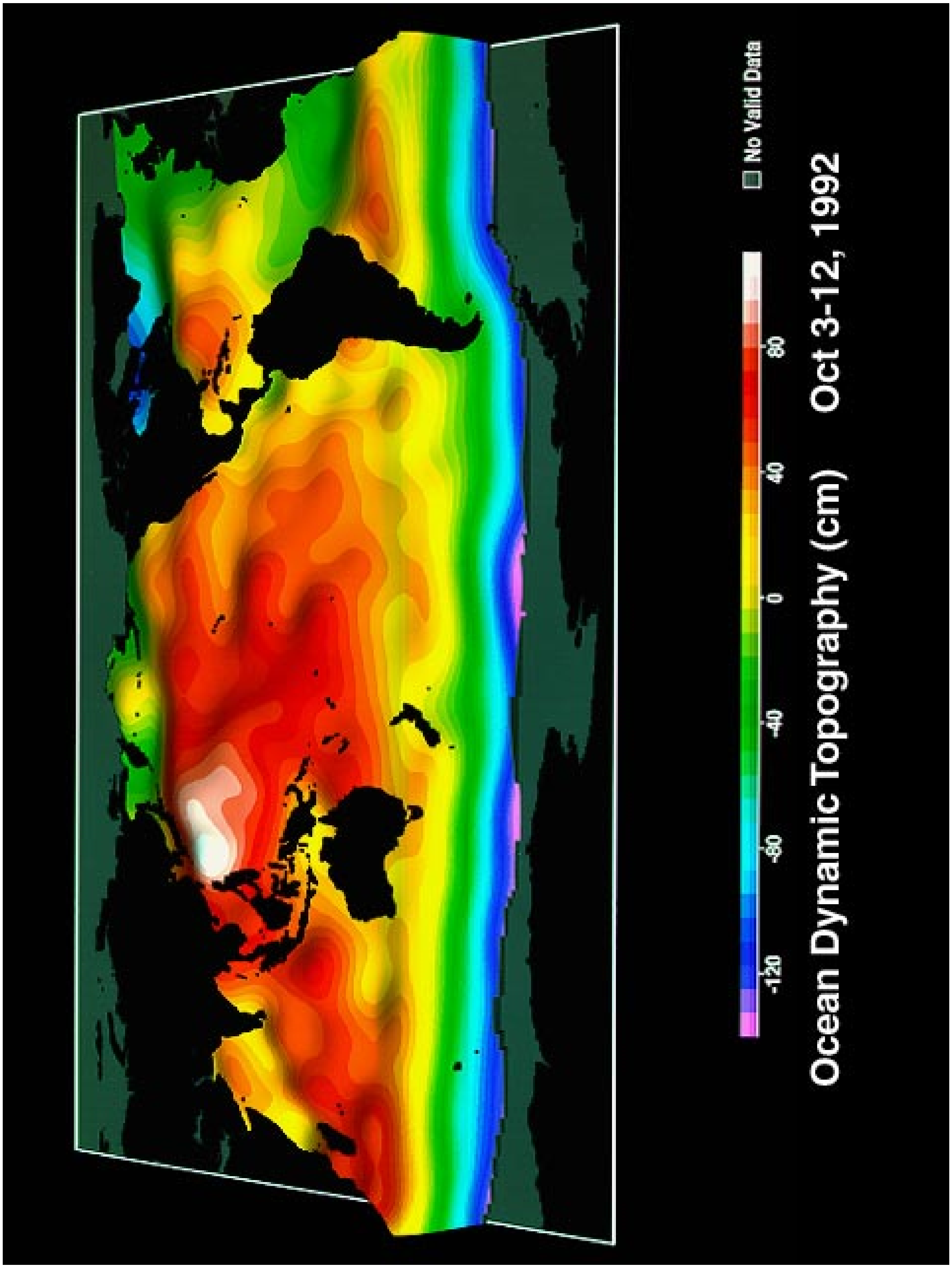
No Valid Data
-120
-80
-40
0
40
80
Ocean Dynamic Topography (cm)
Oct 3-12, 1992

Figure 3.

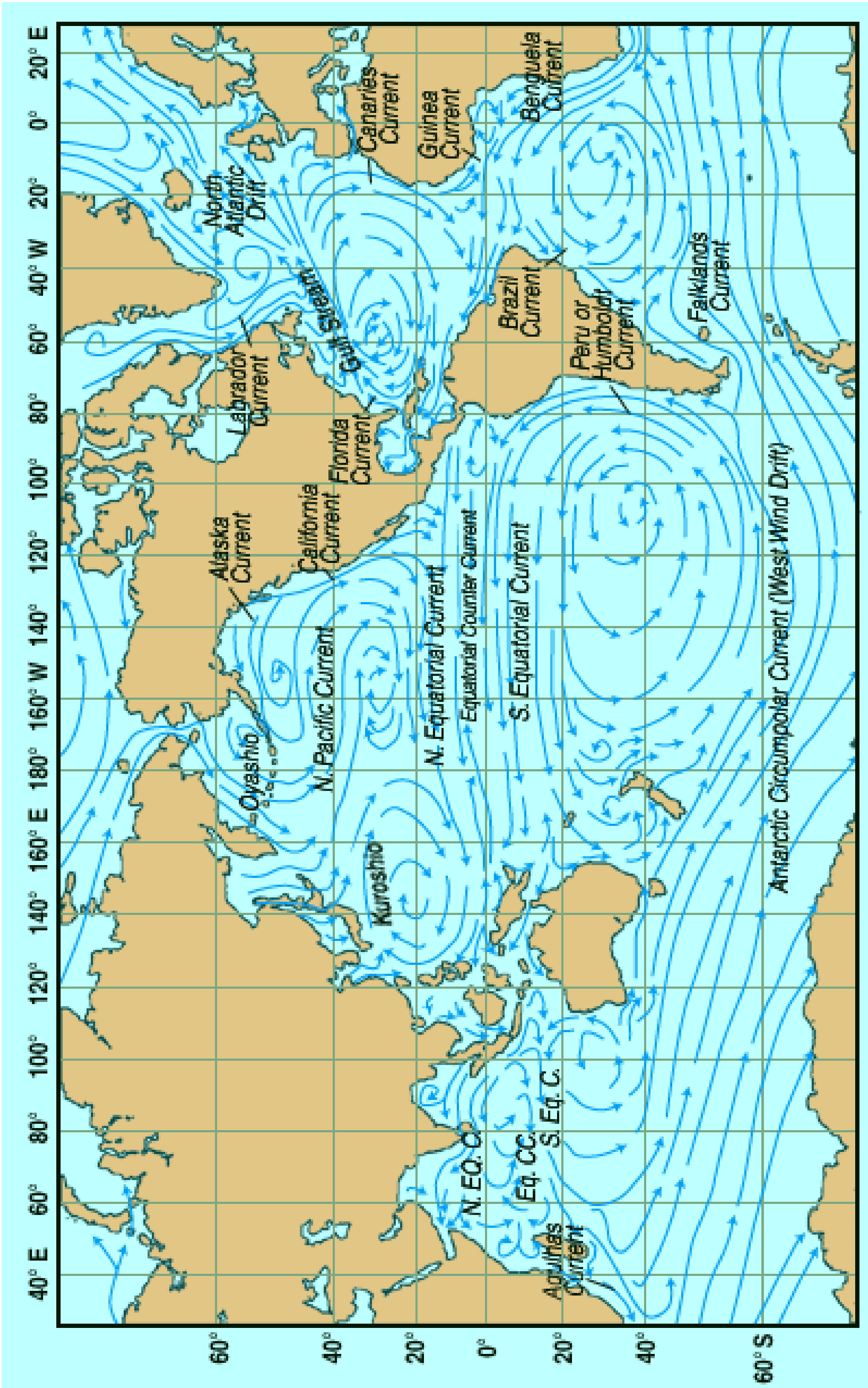

Figure 4. Geostrophic currents in the upper 1000 meters of Earth's oceans.