Surface Circulation in the North Atlantic & off of Southern California: Two Models

Objective
1. To become familiar with large scale surface circulation patterns in ocean.
2. To be able to predict current patterns or eddy development with variations in bathymetry.

Correlations
National Science Education Standards
    Grades 5-8: B, D
    Grades 9-12: B, D
California State Science Education Standards
    Grade 6: 4d?, 7
    Grade 7:
    Grade 8:
    Grades 9-12:
Ocean Literacy Principles and Fundamental Concepts: 1

Introduction
Approximately 10% of the ocean (the uppermost ~400 meters) is involved in surface circulation. Wind, the primary force responsible for surface currents, are driven by uneven solar heating of the earth by the sun and the Earth's spin (which results in the Coriolis effect). Wind direction, gravity, the Coriolis Effect and topography (continents and ocean basins) affect the direction of surface current flow. Most of the Earth's wind energy is concentrated in the westerlies and the trade winds (easterlies) in both hemispheres.

The topmost layer of water in a wind-driven current flows 45 degrees to the right (in the northern hemisphere, while in the southern hemisphere is flows 45 degrees to the left) of the wind direction.

The flow of water around the edge of an ocean basin is called a gyre. There are 6 major current circuits in the ocean. Five are geostrophic gyres and one is the Antarctic circumpolar current. Each gyre has major currents within it: western boundary, eastern boundary, and transverse.

Western boundary currents tend to be narrow (<100km), fast (hundreds of km/day), and deep (up to depths of 2km) and they move warm water toward the poles. They have sharp boundaries, little or no upwelling, and tend to be depleted of nutrients. The Gulf Stream is the largest of the five western boundary currents.

Eastern boundary currents tend to be broad (~1000km across), slow (tens of km/day), and shallow (<500m) and they move cold water toward the equator. They don't have well-defined boundaries, coastal upwelling is common, and eddies tend not to form. The California Current is one of the five eastern boundary currents.

In this activity, students will explore how wind creates surface water currents and how land features can change the direction of these currents.

To read more about surface circulation (and other related processes), download "ch02b.pdf":
http://www.google.com/url?sa=t&source=web&cd=1&sqi=2&ved=0CBUQFjAA&url=http%3A%2F%2Flife.bio.sunysb.edu%2Fmarinebio%2Fbio353%2Fchapters%2Fch02b.pdf&rct=j&q=ch02b.pdf%20coriolis&ei=OXc0TrzvBIreiAKE8u2gDw&usg=AFQjCNGD50fTOAmOlhl6ifPYCcOuNgwzcg&cad=rja
(tiny url: **http://tinyurl.com/surfcirc**)
Also, see Tom Garrison's "Oceanography: An Invitation to Marine Science"

Surface Circulation in the North Atlantic

Materials
- Heavy duty stainless steel baking tray (10” x 16”) (or you can use a clear pyrex dish or cookie sheet with a raised edge)
- Modeling clay
- Laminated bathymetric maps of the Eastern USA Coast, 1 per group
- Convection Fluid (from Carolina Biological Supply, Carolina™ Convection Fluid, Item # GEO8450, $17.35 per bottle)
- funnel (helpful in returning Convention Fluid to its bottle)
- Hair dryer, small fan or straws (bendable straws are nice, but not necessary)

Procedure
1. In groups of 3 to 5 people, use the modeling clay to build a model of the North Atlantic. Use the bathymetric map provided to guide you. (If you have a clear dish, you can put the bathymetric map underneath which might help you somewhat.) Be sure to include the continental shelf, continental slope, capes, seamounts, and other seafloor features. Make sure your final clay model is not taller than your pan (1 to 2 inches high is probably the highest you would want to build it).

2. Pour in a diluted solution of Convection Fluid to a depth which just covers the sea floor features of your model.

3. Set up a gentle "wind" (using the hair dryer, small fan or your breathe through a straw) blowing from the south north along the coast to simulate the Gulf Stream. Make observations on the current patterns that develop.

Visit the following website for general information about the Gulf Stream and images of eddies. http://oceancurrents.rsmas.miami.edu/atlantic/gulf-stream.html

4. Change wind direction and speed. Observe any changes in the current patterns.

5. Describe and illustrate your observations, especially the patterns affected by the shoreline or around subsurface features.

6. Try to create surface current patterns (such as eddies and meanders) that have been previously recorded in the Gulf Stream. What conditions were necessary to create the surface patterns?

An example of an eddy: there is one east of North Carolina
http://fermi.jhuapl.edu/avhrr/gs/averages/10jan/gs_10jan22_0328_mult.png

An example of a meander: there is one off the coast of South Carolina
http://fermi.jhuapl.edu/avhrr/gs/averages/10jan/gs_10jan30_0159_multi.png

The Gulf Stream surface circulation patterns are evident in the images of sea surface temperature. Explore the variation in circulation here: http://fermi.jhuapl.edu/avhrr/gs/averages/

7. When finished, return the Convection Fluid to the bottle. Remove clay from container and roll into ball.

Bathymetry Map of the North Atlantic
http://oceancurrents.rsmas.miami.edu/atlantic/img_topo2/gulf-stream2.jpg
(see Appendix A)

Surface Circulation in the North Atlantic Worksheet

1. Draw a picture of your model and label which way your wind was directed and the directions of the currents that were generated by the wind.

2. Did the shelf, slope, capes or other features affect the surface current? Describe and explain.

3. Do you think the Gulf Stream would have a greater impact on weather of the southeast USA or the northeast USA? Explain.

4. What other factors, besides wind, might affect the Gulf Stream current?

Surface Circulation off of southern California

Materials
- Heavy duty stainless steel baking tray (10” x 16”) (or you can use a clear pyrex or cookie sheet with a raised edge)
- Modeling clay
- Bathymetric map of the Western USA Coastline, 1 per group
- Convection Fluid (from Carolina Biological Supply, Carolina™ Convection Fluid, Item # GEO8450, $17.35 per bottle)
- funnel (helpful in returning Convention Fluid to its bottle)
- Hair dryer, small fan or straws (bendable straws are nice, but not necessary)

Procedure
1. In groups of 3 to 5 people, use the modeling clay to build a model of the southern California coast. Use the bathymetric map provided to guide you. (If you have a clear dish, you can put the bathymetric map underneath which might help you somewhat.) Be sure to include the continental shelf, continental slope, capes, seamounts, and other seafloor features. Make sure your final clay model is not taller than your pan (1 to 2 inches high is probably the highest you would want to build it).

2. Pour in a diluted solution of Convection Fluid to a depth which just covers the sea floor features of your model.

3. Set up a gentle "wind" (using the hair dryer, small fan or your breathe through a straw) blowing from the south north along the coast to simulate the Gulf Stream. Make observations on the current patterns that develop.

Visit the following website for general information about circulation in the southern California bight:
http://www.cnsm.csulb.edu/departments/geology/people/bperry/scbweb/circulation.htm

4. Change wind direction and speed. Observe any changes in the current patterns.

5. Describe and illustrate your observations, especially the patterns affected by the shoreline or around subsurface features.

6. Try to create surface current patterns (such as eddies and meanders) that have been previously recorded in the Gulf Stream. What conditions were necessary to create the surface patterns?

Visit this website again for images showing circulation patterns in the southern California bight:
http://www.cnsm.csulb.edu/departments/geology/people/bperry/scbweb/circulation.htm

Visit the following website for a larger scale view of the southern California area:
http://www.osdpd.noaa.gov/data/sst/contour/californ.fc.gif

7. When finished, return the Convection Fluid to the bottle. Remove clay from container and roll into ball.

Bathymetry map of southern California coast
http://www.ngdc.noaa.gov/mgg/coastal/grddas06/grddas06.htm
(see Appendix B)

Surface Circulation off of Southern California Worksheet

1. Draw a picture of your model and label which way your wind was directed and the directions of the currents that were generated by the wind.

2. Did the shelf, slope, points, islands, etc. affect the surface current? Describe and explain.

3. Do you think the ocean currents might have a greater affect on weather south vs. north California? Explain.

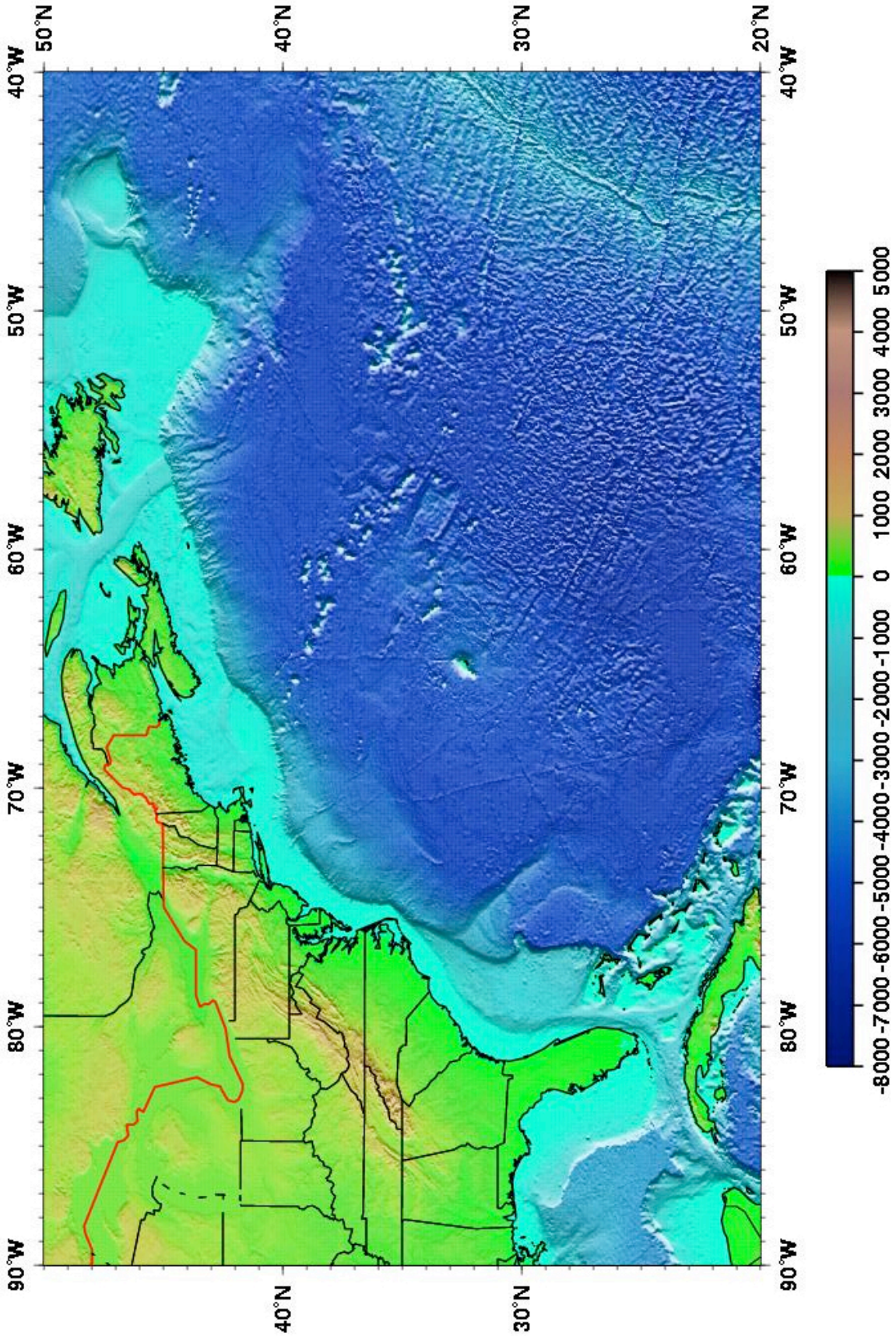
4. What other factors, besides wind, might affect the California current? How about the California counter current?

Suggestions for thought questions after looking at both models.

1. Is the surface circulation of the North Atlantic and the southern California coasts affected by the same parameters? Think about the difference in scale between the North Atlantic model and the southern California model.

2. How does southern California ocean circulation differ from the North Atlantic circulation?

Appendix A. http://oceancurrents.rsmas.miami.edu/atlantic/img_topo2/gulf-stream2.jpg



Appendix B. Pieced together from: http://www.ngdc.noaa.gov/mgg/coastal/grddas06/grddas06.htm