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Islands in the Stream 2002: Exploring Underwater Oases

In Gyre Straits

Focus

Inferring bathymetry that causes eddies

Grade Level

9-12 Earth Science (May be adapted for Grades 7-8 Earth Science

Focus Question

What geologic feature(s) in the structure of the ocean floor may cause an eddy to form in the current above it?

Learning Objectives

Simulating the Charleston Gyre (an eddy) found in the South Atlantic Bight, students will use inquiry to infer the bathymetry of the ocean floor located below the ocean surface that causes the formation of an eddy in the Gulf Stream.

Students will test their ocean floor designs by building models that simulate the Gulf Stream's course over their ocean floor while observing if an eddy forms or not and discussing why it does or does not form. If they find that an eddy does not form, they will then predict what changes to their model may produce an eddy.

Using a given pattern to follow, students will reconstruct a simple model of the actual ocean floor that results in the Charleston Gyre and compare it to their test models.

Additional Information for Teachers of Deaf Students

In addition to the words listed as Key Words, the following words should be part of the list.

Eddies
Coriolis Effect
Geological
Upwelling
Topography
Flow
Deflection
Features
Canyons
Ridges
Underwater volcanoes
Plains
Rocky outcrops
Coral reefs
Reroute

There are no formal signs in American Sign Language for any of these words listed as key 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 lesson might require 3 class periods once the teacher demonstration is added. Be certain that the students have 30 minutes to work on their model on Day 2. It is tempting to give the students as much time as they need, but by limiting the time, you allow them to look at things they might change and also to work rapidly.

Prior to the lesson on Day One, set up the following: A long pan with dirt and rocks placed to represent a stream. Have water available. When you get to Step 3 on Day One, ask the students the question and then demonstrate and see if their predictions were correct. Then ask the next question regarding rock placement. After their answer, conduct the demonstration again.

Materials

- ❒ Map of the North Atlantic Gyre showing the Gulf Stream current and the Charleston Gyre (provided - make one copy on an overhead transparency (Optional: Make one hard copy per pair of students) See Attachment 1
- ❒ (OPTIONAL) - A wall map of the world that shows the North Atlantic Ocean (the gyre, the Gulf Stream current and the Charleston Gyre may be pointed out by the teacher)
- ❒ Script of a brief explanation of gyres and eddies by the teacher (script provided)
- ❒ Script of an explanation of bathymetry (script provided)
- ❒ Script of an explanation of the importance of the Charleston Bump to the fishery industry (script provided) See Attachment 2
- ❒ Aluminum foil - 1 roll per team of 4 students; used to build the sea floor
- ❒ Clay - 1 pack of 4 tubes per pair of students; used to hold down the aluminum foil
- ❒ Plastic shoebox with a transparent bottom -1 per pair of students, or any rectangular or square plastic container no smaller than a sandwich box or larger than a shoebox. NOTE: If a smaller container is used (like a sandwich-sized box), then clay may be used exclusively to build the sea floor - 2 packs of 4 tubes per pair of students
- ❒ Water - enough to fill the plastic box per pair of students
- ❒ Straw - one per student
- ❒ Food coloring - 1 bottle per pair of students
- ❒ Colored plastic confetti circles (purchased or use a hole punch with a transparency sheet colored with permanent markers). Any color will work, but if you also want to simulate the warm current of the Gulf Stream coming from the Equator, use red circles and red food dye.
- ❒ Pattern for the "Bathymetry of the South Atlantic Bight"- provided (copy one for the teacher if lesson completed as a demonstration or copy one per pair of students if completed as a team activity. Use the magnification mode on the copy machine to adjust the size of the pattern to fit the size of the bottom of the plastic boxes the students will be using.) See Attachment 3
- ❒ Colored pencils - 1-3 per student; any color, but one should match the color (red) of the food dye or confetti
- ❒ Transparency copy of "Conclusion Questions" See Attachment 4
- ❒ students provide their own science notebooks, pencils/pens
- ❒ suggested rubric for evaluation of student jotter, See Attachment 5

Audio/Visual Materials

- ❒ Overhead transparency/screen
- ❒ (Optional): digital camera or video camera to capture student test results
- ❒ (Optional): use of PowerPoint to present student models, tests in progress and results
- ❒ (Optional): use of computer and LCD projector or aver key (hooked up to television set) to view animation of Gulf Stream in motion, showing Charleston Gyre at http://www.140.90.191.231/oppt/loops/goes_sst/gstream_10.html

Teaching Time

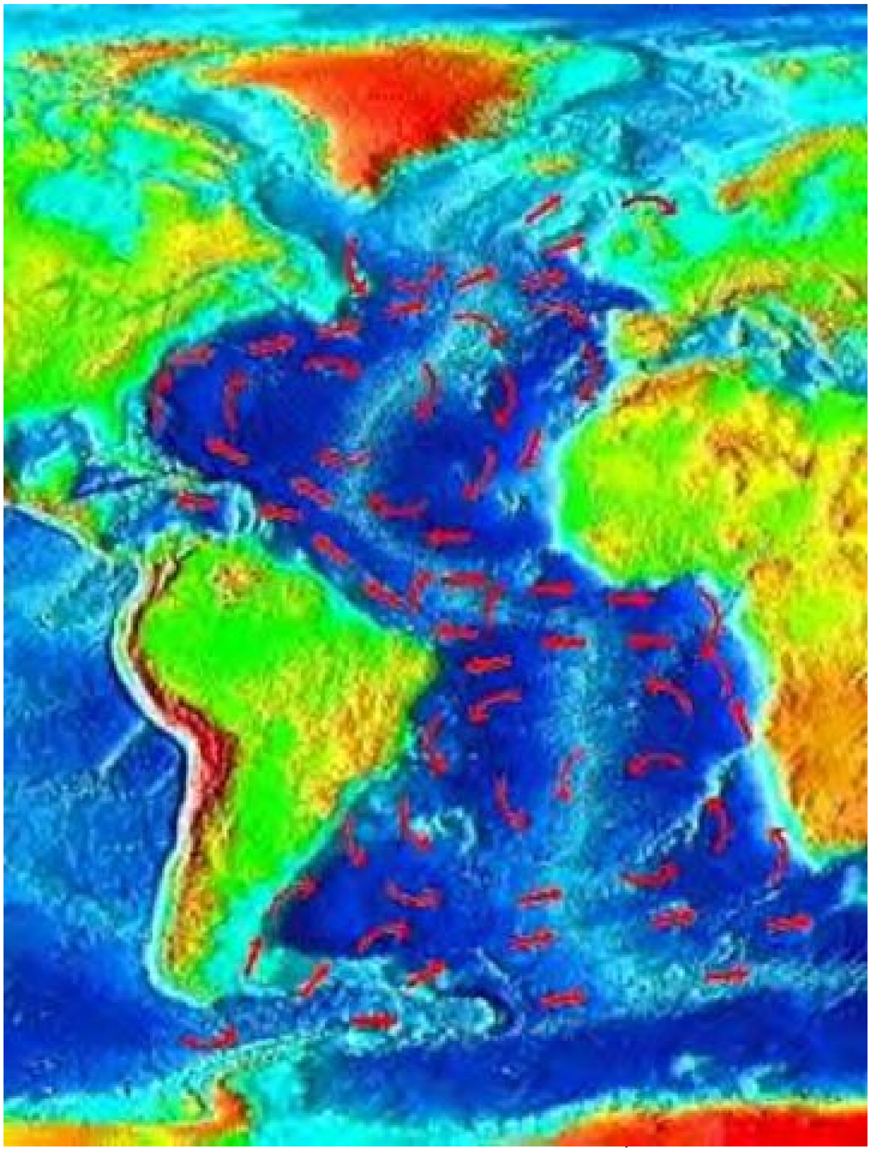
Two 45-minute class periods
(Extensions require more time, one or two 45-minute periods)

Seating Arrangement

Teams of four, with students working in pairs

Maximum Number of Students

Any size that the teacher feels comfortable managing in an inquiry investigation (24-32)



from NASA (NGDC)
http://www.meer.org/M10.htm

Key Words

Gyre
Eddy
Bathymetry
Charleston Bump
Charleston Gyre

Background Information

Due to the influence of wind currents and the influence of the Earth's rotation (called the Coriolis Effect), the ocean currents follow a regular circular pattern in their respective ocean basins, called gyres. The oceans of the Northern Hemisphere (the northern Atlantic and Pacific Ocean basins) flow in a clockwise direction, whereas the oceans of the Southern Hemisphere (the southern Atlantic and Pacific basins) flow in a counter-clockwise direction. Irregularities in the ocean floor and shape of the continental margins will affect smaller, localized areas, causing eddies to spin off from the general current flow which resemble miniature gyres.

An example of just such an eddy of extremely great importance to the fishery industry is the "Charleston Gyre." Although misnamed, this eddy is formed by a geological feature in the Atlantic Ocean, about 100 miles southeast of Charleston, South Carolina, called the "Charleston Bump." Formed by the deflection of the Gulf Stream offshore, the Charleston Gyre produces a constant process of upwelling, by which nutrients are brought to the ocean surface. Because of this upwelling, scientists think the Charleston Bump "ìmay have a significant oceanographic effect on primary productivity, dispersal and retention of larval organisms, cross-shelf transport of nutrients and fauna, and life history of fishes. The interaction of the Charleston Bump and the Gulf Stream may play a role in the recruitment of large pelagic fishes, such as swordfish and other billfishes to nursery areas in the vicinity." (Sedberry, 2001) It is because of the diversity of life found at the Charleston Bump that it is one of the sites focused on by the NOAA Ocean Exploration Expedition Islands in the Stream 2002.

The depth differences of the ocean floor is called bathymetry. Just as the Earth's land features affect the changing elevation of the landscape, or topography, the ocean floor features will decrease depth (at underwater volcanoes or ridges) or increase depth (at underwater trenches and canyons). Irregularities in the ocean floor (geologic features) affect the flow of the ocean currents, both deep and surface currents. Mapping and studying the bathymetry of the ocean floor is one way scientists infer the causes of irregularities in ocean currents, such as the formation of the Charleston Gyre.

Learning Procedure

Note that Day 1 is an inquiry investigation. For this reason, students are to use a bound science jotter (notebook) to record observations, questions, hypotheses, diagrams, data, and other information deemed appropriate by the teacher. No worksheet is used, although the teacher uses questioning techniques (lots!) to guide the students in their investigations and use of the jotter. Although most of these questions are intended to be open-ended, a specific answer may be needed to focus the lesson and the students' discussion may be guided toward that purpose. Possible answers to open-ended questions are listed, although student answers are in no way limited to those listed here! Although Day 2 is more teacher-led, it is strongly suggested that students continue to use their jotters.

Day 1 (45 minutes)

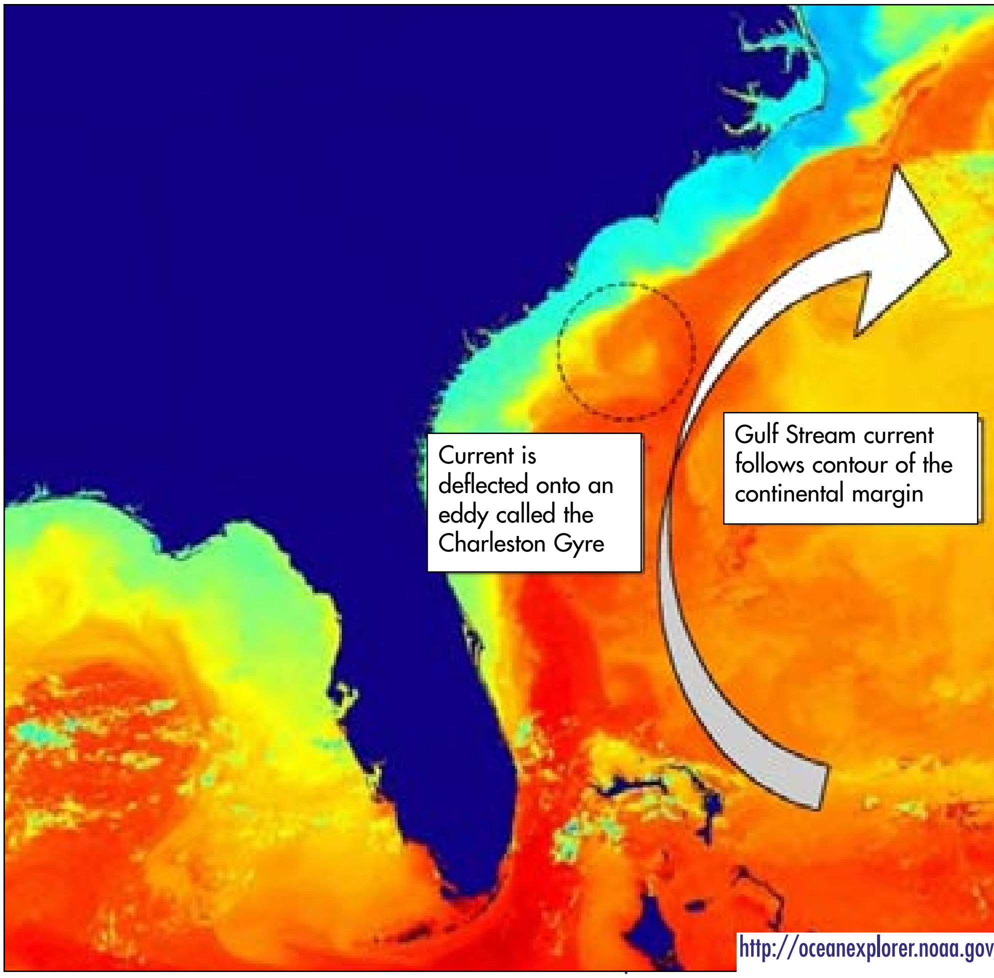
1. Opener: As students enter the classroom at the beginning of the class period, the teacher stands in the middle of the doorway (or another convenient spot) so that students have to walk around him/her to get to their desks.

2. Once students have entered and are seated, initiate a discussion regarding the position of the teacher in the doorway and the affect this had on the flow of students entering the classroom. (NOTE: Discussions are led at the discretion of the teacher. Depending on the level of ability and enthusiasm of the students, class discussion by show of hands, choral response or calling on individuals with random cards are three discussion methods that would apply here). Lead students in using the terms "flow" and "deflection." Ask questions that encourage them to think about the flow of students as a "current," the position of the teacher as a "geologic feature" of the classroom floor, and the affect of the position of this geologic feature on the current of students (they were deflected).

   What happened when you encountered the object (me, the teacher) in the doorway and I did not move out of the way? The students moved around the obstacle.

   Did other students follow your path? Why? Yes, it was easy to follow the path once it was started, there was no other way to go, other students from behind were pushing me to follow, etc.

   What is the word used to describe bouncing off or avoiding another object, such as when you may put up your arms to allow a football to bounce off your body, rather than catch it? (Deflection)



http://oceanexplorer.noaa.gov/gallery/maps/maps/#atl

3. Continue questioning, leading the students to connect this doorway experience to water currents and geologic features encountered in a stream or river and the ocean.

   If I were a rock in a stream, how would you expect the water to travel when it encountered me? The water would flow around or be pushed over it. How deep could the rock be placed before it no longer affected the flow of the current? Answers vary.

   Do you think rocks on the bottom of the ocean could affect ocean currents (deep or surface currents)? Answers vary. How deep could these rocks be placed and still affect the surface currents? Answers vary.

   Are there other ocean floor features that may affect the surface currents? Explain. Canyons, ridges, underwater volcanoes, plains, rocky outcrops, coral reefs, and other ocean features are all possibilities. They may deflect, reroute, or even interrupt the flow of the current.

4. Tell students to take out their science notebooks (or jotters). Record the date and time and title (In Gyre Straits) of today's lesson. Prepare to record observations, questions, and relevant information.

5. Introduce the North Atlantic Gyre using the transparency overhead (Attachment 1). Have students record observations of the

Gyre (where it is located, direction of flow, irregularities). Note that this is a simplified diagram, with the only irregularity being the Charleston Gyre for the purpose of this investigation. If available, view the animation of the Gulf Stream as it flows through the South Atlantic Bight. Lead students to recognize the irregularity called the Charleston Gyre. Give a brief explanation of gyres and eddies. (If needed, a script of this explanation is provided. First half of Attachment 2)

Additional Questions:

What is wrong with the name "Charleston Gyre?" A gyre is the whole-ocean current that travels clockwise in the northern Atlantic Ocean. The Charleston Gyre is actually an eddy that spins off the Gyre.

Do you think this is the only eddy associated with the Gulf Stream? No, but the other eddies are not shown on our diagram.

Extension 1: Students may research what other eddies and irregularities are associated with the Gulf Stream.

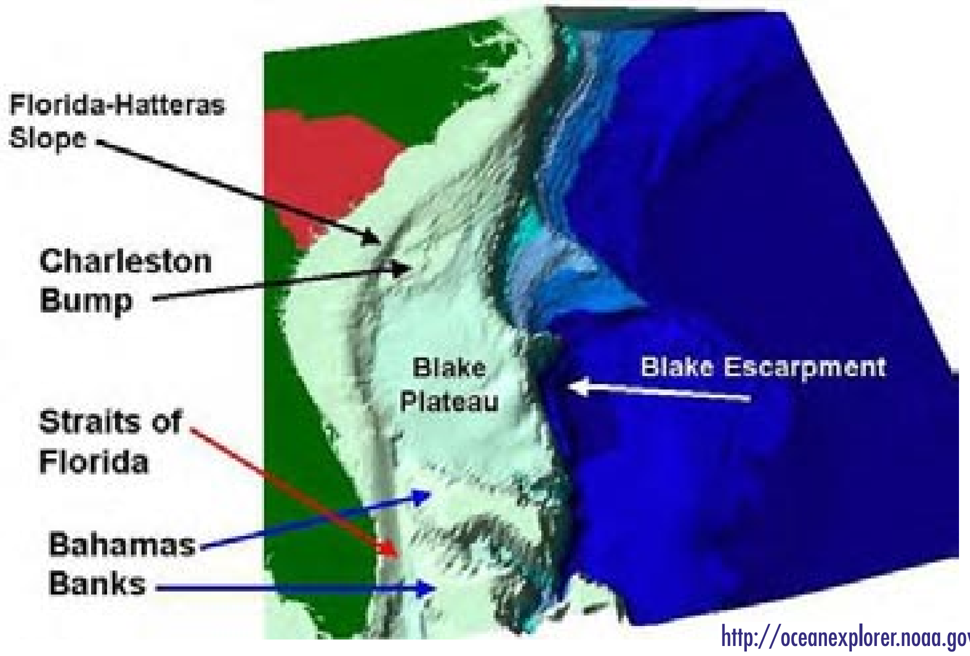
6. Instruct students to record a hypothesis of what may be causing this eddy and why they think that. Choose students to share their hypotheses, taking volunteers afterwards to also share. Using a student's idea that the ocean floor features may be deflecting the Gulf Stream, introduce bathymetry. If no student comes up with this idea on his/her own, use questioning to help students relate the lesson's opener and discussion with what may be happening in the Gulf Stream (something about the ocean floor is deflecting the current as the teacher was deflecting the flow of students or as a rock in a stream deflects the water flow). See script provided. (Middle of Attachment 2)

7. Instruct students that given a set amount of time (the remaining 20-30 minutes of the class period), they are to sketch in their jotter what they think the bathymetry of the ocean floor looks like in order to cause the Charleston Gyre above it, in the otherwise straight-flowing Gulf Stream. In pairs, they will then construct the ocean floor in their plastic box using clay and aluminum foil, pouring enough water to cover the model. Using a straw, they are to blow from the origin of the Gulf Stream current (for our purposes, from the bottom or southern end of the box/coastline), observe the resulting current and determine if an eddy is formed. Students may use plastic confetti (colored red) sprinkled on the surface of the water to better view the flow of current. Red food dye may also be used, but unless students have easy access to fresh water to change out the old red water, it would best be used once at the end of the investigation when students feel they have found a model that produces an eddy. Remind students and monitor that they draw and label their predicted design before they start to build their model. They are to sketch the results of each model test as data, and record any changes they make as they test their models. Colored pencils should be available for students to sketch their models, using red pencil (or color to match the food dye and confetti) to sketch in the current flow for each test. OPTIONAL: Take digital pictures or record on videotape the tests in progress and successful and unsuccessful results for discussion on Day 2.

Extension 2: Students adept at using Power Point may compile the class photos into a slides how presentation to be shared on Day 2.

Questions to help guide the investigation include, but are not limited to:

How will you keep the aluminum foil from floating? (Use clay to secure to bottom of box)



http://oceanexplorer.noaa.gov/gallery/maps/maps/#atl

How deep should your ocean floor be in your box? Answers vary.

How much water should cover your floor? Answers vary.

Will the entire bottom of your shoebox be covered by ocean floor? Answers vary.

How deeply should your straw blow into the water? At the surface, mid-depth, ocean bottom? Answers vary.

How hard should you blow through the straw? Answers vary.

Why are we using red to mark the Gulf Stream current? (Because it is a warm current originating at the equator.)

Why do you think this particular design is not creating an eddy? What change to your model may produce an eddy? Answers vary.

8. Allow time for clean-up. If space allows, students may store their floor models (minus the water) for discussion on Day 2. Use the last 5 minutes of class to allow students to record their final thoughts on what the purpose of today's investigation was, what they learned, and what further questions they may have. (Note: Students may jot their final thoughts down on a quarter piece of paper and hand it to the teacher as they exit the classroom. This is called the "Exit Slip.")

Day 2

1. Initiate discussion of what bathymetric designs worked (produced an eddy) and why students thought they worked. Allow 2-3 volunteers to share their successful designs using the data and diagrams in their science jotters, models stored in the plastic boxes, if available, and/or videotaped/ digitally-captured tests in action (See Extension 2). Also, allow students to share who may have been unsuccessful, but still yielded interesting results. Discuss why those designs may not have produced an eddy.

Extension 3: Each pair of students may present a short oral presentation of their investigation, including hypothesized model design, changes made to their design, description of current flow, etc.

Extension 4: Students may prepare a poster of their investigation with labeled diagrams to be used during the short oral presentation of Extension 3. The posters may then be hung in a hall display to communicate the investigation with other students and teachers in the school.

2. Produce the "Pattern for the Bathymetry of the South Atlantic Bight" on the overhead projector (Attachment 3). Have students record observations in their notebook of the ocean floor feature(s) that may be causing the Charleston Gyre. Identify the Charleston Bump. Explain briefly the importance of the Charleston Bump to the fisheries industry and the need for conservation efforts for those species that depend on this area to reproduce. For example, why there is a big push by conservationists to encourage the public to not order swordfish in local (Southeastern) restaurants. (They are being caught too young to reproduce, although the young ones may weigh 80 pounds). (See The "Me" Connection) See script provided (Last half of Attachment 2).

Extension 5: Students may investigate further the fishing regulations and the effects of conservation efforts based on studies associated with the Charleston Bump. They may make a list of fishes to avoid when ordering at restaurants (See The BRIDGE Connection).

3. Distribute Attachment 3, "Pattern of the Bathymetry of the South Atlantic Bight" (1 per pair of students). Instruct them to tape the pattern to the outside bottom of the plastic box so that it can be viewed through the bottom. (If the boxes do not have transparent bottoms, the students can design their ocean floor using the pattern and then transfer the model to the box). Using the pattern, construct the actual shape of the Charleston Bump out of aluminum foil and clay. Pour water to cover the ocean floor and use a straw to blow the origin of the Gulf Stream current as conducted on Day 1 with plastic confetti or red food dye to better mark the flow of current and the formation of the eddy. Remind students to record a diagram with labels of this model, including the flow of the current and observations in their jotter (now labeled with Day 2's date and time).

Alternate Strategy: To reduce time and materials, the teacher may decide to set up a model of the actual bathymetry of the South Atlantic Bight as a class demonstration. Or, the first class of the day may build one model per team of 4 students, and the teacher may keep those pre-built models for observation by the next classes.

4. In conclusion: Instruct students to record conclusions for this two-day investigation in their jotter. Students may copy conclusion questions from the overhead transparency or may glue the evaluation worksheet in their jotter to answer the questions in complete sentences (See Attachment 4). Remind students that every answer must be complete, thoughtful and relevant to the investigation, "In Gyre Straits." Answers not accepted are "I don't know," "doesn't apply to me," or blank spaces.

The BRIDGE Connection

http://vims.edu/bridge/archive0299.html
Swordfish on the Decline

The "Me" Connection

Explain briefly the importance of the Charleston Bump to the fisheries industry and the need for conservation efforts for those species that depend on this area to reproduce. For example, why there is a big push by conservationists to encourage the public not to order swordfish in local (Southeastern) restaurants? (They are being caught too young to reproduce, although the young ones may weigh up to 80 pounds).

Connections to Other Subjects

English/Language Arts, Oceanography, Geography, Meteorology (currents), Life Science (habitats, reproductive adaptations)

Evaluation

Observe and monitor students as they test their ocean floor models on Day 1. Use questioning to guide those who may flounder in their investigative technique.

Teacher may use an Exit Slip at the end of the first day to judge students' understanding and level of satisfaction with the investigation in order to make adjustments to the lesson.

Jotters may be turned in to the teacher for formal evaluation, especially the diagramming and data collected from the model testing on Day 1 and the evaluation of the investigation (conclusion questions) from Day 2. See suggested rubric (Attachment 5). This rubric may be used as a peer evaluation instrument before the jotter, or student journal, is turned in to the teacher. It allows students a chance to identify weaknesses and correct them in their jotter (especially useful for the first time jotters are evaluated or every time for middle schoolers.)

Students may be given a formal evaluation testing their investigative technique and conclusions drawn for this lesson.

If students produced posters and gave an oral presentation, these may also be formally evaluated.

Extensions

(These are listed in the learning procedure where appropriate to insert.)

1. Students may research what other eddies and irregularities are associated with the Gulf Stream.
2. Students adept at using PowerPoint may compile the class photos into a presentation to be shared on Day 2.
3. Each student may present a short oral presentation of their investigation including: hypothesized model design, changes made to their design, description of current flow, etc.
4. Students may prepare a poster of their investigation with labeled diagrams to be used during the short oral presentation of Extension 3. The posters may then be hung in a hall display to communicate the investigation with other students and teachers in the school.
5. Students may investigate further the fishing regulations and the effects of conservation efforts based on studies associated with the Charleston Bump. They may make a list of fish to avoid when ordering at restaurants (See The BRIDGE Connection).

Resources

Sedberry, George R., Editor. "Summary." *Island in the Stream: Oceanography and Fisheries of the Charleston Bump*. American Fisheries Society, 2001.

http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup11_bump.html, "A Profile of the Charleston Bump" by George R. Sedberry, Senior Marine Scientist, Marine Resources Research Institute, South Carolina Department of Natural Resources

http://oceanexplorer.noaa.gov/gallery/maps/maps.html#atl Gallery of maps provided by Ocean Explorer at NOAA (Original images used in the Learning Procedure came from this site)

http://www.cia.gov/cia/publications/factbook/geos/zh.html The Atlantic Ocean Fact Book - general information (Original world map came from this source.)

Menzel, David W., editor. "Cover Art." *Ocean Processes: U.S. Southeast Continental Shelf: A summary of research conducted in the South Atlantic Bight under the auspices of the US Department of Energy from 1977 to 1991*. US Department of Energy, 1993. (Cover illustration was the inspiration for the pattern of the bathymetry of the South Atlantic Bight)

http://earth.usc.edu/~stott/Catalina/Oceans.html Good explanation of gyres and ocean currents

National Science Education Standards

Science as Inquiry-Content Standard A:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Earth and Space Science-Content Standard D:
- Structure of the Earth system

Science and Technology-Content Standard E:
- Abilities of technological design (model-building)

Science in Personal & Social Perspectives-Content Standard F:
- Populations, resources, and environments

For More Information

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Acknowledgements

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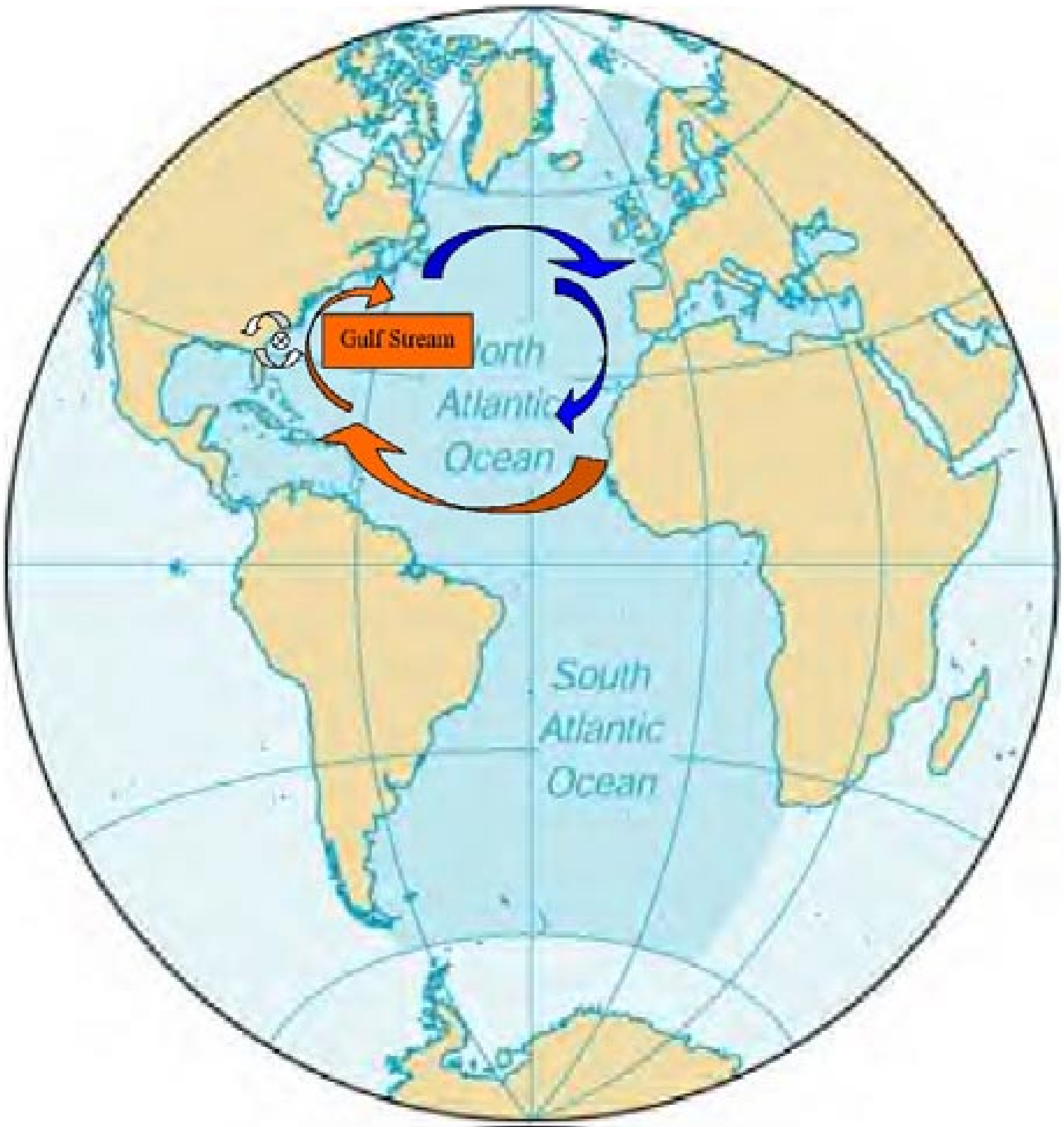
http://oceanexplorer.noaa.gov

Student Handout

Attachment 1.

Map of the North Atlantic Gyre showing the Gulf Stream current and the Charleston Gyre

From: http://www.cia.gov/cia/publications/factbook/maps/zh-map.jpg



Attachment 2.
Teacher's Script

Gyres and Eddies

Due to the influence of wind currents and the influence of the Earthís rotation (called the Coriolis Effect), the ocean currents follow a regular circular pattern in their respective ocean basins, called gyres. The oceans of the Northern Hemisphere (the northern Atlantic and Pacific ocean basins) flow in a clockwise direction, whereas the oceans of the Southern Hemisphere (the southern Atlantic and Pacific basins) flow in a counter-clockwise direction. Irregularities in the ocean floor and shape of the continental margins will affect smaller, localized areas, causing eddies to spin off from the general current flow which resemble miniature gyres.

Bathymetry

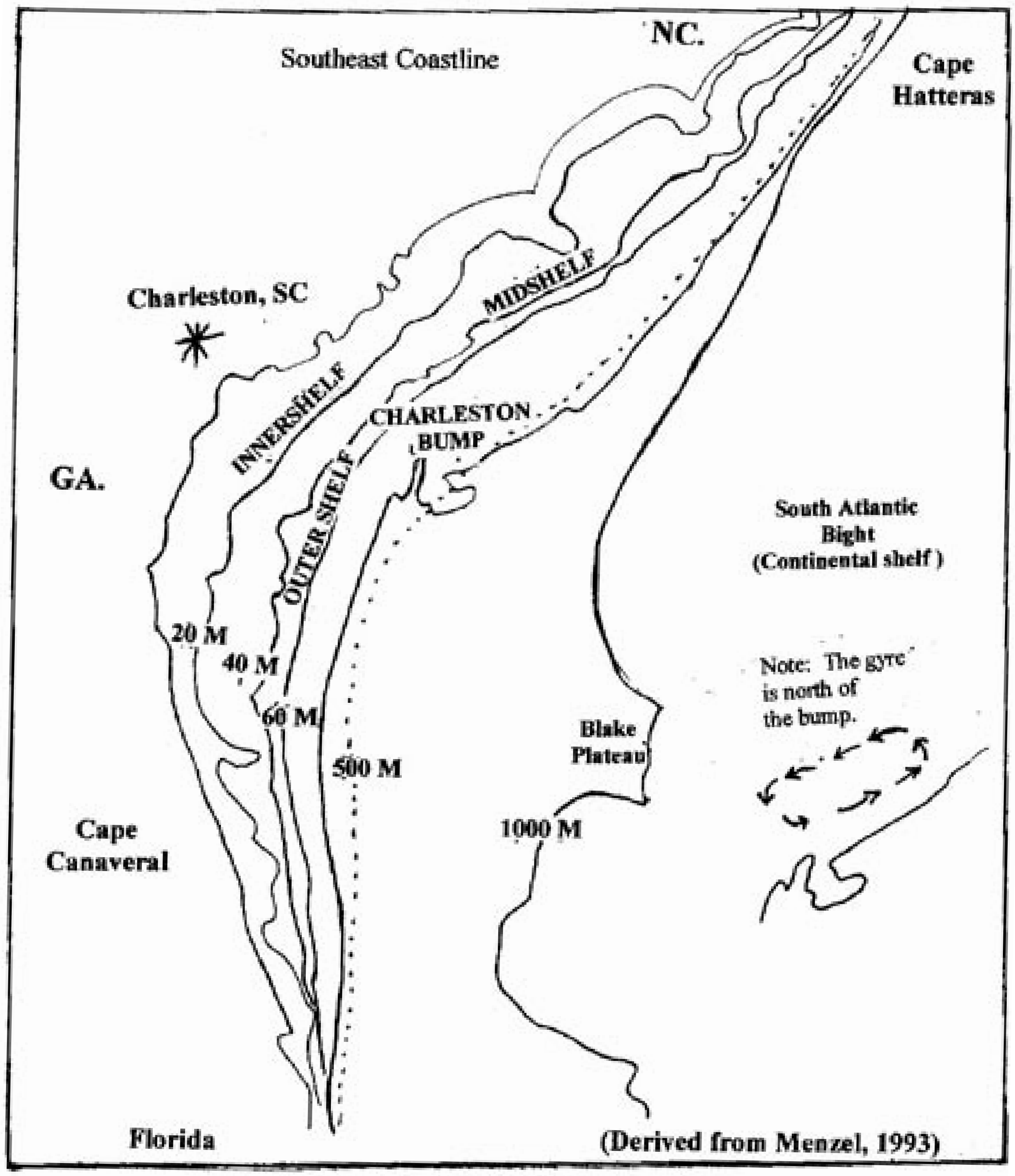
The depth differences of the ocean floor is called bathymetry. Just as the Earth's land features affect the changing elevation of the landscape, called topography, the ocean floor features will decrease depth (at underwater volcanoes or ridges) or increase depth (at underwater trenches and canyons). Irregularities in the ocean floor (geologic features) affect the flow of the ocean currents, both deep and surface currents. Mapping and studying the bathymetry of the ocean floor is one way scientists infer the causes of irregularities in ocean currents, such as the formation of the Charleston Gyre.

The Charleston Bump and the Fishery Industry

Formed by the deflection of the Gulf Stream offshore, the Charleston Gyre produces a constant process of upwelling by which nutrients are brought to shallower waters. Because of this upwelling, scientists think the Charleston Bump "may have a significant oceanographic effect on primary productivity, dispersal and retention of larval organisms, cross-shelf transport of nutrients and fauna, and life histories of fishes. The interaction of the Charleston Bump and the Gulf Stream may play a role in the recruitment of large pelagic fishes such as swordfish and other billfishes to nursery areas in the vicinity" (Sedberry, 2001). It is because of the diversity of life found at the Charleston Bump that it is one of the sites focused on by the NOAA Ocean Exploration Expedition Islands in the Stream 2002. It is through these investigations that the life cycle and reproductive strategies of certain big game fish are discovered and commercial fishing regulations are made. For example, this is one reason why there is a big push by conservationists to encourage the public to not order swordfish in local (Southeastern) restaurants. (The fish are being caught too young to reproduce, although the young ones may weigh up to 80 pounds. Before regulation, the numbers were being greatly depleted).

Student Handout

Attachment 3.
Pattern for the Bathymetry of the South Atlantic Bight



Student Handout

Attachment 4.
Conclusion Questions
(To guide students in their written evaluation of Lesson 1)

1. Of the predicted models, what was the best design that produced an eddy in your class? Why? How did it compare to yours?

2. What were the problems or inaccuracies associated even with the best model? What further improvements could have been made and how would that make the model more accurate?

3. What causes the Charleston Gyre? Why is this significant?

4. What was your favorite part of these last two days and why?

5. What was your least favorite part of these last two days and why?

6. What was the most important thing you learned from the investigation of the Charleston Gyre? Why?

7. What other questions do you have now? What else do you want to know?

8. What suggestions for improvement of the investigation or final comments would you now like to make?

Student Handout

Attachment 5.
Rubric for Evaluation of Student Jotter

Whole Jotter (peer evaluation) Overall: Super ❍ Needs Work ❍ Missing ❍

Super ❍
Needs Work ❍
Missing ❍

Cover
1st and last name
Date
Title
Partner's name
Illustration (optional)

Super ❍
Needs Work ❍
Missing ❍

Table of Contents
Inside front cover
Pages numbered in order
No pages skipped in jotter

Sections
(Each new day is dated labeled clearly.)

Super ❍
Needs Work ❍
Missing ❍

I. Gyres and Eddies
(North Atlantic Gyre diagram and description, Charleston Gyre description, definition of gyres and eddies, further questions, hypothesis of cause of Charleston Gyre and brief identification of bathymetry)

Super ❍
Needs Work ❍
Missing ❍

II. Bathymetry Beneath Charleston Gyre Investigation
(Diagram depicting predicted bathymetry, labeled diagrams in colored pencil of model with resulting current, recorded changes in model and resultant current, final thoughts if not turned in as an exit slip)

Super ❍
Needs Work ❍
Missing ❍

III. What the Bathymetry Really Looks Like
(Diagram of actual bathymetry, explanation of significance of Charleston Bump, observations and labeled diagram of model based on given pattern-whether observed as a class, team or partners)

Super ❍
Needs Work ❍
Missing ❍

IV. Conclusions
(All 8 questions answered in complete sentences)