OCEAN EXPLORATION

Investigation: Seamounts and Biological Productivity

Overview

TOPIC: Seamounts

FOCUS: Students analyze data and use models to make sense of the role seamounts have in increasing productivity in overlying and surrounding ocean waters.

GRADE LEVEL: 9th-12th

TIME NEEDED: Two 45-50 minute class periods (plus additional time for optional extensions)

PHENOMENON (DRIVING QUESTION) How do seamounts establish areas of enhanced biological productivity?

OBJECTIVES/ LEARNING OUTCOMES: Students will:

- Analyze data and use models to explain how seamounts lead to patterns of enhanced biological productivity.
- Evaluate merits and limitations of different models to determine how well they represent patterns of ocean currents around seamounts.

MATERIALS: Seamount Slides (project for the class or print as handouts for students)

- Slide 1: Seamount-induced chlorophyll enhancements (satellite data)
- Slide 2: Measuring Currents
- Slide 3: 3D Diagram of Fieberling Guyot Circulation Cell
- ***Slide 4: Optional extension: Biogeophysical drivers of Seamount-Induced Chlorophyll Enhancements***

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectation (PEs)
HS-ESS2-7

Disciplinary Core Ideas (DCIs)
HS-ESS2-E Biogeology

Crosscutting Concepts (CCs)
Patterns
Cause and Effect
Systems and System Models

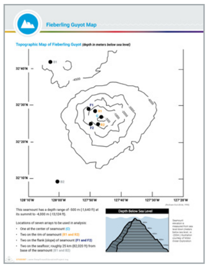
Science & Engineering Practices (SEPs)
Analyzing and Interpreting Data
Developing and Using Models

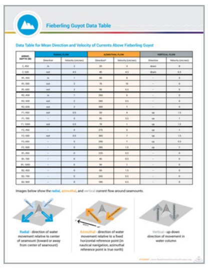
COMMON CORE CONNECTIONS
ELA/Literacy - WHST.9-12.1

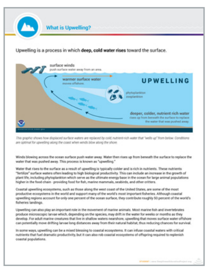
OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
Principle 5: FC f

Overview cont.

MATERIALS cont:







Student Handouts (one per group, print or share digital copies)
- Fieberling Guyot Map
- Fieberling Guyot Data Table
- What is Upwelling? (one per student)

Videos
- Exploring the Deep Waters of American Samoa (3:41) ***NOAA Ocean Exploration***
- Tenants of Titov Seamount (1:17) ***NOAA Ocean Exploration***

Physical Simulation of Seamount Induced Currents
(teacher demonstration or small group activity)

Materials for one set-up:
- 7 quart / 6.6 L, clear plastic storage tub
- 16oz / 500ml laboratory wash bottle
- ~3-4 L warm tap water for storage tub
- ice-cold water to fill wash bottles
- blue food coloring
- modeling clay
- white backdrop
- drill with bit or hot nail that matches size of wash bottle nozzle
- tray to catch spills

Optional: Video Demonstration of Seamount Induced Currents (if physical simulation is not possible):
- Deep, Cold Current Without Seamount demonstration (0:38) ***NOAA Ocean Exploration***
- Deep, Cold Current With Seamount demonstration (0:39) ***NOAA Ocean Exploration***

EQUIPMENT:
- Computer and projector for class viewing of videos and slides or online sharing capability
- White board and dry erase marker or online platform to record class findings
- Student notebooks for students to record their observations, questions, and explanations
- ***Optional: Student laptops or tablets for extensions and/or additional research***

SET-UP INSTRUCTIONS: **For online learning:**
- Share links or digital copies of all materials listed above with students using a preferred online platform.

For in-person instruction:
- Cue up all videos and slides for student viewing.
- ***If projecting these for the class is not an option, print or share digital copies with students.***

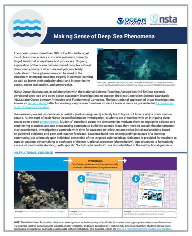
Educator Guide

Background

Seamounts represent some of Earth's tallest peaks, unexplored territories, and critical habitats supporting important fisheries across the globe. Many seamounts sustain diverse ecological communities and support surprising levels of biological productivity in nearby waters. Scientists continue to study how these rugged underwater mountains formed by volcanic processes can support diverse and productive ecosystems while surrounded by largely barren abyssal plains. Students will apply the phenomenon of upwelling of deep ocean water to coastal areas to determine how the presence of seamounts in the deep ocean can lead to enhanced biological productivity.

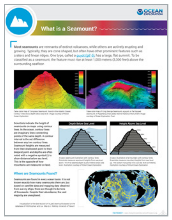
Educator Note

- Students should be familiar with photosynthesis and the factors affecting the process, upwelling processes, biodiversity/biological productivity, and seafloor topography. Fact Sheets can be used as a resource.
- A variety of student interaction techniques and examples of student questions are provided throughout this activity to engage students in the process of sensemaking to move their learning forward.
- Learn more about the instructional strategies and tools included in the NOAA Ocean Exploration student investigations.

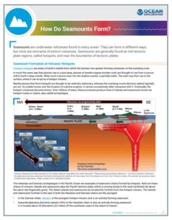


FOR MORE INFORMATION:

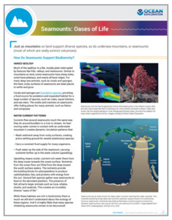
- ***What is a Seamount?*** ***Fact Sheet***



- ***How Do Seamounts Form?*** ***Fact Sheet***



- ***Seamounts: Oases of Life*** ***Fact Sheet***



Experience the Phenomenon

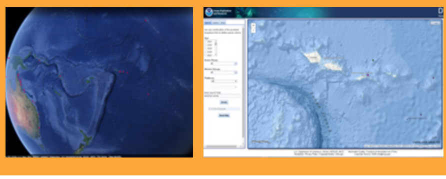
Inform students you will be sharing a phenomenon that occurs throughout the ocean with a focus on an area of the Pacific Ocean roughly centered around American Samoa. Then, use a world map to show students the location of American Samoa.

Now, **tell** students they are going to hear from one of the scientists who worked on a 2017 NOAA expedition that explored seamounts around American Samoa. Show a segment of Exploring the Deep Waters of American Samoa and pause at **2:16 minutes**.

Let students know that other scientific teams have studied many seamounts in a large area of the Pacific Ocean that includes American Samoa, and that the class is going to look at some data that was collected by those teams.

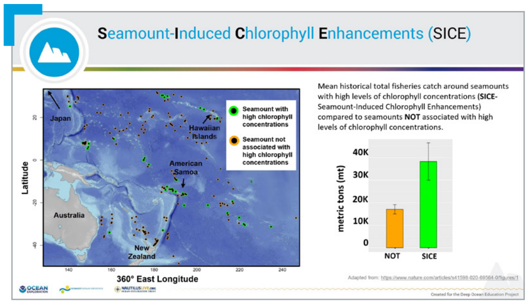
LEARN MORE

Try using Google Earth or the NOAA Ocean Exploration Digital Atlas.



Video courtesy of NOAA Ocean Exploration.

Educator Guide cont.



Experience the Phenomenon cont.

Project Slide 1. Seamount-induced chlorophyll enhancements and ask students to share what they notice about the figure and accompanying text. Point out the place names provided on the map to help them get a sense of the area that was studied.

Use student observations to highlight the important features of the slide without giving away patterns or providing any explanation for the phenomenon. Once students have gotten oriented to the map and major features of the figure, ask them what patterns they observe. Have students share patterns with a partner and then with the whole class.

Some patterns students might notice include the following:

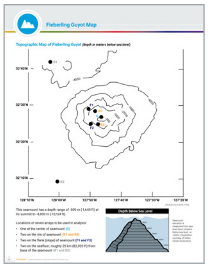
- ***Seamounts appear to occur in clumps or linear groupings.***
- ***There seem to be more orange circles than green circles.***
- ***Seamounts occur both adjacent to and far from landmasses.***
- ***Green and orange circles can be directly next to each other.***
- ***More fish are caught near seamounts associated with enhanced chlorophyll levels.***

Ask students to think about questions they have about the patterns the class has observed. Have students record and share questions with a partner and then with the whole class. Students may ask a variety of questions, but they will likely focus on why some seamounts are associated with higher levels of chlorophyll and how that leads to more fish being caught.

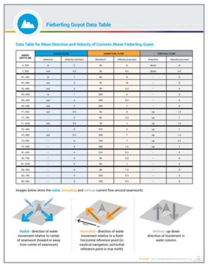
Ask the students, ***"What is needed for chlorophyll concentrations to be higher like they are near some of these seamounts?"*** If needed, you can prompt students to think about the process that uses chlorophyll (photosynthesis) and the factors that would increase the rate of that process. Students might suggest factors like sunlight, warm temperatures, carbon dioxide, and nutrients. Assuming students have previously studied coastal upwelling, then they will likely connect the seamount phenomenon to that one. In that case, ask students what data they might need to determine if upwelling occurs around some seamounts.

Investigate

Analyzing Data and Evaluating Models



Tell students they will analyze a data set collected from a study in which direct measurements of currents were taken at various points on and around the seamount over a one-year period. This data was used to discover how water moves around seamounts. Show Slide 2. Measuring Currents to explain how the current measurements were taken.



Share the Fieberling Guyot Map and Fieberling Guyot Data Table. Ask students to analyze and ask questions about how the key features of the topographic map correspond to the data table. You might prompt students with the questions, ***"What information is this conveying? What do we need to know to make sense of it?"*** Use student observations and questions to help the class understand the nature of the data.

Educator Guide cont.

Analyzing Data and Evaluating Models cont.

Ask students to identify patterns in the data. Possible patterns that students might identify include:

- ***Water moves up along the sides of the seamount flanks (F1 and F2) but down at the top (C).***
- ***At locations C, R1, and R2 water moves in at shallower depths and out at deeper depths.***
- ***Water is moving in different azimuthal directions at different locations and depths.***
- ***At stations B1 and B2, currents are weak, with no definite movement in any of the three directions.***
- ***No pattern can be determined.***

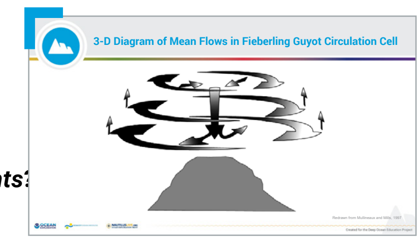
Students are likely to note that there is not a simple pattern. You might prompt students by asking them to try and describe the overall flow of water near the seamount or by asking, ***"How can we explain that the water is moving in different directions at different points?"*** This might help students visualize that the water is circulating, but you do not need to push this idea at this point. It will become apparent as students look at various models.

Ask students, ***"What are some ways that we could visualize these data to help us better understand how the water is moving?"*** You can create a class-wide T-chart comparing the pros and cons of each suggested model. For each suggestion students make, ask the following:

- ***What are some benefits of your proposed models?***
- ***What are the limitations of these models?***

Share and discuss the following models.

- Slide 3. Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell
- Physical Simulation (see below)



For each model, have students consider and discuss the following questions. Track student ideas about each model on a class chart or whiteboard.

- ***What new information or insight does this model provide?***
- ***How does this model help us better understand how ocean currents move around seamounts?***
- ***How is this model limited? How could it be improved?***

Using a Physical Simulation Model

This simple physical simulation shows what happens when deep ocean currents interact with seamounts. Demonstrate this simulation as a whole-class or have students conduct it in small groups.

- ***For each simulation setup, you will need a clear plastic storage tub, a laboratory wash bottle, warm tap water, ice-cold water, blue food coloring, modeling clay, and a white backdrop.***
- ***Use a drill or hot nail to create a hole in the tub that matches the size of the wash bottle nozzle. If needed, use modeling clay to create a seal.***
- ***Build a seamount out of the modeling clay.***
- ***Demo 1: Fill the plastic tub about halfway with warm tap water and the wash bottle with ice-cold water and a few drops of blue food coloring.***
  - ***Squeeze the ice-cold (blue) water from the wash bottle into the hole, and have students observe and record what happens to the stream of water.***
- ***Demo 2: Place the clay seamount model in the center of the plastic tub of clear warm water.***
  - ***Squeeze the ice-cold blue water from the wash bottle into the hole and have students observe and record what happens to the stream of water as it comes in contact with the seamount.***

Student observations may include the following:

- ***When a seamount is not present, the cold, blue water (deep ocean current) flows into the warm, clear water slowly and stays at the bottom.***
- ***When a seamount is present, the cold, blue water (deep ocean current) flows in and covers the seamount. The blue water flows in various directions around the seamount, spreading out more quickly through the warm, clear water versus the demonstration with no seamount.***

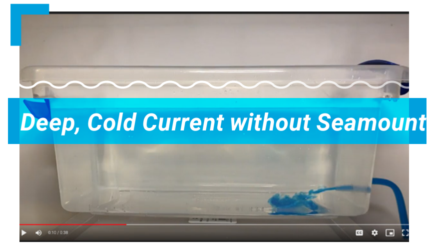
Current flow demo model setup.

Educator Guide cont.

Using a Physical Model cont.

LEARN MORE

Optional: Video demonstrations of deep, cold current flows with and without a seamount can be used if the physical simulation is not possible.



Video courtesy of NOAA Ocean Exploration.

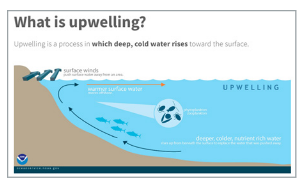
Video courtesy of NOAA Ocean Exploration.

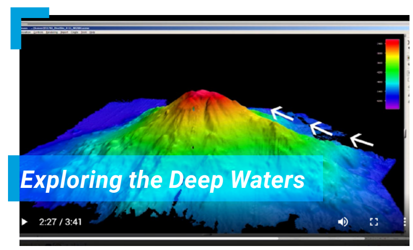
After sharing the simulation with students, have them share their observations and questions. Then, ask and discuss the following questions:

- ***How is this simulation similar to and different from Slide 3. Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell?***
- ***How do you think this simulation is similar to and different from reality?***
- ***What do these models help us figure out about currents around seamounts and their effect on biodiversity?***

Put the Pieces Together

Watch the remainder of the Exploring the Deep Waters of American Samoa video **(2:17-3:41 minutes)**. Say to students, "So, Dr. Herrera confirms what we were thinking. A type of upwelling can occur at some seamounts. Let's remind ourselves how upwelling leads to more photosynthesis and more fish." Have students read What is Upwelling?. Then, let them see the resulting biodiversity on seamounts by showing this video: Tenants of Titov Seamount.





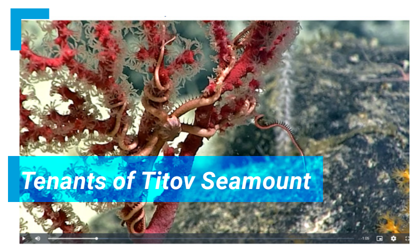
Video courtesy of NOAA Ocean Exploration.

Say to students:

We saw incredible biodiversity in that video, and we heard Dr. Herrera say that we can think of seamounts as hotspots of biodiversity. Why is that so important?

Conclude the lesson by asking students to respond to the following writing prompt.

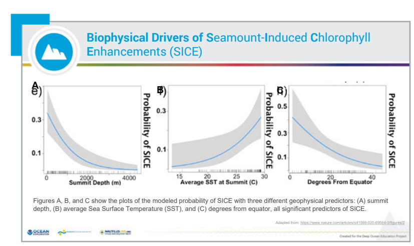
Seamount ecosystems form through unique interactions among the geosphere, hydrosphere, and biosphere. Use what you have learned to explain why seamounts are such unique ecosystems and why it is important to understand them.



Video courtesy of NOAA Ocean Exploration.

Extension

- Have your students explore the question of why not all seamounts are associated with higher levels of productivity. The scientists who conducted the Evidence for long-term seamount-induced chlorophyll study of Pacific Seamounts looked at three factors: ***summit depth, average sea surface temperature at the summit, and degrees from the equator***.



- **Use** Slide 4. Biogeophysical drivers of seamount-induced chlorophyll enhancements to help students understand how those three factors influenced productivity. Challenge students to explain the patterns shown in the data and to think of additional factors that might affect which seamounts are associated with enhanced productivity.

Educator Guide cont.

Scientific Terms

Biodiversity: The variety of organisms found within an ecosystem.

Biological productivity: The rate at which energy is converted into organic substances or biomass.

Chlorophyll: The green pigment that plants and algae use to make food during photosynthesis.

Seamount: An undersea mountain-like formation created by volcanic activity (but can form in different ways) with a peak that does not rise to the ocean surface.

Upwelling: A process in which deep, cold, typically nutrient-rich sea water rises toward the surface.

Assessment

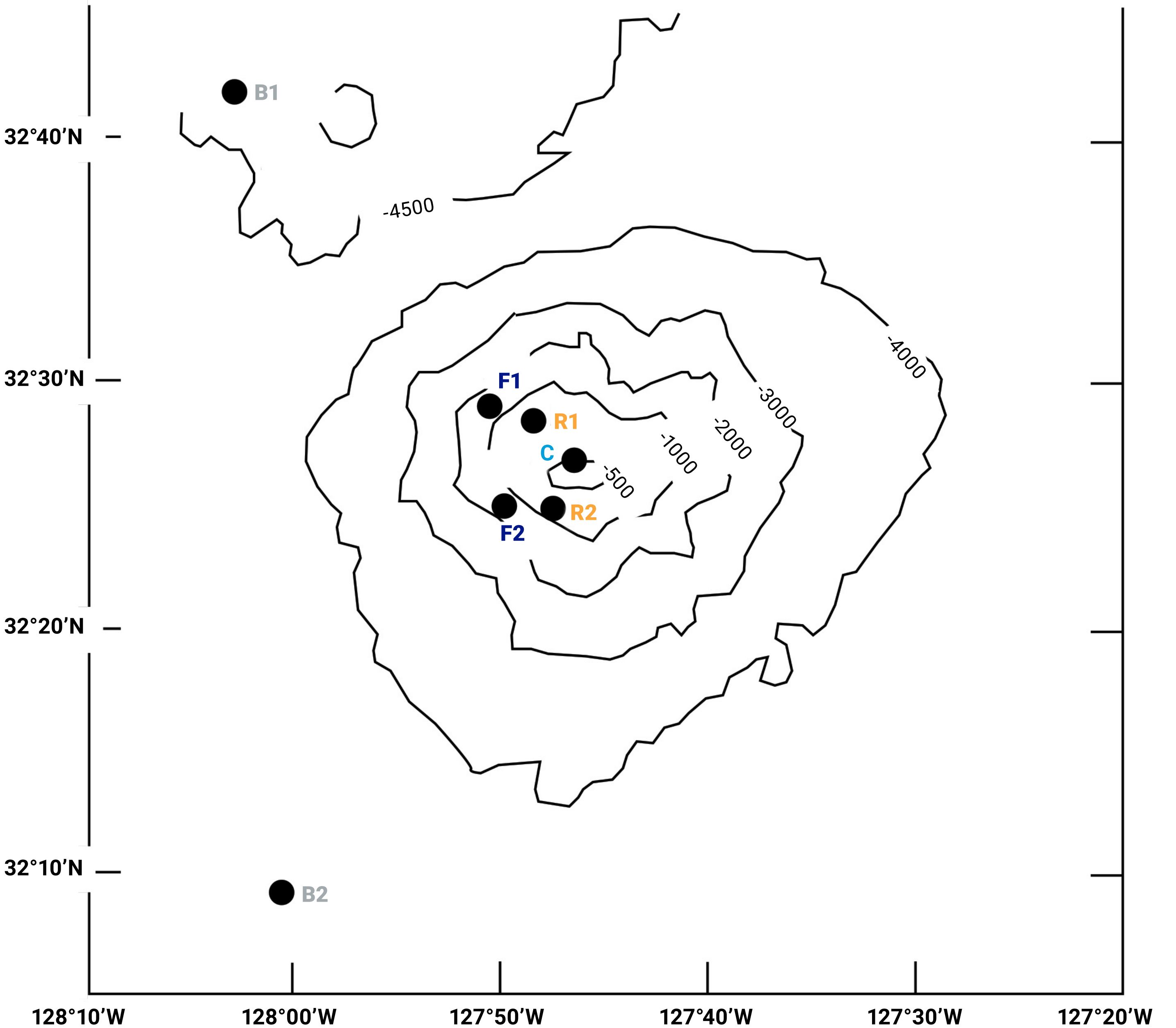
Opportunities for formative assessment are embedded throughout the lesson. The student explanations that are developed at the end of the lesson could be used as an opportunity for summative assessment of learning.

LOOK FORS:

The following components should be included in students' final explanations.

- Seamounts are underwater mountains that are formed through volcanic activity and do not reach the ocean surface.
- Seamounts represent underwater "islands" in the abyssal plain. The thick sediments along the abyssal plain are not suitable habitat for most organisms, but the rocky surfaces of seamounts provide attachment points for many filter-feeding animals, like corals and sponges.
- Seamounts disrupt the flow of deep ocean currents, causing cold water from the aphotic zone ("without light") of the water column to flow upward and mix with water closer to the surface.
- This deep, cold water often contains high levels of nutrients.
- When this nutrient-rich water flows high enough to reach the photic zone, it promotes the growth of phytoplankton that carry out photosynthesis. This leads to higher concentrations of chlorophyll.
- These phytoplankton serve as the basis of a food web that supports organisms on the slopes of the seamount and fishes and other organisms that live around or travel to the seamount.
- Seamounts provide habitats that are unlike any others on Earth. Many organisms can be found only on seamounts, and seamount ecosystems support fish populations that are important sources of human food.

Topographic Map of Fieberling Guyot *(depth in meters below sea level)*

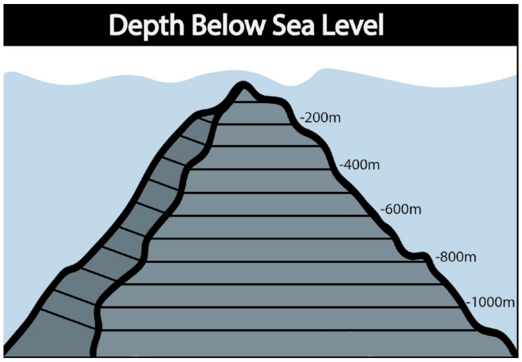


(Redrawn from Brink, 1995)

This seamount has a depth range of -500 m (-1,640 ft) at its summit to -4,000 m (-13,124 ft).

Locations of seven arrays to be used in analysis:

- One at the center of seamount **(C)**
- Two on the rim of seamount **(R1 and R2)**
- Two on the flank (slope) of seamount **(F1 and F2)**
- Two on the seafloor; roughly 25 km (82,020 ft) from base of the seamount **(B1 and B2)**



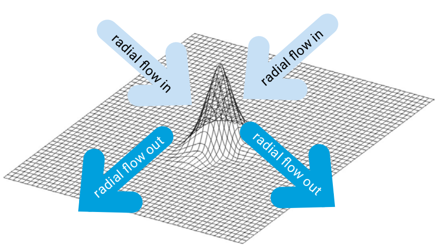
Seamount elevation is measured from sea level down (meters below sea level, i.e. -200m.) *Illustration courtesy of NOAA Ocean Exploration.*

Data Table for Mean Direction and Velocity of Currents Above Fieberling Guyot

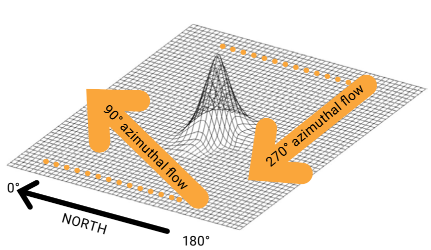
ARRAY, DEPTH (M)	RADIAL FLOW		AZIMUTHAL FLOW		VERTICAL FLOW	
	Direction	Velocity (cm/sec)	Direction*	Velocity (cm/sec)	Direction	Velocity (cm/sec)
C, -450	in	2	20	4	down	8
C, -500	out	4.5	45	4.5	down	6.5
R1, -450	in	1	60	8	–	0
R1, -500	out	2	76	10	–	0
R1, -600	out	3	90	6.5	–	0
R2, -450	in	1	290	6	–	0
R2, -500	out	2	280	9.5	–	0
R2, -600	out	3	300	7	–	0
F1, -450	out	0.5	50	4	up	1.5
F1, -700	–	0	85	3.5	up	1
F1, -1000	out	0.5	78	1	up	1.5
F2, -450	–	0	275	5	up	1
F2, -500	out	0.5	300	7	up	1.5
F2, -650	–	0	290	7	up	0.5
F2, -900	–	0	285	1.5	up	1
B1, -450	–	0	220	0.5	–	0
B1, -700	–	0	45	0.5	–	0
B1, -1000	–	0	90	1	–	0
B2, -450	–	0	60	1.5	–	0
B2, -700	–	0	265	0.5	–	0
B2, -900	–	0	180	0.5	–	0

***** Degrees clockwise from true north*

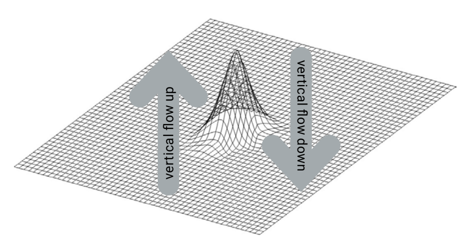
Images below show the radial, azimuthal, and vertical current flow around seamounts.



Radial - direction of water movement relative to center of seamount (toward or away from center of seamount)



Azimuthal - direction of water movement relative to a fixed horizontal reference point (in nautical navigation, azimuthal reference point is true north)



Vertical - up-down direction of movement in water column

Seamounts

Page 1:
- Seamount Slides (pdf): https://oceanexplorer.noaa.gov/edu/materials/seamount-slides.pdf

Page 2:
- What is Upwelling? (pdf): https://oceanexplorer.noaa.gov/edu/materials/upwelling-information-handout.pdf
- Exploring the Deep Waters of American Samoa (3:41) (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/dailyupdates/media/video/exploring_as/exploring_640x360.mp4?640
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- Deep, Cold Current With Seamount demonstration (0:39) (video): https://oceanexplorer.noaa.gov/edu/materials/current-demo-with-seamount.mp4

Page 3:
- Making Sense of Deep-Sea Phenomena (pdf): https://oceanexplorer.noaa.gov/edu/materials/NOAA-NSTA-sensemaking-phenomenon.pdf
- What is a Seamount? (fact sheet): https://oceanexplorer.noaa.gov/edu/materials/what-is-a-seamount-fact-sheet.pdf
- How Do Seamounts Form? (fact sheet): https://oceanexplorer.noaa.gov/edu/materials/how-seamounts-form-fact-sheet.pdf
- Seamounts: Oases of Life (fact sheet): https://oceanexplorer.noaa.gov/edu/materials/seamounts-oases-of-life-fact-sheet.pdf
- Google Earth (webpage): https://earth.google.com/web/
- NOAA Ocean Exploration Digital Atlas (webpage): https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm
- Exploring the Deep Waters of American Samoa (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/dailyupdates/media/video/exploring_as/exploring_640x360.mp4?640

Page 4:
- Slide 1. Seamount-induced chlorophyll enhancements: https://oceanexplorer.noaa.gov/edu/materials/seamount-slides.pdf
- Slide 2: Measuring Currents: https://oceanexplorer.noaa.gov/edu/materials/seamount-slides.pdf

Page 5:
- Slide 3. Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell (slides): https://oceanexplorer.noaa.gov/edu/materials/seamount-induced-currents.pdf
- Current flow demo model (photo): https://oceanexplorer.noaa.gov/edu/materials/current-flow-demo-setup-seamount.jpg

Page 6:
- Deep, Cold Current Without Seamount (video): https://oceanexplorer.noaa.gov/edu/materials/current-demo-without-seamount.mp4
- Deep, Cold Current With Seamount (video): https://oceanexplorer.noaa.gov/edu/materials/current-demo-with-seamount.mp4
- Slide 3. Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell (slides): https://oceanexplorer.noaa.gov/edu/materials/seamount-slides.pdf
- Exploring the Deep Waters of American Samoa (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/dailyupdates/media/video/exploring_as/exploring_640x360.mp4?640
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- Tenants of Titov Seamount (video): https://oceanexplorer.noaa.gov/video_playlist/titov.html
- Evidence for long-term seamount-induced chlorophyll enhancements (webpage): https://www.nature.com/articles/s41598-020-69564-0
- Slide 4: Biogeophysical drivers of seamount-induced chlorophyll enhancements (slides): https://oceanexplorer.noaa.gov/edu/materials/seamount-slides.pdf

Page 8:
- Seamount elevation (diagram): https://oceanexplorer.noaa.gov/edu/materials/seamount-contour-lines-illustration.jpg

Partners

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