

INDEX/SATAL 2010

Tools of Exploration: Multibeam



Image captions/credits on Page 2.

lesson plan

Focus

Multibeam sonar

Grade Level

9-12 (Earth Science/Physical Science/Technology)

Focus Question

How does multibeam sonar help explore Earth's deep ocean?

Learning Objectives

- Students will be able to describe multibeam sonar.
- Students will be able to discuss the advantages of multibeam sonar bathymetry compared to two-dimensional topographic bathymetry.
- Students will be able to interpret three-dimensional multibeam bathymetric data.

Materials

- Copies of the *Introduction to Multibeam Imagery Worksheet*, one copy for each student group

Audio-Visual Materials

- Video projector or large screen monitor for showing downloaded videos (see Learning Procedure, Step 3)

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

30

Key Words

Multibeam Sonar
Bathymetric Survey

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this



The NOAA Ship *Okeanos Explorer*

Formerly: USNS *Capable*
 Launched: October 28, 1988
 Transferred to NOAA: September 10, 2004
 Commissioned: August 13, 2008
 Class: T-AGOS
 Length: 224 feet
 Breadth: 43 feet
 Draft: 15 feet
 Displacement: 2,298.3 metric tons
 Berthing: 46 (19 Mission/science)
 Speed: 10 knots
 Range: 9600 nm
 Endurance: 40 days

Systems and Instrumentation:

Kongsberg EM302 Multibeam rated to
 7,000 m
 SBE 911 Plus CTD
 ROVs -
 Little Hercules - 4,000 m depth rating;
 USBL tracking; depth, altitude,
 attitude/heading sensors; Seabird SBE
 49 FastCat CTD; HD camera and HMI
 lights
 Camera platform with depth/altitude/
 heading sensors, HD camera and HMI
 lights.
 Telepresence

Operations:

Ship crewed by NOAA Commissioned Officer
 Corps and civilians through NOAA's
 Office of Marine and Aviation Operations;
 Mission equipment operated by NOAA's
 Office of Ocean Exploration and Research

For more information, visit <http://oceanexplorer.noaa.gov/okeanos/welcome.html>.

Images from Page 1 top to bottom:

The ROV Hercules being lowered into the water from the NOAA Ship *Okeanos Explorer*. Image credit: NOAA OER.

NOAA scientists examining live video feed from the ROV Hercules. Image credit: NOAA OER.

Mussels, shrimp, limpets, and crabs cover the slope of an underwater volcano near a hydrothermal vent. Image credit NOAA
<http://www.photolib.noaa.gov/bigs/expl0071.jpg>

Black smokers on the Kermadec Arc. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration, NOAA Vents Program, the Institute of Geological & Nuclear Sciences and NOAA-OE.
http://oceanexplorer.noaa.gov/explorations/07fire/logs/july31/media/brothers_blacksmoker_600.jpg

material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

During the summer of 2010, scientists from Indonesia and the United States will work together on an expedition to explore the deep ocean surrounding Indonesia. This mission is called INDEX/SATAL 2010, since the expedition is focussed on INDonesia, EXploration, and the Sangihe Talaud (SATAL) region. Working from the Indonesian Research Vessel *Baruna Jaya IV* and the NOAA Ship *Okeanos Explorer*, these ocean explorers expect to find new deep-sea ecosystems, undiscovered geological features, and living organisms that have never been seen before. New discoveries are always exciting to scientists; but information from ocean exploration is important to everyone, because:

- Biodiversity in deep-sea ecosystems includes new species that can provide important drugs and other useful products;
- Some deep-sea ecosystems include organisms that can be used for human food;
- Information from deep ocean exploration can help predict earthquakes and tsunamis; and
- Human benefits from deep ocean systems are being affected by changes in Earth's climate and atmosphere.

A major objective of the INDEX/SATAL 2010 expedition is to locate submarine volcanoes, hydrothermal vents, chemosynthetic ecosystems, and seamounts associated with active geologic processes in Indonesia's deep sea. The primary strategy used aboard the *Okeanos Explorer* to find these kinds of features involves searching for anomalies; conditions that are different from the surrounding environment. Changes in chemical properties of seawater, for example, can indicate the presence of underwater volcanic activity, hydrothermal vents, and chemosynthetic communities. This strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Multibeam sonar is a key technological capability aboard the *Okeanos Explorer* that is involved in all three of these activities.

Sonar (which is short for SOund NAVigation and Ranging) systems are used to determine water depth, as well as to locate and identify underwater objects. In use, an acoustic signal or pulse of sound is transmitted into the water by a sort of underwater speaker known as a transducer. The transducer may be mounted on the hull of a ship, or may be towed in a container called a towfish. If the seafloor or other object is in the path of the sound pulse, the sound bounces off the object and returns an "echo" to the sonar transducer. The time elapsed between the emission of the sound pulse and the reception of the echo is used to calculate the distance of the object. Some sonar systems also

measure the strength of the echo, and this information can be used to make inferences about some of the reflecting object's characteristics. Hard objects, for example, produce stronger echoes than softer objects. This is a general description of "active sonar." "Passive sonar" systems do not transmit sound pulses. Instead, they "listen" to sounds emitted from marine animals, ships, and other sources.

Multibeam sonar is one of the most powerful tools available for modern deep sea exploration. A multibeam system uses multiple transducers pointing at different angles on either side of a ship to create a swath of signals. The *Okeanos Explorer* is equipped with a Kongsberg Simrad EM 302 multibeam system that can produce up to 864 depth soundings in a single swath, and over 10 swaths per second. The time interval between signal transmission and return echo arrival is used to estimate depth over the area of the swath. In some systems, the intensity of the return echo is also used to infer bottom characteristics that can be used for habitat mapping. In addition to high-resolution maps, multibeam data can be used to create three dimensional models or even "fly-by" videos that simulate a trip across the area being mapped. For a fascinating example of this, see <http://oceanexplorer.noaa.gov/explorations/02fire/logs/jul08/media/sm2k.html>. This 3D fly-through movie shows the seafloor in the Magic Mountain area of Explorer Ridge (near the coast of Victoria, British Columbia) where there are active hydrothermal vents. To see what the vents look like, you can view other fly-throughs of the same area at <http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain>. Recently, a new generation of multibeam sonars has been developed that are able to map features in the water column as well as the seafloor. This ability will potentially allow multibeam sonars to map the location of fish and marine mammals, as well as a wide range of physical oceanographic processes. For more information about sonar systems, see <http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html>.

An important technique for studying multibeam images uses a 3D data visualization system called Fledermaus (which is the German word for "bat," and is pronounced "FLEE-der-mouse"). This lesson introduces students to multibeam technology and simple analysis of multibeam data using free viewing software for multibeam imagery in the Fledermaus file format. In the future, students will have the opportunity to apply their analytic skills to investigate new multibeam images as the *Okeanos Explorer* continues its voyages of discovery in Earth's deep ocean.

[Note: mention of proprietary names does not imply endorsement by NOAA.]

Learning Procedure

NOTE: Depending upon available time and instructional objectives, educators may want to have students complete the topographic mapping exercise described in "Mapping the Deep Ocean Floor" (<http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/mapping.pdf>).

In this exercise, students construct a three-dimensional topographic model from bathymetric soundings. The resulting model has much less detail than the multibeam image of the same area used in this lesson, which underscores the value of multibeam technology and illustrates the extent to which this technology has enhanced our ability to explore the deep ocean.

1. To prepare for this lesson:
 - (a) Review introductory essays for the INDEX/SATAL 2010 Expedition at <http://oceanexplorer.noaa.gov/oceanos/explorations/10index/welcome.html>
 - (b) Review information about the importance of deep ocean exploration in the Background section of the *Earth's Ocean is 95% Unexplored: So What?* lesson;
 - (c) Review background information on multibeam sonar technology and questions on the *Introduction to Multibeam Imagery Worksheet* and make copies of the Worksheet for each student group.
 - (d) Download the iView4D software from <http://www.ivs3d.com/products/iview3d/>, and Download the data file EX0903_mb_1.sd from http://oceanexplorer.noaa.gov/oceanos/edu/resources/media/ex0903_mb_1.sd and install these on computers that students will be using to complete the Worksheet activity. Alternatively, you may have students download these resources onto their own computers.
 - (e) Download or bookmark the video (http://ccom.unh.edu/NOAA_oceanexploration/PlumePoints2.mov) referenced in Step 3.
2. Briefly introduce the INDEX/SATAL 2010 Expedition, and point out that this expedition is the maiden voyage of the *Okeanos Explorer*, which is the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean for the purposes of discovery and the advancement of knowledge. Ask students for their ideas about why this kind of exploration might be important, and highlight some of the reasons referenced in Step 1b. Be sure students understand that discoveries of deep sea chemosynthetic communities during the last 30 years are major scientific events that have changed many assumptions about life in the ocean and have opened up many new fields of scientific investigation.

Review the overall exploration strategy used by *Okeanos Explorer*, highlighting the concept of finding anomalies, and that this strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties “from top to bottom” while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

Key technologies involved with this strategy include:

- Multibeam sonar mapping system;
- CTD and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery in depths as great as 4,000 meters.

A fourth technological capability that is essential to the *Okeanos Explorer* exploration strategy is advanced broadband satellite communication. This capability provides the foundation for “telepresence” technologies that enable people to observe and interact with events at a remote location. Telepresence allows live images to be transmitted from the seafloor to scientists ashore, classrooms, newsrooms and living rooms, and opens new educational opportunities that are a major part of *Okeanos Explorer’s* mission for advancement of knowledge. In addition, telepresence makes it possible for shipboard equipment to be controlled by scientists in shore-based Exploration Command Centers. In this way, scientific expertise can be brought to the exploration team as soon as discoveries are made, and at a fraction of the cost of traditional oceanographic expeditions.

3. Ask students what they know about sonar, and provide additional information as necessary. Be sure students understand that sonar uses acoustic signals or pulses of sound that are transmitted into the water by a transducer, which may be mounted on the hull of a ship or towed in a container called a towfish. If the seafloor or other object is in the path of the sound pulse, the sound bounces off the object and

returns an “echo” to the sonar transducer. The time elapsed between the emission of the sound pulse and the reception of the echo is used to calculate the distance of the object. Multibeam sonar systems use multiple transducers pointing at different angles on either side of a ship to create a swath of signals.

Tell students that on May 17, 2009, the *Okeanos Explorer* was testing its multibeam sonar mapping system off the coast of California. Suddenly, the multibeam image showed a plume of gas bubbles rising vertically 1000 meters from the ocean floor. No such feature had ever been reported from this area before. Show students a video simulation (http://ccom.unh.edu/NOAA_oceanexploration/PlumePoints2.mov) that shows how multibeam sonar discovered this plume, and also provides a graphic overview of how multibeam works. In the first part of the video, *Okeanos Explorer* is travelling toward us from the top of the screen along the white line which represents the course of the ship. The swath of multibeam sonar signals radiates from either side of the ship in shades of blue and green. As the video continues, the viewing angle moves around the starboard (right) side of the ship until we are looking toward the stern of the vessel as it moves away from us. Now we can see the plume rising from the bottom of the “amphitheater.” In the last segment of the video, the viewing angle continues to pan around the plume. When the angle is perpendicular to the track of *Okeanos Explorer*, we can see the segments of the multibeam image, sort of like slices of an onion, each produced by a single cycle of pulses from the multibeam transducers. The assembled “slices” produce the three dimensional image of the plume.

4. Provide each student group with a copy of the *Introduction to Multibeam Imagery Worksheet*, and ensure that students have access to the software and file referenced in Step 1d. Tell students that this activity is intended to familiarize them with multibeam imagery and how it can be manipulated to answer basic questions about features on the ocean floor. You may also want to mention that this skill will allow them to investigate additional images that will be available from future *Okeanos Explorer* missions.
5. When students have answered questions on the Worksheet, lead a discussion of their results. This discussion should include:
 - The northern and southern latitude boundaries for the image are about $40^{\circ}43'04''$ N latitude and about $40^{\circ}28'43''$ N latitude respectively.
 - The eastern and western longitude boundaries for this image are about $124^{\circ}36'21''$ W longitude and about $124^{\circ}53'17''$ W longitude respectively.

- The deepest parts of the image are approximately about 2500 meters deep.
- The deep canyon near the middle of the image runs in an east-west direction (note that the upper Rotation Control Ring has North indicated on the Ring to help keep track of how the image is oriented).
- Over most of its length, the floor of this canyon is about 1700 meters deep, which corresponds to the light blue color coding on the image.
- The depression at 40°38'6" N latitude, 124°45'48" W longitude is about 2,000 meters deep.
- The slope at 40°39'34" N latitude 124°44'49" W longitude is steep.
- The difference in depth between the location at 40°31'00" N latitude, 124°44'00" W longitude and the location at 40°33'00" N latitude, 124°45'00" W longitude is about 1085 m - 1104 m = 19 m.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over “Ocean Science Topics” in the menu on the left side of the page, then “Habitats” then select “Deep Ocean” for activities and links about deep ocean ecosystems.

The “Me” Connection

Have students write a brief essay describing a backpacking trip across a landscape having the topography shown in the multibeam image used for the Worksheet activity.

Connections to Other Subjects

English/Language Arts, Social Studies

Assessment

Students answers to Worksheet questions and class discussions provide opportunities for assessment.

Extensions

1. Visit <http://oceanexplorer.noaa.gov/oceanos/explorations/10index/welcome.html> for the latest activities and discoveries by the INDEX/SATAL 2010 Expedition.
2. Visit the Okeanos Explorer Digital Atlas (http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm) and Web page (<http://oceanexplorer.noaa.gov/oceanos/welcome.html>) for reports, images, and other products from *Okeanos Explorer* cruises.

Multimedia Discovery Missions

<http://oceanexplorer.noaa.gov/edu/learning/welcome.html> – Click on the links to Lessons 1, 5, and 6 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

The Ridge Exploring Robot

(PDF, 1.6 Mb) (from the INSPIRE: Chile Margin 2010 expedition)

<http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/robot.pdf>

Focus: Autonomous Underwater Vehicles/Marine Navigation (Earth Science/Mathematics)

Students will explain a three-phase strategy that uses an autonomous underwater vehicle (AUV) to locate, map, and photograph previously undiscovered hydrothermal vents, design a survey program to provide a photomosaic of a hypothetical hydrothermal vent field, and calculate the expected position of the AUV based on speed and direction of travel.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

<http://oceanexplorer.noaa.gov/oceanos/explorations/10index/welcome.html> – Web site for the INDEX/SATAL 2010 Expedition, with links to lesson plans, career connections, and other resources

<http://oceanexplorer.noaa.gov/oceanos/edu/welcome.html> – Web page for the NOAA Ship *Okeanos Explorer* Education Materials Collection

<http://celebrating200years.noaa.gov/edufun/book/welcome.html#book> – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about the NOAA Ship *Okeanos Explorer*

<http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html> – Links to virtual fly-throughs and panoramas of the Magic Mountain hydrothermal vent site on Explorer Ridge in the NE Pacific Ocean, where two tectonic plates are spreading apart and there is active eruption of submarine volcanoes.

Gardner, J. V., M. A. Malik, and S. Walker, 2009. Plume 1400 Meters High Discovered at the Seafloor off the Northern California Margin. EOS Transactions, American Geophysical Union, 90(32): 275 - 275.

Doucet M., C. Ware, R. Arsenault, T. Weber, M. Malik, L. Mayer, and L. Gee. Advanced Mid-Water Tools for 4D Marine Data Fusion and Analysis. Paper presented at OCEANS 2009, Biloxi, Mississippi, October 26-29, 2009; available online at <http://www.ivs3d.com/news/PID985675.pdf>

http://ccom.unh.edu/NOAA_oceanexploration/ – Video simulations of the NOAA Ship *Okeanos Explorer* discovering a midwater plume on May 17, 2009 using multibeam sonar; video formats are provided for PC users and Macintosh users

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Nature of scientific knowledge

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

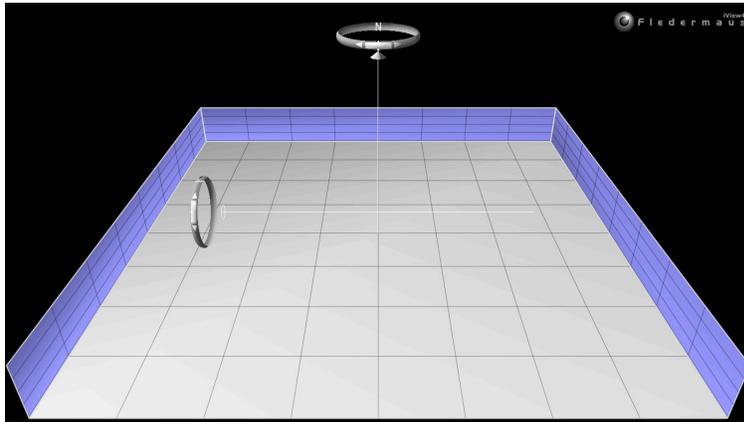
Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Tools of Exploration: Multibeam Sonar

Introduction to Multibeam Imagery Worksheet

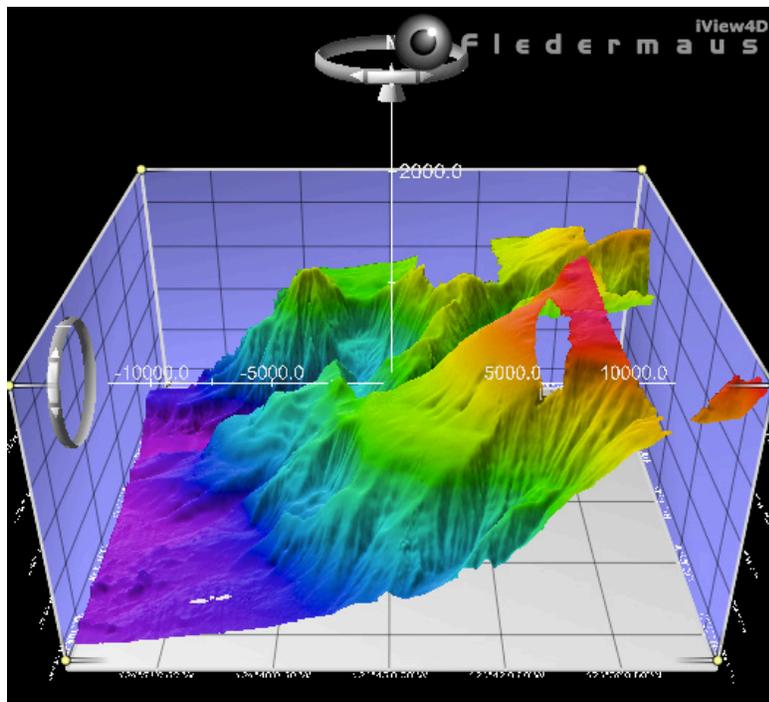
1. Launch the iView4D software. Your screen should resemble Figure 1. Note the Rotation Control Rings near the top center and mid-left side of the screen. If your screen doesn't look like Figure 1, be sure "Bounds" is checked under the "View" drop-down menu.

Figure 1. Multibeam Screen 1



2. Open the file, Plumery_Final30mGeo.sd. Now your screen should resemble Figure 2. This is a multibeam sonar image of the ocean floor near the site where the *Okeanos Explorer* discovered a gas plume on May 17, 2009 (the plume itself is not shown in this image).

Figure 2. Multibeam Sonar Image of the ocean floor



Tools of Exploration: Multibeam Sonar

Introduction to Multibeam Imagery Worksheet - page 2

The ocean floor is shown as a three-dimension image. The x-axis represents longitude, the y-axis represents latitude, and the z-axis represents depth. When you move the cursor over the image, the window near the bottom of the screen shows the geo coordinates (x, y, and z) for the location beneath the cursor.

The Rotation Control Rings near the top allows you to rotate the image around the vertical axis, and the Rotation Control Rings on the left allows you to rotate the image around the horizontal axis. Alternatively, you can left-click (simple click on a Macintosh platform) and drag up or down to rotate the image around the horizontal axis, or left-click and drag left or right to rotate the image around the vertical axis.

You can zoom the image by right-clicking (or control-clicking on a Macintosh platform) in the middle of the image then dragging to zoom in or out.

Some images use “vertical exaggeration” to show features more clearly. This means that the vertical scale is larger than the horizontal scale so vertical features are magnified. You can control the amount of vertical exaggeration by clicking and dragging the cone shaped object on the vertical scale line near the middle of the image. Numbers on the scale lines show the relative horizontal and vertical scales.

3. Experiment with these controls to find out how they allow you to manipulate the image, then answer the following questions:
 - a. What are the northern and southern latitude boundaries for this image?
(Hint: Be sure to notice that latitude grid lines are spaced 3' apart)
 - b. What are the eastern and western longitude boundaries for this image?
(Hint: Longitude grid lines are also spaced 3' apart)
 - c. The deepest parts of the image are approximately how deep?
 - d. The deep canyon near the middle of the image runs in which direction (east-west or north-south)? (Hint: Look carefully at the upper Rotation Control Ring)
 - e. Over most of its length, the floor of this canyon is about how deep?
 - r. What is the approximate depth of the depression at 40°38'6" N latitude, 124°45'48" W longitude? [Hint: If you zoom in, it is easier to position your cursor on a precise location]
 - g. Is the slope at 40°39'34" N latitude 124°44'49" W longitude gentle or steep?
 - h. What is the difference in depth between the location at 40°31'00" N latitude, 124°44'00" W longitude and the location at 40°33'00" N latitude, 124°45'00" W longitude?