



The Galápagos Rift Expedition 2011

The *Okeanos Explorer* Atlas

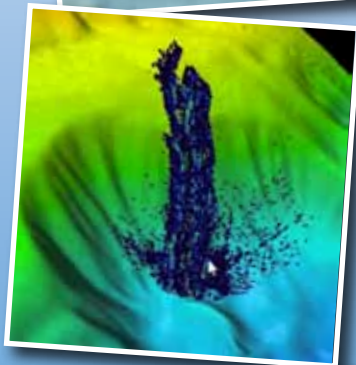


Image captions/credits on Page 2.

lesson plan

Focus

Time, speed, distance, velocity, and information about NOAA Ship *Okeanos Explorer* missions

Grade Level

5-6 (Physical Science/Earth Science)

Focus Question

How are time, speed, distance, and velocity related; and how can information be obtained about NOAA Ship *Okeanos Explorer* missions?

Learning Objectives

- Students will define velocity, and explain why this is a vector quantity.
- Students will use the *Okeanos Explorer* Atlas to obtain information about position and movement of the NOAA Ship *Okeanos Explorer*.
- Students will calculate velocity from information about geographic position at two different times.

Materials

- Copies of the *Okeanos Explorer Atlas User's Guide*, and the *Up to Speed Challenge Worksheet*; one copy for each student group
- Computers with Internet access

Audio-Visual Materials

- (Optional) Interactive white board or computer projection equipment; see Learning Procedure Steps 1 and 3.

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

30

Key Words

Okeanos Explorer
Okeanos Explorer Atlas
Velocity

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as “America’s Ship for Ocean Exploration;” the only U.S. ship whose sole assignment is to systematically explore our largely unknown ocean for the purposes of discovery and the advancement of knowledge. To fulfill this mission, an exploration strategy is used that 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 and samples in depths as great as 6,000 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 allow 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 the 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

Images from Page 1 top to bottom:

An overview of the Galápagos Islands. They are produced by volcanic activity caused by magma upwelling at the Galápagos hotspot. Green to white indicates the coastline, outside this is below sea level. Image produced by Ken Macdonald using GeoMapApp courtesy of Lamont Doherty Earth Observatory.

http://oceanexplorer.noaa.gov/explorations/05galapagos/background/hotspots/media/Galapagos_IS_Topo_600.html

Multibeam image of Mendocino Ridge Plume taken with the Kongsberg EM302 multibeam bathymetric mapping system. Image courtesy INDEX-SATAL 2010 Expedition.

http://oceanexplorer.noaa.gov/okeanos/media/movies/mendocino_ridge_plume_video.html

Close-up imagery showing a type of gooseneck barnacle, shrimp and a scaleworm on Kawio Barat submarine volcano. Image captured more than 1,850 meters deep by the *Little Hercules* ROV on August 3, 2010. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/slideshow/ex_july_highlights/gallery/hires/barnacle_zoom_hires.jpg

Doug Jongeward, a highly skilled IT Specialist, works in the control room of the *Okeanos Explorer* managing the enormous amounts of video and data that is collected each day on board the ship. Image courtesy of NOAA *Okeanos Explorer* Program.

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/8_doug_jongeward_hires.jpg



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 911plus 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>.



Aft view of the *Okeanos Explorer*.

http://oceanexplorer.noaa.gov/okeanos/media/slideshow/gallery/ex2010/hires/aft_view_hires.jpg

the exploration team as soon as discoveries are made, and at a fraction of the cost of traditional oceanographic expeditions.

Hydrothermal vent communities and other deepwater chemosynthetic ecosystems are fundamentally different from other biological systems on Earth, and there are plenty of unanswered questions about the individual species and interactions between species found in these communities. Many of these species are new to science, and include primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Although much remains to be learned, useful products have already been discovered in hydrothermal vent organisms. At present, almost all drugs produced from natural sources come from terrestrial plants, but marine animals produce more drug-like substances than any group of organisms that live on land. Some chemicals from microorganisms found around hydrothermal vents (the exopolysaccharide HE 800 from *Vibrio diabolicus*) are promising for the treatment of bone injuries and diseases, while similar chemicals may be useful for treating cardiovascular disease. Other examples of useful products include a protein from *Thermus thermophilus*, which is a microorganism that is adapted to live under extremely high temperature conditions near hydrothermal vents. One of these adaptations is the protein Tth DNA polymerase that can be used to make billions of copies of DNA for scientific studies and crime scene investigations. Another microorganism (genus *Thermococcus*) produces a type of protein (an enzyme called pullulanase) that can be used to make sweeteners for food additives.

In 2002 and 2005, NOAA's Office of Ocean Exploration and Research sponsored expeditions to the Galápagos Rift (see <http://oceanexplorer.noaa.gov/explorations/02galapagos/welcome.html> and <http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html> for more information about these expeditions). A major objective of the 2002 expedition was to revisit a hydrothermal vent site named Rose Garden to investigate changes that might have occurred in the community of living organisms around the vent since it was discovered in 1977. Scientists found that significant changes had indeed taken place: Rose Garden had completely disappeared! In its place was a fresh sheet of lava that had apparently buried the vent and all of the surrounding organisms. About 300 meters away, a new vent field (which the scientists named Rosebud) was discovered with typical hydrothermal vent species beginning to colonize cracks in recently-formed lava. These discoveries underscored a growing awareness that the deep ocean environment can change much more quickly than was previously believed. The 2005 expedition focused on a portion of the GSC that had never been explored for hydrothermal vents. Scientists hoped that they would find black smokers, because at that time high temperature (several hundred degrees C) vents had not been found in the Galápagos region; only vents whose temperatures were less than

50°C. Using chemical and physical clues, explorers eventually made the first discovery of black smokers on the Galápagos Rift!

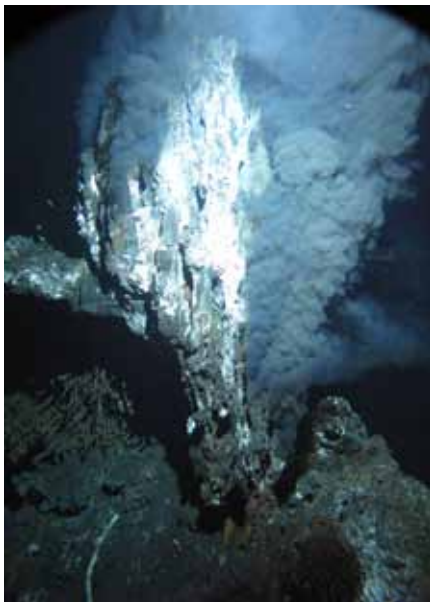
These discoveries set the stage for the Galápagos Rift Expedition 2011, which will use the state-of-the-art exploration capabilities of NOAA Ship *Okeanos Explorer* to obtain detailed information about the biology and geology of Galápagos hydrothermal ecosystems, and determine whether different ecosystems are found at different vent fields within the Galápagos region. A major objective of the Expedition is to survey and map known hydrothermal vent sites, and to search for new hydrothermal vents in unexplored regions of the Galápagos Rift.

Okeanos Explorer missions are always full of surprises, because they often take place in places where literally no one has gone before. To help share the excitement of ocean exploration, NOAA's National Coastal Data Development Center (NCDDC) provides a map-based atlas that links to information about current and past cruises of the *Okeanos Explorer* (the *Okeanos Explorer* Atlas), and a second atlas that links to expeditions of NOAA's Ocean Explorer program that began in 2001 (http://www.ncddc.noaa.gov/website/google_maps/OE/mapsOE.htm). In this activity, students will learn to use the *Okeanos Explorer* Atlas to obtain information about the Galapagos Rift Expedition 2011, and will use some of this information in basic calculations involving time, speed, distance, and velocity.

Learning Procedure

[NOTE: Hydrothermal vents are not the primary focus of this lesson; but their discovery was scientifically significant and fundamentally exciting, and may provide a compelling context for the content of this lesson as well as a variety of other activities. There is a wealth of information available on the geology and ecology of vent ecosystems, and several sources are highlighted below. Educators are encouraged to investigate these, and select combinations that are most appropriate to their own students and specific curriculum needs.]

1. To prepare for this lesson:
 - (a) Review introductory essays for the Galápagos Rift Expedition 2011 at <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/welcome.html>.
 - (b) Review background information about plumes and CTDs discussed in the Galapagos Rift Expedition 2011 Expedition Education Module (EEM).
 - (c) Review procedures on the *Okeanos Explorer Atlas User's Guide*, and the *Up to Speed Challenge Worksheet*.
 - (d) You may also want to review Multimedia Discovery Missions [<http://oceanexplorer.noaa.gov/edu/learning/welcome.html>] Lessons 1 and 5 on Plate Tectonics and Hydrothermal Vent Life; as well as background information on hydrothermal vents from one or more of these Web sites:



A black smoker chimney named 'Boardwalk' emitting 644°F (340°C) hydrothermal fluids in the northeastern Pacific Ocean at a depth of 7,260 feet (2,200 m). Microbes grow within and on the surface of such mineral formations. Image courtesy of James F. Holden, University of Massachusetts, Amherst.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/boardwalk_black_smoker_hires.jpg



Hydrothermal vents on Kawio Barat submarine volcano spew white smoke. Image captured more than 1,850 meters deep by the *Little Hercules* ROV on August 3, 2010. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/slideshow/ex_july_highlights/gallery/hires/white_plumes_hires.jpg

- <http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html> – This site links to virtual fly-throughs and panoramas of the Magic Mountain hydrothermal vent site on Explorer Ridge in the NE Pacific Ocean, about 150 miles west of Vancouver Island, British Columbia, Canada. Explorer Ridge is a spreading center where two tectonic plates are spreading apart and there is active eruption of submarine volcanoes.
- <http://www.pmel.noaa.gov/vents/nemo/index.html> – Web site for NOAA’s New Millennium Observatory (NeMO), a seafloor observatory at an active underwater volcano near the spreading center between the Juan de Fuca and Pacific tectonic plates. The “Explore” section of the site offers images and essays that include mid-ocean ridges, hydrothermal vents, and seafloor animals. The “Education” section of the site provides Powerpoint® presentations and curriculum materials.
- <http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html> – National Geographic Xpeditions lesson plan, “We’re in Hot Water Now: Hydrothermal Vents,” includes links to National Geographic magazine articles and video with an emphasis on geography and geographic skills.
- <http://www.divediscover.whoi.edu/vents/index.html> – Woods Hole Oceanographic Institution’s Dive and Discover Web site about hydrothermal vents includes details about vent formation, education resources, and the story of the discovery of the first hydrothermal vent in 1977.

If an interactive white board or computer projection facilities are available, you may want to bookmark selected Web pages or download some images from these sites to show your students. If you decide to include materials about hydrothermal vents and students are not familiar with the concept of plate tectonics, consider completing part or all of the “When Plates Collide” lesson (<http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/whenplates.pdf>).

2. Briefly introduce the Galapagos Rift Expedition 2011, and the NOAA Ship *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. 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 strategy for ocean exploration used aboard the *Okeanos Explorer*, and the primary technologies involved with this strategy (discussed above). Be sure students understand how CTDs can be used to detect plumes that may signal the presence of hydrothermal vents.

3. Tell students that they are going to learn how to find out exactly where the *Okeanos Explorer* is or was at any given time, as well as information about discoveries and scientific data collected by the ship. Demonstrate some capabilities of the *Okeanos Explorer* Atlas with the following example that uses information from the 2010 INDEX-SATAL Expedition, which was the *Okeanos Explorer*’s maiden voyage (this can be done with an interactive white board, or by having students perform the following steps on individual computers):

- Open the *Okeanos Explorer* Atlas at http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm.
- In the Cruise Selection window, choose “EX1004L2 Jun 24 - Jul 13”. Tell students that cruises are named with an abbreviation of the ship name (“EX”), the last two digits of the year in which the cruise took place (“10”), the number of the cruise (this was the fourth cruise for 2010), the segment or leg (this was the second leg of cruise 04), and the starting and ending dates for this portion of the cruise.

Figure A.



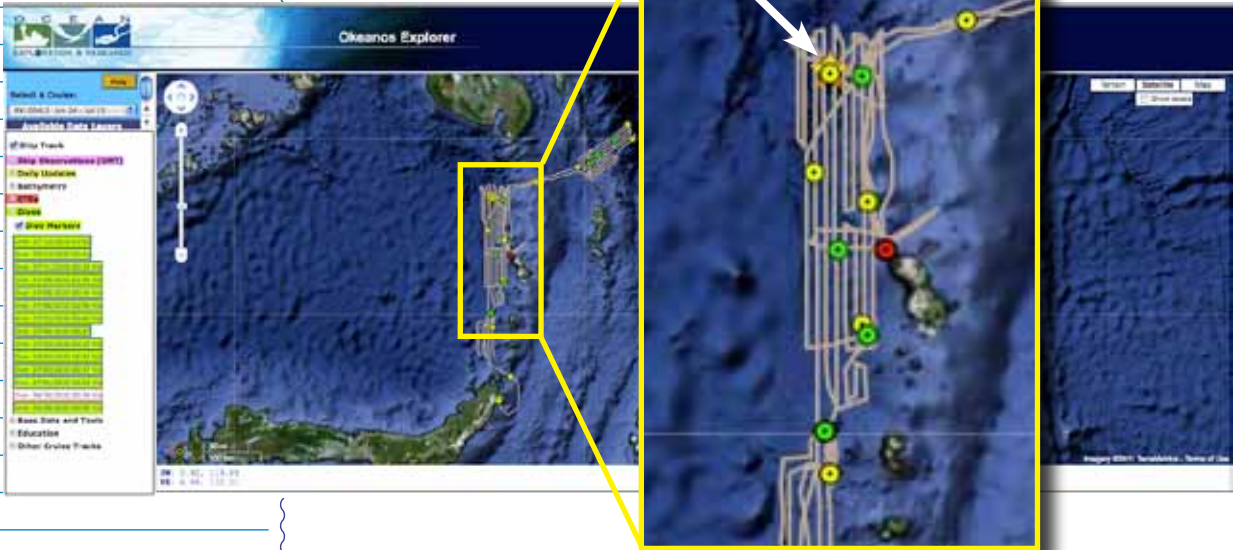
c. You should see something that resembles Figure A. Point out the light blue line, which is the ship’s track, and ask students why the ship seems to be zigzagging back and forth. Understanding that the first step in the ship’s exploration strategy is mapping, students should realize that the ship is obtaining high resolution multibeam maps of the area being explored (this is called “mowing the lawn,” for obvious reasons). Point out that the colored circles along the ship’s track correspond to various types of data listed in the “Available Data Layers” window.

Click on the “Daily Updates” layer title to expand the legend. Now you can see a complete list of daily observations. Place your cursor over one of the listed dates, and you should see a star appear in the map window that shows the ship’s location on that date.

d. Click on the “Daily Updates” layer title again to collapse the legend. Click on the “Bathymetry” layer title to expand the legend, and check the box labeled “Cumulative 50m Interpretation.”

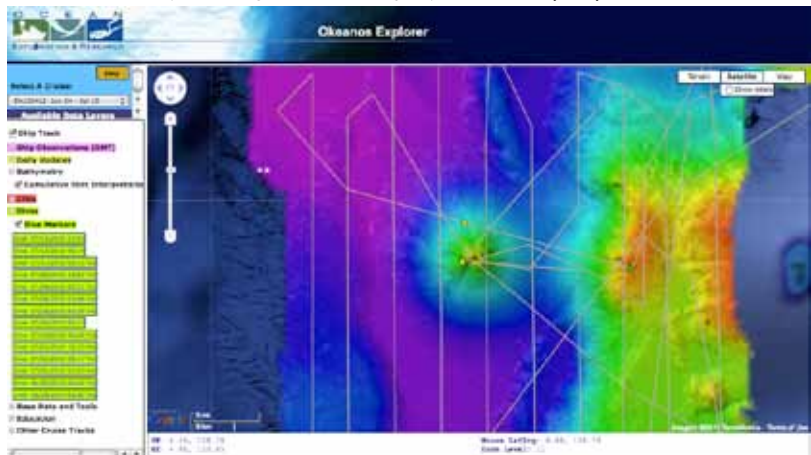
e. Click on the “Dives” layer title to see the dates of each ROV dive for this leg of the cruise. Place your cursor over the box for the dive on 6/30/2010 (but do not click!). You should see a yellow star appear beneath a yellow circle near the top center of the map window (Figure B).

Figure B.



f. Using the Navigation and Zoom tools, zoom into this spot so that your screen resembles Figure C. Note that the “Zoom Level” is 11. Now you should see part of a green circle indicating an ROV diver and part of a red circle indicating a CTD cast underneath the yellow circle corresponding to the Daily Update for 6/30/2010. You should

Figure C.



also see a lot of zigzags in the same area, and a cone-shaped formation under the circles. What was going on?

- g. Click on the "Ship Observations (GMT)" layer title to expand the Ship Observations legend, and click in the check box next to "Observation Markers." Now you will see magenta triangles that show where the ship was at the beginning of each day. The beginning of a day is defined as midnight Greenwich Mean Time (GMT), written 00:00:00. Click on the box for 6/30/2010. A new window will open in the Map Window showing the ship's location, speed, course, and meteorological and oceanographic measurements at 00:33:43 (a little after midnight) on June 30, 2010 (Figure D). Close this window by clicking the "x" in the upper right corner, and collapse the Ship Observations legend by clicking again on the "Ship Observations (GMT)" layer title.

Figure D.



Figure E.

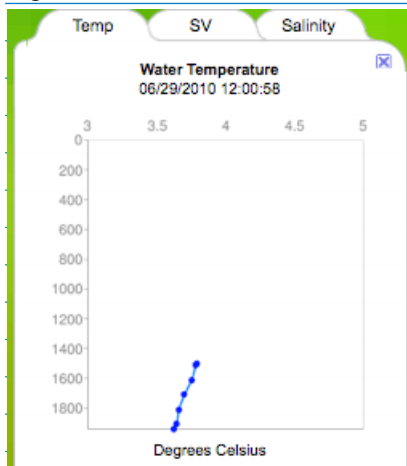
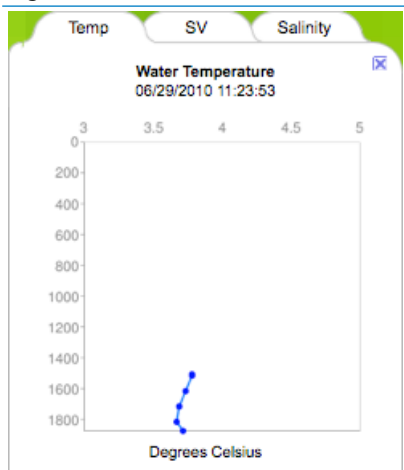


Figure F.



- h. Click on the box for the dive on 6/30/2010 in the expanded "Dives" legend. A new window will open with a link to a video captured by the *Little Hercules* ROV on an underwater volcano named Kawio Barat.
- i. Expand the "Daily Update" legend, and click on the box for June 30, 2010. Now you can link to an article about hydrothermal vents that were discovered during the ROV dive.
- j. Expand the "CTDs" legend. Notice that there were two CTD casts on 6/29/2010. From the circles on the map, you can also see that these were both near to the ROV dive location. Click on the box for the CTD cast at 12:00:58, and a window will appear showing a graph of temperature vs. depth (Figure E). Click on the box for the CTD cast at 11:23:53, and a window will appear showing another graph of temperature vs. depth (Figure F). Comparing the two graphs, you can see that data collected at 12:00:58 showed water temperature decreasing steadily as depth increased. But the data collected at 11:23:53 showed that water temperature increased

near the bottom; possibly because of hydrothermal vent activity. This was an important clue that suggested that an ROV dive near the site might produce some new discoveries; and it did!

Notice that the CTD windows (Figures E and F) have three tabs labelled "Temp," "SV," and "Salinity." Clicking on the "SV" or "Salinity" tabs will show graphs of sound velocity vs. depth and salinity vs. depth, respectively. Sound velocity measurements are used to calibrate the multibeam sonar, and are calculated from measurements of temperature, salinity, and water pressure (which is also used to estimate depth). If you click the box labelled "Compare to Historical," the window will show a graph of average temperature data from the World Ocean Atlas.

Now that your students should have some idea about what can be done with the *Okeanos Explorer* Atlas, it's time for them to find out about discoveries on the Galápagos Rift in 2011!

4. Provide each student group with copies of the *Okeanos Explorer Atlas User's Guide*, and the *Up to Speed Challenge Worksheet*. Depending upon curriculum needs and students' familiarity with the concepts, you may wish to provide some basic information about how speed and velocity are calculated, and the difference between vector and scalar quantities. You may also need to review the concepts of latitude and longitude (see Appendix A).
5. When students have completed the *Up to Speed Challenge*, lead a discussion comparing their results. Appropriate responses are:
 - 1) Students should expand the Ship Observations legend and find that on June 13, 2011 at 00:45:36 the position of *Okeanos Explorer* was 20.78° N, 118.96° W. "00:45:36" means the time is 0 hours, 45 minutes, 36 seconds; or 45 minutes and 36 seconds past midnight. GMT means Greenwich Mean Time, which is also called coordinated universal time (abbreviated UTC), "zulu time," or "world time."
 - 2) The information needed to describe the ship's velocity from the Ship Observations for 06/13/2011 at 00:45:36 is Speed Over Ground and Course Over Ground.
 - 3) The ship's location on 06/14/2011 at 00:45:37 was 17.11° N, 118.38° W. Students may find the distance between the two positions by zooming into the ship track, using a ruler to measure the distance between the two points, and calculating the distance from the Scale Bar. The result should be about 250 mi. An alternative method is to use an online calculator to find the distance between two points whose latitude and longitude are known. By this method, the distance is 256.7 mi.

4) If students estimated the distance in Question 3 as 250 mi, the answer in nautical miles is 217 nm; if students estimated the distance as 256.7 mi, the answer in nautical miles is 223 nm.

5) The ship's average speed in knots between 06/13/2011 at 00:45:36 and 06/14/2011 at 00:45:37 was

$$217 \div 24 = 9.04 \text{ kts}$$

or

$$223 \div 24 = 9.29 \text{ kts}$$

To state the ship's average velocity during this period, you would need to know the average direction of travel, which was approximately 175° .

6) From the Daily Update for June 14, 2011, students can learn that this was when the new CTD altimeter and sensors were tested.

7) Clicking on the red circle for CTD cast CDT01 (which took place on 06/14/2011 at 19:39:22 GMT) opens a window with a graph of the temperature recorded during the CTD cast, which indicates a temperature of approximately 1°C at 3,000 m depth.

8) From the Daily Update for June 23, 2011, students can learn that this was when tow-yo operations began. Clicking on the yellow circle for this date opens a window with a link to a short article that explains the process: The CTD with its new sensor package is towed behind the ship, and continuously winched up and down, forming a sawtooth pattern through the water column near the seafloor. Ocean explorers hope that the CTD sensor package will identify anomalies in the water column that signal the possible presence of hydrothermal plumes.

9) Clicking on the yellow circle for June 24, 2011, students can find out that plumes, possibly from hydrothermal vents, were detected by the light scattering sensor (LSS) attached to the CTD. The update does not say that earlier in the day there was a problem with the LSS, and the CTD had to be brought on deck for repair. Senior Survey Technician Colleen Peters describes the event in Appendix B.

10) During tow-yo operations on June 24 through June 26, 2011, the ship's average speed in kts from 06/24/2011 00:32:20 to 06/27/2011 00:32:25 was 1.46 kts. The ship's position on the two dates was 0.79°N , 89.17°W ; and 0.70°N , 87.42°W , respectively. The distance between these points is about 105.3 nm.

$$105.3 \text{ nm} \div 72 \text{ hr} = 1.46 \text{ kts}$$

If students look closely at the ship track, they may notice that the ship took a slight detour for four hours on 6/25. This is ignored in the calculation above.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on “Ocean Science Topics” in the menu on the left side of the page, then select “Geology” or “Habitats” for activities and links about hydrothermal vent formation and ecology.

The “Me” Connection

Have students write a brief essay discussing how they personally use (or might use) information from maps.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Written reports and class discussions provide opportunities for assessment.

Extensions

1. Visit <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/welcome.html> for the latest activities and discoveries by the Galápagos Rift Expedition 2011.
2. Visit the education sections of Web sites provided in Step 1 for additional activities about hydrothermal vents.

Multimedia Discovery Missions

<http://oceanexplorer.noaa.gov/edu/learning/welcome.html> – Click on the links to Lessons 1 and 5 on Plate Tectonics and Hydrothermal Vent Life.

Other Relevant Lesson Plans from NOAA’s Ocean Exploration Program

And Now for Something Completely Different...

(from the 2005 GalAPAGos: Where Ridge Meets Hotspot Expedition)
http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_dfferent.pdf

Focus: Biological communities at hydrothermal vents (Life Science)

In this activity, students will identify and describe organisms typical of hydrothermal vent communities near the Galápagos Spreading Center, explain why hydrothermal vent communities tend to be short-lived, and identify and discuss lines of evidence which suggested the existence of hydrothermal vents before they were actually discovered.

Earth’s Ocean is 95% Unexplored: So What?

(from the INDEX-SATAL 2010 Expedition)

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep ocean exploration (Life Science/Earth Science)

Students describe at least three different deep ocean ecosystems, explain at least three reasons for exploring Earth’s deep ocean, and explain at least three ways that deep ocean ecosystems may benefit humans.

Let’s Make a Tubeworm!

(from the INDEX-SATAL 2010 Expedition)

<http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/tubeworm.pdf>

Focus: Hydrothermal vent ecosystems (Life Science)

Students explain the overall structure of hydrothermal vents and how they are related to the motion of tectonic plates; describe the process of chemosynthesis in general terms; contrast chemosynthesis and photosynthesis; describe the anatomy of vestimentiferans; and explain how these organisms obtain their food.

To Explore Strange New Worlds

(Grades 7-8; adaptations for Grades 5-6 & 9-12) (from the *Okeanos Explorer* Education Materials Collection, *Volume 2: How Do We Explore?*)

http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_toexplore.pdf

Focus: Strategies for exploring unknown areas on Earth (Life Science/Physical Science/Earth Science)

Students describe requirements for explorations of unknown areas on Earth; discuss factors that influenced exploration strategies of the Lewis and Clark and *Challenger* Expeditions; describe the overall exploration strategy used aboard the NOAA Ship *Okeanos Explorer*; and describe how fractal geometry models natural systems, and how scale influences exploration strategy and results.

A Day in the Life of an Ocean Explorer

(from the *Okeanos Explorer* Education Materials Collection, *Volume 2: How Do We Explore?*)

http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_56_dayinlife.pdf

Focus: Telepresence and communications for ocean exploration (Physical Science)

Students identify the basic requirements for human communication; describe at least three ways in which humans communicate; discuss the importance of scientific communication; and explain the concept of telepresence, how it is implemented aboard the NOAA Ship *Okeanos Explorer*, and how it is used to increase the pace, efficiency, and scope of ocean exploration.

When Plates Collide

(from the INSPIRE: Chile Margin 2010 Expedition)

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

Focus: Plate Tectonics – Movement of plates, results of plate movement, and the Chile Triple Junction (Earth Science)

Students describe the motion of tectonic plates, compare and contrast three typical boundary types that occur between tectonic plates, describe the plate boundaries that occur and the Chile Triple Junction, and explain why a variety of chemosynthetic communities are expected to occur in this area.

Living With the Heat

(from the Submarine Ring of Fire 2006 Expedition)

<http://oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.LivingHeat.pdf>

Focus: Hydrothermal vent ecology and transfer of energy among organisms that live near vents. (Life Science/Earth Science)

Students describe how hydrothermal vents are formed and characterize the physical conditions at these sites; explain what chemosynthesis is and contrast this process with photosynthesis; identify autotrophic bacteria as the basis for food webs in hydrothermal vent communities; and describe common food pathways between organisms typically found in hydrothermal vent communities.

InVENT a Deep-Sea Invertebrate

(from the 2002 Galápagos Rift Expedition)

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr5_6_l3.pdf

Focus: Galápagos Rift Ecosystem - Structure and Function in Living Systems (Life Science)

Students design an invertebrate capable of living near deep-sea hydrothermal vents, and learn about the unique adaptations that organisms must have in order to survive in the extreme environments of the deep sea.

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/ex1103/welcome.html> – Web site for Galápagos Rift Expedition 2011, 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://oceanexplorer.noaa.gov/explorations/02galapagos/welcome.html> – Web site for the 2002 Galápagos Rift Expedition

<http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html> – Web site for the 2005 GalAPAGoS: Where Ridge Meets Hotspot Expedition

<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

<http://www.pmel.noaa.gov/vents/nemo/index.html> – Web site for NOAA's New Millennium Observatory (NeMO), a seafloor observatory at an active underwater volcano near the spreading center between the Juan de Fuca and Pacific tectonic plates

<http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html> – National Geographic Xpeditions lesson plan, *We're in Hot Water Now: Hydrothermal Vents*, includes links to *National Geographic* magazine articles and video with an emphasis on geography and geographic skills

<http://www.divediscover.whoi.edu/vents/index.html> – Woods Hole Oceanographic Institution's Dive and Discover Web site about hydrothermal vents includes details about vent formation, education resources, and the story of the discovery of the first hydrothermal vent in 1977.

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard B: Physical Science

- Motions and forces
- Transfer of energy

Content Standard D: Earth and Space Science

- Structure of the Earth system
- Earth's history

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Science and technology in society

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

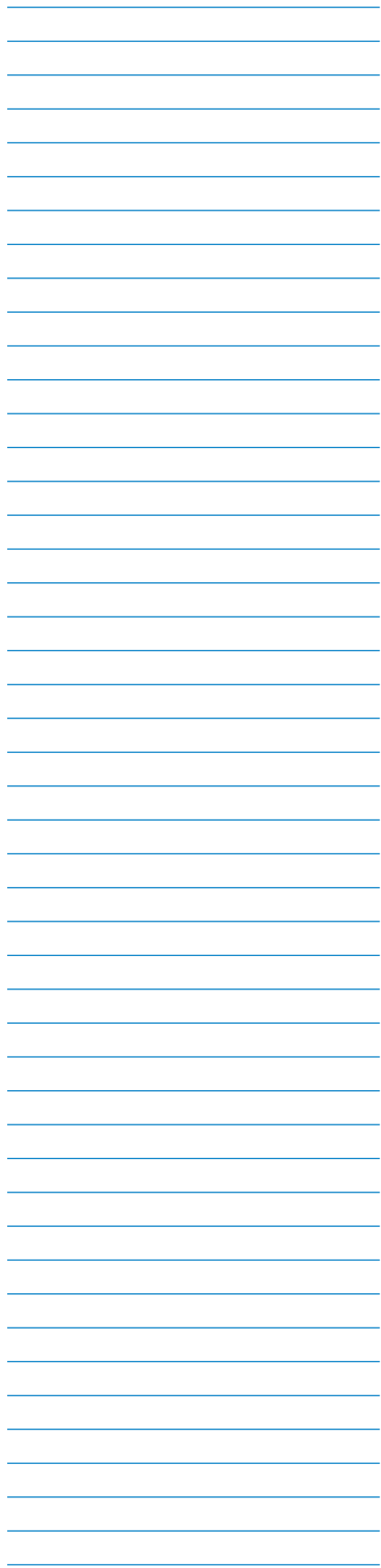
The Earth has one big ocean with many features.

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.

Essential Principle 2.

The ocean and life in the ocean shape the features of the Earth.

Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.



Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation’s explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to:

oceanexeducation@noaa.gov.

For More Information

Paula Keener, Director, Education Programs
NOAA Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818 843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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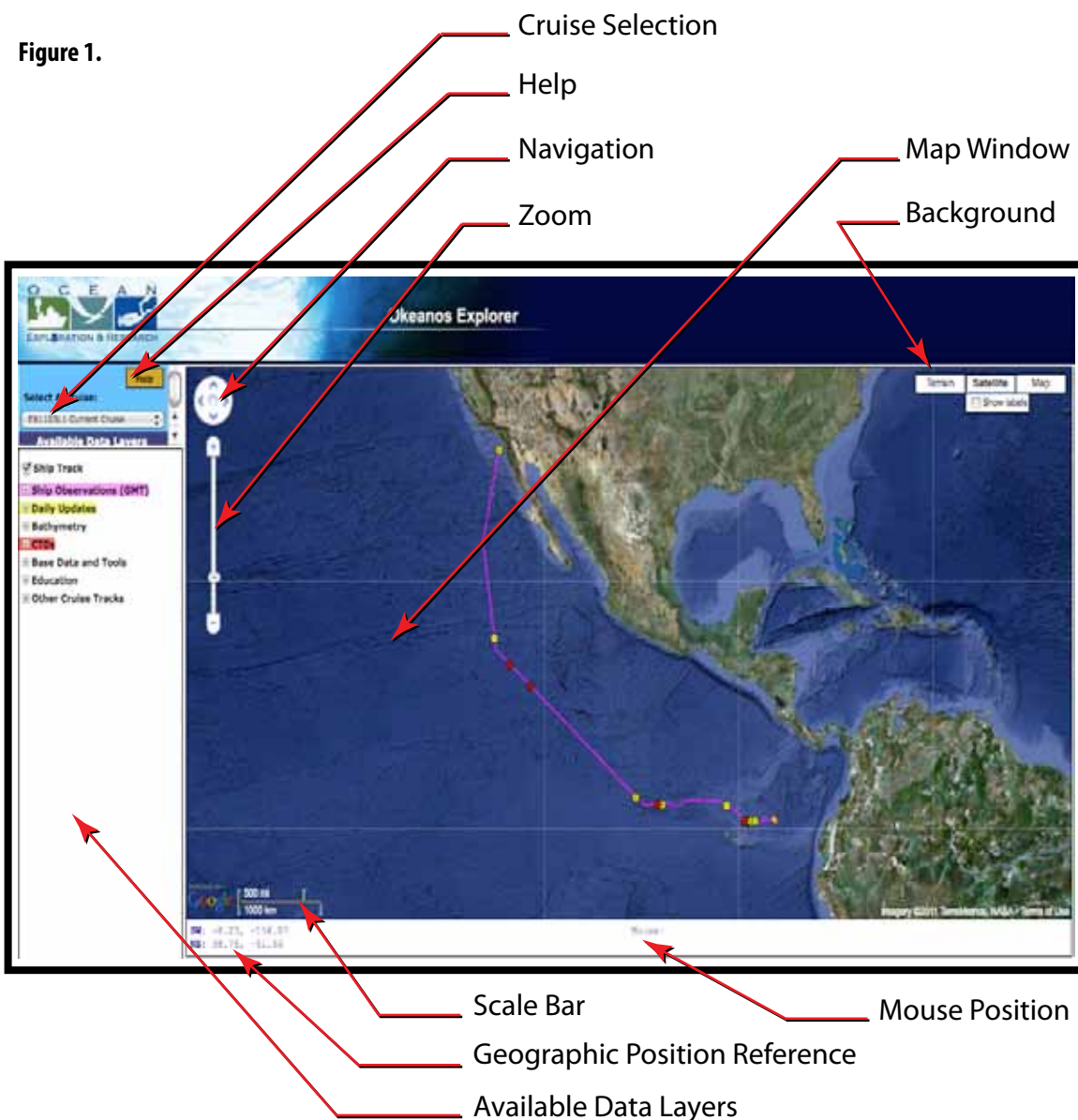
Credit

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The *Okeanos Explorer* Atlas

Okeanos Explorer Atlas User's Guide

Figure 1.



The purpose of the *Okeanos Explorer* Atlas is to display the navigational track and data collected during ocean exploration expeditions conducted aboard the NOAA Ship *Okeanos Explorer*. The goal is to provide a picture of where data were collected, and of the kinds of activities necessary to collect those data. Information may be posted from the ship to the map almost as soon as it is collected, unless additional processing is needed before the data can be understood. Additional information about the area being explored is provided in base map layers.

Here's how to start exploring with the *Okeanos Explorer* Atlas:

Open the *Okeanos Explorer* Atlas at http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm. When the Atlas has opened, you will see a satellite image of a portion of Earth's surface, and an icon showing the current location of the *Okeanos Explorer*. If a cruise is underway, you will see a magenta line that shows the path of the ship since the cruise began. The location shown for the ship is usually accurate to within one hour. If the ship is in port, the location of the port will be shown. You may also see colored circles along the magenta line (these will be explained below).

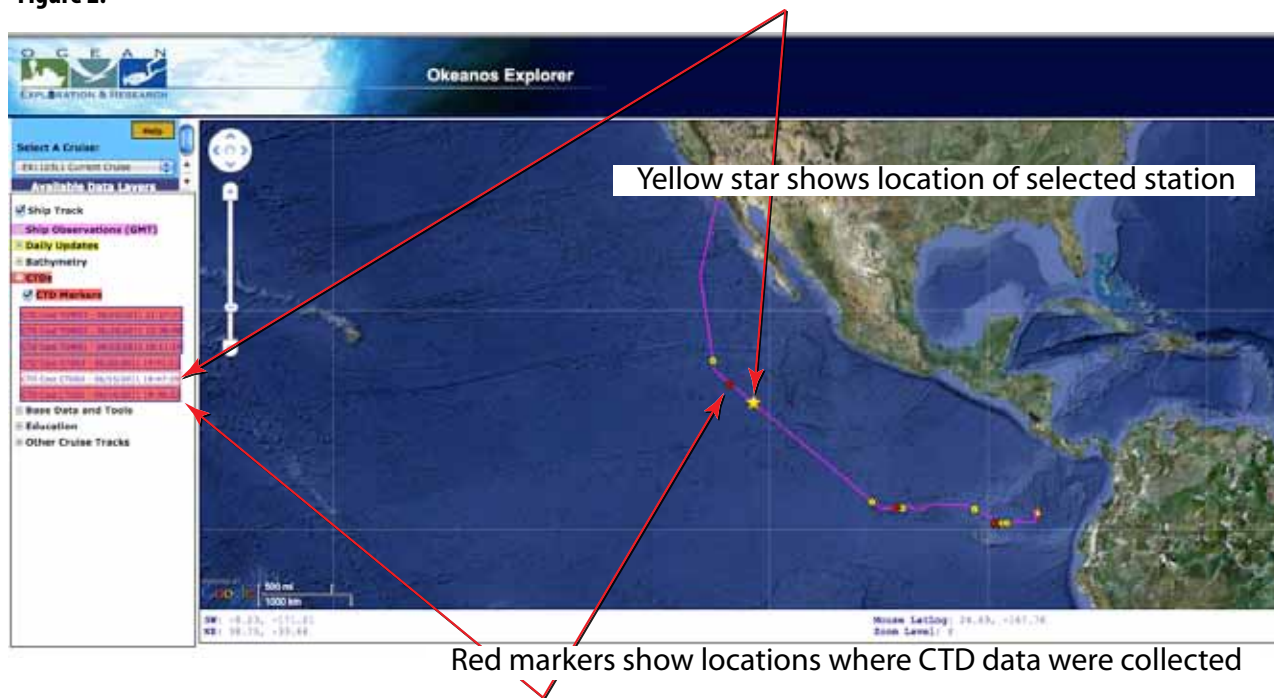
Figure 1 shows the major parts of the *Okeanos Explorer* Atlas window that are visible when the Atlas first opens:

- **Map Window** – Links various data sets to specific geographic locations.
- **Help Box** – Provides general information about the Atlas, available data, and controls.
- **Cruise Selection Window** – Clicking here produces a drop-down list of all expeditions.
- **Navigation Tool** – Moves the map window north, south, east or west; you can also navigate by clicking inside the window and dragging in the direction that you want the window to move.
- **Zoom Control** – Sets the zoom level.
- **Scale Bar** – Shows the scale of the current zoom level.
- **Background Controls** – Allows you to choose a map or satellite image as the background; checking the "Show Labels" box adds labels to the satellite view.
- **Geographic Position Reference** – Shows the latitude and longitude of the southwest and northeast corners of the map window.
- **Mouse Position** – Shows the latitude and longitude of the point in the map window that is directly beneath the cursor, when the cursor is somewhere over the map. "Zoom Level" displays a number that indicates how much zoom is applied to the window; the higher the number, the greater the magnification.
- **Available Data Layers Window** – Data in the *Okeanos Explorer* Atlas are stored in layers; each layer contains a specific type of data. Data layers are shown with a text background color that matches the marker color on the map. For example, CTD station locations are shown as red markers on the map to match the red text highlight. For most

cruises there are nine data layers: Ship Track, Ship Observations, Daily Updates, Bathymetry, CTD, Dives, Base Data and Tools, Education, and Other Cruise Tracks. If no data were collected for a particular layer during a cruise, the Available Data Layers window may not list that layer. Figure 1 does not include a “Dives” layer because no ROV dives had been done during the cruise at the time Figure 1 was captured.

Clicking on the title of a data layer will expand the legend for the data layer so that it shows a list of each observation. Clicking the title of an expanded legend will collapse the list. You can also click the small check box that contains a + or - to expand or collapse a legend. Figure 2 shows an expanded legend for the “CTDs” data layer. The check box labelled “CTD Markers” allows you to show or hide the CTD stations on the map. Since the check box is checked, the map shows a red marker at each station where CTD data were collected. If you place your mouse on top of a station in the CTD data layer, the red dot will change to a yellow star to show the location of that station.

Figure 2.



Here's what the other data layers contain:

Ship Track – The location of the *Okeanos Explorer*, recorded each hour. The most recent location and heading of the ship are highlighted with a yellow directional marker.

Ship Observations – During an expedition, shipboard systems report meteorological and oceanographic conditions each hour. These are displayed on the map in Greenwich Mean Time (GMT).

Daily Updates – Information about expedition highlights, including links to videos, images and articles written by expedition scientists. Clicking on a listing or a marker on the map will display a popup window that shows the information and any links. NOTE: these links take the user to a new website.

Bathymetry – Seafloor mapping images created from data collected aboard the *Okeanos Explorer* can be overlaid onto the base bathymetry layer.

Dives – Remotely Operated Vehicle (ROV) dive locations.

Base Data and Tools – Base data provide additional information about the area in which the ship is operating, such as volcanoes, place names, sea surface temperature, vertical temperature profiles, and plate tectonics. The “Go To Google Tour” tool takes the user to a new website that explains Google services and products.

Education – Provides access to an array of materials developed for educators. The materials will vary depending upon the expedition.

Other Cruise Tracks – Displays a list of all cruises except the currently selected one. Check the box to display the cruise track. The background color of the cruise in the list will be the color of the track line displayed on the map.

For more information, click inside the “Help” box.

The *Okeanos Explorer* Atlas Up to Speed Challenge Worksheet

For this Challenge, you will use the *Okeanos Explorer* Atlas to find information about the movement and activities of NOAA Ship *Okeanos Explorer* during the Galapagos Rift Expedition 2011.

To get started, use the *Okeanos Explorer Atlas User's Guide* to get acquainted with the Atlas. Try the Zoom and Navigation tools, and open the various Data Layers to see what kinds of information they contain. If you get stuck, you can always re-launch the Atlas to start over. Once you feel comfortable with how the Atlas works, move on to the Challenge:

1. Where was the *Okeanos Explorer* on June 13, 2011 at 00:45:36? What does 00:45:36 mean? What does GMT mean?
2. What information do you need to describe the ship's velocity from the Ship Observations for 06/13/2011 at 00:45:36?
3. Based on the ship's location on 06/14/2011 at 00:45:37, how far had the ship travelled in 24 hours?
4. The Scale Bar in the lower left corner of the map window shows distance in mi and km. The abbreviation mi stands for statute miles, which is the familiar unit of measurement used in the U.S. Aboard ships, distance is usually measured in nautical miles, and speed is measured in knots (abbreviated kts or kn), which is equal to nautical miles per hour. One nautical mile is equal to approximately 6,076 feet, while a statute mile is equal to 5,280 feet. What is the answer to question 3 in nautical miles?
5. What was the ship's average speed in knots between 06/13/2011 at 00:45:36 and 06/14/2011 at 00:45:37? What additional information would you need to state the ship's average velocity during this period?
6. What activity took place aboard the ship on 06/14/2011?
7. What was the water temperature at a depth of 3,000 m at the ship's location on 06/14/2011 at 19:39:22 GMT?

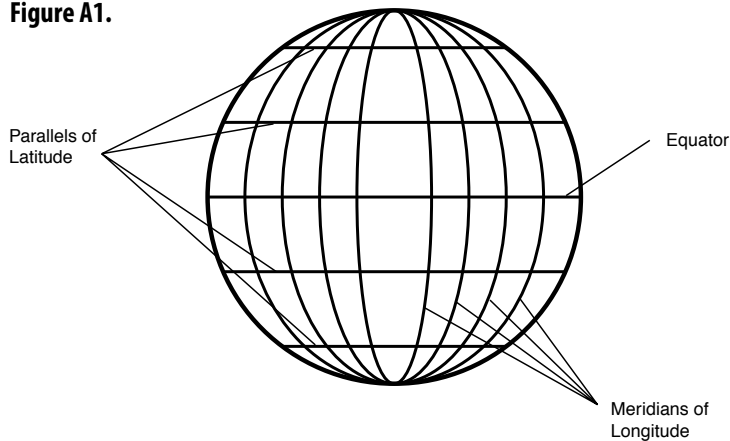
8. What new activity began on June 23, 2011? What happens during this activity? Why is this activity useful to ocean explorers?
9. What happened on June 24, 2011?
10. Between June 24 and June 26, 2011, the ship was conducting the activity discussed in Question 9. What was the ship's average speed in kts from 06/24/2011 00:32:20 to 06/27/2011 00:32:25?

Appendix A

Latitude and Longitude

All nautical charts are based on a system of geographic coordinates that can be used to describe a specific location on a body of water. One of the best-known and most widely used set of geographic coordinates is the latitude - longitude system. This system is based on two sets of imaginary circles on the Earth's surface. One set includes circles that pass through the north and south poles. These circles are known as "meridians of longitude." The other set includes circles that would lie on plane surfaces cutting through the Earth perpendicular to the polar axis (and therefore perpendicular to meridians of longitude). This second set of circles is known as "parallels of latitude" (see Figure A1).

Figure A1.



Geographic coordinates using the latitude - longitude system are measured in terms of degrees. The reference point for all measurements of longitude is the meridian passing

through Greenwich, England; this meridian is called the "prime meridian," and is represented by 0 degrees. The meridian of longitude that passes through any position on Earth is described in terms of how many degrees that meridian is to the east or west of the prime meridian. The maximum in either direction is 180 degrees. Sometimes, meridians to the west of the prime meridian are given a negative sign to distinguish them from meridians to the east of the prime meridian. Parallels of latitude are measured in terms of how many degrees a given parallel is north or south from the equator (which is assigned a latitude of 0 degrees). Fractions of degrees are expressed in minutes (there are 60 minutes in one degree) and seconds (there are 60 seconds in one minute). Minutes and seconds are sometimes divided decimally for very precise descriptions of geographic location. Each degree of latitude corresponds to sixty nautical miles, so one minute of latitude corresponds to one nautical mile (a nautical mile is equal to about 6,076 ft, or about 1.15 statute miles).

Appendix B

Reality Check: When the CTD Stops WorkingColleen Peters, Senior Survey Technician, NOAA Ship *Okeanos Explorer*

I was in a deep post-watch slumber, when I dreamt that someone was calling my name. A hand reached around the curtain of my rack to lightly tap my arm. “Colleen.... The CTD is on deck, there’s a problem with the LSS”. It was Megan [Lieutenant Megan Nadeau, the *Okeanos Explorer’s* Operations Officer]. If anyone needs to be woken up in the middle of the night, I highly recommend that Megan be the one to do it.

I got up in the darkness, and still groggy, tried not to wake up my roommate while I blindly searched for yesterday’s clothes and shoes. I got dressed, pulled back my hair and headed into the bright passageway and made my way to the control room to see what had happened.

It was 4 AM (I had only been asleep for two hours) and the tow-yos had only begun 16 hours prior. The night watch had experienced a problem with one of the sensors, the Light Scattering Sensor (LSS) was spiking in such a way that it was not collecting real data. We have two for redundancy, but one of the sensors had stopped working properly shortly after the CTD was in the water—but we had continued with the tow because we had the second LSS. When the second sensor stopped working, it was time to troubleshoot, because the LSS is our primary plume-detecting sensor. At the request of shore-side scientists, the CTD was pulled back to the surface and brought on deck to be investigated.

I grabbed some tools on my way out the door. A new cable, silicone grease, a cotton swab, some electrical tape, a pair of dykes [diagonal side-cutters], some zip ties, and a rubber mat. When I arrived on deck, I placed the mat near the top end of the CTD where all the auxiliary cables connect. The deck is coated with heavy duty nonskid that can rip a pair of jeans, never mind your skin. I disconnected both of the LSS cables from the CTD. I inspected the cables for signs of leakage. All clear.

I then disconnected both the sensors from their cables. On the one that was working but had just started spiking, I simply cleaned out the cables and connectors and with a little bit of grease to help keep water out and reconnected the cable. The LSS that was not working was likely due to a cable issue—we did not have the correct cables on board (they were not sensitive enough) and so we used modified ones. I replaced the modified cable with one of the original ones. This way, we can still collect valuable data, make a comparison between the sensitivities, and have the modified cable repaired in time for the next tow-yo.

Since I was still sleepy, trying to remember how things were configured, I took my time to make sure I got everything right. It costs the ship a lot of extra time to have to pull the CTD on deck, so it was better to not have to do it twice. Once the cables were all connected, I had to button them up—lash them to the frame with electrical tape so that nothing would come loose during the tow and adversely affect the data or the equipment. Once that was complete, I assisted the deck department in deploying the CTD.

Once the CTD was in the water, I returned to the lab to start the cast. Being the resident technician, I took the lead, and had the watch leader observe. We started the data, and made sure that everything looked right before proceeding down. I stayed to watch the CTD descend to around 1000 meters, (about half way down) before turning things over, because I needed to make the call of whether or not the troubleshooting was successful. The data looked good. The LSS’s were mimicking each other—the signals were of the same pattern, but because of the difference in sensitivities of the two cables, they were simply on two different scales. As far as I was concerned, it was a success. I turned it back over to the watch leader, and he proceeded with the tow... and I proceeded back to bed.