



## Gulf of Mexico 2012 Expedition Tools for Classroom Explorers

# The *Okeanos Explorer* Atlas



Image captions/credits on Page 2.

# lesson plan

### Focus

Information about NOAA Ship *Okeanos Explorer* missions

### Grade Level

5-12 (Physical Science/Life Science/Earth Science)

### Focus Question

How can information be obtained about the NOAA Ship *Okeanos Explorer* missions?

### Learning Objectives

- Students will use the *Okeanos Explorer* Atlas to obtain information about:
  - Position and movement of the NOAA Ship *Okeanos Explorer*;
  - Meteorological and oceanographic (METOC) observations; and
  - Exploration activities undertaken during specific cruises.

### Materials

#### For one student group:

- Copies of the *Okeanos Explorer Atlas User's Guide*; one copy for each student group
- (Optional) Copies of *Okeanos Explorer METOC Supplemental Datasheets* for one or more *Okeanos Explorer* cruises
- Computers with Internet access

### Audio-Visual Materials

- (Optional) Interactive white board; see Learning Procedure Step 3.

### Teaching Time

One 45-minute class period; (more if students complete METOC Supplemental Datasheets)

### Seating Arrangement

Groups of two to four students

### Maximum Number of Students

30

### Key Words

NOAA Ship *Okeanos Explorer*  
*Okeanos Explorer* Atlas

## Background Information

*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 (ECCs). In this way, scientific expertise can be

### Images from Page 1 top to bottom:

Backdeck: Bobby Mohr, Tom Kok, and Jeff Williams discuss ‘the plan’ on the back deck. Image courtesy of the NOAA *Okeanos Explorer* Program.

<http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar21-2-hires.jpg>

Anchor resting on the top of the Site 15429 wreck. *Lophelia* coral is also visible.

After a great first marine archaeology dive on March 27, everyone was excited about exploring a second target. Site 15429 was initially located in 2009 with the National Institute for Undersea Science and Technology’s (NIUST) *Eagle Ray* autonomous underwater vehicle (AUV). The data showed a potential vessel resting on the seafloor. The remotely operated vehicle (ROV) dive confirmed what several members of the Science Team expected. The wreck appears to be a hotspot for *Lophelia* coral. It was a great day for both the marine archaeologists and the biologists. Image courtesy of NOAA *Okeanos Explorer* Program.

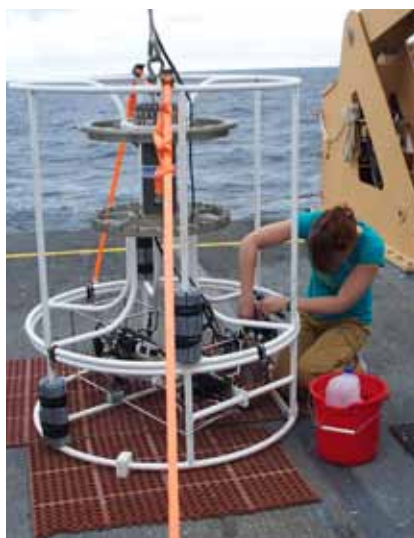
[http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar29\\_hires.jpg](http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar29_hires.jpg)

Image of gridded bathymetry shown as a wireframe and draped over gridded backscatter data. Ever since the Team on Leg I of the Gulf of Mexico expedition mapped the DeSoto Canyon area in early March 2012, there was lots of speculation about one specific seafloor feature in approximately 400 meters of water. Not only did the feature seem to be the one spot of significant relief in an otherwise fairly flat area, but it also showed up in the backscatter data as a very ‘hard’ target. Image courtesy of NOAA *Okeanos Explorer* Program.

[http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar28\\_update\\_hires.jpg](http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar28_update_hires.jpg)

Through the power of technology, scientists on the ship and on shore are able to view and learn about the complex ecosystems in the Gulf of Mexico. Deep-sea corals flourish in the dark depths of the Gulf of Mexico, providing foundations that attract lush communities of other animals, including brittle stars, anemones, crabs, and fish. This diversity of life on the seafloor may be out of sight, but it is has been squarely on the minds of scientists seeking to determine the short- and long-term ecological impacts of the Deepwater Horizon oil spill. Image courtesy of the NOAA *Okeanos Explorer* Program.

<http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/mar24-2-hires.jpg>



Senior Survey Technician Elaine Stuart works on the CTD while the altimeter battery recharges. Water sampling bottles, which are often attached to the rosette frame, have been removed for tow-yo operations. Sensors are mounted in the lower part of the frame where SST Stuart is working. Image courtesy of NOAA *Okeanos Explorer* Program.



A CTD with water sampling bottles attached to the rosette frame. Image courtesy of NOAA *Okeanos Explorer* Program.

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

*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 (the Ocean Exploration Digital Atlas).

This lesson describes how the *Okeanos Explorer* Atlas can be used to obtain information about the location and movement of the NOAA Ship *Okeanos Explorer* during a specific cruise, meteorological and oceanographic (METOC) observations made during the cruise; and details about exploration activities undertaken during the cruise. The techniques presented in this lesson may be used to complete *Okeanos Explorer* METOC Supplemental Datasheets, which are linked from the "Education" layer of the *Okeanos Explorer* Atlas for selected cruises, as well as from the Education section of Web pages provided for these cruises (<http://oceanexplorer.noaa.gov/okeanos/explorations/explorations.html>).

### Learning Procedure

1. To prepare for this lesson, review procedures on the *Okeanos Explorer Atlas User's Guide*; and, optionally, one or more *Okeanos Explorer METOC Supplemental Datasheets*.
2. Briefly introduce 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. Review the overall strategy for ocean exploration used aboard *Okeanos Explorer*, and the primary technologies involved with this strategy (discussed above).

Provide a general description of a CTD. Tell students that the letters stand for conductivity, temperature, and depth, and refer to a package of electronic instruments that measure these properties. Conductivity is a measure of how well a solution conducts electricity and is directly related to salinity, which is the concentration of salt and other inorganic compounds in seawater. Salinity is one of the most basic measurements used by ocean scientists. When combined with temperature data, salinity measurements can be used to determine seawater density which is a primary driving force for major ocean currents. Often, CTDs are attached to a much larger metal frame called a rosette, which may hold water sampling bottles used

to collect water at different depths, as well as other instruments that can measure additional physical or chemical properties.

Ocean explorers often use CTD measurements to detect evidence of volcanoes, hydrothermal vents, and other deep-sea features that cause changes to the physical and chemical properties of seawater. Masses of changed seawater are called plumes, and are usually found within a few hundred meters of the ocean floor. Since underwater volcanoes and hydrothermal vents may be several thousand meters deep, ocean explorers usually raise and lower a CTD rosette through several hundred meters near the bottom as the ship slowly cruises over the area being surveyed in an effort to detect plumes. This repeated up-and-down motion of the towed CTD may resemble the movement of a yo-yo; a resemblance that has led to the nickname “tow-yo” for this type of CTD sampling.

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 *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):

- a. Open the *Okeanos Explorer* Atlas at [http://www.ncddc.noaa.gov/website/google\\_maps/OkeanosExplorer/mapsOkeanos.htm](http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm).
- b. 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” is used as an abbreviation for *Okeanos Explorer*), 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.
- 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 zig-zagging 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.

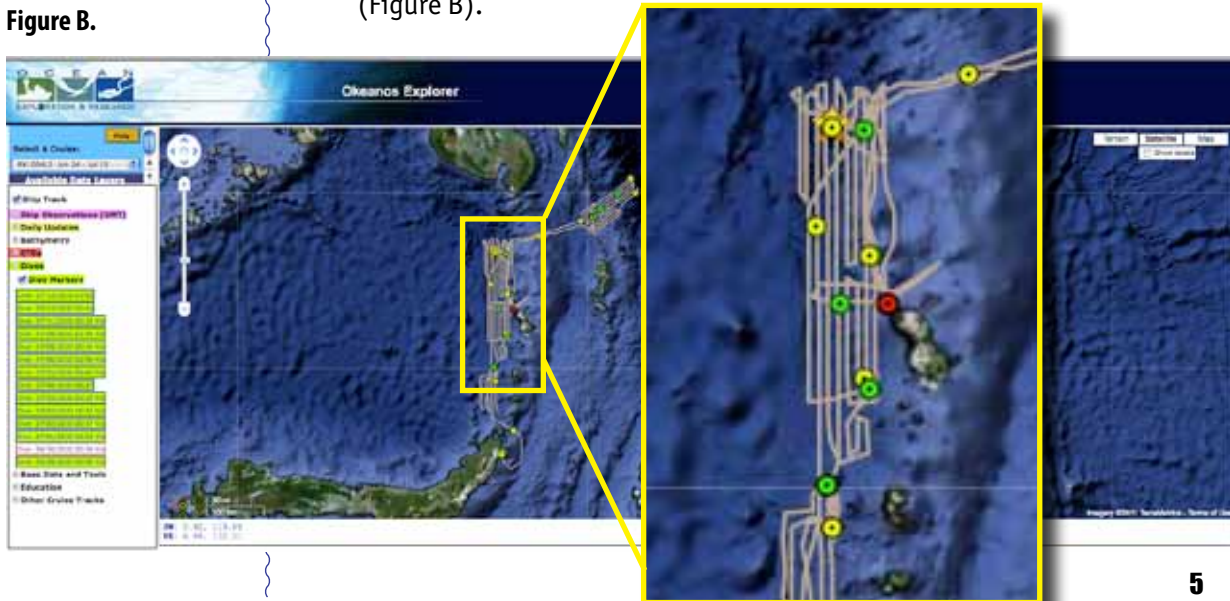
Figure A.



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 "50m Interpretation Bathymetric."

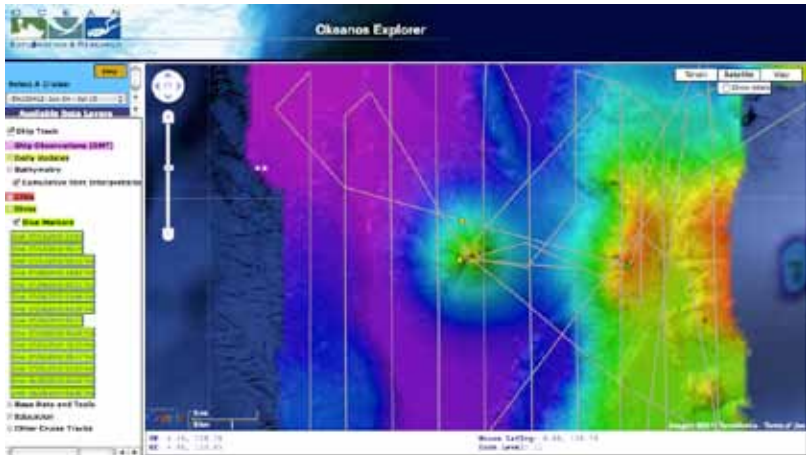
e. Click on the "Dives" layer title to see the dates of each ROV dive for this leg of the cruise. Place your cursor over the box for the dive on 6/30/2010 (but do not click!). You should see a yellow star appear beneath a yellow circle near the top center of the map window (Figure B).

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

Figure C.



g. Click on the "Ship Observations (GMT)" layer title to expand the Ship Observations legend, and click in the checkbox 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). Tell students that meteorological and oceanographic measurements are often called "METOC data." 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.



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- 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. Collapse the “Daily Update” legend and expand the “CTDs” legend. Notice that there were two CTD casts on 6/29/2010. Note that these were not “tow-yos;” the CTD was raised and lowered while the ship was stationary. 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!

Figure E.

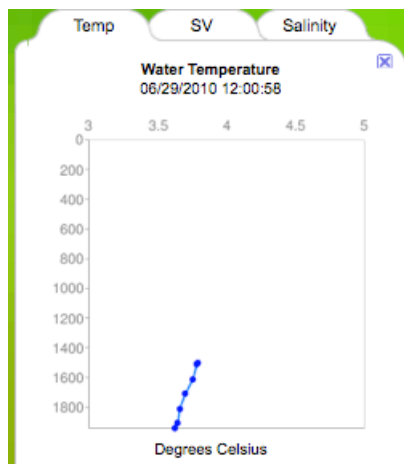
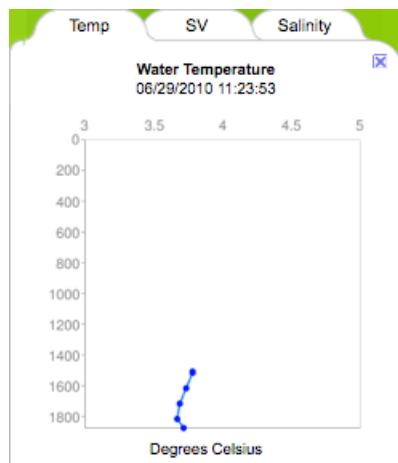


Figure F.



Notice that the CTD windows (Figures E and F) have three tabs labeled “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). While in the Temperature graph, if you click the box labeled “Compare to Historical,” the window will show a graph of average temperature data from the World Ocean Atlas.

Now that your students have some idea about what can be done with the *Okeanos Explorer* Atlas, they are ready to put their knowledge to work with *Okeanos Explorer* METOC Supplemental Datasheets. These Datasheets are developed for selected cruises and are linked from the “Education” layer of the *Okeanos Explorer* Atlas for individual cruises, as well as from the Education section of Web pages provided for these cruises. Datasheets are named, “*Okeanos Explorer* METOC Supplemental Datasheet #x for Cruise yy.nn” where yy is the last two digits of the year in which the cruise took place and nn is the number of the cruise. So Datasheet #1 for cruise EX1004L2 Jun 24 - Jul 13 would be named “*Okeanos Explorer* METOC Supplemental Datasheet #1 for Cruise 10.04”.

**The BRIDGE Connection**

[www.vims.edu/bridge/](http://www.vims.edu/bridge/) – Click on “Research and Data Connections” in the menu on the left side of the page, then select “Virtual Expeditions” for activities and links about to online activities about various types of exploration activities.

**The “Me” Connection**

Have students write a brief essay discussing how they personally use (or might use) information from map-based datasets similar to the *Okeanos Explorer* Atlas.

**Connections to Other Subjects**

English/Language Arts, Earth Science

**Assessment**

Ideas for assessment are provided with individual *Okeanos Explorer* METOC Supplemental Datasheets.

**Extensions**

Visit <http://oceanexplorer.noaa.gov/okeanos/explorations/explorations.html> for links to individual voyages of discovery by the NOAA Ship *Okeanos Explorer*.

**Other Relevant Lesson Plans from NOAA’s Ocean Exploration Program**

**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](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.

**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](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](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.

### **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://www.ncddc.noaa.gov/website/google\\_maps/OkeanosExplorer/mapsOkeanos.htm](http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm) – Web site for the *Okeanos Explorer* Atlas

<http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html> – Web page for the *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

### **Correlations to A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas**

#### **Framework for K-12 Science Education**

##### **Dimension 1. Scientific and Engineering Practices**

1. Asking questions (for science) and defining problems (for engineering)

- 2. Developing and using models
- 4. Analyzing and interpreting data
- 5. Using mathematics and computational thinking
- 8. Obtaining, evaluating, and communicating information

**Dimension 2. Crosscutting Concepts**

- 3. Scale, proportion, and quantity
- 4. Systems and system models

**Dimension 3. Disciplinary Core Ideas**

**Physical Sciences**

Core Idea PS2: Motion and Stability: Forces and Interactions

PS2.A: Forces and Motion

Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer

PS4.C: Information Technologies and Instrumentation.

**Earth and Space Sciences**

Core Idea ESS2: Earth’s Systems

ESS2.B: Plate Tectonics and Large-Scale System Interactions

**Engineering, Technology, and the Applications of Science**

Core Idea ETS2: Links Among Engineering, Technology, Science, and Society

ETS2.A: Interdependence of Science, Engineering, and Technology

**Ocean Literacy Essential Principles and Fundamental Concepts**

**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](mailto:oceanexeducation@noaa.gov).

**For More Information**

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**Acknowledgements**

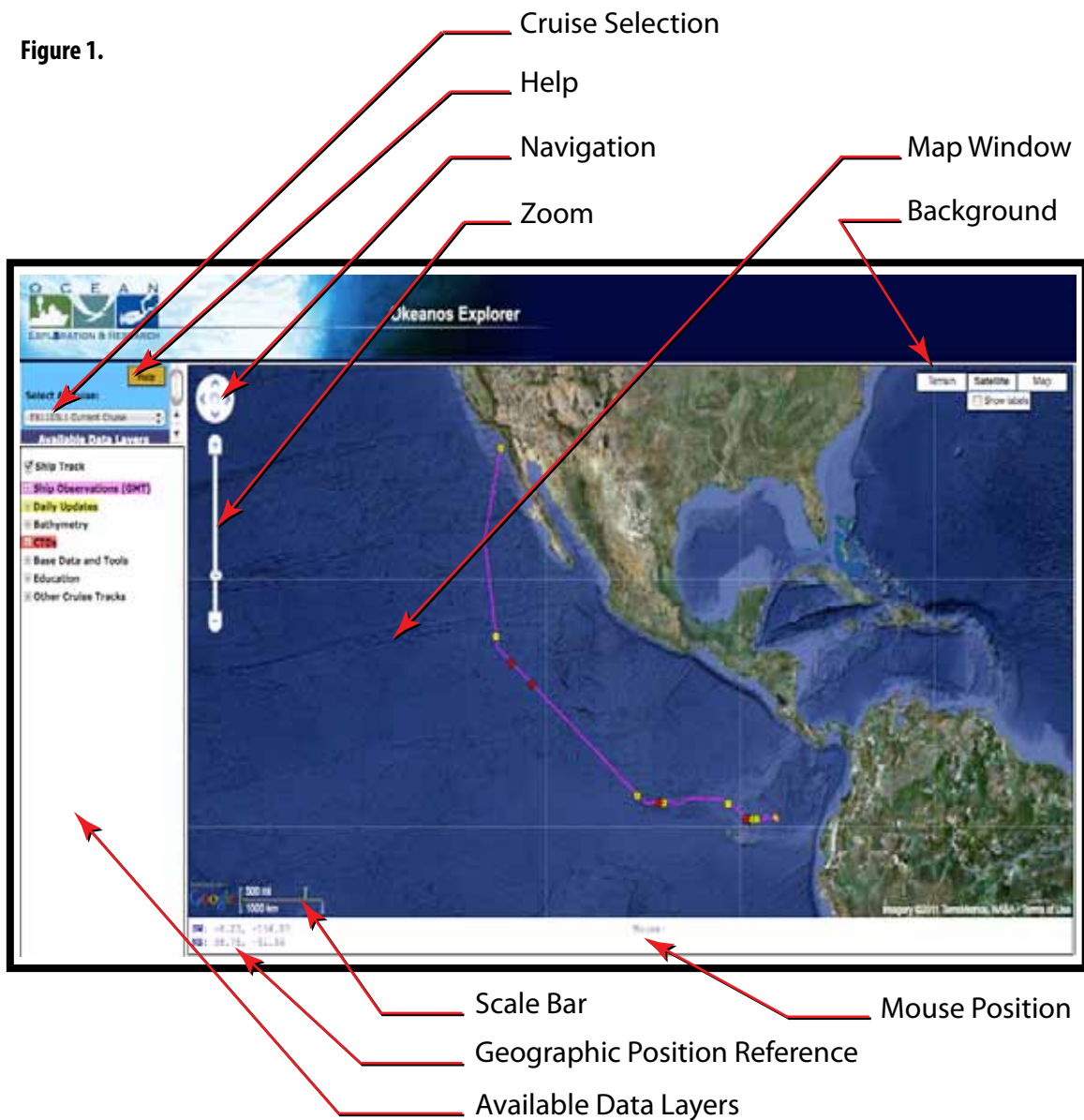
This lesson was developed and written for NOAA’s Office of Ocean Exploration and Research (OER) by Dr. Mel Goodwin, Science and Technology Consultant to OER’s Education Team.  
Design/layout: Coastal Images Graphic Design, Mt. Pleasant, SC.

**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 Data layers that are listed on the left side of the Atlas window.

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](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).

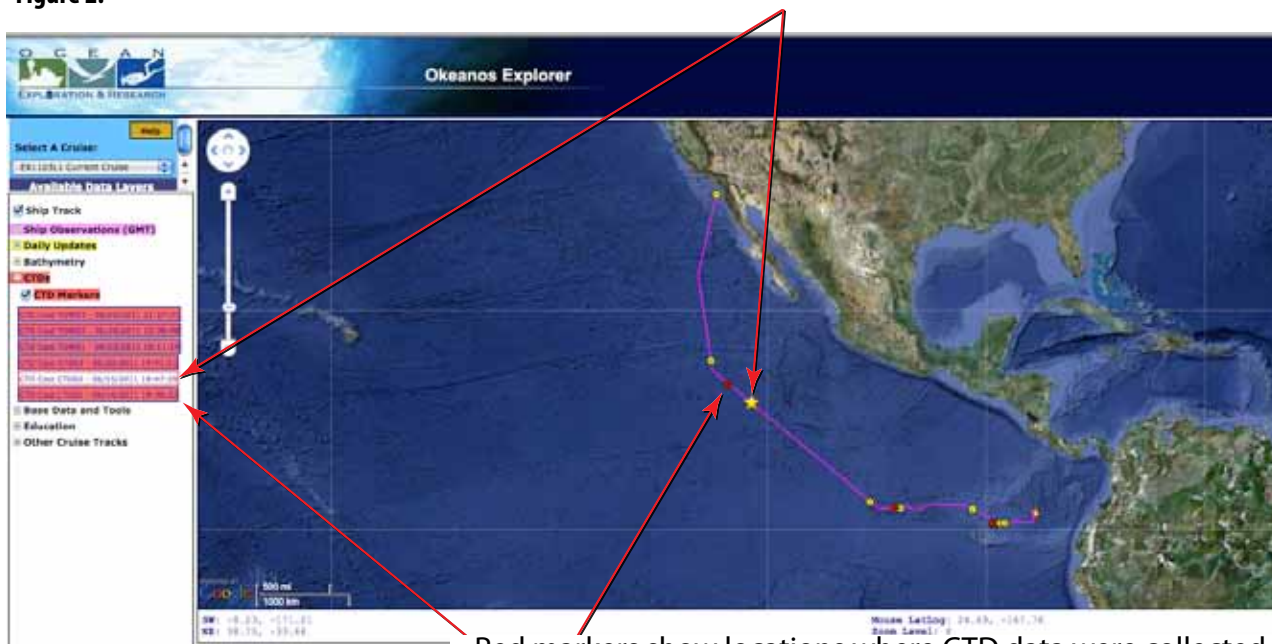
Figure 1 shows the major parts of the *Okeanos Explorer* Atlas window that are visible when the Atlas first opens:

- **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. Hold the cursor over any cruise code to identify the location of the expedition.
- **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 (in decimal degrees) of the southwest and northeast corners of the map window.
- **Mouse Position** – Shows the latitude and longitude (in decimal degrees) 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 conducted 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.**



Red markers show locations where CTD data were collected

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.

**Additional Data and Tools** – Data that 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.

**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.

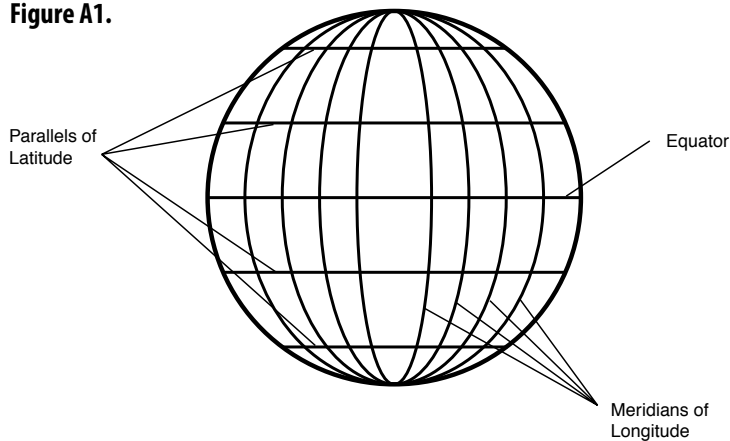
For more information, click on the “Help” box.

## 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).