OCEAN EXPLORATION & RESEARCH

Section 4: Water Column Investigations for Volume 2: How Do We Explore?

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

A Quest for Anomalies

Focus
CTD (conductivity, temperature, depth profiler)

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

Focus Question
How is a CTD used aboard the *Okeanos Explorer* to help explore Earth's deep ocean?

Learning Objectives
- Students will describe and explain redox potential and optical backscatter.
- Students will explain how redox potential and optical backscatter are related to deep-sea ecosystems and geologic features.
- Students will analyze data from CTD casts aboard the *Okeanos Explorer* for the presence of anomalies.

Materials
- Copies of *Introduction to CTD Data Worksheet*; one copy for each student or student group

Audio Visual Materials
- Video projector or large screen monitor for showing downloaded videos (see Learning Procedure, Step 2)

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

Seating Arrangement
Groups of two to four students

Maximum Number of Students
30

Key Words and Concepts
Ocean Exploration
Okeanos Explorer
CTD
Oxidation reduction potential
Optical backscatter
Plume

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 Earth's largely unknown ocean. The strategy for accomplishing this mission is to use state-of-the-art technologies to search the ocean for anomalies; things that are unusual and unexpected. When an anomaly is found, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is the distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to justify follow-up by future expeditions.

The *Okeanos Explorer* 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.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four types of technology:
- Telepresence;
- Multibeam sonar mapping;
- CTD (an instrument that measures conductivity, temperature, and depth) 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 4,000 meters.

In many ways, telepresence is the key to the *Okeanos Explorer*'s exploration strategy. This technology allows people to observe and interact with events at a remote location. The *Okeanos Explorer*'s telepresence capability is based on advanced broadband satellite communication through which live images can be transmitted from the seafloor to scientists ashore, classrooms, and newsrooms, and opens new educational opportunities that are a major part of *Okeanos Explorer*'s mission for advancement of knowledge.

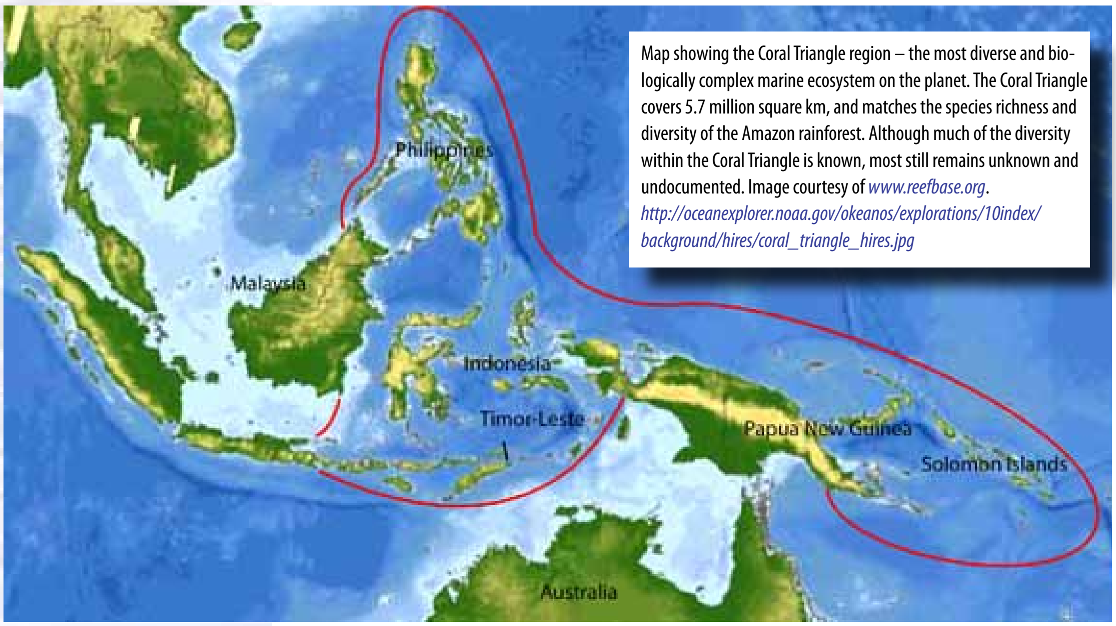
NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Okeanos Explorer Vital Statistics:

Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
Follow voyages of America's ship for ocean exploration with the *Okeanos Explorer* Atlas at *http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the global heart of shallow-water marine biodiversity. A major objective of the expedition was to advance our understanding of undersea ecosystems, particularly those associated with submarine volcanoes and hydrothermal vents. Among the Expedition's many "firsts," this was the first time scientists have been able to use an underwater robot to get a first-hand look at deepwater biodiversity in the waters of the Sangihe Talaud Region. For more information about the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.



Map showing the Coral Triangle region – the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of *www.reefbase.org*. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg*

One of the most exciting and significant scientific discoveries in the history of ocean science was made in 1977 at a divergent plate boundary near the Galapagos Islands. Here, researchers found large numbers of animals that had never been seen before clustered around underwater hot springs flowing from cracks in the lava seafloor. Similar hot springs, known as hydrothermal vents, have since been found in many other locations where underwater volcanic processes are active. Hydrothermal vents are formed when the movement of tectonic plates causes deep cracks to form in the ocean floor. Seawater flows into these cracks, is heated by magma, and then rises back to the surface of the seafloor. The water does not boil because of the high pressure in the deep ocean, but may reach temperatures higher than 350° C. This superheated water dissolves minerals in Earth's crust. Hydrothermal vents are locations where the superheated water erupts through the seafloor. The temperature of the surrounding water is near-freezing, which causes some of the dissolved minerals to precipitate from the solution. This makes the hot water plume look like black smoke, and in some cases the precipitated minerals form chimneys or towers.

The presence of thriving biological communities in the deep ocean was a complete surprise, because it had been assumed that food energy resources would be scarce in an environment without sunlight to support photosynthesis. Researchers soon discovered that the organisms responsible for this biological abundance do not need photosynthesis, but instead are able to obtain energy from chemical reactions through processes known as chemosynthesis. Photosynthesis and chemosynthesis both require a source of energy that is transferred through a series of chemical reactions into organic molecules that living organisms may use as food. In photosynthesis, light provides this energy. In chemosynthesis, the energy comes from other chemical reactions. Energy for chemosynthesis in the vicinity of hydrothermal vents often comes from hydrogen sulfide.

In chemosynthesis, energy from chemical reactions is captured and stored in other molecules. This energy moves from one molecule to another when electrons are transferred between the molecules. These transfers take place in a series of reactions called an electron transport chain. The electron transport chain begins with the loss of an electron from a substance such as hydrogen sulfide or methane. This electron is captured by an organic molecule, which releases an electron to a second organic molecule, and the process continues through several other molecules. Each time an electron is transferred, the molecule that gains the electron also gains energy; and the molecule that loses the electron loses energy. The last molecule in the chain keeps the electron, and has a higher energy content than before it received the electron. Some energy is lost each time an electron moves from one molecule to another. The energy captured by the electron transport chain is used by chemosynthetic organisms to convert carbon dioxide into molecules that can serve as energy sources (food) for living organisms.

When an atom or molecule loses an electron it is said to be oxidized, and when an atom or molecule gains an electron it is said to be reduced. A reducing substance is a substance that causes another substance to be reduced; in other words, a reducing substance donates electrons. Similarly, an oxidizing substance is a substance that causes another substance to be oxidized; that is, an oxidizing substance receives electrons. A reaction in which one or more electrons are transferred between two molecules is called a redox reaction. Note that the terms oxidation, reduction, and redox may also be used in slightly different ways for some types of chemistry, but these distinctions are not important for this discussion. Chemosynthesis depends upon the availability of reducing substances such as hydrogen sulfide or methane that can donate electrons. Habitats in which these substances occur are called reducing habitats.

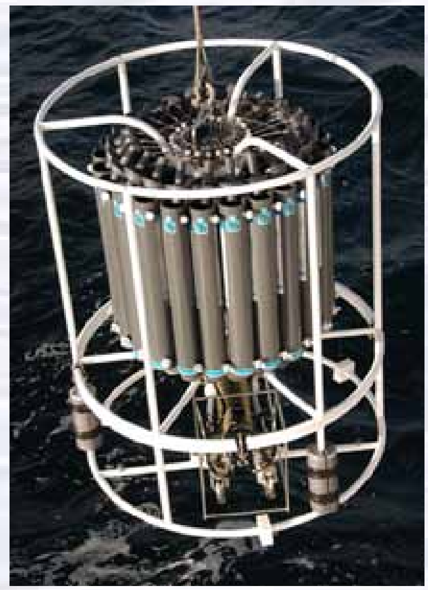
Hydrothermal vents and chemosynthetic communities are often associated with changes in the chemical properties of seawater. To look for these changes, ocean explorers use an instrument known as a CTD, which stands for conductivity, temperature, and depth. A CTD is a package of electronic instruments that measure these properties. Conductivity is a measure of how well a solution conducts

CTD Systems Aboard *Okeanos Explorer*

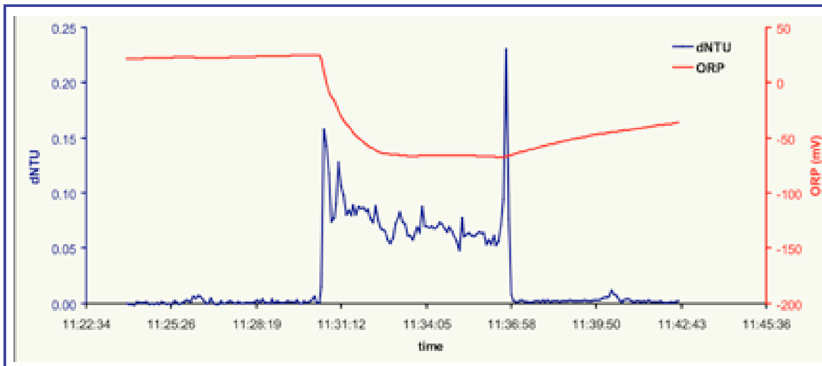
The *Okeanos Explorer* is equipped with a Seabird Electronics Model 9/11+ CTD system mounted on an SBE 32 rosette frame. This rosette includes 24 sampling bottles that can be individually triggered to collect samples at various depths. On many CTD casts, additional sensors to measure oxidation reduction potential and optical backscatter are added to the instrument package, because these parameters can also signal the presence of hydrothermal vents and reducing communities.

The SBE 9+ CTD unit has a depth rating of 6,800 meters. The ship also carries an expendable bathythermograph (XBT) that is used to measure the velocity of sound in the ocean at various depths. This information is needed by the multibeam sonar system to collect accurate bathymetric data.

Note: Mention of proprietary names does not imply endorsement by NOAA.



A CTD rosette is lowered to measure the salinity, temperature, depth and concentration of particles in the water column. Scientists use particle concentration and oxygen reduction potential as the most sensitive indicators of hydrothermal plumes. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june27/media/ex_ctd.html



Plot showing light scattering (dNTU) sensor and oxygen reduction potential (ORP) data, versus time, acquired by the CTD/rosette as it passed through a plume overtop of Kawio Barat volcano. There was an intense particle anomaly and ORP decrease in the bottom 30 meters of the water column when the plume was encountered. A drop in the ORP, like you see here, means that there are more electron donor compounds in the water produced by enrichment of seawater in dissolved metals and chemicals billowing out of hydrothermal vents. The ORP values begin to increase again, recovering slowly, when the CTD leaves the plume. Image courtesy of Sharon Walker, PMEL.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/kawio_barat_hires.jpg

A CTD is attached to a metal frame called a rosette, or carousel along with numerous water sampling bottles. This "hydrocast" is deployed off the side of a vessel, and provides information about the composition of the water column.
http://oceanexplorer.noaa.gov/technology/tools/sonde_ctd/media/ciwsam1.html

STEM Connections

Ocean exploration aboard the *Okeanos Explorer* is a real-world example of STEM concepts in action:

Science provides the overall objective – to better understand Earth's ocean – as well as a methodology for systematically acquiring this understanding;
Technology includes the tools, systems and processes that have been made to make deep-ocean exploration possible;
Engineering designs the technologies that can function in the deep-ocean environment;
Mathematics provides the basis for measurements, data analysis, and engineering design.

With increasing attention to developing integrated approaches to STEM education and technological literacy, the How Do We Explore? theme offers an exciting context for educators who wish to bring more STEM content to their classrooms.

To assist with such efforts, most lessons developed for the *How Do We Explore?* theme identify opportunities to include specific benchmarks and standards for technological literacy that have been developed by the International Technology and Engineering Education Association (ITEA, 2007). While these standards have not been widely adopted, they provide useful guidance for efforts to enhance STEM content in advance of its inclusion in formal curricula.

In addition, the *How Do We Explore?* suite of lessons includes activities that are intended to provide opportunities to apply design processes, build technological devices, and develop some of the hands-on abilities that are an integral part of most concepts about STEM education. These activities are directly tied to the technologies and scientific methodologies used for ocean exploration aboard the *Okeanos Explorer*.

For more information, see: *http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html*

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

CTD measurements provide evidence of volcanoes, hydrothermal vents, and other deep-sea features that cause changes to the physical and chemical properties of seawater. Masses of seawater with unusual characteristics 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 often raise and lower a CTD rosette through several hundred meters near the bottom as the ship slowly cruises over the area being surveyed. 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. See *http://oceanexplorer.noaa.gov/technology/tools/sonde_ctd/sondectd.html* and *http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html* for more information.

Temperature measurements from CTD sensors can be used to detect water temperature anomalies that may indicate the presence of volcanoes or hydrothermal vents. Two other sensors are also important to the search for these deep-ocean features. Optical backscatter (OBS) sensors detect the presence of suspended particles that may come from hydrothermal vents or from the oxidation of methane which causes precipitates of carbonate material to form. Oxidation reduction potential (ORP) sensors measure the tendency of a substance to gain or lose electrons. ORP is measured in volts, and increases directly with the tendency of a substance to gain electrons and become reduced. Because chemosynthetic communities are based on chemical substances that can donate electrons, these chemical substances have a tendency to lose electrons. So a drop in ORP may signal the presence of chemosynthetic communities nearby.

This lesson introduces students to simple analysis of CTD data. In the future, students will have the opportunity to apply their analytic skills to investigate additional information from CTDs as the *Okeanos Explorer* continues its voyages of discovery in Earth's deep ocean.

Learning Procedure

1. To prepare for this lesson:
   a) Review:
      - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*);
      - Background information on CTD technology at *http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html*

   (b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.
   (c) Review questions on the "Introduction to CTD Data Worksheet."
   (d) Download the data file **EX0904_ctd_1.xls** from *http://oceanexplorer.noaa.gov/okeanos/edu/resources/media/ex0904_ctd_1.xls*, and install it

on computers that students will be using to complete the *Worksheet* activity. Alternatively, you may have students download this file onto their own computer systems. Students will also need access to Microsoft Excel™ to complete this activity.
(e) If desired, download images referenced in Step 2.

2. Briefly introduce the NOAA Ship *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition. Briefly discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf*). Highlight the overall exploration strategy used by *Okeanos Explorer*, including the following points:
    - The overall strategy is based on finding anomalies;
    - This strategy involves
        - Underway reconnaissance;
        - Water column exploration; and
        - Site characterization;
    - This strategy relies on four key technologies:
        - Multibeam sonar mapping system;
        - CTD and other electronic sensors to measure chemical and physical seawater properties;
        - A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters; and
        - Telepresence technologies that allow people to observe and interact with events at a remote location.

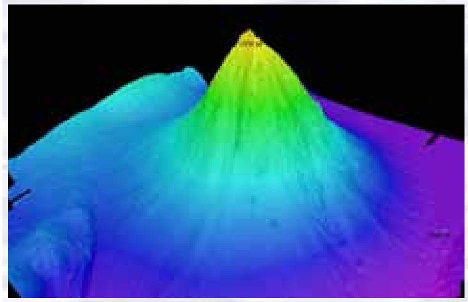
    You may want to show some or all of the images in the adjacent sidebar to accompany this review.

3. Ask students why oceanographers would want to measure conductivity, temperature, and depth. Be sure students understand the relationship between conductivity and salinity. Briefly describe a CTD, emphasizing that these devices are often capable of measuring many other parameters in addition to conductivity, temperature, and depth. You may want to use information and/or images from the site referenced in Step 1a. Discuss how OBS and ORP may be affected by hydrothermal vent activity.

4. Tell students that their assignment is to look for anomalies in CTD data collected aboard the *Okeanos Explorer* in 2009. Provide each student group with a copy of the *Introduction to CTD Data Worksheet*, and ensure that students have access to the file referenced in Step 1d. Tell students that this activity is intended to familiarize them with CTD data and how they can be analyzed to find anomalies that may indicate the presence of undiscovered features on the ocean floor. You may also want to mention that this skill will enable them to investigate additional data 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 time required to complete the entire CTD cast was 7,160 seconds; just under two hours.
    - The maximum depth recorded by the CTD was 2601.255 meters.
    - Students should notice that the maximum depth occurred about half-way

The ROV Little Hercules descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

Scientists in the Exploration Command Center at NOAA's Pacific Marine Environmental Laboratory in Seattle view live video from the *Okeanos Explorer's* ROV. Image courtesy NOAA
http://www.pmel.noaa.gov/images/headlines/ecc.jpg

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20015.jpg

Figure 4.

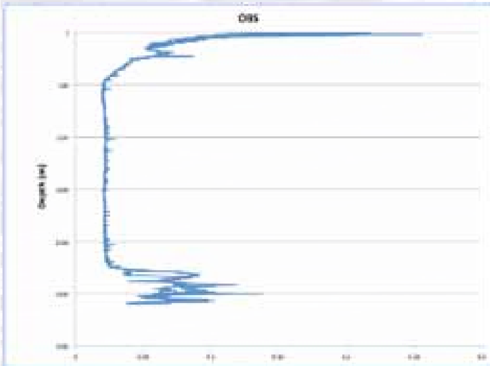
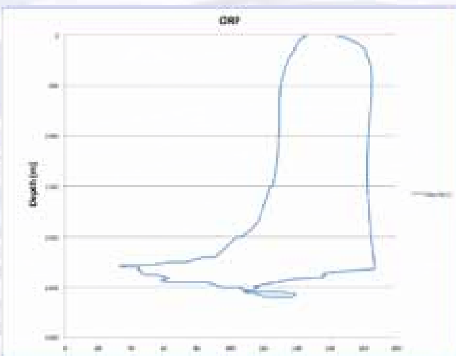


Figure 5.



through the cast; this is because data were recorded during the CTD's ascent (the "up cast"), as well as during its descent (the "down cast").

- Students' plots of OBS and ORP should resemble Figures 4 and 5 respectively.
- Plots of OBS and ORP both show anomalies between depths of 2,000 and 2,500 meters; increased OBS due to precipitates or particulate material and a reduction in ORP are both indicative of plumes from hydrothermal vents.
- Two lines on the ORP plot represent data collected during the downcast and upcast; the numbers are different, in part, because the sensor that measures ORP continues to be affected by reducing substances for a period of time after it leaves the plume.

In late June, during the INDEX-SATAL 2010 Expedition, CTD data showed anomalies that suggested the possible presence of hydrothermal vents nearby. On June 30, 2010, *Okeanos Explorer*'s ROV *Little Hercules* visited the site and found an active hydrothermal vent "surrounded by yellow and black molten sulfur, multiple species of hot-vent shrimp, a 10cm scale worm, and a small patch of stalked barnacles. After departing from the vent, the ROV ascended the summit ridge and encountered fields of sulfide chimneys with vast aggregations of stalked barnacles at their base. The chimneys varied in terms of age and venting characteristics. Some chimneys were fairly oxidized and others covered in white sulfide. Some chimneys were venting clear fluid while others were venting black smoke." You can read more about the site, and see images from *Little Hercules* here: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june30/june30.html*.

6. Discussion of CTD technology may also include the following components of technological literacy (ITEA, 2007):
   - **Scope of technology –** Development of CTD technology is the result of specific, goal-directed research.
   - **Relationships between technologies and other fields of study–** Progress in the development of CTD technology is closely linked to advancements in science and mathematics..
   - **Effects of technology on the environment –** CTD sonar technology provides an effective way to monitor and explore the deep-ocean environment to provide information for decision-making.

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 short essay discussing how discovering a deep-ocean anomaly might turn out of personal benefit.

Connections to Other Subjects

English/Language Arts, Social Studies, Mathematics

Assessment

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

Extensions

Visit the *Okeanos Explorer* Digital Atlas (*http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*) and Web page (*http://oceanexplorer.noaa.gov/okeanos/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

Chemosynthesis for the Classroom

(from the 2002 Gulf of Mexico Expedition)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_chemo_gr912.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Grades 9-12; Chemistry/Biology)

Students observe the development of chemosynthetic bacterial communities, recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive, and explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Hydrothermal Vent Challenge

(from the Submarine Ring of Fire 2004 expedition)

http://oceanexplorer.noaa.gov/explorations/04fire/background/edu/media/RoF.ventchall.pdf

Focus: Chemistry of hydrothermal vents (Grades 9-12; Chemistry)

Students define hydrothermal vents and explain the overall processes that lead to their formation, explain the origin of mineral-rich fluids associated with hydrothermal vents, explain how black smokers and white smokers are formed, and hypothesize how properties of hydrothermal fluids might be used to locate undiscovered hydrothermal vents.

Thar She Blows!

(from the 2002 Galapagos Rift expedition)

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l3.pdf

Focus: Hydrothermal vents (Grades 9-12; Chemistry/Biology)

Students demonstrate an understanding of how the processes that result in the formation of hydrothermal vents create new ocean floor, and demonstrate an understanding of how the transfer of energy effects solids and liquids.

This Life Stinks

(from the 2003 Windows to the Deep expedition)

http://oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_lifestinks.pdf

Focus: Methane-based chemosynthetic processes (Grades 9-12; Chemistry/Biology)

Students define the process of chemosynthesis, and contrast this process with photosynthesis, explain the process of methane-based chemosynthesis, and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

The Tell-Tale Plume
(from the INSPIRE: Chile Margin 2010 expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/plume.pdf
Focus: Hydrothermal Vent Chemistry (Grades 9-12; Chemistry/Biology)
Students describe hydrothermal vents, identify changes that they cause to the physical and chemical properties of seawater, and use oceanographic data to recognize a probable plume from hydrothermal activity.

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.

Anonymous. 2010. Web site for the INDEX-SATAL 2010 Expedition [Internet]. Office of Ocean Exploration and Research, NOAA [cited January 7, 2011]. Available from *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html* – Includes links to lesson plans, career connections, and other resources

Anonymous. Ocean Explorer [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*.

Anonymous. 2011. *Okeanos Explorer* Education Materials Collection [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*

Anonymous. *Okeanos Explorer* America's Ship For Ocean Exploration [Internet]. NOAA Office of Ocean Exploration and Research [cited January 24, 2011]. Available from: *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 *Okeanos Explorer*

Anonymous. CTD and Tow Methods [Internet]. NOAA Pacific Marine Environmental Laboratory [cited January 4, 2011]. Available from: *http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html*

German, C., D. Yoerger, M. Jakuba, T. Shank, C. Langmuir, and K. Nakamura. 2008. Hydrothermal exploration with the Autonomous Benthic Explorer. Deep-Sea Research I 55:203-219

International Technology Education Association. 2007. Standards for Technological Literacy: Content for the Study of Technology. Reston, VA. 260 pp.

Yoerger, D., A. Bradley, M. Jakuba, M. Tivey, C. German, T. Shank, and R. Embley. 2007. Mid-ocean ridge exploration with an autonomous underwater vehicle. Oceanography 20(4):52-61; available online at *http://www.tos.org/oceanography/issues/issue_archive/issue_pdfs/20_4/20.4_yoerger_et_al.pdf*

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
- Chemical reactions
- Motions and forces

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

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

Because most Fundamental Concepts are broad in scope, some aspects of some Concepts may not be explicitly addressed in this lesson. Such aspects, however, can be easily included at the discretion of the individual educator.

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

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

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 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

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 c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

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

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments 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

Acknowledgments

Produced by Mel Goodwin, PhD, Marine Biologist and Science Writer, Charleston, SC for NOAA.. Design/layout: Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: *http://oceanexplorer.noaa.gov*

Introduction to CTD Data Worksheet

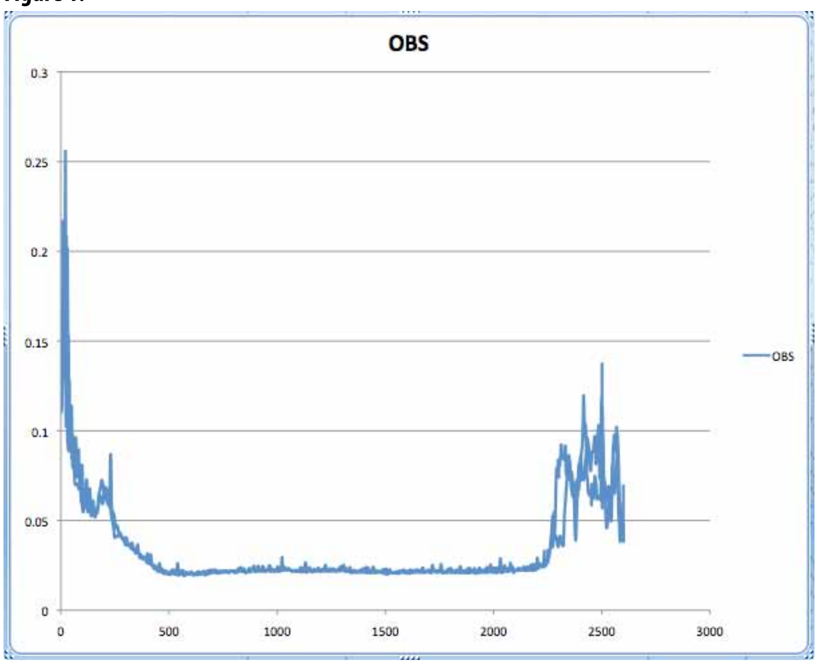
1. Open the **ex0904_ctd_1.xls** file in Microsoft Excel®. These data were collected during a CTD cast aboard the *Okeanos Explorer*. The first row shows the contents of each column: Data and time; Latitude in decimal degrees; Longitude in decimal degrees; Elapsed time since the start of the cast in seconds; Depth in meters; Temperature in °C; Conductivity in Siemens per meter; Salinity in Practical Salinity Units; Optical Backscatter (OBS); and Oxidation-Reduction Potential. (ORP) The units of OBS and ORP aren't really important, because we are only concerned with finding readings that are distinctly different from other readings near the same depth (anomalies).

2. How much time was needed to complete the entire CTD cast?

3. What was the maximum depth recorded by the CTD?

4. Plot OBS as a function of Depth:
   a. Select the Depth and OBS columns
   b. Under the "Insert" menu select "Chart..." A pop-up menu will appear.
   c. In the popup menu, click on the "XY (Scatter)" tab
   d. Click on the "Smoothed Line Scatter" button. Now you should have a graph that resembles Figure 1.

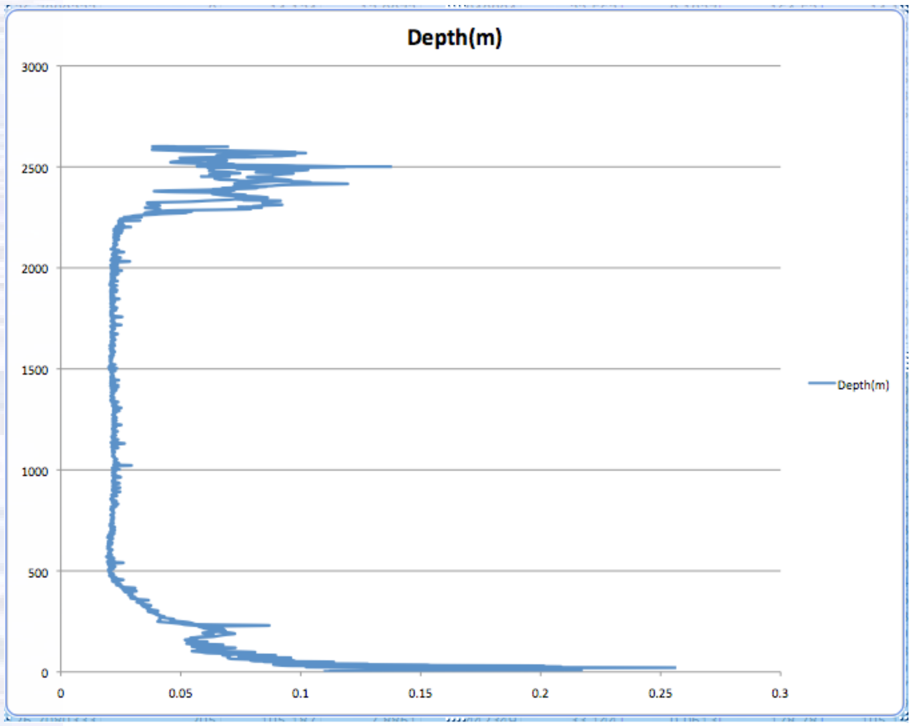
Figure 1.



5. Oceanographers like to plot CTD data with depth on the y-axis and the greatest depths at the bottom of the plot, since that is the way we usually think about a profile of the water column. For an x-y plot, Excel plots the first column on the x-axis. So, to make an "oceanographer's plot" we need to re-arrange the data so that temperature values come before depth values.
   a. Copy the depth column to one of the blank columns on the right side of the spreadsheet.
   b. Select the OBS column and the Depth column to the RIGHT of the Temperature column.

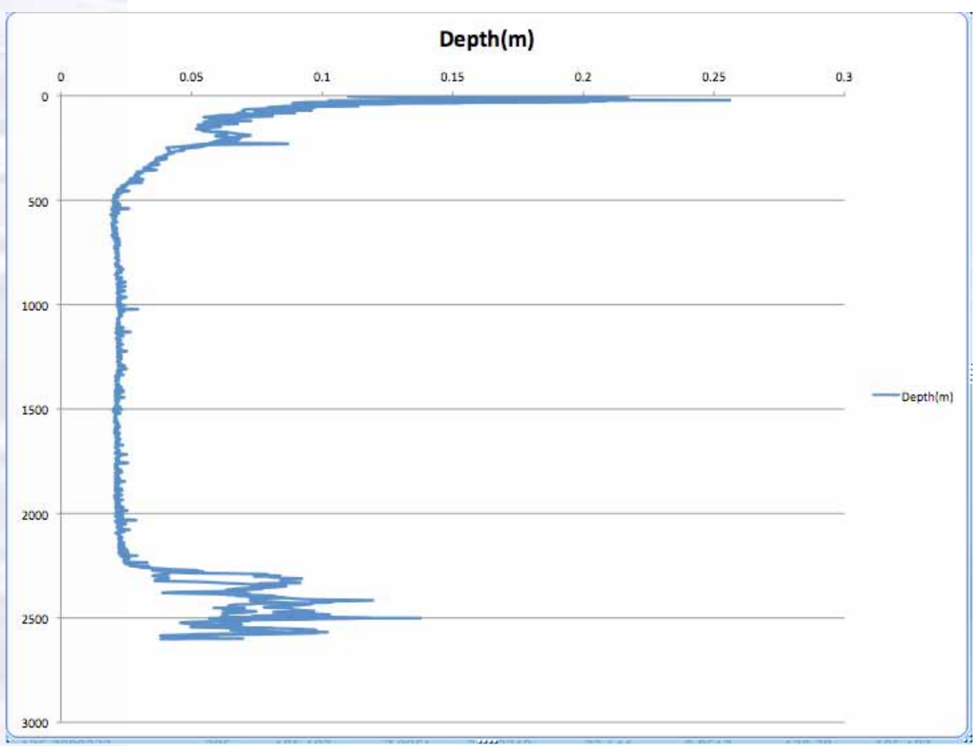
c. Click on the "Smoothed Line Scatter" button (the "XY (Scatter)" tab should still be selected). Now you should have a graph that resembles Figure 2.

Figure 2.



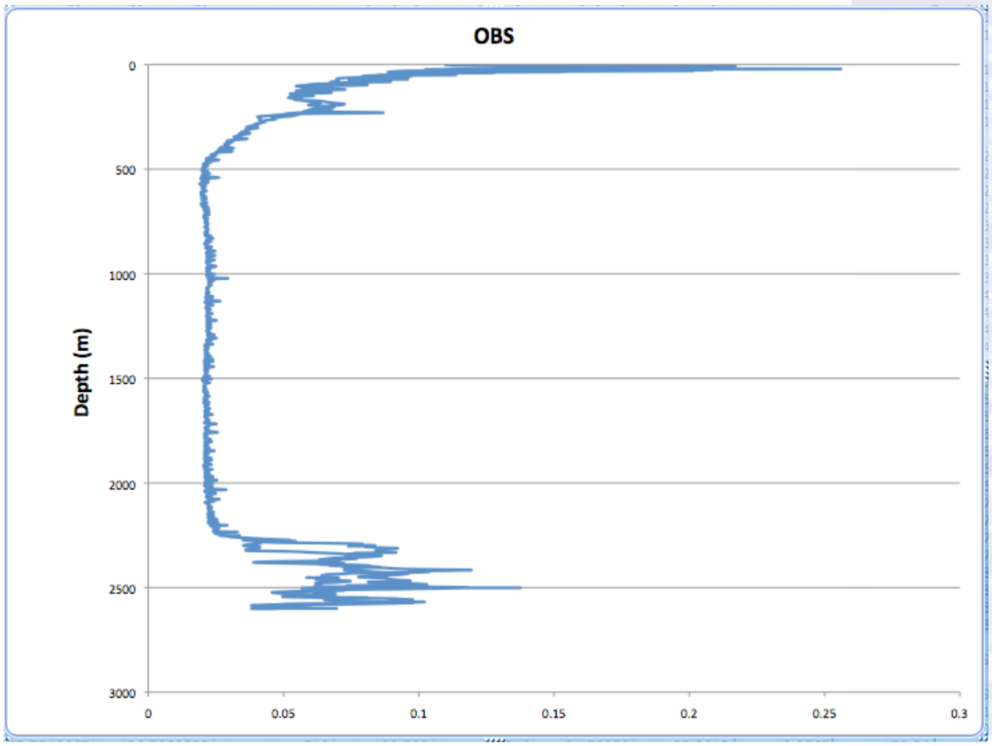
d. To make the greatest depths appear at the bottom of the plot, double click on the y-axis. The "Format Axis" window will appear. Click the "Scale" button on the left side of the window, then check the "Values in Reverse Order" box, then click "OK." Now your graph should resemble Figure 3.

Figure 3.



e. We need to make four more changes. First, the x-axis is now at the top of the plot. To fix that, double click the y-axis again and check the "Horizontal (category) axis crosses at maximum value" box. then click "OK." Next, the title of the graph needs changing: Click on the title, then highlight the text. Type in "OBS." Now remove the legend on the right side of the graph by clicking on the legend and hitting the "Delete" key. Finally, let's add a label to the y-axis: Click inside the plot area, then drag one of the handles on the left side of the plot toward the center to make space for a label. Make the "Drawing" toolbar visible (select from "Toolbars" in the "View" menu), and select the text tool. Click on the left side of the plot and type "Depth (m)." Format the text with tools in the Formatting toolbar (select from "Toolbars" in the "View" menu), then drag the green handle on the text box to rotate the text 90 degrees. Right-click (control click on a Macintosh platform) and drag the text box to the desired location. Now your graph should resemble Figure 4.

Figure 4.



6. Repeat the procedures in Steps 4 and 5 to make an "oceanographer's plot" of ORP as a function of Depth.

7. Do either of your plots show any anomalies? Why does the ORP plot appear to have two lines?