CTD ANALYSIS | EDUCATOR

Links to Next Generations Science Standards |

MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

Links to Common Core Standards |

CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.

Theme | Science
Pacing | 1 class period (45 minutes)
Background Needed | basic graphing, variables, recognizing patterns, basic chemistry, temperature, salinity, depth
Assessment | Scientific Reporting Rubric provided
Materials/Resources |

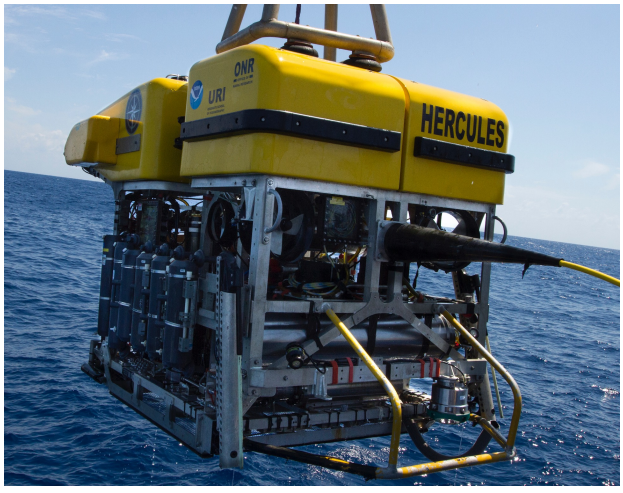
- CTD data worksheet in Student lesson or available here (http://nautl.us/1P4SqAV)
- Graph paper
- Straight edge
- Computers with graphing programs (optional)

Overview

This module is designed to give students an introduction to graphing data collected from Remotely Operated Vehicle (ROV) *Hercules* CTD sensor. A CTD is a water profiling tool that records conductivity (a measure of salinity), temperature, and depth. Students will interpret raw data on temperature, pressure, and salinity and graph them versus depth. Students will analyze the resulting graphs to identify the patterns seen in the graphs.

Objectives & Learning Outcomes

- Students will practice graphing skills using real data from ROV *Hercules*.
- Students will be able to identify thermoclines and haloclines.
- Students will understand how ocean temperature, salinity and pressure change across depth profiles.



Guiding Questions

- How do temperature, pressure and salinity change as you go deeper into the ocean?
- What impact do changes in these variables have on the ecosystem?

Links to Common Core Math Standards |

CCSS.MATH.CONTENT.8.EE.B.5: Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed.

CCSS.MATH.CONTENT.6.EE.C.9: Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

Activity/Tasks

Students will:

- Examine raw CTD data and determine how best to graph the data.
- Discuss patterns and relationships seen in their graphs and form conclusions based on the raw data.
- Share with the class their understanding of how depth affects temperature, pressure and salinity.

Educator: Lesson Procedure/Directions

1. Introduction:
   a. Hand out student data sets and worksheets.
   b. Introduce students to the concept of plotting ocean chemistry data and review with them the different data recorded by a CTD instrument.

2. Graphing:

   ✓ Teacher Tip: Use the Excel Spreadsheet Data for students who have difficulty typing or to cut down on time.

   a. Students will use the provided real ROV data sets to plot 3 different vertical profiles. It is up to the educator to determine the appropriate format for the graphs. Students could plot all data sets on one single graph to search out correlations between the variables or students can produce 3 separate graphs to compare the variables side by side.
   b. After students have graphed data, ask them to identify the pattern/trend in each data set and challenge them to generate a statement to predict the behavior of each variable as it changes with depth.

Student: Lesson Procedure/Directions

1. Look at the provided data. Discuss with your group what you think the best way to set up the graph would be so it is easy to read.

2. Use the student data to graph the variable combinations below on your provided graphing material:
   a. Temperature vs. Depth
   b. Pressure vs. Depth
   c. Salinity vs. Depth

3. Discuss with your group any patterns or relationships you found. Record your conclusions.

Extensions & Adaptations

Introductory |
Research what a CTD sensor measures and define each variable. Discuss the units of measurement for each variable. Reference: http://www.whoi.edu/instruments/viewInstrument.do?id=1003; http://www.pmel.noaa.gov/vents/PlumeStudies/WhatIsACTD/CTDMethods.html.

Advanced |
Research how CTD data can be used to find geologic features on the seafloor. Analyze CTD data for the presence of anomalies. Graph associated data using a program such as Microsoft Excel. Use CTD data to find density of seawater. Reference: http://www.es.flinders.edu.au/~mattom/Utilities/density.html.

Extension |
You can collect CTD data from numerous public databases and correlate to almost any number of variables. Types of biology found and the water quality associated there, types of coral, etc.

Pre-Lab Questions

1. What variables besides temperature, pressure and salinity do you think are important to life in the ocean?
   - ✓ Sample Answers could include: *Oxygen, Carbon Dioxide, Iron, pollutants, toxins, plastics, light are just some examples of other factors important to life in the oceans. Prompting students to give the reason for a factor/variable to be 'important' to life will push students to think critically about what life 'needs' and what resources are limiting and what resources are abundant in the ocean.*

2. In the ocean, what do you think the relationship between temperature and depth is? What is a thermocline?
   - ✓ Sample Answers could include: *Temperature decreases to a point and then remains constant after a certain depth. The thermocline is a layer where there is a sharp difference in the temperature above and below this layer. It can also be a barrier where limited mixing happens below that depth. The ocean often has a variable upper depths and a fairly constant deeper temperature. This is an inverse relationship where as depth increases temperature decreases.*

3. In the ocean, what do you think the relationship between pressure and depth is?
   - ✓ Sample Answers could include: *Pressure will increase constantly and directly proportional to depth. For every 10 meters of depth, the pressure increased by 1 atmosphere.*

4. In the ocean, what do you think the relationship between salinity and depth is? What is a halocline?
   - ✓ Sample Answers could include: *Salinity will typically increase and reach a relatively constant amount at a certain depth. The halocline is an area where there is a rapid change in salinity over a short vertical distance. Haloclines occur at the deepest depths of the mixing of surface waters. Haloclines are also more prominent where freshwater like rivers enters saltwater.*

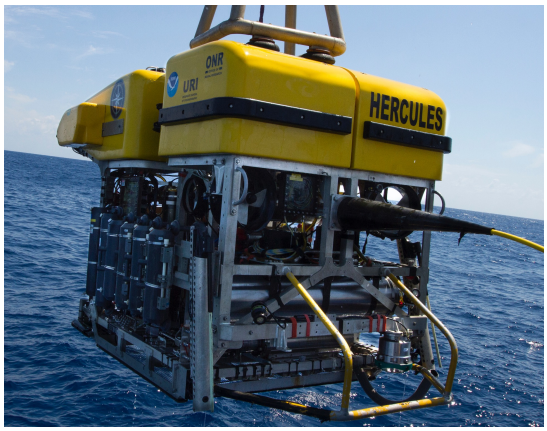
CTD ANALYSIS | STUDENT

Learning Goals

- Graph real data collected by the ROV *Hercules*.
- Learn to identify thermoclines and haloclines.
- Understand how temperature, salinity, and pressure change across depth profiles in the ocean.

Challenge: How does the ocean change as it gets deeper? Search for patterns in the real-world ocean data collected by ROV *Hercules*. Practice your graphing skills so you can follow the trends as the depth increases.

Introduction |



One of the most common instruments used in oceanography is a CTD. CTDs are a tool with a package of electronic sensors to measure Conductivity (salinity), Temperature, and Depth at set intervals. CTDs can measure every second, every minute, or like ROV *Hercules'* CTD at 9 times per second! This tool can be deployed off the side of a ship alone or be integrated as part of an ROV. The CTD on ROV *Hercules* transmits all the data up the tether to scientists in the control room who can track the patterns. In this activity, you will graph selections of real-world data collected during a 1,025-meter dive to the Del Mar methane seep off the coast of California. Learn more about this expedition. (https://nautiluslive.org/cruise/na066) CTDs record some of the basic information (variables) that define what kind of biological, geochemical and physical environment an ROV is exploring. Knowing what the patterns are in an area helps scientists compare their observations to new areas or notice unusual patterns that clue them into asking more questions or planning elaborate experiments.

Guiding Questions |

1. How do you think temperature, pressure, and salinity will change as you go deeper in the ocean?

2. What impact do changes in these variables have on the ecosystem?

Helpful Resources:

Read more about how scientists incorporate CTD data into their work:

Blog: Meet the Team, Mike Brennan http://nautl.us/1TKk4BW

Article: Ocean Properties by Ocean Networks Canada http://www.oceannetworks.ca/article-tags/ctd

Pre-Lab Questions |

1. What variables besides temperature, pressure and salinity do you think are important to life in the ocean?

2. In the ocean, what do you think the relationship between temperature and depth is? What is a thermocline?

3. In the ocean, what do you think the relationship between pressure and depth is?

4. In the ocean, what do you think the relationship between salinity and depth is? What is a halocline?

Procedure |

1. Discuss with your group the best way to graph the three data sets so it will be simple to look for patterns between variables and be easy to read.
2. Using the provided CTD Data Sheet, plot the following data relationships.
   a. Temperature vs. Depth
   b. Pressure vs. Depth
   c. Salinity vs. Depth
3. Examine your graphs and discuss with your group the patterns and relationships you see. Record your conclusions.

CTD DATA SHEET |

DEPTH (Meters)	TEMPERATURE (Degrees Celsius)	CONDUCTIVITY / SALINITY (Practical Salinity Unit 0/00)	DEPTH / PRESSURE (Pounds per Square Inch)
1	18.0	33.2	16.2
35	16.5	33.2	65.7
70	13.4	33.2	116.7
115	11.1	33.5	182.4
150	9.9	33.7	233.4
185	9.4	33.9	284.4
220	9.4	34.1	335.4
255	9.2	34.2	386.5
290	9.0	34.2	437.5
325	8.5	34.3	488.5
360	8.5	34.3	539.5
395	8.0	34.5	590.6
430	7.6	34.3	641.6
465	7.5	34.3	692.6
500	7.0	34.3	743.6
570	6.5	34.3	845.7
605	6.2	34.3	896.7
640	6.0	34.3	947.7
675	5.9	34.4	998.8
710	5.7	34.4	1049.8
745	5.5	34.4	1100.8
780	5.3	34.4	1151.9
815	5.0	34.4	1202.9
850	4.9	34.4	1253.9
885	4.7	34.4	1304.9
920	4.5	34.5	1356.0
955	4.3	34.5	1407.0
990	4.2	34.5	1458.0
1025	4.1	34.5	1509.0

Conclusions |

Write a paragraph about the relationships and patterns you saw in your data plots. Discuss the relationship between the two variables and how each factor changes as depth increases or decreases.

1. **Temperature vs. Depth**

2. **Pressure vs. Depth**

3. **Salinity vs. Depth**

Scientific Reporting Rubric

OBJECTIVE	CRITERIA			
	4 Exemplary	3 Commended	2 Emerging	1 Developing
Communication of Data and Analysis |	Student chooses appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. No errors in data format (includes titles, units, captions, etc.). Student provides a thorough and detailed written summary of data, including key observations, trends, and identification of outliers or anomalies.	Student chooses appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. Data may contain minor errors in format. Student provides a written summary of data, including key observations, trends, and identification of outliers or anomalies.	Student attempts to choose appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. Data may contain errors in format or may be missing some information. Student provides a weak written summary of data.	Student does not choose appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. Data may contain errors in format or may be missing some information. Student provides a minimal written summary of data.
Critical Thinking |	Student includes effective use of sources, facts and data to support what was learned in a conclusion or overview statement. Student is able to reflect on implications, errors and limitations of the data and connect to other topics. Student can suggest next steps or future improvements & modifications to topic(s) addressed.	Student uses sources, facts and data to support what was learned in a conclusion or overview statement. Student is able to reflect on implications, errors and/ or limitations of the data. Student can suggest a next step or future improvement/ modification to topic(s) addressed.	Student uses some sources, facts or data to support what was learned in a conclusion or overview statement. Student is able to weakly reflect on implications, errors and/or limitations of the data. Student attempts at suggesting a next step or future improvement/ modification to topic(s) addressed.	Student uses few sources, facts or data to support what was learned in a conclusion or overview statement. Student is able to weakly reflect on implications, errors and/ or limitations of the data.
Language and Conventions |	Student produces clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience. Demonstrates an exemplary command of standard English conventions.	Student produces writing in which the development, organization and style are appropriate to task, purpose and audience. Demonstrates a command of standard English conventions; errors do not interfere with understanding.	Student produces writing in which some development, organization and style are appropriate to task, purpose and audience. Demonstrates a limited and/or inconsistent command of standard English conventions; errors may interfere with understanding.	Student produces writing in which there is limited development, organization and style appropriate to task, purpose and audience. Demonstrates a weak and/or inconsistent command of standard English conventions; errors interfere with understanding.
Total Score: _____	**Comments:**			