Developing Undergraduates' Scientific Reasoning with OOI Data Visualizations

(and others)

Kathy Browne, Andrea Drewes & Gabi Smalley, Rider University

Sage Lichtenwalner, Rutgers University

Evolution of my efforts to assess student learning

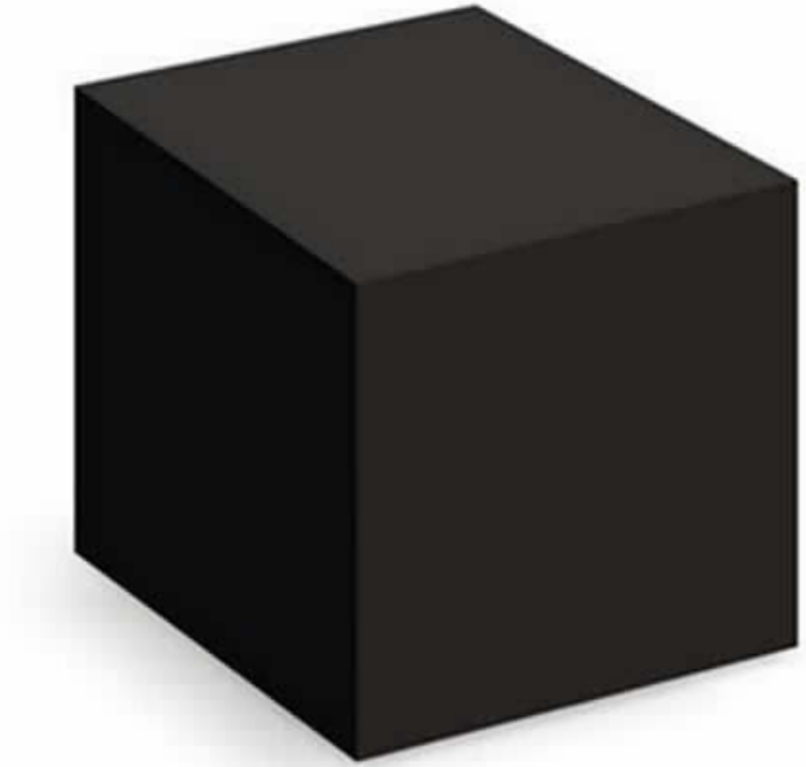
Why…?

Explain why….

Why…? Explain yo

Why…? Explain y
understandable;
reasons for]

Why…? Explai
or understand
the reasons for] To explain, you will need numerous sentences.



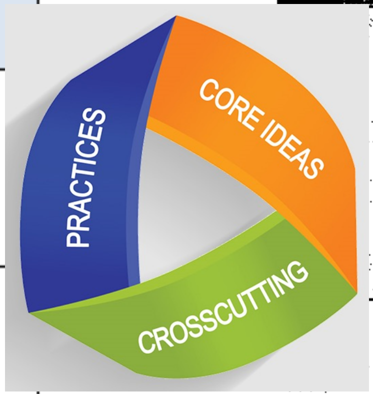
If students could articulate their struggles….

***What is* in an “explanation”?**

K-12 Next Generation Science Standards (NGSS)

9–12 Science Practices: Constructing Explanations
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
• Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
• Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
• Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

www.nextgenscience.org/



Claim-Evidence-Reasoning [CER] Rubric

TABLE 5.5 Base Rubric for Scientific Explanation

LEVEL	Claim	Evidence	Reasoning
	A statement or conclusion that answers the original question/ problem.	*Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.*	*A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
0	Does not make a claim, or makes an inaccurate claim.	Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim).	Does not provide reasoning, or only provides inappropriate reasoning.
Varies from 1 to 5	Makes an accurate but incomplete claim.	Provides appropriate, but insufficient, evidence to support claim. May include some inappropriate evidence.	Provides reasoning that connects the evidence to the claim. May include some scientific principles or justification for why the evidence supports the claim, but not sufficiently.
	Makes an accurate and complete claim.	Provides appropriate and sufficient evidence to support claim.	Provides reasoning that connects the evidence to the claim. Includes appropriate and sufficient scientific principles to explain why the evidence supports the claim.

MacNeill & Krajcik, 2012

Given a map of EQ’s and volcanoes provided for the area near the west coast of South America, explain what kind of plate motion is occurring using both drawings and words to **explain**. Be sure **to use the evidence provided in your explanation**.

OR

Using the data sets provided regarding plate margin activity, describe each set thoroughly and then, using the **claim-evidence-reasoning approach**, respond to the following: How are the 2 different plate boundaries depicted similar and how are they the same?

Note: Essays are worth quite a few points. A short essay if succinct and well composed with lots of info could earn all points. But typically, a 1-2 sentence response does not earn many pts.

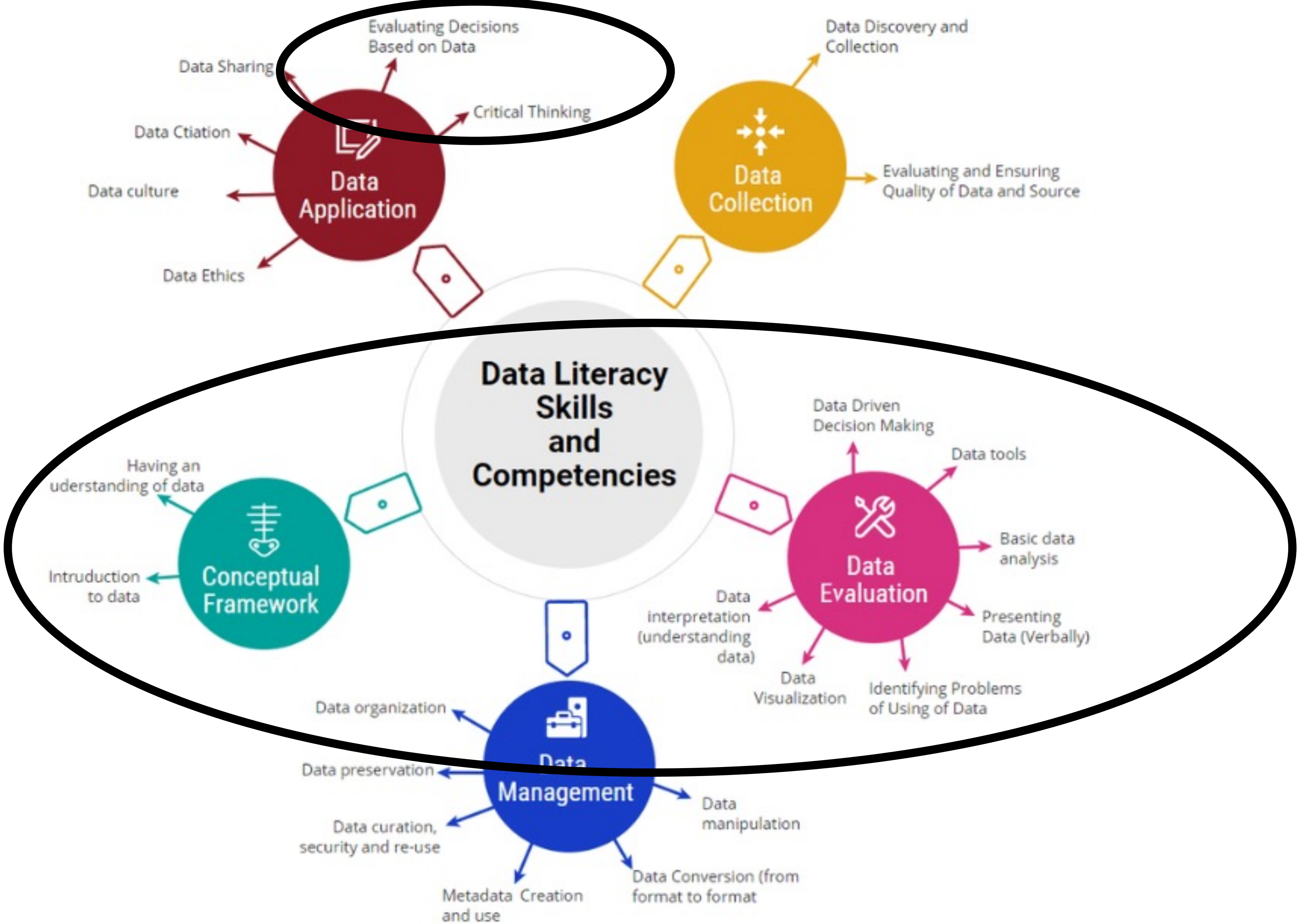
Please note the use of the term “explain” in my question. Students sometimes ignore it…I recommend you keep in mind the meaning of the work “explain”:

EXPLAIN: **to <u>give the reason</u> for or cause of; to <u>show</u> the logical development or relationships of**

This is really important!

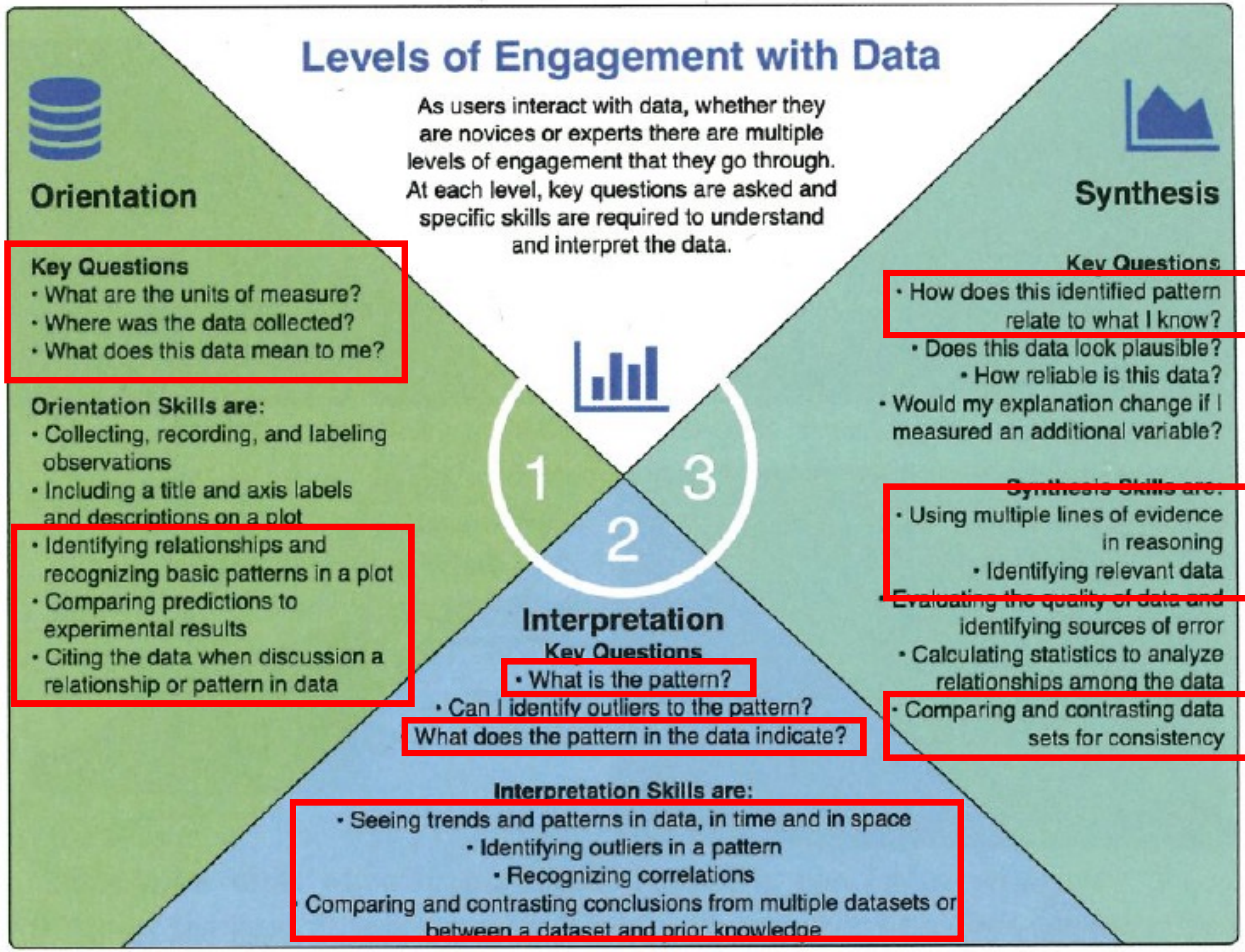
2014

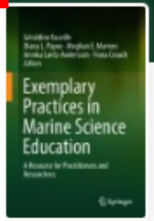
Still wasn’t satisfied…..how to use “evidence”????



Guler, G., 2019

Schematic representation of data literacy skills and competencies. Adapted from Ridsdale et. al. (2015, p. 38)





Exemplary Practices in Marine Science Education pp 207–223

Educating with Data

Liesl Hotaling, Janice McDonnell, Carrie Ferraro, Kate Florio & Sage Lichtenwalner

Chapter | First Online: 29 June 2018

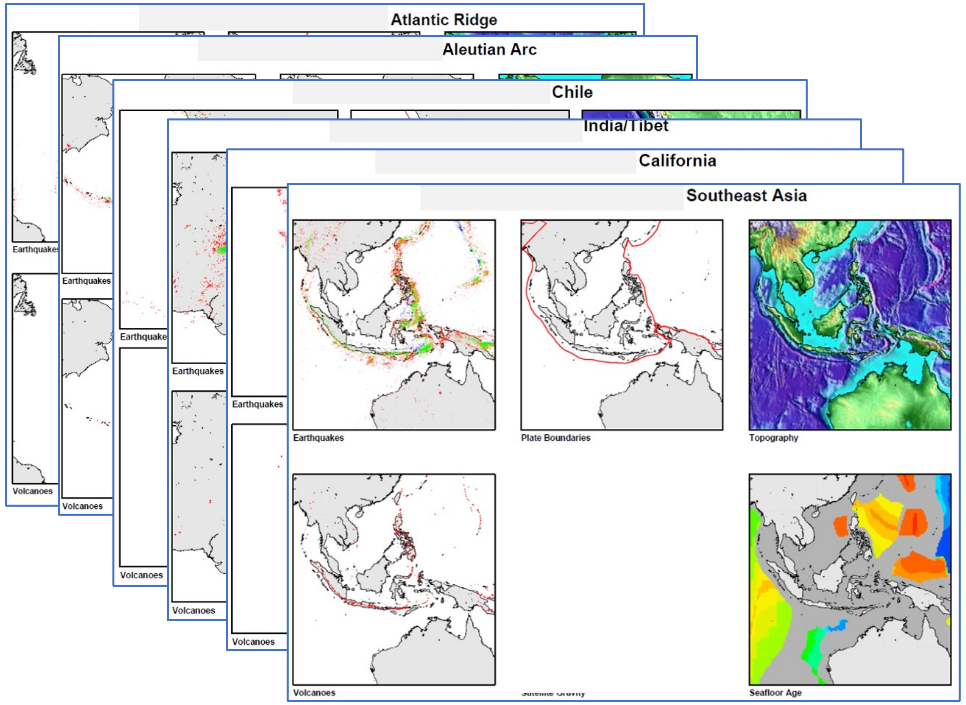
D-C-E-R Framework

- describe data (trends, patterns, ranges, outliers, similarities, differences, etc.) **[Data Descriptions-D]**
- draw conclusions about the data and relevant phenomena, **[Claim-C]**
- and support those conclusions with scientific reasoning that includes proper evidence tied to the students' understanding of relevant science concepts (**Evidence-E** and **Reasoning-R**).

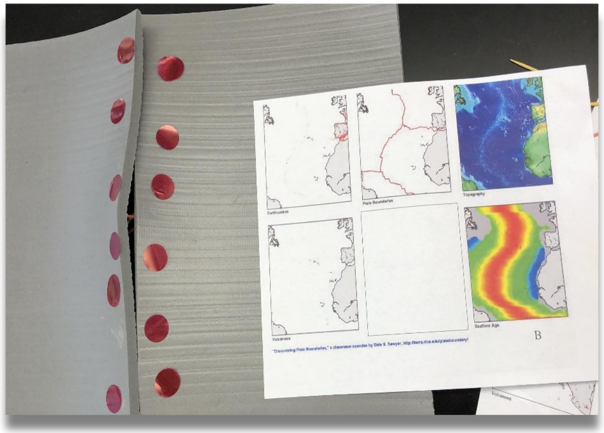
(with other instructional strategies)

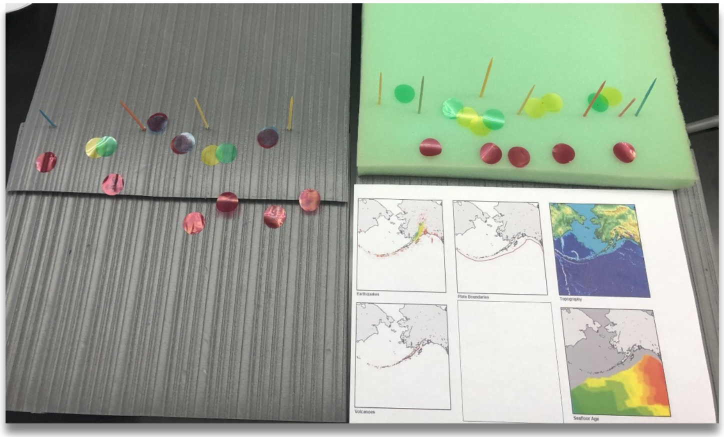
Plate Tectonics Boundary Exercise

- First: reading homework, then introduction to Plate Tectonics and some of the evidence that supports the theory
- Determine the plate boundary at sites assigned using data set from http://plateboundary.rice.edu/



- Construct a model to show the plate margin you concluded and add representation of data that supports your conclusion.
- Review other models and help others improve them.





Learning Steps

- Describe patterns in data sets
- Determine evidence that supports your conclusion
- Use your understanding of scientific principles and evidence to support your conclusion in an explanation
- Feedback provided

Pro's

- Engage students with data; guided to practice identifying patterns in data
- Utilize multiple steps in the scientific process
- Requires multiple levels of thinking and consideration of different perspectives
- Reveals understandings that can be addressed

Con:

- Time consuming (class time; assessing)

Adding D to C-E-R…

- Required students to first describe patterns in words with quantitative details they find
- Likely forced students to make sense of data visualizations more than they would normally, as well as use patterns and evidence to answer questions
- Even with feedback, revisions, and coaching, it was still difficult for students to connect evidence to their understanding of science concepts to support their conclusions
- Subset of low scores for R showed low scores for all components suggesting that:
  - without sufficiently describing trends and patterns found in a data set, it is even more difficult to draw conclusions from the data, identify relevant and sufficient evidence for what conclusions they make, and compose a robust explanation of those conclusions.

Results from an exercise with the following instructions (maximum score of 3 for all components): Using materials provided, develop an experiment to measure temperature of an ice sample as it melts and then boils. Plot data and complete D-C-E-R to explain the results.

	Data Description (D)	Claim (C)	Evidence (E)	Reasoning (R)
All students (n = 26)	2.2 ± 0.8	2.0 ± 0.6	2.3 ± 0.7	1.8 ± 0.8
D < 2 (n = 5)	0.9±0.5	1.3±0.5	1.3±0.4	1.0±0.7

Ocean Data Labs

OOI Data Explorations | Collections | Project Info | Data Labs Home

Home / 2019 Collection / Anoxic Events

Home | Data Labs | O(

Data Explorations

Anoxic Events

Explore the impact and interaction… fisheries

Select the question your instructor has as…

Exploration
Explore the relationship between atmos… processes (wind) and oceanic process… (currents and upwelling), and how thes… processes affect benthic organisms an… ability to fish for them.

OOI DATA

Looking for ways to cor… Observatories Initiative

What are Data E

OOI Data Explorations a… visualizations that incor…

Each Data Exploration v… students in exploration… introductory oceanogra… in-class group activities… some feature a single a… sequenced together for…

An Instructor Guide for… conceptual understandi…

https://data

Instructors' Corner

If you are a professor or teacher intereste… Explorations in your courses, check out th… guidance.

Instructo…

Activity Citation: Browne, K., Sahl, L., F… Anoxic Events. *OOI Data Labs Collection*

This site was developed with the support of the N… OCE-1831625. Any opinions, findings, and conc…

Coastal Endur…
https://datalab.marine.rutgers.edu/ex…

Get Social with #EarthER19

EARTH EDUCATORS' RENDEZVOUS
NASHVILLE, TN, JULY 15-19, 2019

Earth Educators Rendezvous > Previous Rendezvo…

Earth Educators Rendezvous

- Rendezvous 2022
- Previous Rendezvous
  - Rendezvous 2021
  - Rendezvous 2020
  - Rendezvous 2019
    - Community Broadcasts
    - Participant Information
    - Program
      - Sunday Events
      - Morning Workshops
      - Afternoon Mini-Workshop

Data L… Engage…

Tuesday, Wedne…

Afternoon Mini Wor…

Convene…

Ja… N…

Cl… Br…

▸ *Show addition…*

Join us for this … data into under… ocean research… teach with data… environmental … and Universities…

https://serc.carleton.edu/e…

OOI Lab Exercises — You are here: Home / OOI Lab Exercises

EXPLORING THE OCEAN WITH OOI DATA – 2ND EDITION

A collection of laboratory exercises featuring data from the Ocean Observatories Initiative.

Cabled Axial Seamount Array
https://datalab.marine.rutgers.edu/ooi-lab-exercises/

Lab Chapters & Authors

Lab 1 – Introduction to the Ocean Observatories Initiative (OOI) – The collection of oceanographic data

- Denise L. Bristol, Hillsborough Community College-SouthShore
- Anna Pfeiffer-Herbert, Stockton University
- Lauren Sahl, Maine Maritime Academy

Lab 2 – Building Data Skills – The display of oceanographic data

- Lauren Sahl, Maine Maritime Academy
- Anna Pfeiffer-Herbert, Stockton University
- Denise Bristol, Hillsborough Community College-SouthShore

Lab 3 – Geology – Plate Tectonics and the Seafloor

- Benjamin R. Jordan, Brigham Young University-Hawaii
- Kathleen Browne, Rider University

Lab 4 – Geology – Sea Floor Changes in a Volcanically Active Setting

- Kathleen Browne, Rider University
- Benjamin R. Jordan, Brigham Young University-Hawaii

Lab 5 – Ocean Chemistry – Investigating Density and Stratification in the Ocean

- Jacqui Degan, Cape Fear Community College
- Mikelle Nuwer, University of Washington

Lab 6 – Ocean Physics – Waves Generated by Large Storms

- Joseph W. Long, University of North Carolina Wilmington
- Richard W. Dixon, Texas State University

Lab 7 – Primary Production – Identify factors that control Primary Production in the western temperate Atlantic Ocean

- Gabriela Smalley, Rider University
- Rebecca Freeman, University of Kentucky

Lab 8 – Anoxic Events – Solve the mystery of the dying crabs

- Rebecca Freeman, University of Kentucky
- Gabriela Smalley, Rider University

Interactive Data Visualization Designer (all labs)

- Sage Lichtenwalner, Rutgers University

EARTH EDUCATORS' RENDEZVOUS
NASHVILLE, TN, JULY 15-19, 2019

Data Labs: Using Ocean Observatory Initiative (OOI) Data to Engage Students in Oceanography

Tuesday, Wednesday | 1:30pm-4:00pm | TSU - Humphries: 103

Afternoon Mini Workshop

Conveners

Janice McDonnell, Rutgers University-New Brunswick

Sage Lichtenwalner, Rutgers University-New Brunswick

Christine Bean, Rutgers University-New Brunswick

Catherine Halversen, University of California-Berkeley

▸ *Show additional peer leaders*

Join us for this two-day National Science Foundation (NSF) sponsored workshop focused on the integration of Ocean Observing Initiative (OOI) data into undergraduate teaching of introductory oceanography themes and concepts. Harness the constant flow of data streaming in from ocean research arrays to engage students in addressing real world problems and working with data. Participants will explore ways to effectively teach with data, share effective practices, and brainstorm ideas for how to integrate OOI data into introductory oceanography and Earth and environmental science courses. Professors from Community Colleges, Primary Undergraduate Institutions (PUI), and Historically Black Colleges and Universities (HBCU) who teach introductory courses (100 and 200 level) are especially encouraged to attend.

NSF Research Program

Improving Undergraduate STEM Education (IUSE: EHR)

Program Goa

To build knowledge about STEM teaching and learning at the undergraduate level	To incorporate evider based practices in STI teaching and learning all undergraduates
Develop novel, creative, and transformative approaches to undergraduate STEM teaching and learning	Adapt, improve, replicate and incorporate evidence based practices in STEM teaching and learning

Program Tracks and Levels

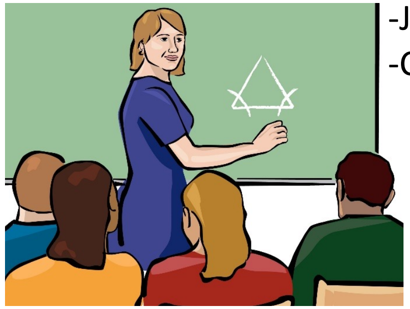
Tracks and Levels	
Engaged Student Learning • Increasing engagement and learning through new tools, resources, and models • Generating knowledge about student learning	**Institutional and Community Transformation** • Spreading and scaling up evidence-based practices using a "theory of change" • Generating knowledge about the organizational change process
Level 1: ≤ $300k, up to 3 yrs **Level 2: $300k - $600k, up to 3 yrs** **Level 3: $600k - $2M, up to 5 yrs**	**Capacity-Building: $150k for single institution or $300k for multiple institutions, up to 2 yrs** **Level 1: ≤ $300k, up to 3 yrs** **Level 2: $300k - $2M for single institution or $3M for multiple institutions, up to 5 yrs**

www.nsfnoyce.org/wp-content/uploads/2020/10/IUSE-TP-Webinar_Oct-2020_slides.pdf

DCER Instructional Framework

Team:
Kathy Browne
Andrea Drewes — Rider University
Gabi Smalley
Sage Lichtenwalner — Rutgers

Instruction to guide learning about ocean concepts.



**Coaching from:
-Janice McDonald (RuU)
-Cathlene-Leary Elderkin (RiU)

Instruction to guide students to study data and compose descriptions of patterns and variability in authentic data sets.
Data sets include authentic data from the Ocean Observatory Initiative (OOI)

Study: Student results in "intervention" vs "comparison" classes with traditional instruction.

Students draw conclusions from the data, discuss their ideas and reasonings to tie specific quantitative evidence to their understanding of relevant science concepts with guidance as.

Finally, students compose individual explanations in class "data studies" & exams.

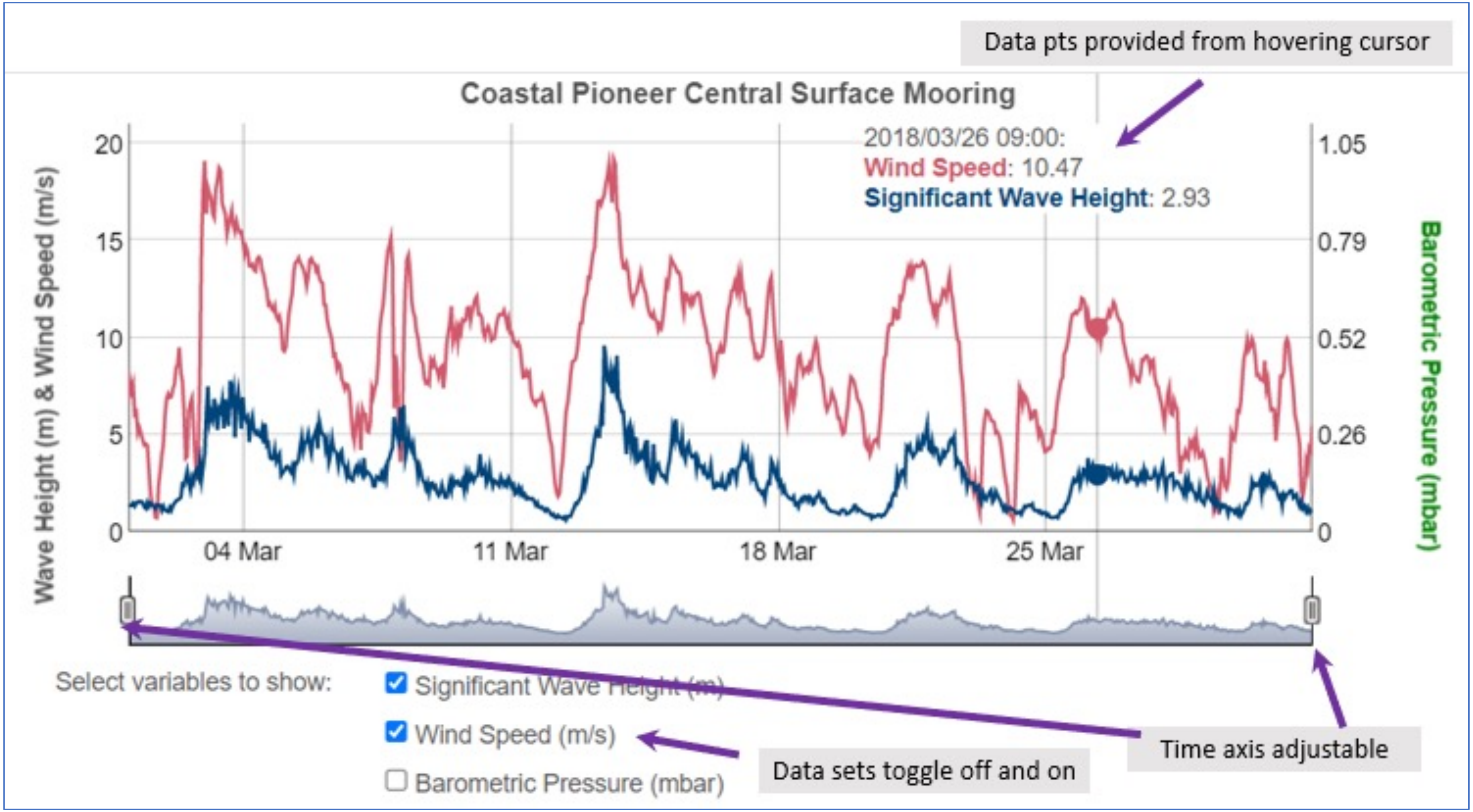
Improving Undergraduate Scientific Explanations: Exploring the Role of Data Literacy Skills in Scientific Reasoning [ID 2021347] 2020-2023

Level 1, Engaged Student Learning Track

Study Timeline

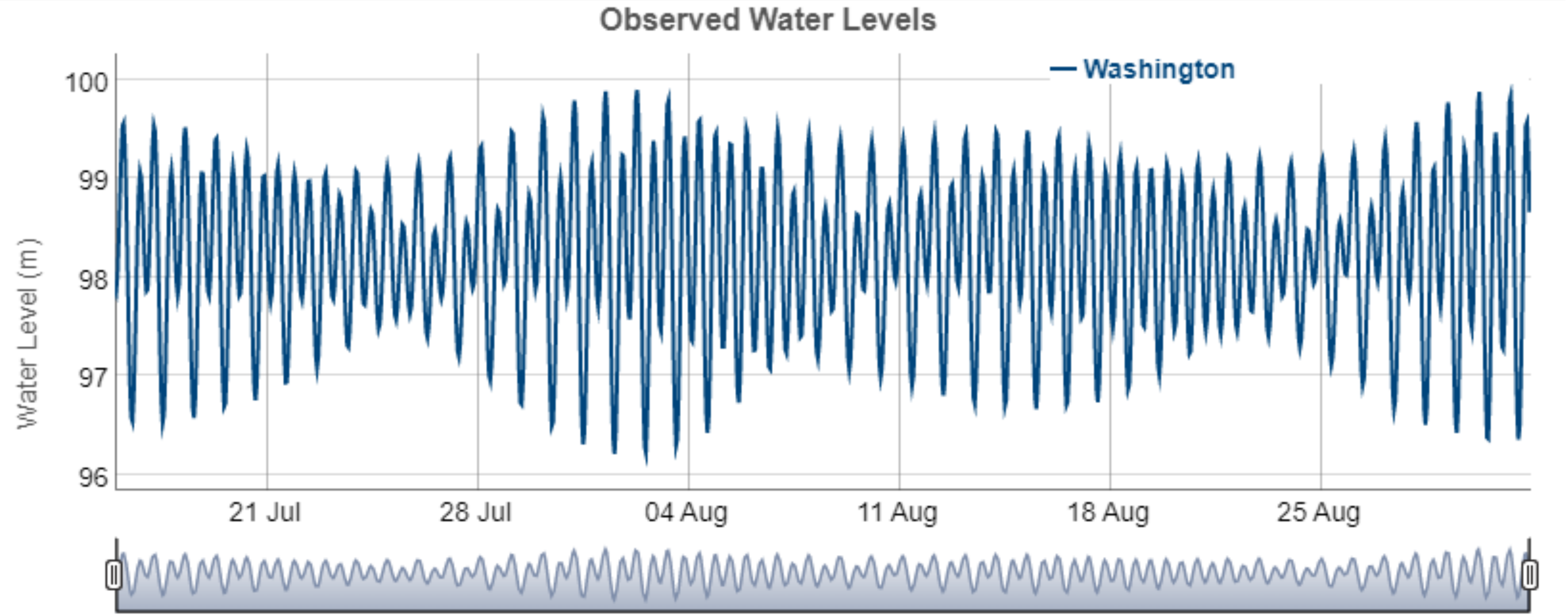
Year 1 (2020-2021; fall, spring and summer): lesson plans, interactive data visualizations, interview protocols, and assessments piloted and revised

Year 2 & 3 (2021-2023): Data collection (fall & spring semesters) & Analyses (summers)



This data is from the Central Surface Mooring at the OOI Pioneer Array.
View location on Google Maps or OOI.

https://datalab.marine.rutgers.edu/explorations/rider/



Select a Station

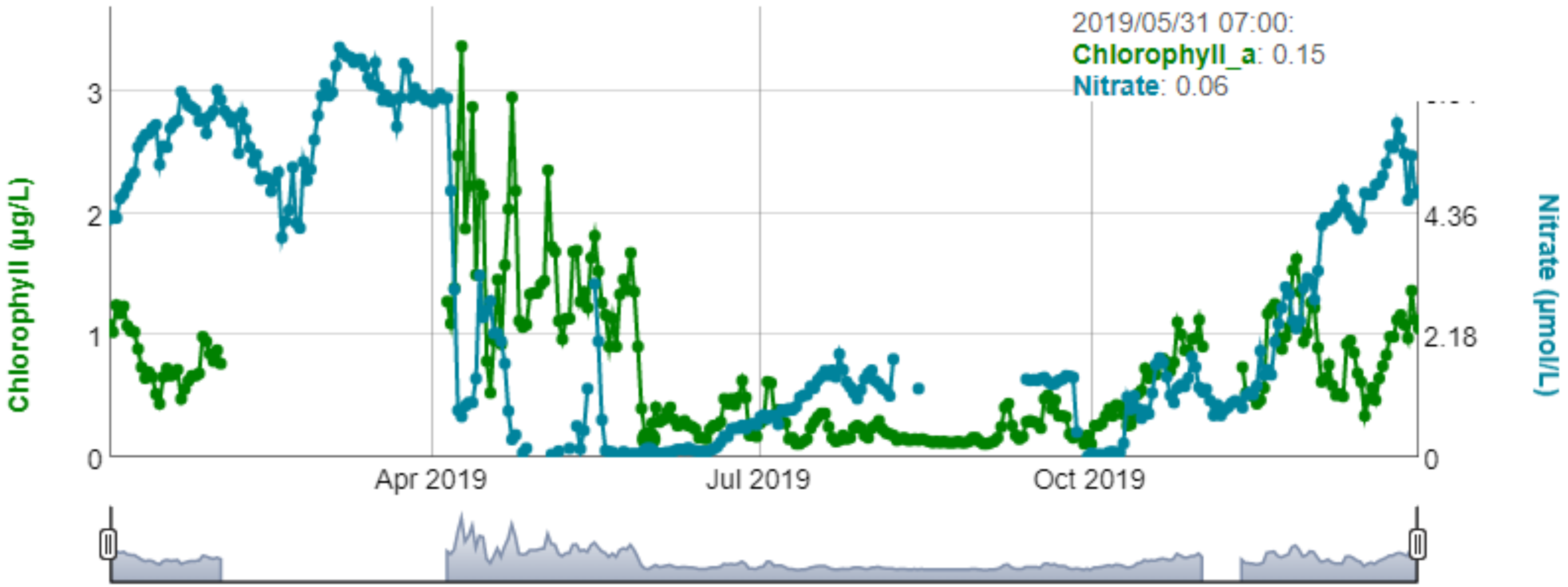
- Washington Shelf (OOI Endurance Array, Washington Shelf Surface Mooring)
- Mid-Atlantic Shelf (OOI Pioneer Array, Inshore Surface Mooring)
- Pensacola, FL (NOS Station #8729840)

Map of Station Locations

Quick Zooms

1 Day | 2 Days | 7 Days | 14 Days | 30 Days

Coastal Pioneer Array Data



Include Chlorophyll-a? ☑ Chlorophyll-a

Select a second parameter

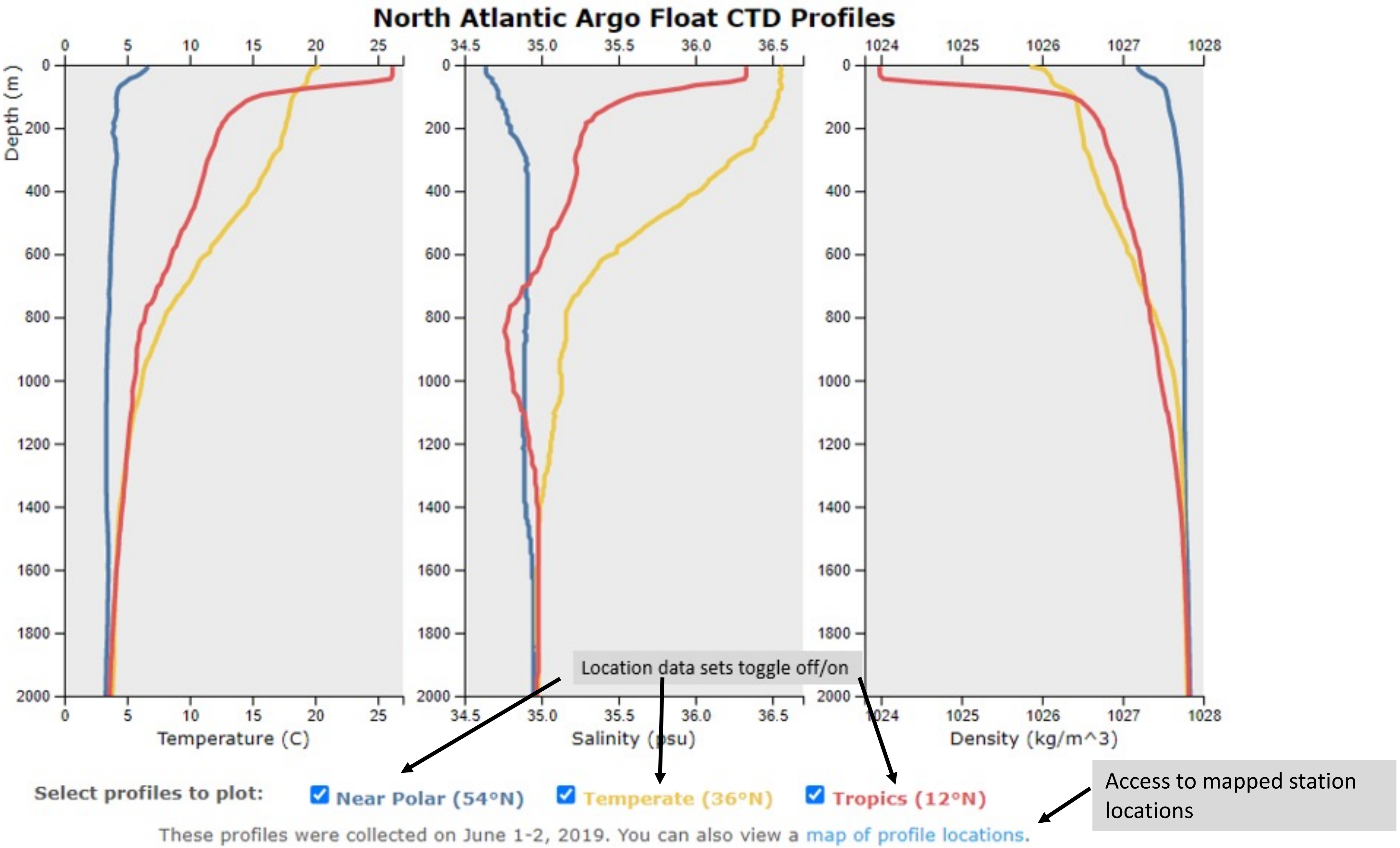
- ○ Temperature
- ○ Irradiance
- ◉ Nitrate
- ○ None

Highlight Seasons

- ☐ Winter (Dec-Feb)
- ☐ Spring (Mar-May)
- ☐ Summer (Jun-Aug)
- ☐ Fall (Sep-Nov)

This data is from the Central Surface Mooring at the OOI Pioneer Array.
View location on Google Maps or OOI.

https://datalab.marine.rutgers.edu/explorations/rider/



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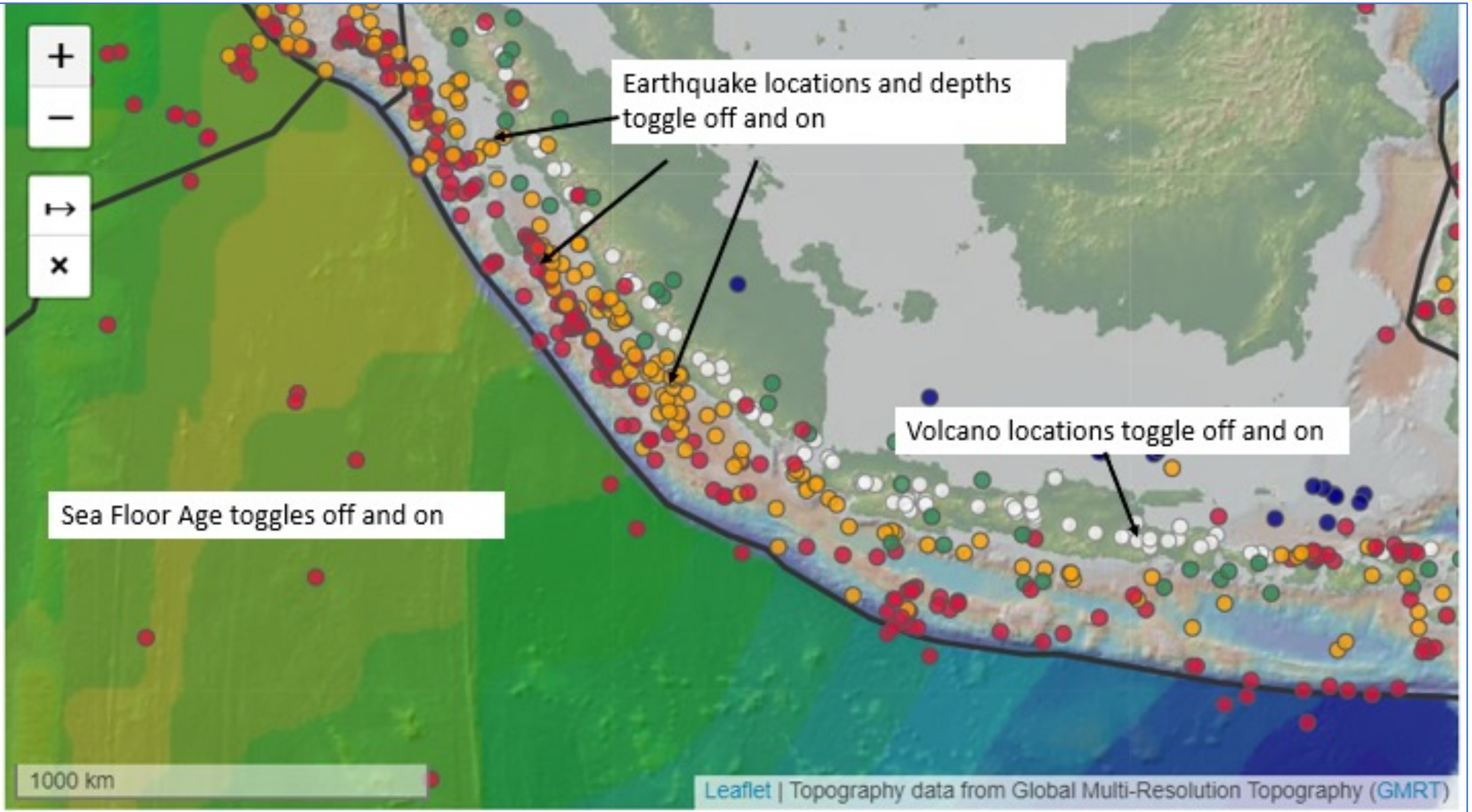


Toggle Layers

- ☑ Seafloor Age
- ☑ Plate Boundaries
- ☑ Volcanoes
- ☑ Large Earthquakes, 5.5+, 20 years
- ☑ All Earthquakes, 0+, 30 days

Bathymetry/Topography

meters: 5000, 4000, 3000, 2000, 1000, 0, -1000, -2000, -3000, -4000, -5000

Seafloor Age

0-10 Ma, 10-20 Ma, 20-30 Ma, 30-40 Ma, 40-50 Ma, 50-60 Ma, 60-70 Ma, 70-80 Ma, 80-90 Ma, 90-100 Ma, 100-110 Ma, 110-120 Ma, 120-130 Ma, 130-140 Ma, 140-150 Ma, 150-160 Ma, 160-170 Ma, 170-180 Ma

Earthquake Depths

- <30 km
- 30-70 km
- 70-300 km
- 300+ km

Volcanoes

○ Volcano

Data Sources

- Bathymetry and topography from Global Multi-Resolution Topography Data Synthesis (GMRT).
- Seafloor Age (Muller et al, 1997). Provided by SERC.
- Plate boundaries from Peter Bird (2003), Geochemistry Geophysics Geosystems. Available on GitHub.
- Volcanoes from NCEI Volcano Location Database.
- Earthquakes from USGS Earthquakes.
  - Large earthquakes dataset includes quakes greater than magnitude 5.5 from 1/1/2001 to 1/1/2021.
  - All earthquakes dataset includes quakes greater than magnitude 0 from January, 2021 only.

Example Exercise

For each of the 2 sites, tropics and polar, follow the questions below to draft thorough written descriptions of data patterns..

Temperature, Salinity, Density

Complete in the table below: What are the minimum and maximum temperature values for the entire profiles? Subtract the bottom from the surface values to calculate the range in temperatures. Do you see a thermocline in the data (Y/N) and if so, at what depths does it occur and what is the range in temperature values in that layer?

	Min & Max	Calculated range	Thermocline, Halocline, or Pycnocline (Y/N)? If so, depths and range in temperature?
Tropics			
Polar			

ii) Describe in detail how the Temp varies from surface to bottom for both profiles including specific quantitative data for both T and depth.

- Tropics:
- Polar:

- **Condensed instructions**
- **Group work**

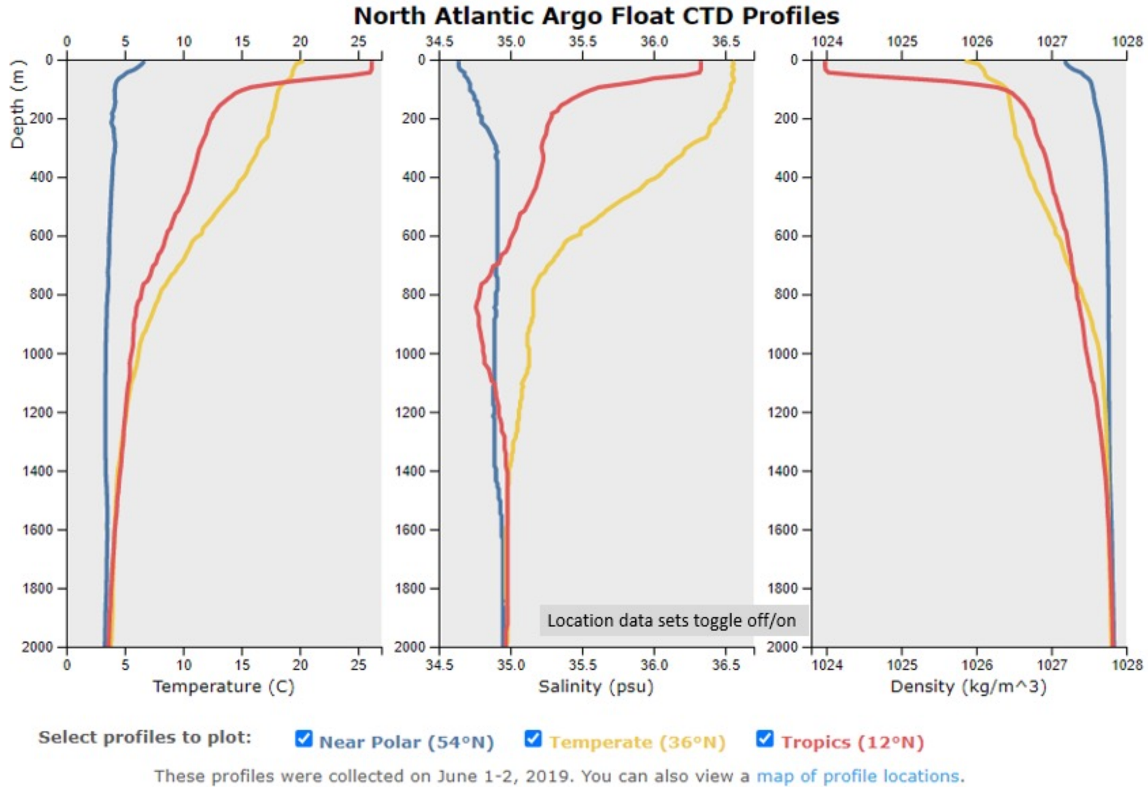
Data comparisons

i) Compare the ranges in salinity, temperature and density for each site; which site has a greater range of each parameter?

ii) For each location (polar and tropics), describe any similarities or differences in the depths of each "-cline".

- Tropics:
- Polar:

iii) Compare the pycnocline for both polar and tropics. How do the depths compare and how do the thicknesses compare?



Complete *individually* in Canvas assignment (compose individually in a word or similar file, then upload it into the T/S/D data study "final" draft answer assignment. Restate your claim. Then, using all relevant information from your work above, compose a scientific explanation that supports your claim. Remember, scientific explanations should tie together all relevant specific data patterns **and your understanding of relevant science concepts introduced for this topic that would explain your claim** in a logical sequence (your "reasoning"!).– *Your answer should take several well integrated sentences to complete this question.*

When you complete your answer, highlight text with the following color coding:

Conclusion/Claim

Yellow- data summaries relevant for your claim ("evidence")

Blue - science background concepts relevant to explain your claim

Green- - text that connects evidence to science concepts

Explanations Rubric

Proficiency level	**D**escriptions	D w/out R? Y/N	**C**onclusion	**E**vidence	**R**easoning
	First, thoroughly describes all trends, patterns, similarities, and/or differences etc. ("T/P/D/S etc.") in the data .		*A statement that answers the original question/problem. If no question is provided, students make their own conclusion from the data studied.*	*Scientific data that support the conclusion. The data need to be appropriate and sufficient to support the conclusion.*	*A justification that connects the evidence to the conclusion. It shows why the data count as evidence by using appropriate and sufficient scientific principles (addressed in this class); also includes reasoning for any data that are not relevant to the conclusion.*
0	None provided; completely irrelevant		None provided; completely irrelevant	None provided; completely irrelevant	None provided; completely irrelevant
1 (weak)	Provides few "T/P/D/S etc." descriptions or mostly inappropriate descriptions and/or level of detail of descriptions.		Provides an inappropriate conclusion given the data used; or restates a data description.	Provides very little (when more is present) and/or inappropriate evidence (evidence that does not support the conclusion). 1a very little evid; 1b inaccurate evid	Provides very little or inappropriate reasoning. 1a - only incl. evidence; 1b - only incl. sci principles; 1c - both evid and principles but are connected inaccurately
2 (passing)	Provides some appropriate "T/P/D/S etc." descriptions; but not all; or level of detail is inappropriate for some described.		Provides an appropriate, but insufficient conclusion. If only one conclusion is needed, this score could be used where students reference the proper feature etc. but does not name it specifcially (etc.).	Provides appropriate, but insufficient evidence (given all data present). Or provides sufficient, but some inappropriate evidence. 2a appro but insuff; 2b suff but inappro	Provides reasoning that connects the evidence to the conclusion. Some, but insufficient scientific principles or justification for why the evidence supports the conclusion.
3 (strong)	Completely describes all "T/P/D/S etc." at an appropriate level of detail. With quantitative details included when available. If interps or explanations included, they are ignored.		Provides an appropriate and sufficient conclusion.	Provides appropriate and sufficient evidence that includes some relevant specific quanititative information and pattern descriptions.	Provides reasoning that connects the multiple pieces (when available) of evidence to the conclusion. Includes appropriate and sufficient scientific principles to explain why the evidence supports the conclusion.

Data to be analyzed

- Group and individual assignment work
- *Exam essays
- Interviews
- *Classroom observations
- *Pre/post surveys re:
    - Ocean concepts
    - Data literacy
    - Scientific reasoning

* comparison & intervention classes

Student S1B03 Results

(Color-coding done by PIs)

Exam 1. Between the 4 data sets I realized that there is a lack of pattern. There are many shallow earthquakes within the area but not very many volcanoes at all. The sediment is mostly thin with some thicker areas and the sea floor is about half extremely old and half younger. These data sets tell me that the **plates in this boundary** have definitely shifted a good bit in order to form the many shallow earthquakes that have occurred within the area circled in the top left map. After considering all of this information and taking a close look at each data set, I believe that the plate boundary that occurs in the Indian Ocean is a transform boundary. Transform boundaries include many shallow earthquakes and very little volcanoes. Since the sea floor in this area is very old, there have been many shifts between the plates over the million years that it has been there and that is why there are shallow earthquakes across this area. The lines that the earthquakes form in the top left map are the areas that the plates slid past each other under the ocean. All of this evidence between earthquakes, volcanoes, sediment thickness, and seafloor age, lead me to believe that in the maps above of the Indian Ocean there is a transform boundary.

Total 4.5	D	C	E	R
	1.5	1	1	1

Exam 3. A) The annual trends of temperate **primary production** are that in the cold-warm months of spring and warm-cold months of fall primary productivity is higher. These trends change annually because the temperate area is not always hot or cold, it changes. The annual trends of tropical primary productivity are that the trend stays the same annually. This is because the tropical region stays warm-hot temperatures. B) These regions' annual trends are different because of their different temperatures and the amount of sunlight as well as nutrients that are able to work together at the surface in order to allow primary producers to photosynthesize. C) My conclusion stated in B relates to A because the primary producers in the temperate and tropic regions are not able to thrive in the same ways. For example, the trends in the temperate area show that chlorophyll is at its highest during the cold-warm spring because that is when there is no thermocline layer in the ocean, since the surface water is still colder during those months. Between March and April in the temperate region, chlorophyll is highest because nutrients are able to move to the surface and there is enough sun to allow for photosynthesis. The tropic region is different because the temperature is warmer there annually, which is why there is no change in primary productivity. The warmer temperatures in this region keep the surface water of the ocean warm, which creates the thermocline layer and blocks nutrients from moving to the surface. Although there is lots of sun in this region year-around, the primary producers cannot photosynthesize unless they have both sunlight and nutrients.

Conclusion/Claim
Yellow- data summaries relevant for your claim ("evidence")
Blue - science background concepts relevant to explain your claim
Green- - text that connects evidence to science concepts

Total 8.5	D	C	E	R
	1.5	3	2	2

Thank you!

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Gabi Smalley
gsmalley@rider.edu
Sage Lichtenwalner
sage@marine.rutgers.edu

Ocean Data Labs widgets for Rider University

These widgets were developed to support courses at Rider University as part of the project *Improving Undergraduate Scientific Explanations: Exploring the Role of Data Literacy Skills in Scientific Reasoning.*

1. Tectonic Plate Boundaries
2. T/S/D Profiles
3. Waves & Weather
4. Coastal Tides
5. Primary Production

This work was developed with the support of the National Science Foundation under Grant No. DUE-2021347. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

https://datalab.marine.rutgers.edu/explorations/rider/

More informative website will be made available.