Preparing students for a data-rich world

Photo Source: Scripps Institution of Oceanography

Ruth Krumhansl, *Principal Scientist*
Founder, Oceans of Data Institute
Education Development Center, Inc.

Presented at East Bay Educational Collaborative Professional Development Center
Warren, Rhode Island, April 12, 2016

LAB-AIDS Experiencing Science

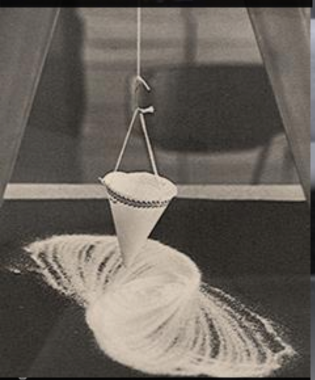
EDC OCEANS of DATA INSTITUTE

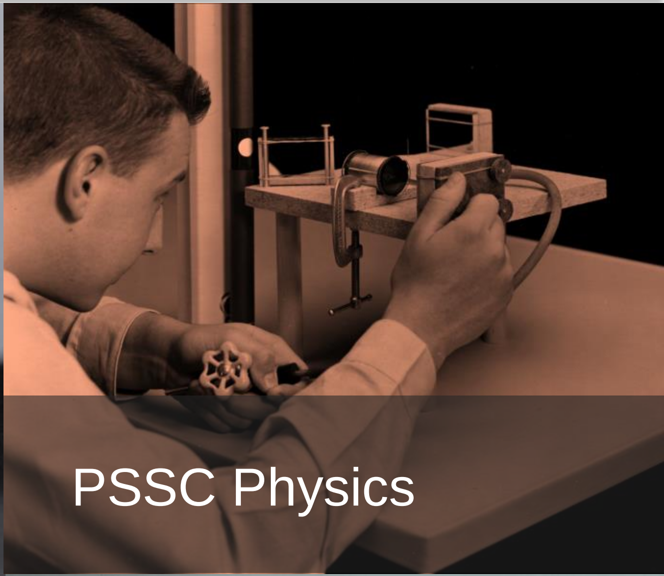
About EDC

A global nonprofit organization that develops innovative programs to solve some of the world's most urgent challenges in education, health, and economic development

EDC OCEANS of DATA INSTITUTE

EDC's history in STEM education



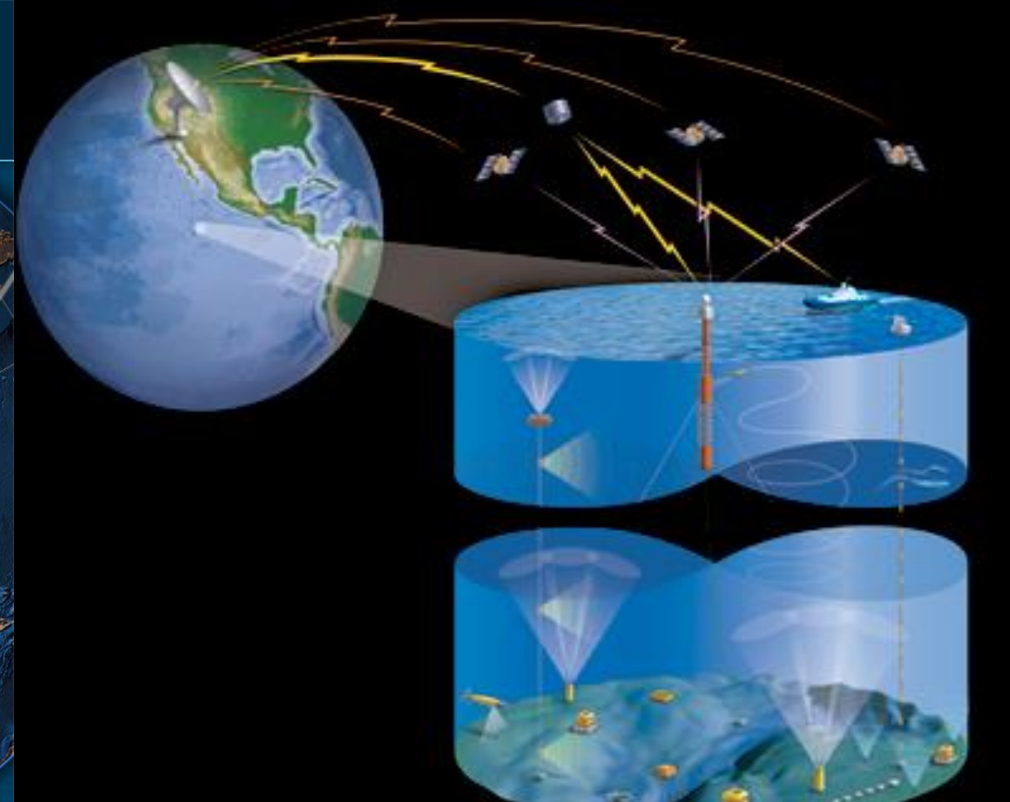
EDC OCEANS of DATA INSTITUTE

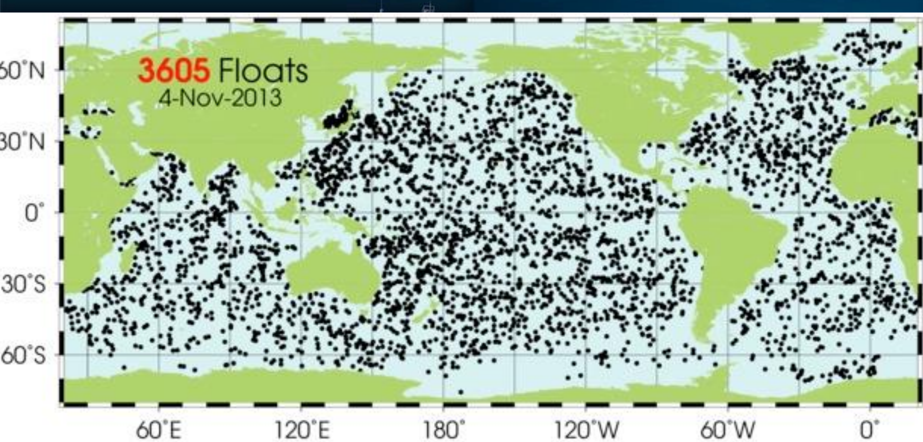
About me: Ruth Krumhansl

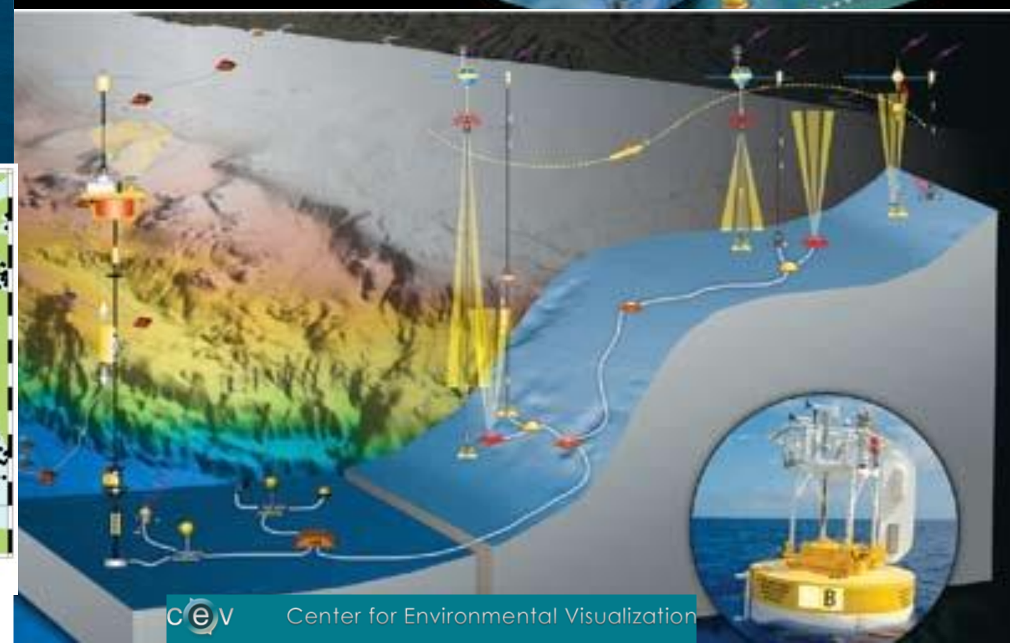
- Geologist
- Applied scientist
- High school teacher
- Education researcher

Why the Oceans of Data Institute?

CYBER-INFRASTRUCTURE







The Oceans of Data Institute: Preparing a generation to unlock the potential of Big Data

A digital copy of the universe, encrypted

Quanta Magazine, October 2, 2013

Source*:* https://www.simonsfoundation.org/quanta/20131002-a-digital-copy-of-the-universe-encrypted/

EDC OCEANS of DATA INSTITUTE

Why teach data literacy skills?

- Workforce imperative
- Educational imperative
- Social imperative

"Decisions based on data and analytics will play an increasingly important role in business and society." Davenport and Kim (Harvard Business School and KNDU Lab for Analytics Research), 2013

EDC OCEANS of DATA INSTITUTE

Challenges

> ***"Basic skills in working with data that every person should have are not being taught in k-16 schools. Thus, they are lacking at the highest levels in the broad array of professions that are becoming increasingly data-driven."***
>
> Juan LaVista, Principal Data Scientist at Microsoft

- **Schools (k-16) aren't adequately developing students' data-using skills**, particularly those skills necessary to work with large, complex data sets.
- **Very little research** has been done that tells us how to develop these skills
- **Limited awareness** of the importance of ramping up the teaching of these skills

EDC OCEANS of DATA INSTITUTE

Data use in the Next Generation Science Standards

Table 3: Distribution of PEs across the practices by disciplines

Practice (SEP)	Earth & Space Science (ESS)	Engineering, Technology & Applications of Science (ETS)	Life Sciences (LS)	Physical Sciences (PS)
1. Asking questions & defining problems	2% (1/57)	21% (3/14)	2% (1/63)	7% (5/72)
2. Developing & using models	23% (13/57)	14% (2/14)	22% (14/63)	21% (15/72)
3. Planning & carrying out investigations	7% (4/57)	7% (1/14)	6% (4/63)	25% (18/72)
4. Analyzing & interpreting data	**16% (9/57)**	**14% (2/14)**	**13% (8/63)**	**7% (5/72)**
5. Using mathematics & computational thinking	7% (4/57)	7% (1/14)	8% (5/63)	7% (5/72)
6. Constructing explanations & designing solutions	21% (12/57)	29% (4/14)	24% (15/63)	19% (14/72)
7. Engaging in argument from evidence	12% (7/57)	7% (1/14)	19% (12/63)	7% (5/72)
8. Obtaining, evaluating & communicating information	12% (7/57)	0% (0/14)	6% (4/63)	7% (5/72)
Fraction of PEs	28% (57/206)	7% (14/206)	31% (63/206)	35% (72/206)

EANS of DATA STITUTE

From: Kastens/ Oceans of Data Institute, 2015

Data use in the Next Generation Science Standards

Across k-12, 46% of the NGSS performance expectations involve data-using skills

- Kastens, 2015, Oceans of Data Institute White Paper

EDC OCEANS of DATA INSTITUTE

Students recognize the need

From a survey of 300+ students from community college and university settings:

- 85% of respondents agreed or strongly agreed that the ability to make sense of data is important to get a good job and will help in their future careers.
- An overwhelming 90% of respondents agreed or strongly agreed that learning to make sense of data will help them be more effective and informed citizens.

EDC OCEANS of DATA INSTITUTE

What does it mean to be data literate in the age of "Big Data"?

Embodied, experiential grasp of the natural setting and data collection methods

Metadata

Photo credits: (left) School in the Forest powerpoint, http://www.blackrockforest.org/docs/about-the-forest/schoolintheforest (right) Using a Digital Library to Enhance Earth Science Education, Rajul Pandya, Holly Devaul, and Mary Marlino)

Slide credit: Kim Kastens

EDC OCEANS of DATA INSTITUTE

What does it mean to be data literate in the age of "Big Data"?

Dozens of data points

Air temperature at noon

Date

Petabytes

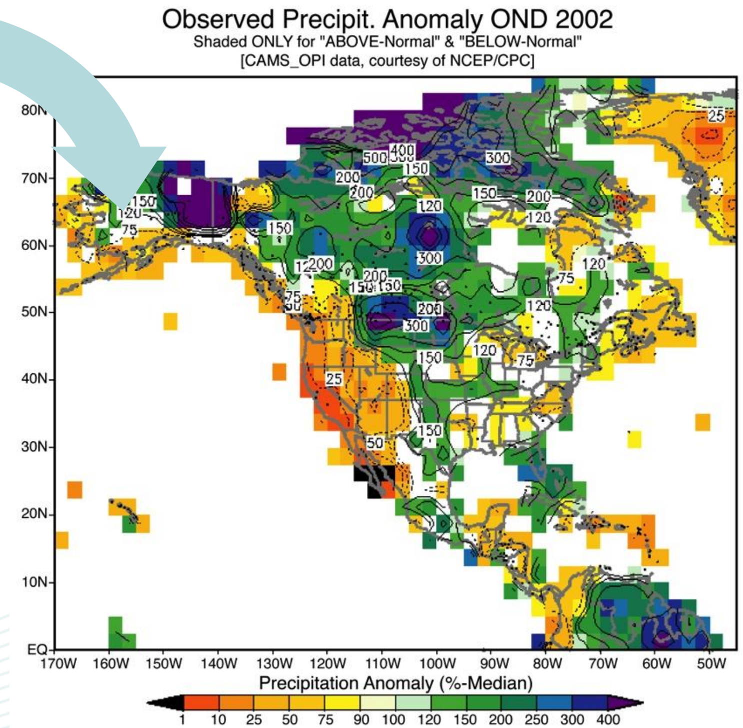


Image credits: (left) from Clement, 2002

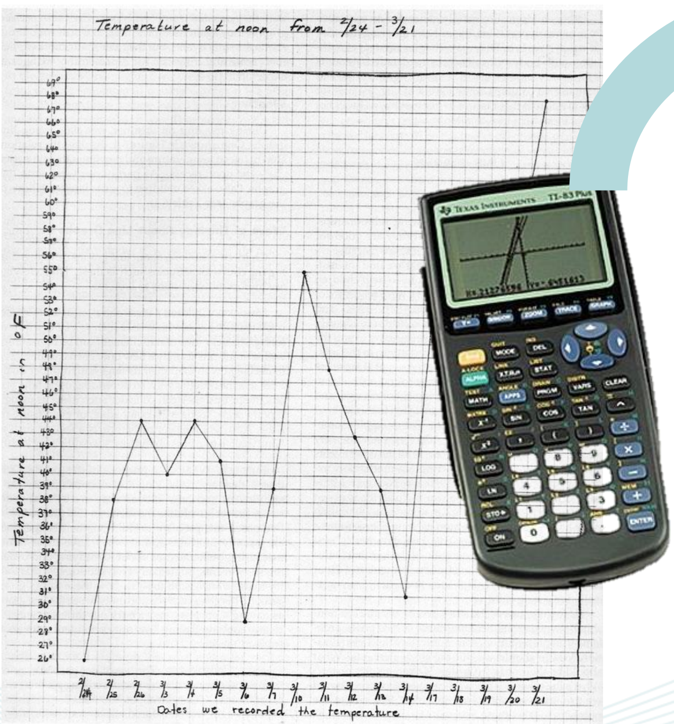
Slide credit: Kim Kastens

EDC OCEANS of DATA INSTITUTE

What does it mean to be data literate in the age of "Big Data"?

Simple, transparent tools and techniques

Air temperature at noon



Date

Sophisticated tools and techniques

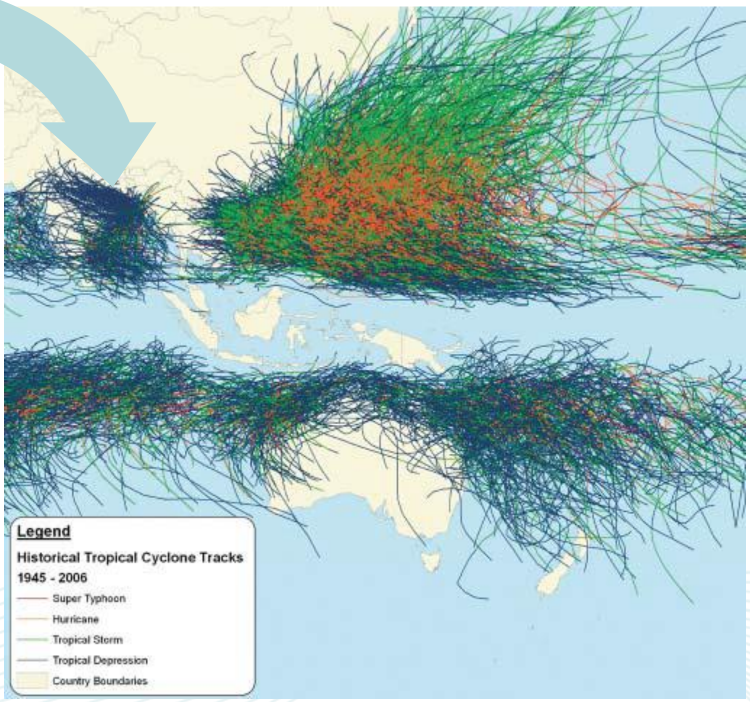


Image credits: (left) from Clement, 2002; (right) http://www.esri.com/library/ebooks/climate-change.pdf

Slide credit: Kim Kastens

EDC OCEANS of DATA INSTITUTE

What's different about "big" data sets?

***C**omplex* – include different types of data, collected different ways

***L**arge* – there are more data than you need to answer any particular question

***I**nteractive* – you are able to explore the data interactively, comparing different sets of data via a variety of data visualizations

***P**rofessionally-collected* – it was collected by "others" (not the student)

EDC OCEANS of DATA INSTITUTE

What do expert “big” data analysts say?

Developing an Occupational Profile: Expert Panel

Medical Informatics

Astrophysics

Telecommunications

Utilities

Law Enforcement/ Forensics

Hydrology

What are the skills, knowledge and behaviors of a "big data-enabled professional"?

Climate Modeling

Education

Hazard Analysis

Marketing

Analytical Journalism

Bioacoustics

EDC OCEANS of DATA INSTITUTE

What do big data analysts do?

- Articulate questions
- Design experiments
- Develop methods and tools
- Collect data/ select data
- Analyze data
- Determine level of confidence in results
- Communicate findings

EDC OCEANS of DATA INSTITUTE

What are the skills, knowledge and behaviors of a "big data-enabled professional"? *

As identified by an expert panel of big data users, and verified by ~150 big data users:

Skills:

- Analytical Thinking (96%)
- Critical Thinking (84%)
- Problem-solving (75%)
- Applying Statistical Methods (74%)
- Data Manipulation (70%)

Knowledge:

- Analytical Thinking (89%)
- Algorithms (e.g., machine learning, statistics) (76%)
- Data Modeling (70%)
- Data Structures (70%)
- Best Practices (69%)
- Statistics (69%)

Behaviors:

- A problem solver (89%)
- A lifelong learner (78%)
- Willing to question (78%)
- A seeker of patterns (67%)
- Open-minded (67%)

EDC OCEANS of DATA INSTITUTE

Building Global Interest in Data Literacy: A Dialogue

Workshop Report

” The experts on the panel *“see a growing urgency for the promotion of global data literacy for the following reasons:*

1. Our world economy and our jobs are increasingly defined by data and by the knowledge and skills required to use them effectively.
2. We are all perpetually producing streams of data, which we need to shape and manage to ensure our privacy and personal security.
3. Effective use of data empowers us to make objective, evidence-based inferences and fundamental decisions affecting our lives, both as individuals and among societies.

Call for Action to Promote Data Literacy
October, 2015

Analytical Thinking Is…

- Clearly defining your goals and how they can be achieved with data
- Taking a (sometimes) difficult problem, breaking it into pieces, and building it back up again togain interesting insights
- Exploring patterns in data with a skeptical, but open mind

Cultivating data literacy: Encourage curiosity, skepticism, and persistence

- Encourage curiosity – “I have all the data in my hands. I want to make sense of it and to tell a story”
- Encourage questioning when something doesn’t make sense
- Push students to identify multiple possible explanations for patterns in data
- Allow students to fail; an idea that fails is part of the process of innovation
- Allow students to struggle

EDC OCEANS of DATA INSTITUTE

Cultivating data literacy: Teach about the process of working with data

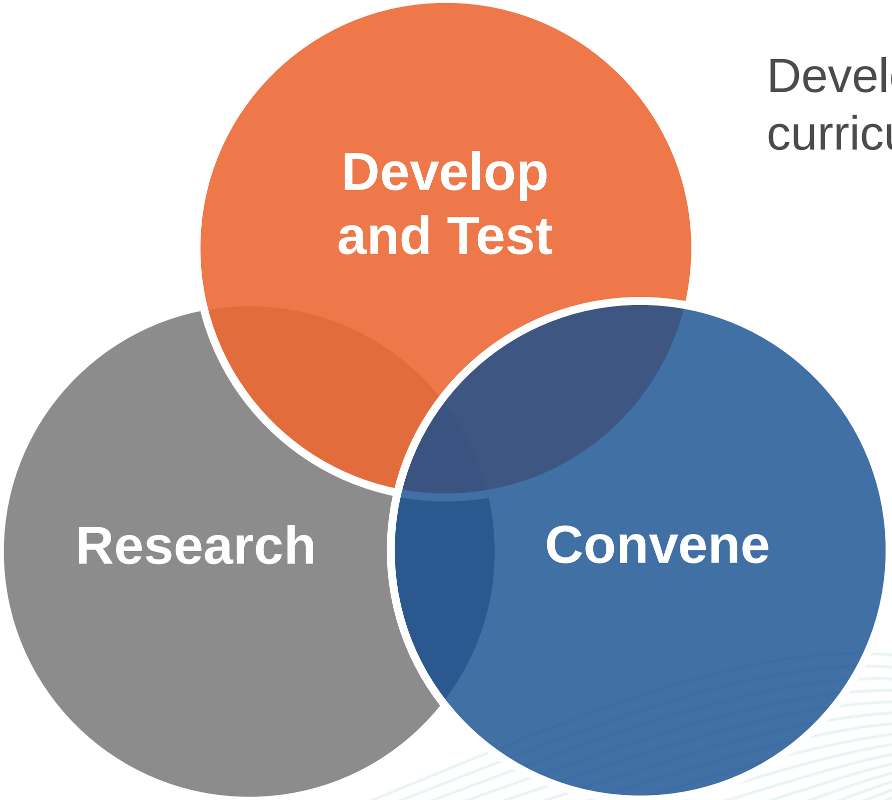
- Teach how to formulate productive questions
- Guide students in how to break down a problem (and encourage them to show their work)
- Give them experience with a variety of types of data visualizations
- It's important for students to do things – give them opportunities to practice and play around with data!

EDC OCEANS of DATA INSTITUTE

Oceans of Data Institute: promoting the data literacy of k-16 students

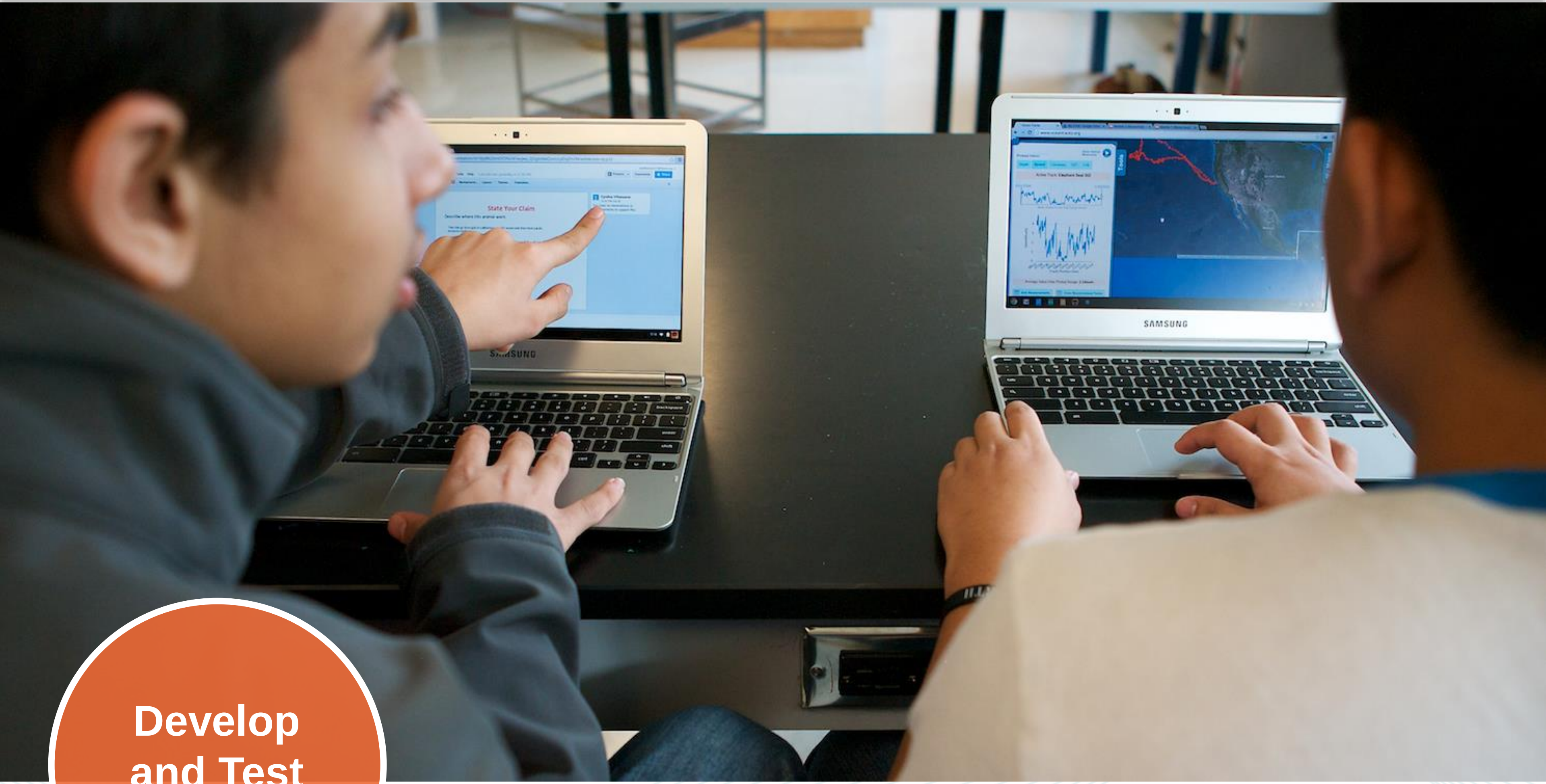
Develop and test curricula and tools

Build a research-based learning progression



Act as a hub for diverse stakeholders

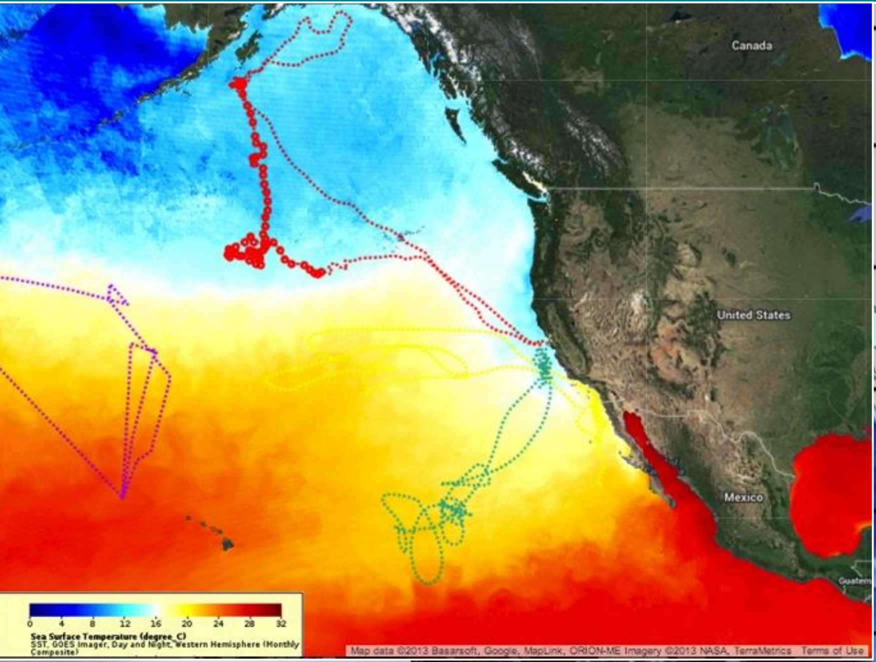
Curricula and tools

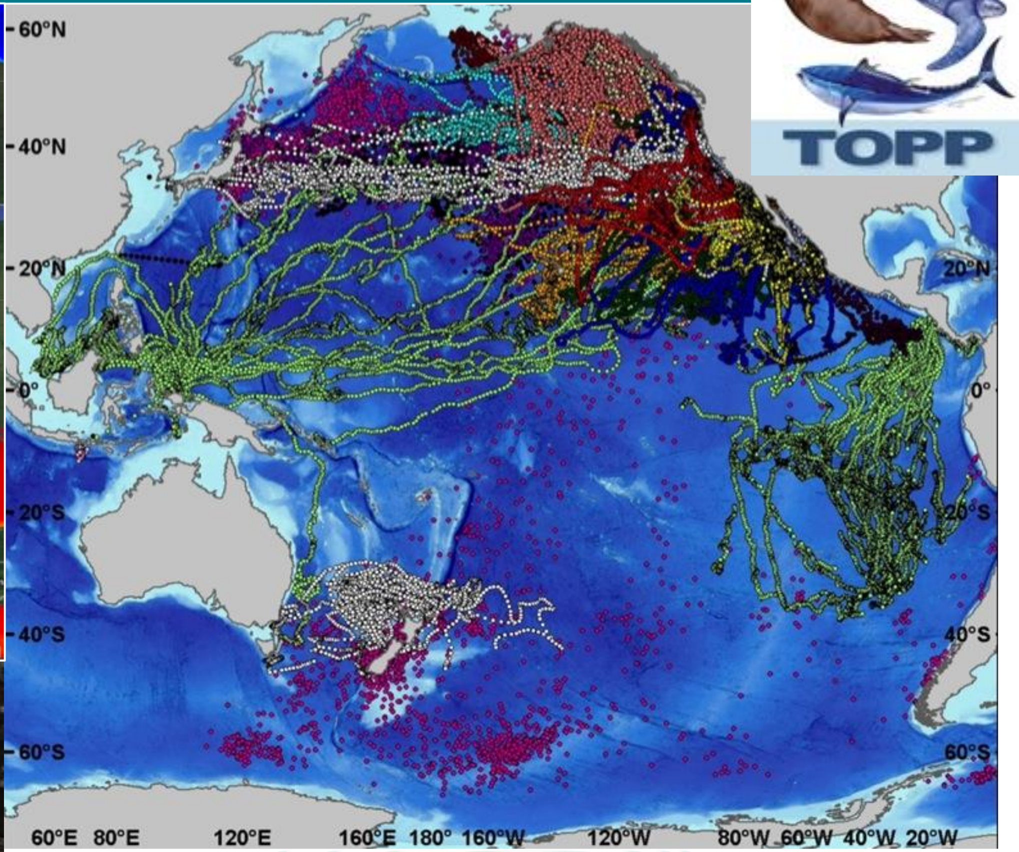


Develop and Test

EDC OCEANS of DATA INSTITUTE

Ocean Tracks: The Data





Goals for students

Explore questions of current scientific interest

- What might influence the movement of marine species?
- How might movement be affected by the ocean environment?
- Can we predict where marine species will congregate in the future, to target for protection?

EDC OCEANS of DATA INSTITUTE

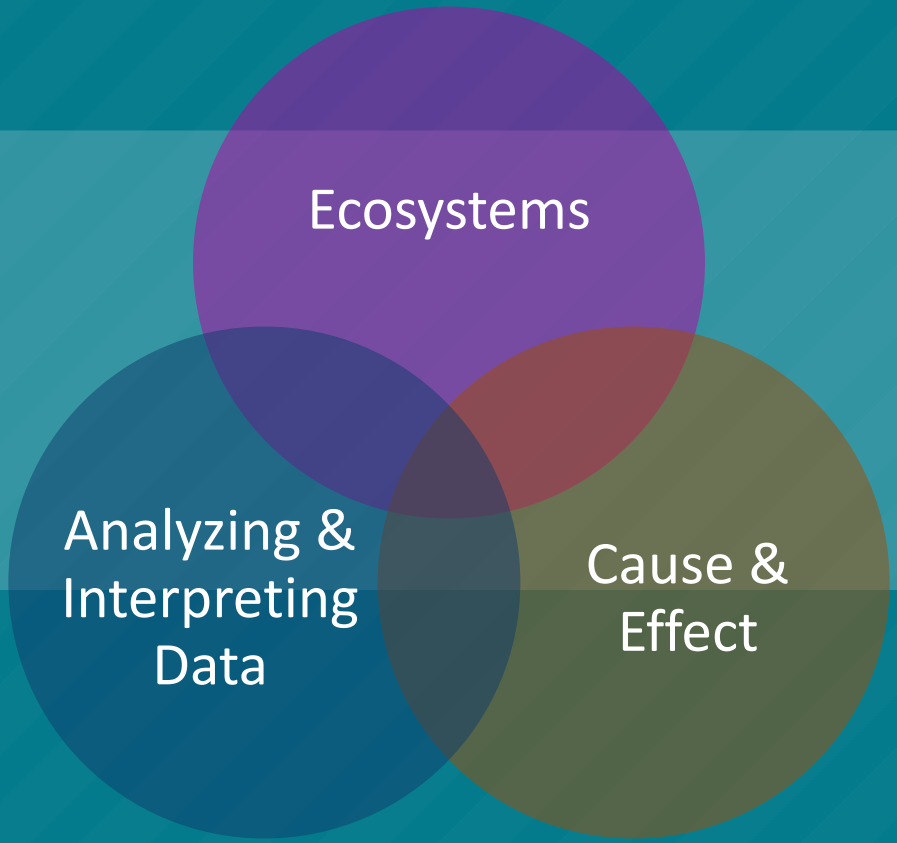
Goals for students

Promote scientific practices

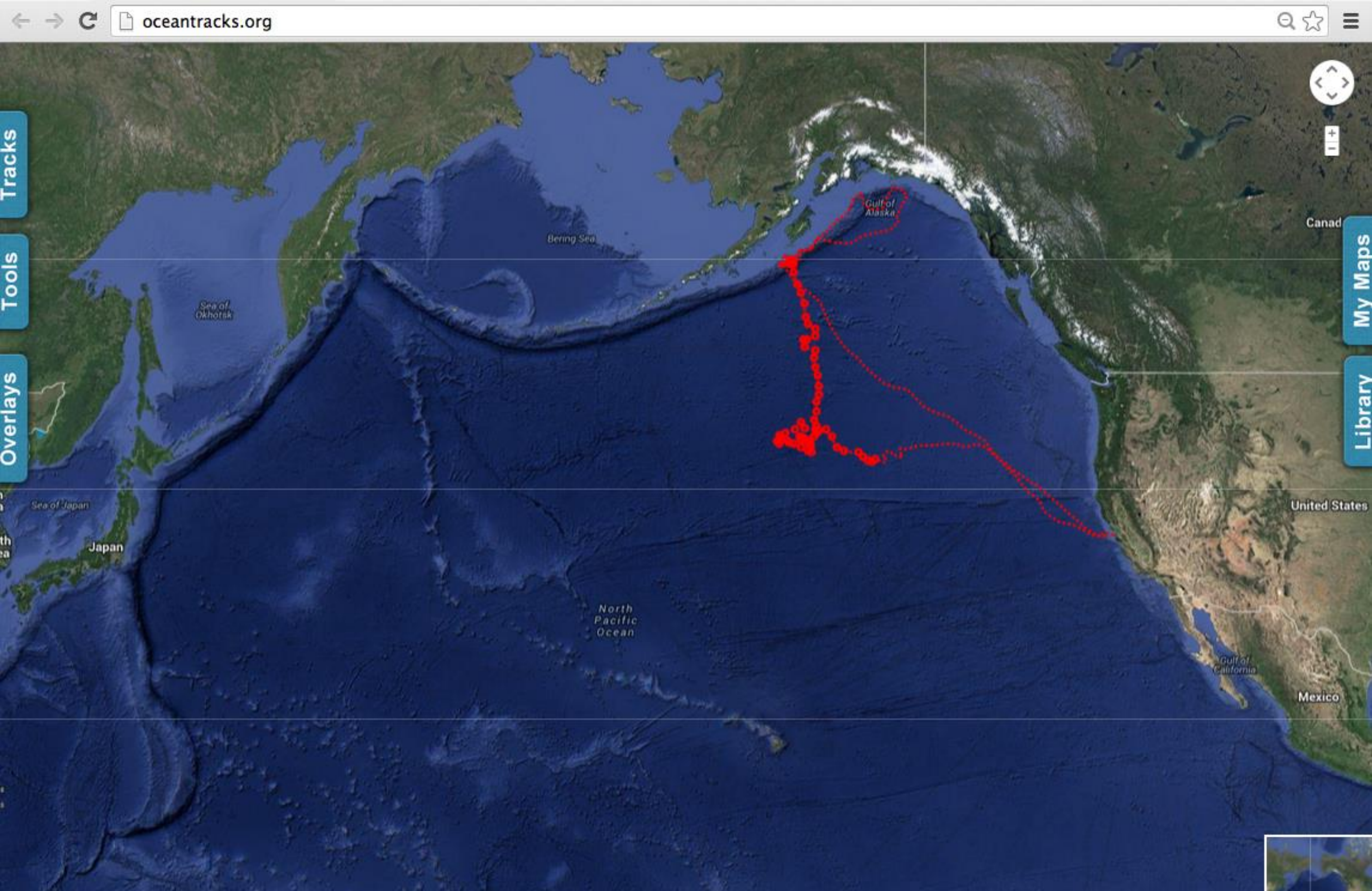
- Select data appropriate to investigate questions
- Create unique data visualizations
- Examine relationships between variables
- Construct explanations from the data
- Use multiple lines of evidence to support claims
- Develop questions that can be investigated using data

EDC OCEANS of DATA INSTITUTE

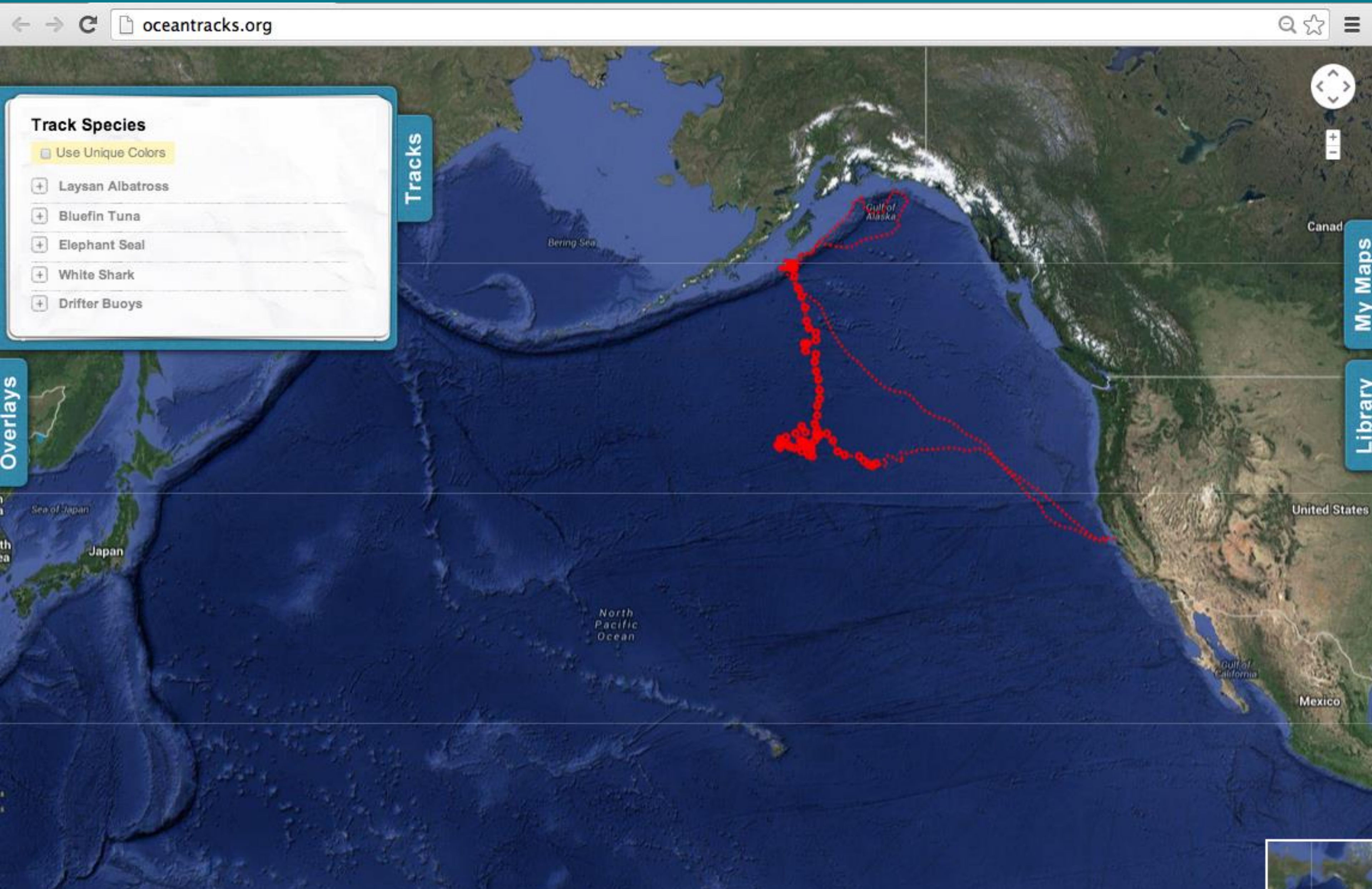
Practices, Cross-cutting Concepts and Core Ideas



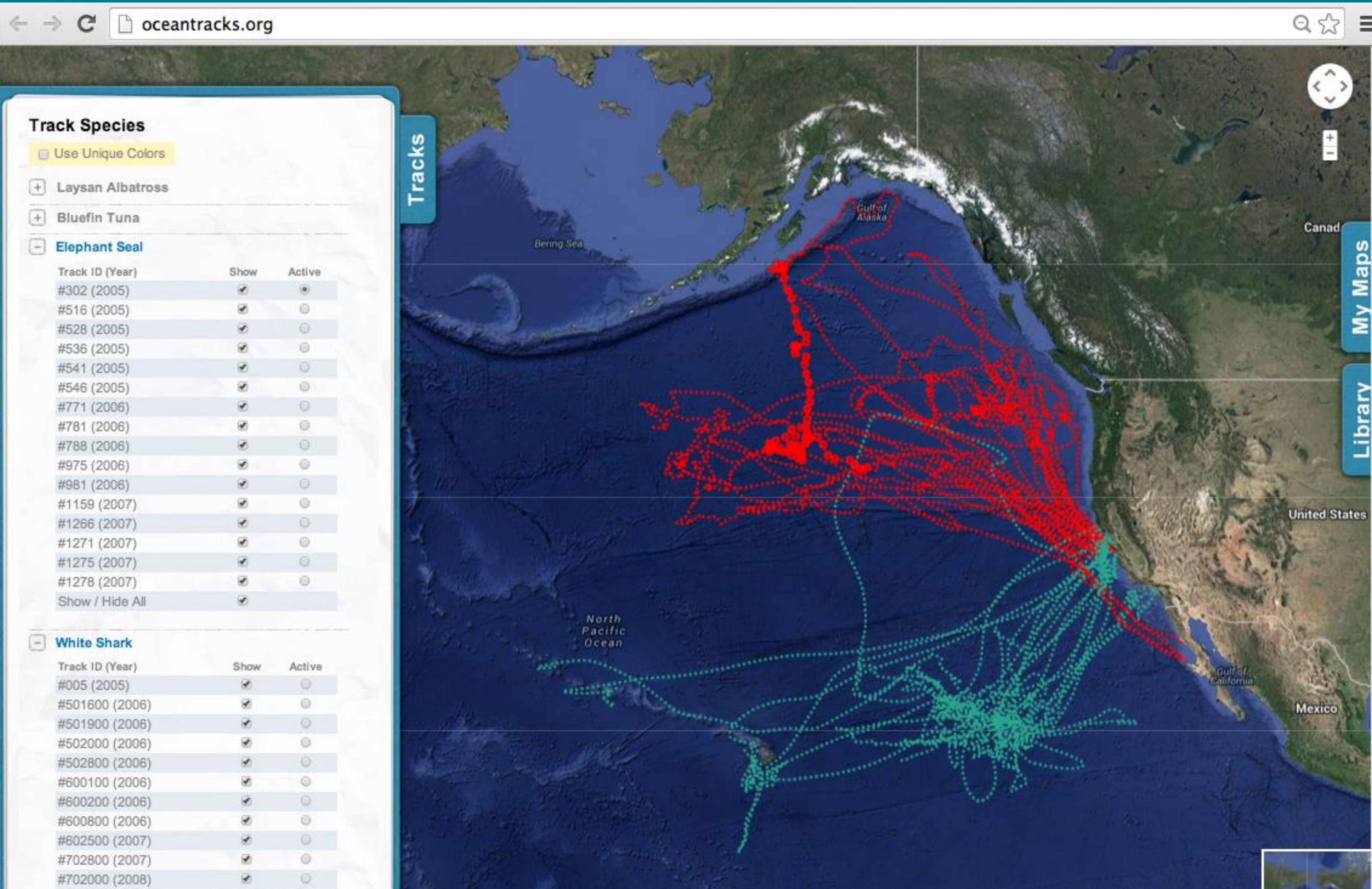
The Ocean Tracks Interface



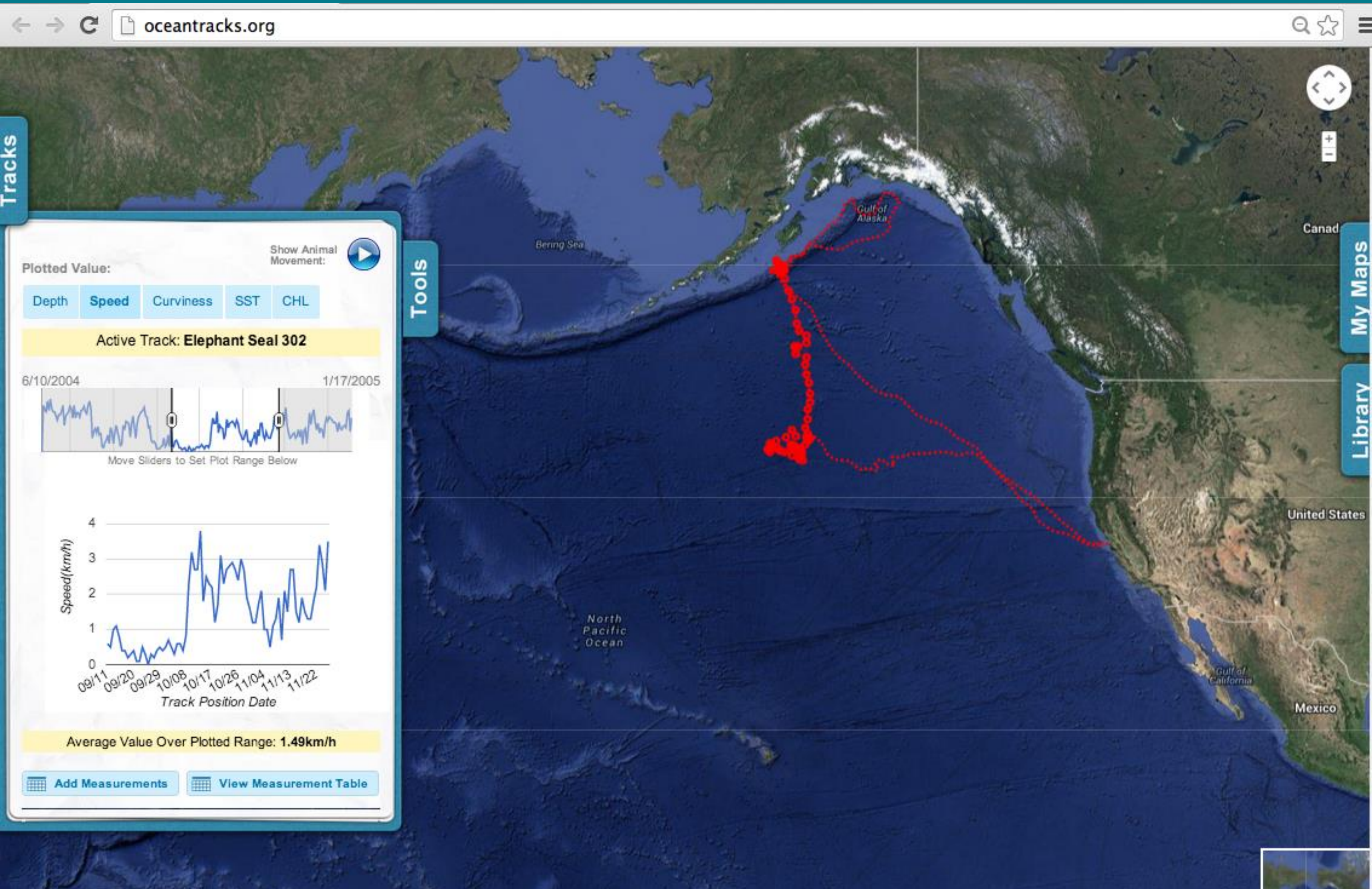
Get students quickly to the data



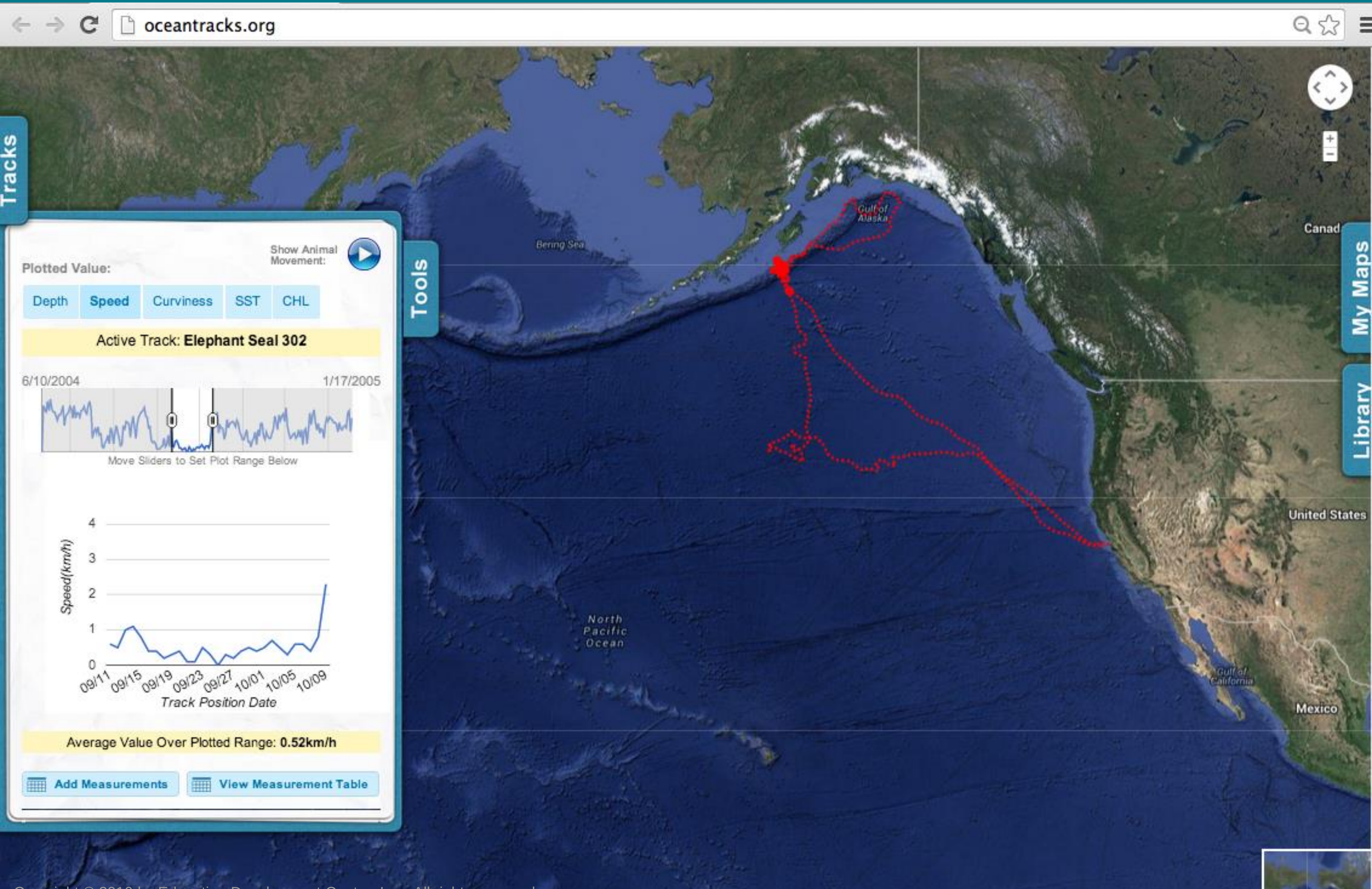
Get students quickly to the data



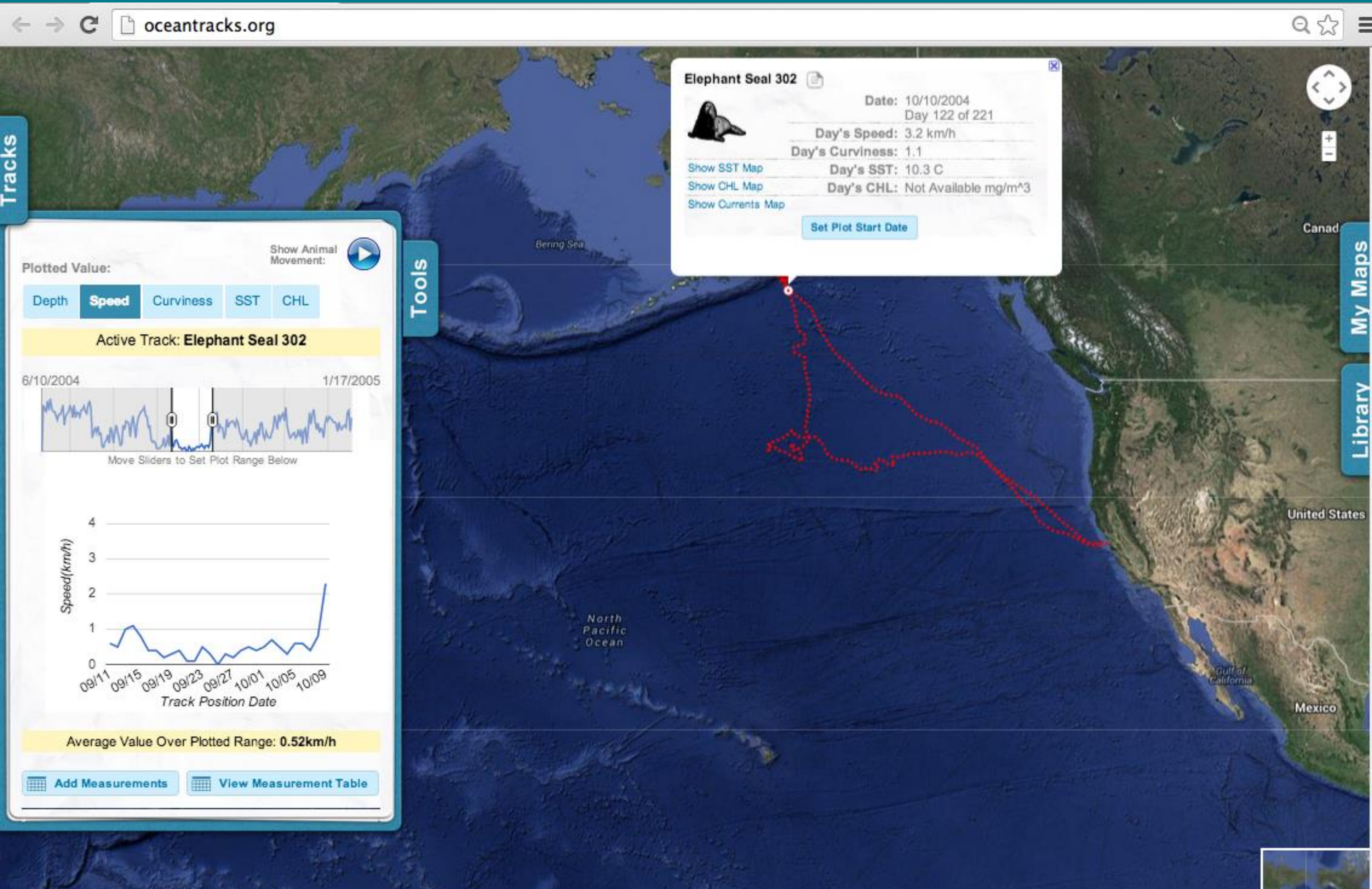
Allow them to easily create and interact with data displays



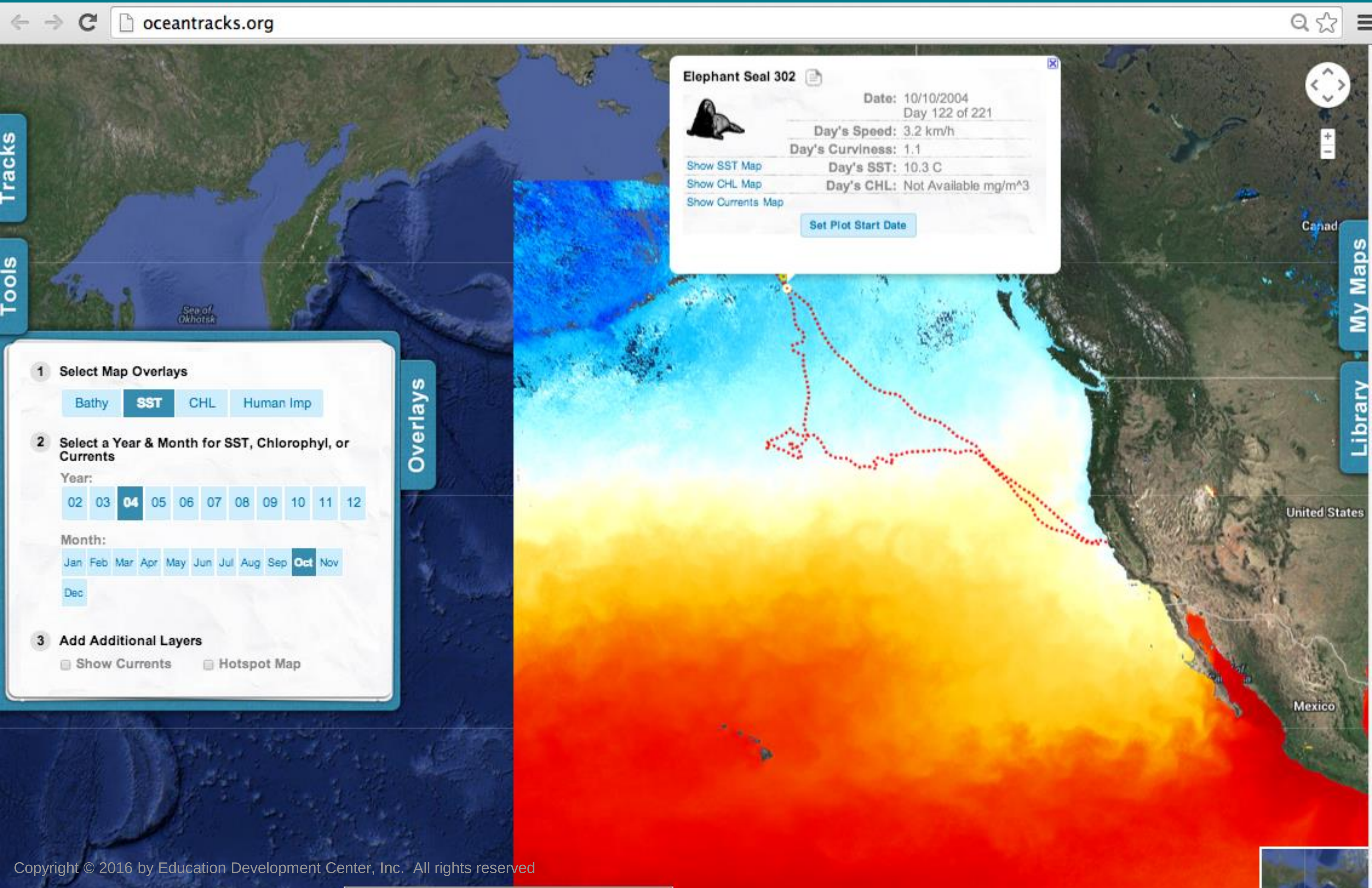
Allow them to easily create and interact with data displays



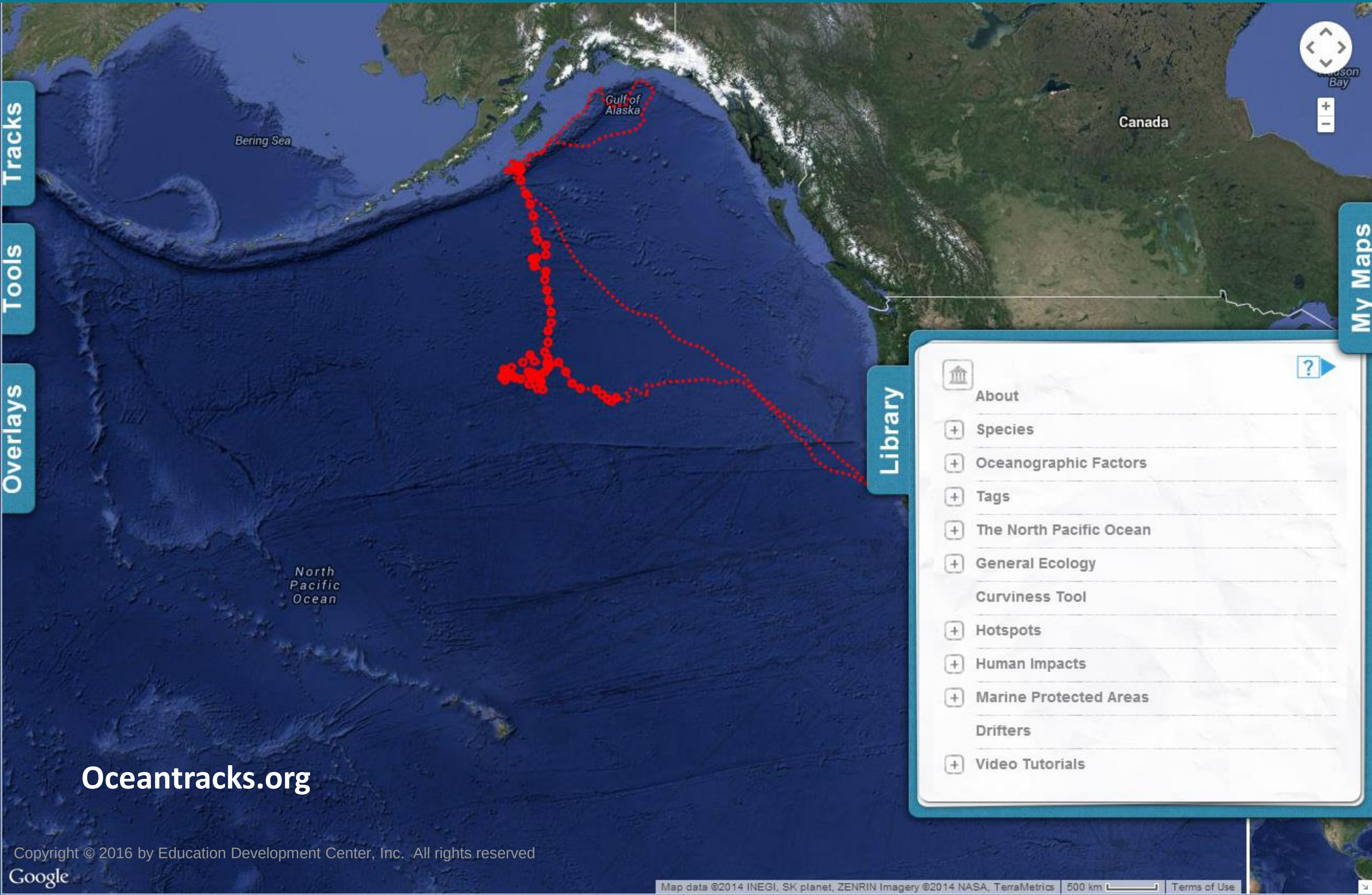
Allow them to easily create and interact with data displays



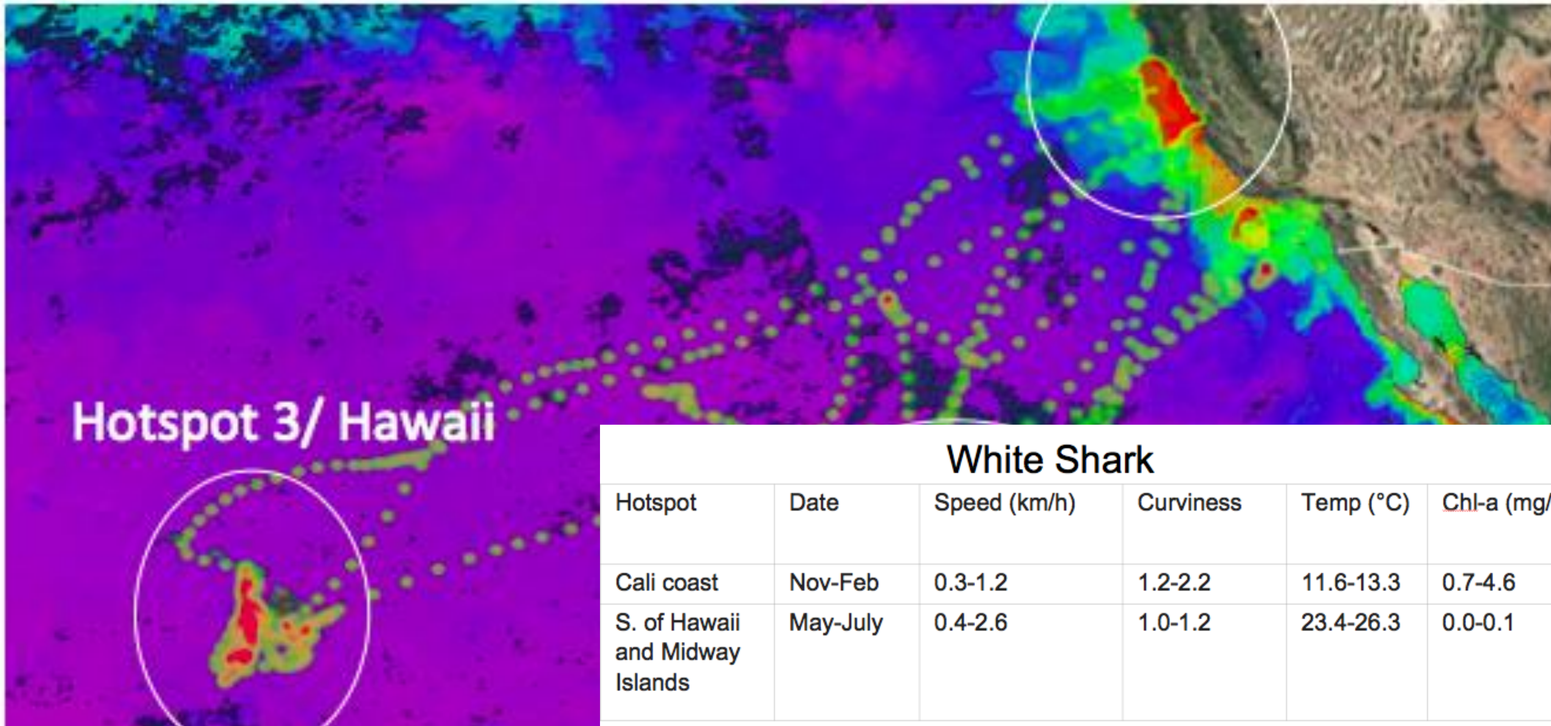
Allow them to easily create and interact with data displays



Provide supports that can be accessed on-demand

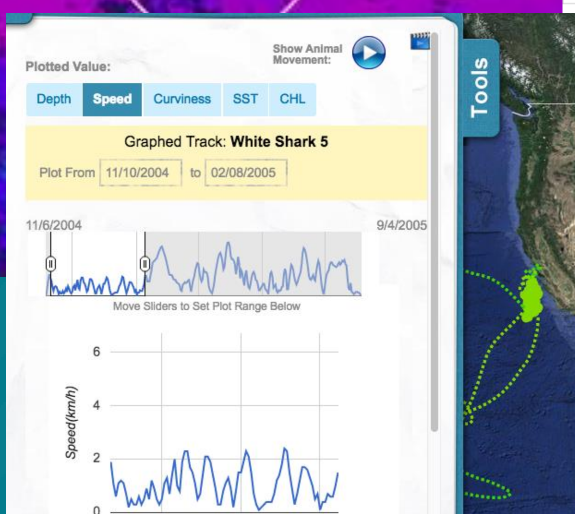


White Shark Hotspot Map

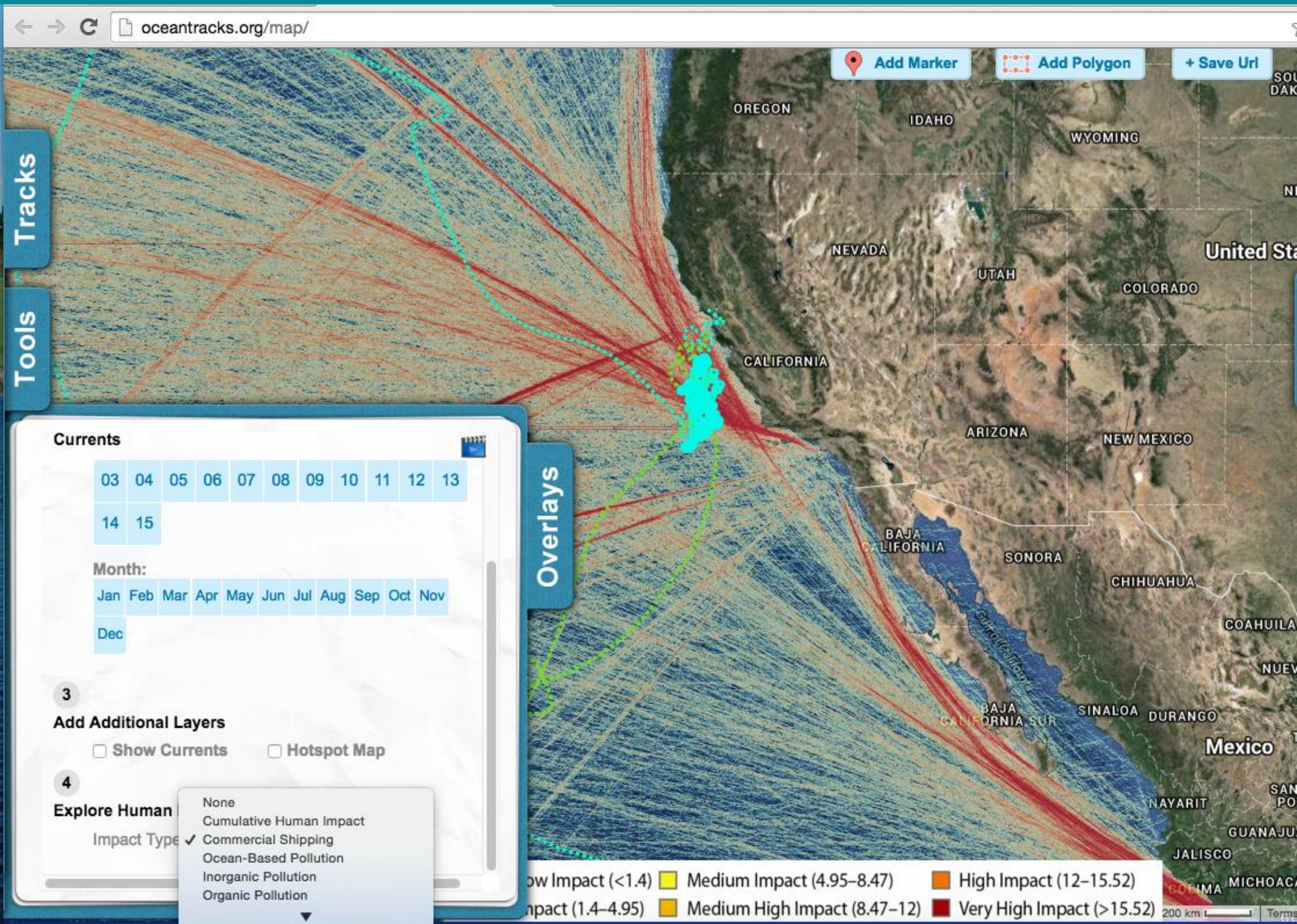


White Shark

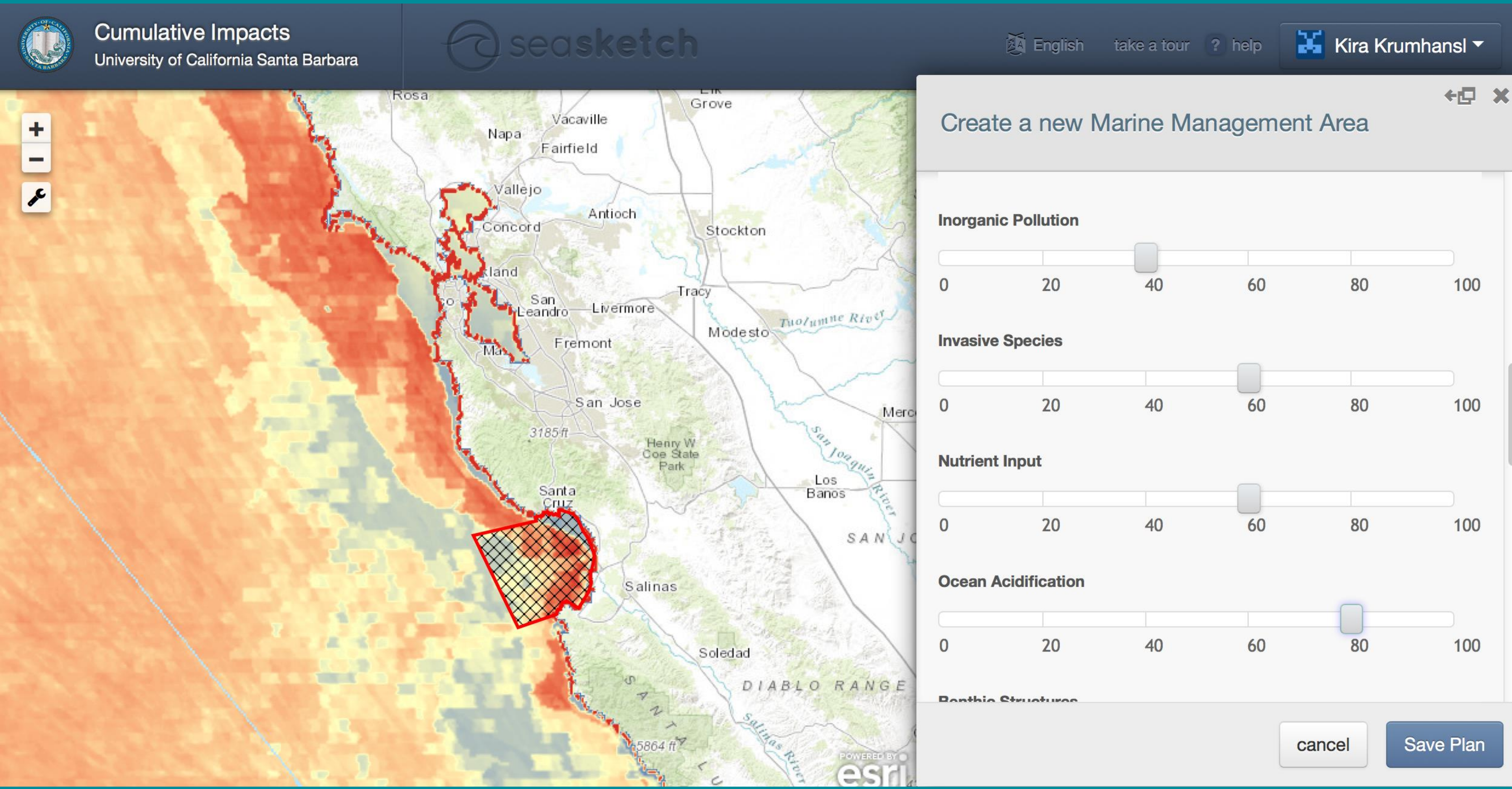
Hotspot	Date	Speed (km/h)	Curviness	Temp (°C)	Chl-a (mg/m^3)
Cali coast	Nov-Feb	0.3-1.2	1.2-2.2	11.6-13.3	0.7-4.6
S. of Hawaii and Midway Islands	May-July	0.4-2.6	1.0-1.2	23.4-26.3	0.0-0.1



HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales


oceantracks.org/map/
Add Marker
Add Polygon
+ Save Url
Tracks
Tools
Overlays
OREGON
IDAHO
WYOMING
NEVADA
UTAH
United Sta
COLORADO
CALIFORNIA
ARIZONA
NEW MEXICO
BAJA CALIFORNIA
SONORA
CHIHUAHUA
COAHUILA
BAJA CALIFORNIA SUR
SINALOA
DURANGO
Mexico
NAYARIT
GUANAJU
JALISCO
COLIMA
MICHOAC
Currents
03 04 05 06 07 08 09 10 11 12 13
14 15
Month:
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Dec
3
Add Additional Layers
Show Currents
Hotspot Map
4
Explore Human
Impact Type
None
Cumulative Human Impact
✓ Commercial Shipping
Ocean-Based Pollution
Inorganic Pollution
Organic Pollution
ow Impact (<1.4)
npact (1.4–4.95)
Medium Impact (4.95–8.47)
Medium High Impact (8.47–12)
High Impact (12–15.52)
Very High Impact (>15.52)
200 km

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.



Sea Sketch http://www.seasketch.org/home.html

EDC OCEANS of DATA INSTITUTE

EDC Earth Science

A data-intensive curriculum for high school students

LAB-AIDS Experiencing Science

EDC OCEANS *of* DATA INSTITUTE

EDC Earth Science: Program Overview

- Full-year course in earth science for high school use, developed with support from the National Science Foundation.
- Aligned with Next Generation Science Framework
- Engages students through real-life case studies, stories from the history of science, and articles from popular media
- Multiple instructional strategies
- Support for literacy and differentiated instruction
- Consistent learning framework

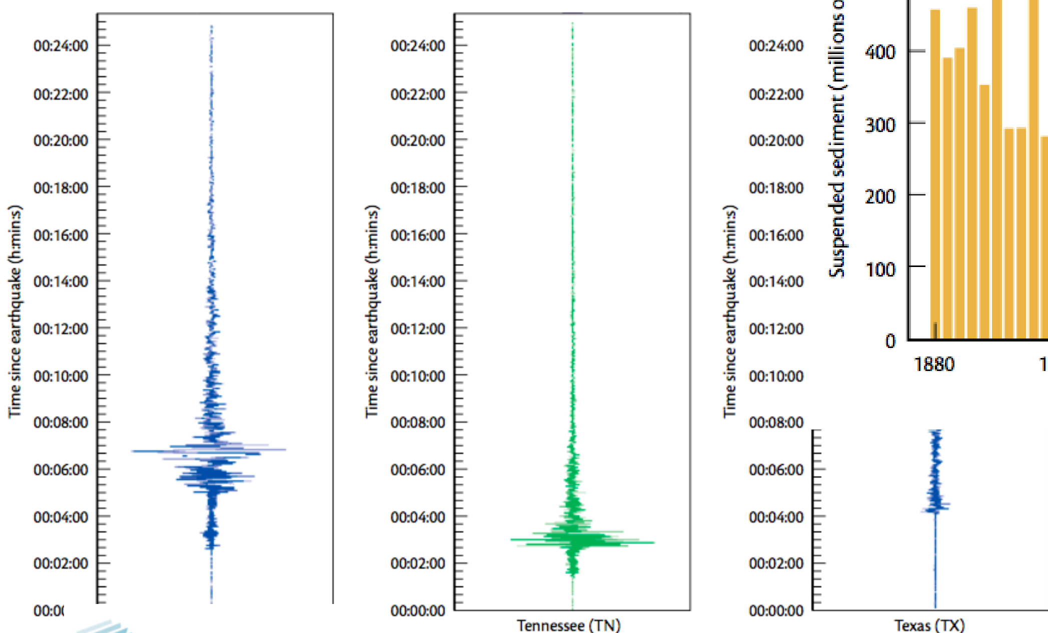
LAB-AIDS Experiencing Science

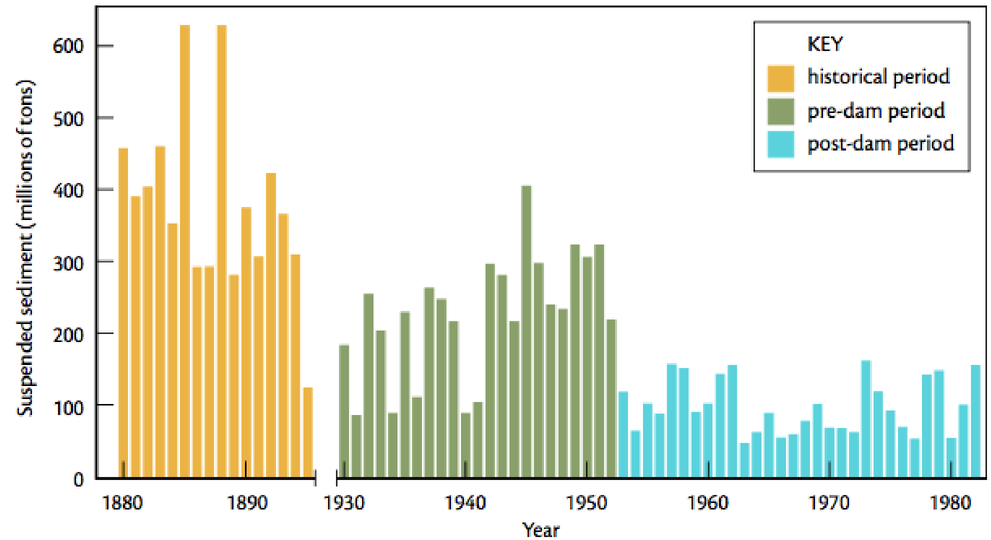
EDC OCEANS of DATA INSTITUTE

EDC Earth Science: Program Overview

And…

- Many opportunities to develop skills in working with data!





LAB-AIDS Experiencing Science

EDC OCEANS of DATA INSTITUTE

Key Authors/Reviewers

- Ruth Krumhansl
  EDC Principal Scientist, Founder, Oceans of Data Institute
- Erin Bardar
  EDC *Astronomer and Curriculum Developer*
- Jan Tullis
  Professor of Geology, Brown University
- Marcia Bjornerud
  Professor of Geology, Lawrence University
- Jacqueline Miller
  EDC Senior Research Scientist, Principal Investigator, Foundation Science
- June Foster
  EDC Senior Research Scientist, Director, Foundation Science

EDC OCEANS of DATA INSTITUTE

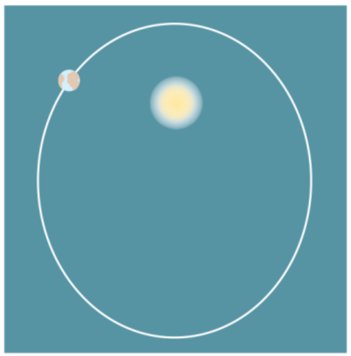
Units organized around Earth Systems

1. **Hydrosphere**
   Water Cycle, surface water, groundwater, ocean circulation
2. **Atmosphere**
   Climate, greenhouse effect, feedback loops, Milankovich cycles
3. **Earth's Place in the Universe**
   Solar system formation, Kepler's Laws, life cycle of stars, Earth's interior
4. **Plate Tectonics**
   Fault boundaries, earthquakes, volcanoes, seafloor spreading, technologies for study
5. **Rock Cycle**
   Erosion and deposition, formation of sedimentary rocks, nature of rocks and minerals, Earth's history
6. **Earth Resources**
   Mineral formation, extraction, fossil fuel formation, exploration technologies

EDC OCEANS of DATA INSTITUTE

Supports Next Generation Science Framework Core Ideas

Core Idea ESS1: Earth's Place in the Universe



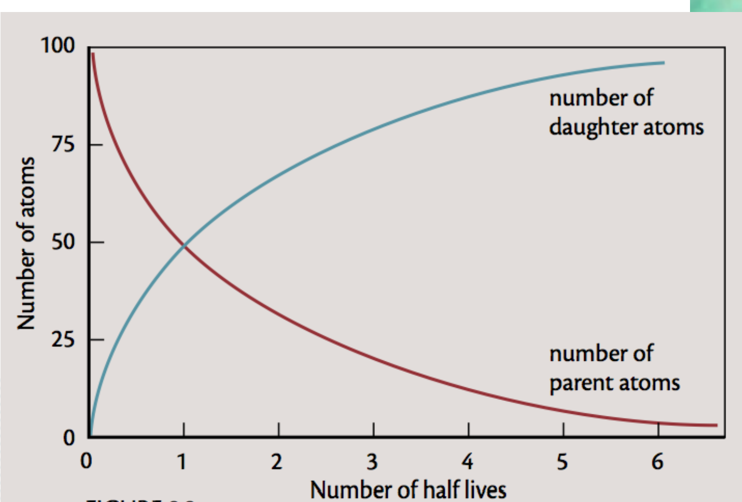
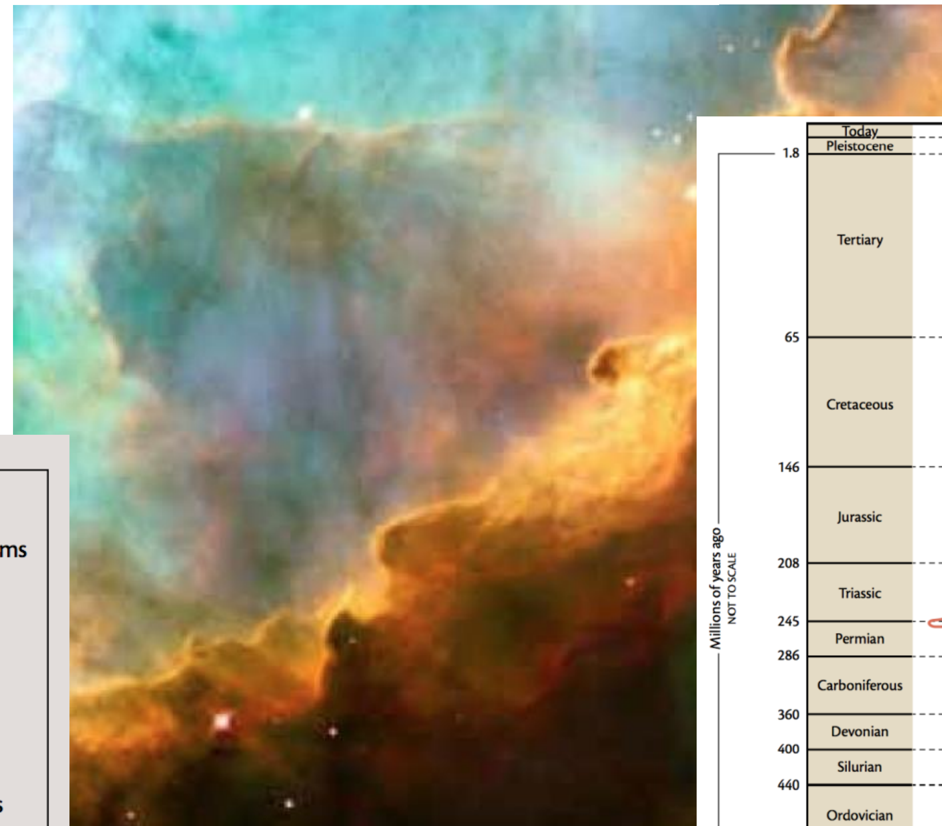
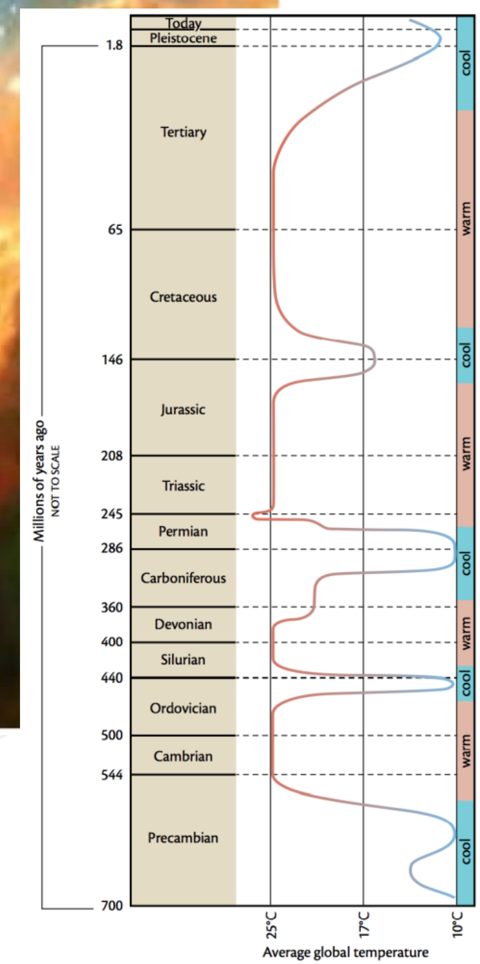


FIGURE 8.2
Radioactive decay



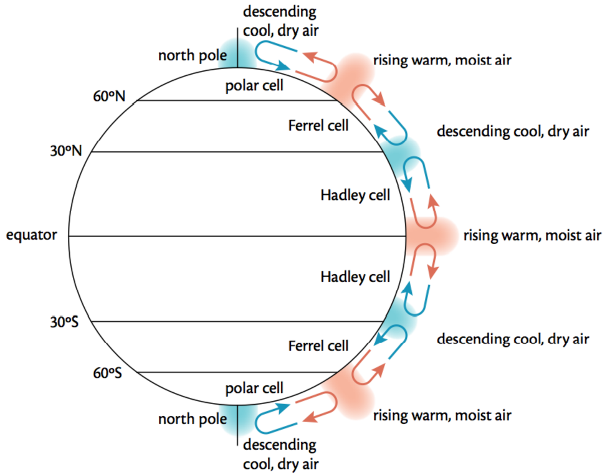


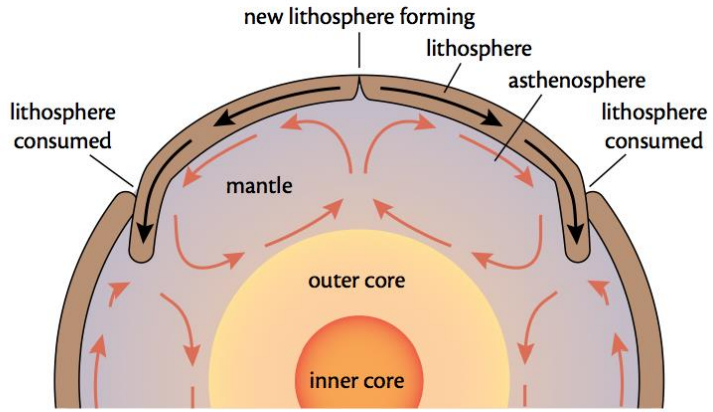
Supports Next Generation Science Framework Core Ideas

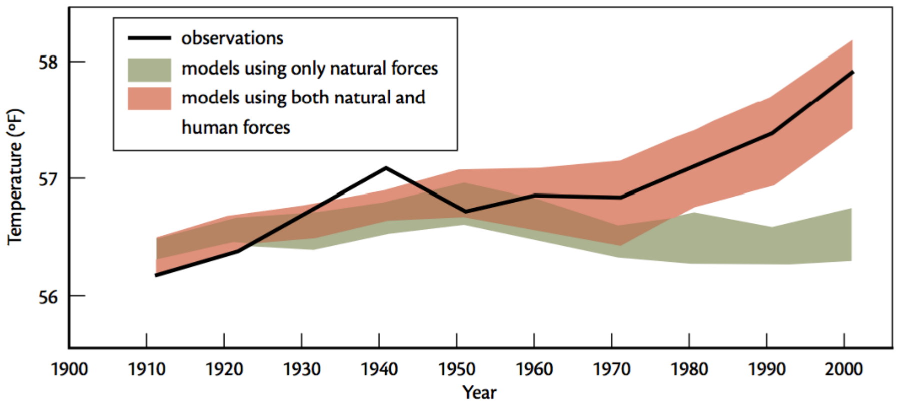
Core Idea ESS2: Earth's Systems

ACTIVITY 5

Interactions Between Ocean and Atmosphere







EDC OCEANS of DATA INSTITUTE

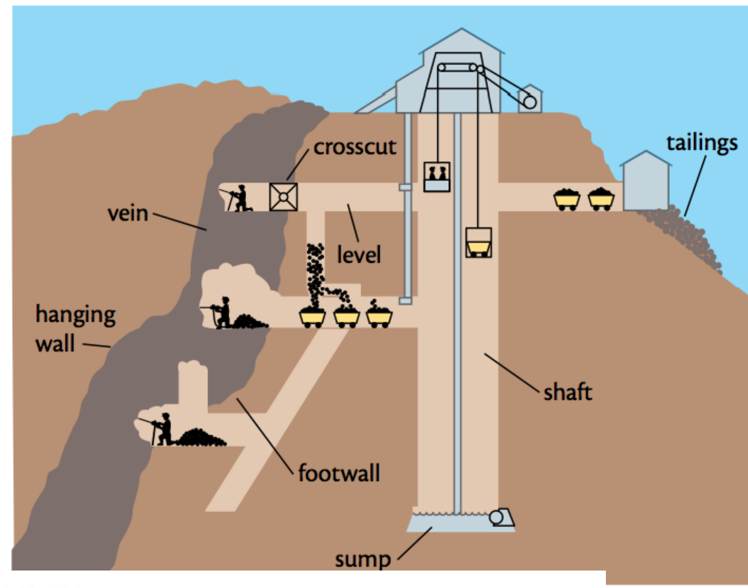
Supports Next Generation Science Framework Core Ideas

Core Idea ESS3: Earth and Human Activity

CHALLENGE

Why is there oil in the Middle East?

Oil seems to be concentrated in certain areas of the world. What special conditions are necessary for oil reservoirs to form within Earth's crust? How do people find oil?



READING

Sorting Out Natural and Human-Induced Climate Change

ACTIVITY 2

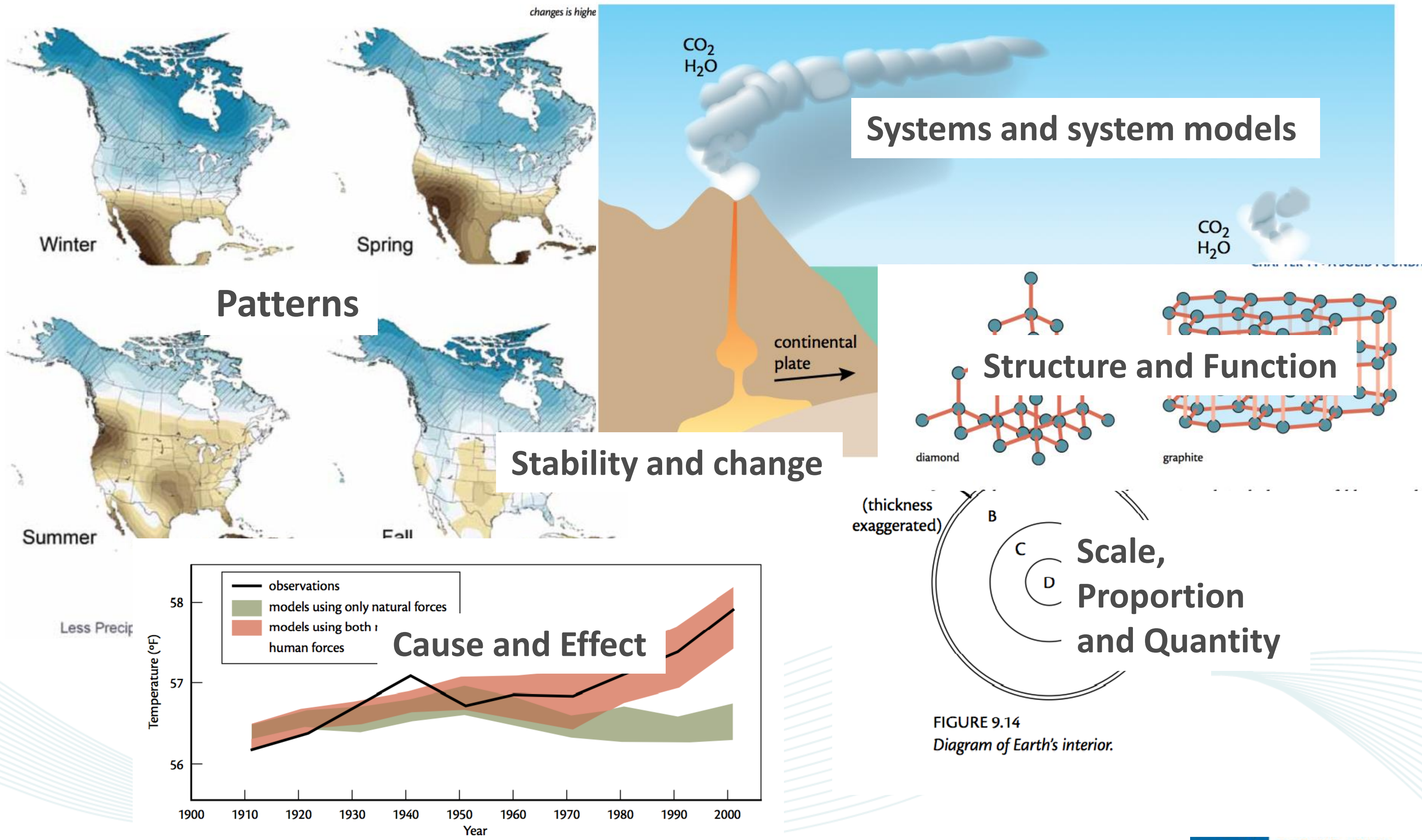
Prospecting for Mineral Ore

Setting the Stage: How Do Geologists Look for Mineral Ore?

Geologists prospecting for a particular mineral ore must first have a good understanding of the geologic environment in which that mineral can become concentrated. Certain minerals, for example, are more typically found concentrated within cooled and crystallized magma bodies near subduction zones

EDC OCEANS of DATA INSTITUTE

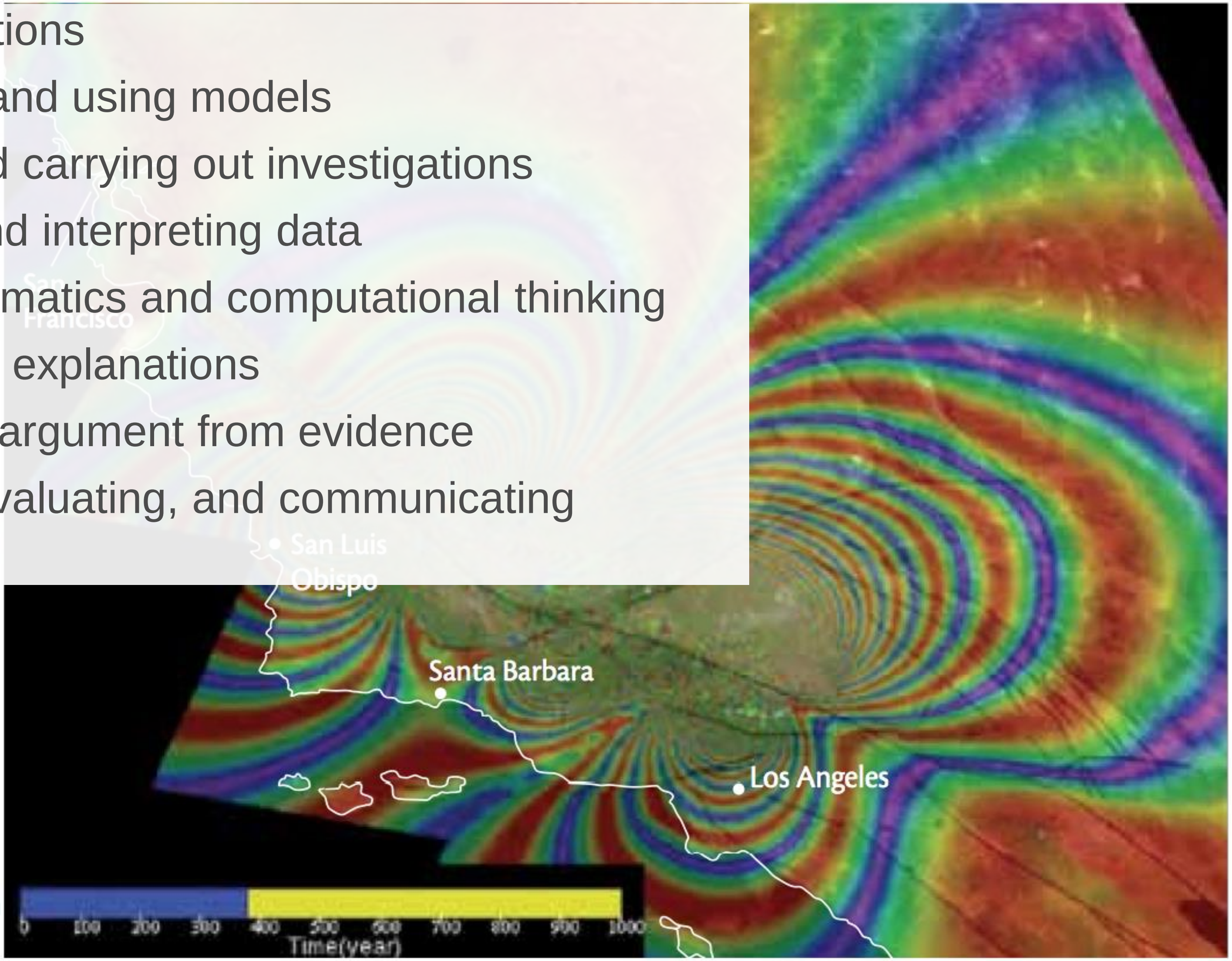
Dimension 2: Crosscutting Concepts



EDC OCEANS of DATA INSTITUTE

Dimension 3: Scientific Practices

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information



ACTIVITY 4

What's Happening Now and What's Projected for the Future?

Pre-Activity Discussion

Discuss the following questions with your classmates:

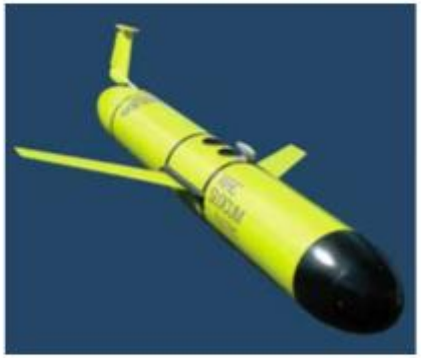
1. In Chapter 4 you looked at graphs of 30-year temperature and precipitation trends in Arizona, New Hampshire, your travel destination, and your local area. Do you see evidence in these eight graphs that Earth's climate has been warming? If so, describe the evidence you see. If not, describe why you can't draw a clear conclusion from the data.
2. If you wanted to get an average temperature for the whole Earth during a particular year, how would you go about doing it?
   a. Where would you sample?
   b. How many measurements would you make?
   c. When would you make the measurements?
3. To learn more about whether the climate is changing, what measurements other than temperature would you take?
4. Scientists use computer models to predict what might happen with Earth's climate in the future. What do you know about how computer models work?

Setting the Stage: Collecting Scientific Data

In order to understand what's happening with the climate, scientists rely on many thousands of ocean, atmosphere, and land measurements taken every day. That's because it's hard to look at just a few areas and understand whether the climate is changing. Ocean water measurements are taken by instruments on floating buoys, remote-controlled gliders (see Figure 6.19), ships, sensors connected to computers on land by cables, and even by satellite-tagged marine animals.

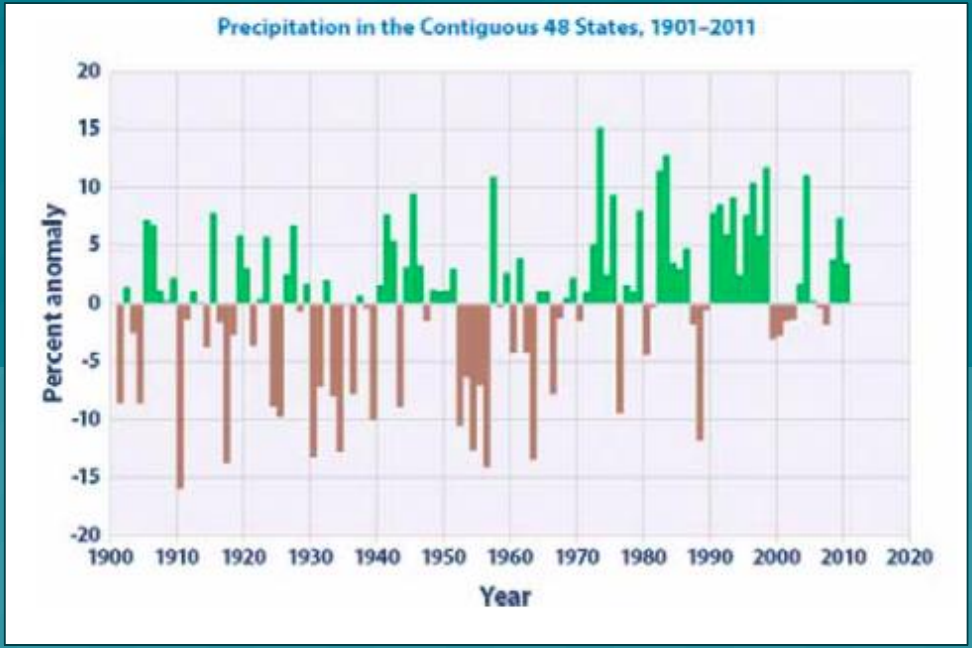
Satellites orbiting the Earth also take measurements of the ocean and atmosphere. On land, climate measurements are taken around the globe, in cities as well as in the most remote areas on the planet. For example, Figure 6.20 shows the locations where temperature measurements are taken as part of the global climate network.

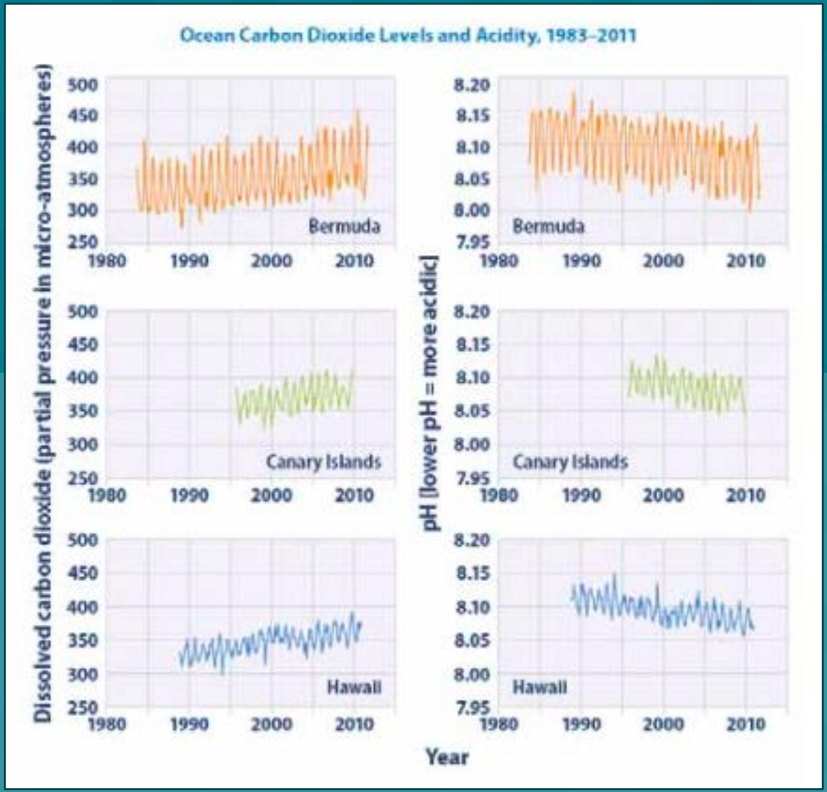
FIGURE 6.19
Submersible robotic gliders, such as the one in this photo, are used to collect physical measurements in ocean water, such as temperature.

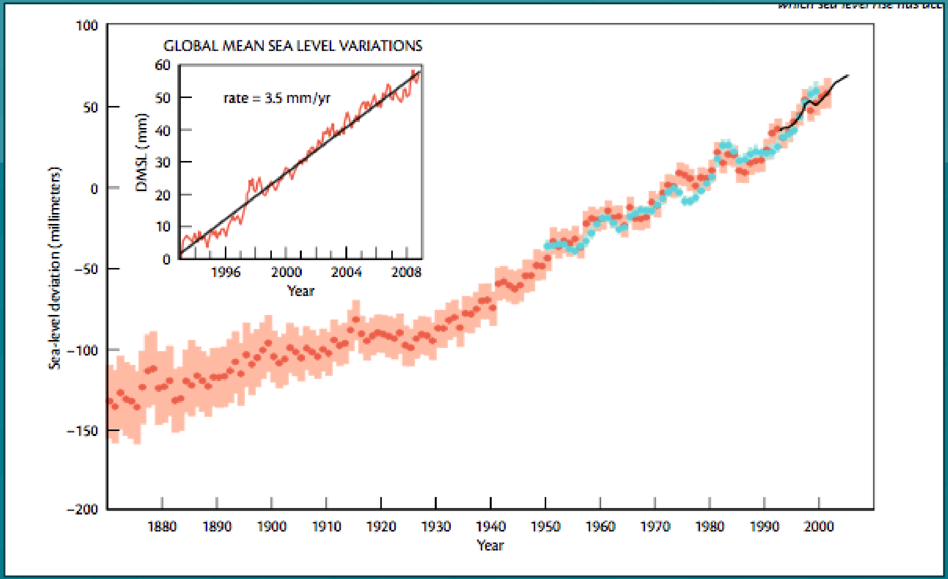


HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

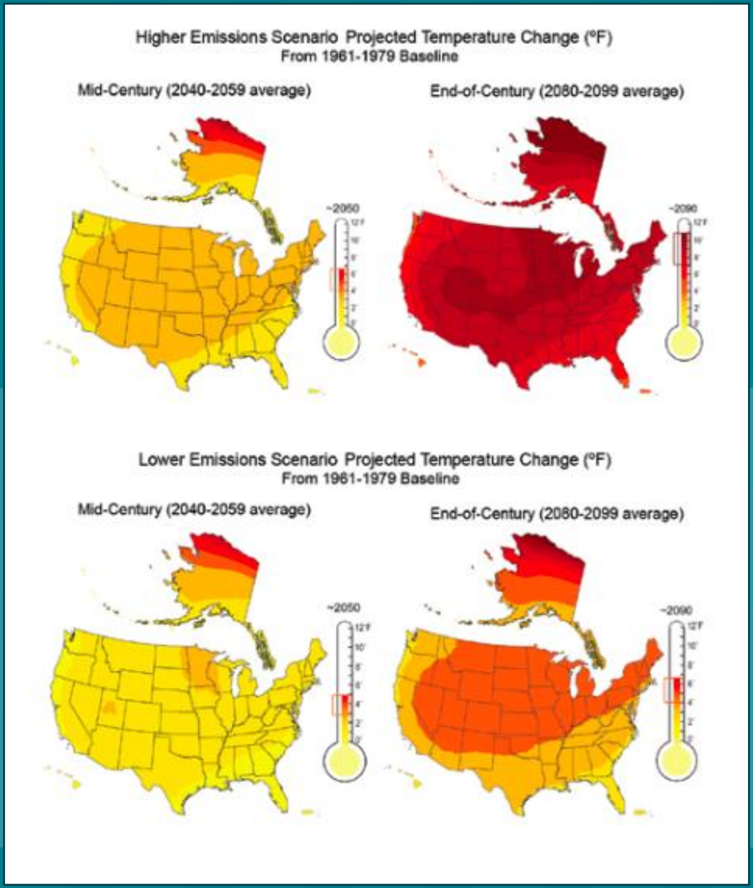
EDC OCEANS of DATA INSTITUTE

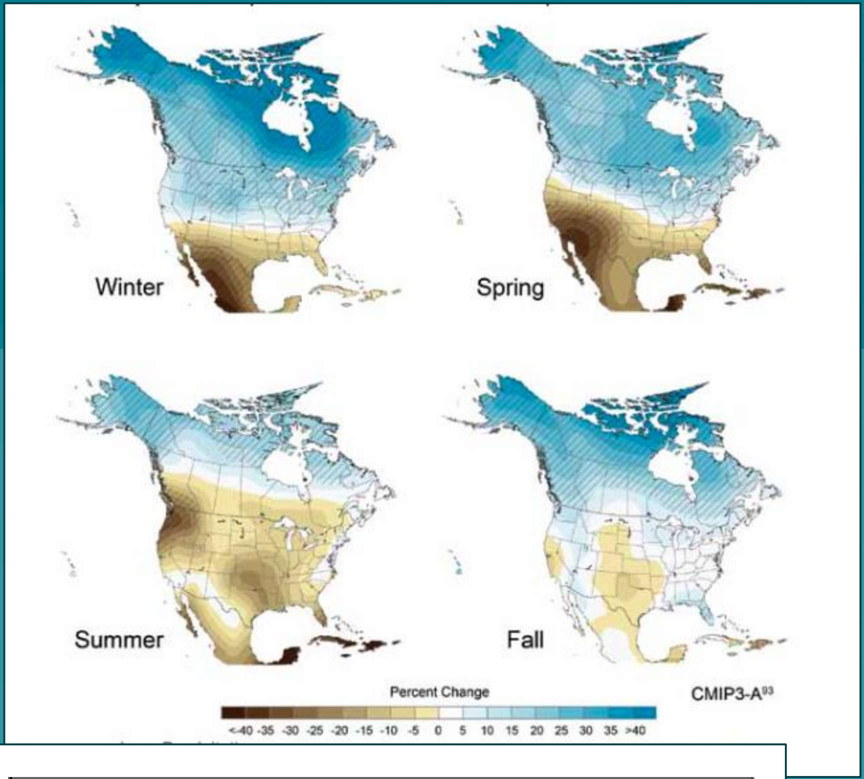


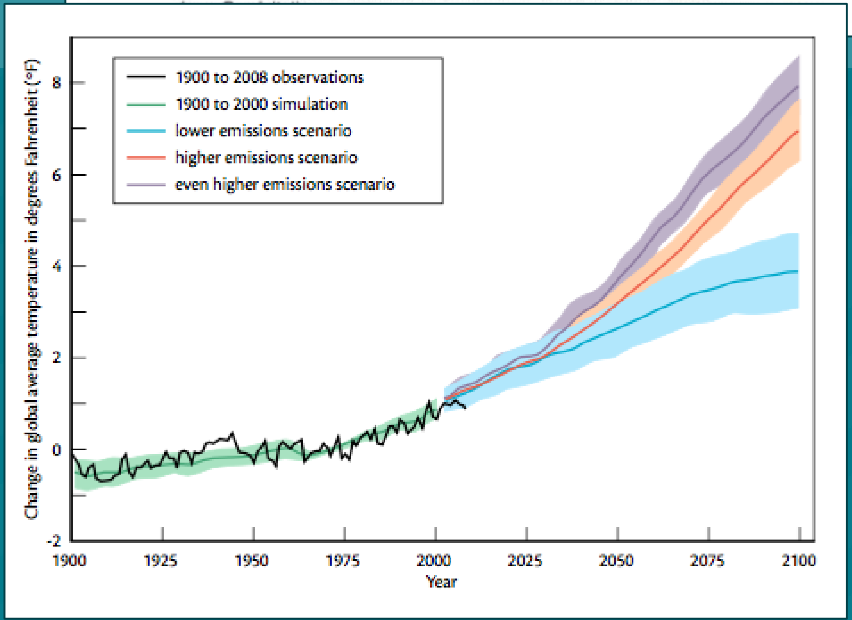




Historical Data







Computer Model Projections

CHAPTER THIRTEEN

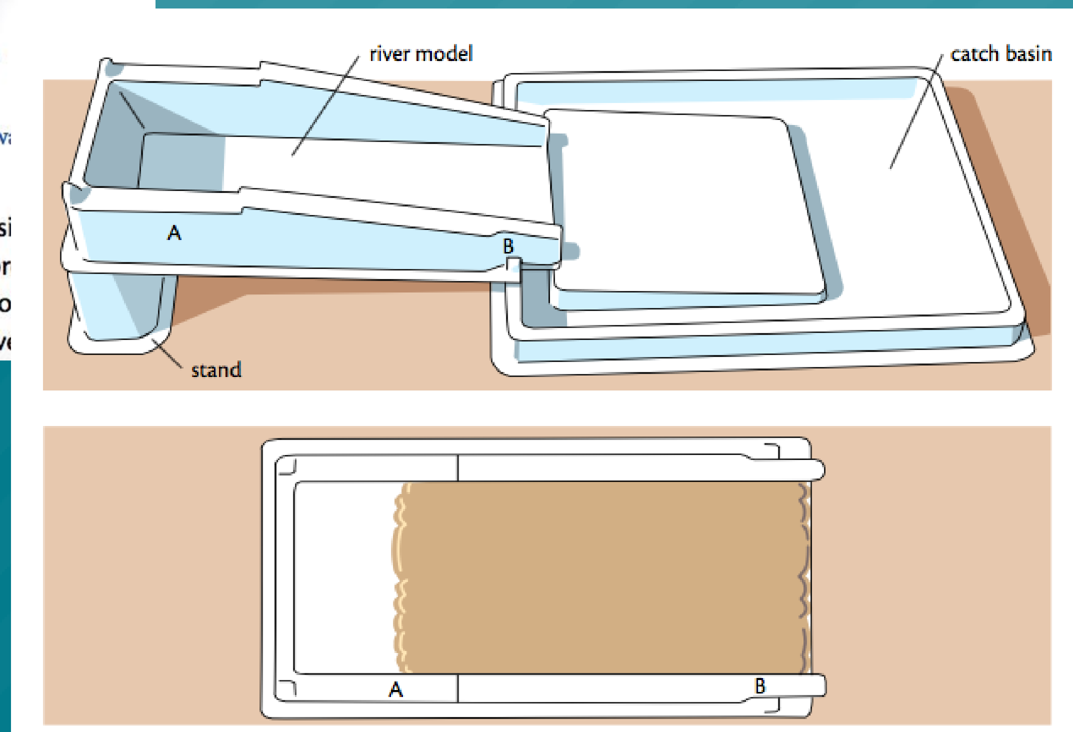
Mississippi Blues: Sedimentary Processes in a Delta

The Mississippi River will always have its own way; no engineering skill can persuade it to do otherwise. . . .[1]

—Mark Tw

What would you do if the land you lived on was si
What if an earthen wall, or levee, was all that pr
you from the water of a river and an ocean? Wo
you feel comfortable with that? In this chapter, you will inve

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.



Consider-Investigate-Process learning cycle

Students investigate questions and solve challenges by gathering information and evidence and THINKING about it!

Learning Cycle: Consider

Purpose:

- Identifies **prior knowledge** and misconceptions
- Provides **contextual background**
- **Engages** students' interest in content of chapter

Consider Investigate Process

TO START THINKING about what you will do in this chapter, discuss your current ideas about what it would be like to try to survive on another planet. Then read a story about two colonists exploring the surface of their new home: Mars.

Brainstorming

In this course, you'll be asked questions during the brainstorming that require you to use your imagination or draw on what you've learned beyond this class. Don't worry if you don't think you have the "right" answer. Just express your ideas.

1. Discuss the following with your partner and be prepared to share your ideas with the class.
   a. You may have gained a sense of space travel through science fiction books or movies. What is your vision of what it would be like to try to live on another planet such as Mars? Write a paragraph describing 5 minutes of your life in this other world.

The following story is excerpted from the science fiction book *Red Mars* by Kim Stanley Robinson. The book is part of a trilogy in which humans colonize Mars. Although this story is fiction, the author tried to make the descriptions of Mars as accurate as possible based on what is known about the planet.

In this excerpt, two colonists from Earth, Nadia and Arkady, explore their new Martian home in an airship (or dirigible). As you read this story, put yourself in the shoes of these two travelers, noting what would feel familiar to you and what would feel different.

FIGURE 1.1: *The dirigible airship Arrowhead, described in the novel Red Mars.*

WHAT'S THE STORY?

Two Travelers in a Distant World

Their dirigible was the biggest ever made, a planetary model built back in Germany and shipped up in 2029, so that it had just recently arrived. It was called the Arrowhead, and it measured 120 meters across the wings, a hundred meters front to back, and forty meters tall. It had an internal ultralite frame, and turboprops at each wingtip and under the gondola; these were driven by small plastic engines whose batteries were powered by solar cells arrayed on the upper surface of the bag. The pencil-shaped gondola extended most of the length of the underside, but it was smaller inside than Nadia had expected, because much of it was temporarily filled with their cargo . . . ; at takeoff their clear space consisted of nothing more than the cockpit, two narrow beds, a tiny kitchen, an even smaller toilet, and the crawlspace necessary to move among these. It was pretty tight, but happily both sides of the gondola were walled with windows. . . .

LAB-AIDS Experiencing Science

EDC OCEANS of DATA INSTITUTE

Learning Cycle: Investigate

Students address a challenge by:

- **Gathering information** from activities and readings
- **Carrying out investigations** and analyzing/ interpreting data
- **Organizing and synthesizing** their ideas
- **Communicating** their thinking and exchanging ideas with others

Consider **Investigate** Process

CHALLENGE

What would it take for people to colonize another world?

The universe is unimaginably big, but scientists still only know of one planet where humans can comfortably live. The human species has evolved to fit perfectly the conditions on Earth. Travel in outer space is dangerous, and Earth's nearest sister planet Venus is so incredibly hot that space probes dropped to its surface must be designed to withstand temperatures hot enough to melt lead. Mars, although also hostile to life, is a more promising possibility. Scientists and others with an adventurous spirit have tried to figure out ways of making Mars habitable for humans. But what would it take?

> *The survival of the human race depends on its ability to find new homes elsewhere in the universe.*[2]
>
> —Stephen Hawking, astrophysicist

GATHER KNOWLEDGE

Your class will form a team that is developing plans for a Mars colony. It's hard to imagine a greater adventure or a greater challenge than colonizing another planet. To make sure you could survive, it is essential to understand the conditions you would encounter. To gather the knowledge you will need, you'll do the following:

- Analyze what makes Earth habitable that you would need to duplicate on Mars.
- Research the conditions you would encounter on Mars, and identify the top five survival challenges.

LAB-AIDS Experiencing Science

EDC OCEANS of DATA INSTITUTE

Learning Cycle: Process

Students demonstrate their mastery of learning objectives by:

- **Sharing** their solutions to the challenge and listening to the ideas of others
- **Discussing** what they have learned and relating to broader contexts

Consider Investigate **Process**

SHARE

Each subgroup will present its findings, summarizing the goals, challenges, and further questions associated with obtaining food, water, shelter, and energy on Mars. As you listen to the other groups, take notes. In addition to recording what other groups say, write down any other ideas or questions you have about the goals and challenges of building a Mars colony.

DISCUSS

Draw on the knowledge you've gained in this chapter as you discuss these questions with your classmates. Your teacher may also ask you to record the answers in your notebook.

1. Think critically about the ideas you and your classmates developed about your colony. What could go wrong? What do you feel the least confident about?

Scientists are interested in what is known, but they get excited about what's ***not*** *known…you may feel like the more you learn the more you realize you don't know. If you feel that way, this may sound strange, but you are definitely on the right track!*

An Open Invitation to Study the Earth

Your home planet is an incredible and largely unexplored place. Less is known about Earth's surface than about the surface of the Moon, or Mars. And most of the planet has never been seen by a human—that's the part beneath the surface, extending from the ground beneath your feet to the core, a distance of almost 4,000 miles.

Earth scientists are interested in what is known about Earth. But they get excited about what is unknown. To seek answers, they use a larger suite of tools than you might imagine. They collect samples and take measurements, in equatorial jungles and in ice-capped polar seas. They deploy robotic sensors in the oceans, and send probes and satellites into space. They do laboratory experiments, and collaborate with other scientists. They combine new data with what is known to imagine complex 3-D "moving pictures," such as magma flowing below the surface of a volcano, shifting faults sending earthquake waves through rock, or oil migrating into reservoirs. To help them visualize these processes, they use everything from sketches in their notebooks, to computer simulations and models. In the activities in *EDC Earth Science,* you'll have a chance to gather, analyze, visualize, and interprete the evidence too.

As you work your way through the chapters of this course, you'll learn things that are well understood by scientists, but fair warning—you'll also encounter uncertainties. That means when you're asked a question, you won't always find the answer by looking back through the readings. You'll be asked to do your own thinking and develop your own answers. You'll be challenged to support your answers with evidence, and encouraged to debate them with your classmates. At the end of this course, you should feel like you've learned many things. You should also have many more questions than you did at the beginning. But most important, you'll have developed skills that will help you explore the unknown.

Onward!

Ruth Krumhansl
Lead Author
EDC Earth Science

Thank you!
Questions?

oceansofdata.org