Session 9: Stability and change in global atmospheric carbon

Overview

In this session, participants gain experience with the difficult task of narrowing a topic area down to a more focused question. They also learn strategies to identify the best-fit line and calculate annual rate of change, and why those are important scientific skills to have when interpreting data. In the process, they learn about the strategies and practice the skills needed to access, download, process and plot online data and to overcome the associated challenges. Participants explore data on different spatial scales by comparing global atmospheric CO_2 collected at Mauna Loa, HI (i.e. the Keeling Curve) with measurements of CO_2 and pH collected in Washington State and recognize that global change is evident in localized places. They come to understand that data can be used to reveal both small-spatial scale and global patterns; carbon dioxide is increasing over time and this is observed in the atmosphere and waters; and scientists think about global patterns using proxies. Finally, they discuss how the crosscutting concepts of stability and change; and scale, proportion and quantity were incorporated into the design of the session experiences. They also brainstorm what makes for good quality data, and reliable sources to obtain data.

Session Goals

Theme	**Goals**
Climate Science Ideas	Understand that: ● Increases in atmospheric and ocean CO_2 and concurrent decreases in ocean pH can be observed locally and globally ● Scientists think about global patterns using proxies
Using Data	Build on skills covered in previous sessions and explore ways to: ● Articulate high quality data and the most appropriate data visualization to use depending on your question and data ● Looking at the overall pattern by developing a line of best fit ● Identify the benefits and limitations of analyzing multiple data sources at one time

	• Identify how the temporal and spatial scale of the data influences what conclusions you can draw from the data
Teaching & Learning	Experience a variety of effective practices for teaching and learning. Practice designing a testable question.
Framework/ NGSS	Learn about how the crosscutting concepts of Stability & Change and Scale, Proportion & Quantity are described in NGSS and the *Framework for K–12 Science Education*

Materials Needed

For the class

- PowerPoint presentation and Digital/data projector
- Whiteboard and pens OR Chart paper and pens
- Masking tape

For each participant

- 1 copy of the following handouts/worksheets:
  - Key to Data Visualizations
  - Sources of online data
  - "Using Environmental Data to Investigate Ocean Acidification" (worksheet)
  - Scattered Data
  - Good Quality Data and Reliable Sources Checklist
  - For Homework:
    - Homework Assignment - Session 9
    - Data Components of Final Project
    - Data Components Glossary
  - Optional: Background information–Using Environmental Data to Investigate Ocean Acidification
- Completed homework from Session 8

For each pair of participants

- 1 copy of the following:
  - NRC *Framework for K–12 Science Education,* Stability and Change, pp. 98 - 101

- NRC *Framework for K–12 Science Education,* Scale, Proportion and Quantity pp. 89 - 91 (provided in Session 8)
- Crosscutting Concepts Prompts handout

Preparation of Materials

1. **Laptops.** Encourage participants to bring their laptops to this session of the course. If participants do not have access to laptops, you may want to project the *Washington State/PMEL* CO_2 slide and *Slide #3: Surface Water pH at Padilla Bay NERR, Washington* or print out copies for them to use in class. Versions of the worksheet with and without the images are provided; determine which is most appropriate to use for your participants and situation. Also consider that it often takes longer to do the online activities when participants are using their own laptops as troubleshooting is often required. On the other hand, participants find it highly engaging to access the authentic data themselves.
2. **Make copies.**
   a. Make copies of the following for each participant:
      i. Key to Data Visualizations
      ii. Sources of online data
      iii. Using environmental data to investigate ocean acidification (worksheet)
      iv. Scattered Data
      v. Good Quality Data and Reliable Sources Checklist
      vi. Homework:
         1. Homework Assignment - Session 9
         2. Data Components of Final Project
         3. Data Components Glossary
      vii. Optional: Background information–Using Environmental Data to Track Ocean Acidification (see pg 10 Instructor Note)
   b. Make copies of the following for each pair:
      i. Crosscutting Concepts Prompts
      ii. NRC *Framework for K–12 Science Education,* Stability and Change, pp. 98 - 101
      iii. NRC *Framework for K–12 Science Education,* Scale, Proportion and Quantity pp. 89 - 91 (provided in Session 8; make a few copies in case participants have misplaced their copy)

Session at a Glance

Task	Description	Time (minutes)
A. Activity & Discussion: *Refining Testable Questions*	Participants revisit their homework assignment and work with a partner to revise their Topic Area Questions into specific testable questions for which they make predictions.	40
B. Data Activities: *Comparing patterns in data from global, regional, and local scales*	Participants use three different data sources to explore patterns in atmospheric CO_2 and surface water pH, estimating the rate of change in these parameters over various time scales. They are asked to make linkages between atmospheric CO_2 and ocean pH and think about the phenomenon of ocean acidification on a global, regional and local scale. Using the CO_2 and pH data, they also practice creating best fit lines.	80
C. Discussion: *Crosscutting Concept(s)*	Participants read and discuss the crosscutting concepts of Stability & Change and Scale, Proportion & Quantity.	15
D. Discussion: *Choosing Data Visualizations*	Participants are introduced to the Key to Data Visualizations, a resource and reference to use as they design their data activity as part of the final project.	15
E. Reflection: *Accessing and Using Real Time and Archived Data*	Participants engage in a discussion about what makes for good quality data, and reliable sources to obtain data, and reflect on using professionally-collected data.	10
F. Homework	1. Explore online data related to their final project and decide on two related, investigable, and more focused questions. 2. Review the *Spurious Correlations* website and read about CO_2 and ocean pH to prepare for the next session. 3. Decide on the Testable Question (with partner) and complete Parts 1 –3 of the “Data Components of Final Project” worksheet.	10
	TOTAL: 2hrs 50 min	**170**

Session Details

A. Activity & Discussion: *Refining Testable Questions*

Sharing Session Goals

Display session goals slide. Display the goals and briefly introduce each with a description of how they are connected and flow from one to another.

- **Climate science ideas:** Explore local and global changes in atmospheric and ocean CO_2 and use proxies as scientists do to think about global patterns.
- **Using data:** Learn about the strategies and practice the skills needed to use archived professionally-collected data from online data portals. Interpret data and use it as evidence (i.e. draw conclusions); and use best fit lines to calculate long-term trends in data.
- **Teaching and Learning:** Experience a variety of effective practices for teaching and learning, as well as practice designing a testable question.
- **Framework/NGSS:** Learn about the crosscutting concepts: Stability & Change and Scale, Proportion & Quantity; and the Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information.

Refining Own Topic Area Question

1. **Revisit Testable Question.** Remind participants that as part of their homework, they were asked to do some research on their chosen Topic Area and Topic Area Question (TAQ) and to answer a few related questions. A necessary step in the design of their final project will be to narrow down their TAQ to one that is very specific and fits the SMART checklist for a testable question.

2. **Revisit homework - participants refine own question.** This session they will refine their TAQ about ecological relationships or processes that could be addressed with online data into one or more Focused Questions that explore some narrowed facet of the topic area/concept so that it clearly articulates the 1-2 variables of interest and the location they have chosen.

3. **Pre-think about More Focused Questions - provide examples.** Ask participants to reflect on their TAQ, the additional information about the topic that they learned from their homework, the variables, timeframe, and spatial scale with regards to their TAQ they brainstormed for homework, and other aspects of this phenomenon that would be of interest to them. Show slide of an example TAQ (e.g. "How are light energy (PAR) and dissolved oxygen related?"). Encourage them to think about looking at the relationship at more specific spatial and temporal scales and

what other variables may be needed to further focus the question. Remind participants that they first need to make sure their question is focused around a relationship between the variables (Step 1 - for example this would be looking at DO concentration). To narrow their question further, they can focus in on any one, but preferably all, of these three areas:

a. Make it more specific by where (spatially) they are interested in investigating:
    - What is the relationship between light energy (PAR) and dissolved oxygen (DO) concentration ***in the Jacques Cousteau Research Reserve***?
    - Does the relationship between light energy (PAR) and dissolved oxygen (DO) concentration ***vary north to south*****?** ***east to west*****?** ***inland vs. coastal***?
b. Make it more specific by when (temporally) they are interested in investigating:
    - What is the relationship between light energy (PAR) and dissolved oxygen (DO) concentration ***throughout a day*****?** ***across the seasons*****?** ***over a year*****?** ***over a decade*****?**
    - Does the relationship between light energy (PAR) and dissolved oxygen (DO) concentration vary ***throughout a day*****?** ***across the seasons*****?** ***over a year*****?** ***over a decade*****?**
c. Make it more specific by what other variables they are interested in investigating:
    - What is the relationship between light energy (PAR) and dissolved oxygen (DO) concentration ***as it changes with tides*****?**
    - Does the relationship between light energy (PAR) and dissolved oxygen (DO) concentration vary ***in a hurricane*****?**

4. **Partners initiate work to focus their question and make predictions.** Have pairs (working on the same TAQ) work together to discuss and jot down questions about other aspects of their TAQ that they think would be interesting to investigate. Circulate as they work and provide feedback as needed.

5. **Making predictions.** For each More Focused Question, have them also make a prediction (i.e. hypothesis) about the patterns or relationship they expect to see as they explore professionally-collected data online to answer these questions. Encourage the participants to write down their reasoning and/or prior knowledge as it relates to their predictions for the More Focused Question(s). Remind them that they will have more time to work with their partner to focus their question and make predictions for homework.

6. **Describe next steps.** Tell participants that over the next few weeks, they will test their predictions as they dig deeper into the online data sets, interpreting and analyzing the data, and ultimately come up with conclusions and explanations from the data as it relates to their questions.

7. **Introduce National Estuarine Research Reserve (NERR) System-Wide Monitoring Program (SWMP) data.** Remind participants of the url for the NERR SWMP data: http://cdmo.baruch.sc.edu/get/export.cfm. Tell them that testable questions often can be refined through an exploration of data sets, like those provided in the NERR SWMP data repository. For homework, they will explore this site to further refine their More Focused Questions. During this session, they will gain experience using data from this portal as they explore questions related to global, regional, and local patterns of atmospheric CO_2, and tracking changes in surface water pH.

   Note to instructor: There may be participants who are interested in exploring questions and topics outside of what is testable using the NERR SWMP data. More advanced participants who are savvy with data explorations and manipulation should be encouraged to do so. A handout of various data repositories and portals for ocean, climate and environmental data is provided and can be shared with the participants ("Sources of online data").

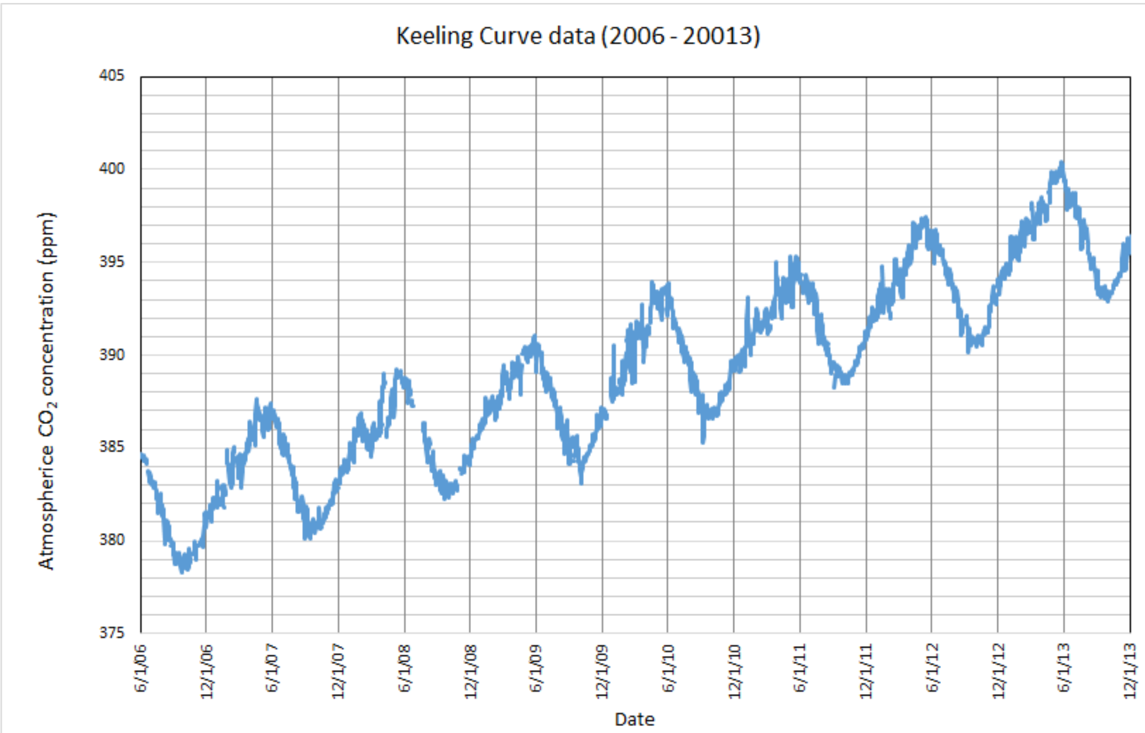
B. Data Activities: *Comparing patterns in data from global, regional, and small (e.g. local to you) scales–Using Environmental Data to Investigate Ocean Acidification*

Note to instructor: *The discussions and the* Using Environmental Data to Track Ocean Acidification *worksheet that the participants complete in this section will be referenced and the results used again in Session 10. Be sure to tell the participants to save their work to refer to later.*

Introduction to data activities worksheet.
Tell participants that in this next activity they will use three different data sources to answer questions that explore patterns in atmospheric CO_2 and surface water pH, estimating the rate of change in these parameters over various time scales. This will lead to discussions and a deeper understanding about the phenomenon of ocean acidification on a global, regional and local scale. The locations include: Part 1) Mauna Loa; Part 2) Washington State Buoys; and Part 3) NERR Site at Padilla Bay, WA.

Part 1: Global Patterns in atmospheric CO_2.

1. **Returning to the Keeling Curve.** Project the **Keeling Curve: CO_2 Levels in the Atmosphere** slide and remind participants that they looked at the Keeling Curve in Session 7. Have them turn and talk with a partner to describe what this graph is showing [*CO_2 levels over time*] and interpret the pattern [*CO_2 levels are increasing over time*].



2. **Review Proxies.** Remind the participants that scientists use the Mauna Loa Observatory in Hawaii to estimate atmospheric CO_2 concentrations around the globe. Project the slide with the definition of proxy "A measured parameter used to estimate or predict another parameter that cannot be measured or quantified directly" and ask the participants "Why do you think that this location in Hawaii was chosen to represent, or be the proxy of, the global levels?" [*It was chosen due to the altitude and the fact that it is unaffected by human activities (i.e. factories), vegetation and other factors and that scientists can sample the air coming in off the ocean.*]

3. **Using global data to track recent changes in atmospheric CO_2 concentrations**. The participants will now engage in an activity using recent atmospheric CO_2 data collected at the Mauna Loa observatory to estimate the annual **rate of change** of global atmospheric CO_2 concentrations.

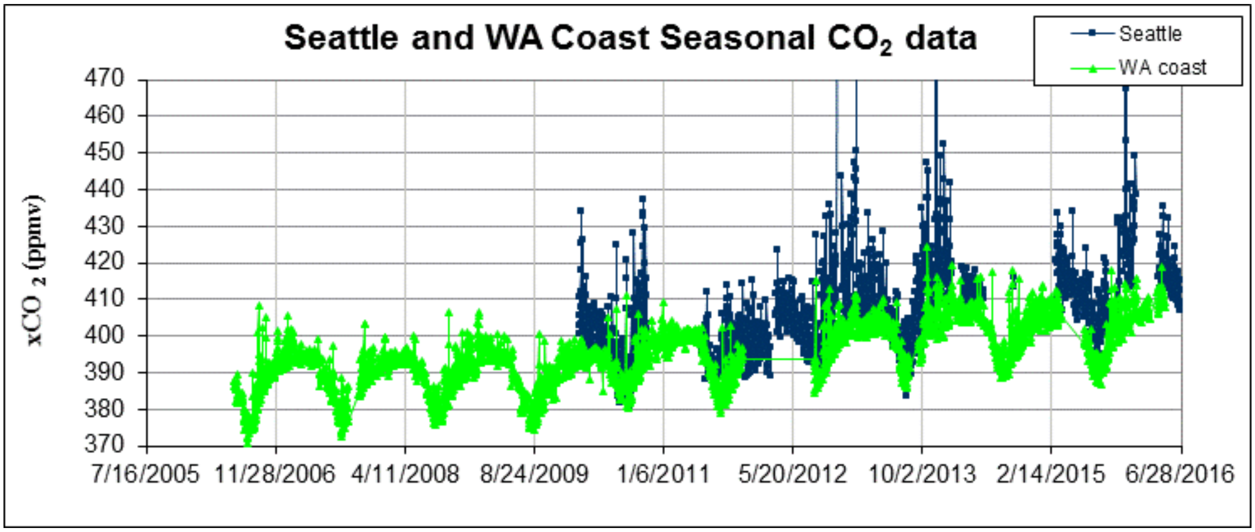
4. **Distribute worksheet "Using Environmental Data to Investigate Ocean Acidification":** Have participants work in pairs to complete the questions on the worksheet. This is a self-directed activity, so the instructor can walk around the room and provide assistance or guidance as needed.

   Questions from page 1 of the worksheet are below:
   1. What time of the year do the lowest concentrations of carbon dioxide occur? *[late summer, early fall]*
   2. Visually estimate the lowest CO_2 concentration in 2006. [*approximately 378 ppm*]
   3. Visually estimate the lowest CO_2 concentration in 2013. [*approximately 393 ppm*]
   4. What is the difference in these CO_2 concentration values between 2006 and 2013? [*approximately 15 ppm*]
   5. Draw a line connecting the lowest values for each year in the graph above. Estimate the **annual** rate of change in CO_2 over this seven-year period. Use units of "ppm per year". [*approximately 2.14 ppm per year*]
   6. How does your estimate compare to the rate of increase of 2.07 per year reported by NOAA? [*very close*][1]

Part 2: Using professionally-collected data to evaluate regional changes in atmospheric CO_2 concentrations.

Continuation of worksheet: When participants are done with page 1 of the worksheet, have them continue the investigation on page 2. In the second part of the activity, they will estimate the change in atmospheric CO_2 concentrations using 8 years of data collected from a CO_2 sensor placed on an offshore buoy on the outer coast of Washington state. *If participants do not have access to laptops, you may want to project the Washington State/PMEL CO_2 slide or make sure you are sharing the handouts that have the data visualizations included.*

[1] Science is not a deterministic field; relationships are never proven. Instead, in science we talk in terms of probability. For example, it is likely that X causes Y or this likely indicates Z. Scientists use statistics to help them determine how confident they can be in the observed relationship or pattern in the data. The less variation, or difference in values, among the data points in general the more confident you can be in stating a conclusion about the relationship. Numbers do not need to be exactly the same in science. In fact, they rarely ever are, but rather scientists look for numbers being "close" together to consider it similar. How close, you might ask? Well that depends on what you are looking at and is an issue of scale. If you are looking at the sizes of whales, a difference of 3 inches is not all that different, but if you are looking at the sizes of cockroaches, a difference of 3 inches would be extremely different. Therefore, scientists consider a difference in averages of the rate of increase of CO_2 concentrations over 8 years between 2.07 and 2.14 to be very close considering it could have been 2.07 vs. 14.0, even though 2.14 is larger than 2.07. In other words, this issue of *Scale, Proportion, and Quantity* is very relevant when considering *Stability and Change*.



Note to Instructor: *The figure above compares the CO_2 concentrations recorded at a buoy located several miles off the coast of Washington State (green line) with that collected on top of the Space Needle in downtown Seattle (blue line). Since prevailing winds are generally from the west, this comparison reveals the additional effect of land and human activities (e.g. burning fossil fuels) on the baseline of rising CO_2 in the atmosphere. NOTE: Gaps in data represent periods of time when buoys and/or sensors were not in operation. Figure provided by the NOAA PMEL Carbon Working Group).*

Note to Instructor: *There is an optional* **Background** *handout you might to provide to your participants after this activity that provides more information about the patterns shown in this graph, including those related to rush hour traffic and heating in winter, but that these patterns are also obfuscated by prevailing winds. Don't provide the handout until participants have had the chance to look for patterns and ask questions about the patterns they observe.*

Questions from page 2 of the worksheet are below:

a. What was the lowest CO_2 concentration value in 2006? [*approximately 370 ppm*]
b. What was the lowest CO_2 concentration value in 2013? [*approximately 385 ppm*]
c. What is the difference in these CO_2 concentration values between 2006 and 2013? [*approximately 15 ppm*]
d. Estimate the annual rate of change in CO_2 over this period. [*approximately 2.14 ppm per year*]
e. How does this estimate of the rate of change in CO_2 concentration off the coast of Washington compare to the annual rate of increase you estimated for data collected in Hawaii. [*They are the same*]

The following are discussion prompts for participants to address in small groups:

a. What explanation can you offer for the difference/similarity in patterns of CO_2 concentrations collected in Hawaii and Washington over the ~10 year period? [*Both are influenced by the Pacific Ocean and season patterns*]

b. What does a comparison of CO_2 concentration data from Hawaii and Washington suggest about changes that are taking place in other parts of the world? What additional evidence would you need to support your conclusion? [*It suggests that these may be global patterns not just regional or local patterns. Finding a similar pattern in multiple other parts of the world would support this conclusion]*.

Note to Instructor*: To have confidence in extrapolating a pattern in one location to global scale requires a large amount of data from significantly more than two locations in order to conclude that it is a global pattern rather than a coincidence that a similar pattern is observed in two locations.*

Part 3. Tracking changes in surface water pH in waters near Seattle, WA (Padilla Bay estuary)

1. **Continuation of worksheet**: When participants are done with page 2 of the worksheet, have them continue the investigation on page 3. They will have observed changes in atmospheric CO_2 over a recent seven-year period using data from the Washington State/PMEL Carbon Study program. They will now consider how the pH of coastal waters in the same region has changed over the same period of time. *If participants do not have access to laptops, you may want to print out and project Slide #3: Surface Water pH at Padilla Bay NERR, Washington for them to use in class.*

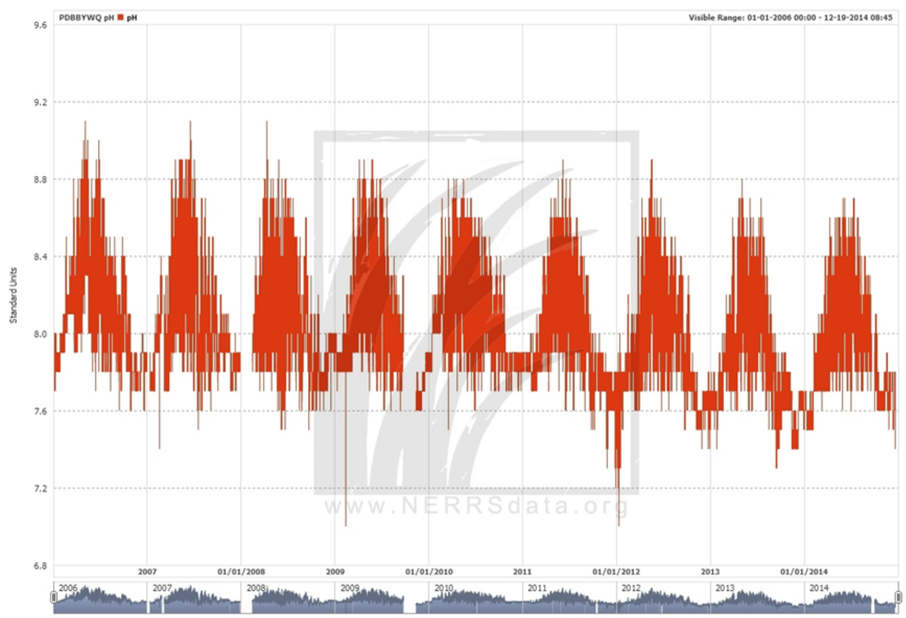
2. **Making connections between atmospheric carbon dioxide and ocean pH**: Participants, in small groups, take a moment to reflect on and review the connections between atmospheric CO_2, ocean CO_2, and ocean pH. The questions below from the worksheet are meant to help with making this cognitive leap and reasoning.
    1) What will happen to global atmospheric CO_2 concentrations with continued combustion of fossil fuels? [*It will increase, because burning fossil fuels releases carbon dioxide*]
    2) If global atmospheric CO_2 concentrations increase, what do you predict will happen to CO_2 concentrations in the surface waters of the oceans? What activity in Session 7 demonstrated this relationship? [*Ocean CO_2 concentrations will also increase, because the CO_2 is being absorbed by the ocean from the atmosphere. The Tracking Carbon Flows through the Ocean Reservoir where they had multiple jars with BTB*

and conducted different investigations with them to track CO_2 provided evidence of this.]

3) When CO_2 is added to water, it combines with the water to form carbonic acid. As CO_2 concentrations increase in the water, what will happen to the amount of carbonic acid in the water? [*As CO_2 concentrations increase in the water, the amount of carbonic acid in the water will increase. Remind participants of the work they have done with BTB and that it indicates carbonic acid in the water, and thus it is reacting with the carbonic acid that is formed when CO_2 is in water.*]
4) As carbonic acid concentrations increase in the water, what will happen to the pH of that water? [*The pH of the water will drop as the water becomes more acidic*].

Note to instructor: *This activity helps participants to see that there is a relationship between CO_2 concentrations in the atmosphere and ocean, and a lower ocean pH. In the next session, they will engage in a discussion about the difference between correlation and causal relationships, and investigate the consequences of lower ocean pH for marine organisms.*

3. **Online Data Exploration**: After reviewing these CO_2/pH relationships, participants will be directed to collect data on the NERR data portal and explore water pH in Padilla Bay between 2006 and 2014. *Below is the image they will get on the screen if data are properly collected.*



4. **Work with participants as they explore and interpret data**: Participants will evaluate the extent and frequency of low pH events in the bay between 2006 and 2014.

Note to instructor*: in the next session participants will make some predictions, and then do an investigation about the impact of low pH on marine organisms.*

Questions from the data activity and answers are listed below.

a. What is the highest pH value in 2006? [*9.1*]
b. What was the highest pH in 2014? [*8.7*]
c. What is the difference in the highest pH values in 2006 and 2014? [-*0.4*]
d. What is the annual rate of change in the pH in Padilla Bay? [-*0.4 over 8 years, or -0.05 per year*]

Part 4: Understanding Patterns in Data

1. **Scattered Data:** Once the participants have completed page 3, pull the class back together and tell them that you are going to pause for a moment to explore a technique that scientists use for easily observing patterns in data sets and visualizations. Explain that they will apply this technique momentarily to the ocean pH data. Project the "Scattered Data" slide and ask the participants to turn and talk with a partner about the pattern they see in the data. Use the following prompts:
    - How would you describe the relationship between the number of Crabs and Black Sea Bass (fish) off Pleasant Point? [*kind of looks like fish decrease as crabs increase*].
    - How would you draw a best fit line (also called a trend line or line of best fit) for these data?

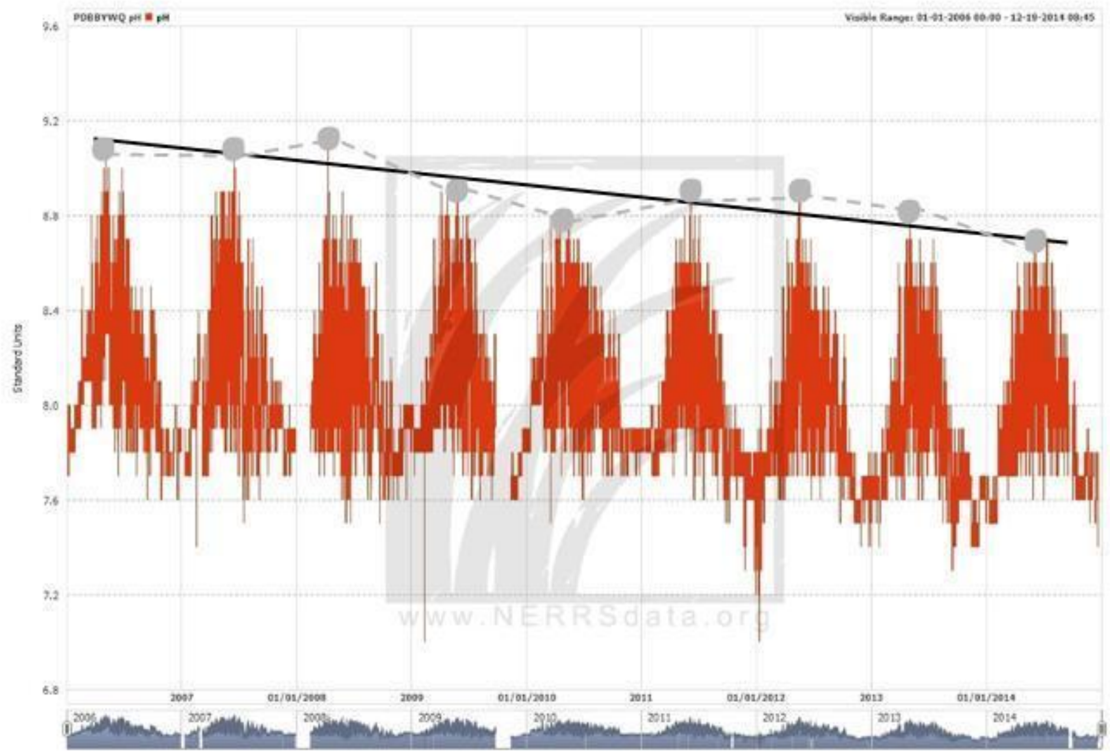
    After a few minutes, ask them to share out some of their ideas. During this initial brainstorming session, don't correct the participants or tell them answers to the questions, but rather encourage them to share their thoughts.

2. **Practicing Drawing Best Fit Lines:** Distribute a copy of the *Scattered Data* handout showing the same data that is projected on the "Scattered Data" slide to each participant. Explain that you will be showing them one way that they can draw a best fit line with their students. Ask the participants to do the following:
    - Draw a line encircling the entire set of data points, trying to enclose the data as best as possible. The resulting ellipse should be as small as possible.
    - Draw a line dividing the ellipse along its longest axis such that there are equal areas on either side of the line. This is your best fit line.

3. **Discussion: Dealing with scattered data and best fit lines**: After everyone has completed drawing their "best fit lines," ask them to discuss the following questions.
    - Did drawing a best fit line in the scattered data help you see the pattern more effectively? [*answers will vary*]
    - Why would a scientist want to use a best fit line? [*to reveal a pattern in a large cloud of data*].

4. **Best Fit Line of pH data**: Project the graph of the pH in Padilla Bay from Part 3 of their *Using Environmental Data to Track Ocean Acidification* worksheet and ask the participants to look at their own graphs from this part of the activity. Have the participants follow the instructions to draw a single "best fit" line through the pH data. After the participants have drawn their best fit lines, review with them how they determined the best fit line [*they made dots at the maximum values and drew a line that bisected the space that they were in*]. After everyone has completed drawing their "best fit lines," ask them to discuss the following questions.
    - ○ Did drawing a best fit line in the pH data help you see the pattern more effectively? [*answers will vary*]
    - ○ How else could you have drawn the best fit line in the pH data? [*lowest points each year, average value per year, or circle technique around all the data points with a line that bisects the area in the circle*.]

    Below is an example of participant work from the data activity that is used to arrive at the answers above. NOTE: Participants could also arrive at the same conclusion by selecting the lowest values of pH.



Part 5: Comparing atmospheric CO_2 and pH

1. **Turn and Talk.** Ask participants to turn to a partner and brainstorm what benefits there could be from looking at two different environmental variables from the same location over the same time period simultaneously. Allow the participants to talk in their partner groups for a few minutes before bringing the class back together. Ask for volunteers to share out what they were talking about. Be accepting of all responses and encourage other partner groups to build off of or counter what is being said.

2. **Comparing pH and CO_2.** After the theoretical discussion about what can be gained from looking at two environmental variables at the same time, ask participants to compare their pH graph to their graph of atmospheric CO_2 concentration measured on Washington Coast. Use the following questions to direct participants' attention to certain aspects of the two graphs:
    - Taken individually, what is similar between the data patterns of the ocean pH and the atmospheric CO_2? [*Both have an annual up and down pattern*]

- What relationship do you notice between the two variables? [*There is an inverse relationship, as the ocean pH is decreasing, the atmospheric* CO_2 *is increasing over time.*]
- What extra information or understanding did we learn from looking at both of these environmental variables together, rather than only looking at them individually, or only at just one? [*Atmospheric* CO_2 *and ocean pH have changed in different directions over the same time period in Washington state, therefore not all environmental variables are increasing over time.*]

3. **Quick Write.** Have participants take a few minutes to write down their own thoughts to the question "In what way(s) are the concentrations of atmospheric CO_2 and ocean pH related or not to one another? How do you know? Why does it matter?" Tell participants that you will be exploring these questions more in the next session.

4. **Share Key concept.** Display the key concept and record it on the Climate Science Ideas chart.
   - Increases in atmospheric and ocean CO_2 and concurrent decreases in ocean pH can be observed locally and globally

C. Discussion: *Crosscutting Concepts*

Examining Crosscutting Concepts: Stability and Change AND Scale, Proportion and Quantity.

1. **Introduce the objective.** Tell participants that they will now be thinking about the last activity: Comparing patterns in data from global, regional and local scales, and discussing how using a frame of Stability & Change, and Scale, Proportion & Quantity might support meaning-making of the data and deeper understanding of the phenomena.

2. **Pairs examine a crosscutting concept.** Tell participants they will work with a partner to read and discuss a crosscutting concept; either Stability and Change, or Scale, Proportion and Quantity. Explain to participants that if they did not read about the crosscutting concept of Scale, Proportion and Quantity in the last session, this session will be their opportunity to find out how this crosscutting concept is described. Distribute the readings (NRC *Framework for K–12 Science Education,* Stability and Change, pp. 98 - 101, and NRC *Framework for K–12 Science Education,* Scale, Proportion and Quantity pp. 89 - 91). Each pair will discuss the reading and communicate

their understanding of the crosscutting concept and how it has been used to frame the phenomena introduced in this session.

3. **Participant pairs discuss prompts related to their focus crosscutting concept.** Project a slide and provide the *Crosscutting Concepts Prompts* handout that lists questions specific to each crosscutting concept and space to record their ideas. Give participants 5 minutes to discuss the prompts related to their assigned crosscutting concept.
    a. **Stability and Change:** What does the data tell us about how the system is stable or changes? What causes stability in this system? What does the data tell us about what affects the stability of this system? What causes change in this system? What is already known about stability and change in this system? What is the time scale for this system to remain stable or change? If the system is changing, what would make it become stable? Are there feedbacks in the system?
    b. **Scale, Proportion and Quantity:** What scales are used to examine the phenomena? How can we study nature at these scales? How can we accurately measure at these scales? What proportions are described by the data? Why is a sense of scale important to look at this phenomenon?

4. **Small groups bring crosscutting concept ideas together.** Ask pairs to join with another pair that read a different crosscutting concept. Have the group of four communicate their findings and ideas about their assigned crosscutting concept, as they address the following prompts to synthesize and connect their ideas:
    - How might a sense of scale, proportion and quantity support a learner's understanding of the phenomena? Why do you think that?
    - How might a sense of stability and change support a learner's understanding of the phenomena? Why do you think that?
    - Was it effective to frame the science concept and explain the phenomena in terms of both of the crosscutting concepts? Did your group feel that one crosscutting concept was more effective in helping to understand the phenomena than the other? Why do you think that?

5. **Whole group discussion.** After 5 minutes, bring the whole group together. Ask small groups to share ideas and observations that they found interesting or surprising. Encourage small groups to:
    - compare and contrast how each of the crosscutting concepts frames the introduced concepts,

- think about how the two big ideas might affect a learner's understanding of the phenomena, and
- whether one would make more sense to use than the other to frame the activities we engaged with today, and why they think that.

Accept all answers without correcting or confirming them. Encourage all participants to engage in the conversations by asking probing questions, asking for supporting evidence for ideas, and challenging others to agree or disagree.

D. Discussion: *Choosing your Data Visualizations*

[**Note to instructor**: *An optional activity using this Key to Data Visualizations was included in Session 4. If you didn't do the optional activity, then distribute the handout now for your participants to use as they work on their final project and design the data activity. If the participants are really struggling to understand what the types of charts on the handout are showing, have them use resources like: The Data Visualization Catalogue (http://www.datavizcatalogue.com/), Introduction to Data Visualizations: Visualization Types (http://guides.library.duke.edu/datavis/vis_types), or the Data Visualization: Examples of Diagrams used for Data Visualization (https://en.wikipedia.org/wiki/Data_visualization).]*

1. **Introduce Variety of Data Visualizations.** Talk with participants about how there are multiple things that you can be interested in showing through a data visualization. The kind of data visualization that you use is largely determined by what your question is and what kind of data you have. However, we rarely teach people the basics of how to choose an appropriate data visualization.

2. **Describe importance of choosing the correct data visualization.** The first step in deciding what type of graph/figure/plot/map etc. to use is to understand what kind of data you have and what you are trying to show. For instance, you may want to show:
   - A comparison of values between variables,
   - Or, the distribution of a variable across a range of possible values,
   - Or, the composition of the components of the variables.

   Each of these different ways of showing data have their own data visualization that should be used. It is important to choose the correct data visualization for the data that you have, and the question you are asking of the data. One way to think about this is that the relationship among data visualizations and the kinds of data are like different sports and their particular equipment to use in each sport; data visualizations are specific to the kind of data that you have. You would not be a very good tennis player if all you had were soccer cleats and shin guards. Similarly, it would be difficult to interpret the distribution of a variable if it were plotted only as a comparison of the average value.

3. **Distribute *Key to Data Visualizations* handout and review words associated with graphs.** Give participants a minute to review the handout. Explain to participants that a great way to think about what kind of graph to use is to think of what words you are using to describe your data. Tell them to look at the handout and locate the appropriate graph as you review some of the associated words as follows:
   - If you are using words like "before/after, categories, compare, contrast, over time, peaks, rank, trend, types, valleys" then you are making a Comparison and will probably want to use a Bar Chart or Line Chart.
   - If you are using words like "cluster, distributed, from/to, plotted, points, spread, spread over, relative to, transfer" then you are looking at Distributions and will probably want to use a Histogram, Bubble Chart, Scatter Chart, or Box Plot.
   - Finally, if you are using words like "components, divided up, group, makes up, of the whole, parts, percentages, pieces, portion, proportion, slices, subsections, total" then you are looking at Compositions and will probably want to use a Pie Chart or Stacked Area Chart.

   Encourage participants to use the Key as a reference as they design their data activity.

E. Reflection: *Accessing and Using Real Time and Archived Data*

1. **Introduce quality and sources of data**. To have strong and reliable evidence to support scientific explanations, you need to have good quality data that comes from reliable sources. Tell participants that we will now look more closely at these important criteria that they will keep in mind as they develop their own activity.

2. **Show slide and do turn and talk – good quality and reliable sources of data.** Show the slide and give participants a couple of minutes to discuss their ideas about each of the categories (What are good quality data? And what is a reliable source of data and how can you tell?) Call on a few volunteers to share ideas with the whole group.

3. **Distribute handout - *"Good Quality Data and Reliable Sources Checklist".*** Distribute the handout and give participants a few minutes to review and ask questions. Tell them to keep this as a resource to use when choosing data sources to include as they develop their own activities.

4. **Optional: Quick Write Reflection on archived data.** Have the participants take 5 minutes to write down their overall reflections about using archived data during today's session. Remind participants of what you covered in Session 2—that archived data "are older data (> 30 days old) that are important and necessary for long-term reference."

F. Homework

Data Lesson Development - (distribute *Homework Assignment*, *Data Components of Final Project* handout and *Data Components Glossary* to participants)

1. **Complete Parts 1, 2 and 3 of the *Data Components of Final Project* worksheet.** Work with your partner to complete the worksheet and bring it to the next class to get feedback from peers and instructor. Use the *Data Components Glossary* as needed.
    a. **Decide on two More Focused Questions.** Work with your partner to finalize your one to two More Focused Questions, (from the list you developed earlier in this session or from further brainstorming), that arise when thinking about investigating your TAQ through the use of data. Make certain your More Focused Questions include the 1-2 variables you are interested in investigating as well as the time and location from which you will gather the data. Remember, there are many interesting things to be learned by asking questions about how ecological processes change temporally (e.g. annually, seasonally, tidally, daily) and/or spatially (e.g. vertically in the water column, along an estuary, among different estuaries, in different parts of the world).
    b. **Review data to refine your More Focused Question(s) into your Testable Question.**
        i. **Explore NERR SWMP data repository to help decide on questions.** One way that Testable Questions might emerge from your More Focused Questions is to explore relevant data repositories. After looking at the data, select one question to be your Testable Question.
        ii. **Review "Sources of online data" that provides additional options.** This list provides the url's of various, additional data repositories and portals for ocean, climate and environmental data in case you are interested in exploring questions and topics outside of what is testable using the NERR SWMP data. You should select one of these options if you have had previous experience with data explorations and manipulation.

c. **List prediction** for your Testable Question.

d. **Describe parameters.** Once you have chosen your Testable Question, describe the geographic location and the time scale (e.g. days, months, seasons, years) of the data that you will need to answer this question.

e. **List the website and URL you explored.** Briefly describe why you think the data included in this website would help to answer your questions. Also describe the process of who you accessed the data on this website. (This ensures you can get back to the same data.)

Spurious Correlations

Review the Spurious Correlations website, find a favorite correlation, and be prepared to share it with the group in the next session: http://www.tylervigen.com/spurious-correlations

Reading

Use the active reading strategy with *"Background on CO_2 and Ocean pH"*