Lesson Plan: CO_2 and Ocean Acidification

Author: Natasha Gownaris, Gettysburg College, 2020 OOI Data Labs Fellow
ngownari@gettysburg.edu

Audience:
Introductory Oceanography class taught in any format. Students need access to a laptop. Can easily be modified for an upper-level course (see some recommendations for integration of scientific papers, etc. below).

Time Allotted:
Approximately 45 minutes, plus time to go over answers.

Learning Goals:
- Identify long-term trends in atmospheric CO_2 and their relationship to ocean CO_2 through ocean-atmosphere gas exchange.
- Increase confidence in analyzing data presented in a variety of formats (spatial data, time series data, correlations).
- Develop an appreciation for the abundance and diversity of oceanographic and atmospheric data collected globally.
- Build connections across oceanographic disciplines – physics (upwelling, density stratification), chemistry (dissolved gases, pH), and biology (photosynthesis, acidification impacts, fisheries) concepts.

Prior Knowledge:
I read the highly relevant publication below for context for this activity. In an upper-level class, this would be a great paper to assign to students.

Evans W, Hales B, Strutton PG. 2011. Seasonal cycle of surface ocean pCO_2 on the Oregon shelf. Journal of Geophysical Research: Oceans. DOI: 10.1029/2010JC006625.

Ideally, students will have learned about the following concepts prior to completing this activity: variation in temperature, salinity, O2, and CO_2 with depth and spatial patterns in these parameters (e.g., Atlantic vs. Pacific CO_2), Coriolis effect and Eckman transport, ocean carbonate chemistry.

I use a jigsaw activity on the first day of class to get students started on thinking about these concepts, but this could be used at any point in your class. This is a nice activity to come back to throughout class as relevant concepts are discussed further.

Step 1) Each home group is provided a depth profile and some "clues" (e.g. a figure showing the relationship between temperature and density, the chemical equation for photosynthesis)

that they use to decipher what is happening in their depth profile. Depth profiles include various locations (Pacific/Atlantic or temperate/polar). Parameters include dissolved oxygen, carbon dioxide, nutrient concentration, density, temperature, salinity.
Step 2) Jigsaw groups (which include one member from each home group) are tasked with finding links among their depth profiles.
Step 3) Class discussion.

Invitation:

- Before class, students are asked to read the transcript of or listen to the podcast episode "Stressed-Out Fish and Ocean Acidification: Consequences of Climate Change" from the podcast "Got Science?" Warning that the ads on this podcast are a bit political! https://www.ucsusa.org/resources/stressed-out-fish-and-ocean-acidification
- The visualization "A Year in the Life of Earth's CO_2" can also be used prior to this activity. This visualization acts as a great discussion starter about what drives global trends in CO_2 and other greenhouse gases. https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11719

Exploration:
Students will use the "Changes in pH and pCO_2" dataset in both the Exploration and Application phase of this activity. During the exploration phase of the activity, students will be asked to describe the general trends in CO_2 and pH throughout the year and to describe the relationship between these two parameters. They will also be asked to determine the times of year that are marked by undersaturation or oversaturation relative to atmospheric CO_2, using a graph of atmospheric CO_2 at Mauna Loa as their basis for atmospheric CO_2 levels in 2015-2016.

Data Lab:
https://datalab.marine.rutgers.edu/explorations/chemistry/activity4.php?level=exploration
Mauna Loa Trends:
https://www.esrl.noaa.gov/gmd/ccgg/trends/

Concept Invention:
Students will be asked to describe spatial data on wind and chla along the coast near Newport, Oregon during December 2015 and July 2016 and to discuss how these data are related. These data are available from NANOOS; students can be instructed to zoom into the region surrounding Newport to reduce confusion (e.g., if wind direction is not consistent along the US West Coast).

NANOOS Mapper:
http://nvs.nanoos.org/Climatology

Application:
Students will be asked to go back to the OOI data widget "Changes in pH and pCO_2" and apply what they learned from NANOOS to understanding the annual trend in pH and pCO_2, with a focus on the two months they explored using the mapper (December 2015 and July 2016).

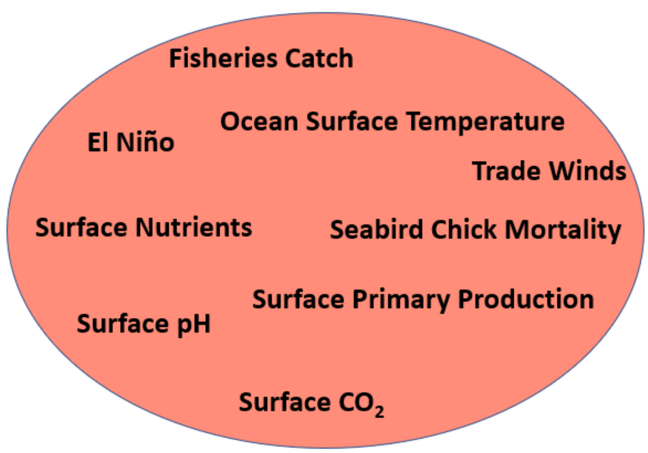
Data Labs:
https://datalab.marine.rutgers.edu/explorations/chemistry/activity4.php?level=exploration

Reflection:

Brief discussion about the implications of the observed trends (temporal, seasonal, with depth) for ocean life and for fisheries.

Potential Follow-Up Activities:

After talking with students about upwelling and completing this activity, I generally move on to discussing the El Niño-Southern Oscillation. I show students some examples of concept maps and have them work together in groups on Google Slides to create a concept map linking the below terms.



In upper-level courses, students could also be assigned the following paper to build on the knowledge gained from this activity.

Chatterjee, A., Gierach, M.M., Sutton, A.J., Feely, R.A., Crisp, D., Eldering, A., Gunson, M.R., O'Dell, C.W., Stephens, B.B. and Schimel, D.S. 2017. Influence of El Niño on atmospheric CO_2 over the tropical Pacific Ocean: Findings from NASA's OCO-2 mission. DOI: 10.1126/science.aam5776