CO_2...
From the Atmosphere to the Oceans

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Document Overview:
Atmospheric carbon dioxide due to human activity has been documented to be increasing. A much less commonly known concept is that atmospheric carbon dioxide is being absorbed by the global ocean and is effecting the ocean's acidity. This series of activities and discussion points introduce students to oceanic carbon dioxide measurements and the changes occurring to the ocean as a result of carbon dioxide present in the atmosphere.

Minnesota Academic Standards in Science:

9.2.4.1.2 Describe the trade-offs involved when technological developments impact the way we use energy, natural resources, or synthetic materials.
9.3.2.3.1 Trace the cyclical movement of carbon, oxygen and nitrogen through the lithosphere, hydrosphere, atmosphere and biosphere.
9.3.4.1.1 Analyze the benefits, costs, risks and tradeoffs associated with natural hazards, including the selection of land use and engineering mitigation.
9.3.4.1.2 Explain how human activity and natural processes are altering the hydrosphere, biosphere, lithosphere and atmosphere, including pollution, topography and climate.
9.4.4.1.2 Describe the social, economic and ecological risks and benefits of changing a natural ecosystem as a result of human activity.
9C.2.1.2.1 Explain how elements combine to form compounds through ionic and covalent bonding.
9C.2.1.2.7 Explain the role of solubility of solids, liquids and gases in natural and designed systems.

Objectives:

- Students will measure the alkalinity and pH of several solutions and see how they are affected as carbon dioxide gas is added.
- Students will develop an understanding of the ocean as a carbon sink
- Students will understand how carbon dioxide in the ocean alters its acidity
- Students will interact with oceanic carbon dioxide data from ship transects
- Students will view a short documentary and respond to questions about acidification
- Students will be exposed to their impact on ocean changes and challenged to consider possible changes

Type of Activity:

Classroom introductory lab or demonstration
Reading and discussion about the topic
Audio and video clips with discussion guides

Duration:

4-45 minute class sessions. Teachers are encouraged to follow these materials in the sequence they are presented for a logical flow of concepts.

Connection to Nobel Speakers:

The research of environmental oceanographer Christopher Sabine concentrates on the global carbon cycle. He was among the first to publish scientific data about human-derived carbon dioxide in the ocean and its impact on marine ecosystems, work that helped shape the Federal Ocean Acidification Research and Monitoring Act passed by Congress in March 2009. He was named the third director of the National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory in November 2011.

Teacher Tips:

This is setup as a lab or demo followed by teacher led class discussion and with video, audio, readings, and student homework. Pace this discussion as needed to fit the student group being addressed. Student questions are provided to help guide the discussion and movies.

This is most ideally used before the Nobel Conference to familiarize students with the concept of ocean acidification. But it can also be quite relevant as a way to further explore the topic after hearing Dr. Sabine's talk.

Concepts:

Atmospheric CO_2 is being dissolved into the global ocean and changing the ocean's characteristic properties.
Combining CO_2 with water yields carbonic acid.

Description:

Day 1
Have students respond to the first three questions on the sheet titled "Day 1-2 Student Response Questions About Dr. Sabine's Work" after experiencing these first two days of basic information. They can be found at the end of this document.

Introductory Activity: Classroom demo or student lab
Carbon dioxide, when combined with water, creates carbonic acid. This activity has students use their own CO_2 to acidify water by exhaling through a straw into water and other liquids. Essentially, placing carbon dioxide into a liquid can cause carbonic acid to form and lower the pH of the liquid. With either a universal indicator or a grocery store style indicator made from cabbage juice, the change can be easily observed. The amount of change depends on the characteristics of the solution. The activity includes four liquids meant to how ocean water behaves differently than tap water. The activity has been written through the Ocean Carbon and Biogeochemistry Program, and is called "Lab 2-- Ocean Acidification in a Cup" and is used by permission from Sarah Cooley, at the Woods Hole Oceanographic Institution.

Using the Woods Hole Activity:
The student activity begins on page 12 and runs through page 20 in the pdf (these page numbers refer to the numbers written on the bottom of each page in the pdf).
The materials list is well developed for two different sizes of groups and appears on page 12.
It is recommended that the sea-water is pre-made to minimize the classtime needed for prep.
There is a teachers guide to the student worksheet starting on page 24 and a nice set of additional resources at the end of this pdf. Pilot teachers found that, while cabbage juice will show a change in color in this activity, universal indicator or pH paper is also needed to quantitatively identify the pH of solutions.

After the lab activity...listen to this radio interview with Chris Sabine (about 6 minutes):
http://www.nanoos.org/data/products/noaa_ocean_acidification/scientists_talk.php
(use the first link, "Dr. Christopher Sabine discusses global warming")

Either to end the day 1 class period or start day two:

Facilitate a discussion around "Why do we care and what do we already know about acidification?" Students have seen how their CO2 can alter the acidity of a few solutions. Relate this process to what happens when the CO2 in the atmosphere is absorbed by the ocean.

Discuss the atmospheric CO_2 build-up from human activity...ie "An Inconvenient Truth", etc. The last thirty years have seen significant, human caused, changes in our atmosphere. These changes are now rapidly influencing the world's oceans more quickly than many expected.

Assign the first three "Day 1-2 Student Response Questions" for day two.

Day 2

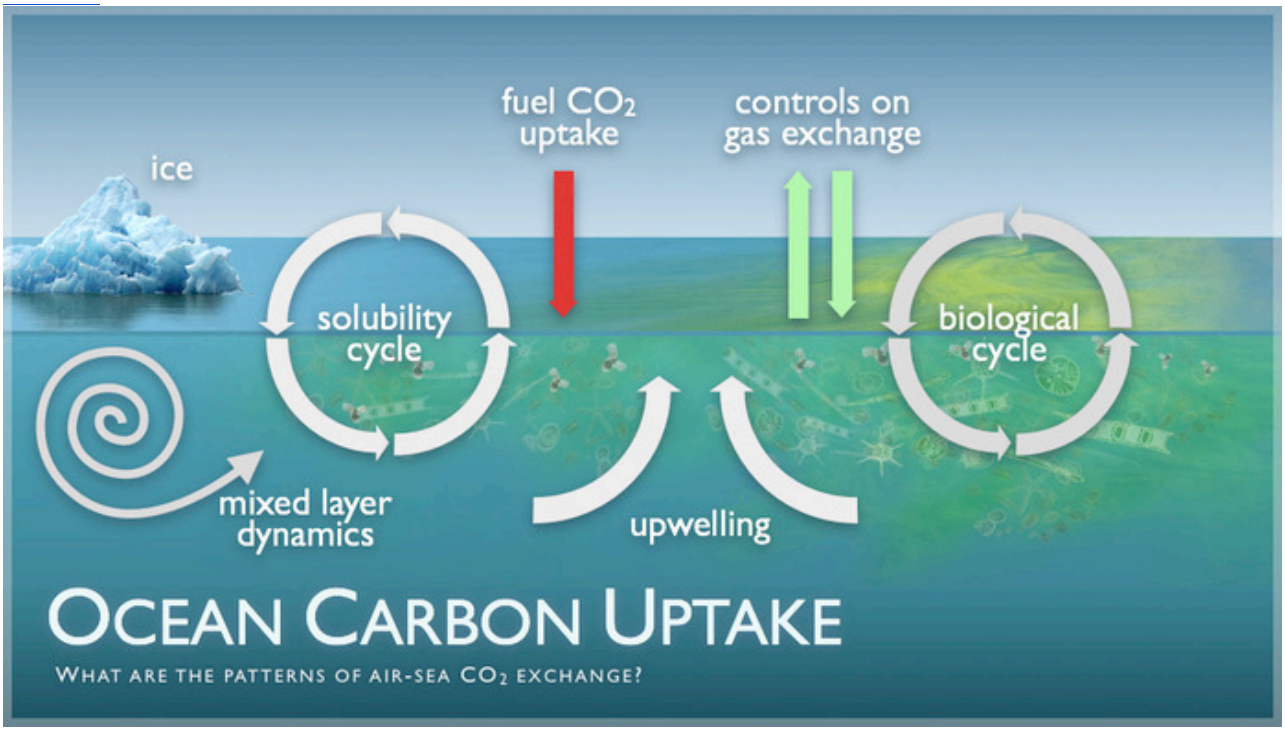
Present a discussion on the gap between human CO_2 output quantity and known atmospheric CO_2 quantity with data. Pose the question...'where is the rest of the CO_2?' Sabine's work has documented that a significant portion of the CO_2 produced by humans has been absorbed into the oceans. Without the oceans absorbing properties, our atmosphere would have about 118 billion metric tons of additional CO_2 than it currently does.

Then read this article and view the map that documents the CO_2 absorbed by the ocean.
http://www.noaanews.noaa.gov/stories2004/s2261.htm

Complete the Day1-2 questions after reading this article and reviewing the map.

Further Classwork or Homework for Day 2:
What have people done in the past?
Read this short article from National Geographic illustrates the historical presumption and mantra that "dilution is the solution to pollution":
http://ocean.nationalgeographic.com/ocean/critical-issues-marine-pollution/

Day 3



http://www.pmel.noaa.gov/co2/file/Ocean+Carbon+Uptake+Image

Hold a discussion about how perceptions have changed about the 'right thing to do' with pollution. Unfortunately, the atmospheric CO_2 humans have released is being absorbed into the oceans now and significantly affecting the ocean chemistry on a global scale.

How do we know?
Watch a video clip of "A Sea Change" on measuring oceanic CO2 levels.
"Sea of Change" excerpt (2 minutes):
http://www.youtube.com/watch?v=kJ0Z_hVYS_k
(Also avaible here: http://www.pmel.noaa.gov/co2/story/A+Sea+Change)

Look at data from a sea buoy and ship transects. It is available graphically here:
http://www.pmel.noaa.gov/co2/map/index
Click on the "load map" button on the left. Then, on the map on the right, clicking on any ship track or buoy access the water and atmospheric CO_2 data collected. Students could explore a particular voyage of a ship and identify the data collected.

This article provides a summary of data about the ocean serving as a CO_2 sink. Review the abstract of the article for the basic concepts as research by Dr. Sabine.
http://www.sciencemag.org/content/305/5682/367.full

Then watch this mini-documentary called "Acid Test" from the Natural Resources Defense Council. This provides a 22 minute overview of the concepts of acidification. The last few minutes are a 'what can be done' message about reducing carbon dioxide atmospheric output. Use the video questions provided at the end of document as students watch this documentary.

Click on the link on the top right of the page to watch the movie.
http://www.nrdc.org/oceans/acidification/default.asp

This partner website has further information on the film:
http://www.nrdc.org/oceans/acidification/aboutthefilm.asp

This website provides a nice tutorial on acidification AND summarizes some of the ocean CO_2 data that can be seen on the maps in the previous section.
http://www.nrdc.org/oceans/acidification/figures.asp

Homework for day 3:
Complete "Acid Test" questions and review additional web resources listed above.

What other factors are important?

▪Day 4
Weather has caused many places in the ocean to experience upwelling. This is a turning over of the ocean water which brings with it the carbon rich sediment from the bottom of the ocean. This increase in concentration of the dissolved carbon reduces the ocean's ability to further absorb carbon dioxide from the atmosphere. Read the abstract of this article and consider the future implications.
http://www.sciencemag.org/content/316/5832/1735.full?sid=4b47c2b0-2c94-4766-951f-f20d6b133fb2

Here is a video clip of Chris Sabine referring to a similar upwelling of the ocean on Pacific rim of the United States (about 2 minutes)
http://www.youtube.com/watch?v=818TrQmBJ2A

Facilitate a wrap up discussion about how Dr. Sabine will likely address these topics at the Nobel Conference. As an optional extension, explore the engineering proposal about adding iron to

ocean water introduced in the news article linked below. Several other relevant articles are linked below.

Additional resources to use on ocean acidification
PMEL News Page
http://www.pmel.noaa.gov/co2/news

Acidification tutorial from NRDC
http://www.nrdc.org/oceans/acidification/figures.asp

"The Oceanic Sink for Anthropogenic CO2", Chris Sabine, Science Magazine, 16 July, 2004, #1097403

http://www.sciencemag.org/content/305/5682/367.full

Ocean Acidification article:
http://www.pmel.noaa.gov/co2/story/Ocean+Acidification

An article on effects of acidification on the southern oceans
http://www.sciencemag.org/content/316/5832/1735.abstract

"Can Adding Iron to Oceans Slow Global Warming?" MN Public Radio, 7/18/12
http://minnesota.publicradio.org/features/npr.php?id=156976147

"How Climate Change is Affecting the Oyster Business" NPR News, 8/2/12
http://www.npr.org/blogs/thesalt/2012/08/01/157733954/how-climate-change-is-changing-the-oyster-business?sc=ipad&f=1001

Day 1-2: <u>Student Response Questions About Dr. Sabine's Work</u>

Name: _____ Per: ___

1) What role does the ocean play in interacting with the carbon dioxide humans have produced?

2) What impacts can carbon dioxide have on the oceans of the world?

3) What chemical reaction is taking place in the ocean due as CO_2 is added to water?

4) How do the changes in CO_2 vary around the planet? Look at the map of the earth from NOAA. What regions have absorbed the most CO_2? The least?

5) What other criteria appear to have a role in effecting how much CO_2 the ocean can absorb?

6) How have humans used the concept of dilution to effect the ocean via the Earth's atmosphere?

Questions on the Documentary "Acid Test" Name: _____ Per: ___

1. What impacts of ocean acidification are effecting the commercial fishing industry?

2. How does the increasing acidity of the ocean environment negatively impact organisms that create shells?

3. How much of atmospheric carbon dioxide has been estimated to have been absorbed by the ocean?

4. How are changes to fish ecosystems expected to affect the behaviors of humans?

5. In what timeframe might we lose significant portions of coral reefs, according to the comments of Ove Hoegh-Guldberg?

6. What percentage of ocean life is estimated to inhabit a coral reef?

7. What actions must humans take to avert the changes that are taking places in the global oceans now? How do these changes compare to those required to defend ourselves against global climate change?

8. When has this magnitude of species change occurred before in the history of the Earth due to rising ocean CO_2 levels?

9. How is the high CO_2 situation we're experiencing now different than the same problem that occurred about 100 million years ago?

10. How is time the enemy of human-kind in this situation? Over how much time have humans created this atmospheric and oceanic problem?

11. List several positive actions humans are taking to minimize the effects of this problem?

12. What is the single, bottom line change that humans must make to avert these problems to the Earth?