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Cerro Tololo Inter-American Observatory in Chile is the operated by the National Optical Astronomy Observatory. This image is composed of 316 individual 15 second exposures taken with a Canon 60D and a Sigma 10mm fisheye lens at f/2.8 and ISO6400. The star trails trace the motion of the night sky over 79 minutes. The stars move around the south celestial pole in very small circles in the upper right of the image. The celestial equator can be seen in the lower left of the image. Photo by Robert Sparks. To see more of Robert's work, go to http://www.flickr.com/photos/halfastro/

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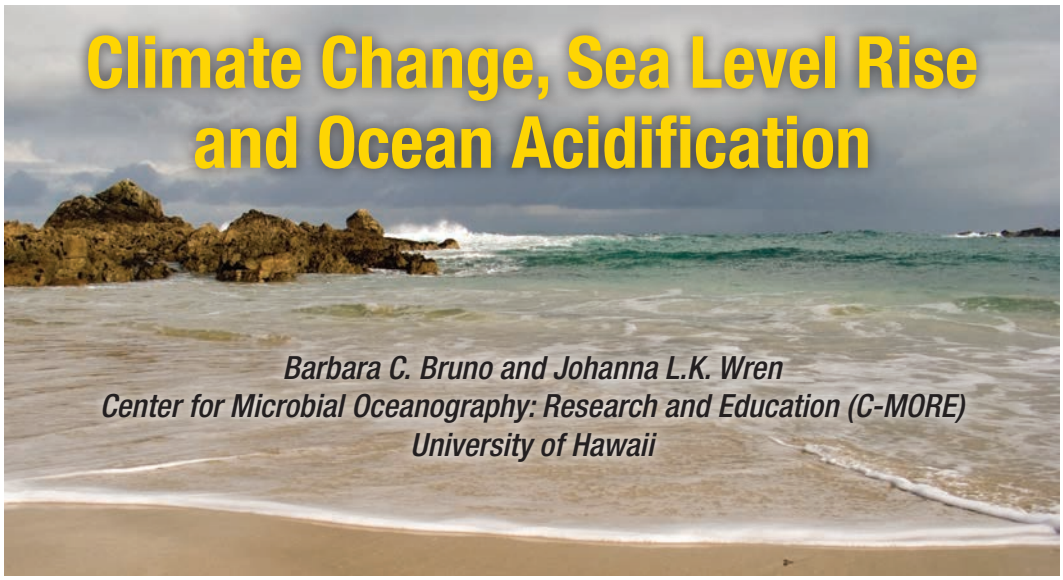

Climate Change, Sea Level Rise and Ocean Acidification

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Introduction

Climate change is happening now! Based on many different data sets, scientists have reached a strong consensus that our global climate is changing beyond what can be reasonably expected from natural cycles **(Figure 1)**. Carbon dioxide (CO_2) is rapidly increasing, largely due to anthropogenic activities such as burning fossil fuels. Average global temperatures are warming, glaciers and ice sheets are melting, and sea levels are rising. Our oceans are warming, providing fuel for more extreme weather events. Atmospheric CO_2 is dissolving into the ocean, producing carbonic acid and lowering pH levels. This "ocean acidification" poses serious threats to coral reefs and calcareous plankton, which form the base of the marine food web (e.g., Doney et al 2007). For all of these reasons, it is essential that climate change be incorporated into science curricula. Fortunately, climate change science can be used to address Next Generation Science Standards **(Box 1)**. Presented in this article are two hands-on activities, which can be tailored to different grade levels and incorporated into various subject areas.

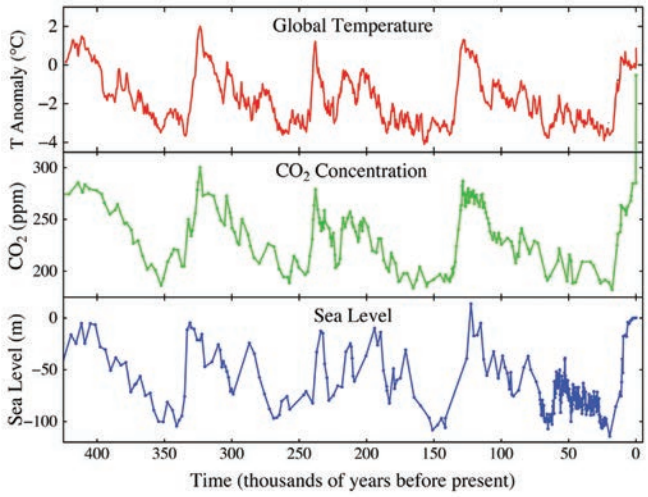

Figure 1. CO_2, Temperature and Sea Level versus time. Note (a) The amount of CO_2 in our atmosphere (~400 ppm) is higher than it's ever been in human history (data from NOAAa, NOAAb); and (b) CO_2 concentration is closely, positively correlated with global temperature and sea level. Thus the recent CO_2 spike is of great concern (modified from Hansen et al, 2008).

Earth Systems Science
- ESS2 Earth's Systems (Earth Materials and Systems; Weather and Climate)
- ESS3 Earth & Human Activity (Natural Hazards; Human Impacts; Global Climate Change)

Physical Science
- PS1 Matter and Its Interactions (Chemical Reactions)
- PS4 Waves (Electromagnetic Radiation)

Cross-Cutting Concepts:
1. Patterns
4. Systems and System Models

Science and Engineering Practices:
4. Analyzing and interpreting data
8. Obtaining, evaluating & communicating information

Box 1. Next Generation Science Standards (NGSS) addressed through these activities

Activity 1: Debunking Climate Myths (Grades 6 and older)

Climate deniers do an excellent, although highly misleading, job of suggesting that climate change is a conspiracy, "just a theory" or part of a natural cycle. In their attempt to discredit climate change science, they have popularized numerous myths. As expected, scientists are actively refuting these myths and letting the public know what the science really says. One website (www.skepticalscience.com) does a particularly excellent job of using these "climate denier" myths as a framework for presenting scientific research on climate change in clear, jargon-free language. Research is presented at two levels: basic and intermediate. The "basic" level conveys the essential results that can be readily understood by non-specialists. Importantly, the website also offers an "intermediate" level which allows more in-depth examination of the data and provides references to original sources in the peer-reviewed scientific literature.

In this activity, students access the Skeptical Science website, pick a myth, evaluate the science arguments, and share their results with their peers. Or the teacher can print out selected myths and do the activity in hard-copy. The authors believe that the arguments debunking several myths (e.g., "The CO_2 record is unreliable") can be understood by middle school students whereas others (e.g., CO_2 lags temperature) are better suited to high school or college students.

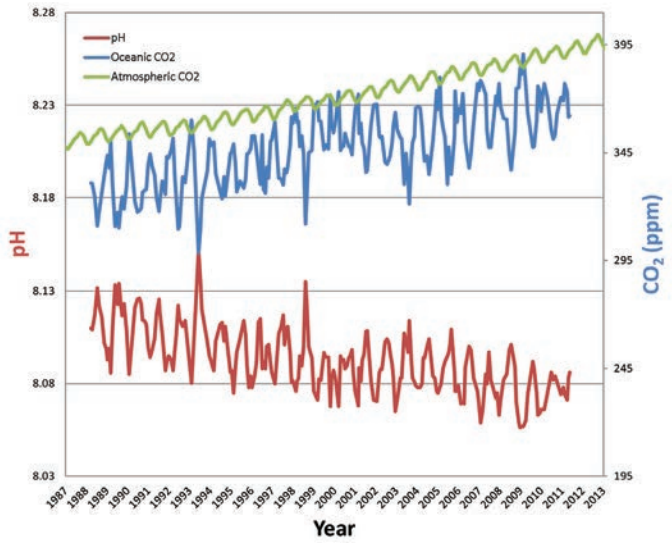

Figure 2. Hawaii Ocean Time-series (HOT) data of oceanic CO_2 (blue) and pH (red) versus time. Also shown is the "Keeling Curve" of atmospheric CO_2 (green).

Activity 2: How has the ocean chemistry changed in the past 25 years? (Grades 8 and older)

Most people think of global climate change as *the* CO_2 problem. But, when human activities put excess CO_2 in the atmosphere, this causes another, related problem: ocean acidification. Here's how it works: Some of the atmospheric CO_2 gets dissolved in the ocean, where it combines with water (H_2O) to form carbonic acid (H_2CO_3). This causes the ocean to become more acidic (lower pH).

How do we know this? Since October 1988, scientists from the Hawaii Ocean Time-series (HOT) program have been making monthly measurements of seawater. These time-series data show that the ocean CO_2 has increased and pH has decreased over the past 25 years. In this activity, students first graph HOT data either by hand or electronically (e.g., with Microsoft Excel) to reproduce **Figure 2**. They can optionally also graph the atmospheric

Box 2. Questions for Activity 2

1. Why do you think the atmospheric CO_2 levels fluctuate in such a regular (saw-toothed) pattern?
2. The atmospheric and oceanic CO_2 levels both generally increase with time. Why?
3. The oceanic CO_2 and pH data appear to be mirror images of each other. Why?
4. About how much has the atmospheric CO_2 increased from 1988 to 2011?

   Increase in ppm: _____

   Percentage Increase: _____
5. About how much has the ocean CO_2 increased from 1988 to 2011?

   Increase in ppm: _____

   Percentage Increase: _____
6. About how much has the ocean pH decreased from 1988 to 2011?

   Decrease in pH units: _____

   Increase in acidity*: _____

   *Note: pH scale is logarithmic: a decrease from 9.0 to 8.0 equals a 10x increase in acidity.
7. Hypothetically, at some point in the future, suppose the pH of the ocean decreased to 8.0. How much of an increase in acidity would that represent (from 1988)?
8. What could be done to prevent the scenario in the above question from happening?

CO_2 data. They then interpret their graph by answering a series of questions **(Box 2).** The data and graphing instructions can be downloaded from the "Other Fun and Exciting Resources" Section of the C-MORE K-12 Teacher page http://cmore.soest.hawaii.edu/education/teachers/index.htm (they are listed under the activity title: How has the ocean chemistry changed in the past 25 years?). Answer keys will be gladly provided upon request (email barb@hawaii.edu).

Conclusions

Human activities such as burning fossil fuels are radically affecting our planet. Atmospheric CO_2 levels are rapidly increasing, causing average global temperatures to warm and sea levels to rise. Beaches are disappearing, coasts are eroding and saltwater is intruding into groundwater. Extreme weather events are becoming more common and having devastating effects on human life and property. The oceans are acidifying, posing threats to marine organisms and ecosystems. These issues are critically important, and we strongly urge teachers to bring climate change science into their classroom in all subject areas and at all grade levels. Teachers are encouraged to contact the authors about any aspect of this paper, or to share comments, questions or suggestions.

Acknowledgments

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References

Doney, S. C., Mahowald, N., Lima, I., Feely, R. A., Mackenzie, F. T., Lamarque, J. F., & Rasch, P. J. (2007). Impact of anthropogenic atmospheric nitrogen and sulfur deposition on ocean acidification and the inorganic carbon system. *Proceedings of the National Academy of Sciences*, *104*(37), 14580-14585.

Hansen, J., Sato, M., Kharecha, P., Beerling, D., Berner, R., Masson-Delmotte, V., ... & Zachos, J. C. (2008). Target atmospheric CO2: Where should humanity aim?. *arXiv preprint arXiv:0804.1126*.

Next Generation Science Standards: http://www.nextgenscience.org/

NOAAa: ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt

NOAAb: ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/vostok/co2nat.txt

Skeptical Science: http://skepticalscience.com

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