

Title: What is the possible impact of Increasing Carbon Dioxide on the food web in the Arctic Ocean?

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Introduction:

Weather is the day-to-day experience of the atmosphere at a given location and climate is the long-term average of the weather. Both weather and climate can be described by temperature, precipitation, humidity, sunlight and wind. Weather is the short-term patterns and climate is the long-term patterns.

Energy that originates from the fusion of hydrogen ions in the sun drives Earth's climate system. It is the uneven heating of Earth's surfaces by the sun's rays that creates daily weather and the long-term patterns of weather are climate. The atmosphere is the most dynamic and rapidly changing portion of the climate. The atmosphere constantly interacts with the hydrosphere, lithosphere, and biosphere. In the troposphere, global winds circulate interacting with the surface of the ocean and the surface of the land. Water vapor evaporates transferring heat from the oceans and the lands to the atmosphere. Atmospheric circulation is based on the simple premise that hot air rises and cool air sinks. The direct sunlight at the equator causes air to warm and rise generating a region of low pressure. As the air moves towards the poles in the Hadley cells it cools and sinks at about 30° latitude creating a high-pressure region. As this air falls to the Earth's surface it flows either back towards the equator, or toward the pole.

Earth's surface is 70% covered by water and the unique properties of water influence Earth's climate. Water has a high specific heat capacity. Water's high heat capacity is a property caused by hydrogen bonding among water molecules. When heat is absorbed, hydrogen bonds are broken and water molecules can move freely. When the temperature of water decreases, the hydrogen bonds are formed and release a considerable amount of energy. Water has the highest specific heat capacity of any liquid. Specific heat is defined as the amount of heat one gram of a substance must absorb or lose to change its temperature by one degree Celsius. For water, this amount is one calorie, or 4.184 Joules. As a result, it takes water a long time to heat and a long time to cool. In fact, the specific heat capacity of water is about five times more than that of sand. This explains why the land cools faster than the sea (Boundless, 2015). This uneven heating and cooling of the water, land and atmosphere generate the winds along with the Coriolis effect from the rotating Earth (Fletcher, C., 2013).

At the equator and mid-latitudes the ocean is a dark surface absorbing the Sun energy warming the water. The increased energy stored in the water provides the energy necessary to increase the evaporation rate thereby increasing the water vapor level. This increased water vapor at the equator this generates the frequent tropical rains. Cool air has a lower water vapor level and at the poles the air is quite dry resulting in a very cold desert region. The changing water vapor level creates local weather events that influence climate (Mathez, E. 2009).

For much of the year the Arctic region is covered with ice. Ice has a high albedo reflecting most of the light striking its' surface. Albedo is a non-dimensional measure of the percentage of the light striking a surface is reflected. New snow has a high albedo at 0.9 meaning that 90% of the incoming light energy is reflected back from the Earth's surface to outer space. Only 10% of the incoming energy is absorbed. The albedo of the ocean's surface can range from 0.15 to 0.35 depending on the angle of incidence and if the surface is smooth or rough. The average albedo for the Earth is 0.31 (Boundless, 2015).

The climate system is driven by strong positive and negative feedback loops between the processes that influence the atmosphere, ocean and terrestrial surfaces. Nowhere on the Earth are the feedback loops having a stronger affect than at the poles. The loss of sea ice is a positive feedback loop whereby the melting of the snow exposes more ocean water and dark soil both having a low albedo to absorb the sun's light energy further heating the atmosphere causing more melting of snow and ice. The very long summer sun further magnifies the warming effect of the sun's light (Fletcher, C., 2013; Mathez, E., 2009). The increasing warmth of the Arctic appears to be starting to shift the winds in the upper atmosphere resulting in extremely cold temperatures in the mid latitudes during the winter months (Cohen, J et.al 2013).

Learners: The target audience is 8th to 10th grade students enrolled in a physical science course. The lessons are designed for whole class instruction, with modifications for small group and hands-on learning included.

Standards:

PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Topic: Radiant Energy from the Sun heats the Earth's surface and atmosphere unevenly, contributing to changes in weather and climate.

Curriculum Links:

Prior instruction assumed in:

- What are the layers of the atmosphere?
- How is thermal energy transferred through the atmosphere?
- How do clouds form?
- What processes are involved in the water cycle?
- Why do difference in air pressure produce global wind?
- How do air masses interact along warm and cold fronts?
- What are the characteristics of severe storm systems?
- What factors determine climate?
- What is a climate system?

Prior vocabulary

1. Nucleus
2. Troposphere
3. Temperature inversion
4. Greenhouse effect
5. Gradient
6. Jet stream
7. Coriolis Effect
8. Air mass
9. Weather front
10. Maritime climate
11. Continental climate
12. Sea breeze
13. Hydrosphere
14. Lithosphere
15. Biosphere
16. Atmosphere

New vocabulary

1. Albedo
2. Cryosphere
3. Forcings
4. Global Warming
5. El Nino
6. La Nina

Objectives:

Students will:

- develop an understanding of factors influencing the climate in the Arctic.
- develop an understanding of factors that impact data interpretation.
- Investigate how light and dark surfaces reflect or absorb light energy.
- analyze data from a model of the how albedo will influence heat transfer.
- observe the impact changing temperatures may have on living organisms.

Scope and Sequence:

Students will learn about factors influencing the Arctic climate in a didactic manner while concurrently collecting data to analyze on a model to demonstrate the impact albedo has on the ambient temperature.

Day 1

Introduce unit.

Students will graph (by hand) the amount of Arctic Sea Ice for March (maximum) and September (minimum) for the time interval 1979 to 2014.

Day 2

Discuss graphs of Arctic Sea Ice 1979-2014.

Guiding Questions

- What patterns are apparent?
- How does the September 1979 value compare to September 2014?
- How does March 1979 value compare to the March 2014?
- What factors might influence the amount of sea ice?

Presentation: **Sea Ice in the Arctic**

Day 3

Discuss data from Days 1 and Day 2 Lab.

Guiding Questions

- How did the temperature measurements compare between a bottle placed on a white surface and a black surface?
- How did the temperatures compare between the bottle with an elevated CO₂ and a room air level of CO₂?
- What are greenhouse gases?

- What might happen if the CO₂ level doubled?

Presentation: **Greenhouse Gases and Climate Change**

Day 4

Discuss data from Day 3.

Guiding Questions

- How did the CO₂ levels from Day 2 compare to Day 3?
- How did the temperatures from Day 2 compare to Day 3?
- How might an increasing temperature influence living organisms?
- What is it like to run a cross country race in August? In October?
- What is like to have football practice in August? In October?

Presentation: Arctic Food Web

Day 5

Discuss the behavior of the retdailed fairy shrimp in the bottle with the elevated CO₂.

Guiding Questions

- What might happen if the temperature increases in the Arctic Ocean?
- How might that affect the Arctic Ocean food web?

Assessment

Write an extended response to explain, "How does a rising CO₂ affect the Arctic Ocean?"

See Grading Rubric

Lab: How does Albedo Influence Ambient Temperature?

Objective: Develop an understanding of factors that influence ambient temperature and the impact a change in ambient temperature might have on living organisms based on experimental data.

Materials:

2- 2 liter clear soda bottles
2-stoppers with a single hole
2 instant read thermometers
white surface to place under a jug
black surface to place under a jug
NaHCO₃ (baking soda)
C₂H₄O₂ (vinegar)
Light source
Redtail Fairy Shrimp (www.arizonafairyshrimp.com) Note -Redtail fairy shrimp are a freshwater aquatic crustaceans in the branchiopod order **Anostraca** that is analogous to the crustaceans in the Arctic Ocean just simpler to work with because a salt water setup is not required.
Triops (for extension activity) Note – Triops is a freshwater carnivore that is easy to work with in a classroom
Water
Duct tape

Setup

Split a clear 2 liter bottle near the top to allow easy access to the bottle. (both bottles)
Tape a thermometer against the side of the bottle. Position the thermometer on the side to allow the thermometer to be read once the bottle is closed.
Fill both bottles with 500mL of water.
Place one bottle on a reflective surface (white paper)
Place the other bottle on a dark surface (black paper)
On days 2-5 on a 50% white/black paper (to eliminate albedo as a variable)

Day 1

Lab: Compare the impact albedo has on temperature in a closed system. Record temperature either every 10 minutes for 60 minutes.

Day 2

On day 2 place a small beaker in each 2 liter bottle in the water. In this small beaker add 50mL acetic acid (vinegar) and add 10cm³ baking soda into the beaker. Quickly close the bottle to capture the CO₂ gas being produced. A long funnel can be used to place the baking soda in the vinegar.

On day 2 place 50mL of water in the beaker of the second as a control.

Compare the impact an increase in carbon dioxide has on temperature. (Note – Each is placed on a 50% white, 50% black surface). Record temperature either every 10 minutes for 60 minutes.

Day 3

On day 3 place a small beaker in each 2 liter bottle in the water. In this small beaker add 50mL acetic acid (vinegar) and add 20cm³ baking soda into the beaker. Quickly close the bottle to capture the CO₂ gas being produced. A long funnel can be used to place the baking soda in the vinegar.

On day 3 place 50mL of water in the beaker of the second as a control.

Compare the impact an increase in carbon dioxide from day 2 has on temperature. (Note – Each is placed on a 50% white, 50% black surface). Record temperature either every 10 minutes for 60 minutes.

Day 4

Maintain carbon dioxide concentration from Day 3 and introduce redbtail fairy shrimp to each “ecosystem”. (Note – Each is placed on a 50% white, 50% black surface). Record temperature either every 10 minutes for 60 minutes.

Place the redbtailed fairy shrimp in both bottles.

Day 5

Continue Day 4 setup and record behavior of redbtail fairy shrimp

Optional Extension: The next week an extension can be done by introducing triops that will use the redbtail fairy shrimp as a food source. Observe what occurs in both the control (regular air) and experimental setup (increased CO₂).

Data collection:

A series of temperature measurements will be collected, graphed and analyzed.

Assessment:

Written extended response based on the data.

Resources:

Arctic Ocean Climate Change Impacts <https://www.youtube.com/watch?v=pHEWK9j1EhA>
Climate Change: Arctic Warming pushes winter weather further south <https://www.youtube.com/watch?v=HBILP6KTrsE>
The Ocean: a driving force for weather and climate <https://www.youtube.com/watch?v=6vgvTeuoDWY>
General Circulation <http://kingfish.coastal.edu/marine/Animations/Hadley/hadley.html>

References:

Boundless (2015). "Water's High Heat Capacity." Boundless Biology. Boundless, 06 Jan. 2015. Retrieved 14 Mar. 2015 from <https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-chemical-foundation-of-life-2/water-51/water-s-high-heat-capacity-283-11416/>

Cohen, J., J. Jones, J.C. Furtado, and E. Tziperman. 2013. Warm Arctic, cold continents: A common pattern related to Arctic sea ice melt, snow advance, and extreme winter weather. *Oceanography* 26(4):150–160, <http://dx.doi.org/10.5670/oceanog.2013.70>.

Fletcher, C. (2013). *Climate Change: What the Science Tells Us*. University of Hawaii, John Wiley & Sons, Inc.

Mathez, E. (2009). *Climate Change The Science of Global Warming and Our Energy Future*. Columbia University Press. New York City.

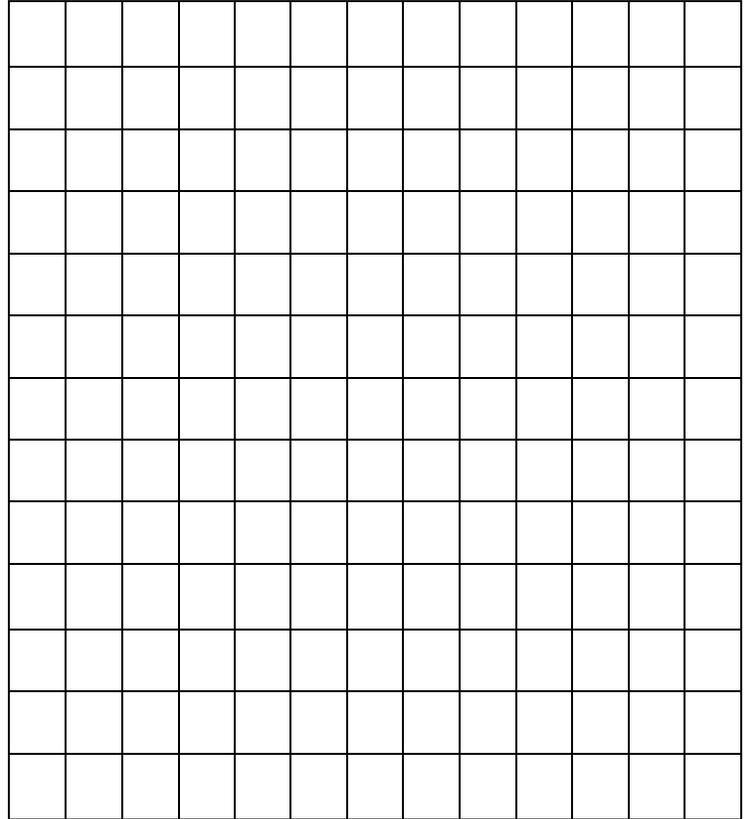
NASA Cryosphere Research Portal <http://neptune.gsfc.nasa.gov/csb/index.php?section=234>, data retrieved March 14, 2015.

Data:

Record data in the table below.

Time	White Surface (Light Albedo)	Dark Surface (Low Albedo)
Start (time zero)		
5 min		
10 min		
15 min		
20 min		
25 min		
30 min		
35 min		
40 min		
45 min		
50 min		
55 min		
60 min		

Graph the data as a line graph. Use a different color for each thermometer. Include a key.



Key

Subtract the starting temperature from the final temperature for each thermometer.

White:

$$\frac{\text{_____}}{\text{(final temperature)}} - \frac{\text{_____}}{\text{(starting temperature)}} = \frac{\text{_____}}{\text{(increase temperature)}}$$

Black:

$$\frac{\text{_____}}{\text{(final temperature)}} - \frac{\text{_____}}{\text{(starting temperature)}} = \frac{\text{_____}}{\text{(increase temperature)}}$$

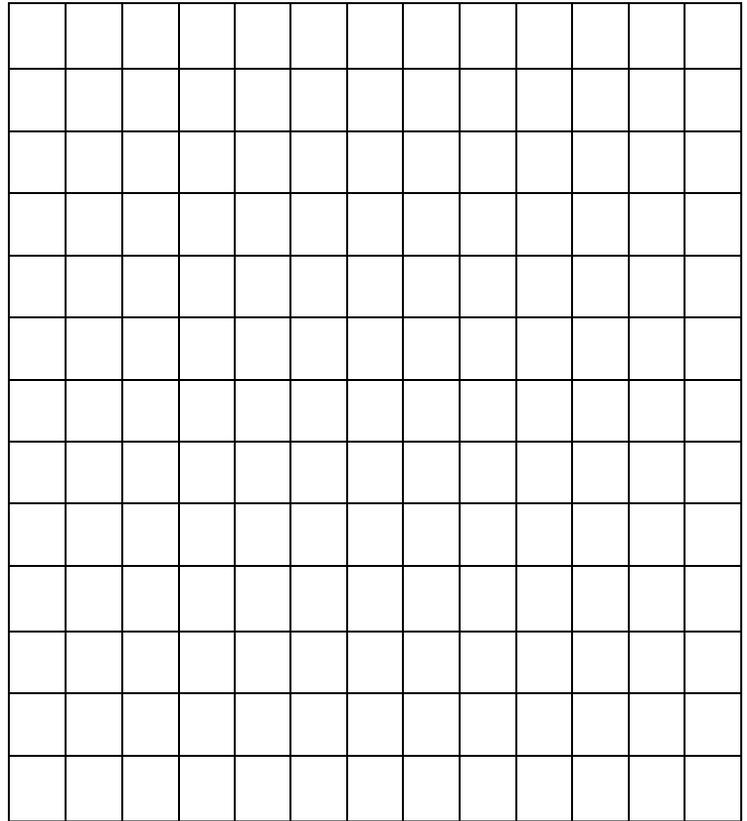
Day 2

Data:

Record data in the table below.

Time	Ambient CO ₂	Increased CO ₂
Start (time zero)		
5 min		
10 min		
15 min		
20 min		
25 min		
30 min		
35 min		
40 min		
45 min		
50 min		
55 min		
60 min		

Graph the data as a line graph. Use a different color for each thermometer. Include a key.



Key

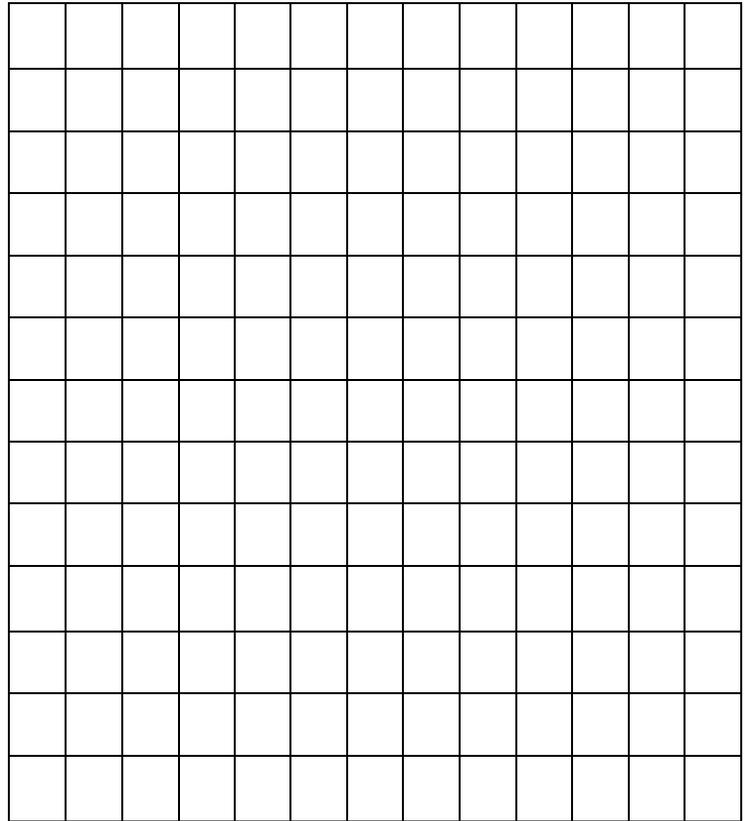
Day 3

Data:

Record data in the table below.

Time	Ambient CO ₂	Increased CO ₂
Start (time zero)		
5 min		
10 min		
15 min		
20 min		
25 min		
30 min		
35 min		
40 min		
45 min		
50 min		
55 min		
60 min		

Graph the data as a line graph. Use a different color for each thermometer. Include a key.



Key

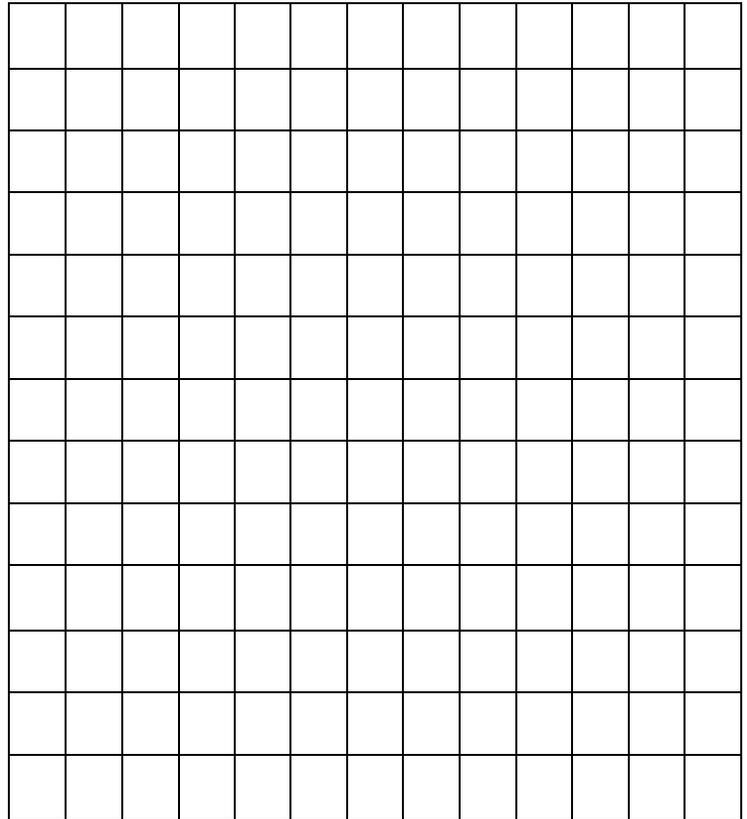
Day 4

Data:

Record data in the table below.

Time	Ambient CO ₂	Increased CO ₂
Start (time zero)		
5 min		
10 min		
15 min		
20 min		
25 min		
30 min		
35 min		
40 min		
45 min		
50 min		
55 min		
60 min		

Graph the data as a line graph. Use a different color for each thermometer. Include a key.



Key

Describe the behavior of the redbtail fairy shrimp.

Assessment Grading Rubric

Definitions the vocabulary used to define the terms needs to be aligned with the students' reading ability (ei. If the student has a 2nd grade reading level a definition written at a 2nd grade level will receive full credit likewise if a student has a 9th grade reading level the definition needs to be written at a 9th grade level.

Extended Response - Explain the relationship between albedo and temperature.

- 5 – States that a white surface reflects 90% of the incoming light energy and a dark surface absorbs 85% of incoming energy. Makes an analogy to the Arctic environment. All grammar conventions, unless excluded by an IEP.
- 4 - States that a white surface reflects 90% of the incoming light energy and a dark surface absorbs 85% of incoming energy. Does not make an analogy to the Arctic environment or the analogy is inaccurate. All grammar conventions, unless excluded by an IEP.
- 3 - States that a white surface reflects 90% of the incoming light energy OR a dark surface absorbs 85% of incoming energy. Does not make an analogy to the Arctic environment or the analogy is inaccurate. All grammar conventions, unless excluded by an IEP.
- 2 – Is able to state that there is a difference in temperature between a surface with a high albedo (white) and a dark surface. All grammar conventions are followed unless excluded by an IEP
- 1 – Response indicates that there is limited understanding of albedo, no accurate example is provided. All grammar conventions are followed unless excluded by an IEP.

Extended Response – Explain the changes in the fairy redbait shrimp behavior with respect to temperature changes. What are the possible implications for the Arctic Ocean foodweb?

- 5- Describes the change in redtailed fairy shrimp behavior initially and then as it changed as the temperature rose. All grammar conventions, unless excluded by an IEP.
- 4- Describes the change in redtailed fairy shrimp behavior as it changed as the temperature rose. All grammar conventions, unless excluded by an IEP.
- 3- Limited description of redtailed fairy shrimp behavior with no stated relation to the changing temperature. All grammar conventions, unless excluded by an IEP.
- 2- Minimal description of redtailed fairy shrimp behavior with no stated relation to the changing temperature. All grammar conventions, unless excluded by an IEP.
- 1- Response indicates that there is limited understanding of redtailed fairy shrimp behavior with a changing temperature.

Conclusions: I will teach this unit the beginning of April. There is state mandated testing from February 17, 2015 through March 26, 2015. The extended testing to meet federal and state mandates precludes teaching a complex lesson. I have begun the process of revising the 9th grade integrated science curriculum so that the focus is “Physical Science with a focus on the climate” from the current “sound bite” curriculum that is a basic introduction to concepts that will be expanded upon in chemistry and physics.

All students are required to take the physical science course. Advanced students take the course during their 8th grade year at the middle school and the remaining students take the course during their freshman year of high school. To date, there has been no unifying concept for the course so the curriculum is quickly marginalized and forgotten. Deemed insignificant by the students, parents and administrators introducing a focus on understanding climate has the potential to enhance the relevance of the course, and possibly generate some political heat toward me. Like evolution, climate change is topic that one approaches cautiously since many individuals have the impression that evolution and climate change are topics one can “choose” to believe in.

The unit designed was created to “put eyes” on climate change. Heat transfer is a very abstract concept particularly for 9th grade student who have not yet developed formal thought and complex reasoning. One way to make the content memorable for the students is to introduce a living organism with eyes. Personal experience has led me to the conclusion that an organism with eyes has the potential to impact students and their beliefs. I have done labs with daphnias and slugs. The labs with slugs have the potential to change student behavior more effectively than labs that use only daphnias. The daphnias are living, moving organisms, however the slugs even though they are deemed to be garden pests have the potential to engage students because they have eyes (on the end of stalks) and they respond to stimuli. It is my personal opinion that the introduction of redtailed fairy shrimp to the model of the Arctic Ocean will result in a memory that is held longer than the same lab activity done without the shrimp. Student feedback over the next several years will validate or invalidate the assumption.

The challenges I face are: large class sizes in small classroom, a lecture room rather than a lab room and disengaged students. This past winter local temperature records were shattered with low temps reaching -29^o F for several days. Hundreds of temperature records in the state of Ohio were reset to a new lower level when the polar vortex sank low enough to affect Ohio. This new, exceptionally low temperature provided a teachable moment this past year, and I anticipate that the altered weather pattern will continue in the years to come.

I have begun the process of rewriting the curriculum to include a climate focus from the beginning of the school year. I will be creating word problems based on calculating the velocity and acceleration of glaciers rather than toy car. The density problems will be focused on calculating the change in density in the ocean where fresh water enters the ocean along with problems were the students calculate and compare the density of the continental crust with the oceanic crust. For me, the introduction of climate change has the potential to change a course from a meaningless intro course to a meaningful course that has the potential to impact future voter.

All assessments are done as extended response to meet the Common Core Standard of writing to demonstrate learning.

All youtube videos have full links and names provided so that they are available for use in the classroom.

