POLAR TREC Learning Resources

Details

- Arctic
- Less than a week
- Download, Share, Remix
- Middle School and Up

Modeling the Influence of Sunlight on Release of Carbon Dioxide from Thawing Permafrost

Description:

Students will use a model to explore the relationships between sunlight and release of carbon dioxide (CO2) from thawing Arctic watersheds.

After studying the carbon cycle, students are asked to reflect on how natural phenomena – thawing of permafrost, interactions of soil microbes on dissolved carbon, and amount of sunlight – interconnect and influence the release of CO2 into the atmosphere and Arctic watershed leading to ocean waters. Students use a computer model to observe and describe these relationships.

OVERVIEW

Permafrost, soil that is continuously frozen for two or more years, covers 24% of the land in the Northern Hemisphere Climate change is happening most quickly at the polar regions. The amount of carbon stored in permafrost represents more carbon that currently exists in all living things and twice as much carbon as exists in the atmosphere.

Increase in temperature is causing permafrost to thaw, releasing stored carbon into arctic watersheds. Sunlight interacts with bacteria in watersheds to influence the release of carbon. In this lesson, students will use a computer model to explore the relationships between sunlight and release of carbon dioxide (CO2) from thawing Arctic watersheds.

References:

Permafrost; http://www.wunderground.com/climate/permafrost.asp; December, 2015.
Arctic Permafrost – Climate Change; NASA; https://www.

Materials

- Students should have access to online tools to complete research questions. Students may want access to art materials if choosing to create a physical model of carbon cycle. Students need a computer to access NetLogo. The program will not run on a phone or tablet.
- Download the free program NetLogo (https://ccl.northwestern.edu/netlogo/) and become familiar with the computer simulation programs. Students may want to explore the climate change lessons in the program library. NOTE: Students may download the program and save to a thumbdrive to transport between home and school.
- Copies of original source article for background reading.

youtube.com/watch?v=1QDL8tupzaw

OBJECTIVES

- Students will demonstrate understanding of the connections among increasing global temperatures, thawing of permafrost, the carbon cycle, and the influence of sunlight and bacteria on production of carbon dioxide (CO2)
- Students will accurately demonstrate the relationship between amount of sunlight and release of CO2.

LESSON PREPARATION

PRIOR KNOWLEDGE: For most benefit from this lesson, students should have background knowledge in the following concepts:

- The carbon cycle includes atmospheric, terrestrial, and aqueous components.
- Permafrost is soil that has been continuously frozen for at least two years. Arctic permafrost may be thousands of years old.
- Permafrost stores carbon, deposited as part of the carbon cycle.
- Soil contains microbes that may augment geochemical cycles.
- Polar regions are warming more markedly than other areas of Earth. A greater temperature anomaly is seen in the polar regions as when compared to most other geographic regions.

Review graph of authentic data (by Cory et al. See Journal abstract reference)

PROCEDURES

Day One: Exploration of Phenomena

1. Ask students to read PolarTREC journal entry to prepare for class.
   - See:Studying Carbon Release in the Arctic ; Brinker; PolarTREC Higher level students may also read original research work by Rose Cory, PhD: See journal abstract: http://www.pnas.org/content/110/9/3429.abstract
2. Students work in pair to complete research and gain background knowledge in order to be able to discuss the topics below. Students should use both written responses and a descriptive image (graph, map) and provide a reference for the sources.

   - Use a map to locate the Arctic Circle and land north of the Arctic Circle
   - Define permafrost
   - Explain the sources of stored carbon in the permafrost
   - Describe the carbon cycle

- Describe what factors influence the carbon cycle and are studied by scientist

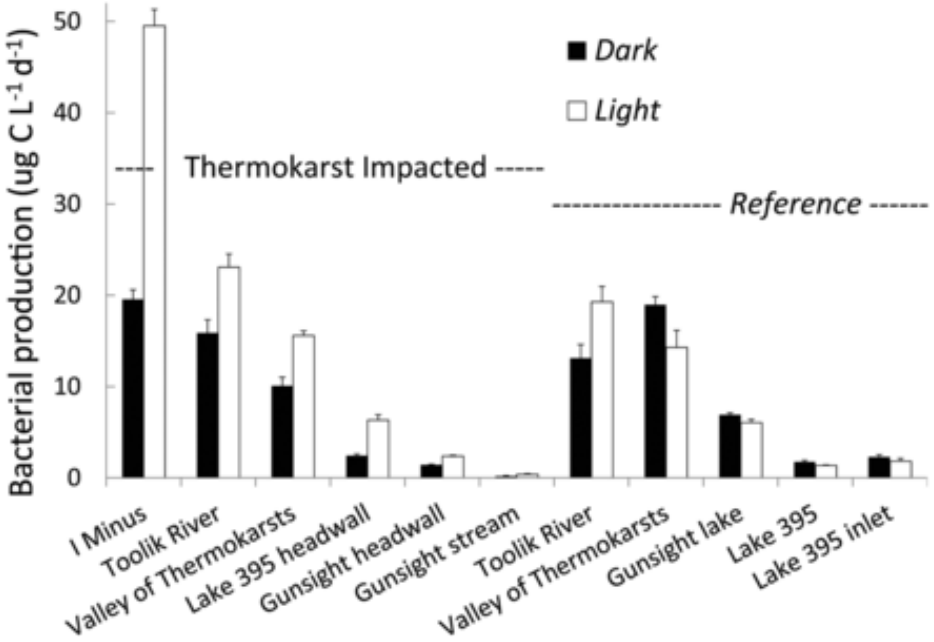
QUESTIONS

Permafrost contains stores of carbon. What are the sources of this carbon? What is the amount of carbon stored? How does the amount of stored carbon compare with current levels of carbon in the atmosphere and in living things?

What is a temperature "anomaly"? What is the temperature anomaly seen in polar regions as compared to other regions? How many hours of sunlight does the Arctic receive each summer day?

Select students to share results from research. Graphs, maps, and reports may be shared with class.

Review and discuss graph of authentic data:
http://www.pnas.org/content/110/9/3429/F1.expansion.html



Bacterial Production in an Arctic Watershed in Light and Dark Conditions
Fig. 1.

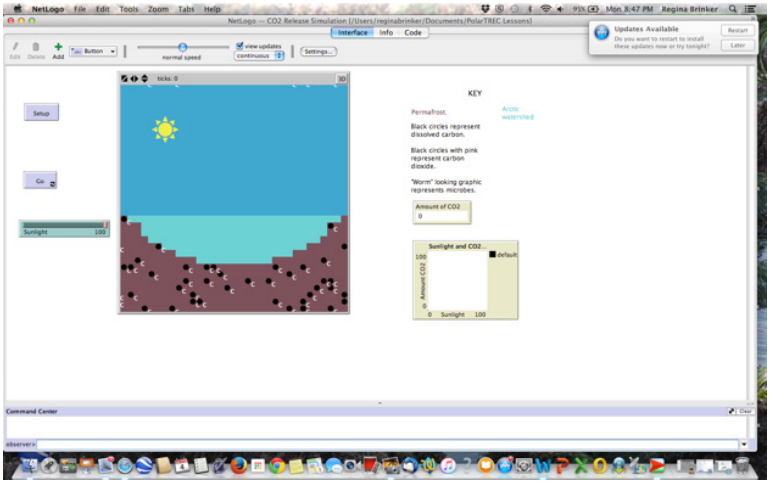
In thermokarst impacted sites (Left), water exposed to natural sunlight stimulated bacterial activity by 46.8% (white versus black bars), whereas in corresponding reference sites the mean response was to decrease bacterial activity by -13.7% (single-factor ANOVA, P = 0.0008, n = 11, SE of three replicate samples for each bar for each site are shown).

Is more bacteria produced under light (high sunshine) or dark conditions? Are these results consistent for all test areas?

Note: A thermokarst is a section of permafrost that has recently thawed, exposing the soils to sunlight.

Day Two: **Review Net Logo Program**
(https://ccl.northwestern.edu/netlogo/)

- Go to the NetLogo homepage. Download the NetLogo program. Notice that the screen is black until a simulation is selected.
- On the NetLogo homepage, select "Modeling Commons" in the menu on the left side of the page. Once on the Modeling Commons page, search for "CO2 Release from Thawing Permafrost. Download program.



- Open program and review with students.

- Click the "setup" button. Notice that graphics appear.
- Click "go" to run the program. Notice how the images change. The crescent shaped images represent bacteria.
- Notice that a graph is created as the simulation runs.
- Selecting "Go" a second time stops the simulation.
- Selecting "Setup" restarts the program.
- Select "Info" tab at the top of the screen to read information about what is shown on the simulation.

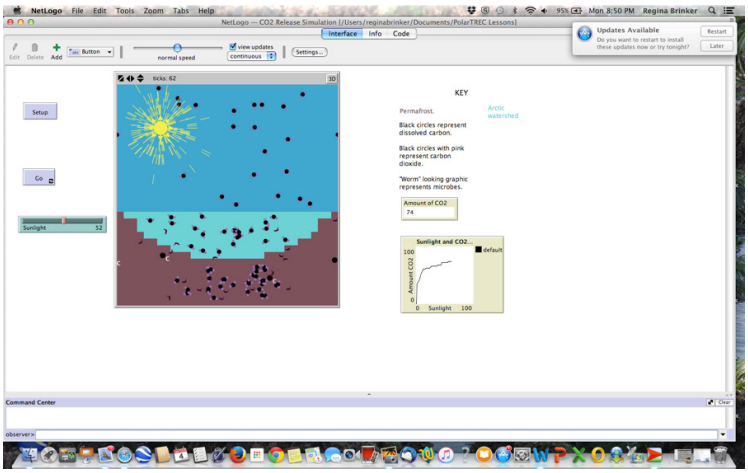
Data Interpretation

Students create a data table to track amount of sunshine and amount of CO2.

- Open Net Logo Program.

- Click "Setup" button.
- Adjust amount of sunshine by using the slider button. Begin with slider to "zero sunshine".
- Click "Go" button. Observe simulation and graph. Once the graph is complete, click "Go" button again to stop program.
- Collect data on amount of CO2 produced. Enter values in data table.

Using the slider button, change the simulation to be carried out among different amounts of sunshine. Run the simulation for each setting. Record data on data table.



Students should use their data and create a graph describing the relationship between sunshine and CO2 production. Students should provide a written description of the relationship between sunshine and bacteria production, and cite data from the simulation to support their conclusion.

EXTENSIONS

Students may research specific weather and climate data to better understand the extreme environment of the Arctic.

What is the typical weather pattern for areas above the Arctic Circle? What are the average temperatures by month? How many days of sun versus clouds are seen? How much solar energy reaches the Arctic in the summer?

Students may view weather data collected at the Toolik Field Station, home base of the PolarTREC research team and other scientists. Students or the teacher will need to provide an address to have one day's access to stored weather data. Students can view a graph showing solar energy in terms of kw/m2
Go to: Toolik Field Station (http://toolik.alaska.edu/)

Students may also use precipitation data found on the Weather Underground web site. Students may enter an Arctic location (Prudhoe Bay, for example), and search "Weather

History for Prudhoe Bay" and collect data on number of days with precipitation over a set time period. See Prudhoe Bay Weather History. Suggestions for other weather observation sites are given on the web site. (http://www.wunderground.com/personal-weather-station/dashboard?ID=KAKPRUDH2#history/s20150804/e20150904/mmonthhttp://www.wunderground.com/personal-weather-station/dashboard?ID=KAKPRUDH2)

Select students to share results from research. Graphs, maps, and reports may be shared with class.

Students may view tutorials on the NetLogo website and learn the coding procedures to create their own simulation or modify a sample simulation.

RESOURCES

Students may use this information to gain background knowledge and review primary source documents.

- http://www.earth.lsa.umich.edu/rmcory/research_arctic_photochemistry.html (abstract)
- Basic description of research by Dr. Cory: Sunlight exposure stimulates conversion of permafrost carbon to CO2; http://rmcory.web.unc.edu/sunlight-exposure-stimulates-conversion-of-permafrost-carbon-to-co2/
- *Surface exposure to sunlight stimulates CO2 release from permafrost soil carbon in the Arctic* http://www.pnas.org/content/110/9/3429.abstract
- Information on global temperature changes: *Modeling Global Climate* https://www-pls.llnl.gov/?url=science_and_technology-earth_sciences-climate_modeling
- NetLog homepage: https://ccl.northwestern.edu/netlogo/
- *Radiocarbon age-offsets in an arctic lake reveal the long-term response of permafrost carbon to climate change* http://onlinelibrary.wiley.com/doi/10.1002/2014JG002688/abstract

VOCABULARY

- Arctic Circle: An imaginary line around the Earth at 66.56° N. Locations north of this mark experience at least one 24-hour period of continuous sunlight each year.
- Permafrost: Soil that is continuously frozen for two or more years.
- Thermokarst: A section of soil that cracks or falls away when previously frozen soil thaws. The open section exposes more permafrost to sunlight and higher temperatures.
- Microbial respiration: Release of CO2 from soil surface. Soil respiration is an indicator of decomposition. Soil respiration is needed for healthy soil and to allow plants to grow.
- Thaw: Softening of permafrost in response in increased temperatures. Note that

permafrost does not melt as in ice melting into water. Permafrost thaws, like frozen meat thawing before cooking.

ASSESSMENT

Teachers may use this activity to check for understanding about the relationships between increased temperatures and Arctic permafrost, steps of the carbon cycle, effect of bacteria on formation of CO2 during the carbon cycle, effect of sunlight on activity of bacteria and production of CO2.

Teachers may have students complete the data table, graph, and written interpretation of results for credit.

AUTHOR/CREDITS

PolarTREC teacher, Regina Brinker created this lesson based on her expedition with Arctic Sunlight and Microbial Interactions 2014. Regina Brinker, Livermore Valley Joint Unified School District, Livermore, California. Regina Brinker <r.brinker@sbcglobal.net>

STANDARDS

Next Generation Science Standards (NGSS)
for Grades 6 - 8
"In grades 6-8, students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study.." (nextgenerationscience.org)

ESS2.A: Earth's Materials and Systems.
-All Earth's processes are the result of energy flowing and matter cycling within and among the planet's systems.

NGSS Crosscutting Concepts
Systems and Systems Models

-Cause and effect relationships may be used to predict phenomena in natural or designed systems (MS_ESS3-1)
-Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-4)

Science and Engineering Practices
-Develop and use a model to describe phenomena.
-Construct a scientific explanation based on valid and reliable evidence obtained from sources

and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.