Modeling Blue Carbon in Salt Marshes

Teaching Notes | Lesson and Answer Key

Notes for Teachers

The lesson "Modeling Blue Carbon in Salt Marshes" includes two exercises for students. Exercise 1 is an online activity; Exercise 2 is a student field study activity. Background about the Bringing Wetlands to Market (BWM) project is included in the student pages.

Before teaching the lesson, please read the Student Pages. These contain more detailed information about the lesson topic that is not included in these notes for teachers.

Some activities for introducing coastal wetlands and their ecological services can be found in the first few pages of this lesson http://waquoitbayreserve.org/wp-content/uploads/BWTM2_1_3_-Wetland-Ecological-Services.pdf

This lesson, "Modeling Blue Carbon in Salt Marshes" may be used in several ways, depending on the amount of time you have and your educational objectives for your students.

a. Focus on interpretation: Students read and discuss the background, review the model, and interpret the results using the data provided in the lesson by responding to the guiding questions.

b. Use the model and interpret results: Students read and discuss the background, then use the provided data to run the model, and interpret the results using the guiding questions.

c. Collect the data, use the model, and interpret the results: Students collect their own data following the guidance for a field study, input their own data into the model, and interpret the results using the guiding questions.

General Notes for a Blue Carbon Field Study

Student field studies provide an opportunity for students to develop science process skills and practice solving technology and engineering problems. Students are more engaged when they analyze data they have collected themselves, and they have a better sense of the factors at work in the systems they are studying. Field studies also present a variety of opportunities for students to become stewards of wetland ecosystems in their own community.

Studying a Local Wetland

The Bringing Wetlands to Market (BWM) project can introduce students to wetlands and includes guidance for carrying out a field study of a wetland in your local area. By conducting a field study, students can learn more about their selected wetland areas and educate others about wetlands and their importance. Students can initiate a stewardship project and communicate about this to the school or the broader community.

The most important considerations when choosing a study site are:

Make sure the site does not pose significant **safety risks** for students, and that it is publicly accessible, or that you can secure permission to visit the site and take soil samples.

Plan activities in a way that **does not harm or damage the site**. When students are discussing a site to select, be sure they propose practices for low-impact sampling to protect their study site from damage.

- When a study site has been selected, it is important to **go to the site** yourself or have a colleague visit the site before bringing students there, to confirm that the site is safe and accessible, and that the students' visit will not cause damage. Be sure to check the tides for the day you are going and take that into account, especially if the timing of the tides is different the day you check out the site.
- It is best if the students can visit their selected wetland site in person. However, if that's not possible, you or a colleague can bring photos and samples back to class for students to observe and process, and the wetland can be studied by the students virtually using photos, maps, and online resources such as google maps.
- Plan **logistics**, including obtaining permission to leave school grounds, transportation to the study site (it is ideal if students can walk to the site), assembling all safety and first aid equipment, and addressing practical considerations such as restrooms, snacks, and drinks for students.
- The data recording sheet for the Coastal Wetland Greenhouse Gas Model 2.0 (CWGM 2.0) is included in the student instructions. The model predicts Net Atmospheric Carbon Removal (NACR) by the coastal salt marshes based on input data on light (PAR), soil temperature, and porewater salinity. NACR refers to the potential (i.e., maximum) wetland carbon storage. An additional data recording sheet is meant to guide general observations about the study site, which may help in interpreting the model results. This general data sheet includes a variety of parameters, but the field studies and research questions your class develops may only require a few of the parameters. **You can modify and adapt the field study data sheet** to use with your classes.

More Information

For more background on the research and model, see the Bringing Wetlands to Market project website http://www.waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/

If you would like to access the computer model use this link http://waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/expanding-blue-carbon-phase-2/model/

For more background and lessons, visit the Bringing Wetlands to Market page for teachers http://waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/phase1/teachers/

If you have questions about the model and excel spreadsheet, you may contact Dr. Omar I. Abdul-Aziz, a member of the Bringing Wetlands to Market team at oiabdulaziz@mail.wvu.edu, or omariaaziz@gmail.com.

If you have questions about this activity, please contact Joan Muller joan.muller@state.ma.us

Sources of Figures in Student Background Pages

Abdul-Aziz, O.I., Ishtiaq, K.S., Tang, J., Moseman-Valtierra, S., Kroeger, K.D., Gonneea, M.E., Mora, J. and Morkeski, K., 2018. Environmental controls, emergent scaling, and predictions of greenhouse gas (GHG) fluxes in coastal salt marshes. Journal of Geophysical Research: Biogeosciences, 123(7), pp.2234-2256. doi.org/10.1029/2018JG004556.

Howard et al. 2017. Clarifying the role of coastal and marine systems in climate mitigation. Frontiers in Ecology and the Environment 15(1):42–50

Howard, J., Hoyt, S., Isensee, K., Telszewski, M., Pidgeon, E. (eds.) (2014). Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses. Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union for Conservation of Nature. Arlington, Virginia, USA.

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The CWGM 2.0 was developed by Omar Abdul-Aziz and Mohammed Zaki. Dr. Abdul-Aziz is an Associate Professor of Civil & Environmental Engineering at West Virginia University, Morgantown. Mr. Zaki is a doctoral student of Civil and Environmental Engineering working with Dr. Abdul-Aziz.

NGSS Alignment for Bringing Wetlands to Market Lesson on the Coastal Wetland GHG Model 2.0 (CWGM 2.0)

Science and Engineering Practices	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information
Disciplinary Core Ideas	**HS-ESS2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.** **ESS2.E Biogeology** The many dynamic feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it. **HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** **HS LS2.B** Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
Crosscutting Concepts	**Fits best:** Systems and Systems Models Energy and Matter: Flows, Cycles, and Conservation **Also fits:** Stability and Change Patterns Cause and Effect: Mechanism and Explanation Structure and Function

Table A1

1) Examine the input values from the data collected from Cape Cod salt marshes in Table A1 and the Model Example Data table. What differences do you observe in the input variables over the growing season?

PAR and soil temperature are higher in summer and lower in spring and fall; soil porewater salinity is lower in early summer

2) What difference do you observe in the value of the Net Atmospheric Carbon Removal output over the course of the season in Table A1?

More carbon is stored in the warmest periods with high PAR and soil temperature.

3) What relationship, if any, can you observe between temperature and carbon uptake (or storage) and release (or emissions)? Look at the columns for uptake and emissions.

As temperatures rise, carbon storage and emissions both rise.

4) Suggest some reasons for the pattern of carbon uptake.

Photosynthesis; metabolic rate; changes from aerobic to anaerobic respiration with tide and salinity levels

Table A2

5) What changes did you notice in the input data in the climate change scenarios in table A2? How are they related to climate change?

Students can examine the example data and results in the model to describe patterns. They can note the changes in soil temperature (e.g., increase by 1˚C) and salinity (e.g., increase by 5 ppt) from the reference conditions and observe how that changes the NACR. Salinity would be expected to increase because of sea level rise. Soil temperature would be expected to rise because of global warming.

6) What happened to the Net Atmospheric Carbon Removal in the Table A-2 climate change scenario when compared to the 2016 rates? Remember, negative numbers indicate more uptake or storage and positive numbers indicate carbon is being emitted or released into the atmosphere.

Students can examine the example data and results in the model to describe patterns. They can interpret the results by comparing NACR before and after climate change. Here, increased NACR refers to increased potential wetland carbon storage and vice versa. NACR decreases under climate change conditions.

7) What practical applications does this model have in understanding the relationship between climate change and greenhouse gas fluxes (direction and amount of flow)?

The model illustrates how changes in light, temperature, and salinity can affect potential wetland carbon storage.

Going Further

1) The results of the Net Atmospheric Carbon Removal model represent the maximum potential amount of carbon removed from the atmosphere through photosynthesis by salt marsh plants, after correcting for loss of carbon back to the atmosphere from plant respiration and decomposition.

What other factors would affect how much carbon is stored in a marsh?

Possibilities include erosion, deposition from tides or from the land, and students may think of many more.

How might you go about measuring these?

You will need to accept a wide variety of answers.

2) Please explain any insights this exercise gave you into the difficulties of developing mathematic models for ecological problems.

Answers will vary but some students may observe that ecosystems are very complex and it is extremely difficult to account for, much less measure, every factor. Also, there are so many variables in individual places.

Table A1: Example Data Table for the Coastal Wetland Greenhouse Gas Model 2.0 (CWGM 2.0)

Units are:

- **Light:** PAR (Photosynthetically Active Radiation): micromoles per square meter per second
- **Soil temp:** degrees C
- **Soil salinity:** parts per thousand
- **Predicted daytime and nighttime carbon dioxide (CO_2) flux (uptake or release) and methane (CH_4) flux:** grams carbon per square meter; **negative numbers represent uptake or storage and positive numbers represent release or carbon emissions.**

EXAMPLE DATA TABLE	DATE	INPUT	INPUT	INPUT	OUTPUT	OUTPUT	OUTPUT	OUTPUT	OUTPUT	OUTPUT
		Light PAR (micro-mole/ m^2/s)	Avg. Soil Temp (C)	Soil Salinity (ppt)	Predicted daytime net uptake fluxes of CO_2, (micromole/ m^2/s)	Predicted nighttime net emission fluxes of CO_2, (micromole/ m^2/s)	Predicted anytime net emission fluxes of CH_4, (nanomole/ m^2/s)	Net CO_2 (uptake minus emission) (gC/m^2)	Net CH_4 emission (gC/m^2)	Net atmospheric carbon removal NACR (gC/m^2)
Date 1 Early in season	5/16/16	1431.54	13.91	20.00	-5.65	1.46	0.65			
Date 2 Mid-season	8/23/16	1673.10	20.30	23.59	-8.79	2.58	2.87			
Date 3 Late in season	10/14/16	993.77	14.46	25.57	-3.66	1.55	0.56			
								-395.63	8.78	-386.84

Table A2: How Will Climate Change Affect Carbon Sequestration Rates?

The table below provides an example comparing daily values of carbon uptake for present conditions and anticipated future conditions with climate change. How do the inputs and results differ in the future scenario?

DATE	INPUT	INPUT	INPUT	OUTPUT	OUTPUT	OUTPUT
	Light PAR (micro-mole/ m^2/s)	Avg. Soil Temp (C)	Soil Salinity (ppt)	Predicted CO_2 Flux (uptake minus emission) (gC/m^2)	Net CH_4 emission (gC/m^2)	Net atmospheric carbon balance (gC/m^2)
23 Aug 2016	1673.10	20.30	23.59	-588.91	18.52	-570.39
Future scenario						
15 July 2030	1673.10	21.30	26	-543.31	20.20	-523.10

Teacher Answer Key

Field Exercise 2: Running the Computer Model

Follow the steps outlined in exercise 1 to enter your own data into the Net Atmospheric Carbon Removal (NACR) Model. You may use the data provided in Exercise 1 to compare with your data.

Interpreting Your Results

1) Examine the input values from the data you collected and compare them with the data on the "example" tab in the model or the simplified Model Example Data table provided in your packet. What dates have observations that most closely match your data?

Answers will vary.

2) How does the value of the Net Atmospheric Carbon Removal (NACR) output vary with different input observations? Describe the pattern.

a. Light (PAR): *As PAR goes up, the amount of carbon stored generally goes up due to photosynthesis.*

b. Soil temperature: *They will likely find that as temperature rises, the marsh tends to store less carbon when both increased uptake and increased emissions are considered due to a higher rate of metabolism.*

c. Soil Porewater Salinity: *Generally, as soil pore water salinity increases, the marsh stores more carbon because methane production is inhibited.*

3) Propose an explanation for the patterns of carbon storage you find in the example data. (for example, during different seasons or with different salinity or temperature values). Use the data to support your claim.

Answers will vary.

4) If you could sample at different times of year, how might you expect this to affect the rate of carbon uptake?

One would expect less carbon to be stored during the winter due to reduce hours of light (less photosynthesis) and fewer living plants (less photosynthesis)

Going Further

5) The results of the Net Atmospheric Carbon Removal model represent the maximum potential amount of carbon removed from the atmosphere through photosynthesis by salt marsh plants, after correcting for loss of carbon back to the atmosphere from plant respiration and decomposition. What other factors would affect how much carbon is stored in a marsh?

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ABOUT BRINGING WETLANDS TO MARKET

This curriculum was supported by the Bringing Wetlands to Market (BWM) project. The BWM project was led by the Waquoit Bay National Estuarine Research Reserve and a multidisciplinary team of partners. For nearly a decade, the BWM team has been at the forefront of blue carbon science, creating the knowledge and tools that communities need to leverage this science to support wetlands management, restoration, and conservation goals, and help facilitate the integration of coastal wetlands into carbon markets.

Support for the project was provided by the National Estuarine Research Reserve System (NERRS) Science Collaborative. By engaging decision makers in the research process, collaborative science projects directly address community needs. Through a national network dedicated to sharing tools and knowledge, local research strengthens all 29 NERR sites and the communities they serve, leaving them better prepared to manage our changing coasts.

To learn more about BWM and access other project resources, please visit: http://waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/