**MODULE TITLE: ENVIRONMENTAL DRIVERS OF ECOSYSTEM CARBON FLUXES FROM MINUTES TO YEARS**

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**BACKGROUND AND OVERVIEW**

In a nutshell description: Students build on fundamental concepts of ecosystem production and carbon cycling, combining this knowledge with open long-term data from ecological (NEON[[1]](#footnote-1) and FLUXNET[[2]](#footnote-2)) and meteorological (NOAA[[3]](#footnote-3)) networks to uncover the environmental drivers of carbon fluxes for an array of different ecosystems. An optional exercise challenges students to develop a simple predictive model from carbon cycling and environmental data.

Learning objectives (LO) are to: 1) develop informed hypotheses related to the drivers of half-hourly, daily, monthly, and annual gross primary production (GPP), ecosystem respiration (Re), and net ecosystem production (NEP) with the aid of data visualization tools and *a priori* scientific knowledge; 2) test hypotheses using data from NEON, FLUXNET, and NOAA; and 3) develop simple empirical models relating Re to primary environmental drivers and infer ecosystem response under different climate warming scenarios.

Data used: This module uses freely available eddy-covariance carbon flux data provided by FLUXNET2015: <http://fluxnet.fluxdata.org/data/fluxnet2015-dataset/>. Forthcoming data from NEON meteorological carbon flux towers (see: <https://www.neonscience.org/data-collection/flux-tower-measurements>) will be available via download from FLUXET shortly, with non-NEON site data currently available for >100 ecosystems.

What to expect, how much time will this lesson take, and what is likely to challenge students?: This activity assumes fluency in general ecological concepts related to ecosystem production and the carbon cycle. Prior to the group lab activity, instructors may choose to prepare students via lecture material and readings, which are provided in this module package. The first and second sections of the lab activity require 3-4 hours of time and are tailored for introductory biology majors. A third optional exercise is more advanced and is best suited to upper level and graduate classes. Students are likely to be challenged by the synthetic nature of this exercise and the large, multi-parameter datasets used. Instructors can use turn this challenge into a teachable moment, helping students to focus hypotheses based on their understanding of what drives each carbon flux process (e.g., ecosystem respiration) and how the local environment is likely to affect the rate of that process or flux at different timescales. The use of a large dataset will require students to identify the variables of interest to them and their hypotheses, and filter through extraneous information. Lastly, the final optional exercise in particular will challenge students to work through the logic and flow of predictive modeling.

Assessment strategy: With knowledge that hypothesis formulation and testing, and modeling are challenging concepts for student to master, we suggest, following the exercise, assessment focus on evaluating progress made by students in these areas. For example, in support of part 1, the instructor could specify for students the carbon flux (e.g., ecosystem respiration), timescale (e.g., hourly), location (e.g., central Virginia), and ecosystem type (e.g., temperate deciduous broadleaf forest) of interest, and ask them to hypothesize what the 24-hour diurnal profile of that flux might look like in July and January. For part 2, the instructor could provide a print-out or projection of downloaded data with its many parameters, and ask students to then test their hypotheses using real data. For the final part 3, learning of the concept and logic of developing and then applying a model to projecting future carbon fluxes could be assessed by showing students an ecosystem respiration-air temperature plot for a site selected by the instructor. The instructor could include a set of linear and non-linear models and ask students to select the most appropriate (likely non-linear) model, and, given a set of parameterizing temperature data, make predictions about future carbon fluxes from that model. A more challenging twist on this would be to substitute ecosystem respiration for a flux they did not model, such as gross primary production, which would require them to work through the logic of modeling with a different carbon cycling process while applying the same basic approach learned in part 3 of the exercise.

What’s included in this module?: 1) Suggested readings and background presentation materials (including slides) to prepare students for the lab exercise; 2) Lab activity instructions for students; 3) an image-based slide tutorial for instructors and, optionally, students, which can be used during the lab activity as a guide; and 4) example carbon flux data for the University of Michigan Biological Station site, US-UMB (<http://ameriflux.lbl.gov/sites/siteinfo/US-UMB>).

**HOW TO PREPARE**

Instructor prep, prior to class: Prior to teaching this module, students should have basic knowledge of primary and ecosystem production, the carbon cycle, and how weather and climate affect these processes. The lab component of this module would pair well with introductory to mid-level course lectures on ecosystem production, the carbon cycle, and climate change.

We suggest instructors review student materials, including readings, and slides on the ‘eddy-covariance’ or meteorological approach to estimating carbon fluxes. The presentation is intended to be a primer, and not exhaustive or overly technical, overview of carbon flux methodology, centering on the eddy covariance approach. In addition to the readings below, NEON Education produced an excellent, nontechnical video overview of the eddy-covariance approach and its application to ecosystem science, titled “Eddy Covariance: Measuring an Ecosystem's Breath”: <https://youtu.be/CR4Anc8Mkas>. A hyperlink to this video is also provided in Part 1 (of 2) of the lecture slides included with this module.

Student prep, prior to class: Consider having students read the following open-access text providing background information on net ecosystem and primary production:

<https://www.nature.com/scitable/knowledge/library/terrestrial...life-17567411?error=cookies_not_supported&code=6b80183d-52bb-4068-ad5a-5c3730e8b54d>.

It may be useful for students to additionally review websites describing the observational networks from which they will acquire data:

The National Ecological Observatory Network (NEON): <https://www.neonscience.org/>

The Ameriflux Network: <http://ameriflux.lbl.gov/>

The National Oceanic and Atmospheric Association (NOAA), Center for Atmospheric Sciences & Meteorology: <http://www.noaa.gov/office-education/epp-msi/csc/noaa-center-atmospheric-science>

Optional, technical readings include:

*Less technical* publications on environment-carbon cycling interactions:

Gough C.M., Vogel C.S., Schmid H.P., and Curtis P.S. 2008. Controls on annual forest carbon storage: Lessons from the past and predictions for the future, BioScience. 58: 609-622.

<https://academic.oup.com/bioscience/article/58/7/609/237048>

*More technical* publications on environment-carbon cycling interactions:

Urbanski S et al. (2007) Factors controlling CO2 exchange on timescales from hourly to decadal at Harvard Forest. Journal of Geophysical Research-Biogeosciences 112. doi: G02020 10.1029/2006jg000293

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2006JG000293>

*Less technical publication* on the eddy-covariance approach:

Baldocchi, Dennis (2008) ‘Breathing’ of the terrestrial biosphere: lessons learned from a global network of carbon dioxide flux measurement systems. *Australian Journal of Botany* **56**, 1-26.

<http://www.publish.csiro.au/bt/BT07151>

*More technical publication* on the eddy-covariance approach (open access):

Burba, G., 2013. Eddy Covariance Method for Scientific, Industrial, Agricultural, and Regulatory Applications: A Field Book on Measuring Ecosystem Gas Exchange and Areal Emission Rates. LI-COR Biosciences, Lincoln, NE, USA, 331 pp.

<https://www.licor.com/env/products/eddy_covariance/ec_book.html>

1. National Ecological Observatory Network (NEON): <https://www.neonscience.org/> [↑](#footnote-ref-1)
2. Global network of meteorological carbon flux towers: <http://fluxnet.fluxdata.org/> [↑](#footnote-ref-2)
3. National Oceanic and Atmospheric Administration (NOAA): <http://www.noaa.gov/> [↑](#footnote-ref-3)