TEACH SKILLS IN ECOLOGICAL FORECASTING: MACROSYSTEMS EDDIE MODULES FOR UNDERGRADUATES

Mary Lofton
Virginia Tech
melofton@vt.edu

Sensing The Earth: Tribal College Faculty Data Science Experience

11-18-2022

Before we start:

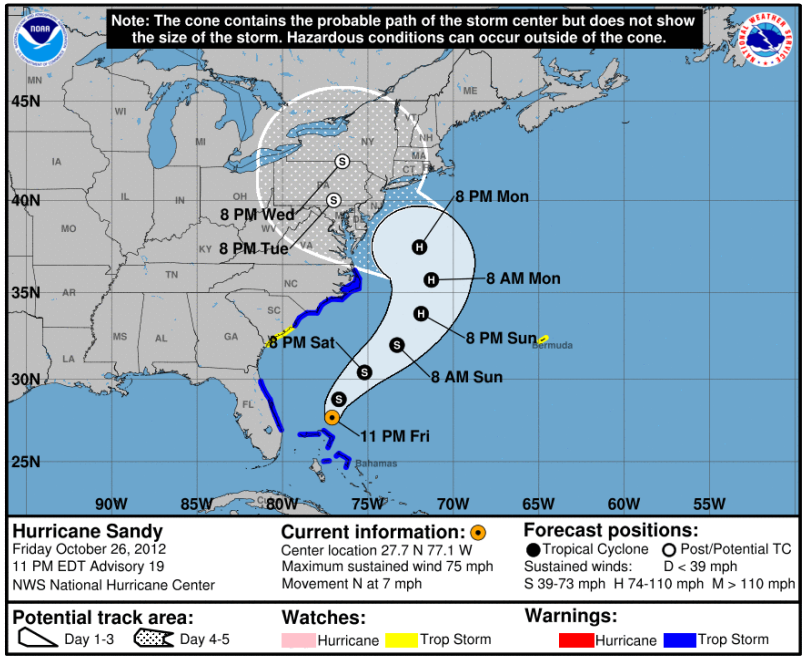
What is a Forecast?

"*A forecast is a prediction of a future event with uncertainty*"

- Events have not yet occurred
- Gives a probability or a likelihood of the event to occur (uncertainty)
- Actionable

What is the purpose of a forecast?

- Preparation
  - e.g., weather forecast – hurricanes
- Action
  - e.g., algal bloom forecasts



There is a pressing need for **quantitative** and **actionable** information about the future of ecological and environmental resources upon which society depends at **day to decadal scales**




Decisions are being made in the context of a rapidly changing environment:

- Algal blooms
- Endangered species
- Bird mitigations
- Fisheries
- Crop productivity
- Carbon dioxide storage
- Forest yields
- Vector borne diseases
- Plant pests and pathogens
- Water supply
- Fall tree colors
- Many others

Decisions

Uninformed decisions

Informed decisions

Image credit: Kristina Davis

Ecological forecasting is an emerging field

- Forecasting methods, software, and approaches are rapidly evolving
- We need both:
  - New training materials for integrating forecasting into curricula
  - Forecasting templates, technology, and models for galvanizing and helping the research community to create forecasts!

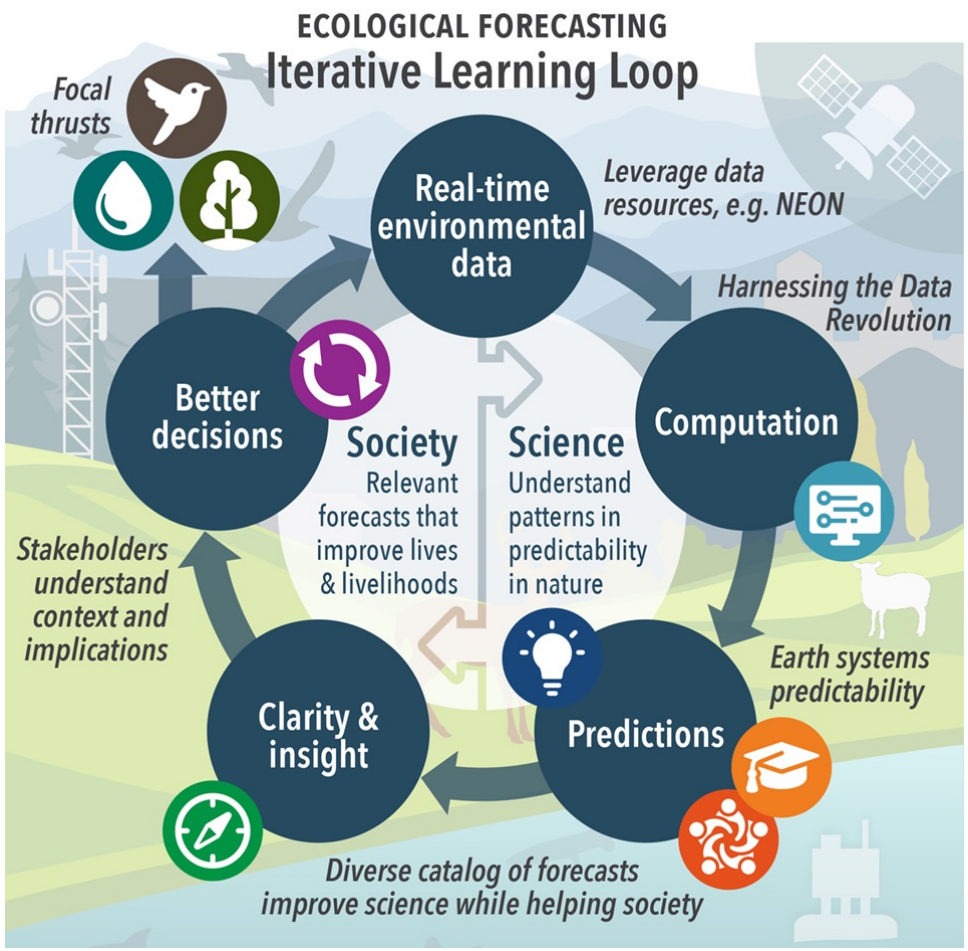
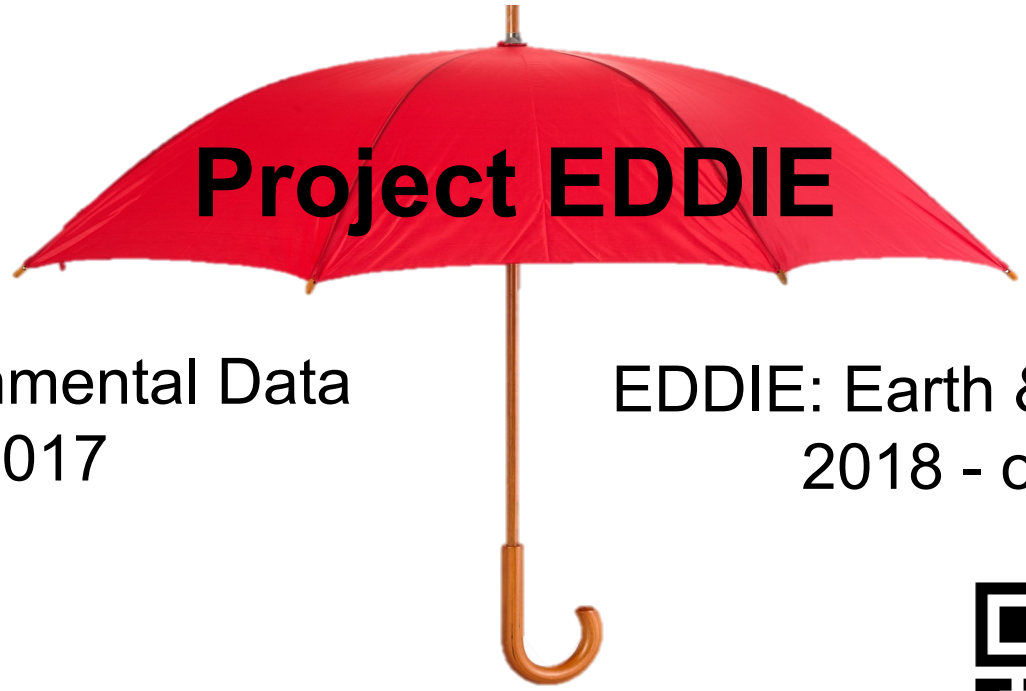


Image credit: Kristina Davis

Macrosystems EDDIE teaching materials for ecological forecasting

- To date, the few existing educational materials for forecasting are targeted for graduate students
- Our goal is to introduce forecasting by developing hands-on, interactive materials that are approachable to **BOTH** undergraduate students and instructors

Project EDDIE: Environmental Data-Driven Inquiry & Exploration



EDDIE: Environmental Data
2012-2017

EDDIE: Earth & Ecosystems
2018 - ongoing

EDDIE: Macrosystems
2017-ongoing

ProjectEDDIE.org

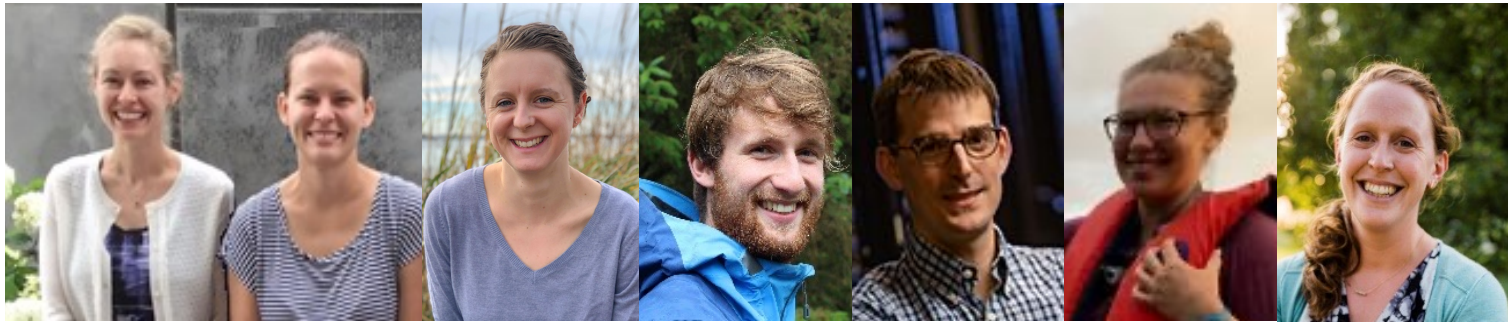
Macrosystems EDDIE: teaching local to continental-scale ecology

Overall objectives:

- Develop & test hypotheses about complex effects of global change
- Run ecosystem models
- Use Shiny apps to generate ecological forecasts

Macrosystems EDDIE
Environmental Data-Driven Inquiry & Exploration in Macrosystems Ecology

MacrosystemsEDDIE.org



Cayelan Carey | Kait Farrell | Alex Hounshell | Tadhg Moore | Quinn Thomas | Whitney Woelmer | Mary Lofton

Pre-packaged, ready to use

EDDIE Module =

- Instructor lesson plan & PowerPoint
- Pre-class readings
- In-class activities & datasets
- Homework & answers


Photo: Grace Hong

Overall learning objectives:

- Build quantitative skills using *real*, *messy* ecological data
- Use large datasets to build ecological understanding
- Develop data visualization and quantitative literacy

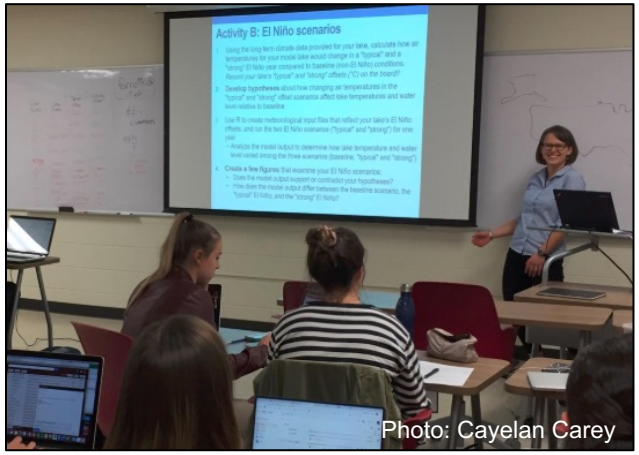


Photo: Cayelan Carey

Suite of Macrosystems EDDIE modules

- *Module 1:* Climate Change Effects on Lake Temperatures
- *Module 2:* Cross-scale Interactions
- *Module 3:* Teleconnections
- *Module 4:* Macro-scale Feedbacks

- ***Module 5:* Introduction to Ecological Forecasting**
- ***Module 6:* Understanding Uncertainty in Ecological Forecasts**
- ***Module 7:* Using Data to Improve Ecological Forecasts**
- ***Module 8:* Using Ecological Forecasts to Guide Decision-making**

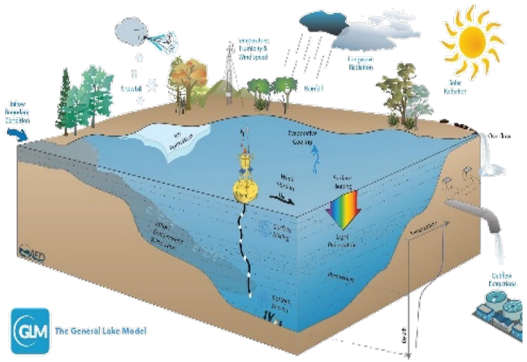
Continental datasets allow students to model lakes across ecoregions

Modules build computational literacy and fundamental ecological understanding

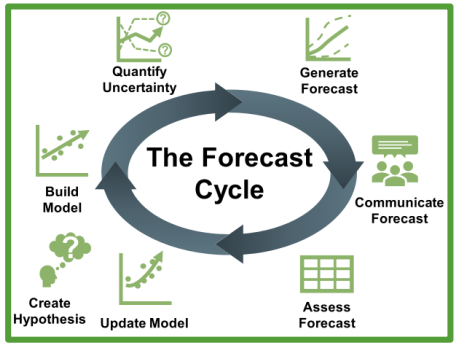
- To date, >10,000 students have completed Macrosystems EDDIE modules
- >600 students and ~50 instructors from ~30 universities have completed pre/post-module assessments
- Modules increased self-reported proficiency and confidence using R software and ecosystem modeling

R software

Simulation modeling

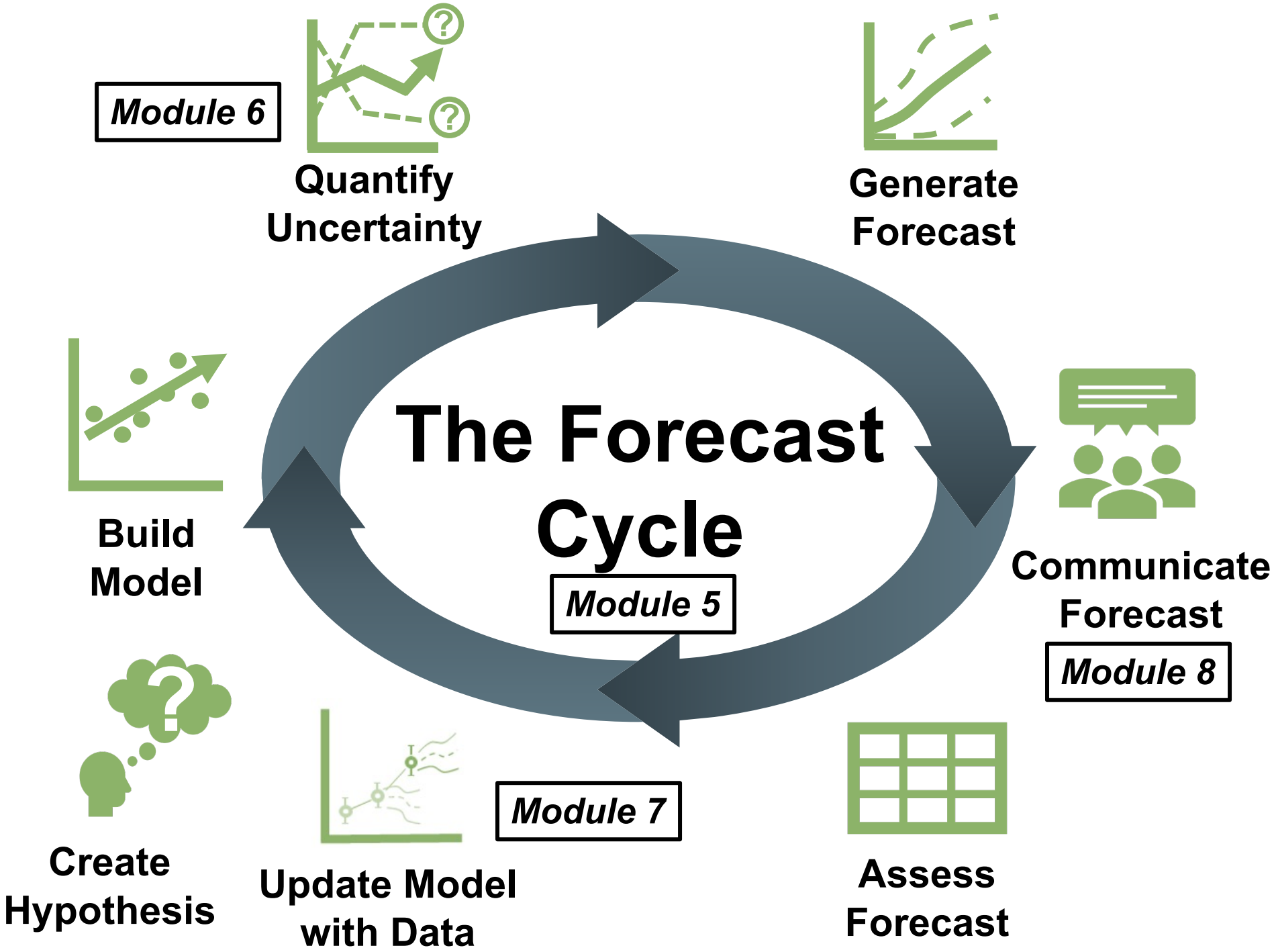


Ecological forecasting



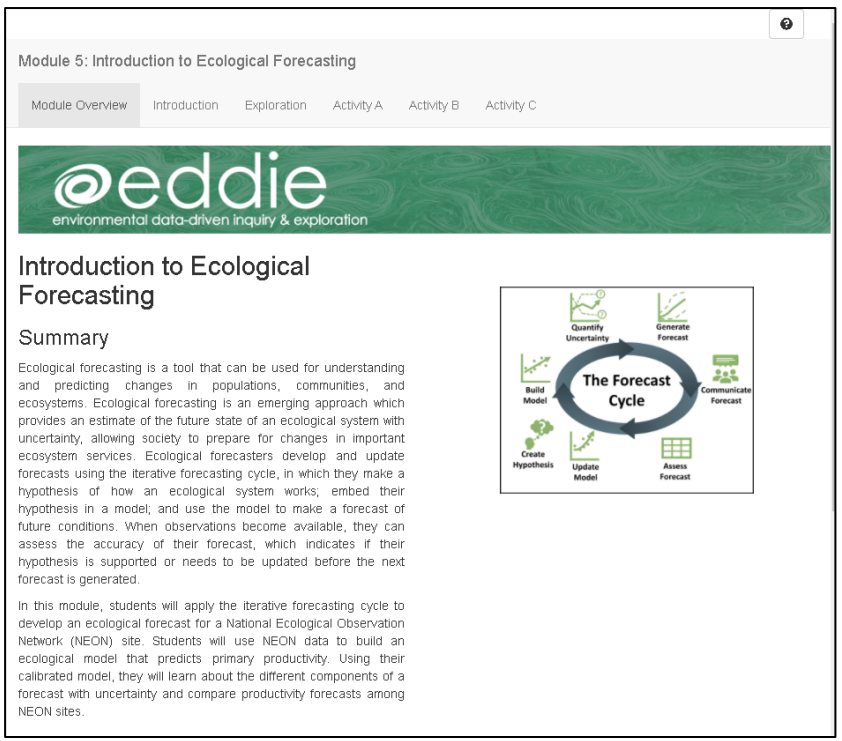
Farrell & Carey 2018 *E&E*; Carey et al. 2020 *E&E;* Hounshell et al. 2021 *Edu Sci*; Moore et al. *in review*

Overview of Ecological Forecasting Modules


Module 6
Quantify Uncertainty
Generate Forecast
Build Model
The Forecast Cycle
Module 5
Communicate Forecast
Module 8
Create Hypothesis
Update Model with Data
Module 7
Assess Forecast

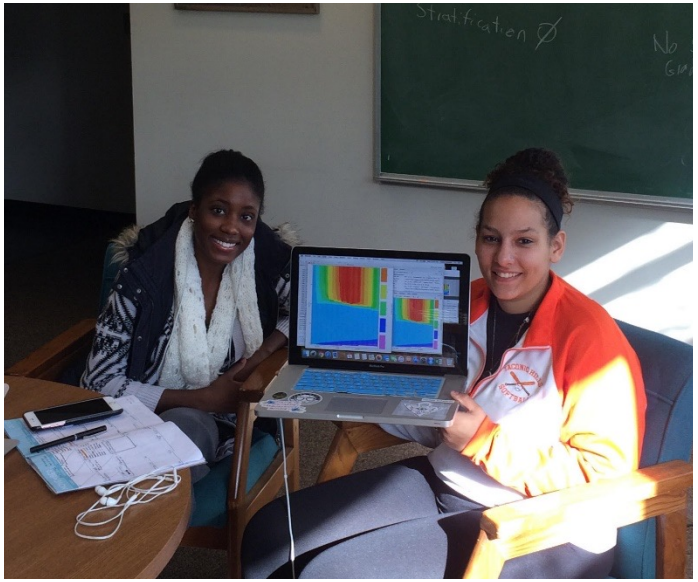
R Shiny App

- Interactive webpage built using R
- Non-intimidating approach – code is under the hood
- Allows for interactive visualization of data
- Easy to share results which are used to lead discussions
- Ideal for engaging both undergraduate and graduate level courses

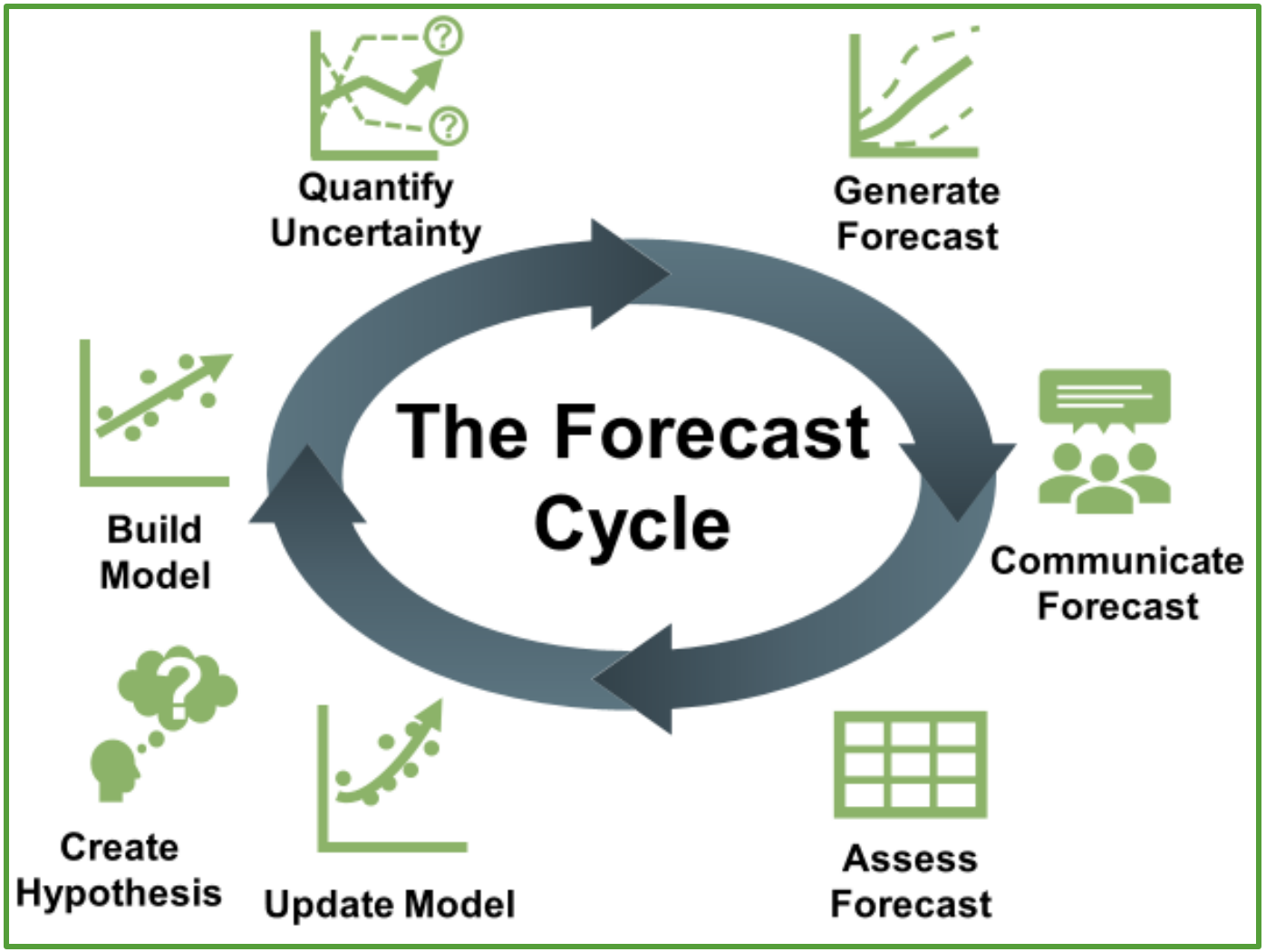


Context for Use

- Adaptable for your classrooms
  - Can be taught in both undergraduate and graduate classes
  - Flexible modality
    - Virtual
    - Face-to-face classrooms
    - Hybrid
- Modules 5, 6, 7
  - Ecology, Environmental Science, Ecological Modeling, and Quantitative Ecology classes
- Module 8
  - Applied Ecology, Environmental Science, Environmental Studies, and Environmental Social Science classes



Module 5: Introduction to Ecological Forecasting

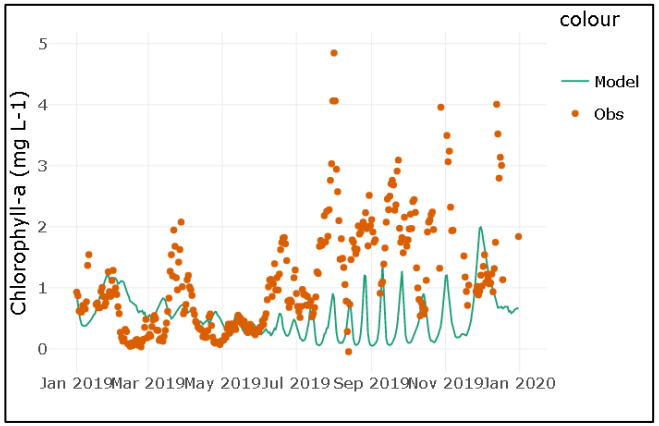


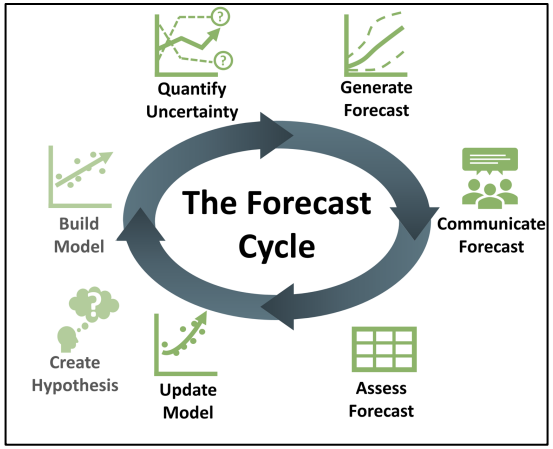
Module 5: Activities

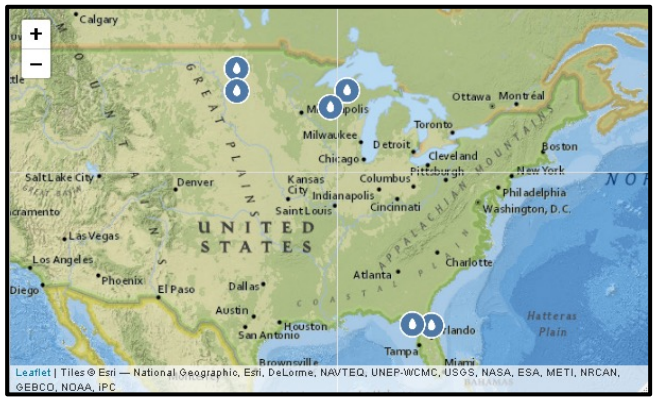
A. Choose a site, explore data and build a model

B. Step through each step of the forecast cycle

C. Test the model at a different site and compare forecasts





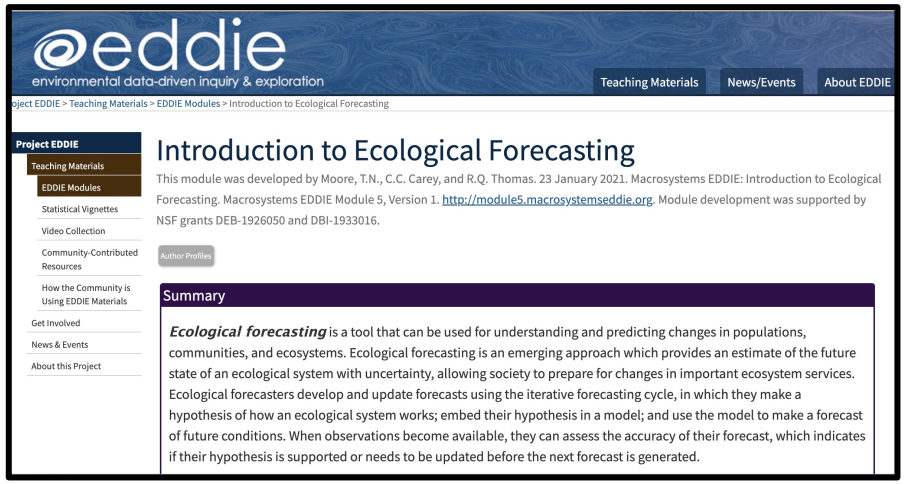


Guided walk-through of a Macrosystem EDDIE Module

Module 5: Introduction to Ecological Forecasting

Module landing page and resources

http://module5.macrosystemseddie.org

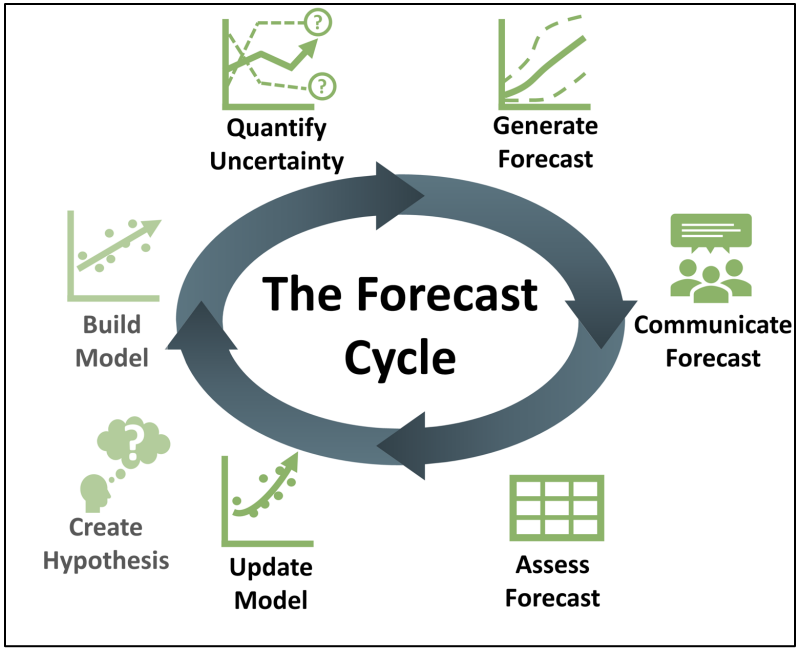


Teaching Materials:

- R shiny app: https://macrosystemseddie.shinyapps.io/module5/
  - To run the R Shiny app locally on your own computer, please see the instructions on the GitHub page: https://github.com/MacrosystemsEDDIE/module5
- Student Handout.docx (Microsoft Word 2007 (.docx) 1.8MB May16 22) - Handout for students to complete prior to the module
- Instructor's Manual (Microsoft Word 2007 (.docx) 1.3MB Oct25 22) - Instructor manual and troubleshooting for the module.
- parameters_EDDIE.zip (Zip Archive 5kB Jul13 21)- Model parameter answer keys for each lake site
- Instructor's Powerpoint.pptx (PowerPoint 2007 (.pptx) 11.4MB Oct25 22) - PowerPoint presentation to introduce core concepts & module activities
  - Getting Started with Shiny.pptx (PowerPoint 2007 (.pptx) 1.7MB Sep6 22) - Additional PowerPoint slides that provide a basic orientation to using an R Shiny app

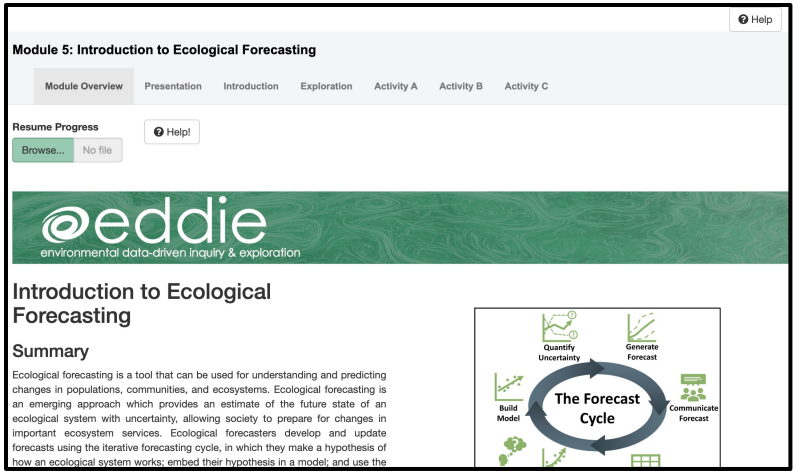
Learning objectives of today's module:

- Describe an ecological forecast and the iterative forecasting cycle
- Explore and visualize NEON data
- Construct an ecological model to generate forecasts of ecosystem primary productivity with uncertainty
- Adjust model parameters and inputs to study how they affect forecast performance relative to observations
- Compare productivity forecasts among NEON sites in different climatic regions



Shiny App

- The module can be accessed: https://macrosystemseddie.shinyapps.io/module5/
- This is an interactive webpage built using R
- It has interactive plots and options embedded which allow you to visualize and explore the data, examine different data assimilation options, and answer questions



Landing Page of the Shiny App

Help

Module 5: Introduction to Ecological Forecasting

Module Overview | Presentation | Introduction | Exploration | Activity A | Activity B | Activity C

Resume Progress

Browse... No file sele

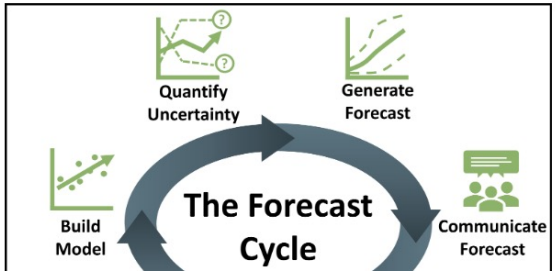
Help!

eddie
environmental data-driven inquiry & exploration

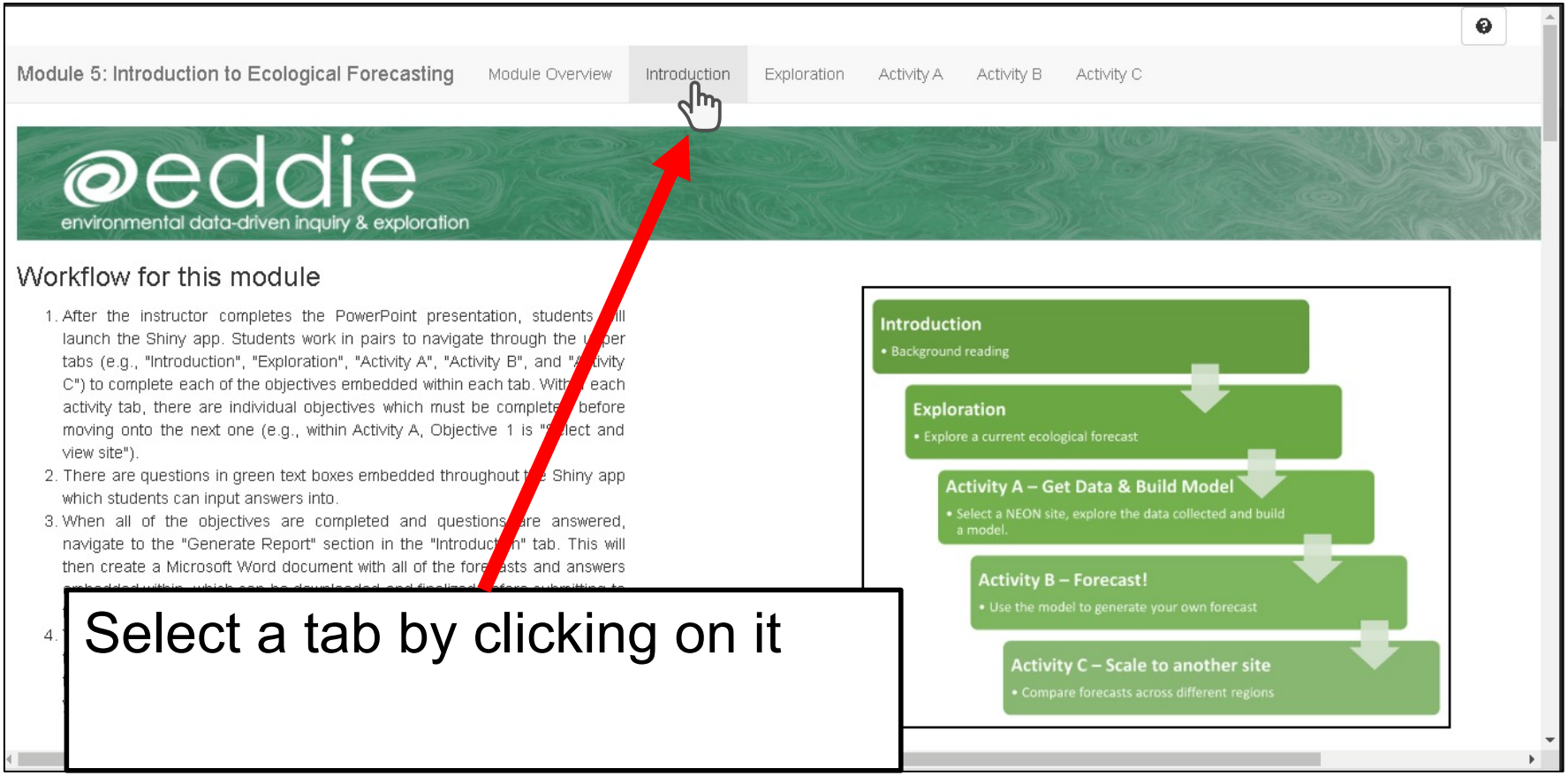
Introduction to Ecological Forecasting

Summary

Ecological forecasting is a tool that can be used for understanding and predicting changes in populations, communities, and ecosystems. Ecological forecasting is an emerging approach which provides an estimate of the future state of an ecological system with uncertainty, allowing society to prepare for changes in important ecosystem services. Ecological forecasters develop and update forecasts using the iterative forecasting cycle, in which they make a hypothesis of how an ecological system works; embed their hypothesis in a model; and use the model to make a forecast of future conditions. When observations become available, they can assess the

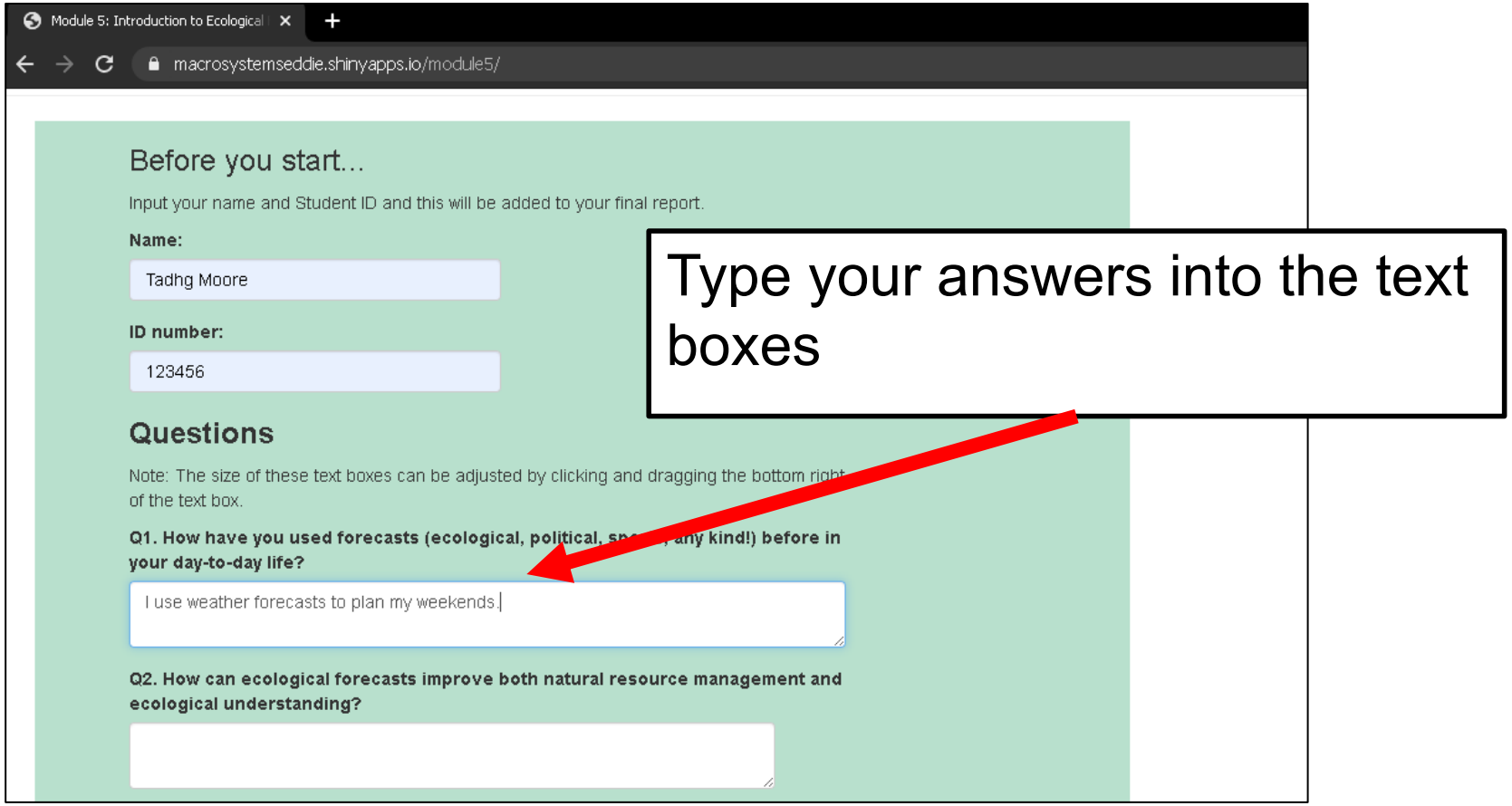


Navigating the Shiny App



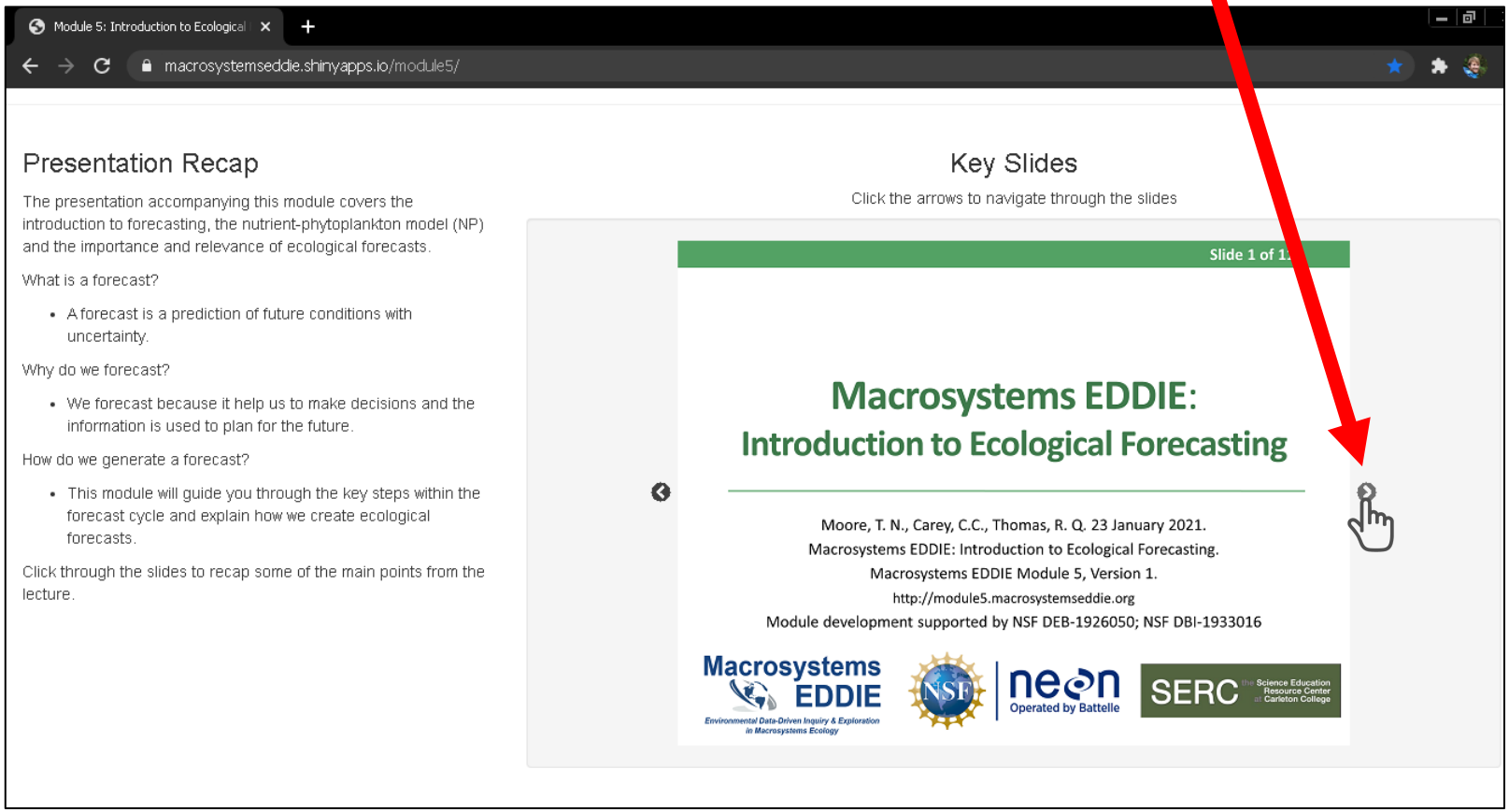
Select a tab by clicking on it

Answer questions

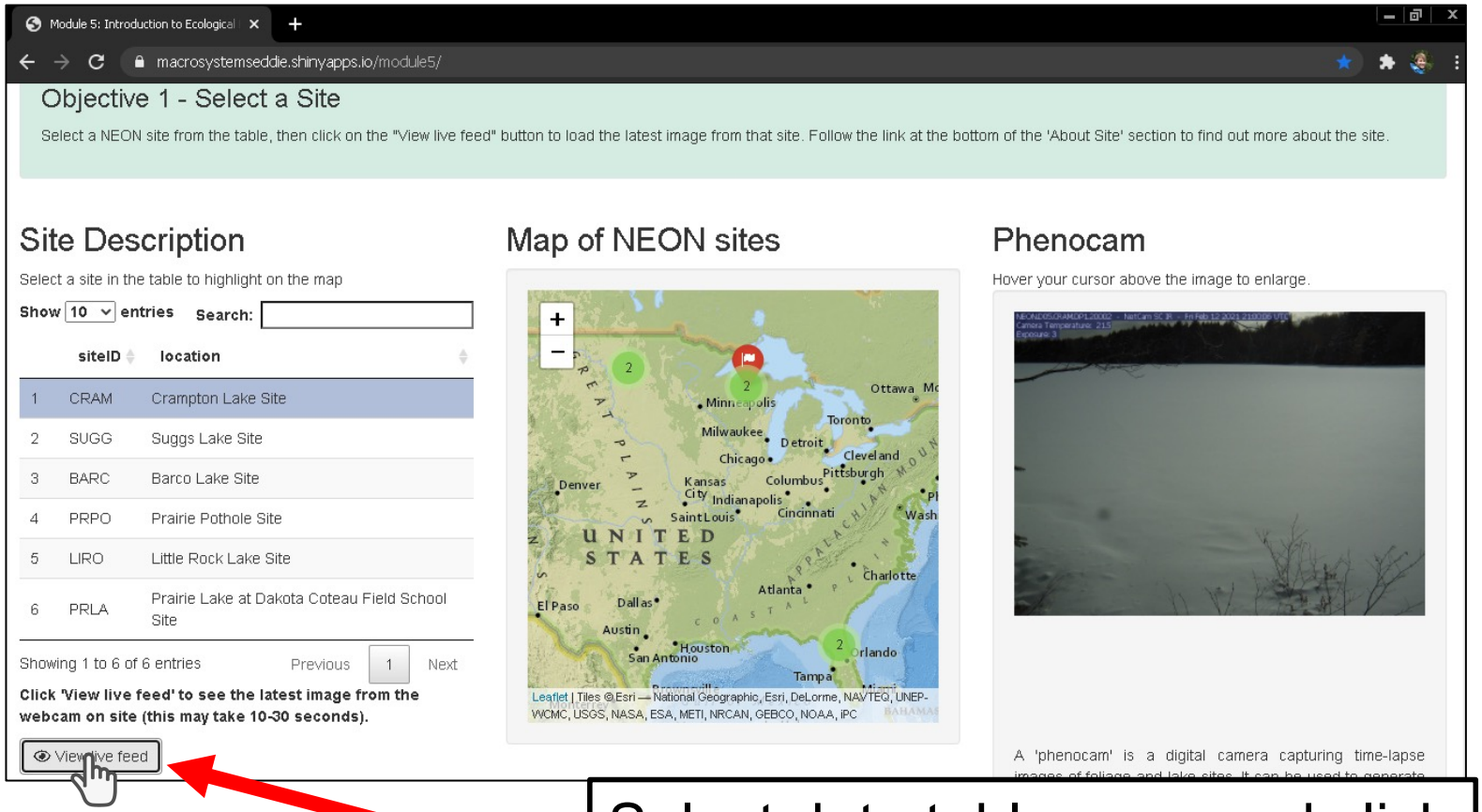


Navigate slides

Advance slides by clicking on the arrows

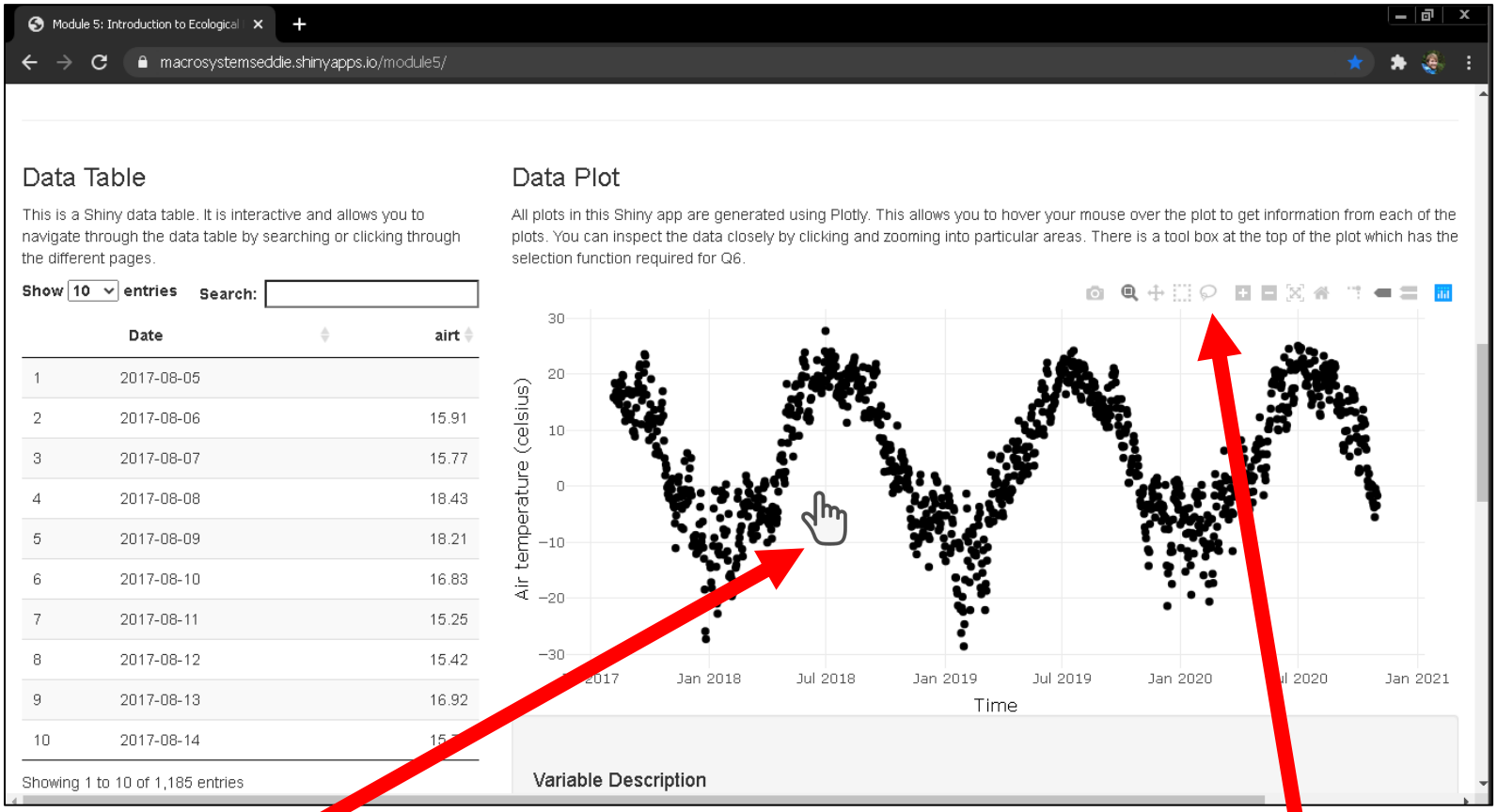


Interact with app



Select data table rows and click buttons

Interact with plots



Hover cursor over points or click and drag to zoom in

Hover cursor over plot to bring up options

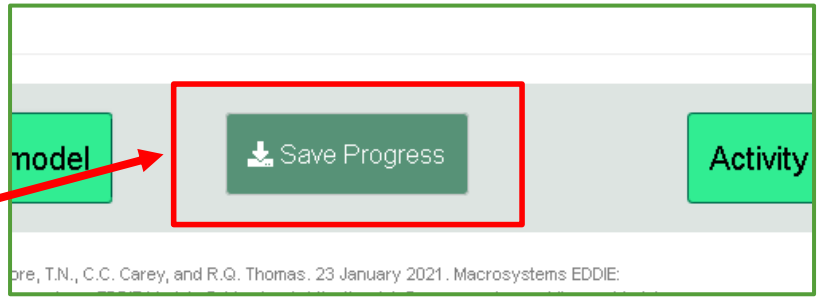
Saving plots

Save plots for downloading with your final report

Saving & Resuming Progress

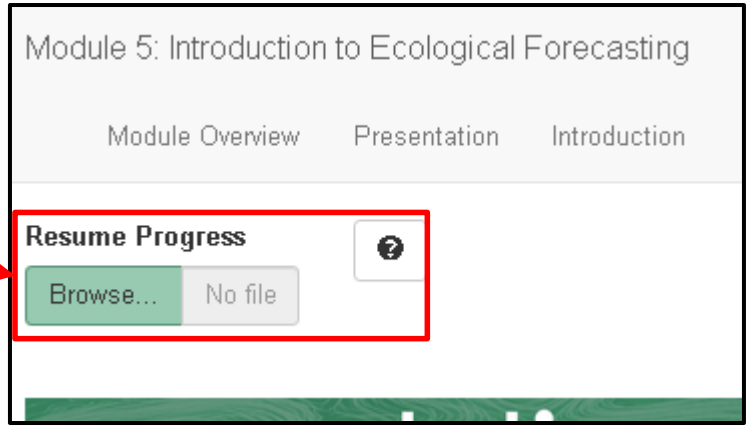
Saving Progress

1. Scroll to bottom of the page
2. Click on the “Save Progress” button. An ‘.eddie’ file will download. Your computer might prompt you to open this in R. This will not work, it only works for uploading to the Shiny app
3. Store this file somewhere safe on your computer



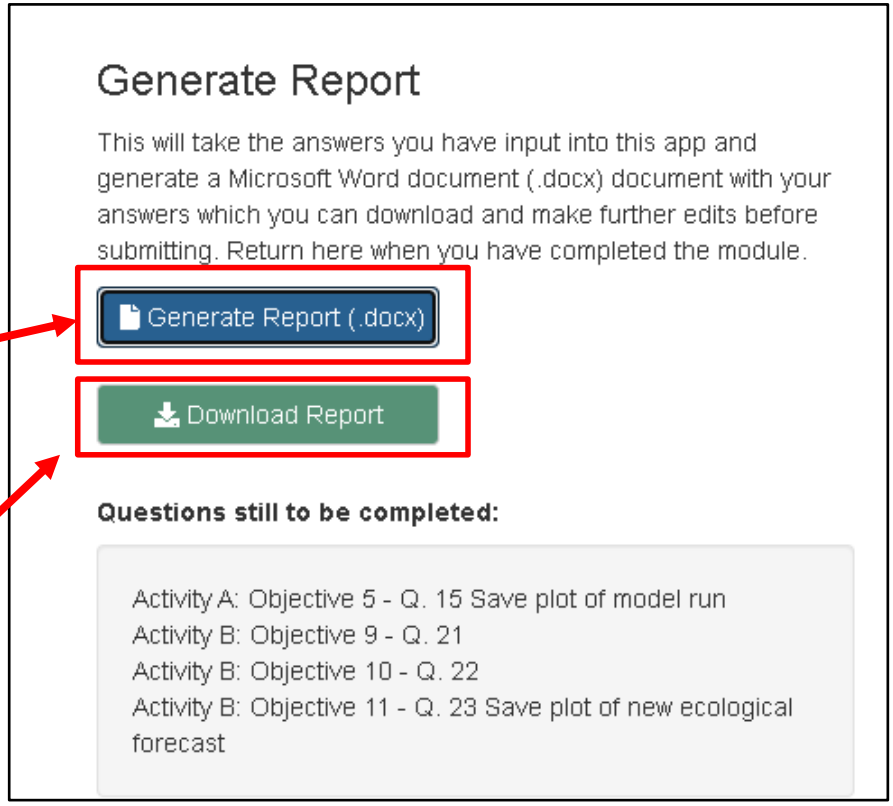
Resuming progress

1. Scroll to the top of the page
2. Upload the ‘.eddie’ file
3. This will populate your saved text answers and saved parameters



Downloading the Report

1. Navigate to the “Introduction” tab
2. Scroll down to “Save your progress” section
3. Click on the “Generate Report (.docx)” button.
4. Then the “Download Report” button will appear. Click this to download the report with answer and plots embedded within a Word document.



Module exploration time

What questions do you have about integrating Macrosystems EDDIE Ecological Forecasting modules into your course?

Ready for Macrosystems EDDIE? We'd love your feedback!

- Will be testing Spring 2023/Fall 2023:
  - Module 6 Understanding Uncertainty in Ecological Forecasts
  - Module 7 Using Data to Improve Ecological Forecasts

- **Are you interested in using this module in your class?**

Let us know!

MacrosystemsEDDIE@gmail.com

Image: dreamstime.com

Thank you!

- **NSF:** EF 1702506, 1926050
- **EDDIE Personnel:** Project EDDIE colleagues, SERC team, & module testers
- **Challenge Personnel**: Quinn Thomas, Ecological Forecasting Initiative colleagues, NEON colleagues
- **Data providers:** NEON, GLEON, LTER, USGS, NOAA

Mary Lofton
melofton@vt.edu
@me_lofton

Cayelan Carey
cayelan@vt.edu
@CareyLab

www.MacrosystemsEDDIE.org