

# The NEON Ecological Forecasting Challenge

Hosted by the  
Ecological Forecasting Initiative Research Coordination Network



Ecological Forecasting Initiative  
UNDERSTAND · MANAGE · CONSERVE



neon  
Operated by Battelle

R. Quinn Thomas  
Associate Professor  
Virginia Tech  
[rqthomas@vt.edu](mailto:rqthomas@vt.edu)

Funded by the National Science Foundation (DEB-1926388)

**More intercompatible forecasts**

from a

**diversity of perspectives and approaches**

that engage

**more partners**



## Ecological Forecasting Initiative

UNDERSTAND · MANAGE · CONSERVE

Grassroots consortium aimed at building an interdisciplinary community of practice in ecological forecasting



Standardized **terrestrial** and **freshwater** data with ongoing collect that freely available at 81 sites across the U.S.



NSF-sponsored

# Ecological Forecasting Initiative Research Coordination Network

## 5-year project

Create a community of practice that builds capacity for ecological forecasting by leveraging NEON data products.

<https://ecoforecast.org/rcn/>

# The current steering committee!





Contents lists available at ScienceDirect

Ecological Informatics

journal homepage: [www.elsevier.com/locate/ecolinf](http://www.elsevier.com/locate/ecolinf)



Predicting the future is hard and other lessons from a population time series data science competition

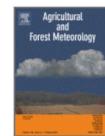


Humphries G.R.W.<sup>a,\*</sup>, Che-Castaldo C.<sup>b</sup>, Bull P.J.<sup>c</sup>, Lipstein G.<sup>c</sup>, Ravia A.<sup>d,e</sup>, Carrión B.<sup>f</sup>, Bolton T.<sup>g</sup>, Ganguly A.<sup>h</sup>, Lynch H.J.<sup>b,i</sup>



Agricultural and Forest Meteorology

Volume 149, Issue 10, 1 October 2009, Pages 1597–1615



## The REFLEX project: Comparing different algorithms and implementations for the inversion of a terrestrial ecosystem model against eddy covariance data

Andrew Fox<sup>a</sup>, Mathew Williams<sup>b</sup> , Andrew D. Richardson<sup>c</sup>, David Cameron<sup>d</sup>, Jeffrey H. Gove<sup>e</sup>, Tristan Quaife<sup>f</sup>, Daniel Ricciuto<sup>g</sup>, Markus Reichstein<sup>h</sup>, Enrico Tomelleri<sup>h</sup>, Cathy M. Trudinger<sup>i</sup>, Mark T. Van Wijk<sup>j</sup>

kaggle

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## A data science challenge for converting airborne remote sensing data into ecological information

Sergio Marconi<sup>1</sup>, Sarah J. Graves<sup>2</sup>, Dihong Gong<sup>3</sup>, Morteza Shahriari Nia<sup>3</sup>, Marion Le Bras<sup>4</sup>, Bonnie J. Dorr<sup>4</sup>, Peter Fontana<sup>4</sup>, Justin Gearhart<sup>1</sup>, Craig Greenberg<sup>4</sup>, Dave J. Harris<sup>5</sup>, Sugumar Arvind Kumar<sup>3</sup>, Agarwal Nishant<sup>3</sup>, Joshi Prabdh<sup>3</sup>, Sundeep U. Rege<sup>3</sup>, Stephanie Ann Bohlman<sup>2</sup>, Ethan P. White<sup>5</sup> and Daisy Zhe Wang<sup>3</sup>

## An open challenge to advance probabilistic forecasting for dengue epidemics

Michael A. Johansson<sup>a,b,1</sup>, Karyn M. Apfeldorf<sup>c</sup>, Scott Dobson<sup>c</sup>, Jason Devita<sup>c</sup>, Anna L. Buczak<sup>d</sup>, Benjamin Baugher<sup>d</sup>, Linda J. Moniz<sup>d</sup>, Thomas Bagley<sup>d</sup>, Steven M. Babin<sup>d</sup>, Erhan Guven<sup>d</sup>, Teresa K. Yamana<sup>e</sup>, Jeffrey Shaman<sup>e</sup>, Terry Moschou<sup>f</sup>, Nick Lothian<sup>f</sup>, Aaron Lane<sup>f</sup>, Grant Osborne<sup>f</sup>, Gao Jiang<sup>g</sup>, Logan C. Brooks<sup>h</sup>, David C. Farrow<sup>h</sup>, Sangwon Hyun<sup>h</sup>, Ryan J. Tibshirani<sup>h</sup>, Roni Rosenfeld<sup>i</sup>, Justin Lessler<sup>i</sup>, Nicholas G. Reich<sup>i</sup>, Derek A. T. Cummings<sup>j,m</sup>, Stephen A. Lauer<sup>k</sup>, Sean M. Mooren<sup>k</sup>, Hannah E. Clapham<sup>k</sup>, Rachel Lowe<sup>q,r</sup>, Trevor C. Bailey<sup>s</sup>, Markel Garcia-Diez<sup>t</sup>, Marilia Sá Carvalho<sup>u</sup>, Xavier Rodó<sup>v,w</sup>, Tridip Sardar<sup>w</sup>, Richard Paul<sup>x,y</sup>, Evan L. Ray<sup>z</sup>, Krzysztof Sakrejda<sup>k</sup>, Alexandria C. Brown<sup>z</sup>, Xi Meng<sup>k</sup>, Osonde Osoba<sup>aa</sup>, Raffaele Vardavas<sup>bb</sup>, David Manheim<sup>bb</sup>, Melinda Moore<sup>aa</sup>, Dhananjai M. Rao<sup>cc</sup>, Travis C. Porco<sup>dd</sup>, Sarah Ackley<sup>dd</sup>, Fengchen Liu<sup>dd</sup>, Lee Worden<sup>dd</sup>, Matteo Convertino<sup>ee</sup>, Yang Liu<sup>ff</sup>, Abraham Reddy<sup>ff</sup>, Eloy Ortiz<sup>gg</sup>, Jorge Rivero<sup>gg</sup>, Humberto Brito<sup>gg,hh</sup>, Alicia Juarrero<sup>gg,ii</sup>, Leah R. Johnson<sup>jj</sup>, Robert B. Gramacy<sup>kk</sup>, Jeremy M. Cohen<sup>kk</sup>, Erin A. Mordecai<sup>kk</sup>, Courtney C. Murdock<sup>mm,nn</sup>, Jason R. Rohr<sup>nn</sup>, Sadie J. Ryan<sup>m,o,p,p</sup>, Anna M. Stewart-Ibarra<sup>qq</sup>, Daniel P. Weikel<sup>rr</sup>, Antarpreet Jutla<sup>ss</sup>, Rakibul Khan<sup>ss</sup>, Marissa Poultney<sup>ss</sup>, Rita R. Colwell<sup>tt</sup>, Brenda Rivera-Garcia<sup>uu</sup>, Christopher M. Barker<sup>vv</sup>, Jesse E. Bell<sup>ww</sup>, Matthew Biggerstaff<sup>xx</sup>, David Swerdlow<sup>xx</sup>, Luis Mier-y-Teran-Romo<sup>yy</sup>, Brett M. Forshey<sup>yy</sup>, Juli Trtan<sup>zz</sup>, Jason Asher<sup>aaa</sup>, Matt Clay<sup>aaa</sup>, Harold S. Margolis<sup>a</sup>, Andrew M. Hebbeler<sup>bbb,ccc</sup>, Dylan George<sup>ccc,ddd</sup>, and Jean-Paul Chretien<sup>ccc,eee</sup>

kaggle

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Featured Prediction Competition

### M5 Forecasting – Accuracy

Estimate the unit sales of Walmart retail goods

University of Nicosia · 3,376 teams · 2 months to go (2 months to go until merger deadline)

Overview Data Notebooks Discussion Leaderboard Rules Join Competition

# The NEON Ecological Forecasting Challenge

R Quinn Thomas<sup>1\*</sup>, Carl Boettiger<sup>2</sup>, Cayelan C Carey<sup>1</sup>, Michael C Dietze<sup>3</sup>, Leah R Johnson<sup>1</sup>, Melissa A Kenney<sup>4</sup>, Jason S McLachlan<sup>5</sup>, Jody A Peters<sup>5</sup>, Eric R Sokol<sup>6</sup>, Jake F Weltzin<sup>7</sup>, Alyssa Willson<sup>5</sup>, Whitney M Woelmer<sup>1</sup>, and Challenge contributors<sup>8</sup>

<sup>1</sup>Virginia Tech \*(rqthomas@vt.edu); <sup>2</sup>University of California-Berkeley; <sup>3</sup>Boston University; <sup>4</sup>University of Minnesota;

<sup>5</sup>University of Notre Dame; <sup>6</sup>National Ecological Observatory Network; <sup>7</sup>US Geological Survey; <sup>8</sup>See WebPanel 1 for additional authors

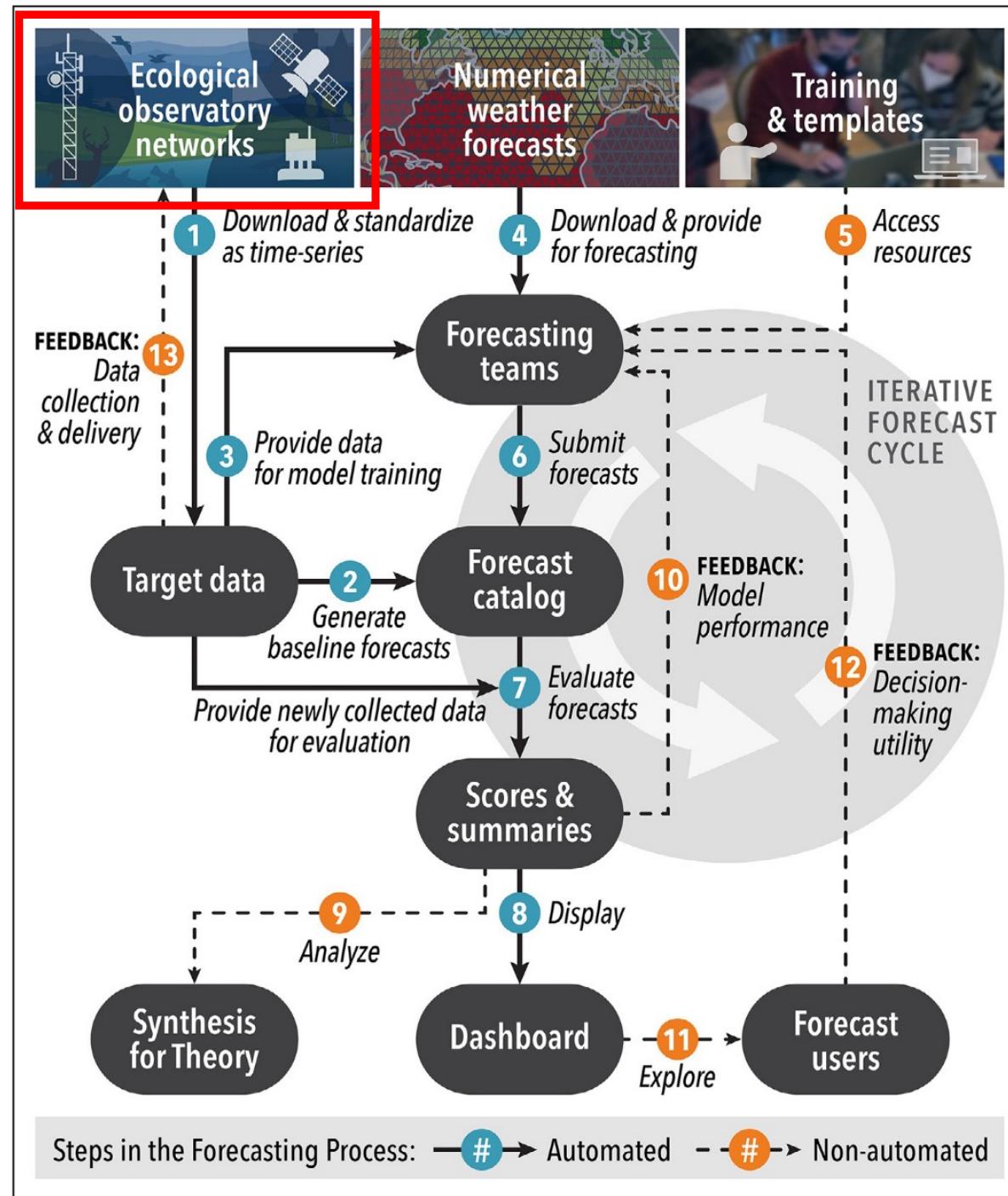
*Front Ecol Environ* 2023; 21(3): 112–113, doi:10.1002/fee.2616

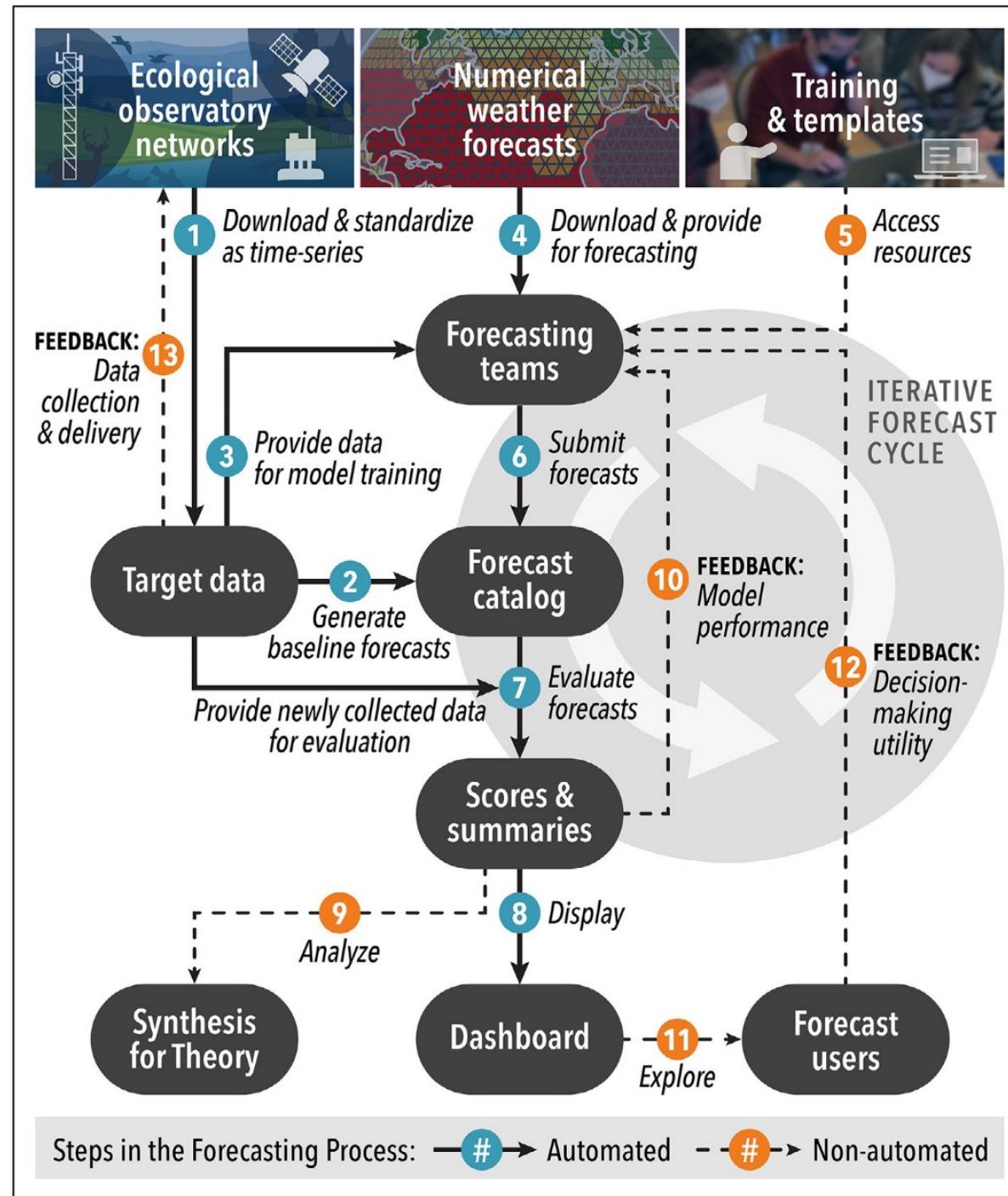


A platform that challenges and empowers  
the community to submit  
iterative near-term forecasts  
of *yet-to-be-collected* NEON data



**neon**  
Operated by Battelle







**neon**  
Operated by Battelle

- 81 sites

- 182 openly available data products standardized across sites
- Planned 30-year horizon (construction completed 2019)
  - Aquatic and Terrestrial
  - Physical, chemical, biological
  - Population, community, ecosystem



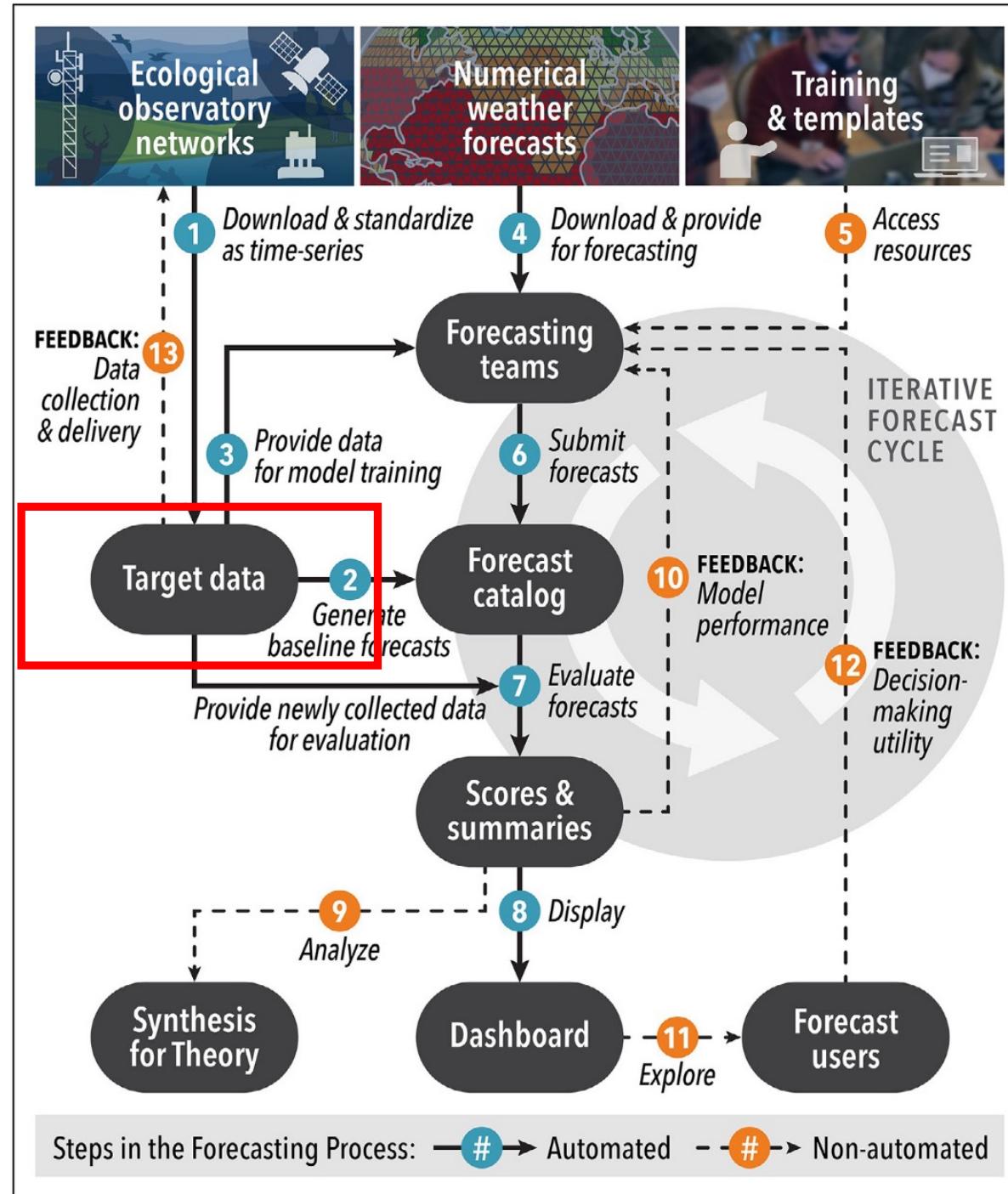
## 2.1. NEON Mission

---

NEON is a National Science Foundation-sponsored facility for research and education on long-term, large-scale ecological change. NEON's goals are derived from the Integrated Science and Education Plan.

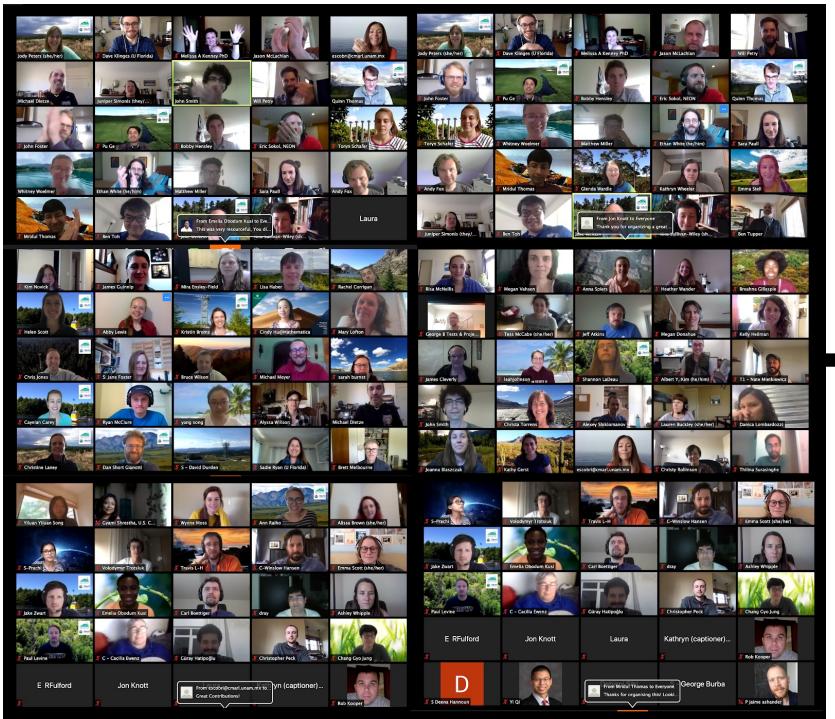
The goals of NEON are to:

- Enable understanding and forecasting of the impacts of climate change, land use change, and invasive species on aspects of continental-scale ecology such as biodiversity, biogeochemistry, infectious diseases, and ecohydrology
- Enable society and the scientific community to use ecological information and forecasts to understand and effectively address critical ecological questions and issues
- Provide physical and information infrastructure to support research, education, and land management.



# Community-designed

May 2020 Virtual Meeting



- Natural climate solutions
- Water quality
- Biodiversity conservation
- Infectious disease

# Challenge focal themes

**Temperature, oxygen, chl-a**

1 to 35-day ahead

34 sites

3-day latency



**Tick larvae abundance**

1 week to 1 year ahead

47 sites

6 month latency

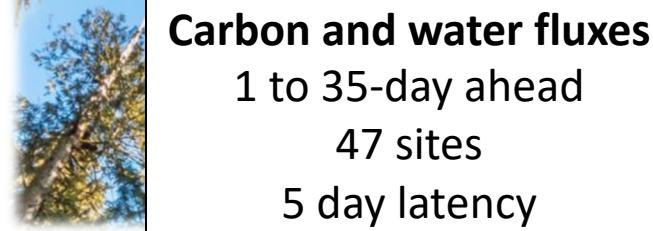


**Carbon and water fluxes**

1 to 35-day ahead

47 sites

5 day latency

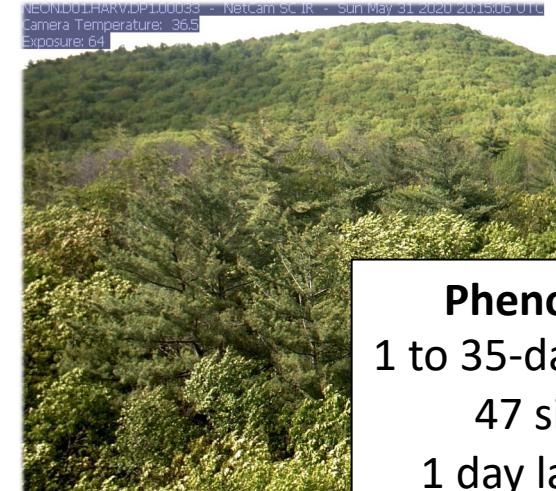


**Beetle community richness**

1 week to 1 year ahead

47 sites

6 month latency



**Phenology**

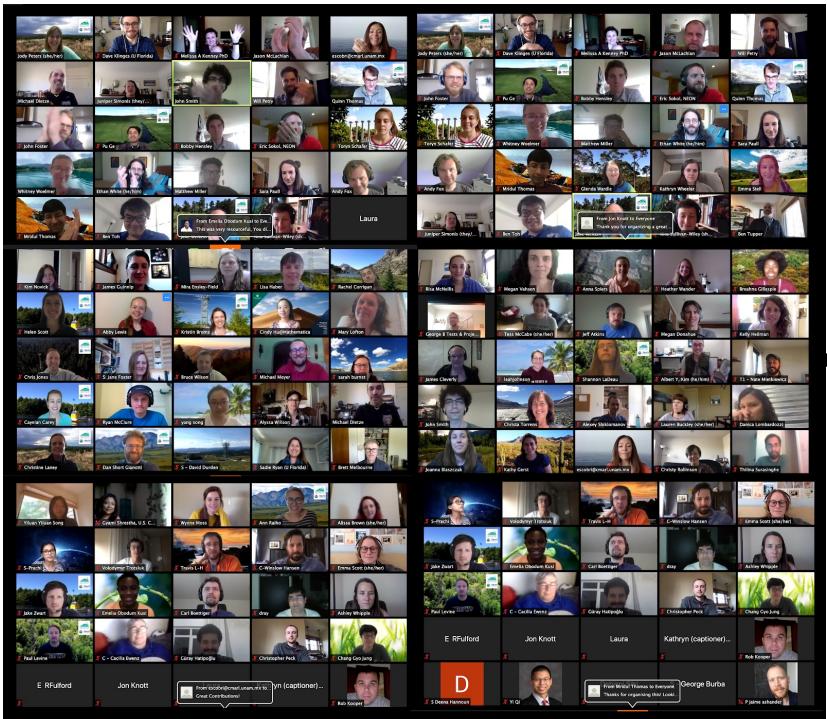
1 to 35-day ahead

47 sites

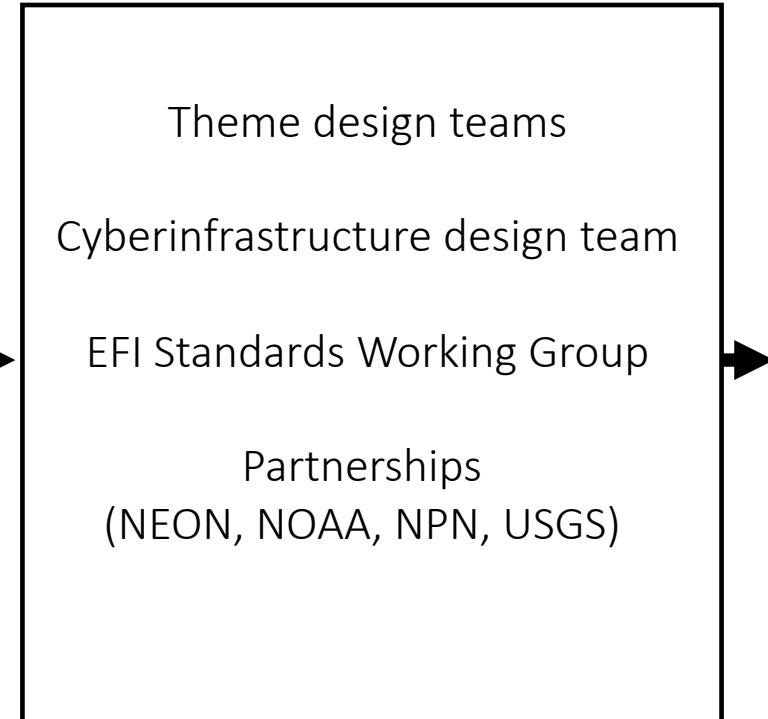
1 day latency

# Community-designed

## May 2020 Virtual Meeting



## Working groups



## 2021: Official Launch

The NSF funded EFI Research Coordination Network (EFI-RCN) is hosting a NEON Ecological Forecast Challenge with the goal to create a community of practice that builds capacity for ecological forecasting by leveraging [NEON data products](#). The Challenge revolves around the five theme areas listed below that span aquatic and terrestrial systems, and population, community, and ecosystem processes across a broad range of ecoregions that uses data collected by NEON.

As a community, we are excited to learn more about the predictability of ecological processes by forecasting NEON data prior to its release. What modeling frameworks, mechanistic processes, and statistical approaches best capture community, population, and ecosystem dynamics? These questions are answerable by a community generating a diverse array of forecasts. The Challenge is open to any individual or team that wants to submit forecasts and includes categories for different career stages. Individuals or team contacts can register to submit forecasts [HERE](#).

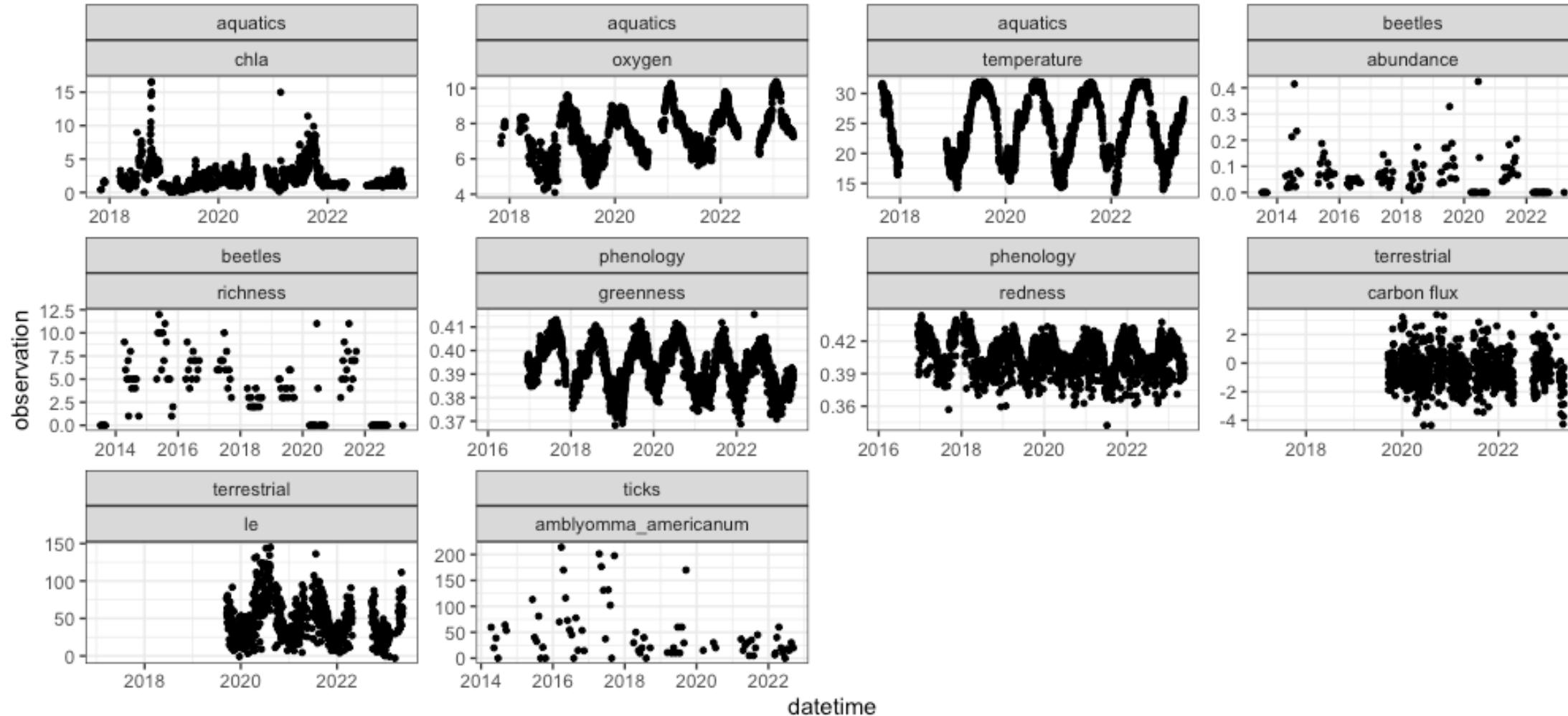
The design of the Challenge is the result of contributions of over 200 participants in the [May 2020 virtual EFI-RCN meeting](#), including partner organizations, and the hard work from the Design Teams that have developed the protocols for each of the themes.

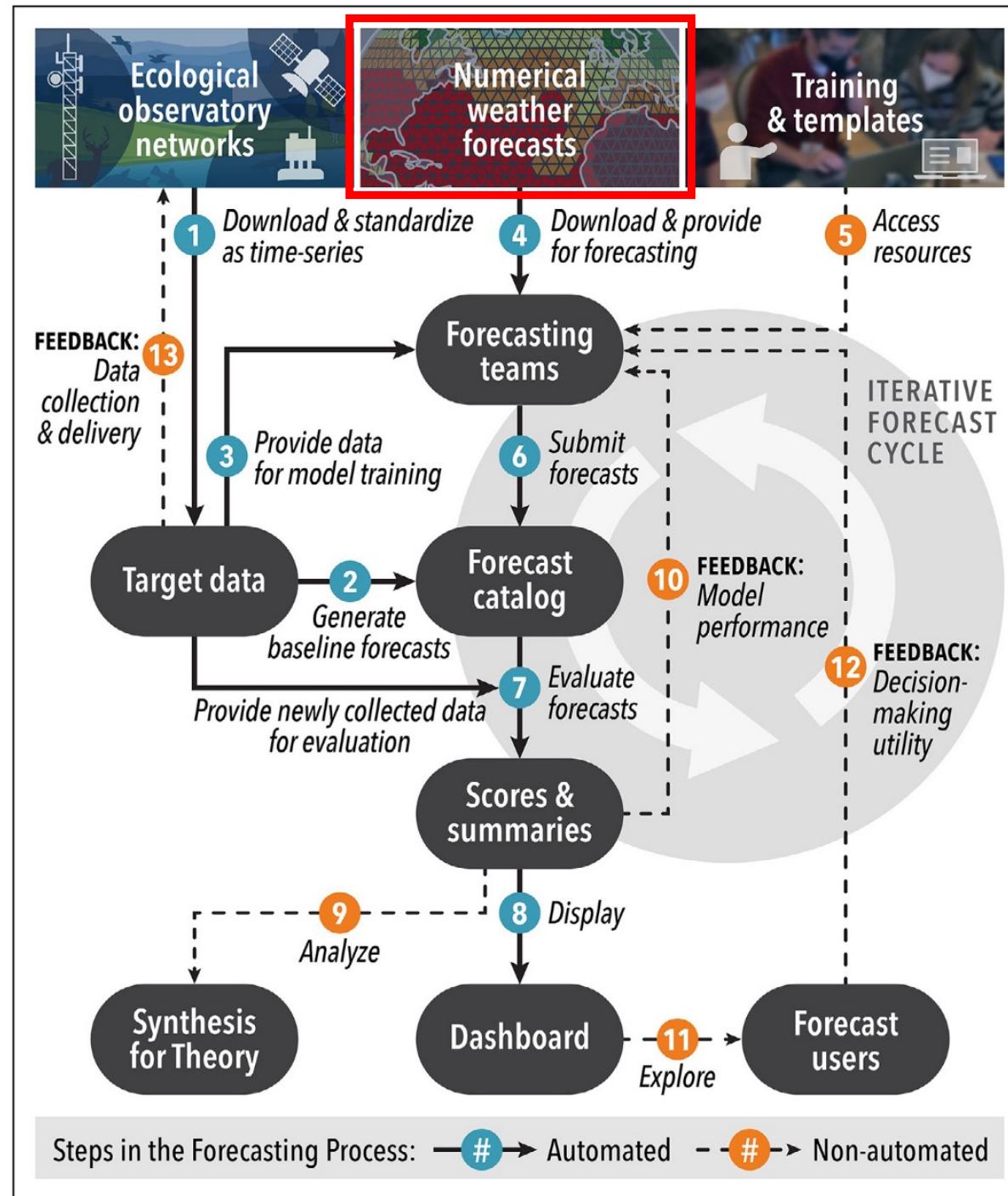
Computational resources are supported by NSF funded [CyVerse](#), [Jetstream](#), and [XSEDE](#).

### Year 1 Challenge Themes

- ▼ Aquatic Ecosystems
- ▼ Terrestrial Carbon and Water Fluxes

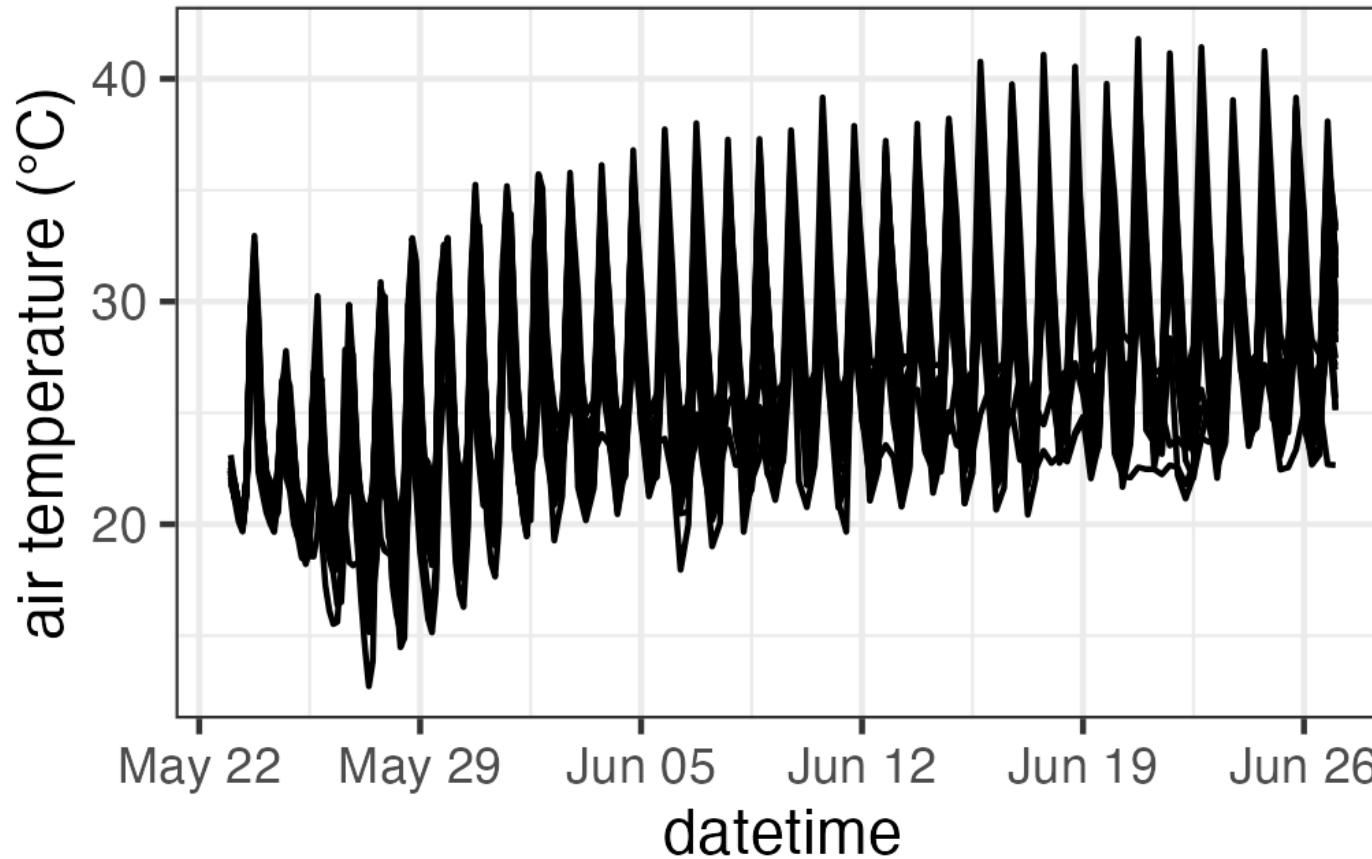
# Targets = automatically updating time series for training and evaluation

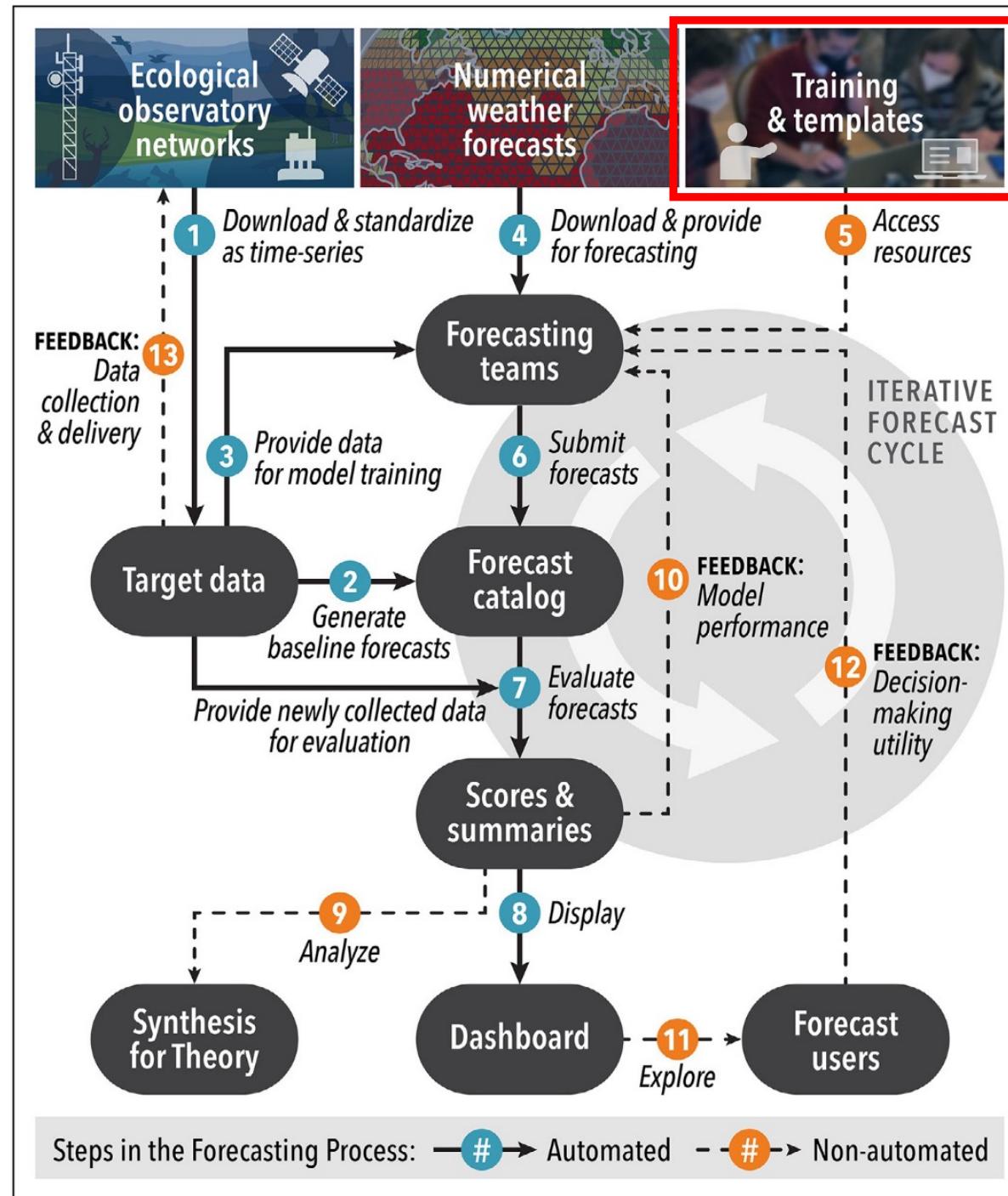




# 35-day ahead weather forecasts available in real-time for every NEON site

```
weather <- neon4cast::noaa_stage1(start_date = "2023-05-23") |>  
  filter(site_id == "BARC", variable == "TMP") |>  
  collect()
```





## Training sessions at meetings (GLEON, ESA, etc.)



Monday, Aug 7  
11:45 AM – 1:15 PM PDT

WK 3 - Can You Predict the Future? Introducing the NEON  
Ecological Forecasting Challenge

Organizer: Freya Olsson – Virginia Tech

Co-organizer: Quinn Thomas – Virginia Tech

Workshop

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## Excellent project in University courses (11 to date)

### CASE STUDY

#### The EFI-NEON Forecasting Challenge in the Classroom

August 12, 2022

Dozens of [individuals and teams](#) have participated in the Ecological Forecasting Initiative Research Coordination Network ([EFI-RCN](#))'s [NEON Ecological Forecasting Challenge](#), which challenges people to create ecological forecasts using data from the NEON program. If you have not had a chance to participate yet, don't worry: this initiative is ongoing. Educators across the country are using the Challenge with their undergraduate and graduate students. Some of them have shared their stories and strategies below.



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Workshop

## Templates and tutorial code

OlssonF / NEON-forecast-challenge-workshop Public Watch 1

Code Issues Pull requests Actions Projects Security Insights

main 1 branch 0 tags Go to file

OlssonF merge changes ... 0b59c51 on main

R update code for getting scores

.gitignore change repo

EFI-NEON\_challenge\_gloss... additional files for workshop

Get\_scores\_tutorial.Rmd Rmd for a basic tutorial to get scores

last month

## Excellent project in University courses (11 to date)

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<https://github.com/OlssonF/NEON-forecast-challenge-workshop>  
<https://github.com/eco4cast/neon4cast-example>

## Training sessions at meetings (GLEON, ESA, etc.)



Monday, Aug 7  
11:45 AM – 1:15 PM PDT

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Organizer: Freya Olsson – Virginia Tech

Co-organizer: Quinn Thomas – Virginia Tech

Workshop

## Templates and tutorial code

The screenshot shows a GitHub repository page for 'OlssonF/NEON-forecast-challenge-workshop'. The repository is public and has 1 watch. The main branch is 'main', and there is 1 branch and 0 tags. The last commit was made by 'OlssonF' on '0b59c51' and involved merging changes. Other commits include 'update code for getting scores', 'change repo', 'additional files for workshop', and 'Rmd for a basic tutorial to get scores'. A thumbnail image shows several people sitting around a table with laptops, presumably during a workshop.

<https://github.com/OlssonF/NEON-forecast-challenge-workshop>  
<https://github.com/eco4cast/neon4cast-example>

## Excellent project in University courses (11 to date)

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## Broadening participation

## Ecology and Evolution

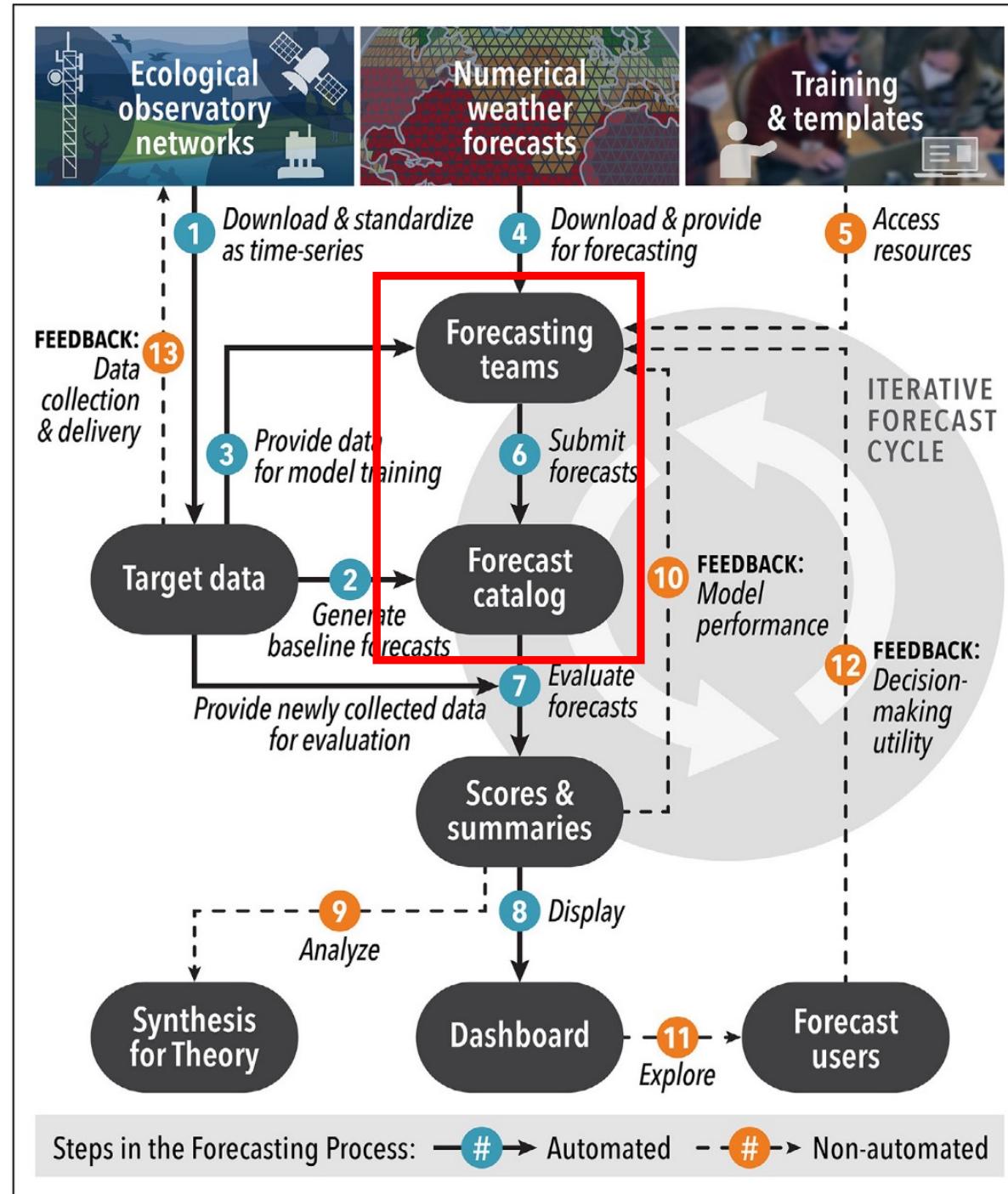
Open Access

ACADEMIC PRACTICE IN ECOLOGY AND EVOLUTION | [Open Access](#) | [CC](#) [i](#) [J](#)

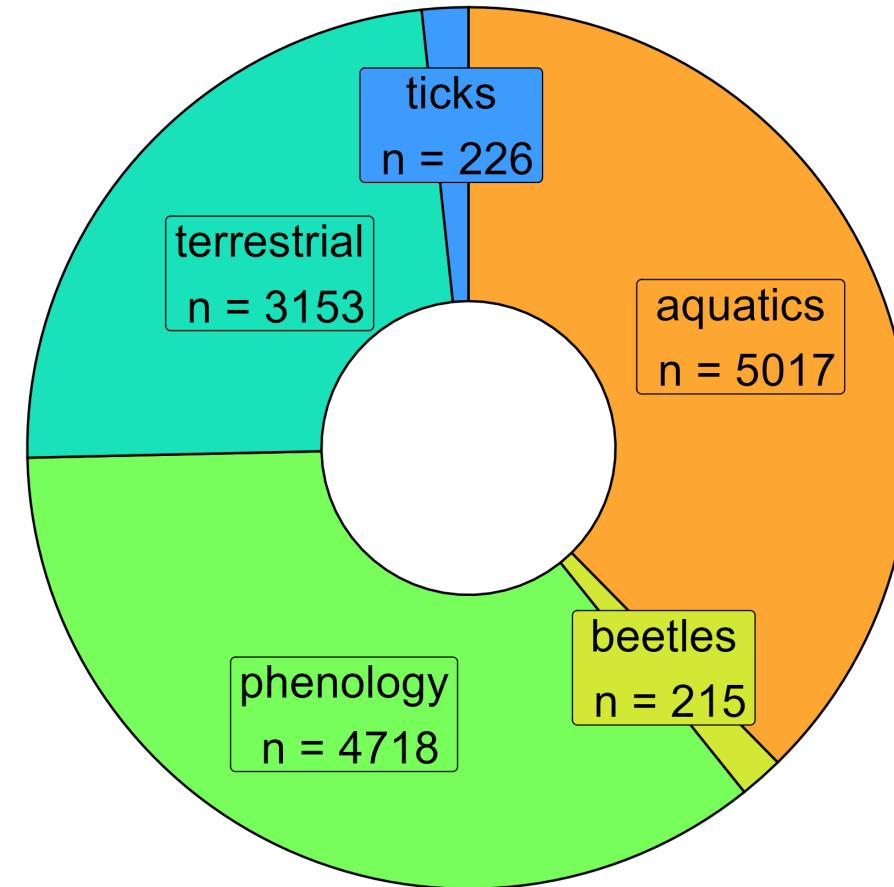
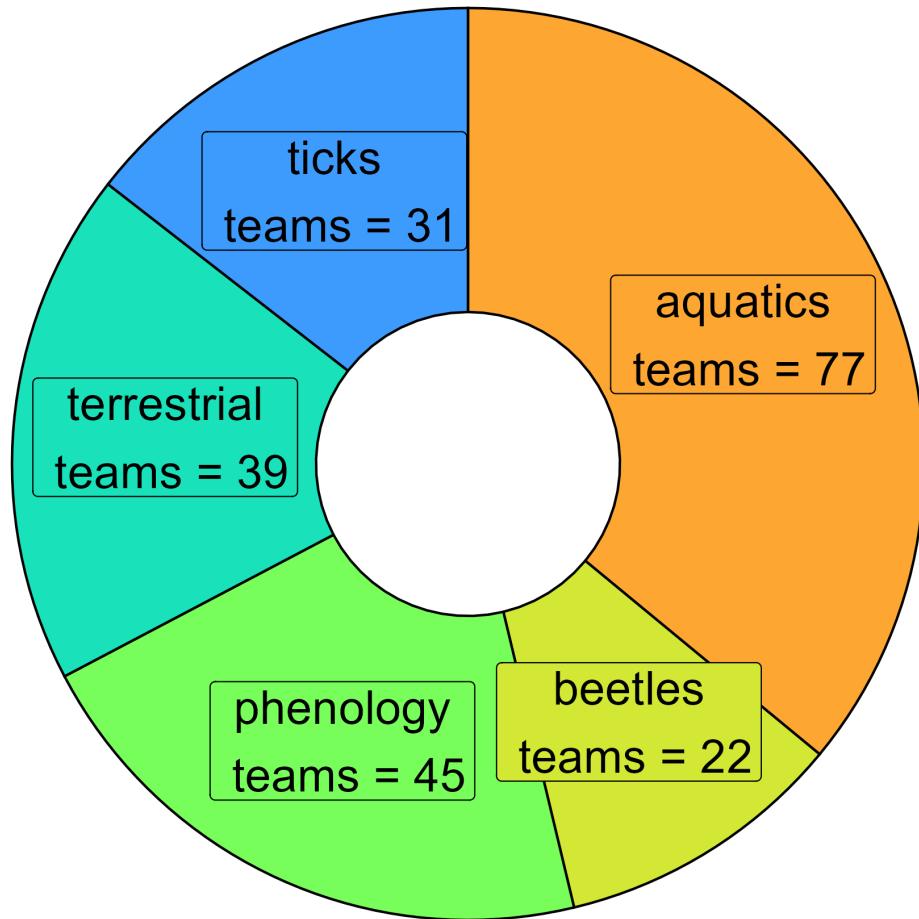
### Assessing opportunities and inequities in undergraduate ecological forecasting education

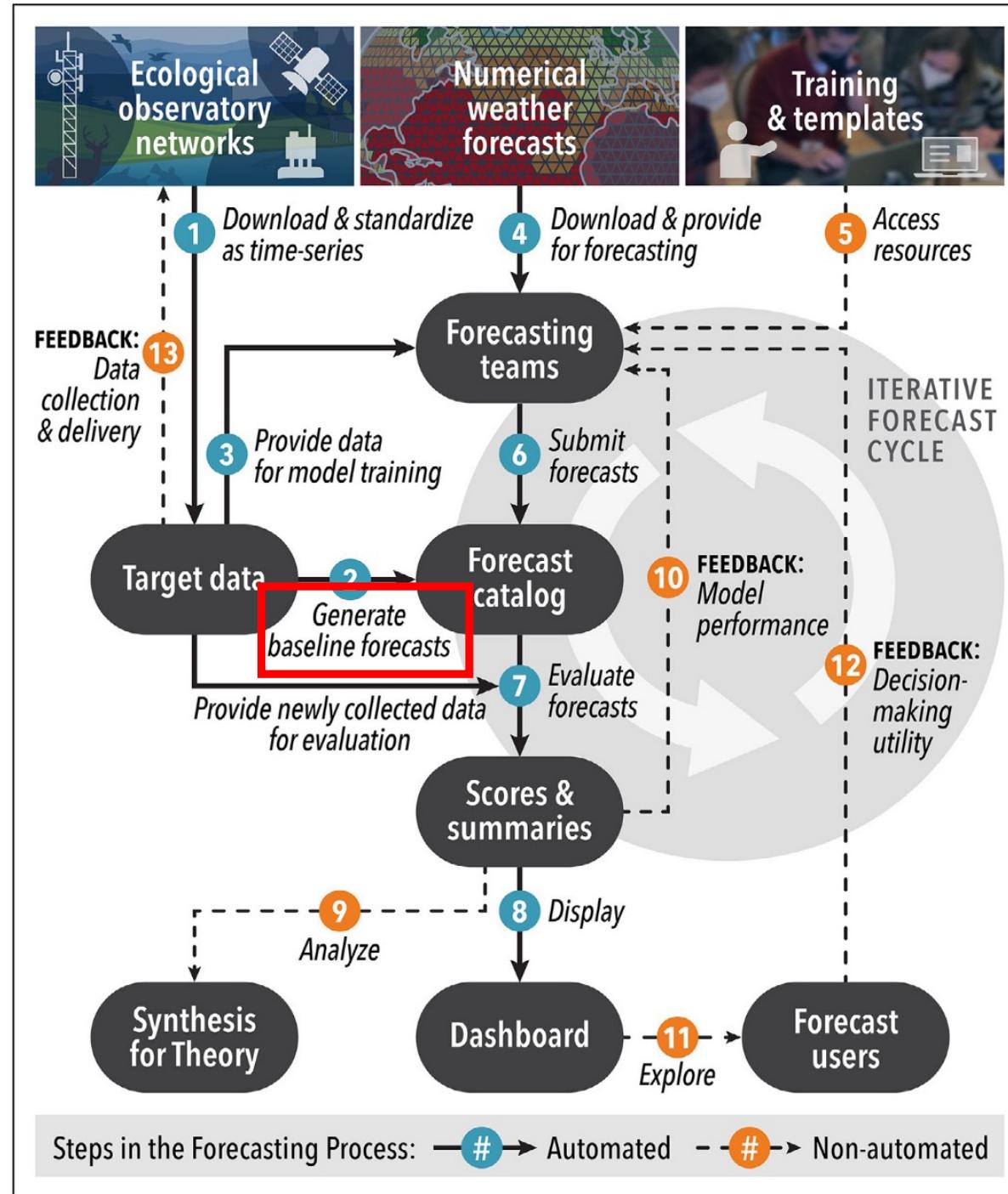
Alyssa M. Willson Hayden Gallo, Jody A. Peters, Antoinette Abeyta, Nievita Bueno Watts, Cayelan C. Carey, Tadhg N. Moore, Georgia Smies, R. Quinn Thomas, Whitney M. Woelmer, Jason S. McLachlan ... [See fewer authors](#) ^

Willson et al. 2023 Ecology and Evolution



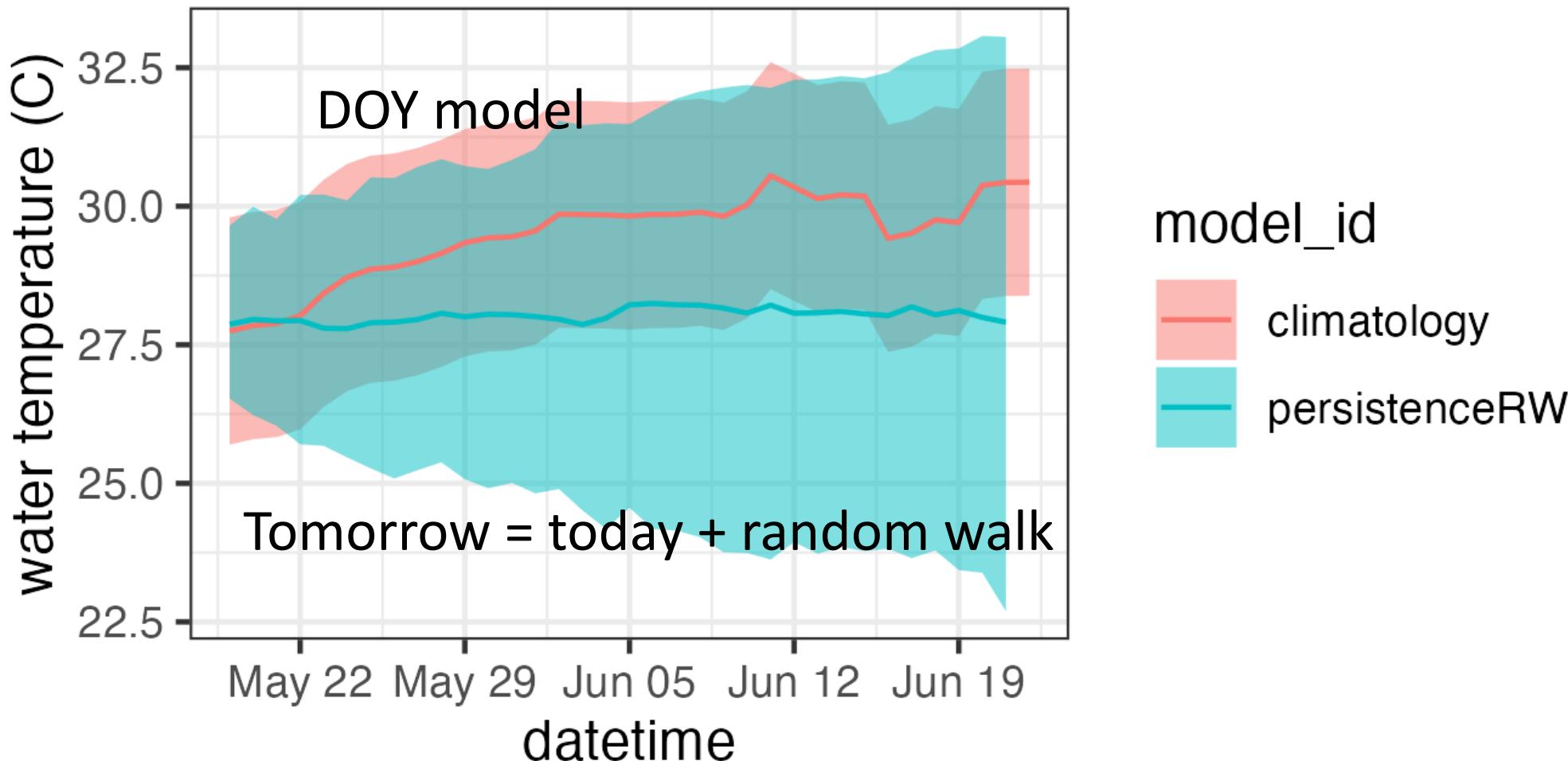
# 214 teams have submitted 13,329 forecasts

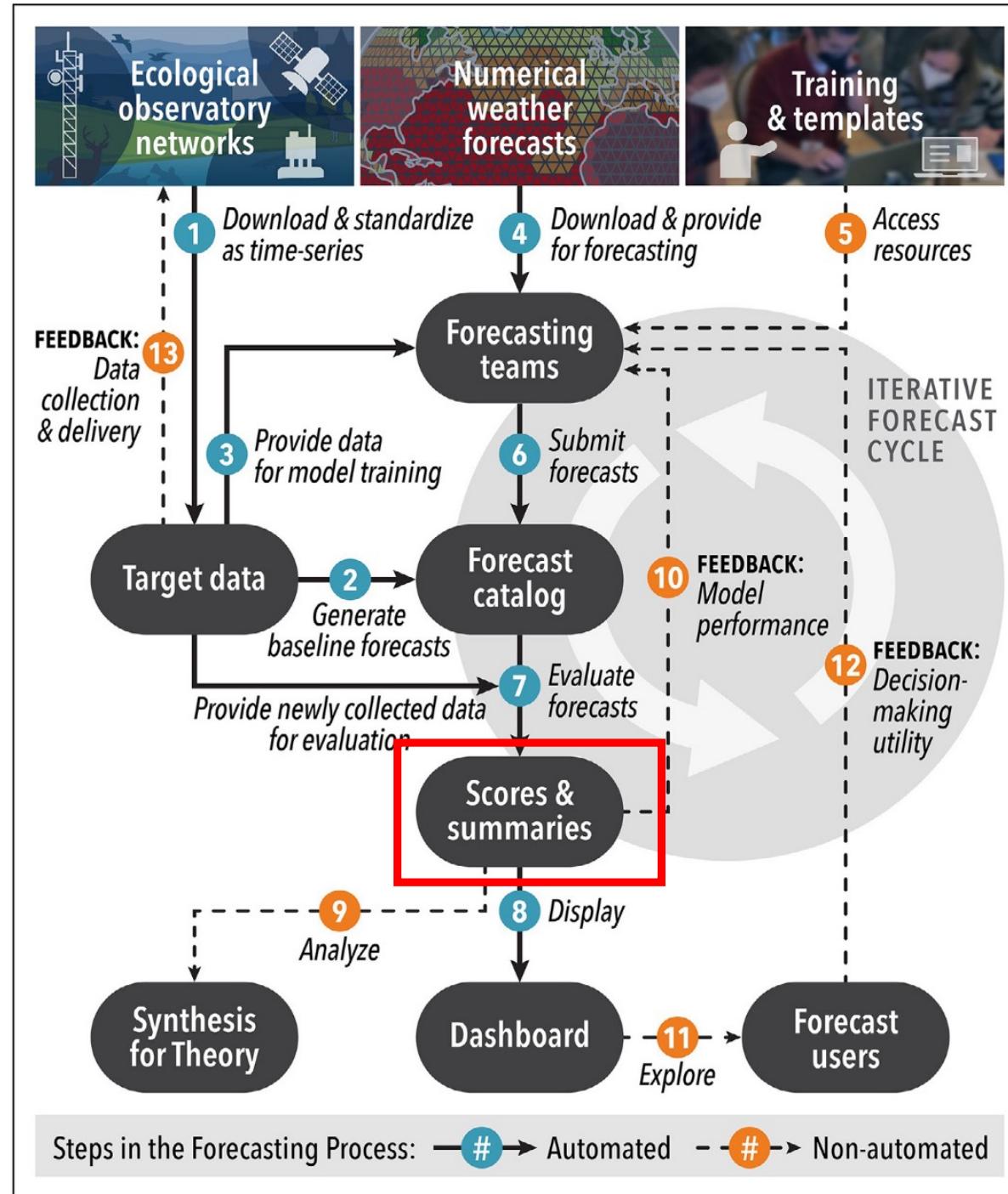




# Simple baseline models

## Water Temperature forecast: BARC

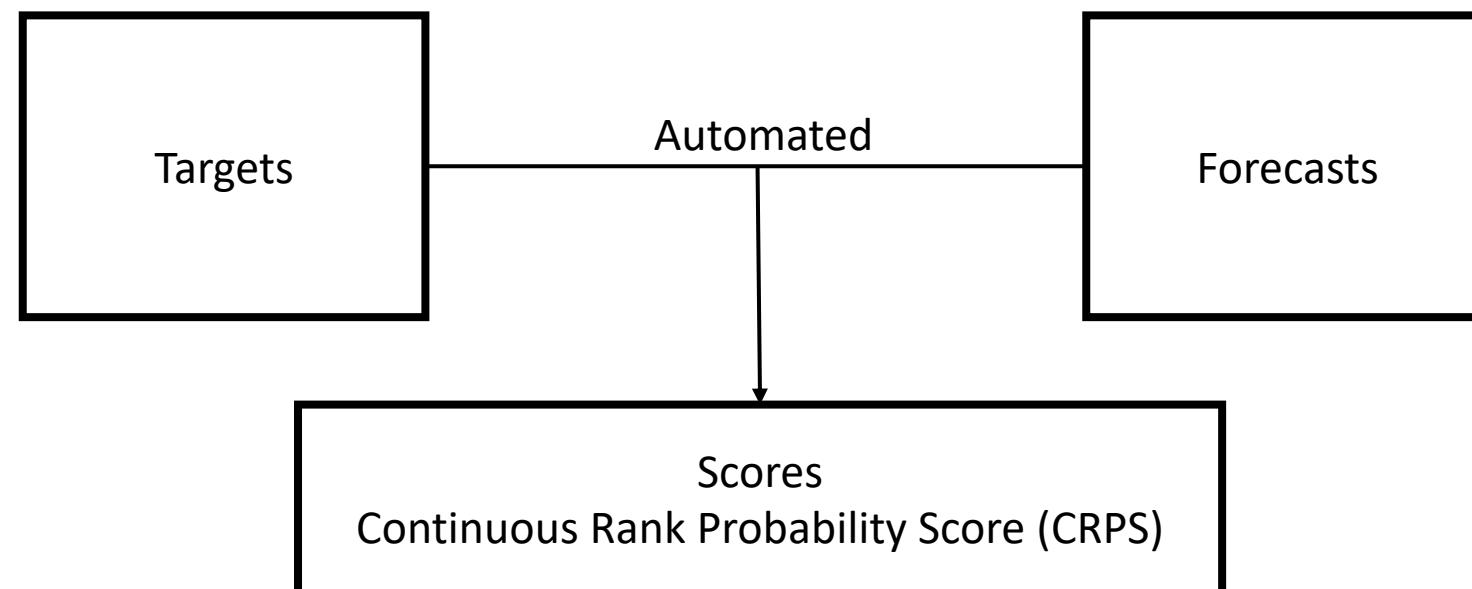




# A Community Convention for Ecological Forecasting: Output Files and Metadata

**AUTHORS**

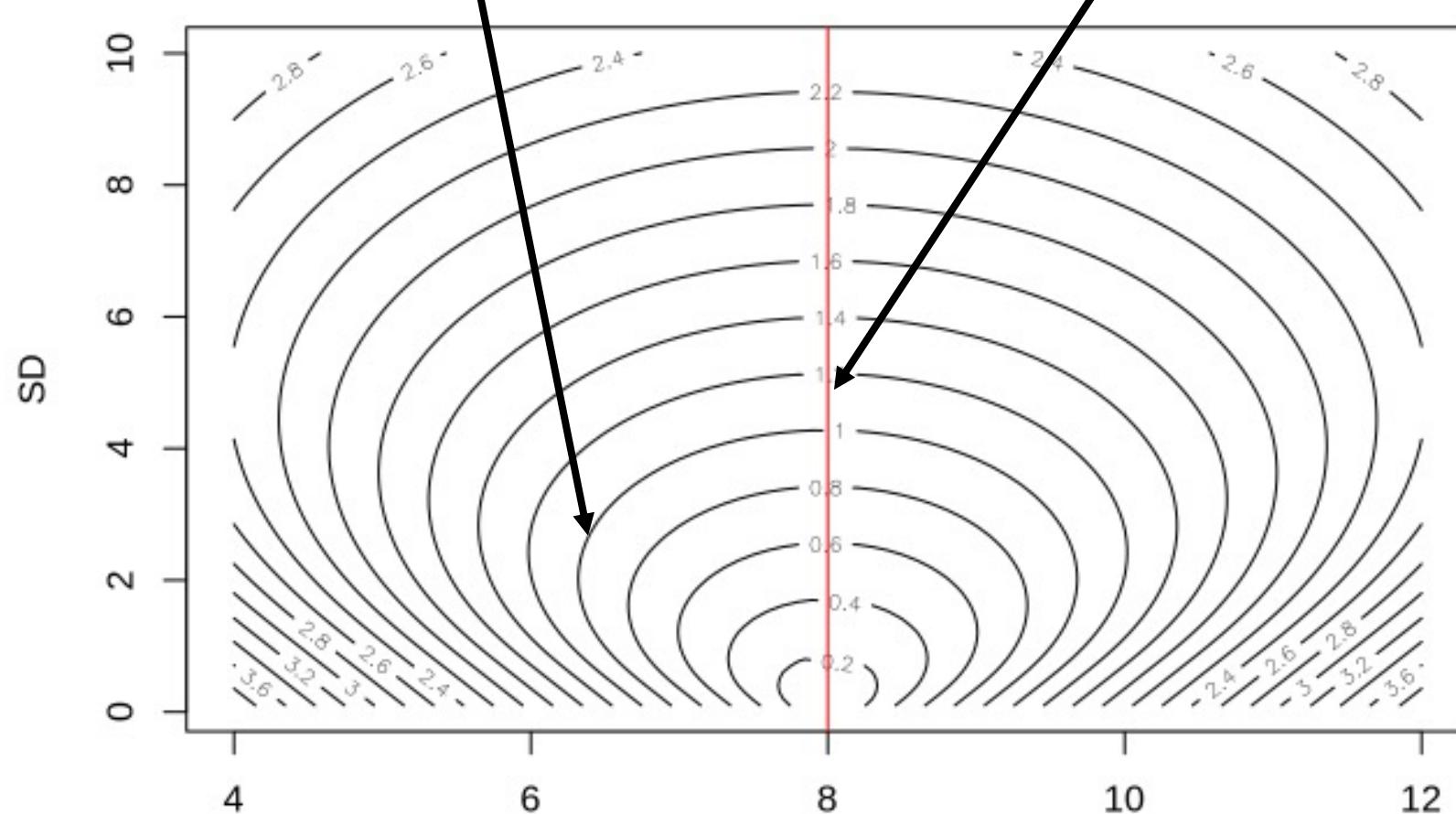
Michael Dietze, R. Quinn Thomas, Jody Peters, Carl Boettiger, Alexey N Shiklomanov, Jaime Ashander

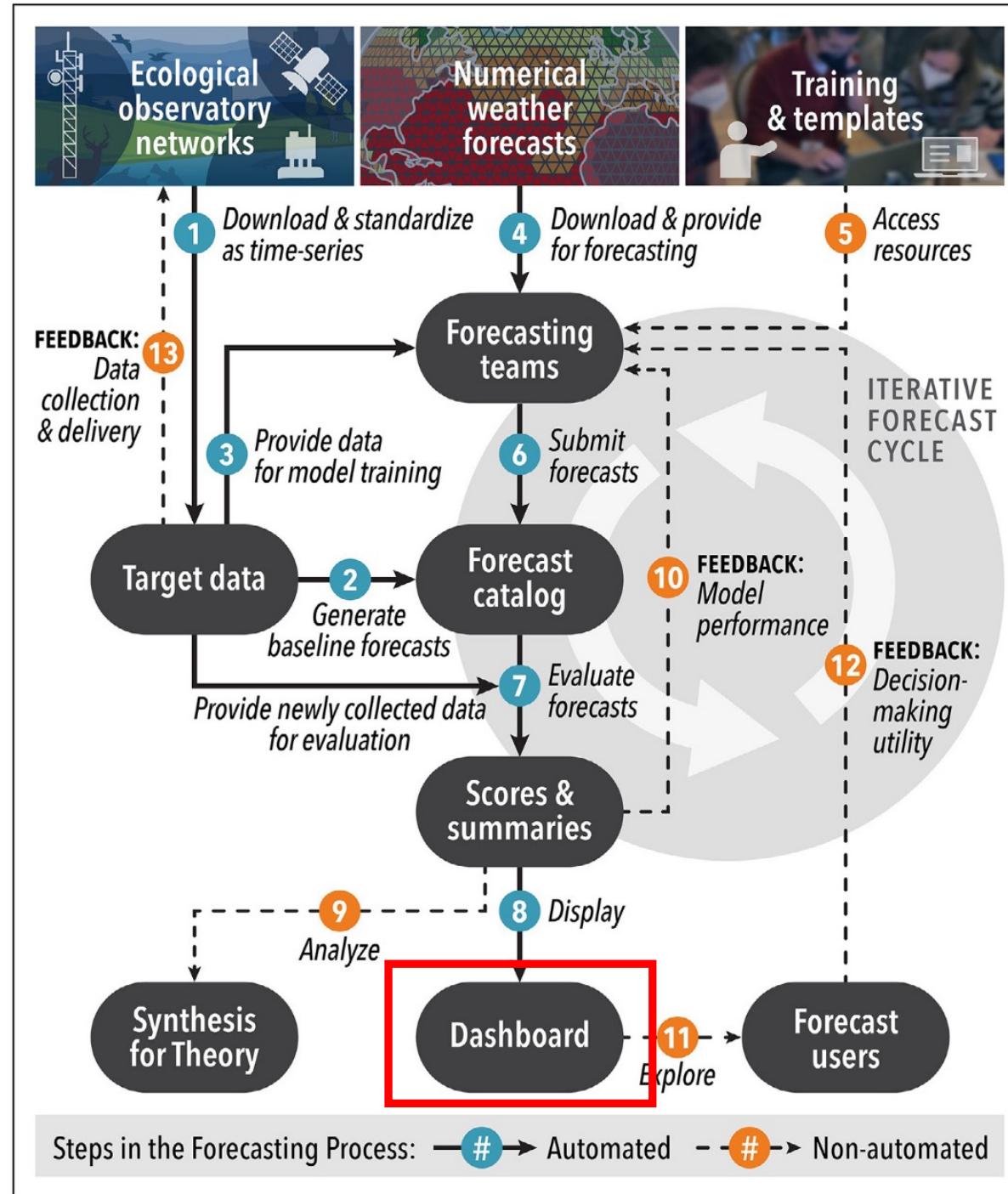


# Scoring emphasizes robust uncertainty estimation

Continuous Rank Probability Score (CRPS)

[Bias of 1.5 and standard deviation of 2] = [Bias of 0 and standard deviation of 4]





# Real-time analysis of submissions

EFI NEON Challenge    Phenology    Aquatics    Terrestrial    Ticks    Beetles    Weather    Status   

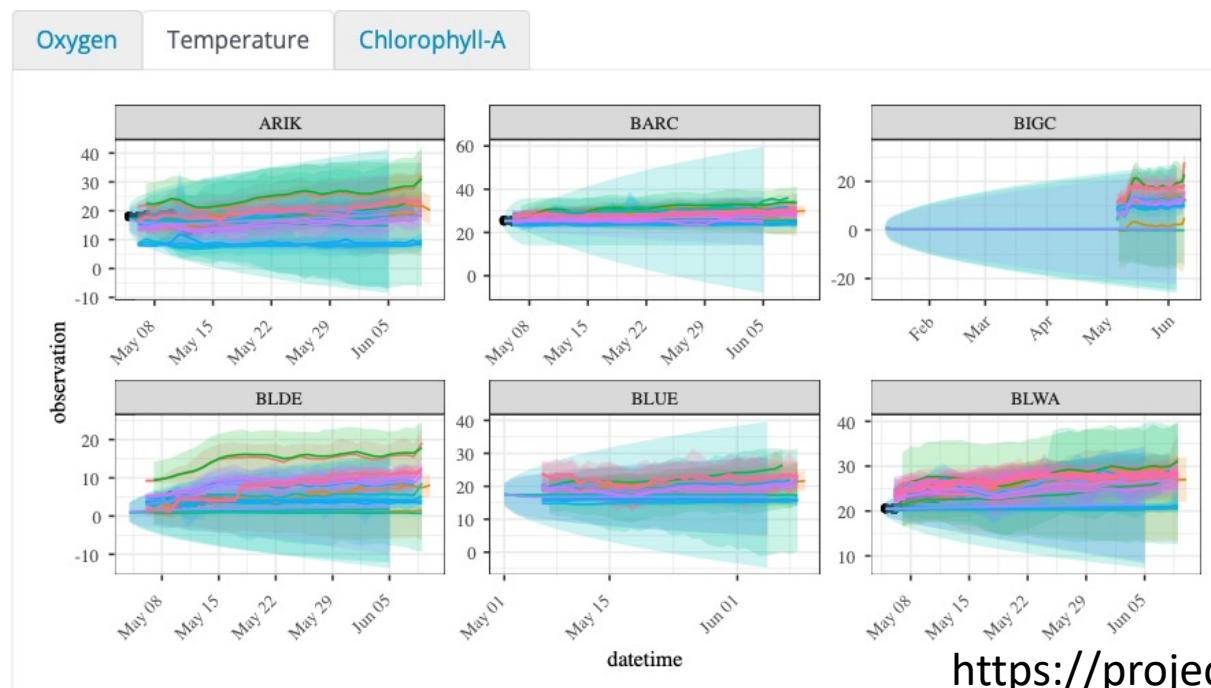
## Aquatics



### Most recent forecasts

Below is the forecasts submitted on the date indicated below. Updates daily, selected to show forecasts for which at least some observational data has since been collected. Mouse over to see the team id, scroll to zoom.

[1] "2023-05-06"



On this page

[Most recent forecasts](#)

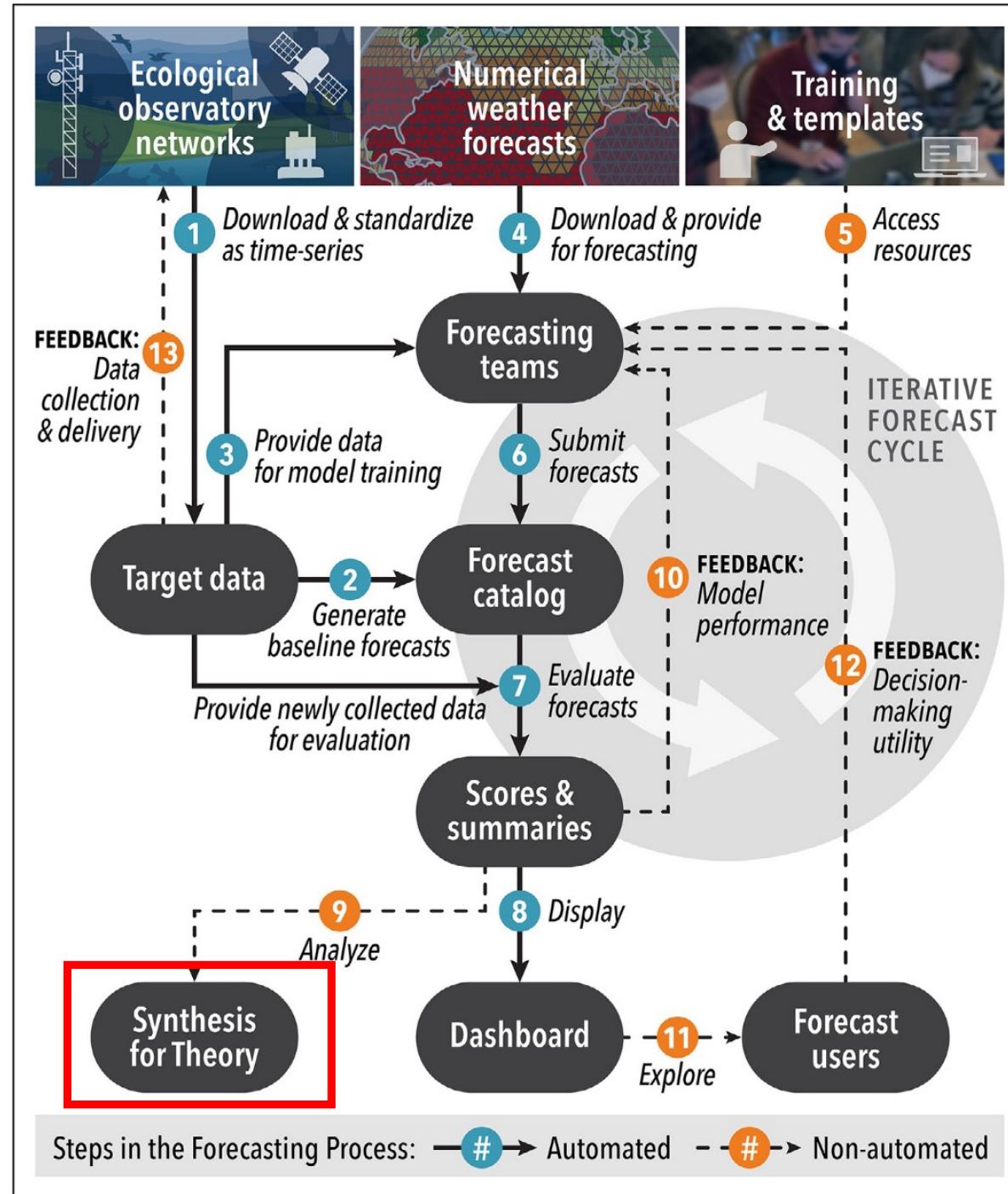
[Leaderboard](#)

[Submission statistics](#)

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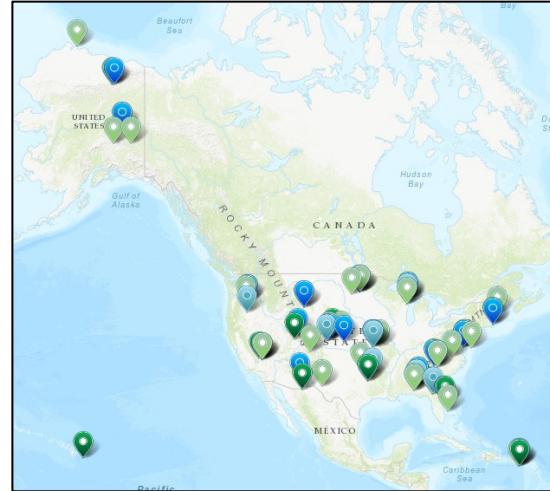


# Building towards a synthetic analysis

Ecological system



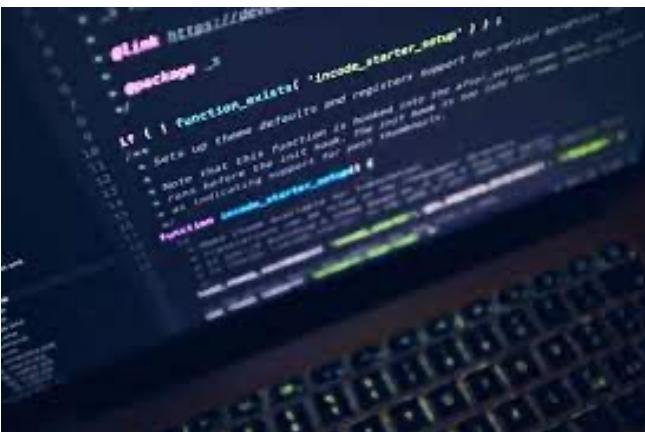
Site



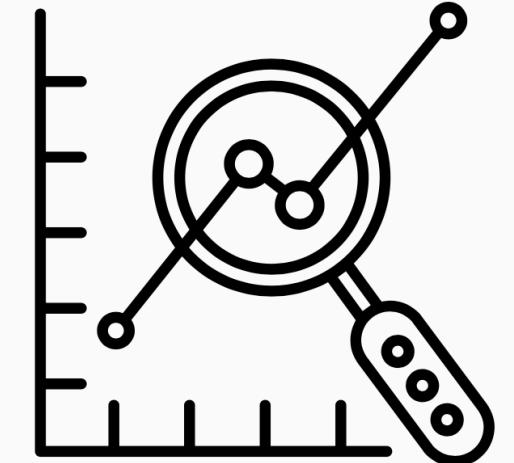
Time of year



Modeling approach

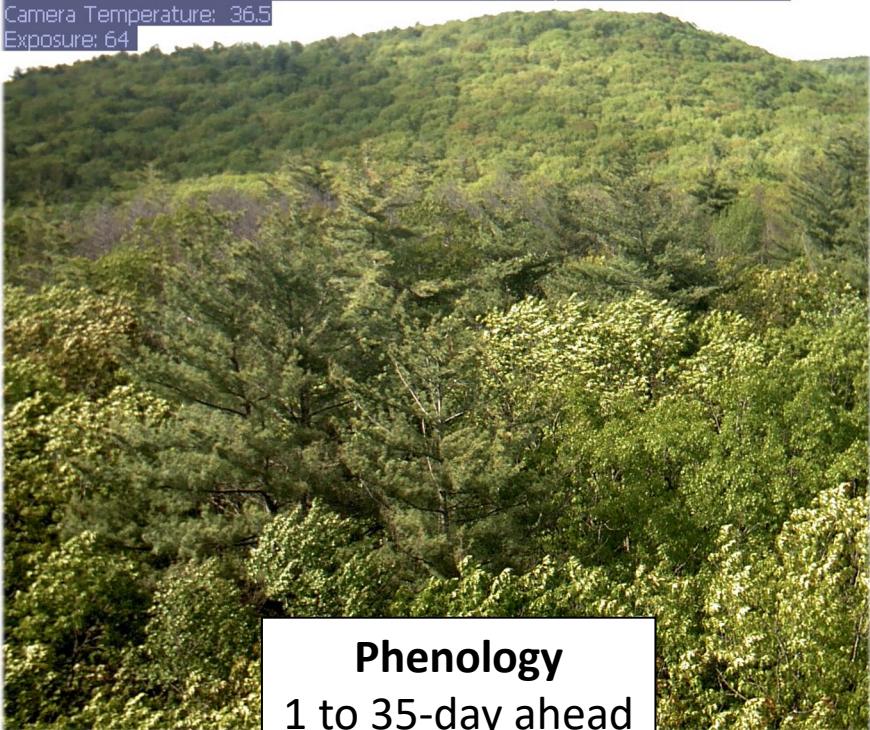


Number of days in future

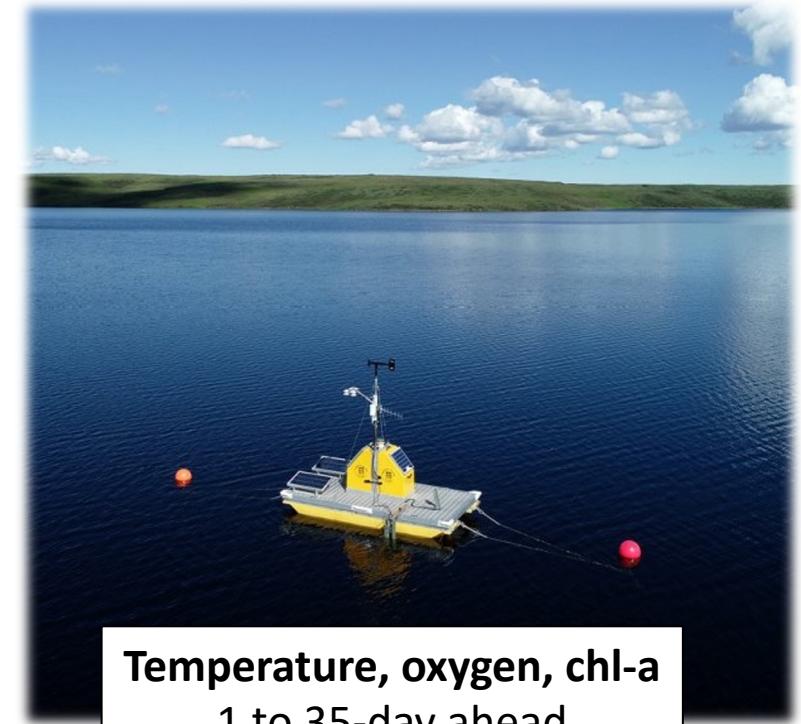


# Challenge focal themes

NEON.D01.HARV.DP1.00033 - NetCam SC IR - Sun May 31 2020 20:15:06 UTC  
Camera Temperature: 36.5  
Exposure: 64



**Phenology**  
1 to 35-day ahead  
47 sites  
1 day latency



**Temperature, oxygen, chl-a**  
1 to 35-day ahead  
34 sites  
3-day latency



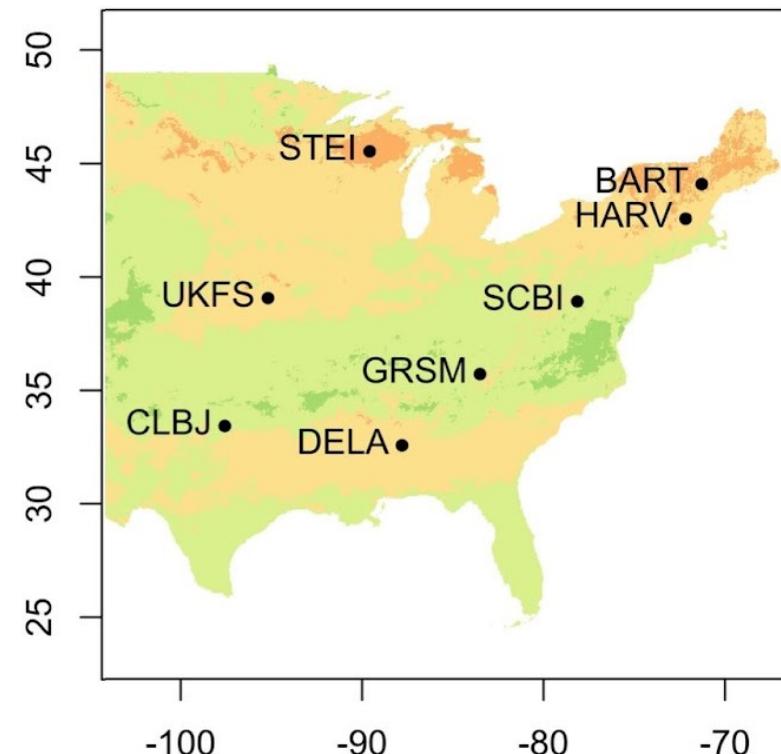
# Predicting Spring Phenology in Deciduous Broadleaf Forests: An Open Community Forecast Challenge

67 Pages • Posted: 13 Feb 2023

Kathryn Wheeler

Boston University; University Corporation for Atmospheric Research; Massachusetts Institute of Technology (MIT)

M. Dietze, D. LeBauer, J. Peters, A.D. Richardson, R.Q. Thomas, K. Zhu, U. Bhat, S. Munch, R.F Buzbee, M. Chen, B. Goldstein, J.S. Guo, D. Hao, C. Jones, M. Kelly-Fair, H. Liu, C. Malmborg, N. Neupane. D. Pal, A. Ross, V. Shirey, Y. Song, M. Steen, E.A. Vance, W.M. Woelmer, J. Wynne and L. Zachmann.





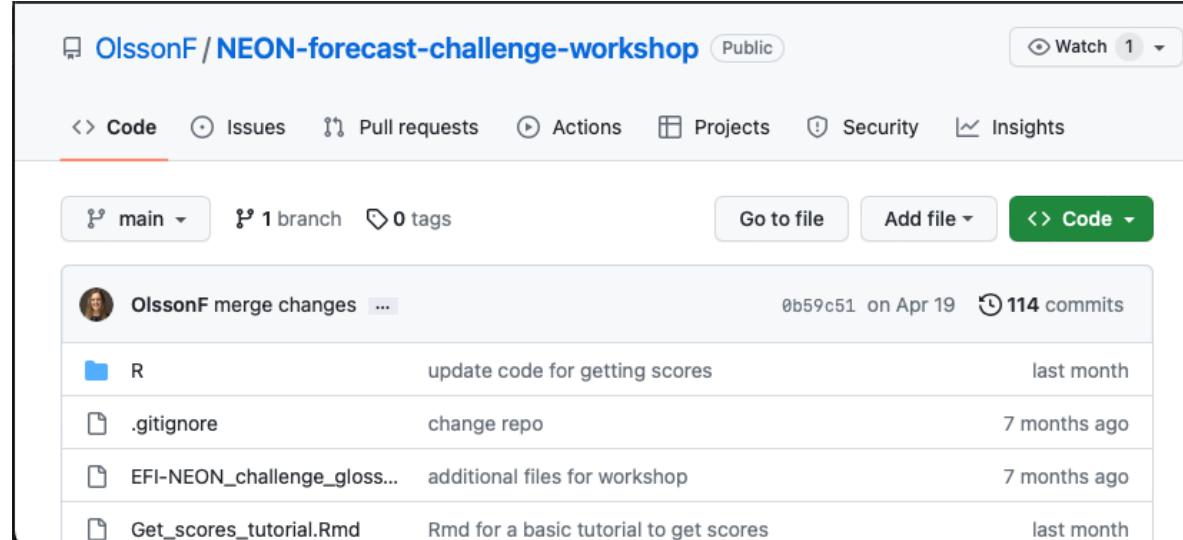
220 RESEARCH COMMUNICATIONS

## Near-term forecasts of NEON lakes reveal gradients of environmental predictability across the US

R Quinn Thomas<sup>1,2\*</sup>, Ryan P McClure<sup>2</sup>, Tadhg N Moore<sup>1,2</sup>, Whitney M Woelmer<sup>1</sup>, Carl Boettiger<sup>3</sup>, Renato J Figueiredo<sup>4</sup>, Robert T Hensley<sup>5</sup>, and Cayelan C Carey<sup>2</sup>

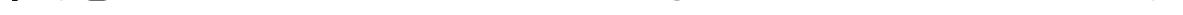
*Front Ecol Environ* 2023; 21(5): 220–226, doi:10.1002/fee.2623

# Growing the number of contributions

OlssonF / NEON-forecast-challenge-workshop (Public)

Code Issues Pull requests Actions Projects Security Insights

main 1 branch 0 tags Go to file Add file Code

OlssonF merge changes ... 0b59c51 on Apr 19 114 commits

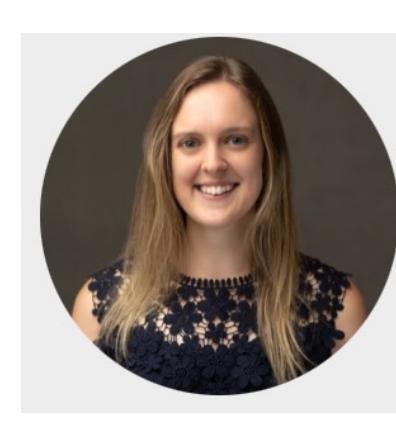
R update code for getting scores last month

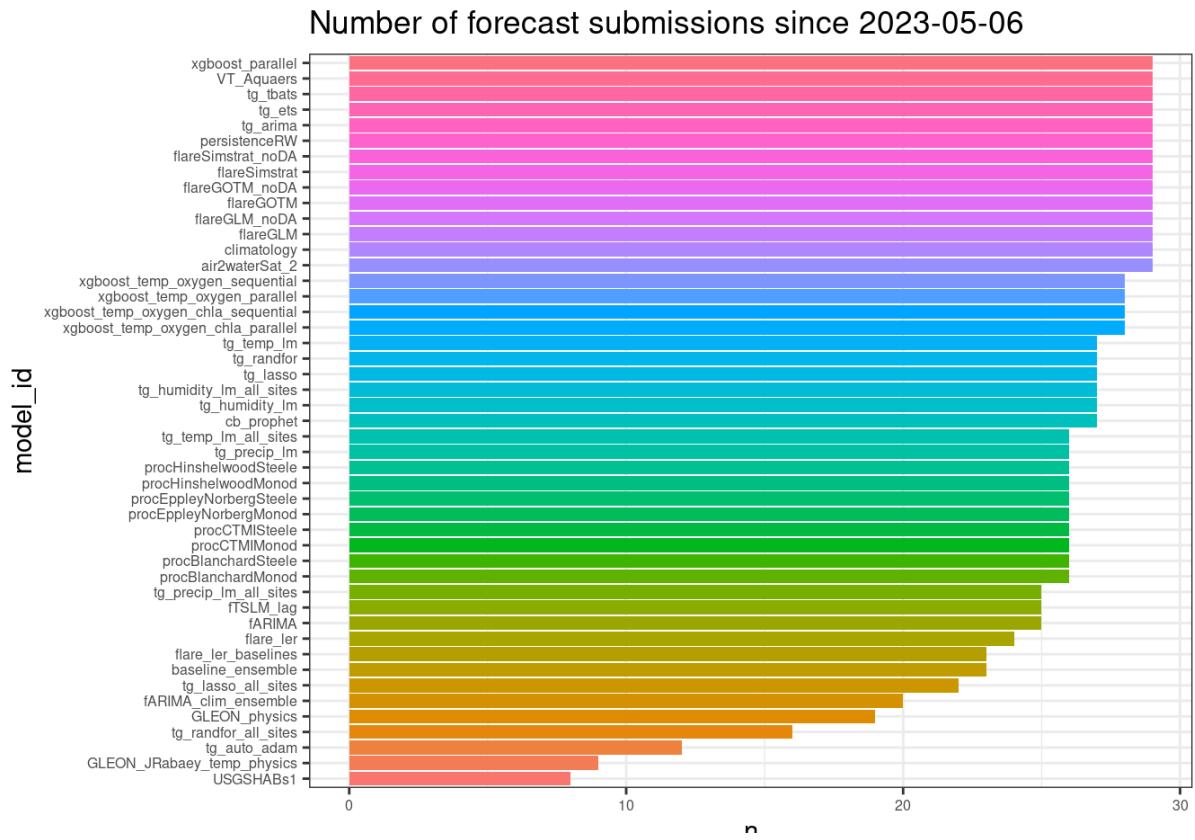
.gitignore change repo 7 months ago

EFI-NEON\_challenge\_gloss... additional files for workshop 7 months ago

Get\_scores\_tutorial.Rmd Rmd for a basic tutorial to get scores last month

A photograph showing several people sitting around a round table in a room with stone walls and large windows. They are looking at laptops and discussing something.

A circular portrait of a woman with long blonde hair, smiling.



Led by Freya Olsson

# Growing the number of contributions

Received: 15 April 2022 | Accepted: 5 July 2022

DOI: 10.1111/2041-210X.13955

Methods in Ecology and Evolution  
BRITISH ECOLOGICAL SOCIETY

PERSPECTIVE

Methods in ecological forecasting

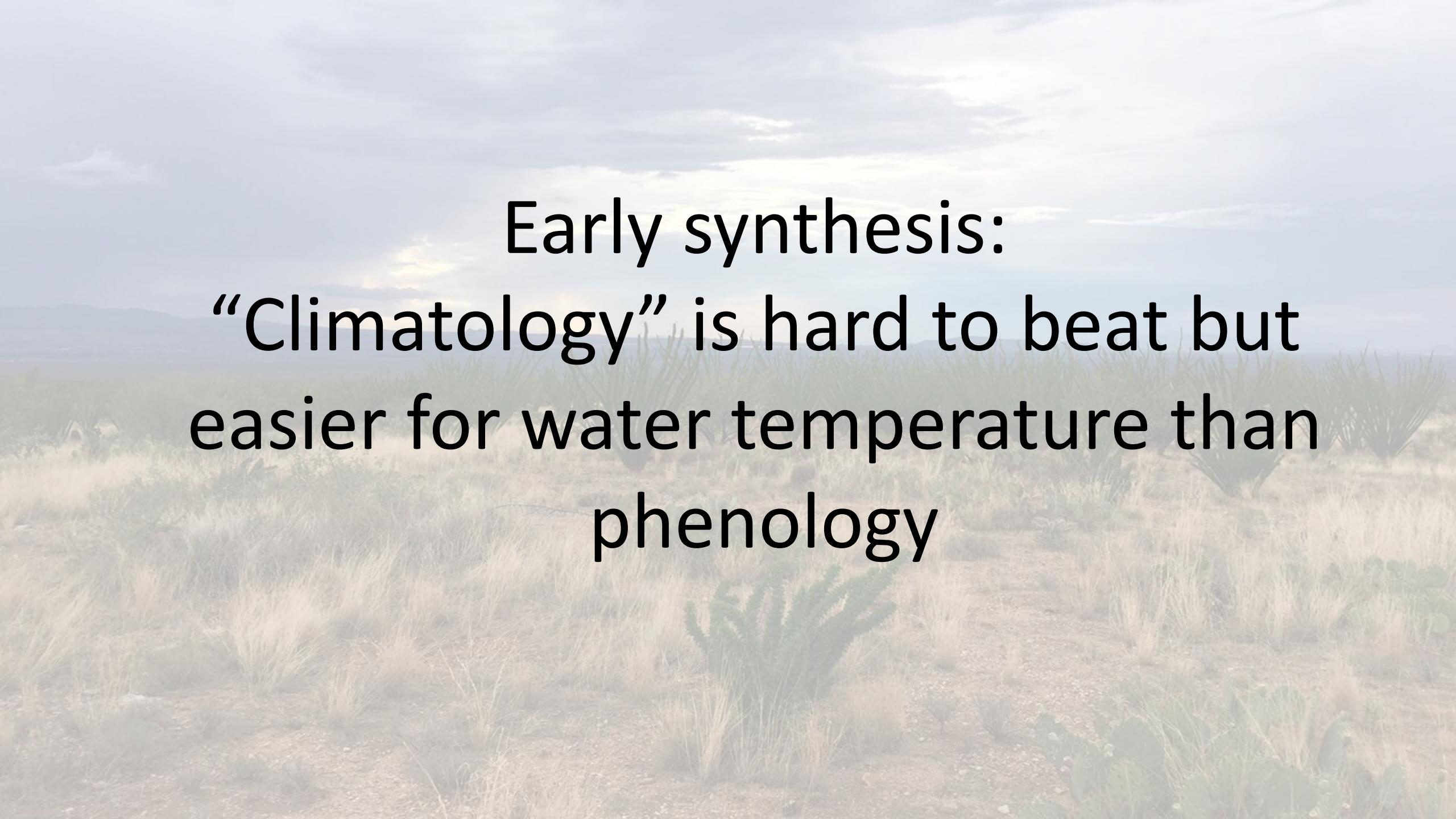
## The power of forecasts to advance ecological theory

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Gerbrand Koren<sup>12</sup>  | Daniel J. McGlinn<sup>13</sup>  | Hassan Moustahfid<sup>14</sup>  |  
Jody A. Peters<sup>15</sup>  | Nicholas R. Record<sup>16</sup>  | Caleb J. Robbins<sup>17</sup>  |  
Jonathan Tonkin<sup>18,19,20</sup>  | Glenda M. Wardle<sup>21</sup> 

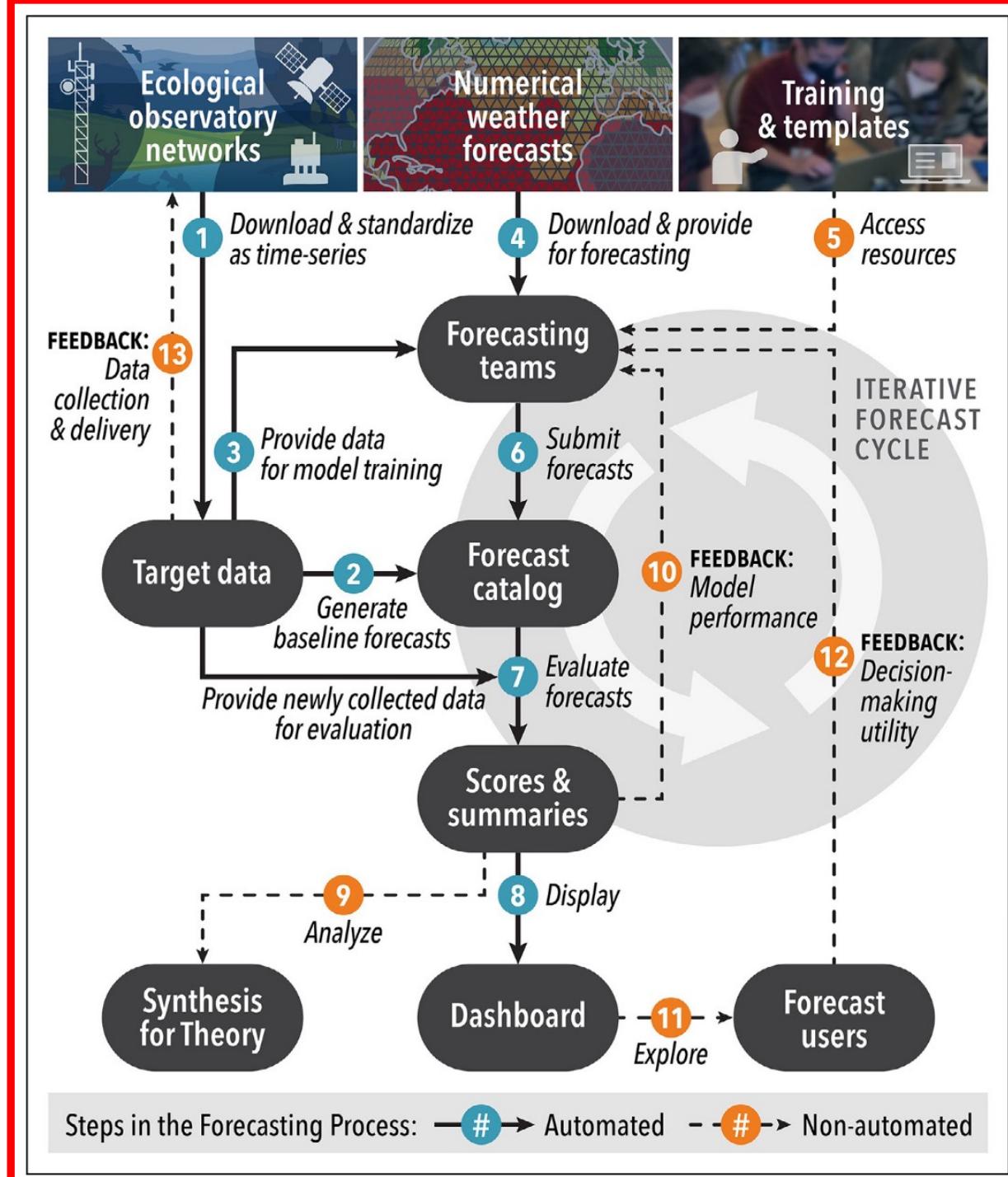
3 | FORECAST TRANSFERABILITY  
EVALUATES THE GENERALITY OF  
ECOLOGICAL FUNCTION ACROSS  
LOCATIONS, VARIABLES AND SCALES



Same models across  
all themes



Early synthesis:  
“Climatology” is hard to beat but  
easier for water temperature than  
phenology



# Thanks!

## How to get involved:

- Join EFI ([eco4cast.org](http://eco4cast.org))
- Submit forecasts ([neon4cast.org](http://neon4cast.org))
- Use Challenge in class



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Funded by the National Science Foundation

DEB-1926388, DEB-1926388, CNS-1737424, DBI-1933016, DBI-1933102, DBI-1942280, and DEB-1926050

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