Ecological forecasting to anticipate ecological responses to environmental stressors

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College of Natural Resources and Environment

VIRGINIA TECH™

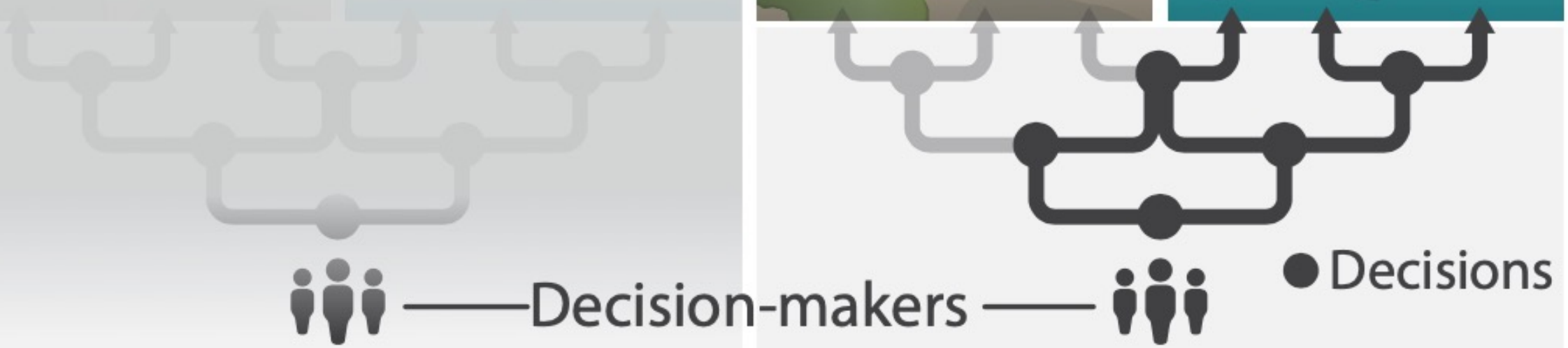
29 July 2021

National Academies of Sciences, Engineering and Medicine

Expertise

- Principal Investigator of NSF-funded Ecological Forecasting Initiative Research Coordination Network
- Develop nationally used training modules in ecological forecasting
- Research on forest demographic responses to nitrogen and sulfur deposition is informing the “Integrated Science Assessment for Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter - Ecological Criteria” by the U.S. Environmental Protection Agency (EPA).

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



Uninformed decisions

Informed decisions

EPA works to **ensure** that:

- Americans have clean air, land and water;
- National efforts to reduce environmental risks are based on the **best available scientific information**;

https://www.epa.gov/aboutepa/our-mission-and-what-we-do

Involves developing forecasts

EPA works to **ensure** that:

- Americans have clean air, land and water;
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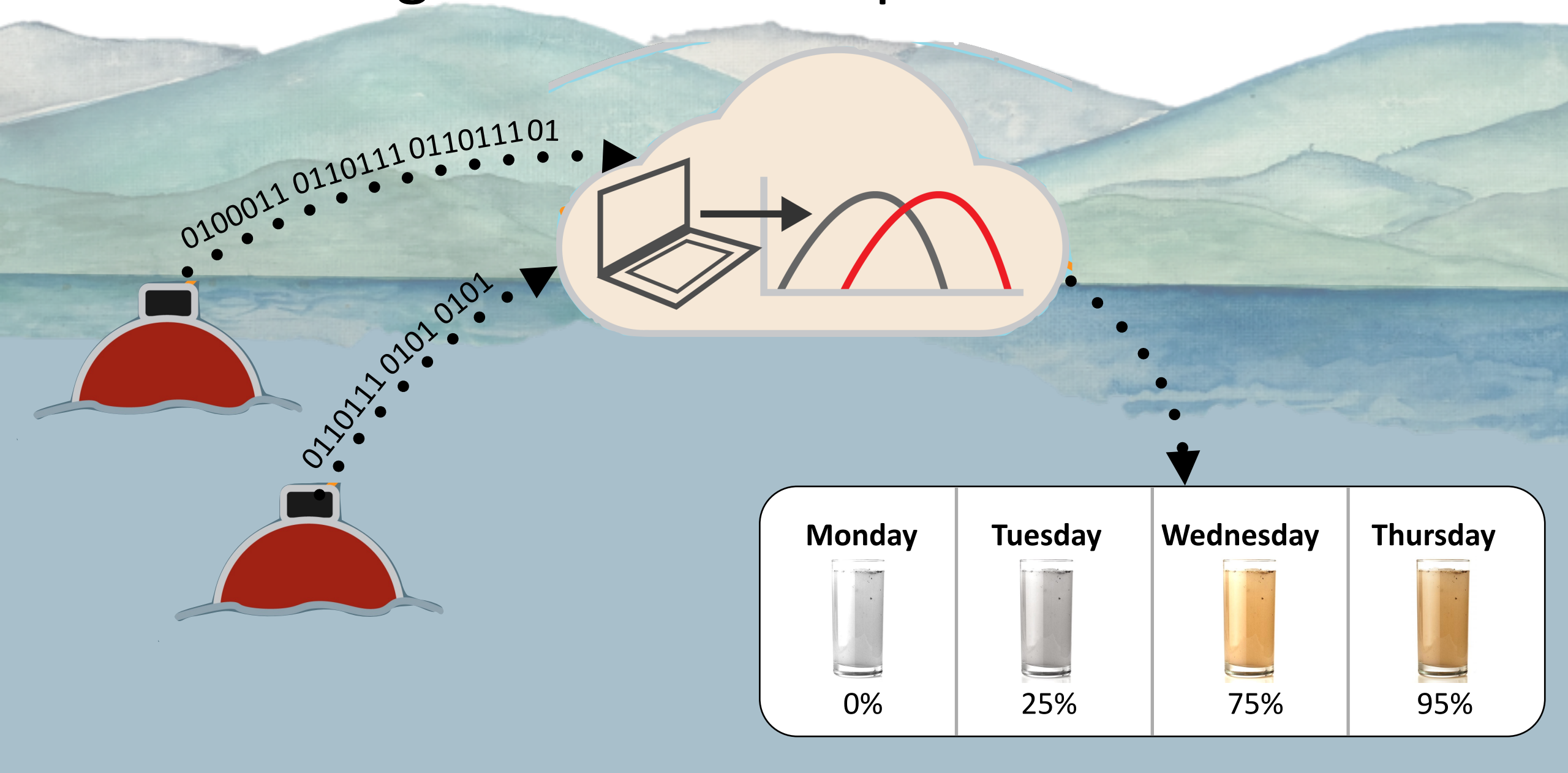
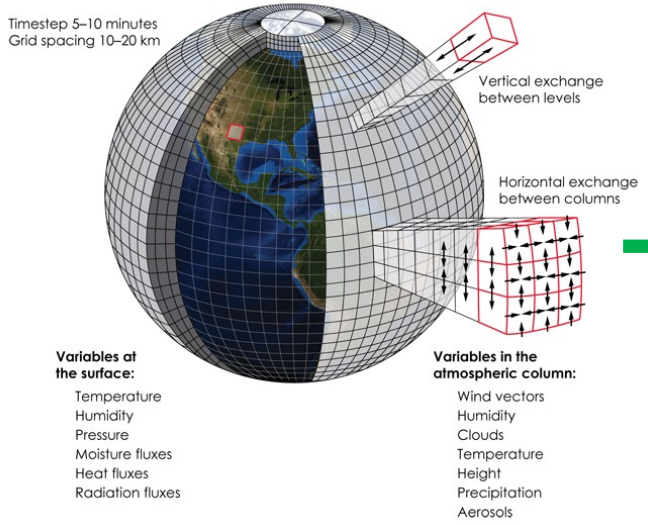
https://www.epa.gov/aboutepa/our-mission-and-what-we-do

Predicting nature like we predict weather

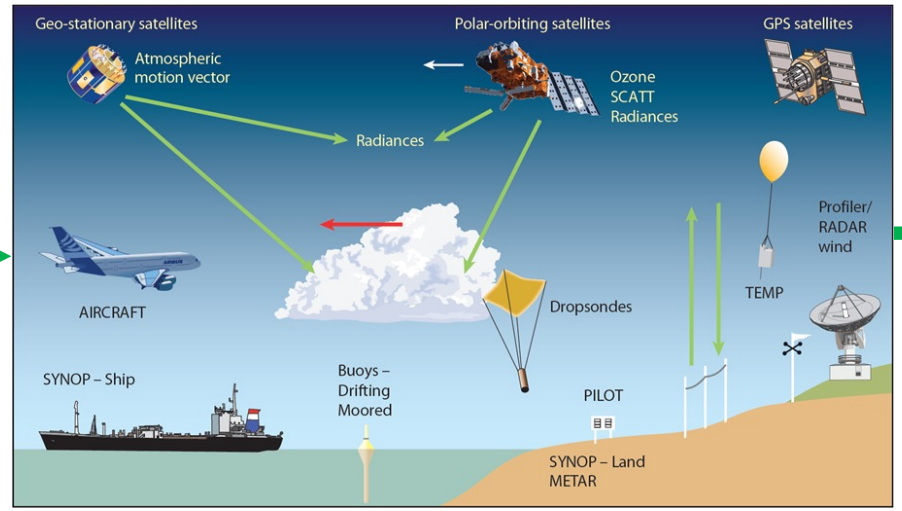


The ecological sciences are undergoing a transformation similar to meteorology and weather forecasting

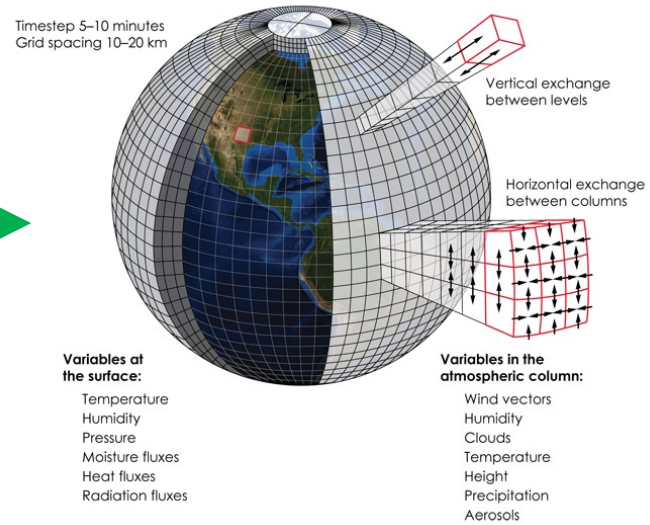
Weather forecast model

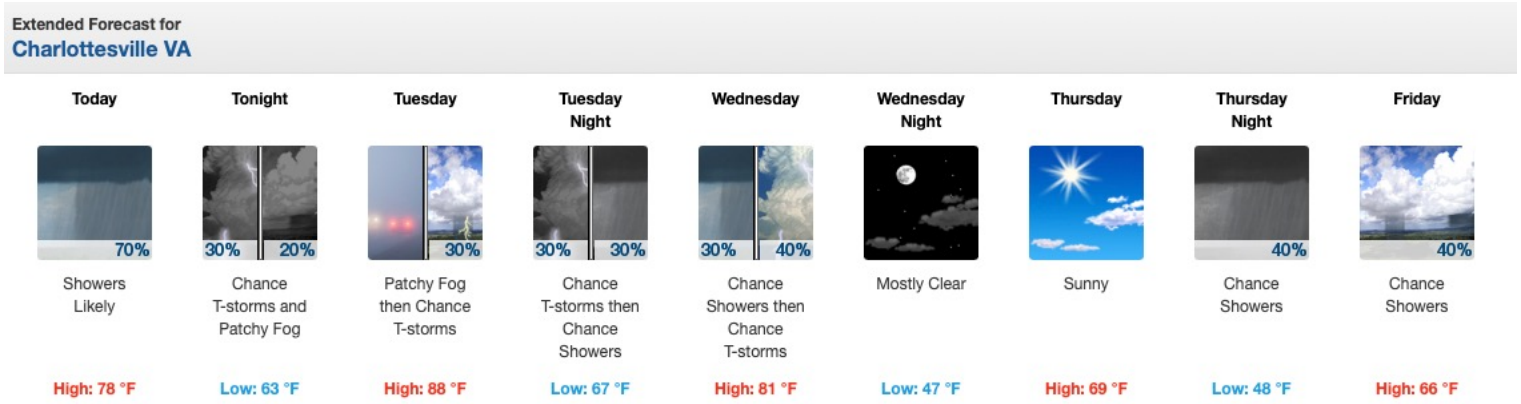


Data-model fusion (aka: data assimilation)



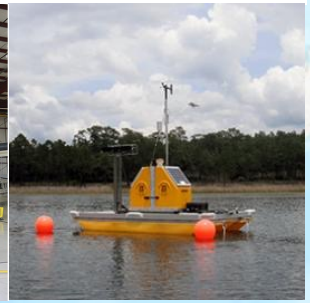
Updated weather model





Decision support

Images: ECMWF
http://wxguys.ssec.wisc.edu



NSF | neon Operated by Battelle

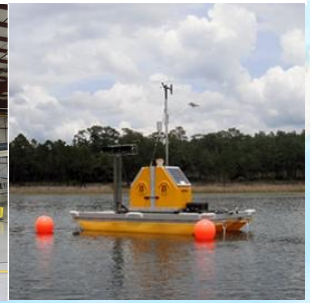
GLEON
global lake ecological observatory network

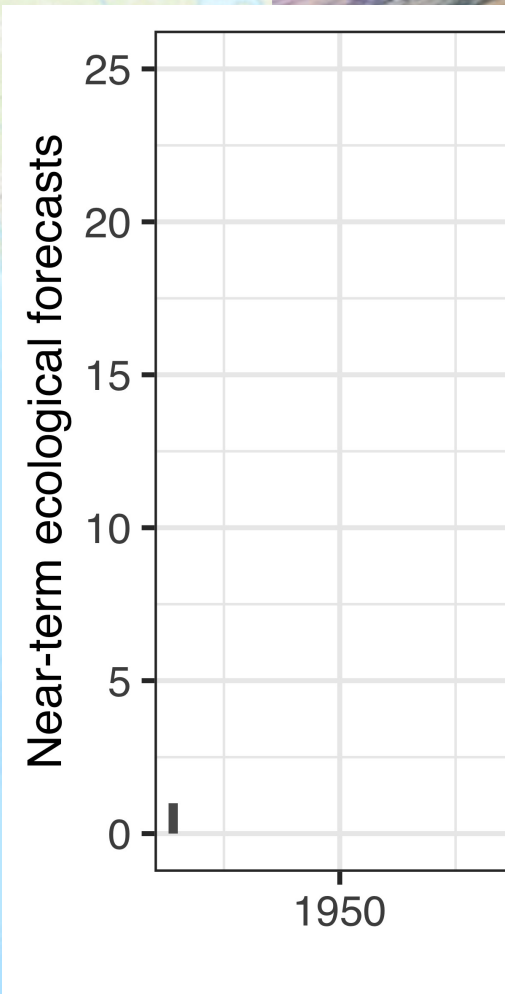
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

NATIONAL SCIENCE FOUNDATION
LTER NETWORK
LONG TERM ECOLOGICAL RESEARCH

USDA Agricultural Research Service

ltar



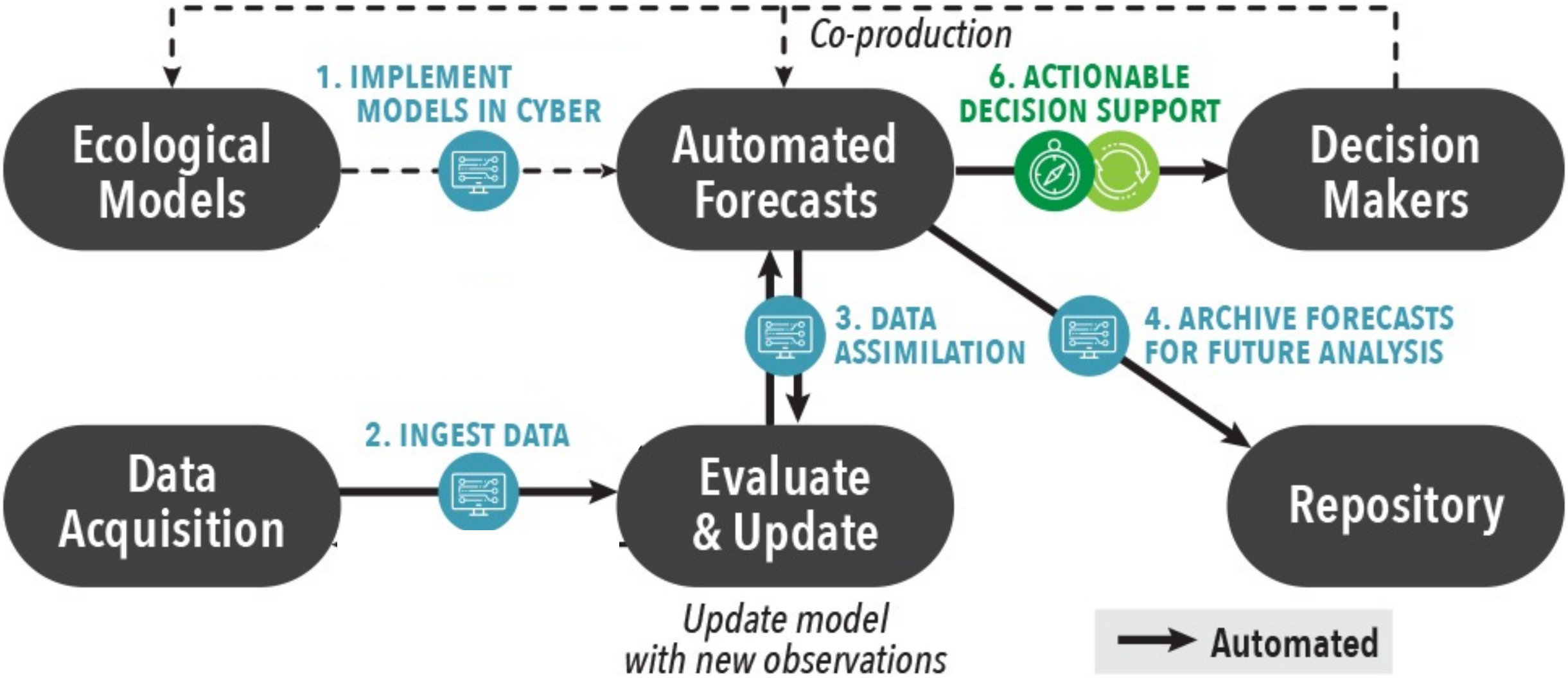


Lewis et al. In Review (pre-print: https://doi.org/10.32942/osf.io/khwdf)

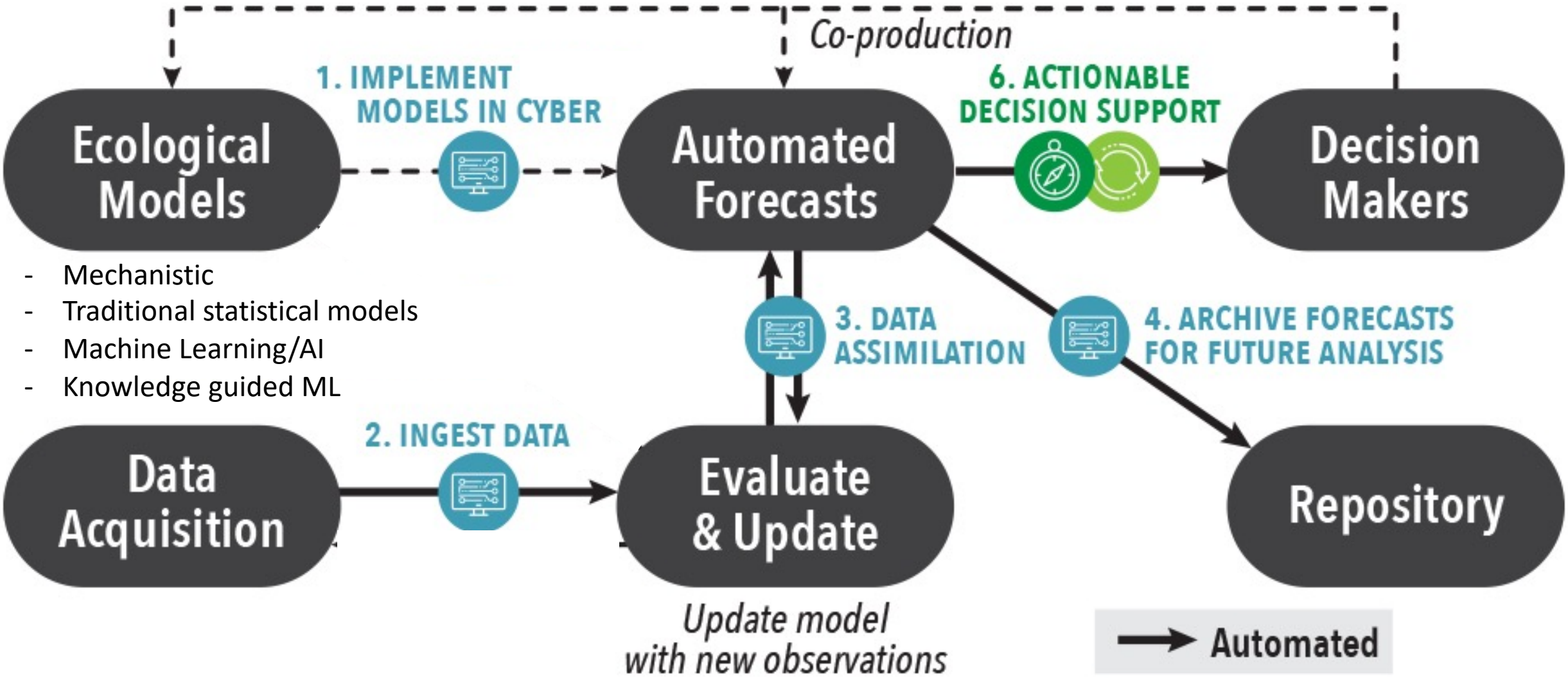
Near-term iterative forecasting helps anticipate ecological responses to environmental stressors

- **Forecast**: a probabilistic prediction of the future
- **Iterative**: repeated forecasts that can be evaluated with data so to gain knowledge from the evaluation and update forecast models
- **Near-term**: forecasts at a time-scale that allows for evaluation - ranges from daily to decadal

Harnessing the data revolution

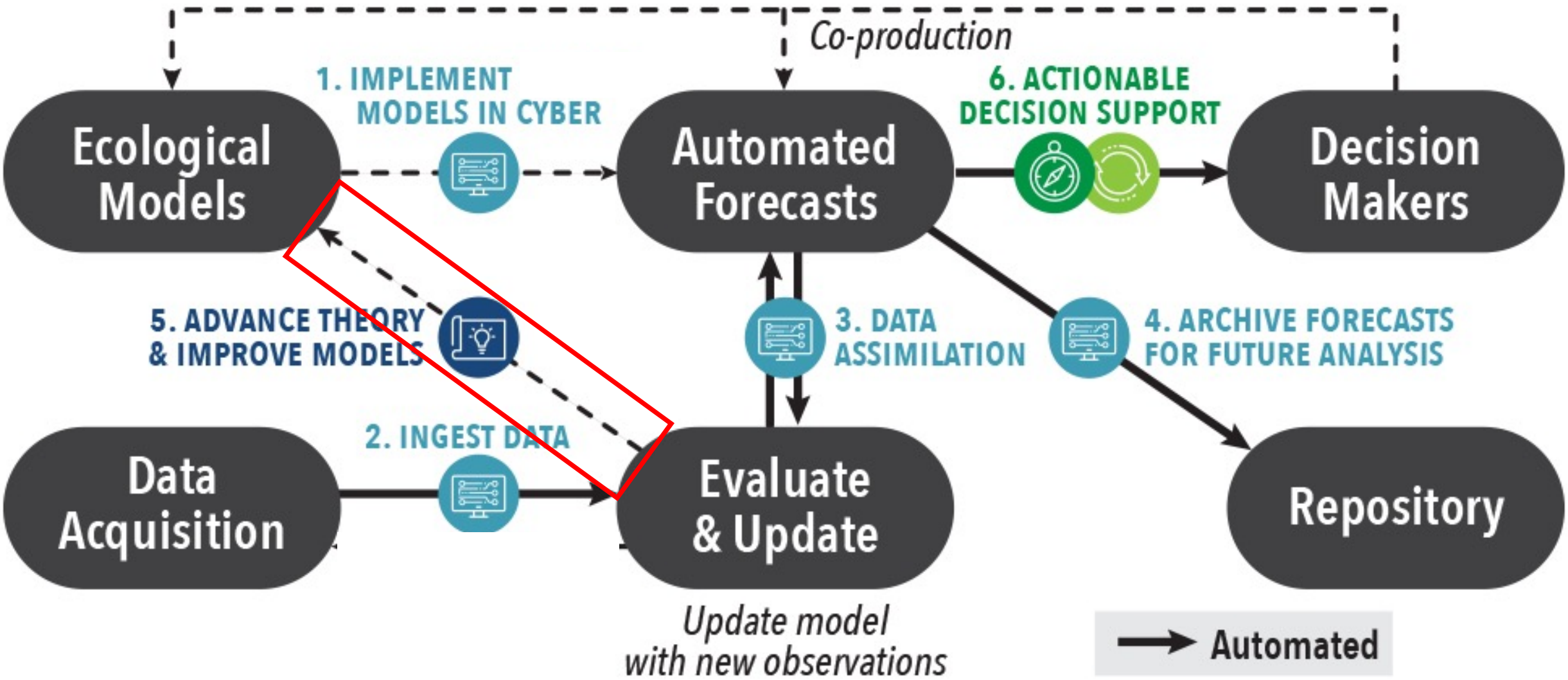


Harnessing the data revolution

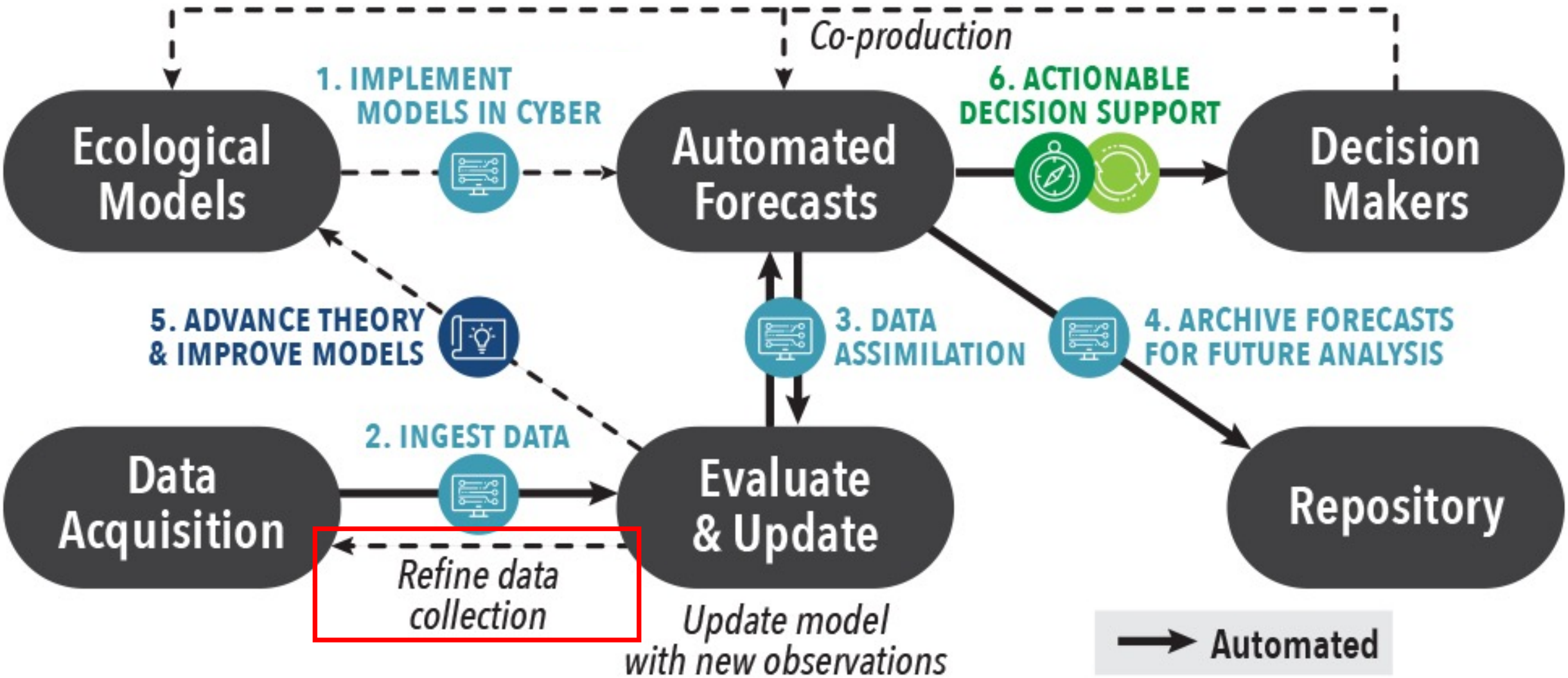


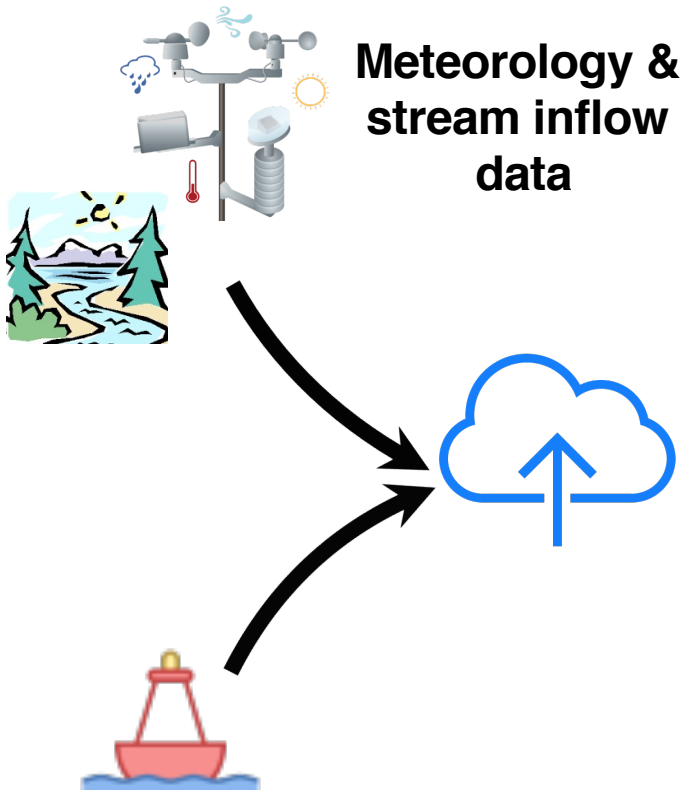
- Mechanistic
- Traditional statistical models
- Machine Learning/AI
- Knowledge guided ML

Harnessing the data revolution

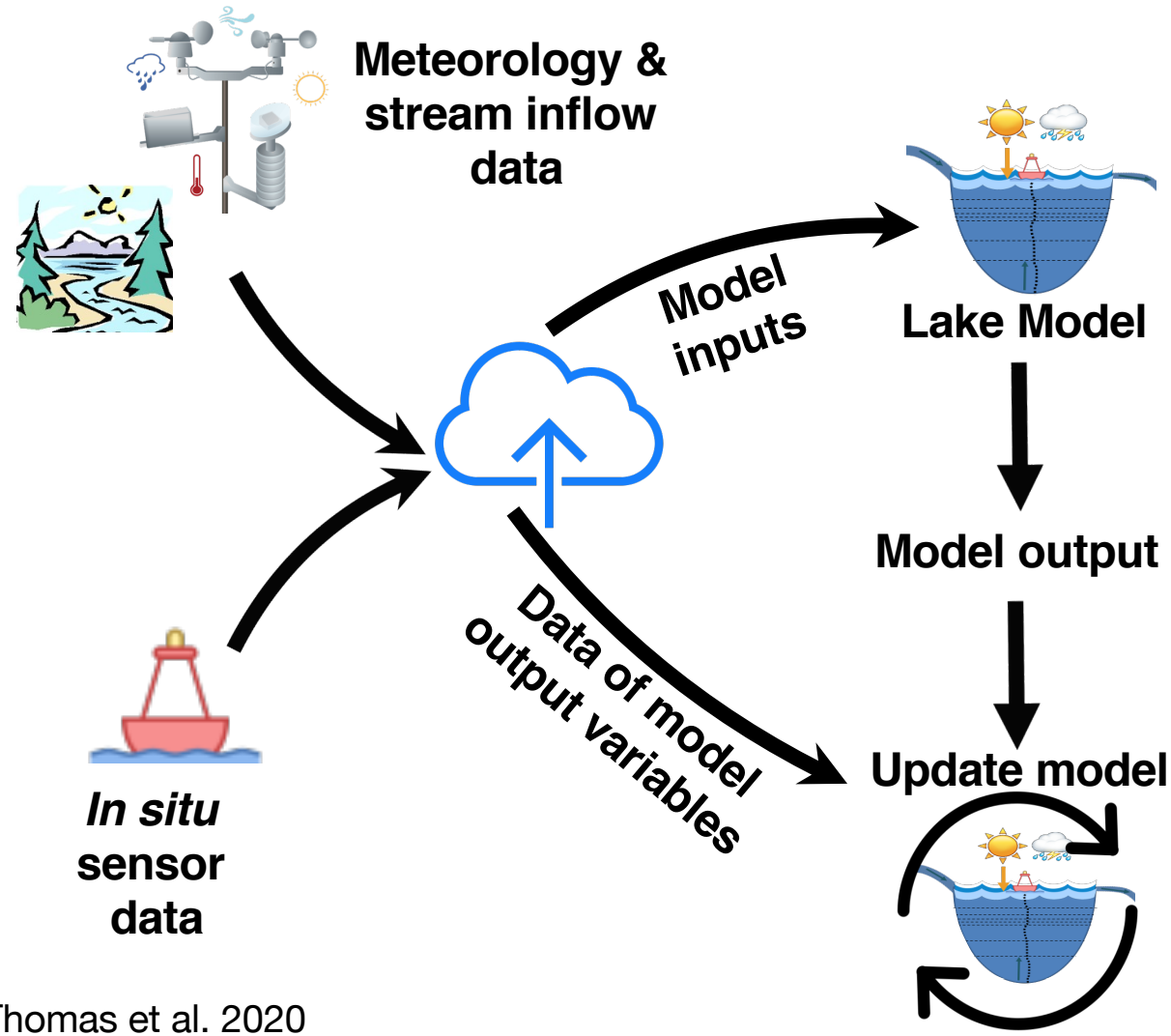


Harnessing the data revolution





Thomas et al. 2020
smartreservoir.org



Thomas et al. 2020
smartreservoir.org

FLARE
Forecasting Lake And Reservoir Ecosystems

Western Virginia Water Authority

Virginia Tech

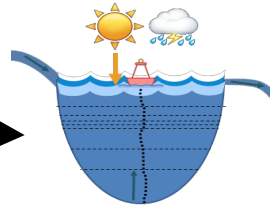
NC State University

University of Florida

Meteorology & stream inflow data

In situ sensor data

Model inputs

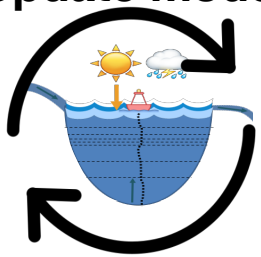


Lake Model

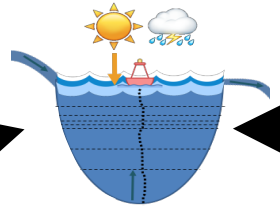
Model output

Data of model output variables

Update model



Best estimate for current conditions

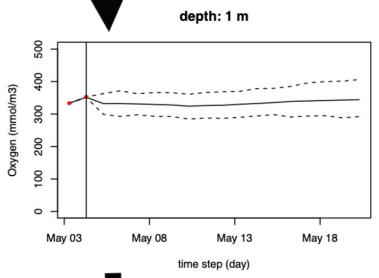


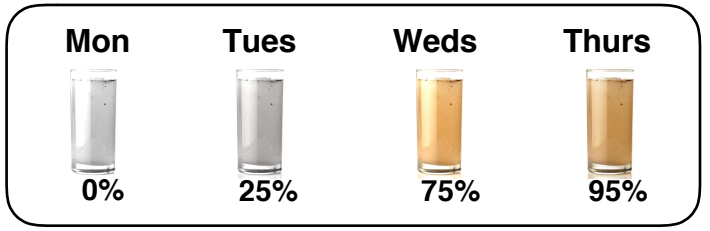
Lake Model

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

Statistically-downscaled 16-day Global Ensemble Forecast (21 members)

16-day forecast output



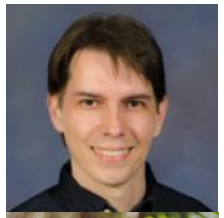
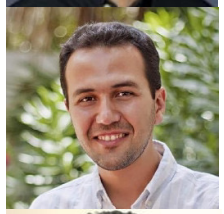
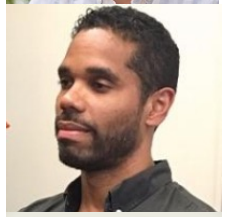
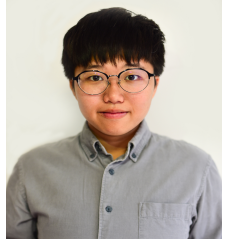


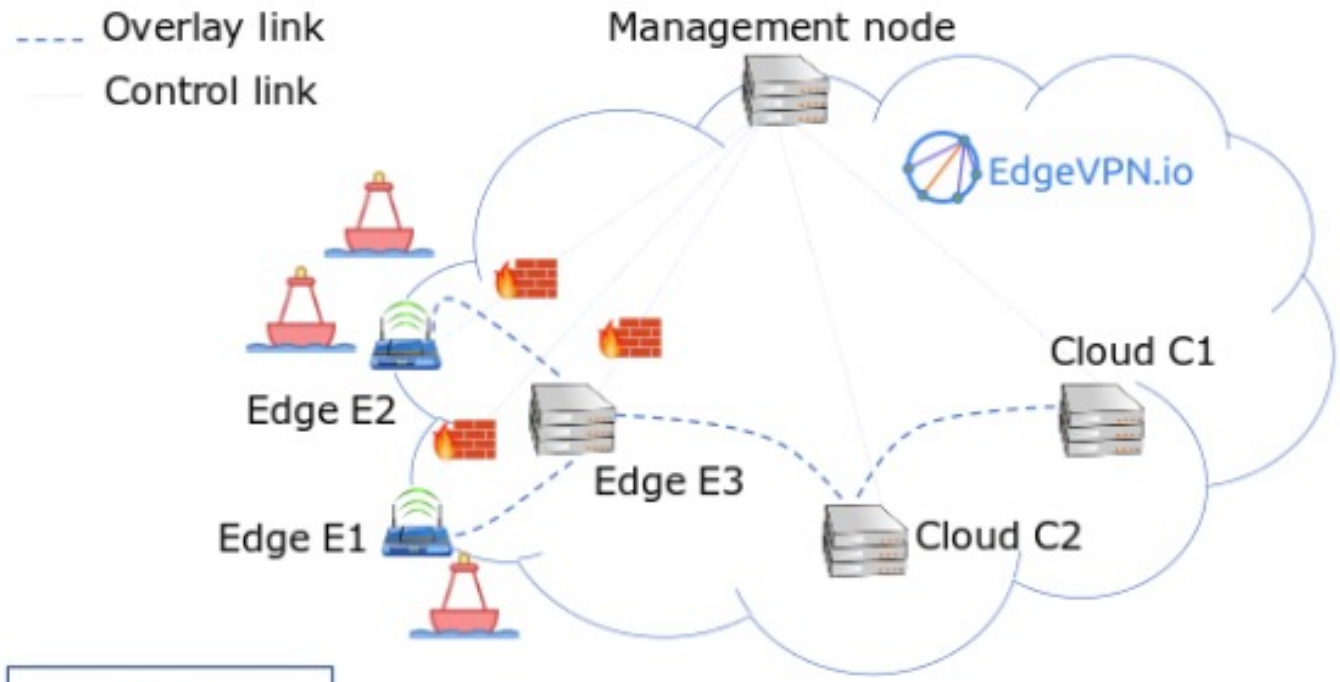
Email to Water Authority

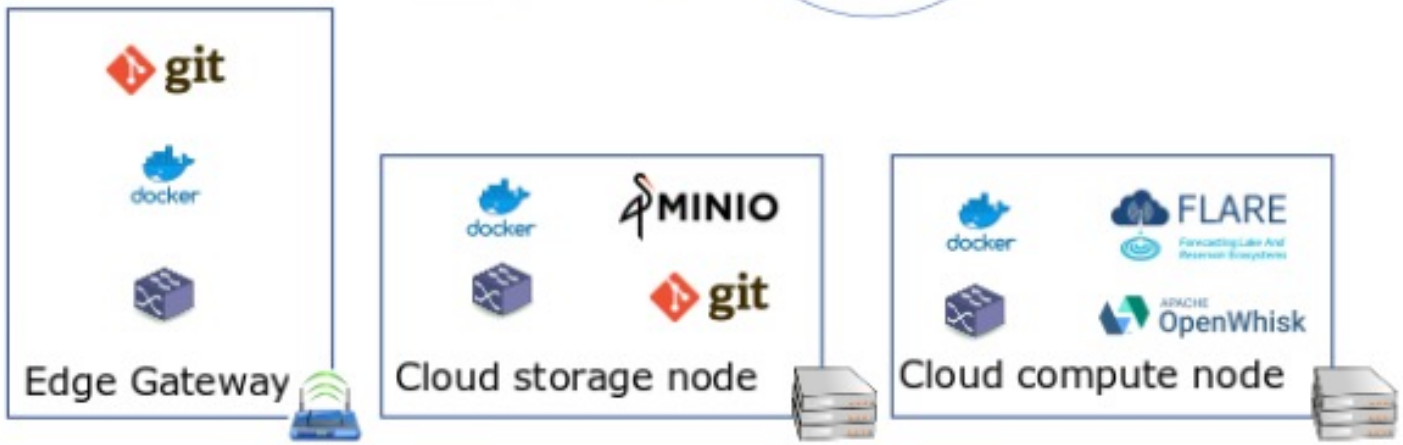
Forecast for managers & decision support tools

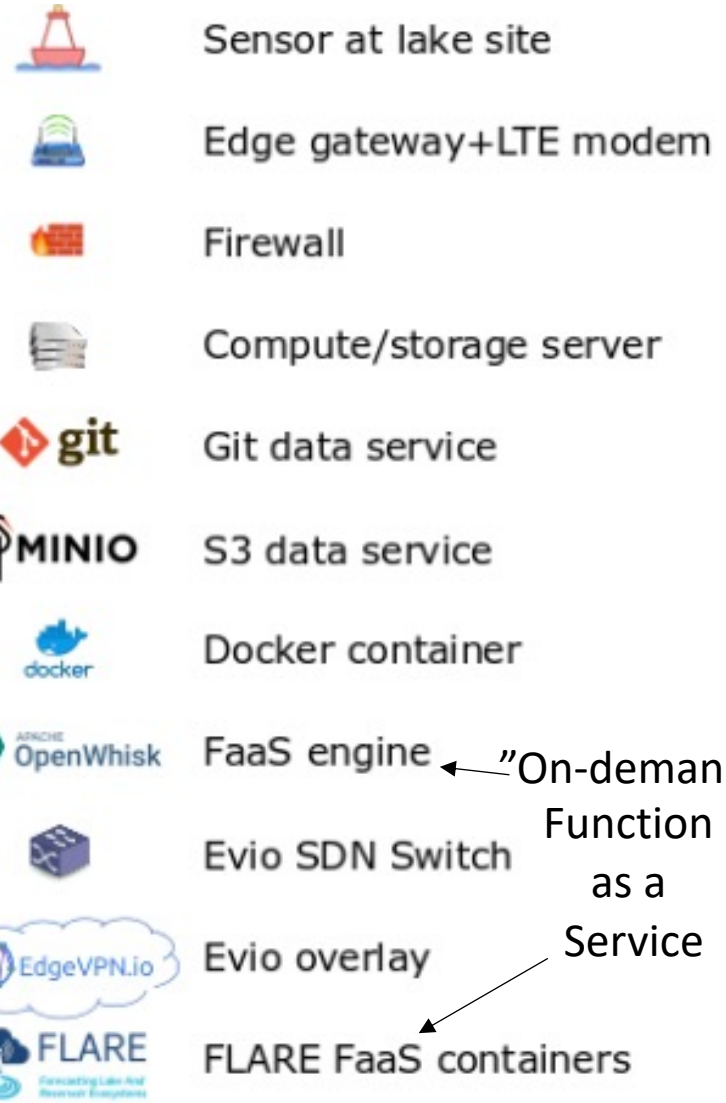
Thomas et al. 2020 Water Resources Research
flare-forecast.org; CNS-1737424, DBI-1933102, DBI-1933016

Cloud-based, event driven, secure transfers







UF UNIVERSITY of FLORIDA

Daneshmand et al. eScience Accepted

Fall turnover = high iron, manganese, and phosphorus from sediments mixed to surface

Thomas et al. 2020 Water Resources Research

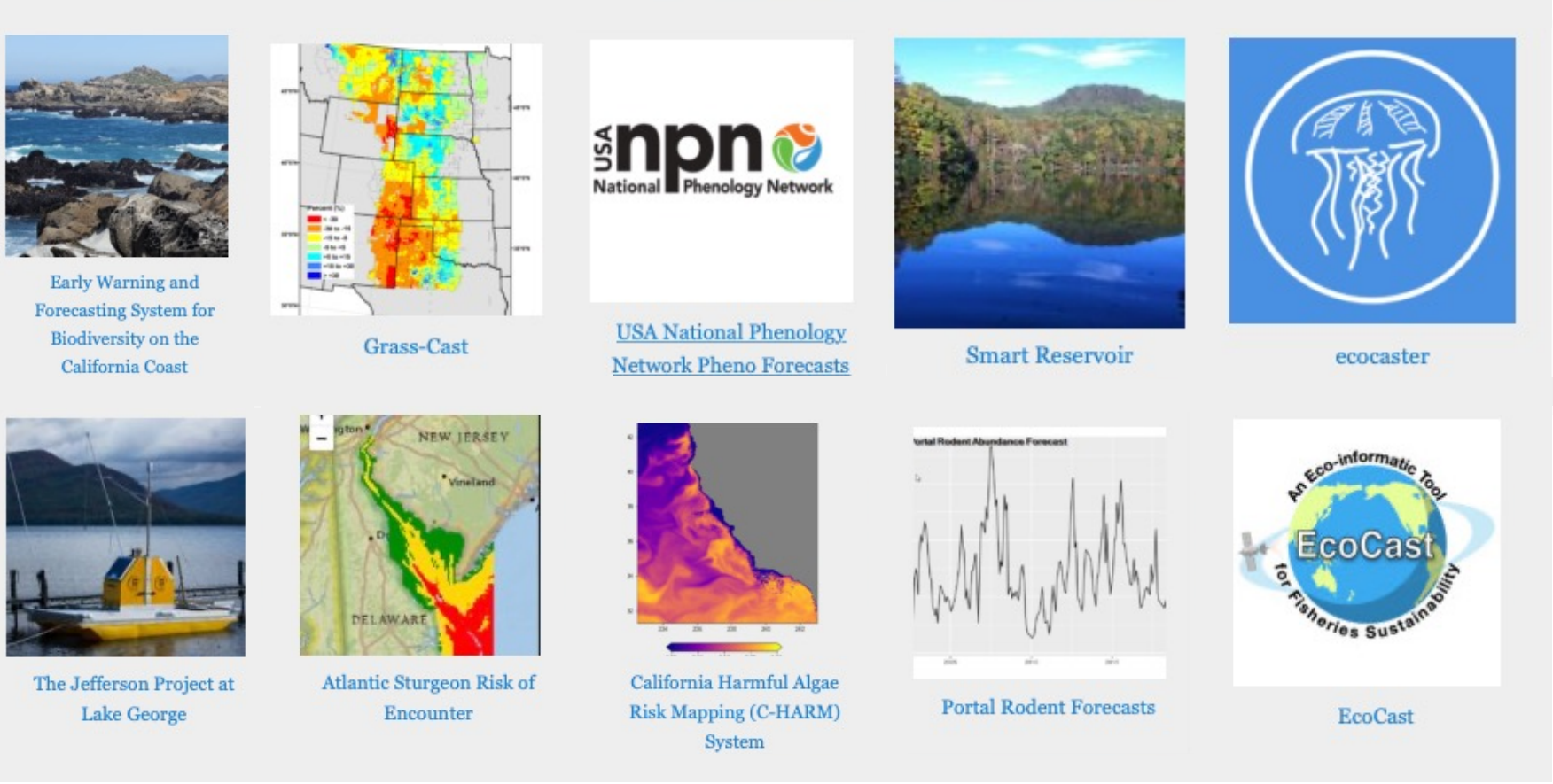
Photo Credit: Bethany Bookout

Field of ecological forecasting is rapidly growing with an emerging community of practice

Ecological Forecasting Initiative

UNDERSTAND · MANAGE · CONSERVE

https://ecoforecast.org/



https://ecoforecast.org/member-forecasting-profiles/

Looking forward

- EPA collaborates with and fund federal, state, and university forecasting efforts to collectively elevate the quantity, quality, and utility of ecological forecasts
  - USGS, NASA, NOAA and others have emerging ecological forecasting thrusts
- EPA increases the integration of near-term iterative ecological forecasting into decision support

USGS
science for a changing world

Ecological Forecasting—21st Century Science for 21st Century Management

Table 3. Promising potential ecological forecasting products identified at the workshop.

Topic	Management need	Forecast description	Partners and collaborators	Stakeholders
Freshwater cyanobacterial blooms	High temporal resolution forecasts of toxin exposure can improve management of drinking water, agricultural irrigation, livestock, fish and wildlife populations	Daily forecasts of cyanobacterial blooms for inland freshwater lakes (near term); daily toxin and health effects forecasts	EPA, NASA, and NOAA	States, Tribal Nations, drinking water utilities, and BLM, BOR, NPS, FWS, and USACE
Coastal marsh erosion	Forecasting vegetation and habitat change resulting from sea-level rise and storm surge can inform siting of living shorelines and anticipate impacts to wildfowl populations	Short-term forecasts of coastal ecosystem vulnerability (resilience) potential	NOAA, EPA, coastal communities, FWS refuges, NPS, EPA, State agencies, NGOs, coastal commercial operations	Governments and residents of coastal zones

Bradford, J.B. et al. 2020, Ecological forecasting— 21st century science for 21st century management: U.S. Geological Survey Open-File Report 2020–1073, 54 p., https://doi.org/10.3133/ofr20201073.

Looking forward

- EPA increases the use of iterative analyses that automatically update as more data become available

nature geoscience
LETTERS
PUBLISHED ONLINE: 22 DECEMBER 2009 | DOI: 10.1038/NGEO721

Increased tree carbon storage in response to nitrogen deposition in the US

R. Quinn Thomas[1]*, Charles D. Canham[2], Kathleen C. Weathers[2] and Christine L. Goodale[1]

Millions of remeasured trees by US Forest Service
Changes in atmospheric deposition

PLOS ONE | https://doi.org/10.1371/journal.pone.0205296 October 18, 2018

RESEARCH ARTICLE

Growth and survival relationships of 71 tree species with nitrogen and sulfur deposition across the conterminous U.S.

Kevin J. Horn[1], R. Quinn Thomas[1]*, Christopher M. Clark[2], Linda H. Pardo[3], Mark E. Fenn[4], Gregory B. Lawrence[5], Steven S. Perakis[6], Erica A. H. Smithwick[7], Douglas Baldwin[7], Sabine Braun[8], Annika Nordin[9], Charles H. Perry[10], Jennifer N. Phelan[11], Paul G. Schaberg[3], Samuel B. St. Clair[12], Richard Warby[13], Shaun Watmough[14]

Millions of remeasured trees by US Forest Service
Changes in atmospheric deposition

How has the sensitivity to nitrogen and sulfur deposition changed?

Looking forward

- Capacity building in ecological forecasting
  - Support for university training, post-doctoral programs, in-house staff with expertise

Near-term iterative forecasting is a win-win

Basic science

Actionable science

Rapid testing of quantitative hypotheses

Forecasts to support decisions

Thank you!

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