Your site is not so special, or is it?

Scaling fluxes from the specific to the general and back again.

Ankur Desai, UW-Madison

Ameriflux Upscaling Workshop

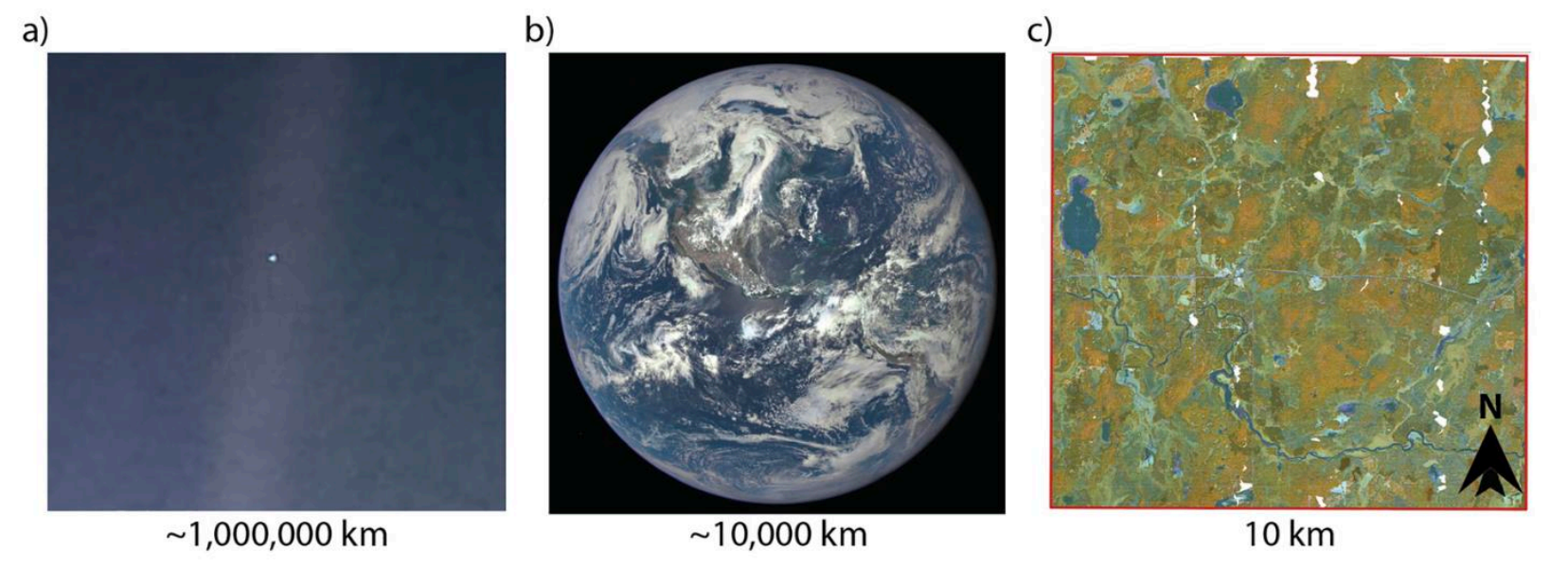
Jul 2024

Photo: B. Butterworth

What is scaling?

Photo: Jeff Miller, UW Communications

Scaling (for us) involves theories and methods that translate states, flows (fluxes), processes, and mechanisms from a specified spatial, temporal, or spectral dimension to a different granularity



Requires understanding what processes are *scale-invariant* vs *scale-dependent*

Is the whole the sum of its parts or something else?

Desai et al., 2022, JGR-Biogeo

Contents lists available at ScienceDirect

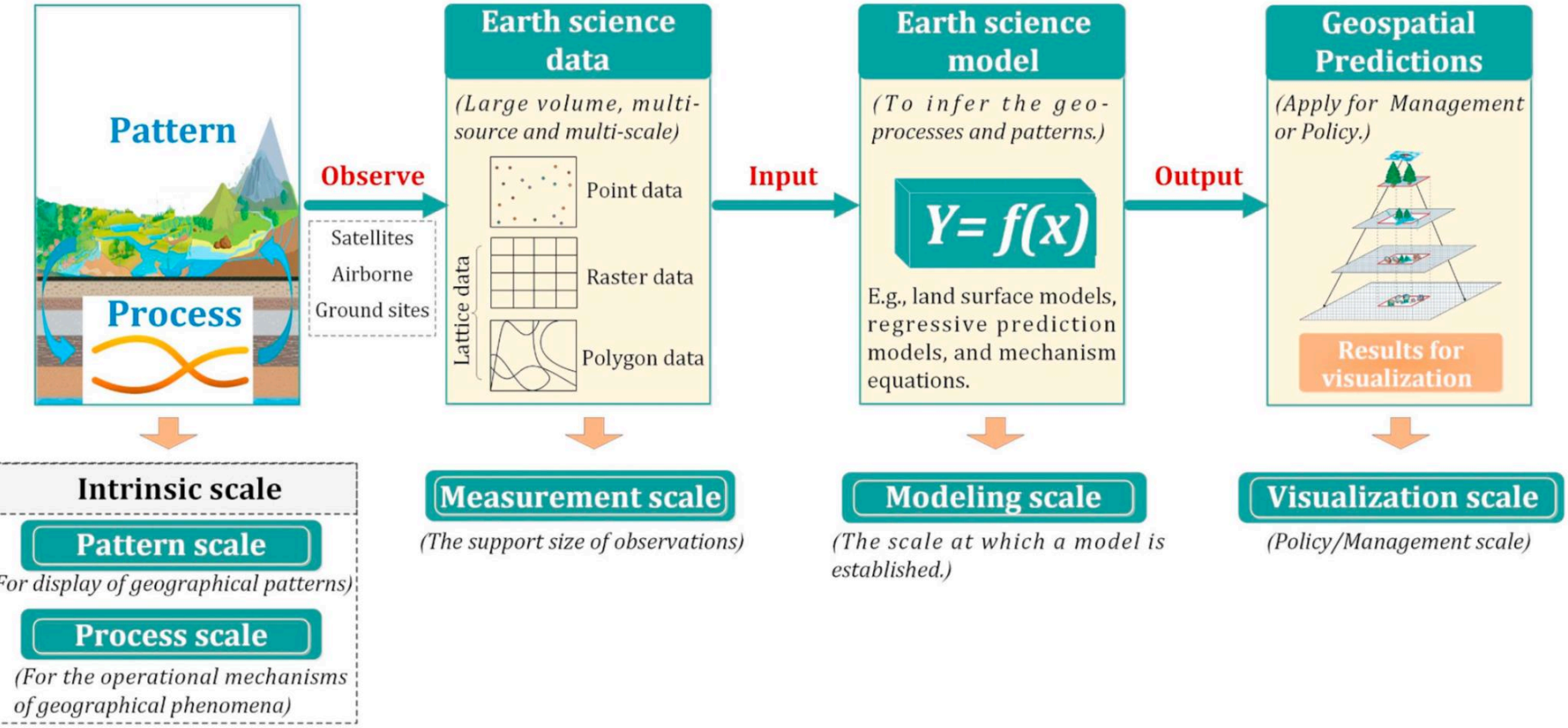
Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Principles and methods of scaling geospatial Earth science data

Yong Ge[a,b,*], Yan Jin[c,d], Alfred Stein[e], Yuehong Chen[f], Jianghao Wang[a], Jinfeng Wang[a], Qiuming Cheng[g], Hexiang Bai[h], Mengxiao Liu[a,b], Peter M. Atkinson[i]

2019

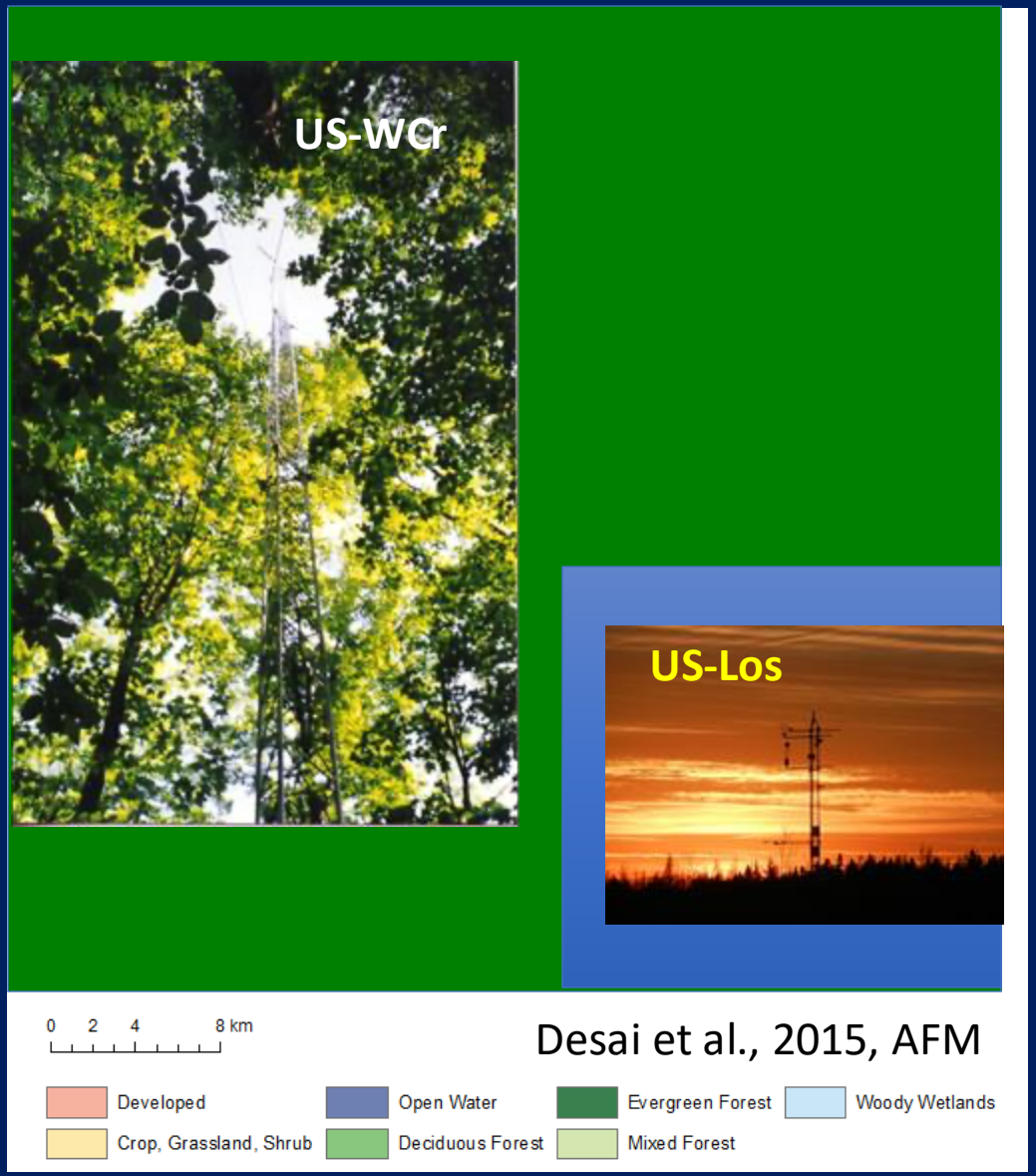


Scaling is essential for Earth system science

- Geophysical biological, aquatic/ocean, and atmospheric processes operate across a broad spectrum of scales
  - From microscale eddies, photons, and genes to gyres, global energy balance, and biomes
  - However, not all scales can be observed or simulated equally well
  - And it varies by process and the observing system
- "Upscaling" and "downscaling" and "rightscaling" are essential to integrate across observations, understand interactions between systems, and extrapolate insights from one scale to another
  - Sometimes it's easy, sometimes it's not!
  - Session 1 focuses on downscaling / rightscaling

Why can't we just "paint-by-numbers?"

Park Falls WLEF tower (US-PFa)
EC fluxes at 30, 122, 396 m

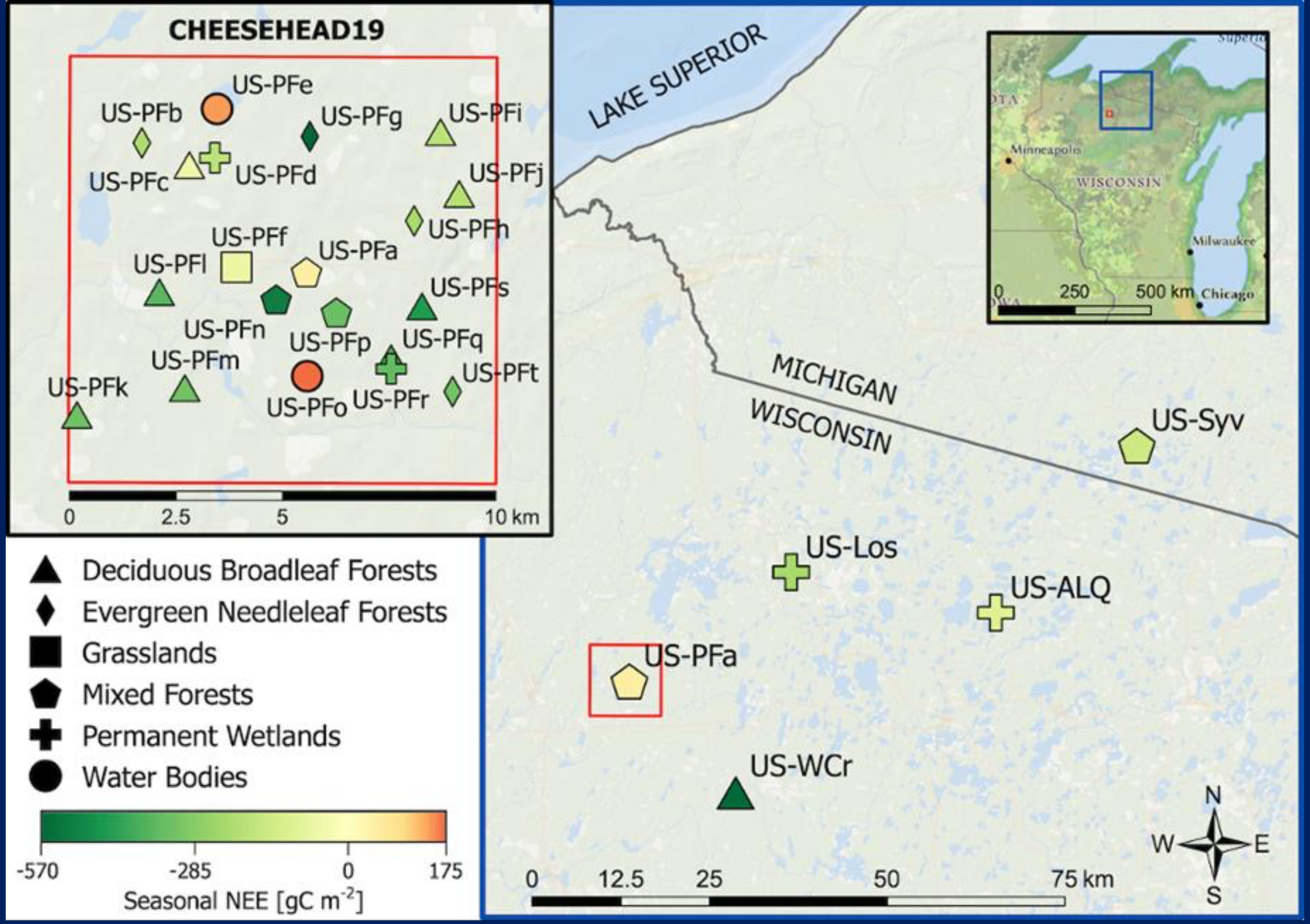


Does it add up?

- US-WCr : Representative forest
  - mean annual NEE -290 gC/m2/yr
- US-Los: Representative wetland
  - mean annual NEE -52 gC/m2/yr

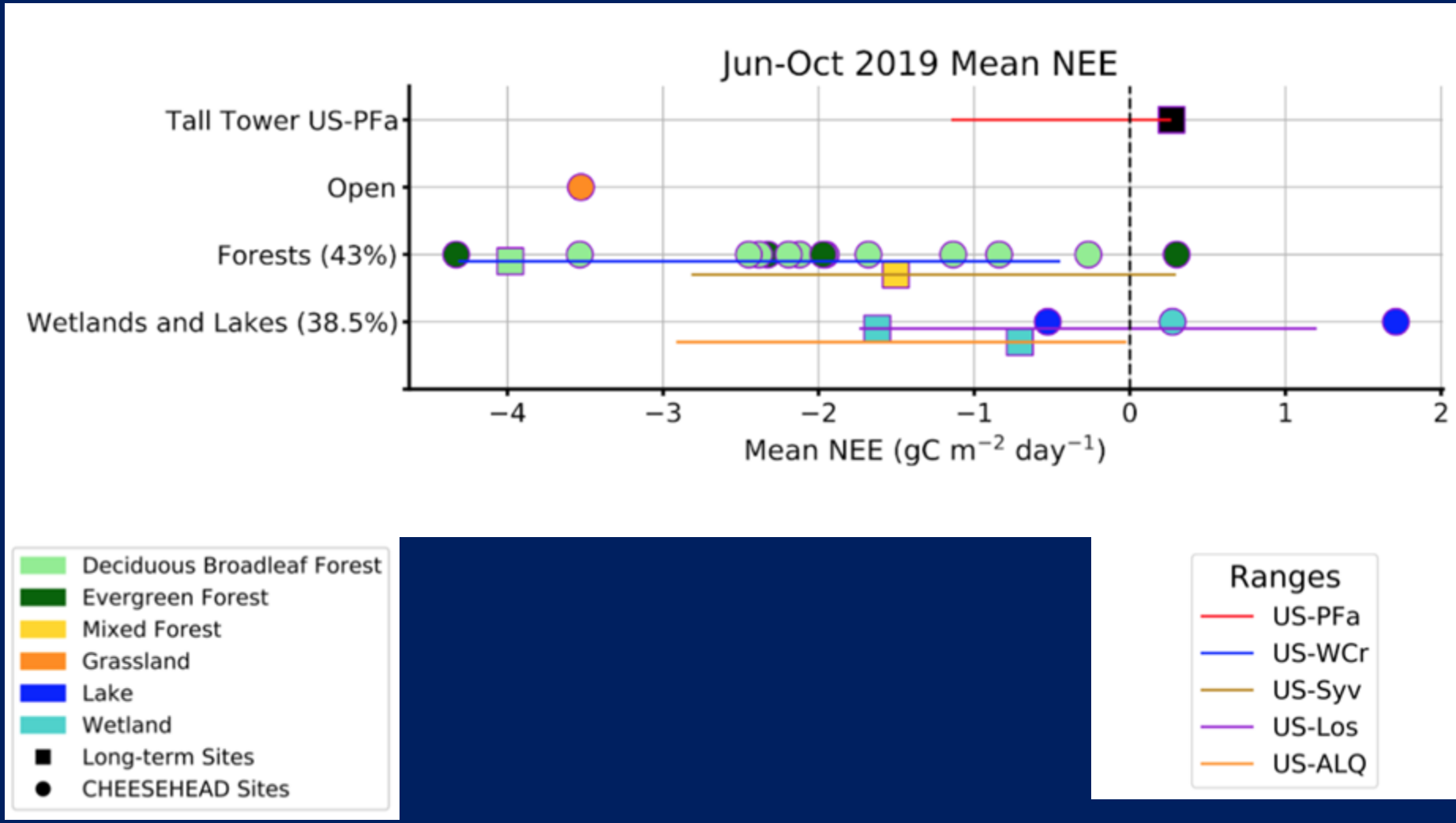
- US-PFa: Landscape – mean NEE +5 gC/m2/yr
- 0.8 * US-WCr + 0.2 * US-Los = -242 gC/m2/yr

- 😢



Desai et al., 2022b, JGR-Biogeo

No, that's not quite it either



Why can't we just "paint-by-numbers?"

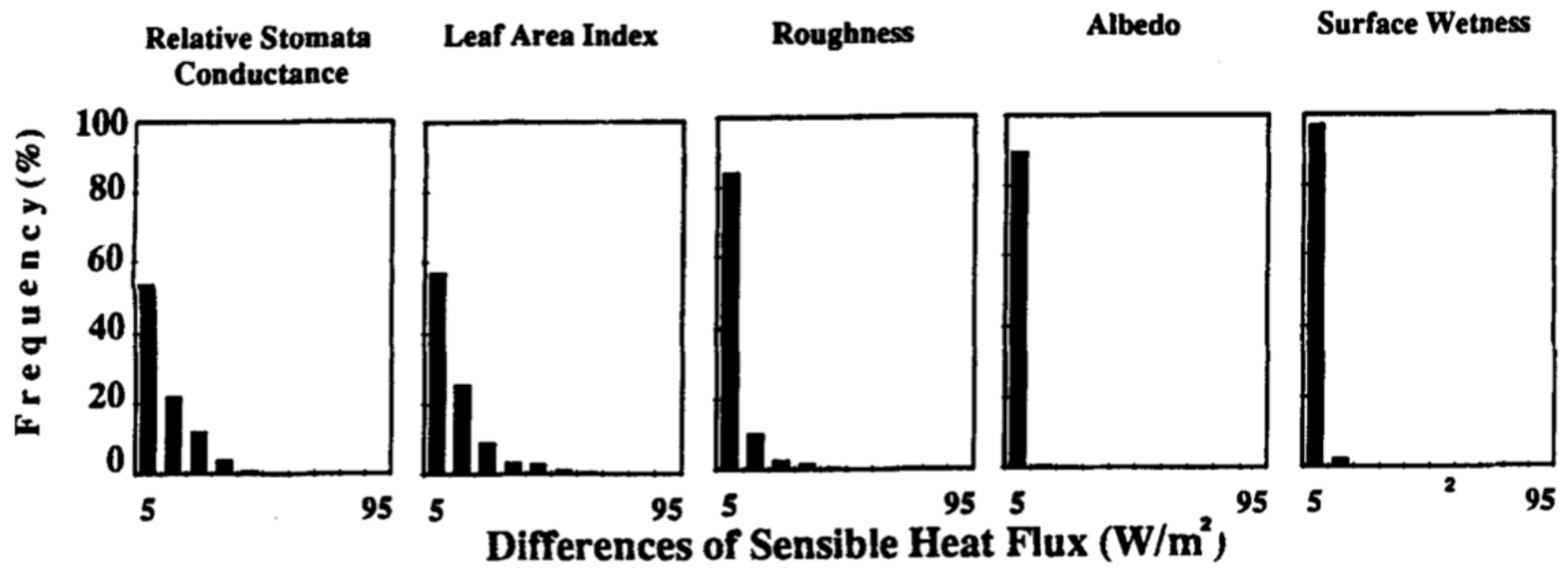
Park Falls WLEF tower (US-PFa)
EC fluxes at 30, 122, 396 m

HYDROLOGICAL PROCESSES, VOL. 9, 679–695 (1995)

SCALING OF LAND–ATMOSPHERE INTERACTIONS: AN ATMOSPHERIC MODELLING PERSPECTIVE

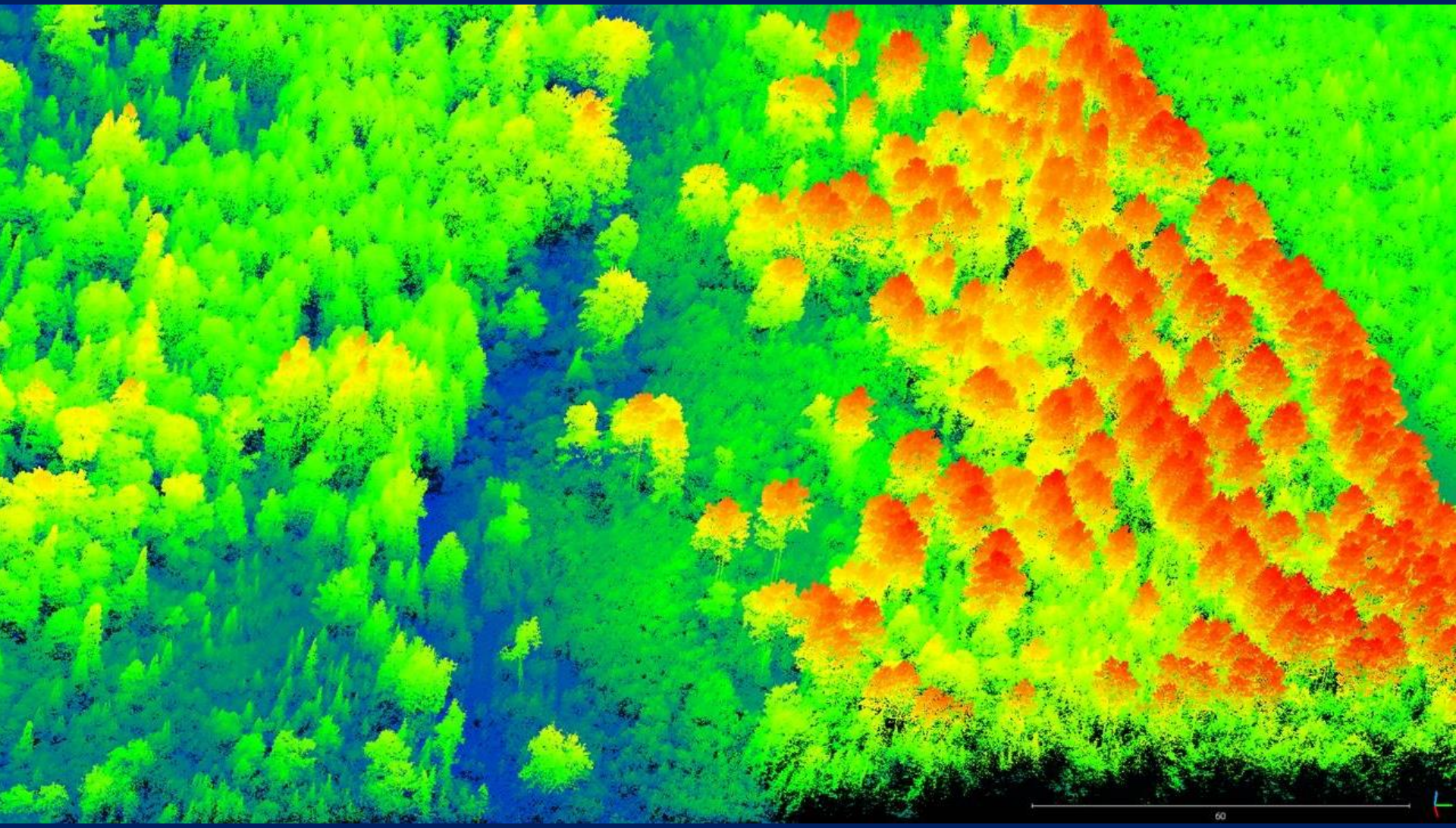
RONI AVISSAR

Department of Meterorology and Physical Oceanography, Cook College, Rutgers University, New Brunswick, NJ 08903, USA

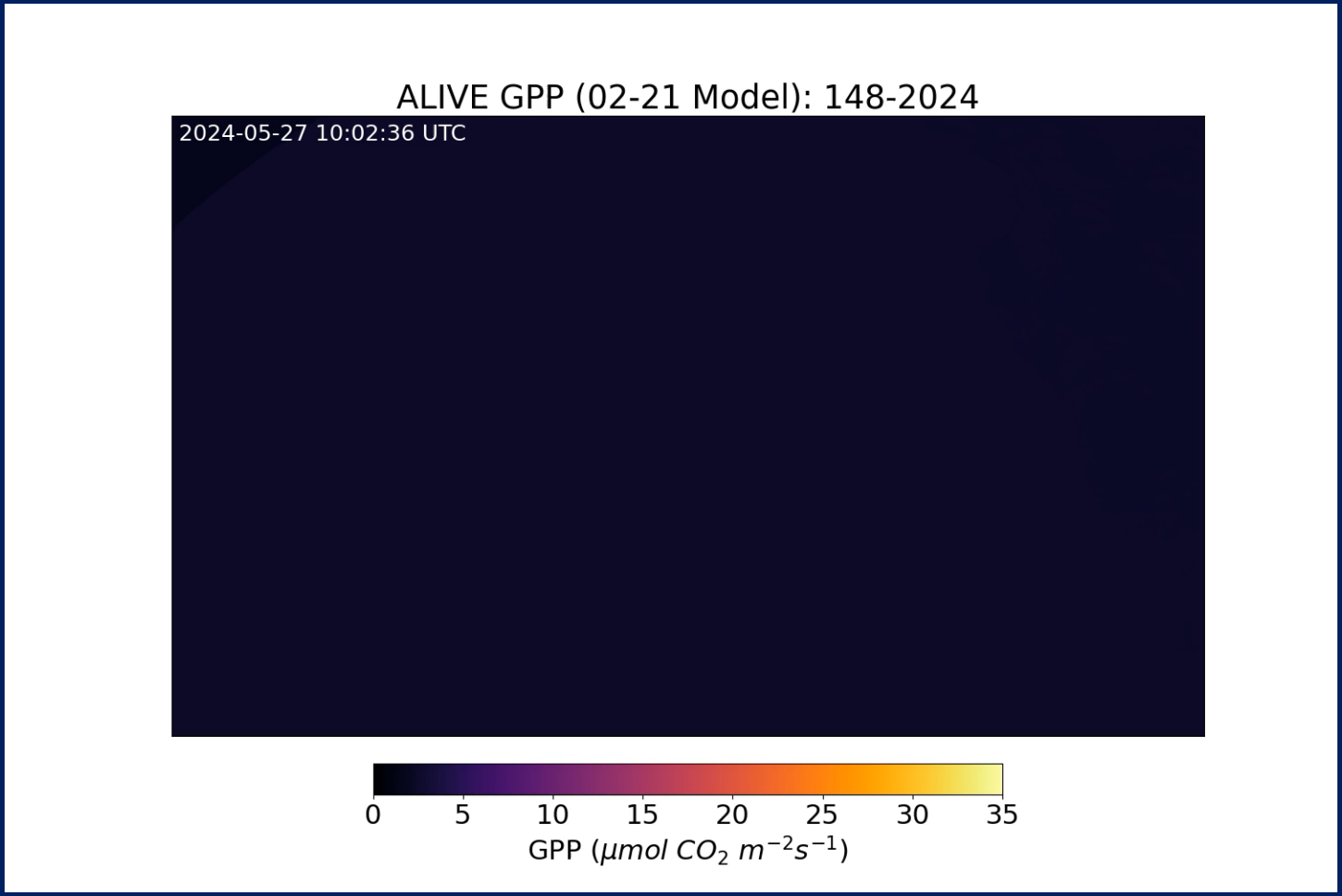


Why does this matter now?

We are entering an era that is: hyperspatial

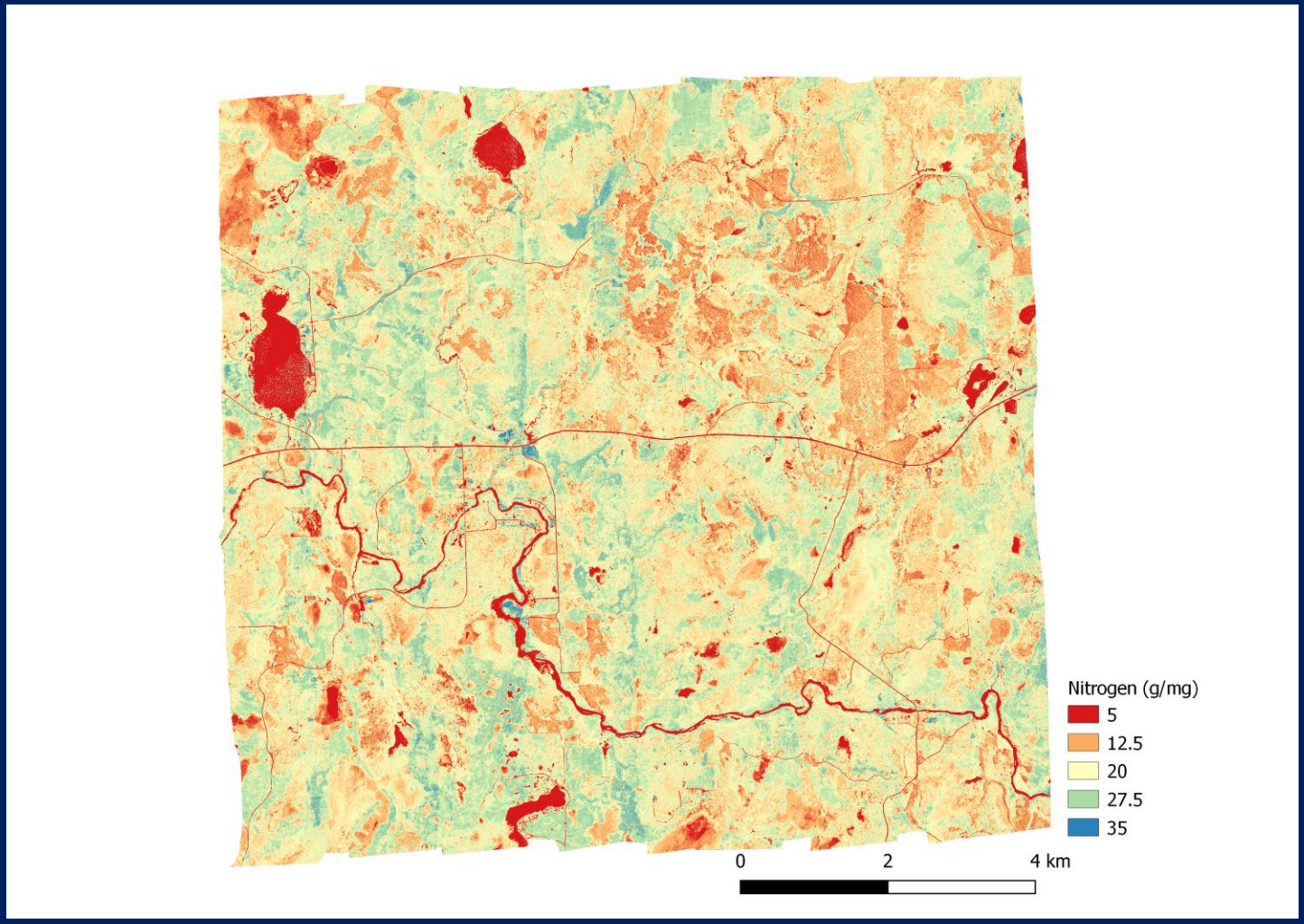


We are entering an era that is: hypertemporal



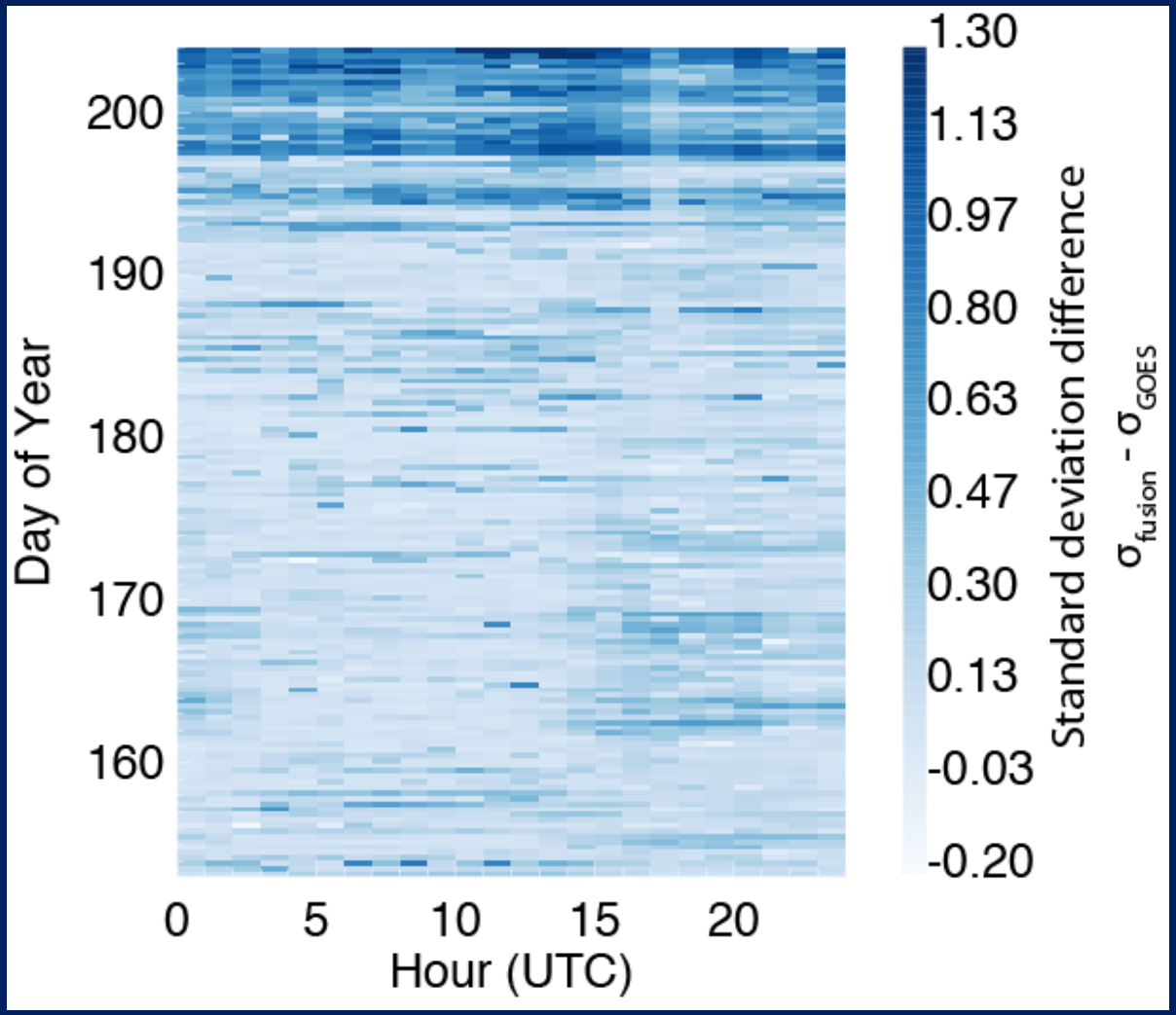
https://alive-abi.github.io/alive/index.html

We are entering an era that is: hyperspectral

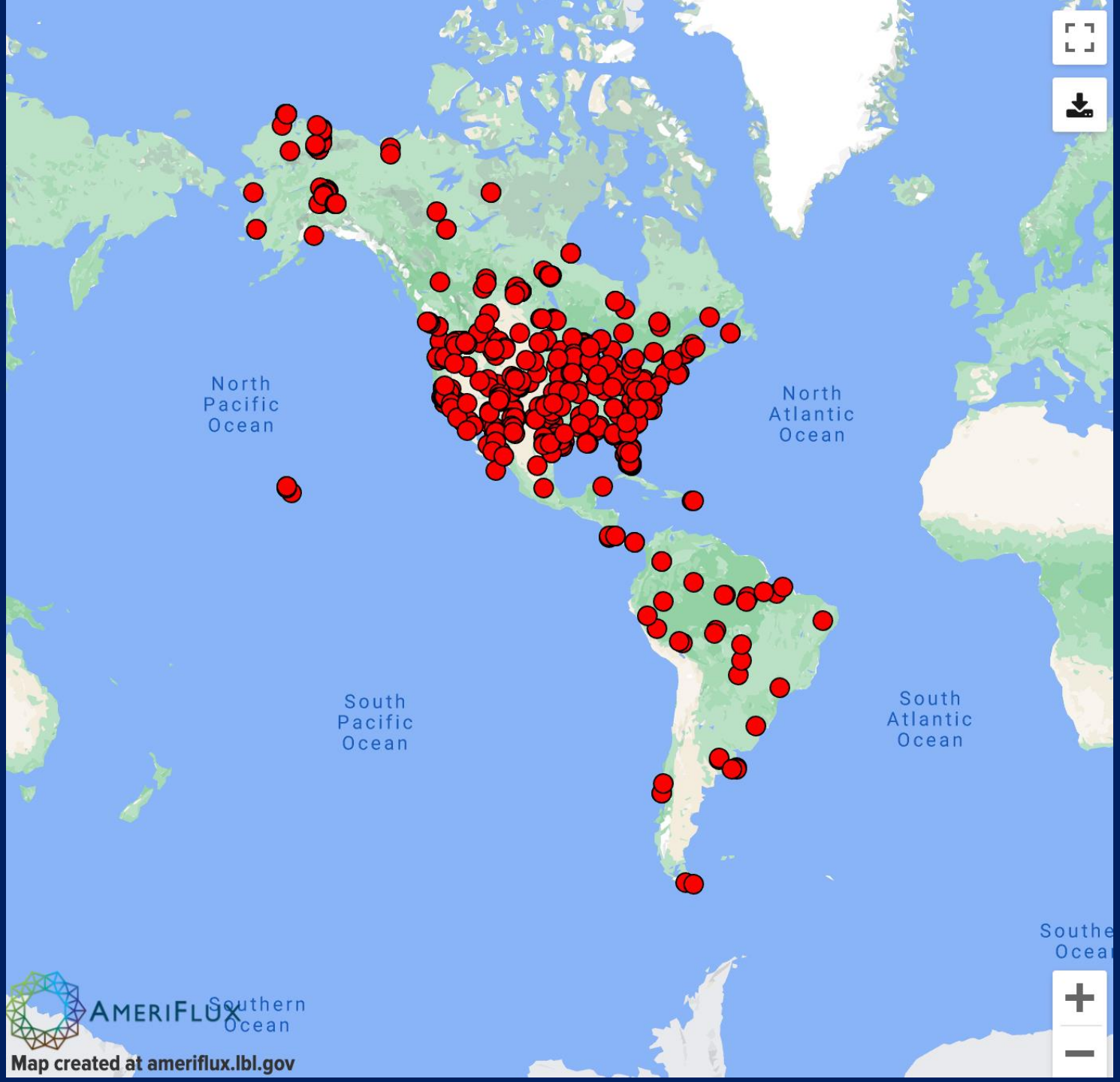


Phil Townsend and Ting Zheng, UW-Madison

And the spatial complexity of these features change in time



Desai et al., 2021, Earth and Space Sci


North
Pacific
Ocean
North
Atlantic
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Atlantic
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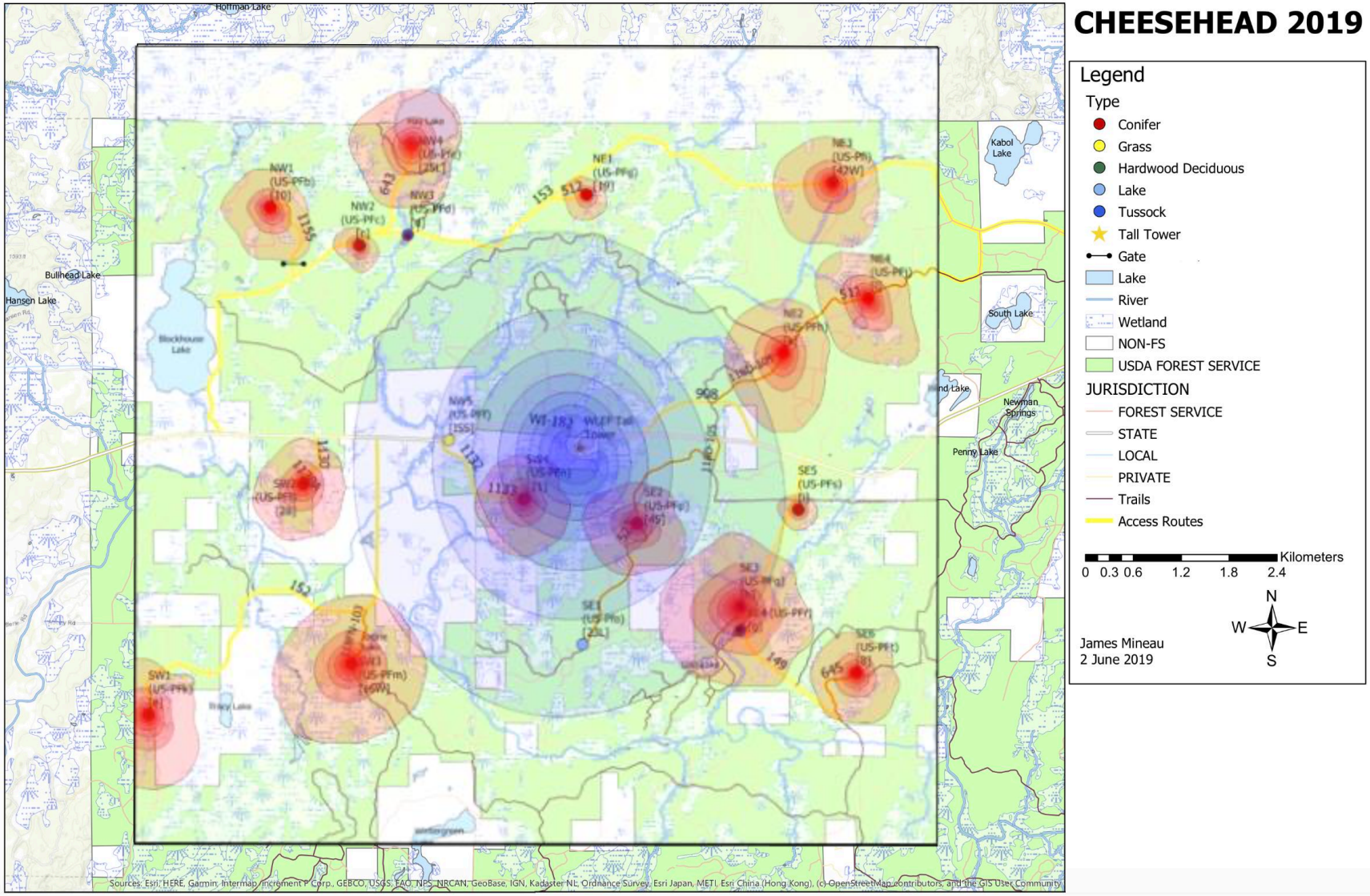
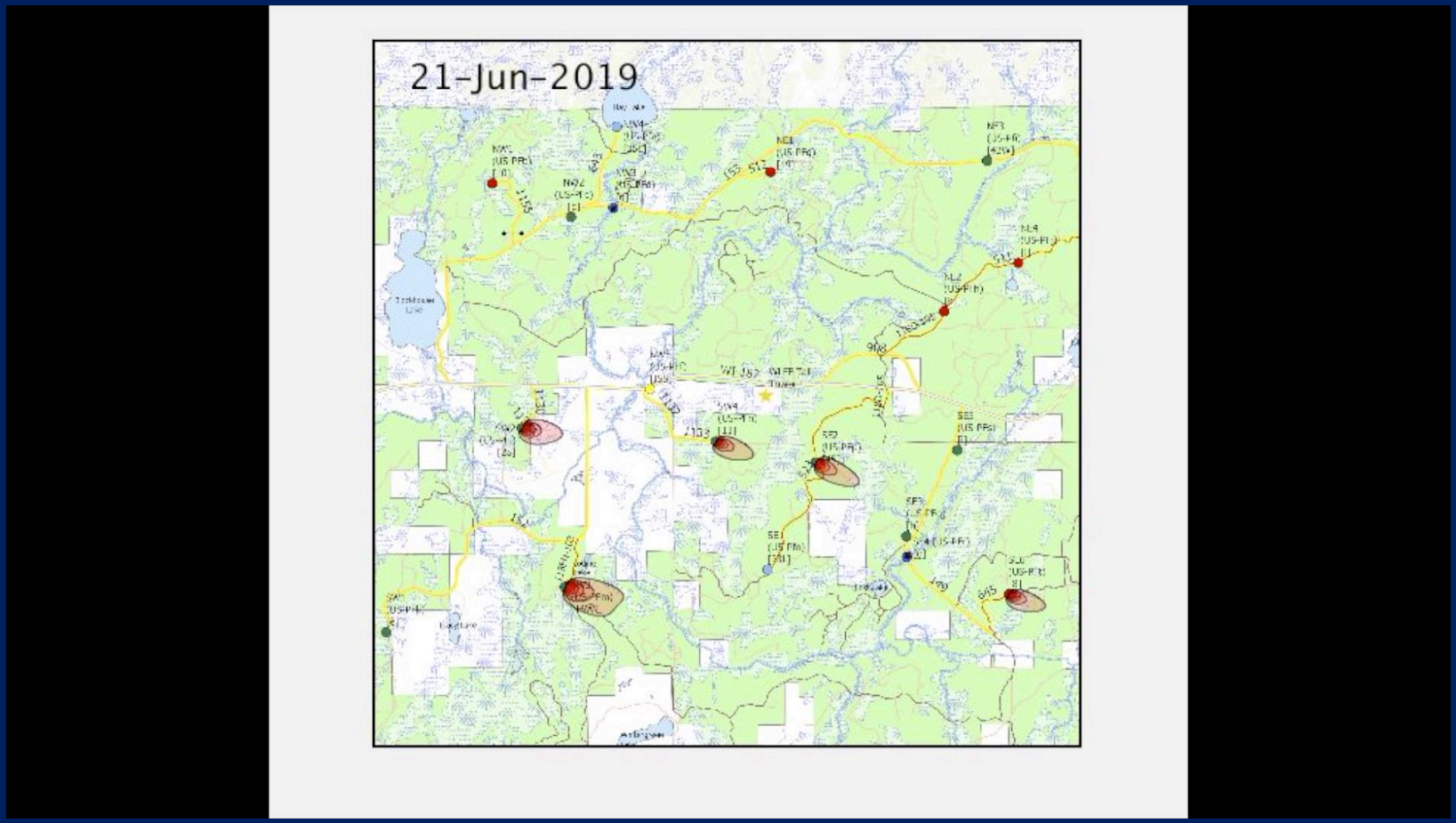
Southern
Ocean
AMERIFLUX
Map created at ameriflux.lbl.gov



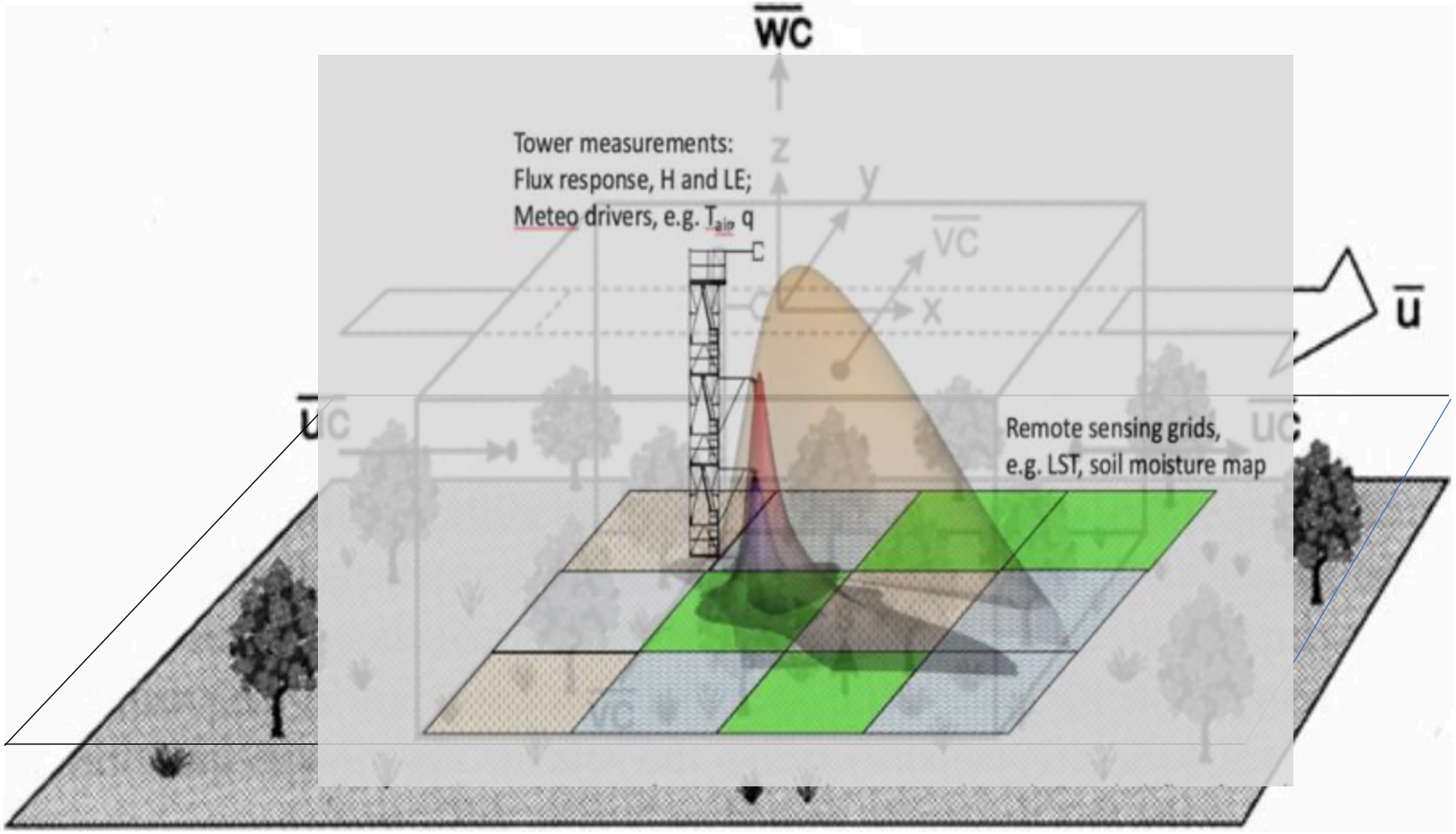
Butterworth et al., 2021

Flux footprints also vary in space and time



B. Butterworth

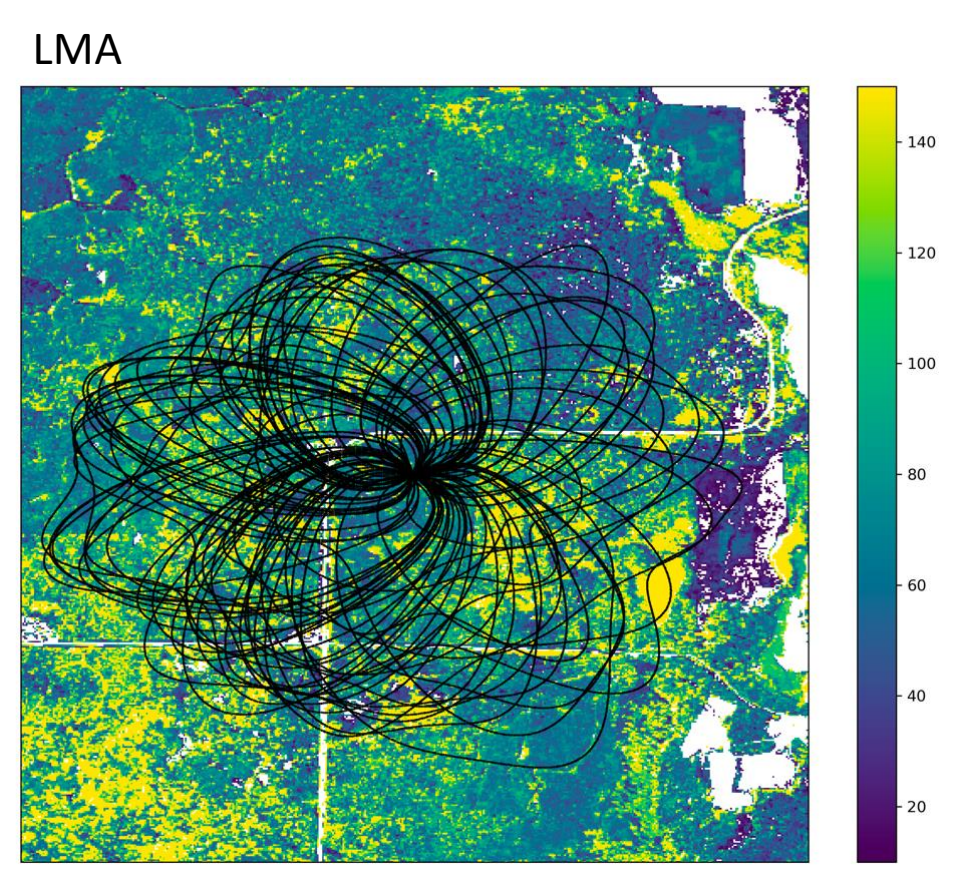
Remote sensing space/time/spectral grids and community research needs call on flux towers to re-think how we calculate and scale eddy fluxes

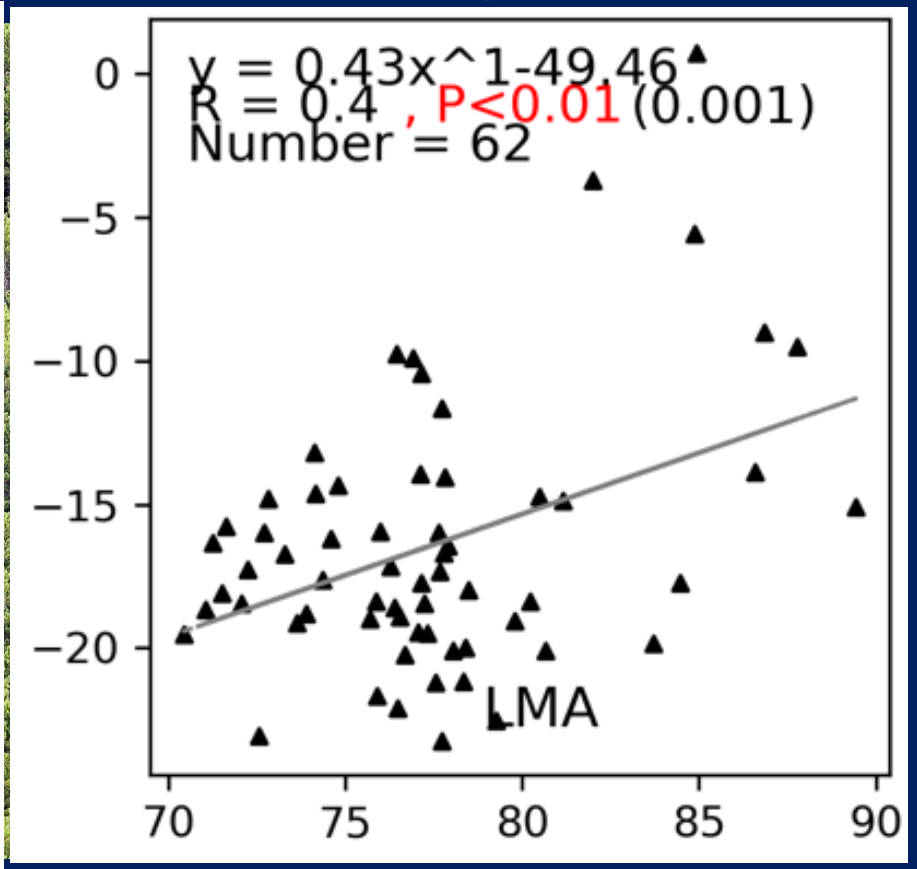


Finnigan et al (2003)

Can't we just assume homogeneity?

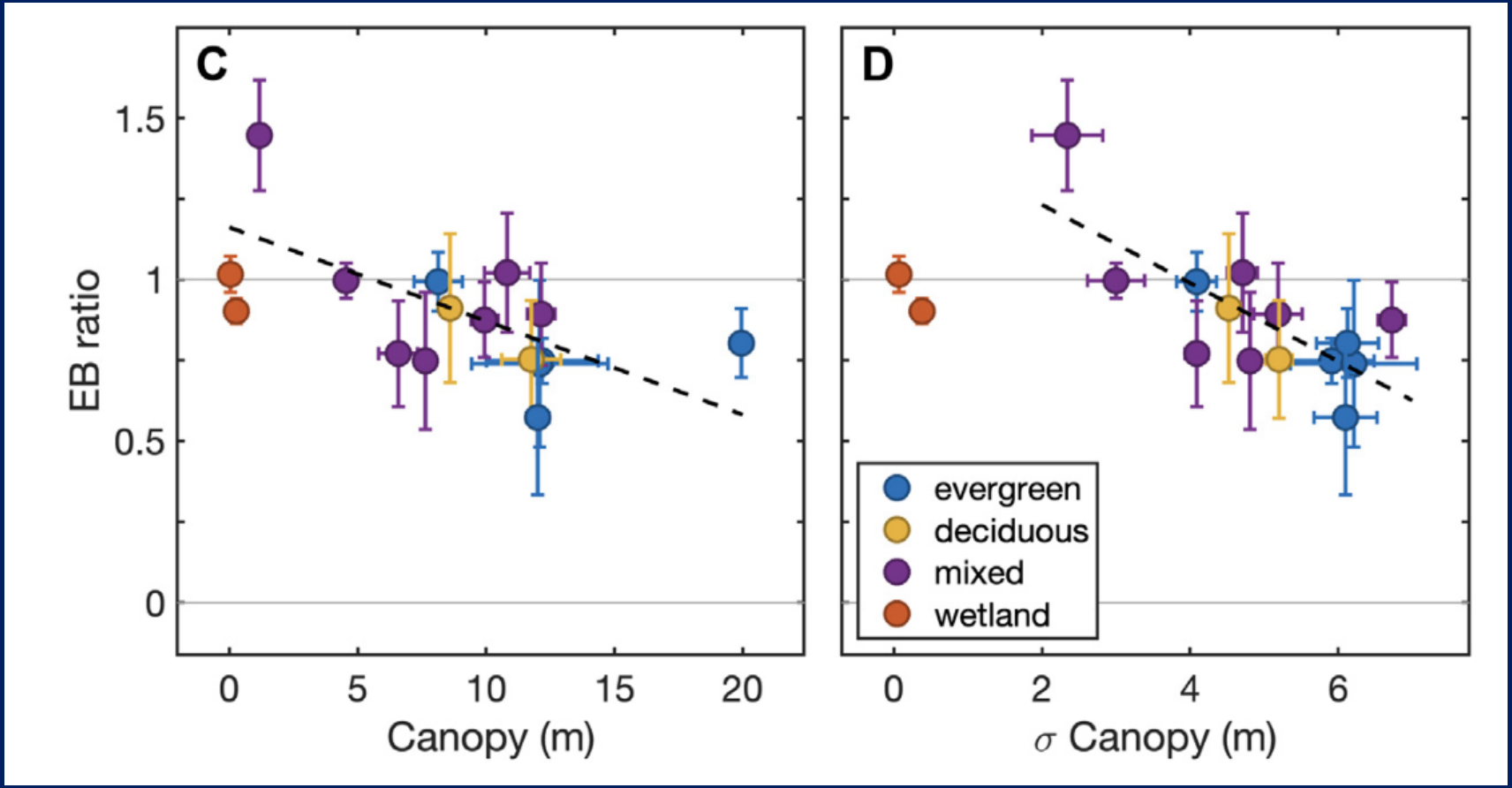
- In many cases, we can ignore it – under homogenous conditions. Is this one homogenous?





Phil Townsend and Ruqi Yang, US-Madison

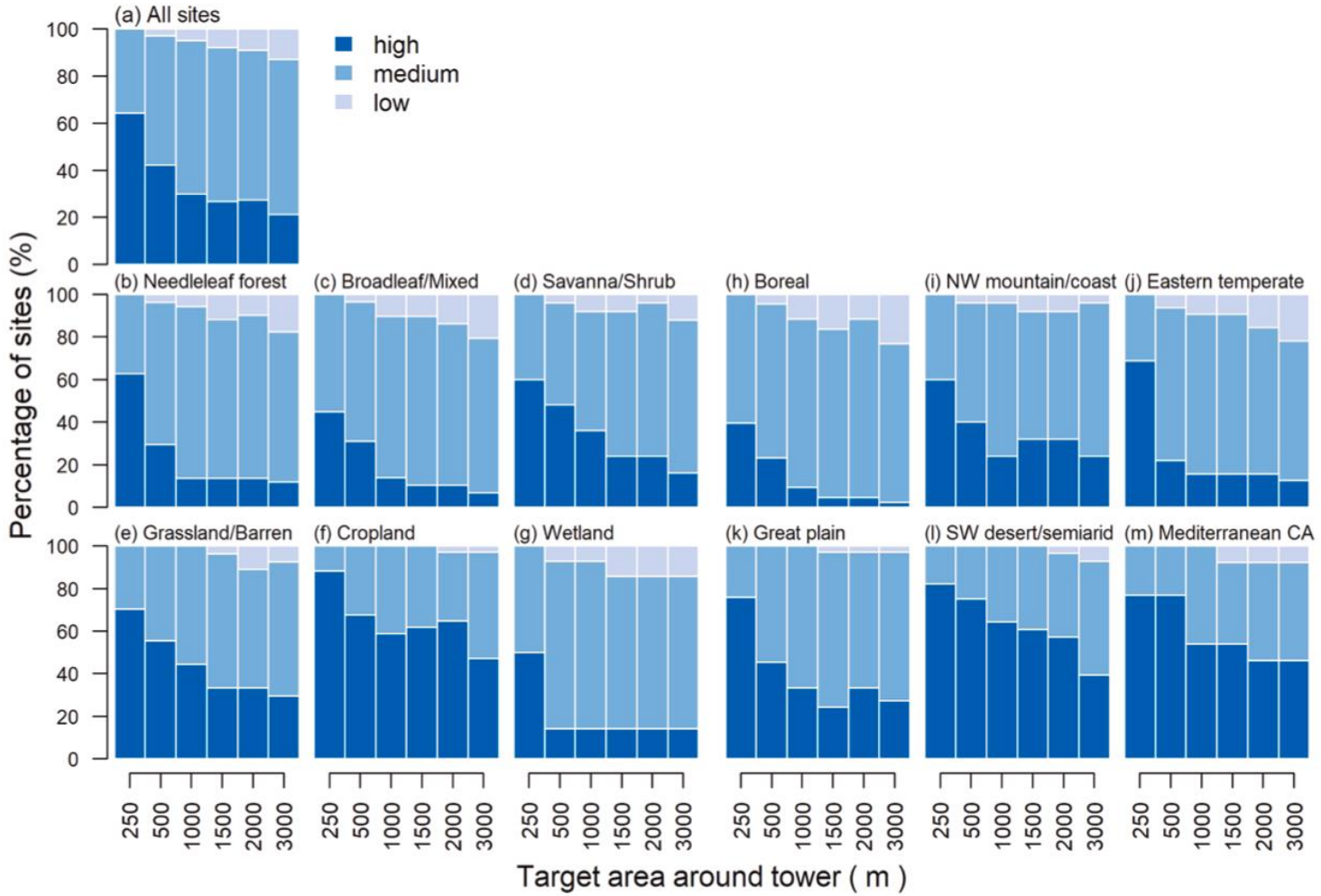
Eddy covariance energy imbalance is sensitive to small scale features



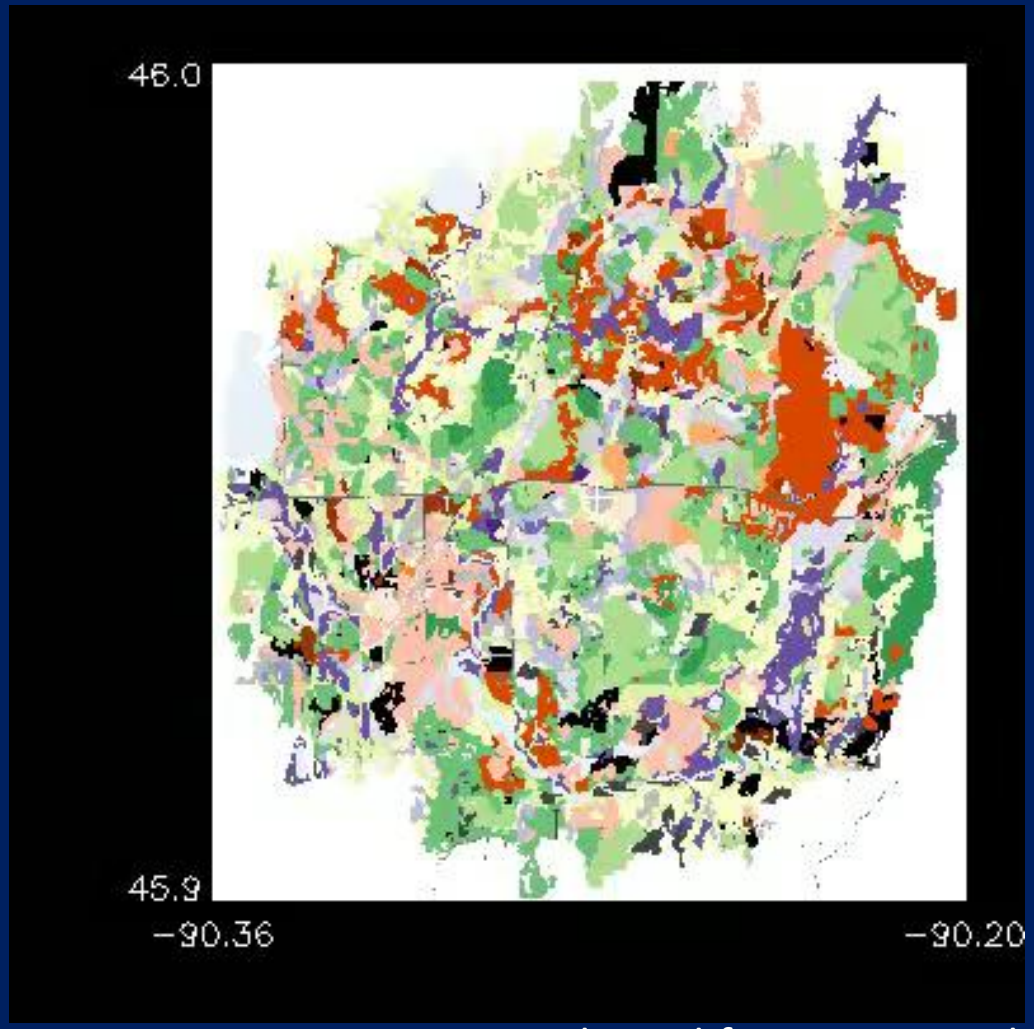
Butterworth et al., 2024

Site footprints are rarely fully “representative”

Agricultural and Forest Meteorology 301-302 (2021) 108350

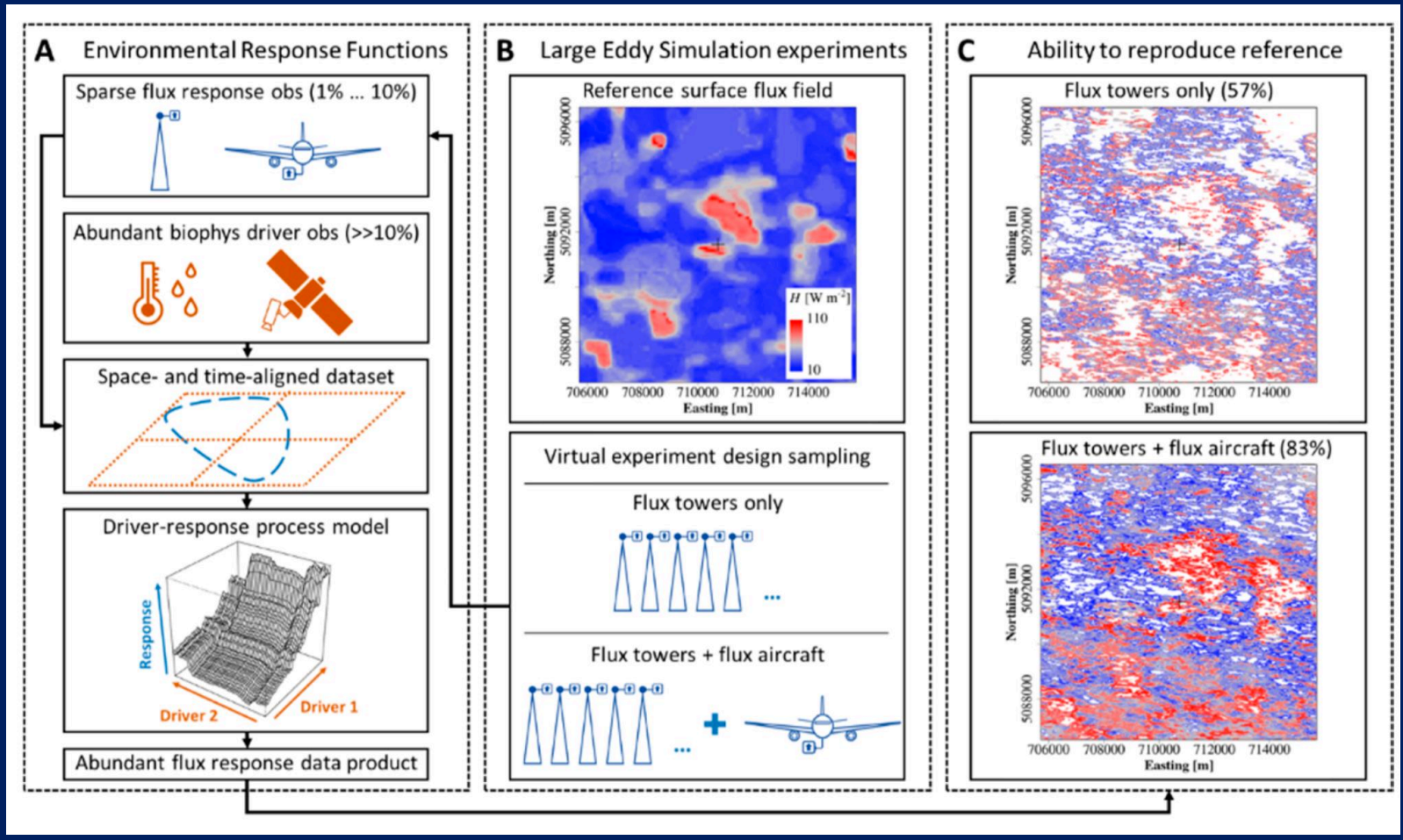


What if we re-envisioned what flux towers do?



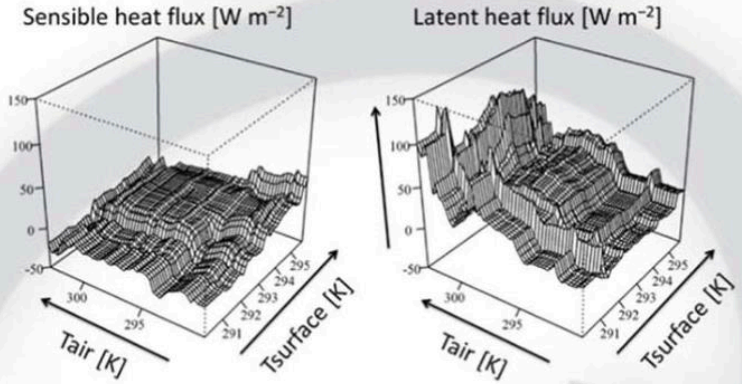
Adopted from a version by HaPE Schmid (KIT)

Mapping fluxes across space

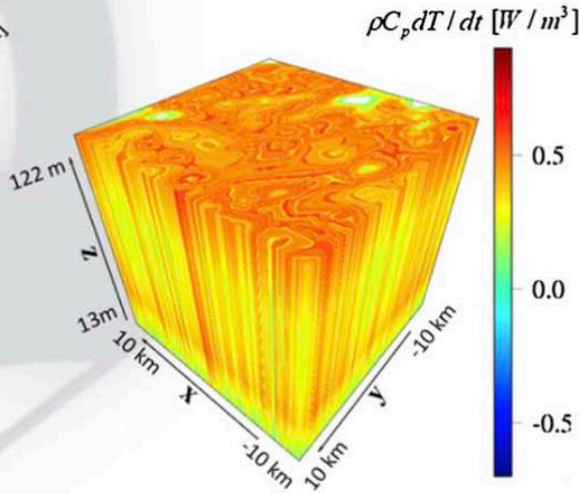


Metzger et al., 2013, 2021 and others

Multivariate responses of surface-atmosphere interactions



Mapped virtual control volume

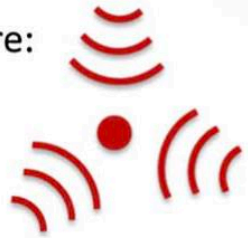


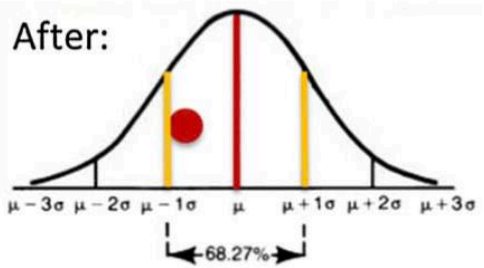
Environmental response function procedure

Ameriflux Park Falls 'very tall tower' (447 m): Eddy flux at 122 m.

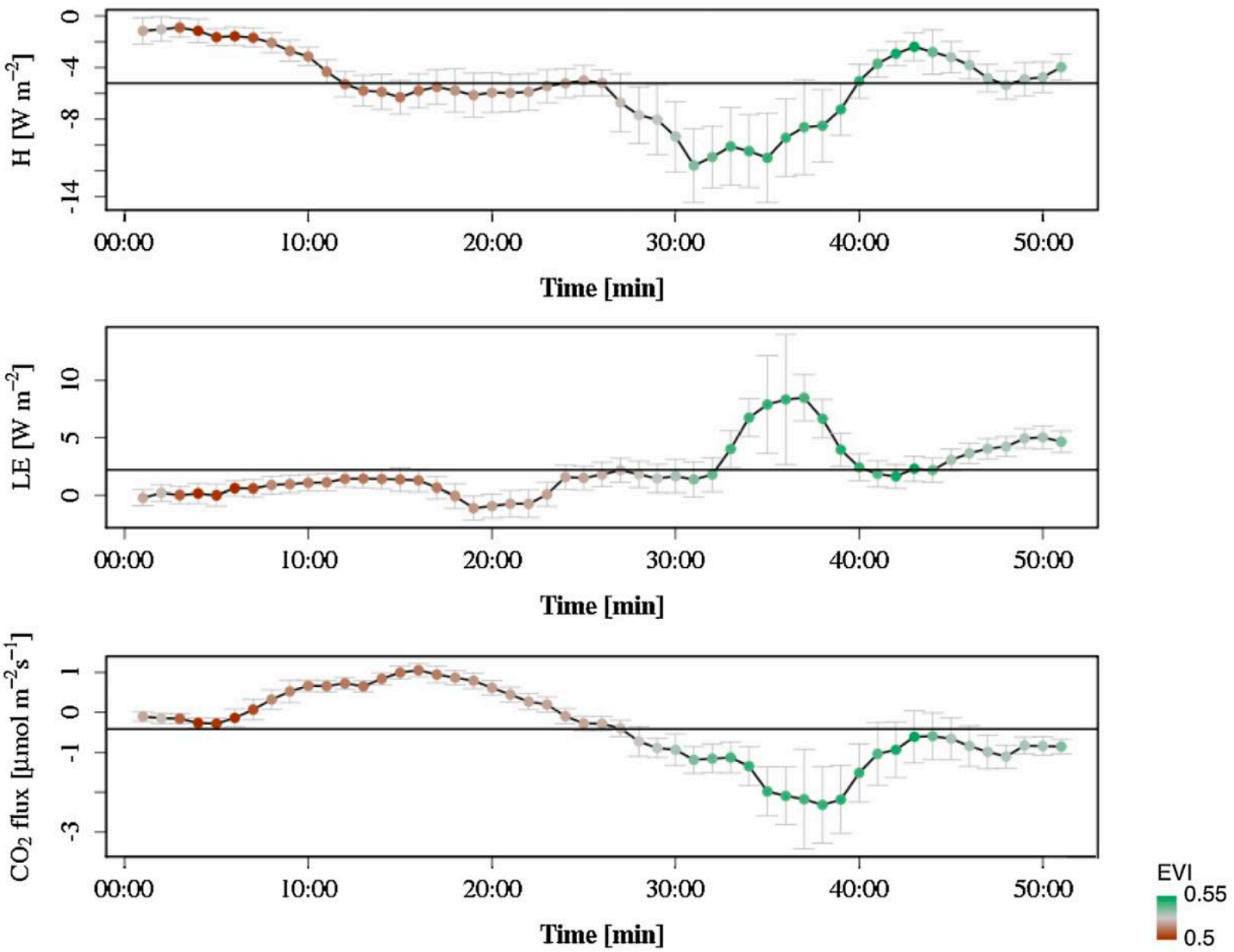
Credit: Matt Rydzik (U Wisconsin)

Before:





Metzger et al., 2013; Xu et al., 2017, 2020


H [W m^{-2}]
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Time [min]
LE [W m^{-2}]
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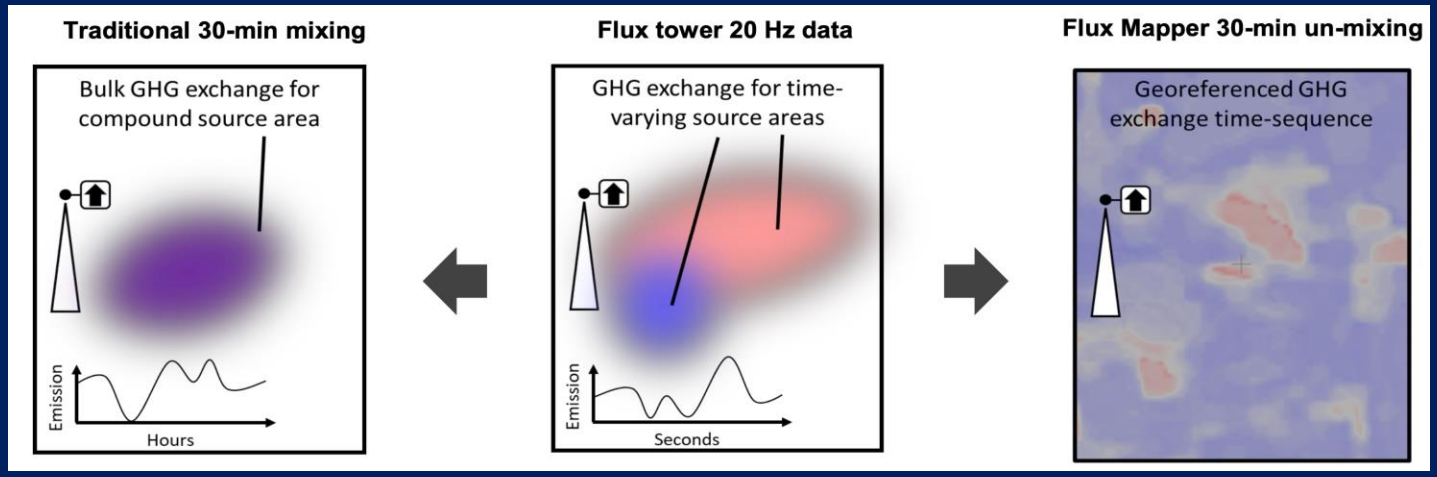
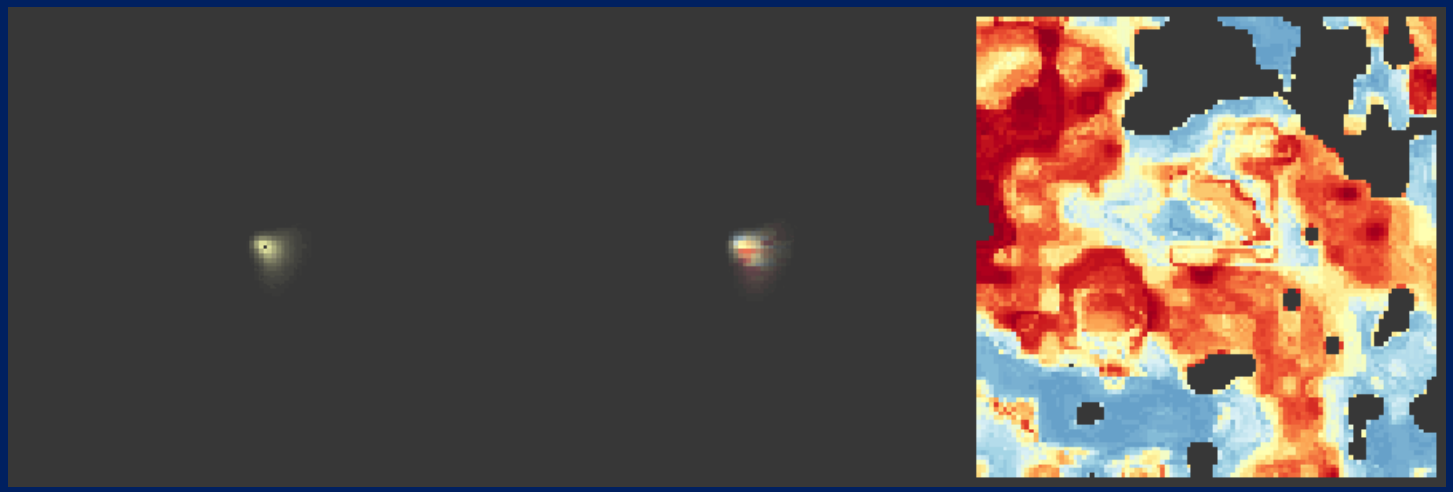
30:00
40:00
50:00
Time [min]
CO_2 flux [µmol m^{-2}s^{-1}]
1
0
-1
-3
00:00
10:00
20:00
30:00
40:00
50:00
Time [min]
EVI
0.55
0.5

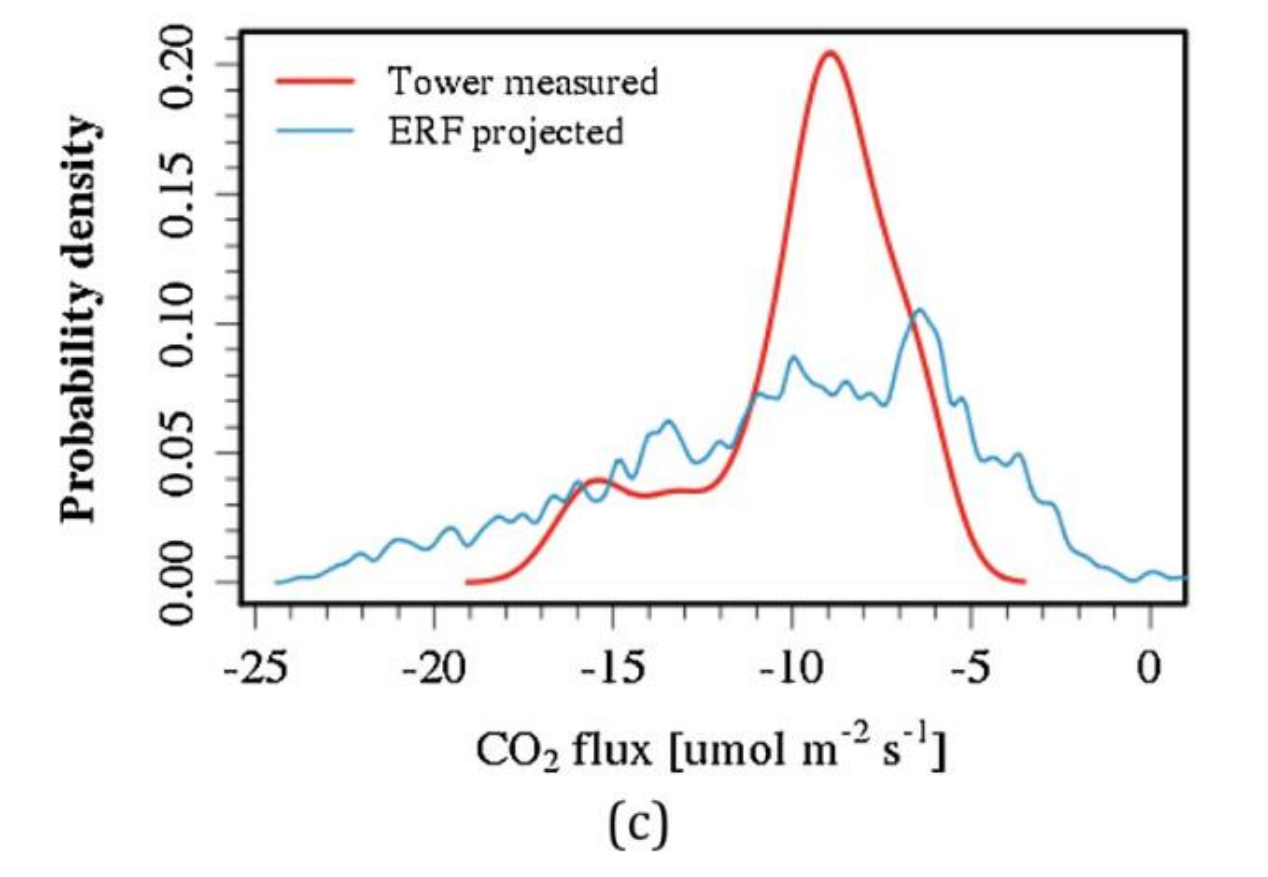
Gaining more information by scaling





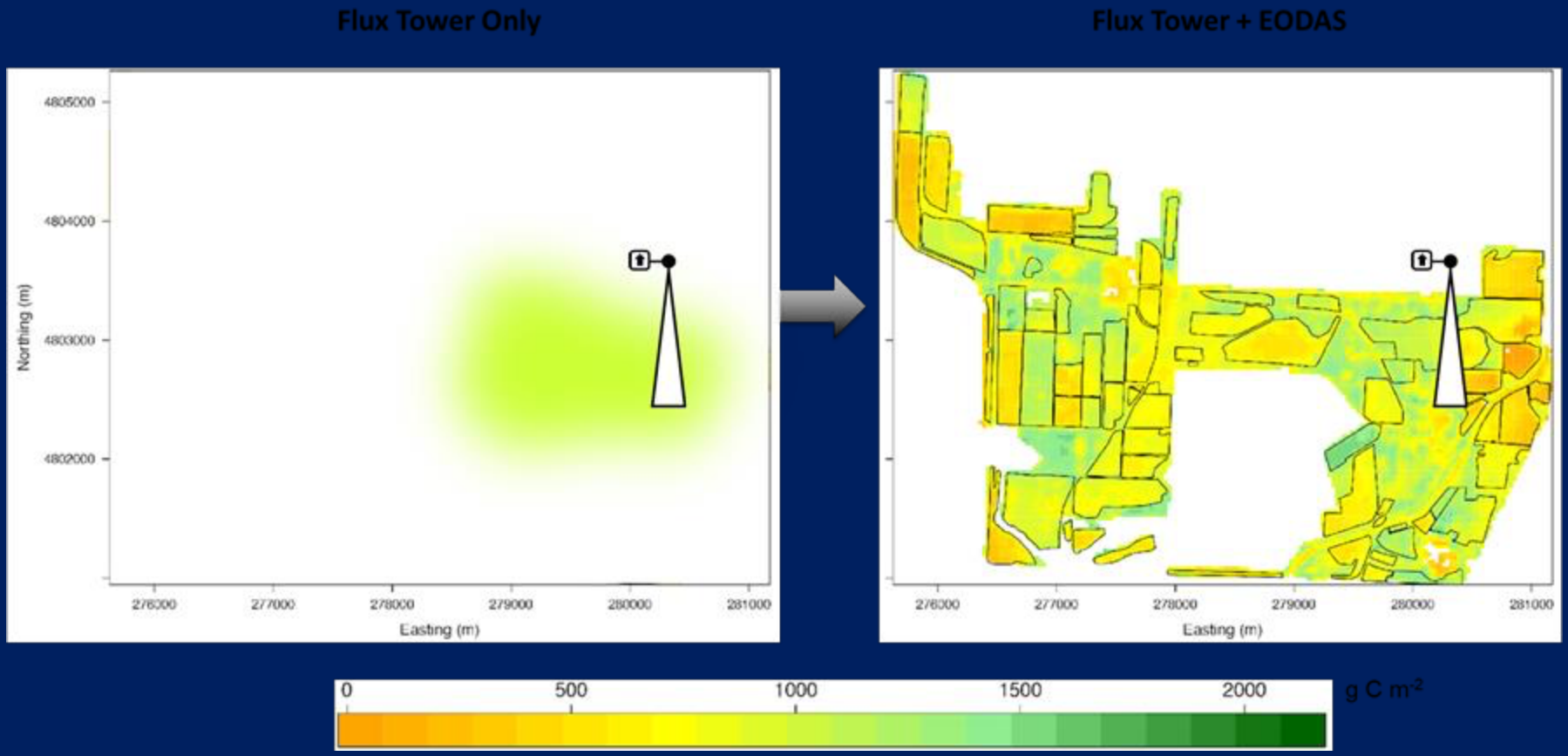
Metzger et al., 2018, AFM
https://www.atmofacts.com/

Right-scaling makes a difference in estimation of mean and spatial variability of fluxes



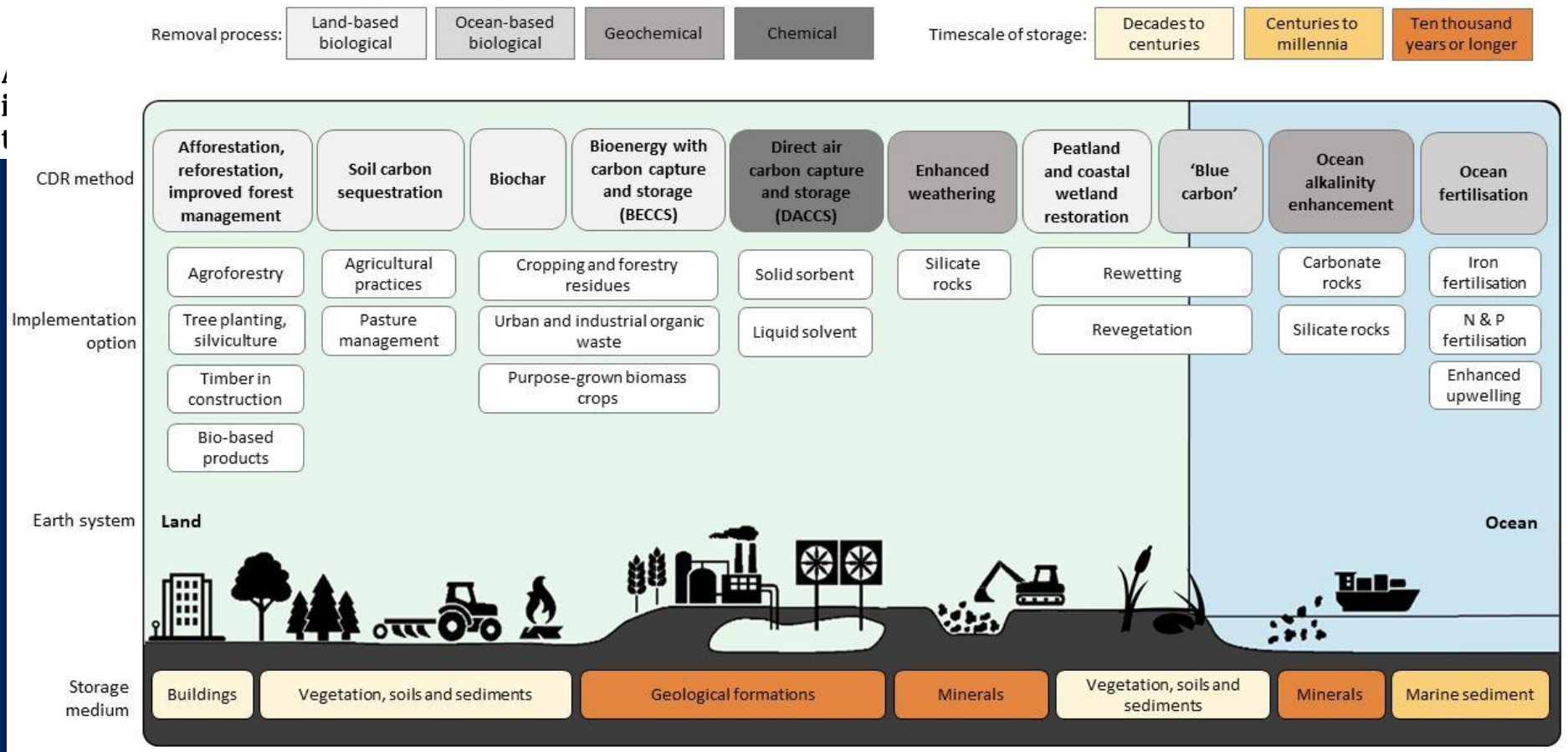
Xu et al., 2017, AFM

And let’s us more reliably upscale too!



S Metzger + Wiesner et al., 2022,, JGR-Biogeo

Corporations invested in carbon offsets



IPCC 6th assessment Working Group 1

Some questions to ponder

- Can we develop community tools for properly down/up/right scale individual site tower fluxes in a world of hyper-everything remote sensing?
- Can we gain information from additional plot-level measurements (and rectify biases with towers)?
- How might this "information-gain" lead to better evaluation of Earth system models, quantification of Nature-based climate solutions, and decision-making around ecosystem resource management?

Thank you!

Ankur Desai
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https://flux.aos.wisc.edu
@profdesai

- Contributions from:
  - Stefan Metzger and many ChEAS Ameriflux core site and CHEESEHEAD19 collaborators
  - Phil Townsend lab @ UW
- Support:
  - DOE Ameriflux Network Management Project contract to ChEAS core site cluster, NSF AGS 2313772 + 1822420 (CHEESEHEAD), NOAA ESRL

Photo: A. Desai

David Durden
09 July 24

From the plot to the plane: NEON's integrated scaled design

This material is based upon work supported by NSF's National Ecological Observatory Network which is a major facility fully funded by the National Science Foundation

National Ecological Observatory Network (NEON)

…a continental-scale, long-term (30 year) Observatory, funded by NSF and operated by Battelle

Enables:

- Analysis: Free and open data and samples on the drivers of and responses to environmental change
- Comparison: Standardized and reliable framework for research and experiments
- Interoperability: Integration with other national and international network science projects

BATTELLE






NSF | neon Operated by Battelle

National Ecological Observatory Network

BY THE NUMBERS

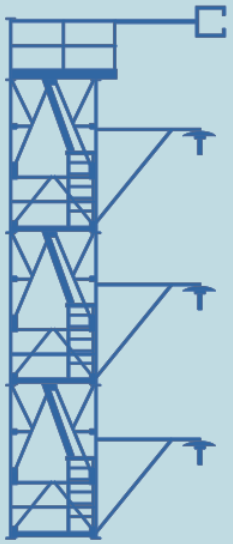
PEOPLE

~600 total staff

320+ full time

250-290 SEASONAL Domain techs

PHYSICAL INFRASTRUCTURE



- airborne observation platforms..... 3
- flux towers..... 47
- water quality stations..... 57
- meteorological stations..... 89
- groundwater wells..... 197
- soil sensor arrays..... 235

34 AQUATIC

47 TERRESTRIAL

81 FIELD SITES

20 ecoclimatic Domains

24 states +1 territory

NSF | neon Operated by Battelle

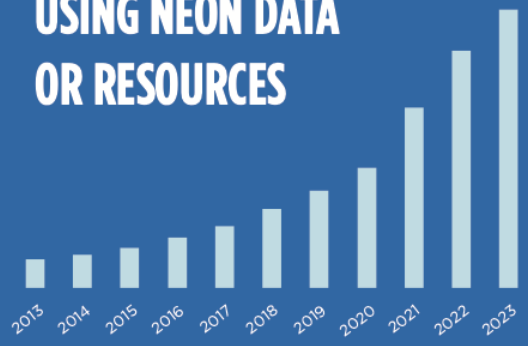
DATA PRODUCTS 180+

500,000+ SAMPLES TO DATE

100,000+ SAMPLES ADDED PER YEAR

900+ PUBS

USING NEON DATA OR RESOURCES



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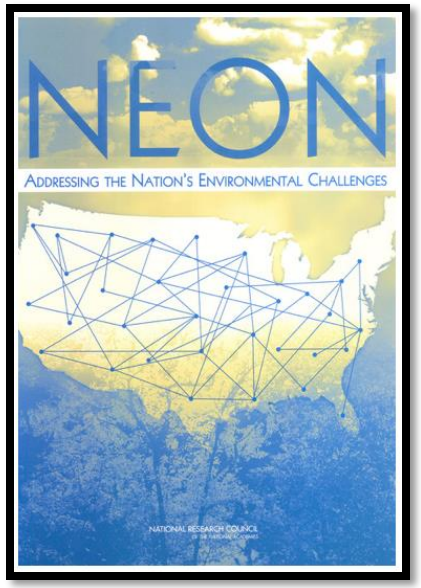
NEON: Designed to understand and forecast the effects of environmental change

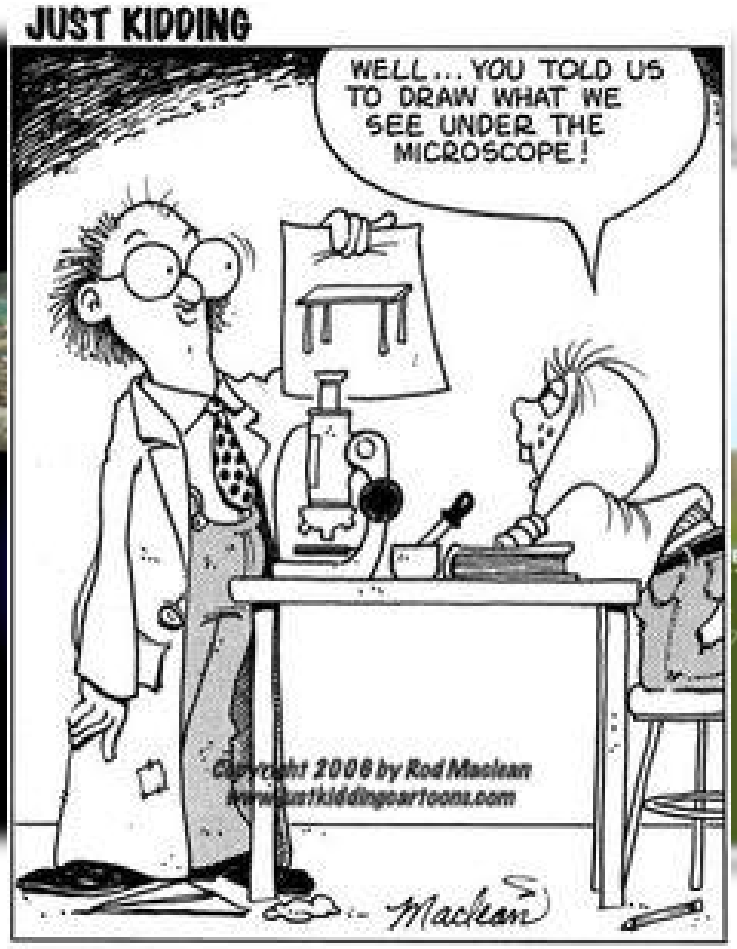


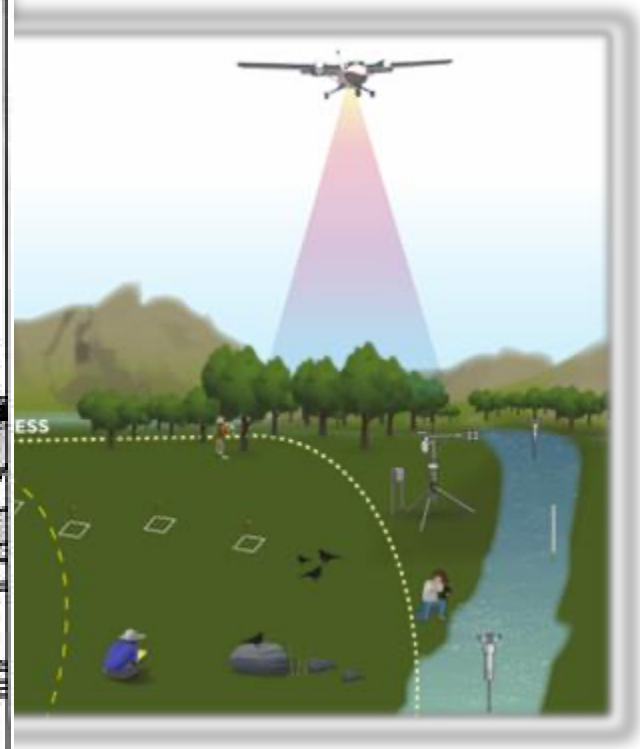
"The central goal of NEON should be to perform comprehensive, regional- to continental-scale experimental and observational research on the nation's natural and managed ecosystems to obtain an in depth understanding of the environment in order ***to assess vulnerability and resilience of ecosystems to environmental change.***"

-NRC, 2003

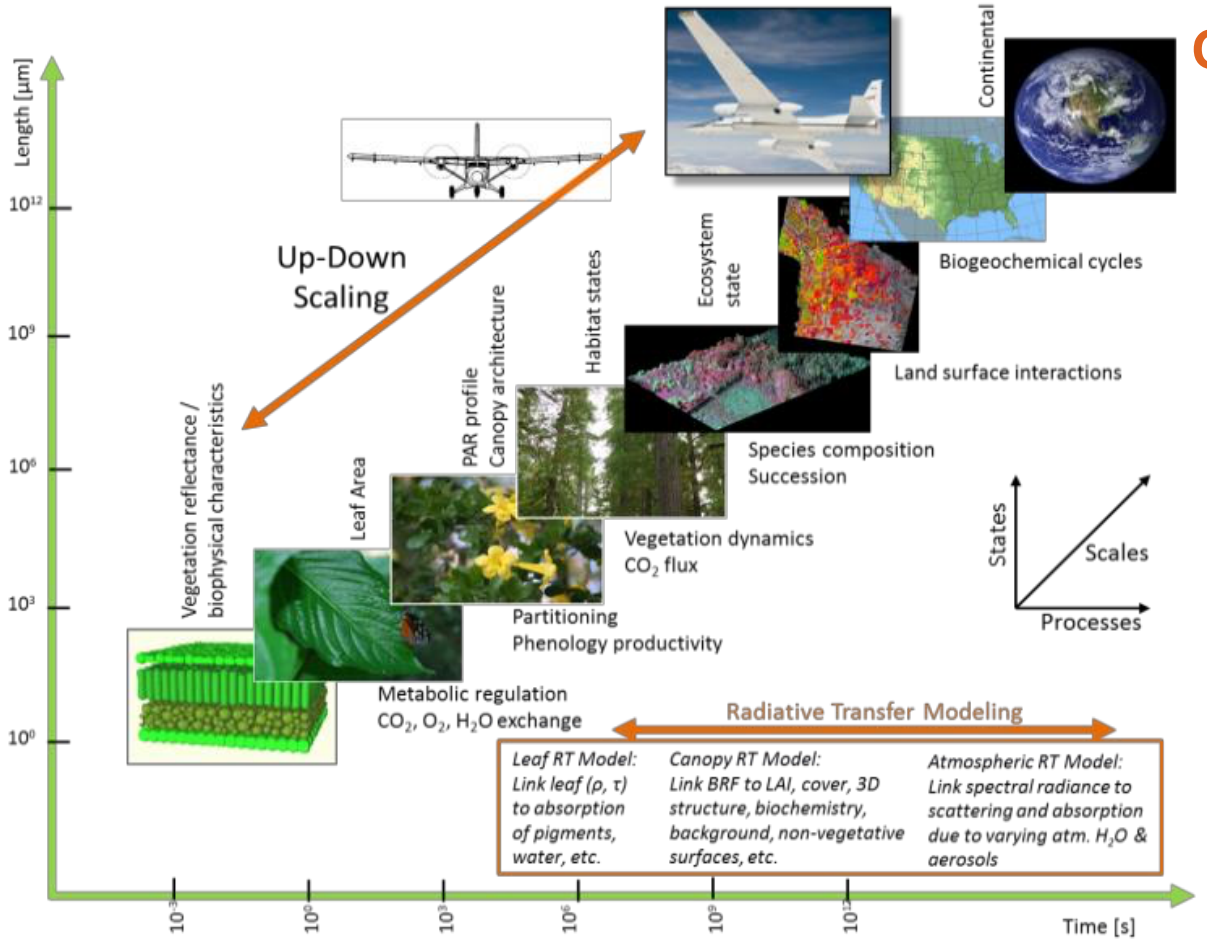
Still an urgent need!

Addressing questions of scale with an observatory





Addressing questions of scale: from the plot to the plane



Observing system design

- Optimize spatial representativeness
  - Eco-climatic domains
  - Representative ecosystems
  - Proper site and measurement density
- Reduce and quantify uncertainty
  - Site selection and design
  - Calibration and maintenance
  - Algorithmic processing
  - QAQC

Scaling techniques

- Data driven
  - Relationships directly from data
- Process driven
  - Theoretically prescribed
- Data fusion & machine learning
  - Using data with models to drive understanding

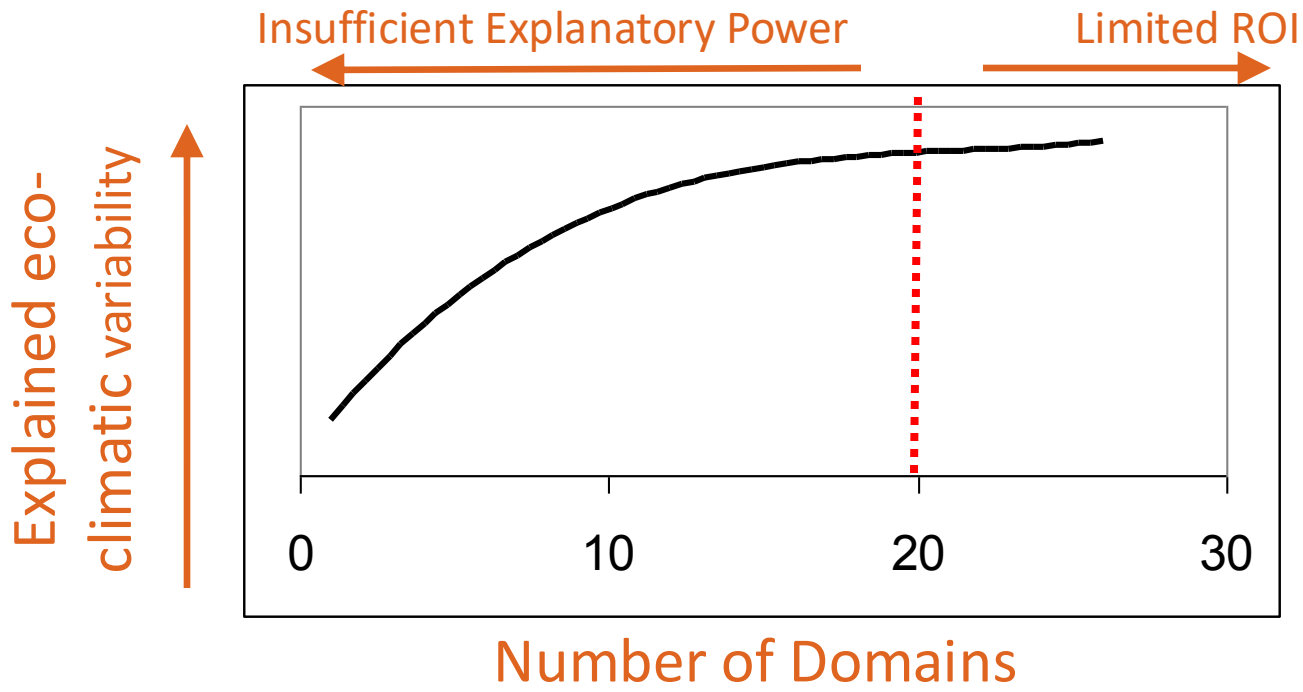
Why 20 domains?

DOI: 10.1007/s00267-003-1084-0

Potential of Multivariate Quantitative Methods for Delineation and Visualization of Ecoregions

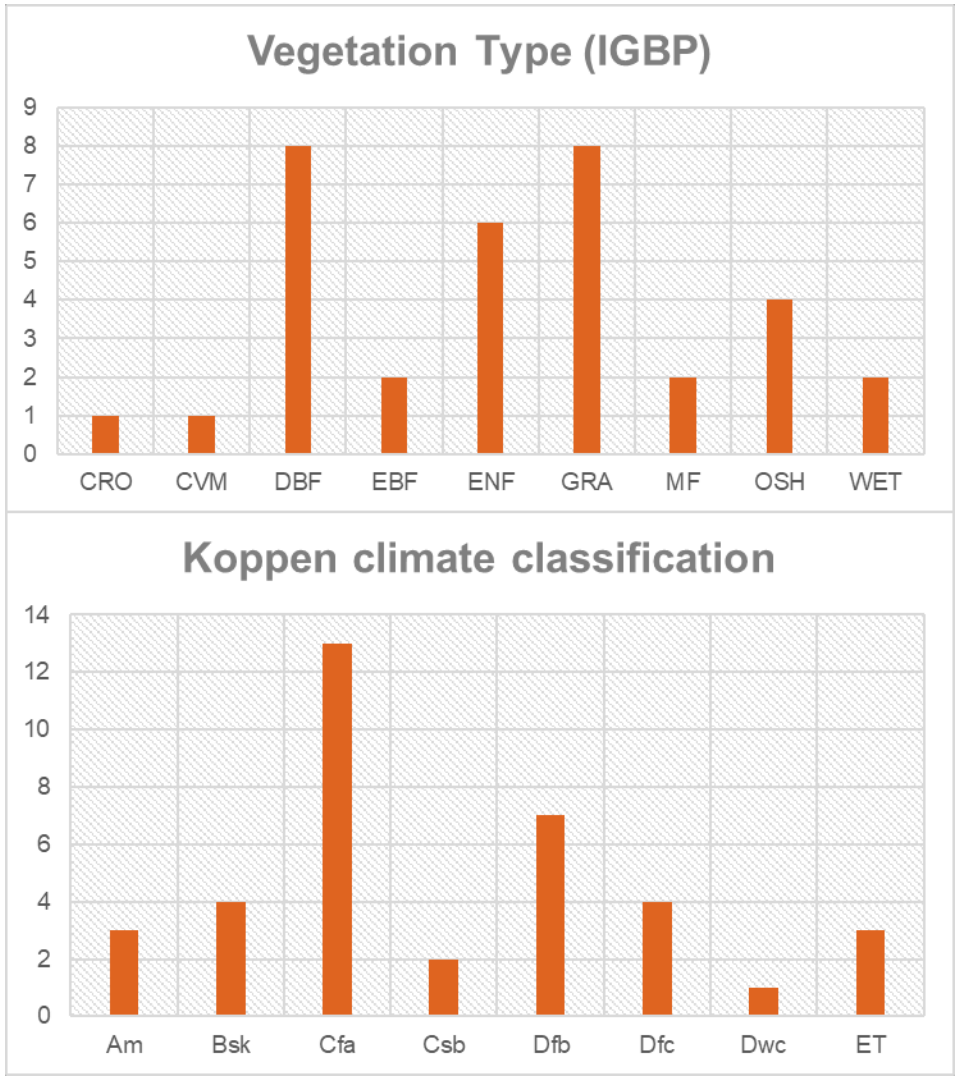
WILLIAM W. HARGROVE*
FORREST M. HOFFMAN
Environmental Sciences Division
Computer Science and Math Division
Oak Ridge National Laboratory
P. O. Box 2008, M.S. 6407
Oak Ridge, Tennessee 37831-6407

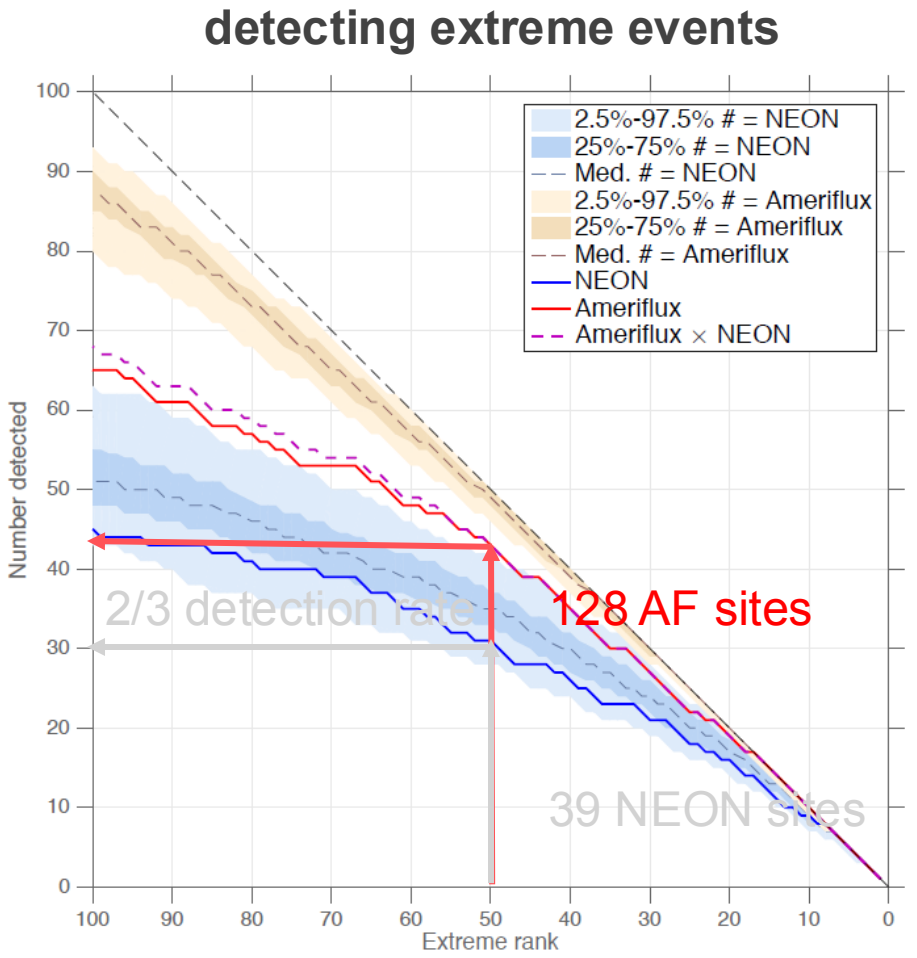
from the limitations of human subjectivity, making possible a new array of ecologically useful derivative products. A red–green–blue visualization based on principal components analysis of ecoregion centroids indicates with color the relative combination of environmental conditions found within each ecoregion. Multiple geographic areas can be classified into a single common set of quantitative ecoregions to pro-



This material is based upon work supported by NSF's National Ecological Observatory Network which is a major facility fully funded by the National Science Foundation

Measurement representativeness

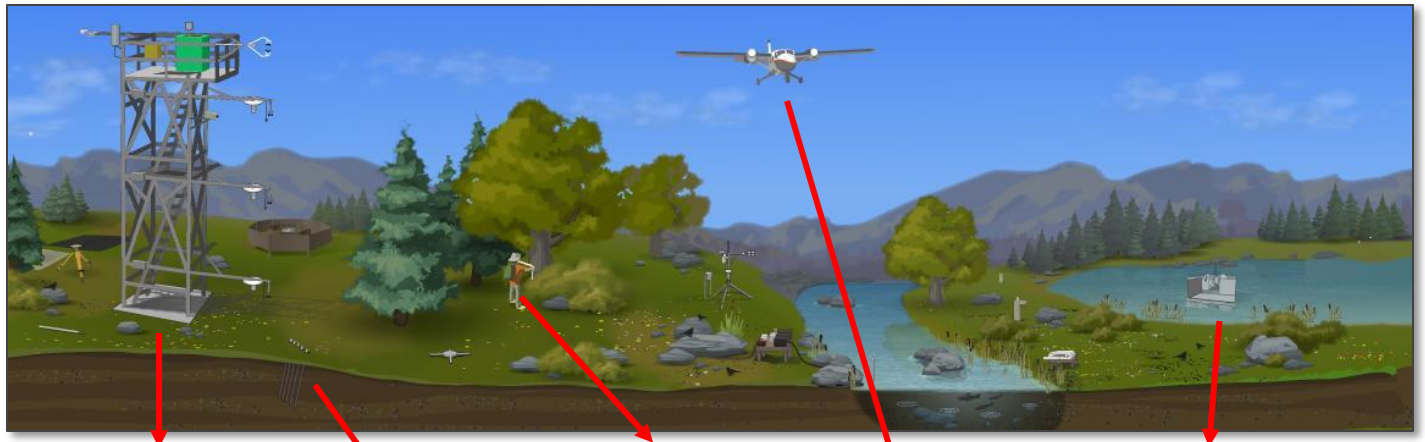




Mahecha et al., 2017

This material is based upon work supported by NSF's National Ecological Observatory Network which is a major facility fully funded by the National Science Foundation

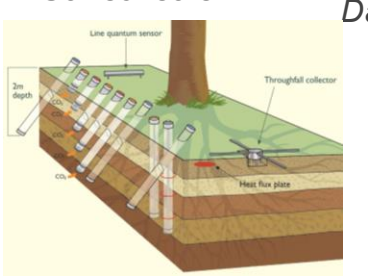
Standardized data collection



Tower for atmospheric data & eddy flux

Terrestrial Instruments

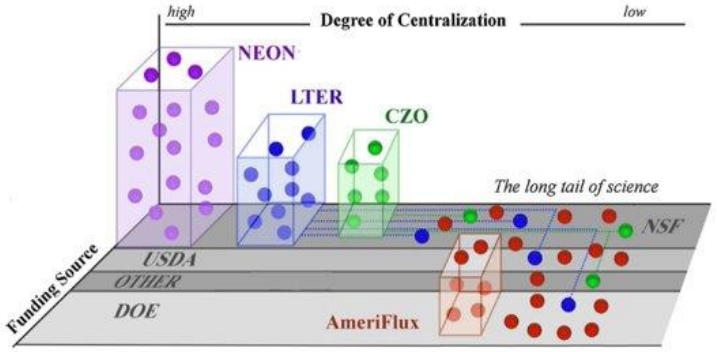
Soil sensors



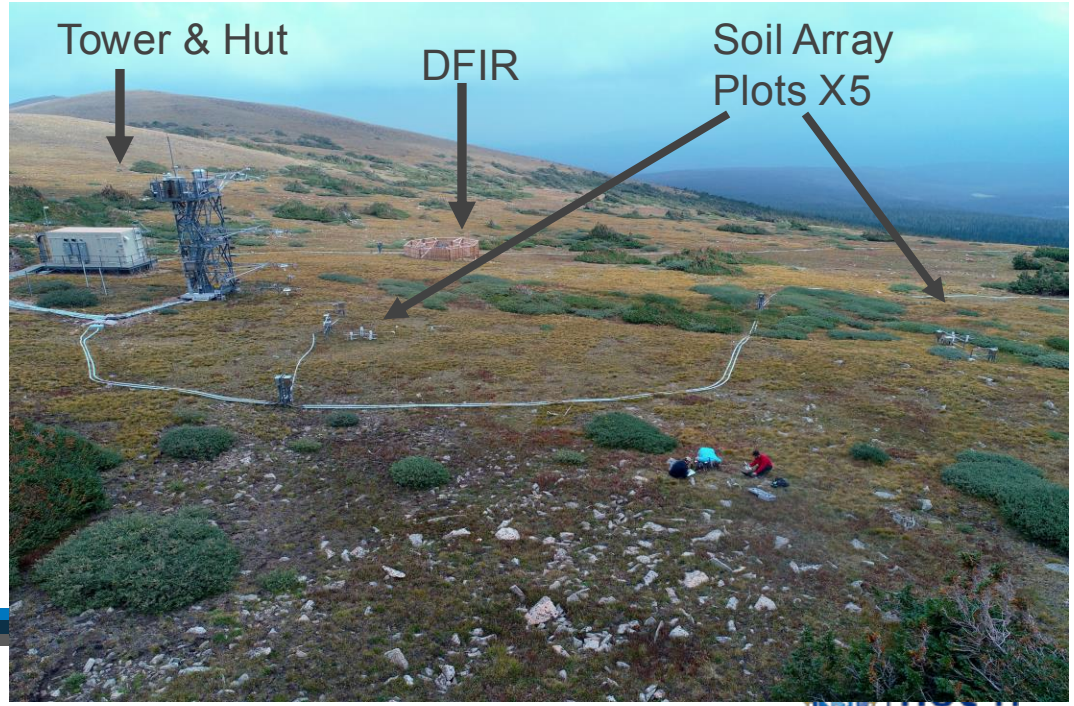
Terrestrial Observations
Data and sampling

Airborne observations
Hyperspectral, LiDAR, RGB

Aquatic Observations & Instruments
Sensors, data, sampling

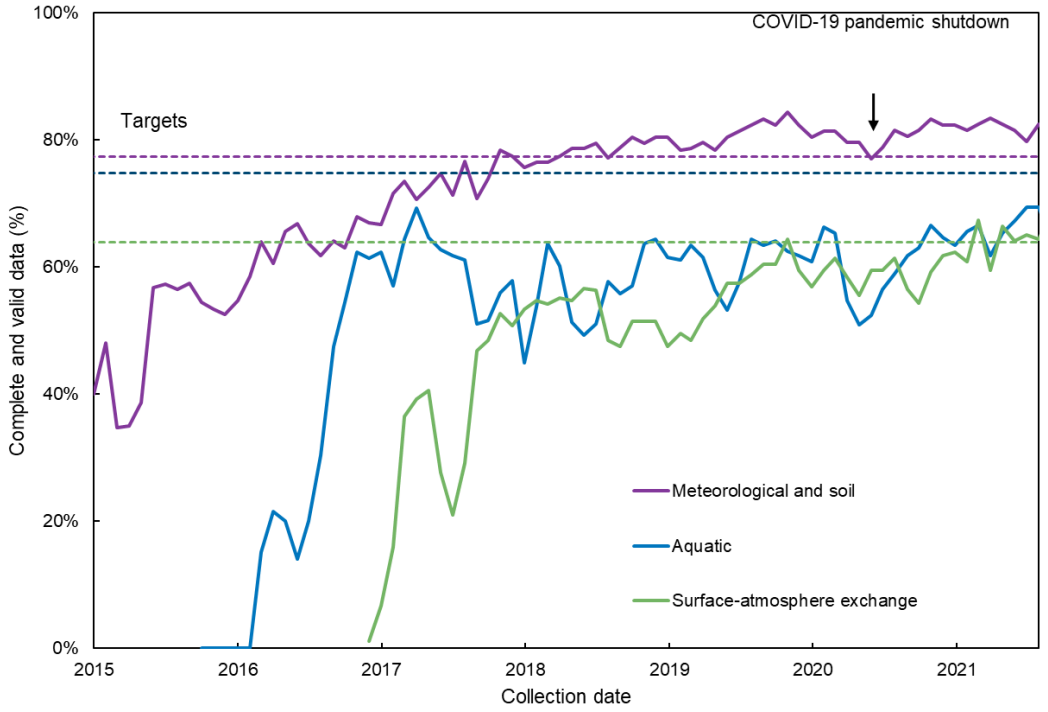


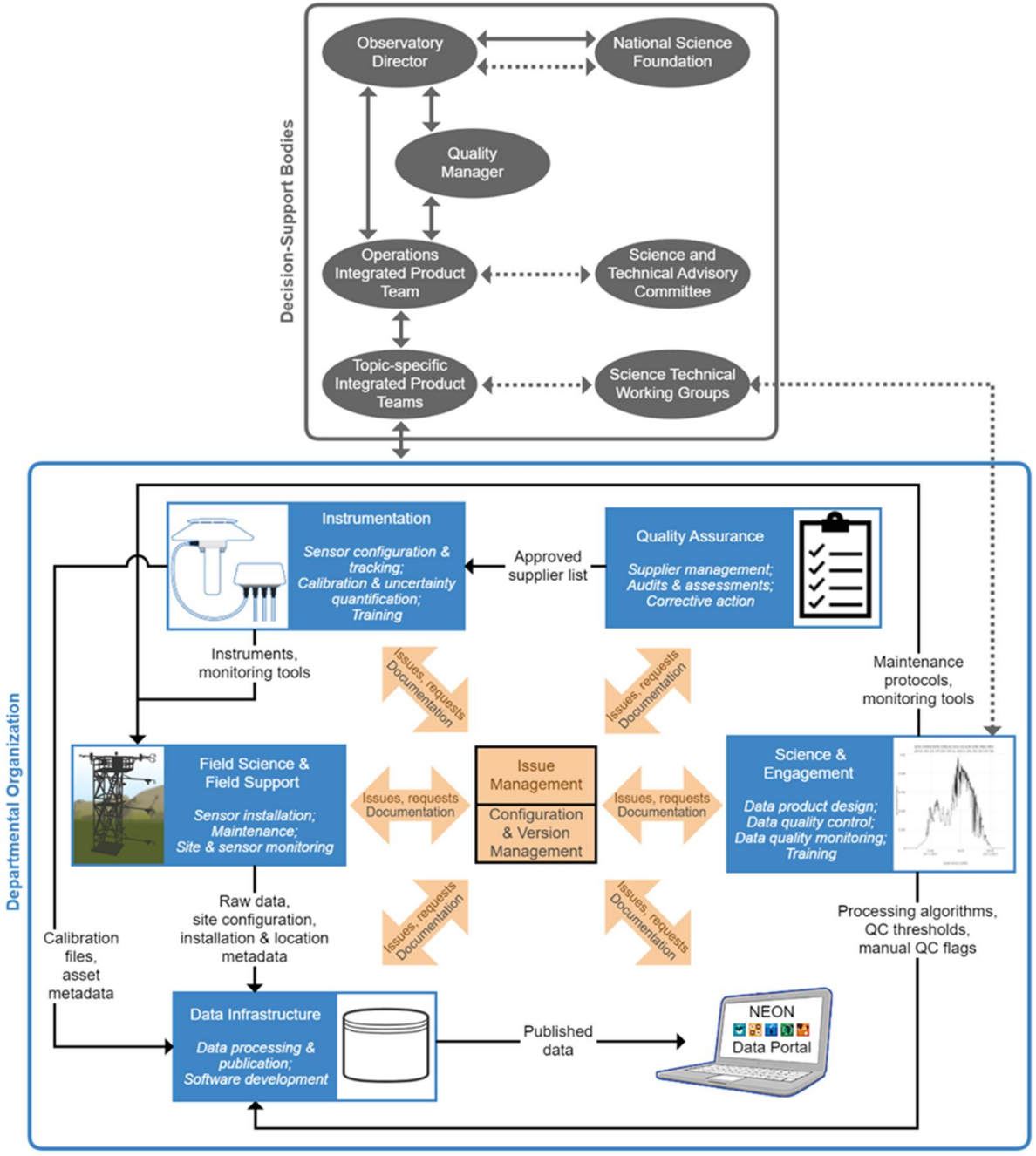
Standardized, colocated methods across sites



Novick et al. 2018

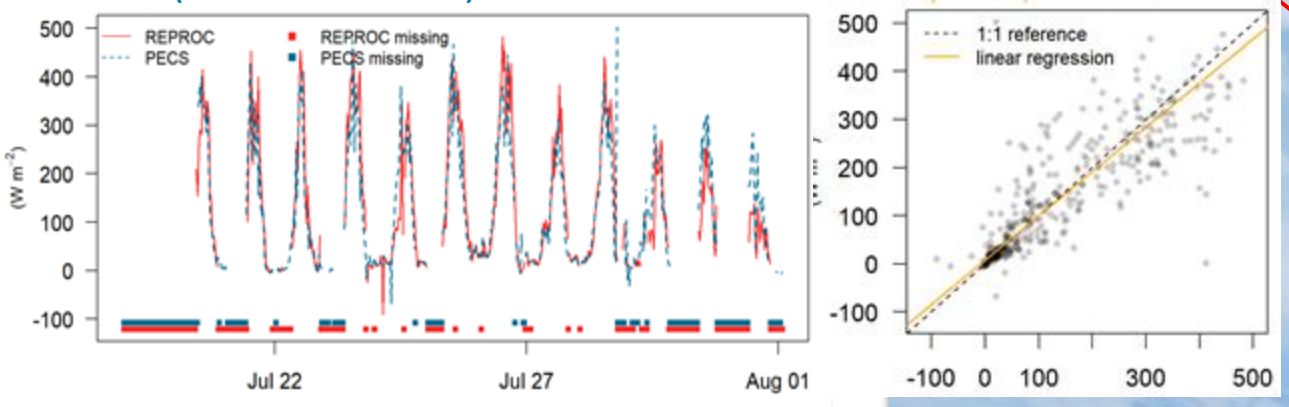
Data Quality



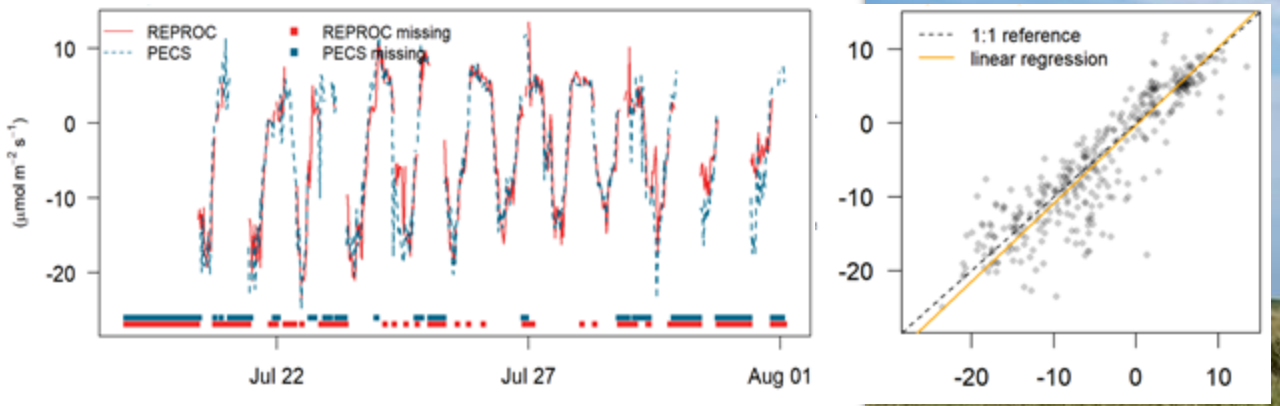


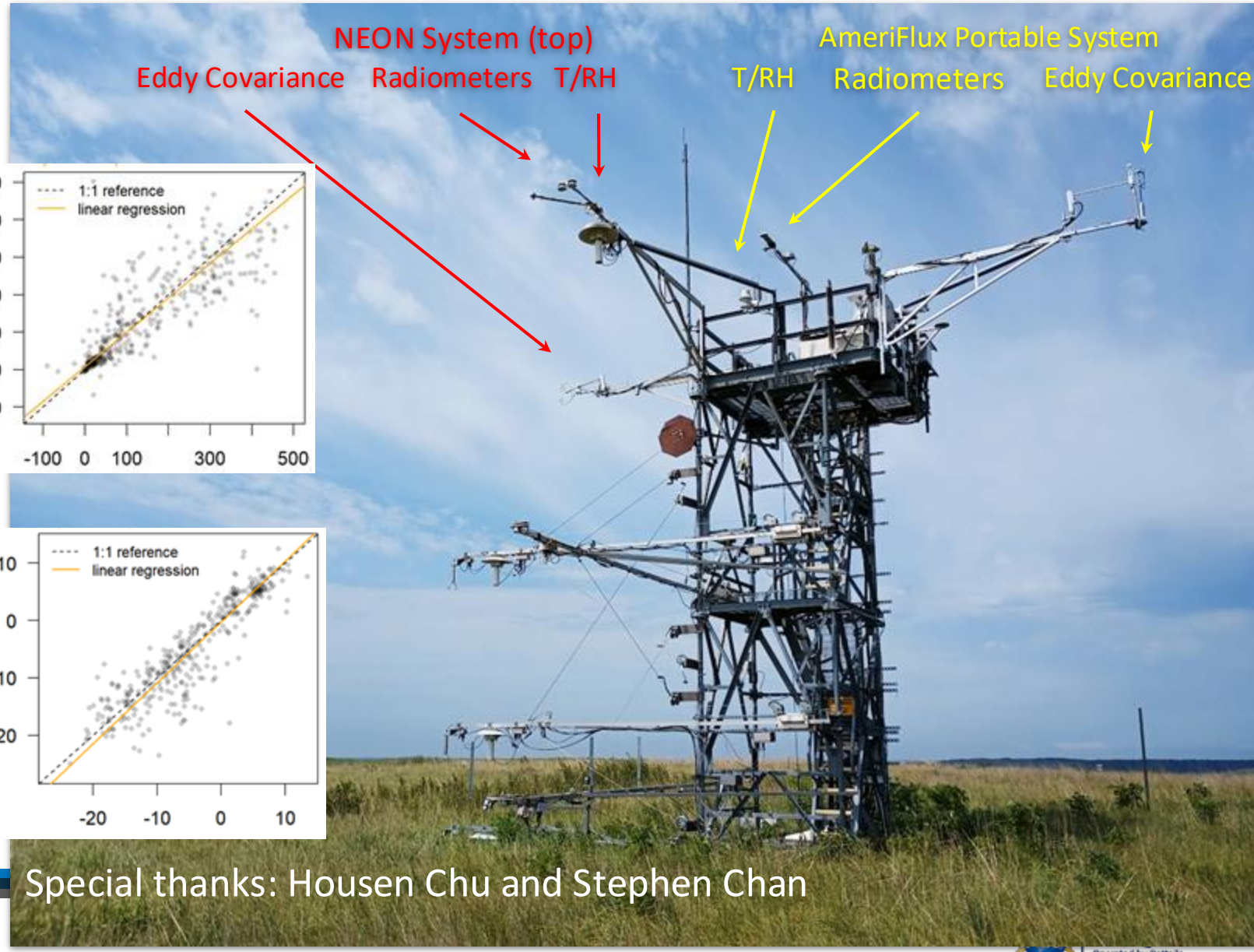
Data quality (continued)

LE (latent heat flux)



FC (CO_2 flux)

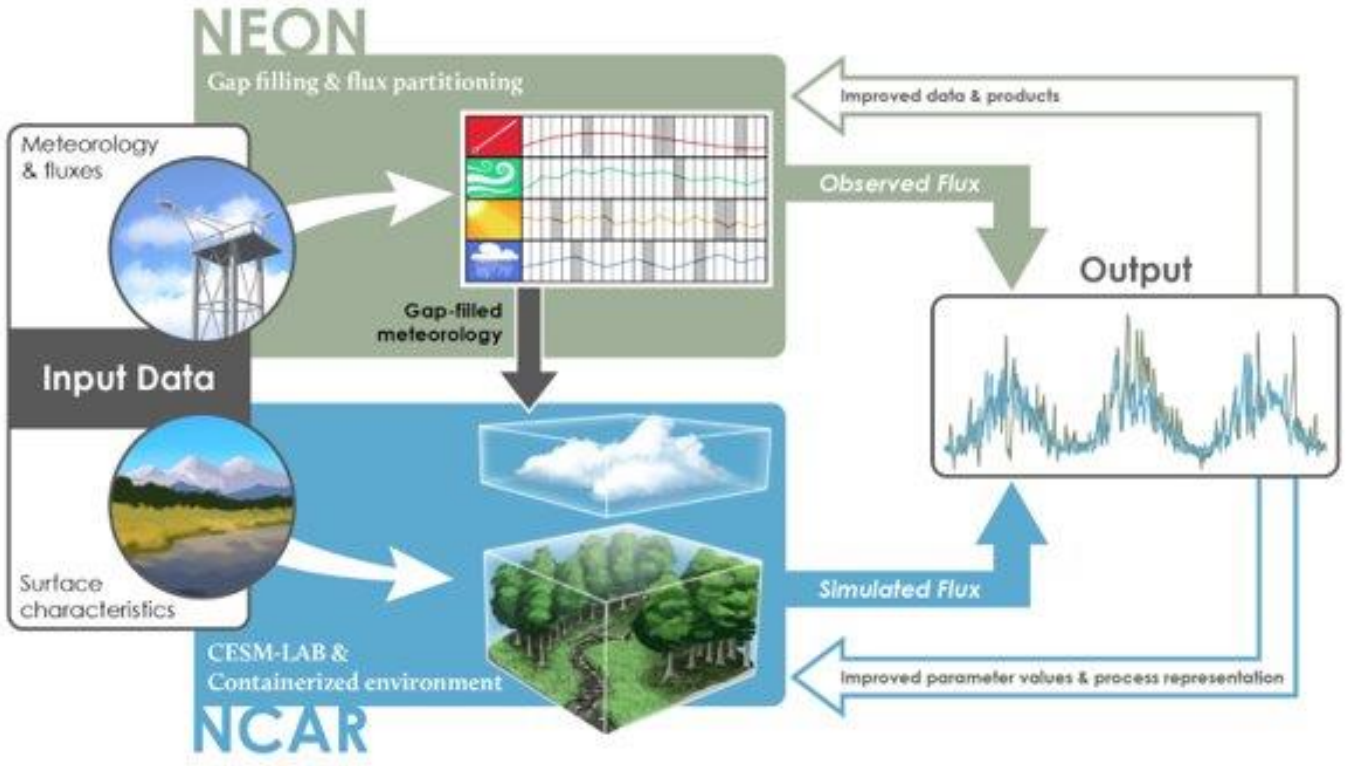




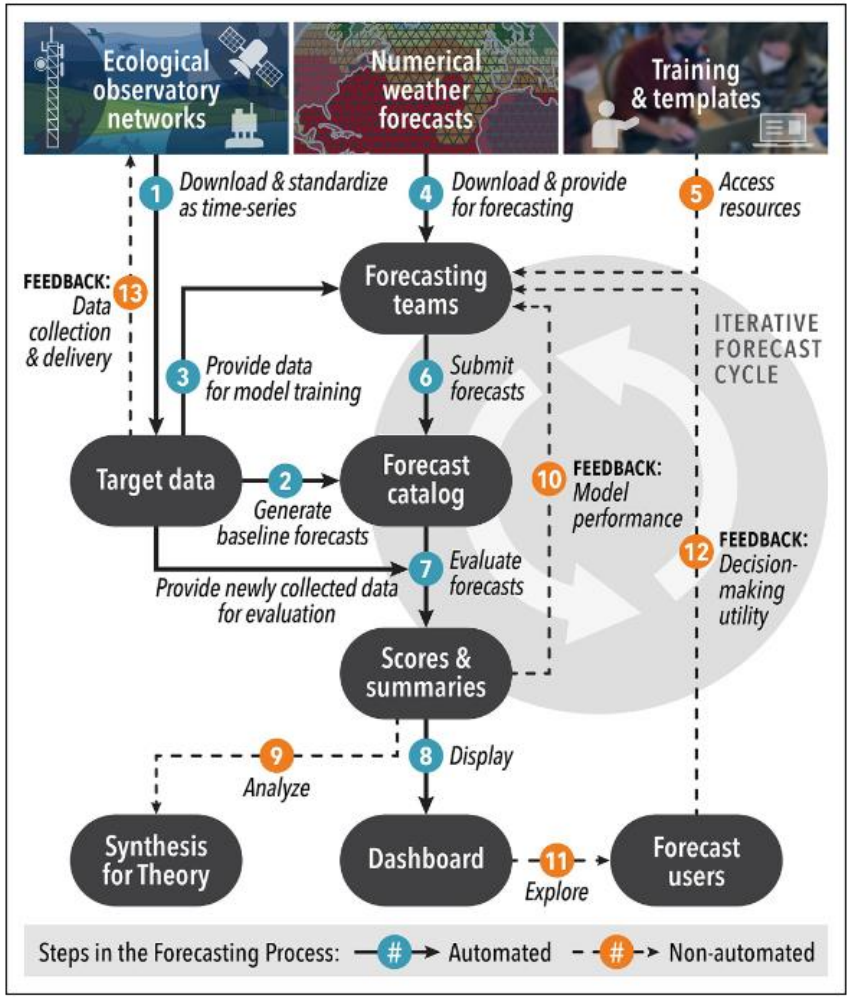
Special thanks: Housen Chu and Stephen Chan

Scaling methods: data-model integration

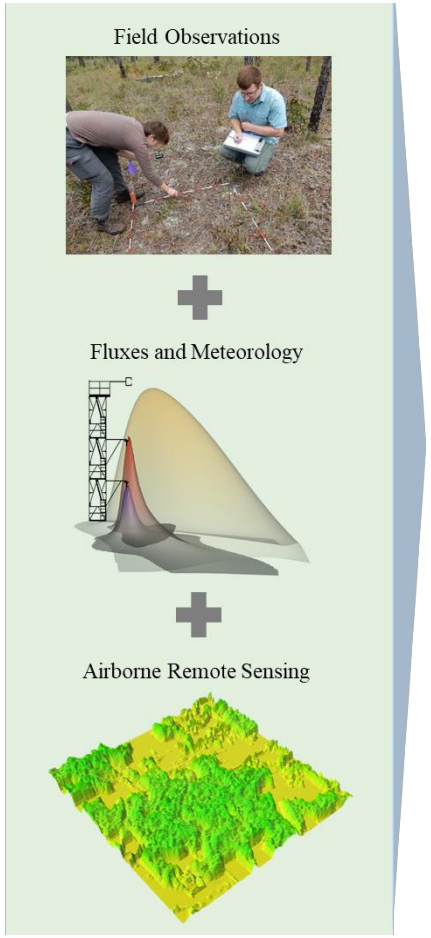
NCAR-NEON model framework

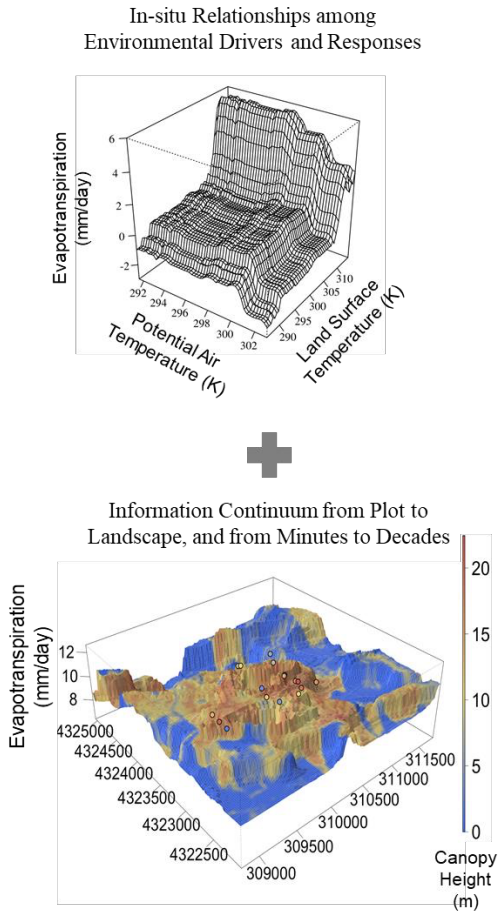


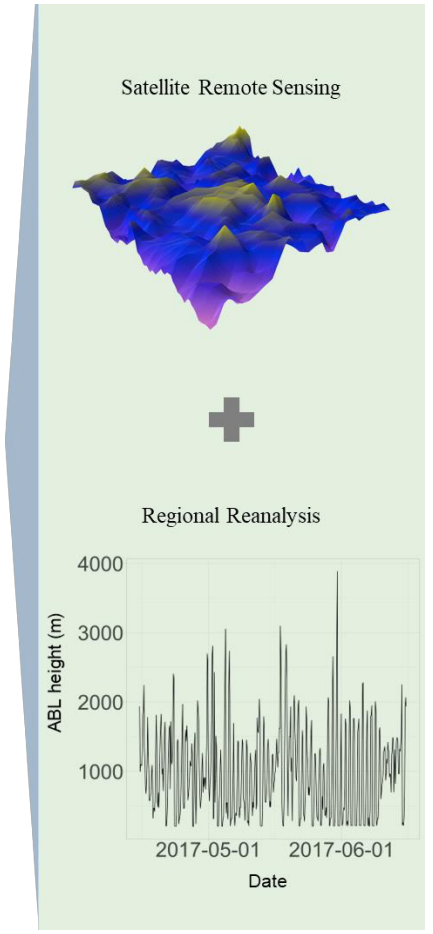
Ecological Forecasting Initiative RCN



Scaling methods: data fusion and machine learning



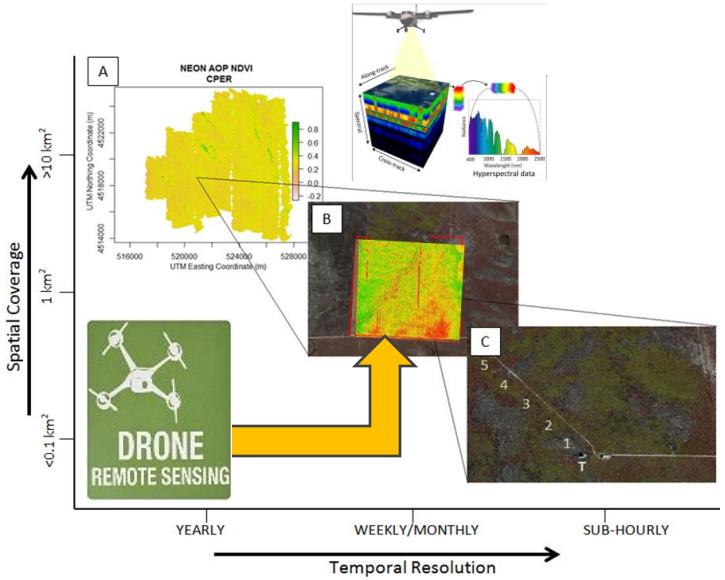




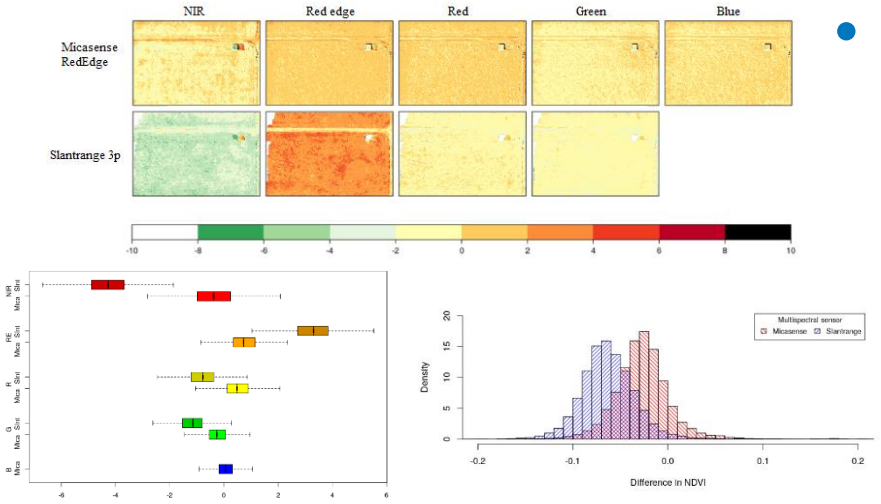
Metzger, S., Ayres, E., Durden, D., Florian, C., Lee, R., Lunch, C., Luo, H., Pingintha-Durden, N., Roberti, J. A., SanClements, M., Sturtevant, C., Xu, K., and Zulueta, R.: From NEON field sites to data portal: a community resource for surface-atmosphere research comes online, Bull. Am. Meteorol. Soc., in review.

Addressing scale gaps: new measurement technologies

Spatiotemporal gaps

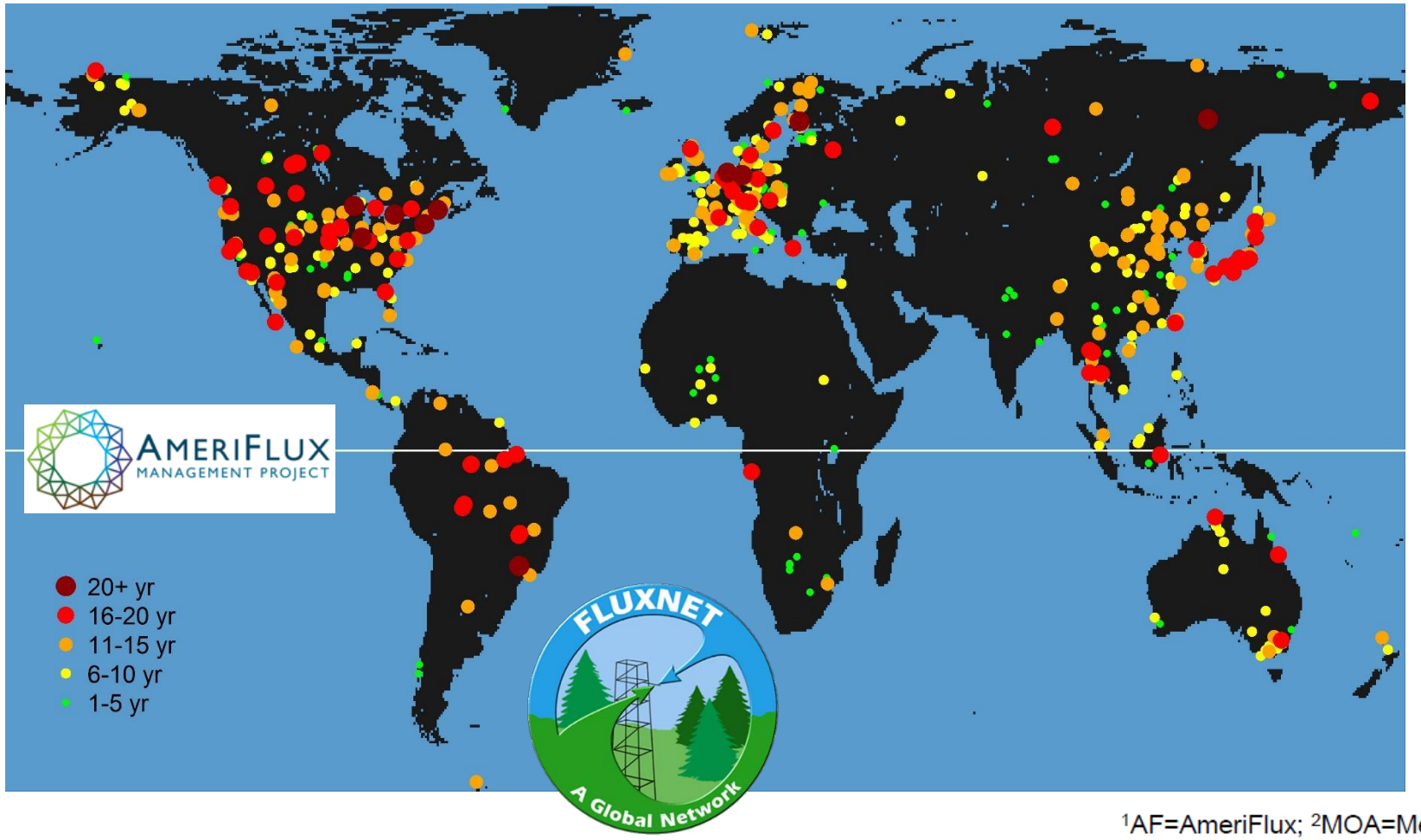


UAS multispectral vs. AOP



- NEON data products span large spatio-temporal scales, e.g. airborne remote sensing and automated tower measurements
- UAS platforms are being evaluated to:
  - provide cost effective and agile remotely sensed data products, with greater temporal resolution
  - enable target-of-opportunity measurement campaigns for extreme ecological events
  - Initial results compared to NEON AOP are promising

Addressing scale gaps: Collaboration (AmeriFlux and FLUXNET)



Our History

2016 White Paper, reciprocal steering committee members

2017 First NEON site @ AF[1], gap-filling collaboration, MOA[2]

2018 First NEON data @ AF

2019 All NEON sites @ AF, biannual data submission

2020 Reciprocal LOCs[3]

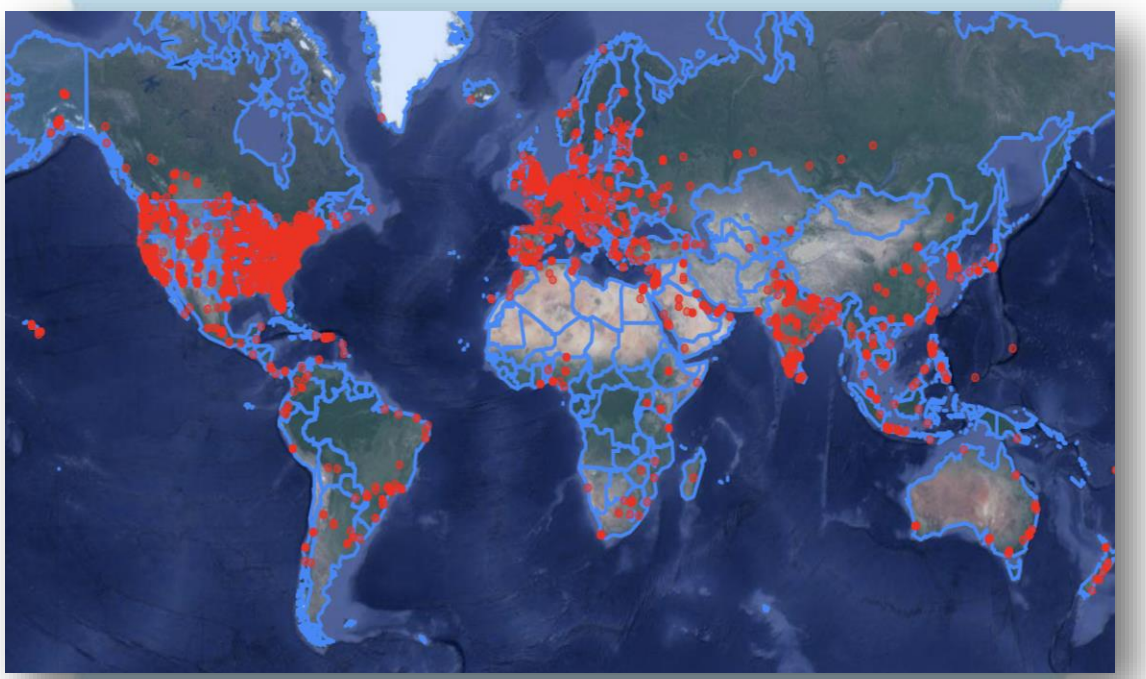
2021 FLUXNET Data Integration

2022 First NEON ONEFlux data

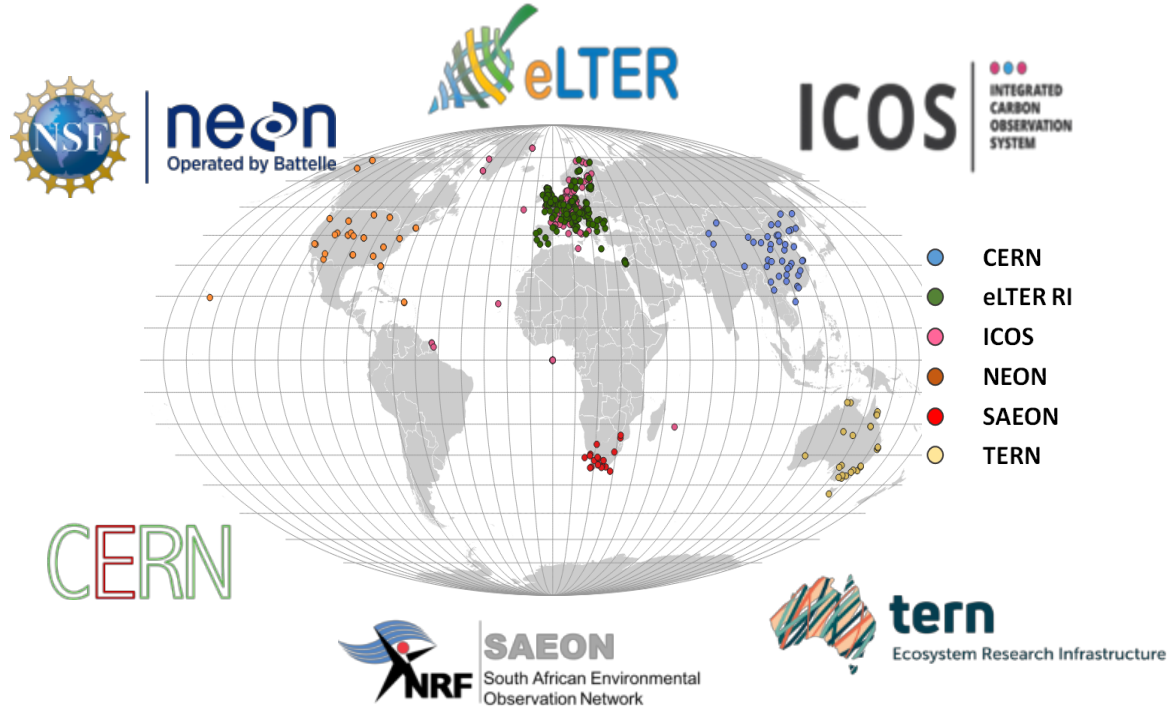
… To be continued…

[1]AF=AmeriFlux; [2]MOA=Memorandum of Agreement; [3]LOCs=Letters of Collaboration;

Addressing scale gaps: Collaboration

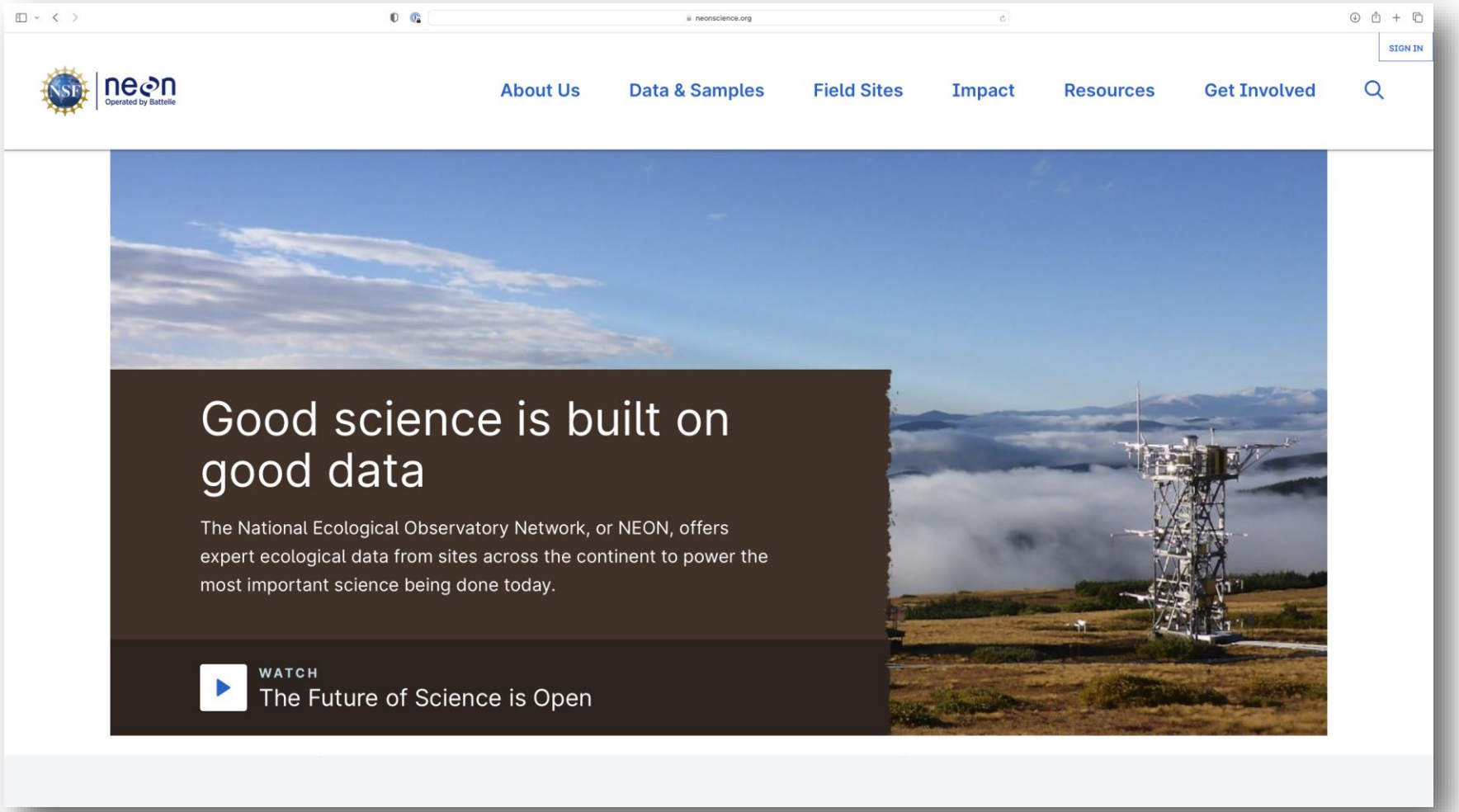


NEON is visited globally
(red dots = IP addresses)

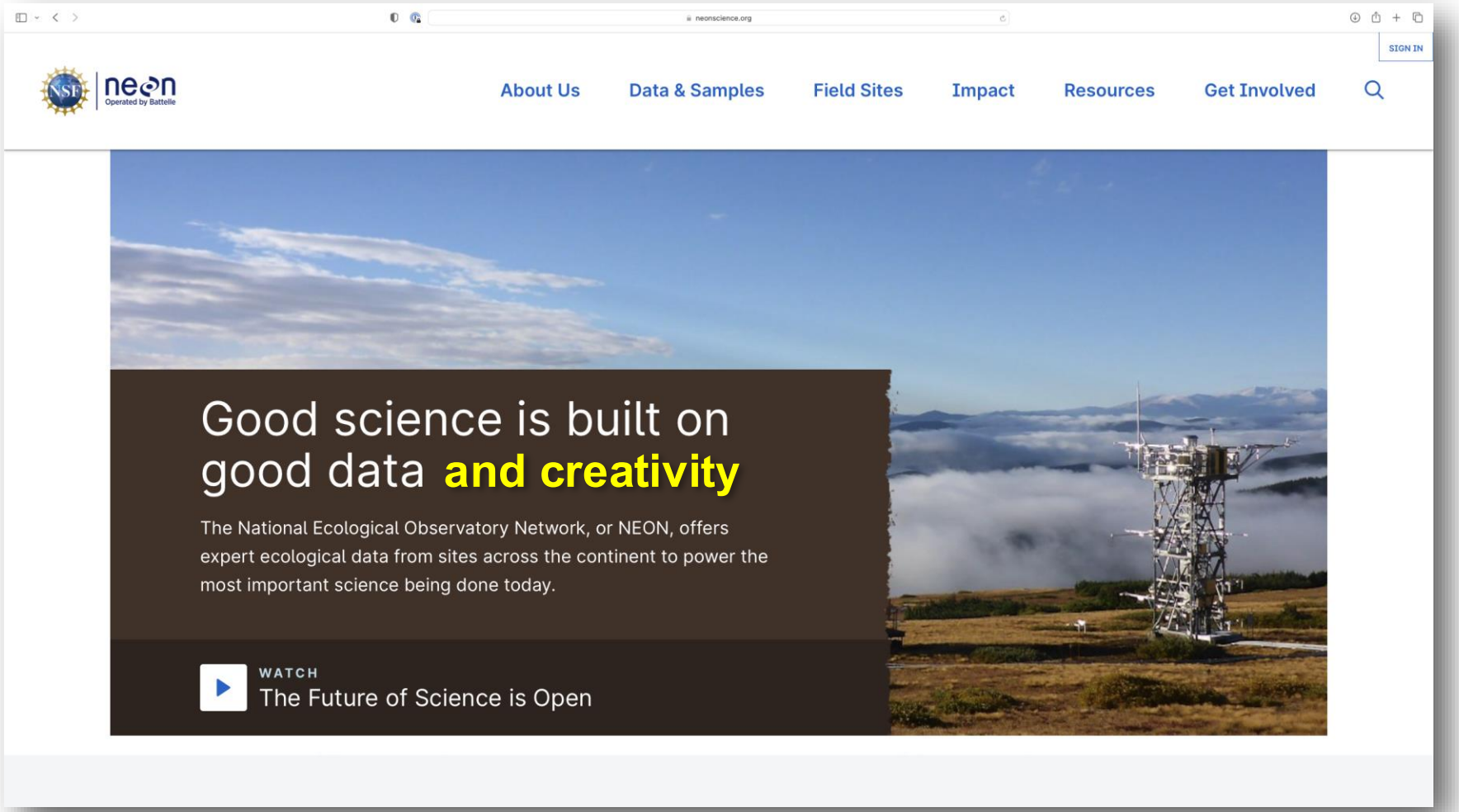


GERI Global Ecosystem Research Infrastructure

Good science is built on good data



, . . . and creativity



Thank You!

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Harnessing Remote Sensing and Flux Measurements for Verified Carbon Standard (VCS) and Agricultural Land Management (ALM) Methodologies

Carolina Cardoso Lisboa,
Manager, Agriculture Innovation

Verra, USA (Germany)

Agenda

- Verra Overview & the Verified Carbon Standard (VCS)
- VCS – Ag Methodologies
- Innovation and Challenges

Verra Overview

The Organization

- Non-profit founded in 2007
- Standard setting organization – environmental and social impacts
- Operate the Verified Carbon Standard
  - World's largest greenhouse gas carbon credit program
- Manage several other standards

Verified Carbon Standard

Jurisdictional & Nested REDD+

Plastic Waste Reduction Standard

Sustainable Development Verified Impact Standard

Climate, Community & Biodiversity Standards

Impact – Global Scope

Environmental Finance Voluntary Carbon Market Rankings 2023 Winner

VCS: Best GHG Crediting Programme 2012, 2013, 2014, 2015, 2016, 2018, 2019, 2020, 2021, 2022, 2023

Verra Registry: Best Registry Provider 2021, 2022, 2023

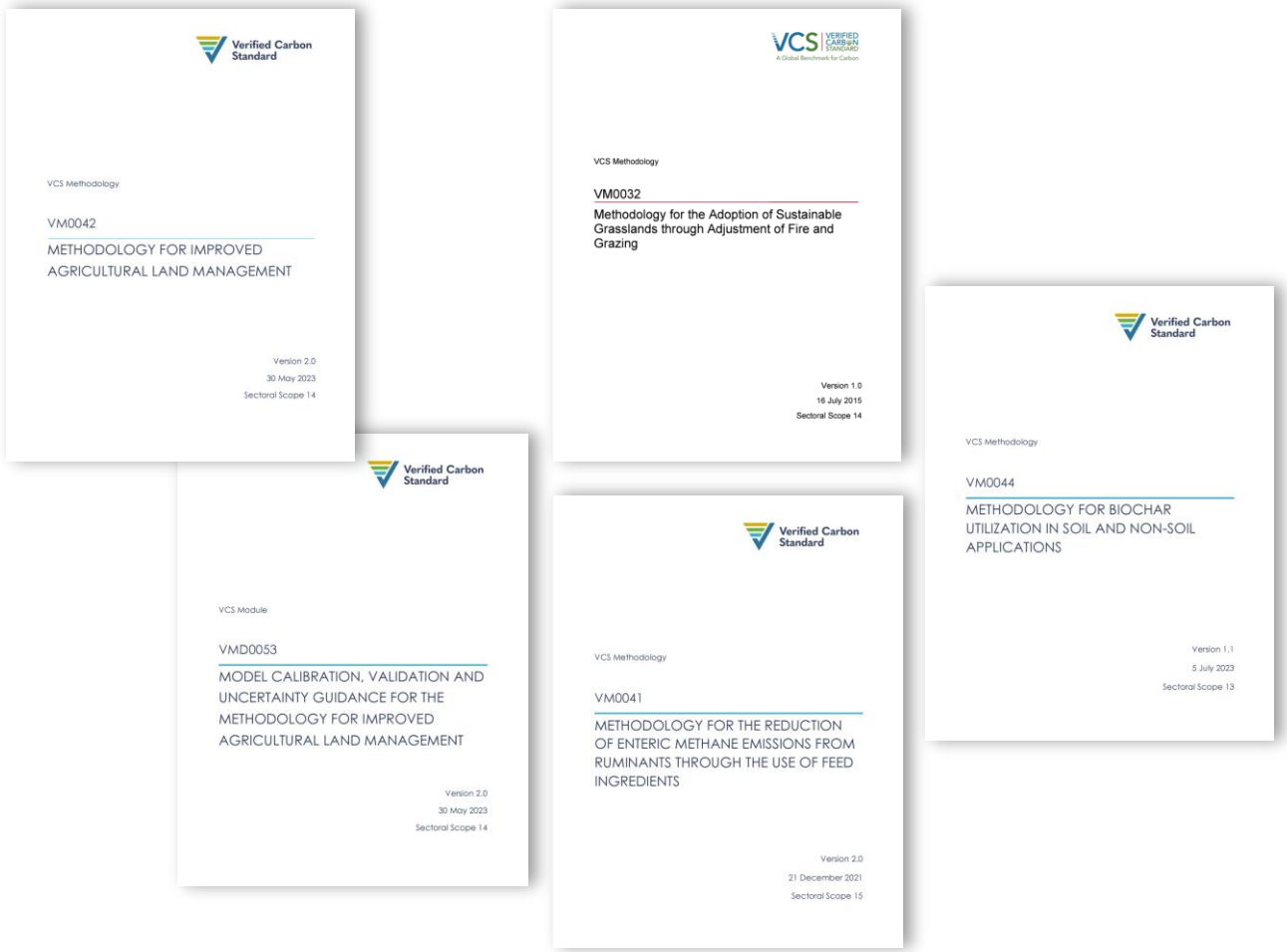
VERRA

VCS Ag Methodologies

Current opportunities to credit agricultural emission reduction and removal activities under the VCS

VERRA

Agriculture Methodologies (Active)



The main characteristics of Ag Methodologies

Gases: N_2O, CH_4, CO_2

Sources and pools:

- Soil (SOC)
- Woody aboveground and belowground biomass
- Fertilizers (i.e., N-fertilization and Liming)
- Enteric fermentation
- Machinery

Quantification of ERRs:

- Direct measurement (*SOC: dry-combustion and CH_4: chamber measurements*)
- Empirical or processed-based models (e.g., Biogeochemical models)
- Default values (e.g., IPCC emission factors)

Innovation and Challenges

Current investment in technology to significantly increase transparency and efficiency and scale up our operations.

VERRA

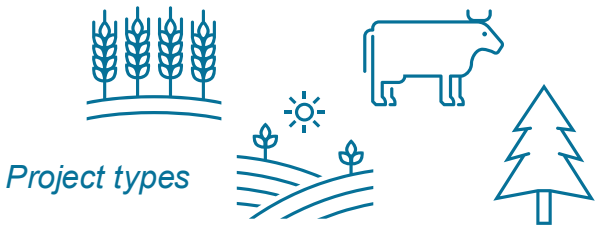
Innovations on GHG Quantifications

Technology Solutions

- **Digital Measurement, Reporting, and Verification (MRV) platform**

Direct Measurements

- Activity data *(e.g., surveys and digital data logs)*
- SOC stocks (Concentration and bulk density)
- CH4 and N2O fluxes *(i.e., chambers)*



Project types

Present
(Well-stablished and implemented)

Indirect Measurements

- Activity data (e.g., image analysis)
- Indirect field measurements of GHG sources and C-pools

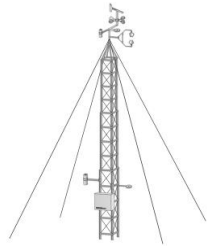
Satellites

Drones

Present
(Well-advanced and under assessment)

Auxiliary Measurements

- Direct and indirect field measurements of GHG sources and C-pools
- Sensors and probes *(e.g., soil temperature and moisture)*



Eddy Covariance towers

Feasible future?

Source: Flux tower figure - https://vecta.io/symbols/321/human-science-research/46/flux-tower

Challenges to Adopt and Scale Innovation

Measurement approaches

- Uncertainty: identification of *error* sources and standard *error* propagation
- High deduction factors to be applied to ERRs
- Stratification of project area
- Standard Protocols
- Equipment costs
- Operational and maintenance needs

Data availability

- Limited access to data sources
- **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable FAIR data principle
- Data Management Plan (DMP)

Organizational infrastructure

- Physical structure and high investment costs
- Technical and operational capacity

Source: Flux tower figure - https://vecta.io/symbols/321/human-science-research/46/flux-tower

Agriculture Methodologies (Under development)

Methodology Draft Development

- Tool for quantifying organic carbon stocks using digital soil mapping: calibration, validation, and uncertainty estimation

SUMMARY OF DEVELOPMENT

The proposed tool was submitted by Perennial Climate Inc. (opens on external site) and is currently at "Step 3: Draft Methodology Development" of the *VCS Methodology Development and Review Process, 4.3 (PDF)*.

Stakeholders interested in collaborating during methodology development or developing projects that this methodology might enable are encouraged to contact methodologies@verra.org. Please include the Methodology Development ID# CN0137 in the subject line.

https://verra.org/methodologies/module-for-quantifying-organic-carbon-stocks-using-digital-soil-mapping-calibration-validation-and-uncertainty-estimation/

Open for Public Consultation

- Improved Management in Paddy Rice Production Systems

SUMMARY OF DEVELOPMENT

Verra is leading the development process for this methodology and has selected ATOA Carbon as the developer (see Section 2.1.1[2] of the *VCS Methodology Development and Review Process, v4.4* (PDF)). The proposed methodology is currently at "Step 4: Public Stakeholder Consultation" of the *VCS Methodology Development and Review Process, v4.4* (PDF).

The consultation for this proposed consolidated methodology is open from June 11, 2024, to July 12, 2024. Stakeholders are encouraged to submit feedback using the M0253 Public Comments Template (xlsx) to methodologies@verra.org.

https://verra.org/methodologies/improved-management-in-paddy-rice-production-systems/

Thank you!

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