



neon  
Operated by Battelle

# Using NEON's airborne remote sensing data to answer ecological questions at scale

# Overview

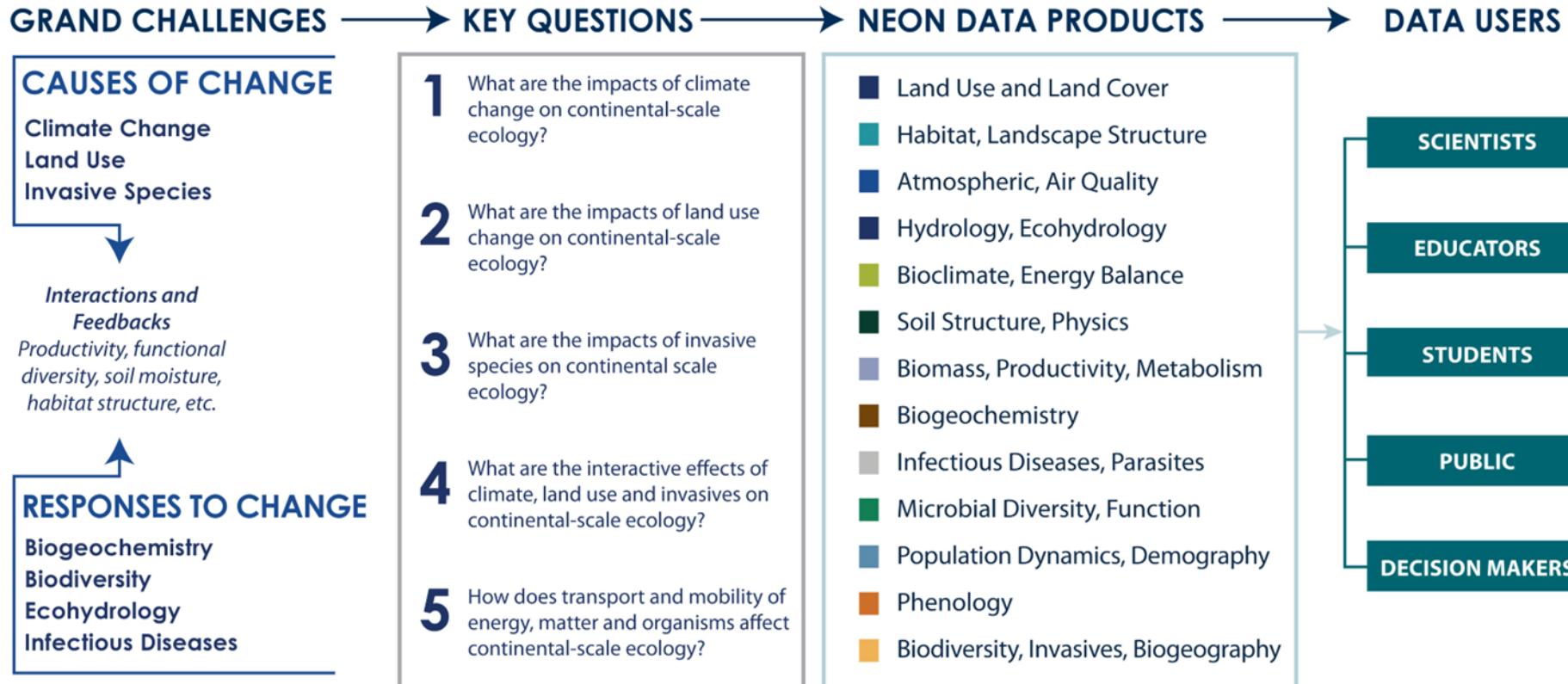
- NEON observatory
- Airborne Observation Platform (AOP)
- AOP data products
- Tutorials and training materials
- Use cases for NEON data

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# NEON Observatory

National Ecological Observatory Network (NEON) is a *continental-scale, long-term (30 year) Observatory, funded by the NSF*.



# Observatory design

81

Field Sites  
(47 Terrestrial  
34 Aquatic)

30

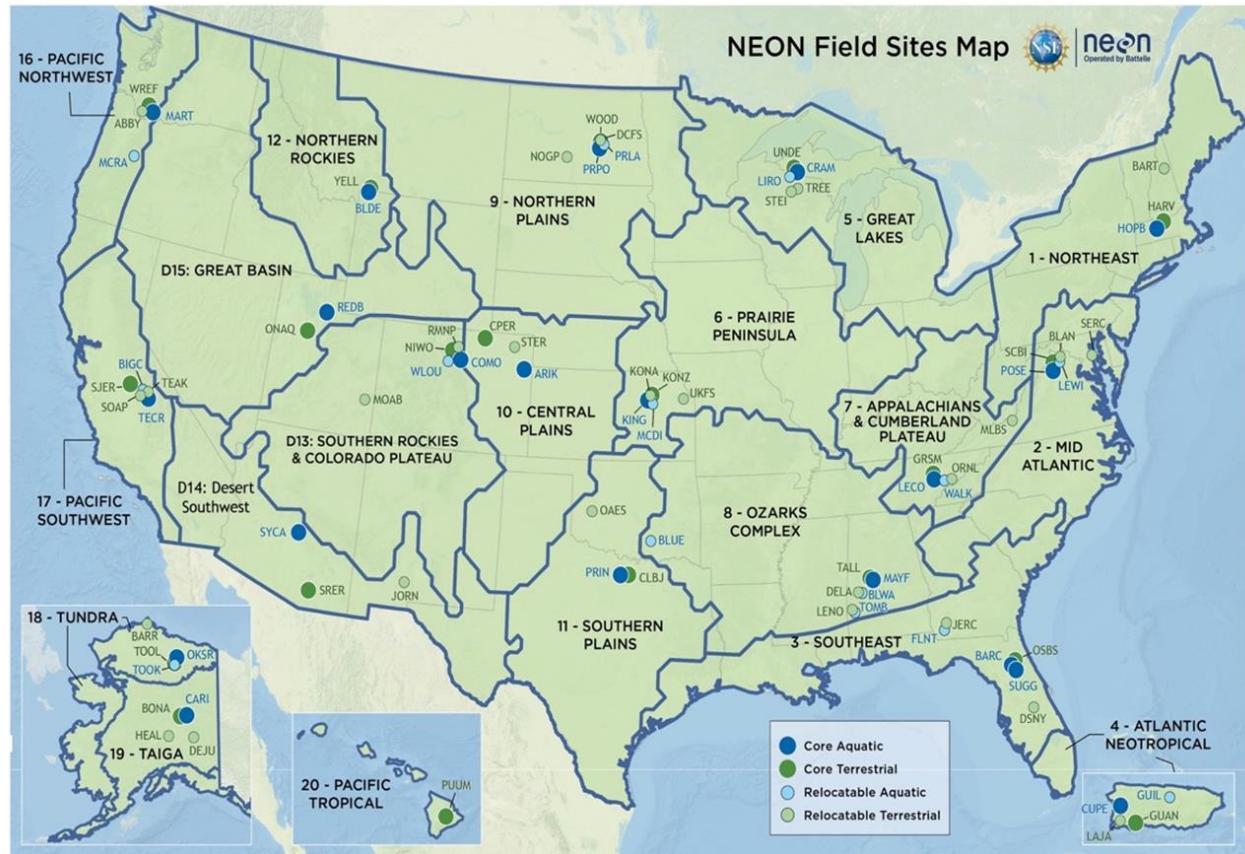
Years  
Planned  
Operations  
(Began 24 May,  
2019)

20

Eco-Domains  
Across the 48  
contiguous states,  
Alaska, Hawaii, and  
Puerto Rico

>180

Data Products  
(Albedo, Leaf Area  
Index, CO<sub>2</sub> Flux, CH<sub>4</sub>  
Concentration, etc)



- Free and open data
- Standardized framework
- Data interoperability for integration with other research networks

# NEON sampling design



Automated  
Instrument Systems



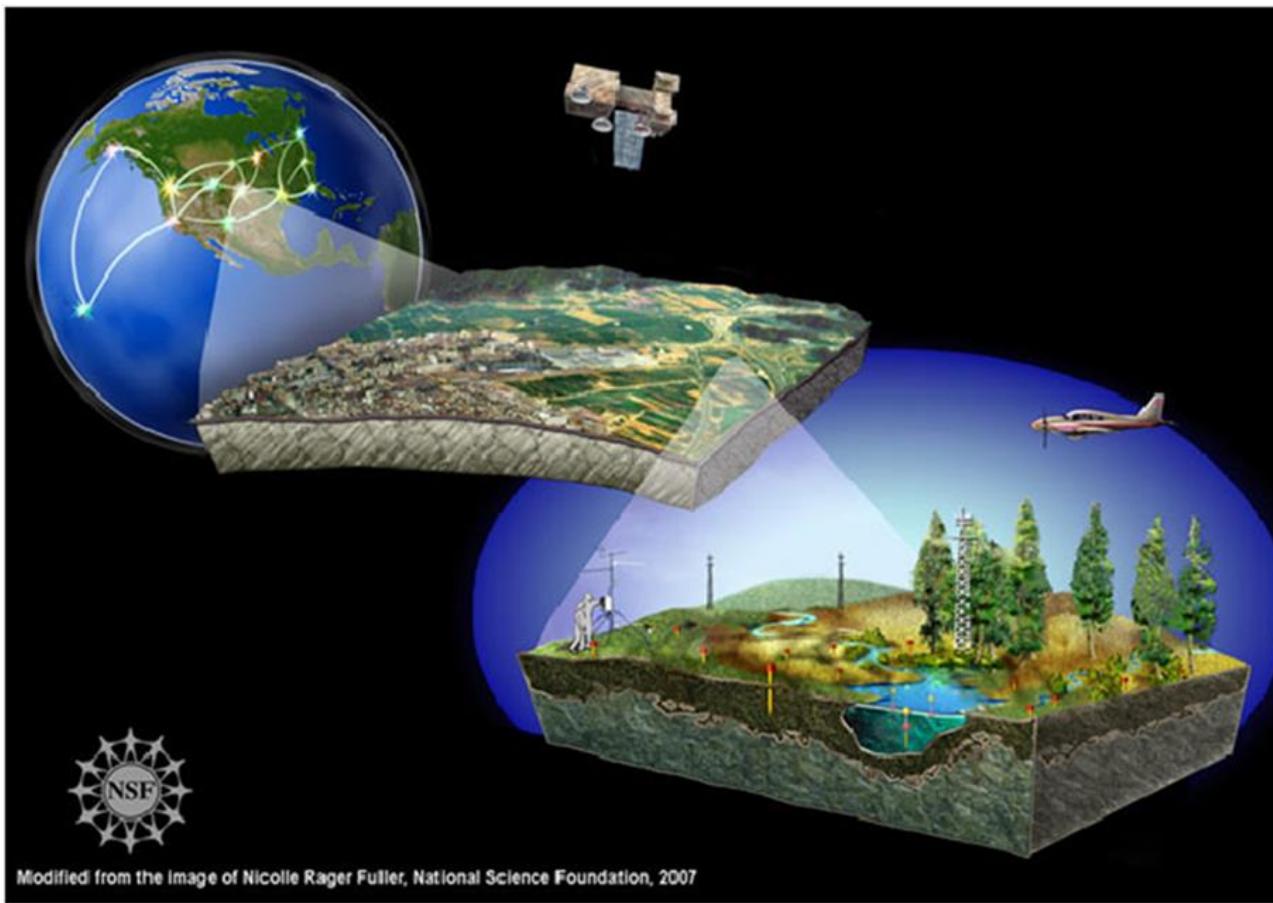
Observational  
Sampling



Airborne Observation  
Platform



# Multi-scale ecological analyses using NEON data



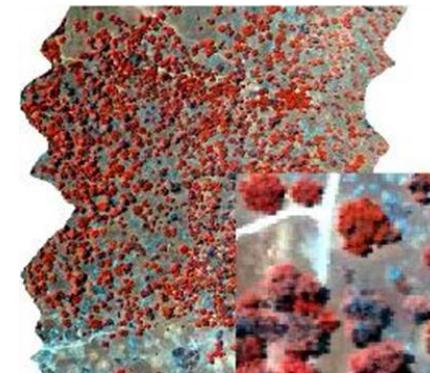
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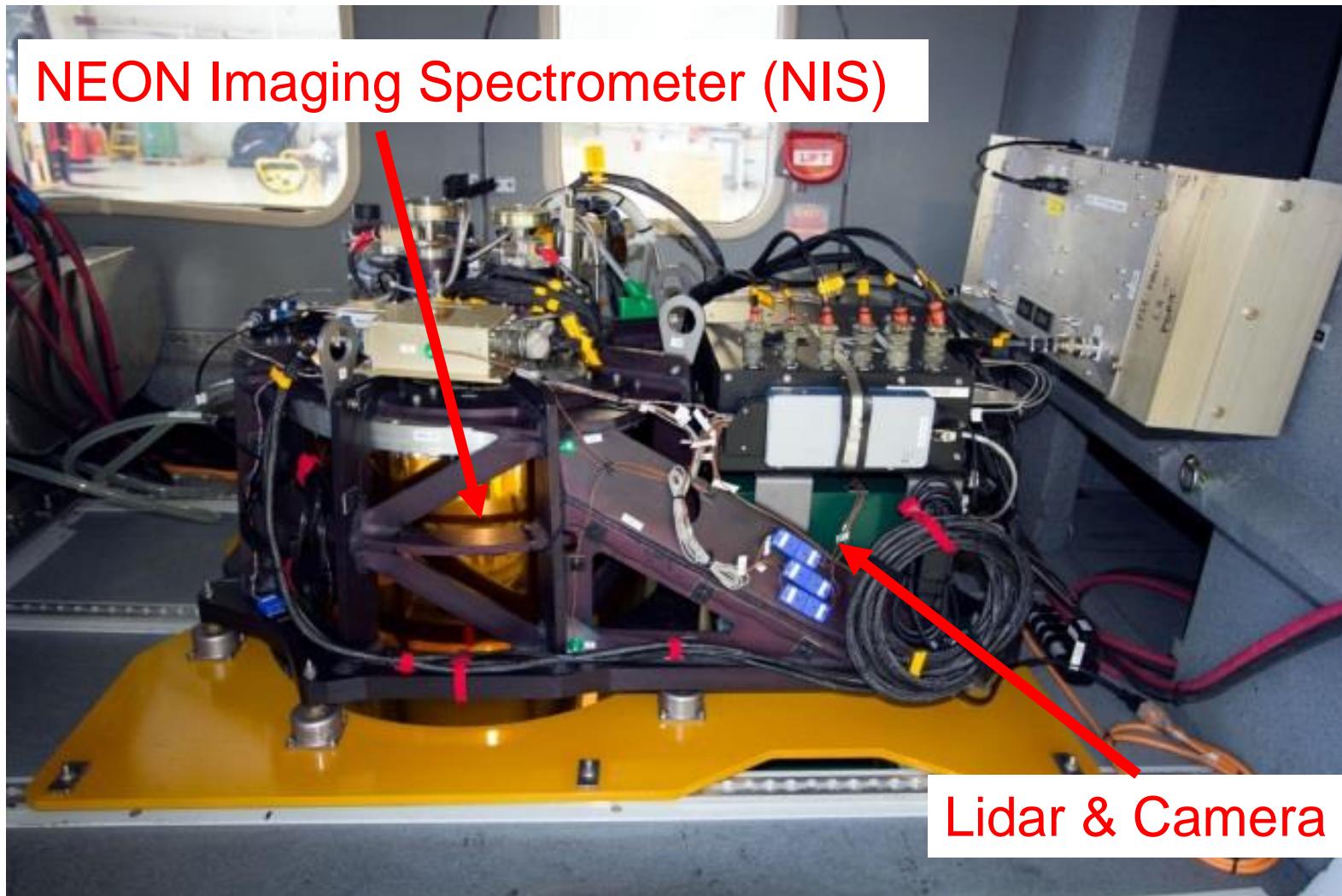


# Airborne Observation Platform (AOP)

- Collects airborne remote sensing data
- Covers 'regional scale' ( $\sim 100 \text{ km}^2$ )
- Data products generated at high spatial resolution ( $\leq 1 \text{ m}^2$ )
- Waveform Lidar, Imaging Spectrometer and RGB camera

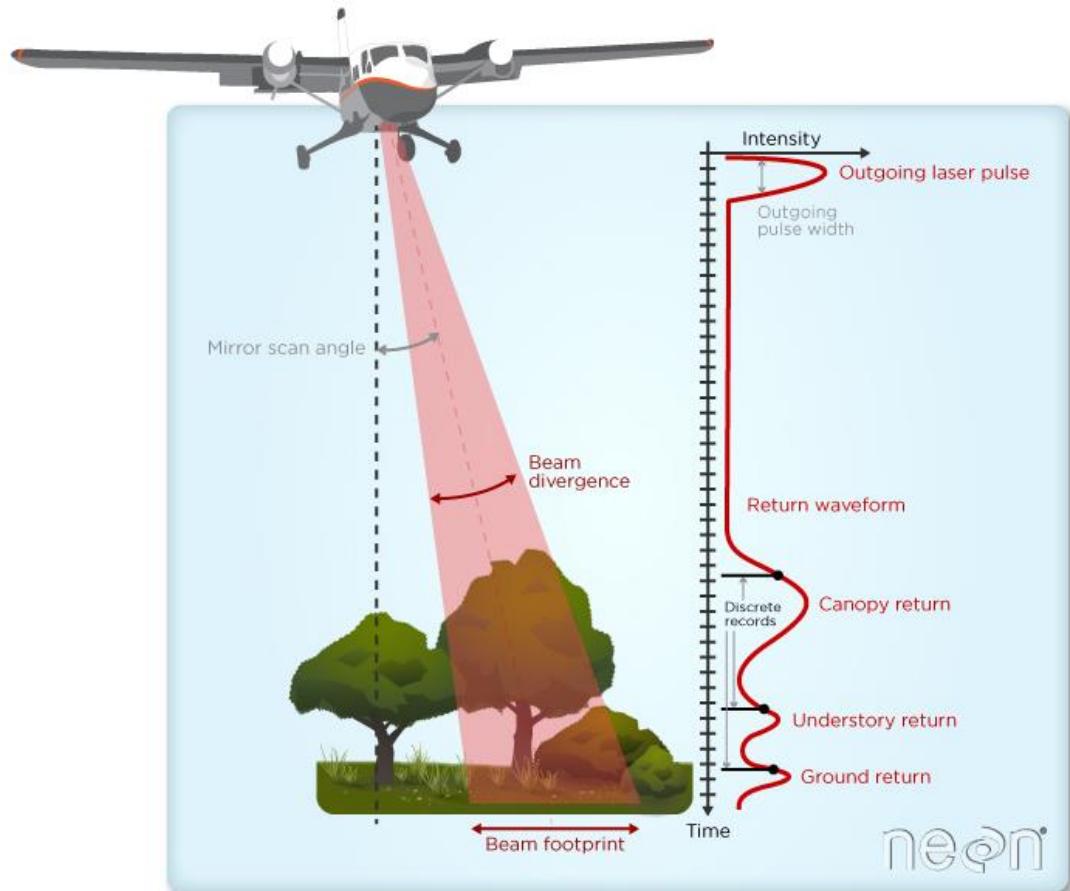


# AOP Payloads



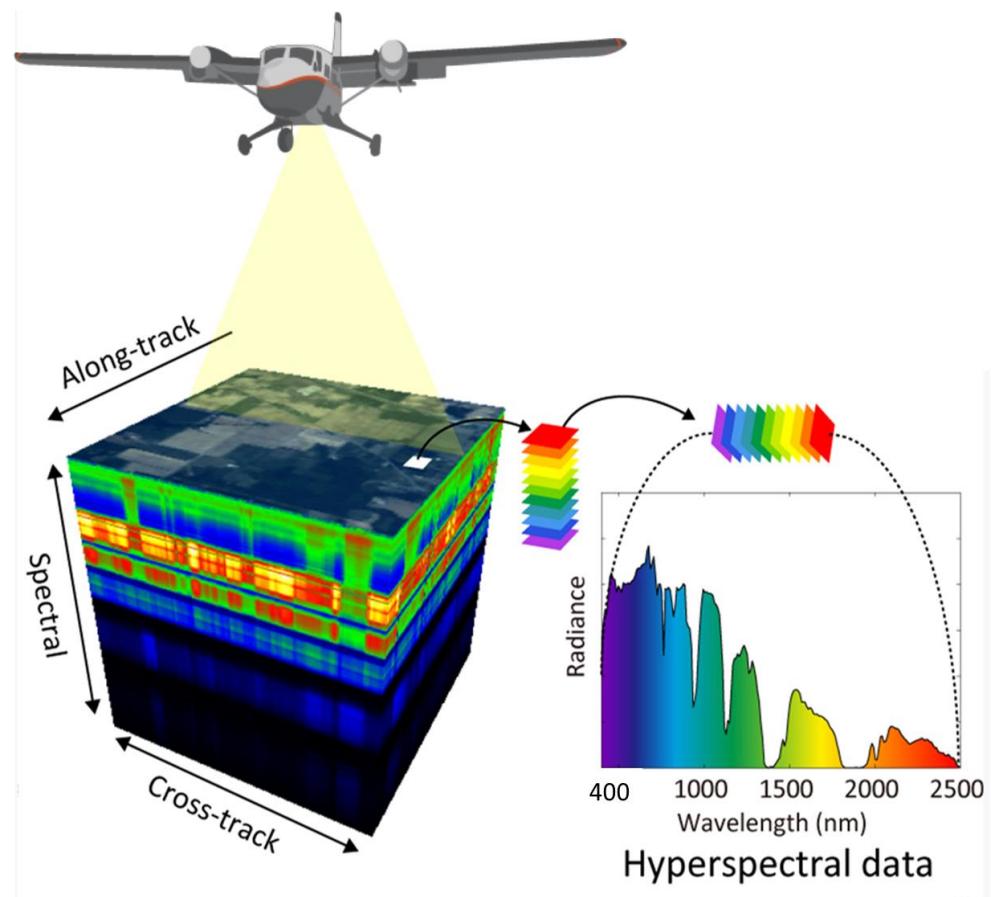
# Waveform LiDAR Sensor

- Active-source instrument
  - 1064 nm
- Transmits laser pulses at up to 1000 kHz
- Capable of recording multiple discrete returns per pulse
- Provides structural (3D) information about the landscape



# NEON Imaging Spectrometer (NIS)

- Images acquired in pushbroom configuration
  - 34 deg across-track
  - 1 mrad along-track
  - 1000m AGL = 1m<sup>2</sup> resolution
- Each 1 mrad pixel imaged light is spread into its component wavelengths 380 - 2510 nm
- 5nm spectral sampling interval with <7.5nm FWHM



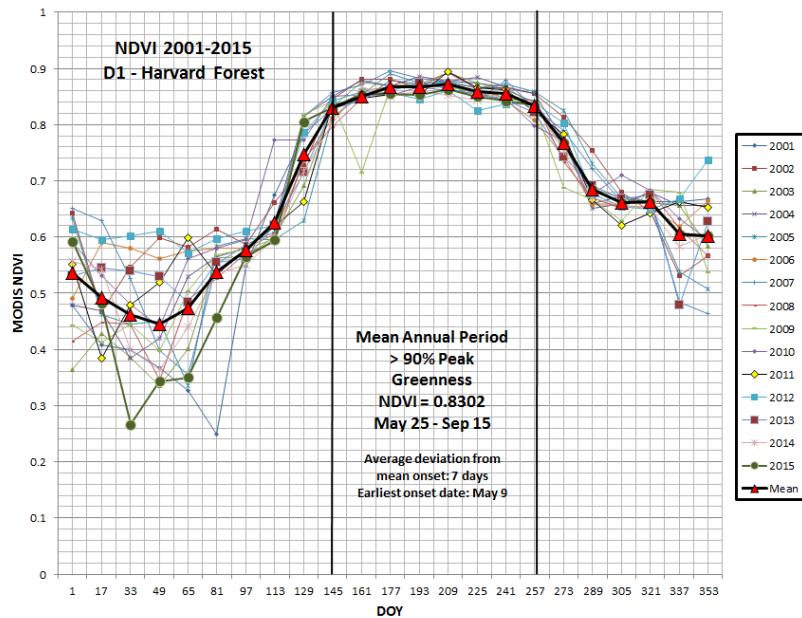
# Digital Camera Sensor

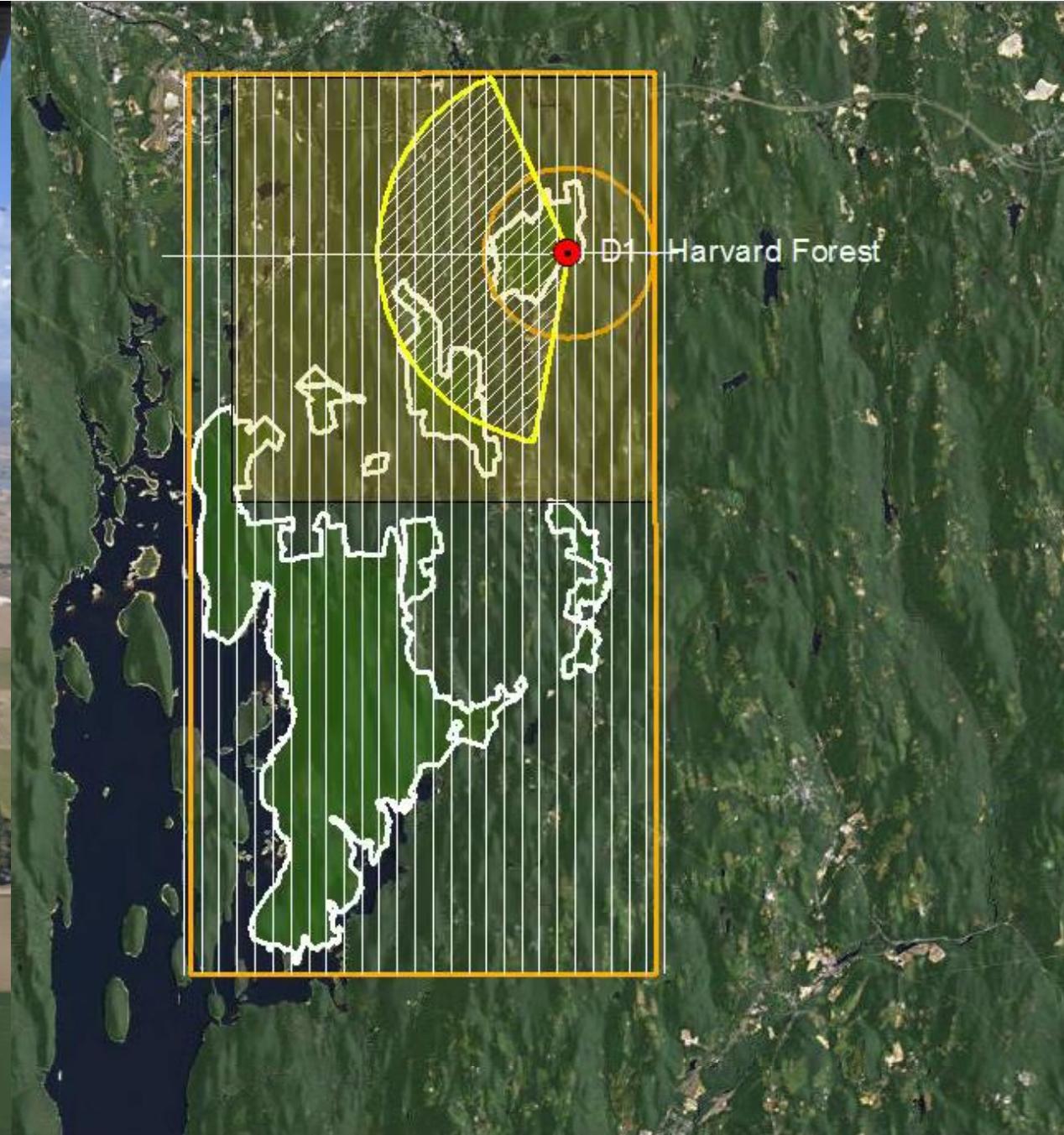
- Commercial instrument delivered with Optech or Riegl lidar system: DiMAC D-8900 or PhaseOne iXA
- Purpose
  - Context for lidar and spectrometer
  - Provides sub-meter sampling of scene @ 1000 m AGL
  - High spatial accuracy



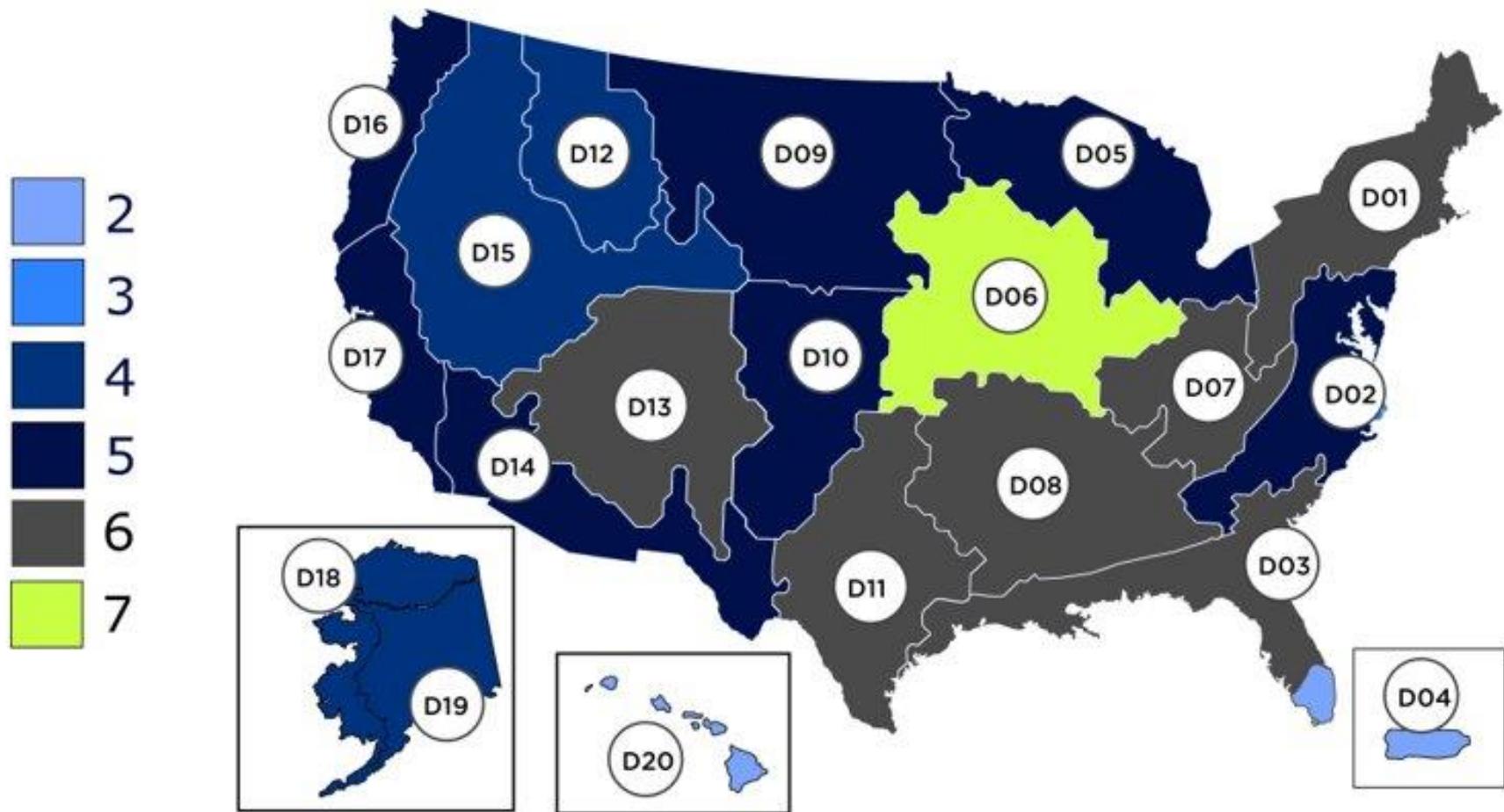
# AOP Sampling Collection Requirements

- Clear skies
- Nominal AOP flying altitude = 1000 m AGL
  - collect data at the scale of individual plants
- Minimum 10 km x 10 km box
  - collect regional scale area around NEON sites
- Fly at peak 'greenness'
  - consistency between annual collections
- Fly N-S lines when solar angles are above 40°





# 2013 – 2022 AOP collections



# Assignable Assets

<http://www.neonscience.org/opportunities/as-signable-assets>

- Mobile Deployment Platform (MPD)
- Sensor Infrastructure
- Observational Sampling Infrastructure
- Airborne Observation Platform (AOP)



# Assignable assets example

Received: 13 May 2020 | Accepted: 13 July 2020

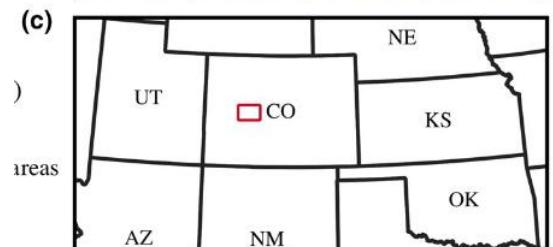
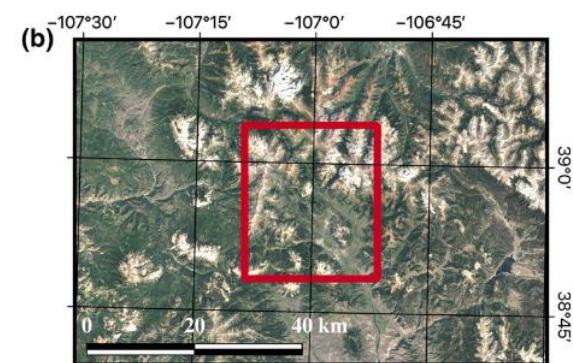
DOI: 10.1111/2041-210X.13463

RESEARCH ARTICLE

Methods in Ecology and Evolution  
BRITISH  
ECOLOGICAL  
SOCIETY

## Integrating airborne remote sensing and field campaigns for ecology and Earth system science

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# NEON AOP data products

## Level 1

- Spectrometer Orthorectified at-Sensor Radiance
- LiDAR Slant Range Waveform
- Discrete Return LiDAR Point Cloud
- Spectrometer Orthorectified Surface Directional Reflectance
- High-resolution Orthorectified camera imagery

Raw data to physical units (flightline)

## Level 2

- Vegetation Indices – Spectrometer
- Canopy Water Content
- Canopy Xanthophyll Cycle
- Albedo - Spectrometer
- LAI - Spectrometer
- fPAR – Spectrometer
- *Canopy Lignin*
- *Canopy Nitrogen*
- *Total Biomass Map (NIS)*

Derived products e.g. spectral indices (flightline)

## Level 3

- Spectrometer Orthorectified Surface Directional Reflectance
- High-resolution Orthorectified camera imagery mosaic
- Albedo - Spectrometer
- LAI – Spectrometer
- fPAR – Spectrometer
- Canopy Water Content
- Canopy Xanthophyll Cycle
- Vegetation Indices – Spectrometer
- Ecosystem Structure
- Elevation – LiDAR

Derived product mosaics (1km x 1km tiles)

ATBDs (Algorithm Theoretical Basis Documents) describe the process for data product creation

# AOP Data Access

- **Data Portal** – manual data download through website  
[data.neonscience.org](http://data.neonscience.org)
- **API** – programmatically automated download
  - R (neonUtilities)
  - Python scripts/tutorials
- **Google Earth Engine** – new and in development!

# NEON AOP data on Google Earth Engine

Data available for five sites, 2-4 years of data per site  
(10 TB limit)

Data product types:

1. Hyperspectral - Surface Directional Reflectance (SDR)
2. Lidar-derived rasters – DTM / DSM / CHM
3. Camera-derived RGB

Domain	Site	Years	Data Products
D08	TALL	2017, 2018	SDR, RGB, CHM, DSM, DTM
D11	CLBJ	2017, 2019	SDR, RGB, CHM, DSM, DTM
D14	SRER	2017, 2018, 2019, 2021	SDR, RGB, CHM, DSM, DTM
D16	WREF	2017, 2018	SDR, RGB, CHM, DSM, DTM
D17	TEAK	2017, 2018	SDR, RGB, CHM, DSM, DTM



# Data products under active development

BRDF- and topographic-corrected reflectance product derived for the NEON spectrometer data

- Approved by the Data quality TWG in November 2022.
- Provisional data to be made available soon followed by a full release.
- Plan on using BRDF- and topographic-corrected reflectance to generate higher-level products.

Mapped plant foliar trait products for NEON sites:

- Leaf mass per area, water content
- Canopy percent N, P
- Canopy lignin
- Pigments (Chlorophyll A, B etc.)
- and more ..

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# <https://www.neonscience.org/resources/learning-hub>



## Workshops & Courses

NEON offers workshops to train students and researchers on key skills to work with NEON and NEON-like data.

[READ MORE](#)

```
S <- mgp_perhorizon

# Join chemical and physical data from biogeo
tables
B <- full_join(mgp_perbiogeosample,
                 mgc_perbiogeosample,
                 by=c('horizonID','biogeoID',
                      'siteID','domainID',
                      'setDate','collectDate',
                      'horizonName','pitID',
                      'biogeoSampleType'))

# Select only 'Regular' samples (not audit)
B <- B[B$biogeoSampleType=="Regular" &
      !is.na(B$biogeoSampleType),]
```

## Code Hub

We provide software code to help you work with NEON data as well as links to code contributed by the community.

[CODE HUB](#)



## Learning Hub

From self-paced tutorials to teaching modules you can use in your classroom, see what we and members of our community provide.

[LEARNING HUB](#)

## Tutorials, Videos and Teaching Modules!

# NEON Code Resources

<https://www.neonscience.org/resources/code-hub>

<https://www.neonscience.org/code-resources-submission>

<b>Tier 1: Community Contributed Code</b>	Community contributed code is reviewed to determine that it is publicly available, generally comprehensible, and involves NEON data. Code functionality is not evaluated.
<b>Tier 2: NEON Certified Code</b>	Certified code goes through a code review, to ensure it performs as described and without error.
<b>Tier 3: NEON Production Code</b>	Production code is used in NEON data processing pipelines, to generate NEON data products. It is the end product of a very long and careful development process.

# Summary of useful R packages



## Forest Ecology and Management

Volume 503, 1 January 2022, 119813



## Open-Source tools in R for forestry and forest ecology

Jeff W. Atkins<sup>a b</sup>   , Atticus E.L. Stovall<sup>c d</sup>  , Carlos Alberto Silva<sup>e</sup> 

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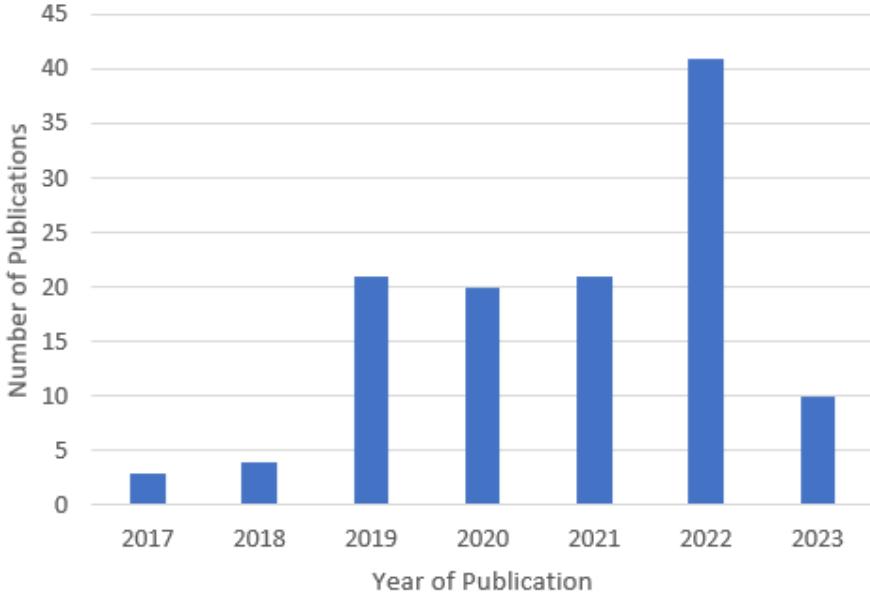
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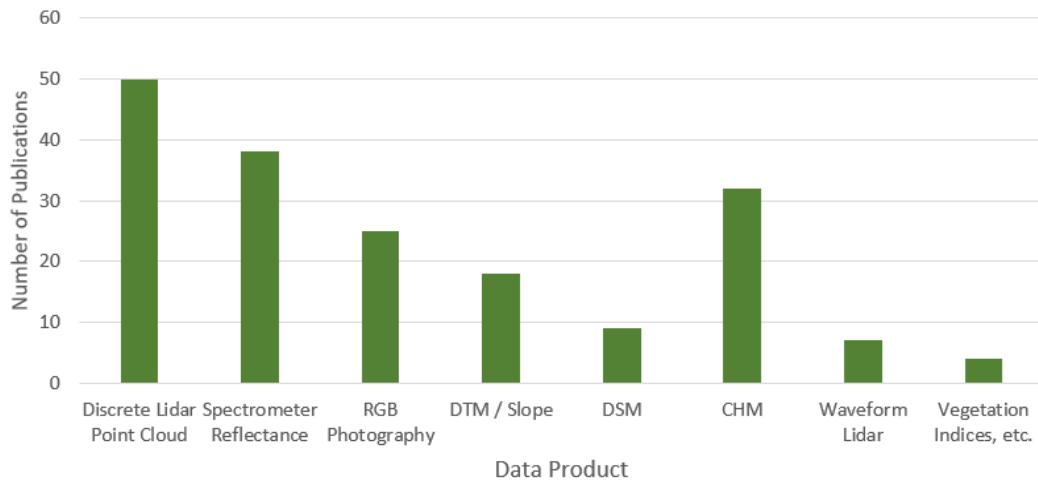
# NEON AOP data citation metrics

Currently, **122** publications have used NEON AOP data products, and counting...

Scientific Publications Using AOP Data



Frequency of Data Product Use in Publications

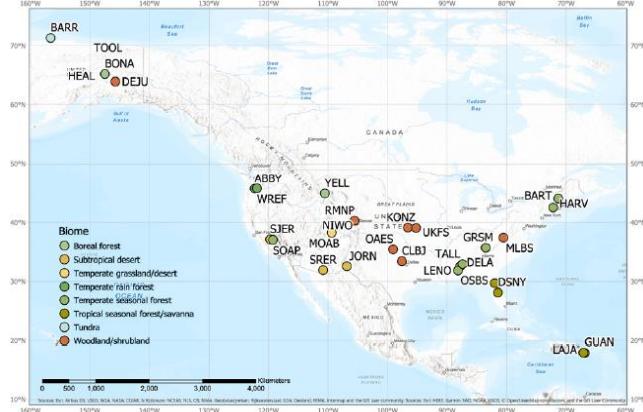


# Example 1: Capturing plant beta-diversity across biomes

## Paper Citation



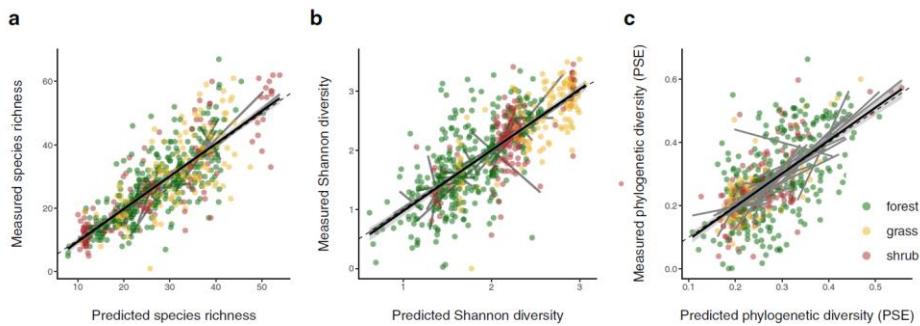
## Spatial Extent



## NEON data used

1. NEON hyperspectral reflectance (DP1.30006.001)
2. NEON plant presence and cover data (DP1.10058.001)
3. NEON woody plant vegetation and structure data (DP1.10098.001)

## Key result



# Example 2: Continental-scale tree species classification

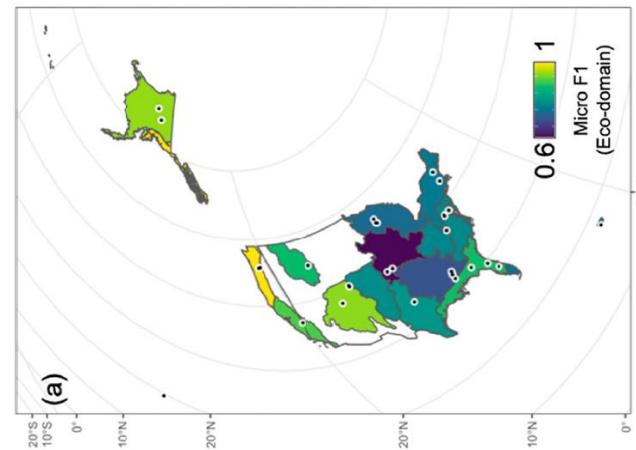
## Paper Citation



Continental-scale hyperspectral tree species classification in the United States National Ecological Observatory Network

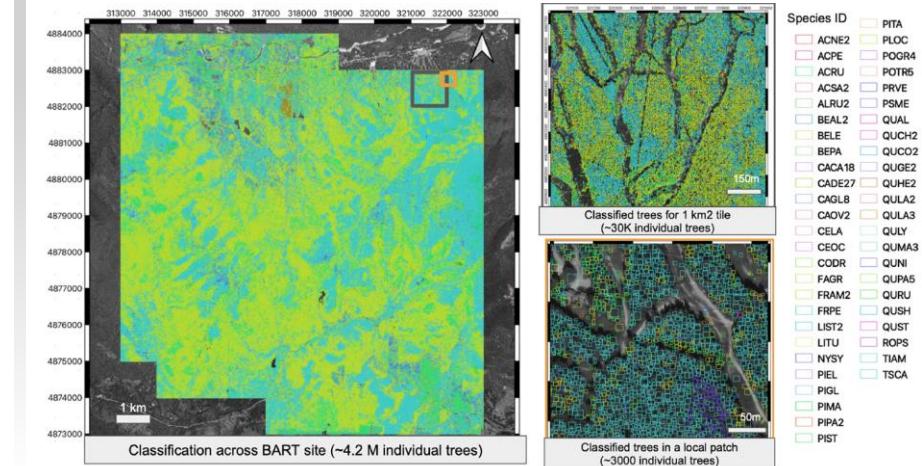
Sergio Marconi<sup>a,\*</sup>, Ben G. Weinstein<sup>a</sup>, Sheng Zou<sup>c</sup>, Stephanie A. Bohlman<sup>b</sup>, Alina Zare<sup>c</sup>, Aditya Singh<sup>d</sup>, Dylan Stewart<sup>c</sup>, Ira Harmon<sup>e</sup>, Ashley Steinkraus<sup>a</sup>, Ethan P. White<sup>a</sup>

## Spatial Extent



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2. NEON woody plant vegetation and structure data (DP1.10098.001)





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