Remote Sensing Data and the AmeriFlux Website

Margaret Torn
Project Lead,
AmeriFlux Management Project

Rachel Hollowgrass
UX Designer,
AmeriFlux Management Project

Goals of this discussion

1. Introduce the R.S. resources at ameriflux.lbl.gov
2. Hear your feedback and suggestions for current and future resources

Data and AmeriFlux

AmeriFlux Today

- Network consists of 665 tower sites.
- Data discovery is organized around sites.

Data

- Flux and ancillary data from sites
- Data from other networks
  - MODIS and PhenoCam
  - Planned: NASA GeoNEX

Discovery of Data

- Users start with sites

Remote sensing products

https://ameriflux.lbl.gov/remote-sensing-products-overview/

Remote sensing products: an overview

This page is a resource about remote sensing sensors and datasets relevant to terrestrial ecosystem research, to help the flux community get started with research using remote sensing. The table describes common remote sensing platforms, sensors, and missions. Information is categorized by scientific and application areas and spatial and temporal resolution and coverage. The two right-hand columns have links to external websites that provide more detail. (Reference: NASA Earthdata, www.earthdata.nasa.gov)

How to use:

- The buttons above the table have dropdown menus to filter information.
- The search bar filters for rows containing specified word(s)
- "Export to CSV file" and "Print" to PDF options are available below the table
- Check out the blog post for useful tips on using the table.

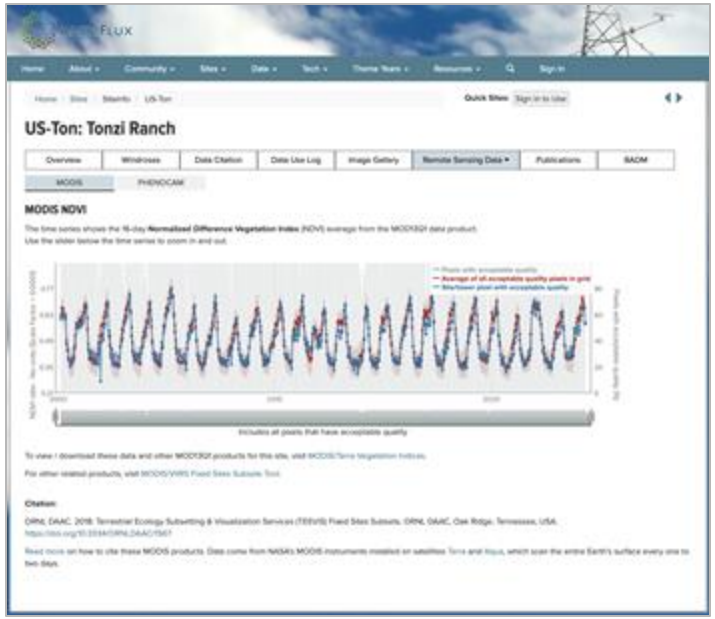
The table for RS product page

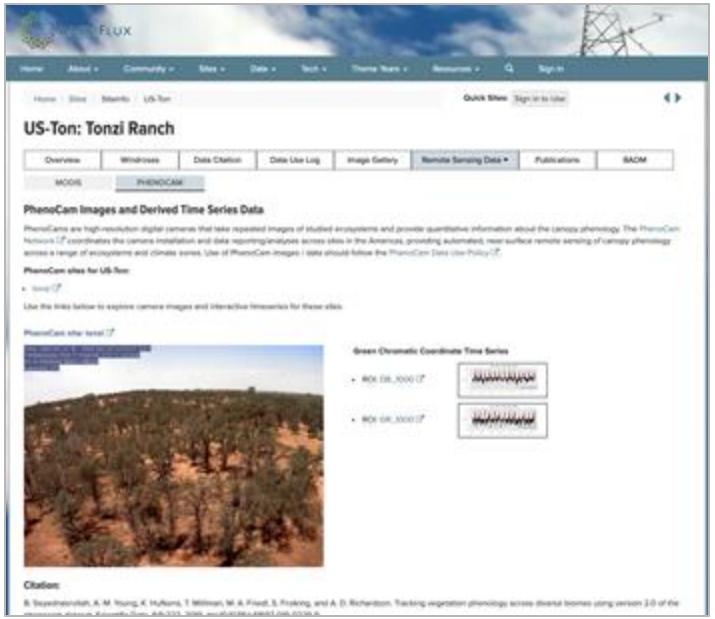
All Classes | Sub-class | Spatial Resolution | Spatial Coverage | Temporal Resolution | Temporal Coverage | Platform/Data type | Satellite/Platform | Sensors | Observation/Model | File Format | Clear Filters | Search

Class	Sub-class	Spatial Resolution	Spatial Coverage	Temporal Resolution	Temporal Coverage	Platform Type	Satellite Name	Sensor/ Model/ Mission Name	Observation or Model	File Format	Link to Platforms/ sensors information	Link to data products
Land Surface	Surface reflectance	15m, 30m	Global	Variable	2000-present	Satellite	Terra	ASTER	Observation	HDF-EOS, GeoTIFF	Terra (NASA), ASTER (JPL), ASTER (LP DAAC)	Earthdata Search , Worldview
Land Surface	Surface reflectance	500m, 1km, 0.05°	Global	1-2 days	2000-present	Satellite	Terra, Aqua	*MODIS	Observation	HDF-EOS5	Terra (NASA), Aqua (NASA), MODIS (NASA), MODIS (LP DAAC)	Earthdata Search , Worldview
Land Surface	Surface reflectance	500m, 1km, 5,600m	Global	1-2 days	2017-present	Satellite	Suomi NPP	*VIIRS	Observation	HDF5, HDF-EOS5	Suomi NPP (NASA), VIIRS (NOAA), VIIRS (LP DAAC)	Earthdata Search , Worldview

AmeriFlux website: Remote sensing data

Remote sensing data is presented with an associated AmeriFlux site on the Site Info page.





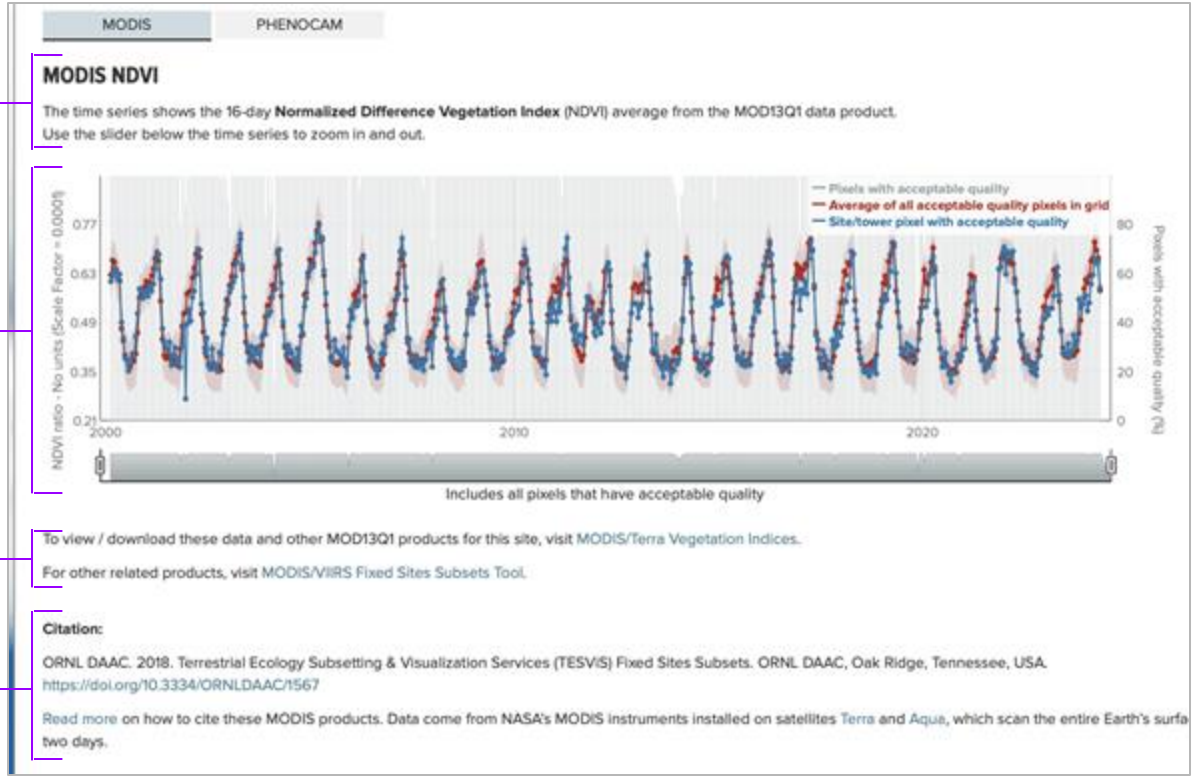
AmeriFlux website: MODIS data

Description

Visualization

Links to source

Citation information



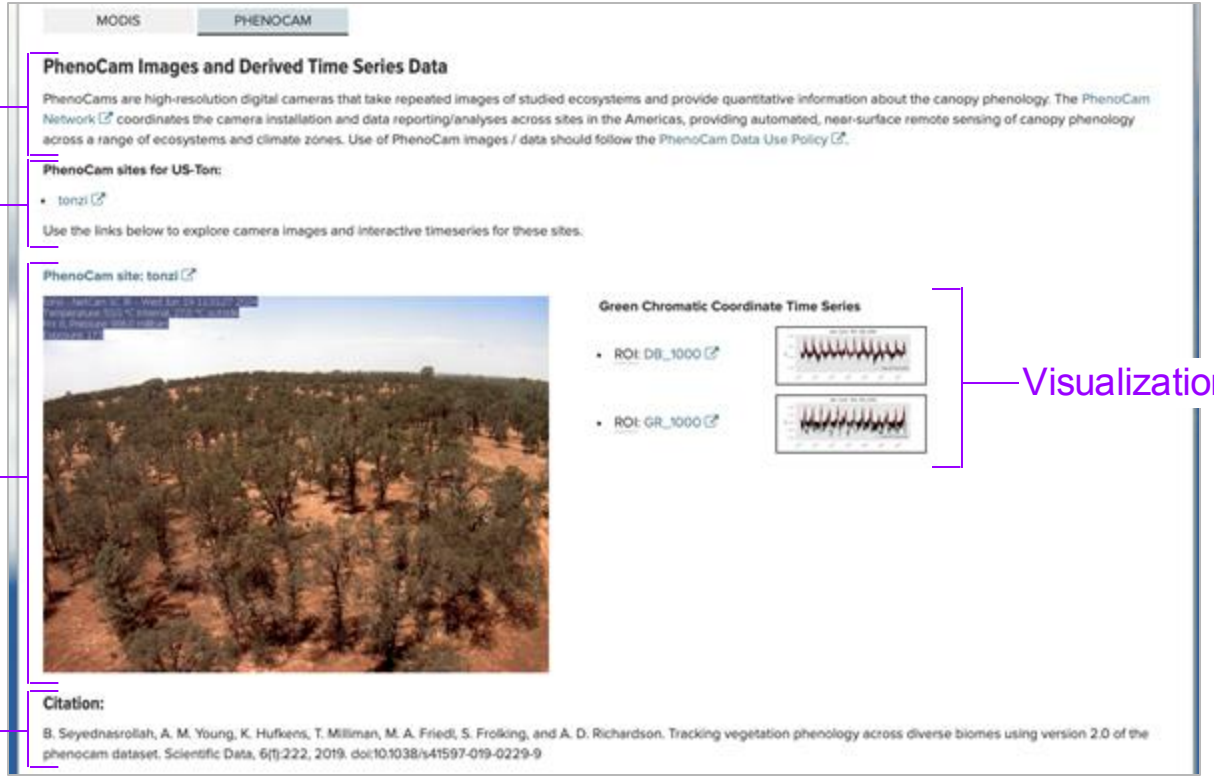
AmeriFlux website: PhenoCam Network

Description

LInk to source

Image

Citation information



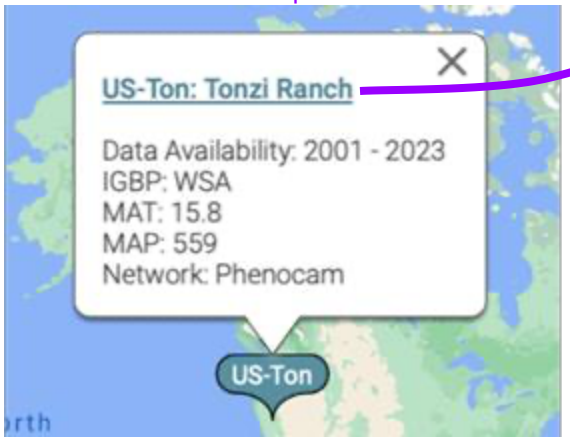
Visualizations

Discovering Data

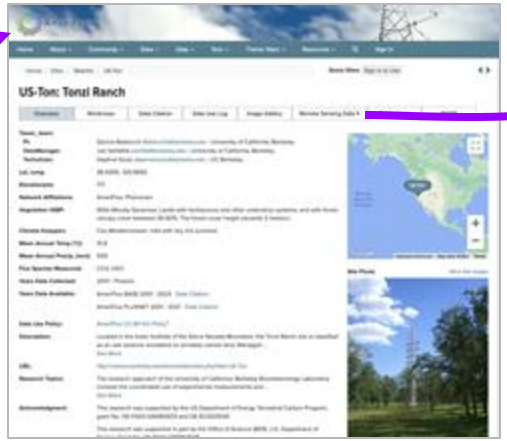
Starting from the map or from Site Search, a link goes directly to the Site Info page. The drop down menu links to the remote sensing data.

Drop Down Menu

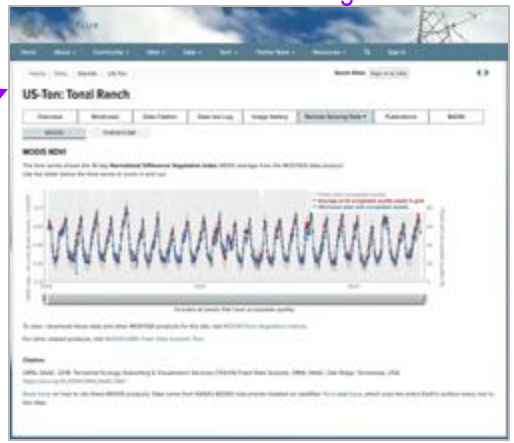
Map



Site Info



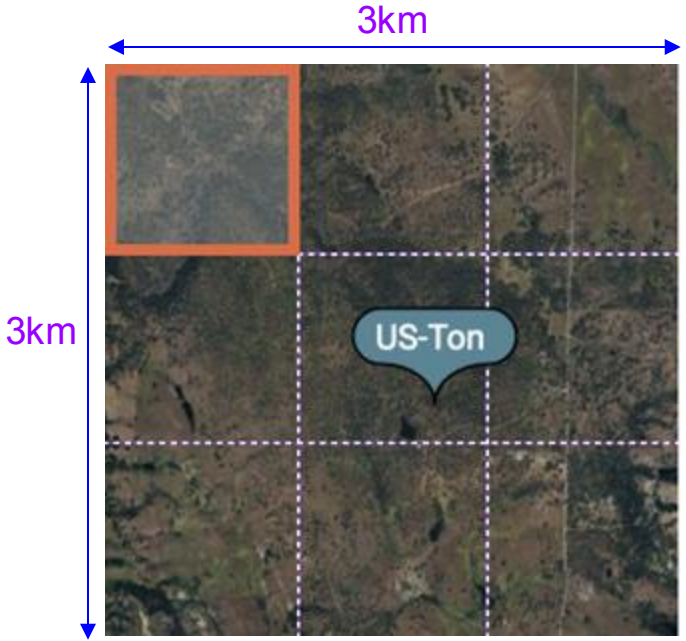
Remote Sensing



Planned Data: NASA GeoNEX

Plan is to normalize the GeoNEX data

- 9km^2 tile area
- Associate data with each AmeriFlux tower site



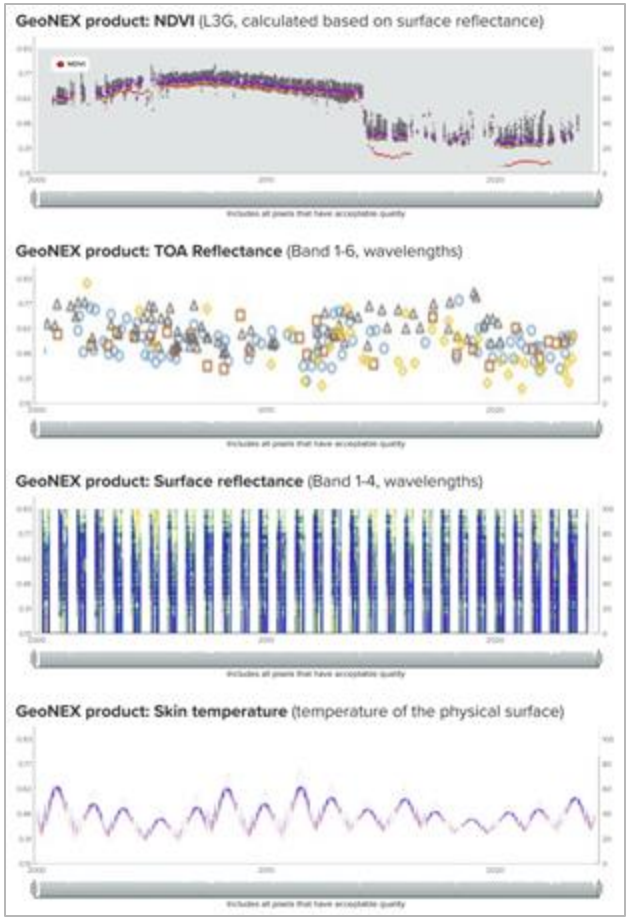
Planned Data: NASA GeoNEX

Plan is to include 4 GeoNEX data products

- NDVI
- TOA Reflectance
- Surface Reflectance
- Skin Temperature

Visualizations

- Will be generated on the AmeriFlux website

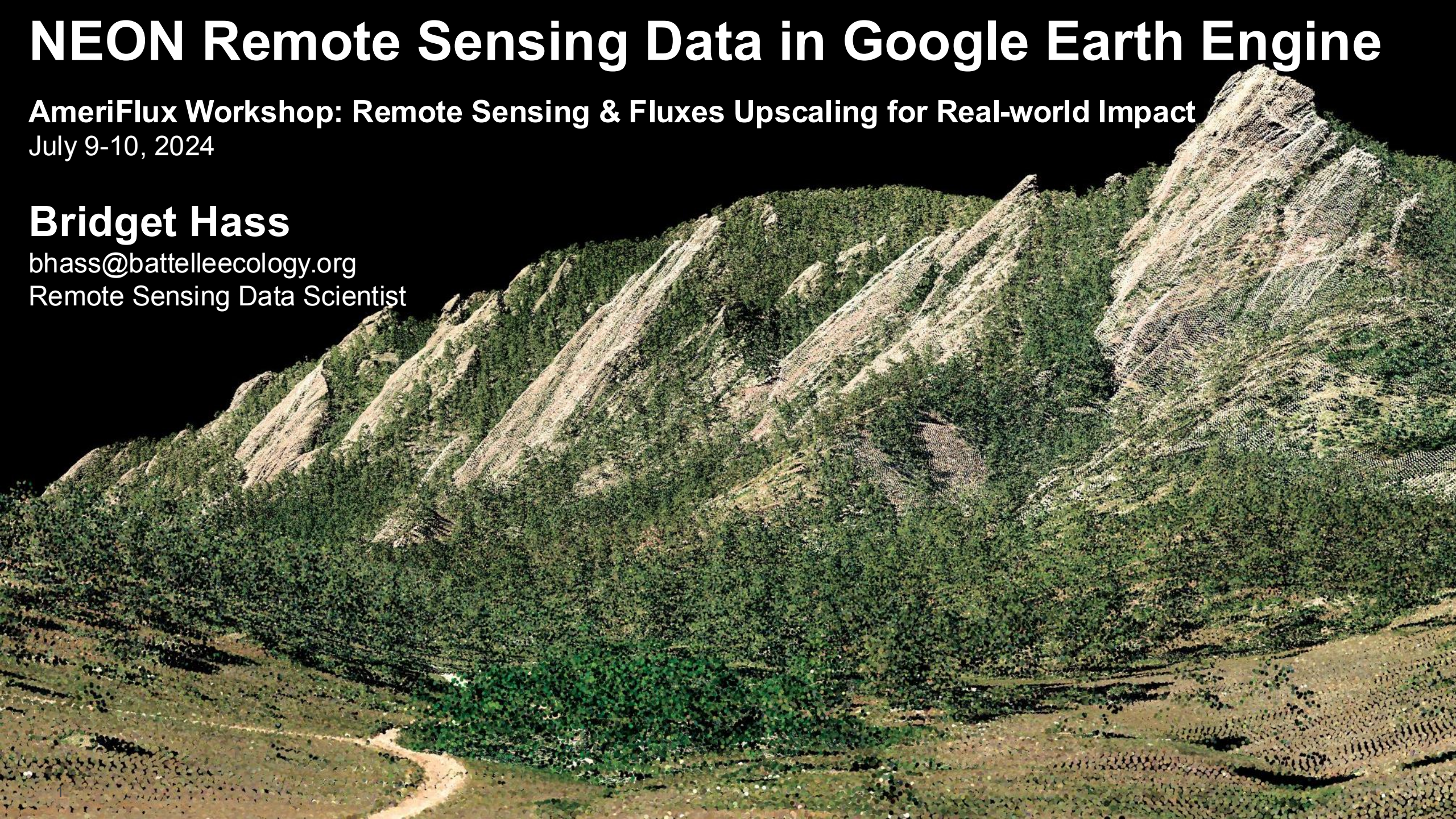


Discussion

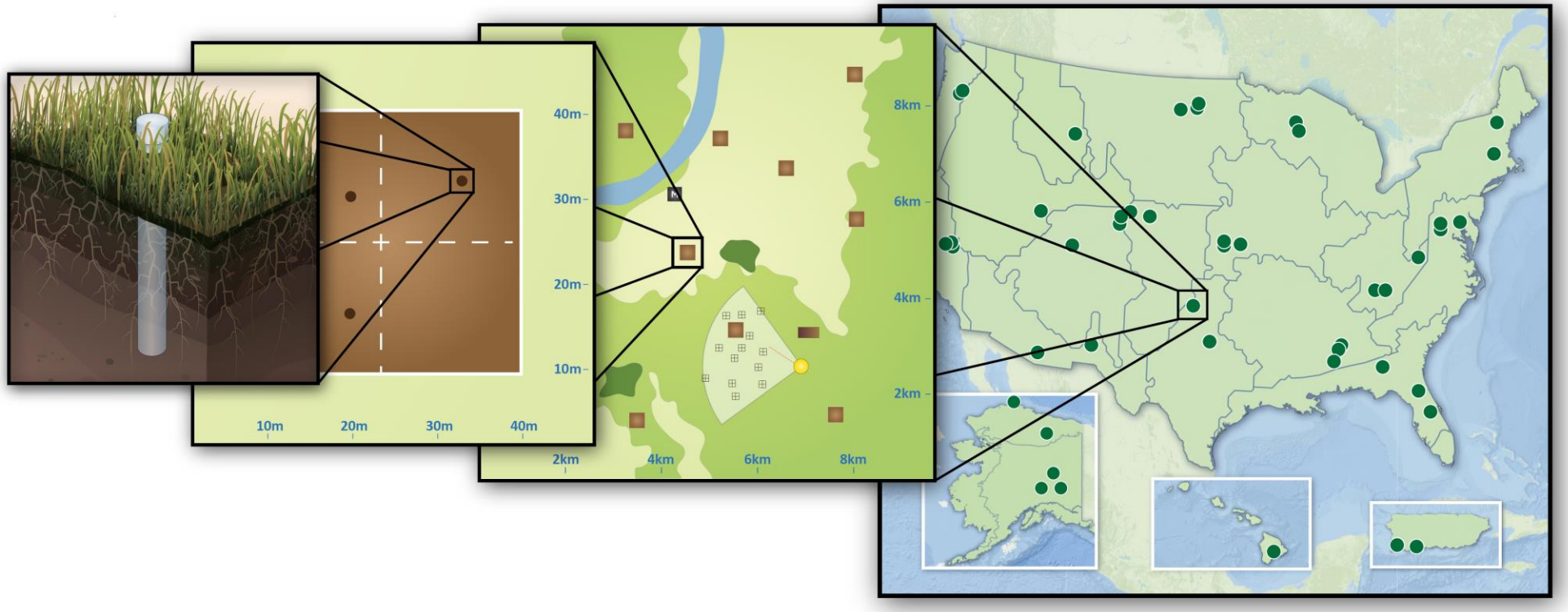
NEON Remote Sensing Data in Google Earth Engine

AmeriFlux Workshop: Remote Sensing & Fluxes Upscaling for Real-world Impact
July 9-10, 2024

Bridget Hass
bhass@battelleecology.org
Remote Sensing Data Scientist



NEON – National Ecological Observatory Network
Continental Scale Ecological Monitoring



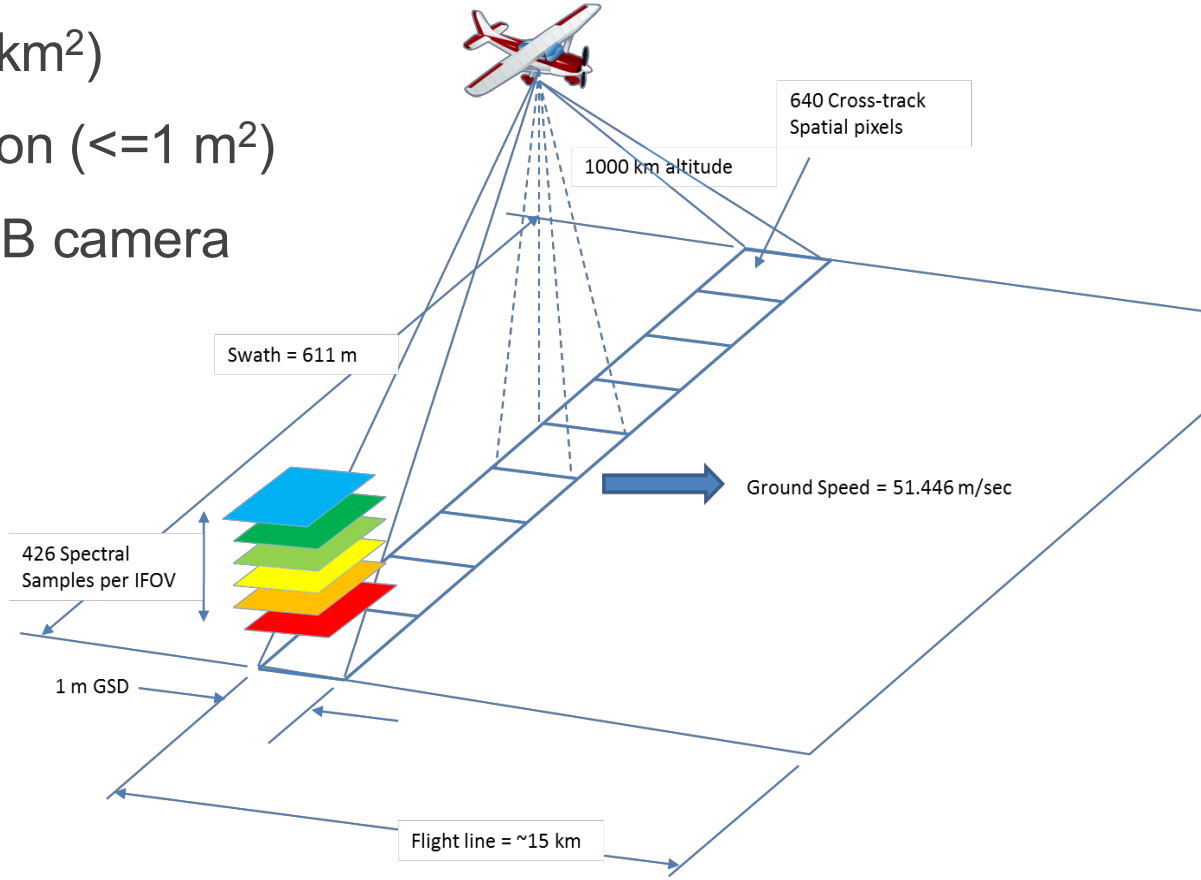
81
FIELD SITES
- 47 terrestrial
- 34 aquatic

Over
180
DATA PRODUCTS

neon Operated by Battelle

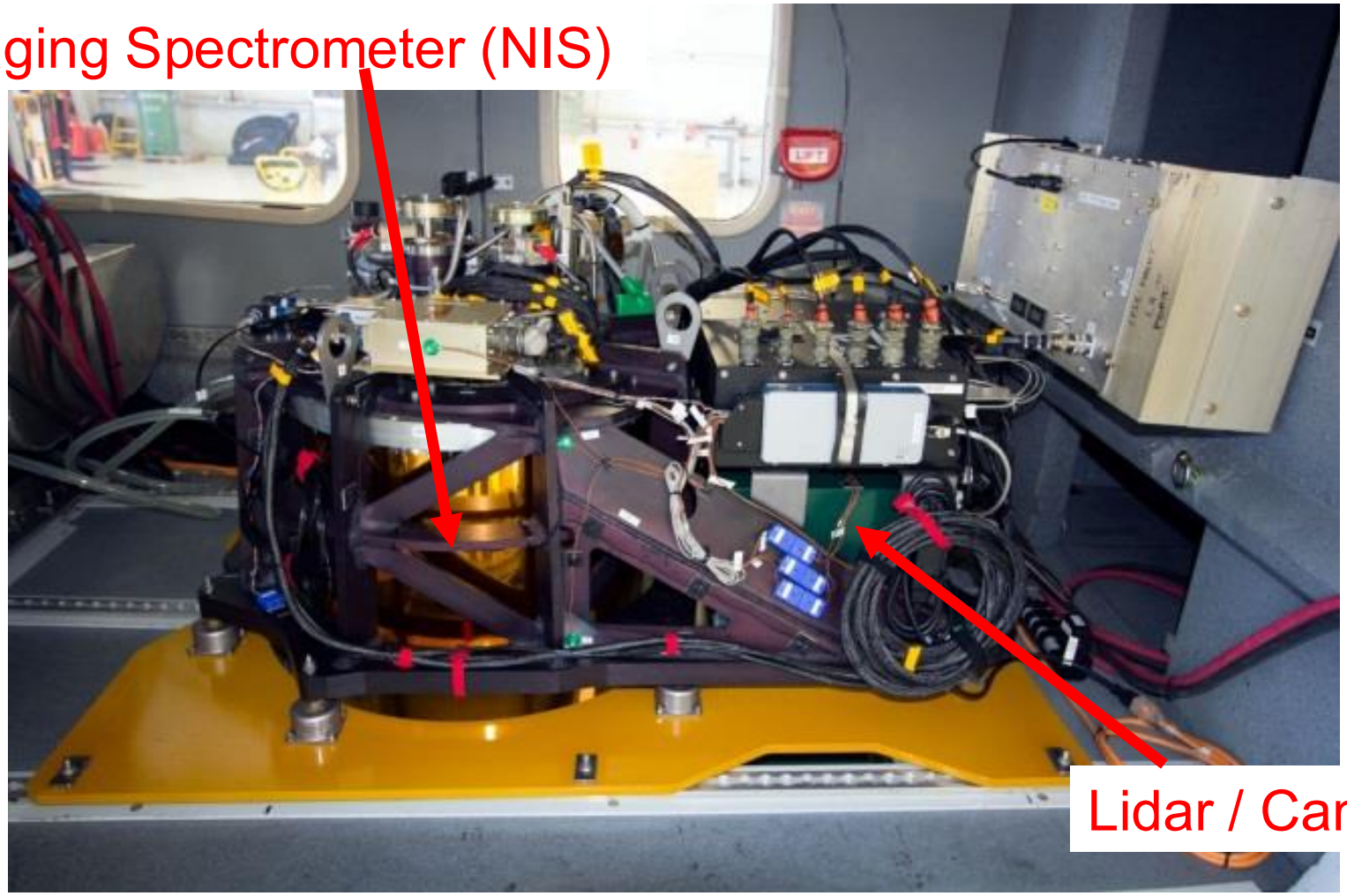
Airborne Observation Platform (AOP)

- Collects airborne remote sensing data
- Covers ‘regional scale’ landscapes (min of 100 km^2)
- Data products generated at high spatial resolution (<=1 m^2)
- Waveform Lidar, Imaging Spectrometer and RGB camera

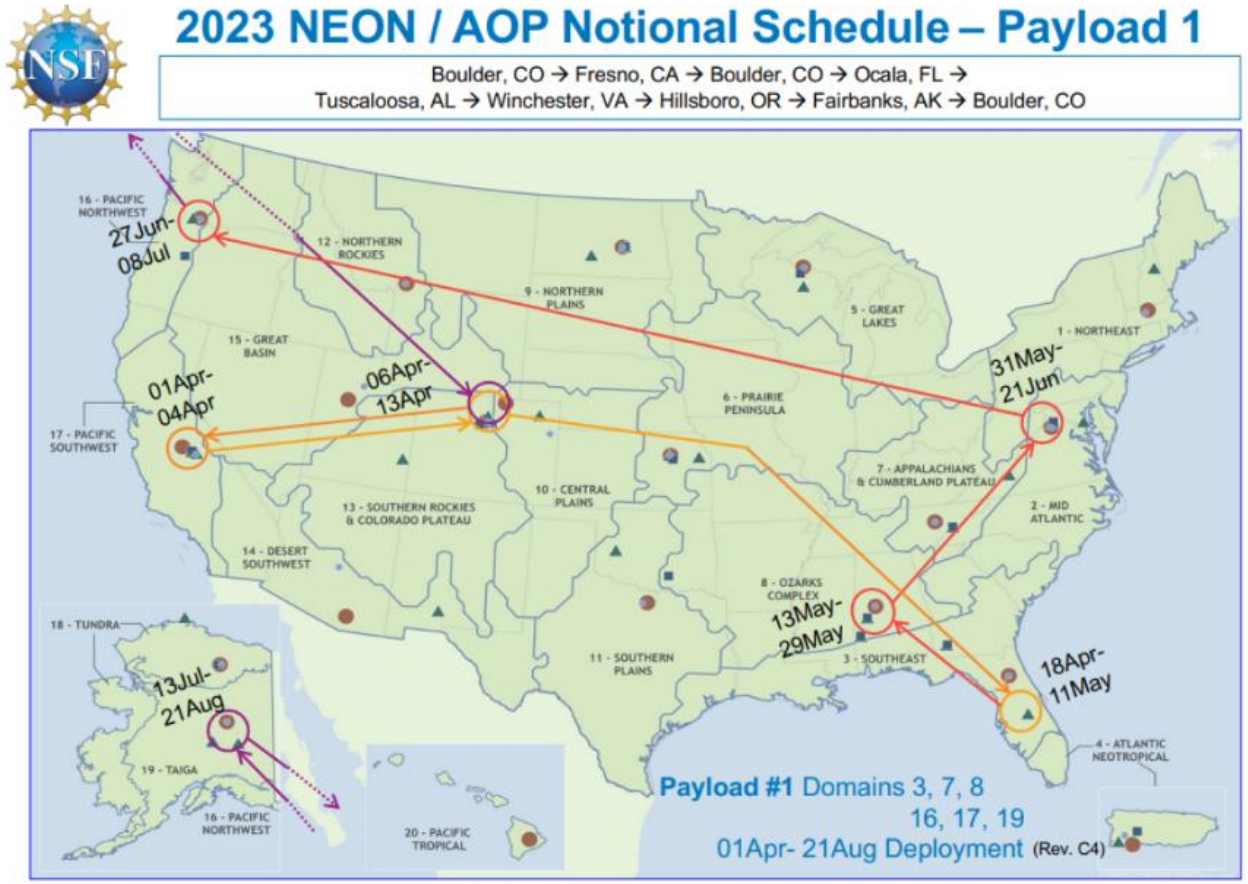


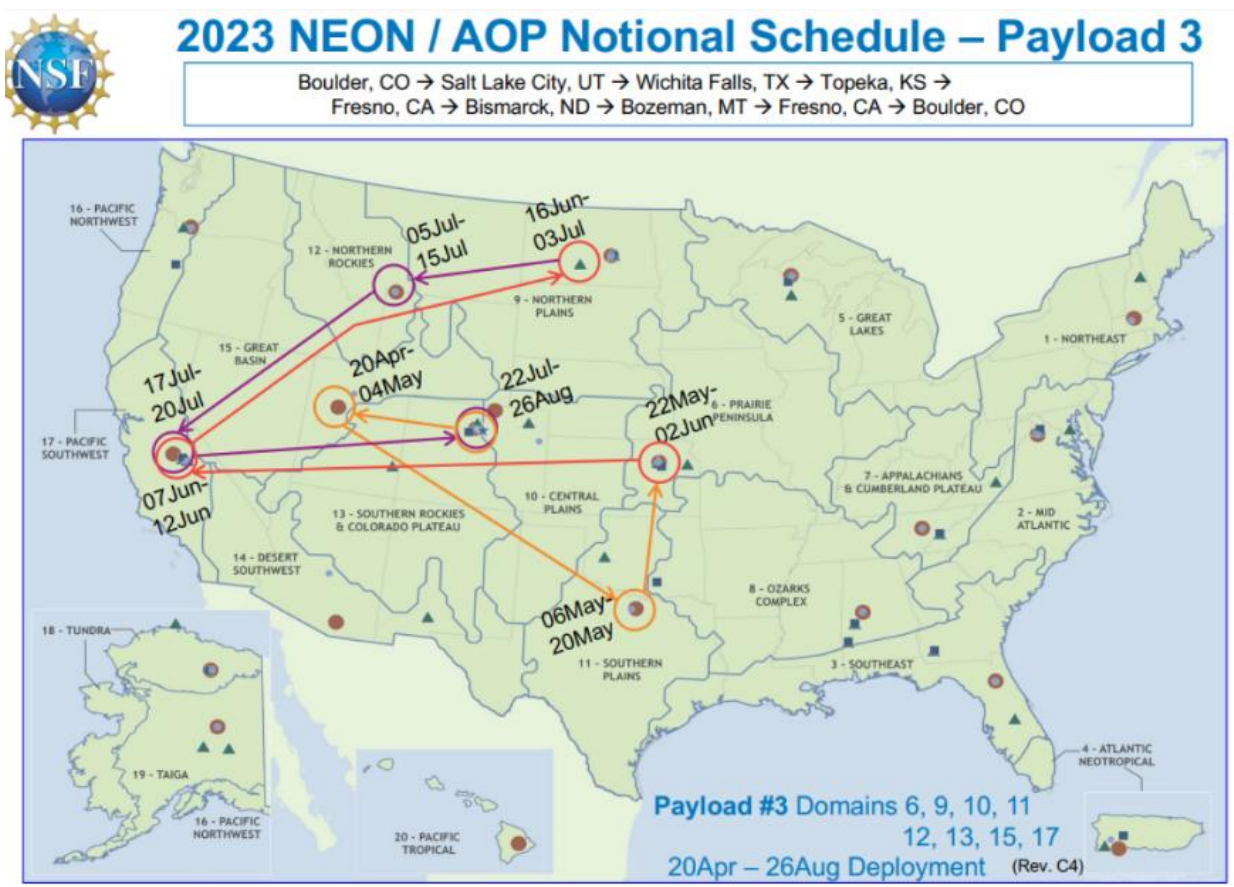
AOP Payloads

NEON Imaging Spectrometer (NIS)



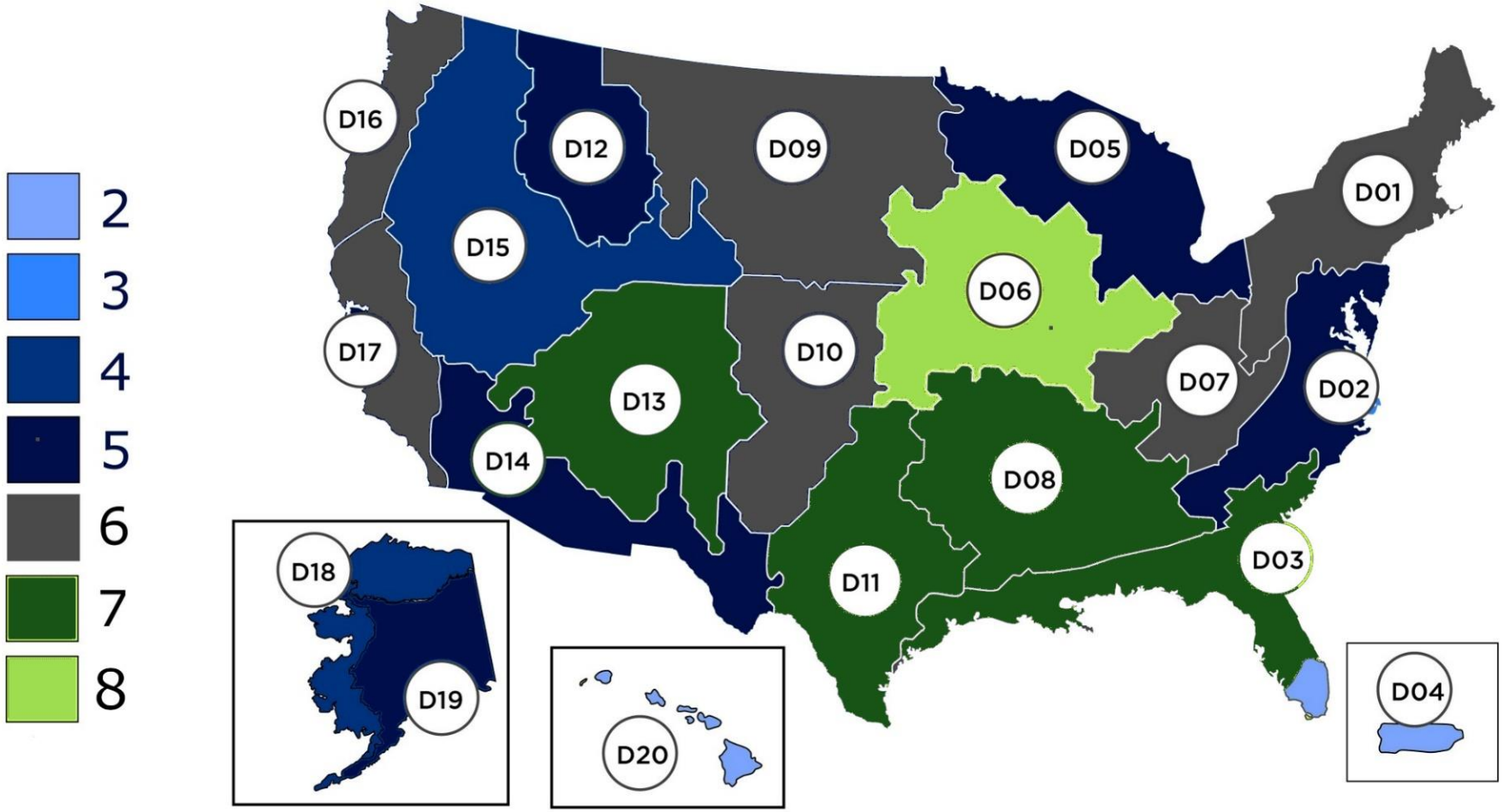
AOP Flight Schedule





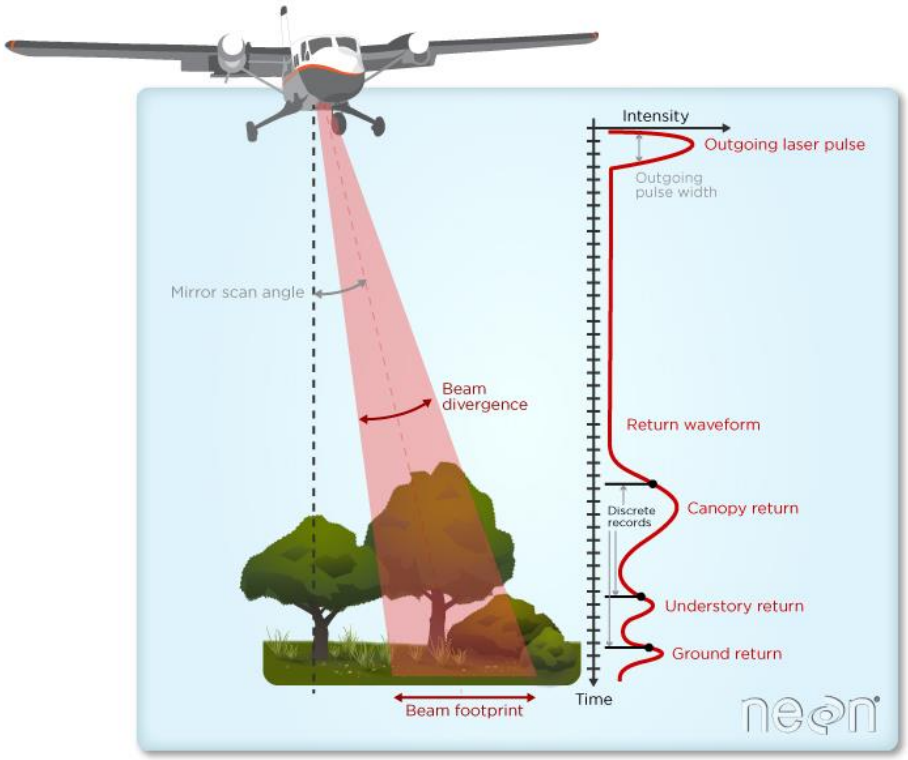
Current & Past AOP Schedule: https://www.neonscience.org/data-collection/flight-schedules-coverage

2013 - 2023 AOP collections

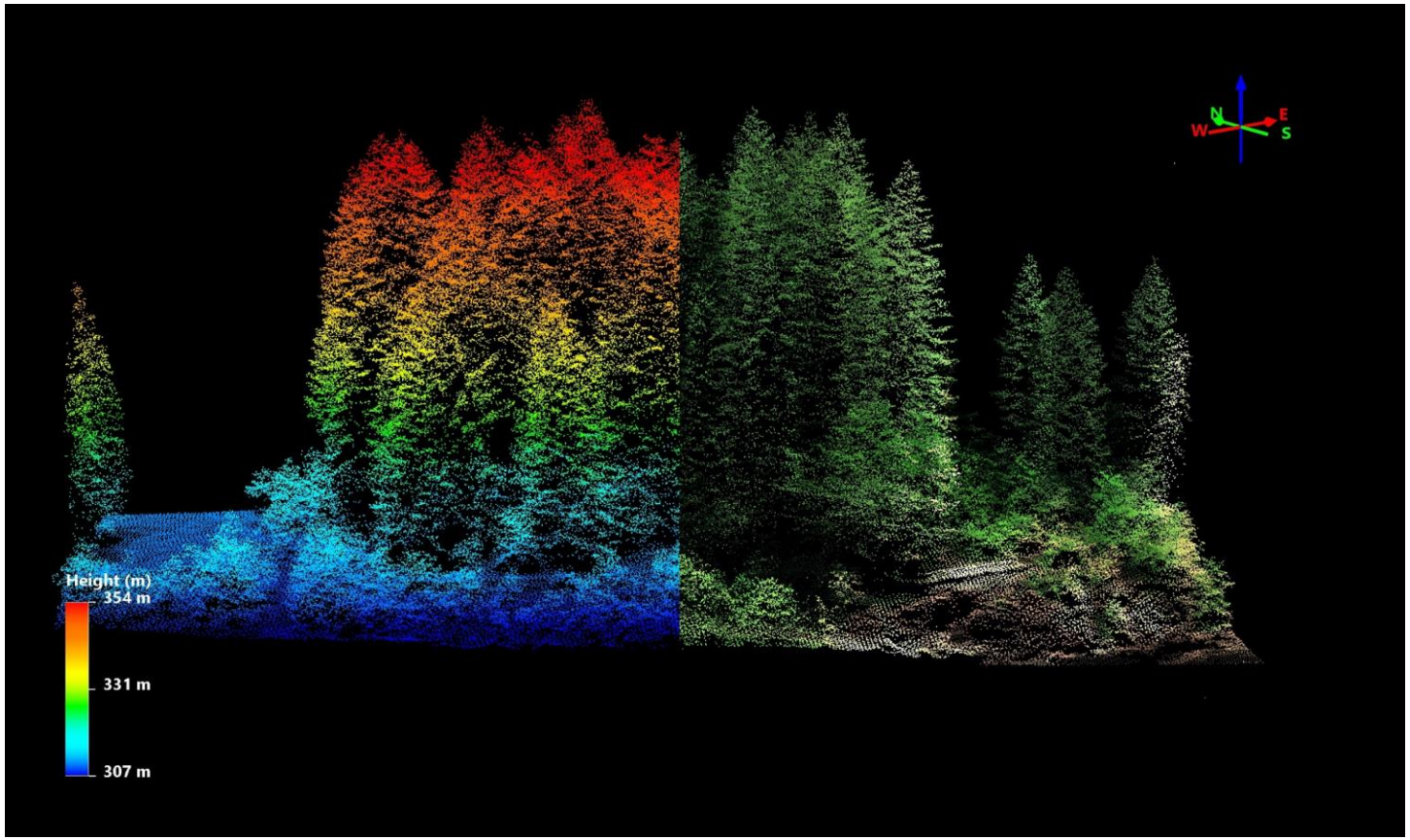


180+ peer reviewed publications using AOP data (https://neon.dimensions.ai/discover/publication)

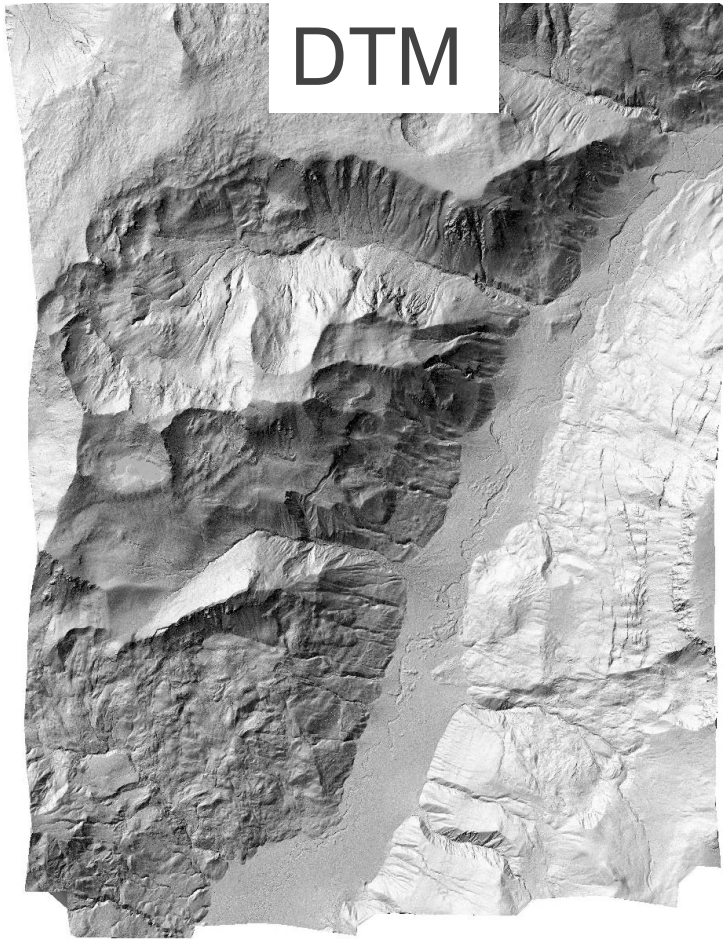
AOP LiDAR



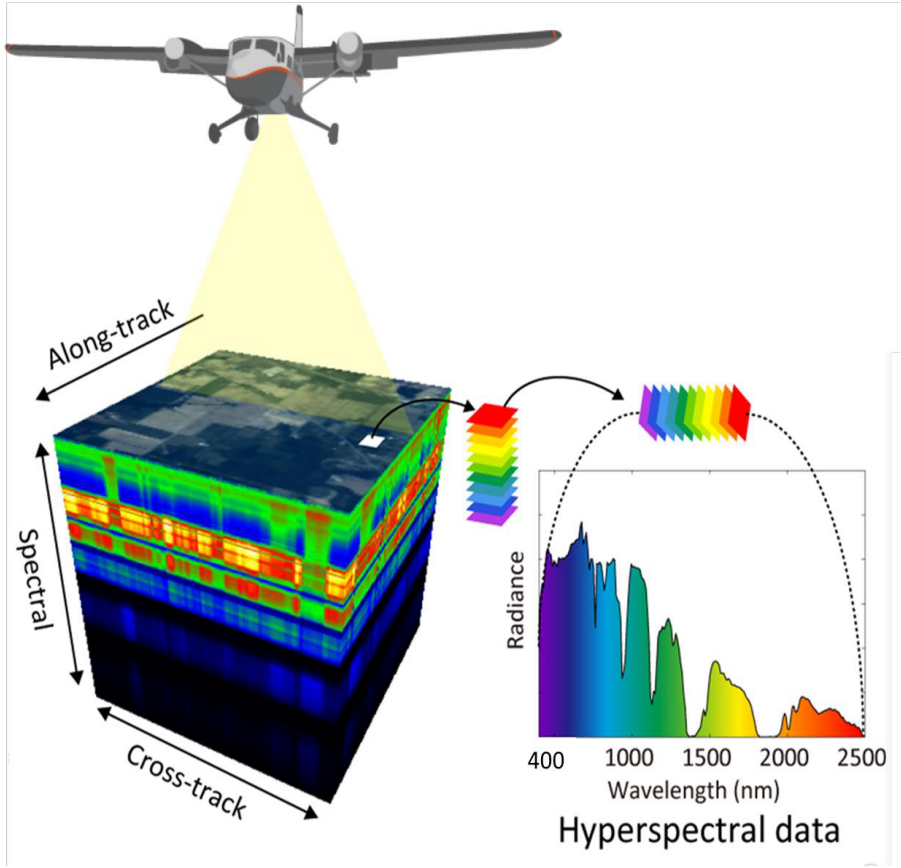
Discrete Point Clouds Classified & Colorized

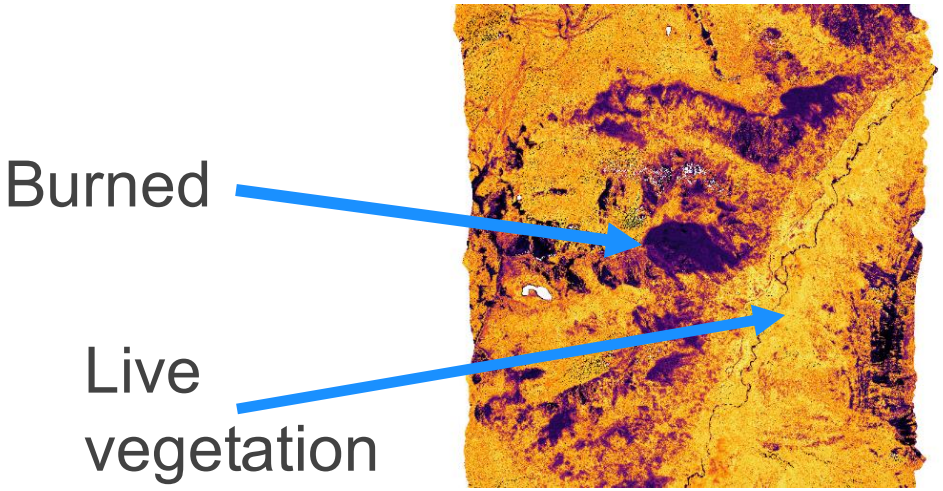


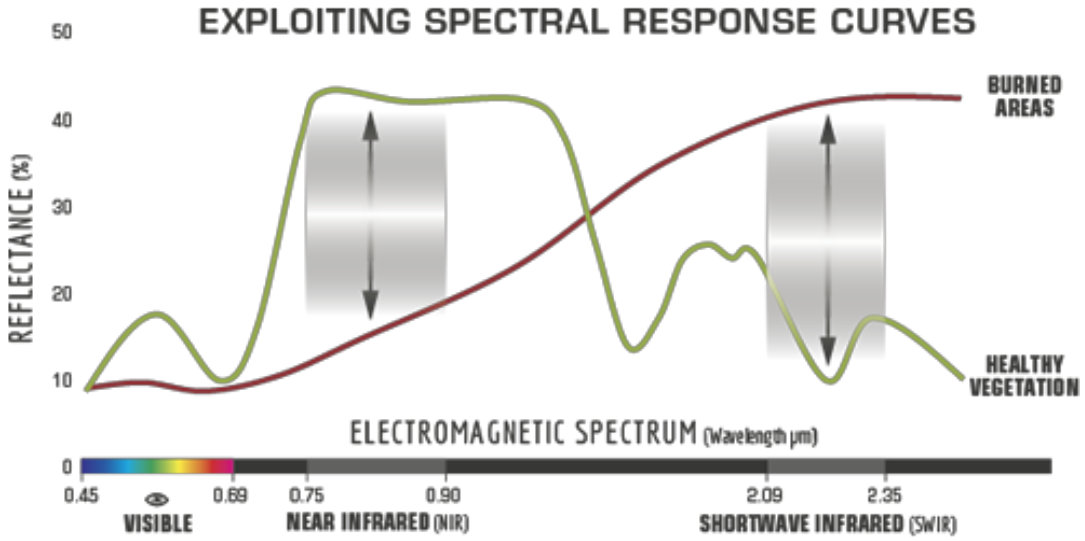
Lidar Raster Data
Elevation Models, Canopy Height, Slope/Aspect



AOP Hyperspectral







https://www.earthdatascience.org/courses/earth-analytics/multispectral-remote-sensing-modis/normalized-burn-index-dNBR/

Hyperspectral Data Products

https://www.neonscience.org/data-collection/imaging-spectrometer

Level 1

- Spectrometer Orthorectified at-Sensor Radiance (DP1.30008.001)
- Spectrometer Orthorectified Surface Directional Reflectance (DP1.30006.001)

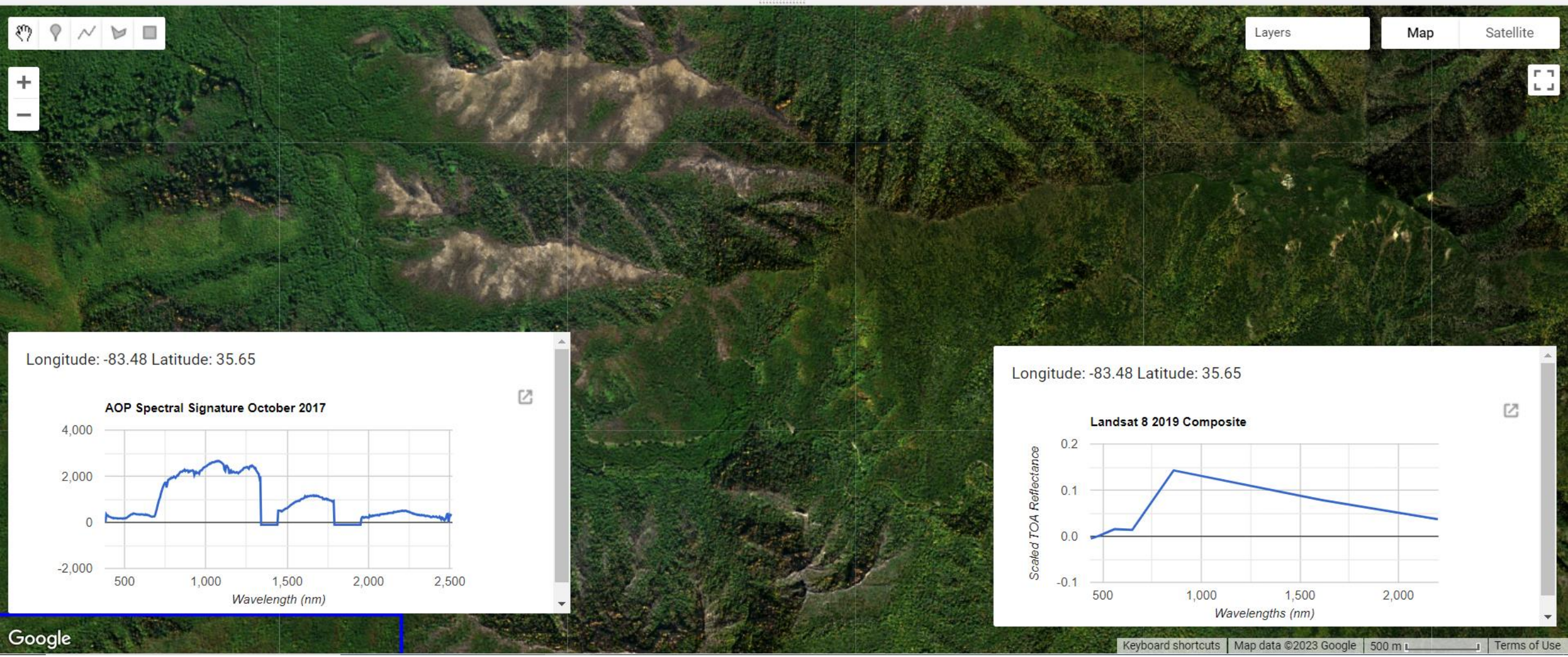
Level 2 / 3

- ~~Canopy Nitrogen (DP2.30018.001)~~
- Canopy Water Content (DP2.30019.001)
- ~~Canopy Xanthophyll Cycle (DP2.30020.001)~~
- ~~Canopy Lignin (DP2.30022.001)~~
- Vegetation Indices - Spectrometer (DP2.30026.001)
- Albedo - Spectrometer (DP2.30011.001)
- LAI - Spectrometer (DP2.30012.001)
- fPAR - Spectrometer (DP2.30014.001)

Moisture Stress Index (MSI)
Normalized Difference Infrared Index (NDII)
Normalized Difference Water Index (NDWI)
Normalized Multi-band Drought Index (NMDI)
Water Band Index (WBI)

Normalized Difference Vegetation Index (NDVI)
Enhanced Vegetation Index (EVI)
Atmospherically Resistant Vegetation Index (ARVI)
Photochemical Reflectance Index (PRI)
Soil Adjusted Vegetation Index (SAVI)

Hyperspectral Resolution



AOP Sampling Collection Requirements

- Clear skies (<10% cloud cover)

high quality, unobscured reflectance data

- Nominal AOP flying altitude = 1000 m AGL

collect data at the scale of individual plants

- Minimum 10 km x 10 km box for terrestrial sites

collect regional scale area around NEON sites

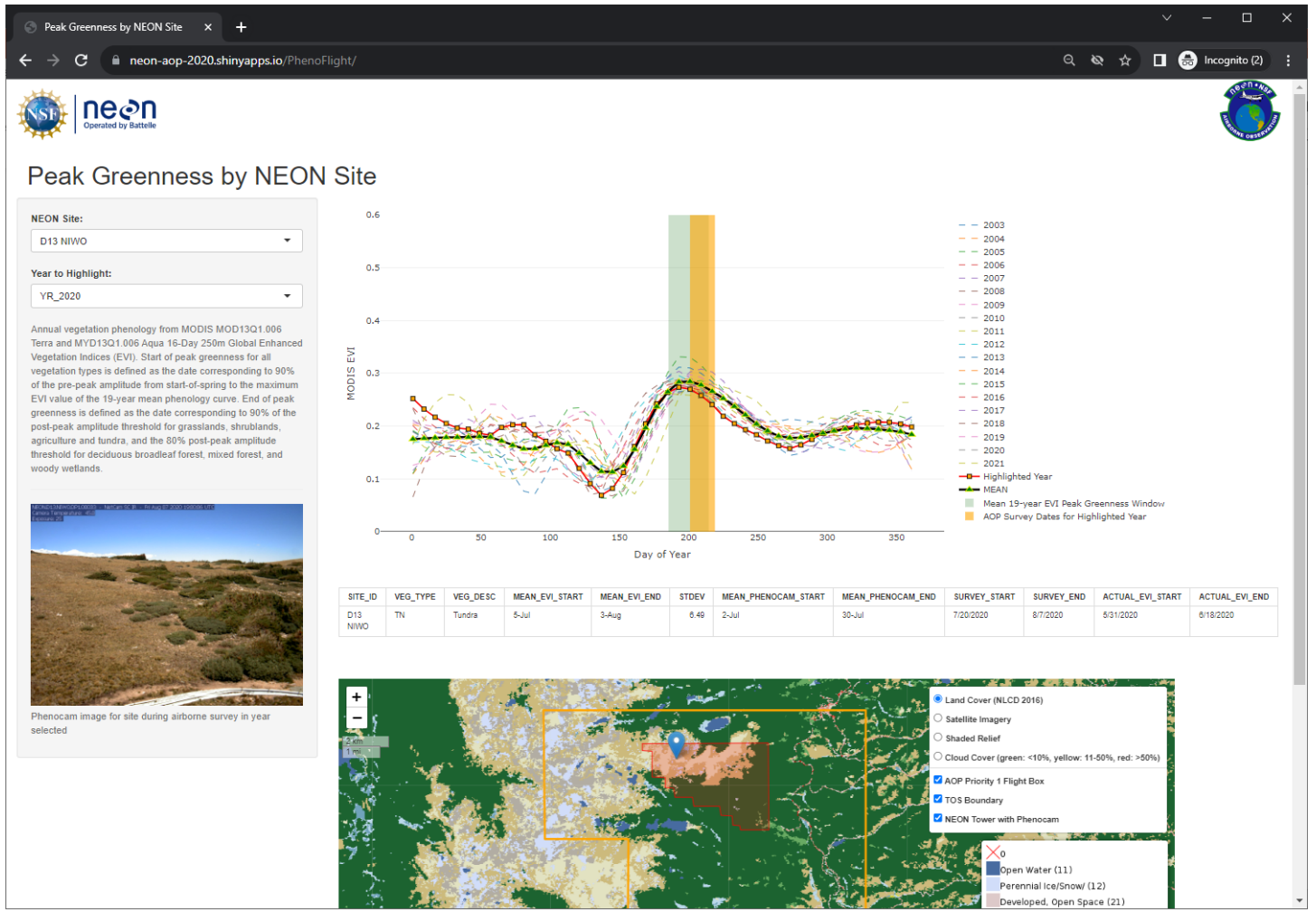
- Fly at peak 'greenness' (phenology)

consistency between annual collections

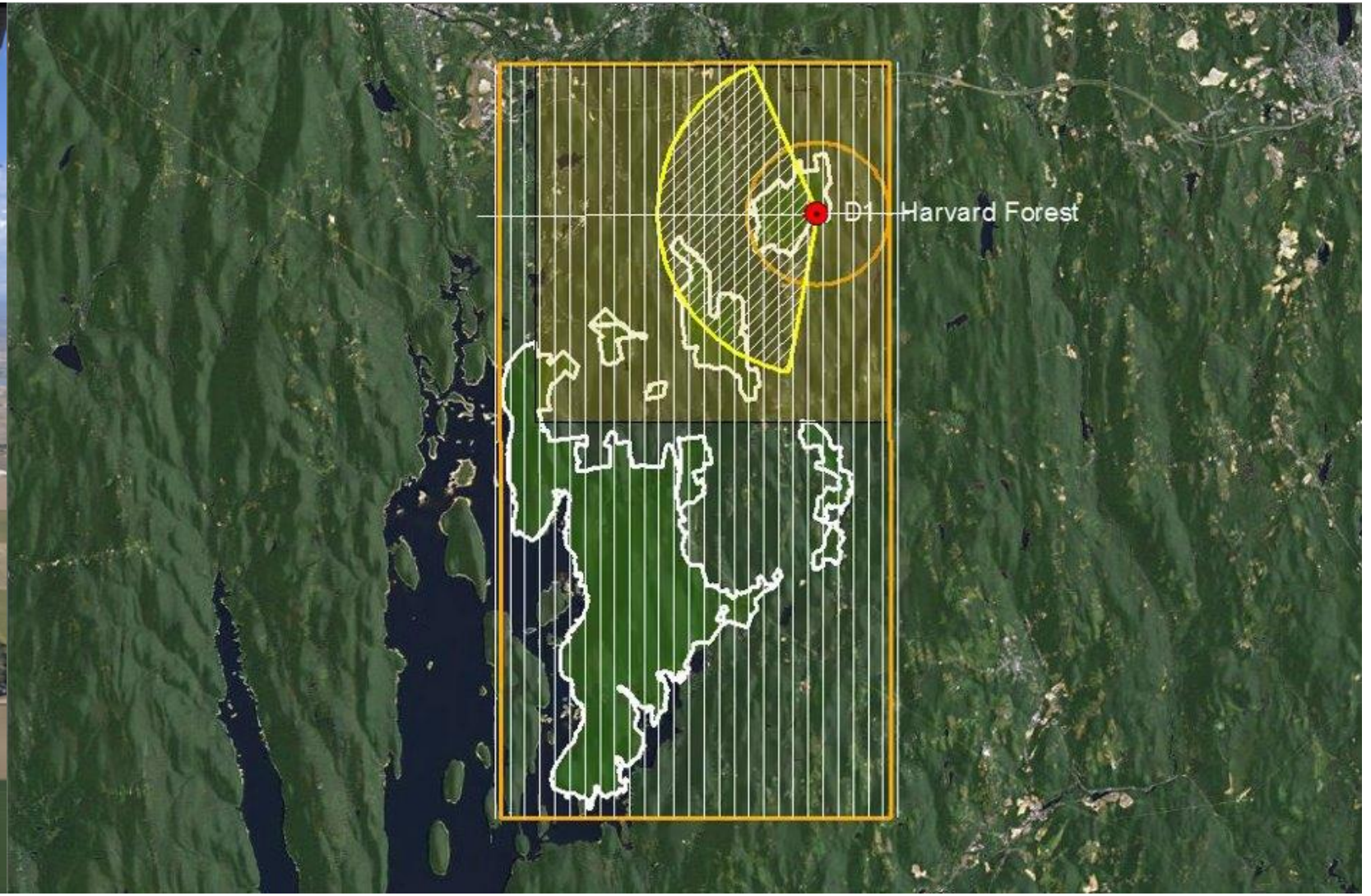
- Fly N-S lines, solar angles above 40°

*consistency between flight lines**

https://neon-aop-2020.shinyapps.io/PhenoFlight/

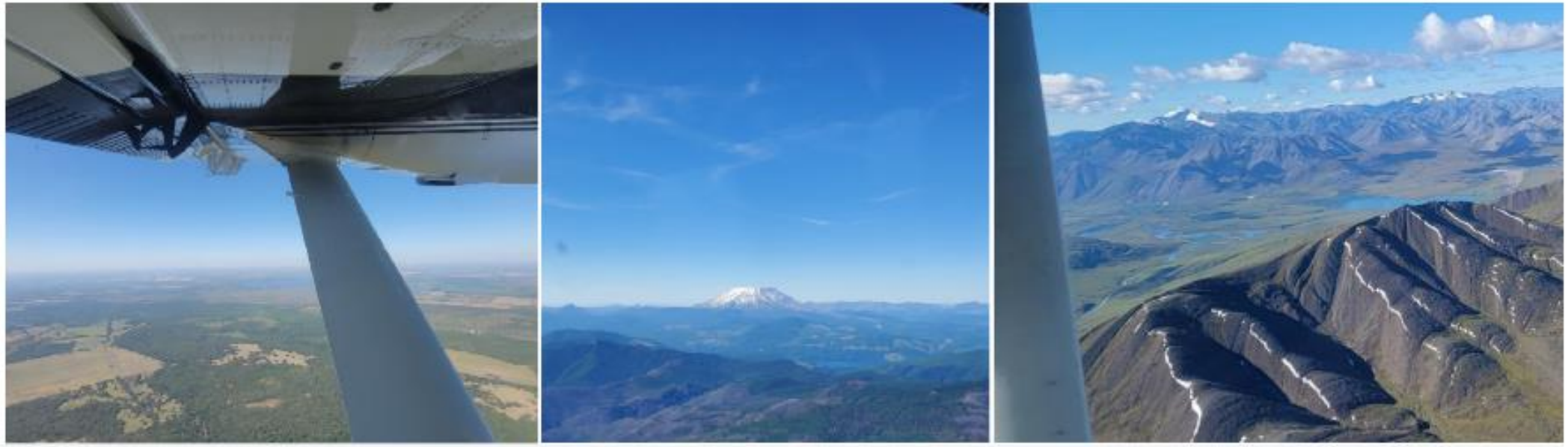


AOP Flight Plan Design



QA & Uncertainty Considerations

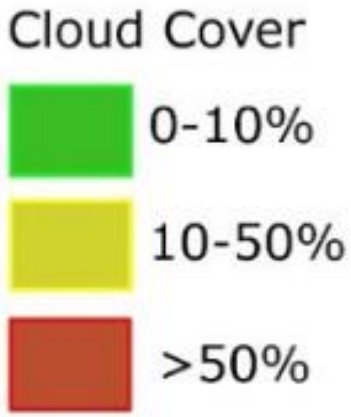
Weather Quality / Cloud Conditions



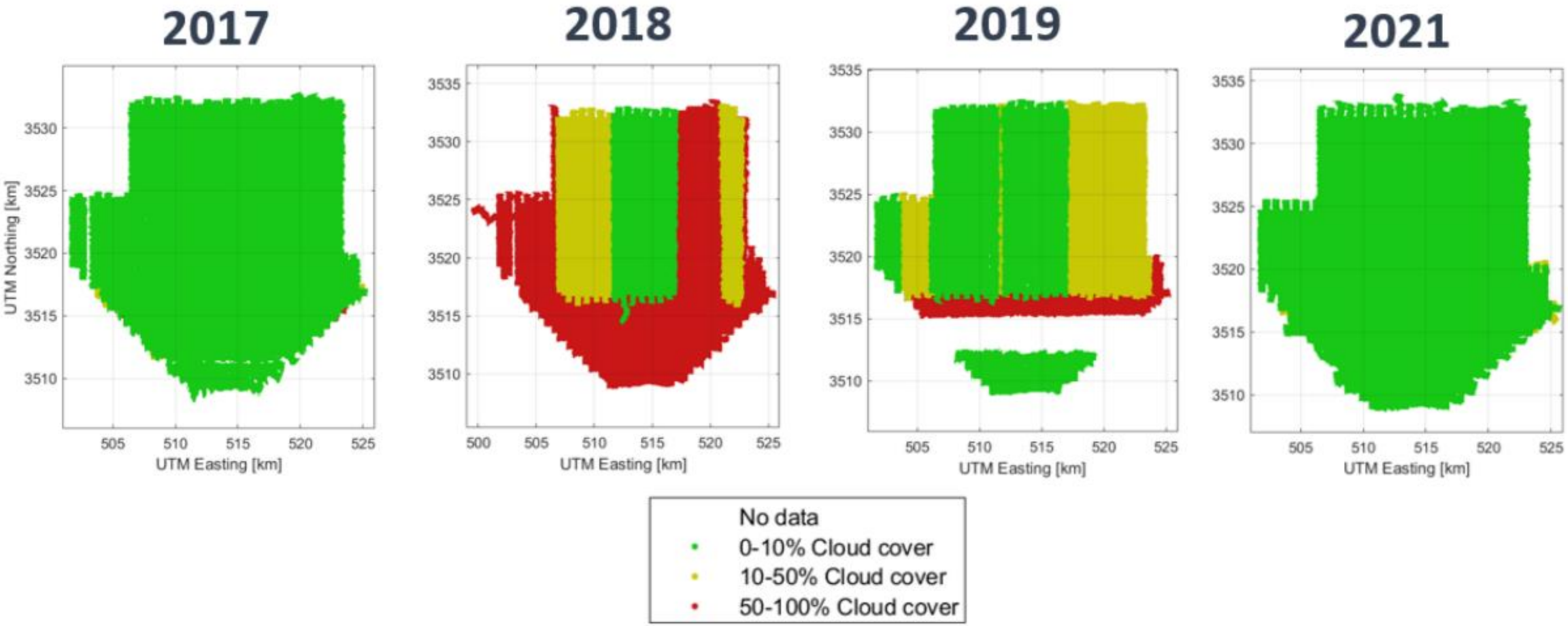
Cloud cover percentage during AOP flights. Left: green (<10%), Middle: yellow (10-50%), Right: red (>50%).

Daily flight reports: https://www.neonscience.org/data-collection/daily-flight-reports

Weather Quality / Cloud Conditions

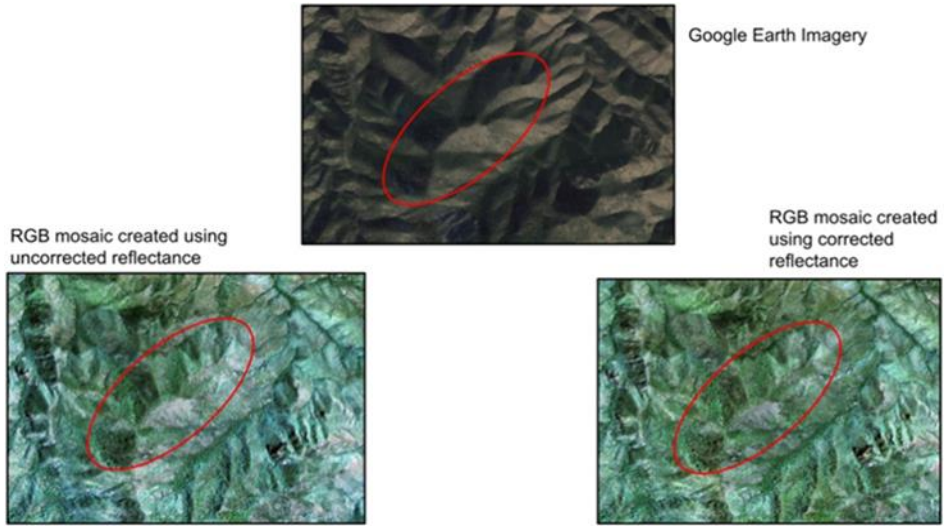


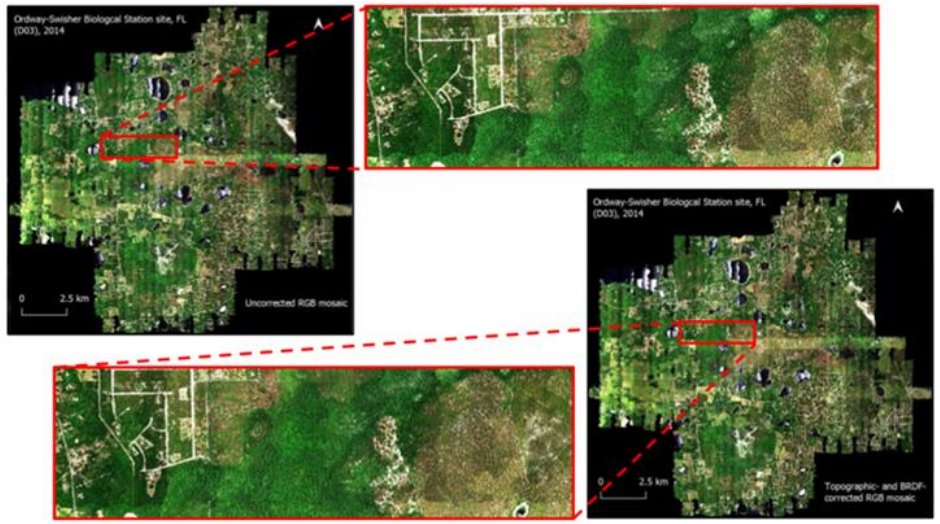
Example weather conditions & coverage @ SRER



Updates to spectrometer-derived data products

- 2022-2024 spectrometer data processing is underway, 2022 spectrometer data available provisionally
- Now generating L1 reflectance data corrected for topographic and BRDF effects using the HyTools Python package[1]. Directional reflectance data (L1) will continue to be generated, but not L3.
- Starting with 2022-2024 data, using the BRDF- and topographic-corrected reflectance data to generate higher level (L2, L3) products (e.g. veg/water indices, LAI, FPAR, foliar trait products).





[1]Queally, Natalie, et al. "FlexBRDF: A flexible BRDF correction for grouped processing of airborne imaging spectroscopy flightlines." *Journal of Geophysical Research: Biogeosciences* 127.1 (2022): e2021JG006622.

AOP Data Access

- **Data Portal** – manual data download through website
  - data.neonscience.org
  - includes important docs and info about NEON data products

- **API** – programmatic download
  - R (neonUtilities)
  - Python scripts/tutorials (Python version of neonUtilities in progress, expected Fall 2024)

- **Google Earth Engine (GEE)**
  - Subset of data available now, adding more
  - Publicly searchable/findable in the GEE Publisher Data Catalog soon!

AOP Image Collections on GEE

```
// Bidirectional (BRDF & topographic corrected) reflectance, DP3.30006.002
var refl002 = ee.ImageCollection('projects/neon-prod-earthengine/assets/HSI_REFL/002')

// Directional reflectance, DP3.30006.001
var refl001 = ee.ImageCollection('projects/neon-prod-earthengine/assets/DP3-30006-001')

// NOTE: directional reflectance will be moved to the path below, by end of July 2024
// var sdrCol = ee.ImageCollection('projects/neon-prod-earthengine/assets/HSI_REFL/001')

// RGB Camera, DP3.30010.001
var rgb = ee.ImageCollection('projects/neon-prod-earthengine/assets/RGB/001')

// CHM (Ecosystem Structure), DP3.30015.001
var chm = ee.ImageCollection('projects/neon-prod-earthengine/assets/CHM/001')

// DEM (DSM & DTM), DP3.30024.001
var dem = ee.ImageCollection('projects/neon-prod-earthengine/assets/DEM/001')
```

GEE Data Demo Links:

Interactive Spectral Visualization App

https://tinyurl.com/d05-spectra-app

GitHub Repo – UNDE Demo Scripts

https://tinyurl.com/unde-aop-gee-demo

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

neon
Operated by Battelle

720.746.4844 | neonscience@battelleecology.org | neonscience.org

Status of AOP Data in Google Earth Engine

- **Why GEE?**
  - Free and openly available for research applications
  - Can easily conduct analysis on full sites over multiple years
  - Pre-loaded satellite imagery for scaling applications
  - Built-in cloud-based algorithms for raster & hyperspectral analysis
- **New in 2023**
  - Added QA bands and metadata information (image properties)
  - Tutorial series for working with AOP GEE Public Datasets
- **Plan for 2024**
  - Add BRDF-corrected reflectance data to GEE (starting with 2022-2024 AOP data)
  - Reflectance, DEM, CHM, RGB Camera datasets available upon request
  - Make AOP datasets publicly searchable on GEE (expected by Aug 2024)

AOP Data Products (Green on GEE)

LIDAR PRODUCT NAME	PRODUCT #
LiDAR Slant Range Waveform	DP1.30001.001
Discrete Return LiDAR Point Cloud	DP1.30003.001
Ecosystem Structure (CHM)	**DP3.30015.001**
Elevation – LiDAR (DTM, DSM)	**DP3.30024.001**
Slope and Aspect – LiDAR	DP3.30025.001

CAMERA PRODUCT NAME	PRODUCT #
High-resolution orthorectified camera imagery	DP1.30010.001
High-resolution orthorectified camera imagery mosaic	**DP3.30010.001**

SPECTROMETER PRODUCT NAME	L1	L2	L3
Spectrometer Orthorectified at-Sensor Radiance	DP1.30008.001		
Spectrometer Orthorectified Surface Directional Reflectance	DP1.30006.001		DP3.30006.001*
Spectrometer Orthorectified Bi-Directional Reflectance*	DP1.30006.002		DP3.30006.002
Vegetation Indices - Spectrometer		DP2.30026.001	DP3.30026.001
Canopy Water Content		DP2.30019.001	DP3.30019.001
…and more!			

Full list of NIS data products can be found here: https://www.neonscience.org/data-collection/imaging-spectrometer

Additional Info on BRDF correction + Suspended AOP Products in Development

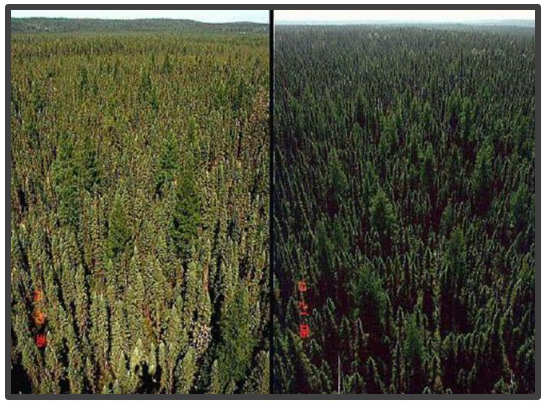
Why BRDF correction?

Surface reflectance anisotropy

Objects look differently when viewed from different angles, and when illuminated from different directions.

Black Spruce Forest

Sun behind observer | Sun opposite observer



All shadows are hidden leading to a bright image

Shadowed centers of trees

Soybeans field

Sun behind observer | Sun opposite observer

Specular (mirror-like) reflection of leaves

Barren field with rough surface

Sun behind observer | Sun opposite observer

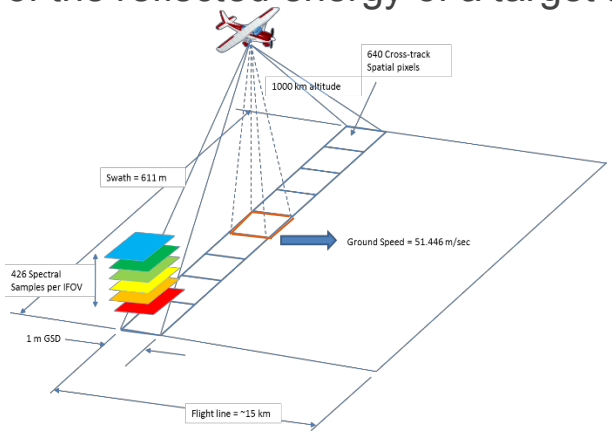
Shadows hidden

Photographs by Donald W. Deering, NASA/GSFC
Source: https://www.umb.edu/spectralmass/terra_aqua_modis/modis

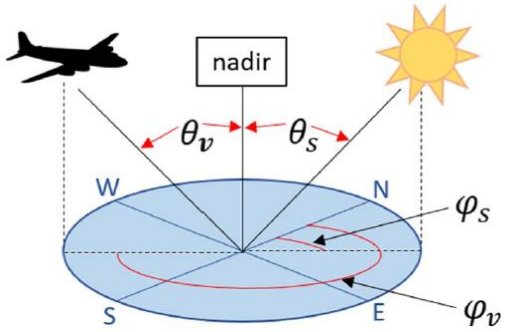
Bidirectional Reflectance Distribution Function (BRDF)

BRDF (units sr^{-1}) describes the directional dependence of the reflected energy of a target as a function of **illumination** and **viewing** geometry

BRDF also depends on
- Wavelength
- Structural and optical properties of the surface

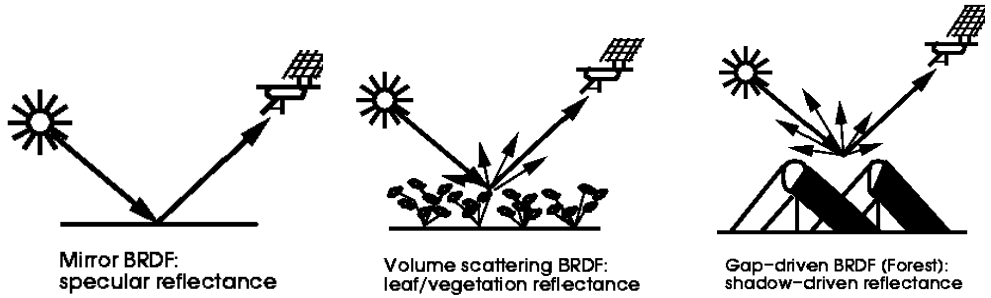


Defining viewing and illumination geometry



θ_s Solar Zenith angle
φ_s Solar Azimuth angle
θ_v View Zenith angle
φ_v View Azimuth angle

Queally, Natalie, et al. "FlexBRDF: A flexible BRDF correction for grouped processing of airborne imaging spectroscopy flightlines." *Journal of Geophysical Research: Biogeosciences* 127.1 (2022): e2021JG006622

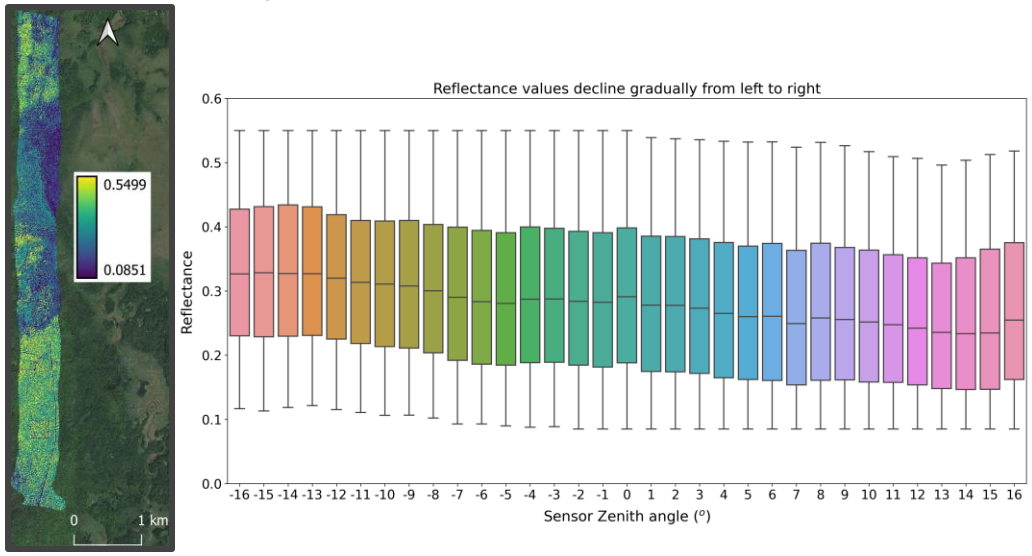


Lucht, Wolfgang, Crystal Barker Schaaf, and Alan H. Strahler. "An algorithm for the retrieval of albedo from space using semiempirical BRDF models." *IEEE Transactions on Geoscience and Remote sensing* 38.2 (2000): 977-998.

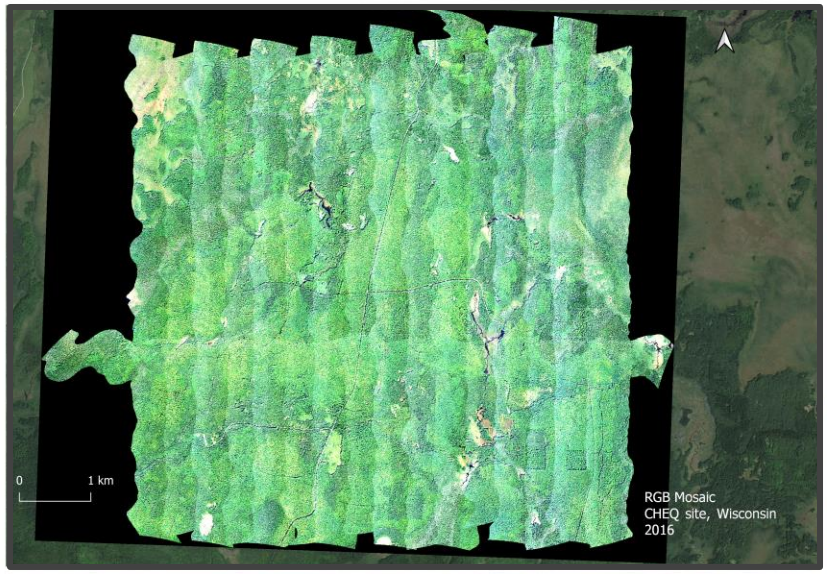
Impact of BRDF effects on reflectance

Within a flight line: Reflectance values decline slightly from left to right in the cross-track direction

Reflectance at Wavelength = 900 nm



Across flight lines: Discontinuity in brightness levels at flight line boundaries



Impact of BRDF effects on higher level products

Colgan, Matthew S., et al. "Mapping savanna tree species at ecosystem scales using support vector machine classification and BRDF correction on airborne hyperspectral and LiDAR data." *Remote Sensing* 4.11 (2012): 3462-3480.

Figure 6. Effect of view zenith angle on reflectance. Spectra shown are for an example tree (**a**) before and (**b**) after applying the BRDF model for four viewing geometries (legend indicates view zenith angle; solar zenith angle and relative azimuth angle were approximately constant).

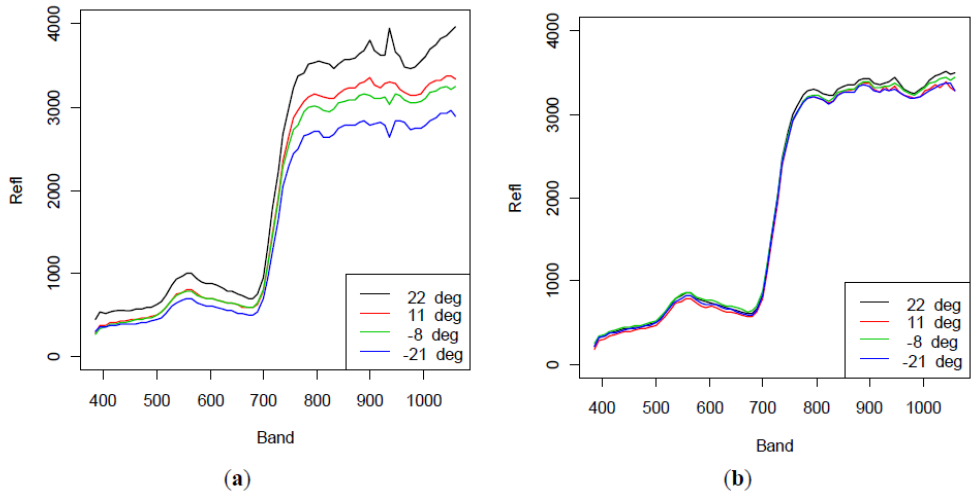
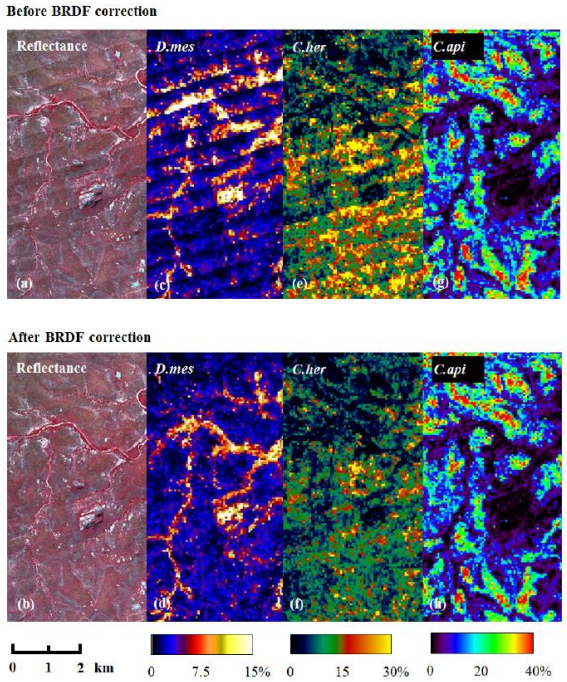


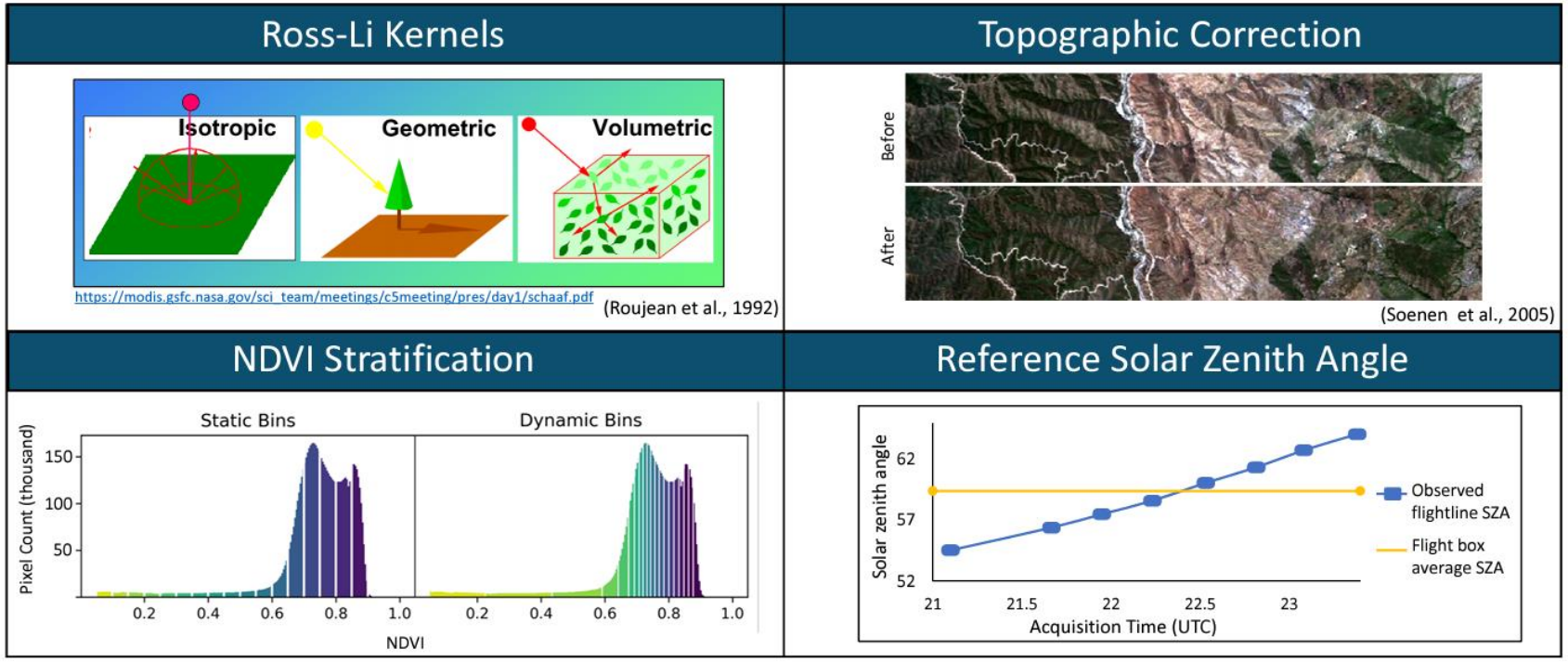
Figure 7. Effect of BRDF correction on species prediction probabilities. The test area spanned 16 flight lines and is the same across all panes. (**a**) False-color infrared of hyperspectral data before BRDF correction and (**b**) after BRDF correction. (**c–h**) Probability maps for several example species. Species with lower mean probabilities (e.g., *D.mes, C.her*) exhibited the largest reduction in flight line artifacts post-BRDF correction, whereas species with higher probabilities (e.g., *C.api*) typically had few or no artifacts before or after BRDF correction. These test maps were generated using SVM Model 1 (hyperspectral data only) to avoid confounding interpretation with additional LiDAR input.



FlexBRDF for performing BRDF and topographic corrections

Queally, Natalie, et al. "FlexBRDF: A flexible BRDF correction for grouped processing of airborne imaging spectroscopy flightlines." *Journal of Geophysical Research: Biogeosciences* 127.1 (2022): e2021JG006622.

HyTools - open-source python package for implementing FlexBRDF https://github.com/EnSpec/hytools/tree/master/hytools

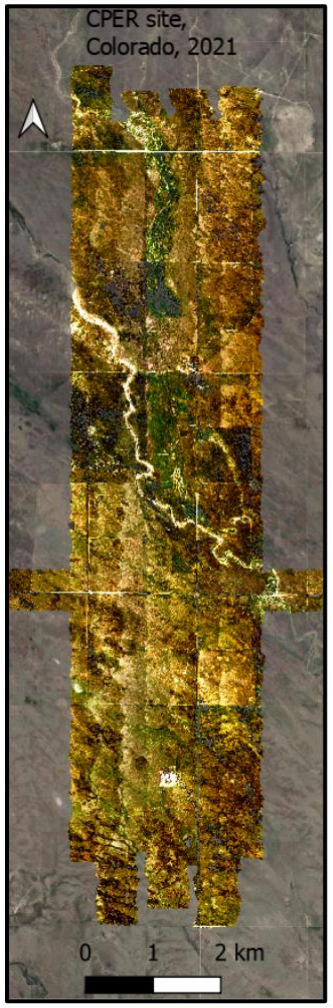


Evaluating BRDF-corrected reflectance

Uncorrected

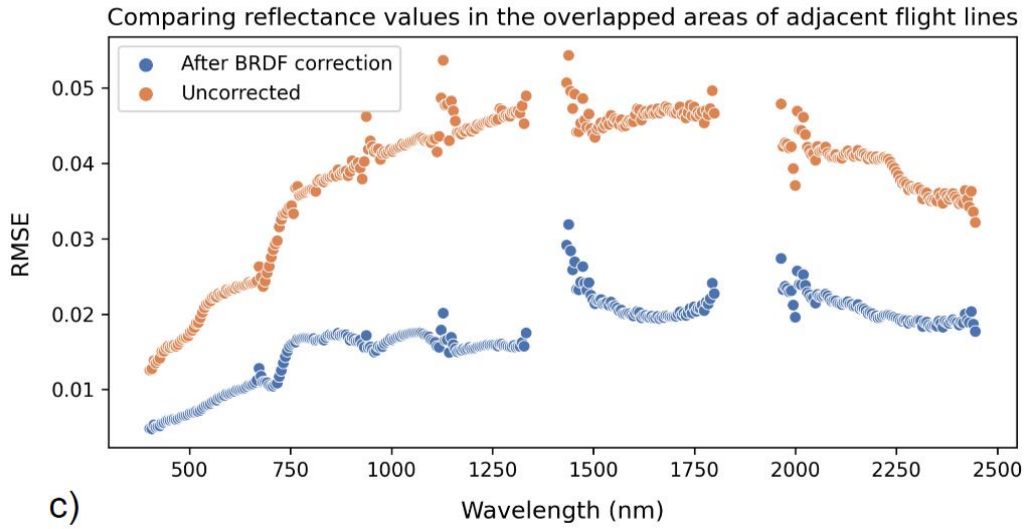
a)

BRDF-corrected



b)

- Corrections tested at multiple sites
- Same parameter set to be used for all sites



c)

Foliar Trait Products in Development - Modeling Workflow

NEON Terrestrial Observation Sampling (TOS) Datasets

Geolocated foliar sampling performed for
- Woody Individuals
- Herbaceous cover

Foliar traits

Biophysical (LMA, canopy water content)
Biochemical (C,N,lignin, chlorophyll, elements etc.)
Stable isotopes (δ13 C, δ15 N)

Veg structure

Years ≥ 2020
Hand-delineated crown polygons

Years < 2020
Stem Distance, Stem Azimuth, Crown diameter → Create Crown polygons

NEON Airborne Observation Platform (AOP) Datasets

Hyperspectral

Level-1 reflectance data, 426 bands (385 - 2500 nm) at 1m resolution

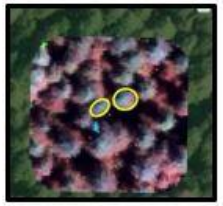
BRDF correction
Topographic correction
Wavelength resampling

Corrected reflectance

Select flight lines which are least cloud-affected

Extract AOP Data for Foliar Sampling Locations

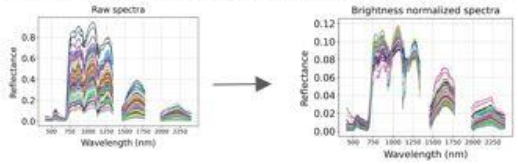
Woody individuals



Herbaceous clip strips

Select only those 1m pixels within a tree crown which are,
1) Vegetated (NDVI > threshold)
2) Not understory vegetation (CHM > threshold)
3) Not affected by cloud shadows (NIR > threshold)

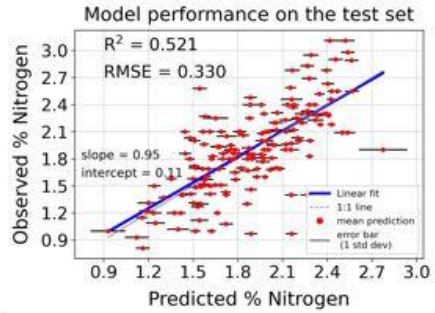
For the remaining 1m pixels within a crown, perform brightness normalization on the spectra to reduce the effect of internal canopy shadows



Calculate average value for the spectra and lidar-derived variables for the tree crown/clip strip

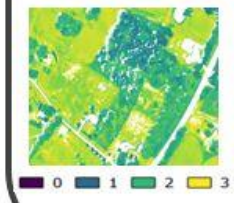
Model inputs: 331 hyperspectral bands

Partial Least Squares Regression (PLSR) modeling

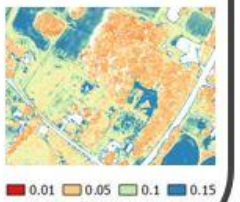


Map Foliar Traits and Characterize Uncertainty

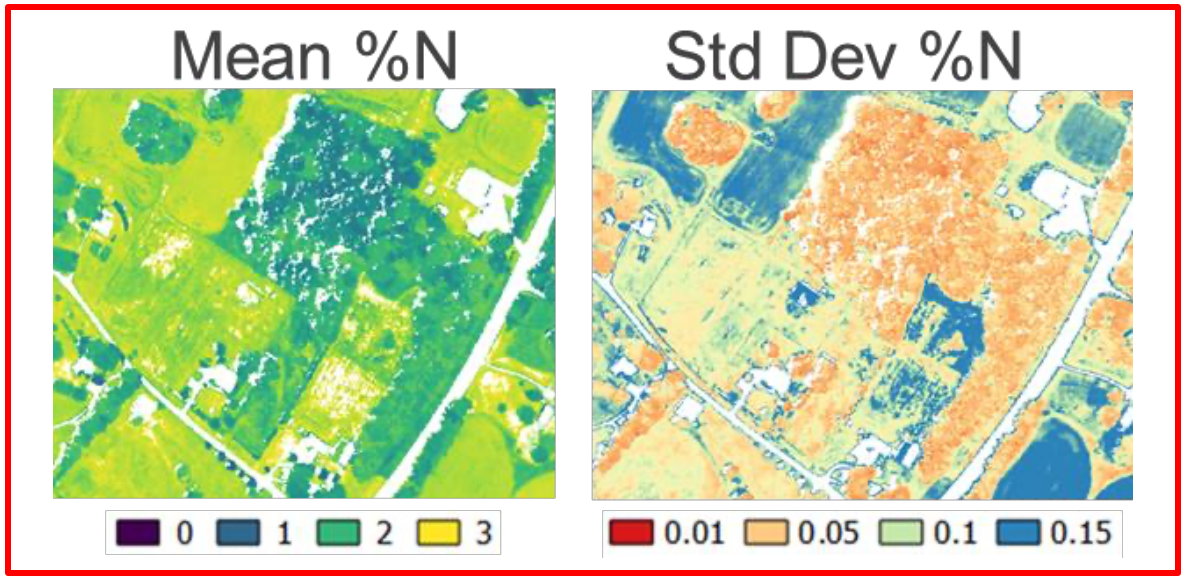
Mean % N

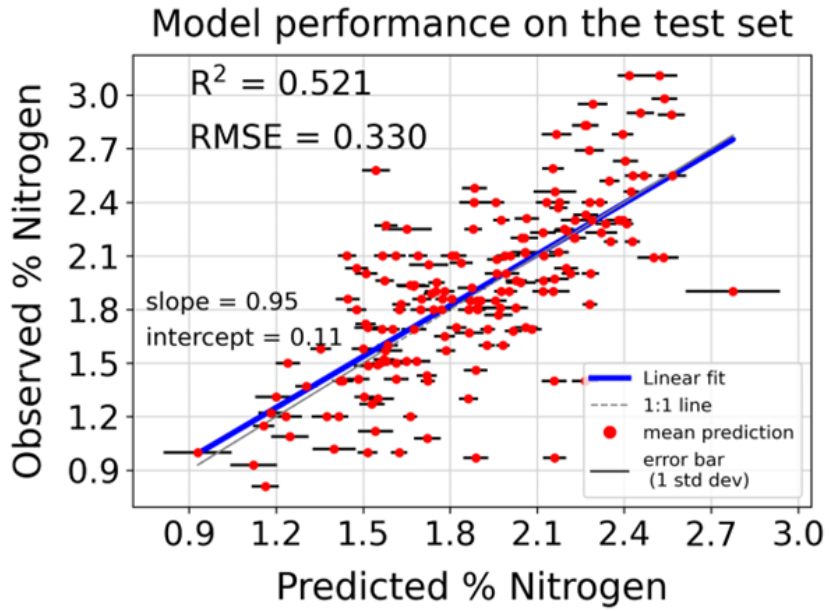


Std dev % N



Preliminary Results





PLSR models trained on percent Nitrogen data collected for three NEON domains (D01, D02, and D07)