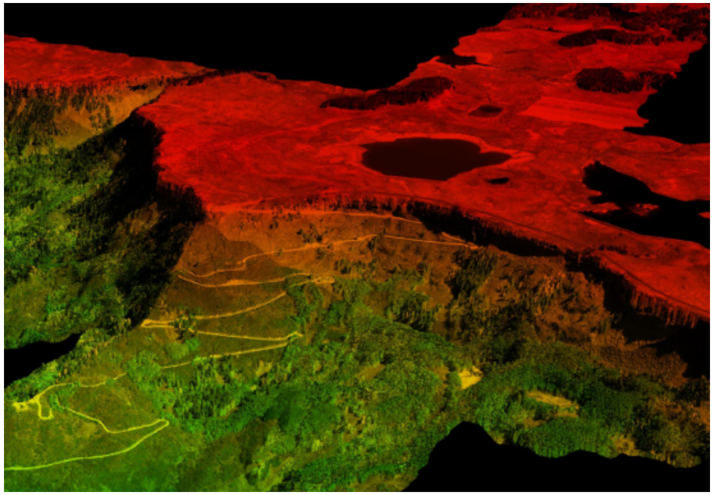
DATA PRODUCTS AND APPLICATIONS FROM THE NEON 2013 AIRBORNE CAMPAIGN AT DOMAIN 17 IN CALIFORNIA



John Musinsky, Staff Scientist, Airborne Observation Program
Tristan Goulden, Associate Scientist, AOP Integrated Product Team Co-lead

2014 HyspIRI Science Workshop
Pasadena, CA
October 14-16, 2014

What is NEON?

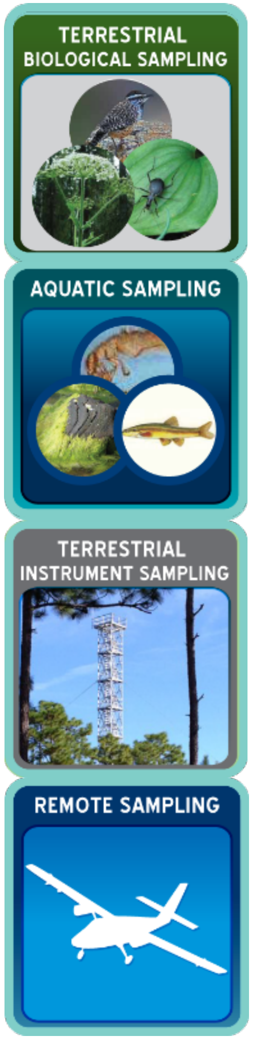
- **National Ecological Observatory Network**
- **Large science facility fully funded by the National Science Foundation**
- **A continental-scale ecological observatory that:**
  - Collects and provides data on the drivers/responses of ecological change
  - Serves as an experimental infrastructure/backbone for research and experiments
  - Develops and provides educational resources to engage communities in working with scientific data
- **Project Timeline**

CONCEPT & DESIGN	SITES BUILT OUT	DATA COLLECTION
2004-2011	2012 - ~2017	~2017 - 2046

A Continental-Scale Design

1. **Core sites:** Located in unmanaged wildland conditions
2. **Relocatable sites:** Representative of human land management effects on ecosystems
3. **Aquatic sites:** Measure changes in aquatic systems over time

NEON Integrated Sampling Strategy



Biological Sampling

- Plant biodiversity
- Plant biomass, leaf area, and chemical composition
- Plant phenology
- Birds
- Ground beetles
- Mosquitoes
- Small mammals
- Infectious disease
- Biogeochemistry
- Soil microbes

Airborne Observations

- Canopy chemistry
- Canopy moisture
- Leaf area
- Canopy structure
- Canopy height
- Land cover
- Diversity
- Disturbance

Aquatic Sampling

Sensor measurements

- In-stream/In-lake
- Micrometeorology
- Groundwater

Field Sampling

- Chemistry / Isotopes
- Biological diversity
- Microbes
- Algae
- Aquatic Plants
- Invertebrates
- Fish
- Morphology, Bathymetry
- Riparian canopy

Atmospheric Measurements

- Key climate inputs
- Bioclimatic variables
- Chemical climate inputs
- Carbon cycle changes
- Water & energy balance

Soil Measurements

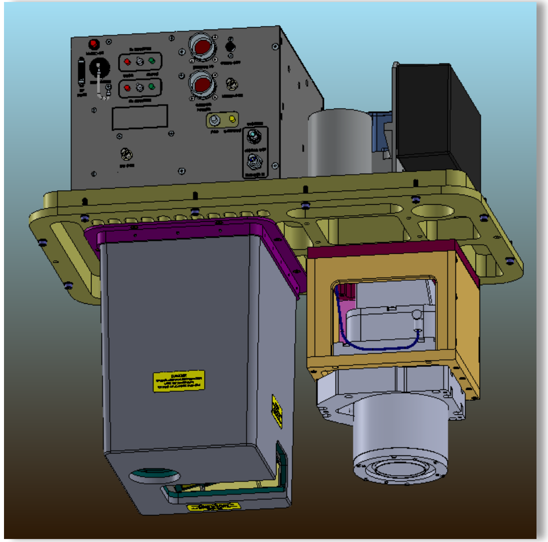
- Temperature
- Moisture
- CO_2
- Root growth and phenology

NEON Remote Sensing Payload

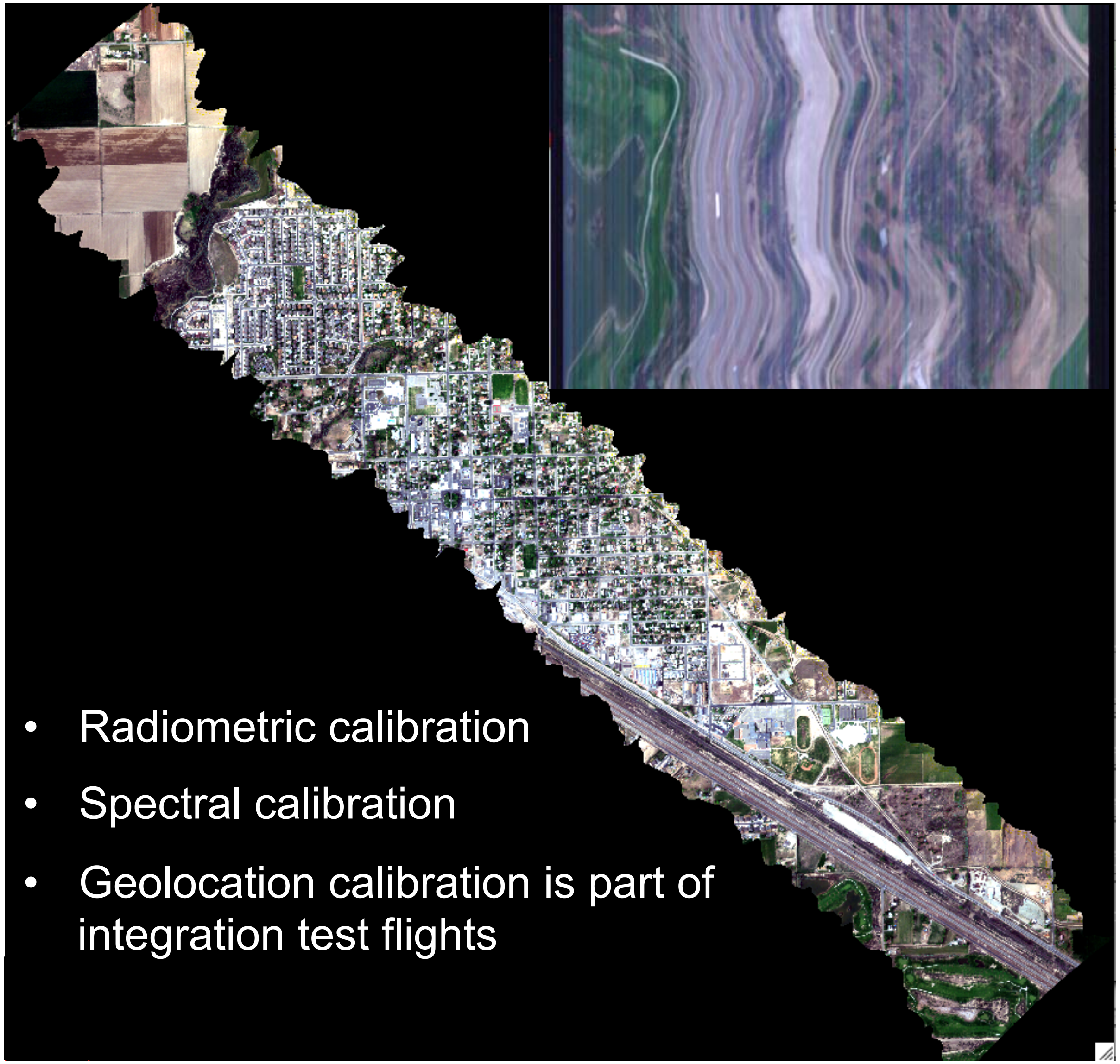
Spectral range	380-2510 nm
Spectral sampling (FWHM)	6 nm
IFOV	1.0 milliradian
Cross-track pixels	> 600 pixels
Cross-track swath	1.0 km @ 1000m altitude

NEON Imaging Spectrometer: high-fidelity visible-to-shortwave infrared (VSWIR) imaging spectrometer built by JPL based on AVIRISng

Waveform LiDAR		Digital Camera	
Laser wavelength	1064 nm	Spectral band-pass	400-700 visible
Laser pulse repetition freq.	100 kHz	Ground sampling distance	8.5 cm @ 1000 m AGL
Scan frequency	50 Hz		
Flying altitudes	1000-1500 m		
Scan angle	Programmable18.5°		
Point density	< 2-4 ppm		

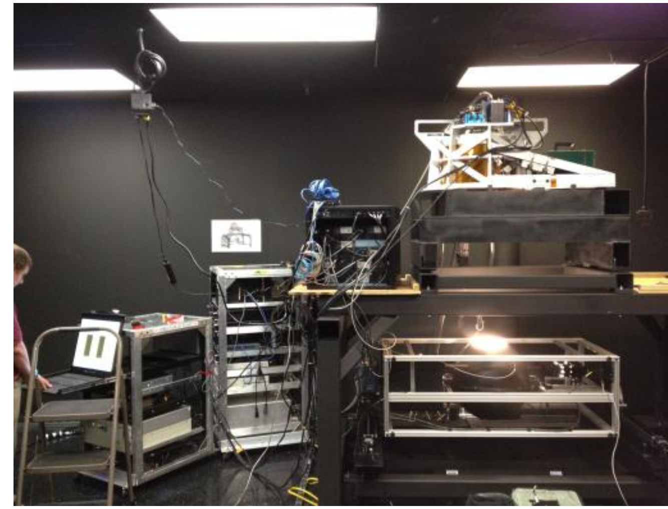


Calibration of the NEON Imaging Spectrometer



- Radiometric calibration
- Spectral calibration
- Geolocation calibration is part of integration test flights

NIST traceable source

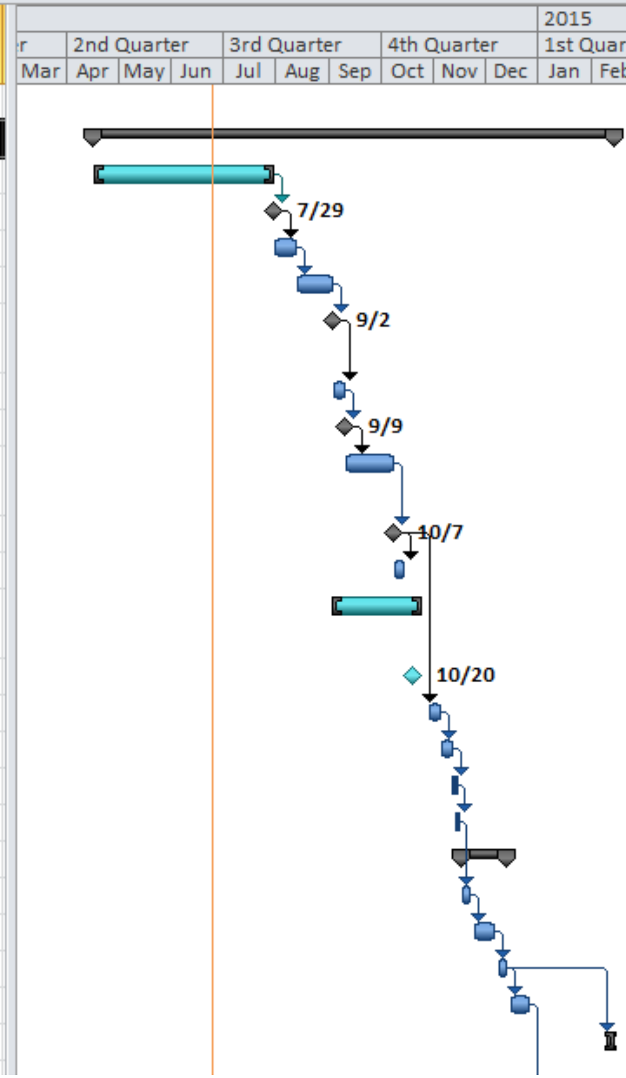


Vicarious Calibration at Railroad Valley

Payload 1 ATRR and Verification Schedule 2014

Table: Entry
View: Gantt Chart
Right-click to select and change tables.

	Task Name	Duration	Start	Finish
18				
19	**ATRR and Verification Activities**	**218 days**	**Wed 4/16/14**	**Fri 2/13/15**
20	Writing drafts of all plans and procedures	15 wks	Wed 4/16/14	Tue 7/29/14
21	Drafts for all plans and procedures complete	0 days	Tue 7/29/14	Tue 7/29/14
22	AOP SE review drafts	2 wks	Wed 7/30/14	Tue 8/12/14
23	Draft revisions	3 wks	Wed 8/13/14	Tue 9/2/14
24	All ATRR documentation reviewed and ready for Agile upload	0 days	Tue 9/2/14	Tue 9/2/14
25	Agile review cycle for ATRR documentation	1 wk	Wed 9/3/14	Tue 9/9/14
26	ATRR documentation ready for NEON SE review	0 days	Tue 9/9/14	Tue 9/9/14
27	NEON SE to review ATRR documentation, generate test plan	4 wks	Wed 9/10/14	Tue 10/7/14
28	NEON SE ATRR test plan to AOP SE	0 days	Tue 10/7/14	Tue 10/7/14
29	AOP SE review of ATRR test plan	1 wk	Wed 10/8/14	Tue 10/14/14
30	Engineering Flights + High Park Campaign (installation to deinstallation)	39 days	Tue 9/2/14	Fri 10/24/14
31	Final day for High Park data collect	0 days	Mon 10/20/14	Mon 10/20/14
32	ATRR flip thrus	1 wk	Wed 10/29/14	Tue 11/4/14
33	ATRR dry runs	1 wk	Wed 11/5/14	Tue 11/11/14
34	ATRR	2 days	Wed 11/12/14	Thu 11/13/14
35	NEON SE ATRR go/no-go assessment	1 day	Fri 11/14/14	Fri 11/14/14
36	**Verification test flights**	**20 days**	**Mon 11/17/14**	**Fri 12/12/14**
37	Installation of Payload 1	1 wk	Mon 11/17/14	Fri 11/21/14
38	Verification flights	2 wks	Mon 11/24/14	Fri 12/5/14
39	Deinstallation of Payload 1	1 wk	Mon 12/8/14	Fri 12/12/14
40	Wrap-up activities	2 wks	Mon 12/15/14	Fri 12/26/14
41	Verification of Lab Calibration	1 wk	Mon 2/9/15	Fri 2/13/15



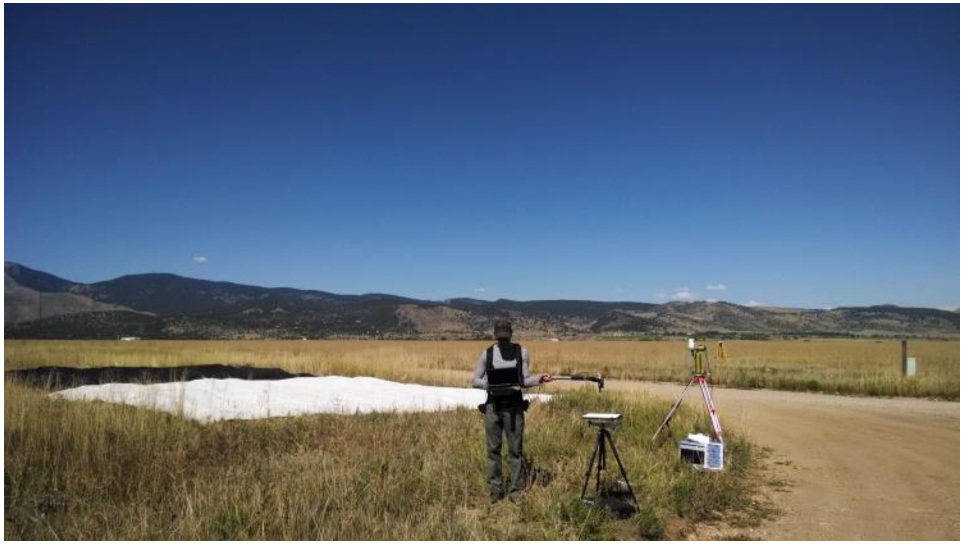
Sep-Oct 2014

Engineering Flights

- Boresight Calibration / Geo-calibration – Greeley, CO (1500m, 1000m, 500m AGL)
- Nominal Runway Survey – Boulder Airport
- Wiggle Timing Test – Boulder Airport
- Radiometric Calibration (RMMA)

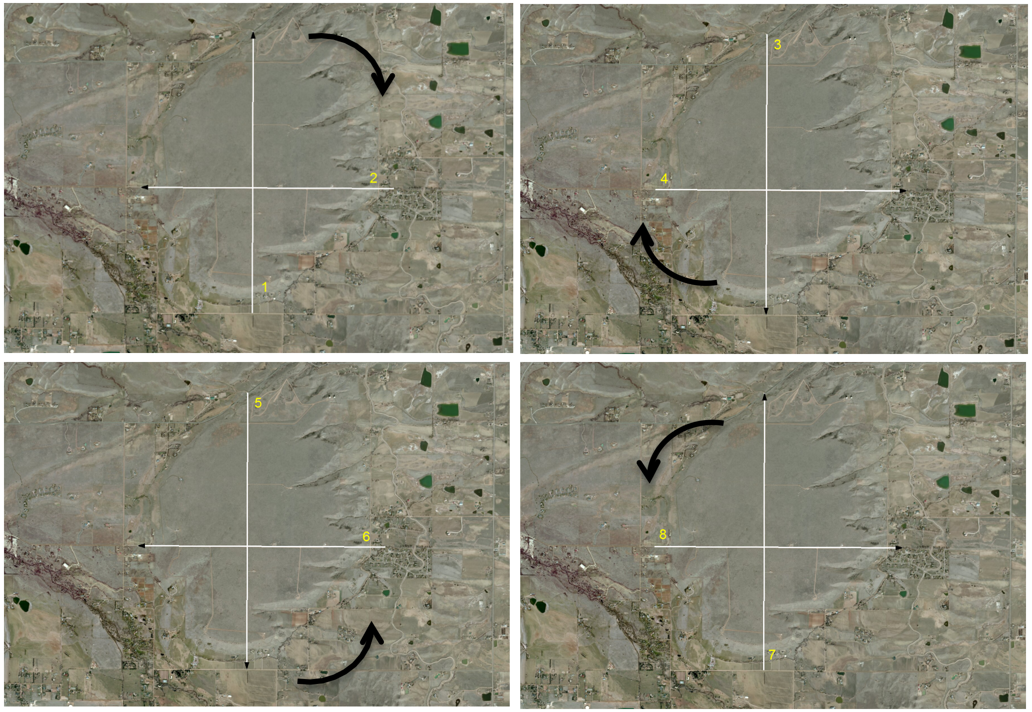
Test Flights

- Spectrometer Sensitivity Analysis
- LiDAR Geolocation Validation
- Flight Banking Sensitivity Analysis
- Variable Altitude Climb-Descend Test
- IMU Drift Test



Science Flights

- High Park



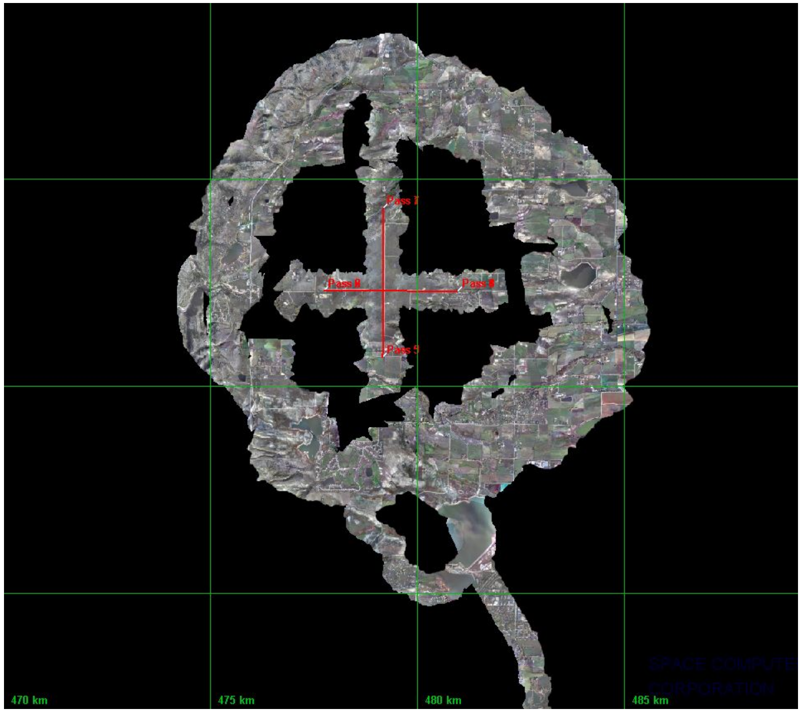
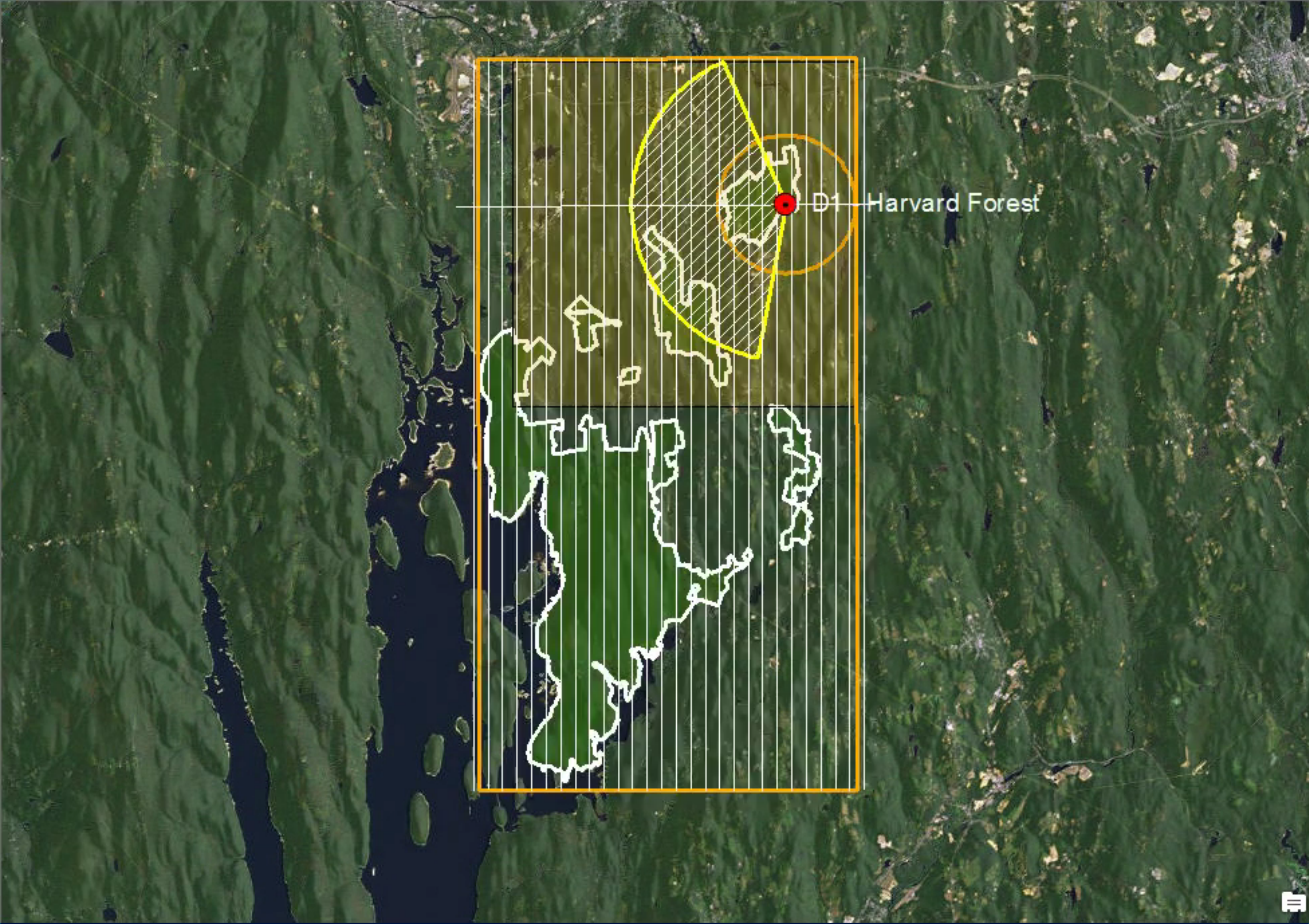


Table Mountain Site

40.130557, -105.23639, 1689-m

Date	20	25	30	35	40	45	50	55	55	50	45	40	35	30	25	20
2014-09-10	14:27:00	14:54:00	15:22:00	15:50:00	16:21:00	16:54:00	17:35:00			20:20:00	21:01:00	21:34:00	22:05:00	22:34:00	23:01:00	23:28:00
2014-09-11	14:28:00	14:55:00	15:23:00	15:52:00	16:22:00	16:56:00	17:38:00			20:16:00	20:58:00	21:32:00	22:03:00	22:32:00	22:59:00	23:26:00
2014-09-12	14:29:00	14:56:00	15:24:00	15:53:00	16:24:00	16:58:00	17:41:00			20:12:00	20:55:00	21:30:00	22:01:00	22:30:00	22:58:00	23:25:00
2014-09-13	14:30:00	14:57:00	15:25:00	15:54:00	16:25:00	17:01:00	17:45:00			20:08:00	20:53:00	21:28:00	21:59:00	22:28:00	22:56:00	23:23:00
2014-09-14	14:31:00	14:58:00	15:26:00	15:56:00	16:27:00	17:03:00	17:48:00			20:04:00	20:50:00	21:25:00	21:57:00	22:26:00	22:54:00	23:21:00
2014-09-15	14:32:00	14:59:00	15:28:00	15:57:00	16:29:00	17:05:00	17:52:00			19:59:00	20:47:00	21:23:00	21:55:00	22:24:00	22:52:00	23:20:00
2014-09-16	14:33:00	15:00:00	15:29:00	15:58:00	16:31:00	17:07:00	17:57:00			19:54:00	20:44:00	21:20:00	21:53:00	22:22:00	22:50:00	23:18:00
2014-09-17	14:34:00	15:02:00	15:30:00	16:00:00	16:32:00	17:10:00	18:01:00			19:49:00	20:41:00	21:18:00	21:50:00	22:20:00	22:49:00	23:16:00
2014-09-18	14:35:00	15:03:00	15:31:00	16:01:00	16:34:00	17:12:00	18:07:00			19:43:00	20:37:00	21:15:00	21:48:00	22:18:00	22:47:00	23:14:00
2014-09-19	14:36:00	15:04:00	15:33:00	16:03:00	16:36:00	17:15:00	18:13:00			19:36:00	20:34:00	21:13:00	21:46:00	22:16:00	22:45:00	23:13:00
2014-09-20	14:37:00	15:05:00	15:34:00	16:04:00	16:38:00	17:17:00	18:20:00			19:28:00	20:31:00	21:10:00	21:44:00	22:14:00	22:43:00	23:11:00
2014-09-21	14:38:00	15:06:00	15:35:00	16:06:00	16:40:00	17:20:00	18:30:00			19:18:00	20:27:00	21:08:00	21:41:00	22:12:00	22:41:00	23:09:00
2014-09-22	14:40:00	15:07:00	15:37:00	16:08:00	16:42:00	17:23:00	18:52:00			18:55:00	20:23:00	21:05:00	21:39:00	22:10:00	22:39:00	23:07:00

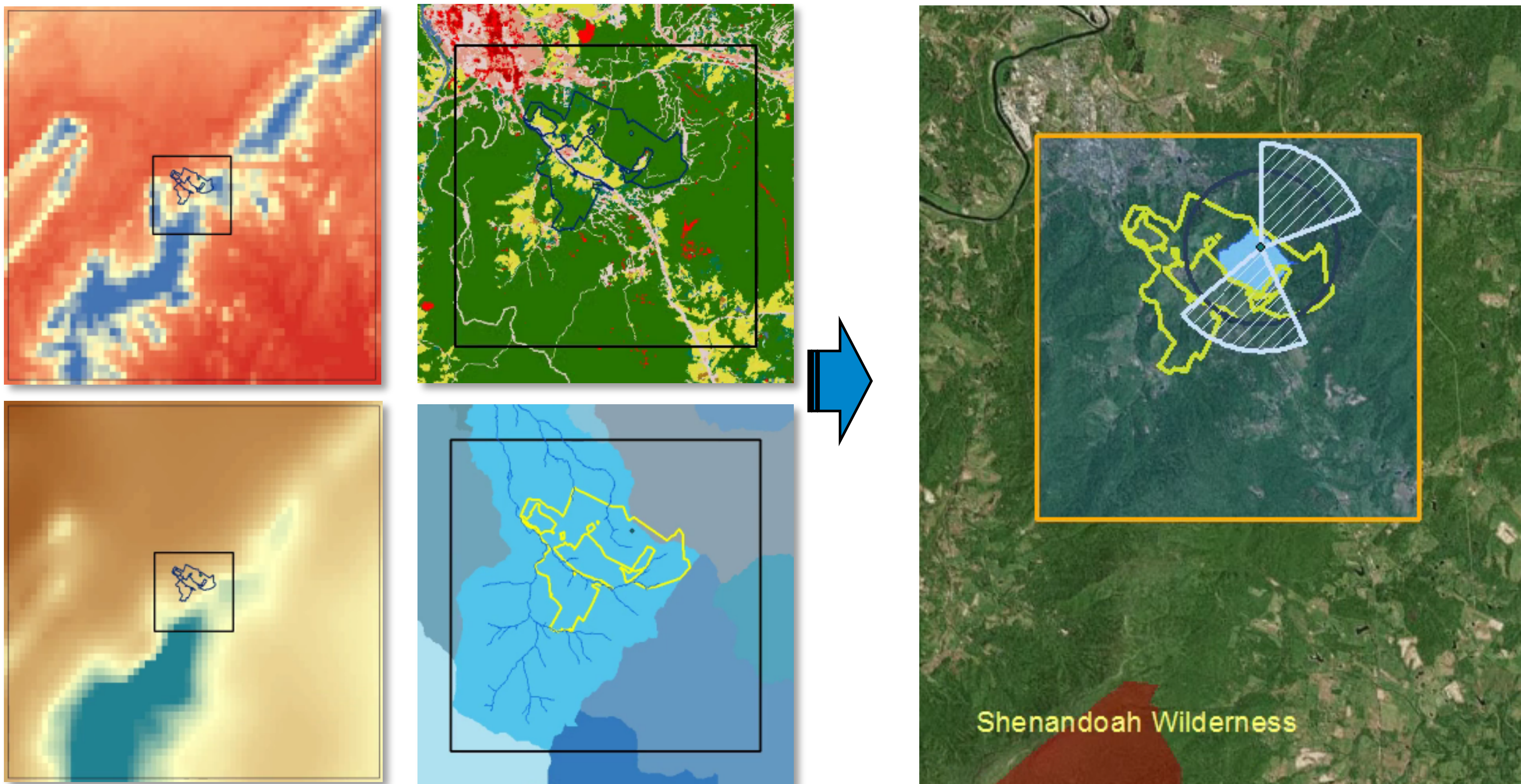

D1 Harvard Forest

Sampling ecologically relevant areas adjacent to TOS boundary

Land Cover / 2000-2012 Forest Change

Average Annual Minimum Temperature (1981-2010)

Average Annual Precipitation (1981-2010)



Watersheds / Topography

Location of 10km x 10km priority 1 flight boundary and delineation of priority 2 flight boundary are designed capture:

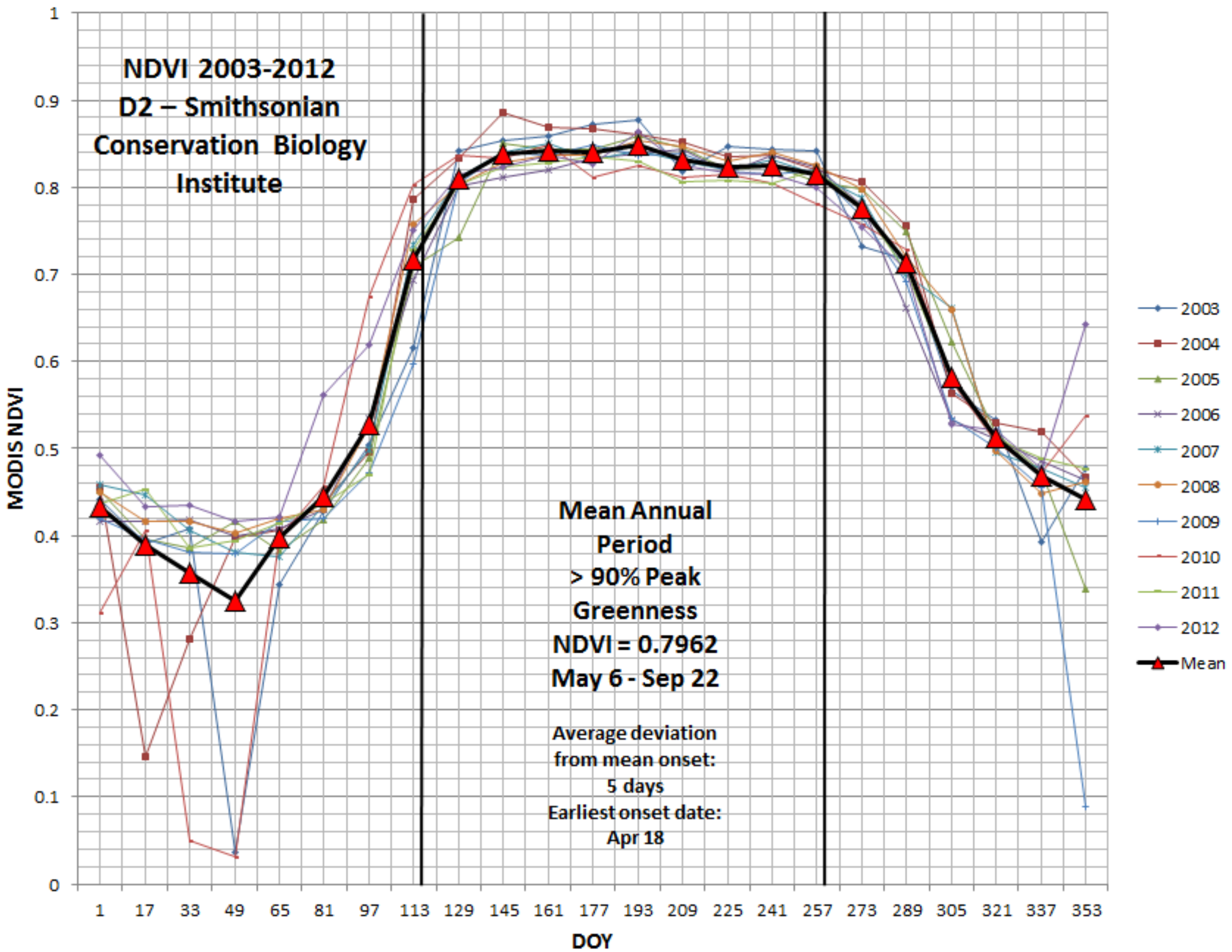
1) Landscape heterogeneity

2) Key ecological features/processes related to science themes

Airborne Survey Planning Constraints - Phenology

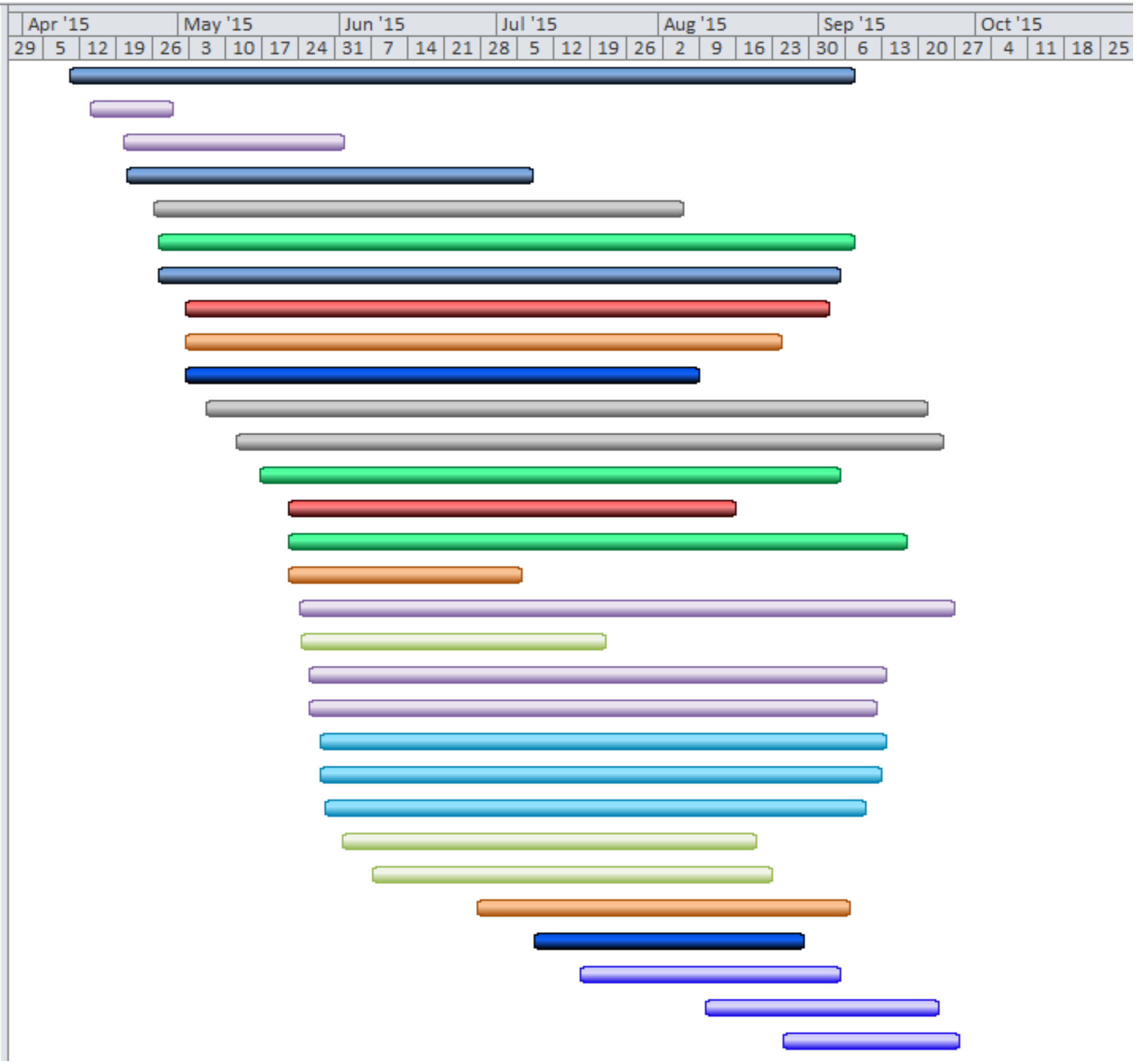
Peak greenness (maximum foliage)

- Surveys required to occur within 90% peak greenness
- Phenology varies by year, among species and by elevation
- Use of 10-year record of MODIS vegetation indices (NDVI/EVI) over TOS sampling area for each site



Planning for Deployments to Multiple Domains

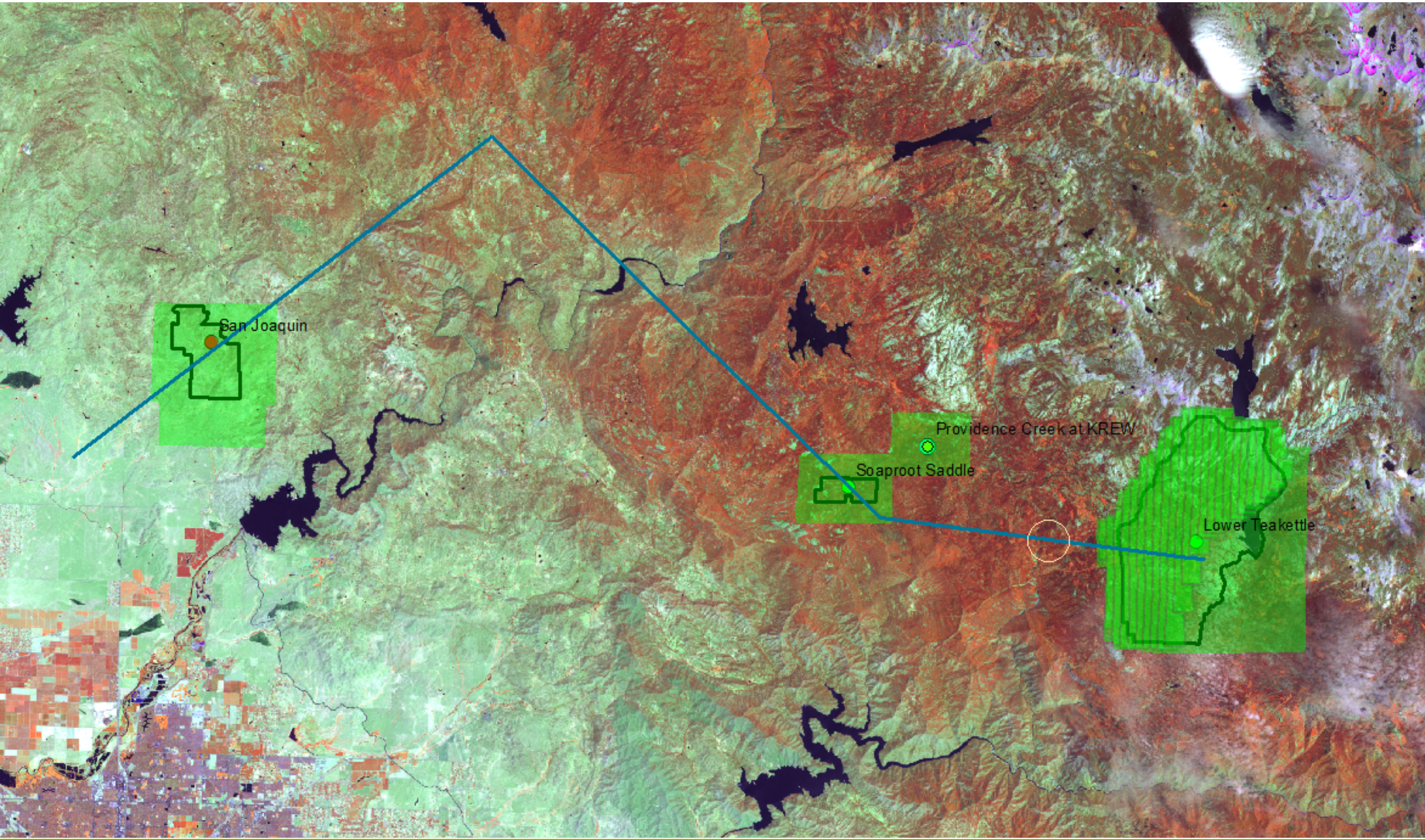
Domain	Summary Site	Start	Finish	Avg. Dev. from Mean	Payload
D8	DELA	Fri 4/10/15	Tue 9/8/15	21	E
D11	KLEM	Tue 4/14/15	Thu 4/30/15	13	E
D11	CLBJ	Mon 4/20/15	Mon 6/1/15	16	E
D8	CHOC	Tue 4/21/15	Wed 7/8/15	15	E
D2	BLAN	Sun 4/26/15	Thu 8/6/15	20	E
D7	ORNL	Mon 4/27/15	Tue 9/8/15	8	E
D8	TALL	Mon 4/27/15	Sat 9/5/15	20	E
D6	KUFS	Sat 5/2/15	Thu 9/3/15	14	E
D10	STER	Sat 5/2/15	Tue 8/25/15	44	E
D13	MOAB	Sat 5/2/15	Sun 8/9/15	30	E
D2	SCBI	Wed 5/6/15	Tue 9/22/15	5	E
D2	SERC	Tue 5/12/15	Fri 9/25/15	22	E
D7	GRSM	Sat 5/16/15	Sat 9/5/15	6	E
D6	KONZ	Fri 5/22/15	Sun 8/16/15	12	E
D7	MLBS	Fri 5/22/15	Fri 9/18/15	6	E
D10	CPER	Fri 5/22/15	Mon 7/6/15	30	E
D1	BURL	Sun 5/24/15	Sun 9/27/15	12	E
D9	NOGP	Sun 5/24/15	Tue 7/21/15	7	E
D1	HARV	Tue 5/26/15	Mon 9/14/15	6	E
D1	BART	Tue 5/26/15	Sat 9/12/15	6	E
D5	TREE	Thu 5/28/15	Mon 9/14/15	6	E
D5	STEI	Thu 5/28/15	Sun 9/13/15	6	E
D5	UNDE	Fri 5/29/15	Thu 9/10/15	8	E
D9	DCFS	Mon 6/1/15	Wed 8/19/15	6	E
D9	WOOD	Sun 6/7/15	Sun 8/23/15	6	E
D10	RMNP	Sat 6/27/15	Mon 9/7/15	16	E
D13	NIWO	Wed 7/8/15	Sat 8/29/15	11	E
D3	JERC	Fri 7/17/15	Sat 9/5/15	9	E
D3	OSBS	Mon 8/10/15	Thu 9/24/15	24	E
D3	DSNY	Tue 8/25/15	Mon 9/28/15	34	E



East Coast Payload (example)

neon
National Ecological Observatory Network

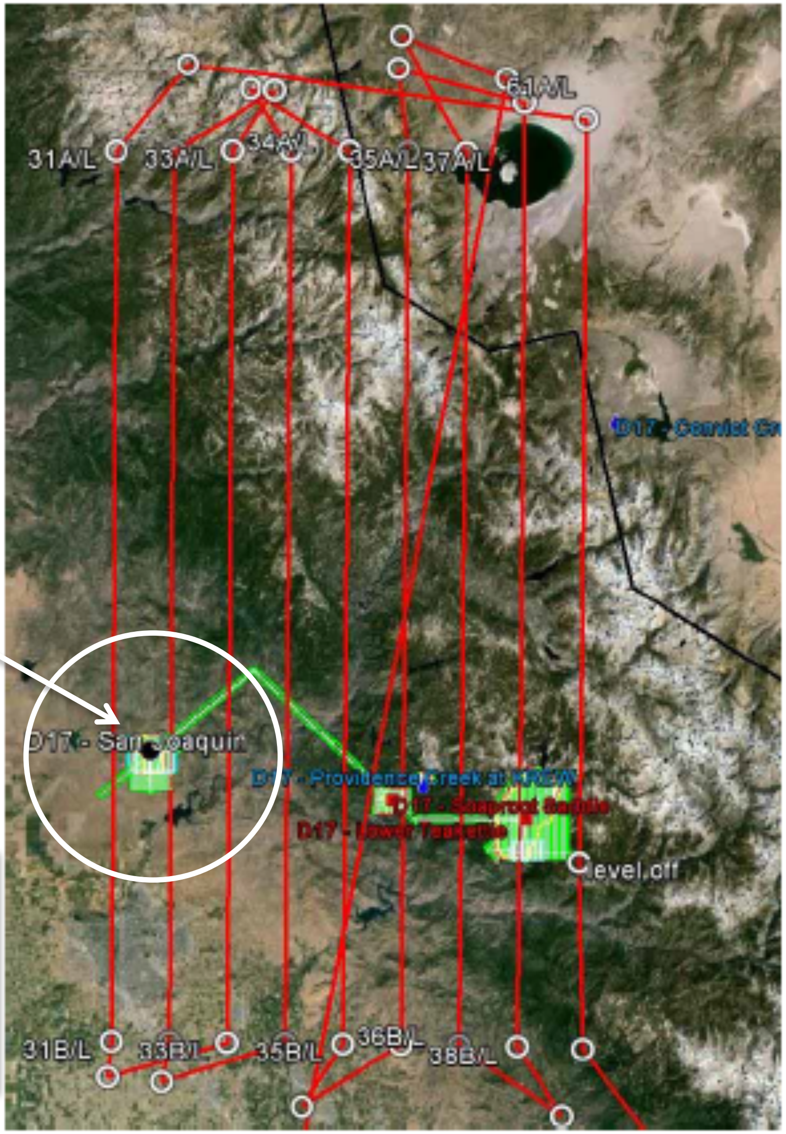
NEON D17 Terrestrial and Aquatic Sites



NEON and the NASA HyspIRI Preparatory Airborne Activities Project

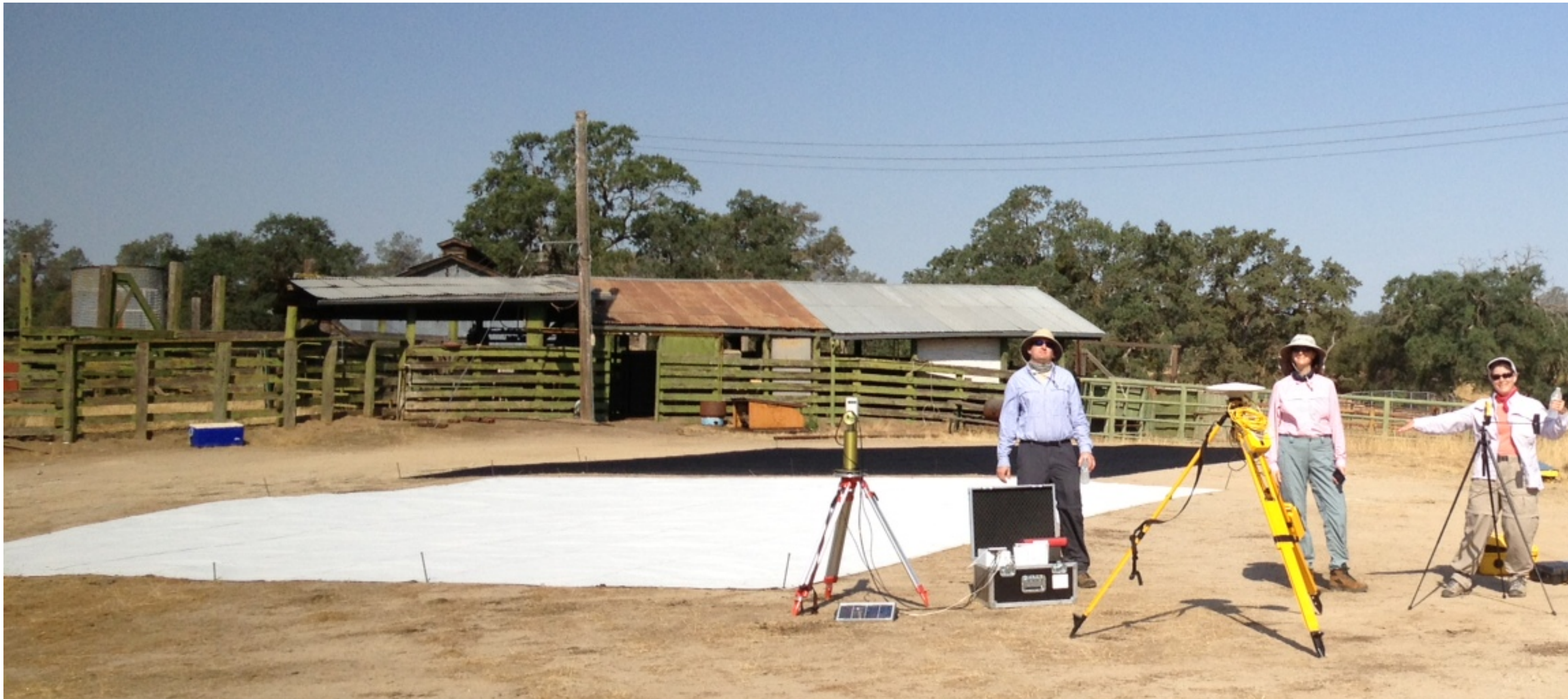
- NASA flew AVIRIS-classic onboard the ER-2 over NEON Domain 17 sites (June 12, 2013)
  - 18m spatial resolution
- NEON flew AOP NIS1 onboard Twin Otter over NEON Domain 17 sites (June 9-15, 2013)
  - 1m spatial resolution
- NEON collected field hyperspectral data and foliar samples for subsequent chemistry measurements

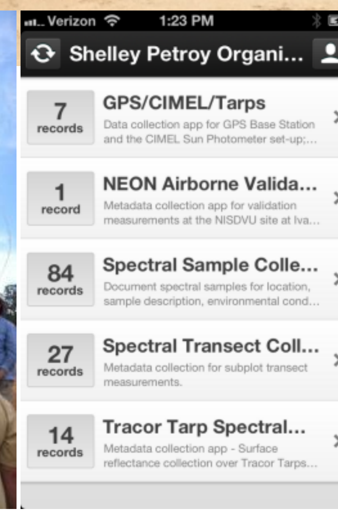
Domain 17: San Joaquin Experimental Range (SJER)



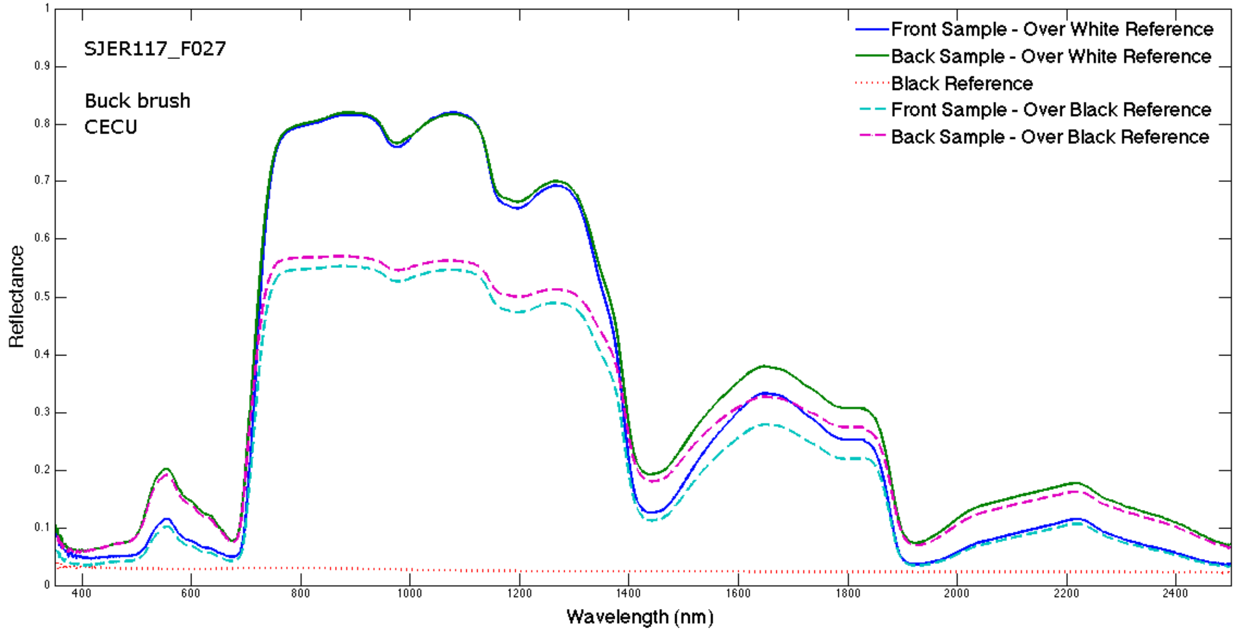
Obtained coincident datasets from hyperspectral instruments at different scales

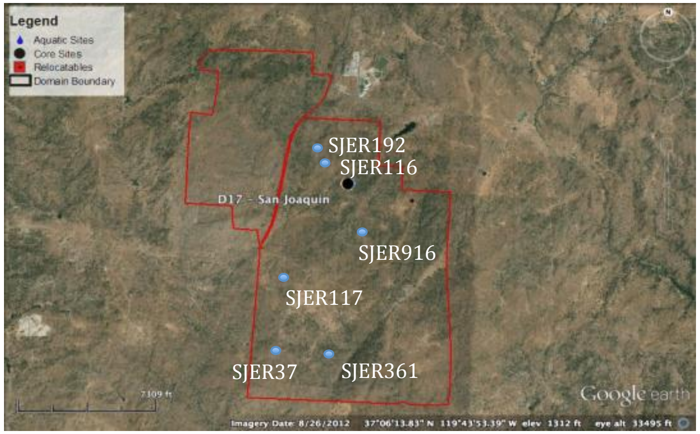
Will enable accurate calibration/validation and a range of ecological studies across multiple scales




Verizon
1:23 PM
Shelley Petroy Organi...
7 records
GPS/CIMEL/Tarps
Data collection app for GPS Base Station and the CIMEL Sun Photometer set-up;...
1 record
NEON Airborne Valida...
Metadata collection app for validation measurements at the NISDVU site at Iva...
84 records
Spectral Sample Colle...
Document spectral samples for location, sample description, environmental cond...
27 records
Spectral Transect Coll...
Metadata collection for subplot transect measurements.
14 records
Tracor Tarp Spectral...
Metadata collection app - Surface reflectance collection over Tracor Tarps...

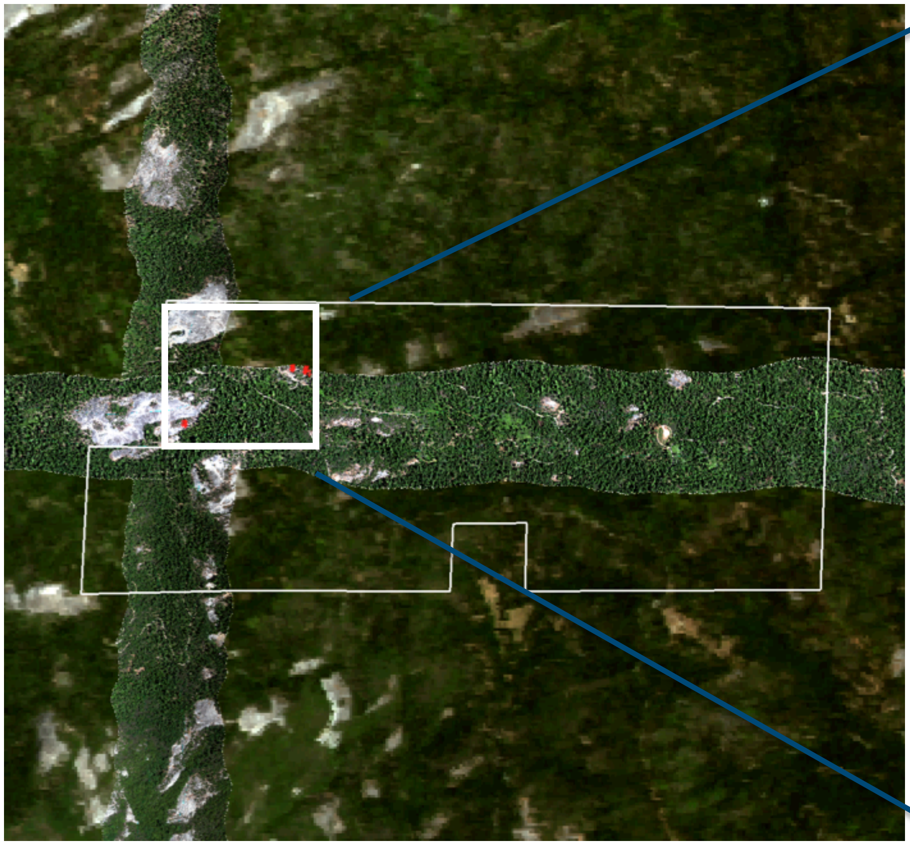
Spectra of foliar samples collected at six locations in SJER





Goal of the plant canopy sampling was to investigate the variation in elemental content (C, N, P, Ca^{2+}, Mg^{2+}, and K^+), isotopic composition (C and N), chlorophyll, and lignin across a range of plant community types

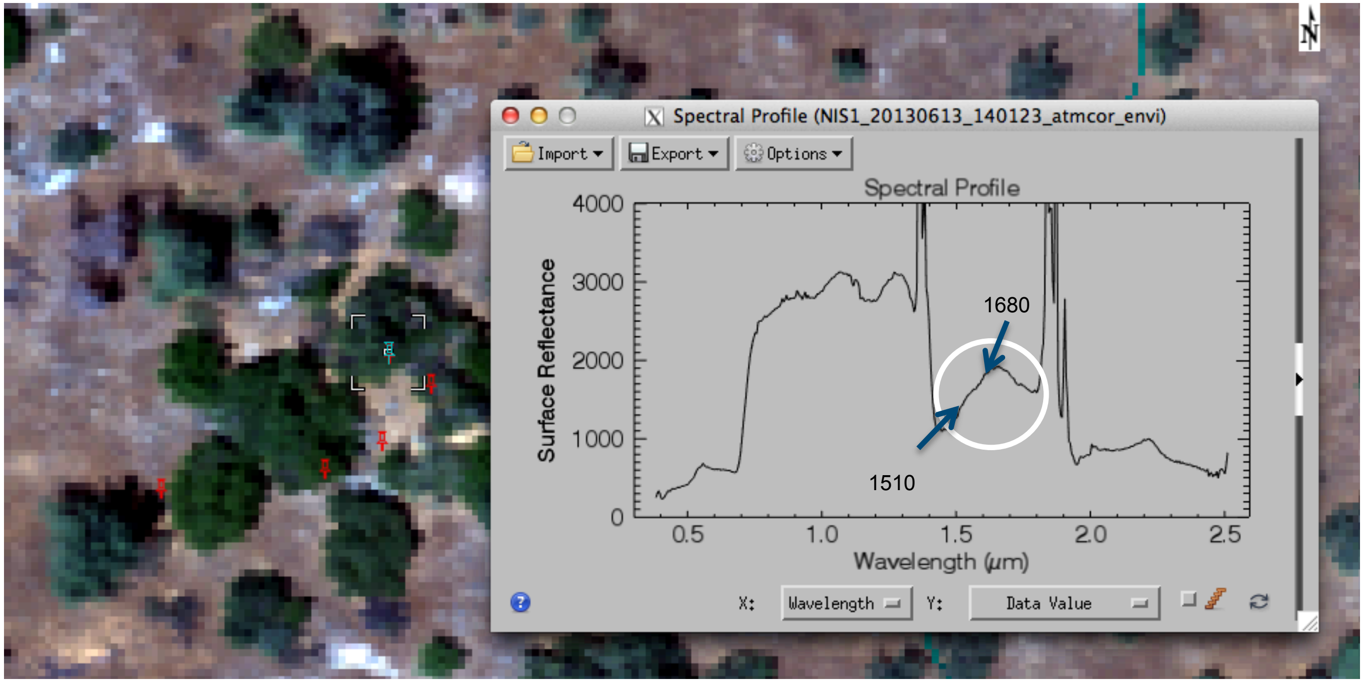
NEON NIS1 and AVIRIS over SOAPROOT SADDLE



AVIRIS Surface Reflectance – 18m spatial resolution

NIS1 Surface Reflectance – 1m spatial resolution
Red push pins mark field sampling sites

Developing higher level Data Products: Normalized Difference Nitrogen Index - NDNI



Normalized Difference Nitrogen Index (NDNI) is designed to estimate the relative amounts of nitrogen contained in vegetation

NDNI – [log (1/R_{1510}) – log (1/R_{1680})] / [log (1/R_{1510}) + log (1/R_{1680})]

- Reflectance at 1510 nm is largely determined by nitrogen concentration of leaves and overall foliage biomass of the canopy
- Compared to a reference reflectance at 1680 nm, which contains a similar signal due to foliar biomass, but without the influence of nitrogen absorption
- The value of this index ranges from 0 to 1; common range for green vegetation is 0.02 to 0.1

Serrano et al., 2002

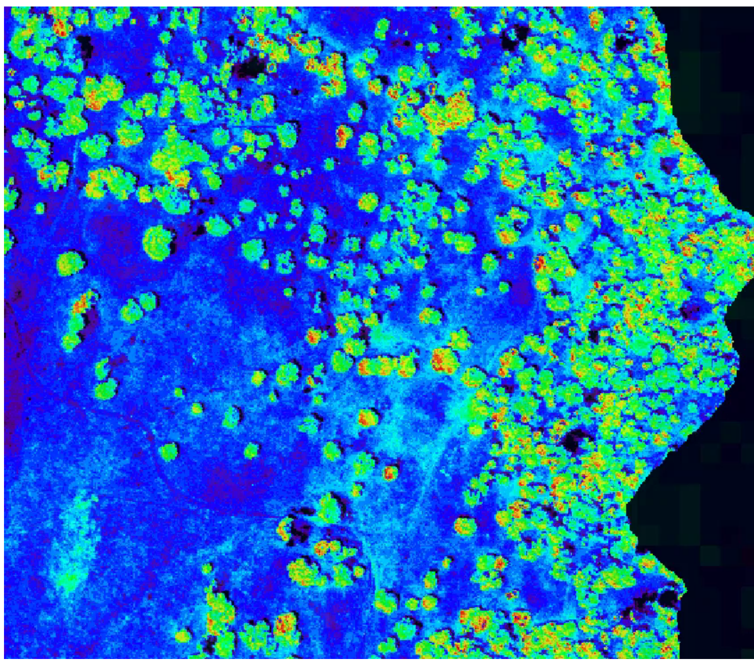
NDNI – NEON NIS1 and AVIRIS

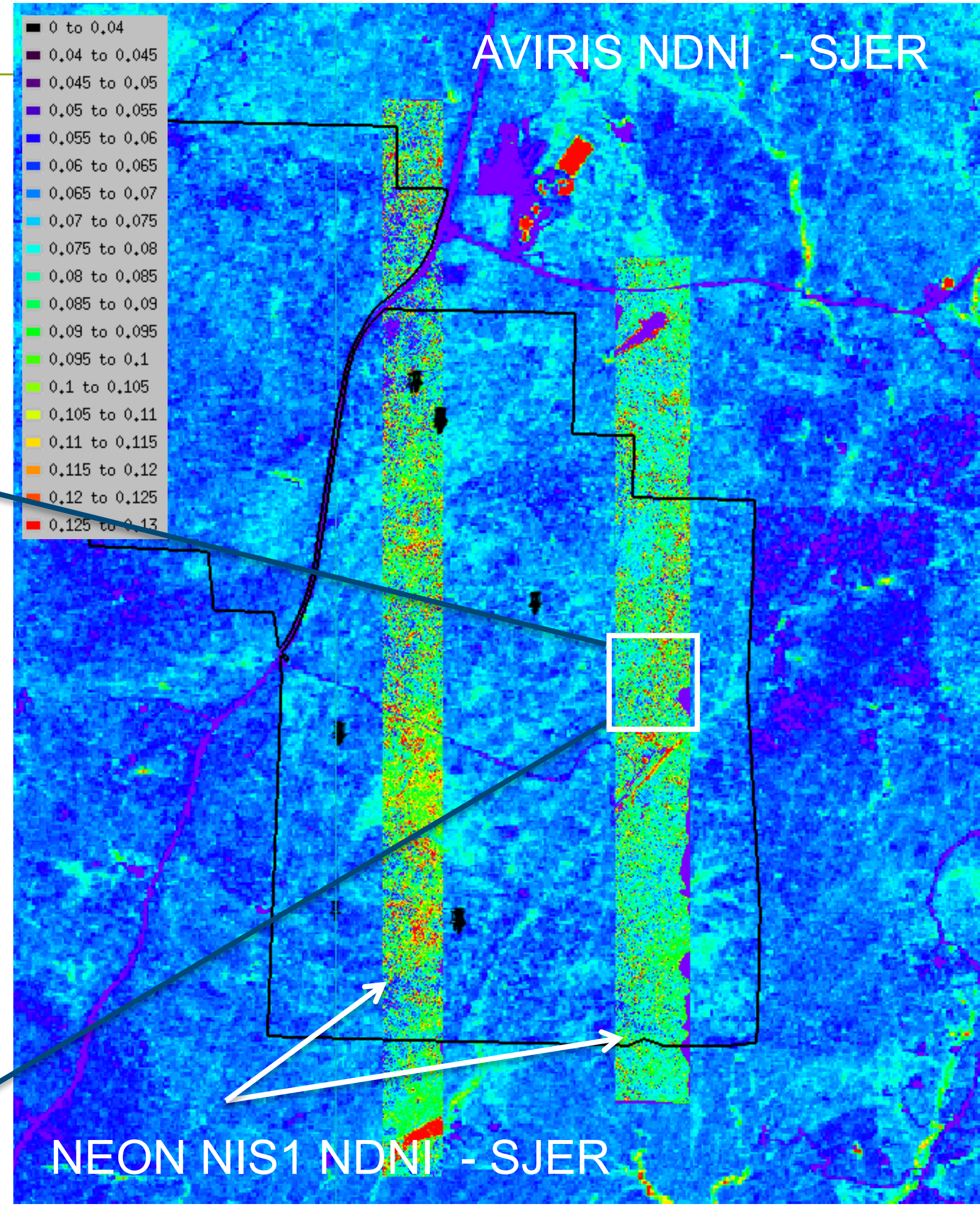
AVIRIS

- NDNI values range 0.04 – 0.129

NEON NIS1

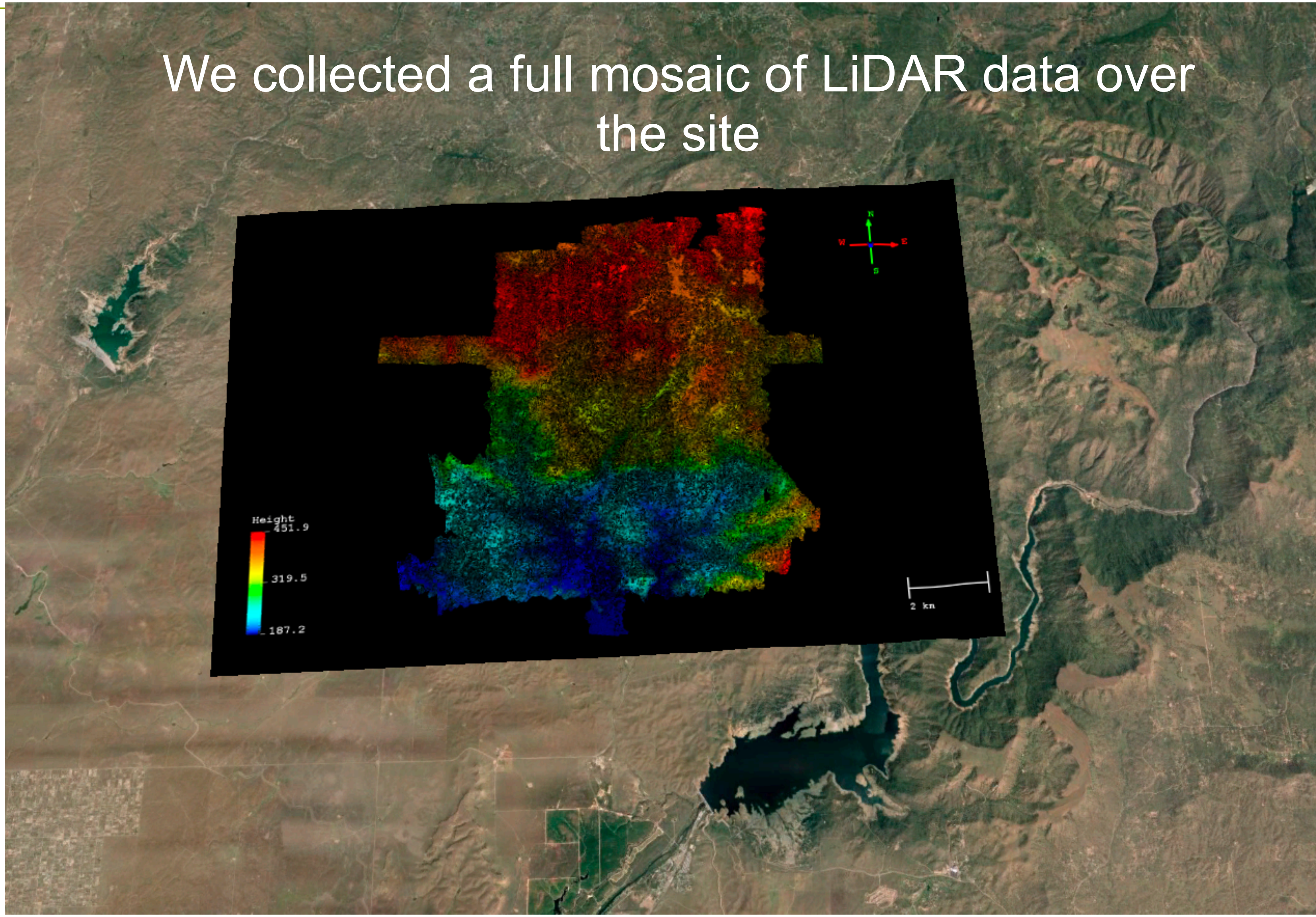
- NDNI values range from 0.04 – 0.18
- Are variations between AVIRIS and NEON NIS1 NDNI due to spatial scaling?
- Are differences resulting from atmospheric correction procedures?



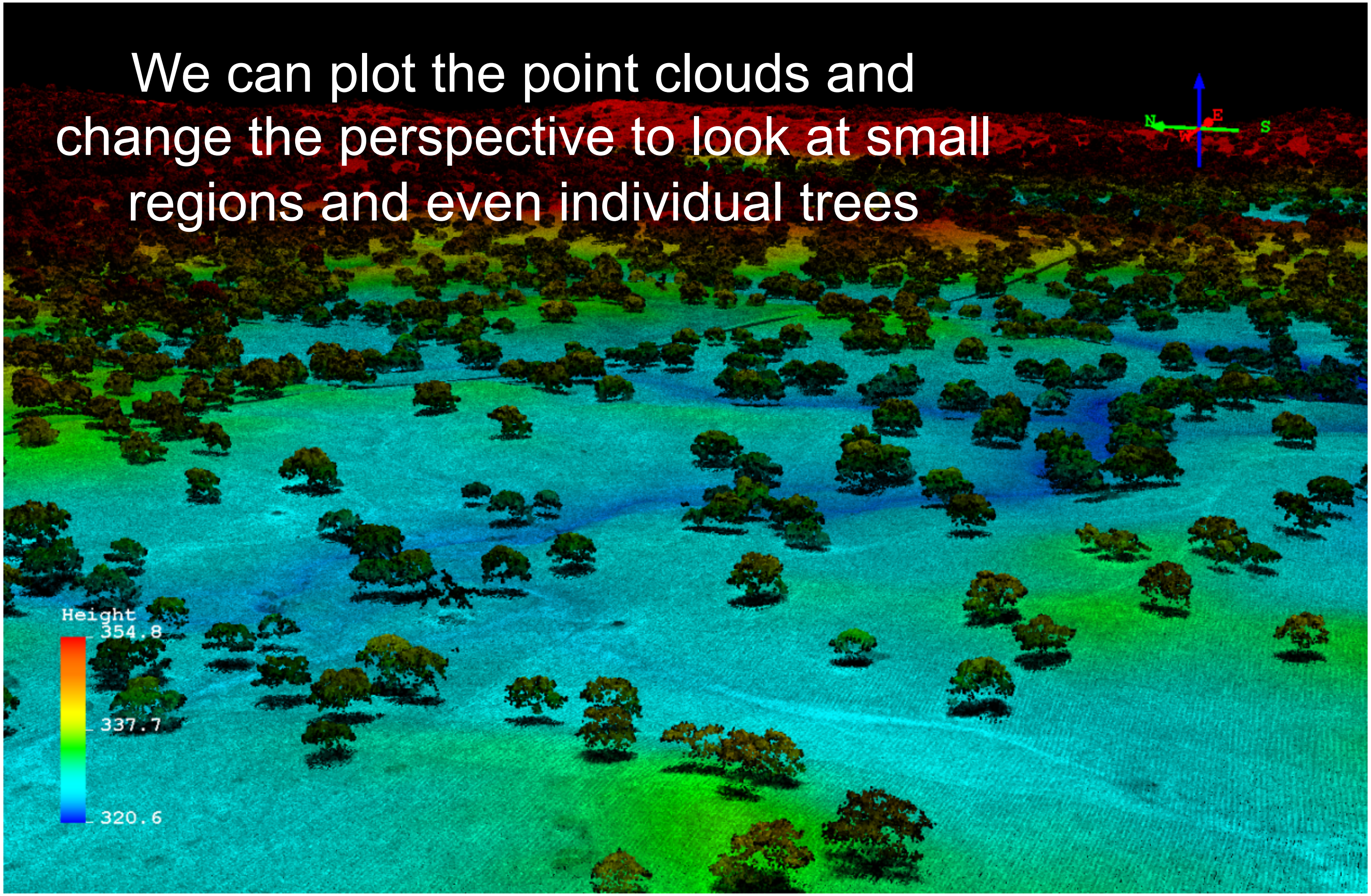


NEON LiDAR Data – Domain 17

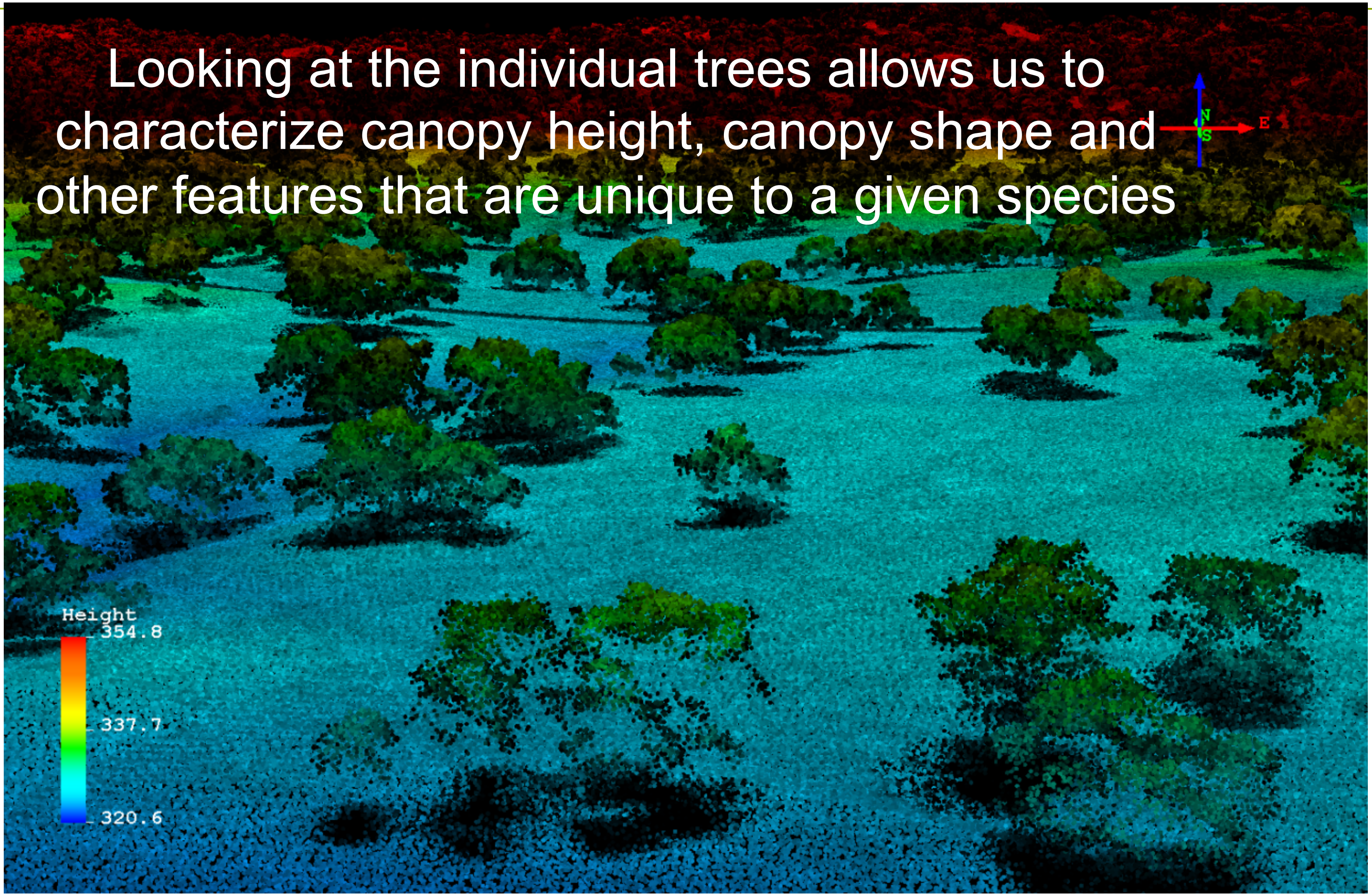
We collected a full mosaic of LiDAR data over the site



NEON LiDAR Data – LAS Point Clouds



NEON LiDAR Data – Canopy Features



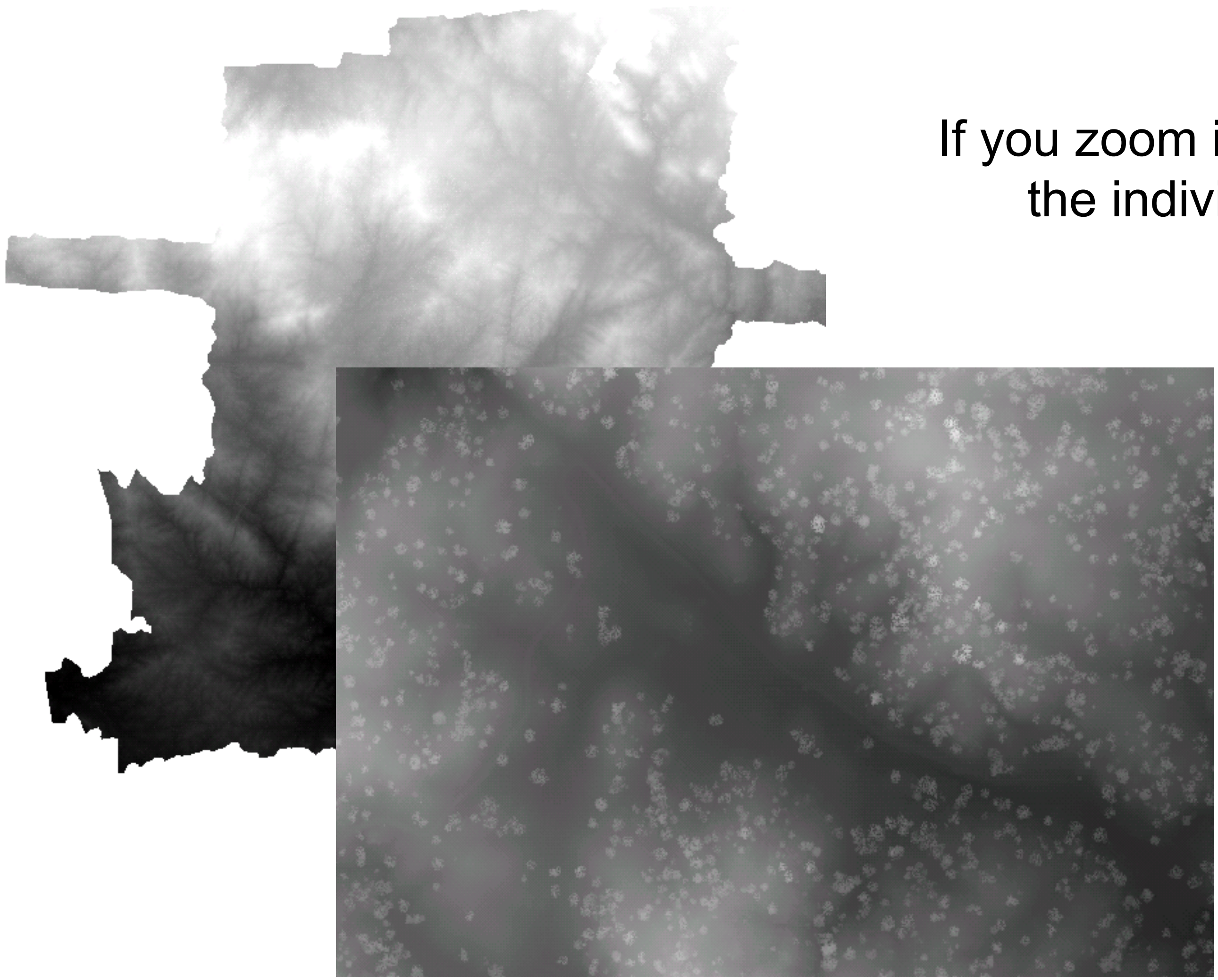
NEON LiDAR Data - DTM

- A standard product is a Digital Terrain Model, or DTM
- This is the elevation of surface with all the natural and man-made structures and features removed (ground returns only)
- Non-ground returns filtered in the point cloud prior to DTM creation

NEON LiDAR Data – DSM

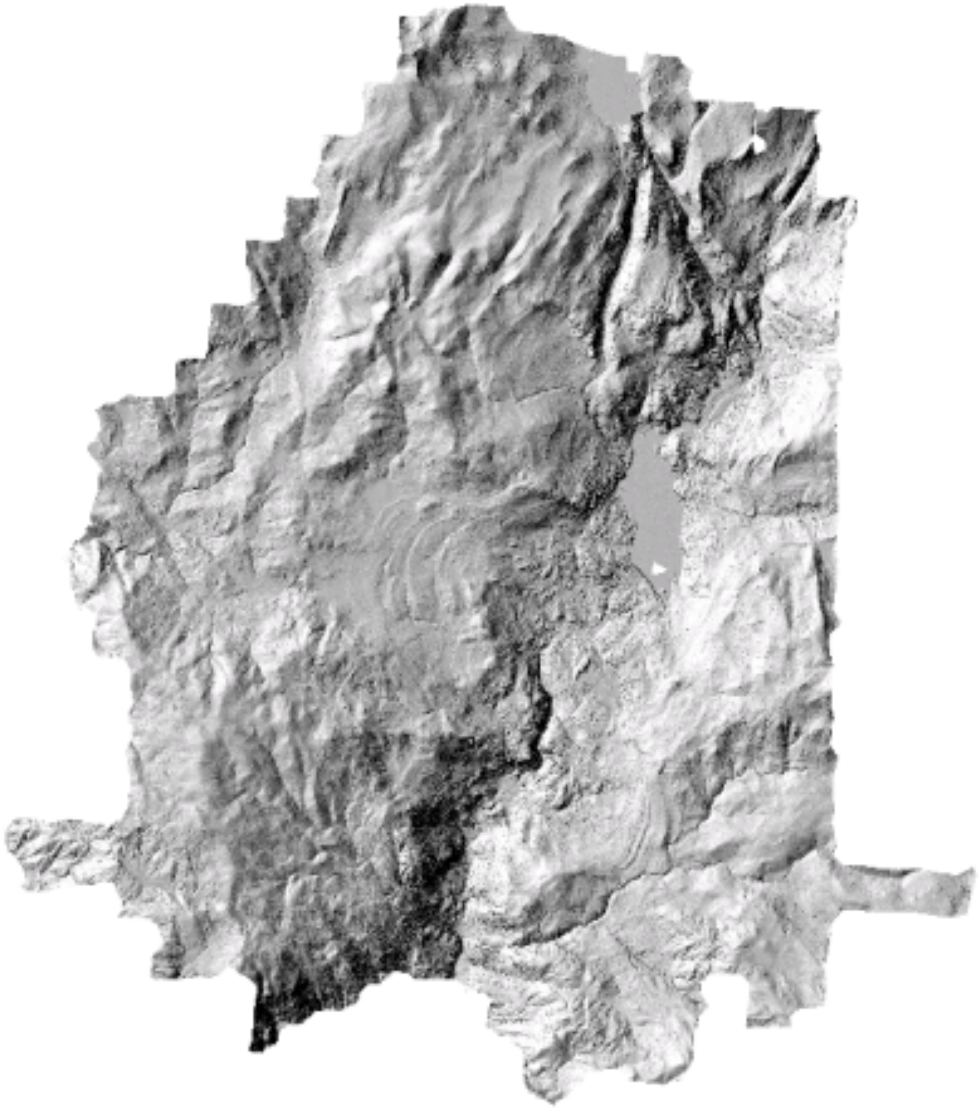
- A second product is a Digital Surface Model, or DSM
- This is the elevation of surface with all the natural and man-made structures and features included (all returns)

NEON LiDAR Data – DTM and DSM



If you zoom in, you can see the individual trees!

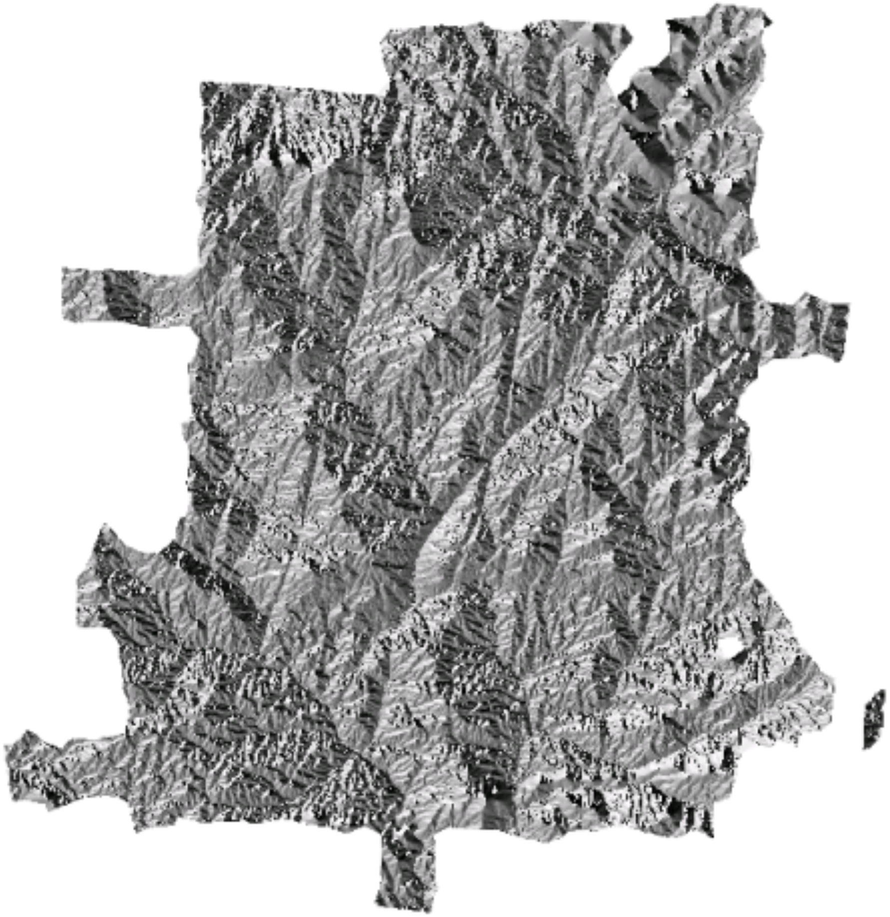
NEON LiDAR Data – DSM vs DTM



NEON LiDAR Data – Topographic indices

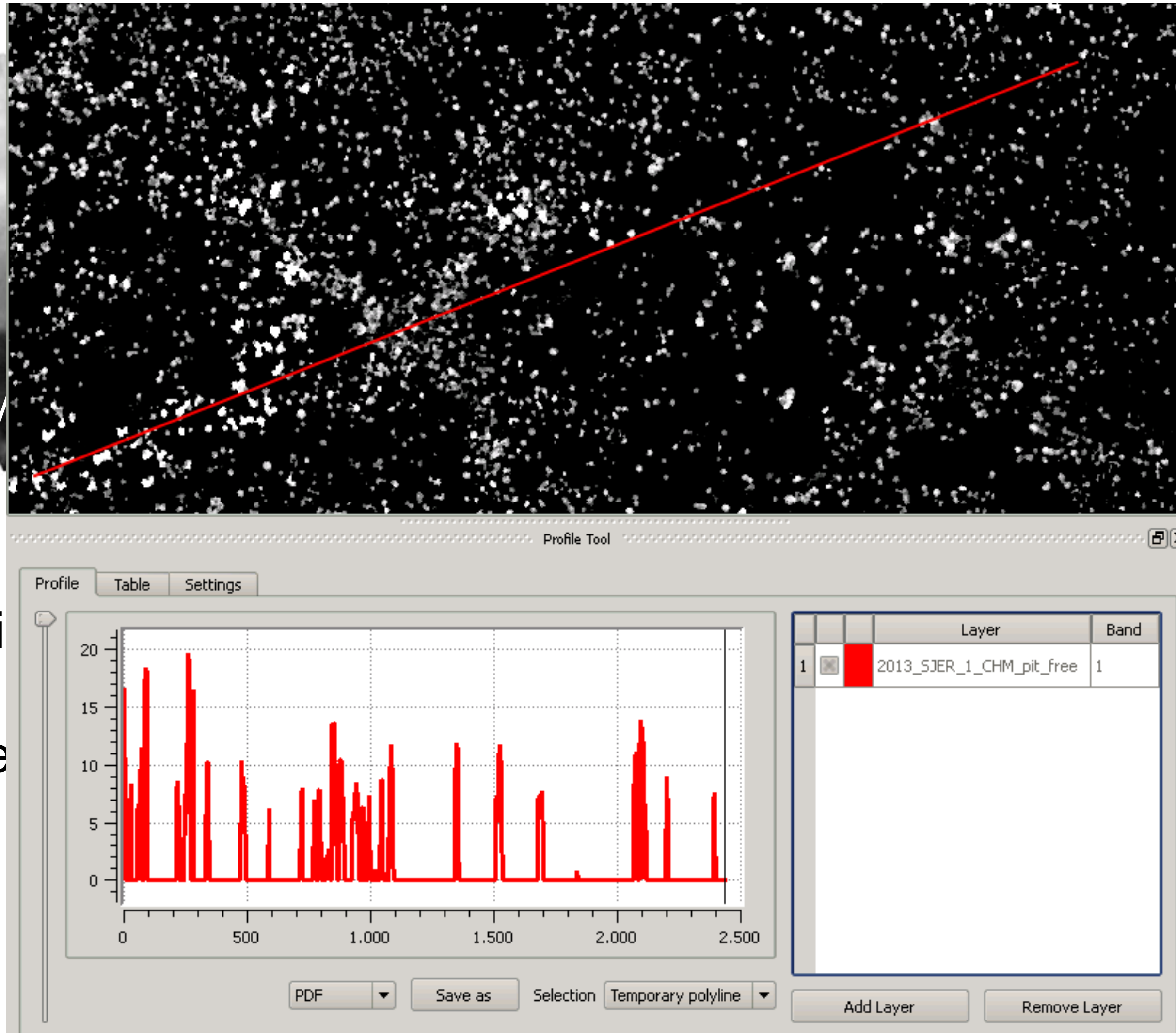
Slope

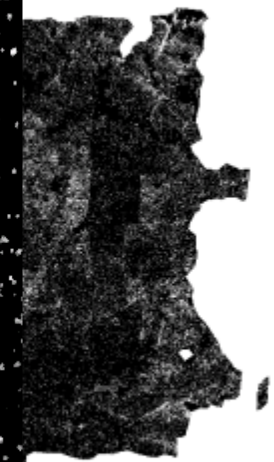
Aspect



NEON LiDAR Data – Canopy Height Model

DSM



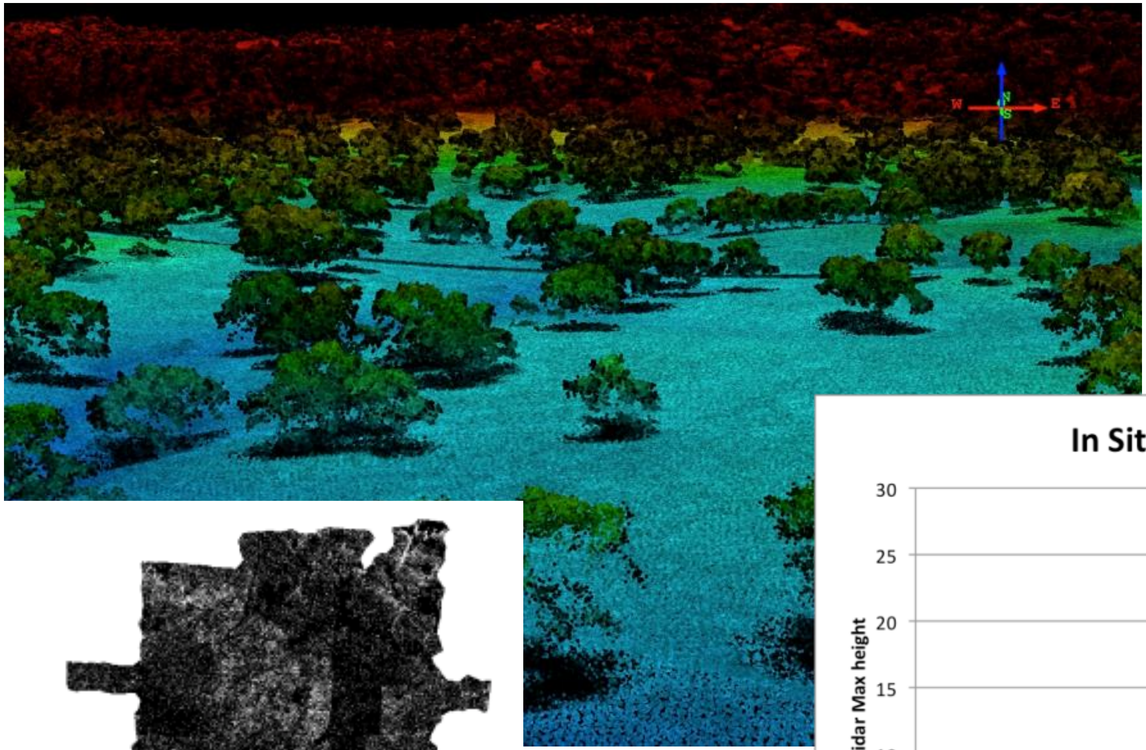


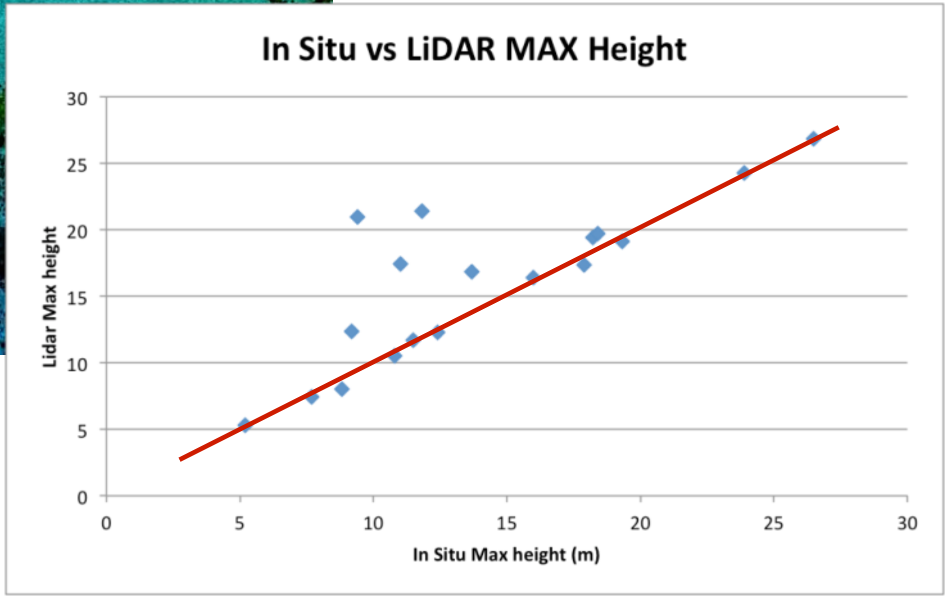
Subtracti … ight Model

This is the … ower poles!)

NEON LiDAR Data – Validating Data Products

We can then plot the "tree height" from the CHM against tree height measured in the field – this provides a good validation of our CHM product





neon Data

The National Ecological Observatory Network Data Portal

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Airborne Data Request

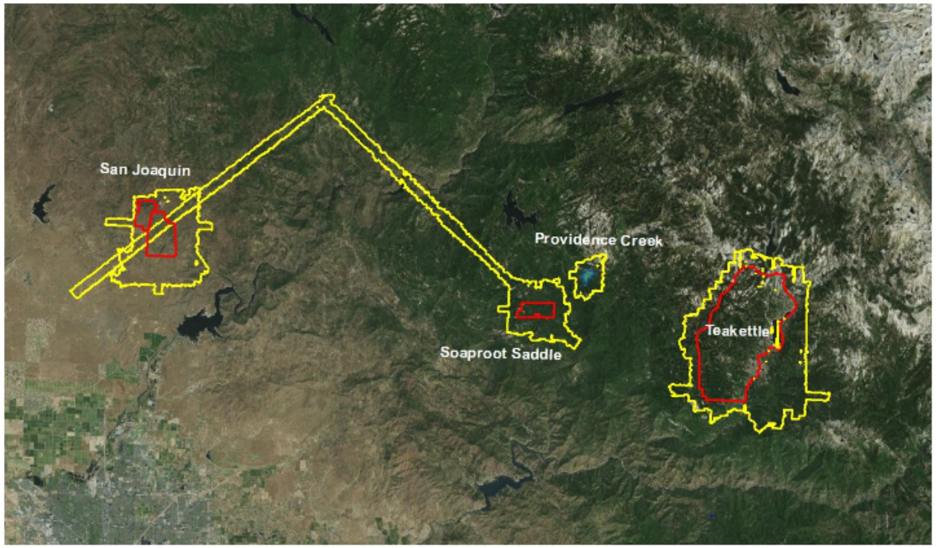
Why register for an account?

NEON 2013 Airborne Campaign at Domain 17

Background

From June 9-15, 2013, NEON conducted a series of airborne remote sensing surveys at three NEON terrestrial sites and one aquatic site located in central California, extending over a large elevation gradient from the southern foothills to the mixed conifer forest zone of the Sierra Nevada. These NEON Domain 17 sites cover diverse ecological sub-regions ranging from open woodland dominated by oaks and foothill pine in the San Joaquin Experiment Range core site, mixed conifer/deciduous forest at the Soaproot Saddle relocatable site and Providence Creek aquatic site, and red fir forest at the Teakettle relocatable site.

The primary objectives of the 2013 combined airborne and field campaign were to test flight operations and nominal flight collection parameters and obtain a prototype dataset supporting spatial/temporal scaling studies underway as part of NASA's HyspIRI Airborne Campaign (http://hyspiri.jpl.nasa.gov/airborne).



NEON Domain 17 sites (red) with LiDAR boundaries (yellow)

Airborne and Field Data

Airborne remote sensing measurements were made using the full NEON Airborne Observatory Platform instrument payload which incorporates a high-resolution imaging spectrometer, a small-footprint waveform-recording LiDAR and a high-resolution digital camera. Supporting ground measurements of field spectral data, vegetation structure data, and foliar samples were made in a subset of sites and conjunction with the airborne observations. (See NEON Technical Memo 005 for full details about the 2013 D17 airborne campaign.)

AOP Data Request Page

http://data.neoninc.org/airborne-data-request

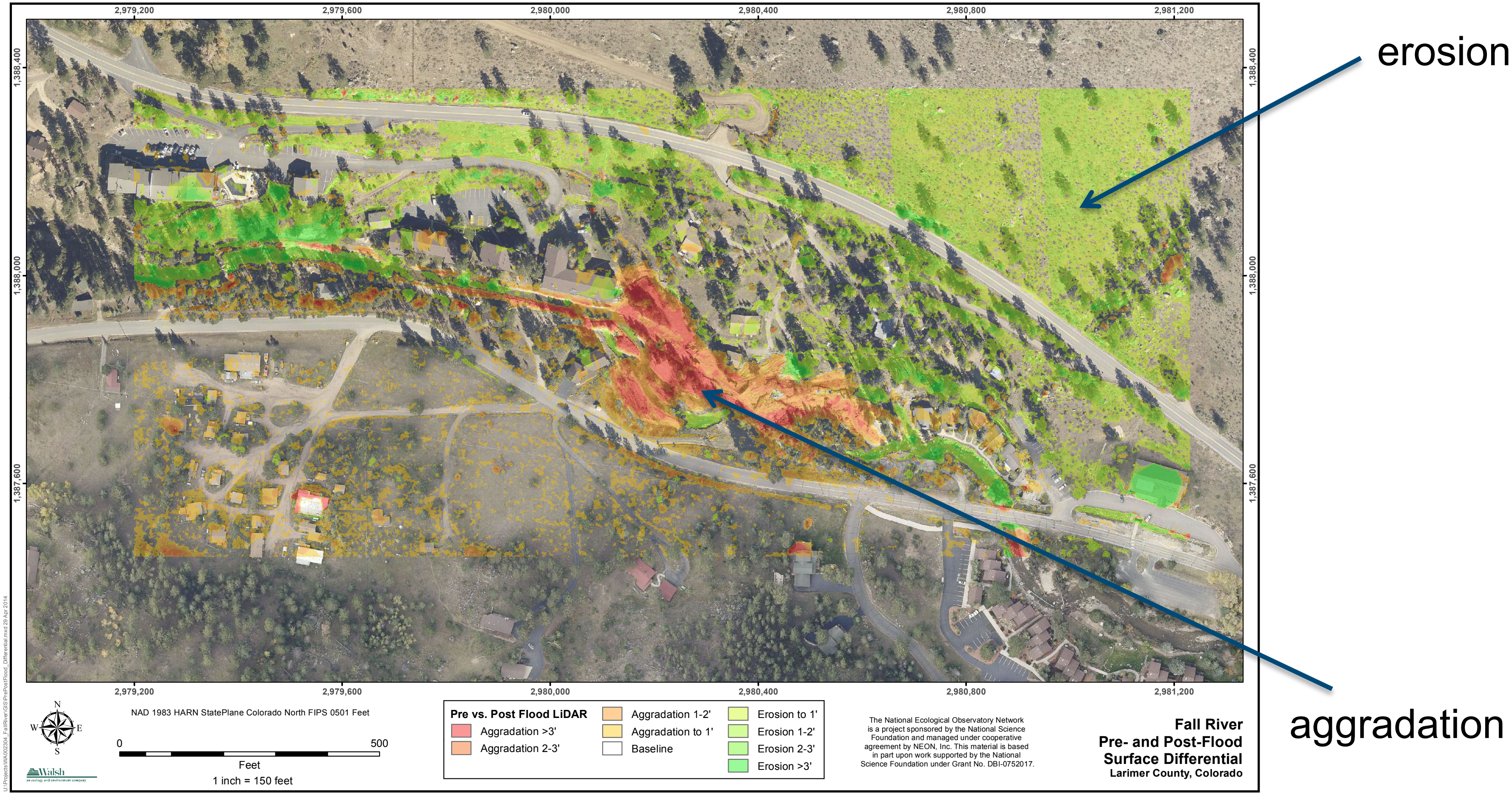
AOP-Data@neoninc.org

FRONT RANGE FLOOD SEPTEMBER 2013

NEON – Supporting Post-Flood Analysis

NEON fortuitously completed several engineering flights over Boulder and near Estes Park two months prior to the devastating floods of Sept 2013

NEON – Estes Park Post Flood Analysis

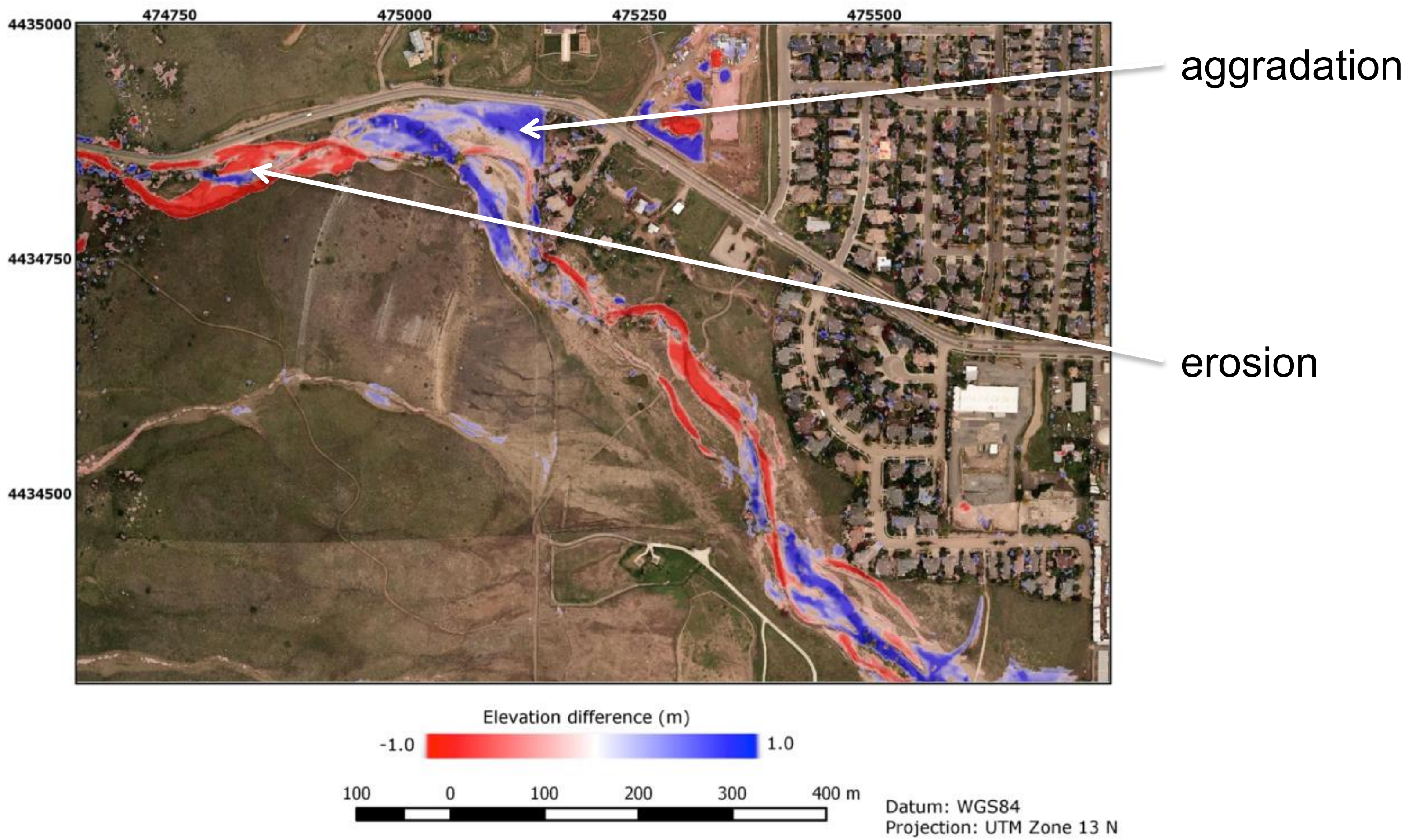


Erosion/Aggradation map produced by Walsh Environmental, using NEON LiDAR data

NEON – Boulder Post Flood Analysis

Pre- and Post-flood high resolution camera images over Lee Hill Drive, Boulder, CO

NEON – Boulder Post Flood Analysis



Erosion/Aggradation map produced by NEON using our LiDAR data