LIDAR ON BOARD THE NEON AIRBORNE OBSERVATION PLATFORM

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Outline

- **Overview of NEON**
- **Overview of the Airborne Observation Platform**
- **Lidar configurations on flight campaigns**
- **NEON data products**
  - **Integration of lidar into NEON higher level data products and workflow**
  - **Fusion with non-airborne-platform data**

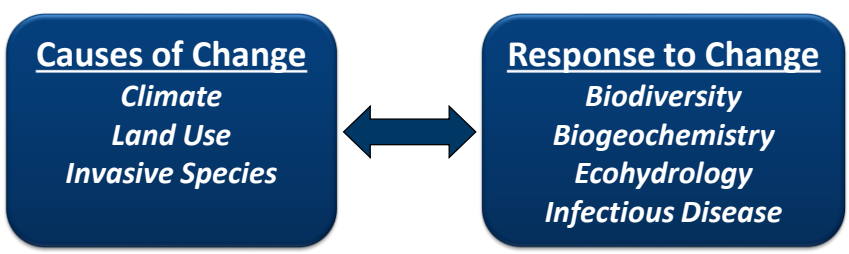
What is NEON?

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

Grand Challenges of NEON

… to *enable understanding* and *forecasting* of the *impacts* of *climate change, land use change* and *invasive species* on *continental-scale ecology*

…by providing infrastructure to support research, education and environmental management in these areas



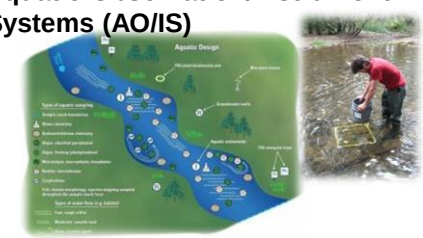
NEON INVESTIGATION STRATEGY

- 20 domains
- 3 sites per domain:
  - Core site
  - Relocatable site
  - Aquatic site
- 60 sites throughout the United States and Puerto Rico

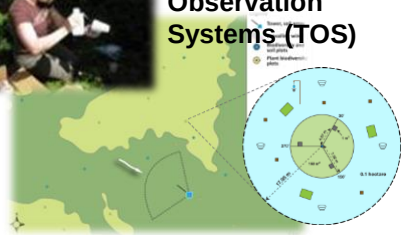
NEON goal: Sampling each site once per year for 30 years

NEON Observation Platforms

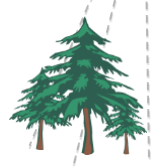
Aquatic Observation/Instrument Systems (AO/IS)



Terrestrial Observation Systems (TOS)



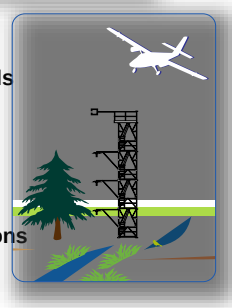
Airborne Observation Platform (AOP)



Terrestrial Instrument Systems (TIS)

What makes NEON unique?

- Continental in scope – distributed over 20 domains
  - Includes Alaska, Hawaii, and Puerto Rico
- Timeframe
  - A decade of community input and design
  - Beginning of a 5-year construction period
  - 30 year period of observations
- Integrated Observations
  - Terrestrial, aquatic, and airborne
  - Standardized instrumentation, procedures, and protocols
  - Representative sampling across replicated gradients
- Collaborative scientific enterprise
  - Free and open access to NEON data and data products
  - Access to NEON infrastructure – research support
  - Synergy with related ecological research and observations



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AOP Payload Instrumentation

NEON Imaging Spectrometer (JPL)

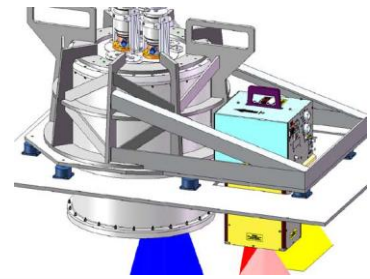
Optech D-8900 High Resolution Digital Camera

Optech ALTM Gemini system

Waveform digitizer

GPS/IMU integrated with LiDAR system

Payload Integration Mount showing integrated remote sensing payload



Key Instrument Parameters

HYPERSPECTRAL IMAGING SPECTROMETER

	Value	Unit
Wavelength range	380-2510	nm
Spectral resolution	5	nm
Spectral channels	~ 400	--
Field of view	34	degrees
Spatial resolution	1	mrad
Spatial pixels	~ 600	--

OPTECH GEMINI WAVEFORM LIDAR

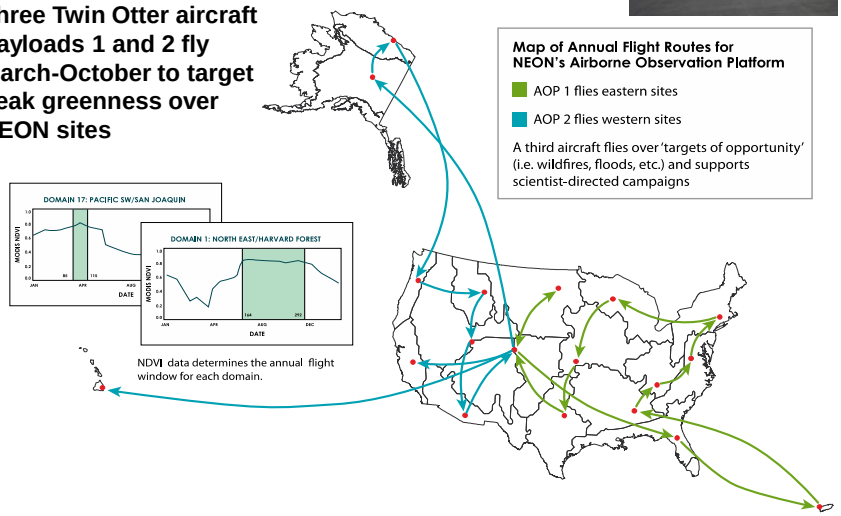
	Value	Unit
Wavelength	1064	nm
PRF	33-167	kHz
Scan frequency	0-70	Hz
Scan half-angle	0-25	degrees
Max energy/pulse	250	µJ
Pulse length	10	ns
Beam divergence	0.8/0.3	mrad
Range sample	15	cm

OPTECH RGB DIGITAL CAMERA

	Value	Unit
Number of Pixels	8900 x 6700	--
Field of View (Xtrack/Along track)	42/32	degrees
iFOV	0.085	mrad

AOP Concept of Operations

- Three identical payloads
- Three Twin Otter aircraft
- Payloads 1 and 2 fly March-October to target peak greenness over NEON sites



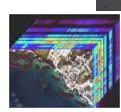
NEON AOP Support

AOP Sensor Technical Facility

- Spectrometer calibration lab
- Sensor maintenance and support facilities
- Lidar calibration lab in process

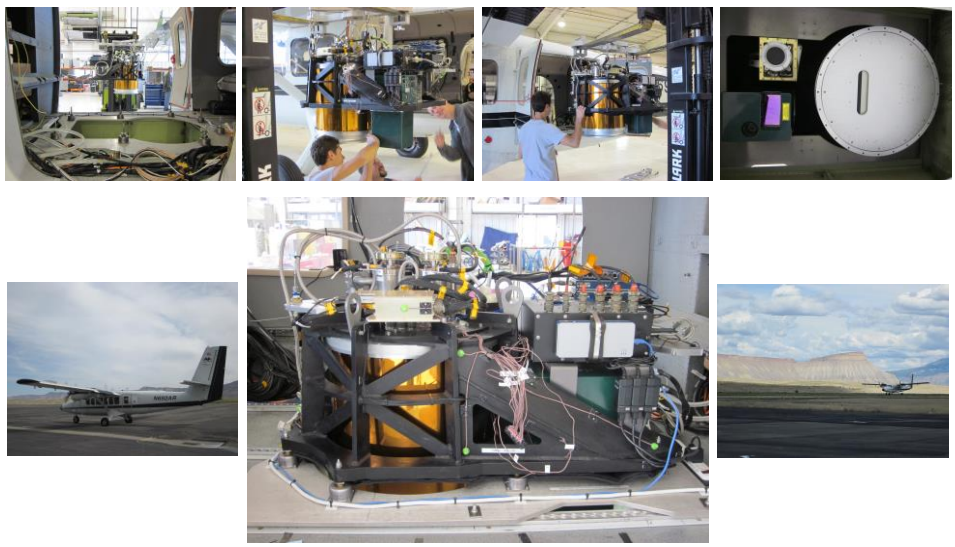
Scientific, Flight & Ground Operations

- 3 leased De Havilland DHC-6-300 twin turbo prop Twin Otter aircraft
- Science Crew: 2 NEON personnel for sensor flight operations
- Scientific staff conducting ground measurements and producing science data products
  - Field spectrometers
  - Sun photometer
  - GPS base stations
  - Wind and temperature measurements





Aircraft Integration of the AOP Instruments



AOP High Level Update

- Two sets of payload instrumentation in house
- Third set to be acquired over the next year
- Test flights in 2012
  - Test flights around Grand Junction, CO and part of Grand Mesa National Forest, CO
  - Radiometric calibration flight at Ivanpah, CA
  - Data collections and instrument/altitude tests at Harvard Forest, MA
  - Two flight campaigns to map the High Park Fire burn scar in Colorado
- Data collection in 2013
  - Test flights in Grand Junction, CO
  - Radiometric calibration in Railroad Valley, NV
  - Data collections in Domain17 (San Joaquin, Soaproot Saddle, and Lower Teakettle, CA)
  - Data collections in Domain10 (CPER, Sterling, and RMNP CASTNET, CO)
  - Re-flight of the High Park Fire burn scar
- Data processing
  - We are currently working on data processing and hope to release provisional data to the science community in the near future

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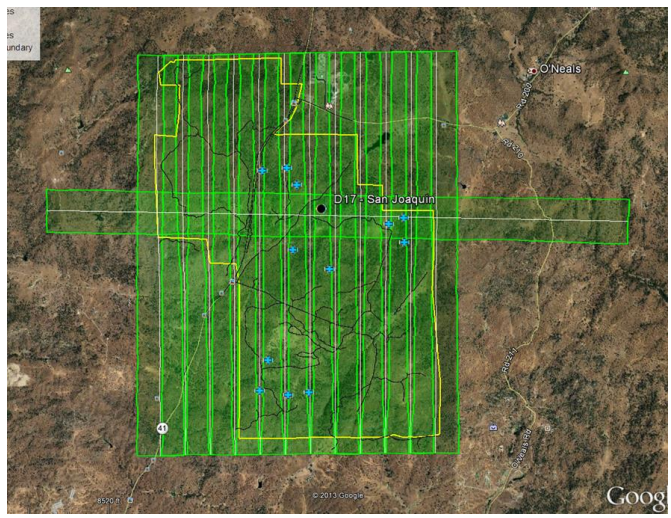
Nominal AOP Flight Collection Parameters

Most lidar collection parameters driven by need to match spectrometer characteristics

Parameter	Value	Unit
Sortie Duration	4	hours
Flight Altitude	1000	m AGL
Aircraft Speed	50 (97)	m/s (kts)
Flight Line Overlap	30	%
Lidar Collection Modes	Discrete Waveform	--
Lidar PRF	100	kHz
Lidar Scan Frequency	50	Hz
Lidar Scan Half-Angle	18.5	deg
Lidar Beam Divergence	0.8 (wide)	mrad
Camera Shot-to-Shot Overlap	50	%
Spectrometer GSD	1	m
Lidar Footprint Diameter	0.8	m
Lidar Beam Spacing	0.524	m
Lidar Point Density	3.82	PPM^2
Camera GSD	0.085	m

Nominal Flight Track

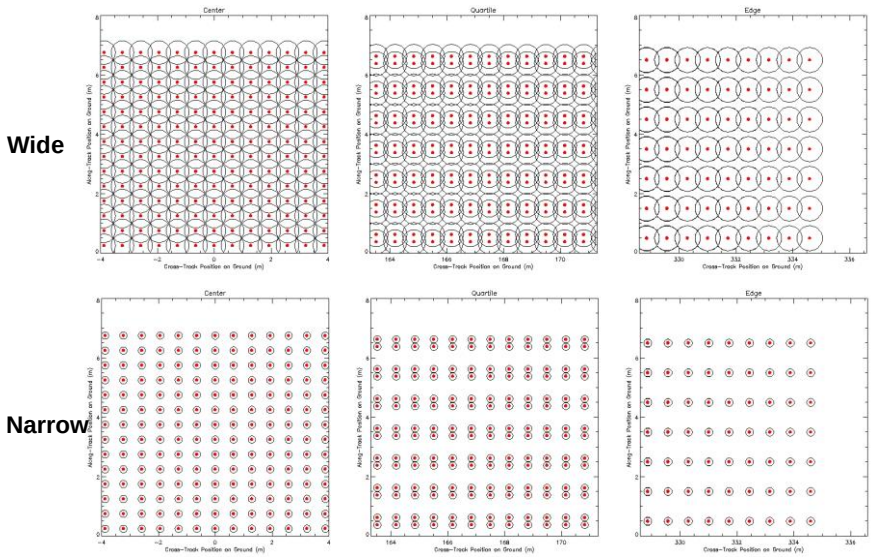
- D17 San Joaquin site
- 1 Cross Strip
- 12 Survey Lines



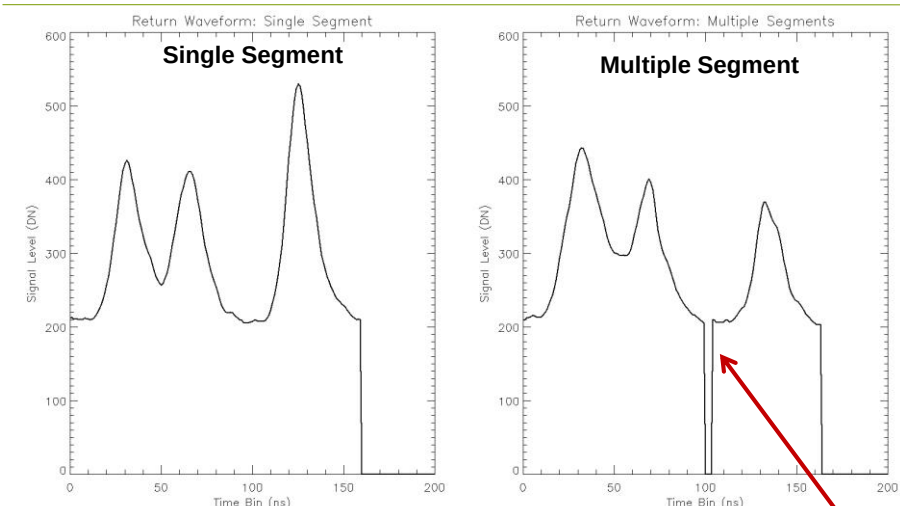
Optimizing Lidar Parameters

- We are also playing with other degrees of freedom to decide what configurations to fly with
  - Wide versus Narrow Divergence
  - Single Segment versus Multiple Segment
  - Trigger Threshold Value
- Parameter set will depend on multiple factors
  - Type of trees and vegetation surveyed
  - Height and structure of canopy
  - Density of canopy
- Experimenting with different parameter settings

Laser Point Spacing, Wide Versus Narrow Beam Divergence

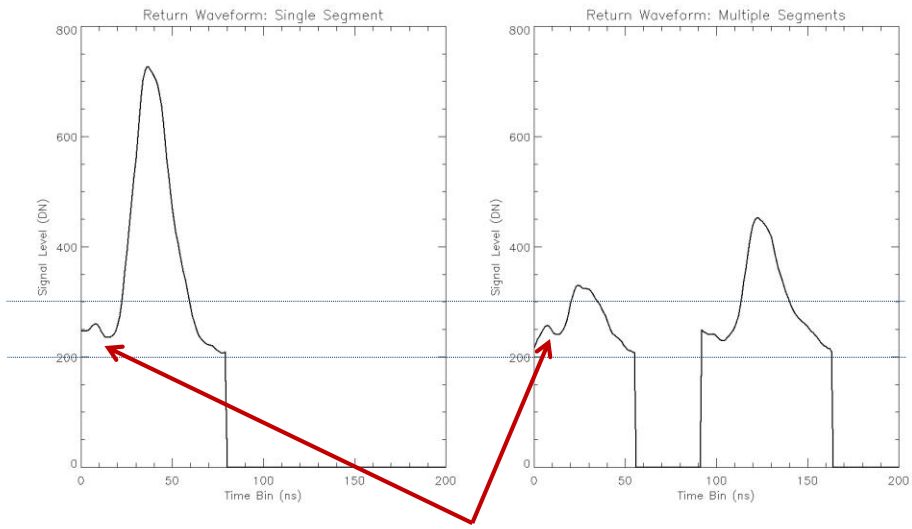


Waveform Recording: Single Segment Versus Multiple Segment



Single segment mode limits the recording to a ~52 m range, however, multiple segments misses small amounts of energy and causes a non-continuous signal

Waveform Recording: Trigger Threshold Value

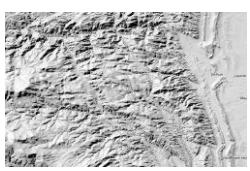


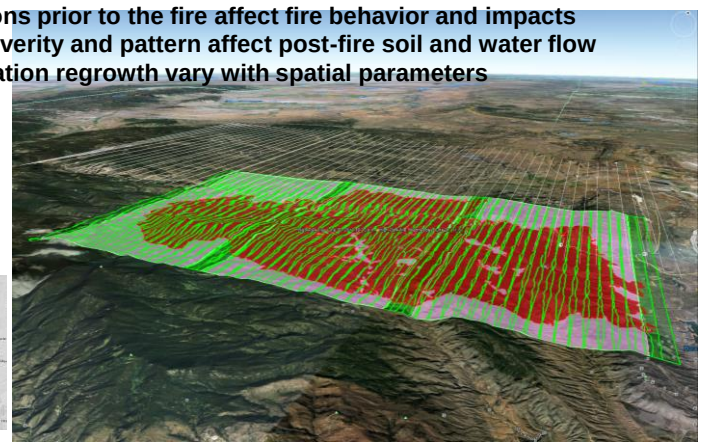
A trigger threshold of 100 DN in this case may miss some signal at the top of trees!

High Park Fire, CO with CSU and Others

2012 High Park fire burned 350 km² in Colorado
NEON, Colorado State University, and others have received a grant to study

- **What is the state of the landscape at the conclusion of the High Park fire**
- **How did conditions prior to the fire affect fire behavior and impacts**
- **How does fire severity and pattern affect post-fire soil and water flow**
- **How does vegetation regrowth vary with spatial parameters**





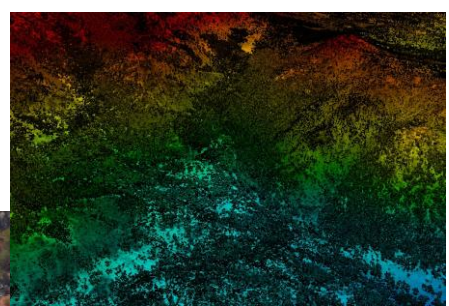
High Park Fire Study

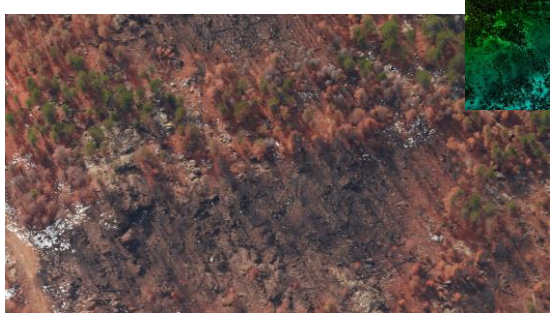
Mini-study to determine best configuration for landscape: what parameters are best to capture 'snags'?

Configuration	A	B	C	D	E
AGL (m)	1500	1000	1000	2200	2200
Divergence	Wide	Wide	Wide	Narrow	Narrow
Divergence Angle (mrad)	0.8	0.8	0.8	0.3	0.3
PRF (kHz)	50	100	70	50	33
Scan Freq (Hz)	28	50	41	35	29
Scan Half-Angle (deg)	19.2	18.5	18.5	9	8.5
Cross Track Sampling (m)	1.237	0.741	0.852	1.053	1.231
Down Track Sampling (m)	1.263	0.707	0.862	1.01	1.219
PPM²	0.64	1.91	1.36	0.94	0.67
Signal Metric	4.0	5.55	10.8	6.11	10.2

High Park Fire Data

Lidar Point Cloud data and High Resolution Camera data from High Park Fire survey area





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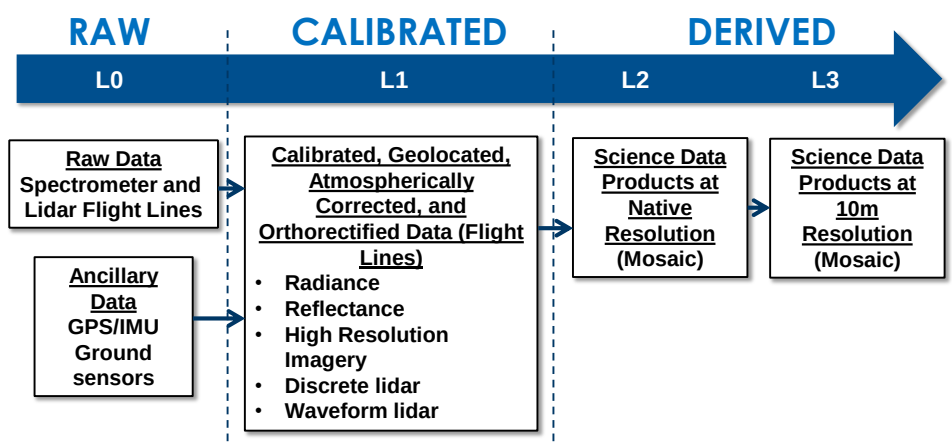
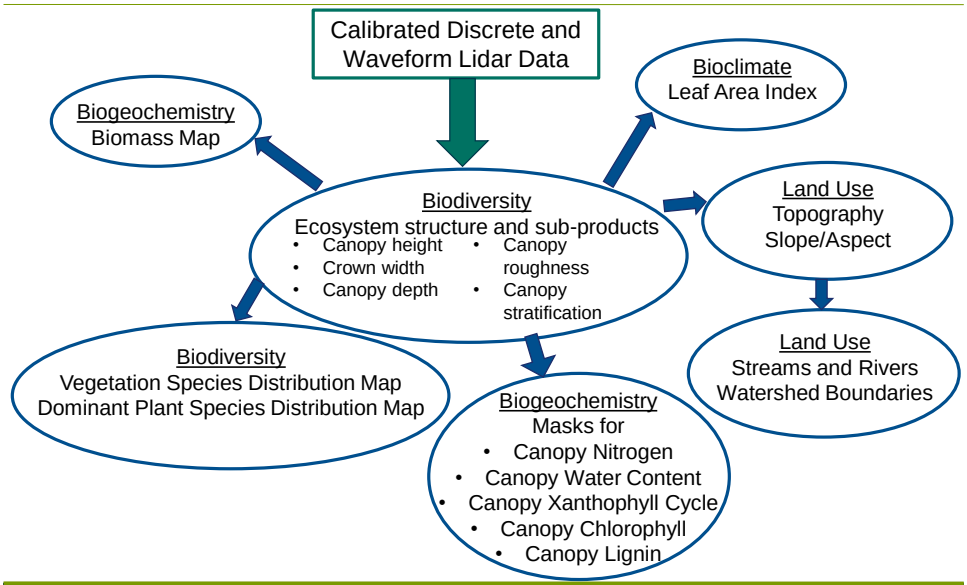
NEON Data Products



NEON AOP Product Tree: Derived Science Products



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Fusion with Non-Airborne Platform Data

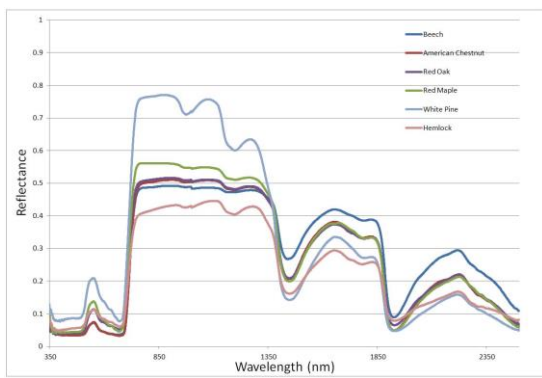
- Airborne Observation Platform data products will fuse contributions from data taken at different scales
- The procedures and protocols of how the NEON higher-level data products will be derived are still TBD
- There is the potential for contributions from ground-based sampling instrumentation
    - Traditional field-sampling collections
    - Ground-based lidar

Ground-Based Spectral Collections at Harvard

Collected Spectra with ASD Plant Probe across Harvard Forest

- Dominant Species collected
- Leaves sent in for chemical analysis
- 220+ individual samples

Could be used for calibration of AOP spectra collected remotely



Other Ground Sampling Schemes

- Collaborations with other institutions to investigate how data products from various ground sampling schemes can support remote sensing calibrations
  - Includes ground-based lidar collections
- Rochester Institute of Technology
- Boston University/University of Massachussetts

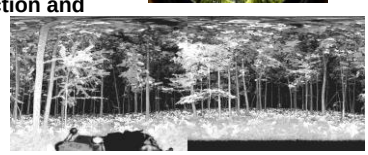
Rochester Institute of Technology Ground Sampling

Measurements and the associated protocols included:

- Ground-based LiDAR scan using a commercial terrestrial laser scanner
- Hemispherical photographs upwards and in cardinal directions
- Wide-angle photographs in cardinal directions
- LAI measurements using the AccuPAR

The ground measurements resulted in the following data products:

- Ground-based LiDAR scans for comparison with the airborne LiDAR scans
- Comprehensive photographs for site selection and analysis
- Leaf area index (LAI)

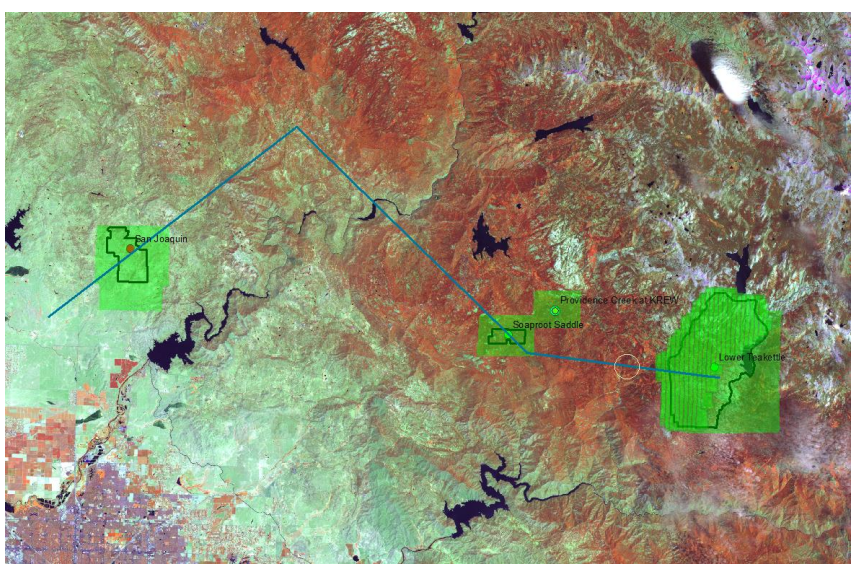


Boston University/University of Massachusetts Boston Ground Sampling

Measurements included:

- **Dual-wavelength Echidna Lidar (DWEL) scans of the Harvard Hardwood site (1064 nm and 1550 nm)**
- **Center location hemispherical photos**
- **Canopy inventory measures**
  - **Stem maps**
  - **DBH**
  - **Dominant tree heights**
  - **Canopy cross-sections**

NEON Domain17 CA Campaign, June 2013 Collaboration With HyspIRI Airborne Prep Mission



Conclusions

- NEON is a continental-scale observatory designed to detect ecological change over 30 years
- Data collected from multiple sources: Aquatic, Terrestrial, and Remote Sensing
- Airborne Observation Platform (AOP) instrument suite
  - Hyperspectral Imager
  - Waveform Lidar
  - High Resolution Camera
- AOP instrument parameters still being optimized during NEON construction phase
- NEON higher-level data products will build on Level 1 Calibrated AOP products to answer questions concerning biodiversity, biogeochemistry, land use, and bioclimate
- Potential for calibrating remotely sensed data using various ground-sampling schemes

American Geophysical Union Meeting 2013 Session B069

https://fallmeeting.agu.org/2013/scientific-program/session-search/sessions/b069-understanding-uncertainty-in-remotely-sensed-vegetation-data-products-2/

TITLE: Understanding uncertainty in remotely sensed vegetation data products
AUTHORS (FIRST NAME INITIAL LAST NAME): T. Ramond[1], J. A. van Aardt[2], J. Stoker[3], L. Wasser[1]
INSTITUTIONS (ALL): 1. NEON Inc., Boulder, CO, United States. 2. Rochester Institute of Technology, Rochester, NY, United States. 3. USGS, Sioux Falls, SD, United States.
Description: Remote sensing of ecosystems is an efficient means to measure multiple biophysical properties over broad geographical regions. Error sources contributing to final derived data products originate from instrumentation and data collection/processing, and may not be well-understood. Well-characterized uncertainties are important for missions such as ICESAT-II, BIOMASS, HyspIRI, and the NEON Airborne Observatory, as they improve product quality and support large-scale modeling efforts. Possible topics include allometric biomass derivation uncertainty, extrapolation between sites sampled at different scales, limitations in calibration/validation and characterization of active and passive sensors, or unexplored noise sources.
CURRENT SECTION/FOCUS GROUP: Biogeosciences (B)
CO-SPONSORING SECTION(S): Global Environmental Change (GC)

The National Ecological Observatory Network is a project sponsored by the National Science Foundation and managed under cooperative agreement by NEON Inc.

BACKUP

Construction Status June 2013

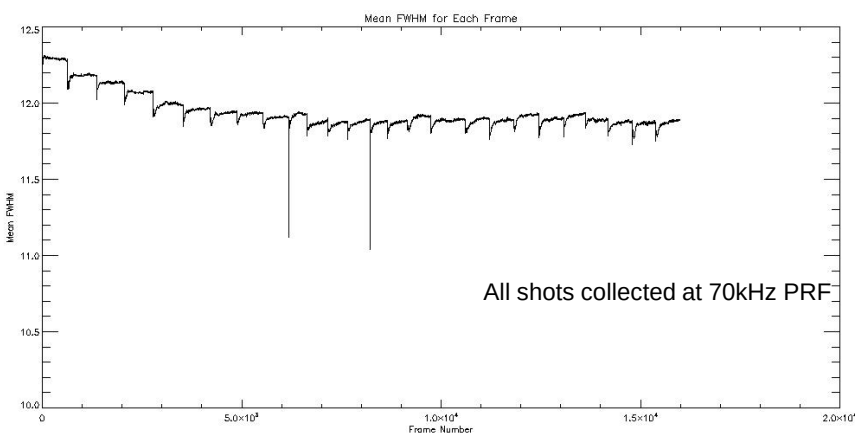
SITES SOON BEGINNING CIVIL CONSTRUCTION:
- D01 Bartlett Experimental Forest (NH)
- D09 Northern Great Plains Research Laboratory (ND)

CIVIL CONSTRUCTION:
- D02 Blandy Experimental Farm (VA): Completed Spring 2013
- D03 Disney Wilderness Preserve (FL): Completed Spring 201
- D03 Jones Ecological Research Center (GA): Completed Spri
- D03 Ordway-Swisher Biological Station (FL): Completed Sprir
- D09 Dakota Coteau (ND): Completed Summer 2013
- D09 Woodworth (ND): Completed Summer 2013
- D10 Central Plains Experimental Range (CO): Completed Spr
- D10 Sterling (CO): Completed Fall 2012
- D11 Klemme Range Research Station (OK): Completed Sumr
- D14 Jornada Station (NM): Completed Summer 2013
- D01 Harvard Forest (MA): Underway
- D02 Smithsonian Conservation Biology Institute (VA): Underw
- D08 Dead Lake (AL): Underway
- D10 Rocky Mountain National Park CASTNET (CO): Underwa

SENSOR INSTALLATION, TESTING AND ACCEPTANCE:
- D10 Sterling (CO): Underway
- D03 Ordway-Swisher Biological Station (FL): Underway
- D10 Central Plains Experimental Range (CO): Underway

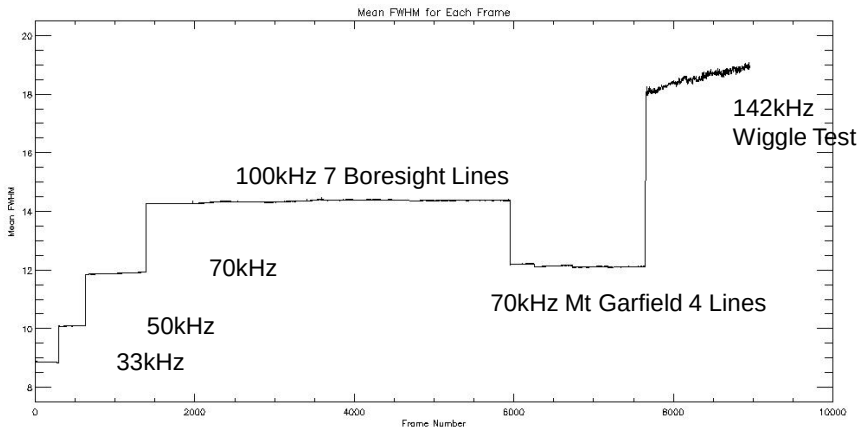

NEON site at Ordway-Swisher Biological Station

T0 FWHM Frame Mean: 5/10/2012



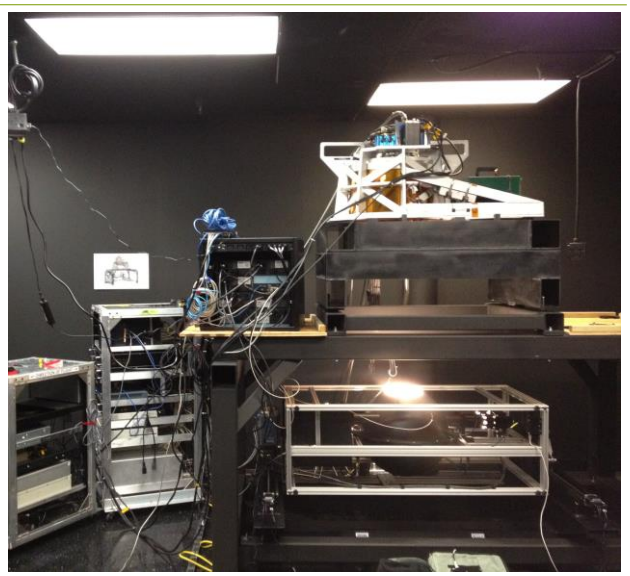
Spikes due to FWHM ramp up on unstable data frames

LiDAR Checkout and Boresight Calibration: T0 FWHM Frame Mean 5/5/12

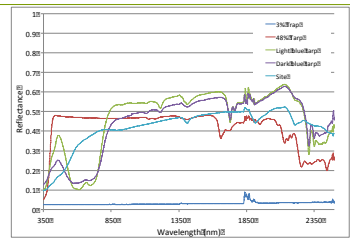


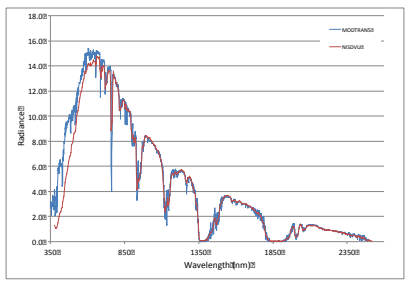
Radiometric Calibration

- Relate NEON Imaging Spectrometer digital output to collected light
  - Light level collected
  - Output of NIS
- Accurate output of source used in calibration is required
  - NIST FEL lamp
  - Spectralon Panel
  - Transfer Radiometer
  - Calibration of sphere radiance
- Transfer Radiometer is vital to this method of calibration



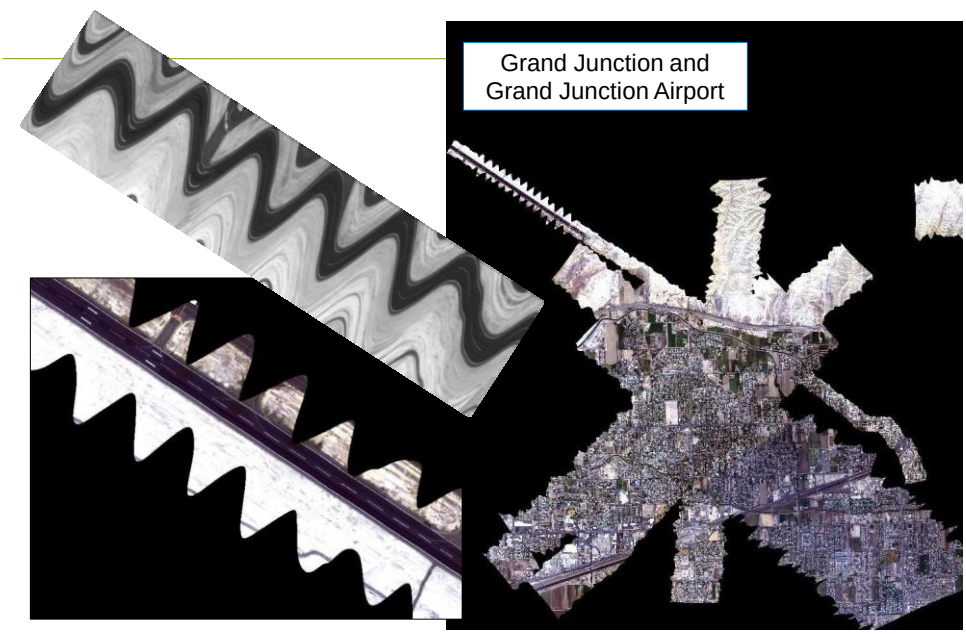
Vicarious Calibration at Ivanpah Playa: Reflectance-based Method



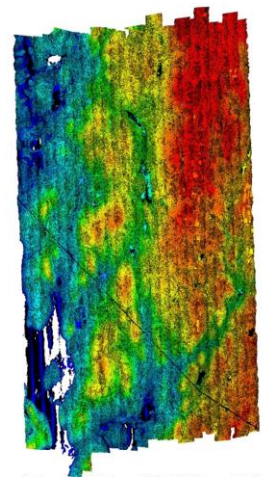


Radiative Transfer Code

Geometric Correction



Harvard Forest and Quabbin Reservoir Test Flight Area



9 km x 16 km @ 1000 m AGL

Data Collection Parameters, Harvard Forest

Date	Area	Altitude (AGL)	% Flight Line Overlap	# of Flight Lines	PRF	Scan Frequency	Scan Half Angle	Beam Divergence	PPM^2
8/7/2012	3 km x 4 km	2000 m	50	4 plus 1 cross strip	50 kHz	25 Hz	18.5 deg	Wide	1.01
8/7/2012	3 km x 4 km	1000 m	50	10 plus 1 cross strip	100 kHz	50 Hz	18.5 deg	Narrow	3.82
8/7/2012	1 km x 4 km	500 m	50	16 plus 1 cross strip	167 kHz	70 Hz	10.0 deg	Narrow	23.15
8/8/2012	High Density Hardwood and Hemlock Sites	1000 m	Center of site at -15, -7.5, 0, 7.5, 15 degrees, four headings	40	100 kHz	50 Hz	18.5 deg	Wide	>3.82
8/14/2012	9 km x 16 km	1000 m	30	24 plus 2 cross strips	100 kHz	50 Hz	18.5 deg	Wide	3.82