NEON 2013 AIRBORNE CAMPAIGN AT DOMAIN 17 TERRESTRIAL AND AQUATIC SITES IN CALIFORNIA

2013 HyspIRI Science Workshop
Pasadena, CA
October 15-17, 2013
What is NEON?

• 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

<table>
<thead>
<tr>
<th>Concept &amp; Design</th>
<th>Sites Built Out</th>
<th>Data Collection</th>
</tr>
</thead>
</table>
The NEON Project: Designed to Address Science Challenges

GRAND CHALLENGES

CAUSES OF CHANGE
Climate Change
Land Use
Invasive Species

Interactions and Feedbacks
Productivity, functional diversity, soil moisture, habitat structure, etc.

RESPONSES TO CHANGE
Biogeochemistry
Biodiversity
Ecohydrology
Infectious Diseases

KEY QUESTIONS

1. What are the impacts of climate change on continental-scale ecology?

2. What are the impacts of land use change on continental-scale ecology?

3. What are the impacts of invasive species on continental scale ecology?

4. What are the interactive effects of climate, land use and invasives on continental-scale ecology?

5. How does transport and mobility of energy, matter and organisms affect continental-scale ecology?

NEON DATA PRODUCTS

- Land Use and Land Cover
- Habitat, Landscape Structure
- Atmospheric, Air Quality
- Hydrology, Ecohydrology
- Bioclimate, Energy Balance
- Soil Structure, Physics
- Biomass, Productivity, Metabolism
- Biogeochemistry
- Infectious Diseases, Parasites
- Microbial Diversity, Function
- Population Dynamics, Demography
- Phenology
- Biodiversity, Invasives, Biogeography

DATA USERS

- SCIENTISTS
- EDUCATORS
- STUDENTS
- PUBLIC
- DECISION MAKERS
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
The NEON Site: From Ground to Sky

- Representative sampling
- Replication of gradients
- Detecting/attributing change over decades
- Comprehensive set biological observations
- Sentinel taxa -- terrestrial and aquatic
- Field and lab analyses state-of-the-art
- Standardized and transparent protocols
- QA/QC -- data quality and uncertainty

A digital rendering of a NEON site
Integrated Data Sampling

Modified from the image of Nicolle Rager Fuller, National Science Foundation, 2007
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

**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
- CO₂
- Root growth and phenology

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

**NEON**
National Ecological Observatory Network
**What Users Get**

**FREE AND OPEN ACCESS TO:**

- **Land Use Analysis Package**
  - Combine NEON data with national data suites
  - Integrate social and economic data with NEON
  - Cross-calibrate NEON data with satellites and in-situ sampling

- **Data products**

- **Protocols**

- **Educational resources**

  ✓ All QA/QC information (process and data)
  ✓ Protocols and procedures used to collect data
  ✓ Instrument specifications, characteristics and performance
  ✓ Algorithms used to process data

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PI users of NEON assignable facilities must comply with the NEON data policy, after a proprietary period, not to exceed 18 months, to validate and prepare data.

*Unless legally protected by the Endangered Species Act or other legislation*
NEON Airborne Observation Platform

- Tom Kampe, AOP Director, Assistant Director - Remote Sensing
- Tanya Ramond, Systems Engineer
- Ty Guadagno, Instrument Engineer, Flight Operations
- Edwin Penniman, Optomechanical Engineer
- Nathan Leisso, Staff Scientist - Remote Sensing Calibration
- Keith Krause, Senior Scientist - Remote Sensing Algorithms
- Bryan Karpowicz, Staff Scientist - Remote Sensing Instrumentation
- Bill Gallery, Staff Scientist - Remote Sensing Algorithms
- John Musinsky, Staff Scientist – Flight Planning and Operations, Science Outreach
- Ian Crocker, Airborne Sensor Operations Technician
- Matt DeVoe, Airborne Sensor Operations Technician
- Stephanie Spetter, Administrative Services Manager
NEON Airborne Observation Platform

Remote sensing payload designed to be compatible with the low altitude DeHavilland DHC-6 Twin Otter research aircraft
### NEON Imaging Spectrometer

- **Spectral range**: 380-2510 nm
- **Spectral sampling (FWHM)**: 6 nm
- **IFOV**: 1.0 milliradian
- **X-track FOV**: 34 degrees
- **SNR**: > 2000 @ 600 nm, > 1000 @ 2200 nm
- **Radiometric accuracy**: > 95%
- **Spectral calibration**: +/- 0.1 nm
- **Spectral uniformity, xtrack**: > 95%
- **Spectral IFOV-variation (in-track)**: < 5%
- **Cross-track pixels**: > 600 pixels
- **Cross-track swath**: 1.0 km @ 1000m altitude

- High fidelity visible-to-shortwave infrared (VSWIR) imaging spectrometer built by JPL
- Based on the AVIRIS Next-Generation Imaging Spectrometer (AVIRISng)
**Waveform LiDAR and High Resolution Digital Camera**

<table>
<thead>
<tr>
<th>Waveform LiDAR</th>
<th>Digital Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser wavelength</td>
<td>Spectral band-pass</td>
</tr>
<tr>
<td>1064 nm</td>
<td>400-700 visible</td>
</tr>
<tr>
<td>Laser pulse repetition freq.</td>
<td>Field of View</td>
</tr>
<tr>
<td>Programmable 33-167 kHz</td>
<td>44 degrees</td>
</tr>
<tr>
<td>Laser pulse width</td>
<td>Ground sampling distance</td>
</tr>
<tr>
<td>12 nsec</td>
<td>0.11 m (@ 1000 m AGL)</td>
</tr>
<tr>
<td>Vertical range</td>
<td>Dynamic range</td>
</tr>
<tr>
<td>65 m nominal</td>
<td>12 bits</td>
</tr>
<tr>
<td>Vertical sampling</td>
<td>Shutter speed</td>
</tr>
<tr>
<td>1 μsec = 0.3 m</td>
<td>1/125 to 1/500</td>
</tr>
<tr>
<td>Scan frequency</td>
<td>Programmable 0-70 Hz</td>
</tr>
<tr>
<td>Programmable 0-70 Hz</td>
<td></td>
</tr>
<tr>
<td>Range of flying altitudes</td>
<td></td>
</tr>
<tr>
<td>1,000 to 2,500 m</td>
<td></td>
</tr>
<tr>
<td>Scan angle</td>
<td>Programmable 0-50°</td>
</tr>
<tr>
<td>&lt; 1 m</td>
<td></td>
</tr>
<tr>
<td>Spatial resolution</td>
<td></td>
</tr>
<tr>
<td>Site</td>
<td>Date</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>SJER</td>
<td>6/9/13, 6/11/13, 6/13/13</td>
</tr>
<tr>
<td>BRDF (SJER)</td>
<td>6/11/13</td>
</tr>
<tr>
<td>Soaproot Saddle</td>
<td>6/12/13</td>
</tr>
<tr>
<td>Providence Creek</td>
<td>6/12/13</td>
</tr>
<tr>
<td>Teakettle</td>
<td>6/14/13, 6/15/13</td>
</tr>
<tr>
<td>BRDF (Soaproot)</td>
<td>6/15/13</td>
</tr>
<tr>
<td>Elevation Gradient Transect</td>
<td>6/12/13, 6/14/13</td>
</tr>
</tbody>
</table>
Many land processes readily observed and quantified using combination of biochemical and structural information provided by spectroscopy and waveform LiDAR

- native and invasive plant canopy biogeochemistry and habitat structure
- pest and pathogen outbreaks
- changes in competitive relationships
- responses to disturbances like wildfire
Route Plans for Three NEON AOP Payloads

- 2 aircraft with identical payloads to cover NEON sites
- 7-months, 1,100 flight hrs flight season
- 3rd Payload for PI-driven science, Rapid Response, Targets of Opportunity

Ship payload to Hawaii

Preseason calibration flight
Airborne Survey Constraints

- Peak greenness (maximum leaf cover)
  - phenology varies among species and by elevation
  - must accommodate inter-annual variability

- Minimum cloud cover
  - high cirrus clouds acceptable?

- Minimize solar angles, topographic shadowing
  - ~10 am – 2 pm

(Garrot et al 2008)
San Joaquin Flight Box Definition

Flight box design must result in robust datasets that:
1) address primary science themes
2) enable scaling to continental scale modeling

Average Annual Minimum Temperature (1981-2010)

Average Annual Maximum Temperature (1981-2010)

Average Annual Precipitation (1981-2010)

Vegetation Types

Topography
BRDF & Elevation Gradient Flights

Soaproot Saddle BRDF Flight

Elevation change along gradient transect from SJER (left) to Teakettle (right)
## Pre-Campaign Engineering Improvements

<table>
<thead>
<tr>
<th>PIM Improvements</th>
<th>Value Added</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighter</td>
<td>Increase flight time</td>
</tr>
<tr>
<td>Stronger</td>
<td>Meet FAA requirements, add safety</td>
</tr>
<tr>
<td>Rigidity</td>
<td>Improve boresight rigidity, leading to better NIS/LiDAR/camera co-registration of features on ground</td>
</tr>
<tr>
<td>Thermal control</td>
<td>Improve boresight stability, Prevent instrument over-heating, Control noise on FPIE (focal plane electronics) box</td>
</tr>
<tr>
<td>Modular aft section</td>
<td>Increase flexibility for mounting instruments, Eliminate loss of boresight alignment during testing and maintenance</td>
</tr>
<tr>
<td>OBC and SOBC now attached to PIM</td>
<td>Minimize variation in OBC (on-board calibration) illumination</td>
</tr>
</tbody>
</table>
Remote AOP Instrument Monitoring

![Monitoring Interface](image)

- **Instrument**
  - NS1

- **Send To User**
  - Everyone

- **Report (Times/Day)**
  - 24

- **Path to ECS data**
  - C:\monitorNS

- **Path to PIM data**
  - C:\Temperature.log

- **Pressure Threshold**
  - 1e-3

- **Temperature Threshold (K)**
  - 300

- **Temperature Threshold Lidar (C)**
  - 35

<table>
<thead>
<tr>
<th>Channel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaN</td>
<td>T0 - LIDAR box right side Chamber Pressure (torr) NaN</td>
</tr>
<tr>
<td>NaN</td>
<td>T1 - LIDAR box front bottom left FPA Temperature (K) NaN</td>
</tr>
<tr>
<td>NaN</td>
<td>T2 - Coolant between PIM and cryocoolers</td>
</tr>
<tr>
<td>NaN</td>
<td>T3 - Coolant outlet from cryocoolers</td>
</tr>
<tr>
<td>T4</td>
<td>Outside air temperature</td>
</tr>
<tr>
<td>NaN</td>
<td>T5 - PIM box</td>
</tr>
<tr>
<td>NaN</td>
<td>T6 - PIM Frame underside center</td>
</tr>
<tr>
<td>NaN</td>
<td>T7 - Subframe underside center</td>
</tr>
<tr>
<td>NaN</td>
<td>T8 - PIM Frame triangle left bottom front</td>
</tr>
<tr>
<td>NaN</td>
<td>T9 - PIM Frame triangle left bottom aft</td>
</tr>
<tr>
<td>NaN</td>
<td>T10 - PIM Frame triangle left top</td>
</tr>
<tr>
<td>NaN</td>
<td>T11 - PIM Frame triangle right bottom front</td>
</tr>
<tr>
<td>NaN</td>
<td>T12 - PIM Frame triangle right bottom aft</td>
</tr>
<tr>
<td>NaN</td>
<td>T13 - PIM Frame triangle right top</td>
</tr>
<tr>
<td>NaN</td>
<td>T14 - Specrometer backplate</td>
</tr>
<tr>
<td>NaN</td>
<td>T15 - Coolant inlet to PIM</td>
</tr>
</tbody>
</table>

Histogram with temperature measurements over time:

- Chamber Pressure
- Collector Temp
- Funnel Pressure

Temperature and Pressure Trends over Time (UTC) from 07-17 to 07-17.
Calibration of the NEON Imaging Spectrometer

• Radiometric calibration
• Spectral calibration
• Geolocation calibration is part of integration test flights
ASD Field Spectrometer Calibration

Legend
- Aquatic Sites
- Core Sites
- Park
- River/Bay

SOAP 1563
SOAP 25
SOAP 55

Reflectance

Wavelength (nm)

3% Tracor (1)
3% Tracor (2)
48% Tracor (1)
48% Tracor (2)
Granite
Transect Spectral Data

- Transect spectral data collected at seven NEON subplots in SJER
- Bulk biomass material harvested and bagged from each subplot to derive bulk N from grasses
- Spectral measurements will be compared to lab data to validate algorithm used to derive the biochemical properties from hyperspectral data
- Validated algorithm will be applied to the NEON NIS data to validate larger scale biomass N maps over SJER
Foliar samples spectra collected at six locations in SJER

- Goal of the plant canopy sampling was to investigate the variation in elemental content (C, N, P, Ca2+, Mg2+, and K+), isotopic composition (C and N), chlorophyll, and lignin across a range of plant community types.

- The objective was to collect plant chemistry and structural measurements that could be compared with remote sensing data collected by the Airborne Observatory Platform.
University of Wisconsin team collected leaf-level reflectance and measured gas exchange.

NEON and UW performed instrument cross-comparisons to measure systematic bias within each ASD field spectrometer.
Rochester Institute of Technology

- Conducted ground-based LiDAR scans, LAI, herbaceous biomass measurements, wide-angle photos, spectral measurements at more than twenty sites centered on existing 20x20m NEON plots
- Data will be used for synthetic scene design using DIRSIG to study the impact of sub-pixel structural variation on pixel-level spectral response

Boston University

- Surveyed three sites with terrestrial waveform LiDAR (DWEL)
Vicarious Calibration at Railroad Valley Playa
Preliminary Science Data

Discreet LiDAR data for Soaproot Saddle

Aerial photo of field sampling site with Tracor reference reflectance tarps
Collaborations

HyspIRI Preparatory Airborne Campaign

May/June 2013 HyspIRI airborne preparatory mission AVIRIS-classic survey of flight boxes in coastal/inland California

June 12 AVIRIS flight overlapped with NEON AOP survey of Soaproot Saddle and the elevation gradient transect

Obtained coincident datasets from hyperspectral instruments at different resolutions with linked field measurements

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

**University of Wisconsin - Ecological Spectral Information System (EcoSIS)**

Designed to enhance the accessibility and utility of new and existing spectral vegetation data
Collaboration with University of Colorado’s Laboratory for Atmospheric and Space Physics to incorporate airborne irradiance monitor into payload

Measures aerosol optical depth above and below aircraft

Should help with cirrus cloud assessment
Moving Forward

• Preliminary calibrated radiance and orthorectified reflectance products, discrete and waveform LiDAR, co-registered photography expected January 2014

• ATBD’s for all data processing will be available online

• Spring 2014 science workshop on application of NEON airborne data

• Annual airborne surveys of D17 begin in 2016

• 52 page Technical Memo on 2013 Airborne Campaign at Domain 17 Terrestrial and Aquatic Sites at http://www.neoninc.org/sites/default/files/tms/TM-005.pdf

The NEON 2013 Airborne Campaign at Domain 17 Terrestrial and Aquatic Sites in California


The National Ecological Observatory Network, 1905 34th St. Suite 100, Boulder, CO

ABSTRACT

The National Ecological Observation Platform instrument payload (AOI), which included a high-resolution, multispectral, imaging spectroscopy (OIS), a small-footprint waveform-recording LiDAR, and a high-resolution, digital camera integrated aboard a Dall-Valldal DHC-6 Twin Otter aircraft. Supporting ground measurements of vegetation species and structure, plant species identification and measurements of key atmospheric variables used in conjunction with the NEON airborne observations at San Joaquin and the Sequoia National Park and in collaboration with field research teams from the University of California, Davis, the University of Wisconsin, Madison, and Rochester Institute of Technology."
Need NEON Data?

Contact: John Musinsky