The Unique Opportunity of ABoVE Airborne Intensives

Charles Miller

ABoVE Deputy Science Lead

ASTM #1 Minneapolis MN 1 October 2015

The Unique Opportunity ABoVE Airborne Intensives

- Obtain unprecedented Arctic-Boreal Region remote sensing data
  - Spatial Resolution
  - Coverage
  - Accuracy
  - Quantified Uncertainties
- Validate existing RS for ABR Ecosystems
- Pioneer new TE sensors, sensor combinations and methodologies
  - Demonstration for future satellite sensors (ES Decadal Survey #2)

Challenges for Implementing Successful ABoVE Airborne Intensives

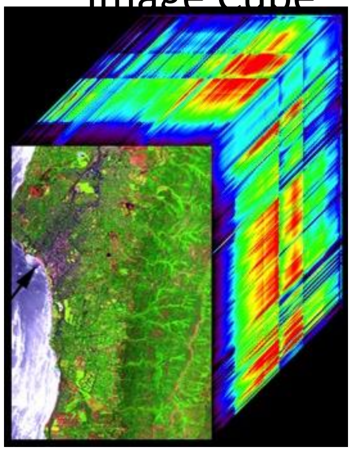
Nominal Schedule:

- 2017 Intensive 1
- { 2018 Bridging }
- 2019 Intensive 2

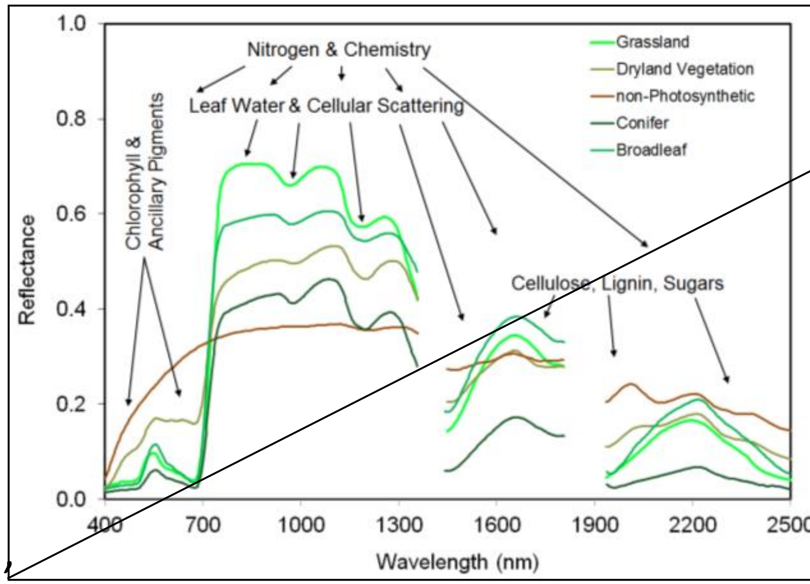
- Schedule for Intensive 1 defines ABoVE **Critical Path**
- Intensive 1 will be planned prior to results from ABoVE Phase 1 field work
- Intensives will be resource limited → Prioritization

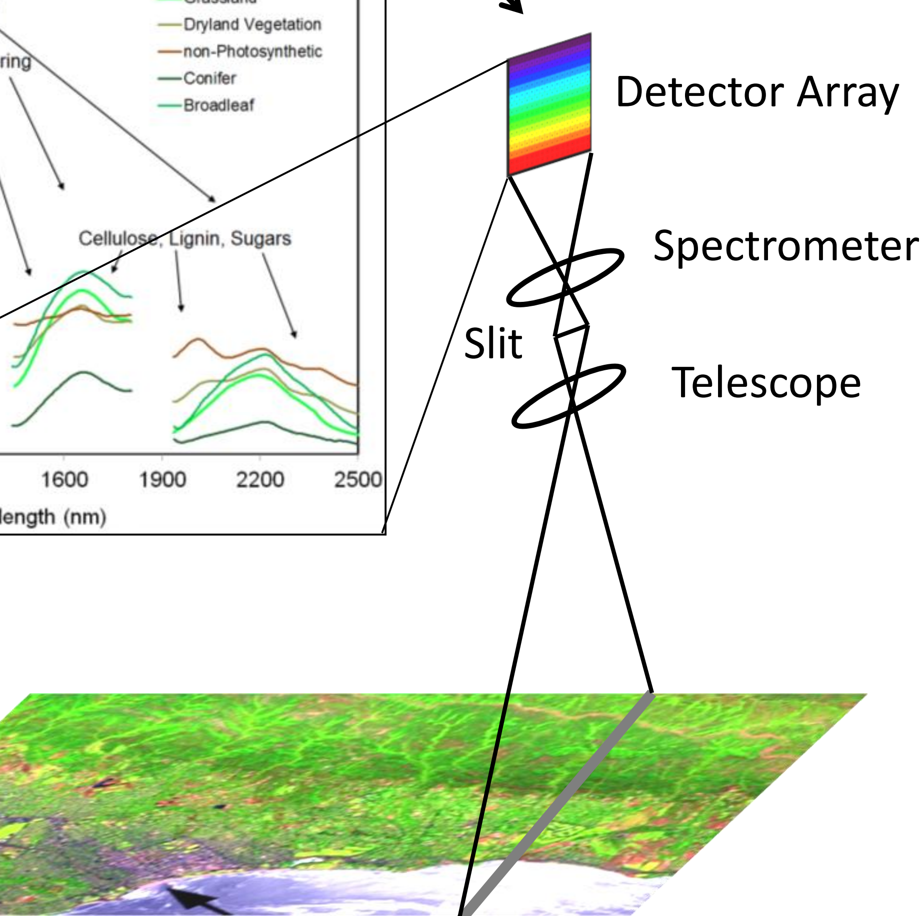
The BOREAS Legacy: AVIRIS-NG VSWIR Imaging Spectroscopy for Carbon Cycle and Ecosystem Science

Calibrated Image Cube

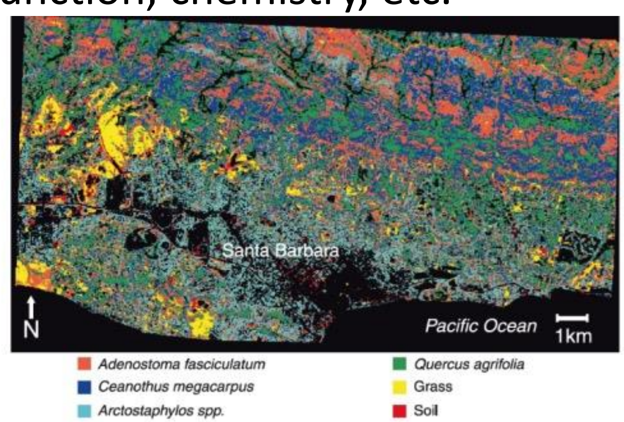


≥100's of Parallel Spectrometers





Ecosystem composition, function, chemistry, etc.

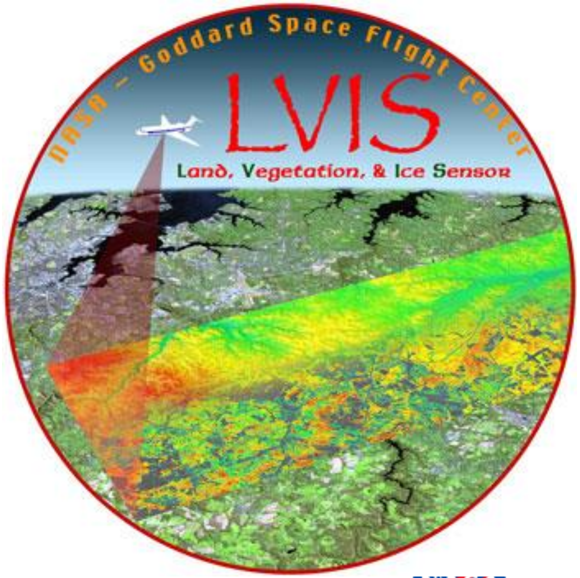


High-Demand Sensors and Sensor Combinations

- Multi-frequency radar measurements (UAVSAR, AirMOSS)
- LIDAR (LVIS)
- Joint LIDAR-RADAR coverage

Targets:

- Permafrost characterization, ALT
- 5% random sample of unmanaged boreal forest (above ground biomass)



New Sensors and Science: Solar Induced Fluorescence (SIF)

- Direct probe of productivity
- Joint deployments of SIF and hyperspectral imagers for direct comparison of SIF and vegetation indices (and chemistry, phenology, water stress, PFTs, etc)
- Validate OCO-2 SIF for ABR ecosystems
- Augment shoulder season coverage

Targets:

- Greening and browning areas identified from satellite RS
- Fire recovery sites

Divide and Conquer: Joint G-LiHT & ASO Deployments

- Comparable payloads & data products
- Joint deployments → 2x simultaneous coverage

Targets:

- Tundra-Taiga boundaries
- Fire succession/recovery areas

Synergies ICEBRIDGE/ARISE

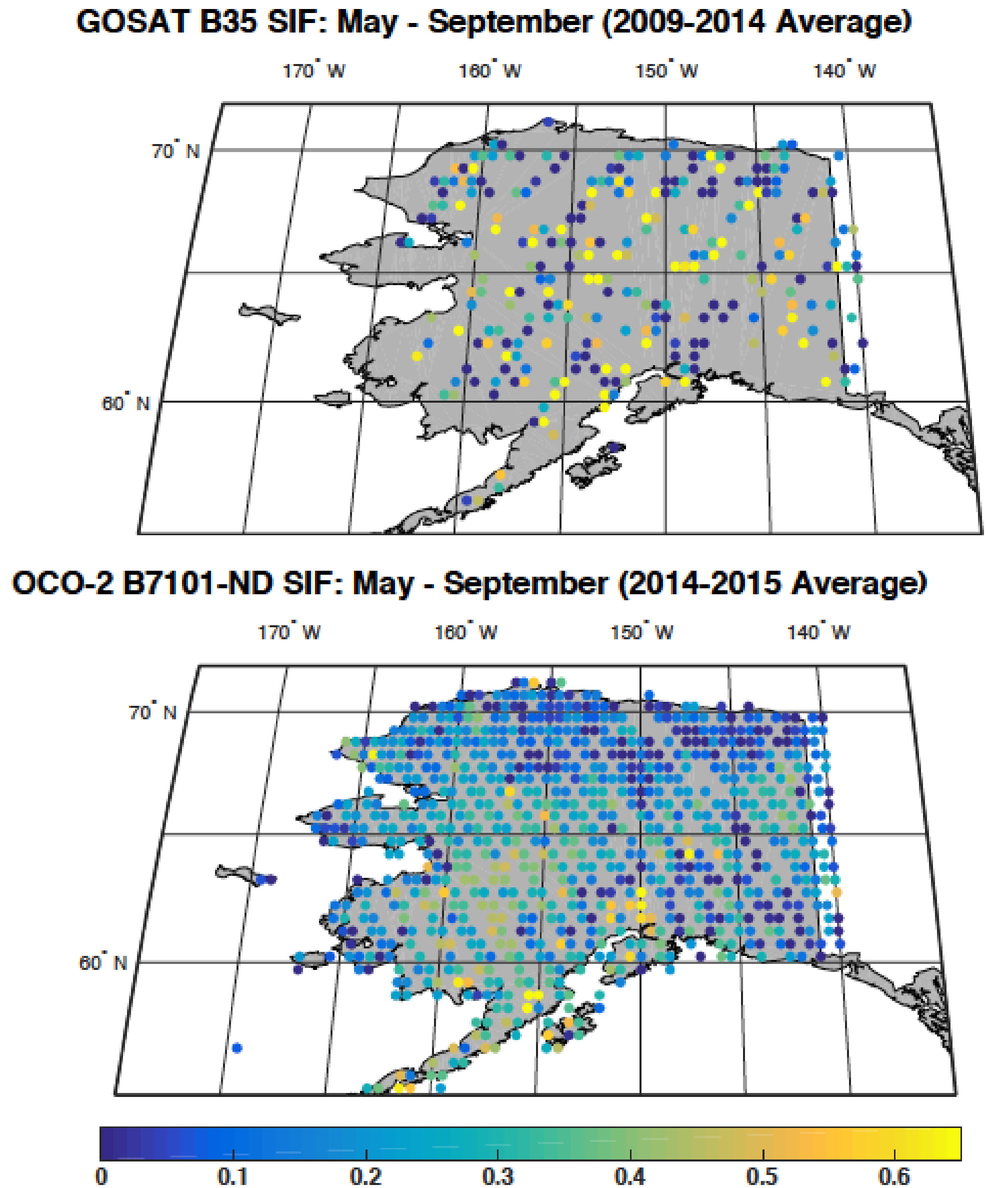
- **How can ABoVE leverage ICEBRIDGE and/or ARISE?**
- **What ICEBRIDGE data are valuable to ABoVE?**
- **What additional payloads or or modified flight lines would benefit ABoVE?**
- **Aircraft: C-130, P-3**

Also: Arctic Colors, ARM/NGEE-Arctic, etc

NASA pilot Jeff Chandler looks out at the sea ice during a flight in NASA's C-130 over the Beaufort Sea on Sept. 13, 2014. Credit: NASA / Patrick Lynch

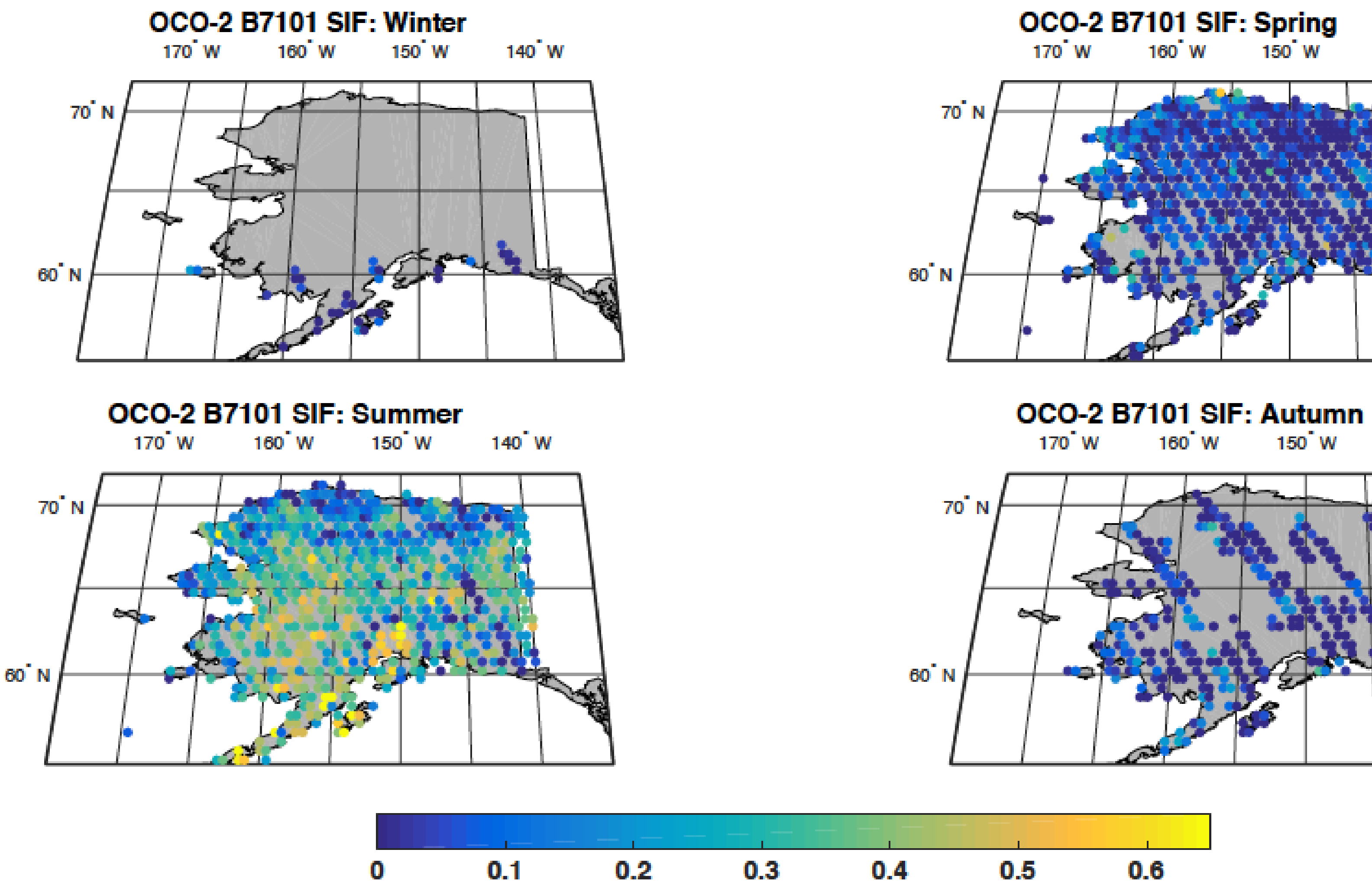
Alaska SIF

- High spatial resolution
- Regional gradients observed across the tundra and boreal forest
- 1 year of OCO-2 data gives 10x more SIF samples (200k) than 5 years of GOSAT (15k)



N Parazoo (JPL), C Frankenberg (Caltech)

OCO-2 SIF: Seasonal coverage for Alaska



N Parazoo (JPL), C Frankenberg (Caltech)


ΛS
NASA AIRBORNE SNOW OBSERVATORY
Measuring Spatial Distribution of Snow Water Equivalent and Snow Albedo

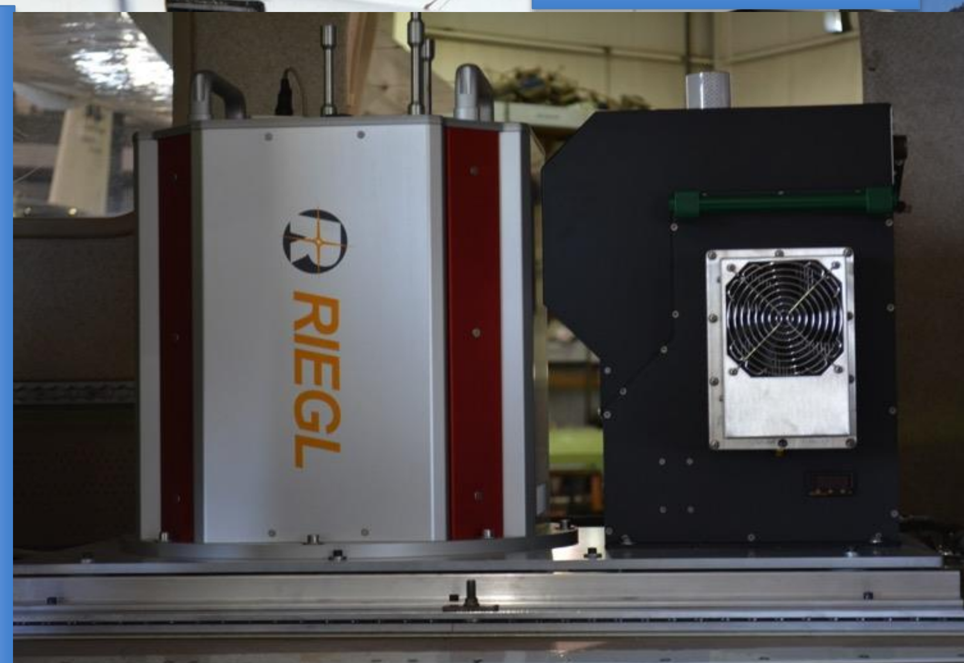
Snow Water Equivalent

Riegl Q1560 3D Scanning lidar
1064 nm, canopy penetration
1 m spatial resolution

Albedo

CASI-1500 Imaging Spectrometer
0.35-1.05 µm
2 m spatial resolution from 4000 m AGL

- < 24 hour turnaround of products
- Quantification of snow volume
- Snow depth uncertainty = 2 ± 1 cm
- Quantification of snowmelt timing
- Quantification of snowfall
- Same payload delivers ecosystem structure, function & chemistry data



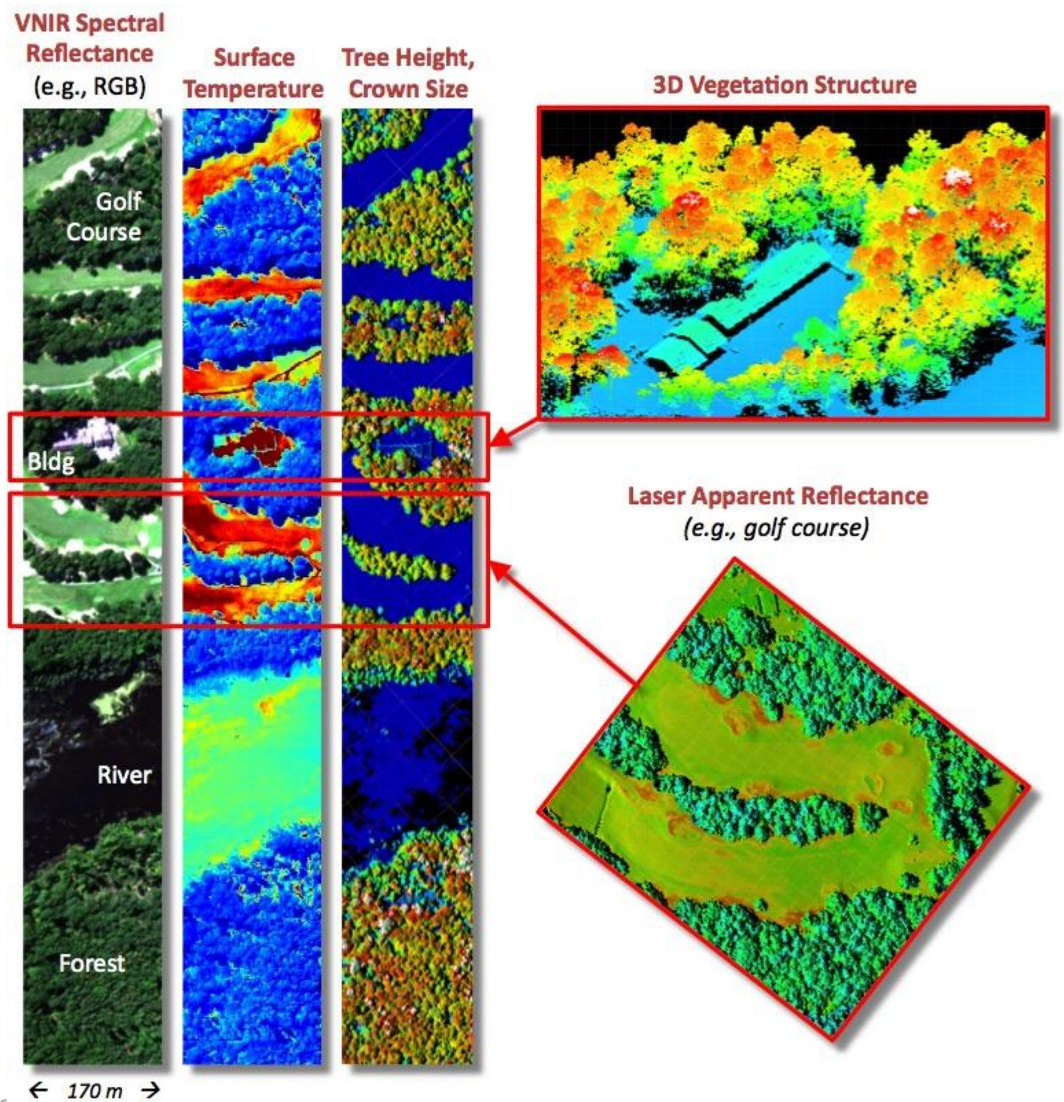
G-LiHT: Goddard's Lidar, Hyperspectral, and Thermal airborne imager

G-LiHT is a portable, airborne imaging system that simultaneously *maps the composition, structure, and function of terrestrial ecosystems* using:

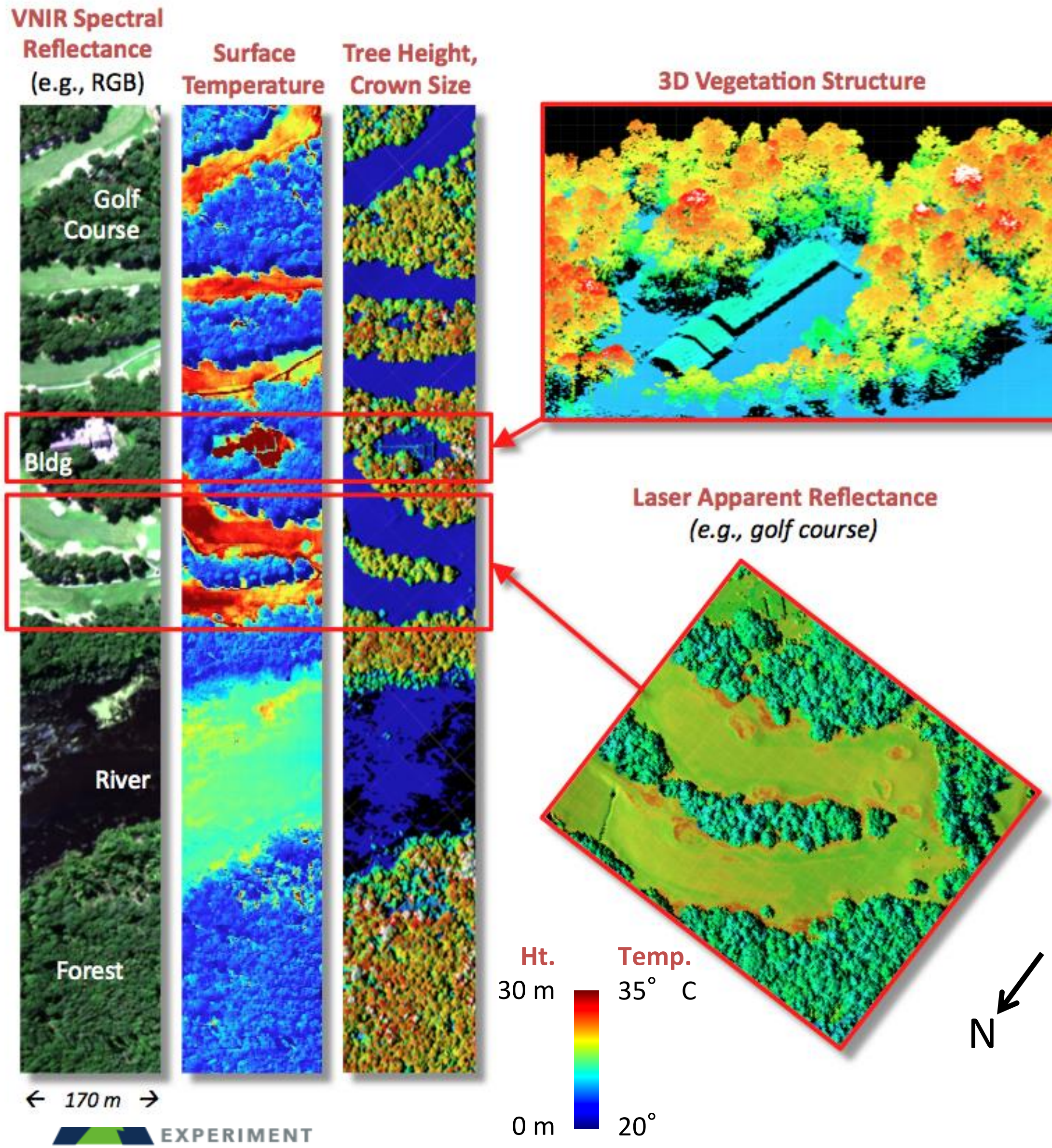
1) *lidar* to provide 3D information about the spatial distribution of canopy elements;

2) *imaging spectroscopy* to discern species composition and variations in biophysical variables (e.g., photosynthetic pigments, nutrient and water content); and

3) *thermal measurements* to quantify surface temperatures and detect heat and moisture stress.



G-LiHT: Goddard's Lidar, Hyperspectral, and Thermal airborne imager



INSTRUMENT SPECIFICATIONS

Scanning lidar (Riegl VQ-480)

Swath width*/FOV	**387 m (60°)**
Footprint diameter	**10 cm** (0.3 mrad)
Maximum ranging distance	450 m
Sampling density at surface†	**3 pulses m^{-2}**
Max. returns per pulse	8

Irradiance spectrometer (Ocean Optics USB-4000)

FOV	hemispheric (180°)
Raw sampling resolution	1.5 nm
Acquisition rate	1 Hz

Imaging spectrometer (Headwall Hyperspec)

Swath width*/FOV	**310 m (50°)**
Cross track pixels	1,004
Spectral range	**420 to 920 nm**
Raw/Binned sampling resolution	1.5/4.5 nm
Spectral resolution (FWHM)	8 to 15 nm
Acquisition rate	50 Hz

Thermal camera (Xenics Gobi-384)

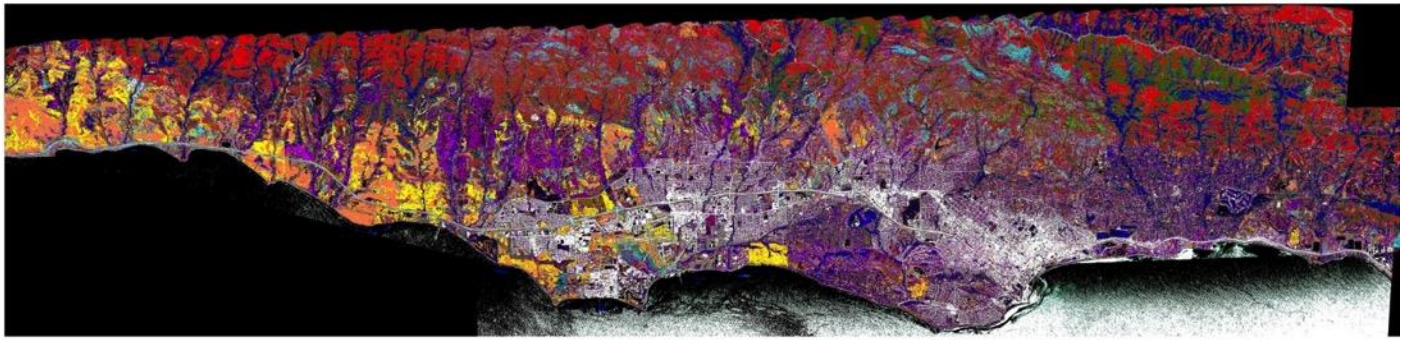
Swath width*/FOV	173 m (30°)
Imaging array size	384 × 288
Spectral range	8 to 14 µm
Sensitivity (NETD)	>50 mK at 30° C
Acquisition rate	25 Hz

GPS-INS (Oxford RT-4041 w/*Omnistar G2)*

Position accuracy	10 cm
Roll/pitch/yaw accuracy	0.03°/0.03°/0.10°

** At **nominal altitude of 335 m (1100 ft) AGL***
† At laser pulse repetition frequency of 150 kHz

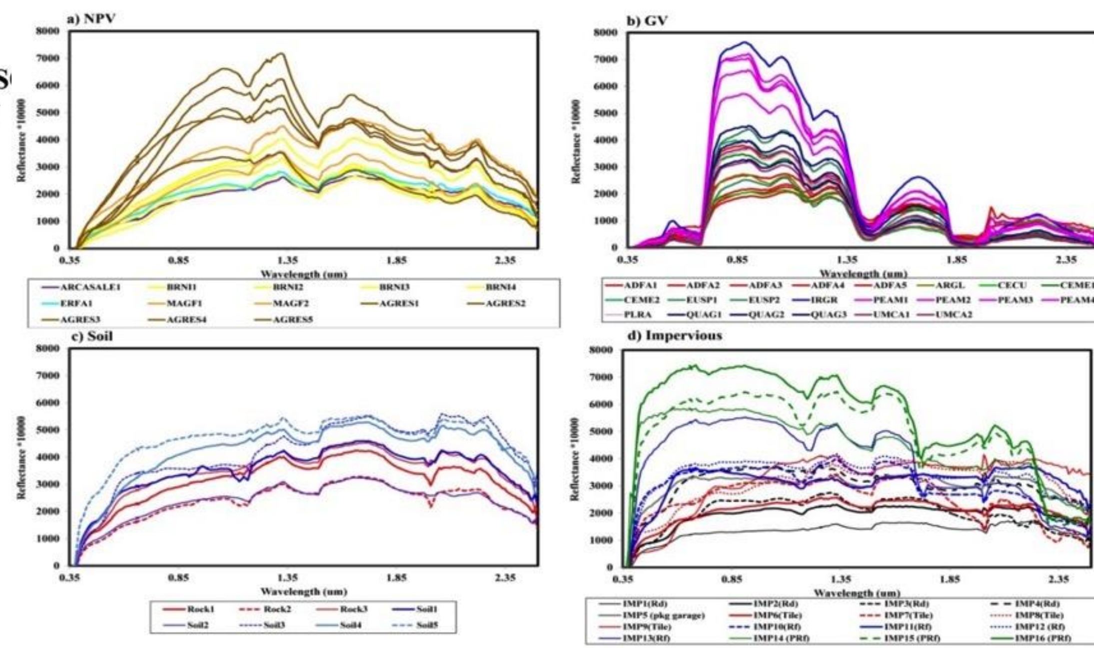
Mapping Plant Species/Land-cover



Legend

ADFA	CEME	MAGF	QUDO
ARCA-SALE	CESP	MARSH	UMCA
ARGL	CISP	PEAM	ROCK/S
BAPI	ERFA	AGRES	URBAN
BRNI	EUSP	PLRA	
CECU	IRGR	QUAG	

- **Map generated using AVIRIS-C and Multiple Endmember Spectral Mixture Analysis (MESMA)**
- **Incorporates within species and cross species spectral variability in mapping**



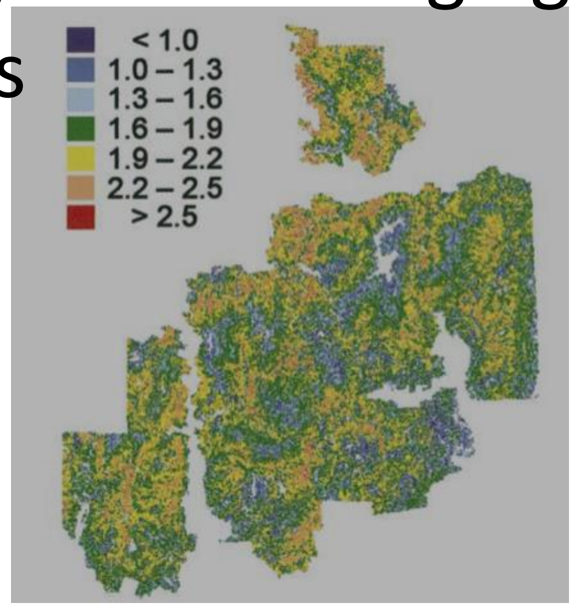
Spectra of (a) NPV; (b) GV; (c) Rocks/soils; (d) impervious materials. Codes = Genus& species: e.g. ADFA = *Adenostoma fasciculatum*

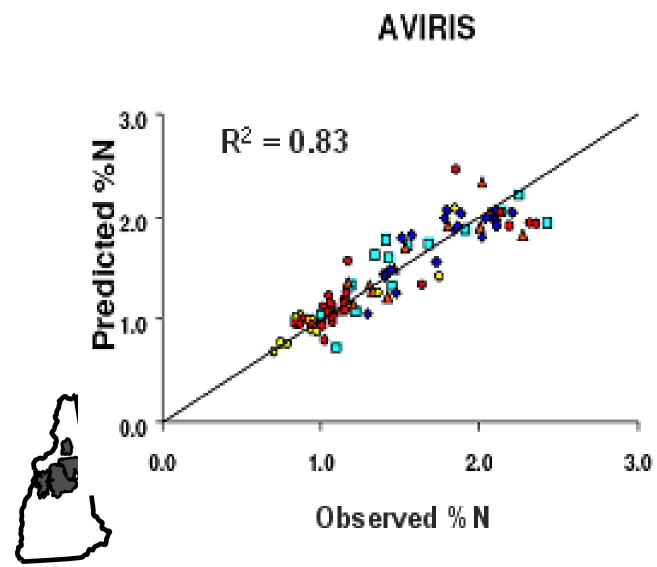
Roberts et al., 2014, in revision RSE

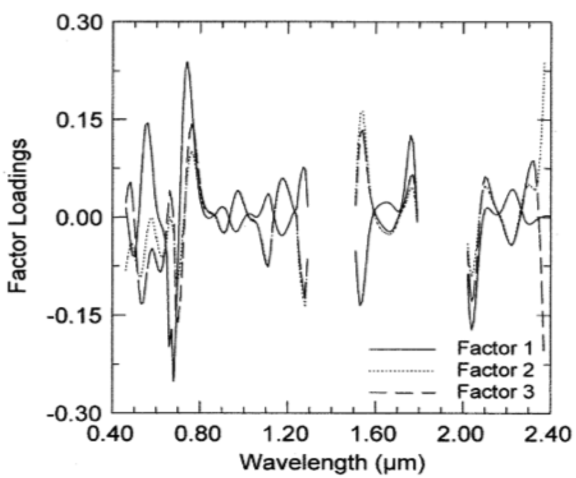
ARCTIC BOREAL VULNERABILITY EXPERIMENT

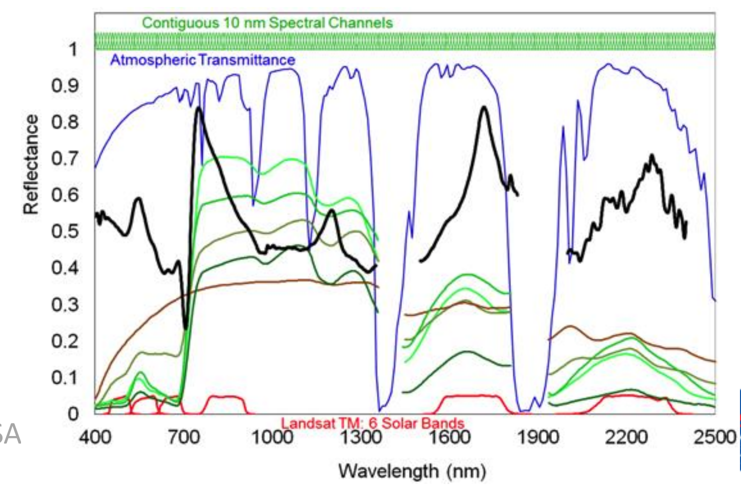
Vegetation Chemistry from Spectroscopy

- Canopy Nitrogen from imaging spectroscopy
  ts



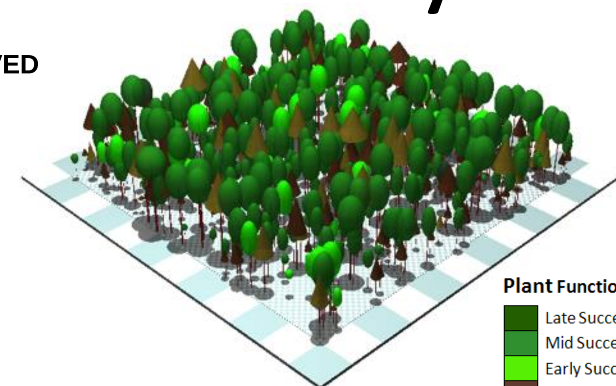


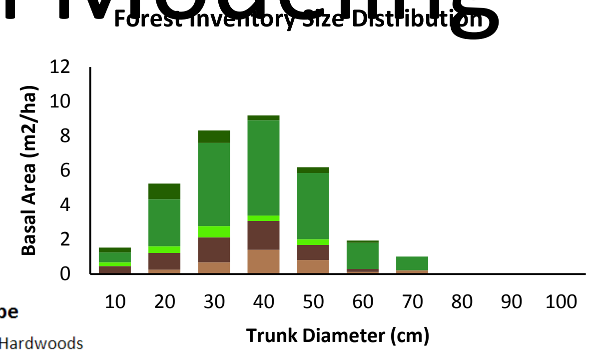




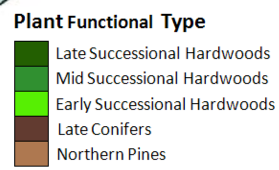
Composition for Ecosystem Modeling

FIELD OBSERVED

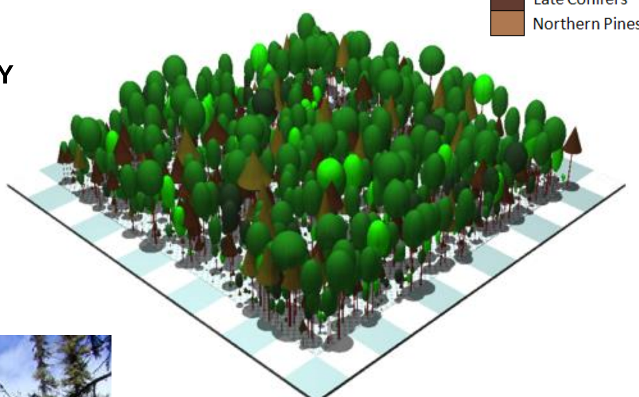


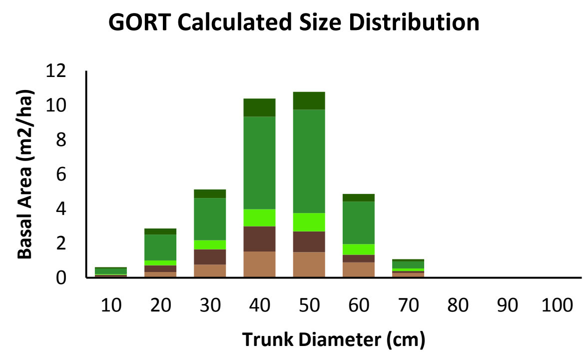


Basal Area = 33.5 m^2/ha



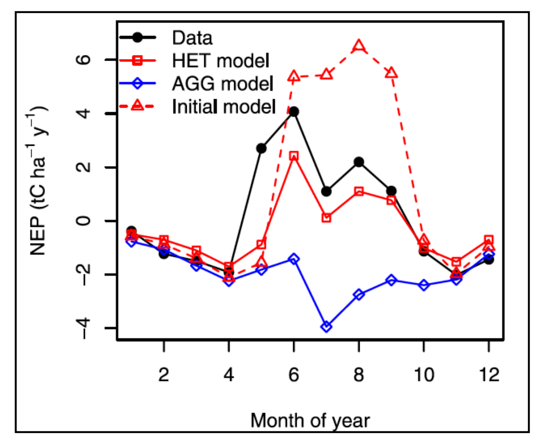
IMAGING SPECTROSCOPY DERIVED





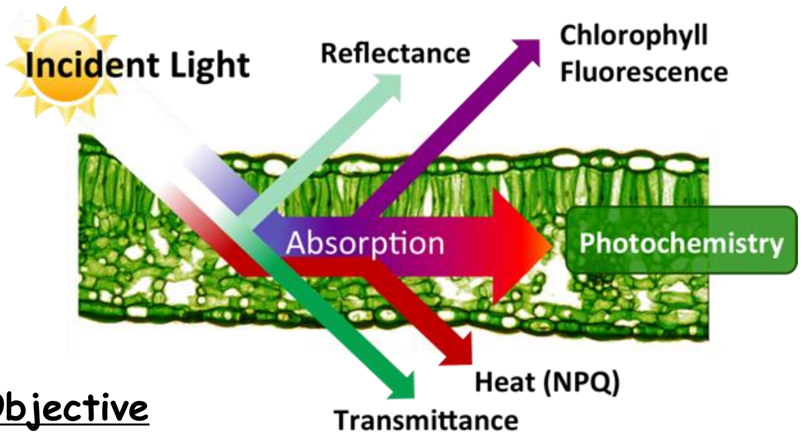
Basal Area = 35.6 m^2/ha

- Initial: Horizontal heterogeneity in canopy structure represented. Parameter values specified from the literature.
- HET: Horizontal heterogeneity in canopy structure. Optimized model parameters.
- AGG: 'big-leaf' model (aggregated model of forest canopy). Optimized model parameters
- **HET model has better predictive capability than AGG model**



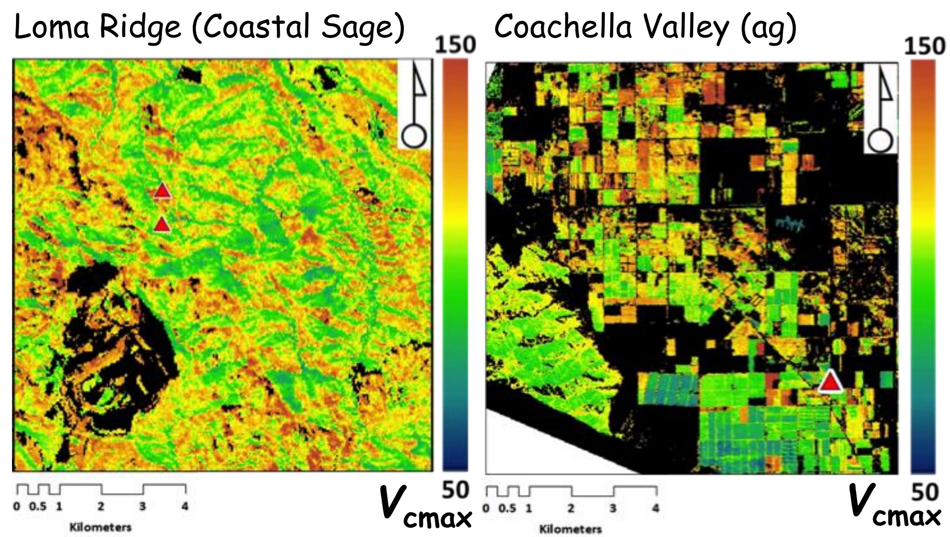
Imaging spectroscopy of plant physiology

PI: Phil Townsend, University of Wisconsin-Madison

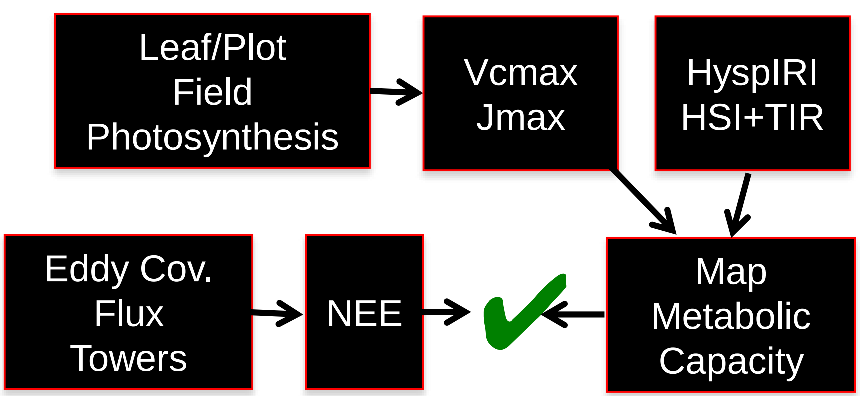


Objective

We proposed to use hyperspectral + thermal IR imagery from HyspIRI to map vegetation metabolic capacity of photochemistry.



Approach:



CoIs: Shawn Serbin (BNL), Mike Goulden (UCI)
Eric Kruger, Ankur Desai, Sean Dubois (UW)

Progress, Plans and Expected Results:

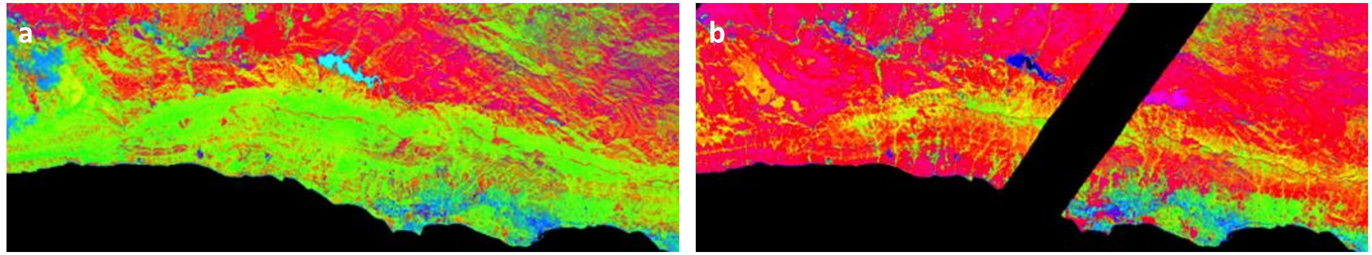
- Calibrations are robust for both broadleaf and conifer species;
- Sampled sites in spring and early summer in 2013 and 2014;
- EC tower flux data inversions in process; data set covers 19 towers and 224 images;
- Maps of V_{cmax} and J_{max} corroborate field measurements;
- Results provide basis to map key metabolic properties needed for earth system models using HyspIRI.

Drought Impacts on Vegetation Species Measured Using Simulated VSWIR Products

Phil Dennison[1], Austin Coates[1], Dar Roberts[2], Ken Dudley[1], and Keely Roth[3]
[1]University of Utah [2]UC Santa Barbara [3]UC Davis

Objective

• Determine the impacts of California's record drought on vegetation species cover and condition



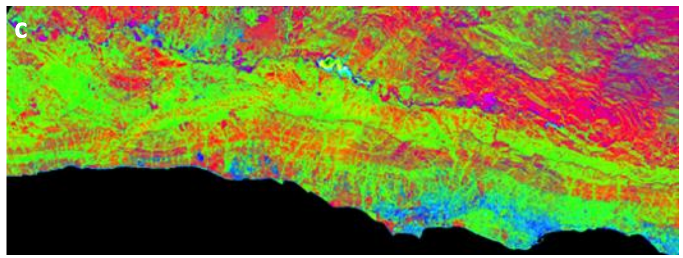
Approach

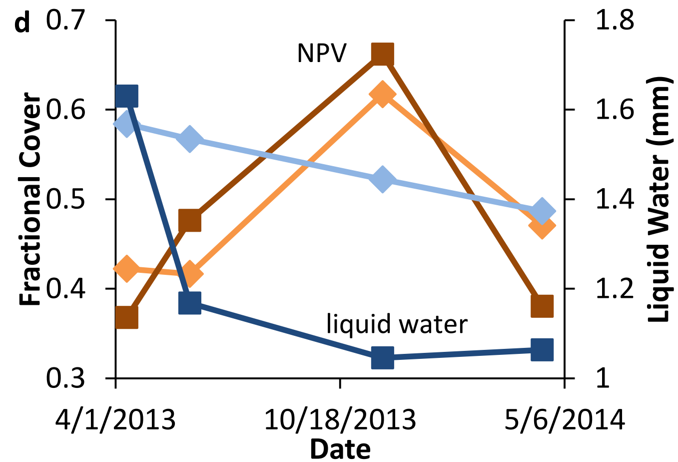
• HyspIRI VSWIR data can resolve differences between non-photosynthetic vegetation (NPV) and soil, measure canopy water absorption, and map dominant vegetation species

-Increased NPV fractional cover indicates senescence and canopy dieback

-Decreased liquid water thickness, a measure of canopy water content, indicates loss of leaf area and moisture

• Fractional cover and liquid water were calculated from simulated HyspIRI VSWIR products for 2013 and 2014 (2nd and 3rd year of drought).





a. Apr. 2013 normalized NPV, GV, and soil fractions; b. November 2013 fractions; c. April 2014 fractions; d. Species time series NPV and liquid water thickness for ADFA (light shades) and CEME (dark shades)

Progress and Expected Results

• Grassland and coastal sage scrub phenology dominate the short term change in fractional cover and liquid water when comparing April 2013 to June 2013

• Evergreen chaparral has strong increases in NPV fraction, indicating canopy dieback, when comparing April 2013 to June 2013 and November 2013

• Rainfall in late February/early March 2014 resulted in (likely temporary) recovery in NPV fraction, but minimal recovery in liquid water

• Ceanothus is more sensitive to long term drought compared to chamise, but also exhibits more recovery in GV and NPV fractions following rain

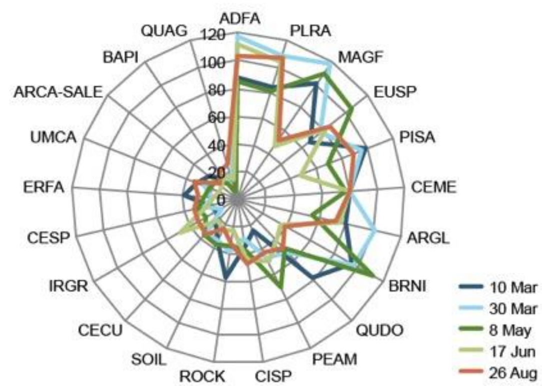
• Further analysis will incorporate 2014 summer and fall data, land surface temperature from MASTER data, and comparison of pre-drought (2011) to 2013-2014 will also be investigated

Mapping Species Using a Phenologically Inclusive Multi-temporal Spectral Library

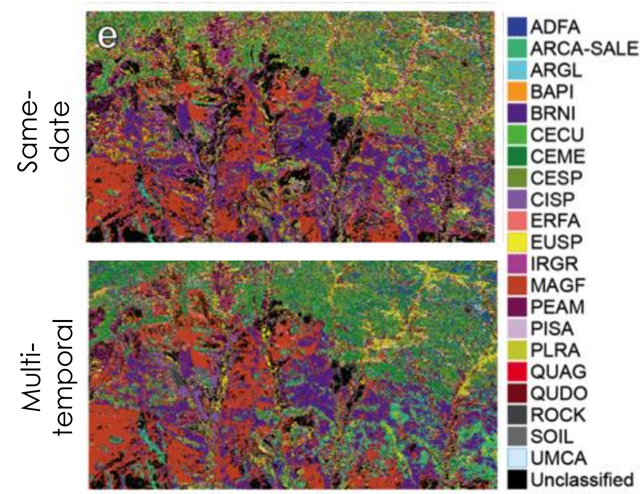
Dudley, K.L., Dennison, P.E., Roth, K.L., Roberts, D.A., Coats, A.R.

Objectives

- Incorporate a wider temporal range of spectra to facilitate mapping species as they vary across spatial, temporal, and phenological gradients
- Compare single-date and multi-temporal endmember library approaches for mapping species

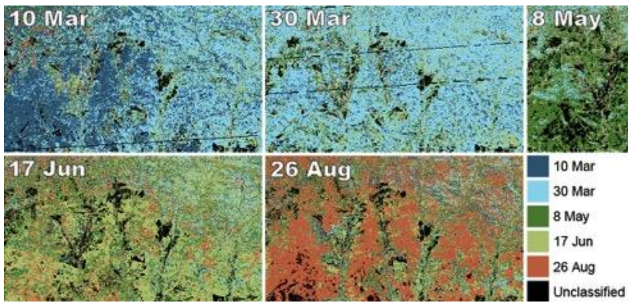


Number of EMs selected by IES for multi-temporal library



Approach

- Utilized 5 2009 AVIRIS image dates for Santa Ynez Mountains, California
- Extracted spectra from species polygons to create 5 single date libraries and a combined multi-temporal library
- Used Iterative Endmember Selection (IES) to select optimal EM subset for single date and multi-temporal libraries
- Used Multiple Endmember Spectral Mixture Analysis (MESMA) to map species using single date and multi-temporal libraries
- Assessed mapping accuracy and dates of endmembers used for mapping



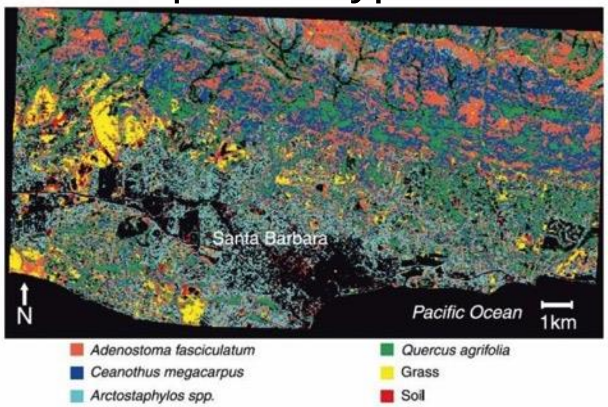
Endmember dates used to classify each pixel

Results

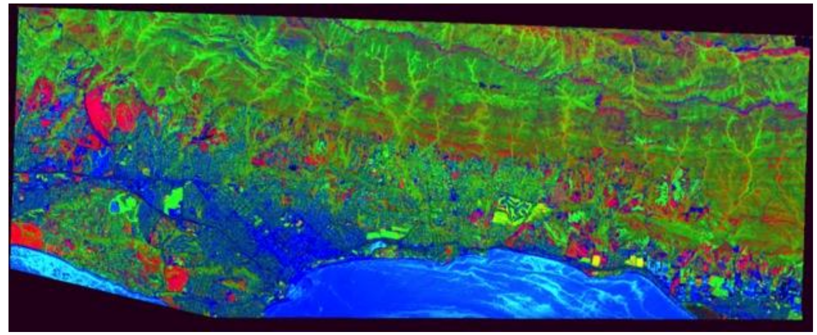
- Number of endmembers used varied by species and date
- Multi-temporal classification had equivalent accuracy to single-date classification (within 1.3%)
- Endmember dates varied over space, and classification accuracy improved for several species

Fire: Risk, Burning, Severity and Recovery

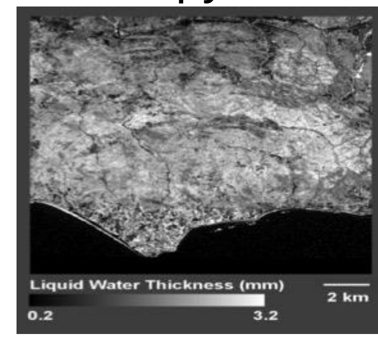
Species Type



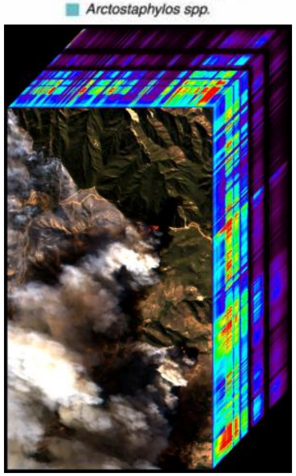
Dry Biomass (Cellulose/Lignin)

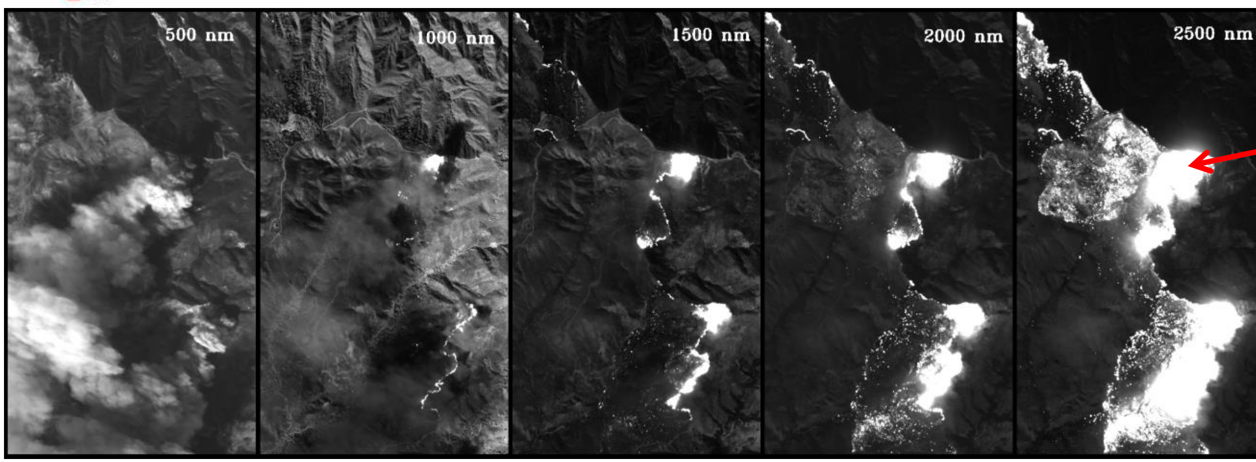


Canopy Water

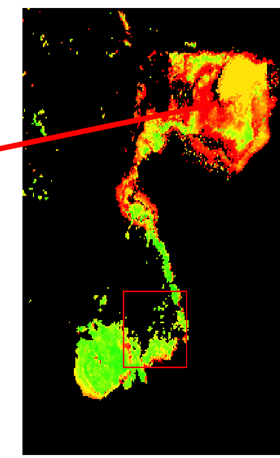


Simi Valley Fire 2003

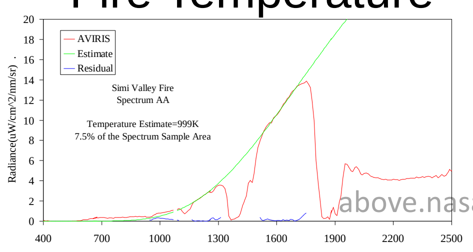




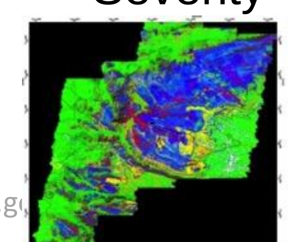
T ~ 1200K



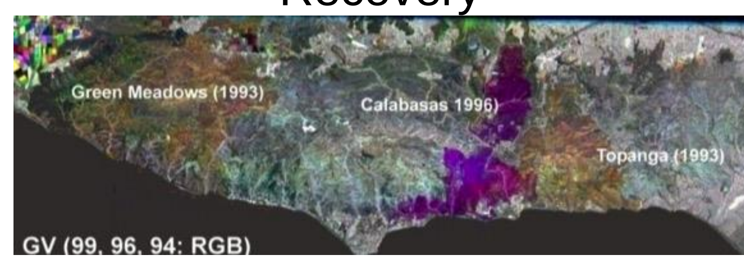
Fire Temperature



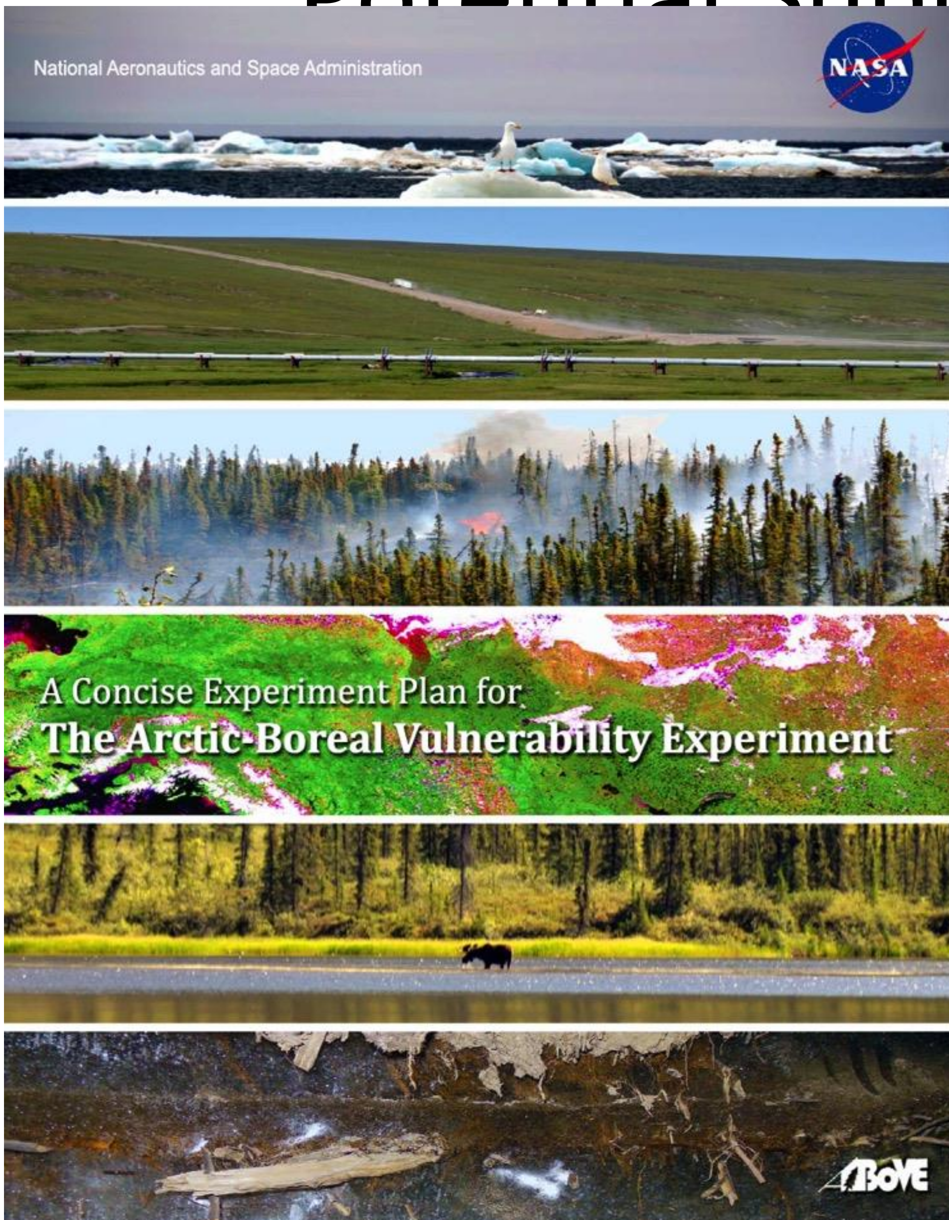
Severity



Recovery



Potential Support To ABoVE



- AVIRIS-NG is being adapted to fly on both the B200 and ER-2
- AVIRIS-NG delivers both level-1 and level-2 (reflectance) product through advanced algorithms developed for HyspIRI
- AVIRIS-NG equals or exceeds all ecosystem capabilities of AVIRIS-C
- With full VSWIR imaging spectroscopy, AVIRIS-NG can contribute in areas of the atmosphere (methane), snow and ice, coastal and inland waters, human infrastructure, etc.
- AVIRIS-C has flown in Alaska and was part of BOREAS

ASA_ABoVE