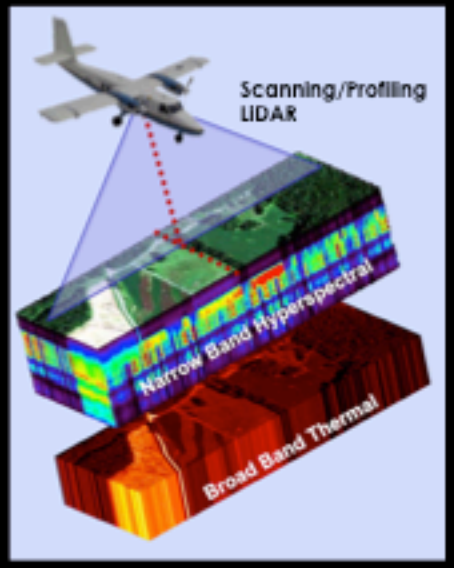
G-LiHT:
Goddard's LiDAR, Hyperspectral and Thermal Airborne Imaging System



Bruce D. Cook, PI

Larry Corp, Ross Nelson, Doug Morton, Betsy Middleton, Jon Ranson, Jeff Masek

NASA Goddard Space Flight Center, Biospheric Sciences Laboratory

Today's Talk

* What is G-LiHT?
* What makes G-LiHT unique?
* Why do we need G-LiHT?
* G-LiHT data products & distribution

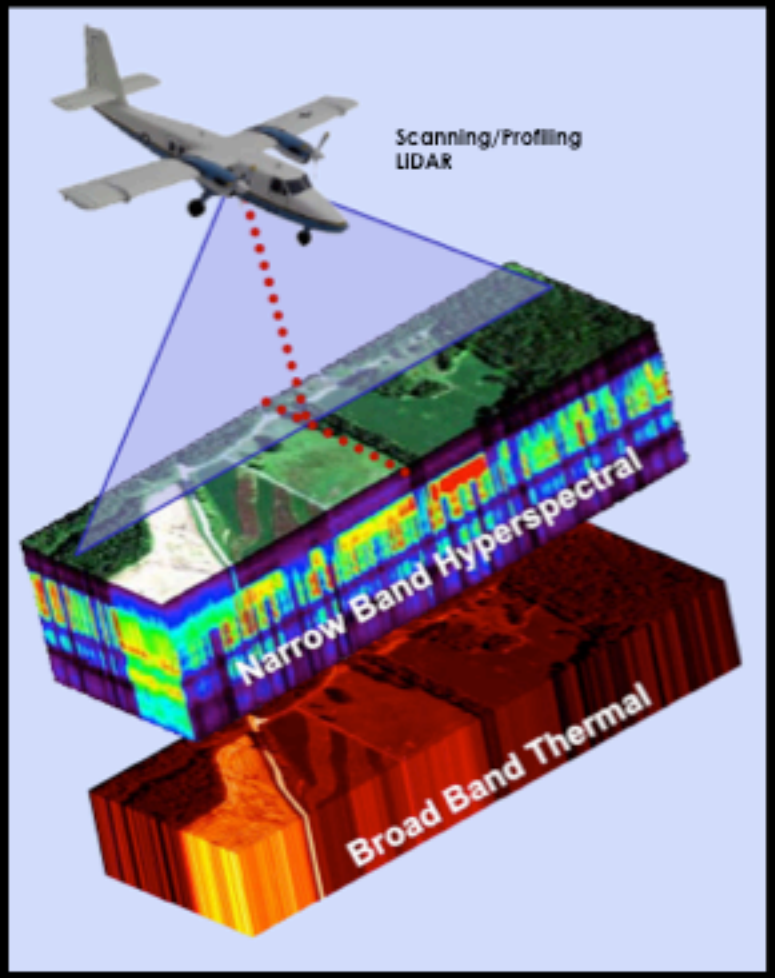
What is G-LiHT?

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;

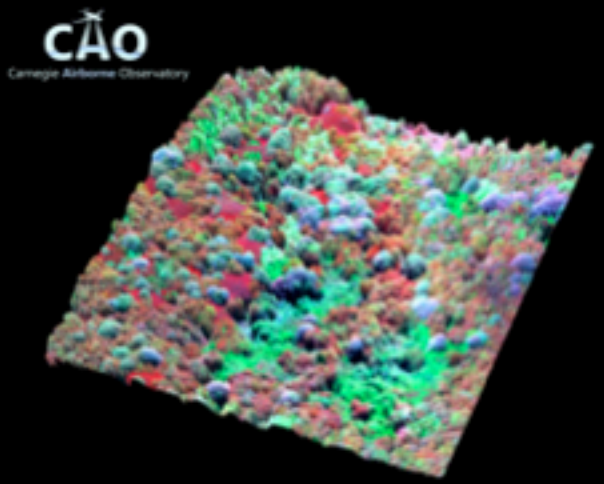
2) *imaging spectroscopy* to discern species composition and variations in biophysical variables (e.g., photosynthetic pigments, nutrient and water content); and

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



Other LiDAR-Spectrometer Systems

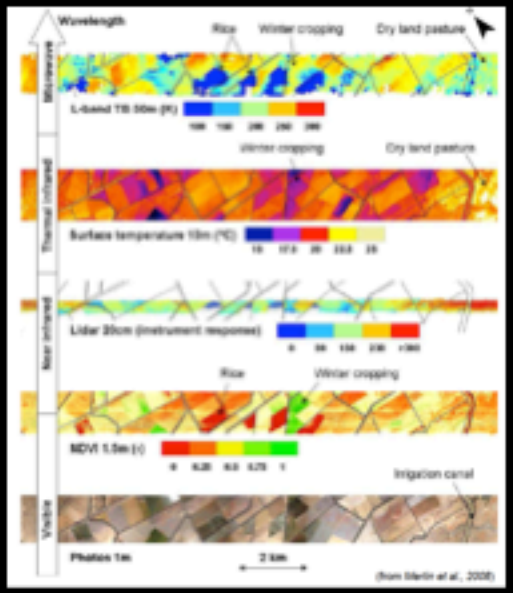
Carnegie Airborne Observatory (CAO)
Greg Asner, PI



Airborne Observation Platform (AOP)
NEON

University of Victoria
Olaf Niemann, PI

Airborne Research Australia (ARA)
Flinders University



What Makes G-LiHT Unique?

- ✓ Off-the-shelf instrumentation (lower costs, higher TRL)
- ✓ Surface temperature observations
- ✓ Downwelling irradiance measurements
- ✓ Profiling *and* scanning LiDAR instruments
- ✓ Eye-safe lasers at two wavelengths (905, 1550 nm)
- ✓ Portability (small, lightweight, non-ITAR)
- ✓ Versatility (adaptable to many platforms, low power)
- ✓ Low operating costs (~$1/ha for acquisition and processing)

Instruments & Specifications

Fully integrated system

Overall Physical Specifications

Size (W×H×L): 30 × 30 × 60 cm
Weight: 37 kg (G-LiHT); 10 kg (pod)
Power: 210 W (7.5 A, 28 VDC)
Date volume: 0.5 to 1 Tb per day
Cost: ~$500k

"Off-the-shelf" Instruments:

① Scanning LiDAR
Riegl VQ-480
50-300 kHz; 1550 nm; onboard waveform processing

② Profiling LiDAR
Riegl LD321-A40
10 kHz; 905 nm; up to 5 returns per laser shot

③ VNIR imaging spectrometer
Headwall Hyperspec
50 Hz; 0.4 to 1 μm, 1.5 nm resolution; pushbroom array

④ VNIR irradiance spectrometer
Ocean Optics USB4000
1 Hz; cosine diffuser mounted above wing

⑤ Thermal imager
Xenics Gobi-384
25 Hz; non-cooled microbolometer, 8 to 14 μm

⑥ GPS-INS
Oxford RT-4041 with OmniStar HP
250 Hz; 10 cm position, 0.1° yaw, 0.03° roll/pitch accuracy

I&T

Fabricated a wing-mounted pod with LaRC that is compatible with all Cessna 206

Boresight error ~15 cm in pod

I&T on other platforms (internal view port)

NASA UC-12B (King Air)

Piper Cherokee

Data Acquisition Specifications*

Specification	Scanning LiDAR	VNIR Spectrometer	Thermal camera
Swath, m	88 (15° FOV) 180 (30° FOV) **387 (60° FOV)**	71 (35 mm lens) 207 (12 mm lens) **310 (8 mm lens)**	**173 (19 mm lens)**
Cross-Track resolution, m	**0.10 (0.3 mrad)**	0.07 (35 mm lens) 0.21 (12 mm lens) **0.31 (8 mm lens)**	**0.45 (19 mm lens)**
Along-Track resolution, m	**0.10 (0.3 mrad)**	**~1 (50 fps)**	**~2 (25 fps)**
Laser pulse density, shots m^{-2} (PRF = 300 kHz)	**7**	---	---

**Flight parameters: 335 m AGL, 110 kt*

Data volume: ~0.5 to 1 TB per day

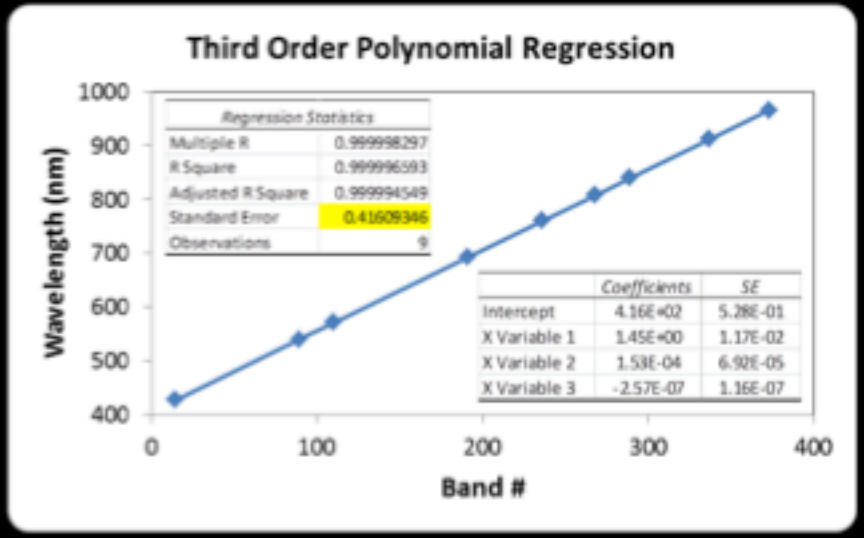
Spectrometer: Wavelength Calibration

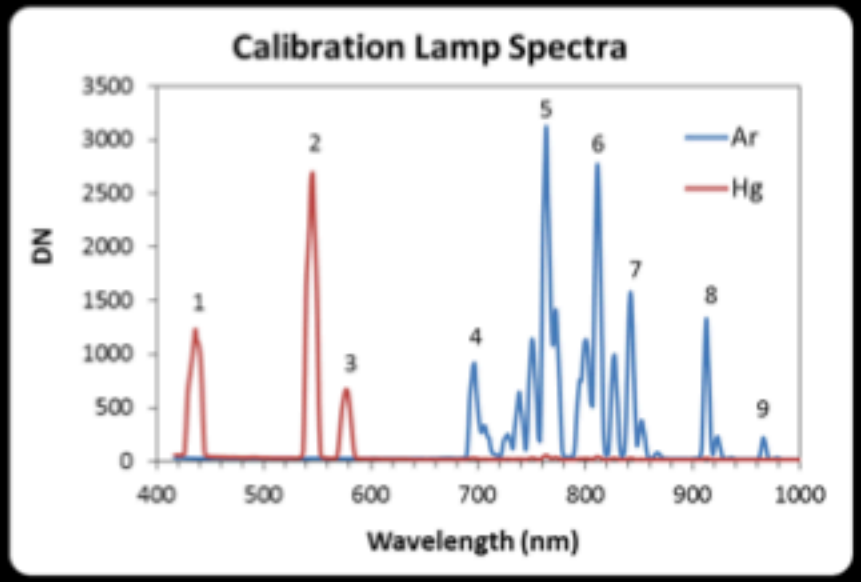
Methods:

* Teflon integrating sphere with Hg and Ar lamps used to map spectral channels to wavelength with sub-nanometer precision.
* Spectrometer is periodically monitored for wavelength stability and drift.
* Typical operation with 2x at sensor spectral binning.

Specifications:

- Spectral Bands: 402
- Wavelength Range: 417.0 to 1007.8 nm
- Nominal Sampling Resolution: 1.5 nm
- Nominal Spectral Resolution: 6 nm FWHM





Spectrometer: Radiometric Calibration

GSFC Biospheric Sciences' Calibration Facility:

A Labsphere 42" large aperture NIST traceable uniform source was used to perform and periodically verify the radiometric calibration of G-LiHT's imaging and down-welling radiance spectrometers.

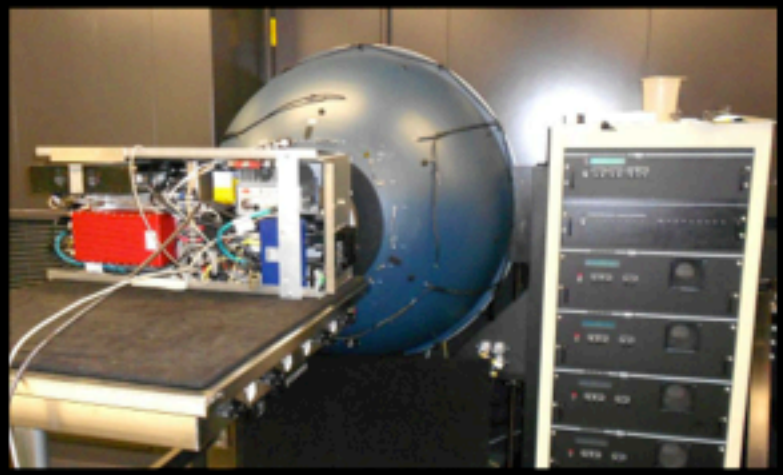


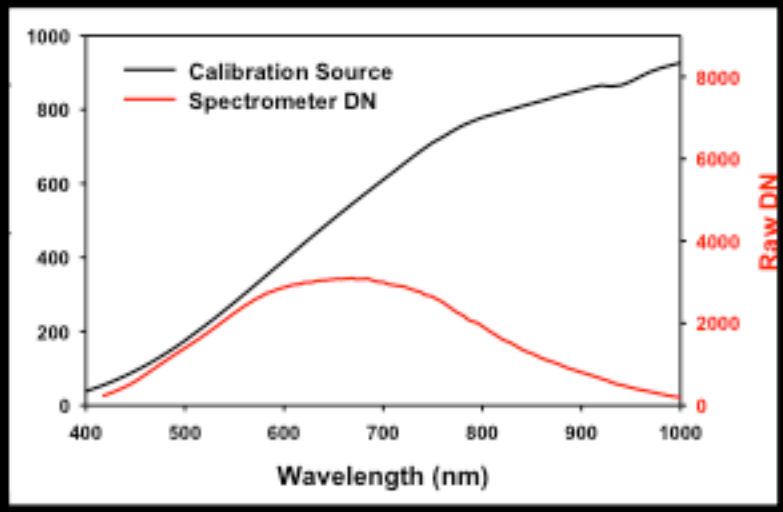
Image Spectrometer Components:

1) Adimec RA1000m/D Imaging Camera

* Ruggedized MILSPEC 12 bit interline CCD System
* 1004 x 1004 full frame format with 7.4 µm pixels
* Dynamic Range: 60 dB
* Up to 50 full fps via Dual CameraLink interface.

2) Hyperspec™ Concentric Imaging Spectrometer

* High efficiency f/2.0 telecentric optics.
* Aberration-corrected convex diffraction grating.
* Dispersion: 100 nm per mm
* Focal Plane: 7.4 mm x 6.0 mm
* Entrance Slit: 25 µm
* C-mount 8 mm objective lens.



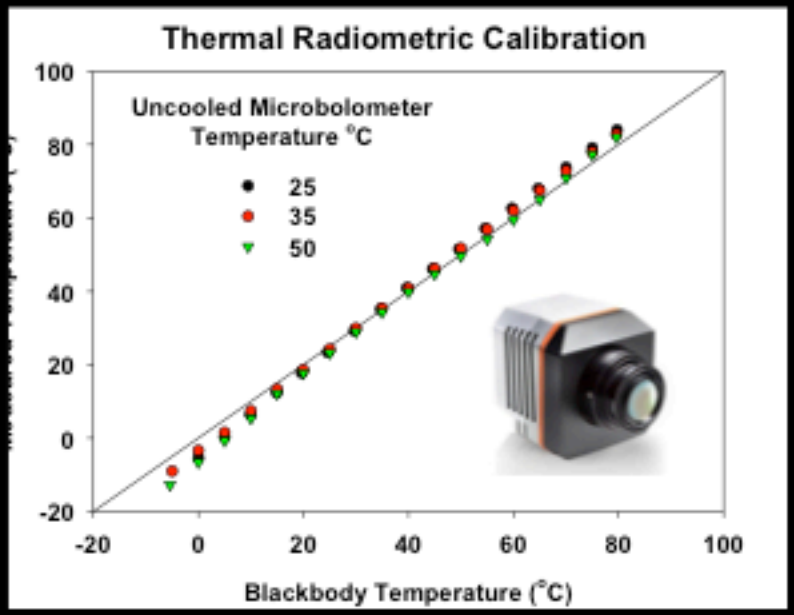
Thermal Image Data and Calibration

Science questions addressed by thermal data:

* How is physiological function affecting water and carbon exchange expressed at the ecosystem scale, especially down-regulation due to environmental stress factors?
* What is the vegetation phenological response to seasonal/interannual changes in temperature due to climate change and how does this response vary at the community/species level?
* What are the feedbacks between changes in canopy composition, crown mortality and canopy temperatures resulting from disturbances in forest ecosystems?
* How do climate-induced temperature changes impact the distribution and spread of invasive species?

Xenics Gobi-384 LWIR Camera:

* Detector: uncooled microbolometer
* Array size: 384 x 288 on 25 µm pixels
* Sensitivity: 8 to 14 µm
* Frame Rate: 25 Hz at 16-bit resolution
* Sensitivity (NETD) >50 mK @ 30°C



LiDAR Geolocation

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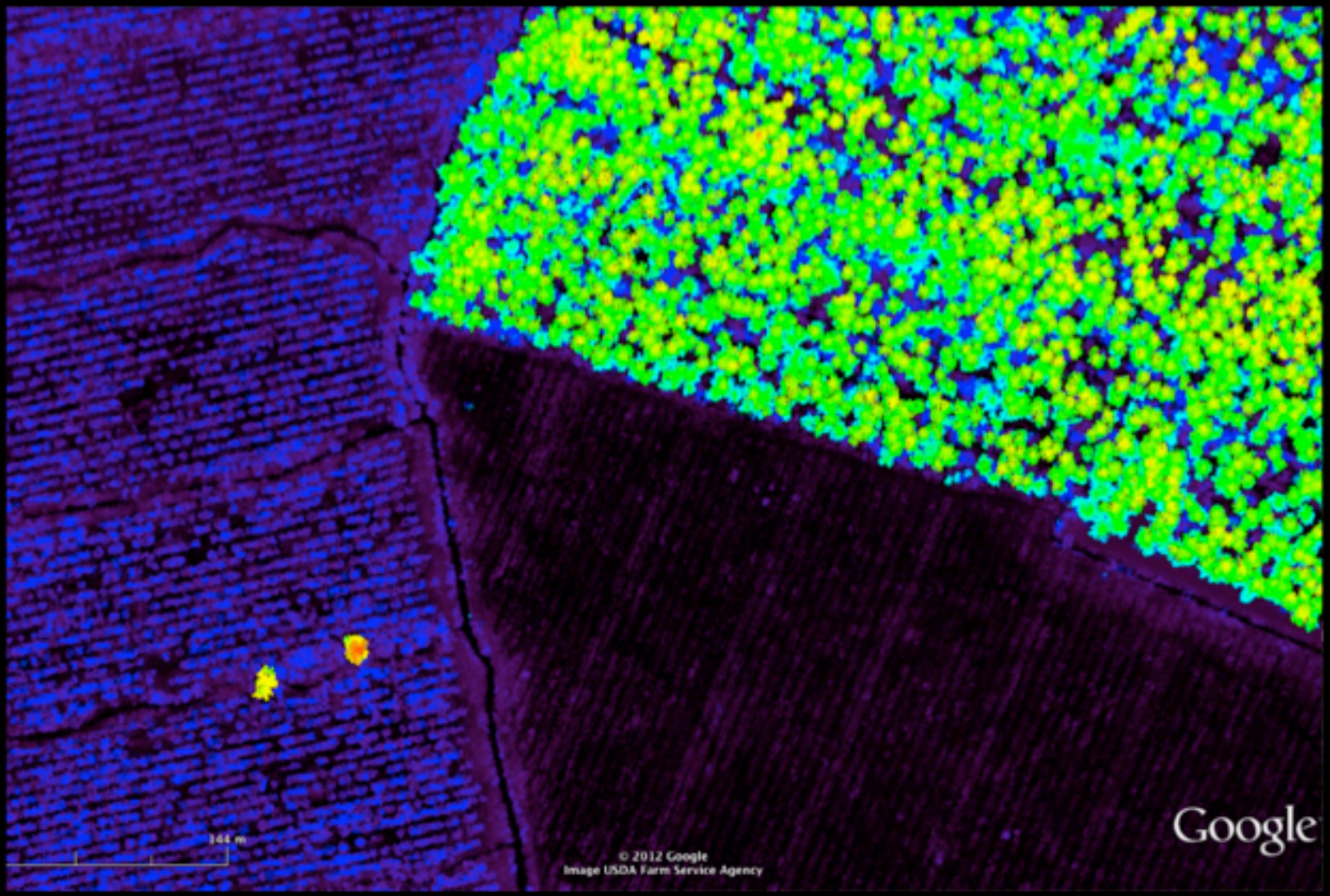
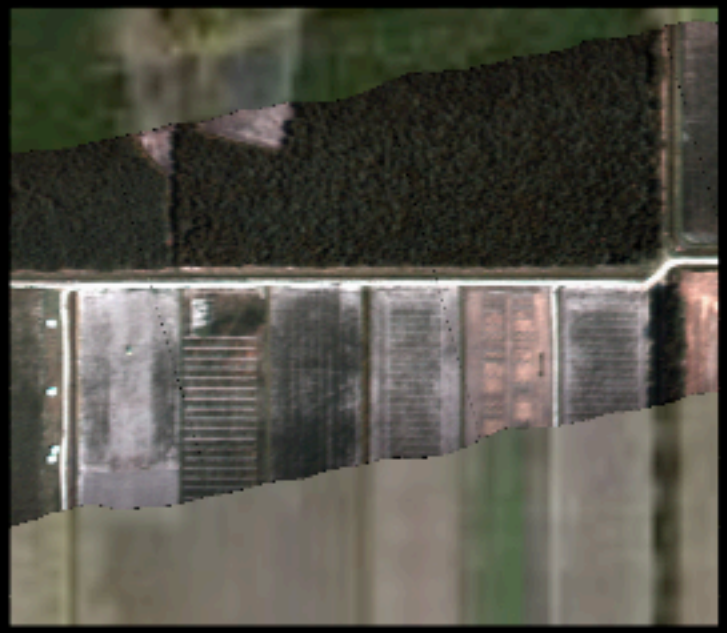
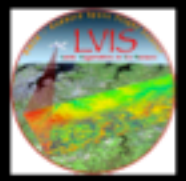


Spectrometer Geolocation

Fine-resolution VNIR spectra at
forest stand and individual tree level



Independent Data for QC



Spectrometer Data:

* NEON AOP (Harvard Forest, 2012)
* Hyperion (Parker Track, 2011; Harvard Forest, 2012)
* Field spectrometer measurements
* Calibration targets (panels, tarps)

Elevation and Height Measurements:

* National Elevation Dataset (NED)
* LVIS: SERC, Harvard Forest, Howland/Penobscot Forests
* Small footprint: SERC, Parker Track, Howland/Penobscot Forests
* Field observations (esp. hard targets such as towers, buildings)

Why G-LiHT?

1) Science
   - Fine-res (<1 m) data is well suited for studying tree-level ecosystem dynamics
   - Full potential of *data fusion* can be evaluated with accurately co-registered data

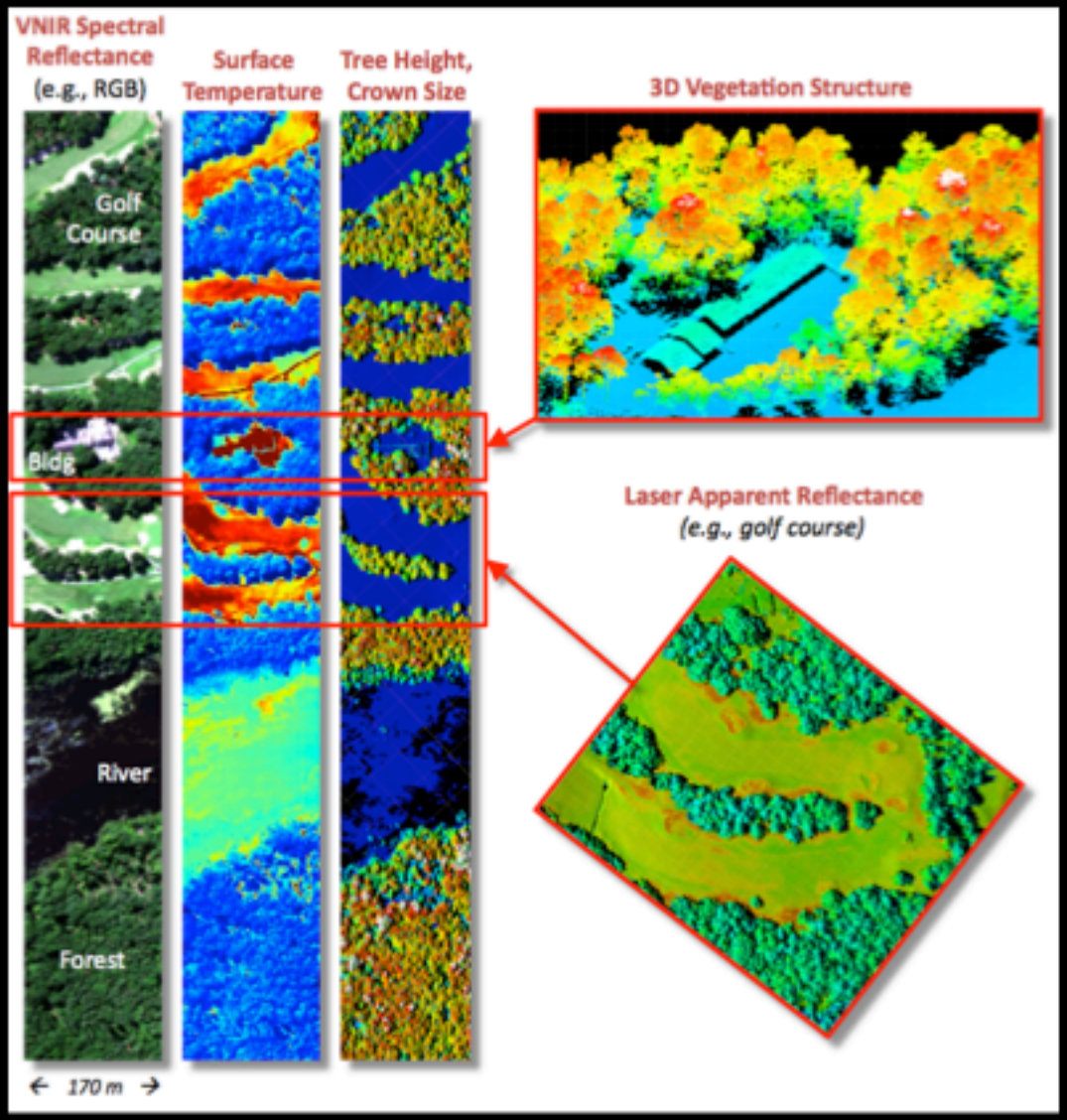
2) Applications
   - Forest health and productivity of forest stands and individual trees
   - *Local-scale mapping* and *regional-scale sampling* of plant biomass, photosynthesis, productivity, and disturbance/degradation

3) Mission support
   - Cal/Val (e.g., ICESat, ICESat-2, ~~DESDynI~~)
   - Algorithm development (e.g., HyspIRI)

4) Portability and Cost
   - Small and lightweight, non-ITAR, compatible with common GA aircraft
   - Less than $1 per hectare for L3 data products

NASA's Initiation of G-LiHT

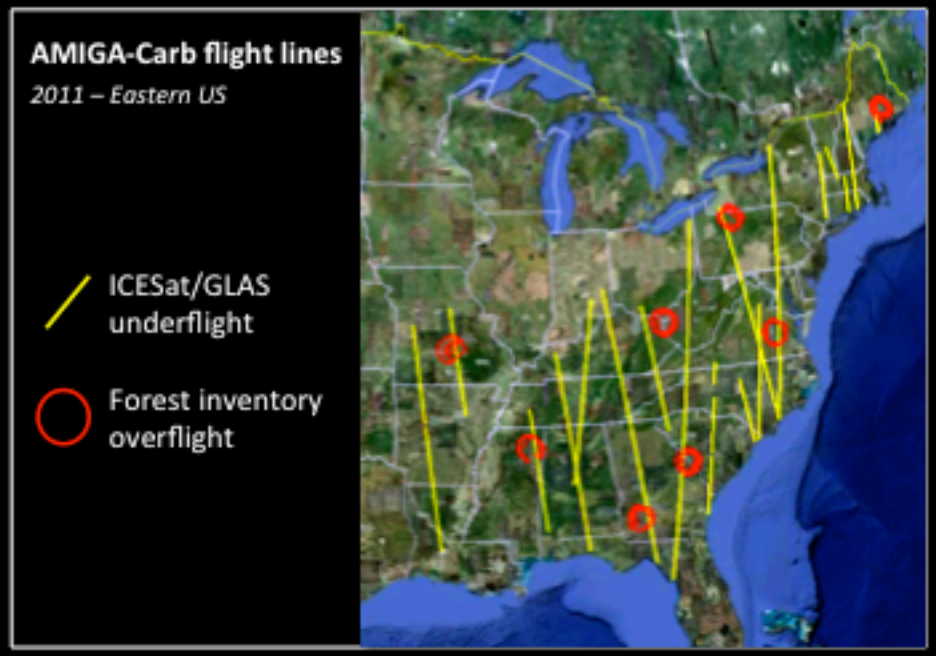
LiDAR-Passive Optical-Thermal Synergy

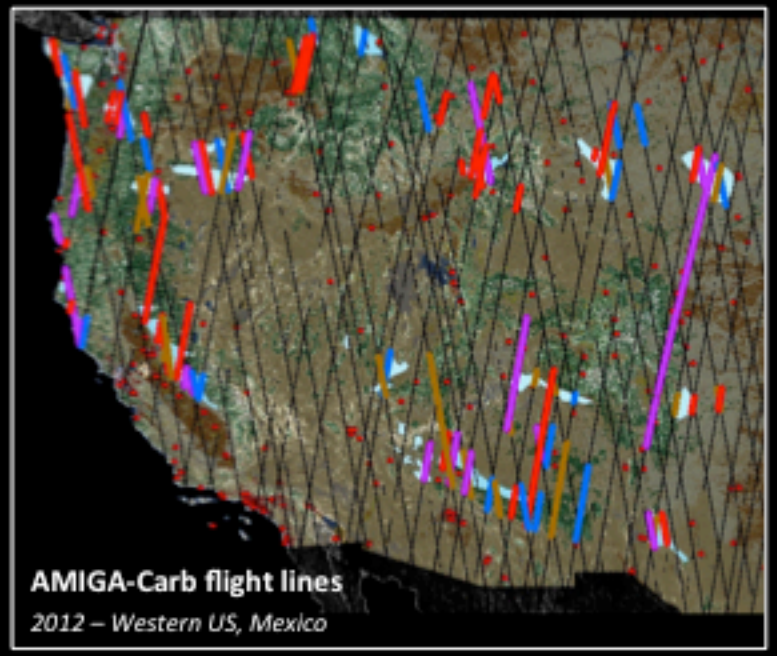


Projects & Mission Support

* Carbon Monitoring System (NASA CMS; B. Cook *et al.*)
  - 2011: Parker Track, NC; Smithsonian Environmental Research Center, MD
  - 2012: Harvard Forest, MA; Howland, Penobscot and Holt Forests, ME; CNNF, WI
* AMIGA-Carb (NASA Carbon Cycle, R. Nelson *et al.*)
  - 2011: Eastern US
  - 2012: Western US
  - 2013: Mexico
* Emerald Ash Borer (EAB) and Tree Health (USDA-FS & NASA pilot project)
  - 2012: Washington, DC and Baltimore region
* Siberian Larch Forests (NASA Terrestrial Ecology, J. Ranson et al.)
  - 2013-15: Acquisitions on MI-8 platform
* ICESat-2 Mission
  - 2012: Coincident G-LiHT/GLAS tracks are being flown by MABEL

AMIGA-Carb: American ICESat/ GLAS Assessment of Carbon

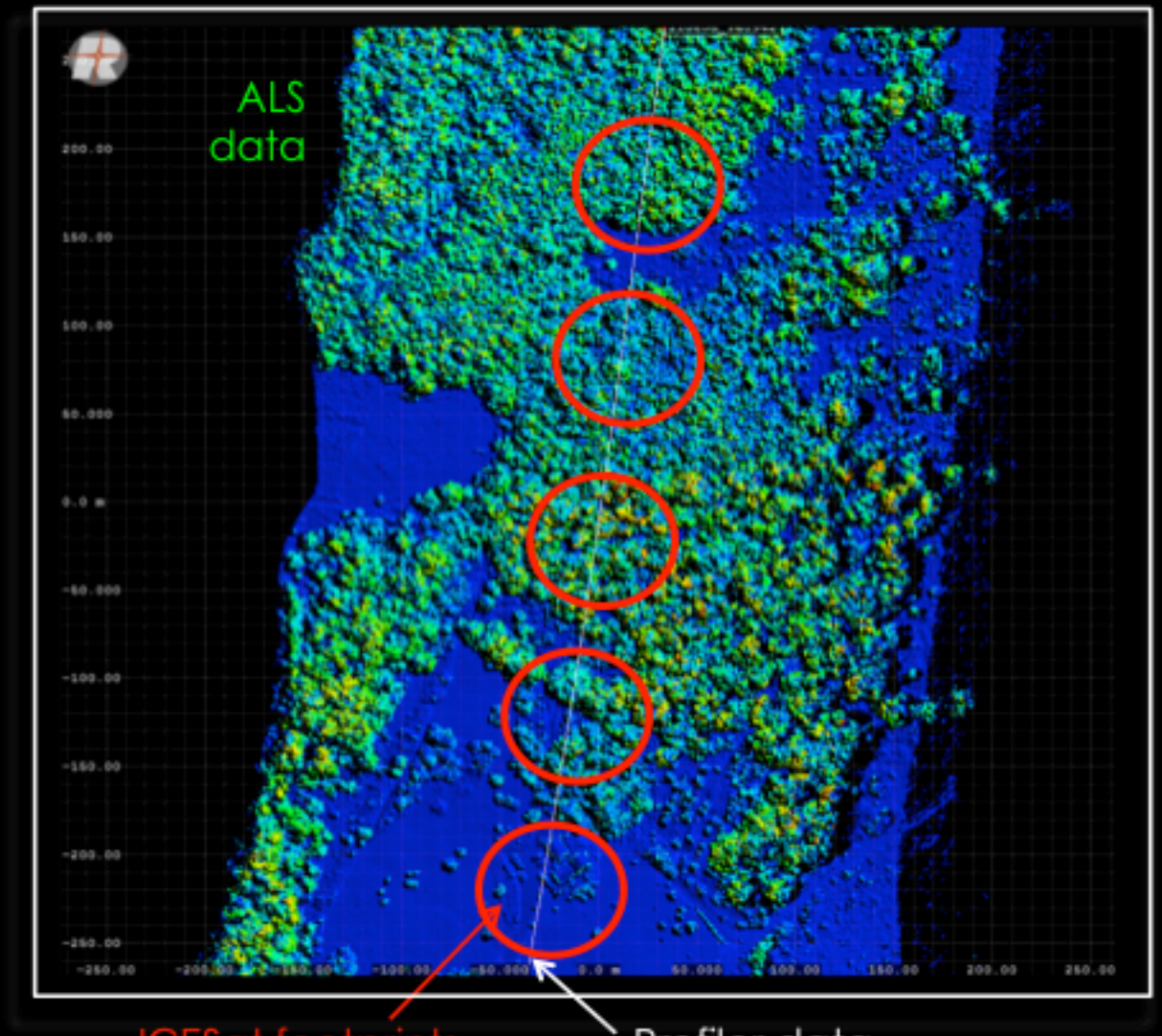


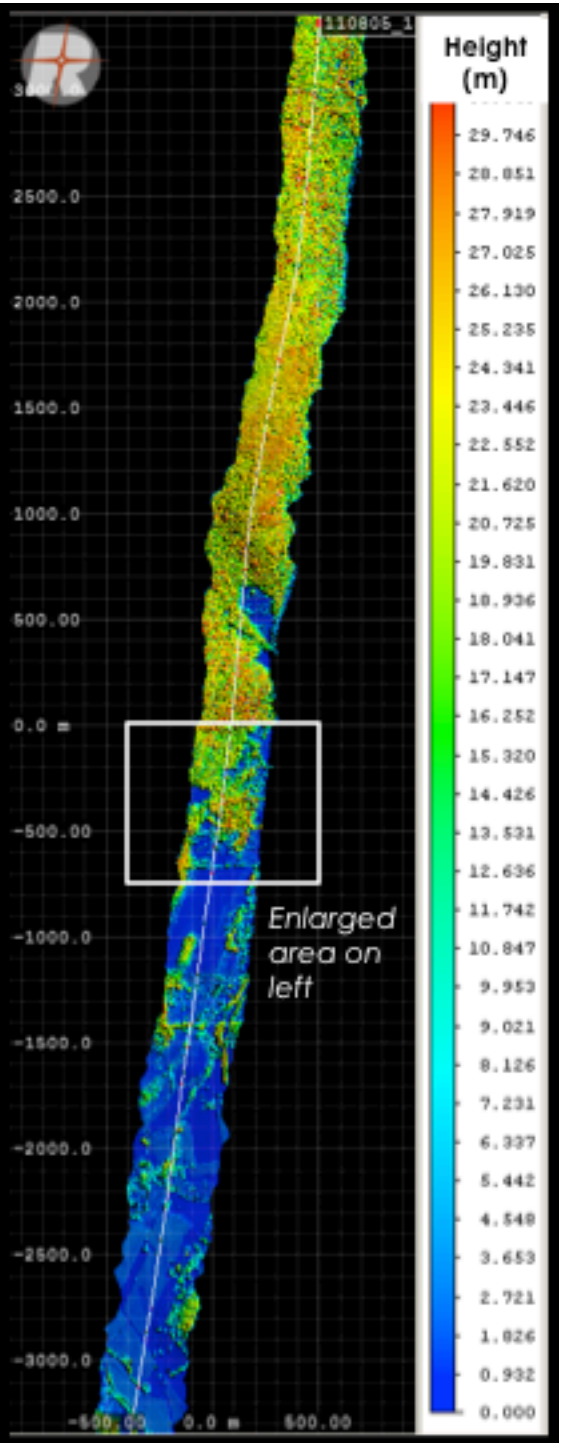


Ross Nelson, PI

…and Mexico in January 2013!

ICESat/GLAS Underflight





Facilitating G-LiHT Data Use

Goal: Provide *open access* to *G-LiHT data* and *higher-level products* in *readily usable formats* (i.e., LAS, floating point GeoTIFFs, and Google Earth kml superoverlays).

LiDAR Products

* Classified point cloud data and feature heights in standard LAS format
* Modeled ground elevation and canopy height (DEM, CHM)
* Common LiDAR metrics

Spectroscopy Products

* Vegetation indices and spectral bio-indicators (e.g., NDVI, PRI, red-edge)
* Reflectance spectra (400-100 nm, 1.5 nm resolution)

Thermal Product (surface temperature)

Associated ground data [where available]

Software tools (e.g., plot extraction)


For more information:
http://gliht.gsfc.nasa.gov