FLEX-US 2013 Airborne Campaign Summary

Collaboration between NASA, ESA, and the FLuorescence Explorer Mission

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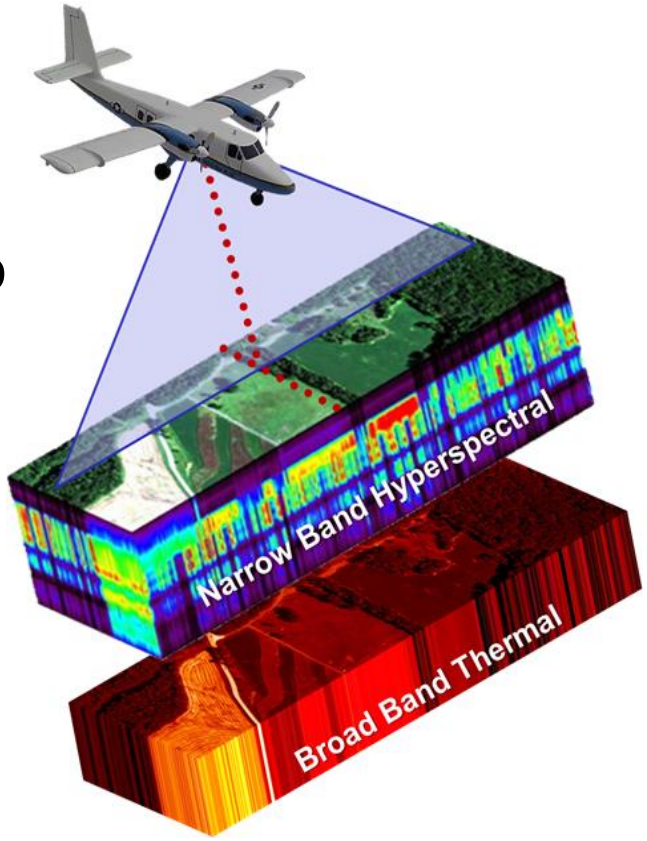


NASA Goddard Space Flight Center
To understand and protect our home planet, to explore the Universe and search for life,
to inspire the next generation of explorers...as only NASA can.
SSAI

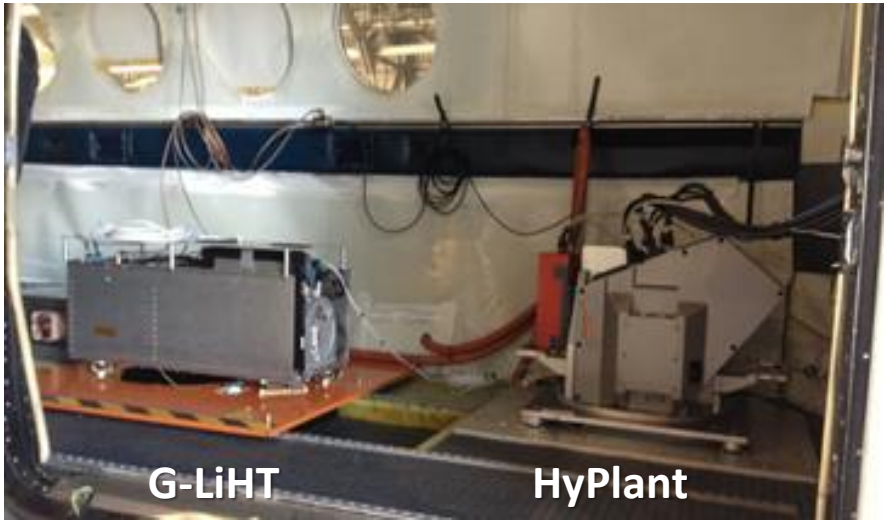
FLEX-US 2013 Airborne Campaign

Collaboration between NASA, ESA, and the FLuorescence Explorer Mission

Objectives:

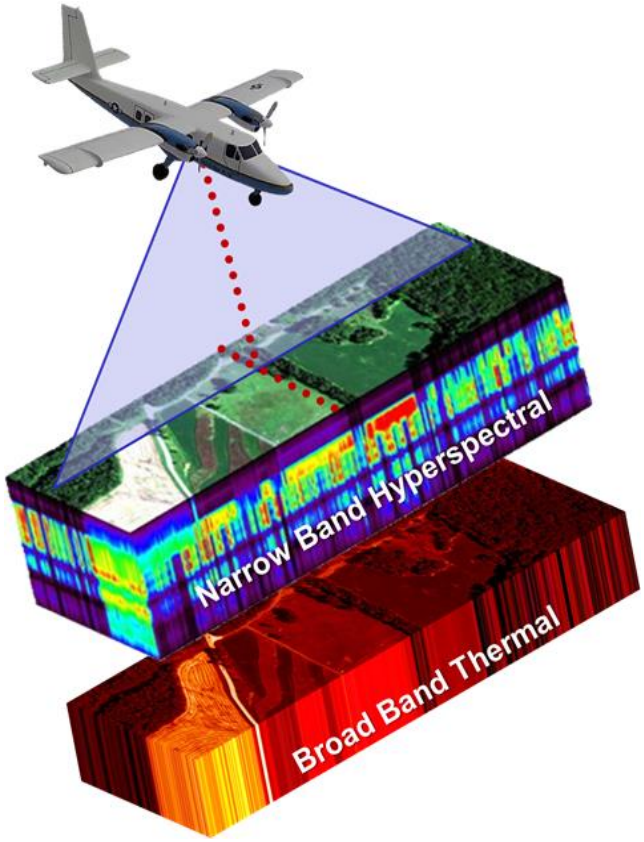
- **Successfully co-manifest a comprehensive set airborne instruments on the NASA LARC KingAir.**
- **Conduct science flights, obtaining morning, mid-day, and afternoon datasets for two unique ecosystems in North Carolina.**

G-LiHT & HyPlant Flight Testing NASA LARC USA

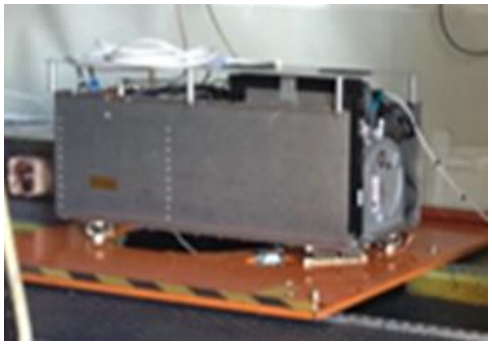


Campaign retreat Monschau Germany

Goddard's LiDAR, Hyperspectral, and Thermal Airborne Imager (G-LiHT)



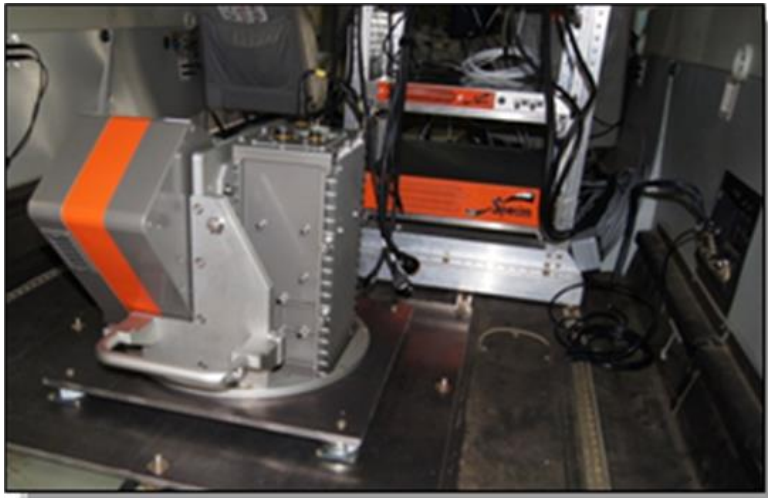
- Scanning LiDAR
- VNIR Imaging Spectrometer
- Broad Band Thermal Imager
- Single Solution GPS-INS
- Irradiance Spectrometer
- Integrated PC
- DSLR Camera



Designed to study composition, structure, and function of terrestrial surfaces using; scanning LiDAR, Hyperspectral & Thermal infrared imaging.

FLEX-US 2013 Airborne Campaign: HyPlant

AisaFENIX: A commercial off the shelf (COTS) solution to VSWIR full spectral range imaging spectroscopy.

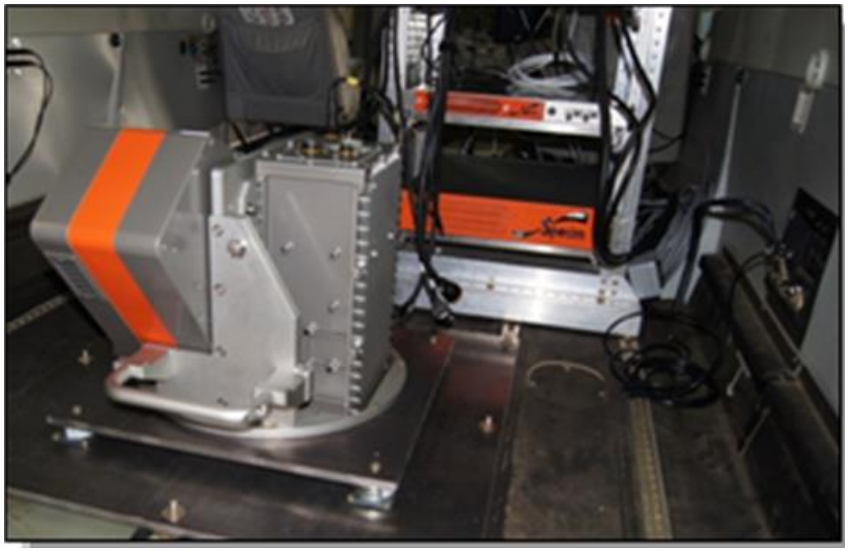


OPTICAL CHARACTERISTICS	TYPICAL SPECIFICATIONS			
	VNIR			SWIR
Spectrograph	High efficiency transmissive imaging spectrograph. Throughput practically independent of polarization. Smile and keystone < 0.2 pixels.			
Numerical aperture	F/2.4			
Spectral range	380 - 970 nm			970 - 2 500 nm
Spectral resolution	3.5 nm			12 nm
Calibration	Sensor provided with wavelength and radiometric calibration file.			
FORE OPTICS				
FOV	32.3 degrees			
IFOV	0.084 degrees			
Swath width	0.58 x altitude			
Altitude for 1 m pixel size	660 m			
ELECTRICAL CHARACTERISTICS				
Detector	CMOS			Stirling cooled MCT
Spectral binning options	2x	4x	8x	-
Number of spectral bands	348	174	87	274
Spectral sampling/band	1.7 nm	3.4 nm	6.8 nm	6 nm
Frame rate, up to (frames/s)	100			
Spatial pixels	384			
Output	12 bits CL			16 bits CL
SNR	600 - 1 000:1 (peak) *			1 300:1 (peak)
	More detailed SNR data in various conditions available from SPECIM.			
Integration time	Adjustable, within frame time			
Shutter	Electromechanical shutter for dark background registration, user-controllable by software.			
Operating modes	Hyperspectral and multispectral. The operator can create application specific band configurations, and quickly change from one mode or configuration to others in flight operation.			
Typical power consumption **	150 W			
Maximum power consumption **	500 W			
ENVIRONMENTAL CHARACTERISTICS				
Storage	- 20 ... +50 °C			
Operating	+ 5 ... +40 °C, non-condensing			

FLEX-US 2013 Airborne Campaign: HyPlant

AisaIBIS Imaging Spectrometer:

Ultra-high spectral resolution from 670 to 780 nm for airborne imaging of Solar Induced Fluorescence.

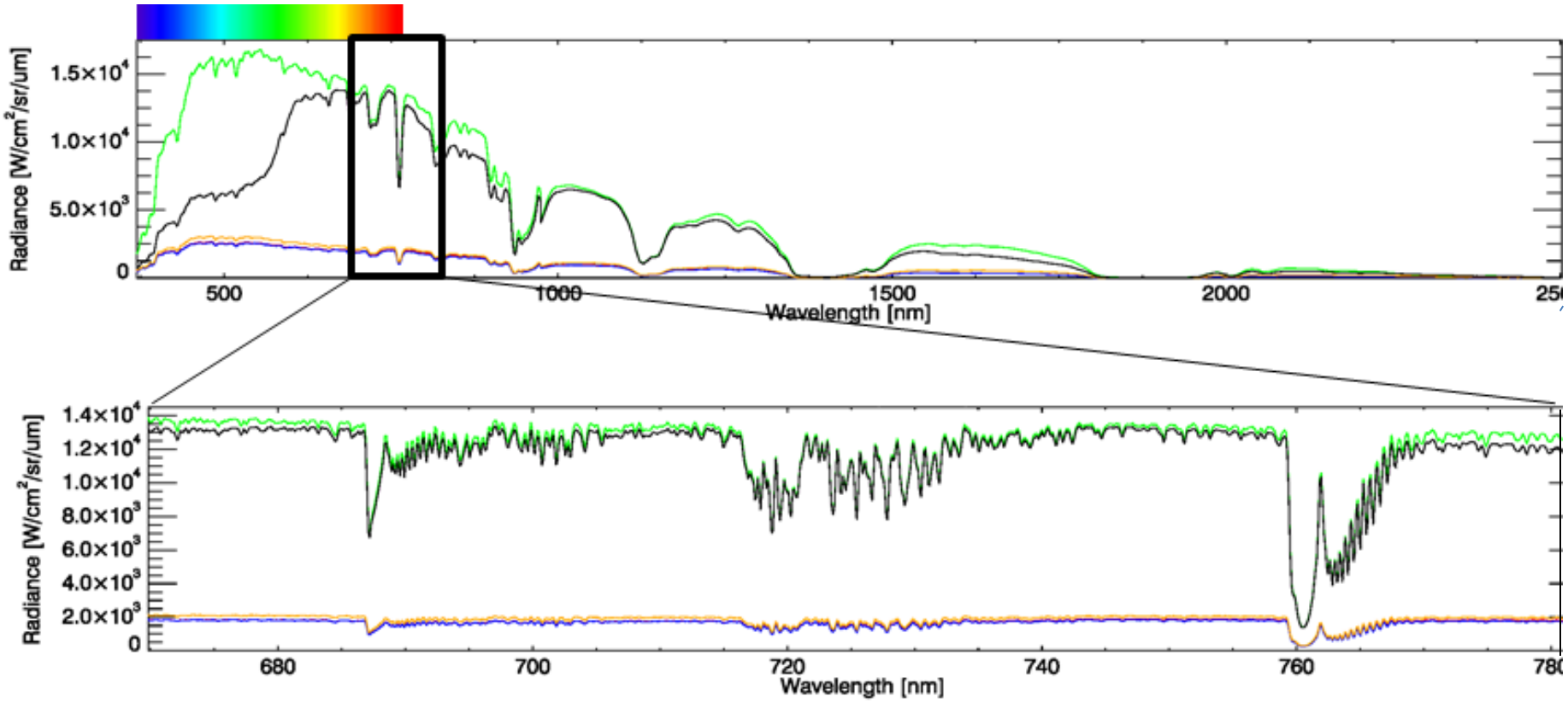


Specim

AisaIBIS		
Optical characteristics		
Spectral range	670 - 780 nm	
Spectral sampling	0.11 / 0.22 nm	
F/#	F/1.7	
FOV, focusing range	32.3, 0.5m to infinity	
Electrical characteristics		
Detector	sCMOS, snapshot mode	
Spatial pixels	384 / 768	
Spectral bands	1 000	
Detector cooling	Peltier	
Optics temperature stabilization	Yes	
Camera output	16-bit CL	
Signal-to-noise ratio	680:1 (at max. signal level)	
Data cable	Length 5 meters	
Frame grabber	BitFlow Karbon CL-4	
Camera control	USB / RS232	
Frame rate	Up to 100 Hz	
Exposure time range	Adjustable within frame time	
Power consumption	Nominal 135 W, Max 200W	
Input voltage	18 - 36 VDC	
Mechanical characteristics		
Size (L x W x H)	Sensor	Power supply & Control unit
	588 x 227 x 160 mm	300 x 190 x 130 mm
Weight	14.2 kg	approx. 5 kg
Shutter	Electro-mechanical shutter for dark image acquisition	
Environmental characteristics		
Storage	- 20 ... +50 °C	
Operating	+ 5 ... +40 °C, non-condensing	
SpectralDAQ support	Yes	
Accessories	Radiometric and geometric calibration, white calibration tile	

FLEX-US 2013 Airborne Campaign: HyPlant

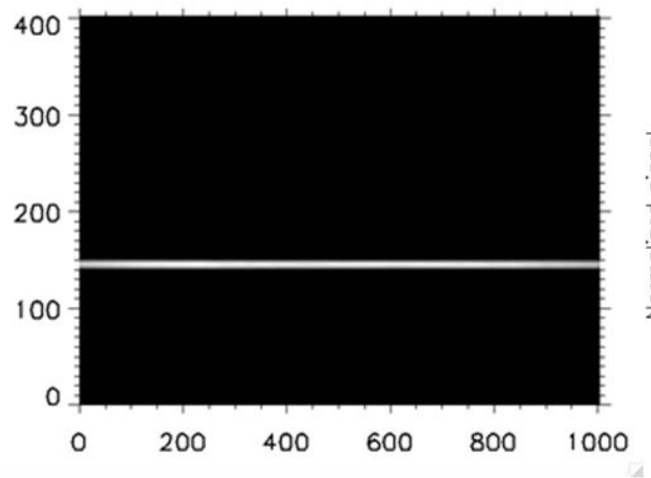
AisaFENIX

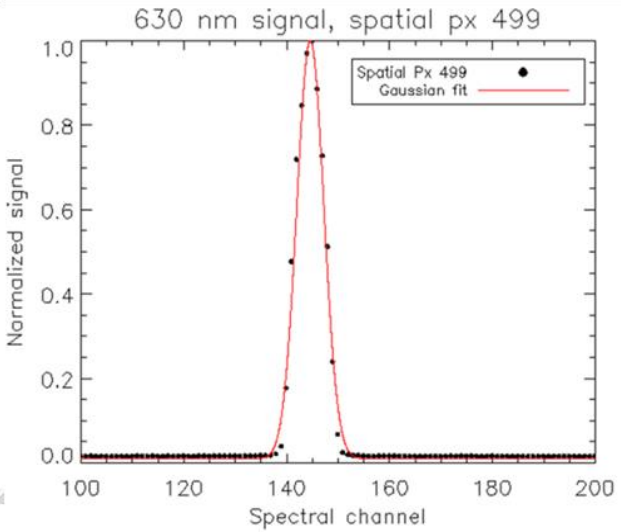


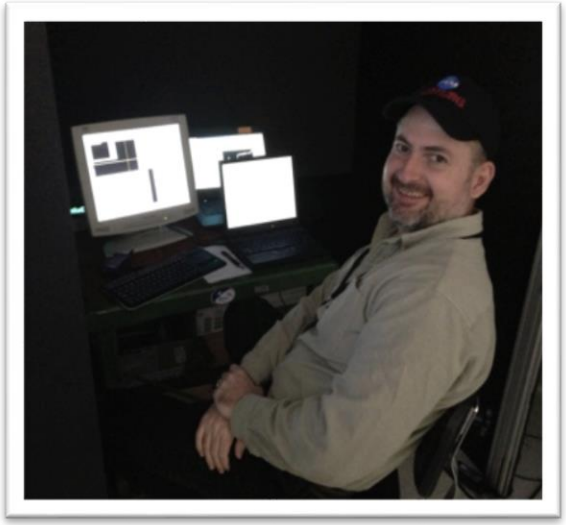
AisaIBIS

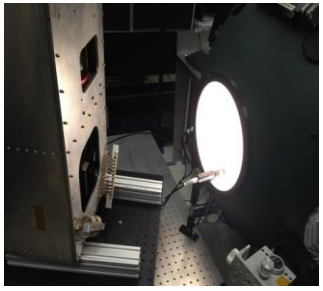
G-LiHT: Calibration & Validation

Spectral Irradiance and Radiance responsivity Calibrations using Uniform Sources
SIRCUS – NIST traceable Absolute Radiometric Response Functions





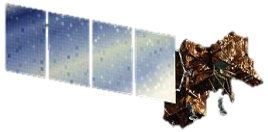




G-LiHT: Calibration & Validation

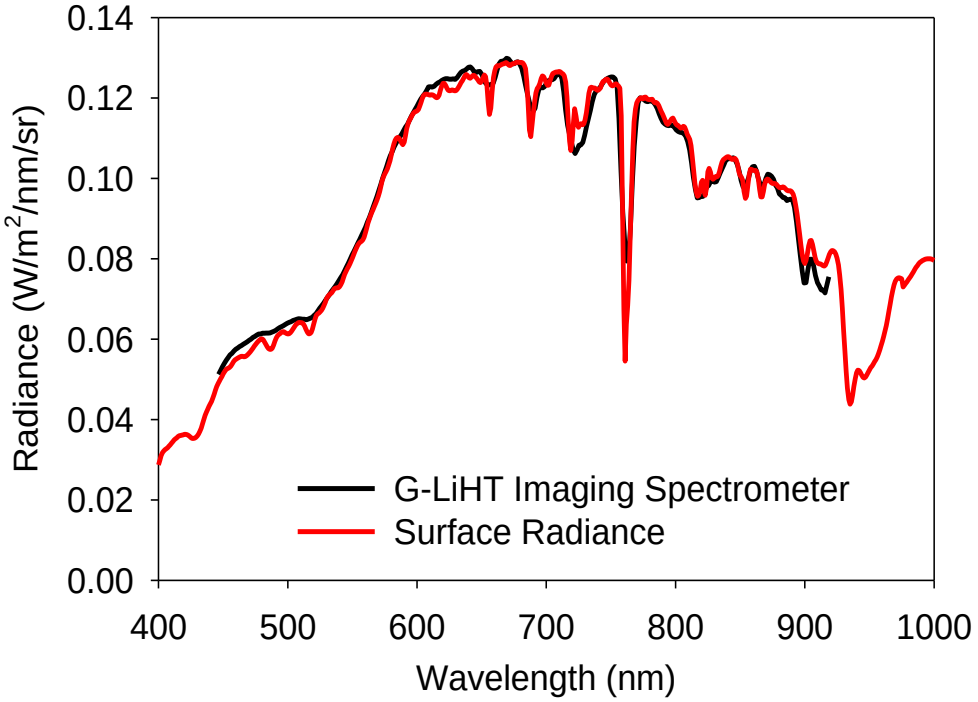
Tandem under flights of Earth Observing Satellites (EOS) for:

- Validation of G-LiHT optical products against ground observations.
- Map topography and optical properties of playas frequently imaged by EOS.

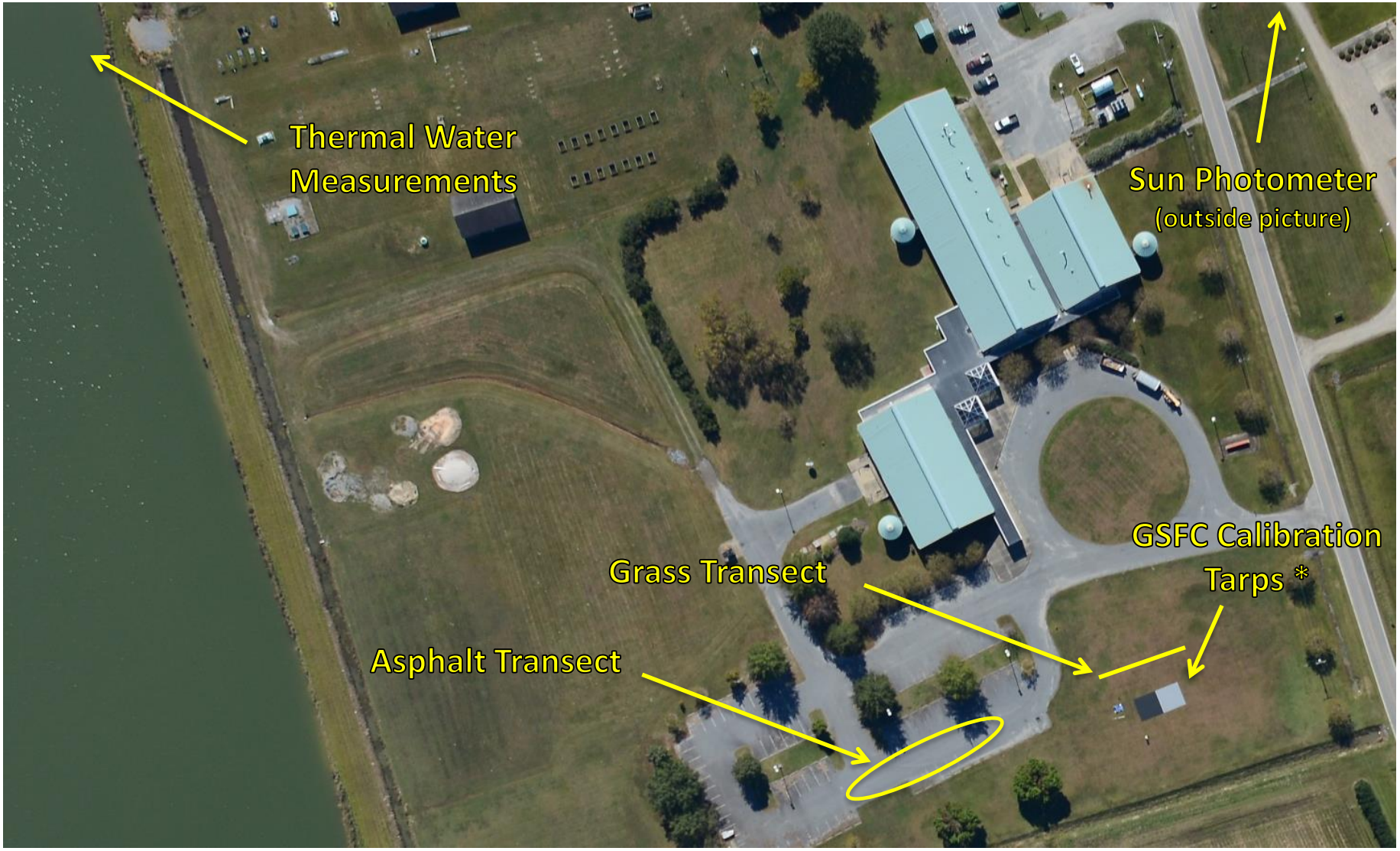


Landsat 7 & 8
World View
Earth Observer 1

Red Lake Playa, Arizona, March 29, 2013



G-LiHT: Calibration & Validation

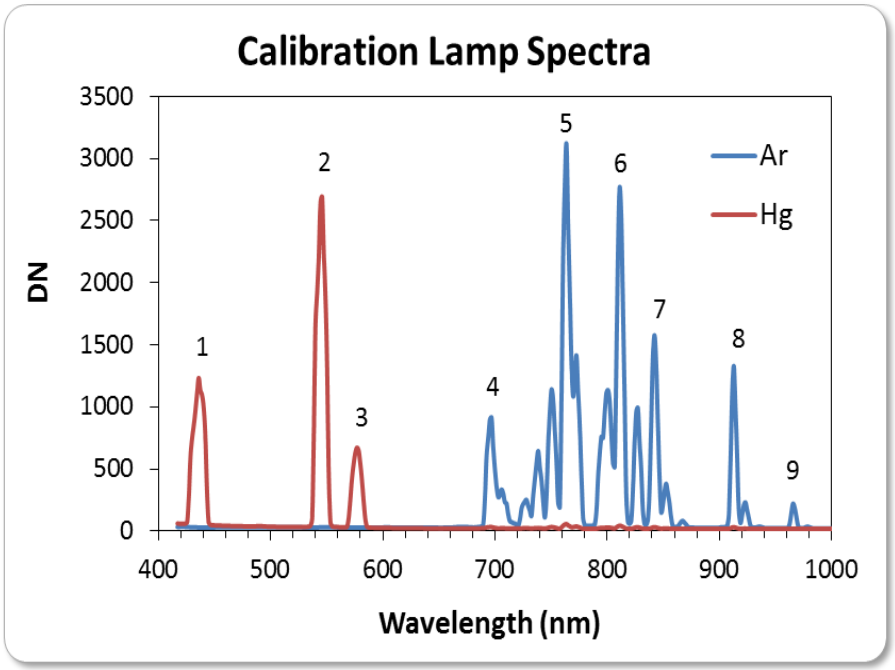


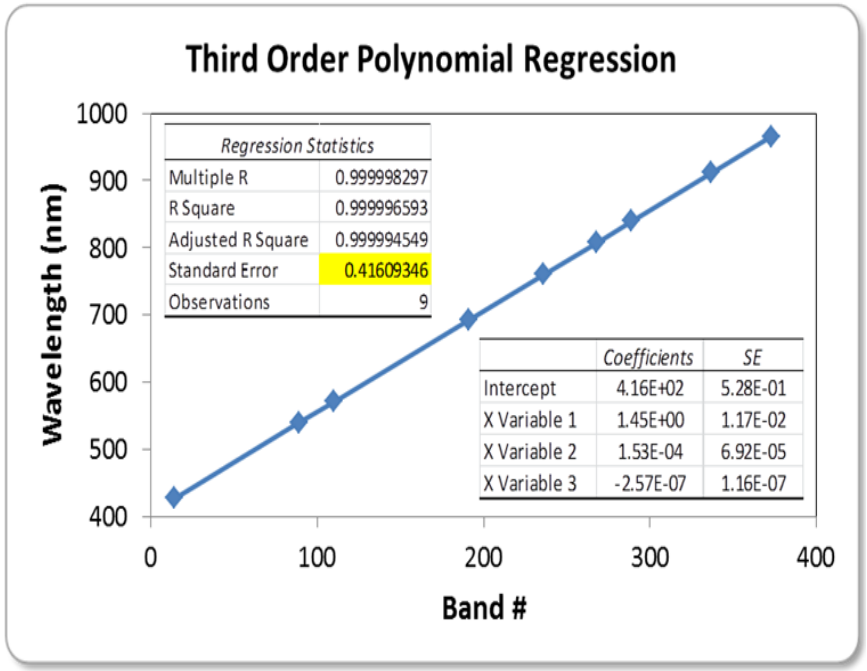
*Coordinates: lat 35.8736, lon -76.6588

G-LiHT: Calibration & Validation

Calibration & Stability:

- Full calibration using SIRCUS performed annually.
- Additional periodic monitoring for radiometric & wavelength stability is performed using a portable Teflon integrating sphere with Tungsten, Hg & Ar lamps.
- Hyperspec deemed very stable for a compact high performance airborne imaging spectrometer capable of operating in harsh environments.

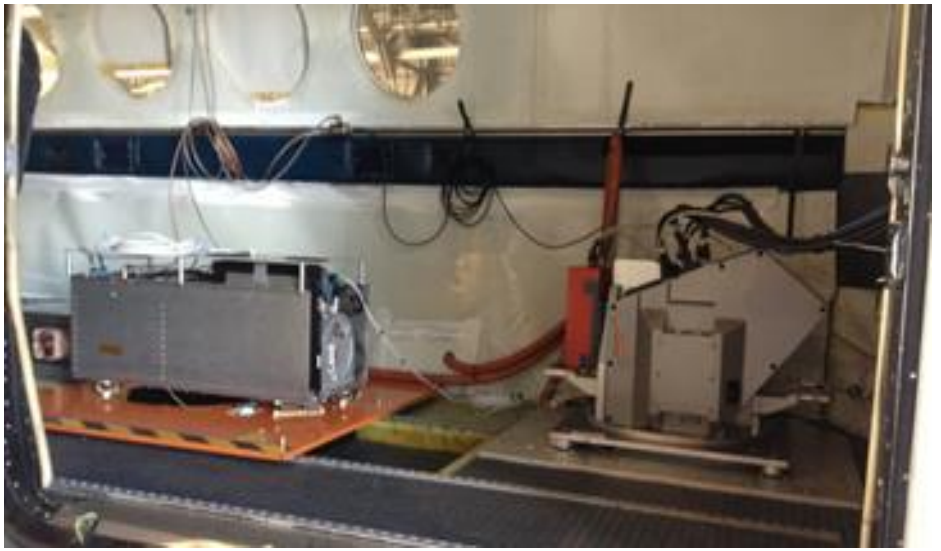




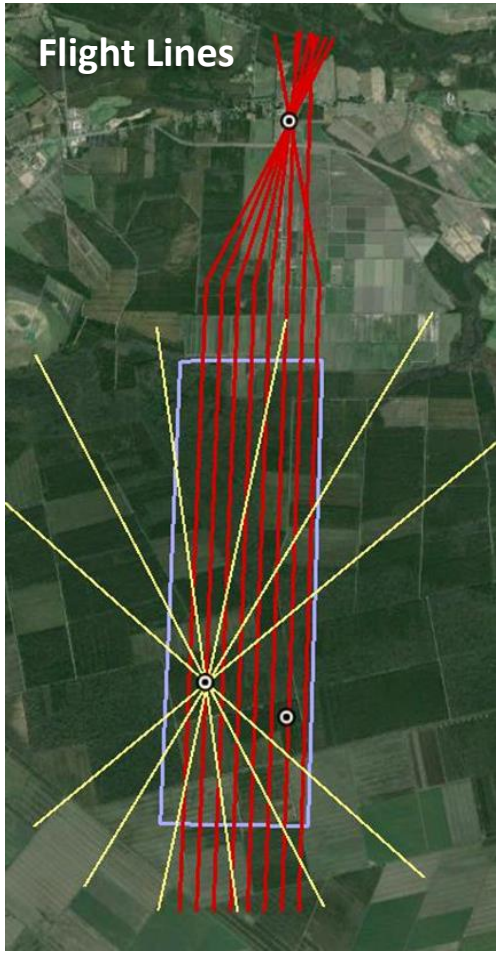
G-LiHT: Aircraft Installs

UC12B King Air at NASA Langley Research Center:

- Instrument mounted over internal camera port.
- Top Right: flying in tandem with the AISA Phenix & IBIS imaging spectrometers.
- Lower Right: flying in tandem with JHU Applied Physics Lab's APFS Fluorescence sensor.



FLEX-US 2013 Airborne Campaign



Parker Tract Loblolly Pine Plantation

- Large areas of uniform stand age.
- Managed for timber production.
- Conservation areas of mixed deciduous & pine.
- NC2 micro-meteorological tower.
- Flat terrain 5 m above MSL.
- Plot level survey data available.

Study Area

Cal/Val Sites

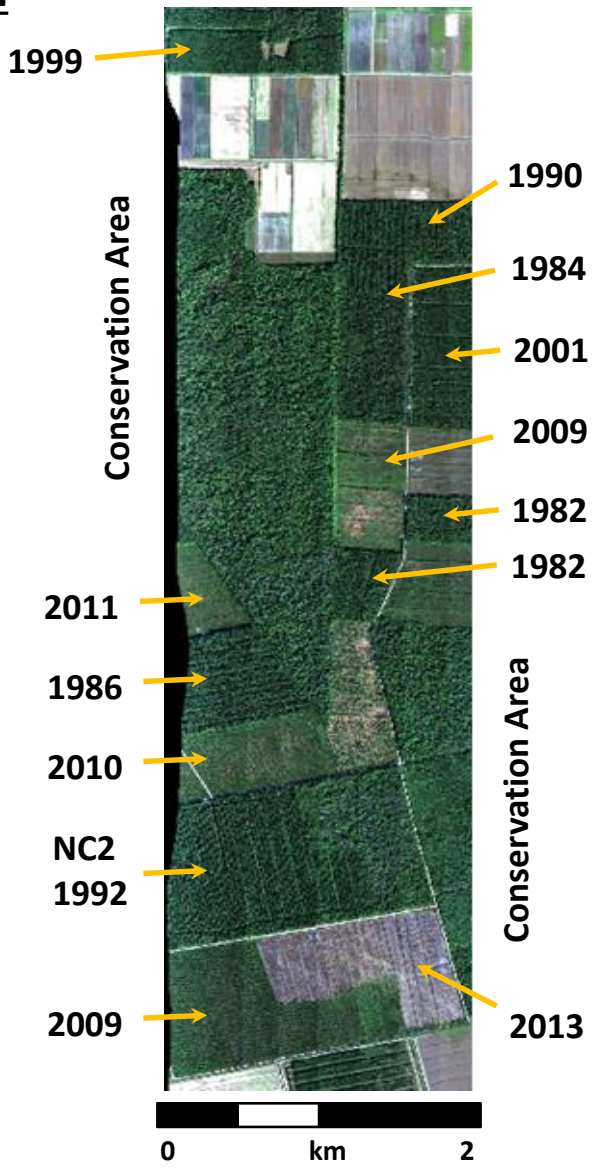
Flight Lines

Solar Lines

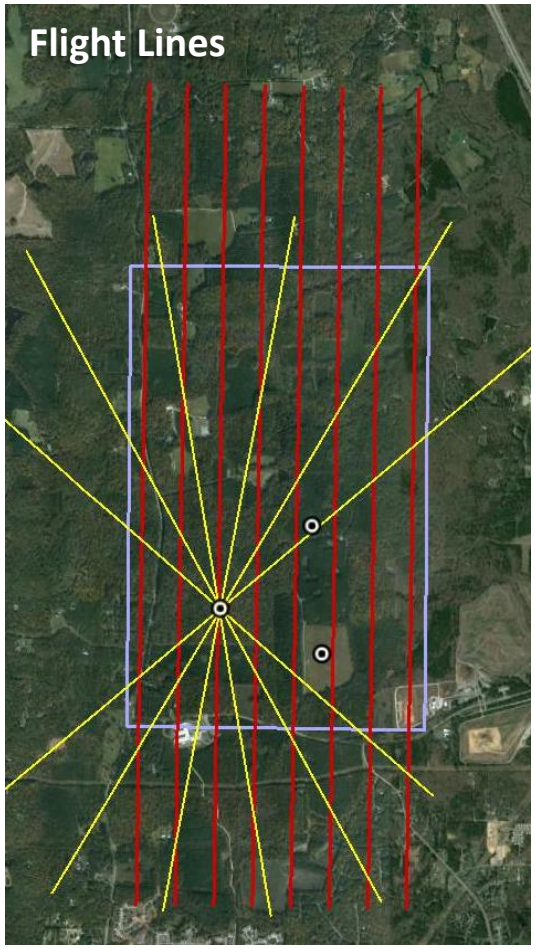
N

Date	Start acquisition time	End acquisition time	Number of flight lines
Oct 26	09:50	11:13	10
Oct 26	12:31	14:09	10
Oct 26	15:03	16:31	10
Oct 27	13:56	15:15	10

G-LiHT RGB Mosaic (2m)



FLEX-US 2013 Airborne Campaign



Duke University Research Forest

- Long history of manipulative experiments.
- Mixed deciduous & pine forests.
- Active DK3 micro-meteorological tower.
- Rolling terrain 100 to 200 m above MSL
- Extensive ground survey data available.

Study Area

Cal/Val Sites

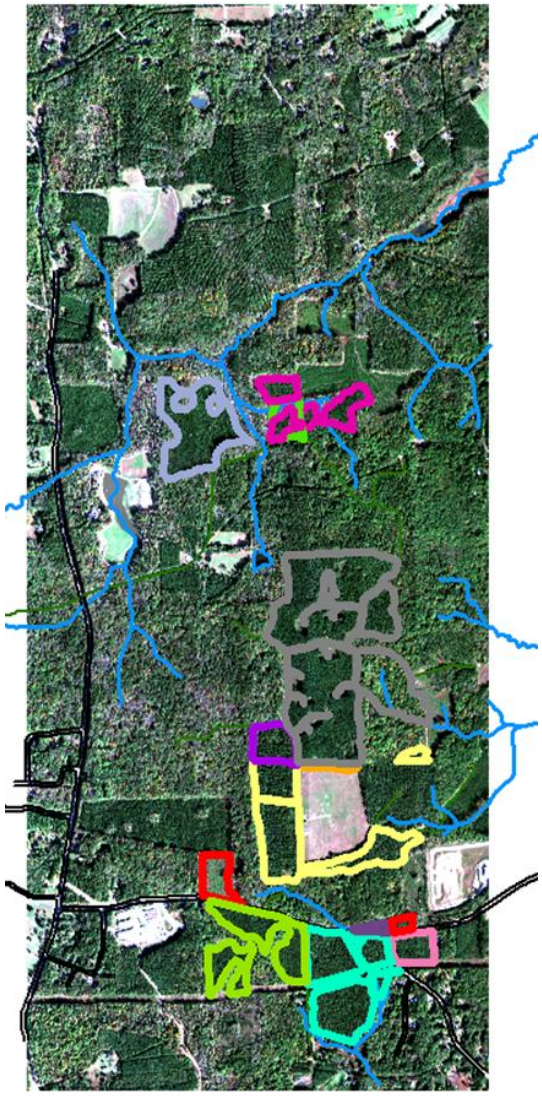
Flight Lines

Solar Lines

Loblolly Pine Planting Year

1948
1950
1951
1981
1982
1983
1985
1987
1993
2001
2002
2005

G-LiHT RGB Mosaic (2m)



Date	Start acquisition time	End acquisition time	Number of flight lines
Sept 30	14:16	15:38	12
Oct 24	10:09	11:24	13
Oct 25	10:10	11:08	10
Oct 25	12:58	14:11	12
Oct 25	15:34	16:40	11
Oct 27	11:08	12:02	10

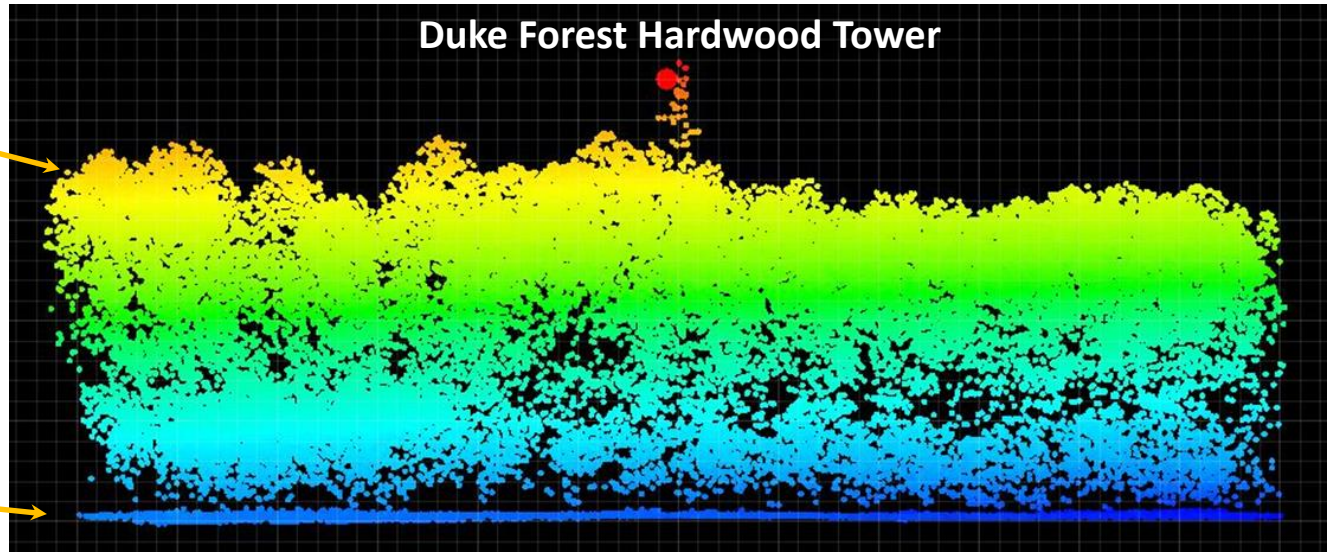
FLEX-US 2013: G-LiHT LiDAR Products

G-LiHT LiDAR Data Products:

- LAS Georeferenced Point Clouds.
- CHM & DTM Surface Models (2 m).
- Surface Rugosity (STD of CHM @ 2m).
- Tree Fractional Cover (14 m)
- Distribution of Canopy Elements (Deciles & Percentiles @ 14 m)

Laser Wavelength	1550 nm
Repetition Rate	150 kHz
Measurement Rate	150,000 per s
Beam Divergence	0.3 mrad
Accuracy	25 cm
Scan Speed	100 per s
Field of View	60^0

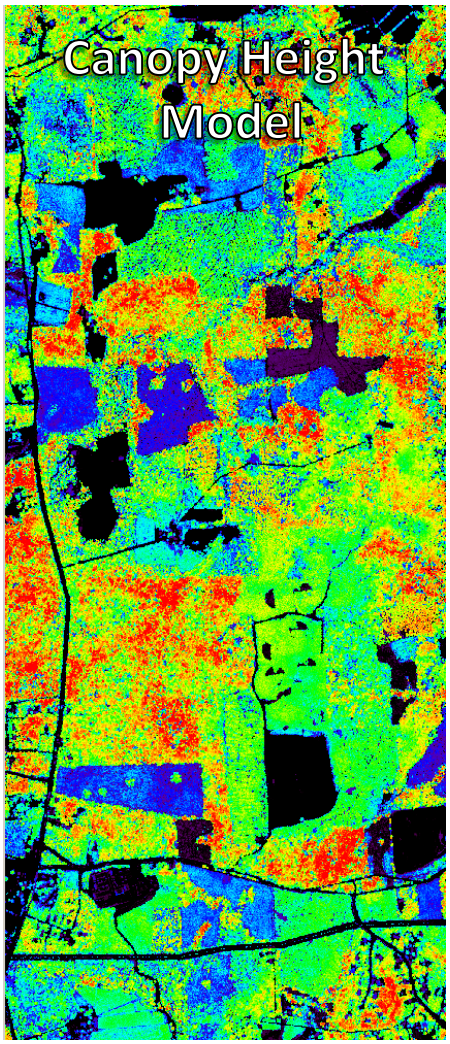
Riegl VQ480 Scanning LiDAR

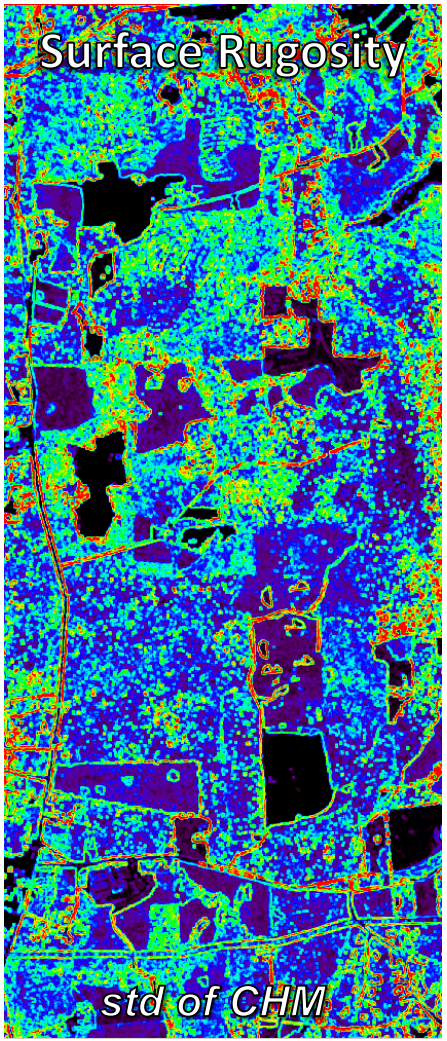


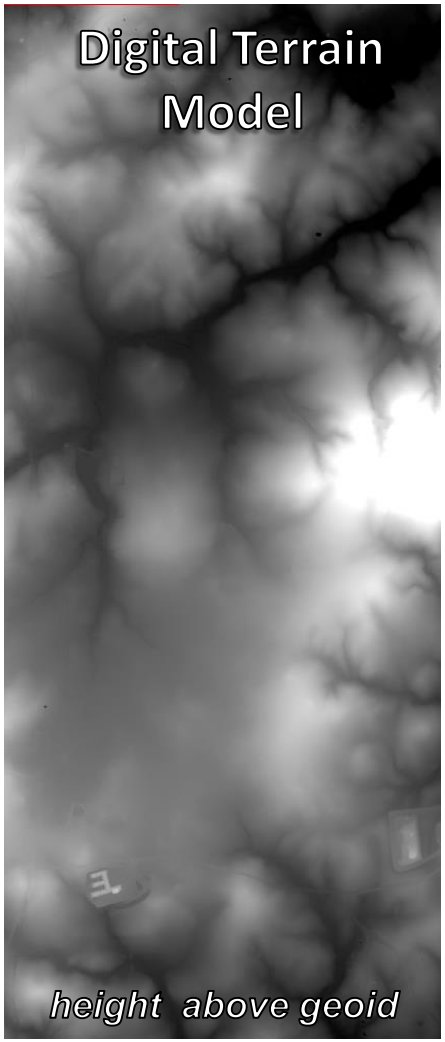
Side View of G-LiHT LiDAR Georeferenced Point Cloud

FLEX-US 2013: G-LiHT LiDAR Products

Duke Forest LiDAR Surface Model Results at 2 m Spatial Resolution

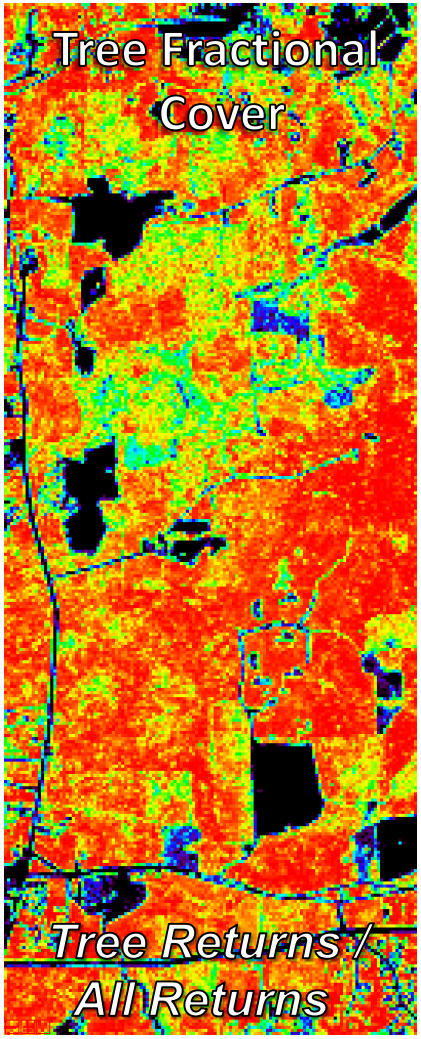


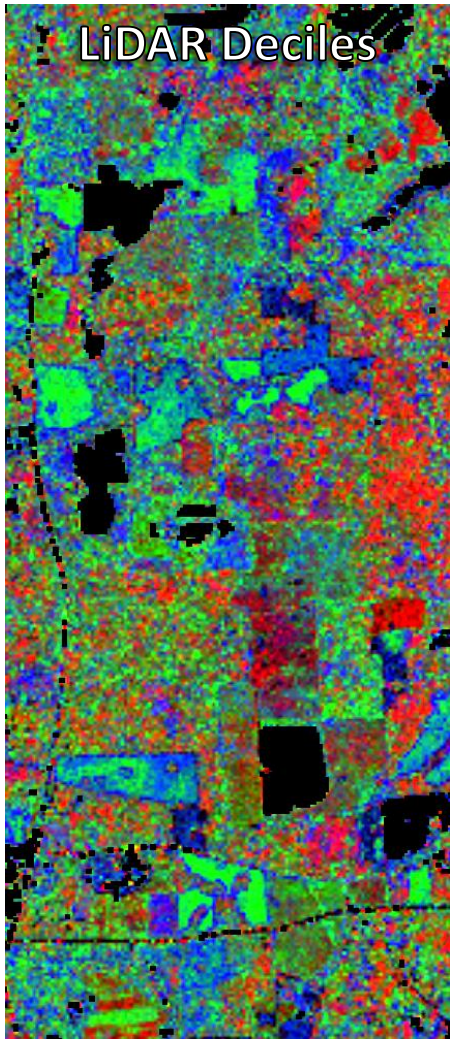


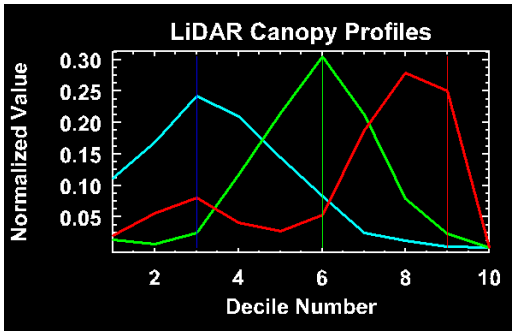


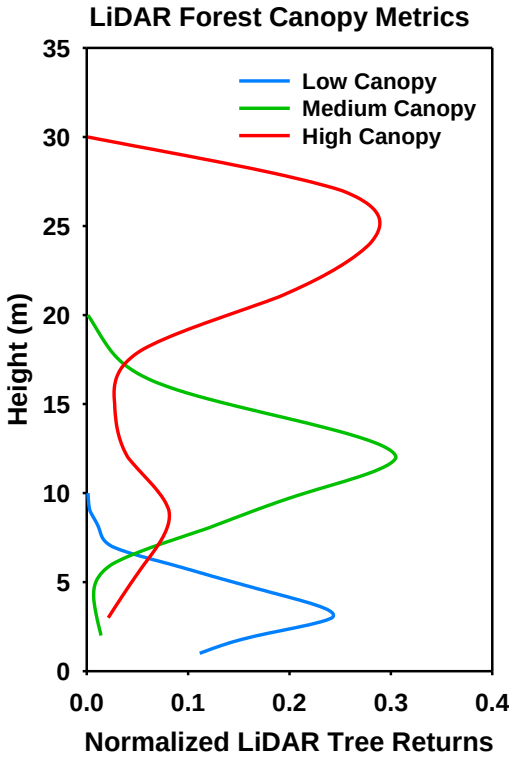
FLEX-US 2013: G-LiHT LiDAR Products

Duke Forest LiDAR Metrics at 14 m Spatial Resolution









FLEX-US 2013: G-LiHT Hyperspectral Products

G-LiHT Optical Data Products:

- Georeferenced at Sensor Radiance & Reflectance Products (2 m).
- Accurate Co-Registration to LiDAR Products.
- Swath Based & Mosaicked Data Products.
- VNIR Spectral Vegetation Indices.

Ancillary Image Files Include:

- Incident PAR
- Cloud Score
- Acquisition Time
- Aircraft Altitude AGL
- Solar Geometry
- Viewing Geometry
- Modeled Clear Sky Radiance

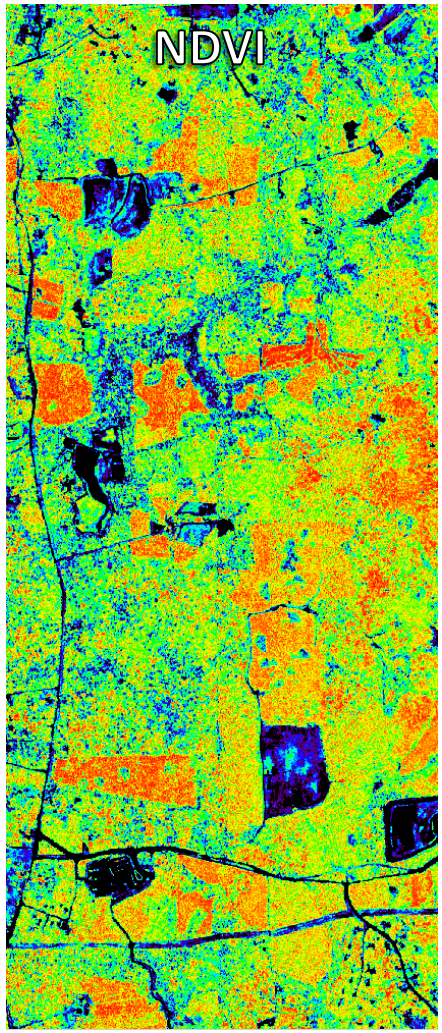
Wavelength Range	420-920 nm
Aperture	F/2.0
Dispersion per pixel	1.5 nm
Slit Width	25 µm
Slit Length	18 mm
Spectral Resolution	10 nm
Spectral Bands	114
Spatial Samples	1004
Frame Rate	30 fps
Field of View	49.6 deg

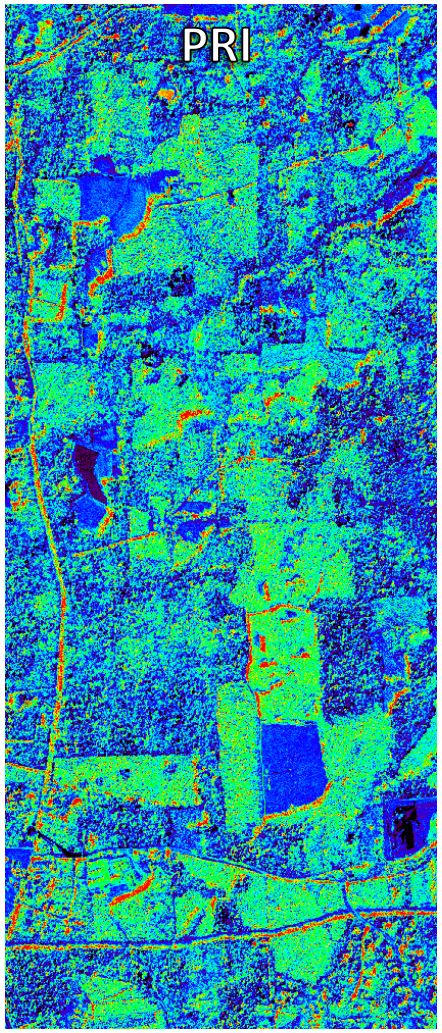
Headwall Photonics Hyperspec™ Concentric Imaging Spectrometer

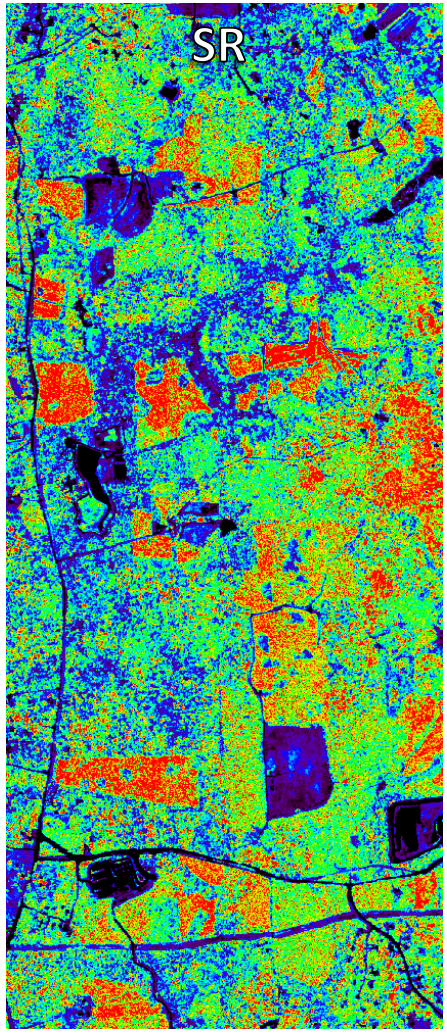
Duke Forest G-LiHT Hyperspectral RGB Overlay on LiDAR Surface Model

FLEX-US 2013: G-LiHT Hyperspectral Products

Duke Forest 10-25 AM Imaging Spectroscopy at 2 m Spatial Resolution







km
0 0.5 1 2

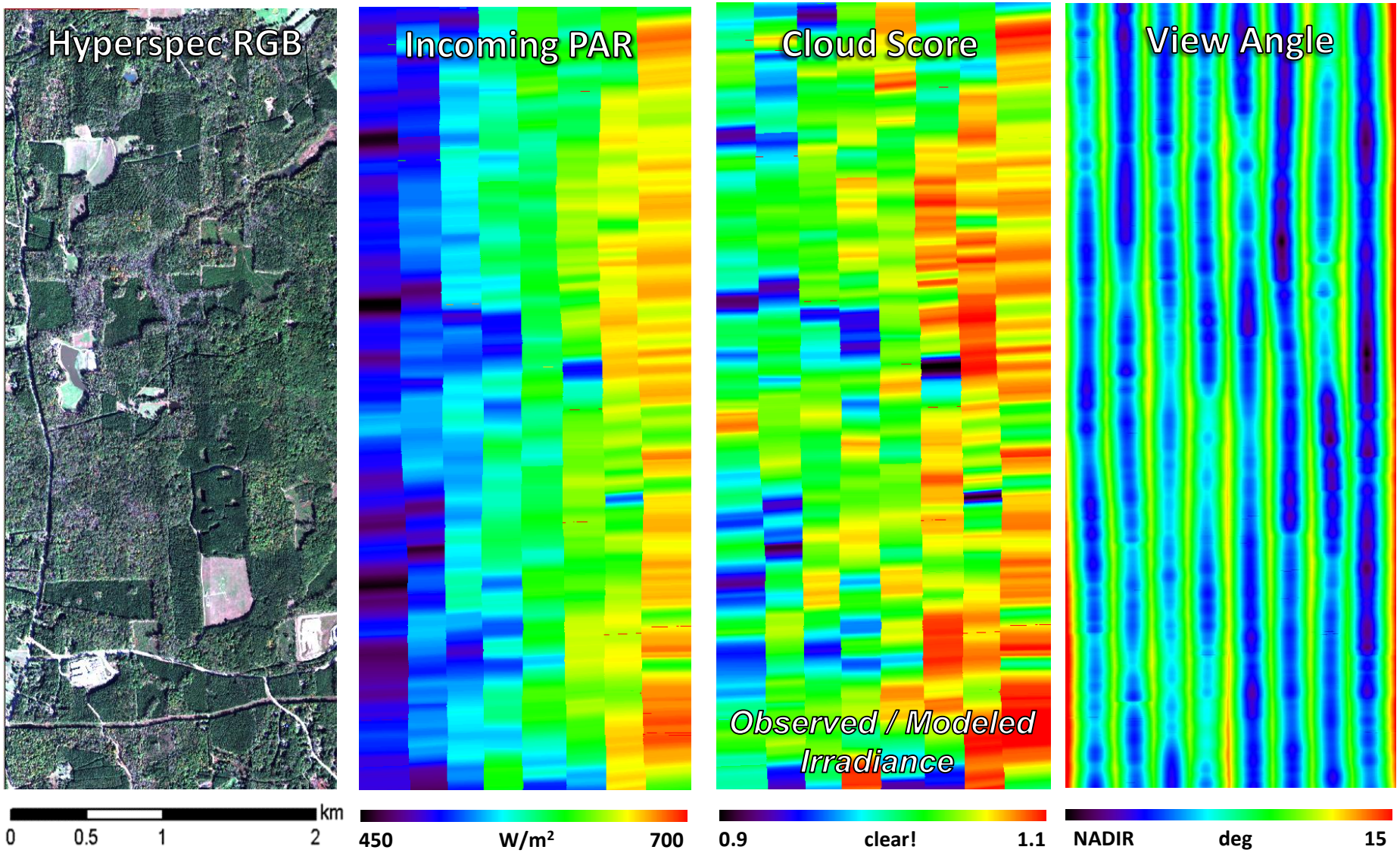
0.5 0.9

-0.12 *photochemistry* 0.05

Low *pigment index* High

FLEX-US 2013: G-LiHT Ancillary Products

Duke Forest 10-25 AM Ancillary Observations (anc) at 2 m Spatial Resolution



FLEX-US 2013: G-LiHT Thermal Products

Array type	Microbolometer
Spectral band	8 µm to 14 µm
# Pixels	384 x 288
Pixel pitch	25 µm
Sensitivity (NETD)	≥ 50 mK @ 30°C
Frame rate (full frame)	25Hz (16 bit)
Operating temperature	-40°C to 50°C
Focal length	18 mm f/1
Power consumption	3.6 W @ 12V

System specifications for the Gobi-384 LWIR thermal imaging camera manufactured by Xenics, Leuven, Belgium.

www.xenics.com

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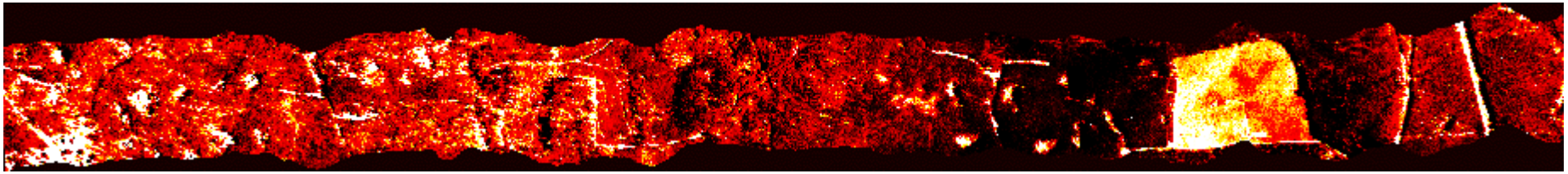
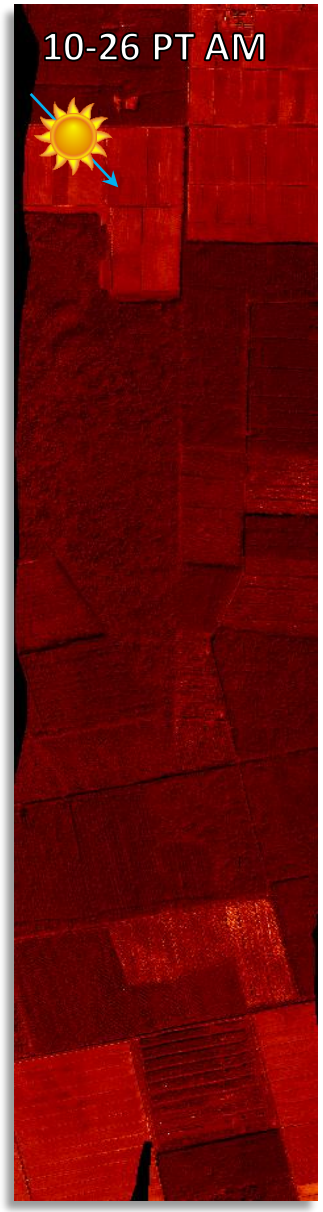
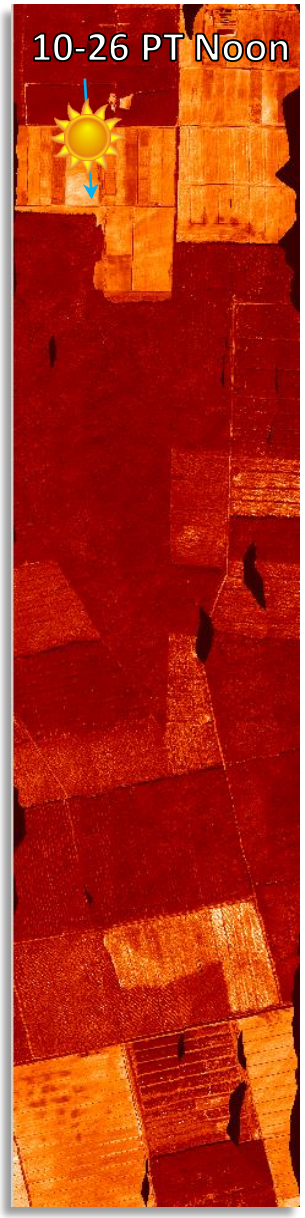
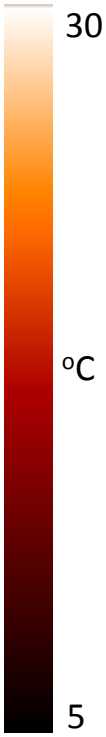


Sample of Georeferenced G-LiHT Duke Forest Surface Temperature Data Product

FLEX-US 2013 Airborne Campaign

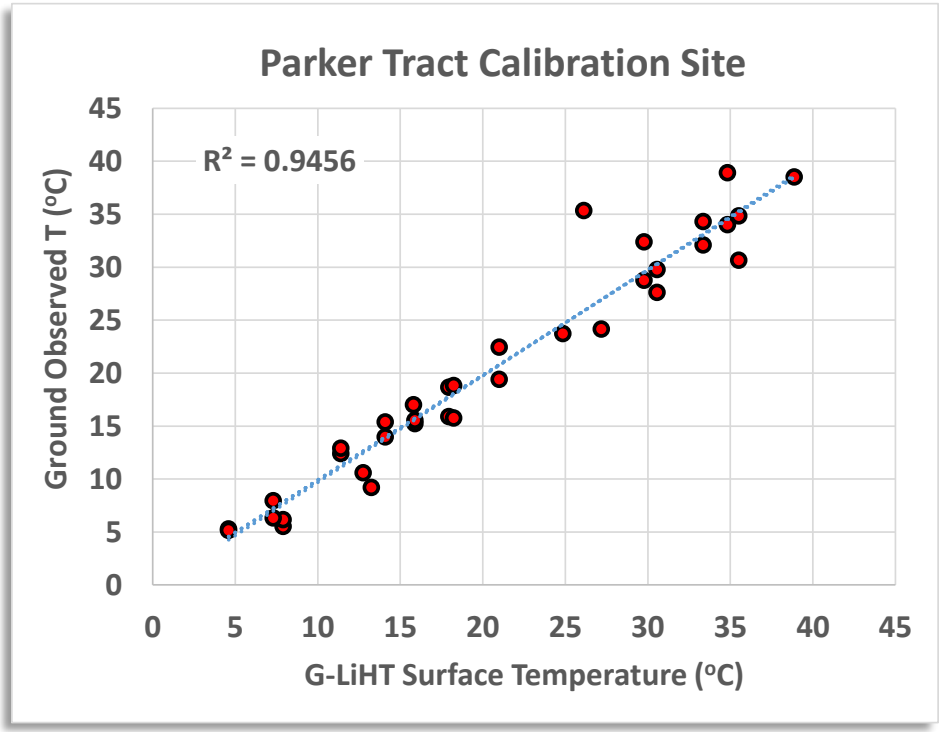






Parker Tract G-LiHT Thermal Data Products

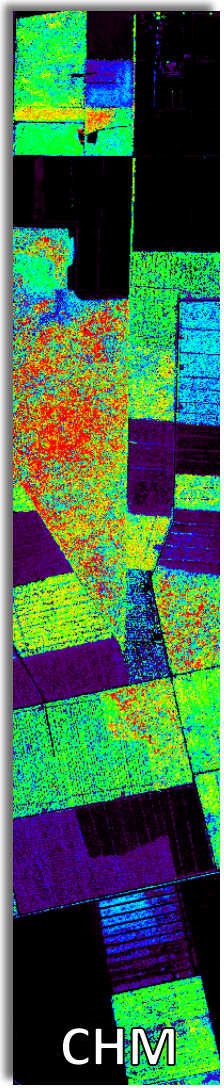
- AM & Noon mosaicked data sets available
- Surface temperature reported in °C
- Data product at 2m spatial resolution

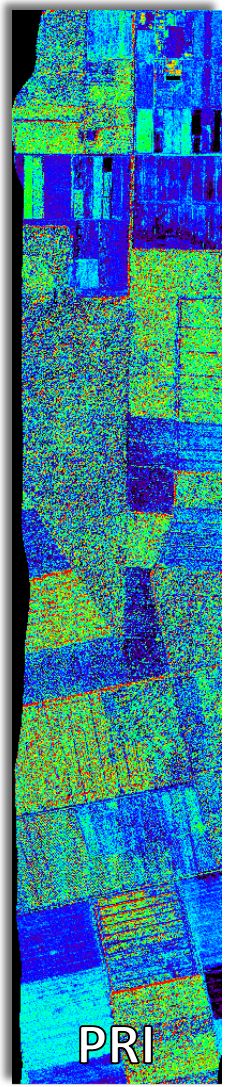


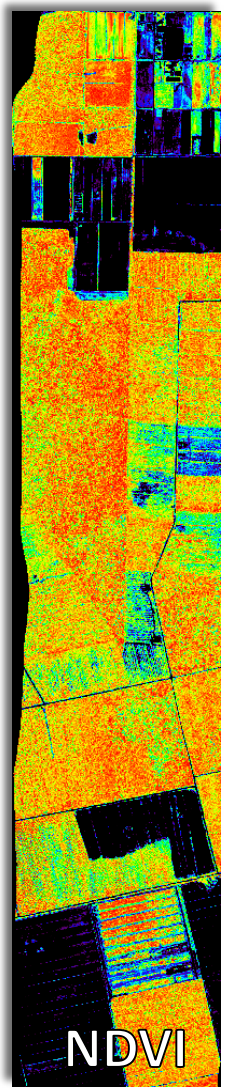
ftp://fusionftp.gsfc.nasa.gov/FLEX-US 013/G-LiHT Thermal
further products available on request

FLEX-US 2013 Parker Tract NC

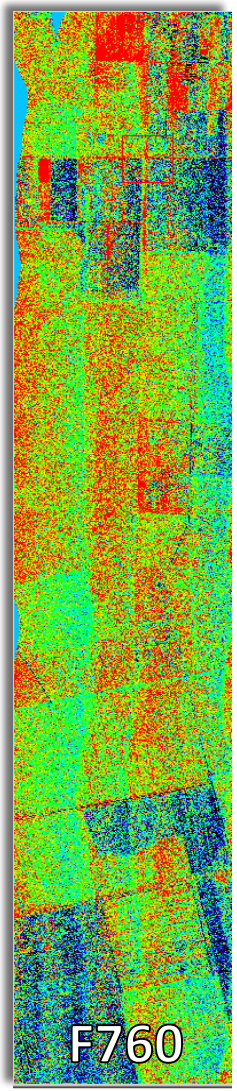
NASA Goddard's LiDAR Hyperspectral Thermal Imager (G-LiHT)

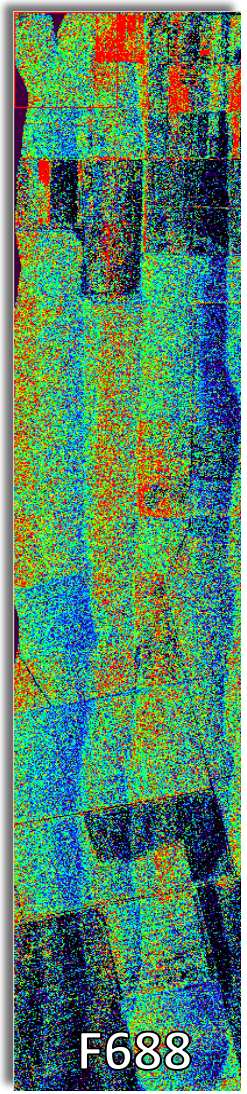






HyPlant Fluorescence (2m)





0 km 2

0 m 35

-0.1 0.03

0.4 0.9

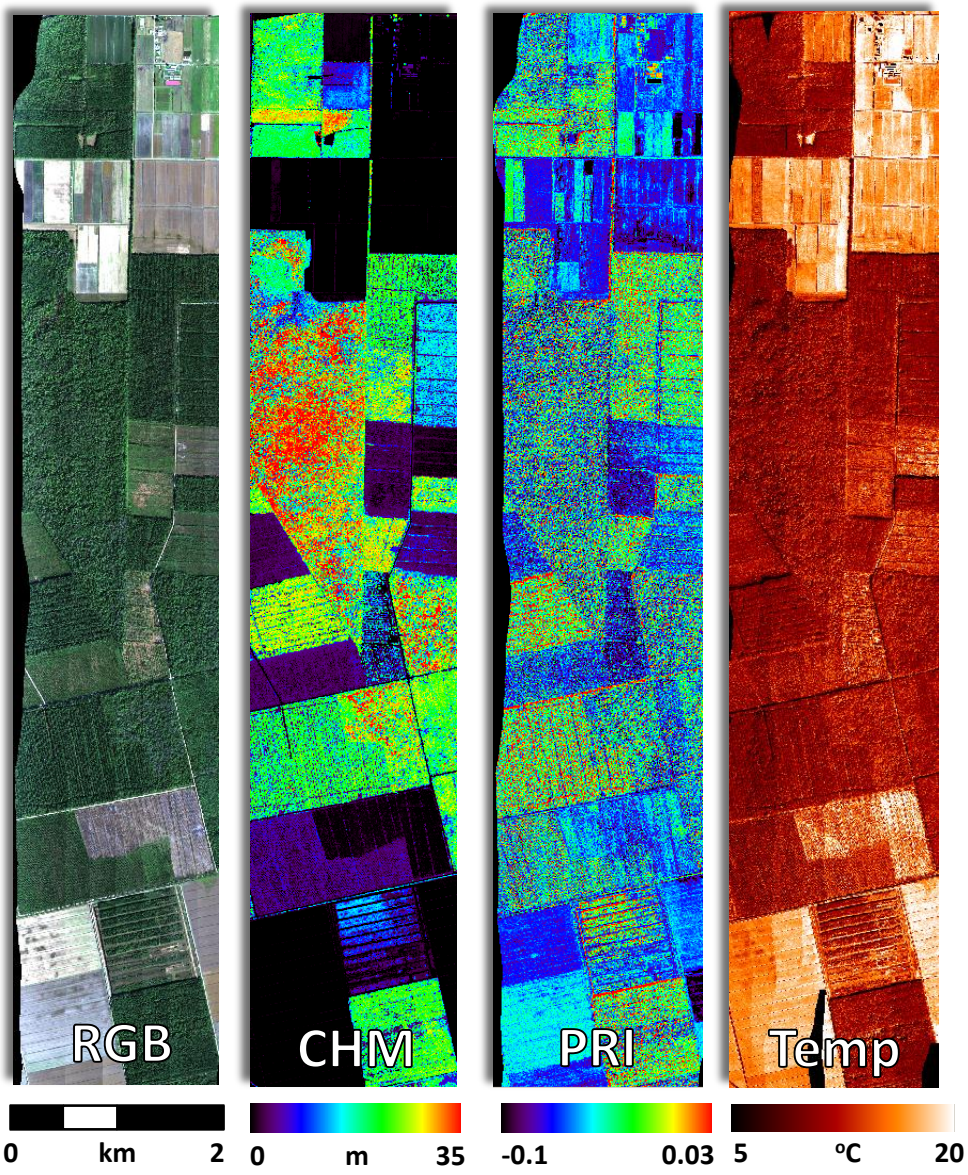
5 °C 20

0 mW/m²/nm/sr 5

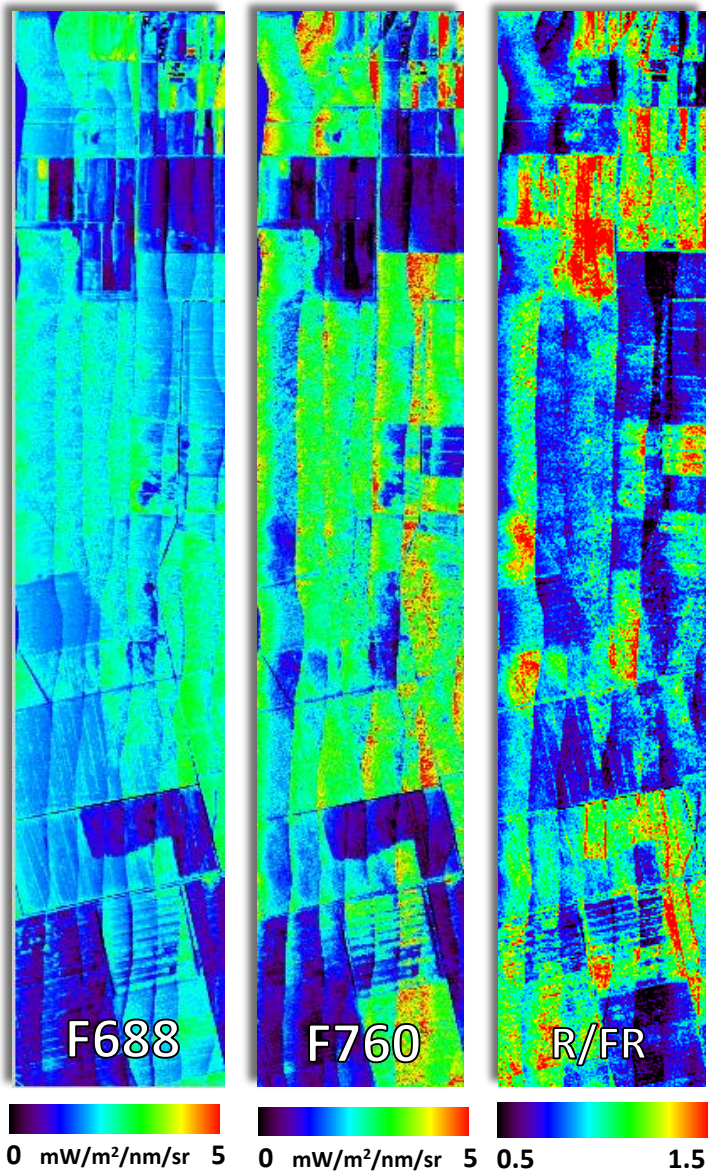
0 mW/m²/nm/sr 5

FLEX-US 2013 Parker Tract NC

Goddard's LiDAR Hyperspectral Thermal Imager (G-LiHT)



HyPlant Fluorescence (14m)

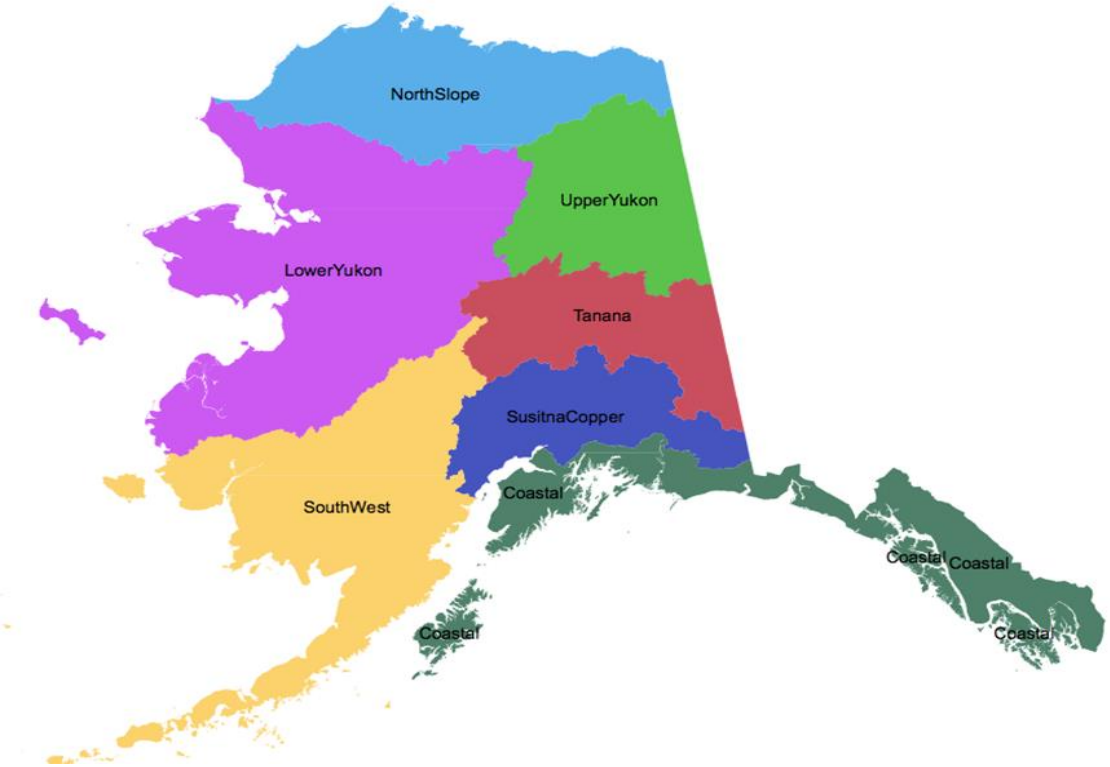


N

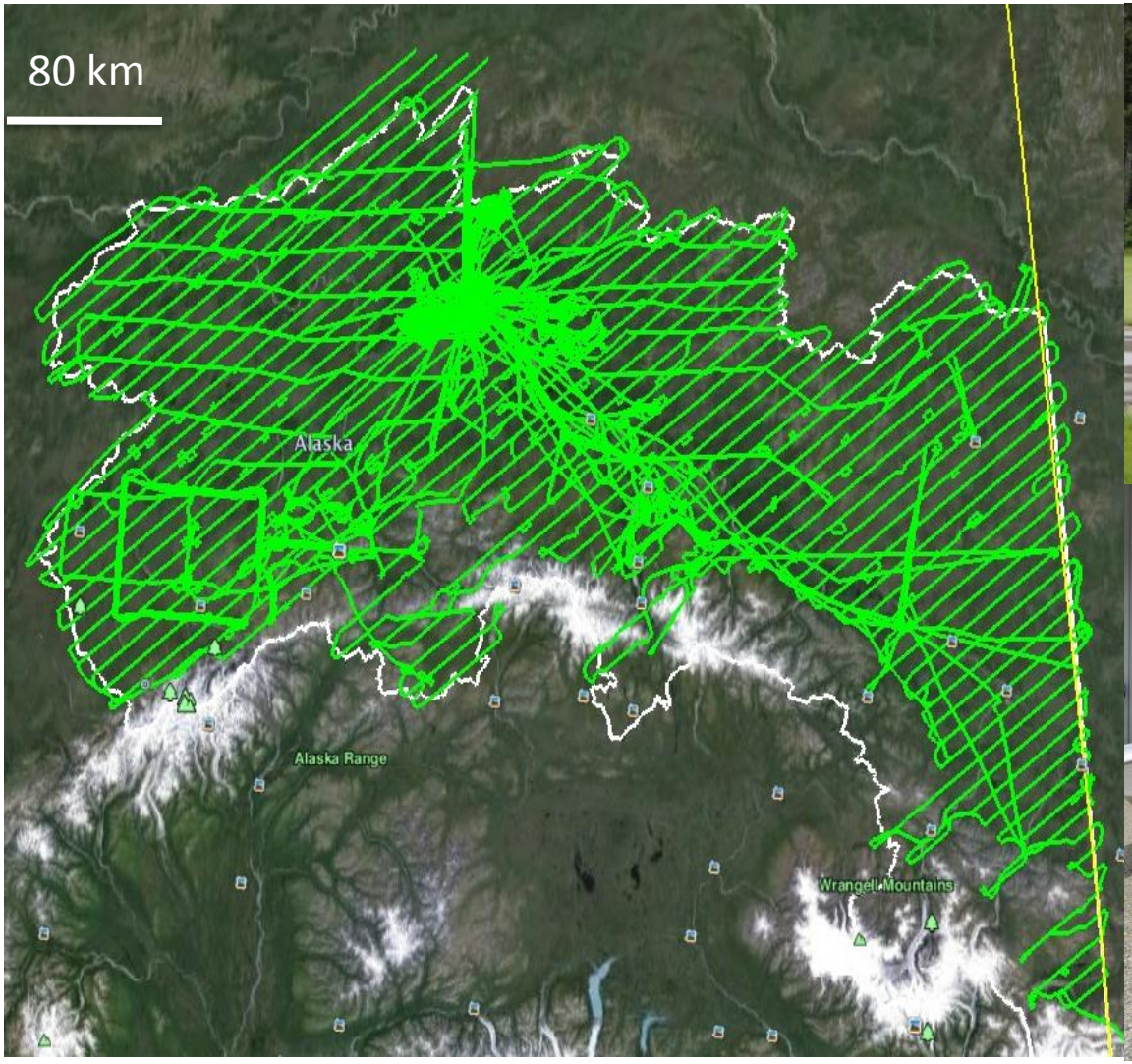
G-LiHT: Tanana Alaska Campaign 2014

A USFS-NASA Pilot Project:

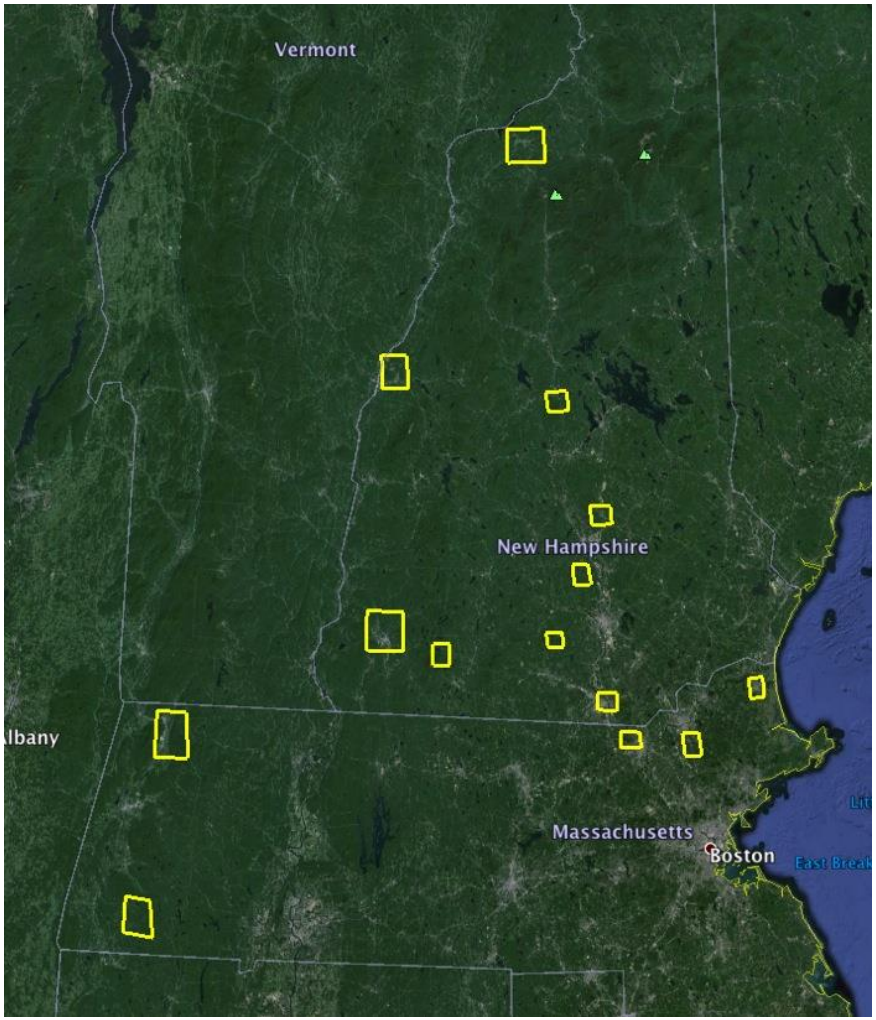
- 44 Days & 230 Flight Hours
- 50,000 km of Flight Lines
- 1,000,000 ha Surveyed
- Mission Cost $100k ($10 per ha)



G-LiHT: Tanana Alaska Campaign 2014



G-LiHT: New England Campaign 2014



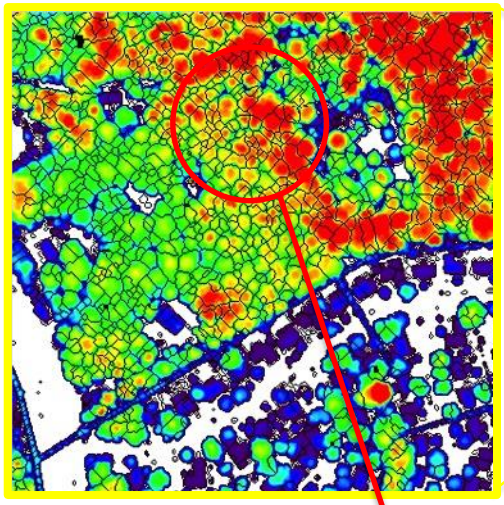
Survey forest decline in the New England area due to Emerald Ash Borer

Damage caused by larvae (NY Times)

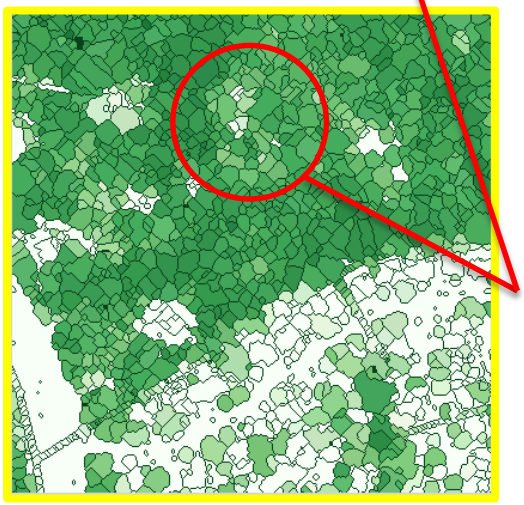
Collaborators Mary Very (USFS), Bruce Cook (NASA), Ryan Hanavan (USFS), and Larry Corp (SSAI)

G-LiHT: New England Campaign 2014

Step 1: Delineate canopies & structures



Step 2: Extract spectral information



Lidar heights & spectral indices are used to separate trees in decline from openings & structures

Summary of G-LiHT Data and Products

- Open access to ~2 *million ha* of data (Over 1,000 flight hours and 85 billion laser pulses since 2011)
- User-friendly data products and formats (LAS, GeoTIFF, JPEG2000, KML)
  - LiDAR Products
    - Point cloud data (classified returns and feature heights)
    - Bare earth elevation and canopy height models (DTM, CHM)
    - Common LiDAR metrics (return height and density statistics, fractional cover, apparent reflectance)
  - Spectrometer Products
    - Co-Registered radiance spectra (420-920 nm, 6 to 10 nm FWHM)
    - At-Sensor reflectance using observed irradiance spectra
    - Vegetation indices and spectral bio-indicators (e.g., NDVI, red-edge)
  - Thermal Product
    - Radiant surface temperatures (°C)

http://gliht.gsfc.nasa.gov/
ftp://fusionftp.gsfc.nasa.gov/G-LiHT/