Summary of HyspIRI Mission Concept and Instruments

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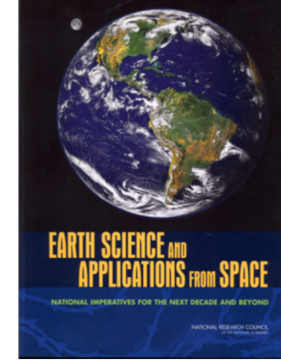
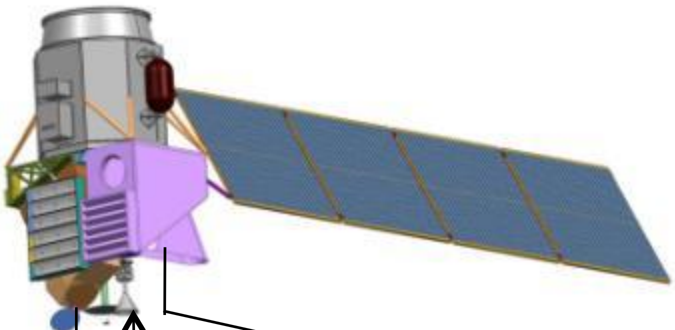
**Goddard Space Flight Center

NRC Decadal Survey
HyspIRI Mission Concept



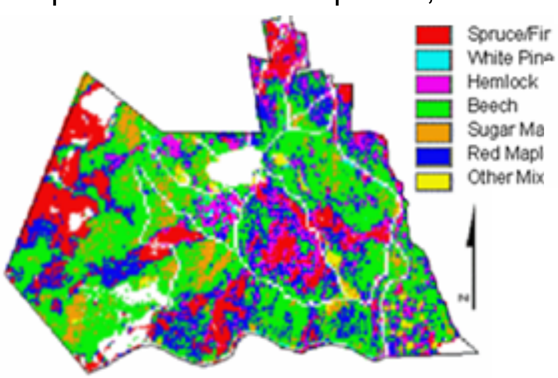


Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer

Intelligent Payload Module Low Latency Data

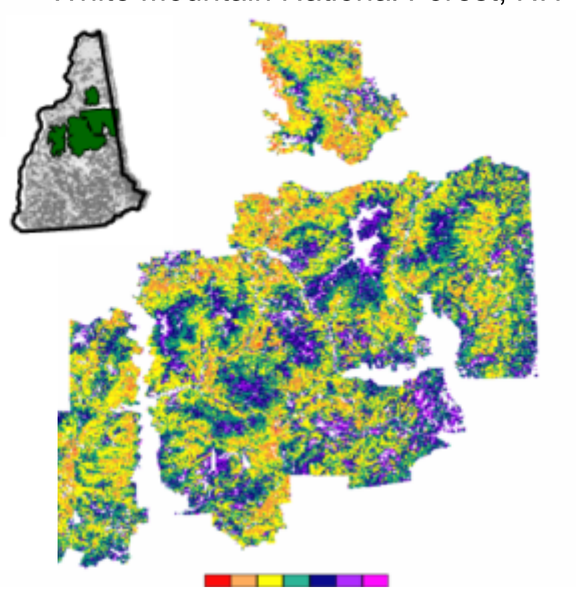
Multispectral Thermal InfraRed (TIR) Scanner

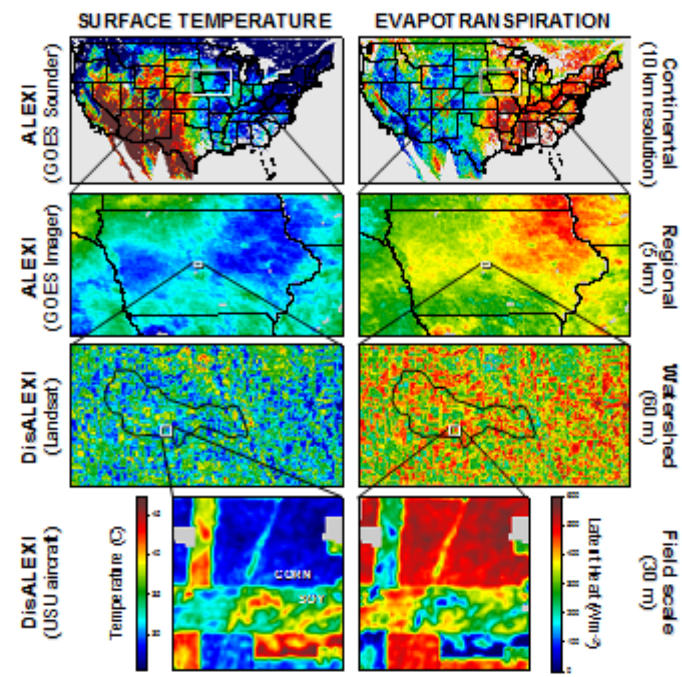
Map of dominant tree species, Bartlett Forest, NH



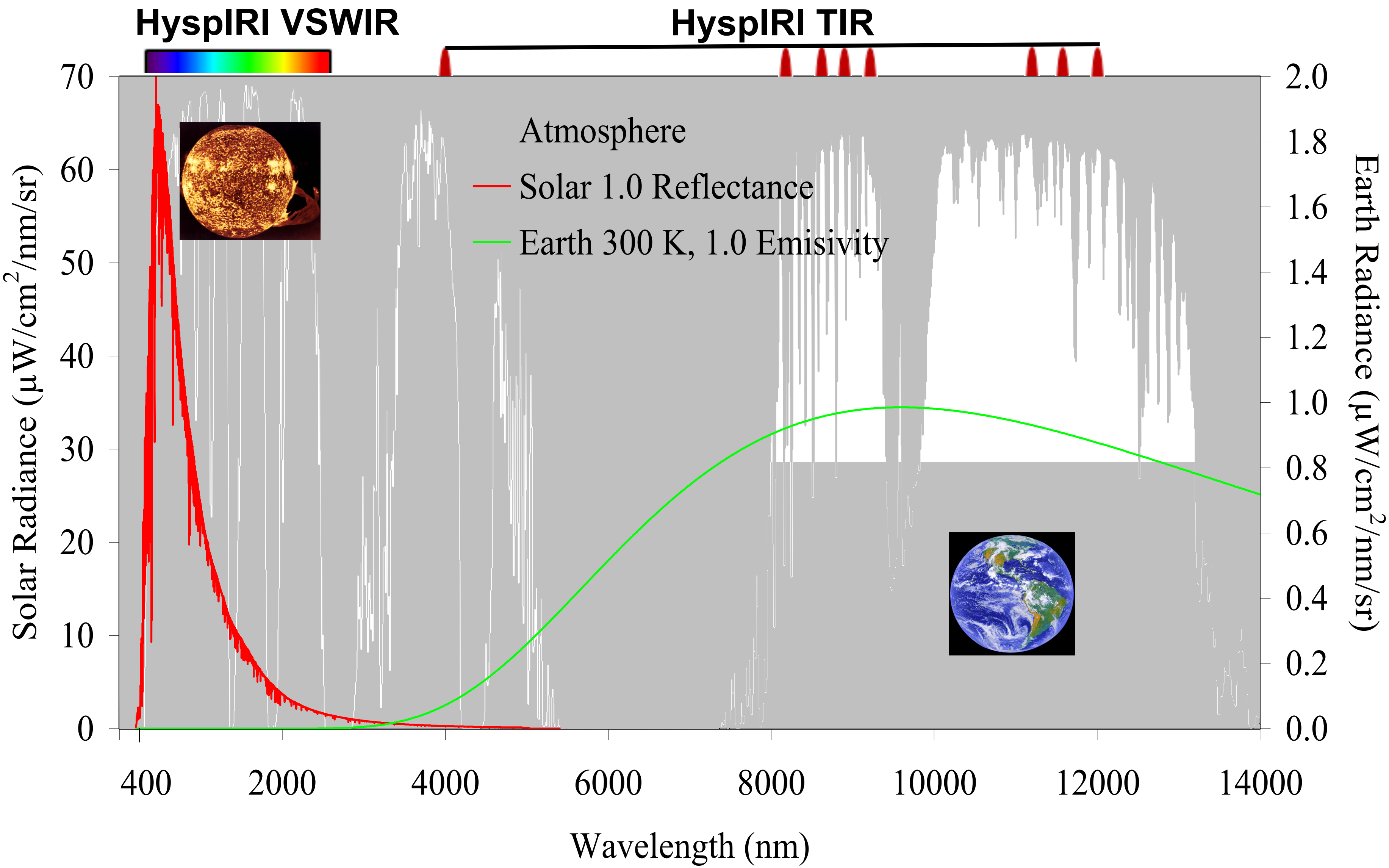
Soil C:N Ratio

White Mountain National Forest, NH



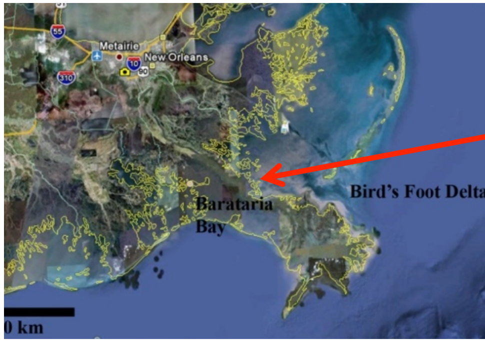


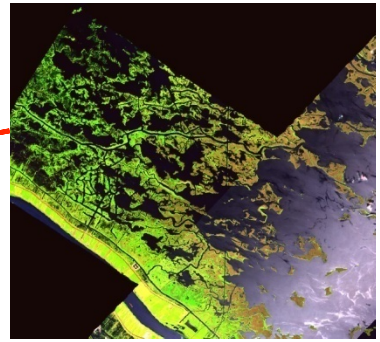
HyspIRI Measures the Optical Spectrum



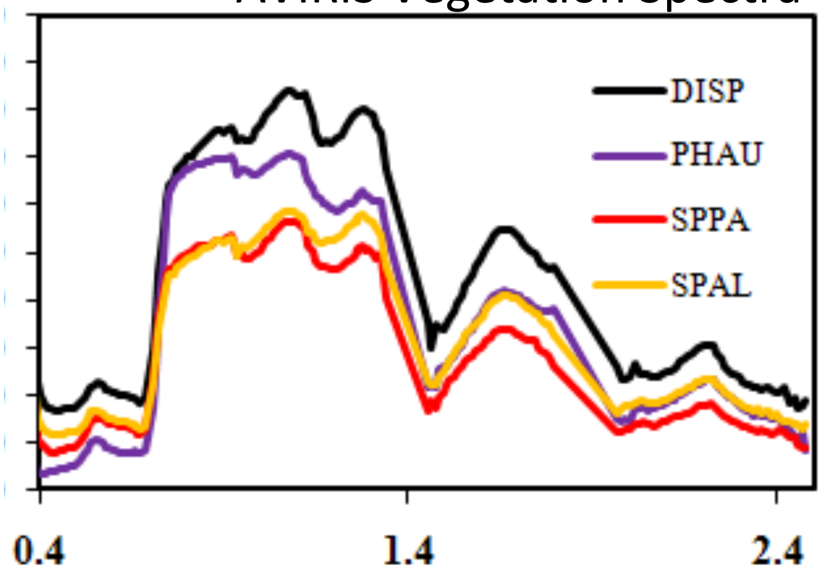
Antecedent Science Examples

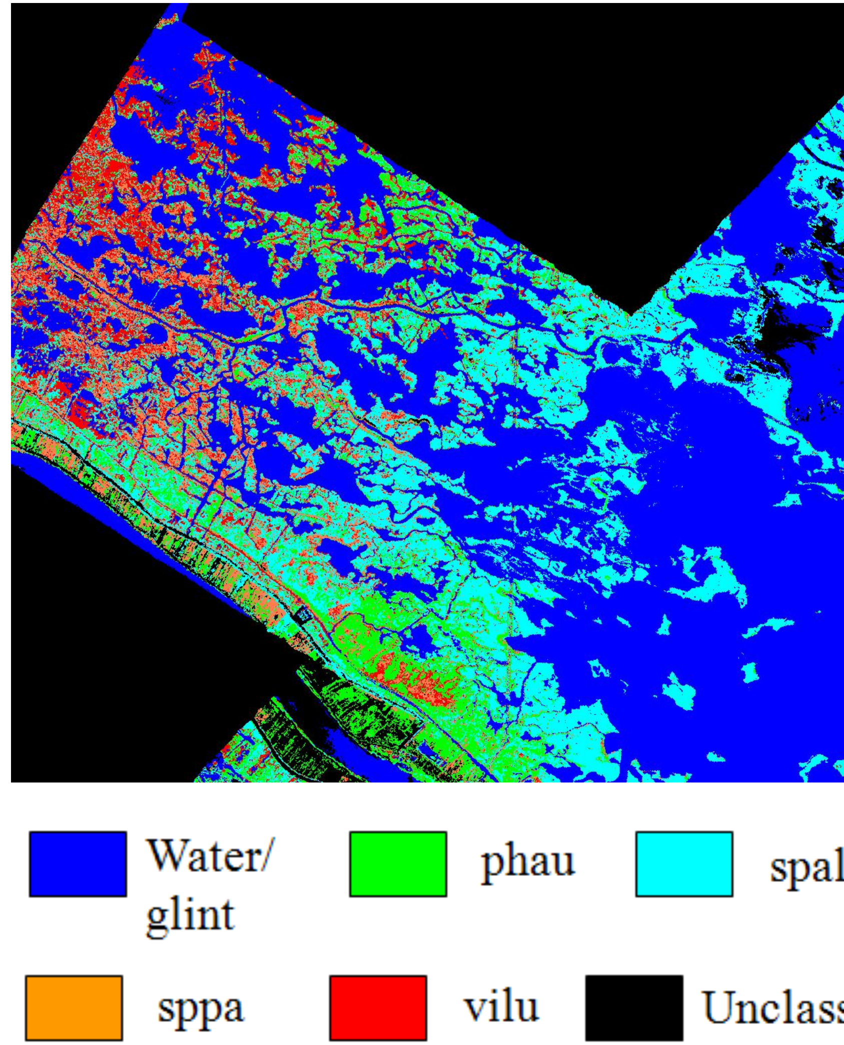
Example: Imaging Spectroscopy Mapping Wetland Dominants 2010





AVIRIS Vegetation Spectra





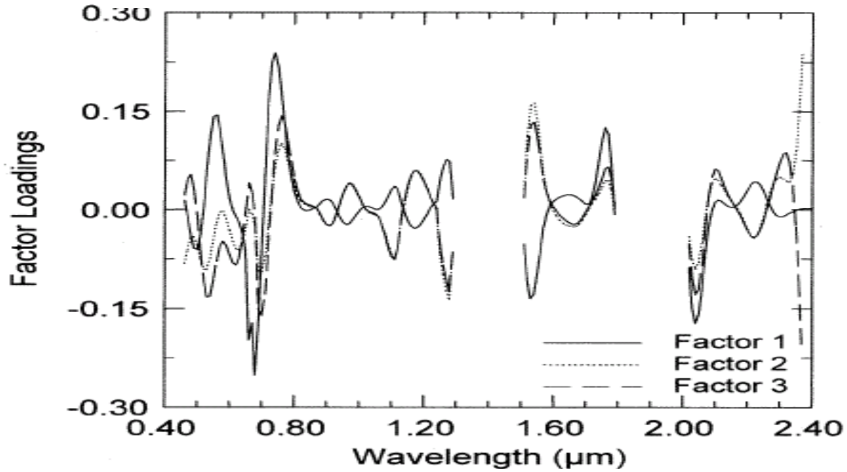
Vegetation mapped cleanly across scene boundaries

- ***Phragmites (phau)***
- ***Spartina alterniflora (spal)***
- ***Spartina patens (sppa)***
- ***Vigna luteola (vilu)***

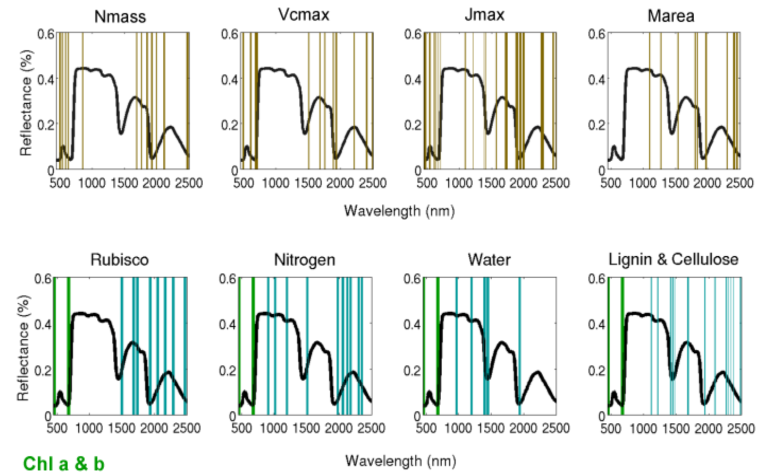
D. Roberts, UCSB

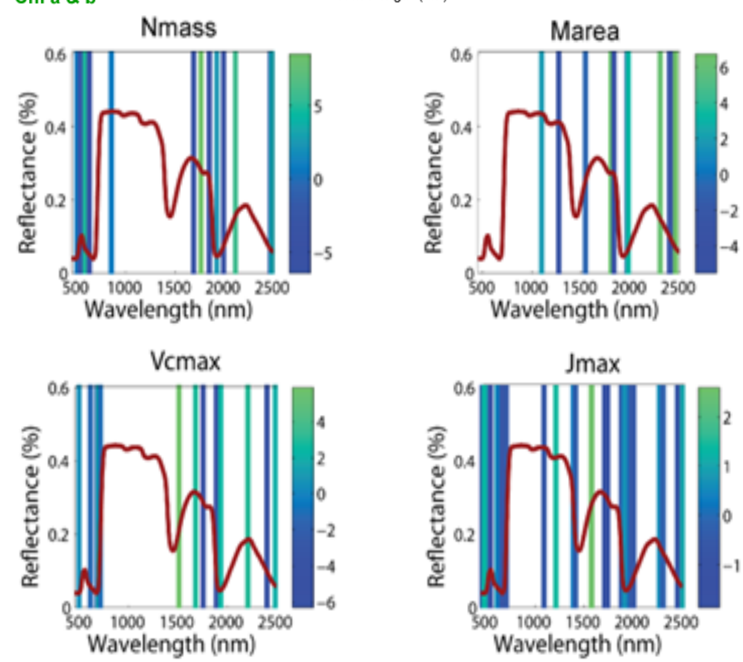
Spectroscopy for Species/Functional-type, Biogeochemistry and Physiological Condition

PLSR weighting for foliar Nitrogen

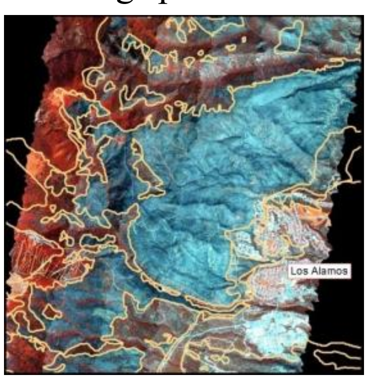


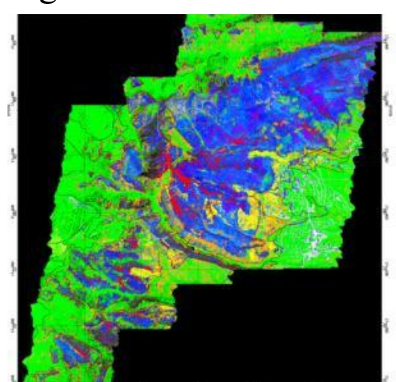
PLSR wavelength selection for one species

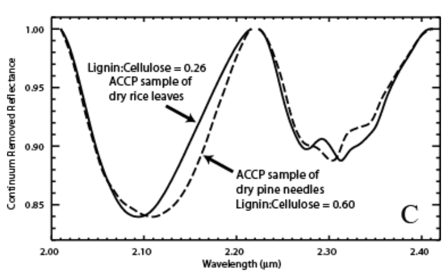


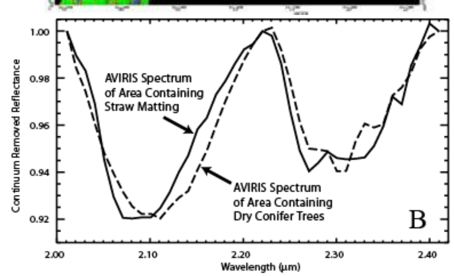


Measuring spectral shift from Lignin : Cellulose ratio

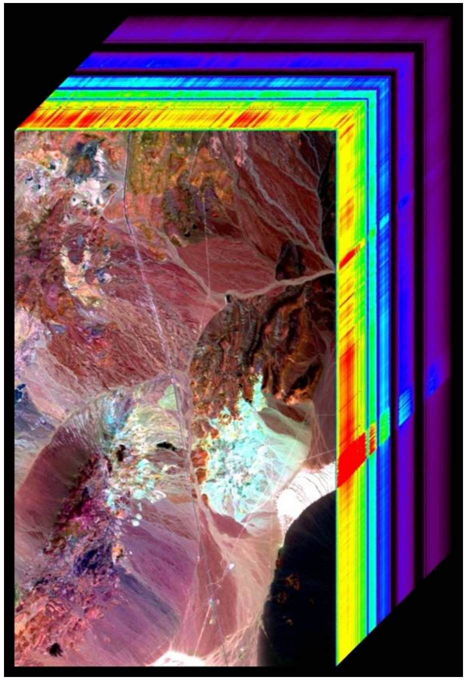


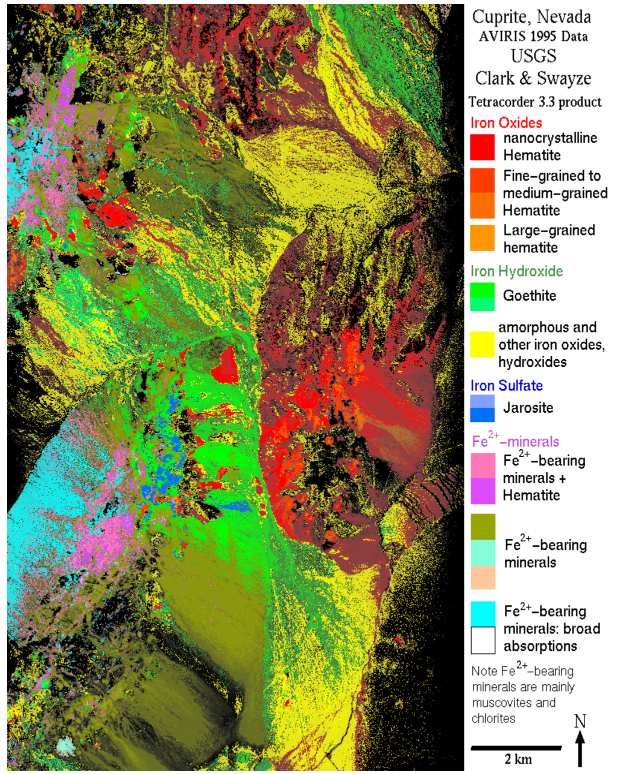


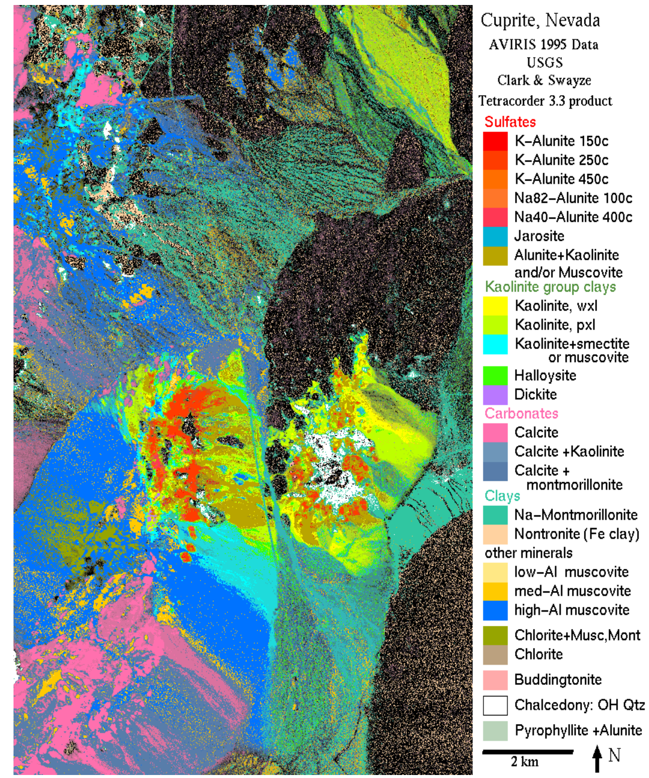


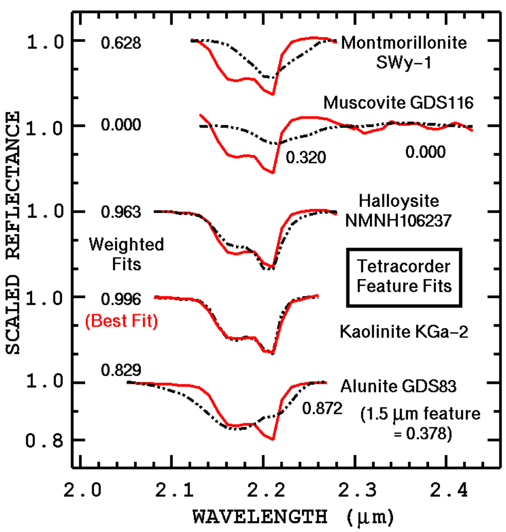


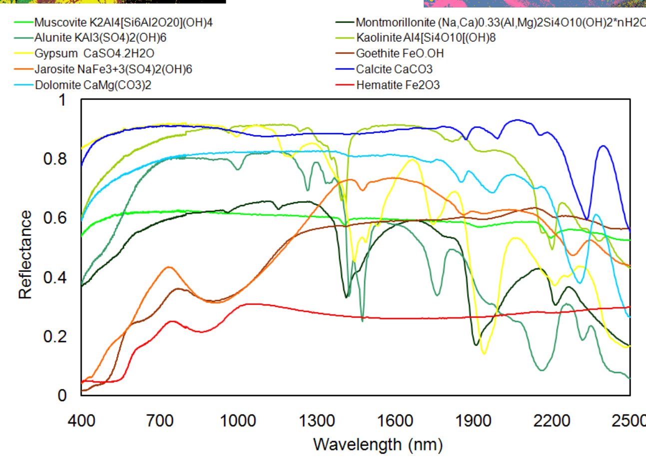
Surface Compositional Derived with Imaging Spectrometer Measurements







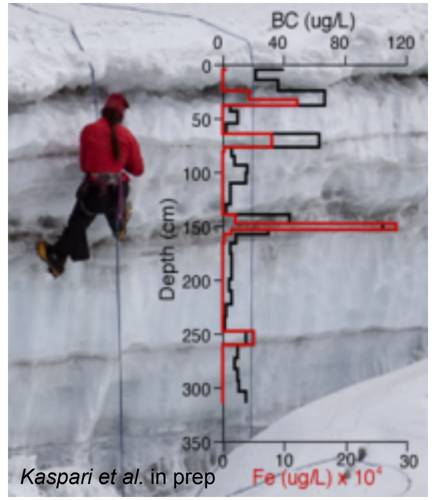


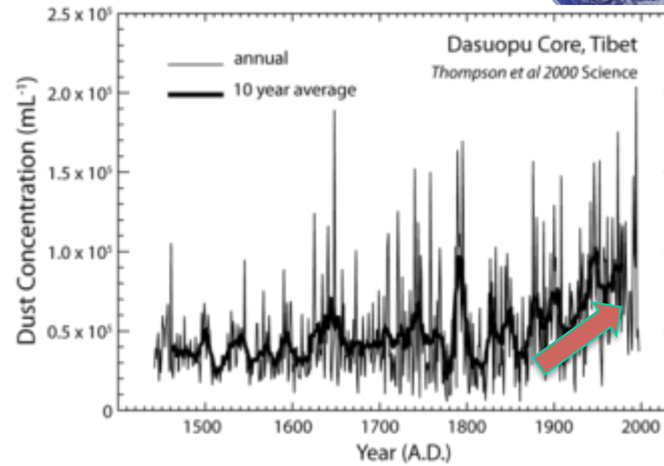


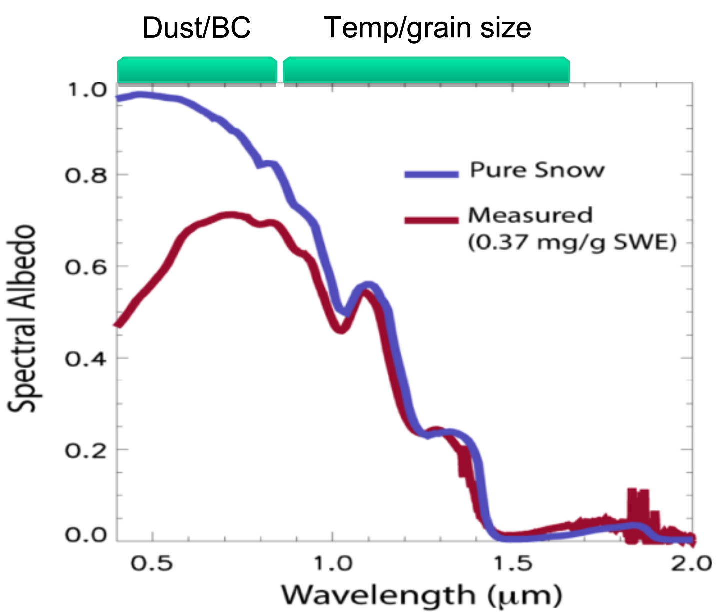
Albedo and Black Carbon/Dust Effects on Snow/Ice

What is causing the downwasting and retreat of Himalayan glaciers and elsewhere?

For snow and ice in the Himalaya, increasing temperatures and increasing dust and soot combine in unknown proportions to accelerate melt through their changes in albedo. Imaging Spectroscopy is the only approach that allows us to attribute changes in albedo into effects from temperature and dust/black carbon and at a fine enough spatial resolution that heterogeneous terrain can be resolved. Multi-band sensors such as NPOESS VIIRS have neither capacity.

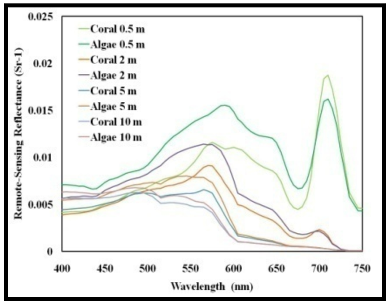


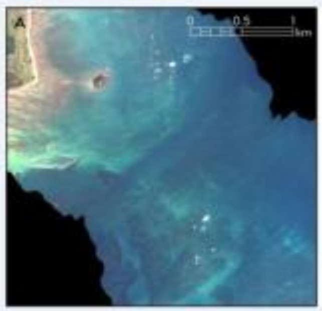


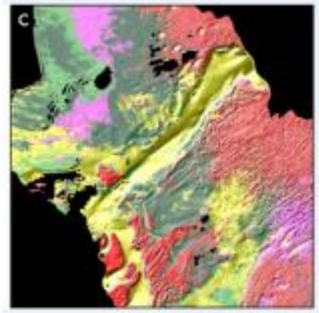


Required Measurement: Global glacial covered area, full solar spectrum, < 100 m spatial, <20 days revisit

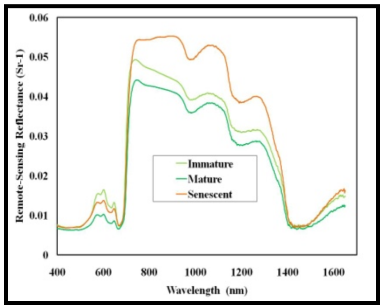
HyspIRI: Coral, Benthic Composition, and Aquatic Vegetation

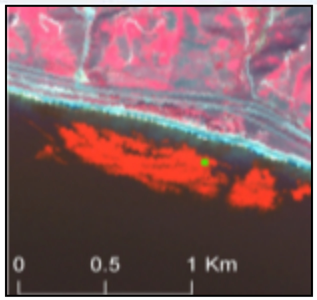




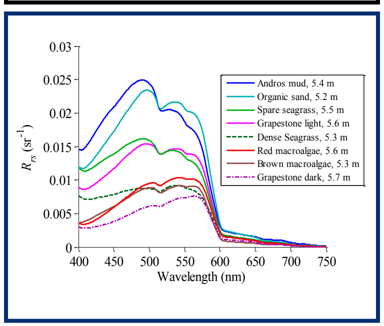


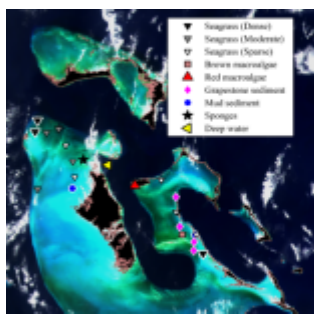
Variation in shallow water HyspIRI-type spectral signatures in coral environments.



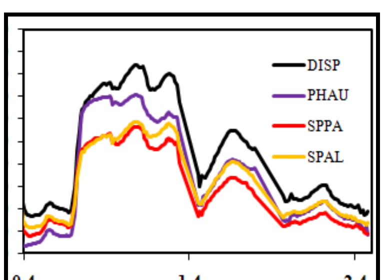


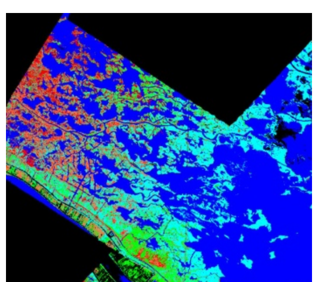
Variation in HyspIRI-type spectral signatures of floating aquatic vegetation (e.g. Kelp)





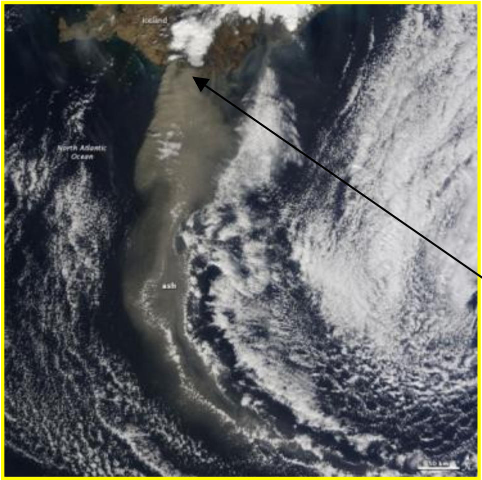
Variation in shallow water HyspIRI-type spectral signatures in seagrass beds and benthic habitat materials





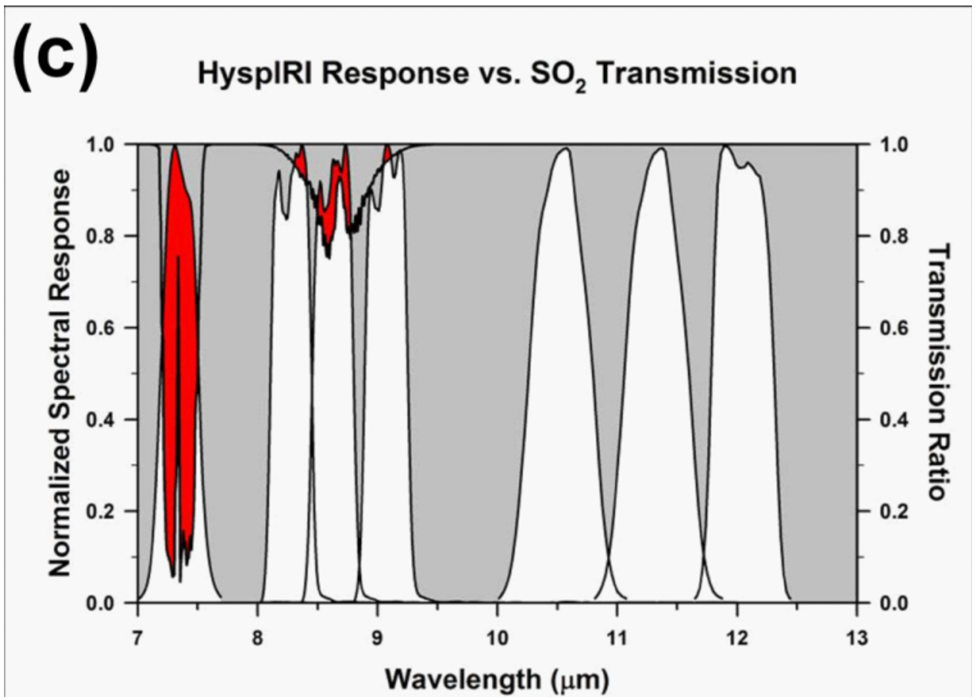
Emergent vegetation signatures are well suited to the HyspIRI measurement. For example mapping in the Gulf of Mexico coastal region with AVIRIS measurements.

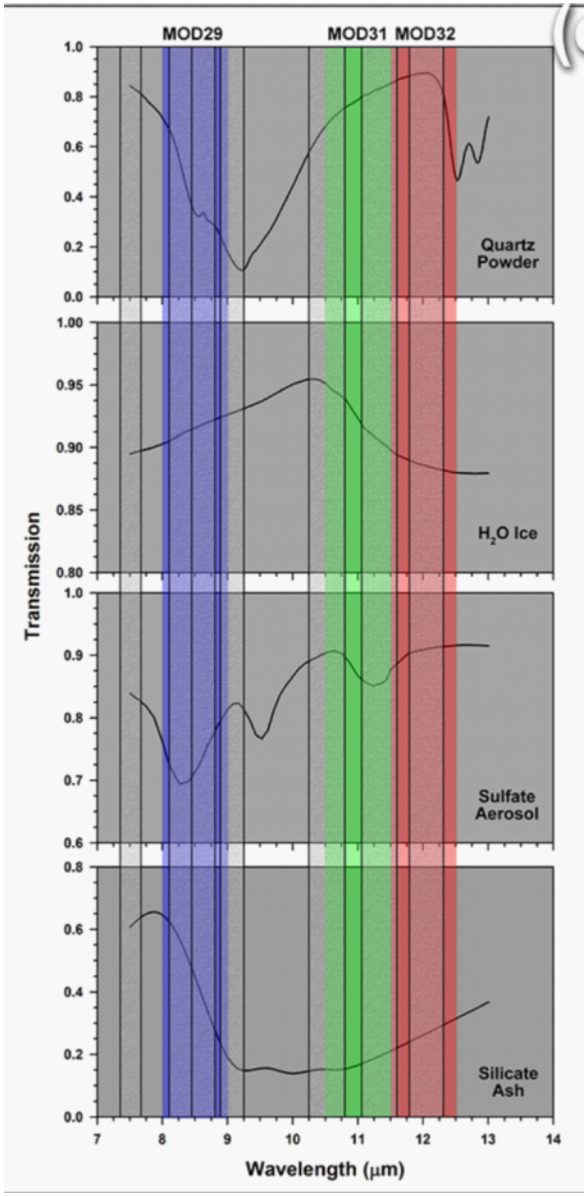
TQ1. Volcanoes/Earthquakes



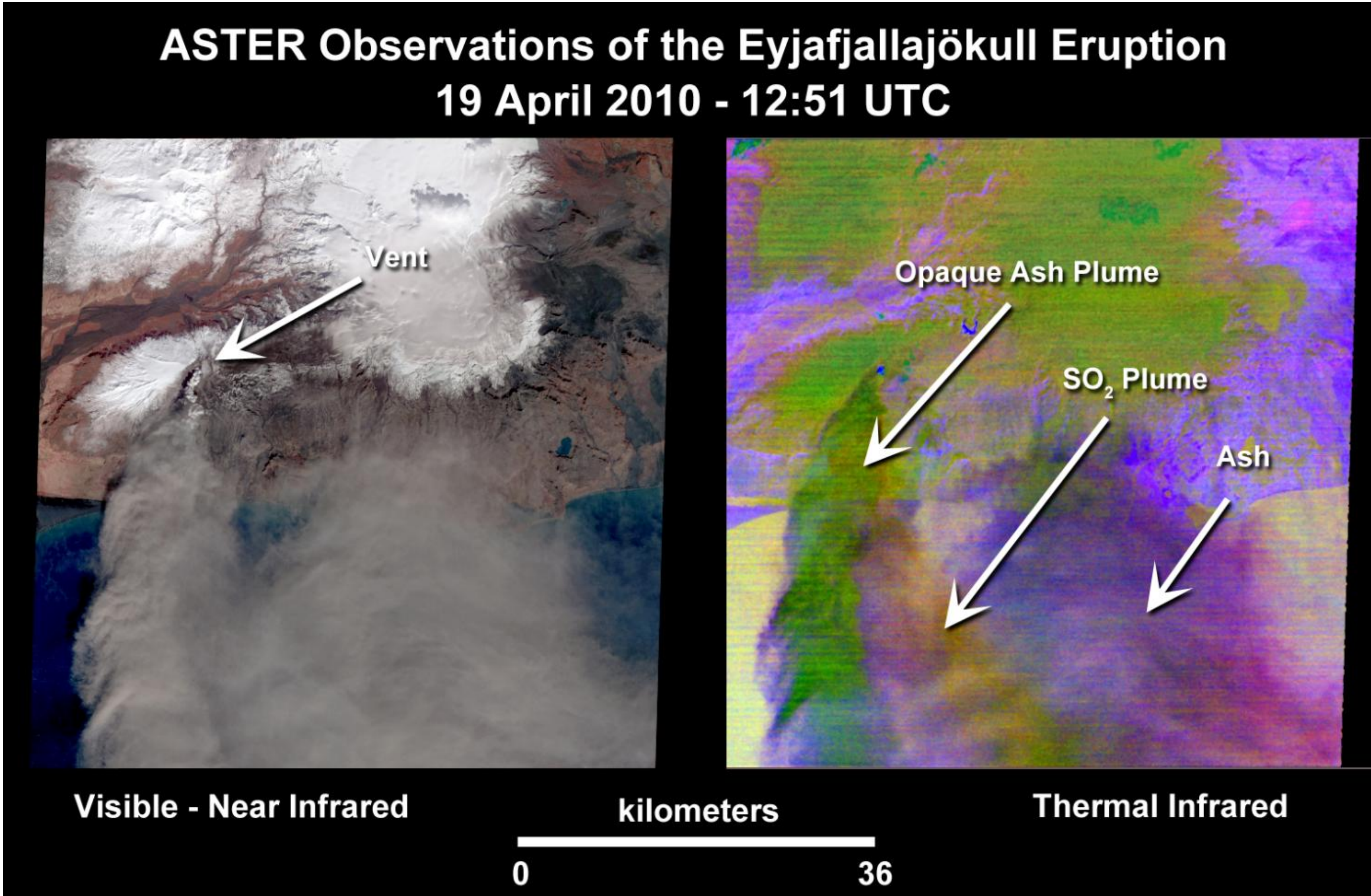
Eyjafjallajökull Iceland Volcano Eruption

April 19 2010 MODIS image of ash plume.

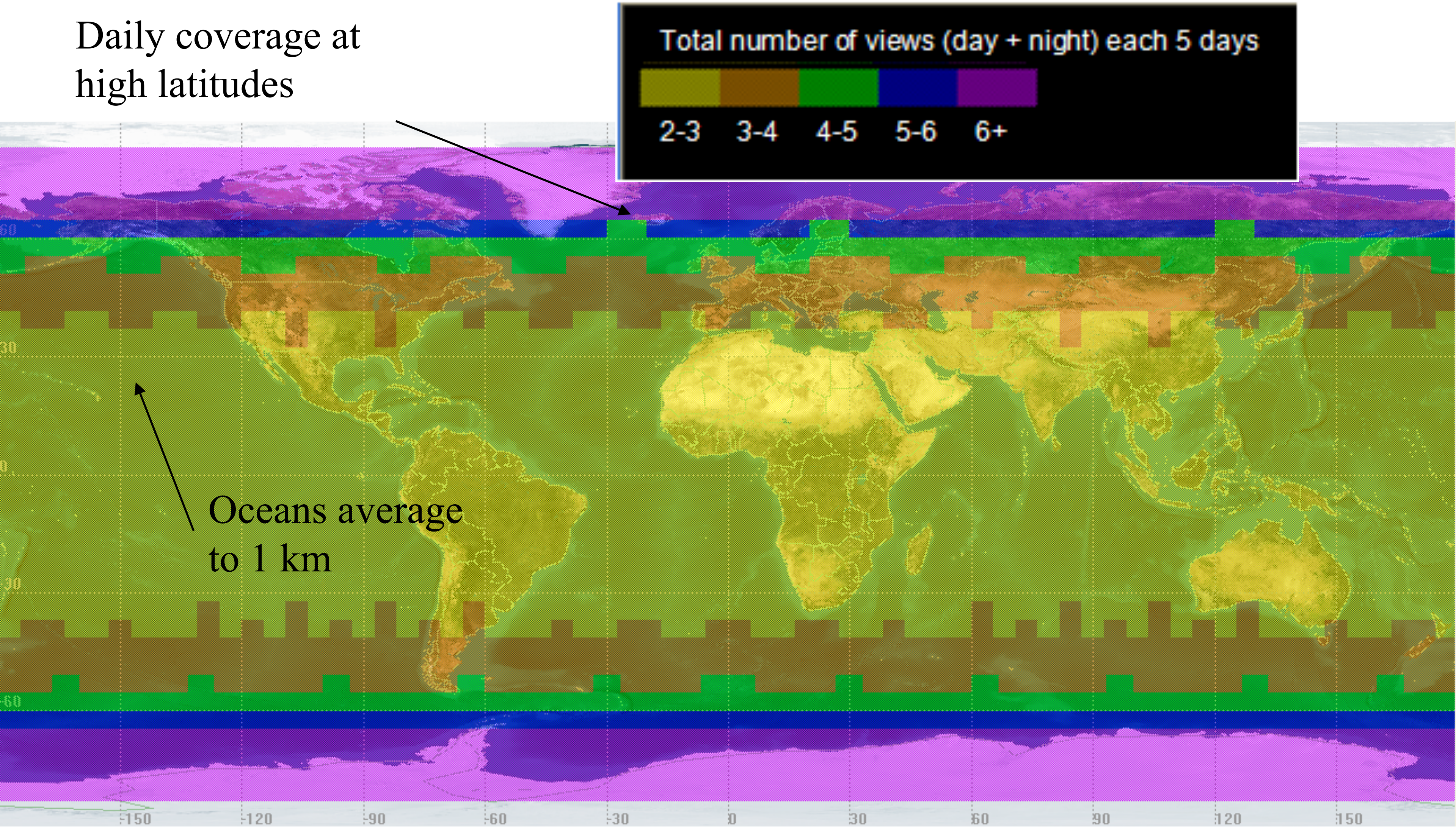




Characterizing and Understanding Volcanic Eruptions



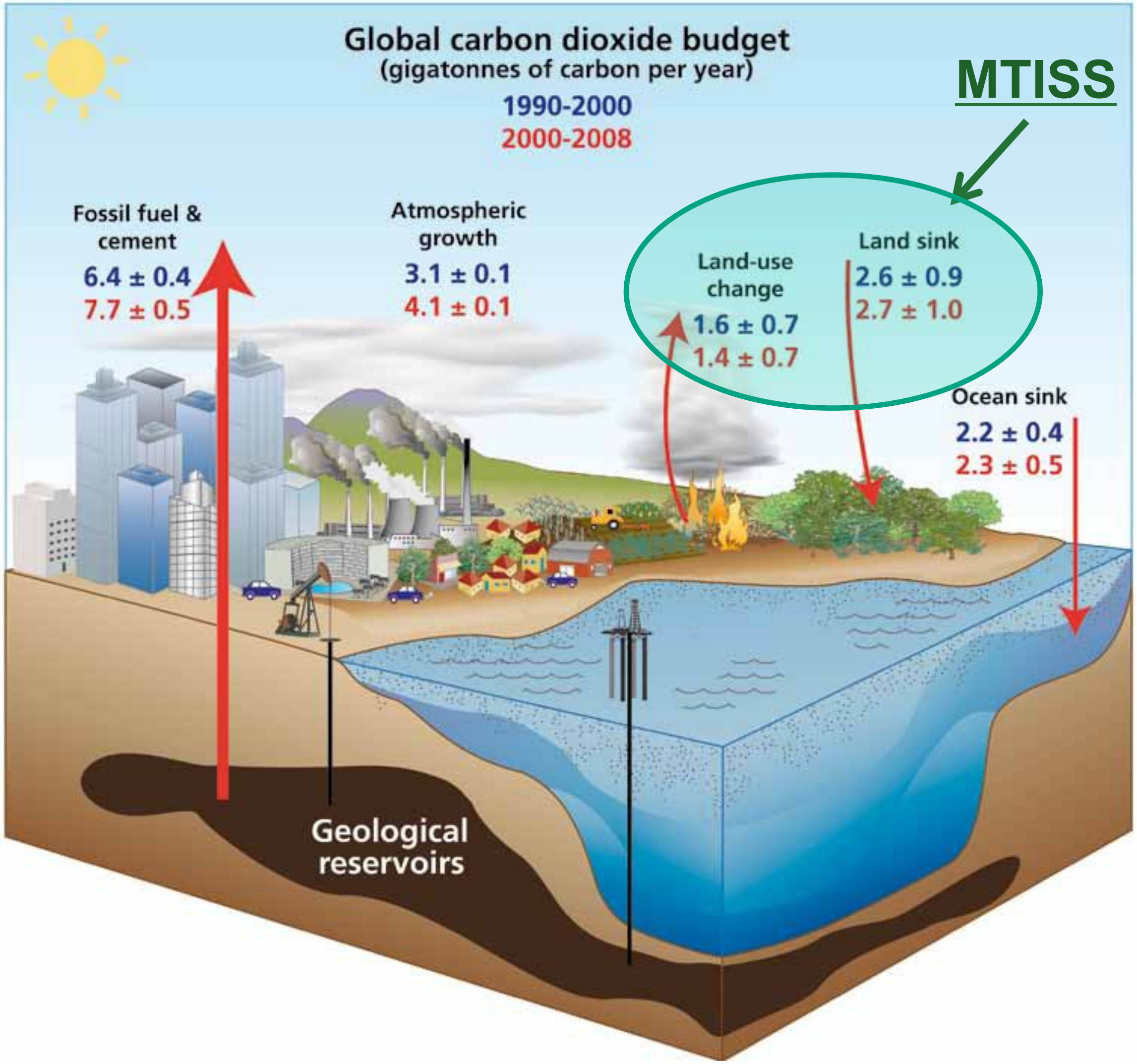
Annual TIR imaging opportunities in a 5-day near-repeating orbit, 1 yr. simulation



Nominal orbit: average alt. 626.8 km, inclination 97.8°. TIR imager FOV: +/- 25.46° (60 m pixel GSD at nadir, 9272 cross-track pixels).

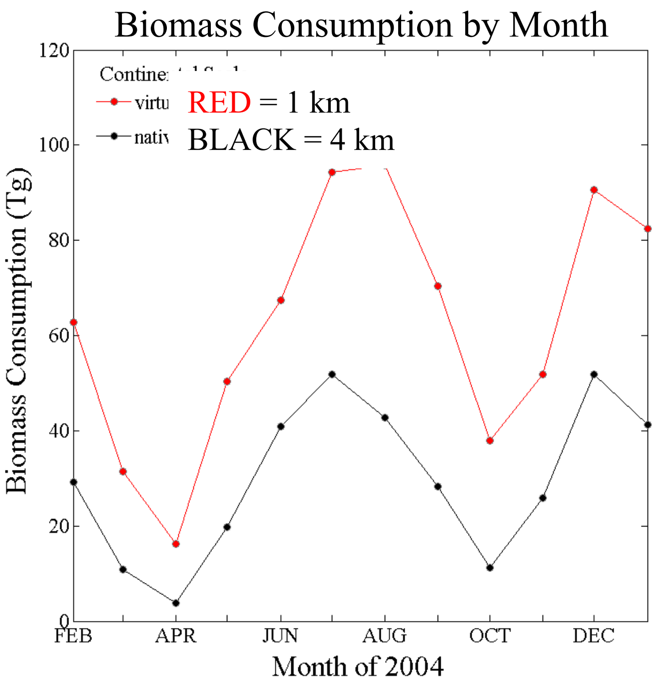
TQ2. Wildfires

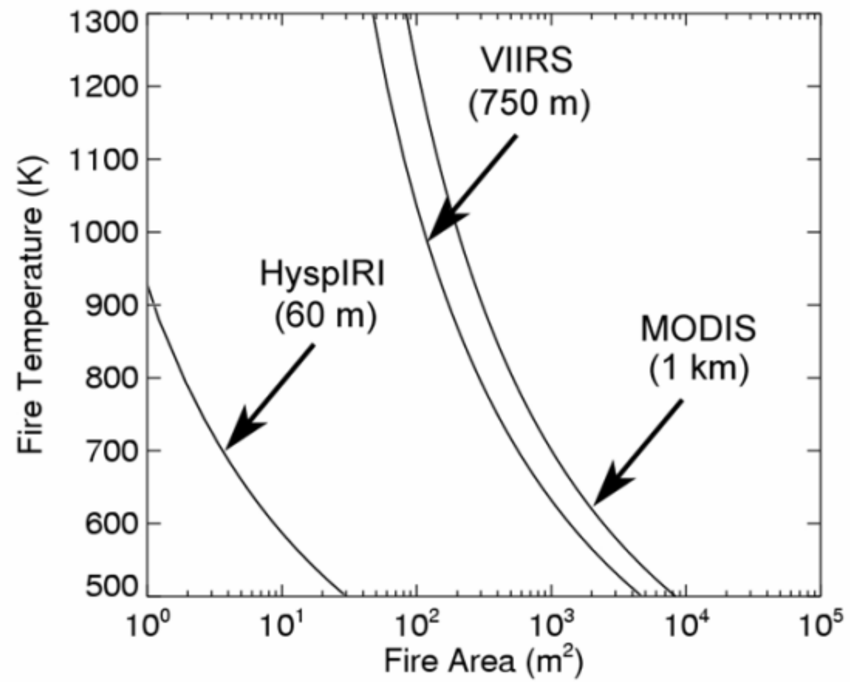
Large error in carbon budget exists due to poor knowledge of Carbon release from fires



Global CO2 budget for 1990-2000 (blue) and 2000-2008 (red) (GtC per year). Emissions from fossil-fuel and land-use change are based on economic and deforestation statistics. Atmospheric CO2 growth is measured directly. The land and ocean CO2 sinks are estimated using observations for 1990-2000 (Denman *et al.* IPCC 2007). For 2000-2008, the ocean CO2 sink is estimated using an average of several models, while the land CO2 sink is estimated from the balance of the other terms.

HyspIRI-TIR Provides Orders of Magnitude Improvement in Measurement Capability

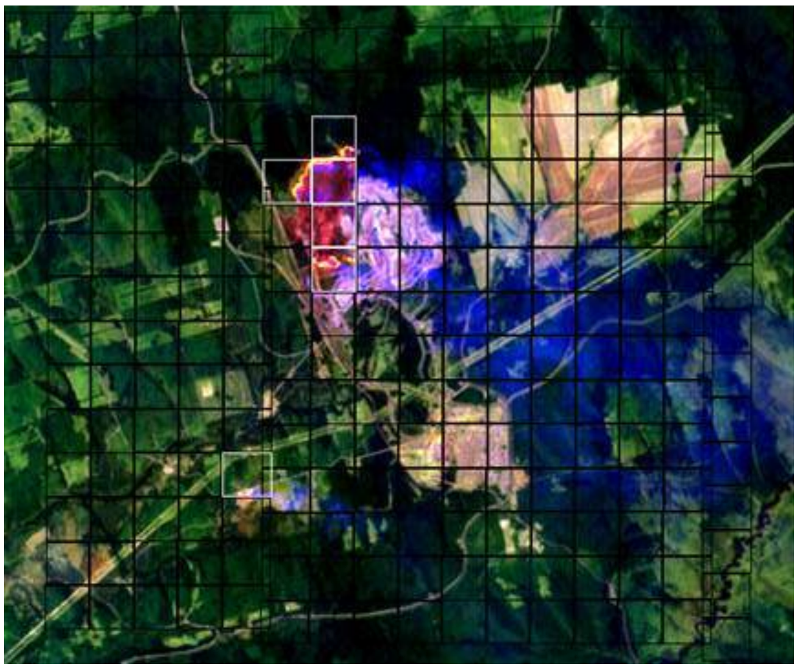




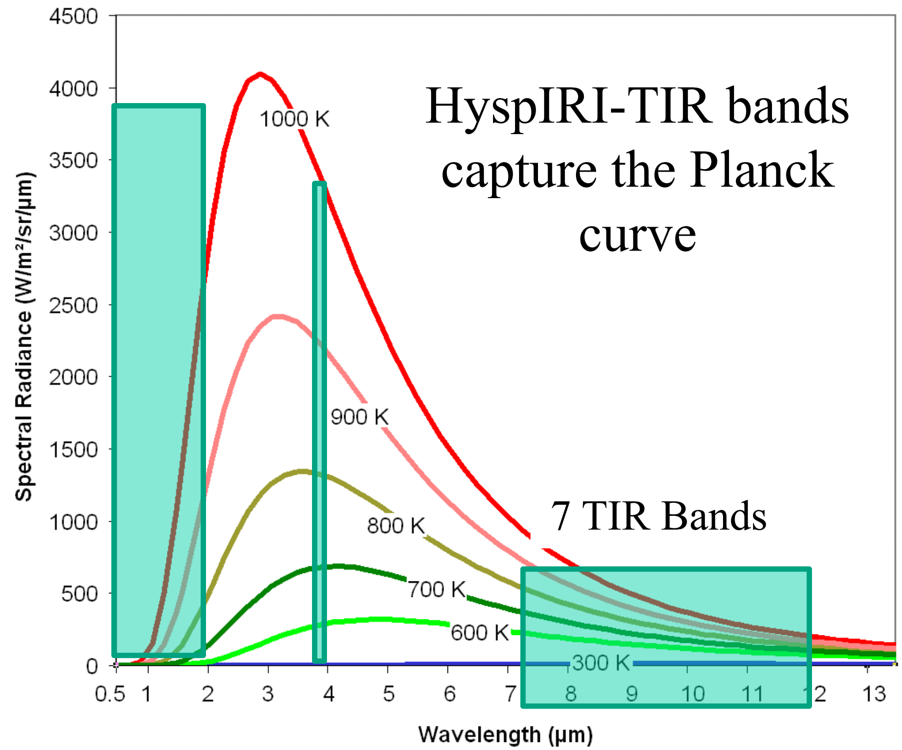
- HyspIRI-TIR measures very small fires as well as large fires. Small fires have a disproportionately large carbon contribution
- Global carbon contribution from peat, agricultural and deforestation fires unknown because cannot be measured with current sensors but see a large discrepancy between 1km MODIS and 4km GOES

Measuring carbon fire emissions requires measurements in the Mid and Thermal Infrared

- Greater sensitivity due to shift in emission peak with temperature
- Measure radiance rather than temperature and avoid mixed pixel problem

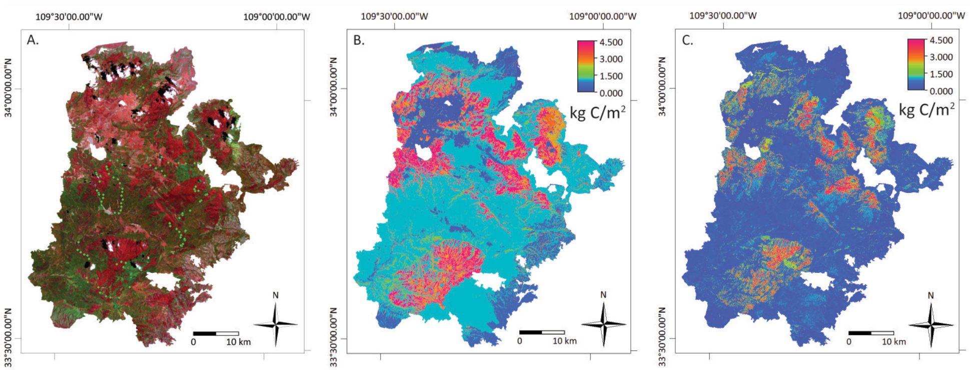


MODIS only detects white boxes (1kmX1km) does not provide information on the fire front or smouldering part of fire



Thermal emission peaks in the MIR (3-5 µm) region for fire temperatures ranging from ~ 650 K (weak smouldering) to ~ 1400 K (strong flaming). MIR is far more sensitive to hot targets than TIR.

Refining carbon emissions from wildfires by using a remotely sensed fire severity product



A. False Color Composite of Wallow fire

B. C emission from modeling

C. C emission from modeling and RS

Fire	Burned area (ha)	Estimation methodology	Total C emission (Tg)	Area normalized C emission (kg/m²)	% C emitted relative to the modeling approach
Wallow (AZ)	218 000	Modeling	3.44	1.57	1
		Modeling & RS	1.52	0.70	0.45
Canyon (CA)	5900	Modeling	0.12	2.02	1
		Modeling & RS	0.09	1.60	0.73

Veraverbeke & Hook (2012) submitted

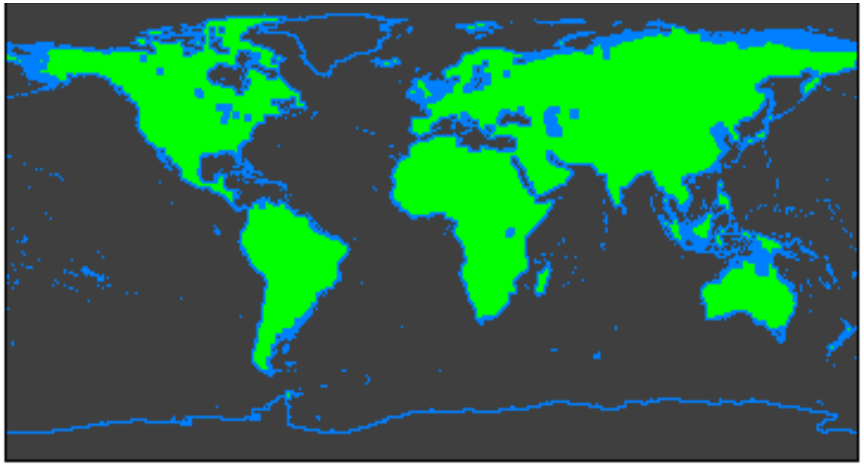
Problem: Carbon emissions from wildfires account for 20-40 % of the total global carbon emissions, however, uncertainties in these estimates are large.

Result: Using field and satellite data over two wildfires in the southwestern US, we have demonstrated that complementing traditional modeling approaches to estimate wildfire emissions with a remotely sensed fire severity product derived from spectral unmixing of VSWIR and MIR leads to significantly lower carbon emission estimates. For the mixed severity Wallow fire (AZ) estimates were 55 % lower and for the dominantly high severity Canyon fire (CA) estimates were 27 % lower.

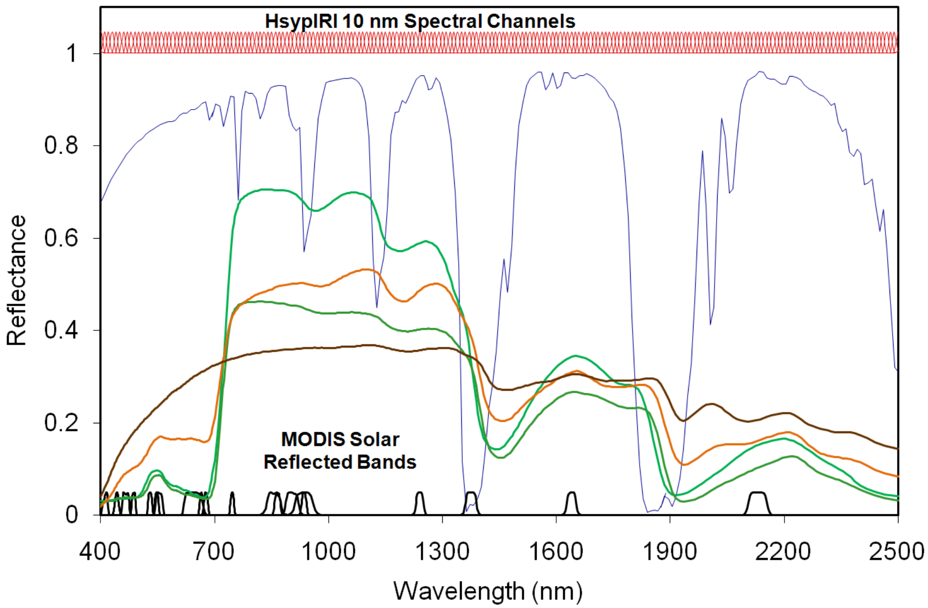
Significance: Current models that estimate carbon emissions from wildfires are subject to large uncertainties. Using remotely sensed fire severity products these uncertainties can be reduced.

Instrument Concepts

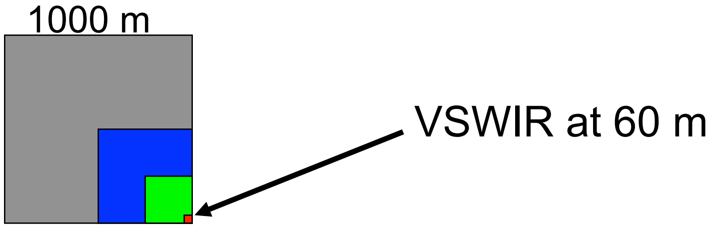
HyspIRI VSWIR Science Measurements



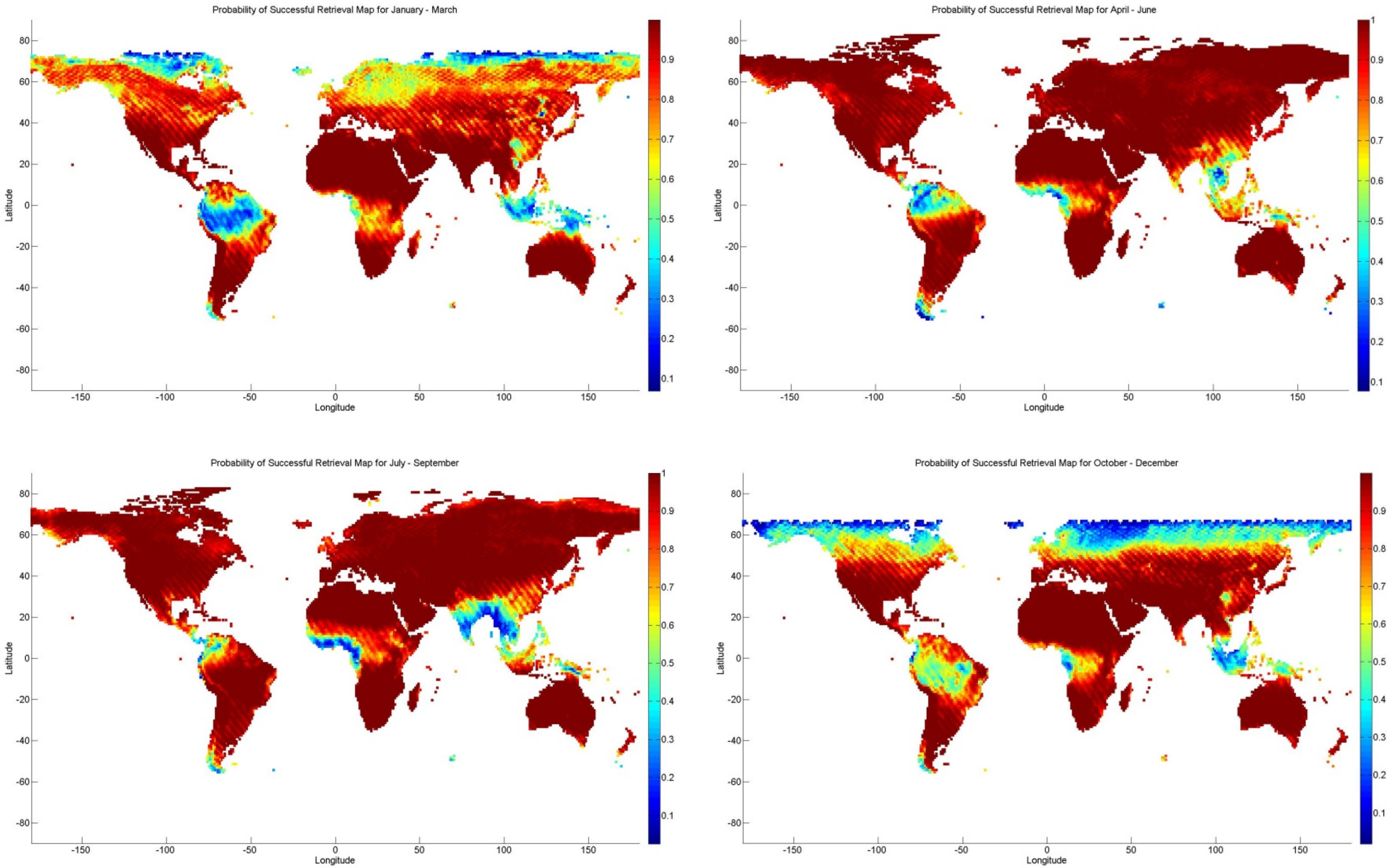
HyspIRI is a global mission, measuring land and shallow aquatic habitats at 60 meters and deep oceans and ice sheets at 1km every 19 days (VSWIR). <u>This will allow seasonal coverage for most of land surface</u>



HyspIRI's VSWIR imaging spectrometer directly measures the full solar reflected spectrum of the Earth from 380 – 2500nm at 10 nm.

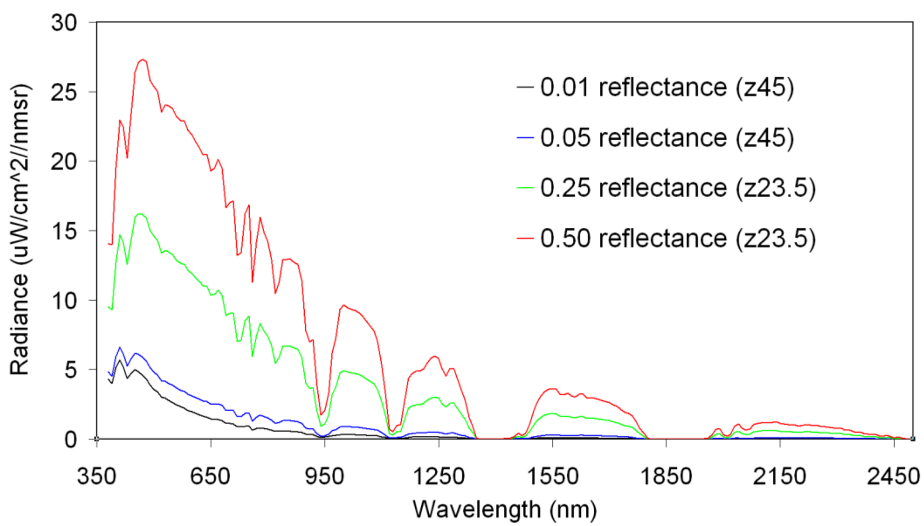


Seasonal and Annual Cloud Probability Maps Validate the HyspIRI Coverage Requirements

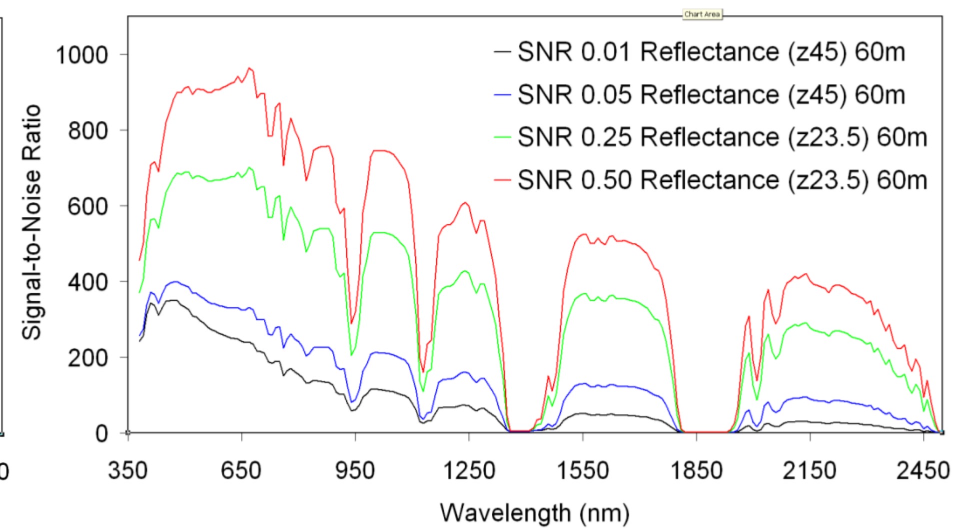


HyspIRI VSWIR SNR and Uniformity Characteristics

Benchmark Radiances

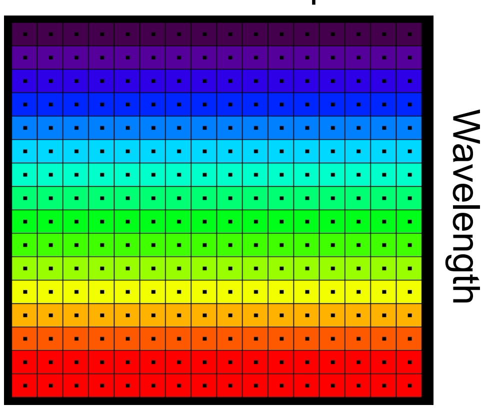


Signal-to-Noise Ratio

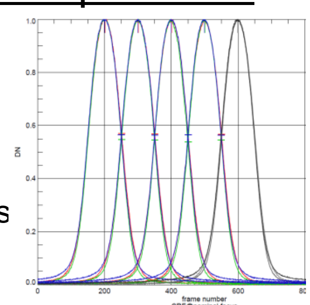


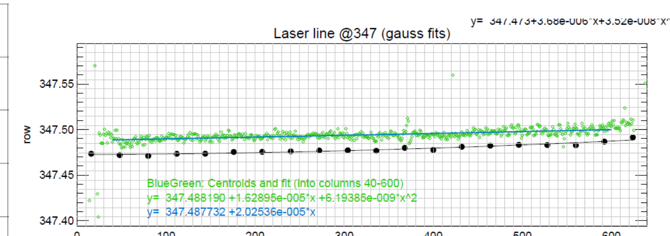
Uniformity Requirement

Cross Track Sample



Depiction
-Grids are the detectors
-Dots are the IFOV centers
-Colors are the wavelengths





Requirement

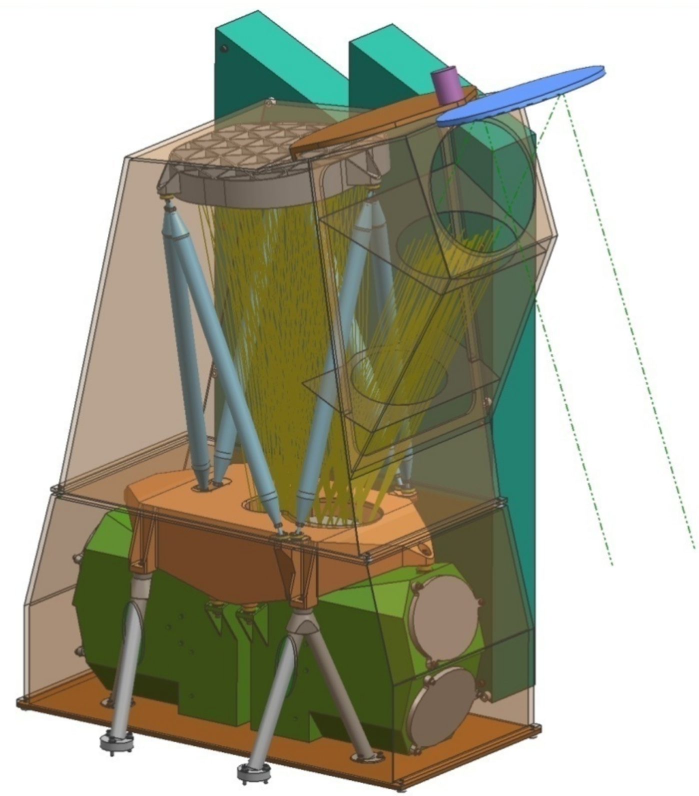
Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

VSWIR - Instrument Concept

Spectral	Requirement	Status
Range	380 to 2500 nm (solar reflected spectrum)	Demonstrated – AVRIS, MaRS, M3
Sampling	<= 10 nm {uniform over range}	Demonstrated – MaRS, M3
Response	<= 13 nm (FWHM) {uniform over range}	Demonstrated – MaRS, M3
Accuracy	<0.5 nm	Demonstrated – MaRS, M3, CAO-VSWIR

Radiometric	Requirement	Status
Range & Sampling	0 to 1.5 x benchmark radiance, 14 bits	Demonstrated via analysis and 14 bit ADC bread board electronics
Accuracy	>95% absolute radiometric, 98% on-orbit reflectance, 99.5% stability	Demonstrated – AVIRIS, MaRS
Linearity	>99% characterized to 0.1 %	Demonstrated via test, MaRS and CAO-VSWIR
Polarization	<2% sensitivity, characterized to 0.5 %	Demonstrated via analysis of design and test data on the grating

HyspIRI – VSWIR

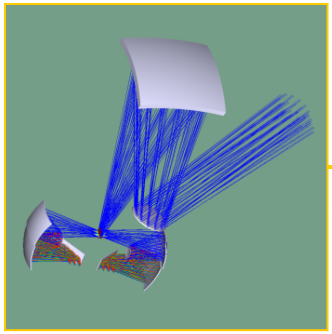


Mass (CBE) ***55Kg***
Power (Ave.) ***41Watts***

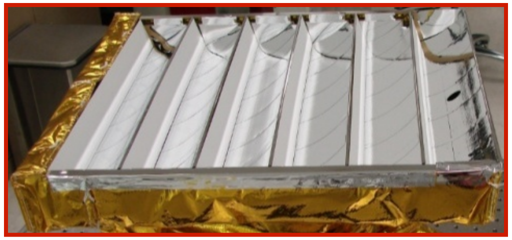
HyspIRI VSWIR Concept

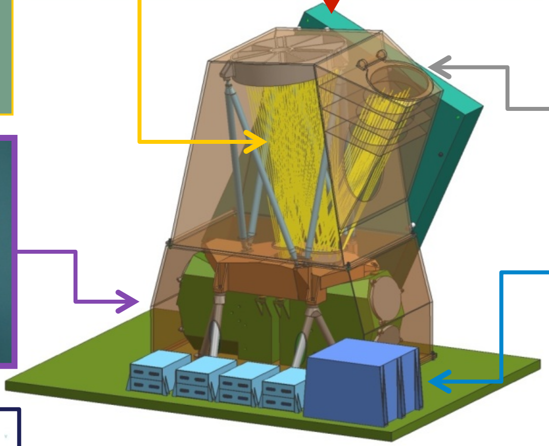
Optics
• Front End Telescope consists of a primary spherical mirror and a secondary aspherical mirror

• Back End Spectrometers consist of 2 optimized Offner spectrometers



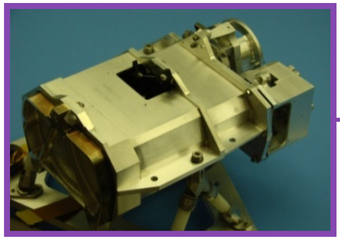
Radiator
• Area 0.6m^2
• M3 technology heritage

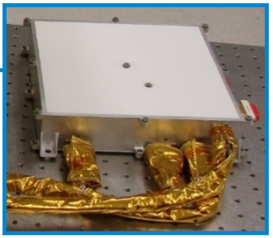




Baffle/Cover/Cal Panel
• *Launch cover*
•*Used as a solar reflectance calibration target*
•*Hyperion Heritage*

Spectrometers (2x)
- 2 identical Offner spectrometers
- Each contains:
  - E-Beam grating
  - Si air slits
  - FPA assembly





Electronics
• M3 Derivative 4x

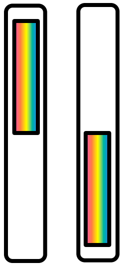
• Electronic concept is based upon available flight approved parts

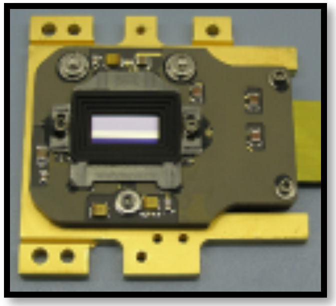
• Ins. control, Data Compression, mode control

FP A (2x)
• Mount is adjustable in 6 DOF

• Thermal strap connects mount to radiator

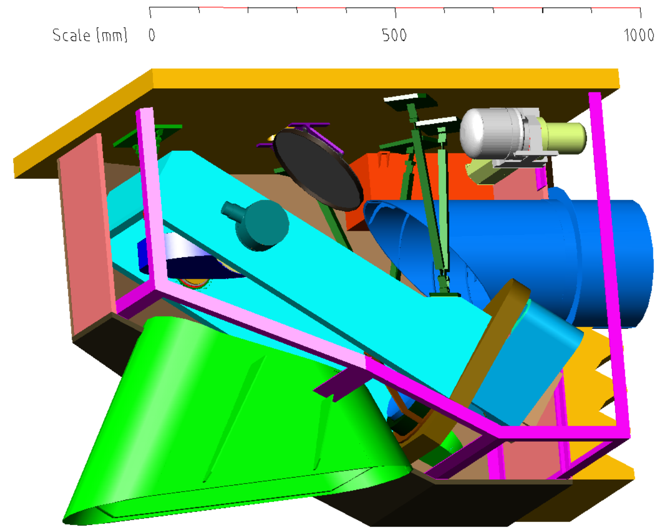
•Includes integral OSF





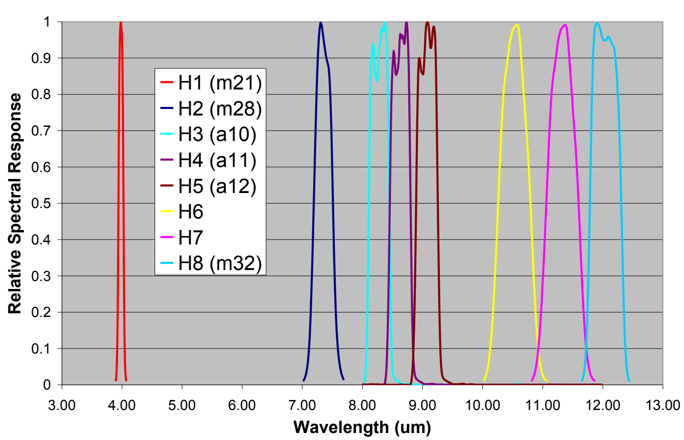
Detectors
- Teledyne 6604b detectors, scaled from 6604a detectors flown on M3
- Analog output
- Each spectrum readout as snapshot, so that there is no time delay, yaw, or jitter impact to the spectral-IFOV-uniformity.

HyspIRI Thermal Infrared Multispectral (TIR) Science Measurements



Measurement:

- 7 bands between 7.5-12 µm and 1 band at 4 µm
- 60 m resolution, 5 days revisit
- Global land and shallow water



Key Measurement Parameters:

Overpass time: 10:30 am

Whisk-Push system

Day and night imaging

Compression: 2:1 lossless

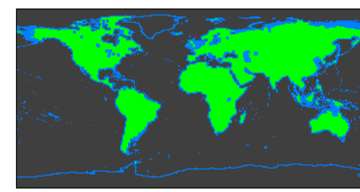
Cross-Track Samples: 10,000

Down-Track Samples: 256

Swath Width: 600 km (±25.5° at 623 km altitude)

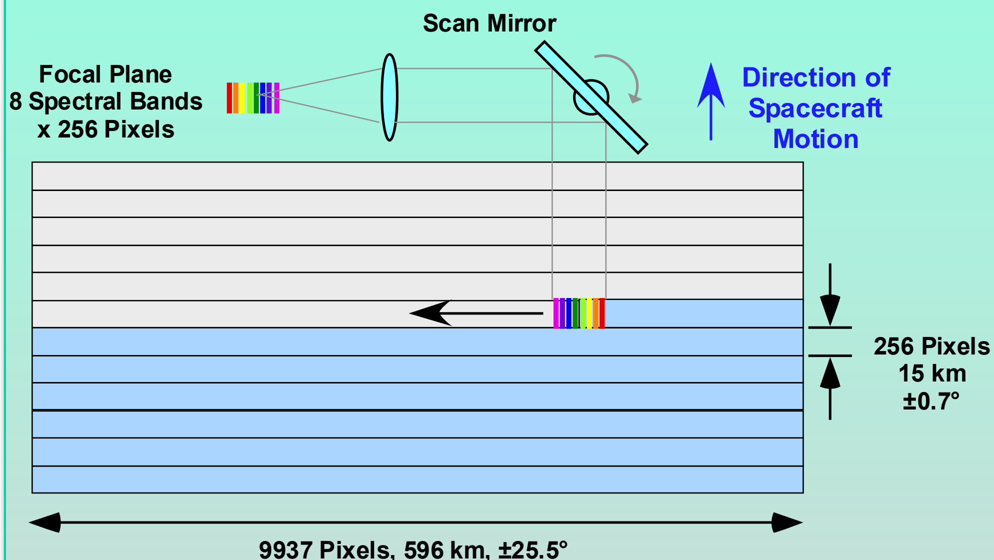
Swath Length: 15.4 km (+/- 0.7-degrees at 623km altitude)

Saturation: Bands 2-8= 200K – 500K; Band 1= 1200K



TIR Instrument Concept

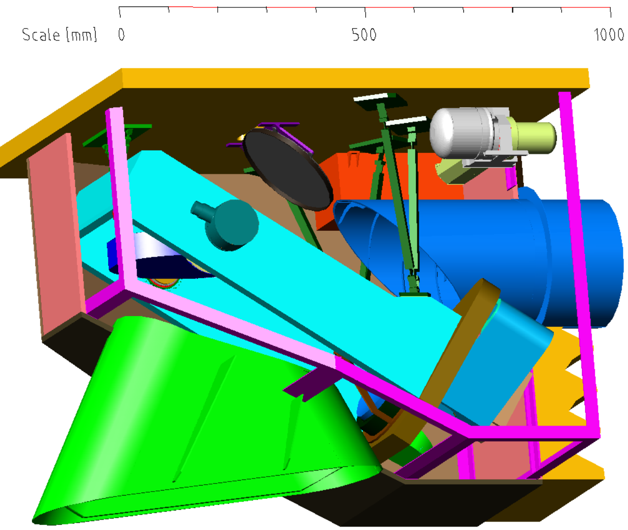
Scanning and Data Rate



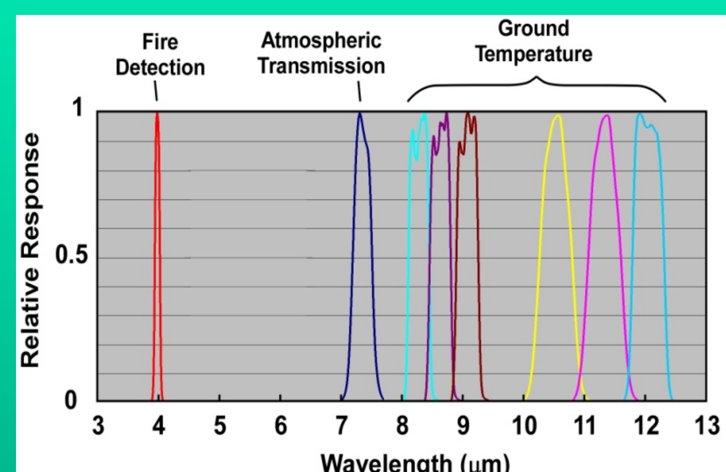
- 60 m Pixel Footprint
- Time-Averaged Science Data Rate 0.024 Gbps
- Assuming 14 bits, 2:1 Compression
- Scan Mirror Rotation Rate 13 RPM
- Pixel Dwell Time 32 microseconds

Mass and Power (JPL Team X)

- Mass CBE 60 kg
- Power CBE 109 W



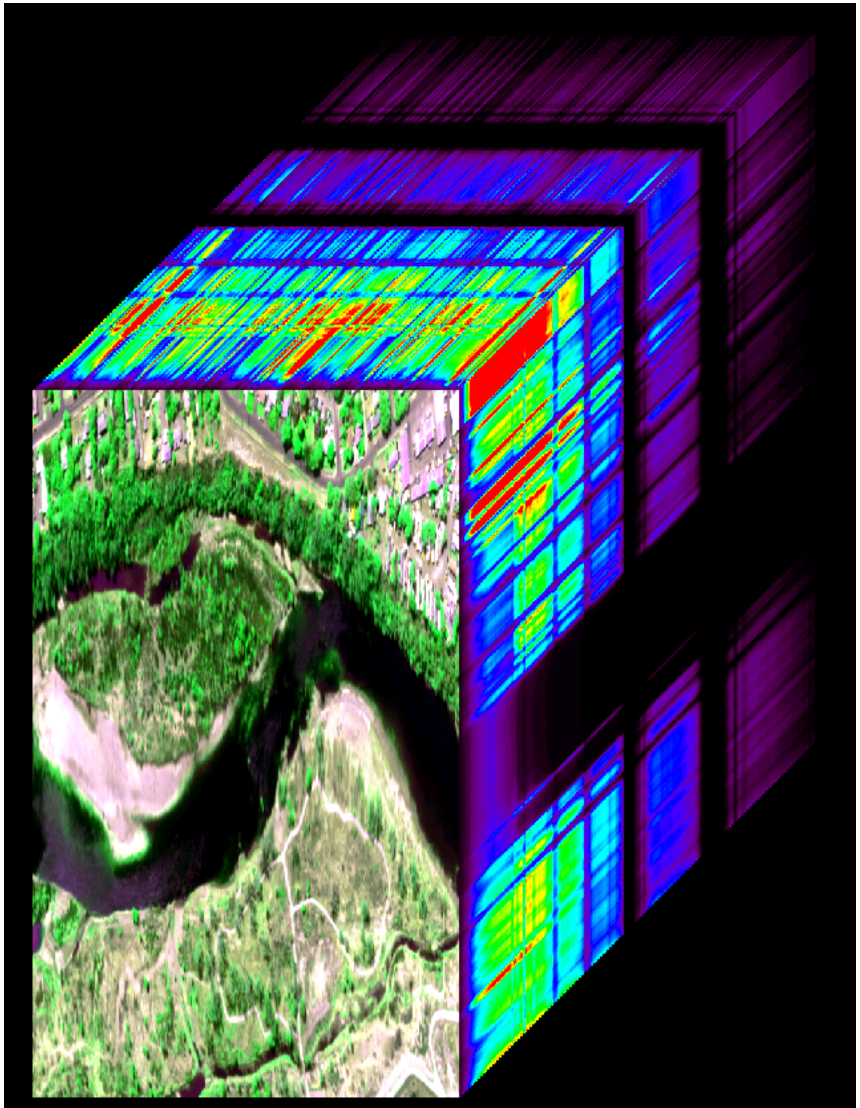
Spectral Bands

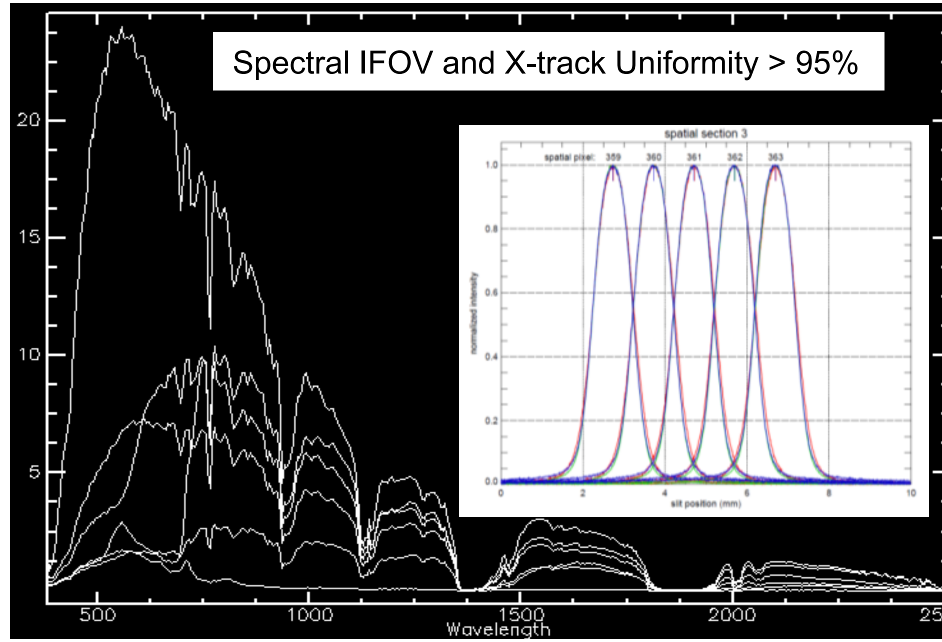


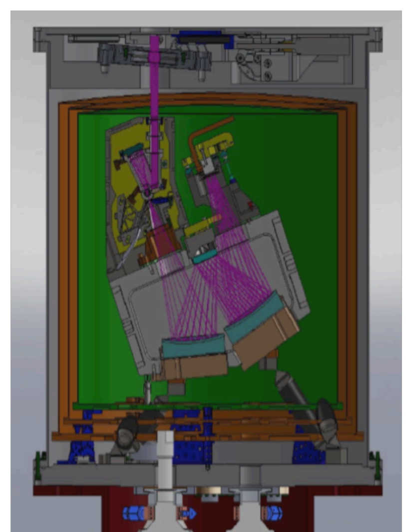
Risk Reduction

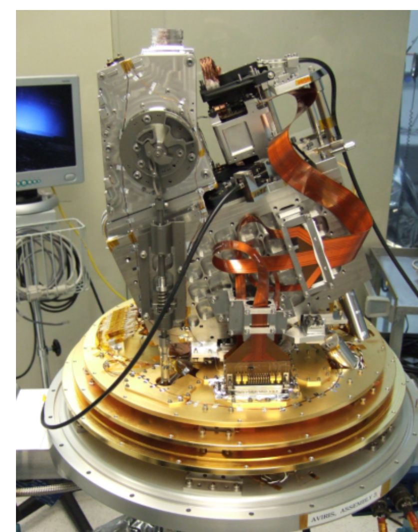
AVIRIS-NG
HyTES
PHyTIR

AVIRIS Next Generation First Spectra 20120422



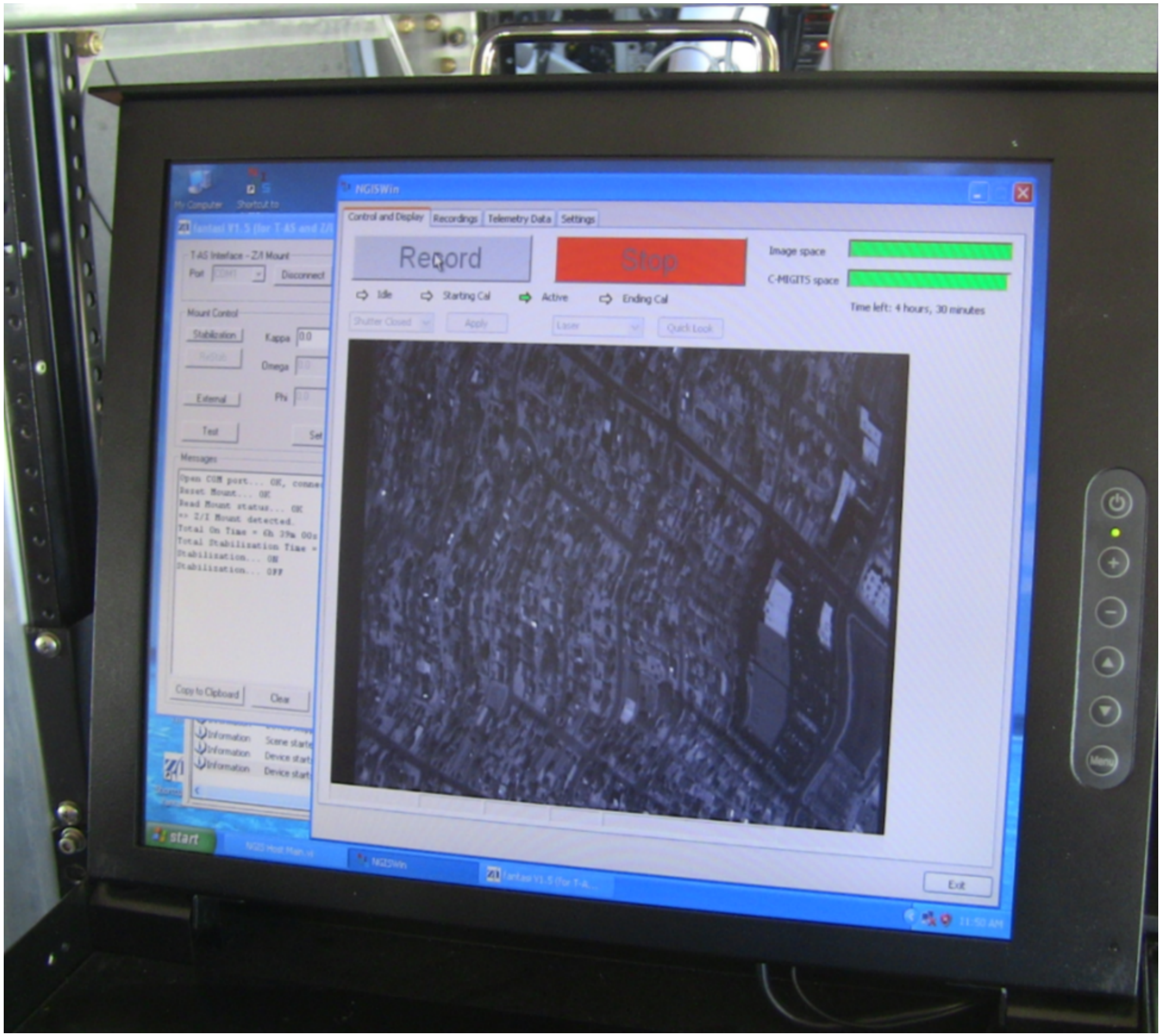


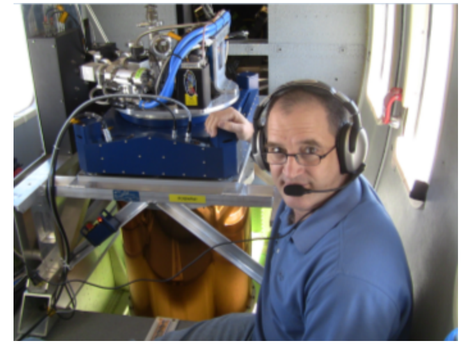


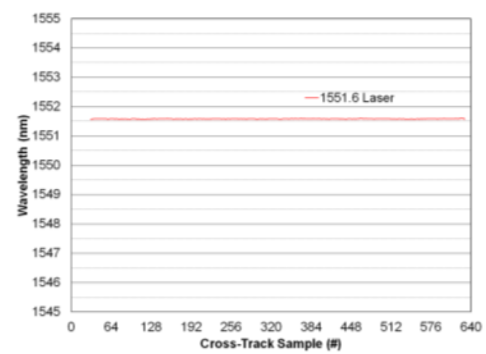


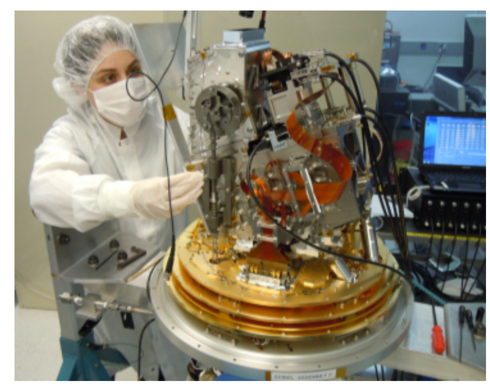
AVIRIS-NG First Flight 22 April 2012

- Photo of the scrolling quicklook. Spectra to follow.



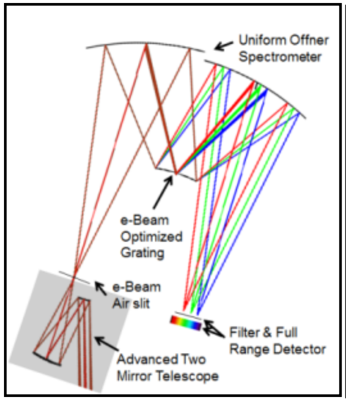


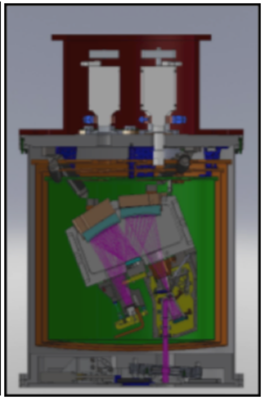


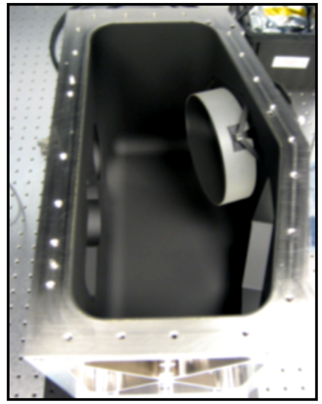


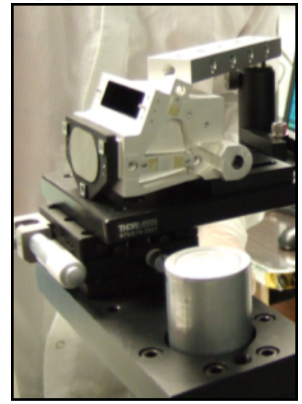
AIRIS Next Generation

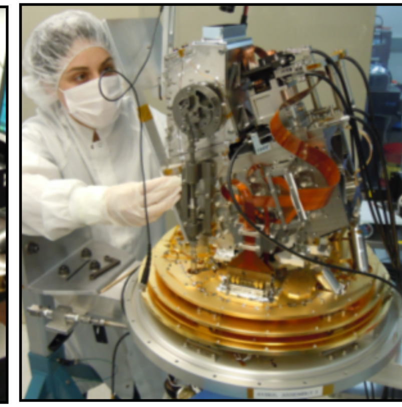
NASA Earth Science and Science Applications





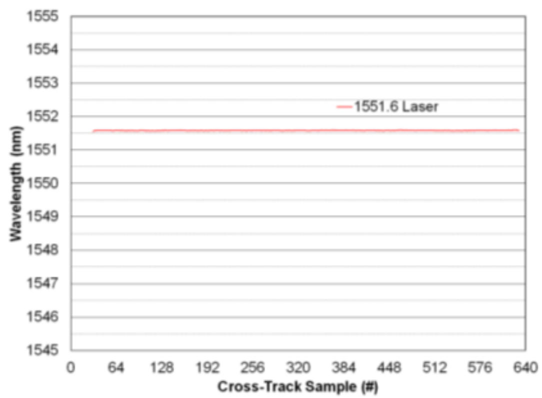




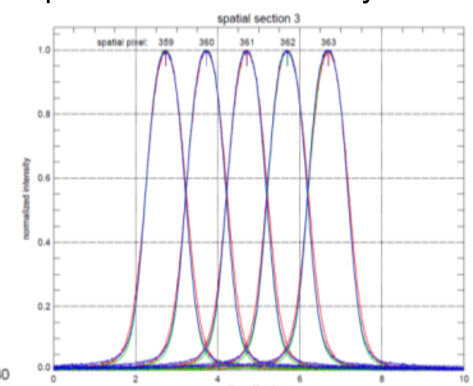


- Designed to exceed AVIRIS-Classic in the spectral, spatial, radiometric and uniformity domains
- Uses 21st century elements: design, grating, slit, mounts, alignment/calibration (many HyspIRI concept VSWIR elements)
- Completed cold alignment on the 30th of March 2012
- Completed calibration on the 6th of April 2012
- All requirements are met
- Test flights planned the week of the 23rd of April 2012

Spectral X-track Uniformity > 95%



Spectral IFOV Uniformity > 95%

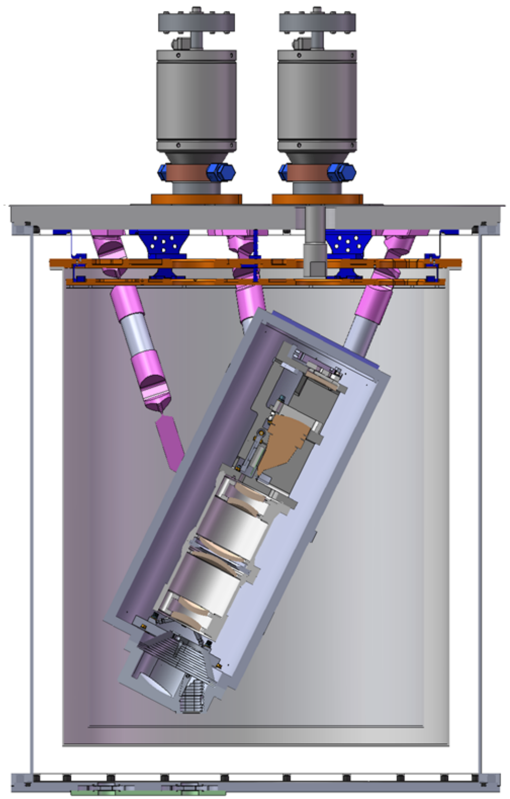


Alignment complete

Initial flights on a Twin Otter aircraft

Hyperspectral Thermal Emission Spectrometer (HyTES)

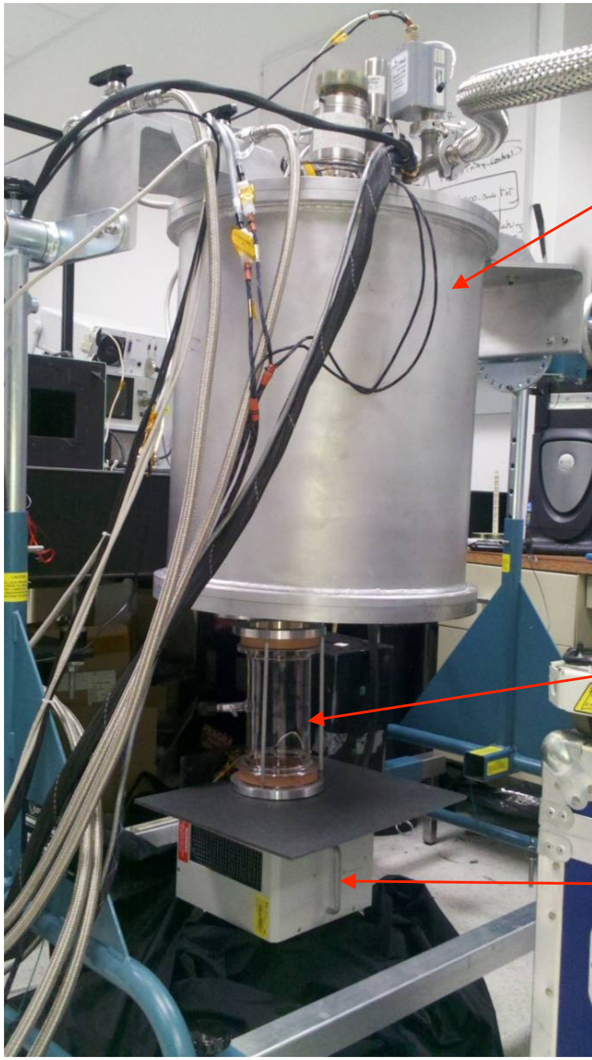
Flights in July 2012



Instrument Characteristic	HyTES
Mass (Scanhead)[1]	12kg
Power	400W
Volume	1m x 0.5m (Cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5-12 um
Integration time (1 scanline)	30 ms
Total Field of View	50 degrees
Calibration (preflight)	Full aperture blackbody
QWIP Array Size	1024x512
QWIP Pitch *	19.5um
QWIP Temperature	40K
Spectrometer Temperature	100K
Slit Width	39 µm
Pixel size at 2000 m flight altitude	3.64m
Pixel size at 20,000 m flight altitude	36.4m

1. Does not include 1 rack of electronics to operate instruments

HyTES Recent Gas Measurements in Lab



HyTES Scan head

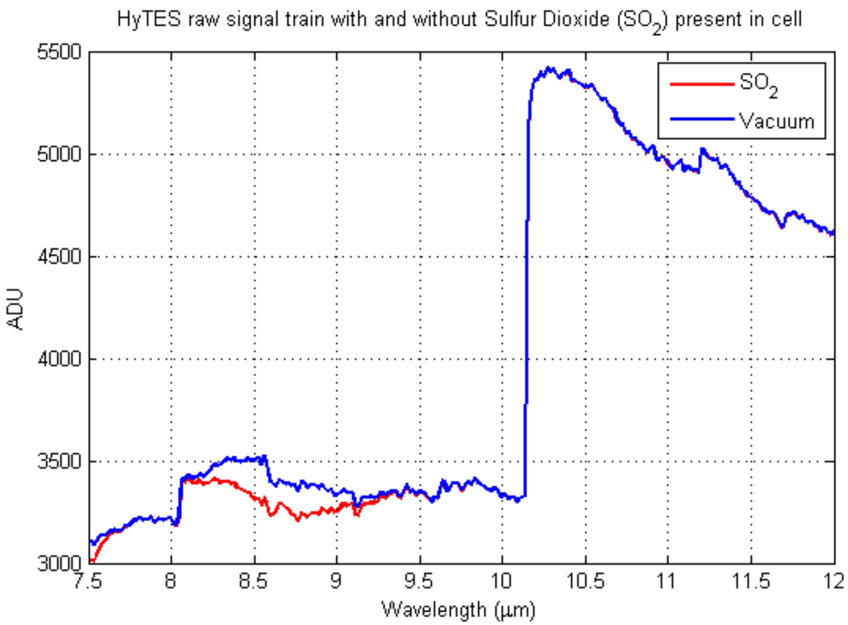
Gas cell housing

Blackbody transmission source

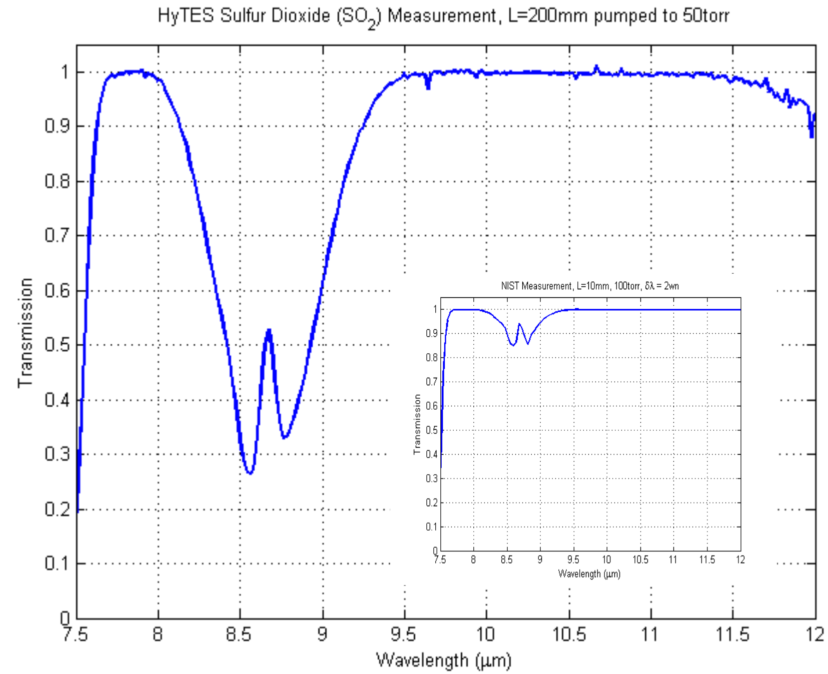
Custom cell housing

- **200mm cell length**
- **ZnSe transmission optics with anti-reflection coatings for maximum transmission.**
- **All gas species are held at 50torr pressure**

HyTES Sulfur Dioxide (SO_2) measurement



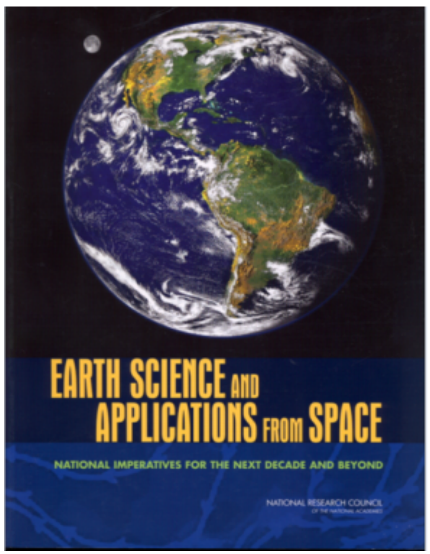
Difference in raw signal between having Sulfur Dioxide present in cell and not.



Pixel 256 of HyTES. HyTES ultimate spectral resolution is about 17.6nm.

Inset: SO2 gas data from NIST Standard Reference Database 69: *NIST Chemistry WebBook. $4cm^{-1}$ resolution.*

The HyspIRI Concept Enables the Full Set of Decadal Survey Science and Science Applications and Climate Science



- Key HyspIRI climate objectives from the Decadal Survey and IPCC
  - Ecosystem Measurement for Climate Feedback
  - Black Carbon/Dust Effects on Snow and Ice
  - Carbon Release from Biomass Burning
  - Evapotranspiration and Water Use and Availability
  - Critical Volcanic Eruption Parameters

Imaging Spectrometer (VSWIR)

  - Pattern and Spatial Distribution of Ecosystems and their Components
  - Ecosystem Function, Physiology and Seasonal Activity
  - Biogeochemical Cycles
  - Changes in Disturbance Activity
  - Ecosystem and Human Health
  - Earth Surface and Shallow Water Substrate Composition

Combined Imaging Spectrometer and Multi-Spectral Thermal Science

  - Coastal habitats, and inland aquatic environments
  - Wildfires
  - Volcanoes
  - Ecosystem Function and Diversity
  - Land surface composition and change
  - Human Health and Urbanization

Questions?