HyspIRI

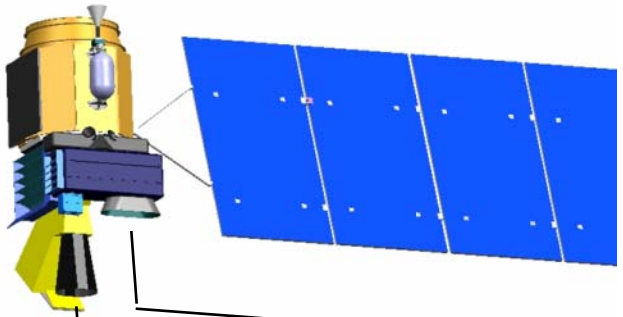
TIR Science Measurement Baseline

NASA Earth Science and Applications Decadal Survey

Simon J. Hook and HyspIRI Team

NRC Decadal Survey HyspIRI

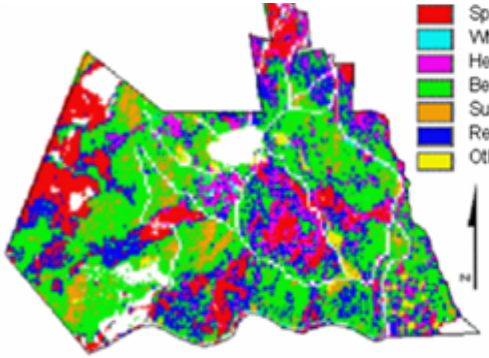
Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer
+
Multispectral Thermal InfraRed (TIR) Scanner

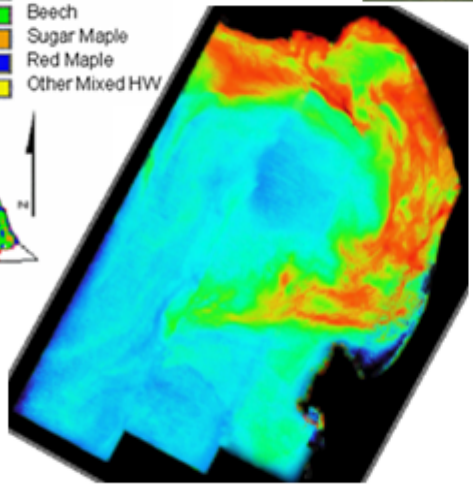


VSWIR: Plant Physiology and Function Types (PPFT)

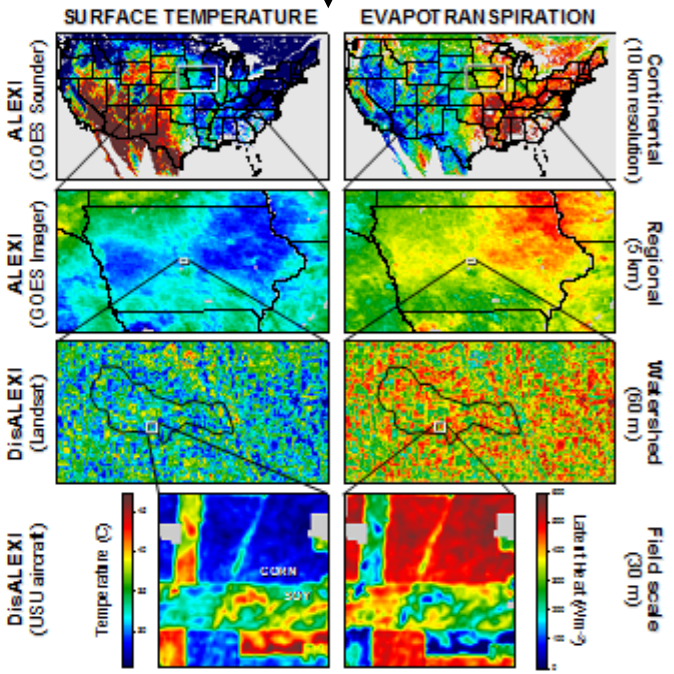
Multispectral TIR Scanner

Map of dominant tree species, Bartlett Forest, NH

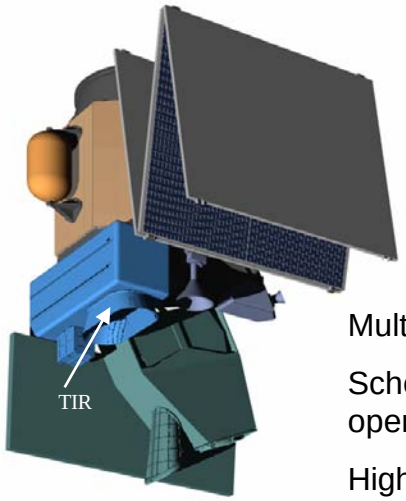


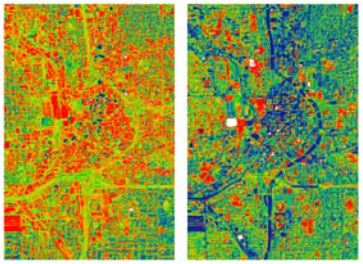


Red tide algal bloom in Monterey Bay, CA



HysplRI Thermal Infrared Multispectral (TIR) Science Measurements





Multispectral Scanner

Schedule: 4 year phase A-D, 3 years operations

High Heritage

Science Questions:

TQ1. Volcanoes/Earthquakes (MA,FF)

– How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

• TQ2. Wildfires (LG,DR)

– What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?

• TQ3. Water Use and Availability, (MA,RA)

– How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?

• TQ4. Urbanization/Human Health, (DQ,GG)

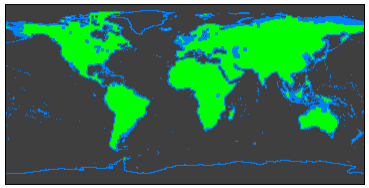
– How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

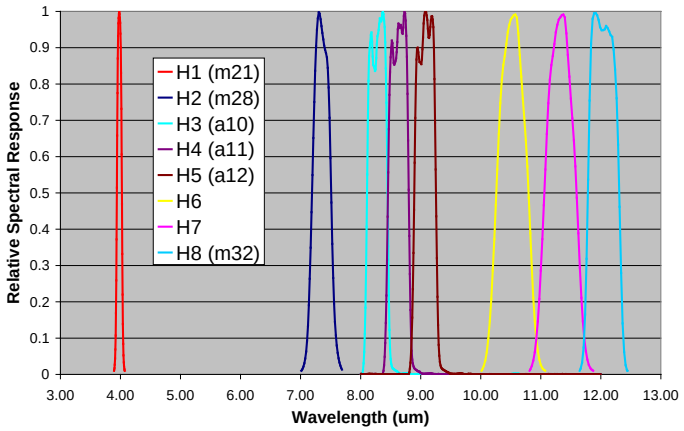
• TQ5. Earth surface composition and change, (AP,JC)

– What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?

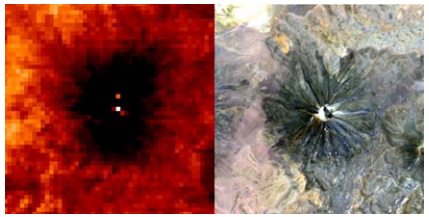
Measurement:

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

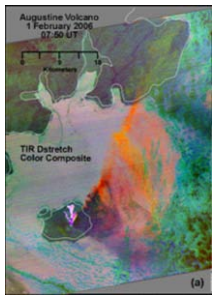




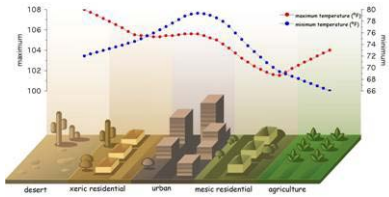
Andean volcano heats up



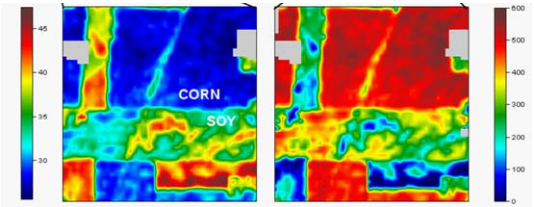
Volcanoes



Urbanization



Water Use and Availability



Surface Temperature

Evapotranspiration

TIR Overarching Science Questions

- **TQ1. Volcanoes/Earthquakes (MA,FF)**
  - How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?
- **TQ2. Wildfires (LG,DR)**
  - What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?
- **TQ3. Water Use and Availability, (MA,RA)**
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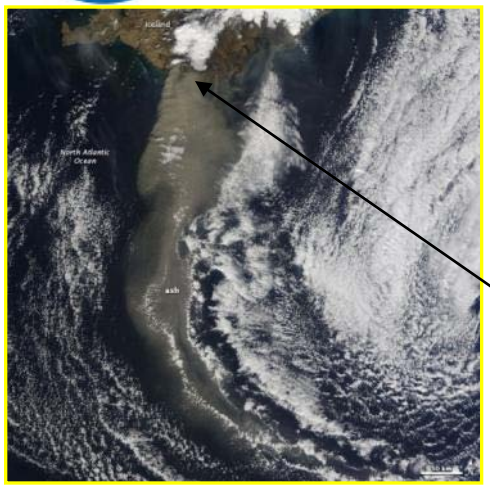
Gas and thermal anomalies, plume composition including SO2 and ash content on weekly basis

Characterizing and Understanding Volcanic Eruptions

"Likewise, the Tier 2 **Hyperspectral Infrared Imager (HyspIRI)** mission would include measurements over a range of optical and infrared wavelengths useful for detecting volcanic eruptions, determining the ash content of volcanic plumes, and identifying the occurrence and effects of associated landslides."

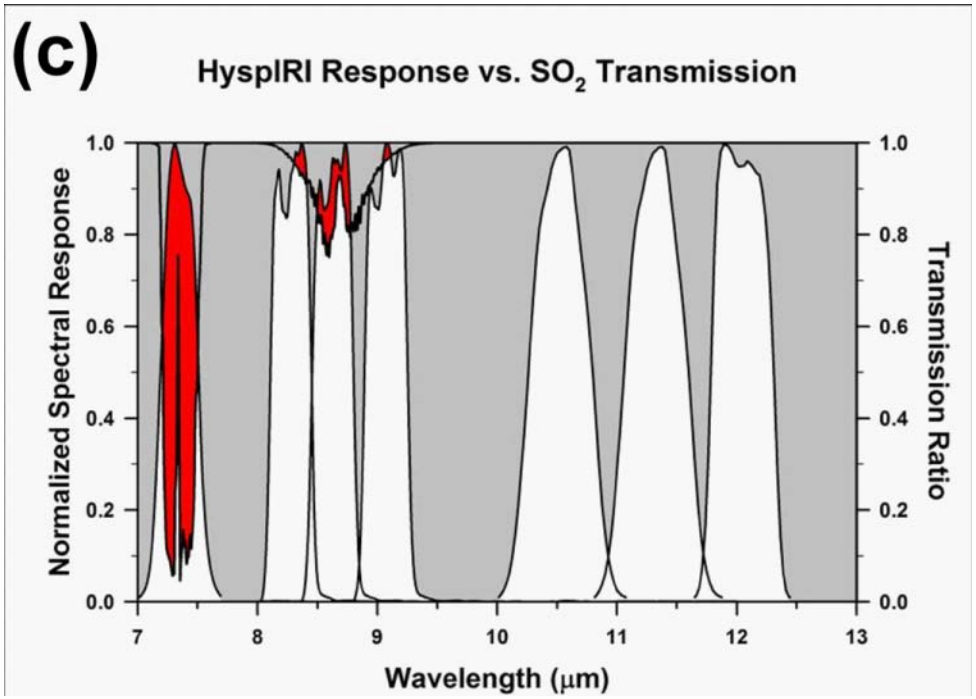
Source: Dr Jack Kaye, Presented to
Subcommittee on Space and Aeronautics
Committee on Science and Technology
United States House of Representatives,
May 5, 2010

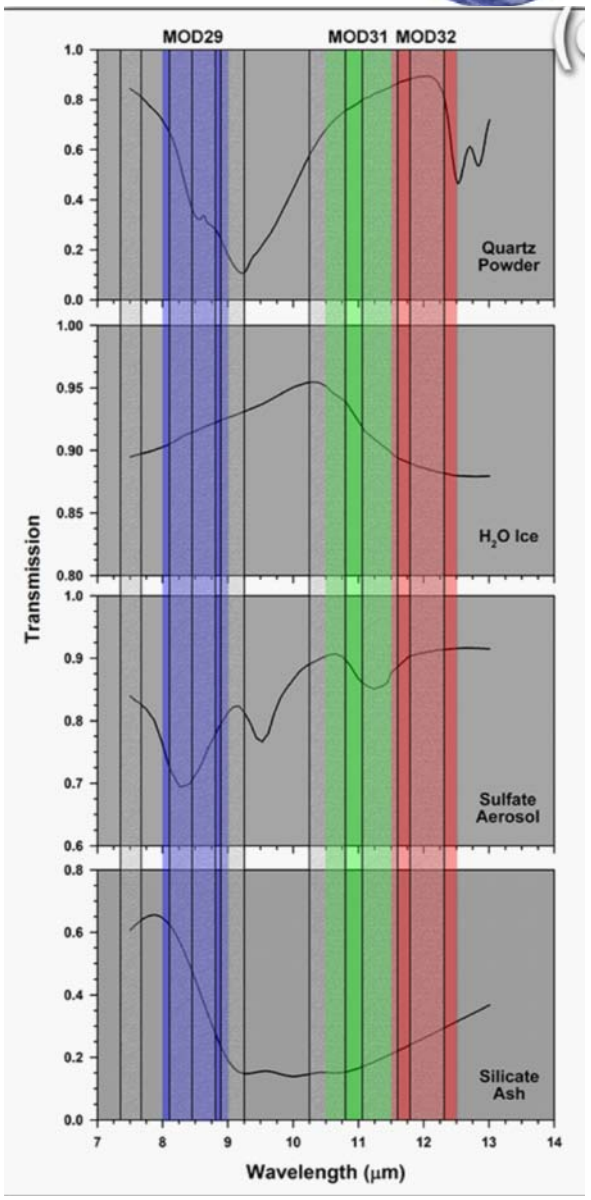
Characterizing and Understanding Volcanic Eruptions



Eyjafjallajökull Iceland Volcano Eruption

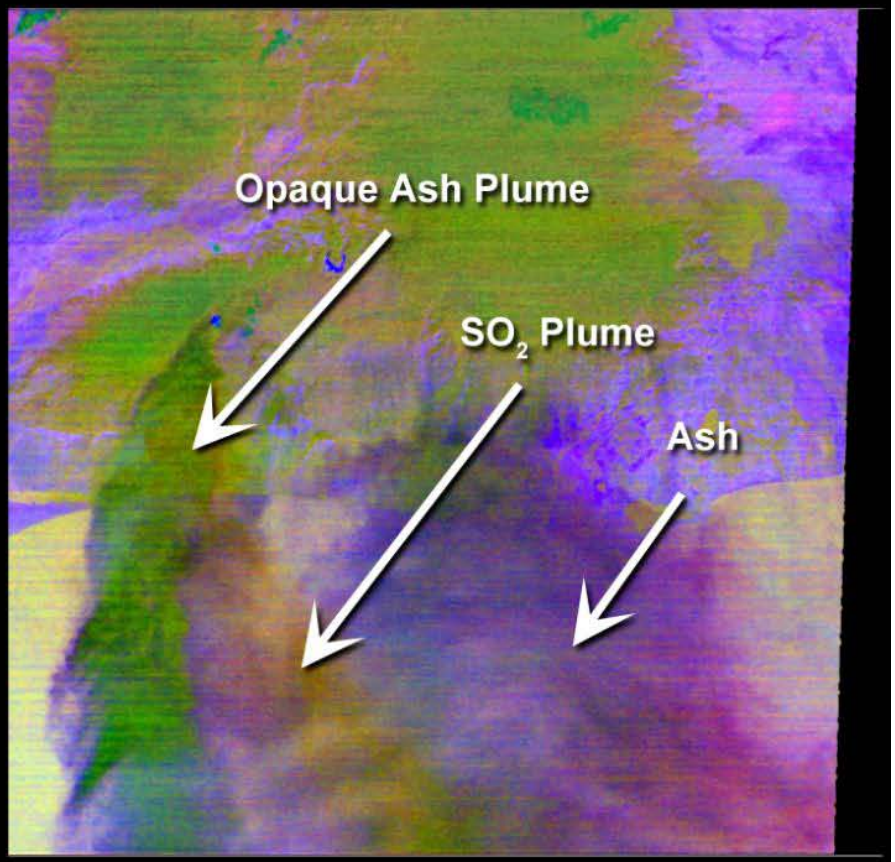
April 19 2010 MODIS image of ash plume.





Characterizing and Understanding Volcanic Eruptions

ASTER Observations of the Eyjafjallajökull Eruption
19 April 2010 - 12:51 UTC



Visible - Near Infrared

kilometers

0 36

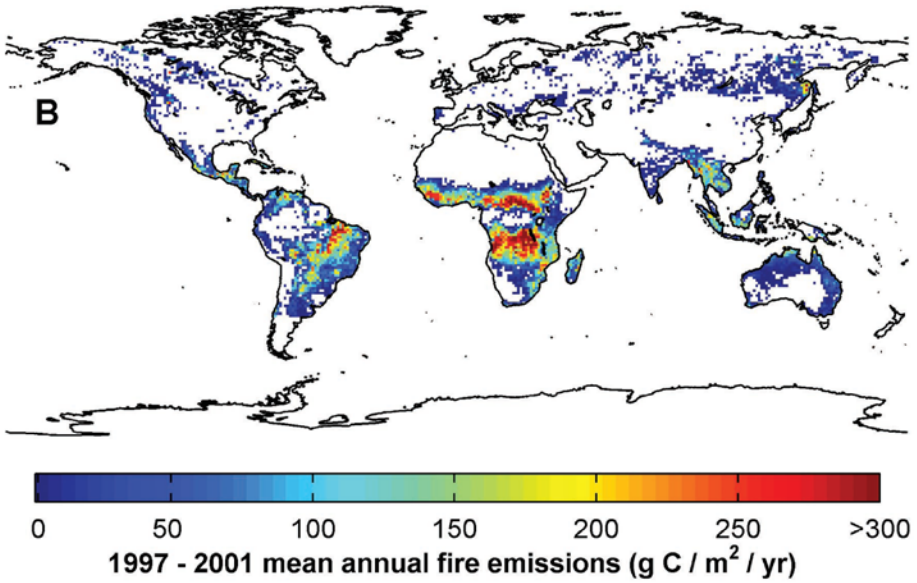
Thermal Infrared

Carbon Release from Biomass Burning

Global Characterization of Fire Emission Sources

Biomass burning and fossil fuel emissions release ~10^{15} g of carbon (C) to the atmosphere each year. Biomass burning constitutes ~36% of all global C emissions.

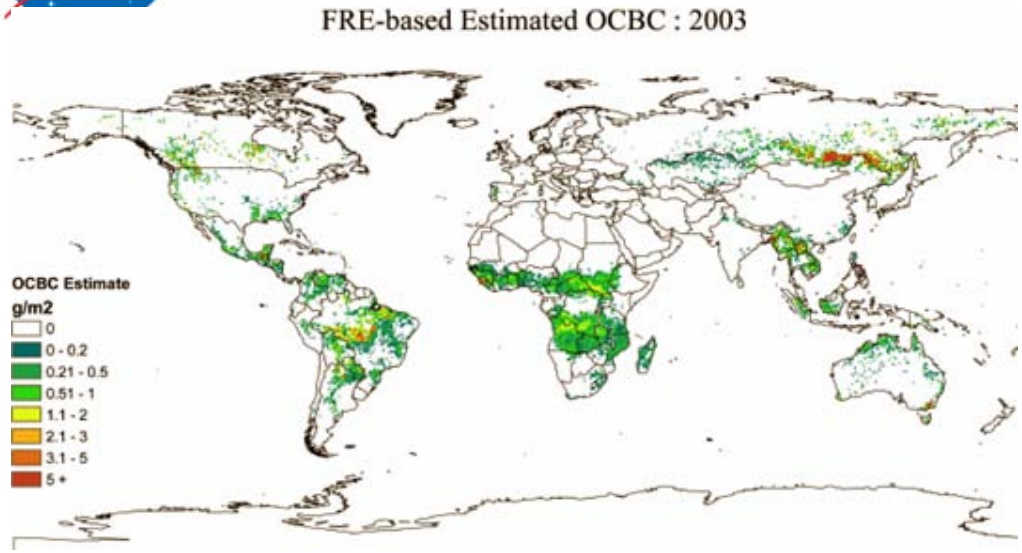
Region	Fire emissions 1997-2001 average (10^15g C yr^{-1})
Central and northern South America	0.27
Southern South America	0.80
Northern Africa	0.80
Southern Africa	1.02
Southeast Asia	0.37
Boreal (north of 38°N)	0.14
Other	0.13
Global	3.53

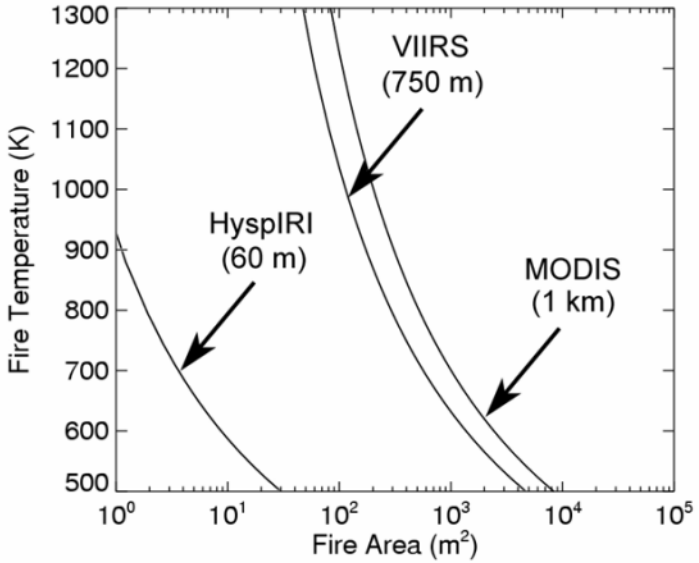


Van der Werf et al., 2004

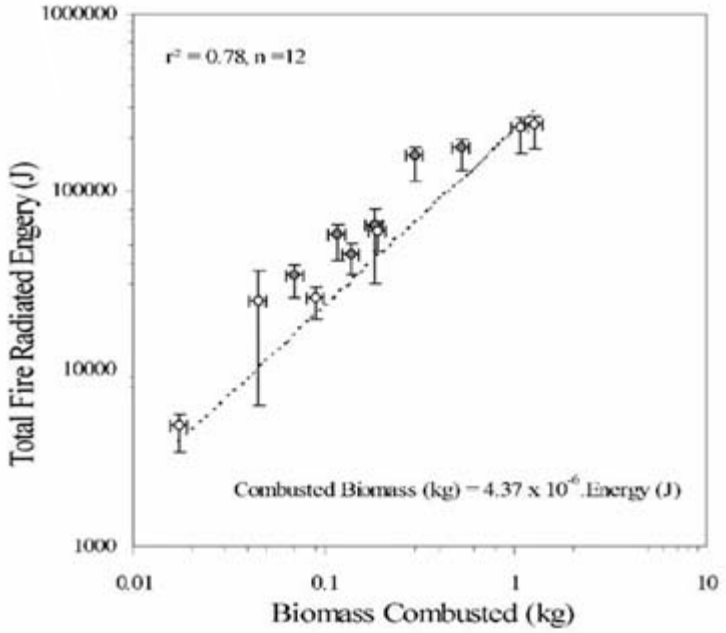
Carbon Release from Biomass Burning

Fire Radiative Energy





90% probability of detection; boreal forest; nadir view



Use Fire Radiative Energy to estimate combusted biomass: Need 3-5 um data

Ellicott et al 2009

Wooster et al 2002 and 2003

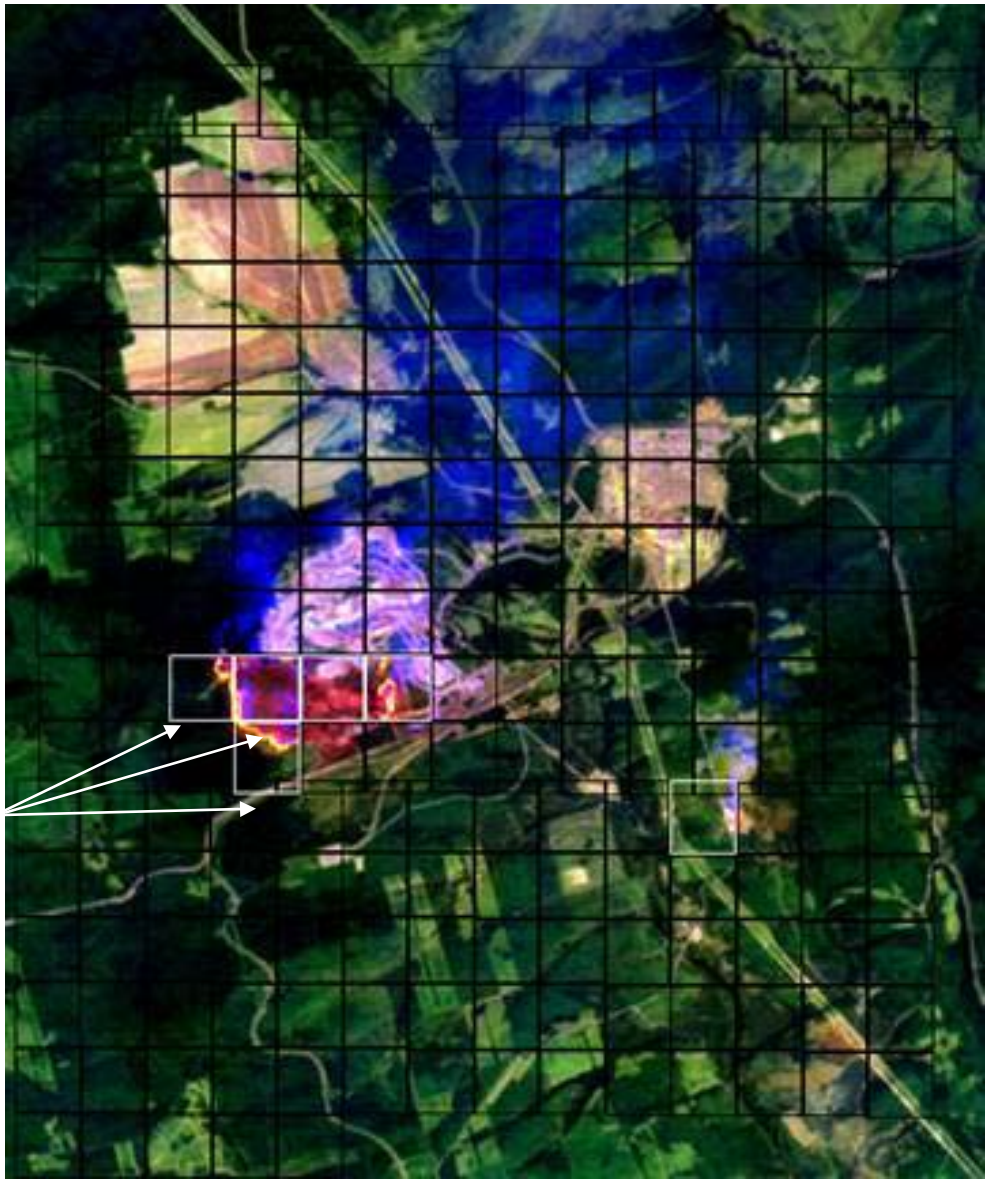
Carbon Release from Biomass Burning

How are global fire regimes changing? (patterns of fire occurrences, frequency, size, severity)

High resolution thermal instrument can distinguish between the forest and non-forest parts of the flaming front allowing the fire type, intensity, etc., to be determined which indicates fire regime.

White squares show fire pixels detected by MODIS. Insufficient information to detect fire type

MIR band provides radiant flux to estimate rate at which biomass combusted and instantaneous emission estimate



30 m ASTER scene with MODIS pixels superimposed (black squares)

Central Siberia

30 May 2001

Science Measurements
Summary Measurement Characteristics

Spectral	
Bands (8) µm	3.98 µm, 7.35 µm, 8.28 µm, 8.63 µm, 9.07 µm, 10.53 µm, 11.33 µm, 12.05
Bandwidth	0.084 µm, 0.32 µm, 0.34 µm, 0.35 µm, 0.36 µm, 0.54 µm, 0.54 µm, 0.52 µm
Accuracy	<0.01 µm
Radiometric	
Range	Bands 2-8= 200K – 500K; Band 1= 1400K
Resolution	< 0.05 K, Linear Quantization to 14 bits
Accuracy	< 0.5 K 3-sigma at 250K
Precision (NEdT)	< 0.2K
Linearity	>99% characterized to 0.1 %
Spatial	
IFOV	60 m
MTF	>0.65 at FNy
Scan Type	Push-Whisk
Swath Width	600 km (±25.5° at 623 km altitude)
Cross-Track Samples	10,000
Swath Length	15.4 km (+/- 0.7-degrees at 623km altitude)
Down-Track Samples	256
Band-to-Band Co-registraion	0.2 pixels (12 m)
Pointing Knowledge	1.5 arcsec (0.1 pixels)

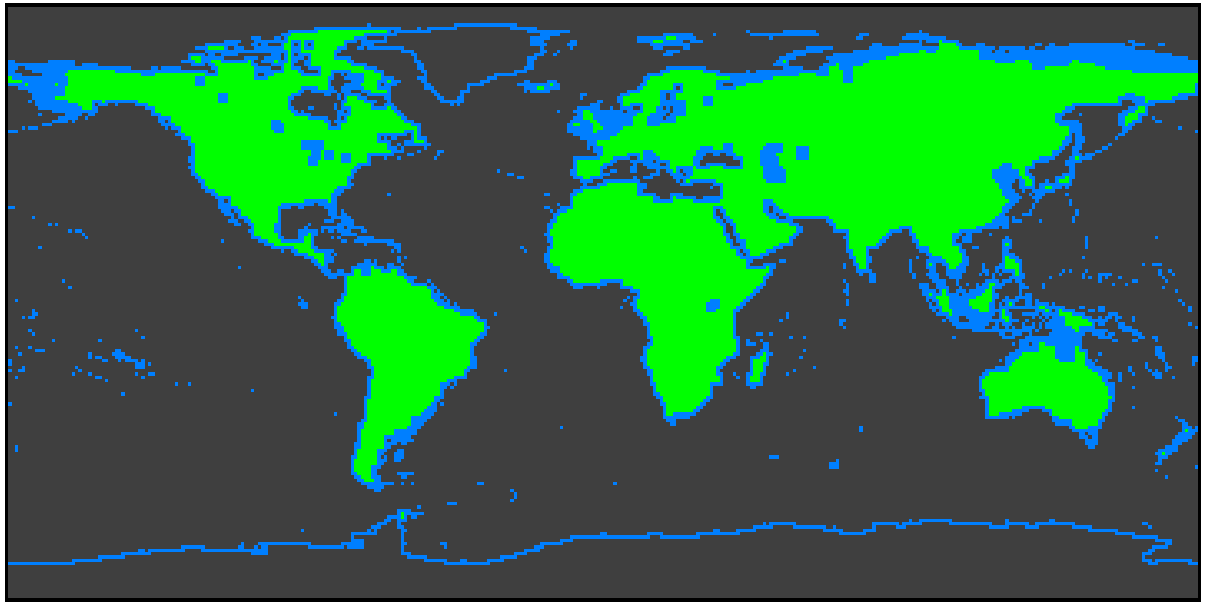
Science Measurements

Characteristics Continued

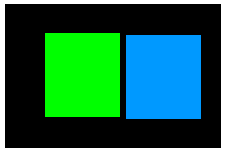
Temporal	
Orbit Crossing	10:30 am sun synchronous descending
Global Land Repeat	5 days at equator
OnOrbit Calibration	
Lunar View	1 per month {radiometric}
Blackbody Views	1 per scan {radiometric}
Deep Space Views	1 per scan {radiometric}
Surface Cal Experiments	2 (d/n) every 5 days {radiometric}
Spectral Surface Cal Experiments	1 per year
Data Collection	
Time Coverage	Day and Night
Land Coverage	Land surface above sea level
Water Coverage	Coastal zone -50 m and shallower
Open Ocean	Averaged to 1km spatial sampling
Compression	2:1 lossless

Mission Concept
Operational Scenario

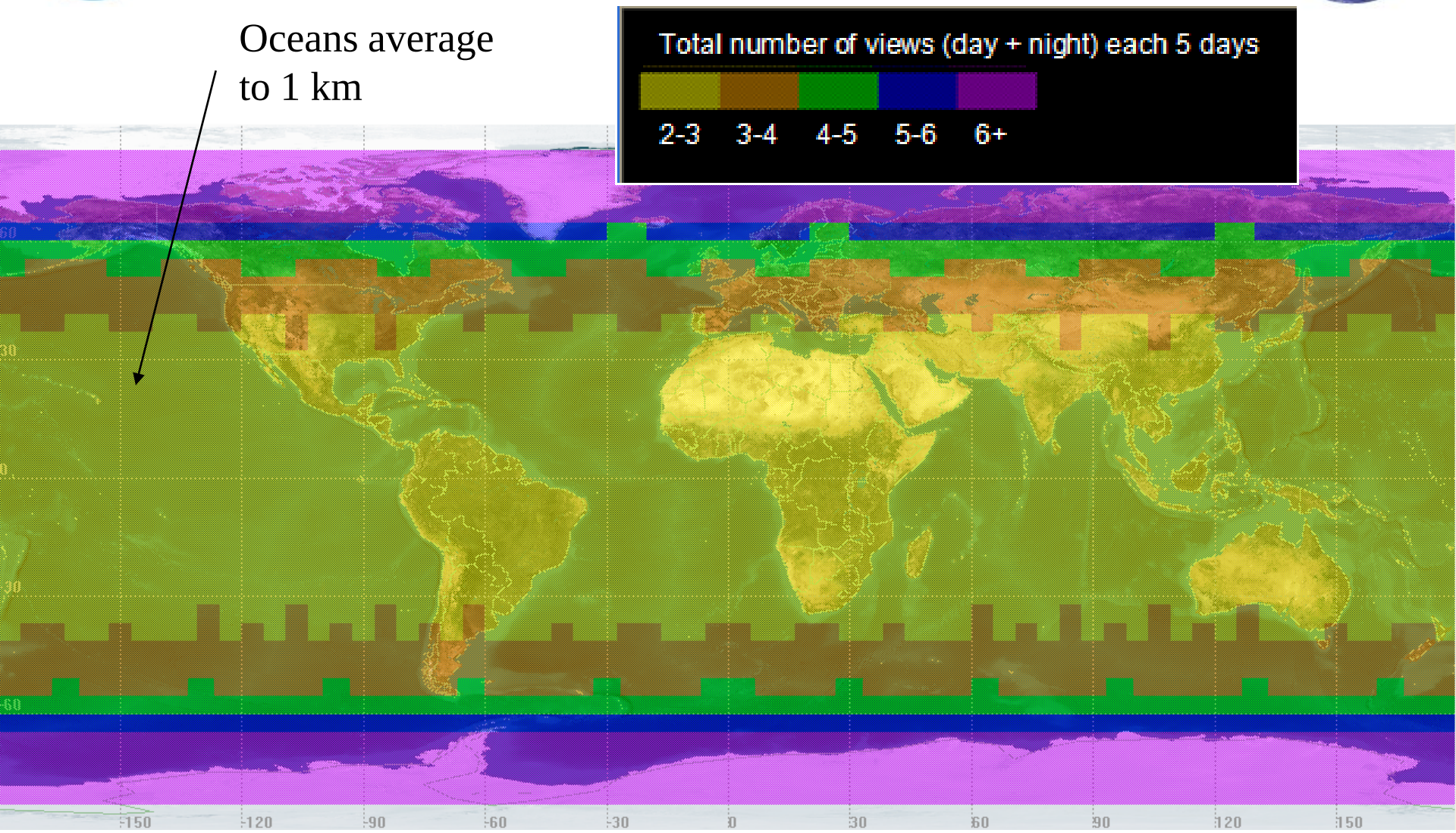
- Following arrival at science orbit, the baseline data acquisition plan is established. Collect data for entire land surface excluding sea ice (Arctic and Antarctic) every 5 days at 60 m spatial resolution in 8 spectral bands
- Data are downlinked and transferred to the science data processing center where calibration and baseline processing algorithms are applied.
- Level 1, 2 products are delivered to the scientific community and general users to pursue the science questions
  - With appropriate cloud screening, compositing, spatial, and temporal subsetting



Land and coastal acquisition



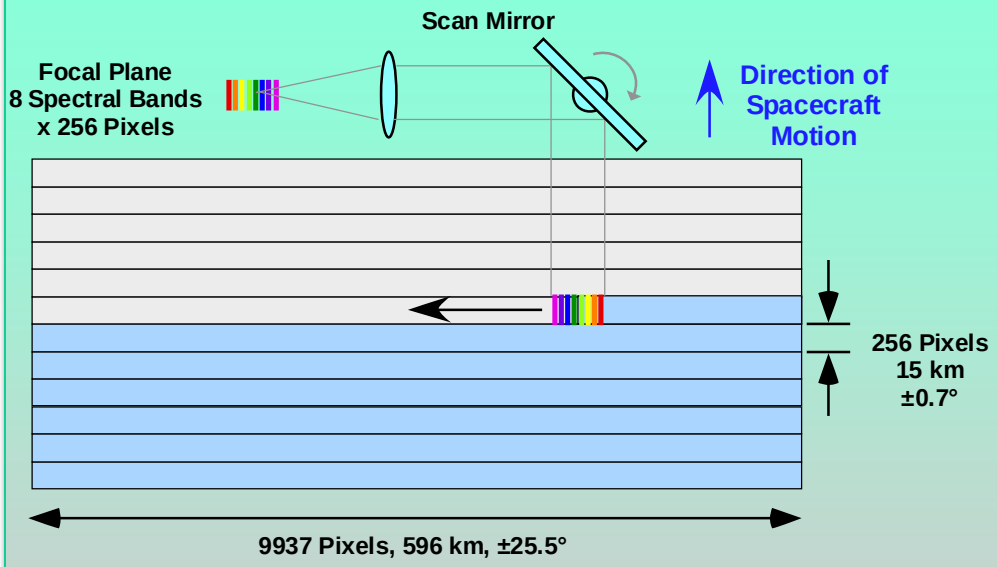
Annual TIR imaging opportunities in a 5-day near-repeating orbit, 1 yr. simulation



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).

TIR Instrument Concept

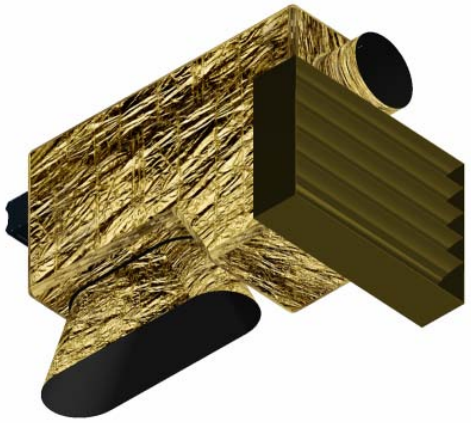
Scanning and Data Rate



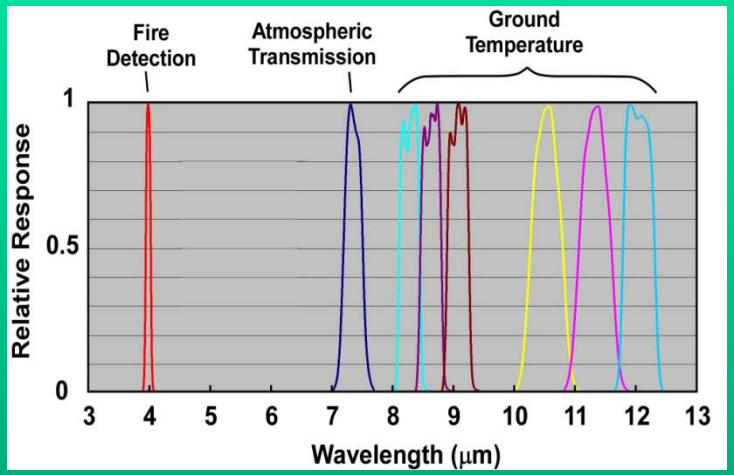
- 60 m Pixel Footprint
- Time-Averaged Science Data Rate 0.024 Gbps
- Assuming 14 bits, 2:1 Compression
- Scan Mirror Rotation Rate 13 RPM
- Pixel Dwell Time 32 microseconds

Mass and Power (JPL Team X)

- Mass CBE 60 kg
- Power CBE 109 W

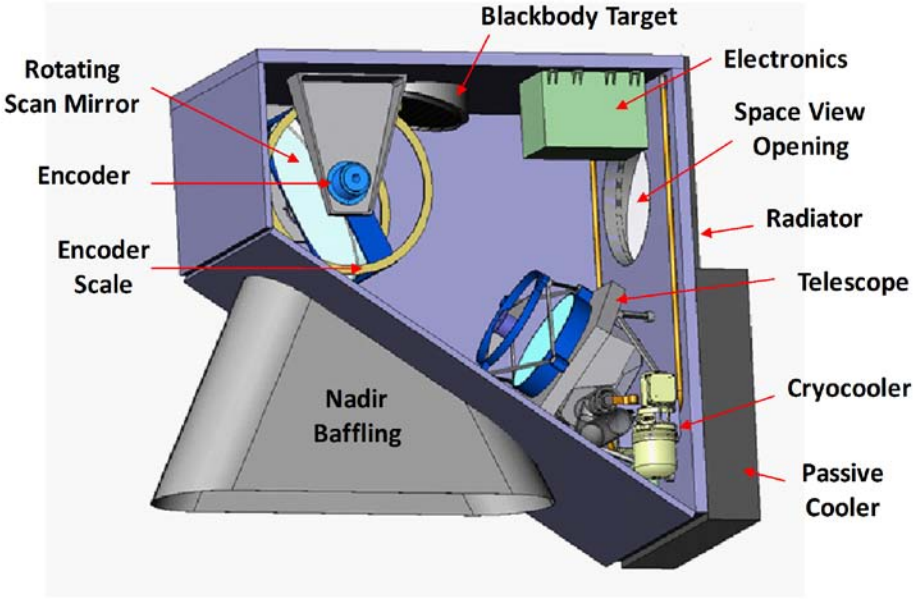


Spectral Bands



Mission Concept
TIR Overview

- Duration: 4 years development, 3 years science
- Coverage: Global land every 5 days
- Day and Night imaging (1 day and night image at a given location obtained every 5 days)
- Data download using dual-polarization X-band at high-latitude stations
- Spacecraft: LEO RSDO bus (SA-200HP)
- Launch: Taurus-class launch vehicle



Summary

We have developed a sets of science questions that are well aligned with the HyspIRI Mission called for in the NASA Earth Science and Applications Decadal Survey. The mission has strong relevance to both climate and society.

We have reviewed and refined these questions that relate to both science and applications objectives and developed traceability to a set of science measurements.

We have established a high heritage and low risk approach for acquiring the HyspIRI VSWIR and TIR science measurements