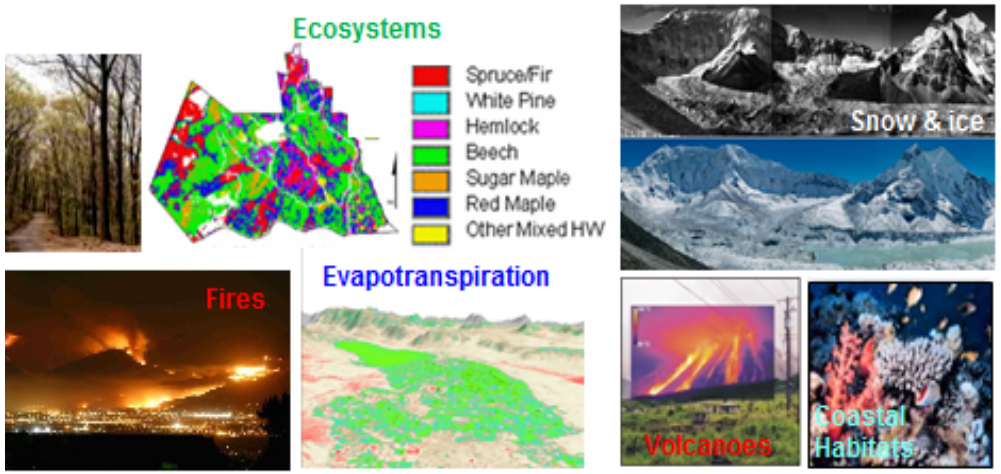
HyspIRI VSWIR/TIR/Combined Science Questions



2017 Workshop

Robert O. Green[1], Simon Hook[1] and Betsy Middleton[2] and the HyspIRI Science Community

[1]Jet Propulsion Laboratory, California Institute of Technology

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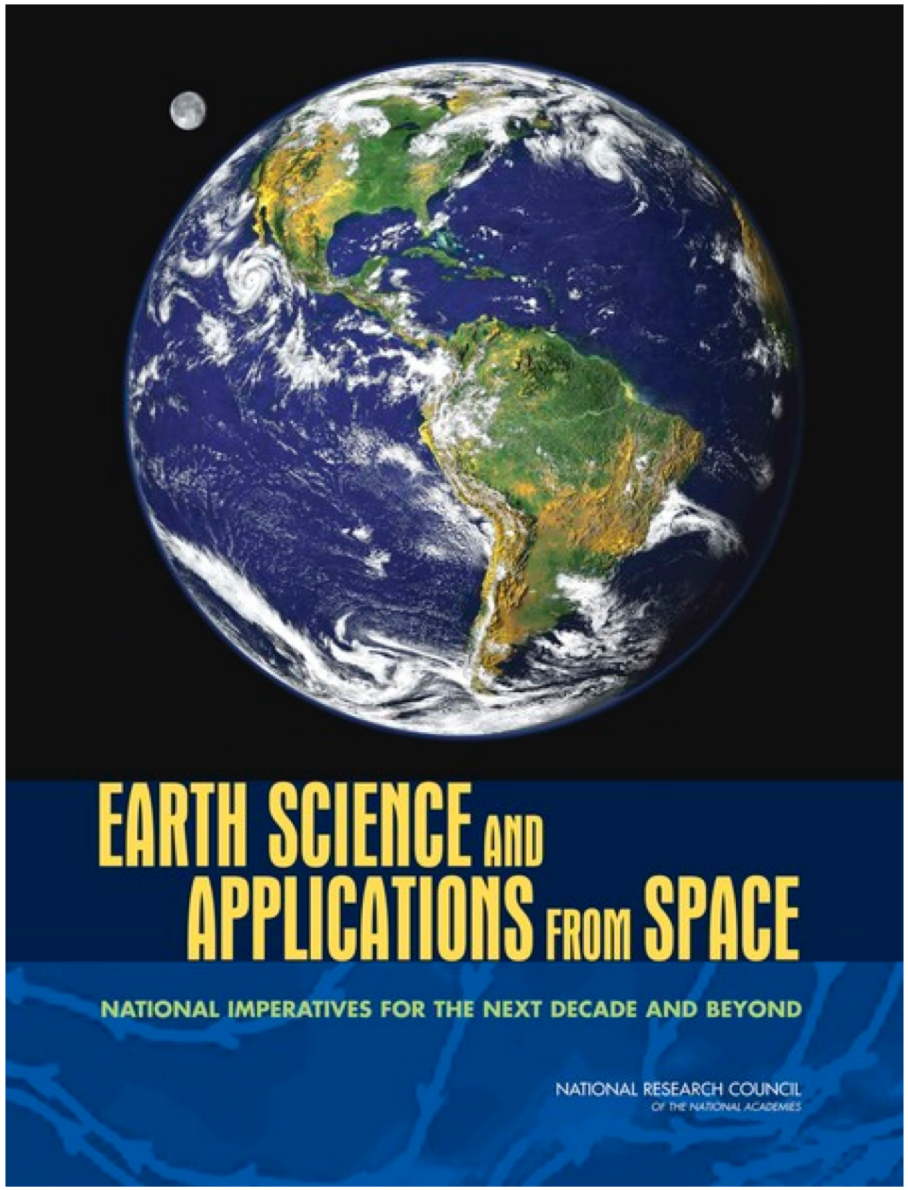
2007 Decadal Survey



In its Decadal Survey Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, the National Research Council of the National Academies recommended a satellite mission to produce global observations of multiple Earth surface attributes for a variety of terrestrial and aquatic studies, the management of terrestrial and coastal natural resources, and forecasting ecological changes and natural hazards.

This concept designated HyspIRI, consists of an **imaging spectrometer in the visible to shortwave infrared (VSWIR)** regions of the electromagnetic spectrum and a **multispectral imager in the thermal infrared (TIR)** portion of the electromagnetic spectrum.

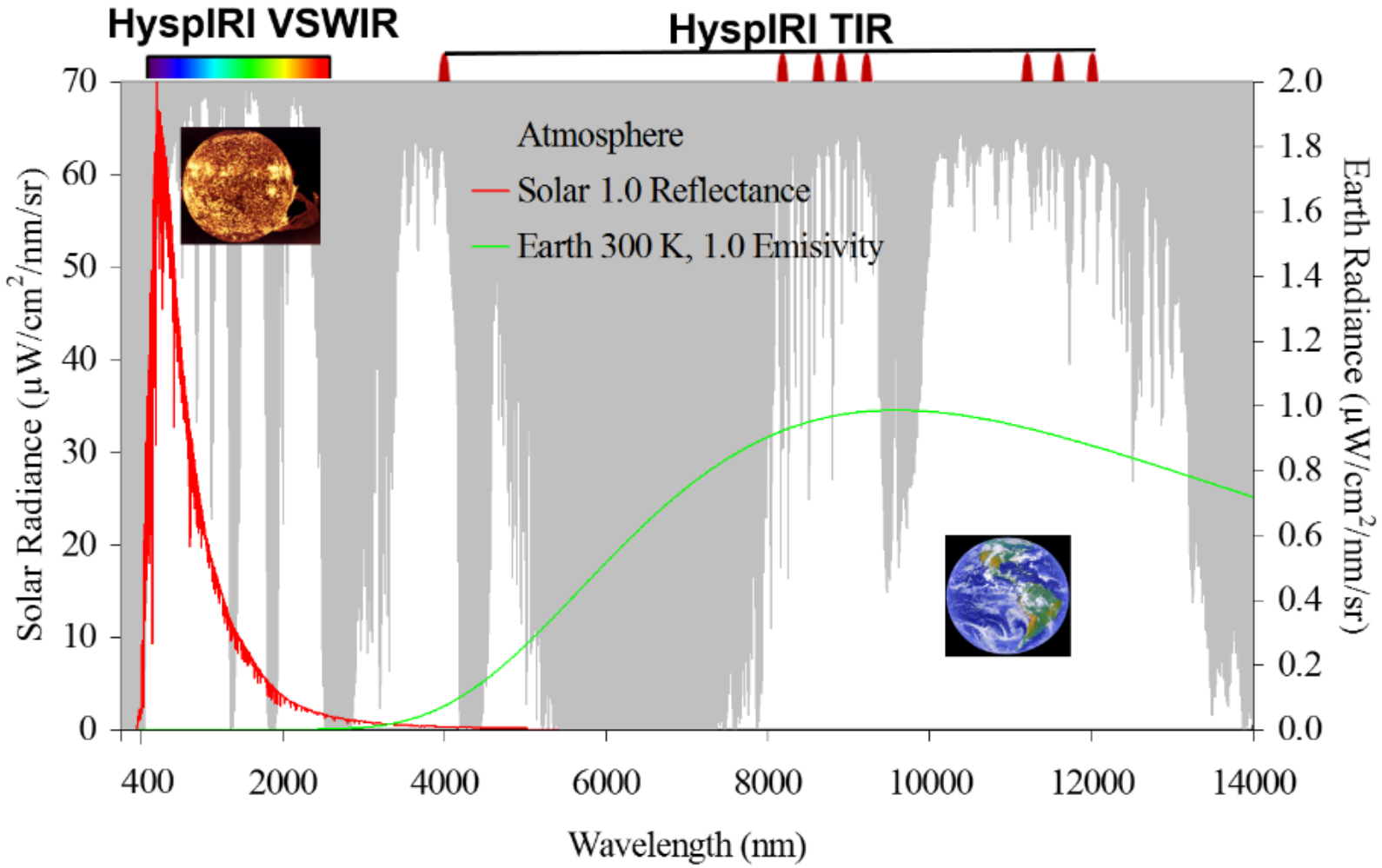
HyspIRI Science Study Group

A diverse group of scientists appointed by NASA to support advancement of the HyspIRI Mission concept

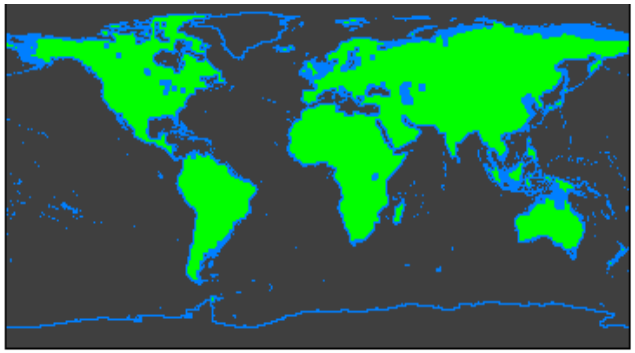
Mike Abrams	Jet Propulsion Laboratory
Rick Allen	University of Indiana
Martha Anderson	US Department of Agriculture
Greg Asner	Carnegie Institute of Science
Alex Chekalyuk	Lamont-Doherty
Ivan Csiszar	University of Maryland
Heidi Dierssen	University of Connecticut
John Gamon	University of Alberta
Louis Giglio	University of Maryland
Greg Glass	John Hopkins University
Robert Green	Jet Propulsion Laboratory
Eric Hochberg	Bermuda Institute of Science
Simon Hook	Jet Propulsion Laboratory
Jeff Luvall	Marshall Space Flight Center
John Mars	US Geological Survey, HQ
David Meyer	US Geological Survey, EROS
Betsy Middleton	Goddard Space Flight Center
Peter Minnett	University of Miami
Frank Muller Karger	University of South Florida
Scott Ollinger	University of New Hampshire
Thomas Painter	Jet Propulsion Laboratory
Anupma Prakash	University of Alaska, Fairbanks
Dale Quattrochi	Marshall Space Flight Center
Michael Ramsey	University of Pittsburg
Vince Realmuto	Jet Propulsion Laboratory
Dar Roberts	University of California, Santa Barbara
Dave Siegel	University of California, Santa Barbara
Phil Townsend	University of Wisconsin
Kevin Turpie	Goddard Space Flight Center
Steve Ungar	Goddard Space Flight Center
Susan Ustin	University of California, Davis
Rob Wright	University of Hawaii

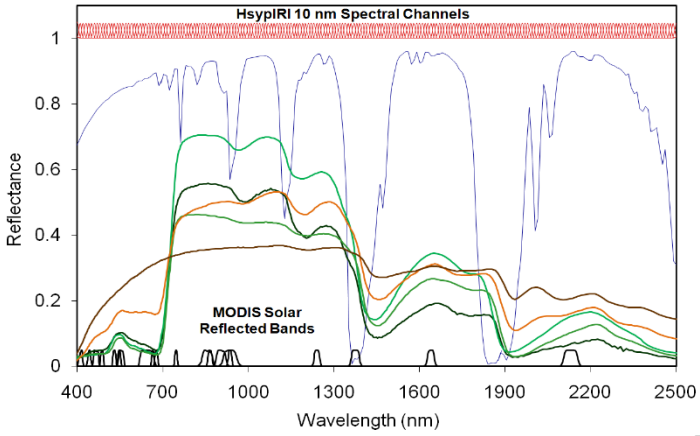
HyspIRI Baseline Measurements

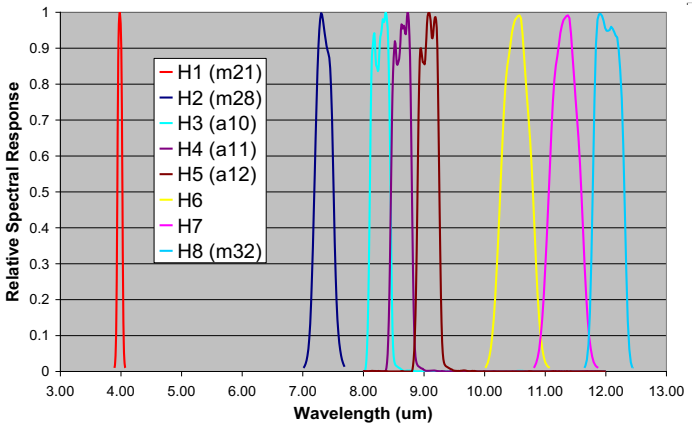
- Global terrestrial and coastal VSWIR spectroscopy and multispectral TIR with real-time downlink of selected products for both.



HysplRI Science Measurements



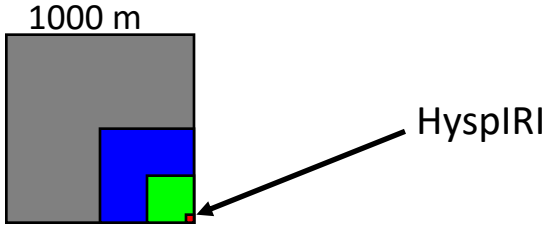




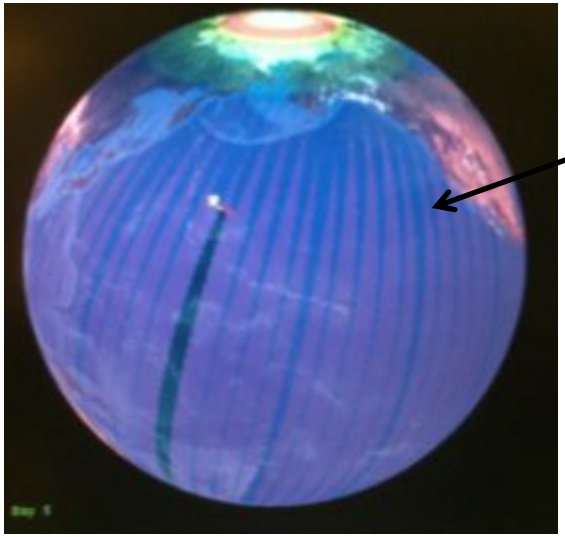
HysplRI is a global mission, measuring land and shallow aquatic habitats every 5 days (TIR) and every <=16 days (VSWIR), deep oceans and ice sheets at 1km

HysplRI's VSWIR imaging spectrometer (30 m) directly measures the full solar reflected spectrum of the Earth from 380 – 2510nm at 10 nm.

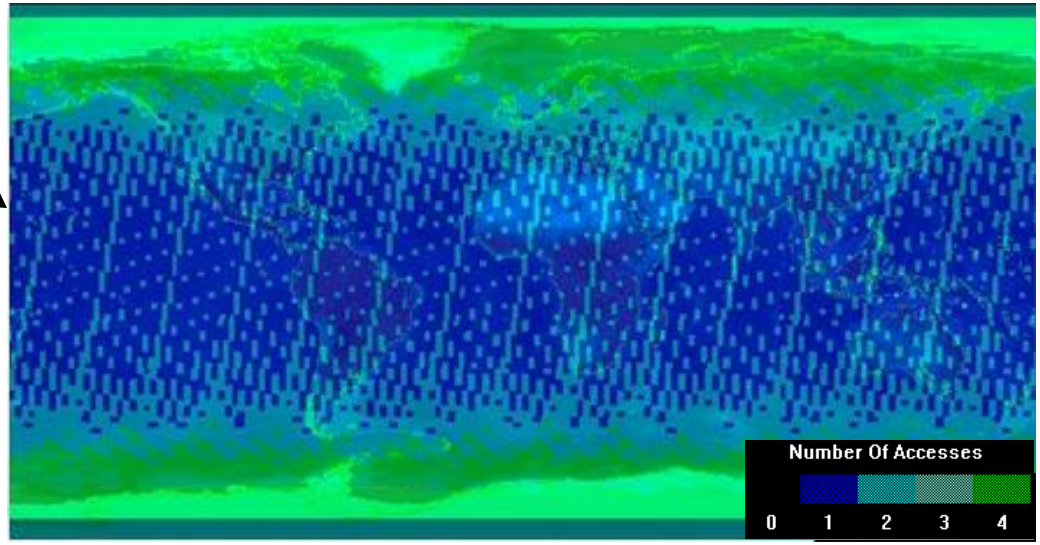
HysplRI's TIR (60 m) directly samples the Earth's emitted thermal energy in 7 bands between 7-12 µm, & 1 band between 3-5 µm

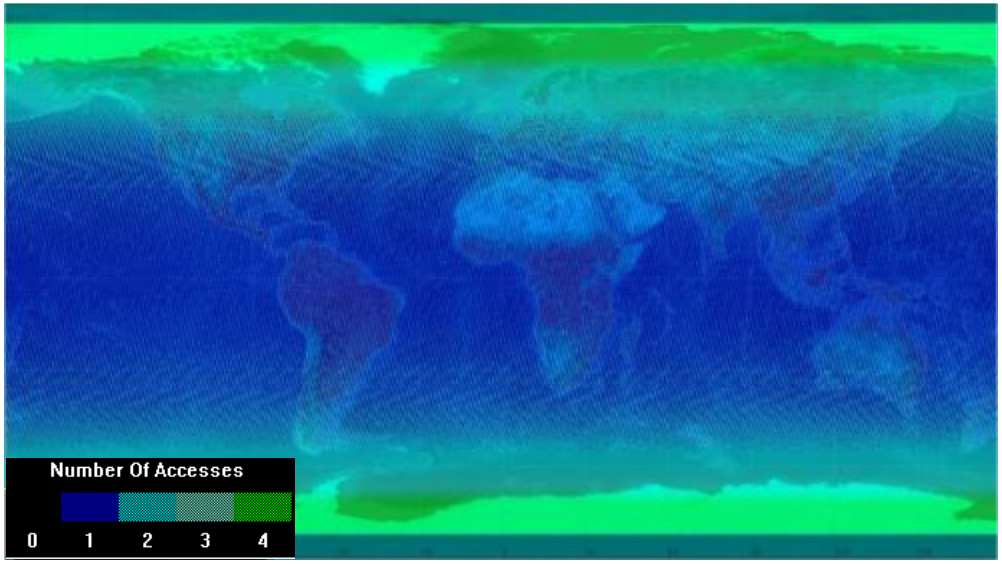


HyspIRI Global Coverage

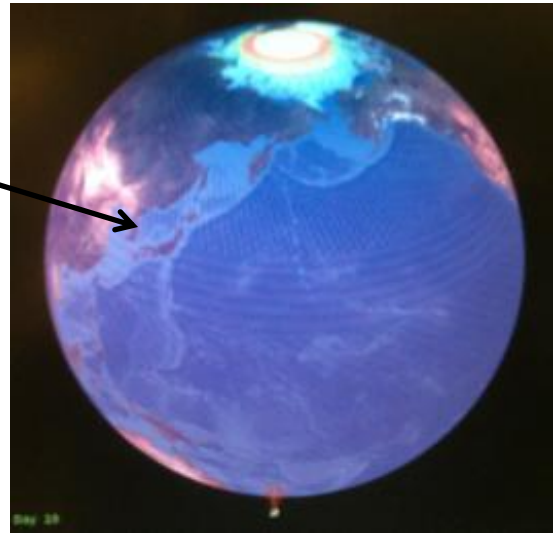


TIR Coverage after 5 days



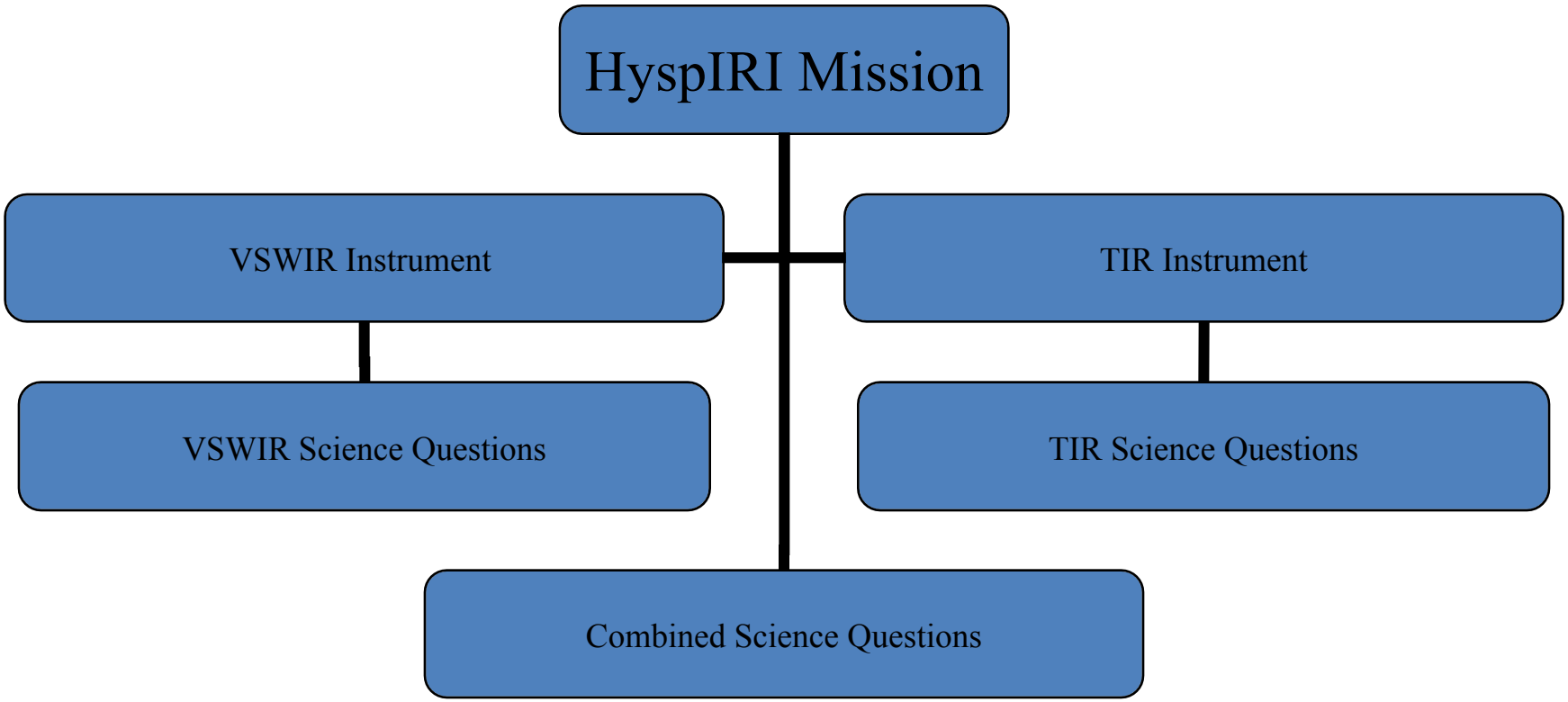


VSWIR Coverage after 16 days



Deep oceans and ice sheets at 1km

HyspIRI Science Questions



Leads and Co-Leads for Questions

- VQ1 – Pattern and Spatial Distribution of Ecosystems and their Components, Dar Roberts, Betsy Middleton,
- VQ2 – Ecosystem Function, Physiology and Seasonal Activity, John Gamon
- VQ3 – Biogeochemical Cycles, Scott Ollinger
- VQ4 – Changes in and Responses to Disturbance, Greg Asner, Bob Knox
- VQ5 – Ecosystems and Human Well-being, Phil Townsend, Greg Glass
- VQ6 – Earth Surface and Shallow Water Bottom Composition, Rob Green, Heidi Dierssen
- TQ1 – Volcanoes and Earthquakes, Mike Abrams, Friedmann Freund
- TQ2 – Wildfires, Louis Giglio
- TQ3 – Water Use and Availability, Martha Anderson, Rick Allen
- TQ4 –Urbanization and Human Health, Dale Quattrochi, Greg Glass
- TQ5 – Surface composition and Change, Anupma Prakash, John Mars
- CQ1 – Coastal, ocean, and inland aquatic environments, Frank Muller-Karger
- CQ2 – Wildfires, Louis Giglio
- CQ3 – Volcanoes, Robert Wright, Vince Realmuto
- CQ4 – Ecosystem Function and Diversity, Dar Roberts, Martha Anderson
- CQ5 – Land surface composition and change, Lyle Mars, Anupma Prakash
- CQ6 – Human Health and Urbanization, Dale Quattrochi, Greg Glass

VSWIR Science Questions

VSWIR Overarching Science Questions

- VQ1. Pattern and Spatial Distribution of Ecosystems and their Components, (DR, EM)
  - What is the global spatial pattern of ecosystems and diversity distributions and how do ecosystems differ in their composition or biodiversity? [DS 195]
- VQ2. Ecosystem Function, Physiology and Seasonal Activity, (JG)
  - What are the seasonal expressions and cycles for terrestrial and aquatic ecosystems, functional groups, and diagnostic species? How are these being altered by changes in climate, land use, and disturbance?[DS 191, 195, 203]
- VQ3. Biogeochemical Cycles (SO)
  - How are the biogeochemical cycles that sustain life on Earth being altered/disrupted by natural and human-induced environmental change? How do these changes affect the composition and health of ecosystems, and what are the feedbacks with other components of the Earth system?
- VQ4. Changes in and Responses to Disturbance (GA,RK)
  - How are disturbance regimes changing, and how do these changes affect the ecosystem processes that support life on Earth?
- VQ5. Ecosystem and Human Health, (PT,GG)
  - How do changes in ecosystem composition and function affect human health, resource use, and resource management?
- VQ6. Earth Surface and Shallow-Water Benthic Composition (RG, HD)
  - What are the land surface soil/rock and shallow-water benthic compositions?

VQ1. Pattern and Spatial Distribution of Ecosystems and their Components (DR, EM)

- How are ecosystems organized within different biomes associated with temperate, tropical, and boreal zones, and how are these changing? [DS 191, 203]
- How do similar ecosystems differ in size, species composition, fractional cover and biodiversity across terrestrial and shallow aquatic biomes? [DS 195]
- What is the current spatial distribution of ecosystems, functional groups, or key species within major biomes including agriculture, and how are these being altered by climate variability, human uses, and other factors? [DS 191, 203]
- What are the extent and impact of invasive species in terrestrial and shallow aquatic ecosystems? [DS 192, 194, 196, 203, 204, 214]
- What are the spatial structure and species distribution in observable phytoplankton blooms? [DS 201, 208]
- How do changes in coastal morphology and surface composition impact coastal ecosystem composition, diversity and function [DS 41]?

VSWIR Vegetation Species Mapping Across Seasons

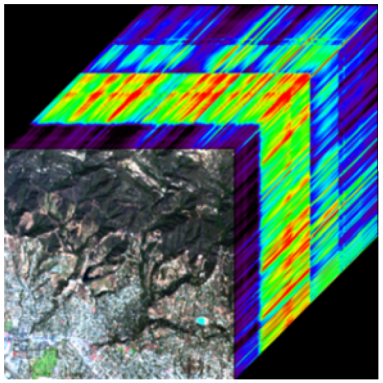
Kenneth Dudley (grad student), **Phil Dennison** – Univ. of Utah, **Dar Roberts** – UC Santa Barbara

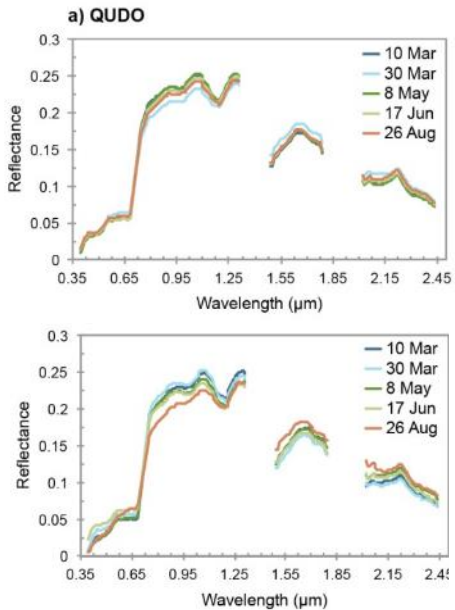
- Objective: Evaluate the ability of imaging spectroscopy data from the HyspIRI Preparatory Campaign to map vegetation species across a range of dates and illumination conditions
  - Imaging spectroscopy contains detailed spectral information that can be used to distinguish vegetation species and functional types
  - Hypothesis: Species can be mapped using a uniform approach even though their phenology varies over space and through time.

- Key Finding: A species map retrieval algorithm that accounts for the range of phenological variability in species reflectance can map species as well as any single date classification
  - A single spectral library created from a range of dates can be applied to any date, allowing species mapping without knowing phenological state in advance

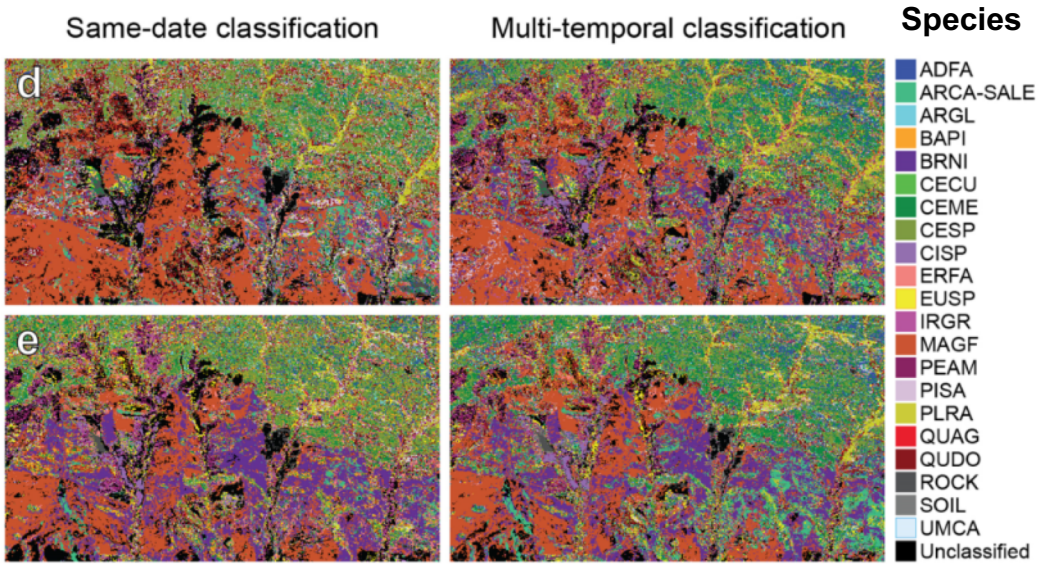
Reflectance of different vegetation species vary through time due to vegetation phenology. Subtle spectral differences can be used to distinguish a) Blue Oak from b) Chamise.

A data cube showing the spectral dimensionality of image spectroscopy data.





A multi-temporal endmember library provides equivalent performance for mapping species compared to single date classifications.



VQ2. Ecosystem Function, Physiology and Seasonal Activity (JG)

- How does the seasonal activity of ecosystems and functional types vary across biomes (terrestrial and shallow aquatic), geographic zones, or environmental gradients between the equator and the poles? How are seasonal patterns of ecosystem function being affected by climate change? [DS 205, 206, 210]

- How do seasonal changes affect productivity, carbon sequestration, and hydrological processes across ecosystems and agriculture? [DS 195, 205, 210]

- How do environmental stresses affect the physiological function of water and carbon exchanges at the seasonal time scale within ecosystems (including agriculture)? [DS 203, 206, 210]

- What is the environmental impact of aquatic plants and coral in inland and coastal water environments at the seasonal time scale? [DS 201, 208]

VQ3. Biogeochemical Cycles (SO)

- How do changes in climate and atmospheric processes affect the physiology and biogeochemistry of ecosystems? [DS 194, 201]
- What are the consequences of uses of land and coastal systems, such as urbanization and resource extraction, for the carbon cycle, nutrient fluxes and biodiversity? [DS 196, 197]
- What are the consequences of increasing nitrogen deposition for carbon cycling and biodiversity in terrestrial and coastal ecosystems? [DS 195, 196]
- How do changes in hydrology, pollutant inputs and sediment transport affect freshwater and coastal marine ecosystems? [DS 196]
- How do changing water balances affect carbon storage by terrestrial ecosystems? [DS 196]
- What are the key interactions between biogeochemical cycles and the composition and diversity of ecosystems? [195, 196]
- How do changes in biogeochemical processes feed back to climate and other components of the Earth system? [DS 190, 192, 195]

VQ4. Changes in and Responses to Disturbance (GA,RK)

- How do patterns of abrupt (pulse) disturbance vary and change over time within and across ecosystems?
- How do climate changes affect disturbances such as fire and insect damage? [DS 196]
- What are the interactions between invasive species and other types of disturbance?
- How are human-caused and natural disturbances changing the biodiversity composition of ecosystems, e.g.: through changes in the distribution and abundance of organisms, communities, and ecosystems?
- How do climate change, pollution and disturbance augment the vulnerability of ecosystems to invasive species? [DS 114,196]
- What are the effects of disturbances on productivity, water resources, and other ecosystem functions and services? [DS 196]
- How do changes in human uses of ecosystems affect their vulnerability to disturbance and extreme events? [DS 196]

VQ5. Ecosystem and Human Health (PT, GG)

- How do changes in ecosystem composition and function affect the spread of infectious diseases and the organisms that transmit them[DS155, 160, 161]?
- How will changes in pollution and biogeochemical cycling alter coastal and inland water quality?
- How are changes in ecosystem distribution and productivity linked to resource use, and resource management? Forestry management, fire effects, biofuels, agricultural management
- How will changes in climate and pollution affect the health and productivity of aquatic and agricultural resources?
- What are the economic and human health consequences associated with the spread of invasive species?
- How does the spatial pattern of policy, environmental management, and economic conditions correlate with the state and changes in ecosystem function and composition? (DS 155 [5-5]?, 230 [8-7])
- What are the impacts of flooding and sea-level rise on ecosystems, human health, and security? [DS 195, 224, 227, 348, 357]

VQ6. Earth Surface and Shallow Water Substrate Composition (RG, HD)

- What is the distribution of the primary minerals and mineral groups on the exposed terrestrial surface? [DS 218]
- What is the bottom composition (sand, rock, mud, coral, algae,SAV, etc) of the shallow water regions of the Earth?
- What fundamentally new concepts for mineral and hydrocarbon research will arise from uniform and detailed global geochemistry of the exposed rock/soil surface [DS227]
- - What changes in bottom substrate occur in shallow coastal and inland aquatic environments? [DS 25]
- - How can measurements of rock and soil composition be used to understand and mitigate hazards? [DS 114,227]

TIR Science Questions

TIR Overarching Science Questions

•TQ1. Volcanoes and Earthquakes (MA,FF)
– How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

• TQ2. Wildfires (LG)
– 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?

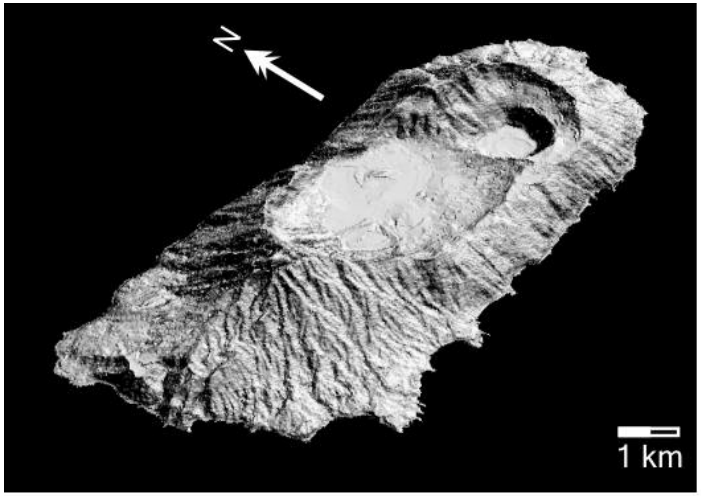
• TQ4. Urbanization/Human Health, (DQ,GG)
– How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

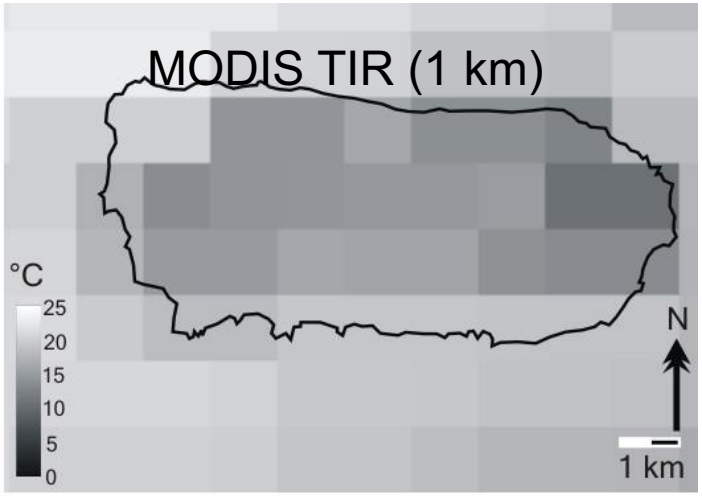
• TQ5. Earth surface composition and change, (AP,JC)
– What is the composition and thermal property of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?

TQ1. Volcanoes and Earthquakes (MA,FF)

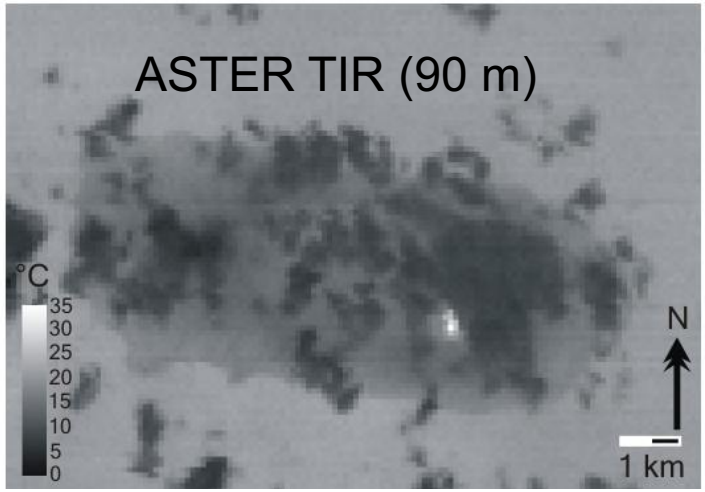
- Do volcanoes signal impending eruptions through changes in surface temperature or gas emission rates and are such changes unique to specific types of eruptions? [DS 227]
- What do changes in the rate of lava effusion tell us about the maximum lengths that lava flows can attain, and the likely duration of lava flow-forming eruptions? [DS 226]
- What are the characteristic dispersal patterns and residence times for volcanic ash clouds and how long do such clouds remain a threat to aviation? [DS 224]
- What do the transient thermal anomalies that may precede earthquakes tell us about changes in the geophysical properties of the crust? [DS 227, 229]
- Can the energy released by the periodic recharge of magma chambers be used to predict future eruptions? [DS 227]

Do volcanoes signal impending eruptions through changes in surface temperature or gas emission rates and are such changes unique to specific types of eruptions?





Anatahan, Marianas. Erupted in 2002, no ground instrumentation, caught people by surprise. Upper right image is a nighttime MODIS TIR image, 1 km resolution. Note that elevated thermal radiance in the vicinity of the east crater is not apparent (hydrothermal activity too small/too cool to show up at this resolution). Below is an ASTER TIR image. The hydrothermal activity is clearly visible (although in this case partially cloud obscured).



TQ2. Wildfires (LG)

- How are global fire regimes changing in response to, and driven by, changing climate, vegetation, and land use practices? [DS 198]
- Is regional and local scale fire frequency changing? [DS 196]
- What is the role of fire in global biogeochemical cycling, particularly trace gas emissions? [DS 195]
- Are there regional feedbacks between fire and climate change?

TQ3. Water Use and Availability (MA,RA)

- How is climate variability (and ENSO) impacting the evaporative component of the global water cycle over natural and managed landscapes? [DS 166, 196, 203, 257, 368]

- What are relationships between spatial and temporal variation in evapotranspiration and land-use/land-cover and freshwater resource management? [DS 196, 203, 368]

- Can we improve early detection, mitigation, and impact assessment of droughts at local to regional scales anywhere on the globe? [DS 166, 196, 203, 368]; How does the partitioning of Precipitation into ET, surface runoff and ground-water recharge change during drought?

- What areas of Earth have water consumption by irrigated agriculture that is out of balance with sustainable water availability? [DS 196, 368]

- Can we increase food production in water-scarce agricultural regions while improving or sustaining quality and quantity of water for ecosystem function and other human uses? [DS 196, 368]

TQ4. Human Health and Urbanization (DQ,GG)

- How do changes in local and regional land cover and land use, in particular urbanization affect surface energy balance characteristics that impact human welfare [DS: 160-161, 166-167, 196, 198]

- What are the dynamics, magnitude, and spatial form of the urban heat island effect (UHI), how does it change from city to city, what are its temporal, diurnal, and nocturnal characteristics, and what are the regional impacts of the UHI on biophysical, climatic, and environmental processes? [DS: 158, 166-168]

- How can the factors influencing heat stress on humans be better resolved and measured. [DS: 156, 158, 160, 183-184]

- How can the characteristics associated with environmentally related health effects, that affect vector-borne and animal-borne diseases, be better resolved and measured? [DS: 156, 158, 160, 183-184]

- How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems, and urbanization? [DS: 156, 160-161, 166-167, 179,184]

TQ5. Earth Surface Composition and Change (AP,JM)

- What is the spectrally observable mineralogy of the Earth's surface and how does this relate to geochemical and surficial processes? [DS 114]
- What is the nature and extent of man-made disturbance of the Earth's surface associated with exploitation of non-renewable resources (oil & gas, mining)? How do these vary over time? [DS 227]
- How do surface temperature anomalies (hot spots) relate to deeper thermal sources, such as buried lava tubes, underground coal fires and engineering structures? How do changes in the surface temperatures relate to changing nature of the deep seated hot source? [DS 243]
- What is the spatial distribution pattern of surface temperatures and emissivities of various land surfaces and how do these influence the Earth’s heat budget?
- What are the water surface temperature distributions in coastal, ocean, and inland water bodies. How do they change, and how do they influence aquatic ecosystems? [DS 378]

Combined Science Questions

Combined Overarching Questions

- CQ1. Coastal, ocean, and inland aquatic environments, FM-K
  - What is the status of inland and coastal aquatic ecosystems in the context of local and regional thermal climate, land-use change, and other environmental factors?
- CQ2. Wildfires, LG
  - How are fires and vegetation composition coupled?
- CQ3. Volcanoes, RW, VR
  - Do volcanoes signal impending eruptions through changes in the temperature of the ground, rates of gas and aerosol emission, temperature and composition of crater lakes, or health and extent of vegetation cover?
- CQ4. Ecosystem Function and Diversity, DR, MA
  - How do species, functional type, and biodiversity composition within ecosystems influence the energy, water and biogeochemical cycles under varying climatic conditions?
- CQ5. Earth surface composition and change, JM, AP
  - What is the composition of exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non anthropogenic drivers?
- CQ6 Human Health and Urbanization, DQ, GG
  - How do patterns of human environmental and infectious diseases respond to leading environmental changes, particularly to urban growth and change and the associated impacts of urbanization?

CQ1. Coastal, ocean, and inland environments (FM-K)

- What are the feedbacks between climate and habitat structure, biogeochemical cycling, biodiversity, and ecosystem productivity of shallow aquatic habitats?
- What are the ecological linkages of landscape-scale ocean-atmosphere interactions including the hydrologic cycle, aerosol production and transport, and cloud radiative forcing?
- How are small-scale processes in shallow benthic habitats related to changes in functional community types (coral reefs, submerged aquatic vegetation and floating aquatic vegetation), productivity, and biogeochemical cycling including material fluxes and water quality?
- How can these observations be used to guide the management and utilization of resources in the shallow aquatic environment?
- What are the seasonal expressions and cycles for terrestrial and shallow aquatic ecosystems, functional groups and diagnostic species? What is the susceptibility and likely response in the context of changes in climate, land use, and disturbance? [DS 191, 195, 203]

CQ2. Wildfires (LG)

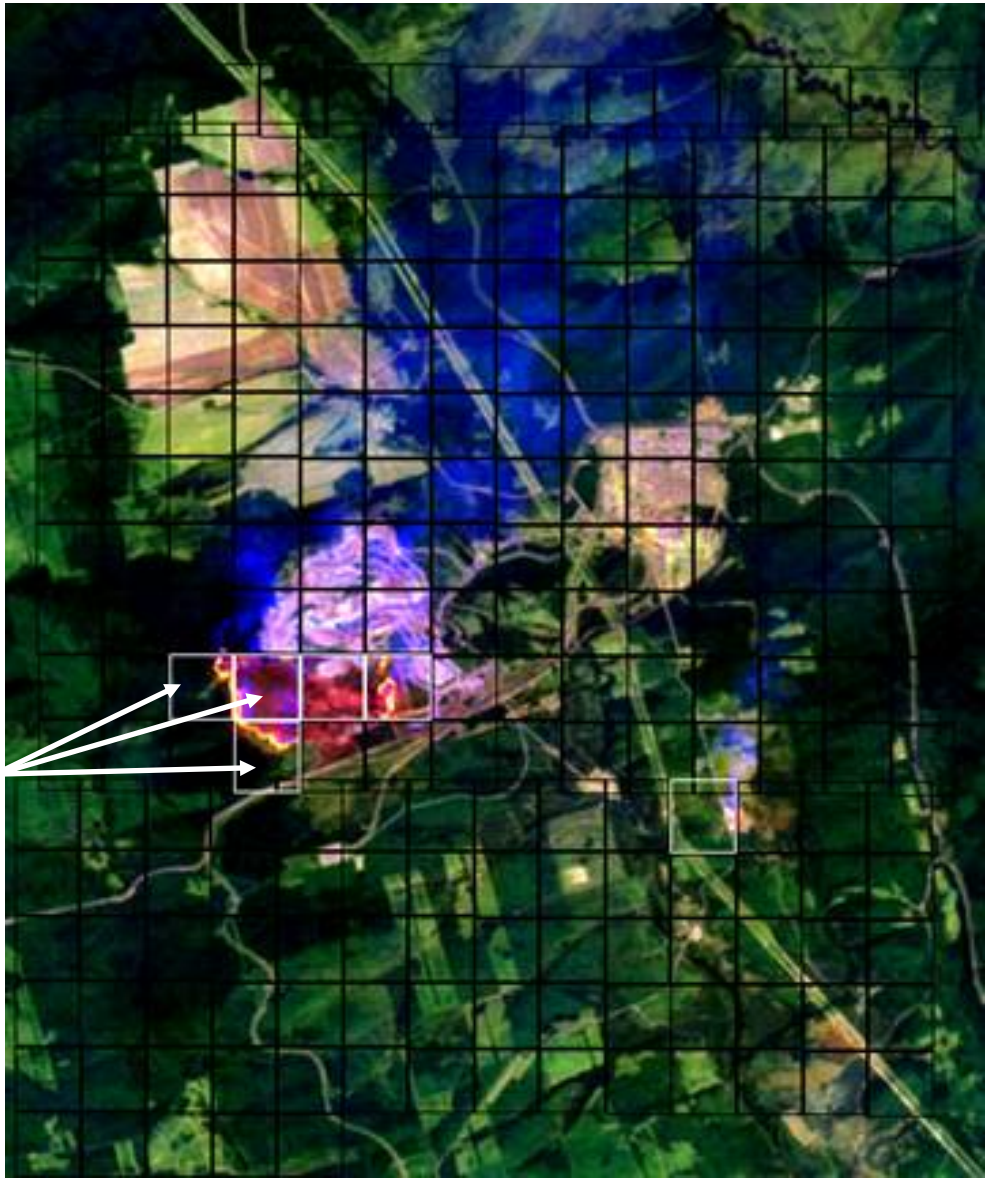
- How does the timing, temperature and frequency of fires affect long-term ecosystem health?
- How does vegetation composition and fire temperature impact trace gas emissions?
- How do fires in coastal biomes affect terrestrial biogeochemical fluxes into estuarine and coastal waters and what is the subsequent biological response? [DS 198]
- What are the feedbacks between fire temperature and frequency and vegetation composition and recovery?
- How does vegetation composition influence wildfire severity?
- On a watershed scale, what is the relationship of vegetation cover, soil type, and slope to frequency of debris flows?
- How does invasive vegetation cope with fire in comparison to native species?

TIR: Wild Fires

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



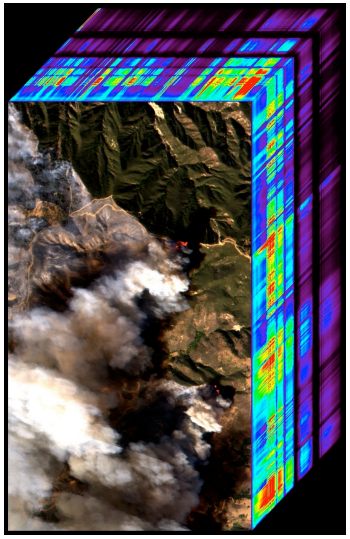
30 m ASTER scene with MODIS pixels superimposed (black squares)

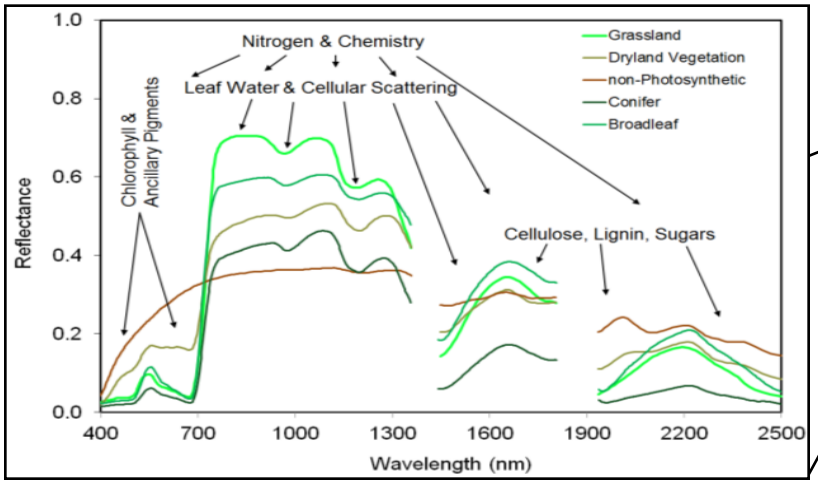
Central Siberia

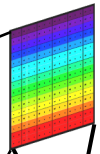
30 May 2001

VSWIR: Wild Fires

Image Cube







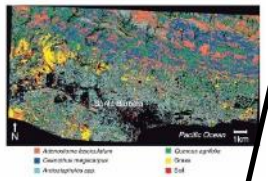
Detector Array

Spectrometer

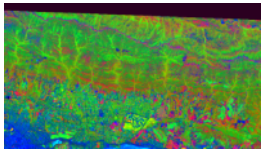
Slit

Telescope

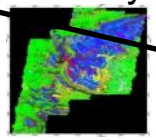
Species



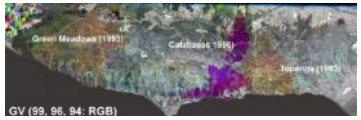
Dry Biomass



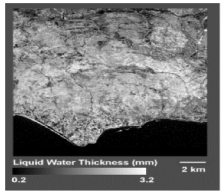
Severity

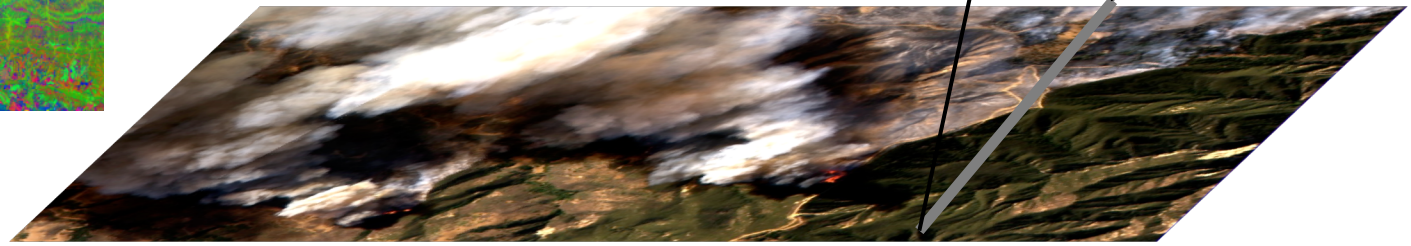


Recovery



Canopy Water





CQ3. Volcanoes (RW, VR)

- What do comparisons of thermal flux and SO2 emission rates tell us about the volcanic mass fluxes and the dynamics of magma ascent? [DS 227; 230]

- Does pressurization of the shallow conduit produce periodic variations in SO2 flux and lava dome surface temperature patterns that may act as precursors to explosive eruptions? [DS 50; 227; 230]

- Can measurements of the rate at which lava flows cool allow us to improve forecasts of lava flow hazards? [DS 50; 226]

- Does the temperature and composition of volcanic crater lakes change prior to eruptions? [DS 226; 227].

- Do changes in the health and extent of vegetation cover indicate changes in the release of heat and gas from crater regions? [DS 230; 231]

CQ4. Ecosystem Function and Diversity, (DR, MA)

- How can we enhance phenological & stress characterization through synergy between reflective and emitted radiation with higher frequency temporal sampling? [DS194, 195]
- How is energy partitioned between latent and sensible heat fluxes as a function of different plant types and fractional cover and how does this impact hydrology? [DS 203]
- How is physiological function affecting water and carbon exchange expressed at the ecosystem scale, especially seasonal down-regulation due to environmental stress factors? [DS 166, 196, 203, 206, 368]
- What is the vegetation phenological response to seasonal and interannual changes in temperature and moisture due to climate change and how does this response vary at the community/species level? [DS 196, 203, 206]
- What are the feedbacks between changes in canopy composition, mortality and retrieved canopy temperatures resulting from disturbances (e.g., disease, moisture deficiency, insect attack, fire, land degradation, fragmentation) in natural and managed ecosystems? [DS 166, 196, 203, 206]
- How do climate-induced temperature and moisture changes impact the distribution and spread of invasive and native species? [DS 196, 203]

CQ5. Surface Composition and Change (JM,AP)

- What is the composition of the exposed terrestrial surface of the Earth? [DS 220]
- How does the surface mineralogy and soil composition relate to the plant physiology and function on the terrestrial surface of the Earth? (DS 114)
- How is the composition of exposed terrestrial surface responding to anthropogenic and non anthropogenic drivers (desertification, weathering, disturbance e.g. logging, mining)? (DS 114)
- How do types and distributions of altered rocks define regional trends in hydrothermal fluid flow for magmatic arcs and tectonic basins, better define hydrothermal deposit models, and assist in the discovery of new economic deposits? (DS 227)
- How do regional trends of minerals and shale thermal maturity within basins better define depositional models and assist in the discovery of new hydrocarbon reserves? (DS 235)

CQ6. Human Health and Urbanization (DQ, GG)

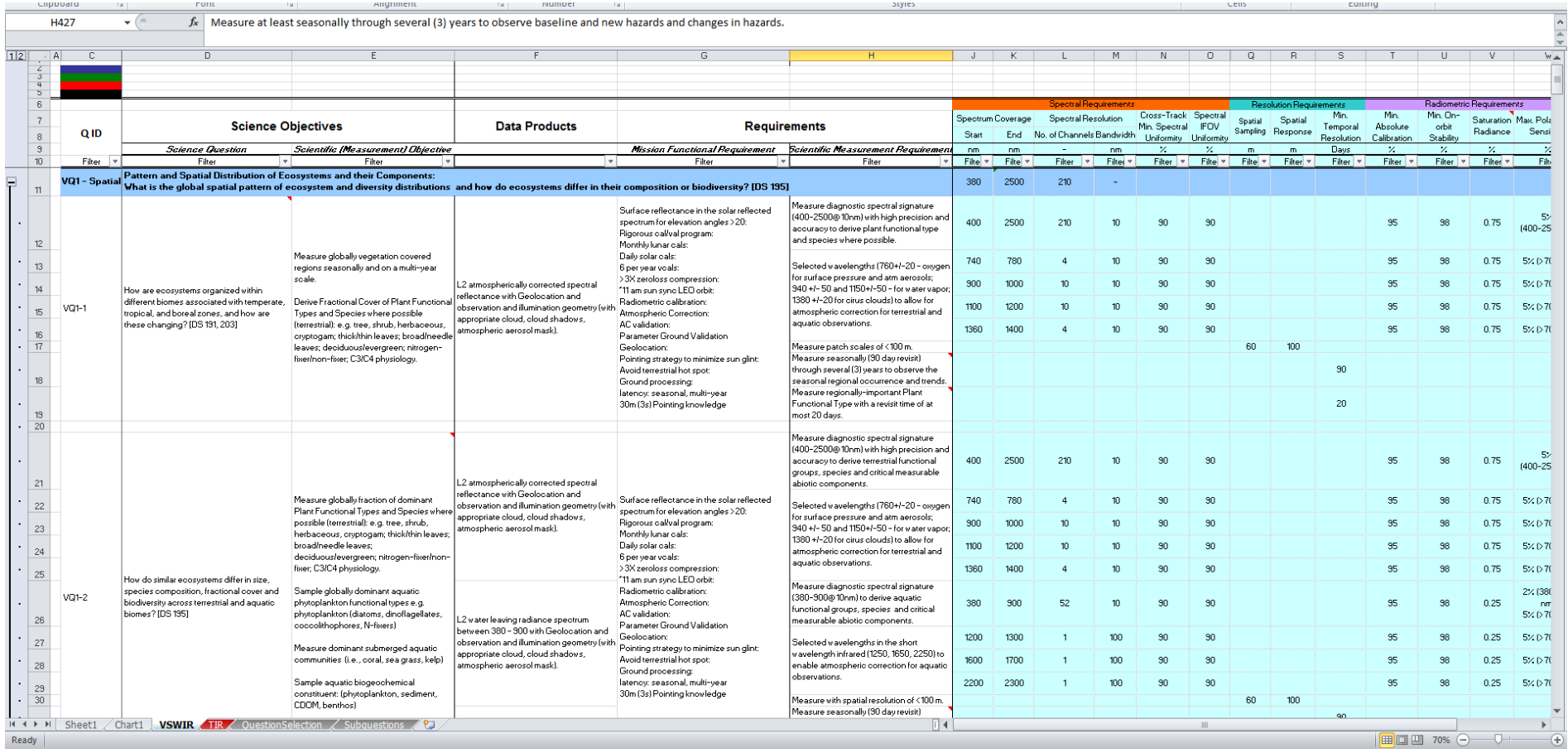
- How do land surface characteristics such as vegetation state, soil moisture, temperature, and land cover composition affect heat and drought, and vector- and animal-borne diseases? (DS 156, 158, 160, 183-184, 198)

- What changes can be observed and measured in emissivities of urban surfaces and how do emissivities change for different cities around the world as they impact the urban heat island and associated land-atmosphere energy balance characteristics? (DS 167-168)

- How does the distribution of urban and peri-urban impervious surfaces affect regional energy balance fluxes, hydrologic processes, biogeochemical fluxes, and what is the response of ecosystems to these changes? (DS 167-168, 198, 203)

HyspIRI Science Traceability Matrices

- These questions were used to develop detailed HyspIRI Traceability Matrices.
- These then informed the development of requirements.
- Example below



H427: Measure at least seasonally through several (3) years to observe baseline and new hazards and changes in hazards.

		Science Objectives		Data Products	Requirements		Spectral Requirements						Resolution Requirements			Radiometric Requirements			
	Q ID						Spectrum Coverage		Spectral Resolution		Cross-Track Uniformity	Spectral IFOV Uniformity	Spatial Sampling	Spatial Response	Min. Temporal Resolution	Min. Absolute Calibration	Min. On-orbit Stability	Saturation Radiance	Max. Pola Sensi
		Science Question	Scientific (Measurement) Objective		Mission Functional Requirement	Scientific Measurement Requirement	Start	End	No. of Channels	Bandwidth	Min. Spectral								
	Filter	Filter	Filter		Filter	Filter	nm	nm	-	nm	%	%	m	m	Days	%	%	%	%
	VQ1 - Spatial	Pattern and Spatial Distribution of Ecosystems and their Components: What is the global spatial pattern of ecosystem and diversity distributions and how do ecosystems differ in their composition or biodiversity? [DS 195]					380	2500	210	-									
	VQ1-1	How are ecosystems organized within different biomes associated with temperate, tropical, and boreal zones, and how are these changing? [DS 191, 203]	Measure globally vegetation covered regions seasonally and on a multi-year scale. Derive Fractional Cover of Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology.	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: >3X zeroless compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Parameter Ground Validation Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: latency: seasonal, multi-year 30m (3s) Pointing knowledge	Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive plant functional type and species where possible.	400	2500	210	10	90	90				95	98	0.75	5% (400-25
						Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations.	740	780	4	10	90	90				95	98	0.75	5% D70
							900	1000	10	10	90	90				95	98	0.75	5% D70
							1100	1200	10	10	90	90				95	98	0.75	5% D70
							1360	1400	4	10	90	90				95	98	0.75	5% D70
						Measure patch scales of <100 m.							60	100					
						Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends.									90				
						Measure regionally-important Plant Functional Type with a revisit time of at most 20 days.									20				
	VQ1-2	How do similar ecosystems differ in size, species composition, fractional cover and biodiversity across terrestrial and aquatic biomes? [DS 195]	Measure globally fraction of dominant Plant Functional Types and Species where possible (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology. Sample globally dominant aquatic phytoplankton functional types e.g. phytoplankton (diatoms, dinoflagellates, coccolithophores, N-fixers) Measure dominant submerged aquatic communities (i.e., coral, sea grass, kelp) Sample aquatic biogeochemical constituent: (phytoplankton, sediment, CDOM, benthos)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: >3X zeroless compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction: AC validation: Parameter Ground Validation Geolocation: Pointing strategy to minimize sun glint: Avoid terrestrial hot spot: Ground processing: latency: seasonal, multi-year 30m (3s) Pointing knowledge	Measure diagnostic spectral signature (400-2500@10nm) with high precision and accuracy to derive terrestrial functional groups, species and critical measurable abiotic components.	400	2500	210	10	90	90				95	98	0.75	5% (400-25
						Selected wavelengths (760+/-20 - oxygen for surface pressure and atm aerosols; 940 +/- 50 and 1150+/-50 - for water vapor; 1380 +/-20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations.	740	780	4	10	90	90				95	98	0.75	5% D70
							900	1000	10	10	90	90				95	98	0.75	5% D70
							1100	1200	10	10	90	90				95	98	0.75	5% D70
							1360	1400	4	10	90	90				95	98	0.75	5% D70
						Measure diagnostic spectral signature (380-900@10nm) to derive aquatic functional groups, species and critical measurable abiotic components.	380	900	52	10	90	90				95	98	0.25	2% (380 nm 5% D70
						Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations.	1200	1300	1	100	90	90				95	98	0.25	5% D70
							1600	1700	1	100	90	90				95	98	0.25	5% D70
							2200	2300	1	100	90	90				95	98	0.25	5% D70
						Measure with spatial resolution of <100 m.							60	100					
						Measure seasonally (90 day revisit)									90				

Sheet1 | Chart1 | VSWIR | TIR | QuestionSelection | Subquestions

Ready

Summary and Conclusions

- With the dedicated work of the HyspIRI Science Study Group a set of key science questions where developed early in the HyspIRI concept study process
- These questions were focused to take advantage of the unique measurements offered by the VSWIR spectroscopy and TIR measurements called for as HyspIRI in the 2007 Decadal Survey
- These questions were used to formulate the HyspIRI traceability matrices and develop level 1 requirements.
- These questions and supporting materials are available to contribute to the 2017 Decadal Survey

Questions

Key Science and Science Applications

Climate: Ecosystem biochemistry, condition & feedback; spectral albedo; carbon/dust on snow/ice; biomass burning; evapotranspiration

Ecosystems: *Global* biodiversity, plant functional types, physiological condition, and biochemistry including agricultural lands

Fires: Fuel status; fire frequency, severity, emissions, and patterns of recovery *globally*

Coral reef and coastal habitats: *Global* composition and status

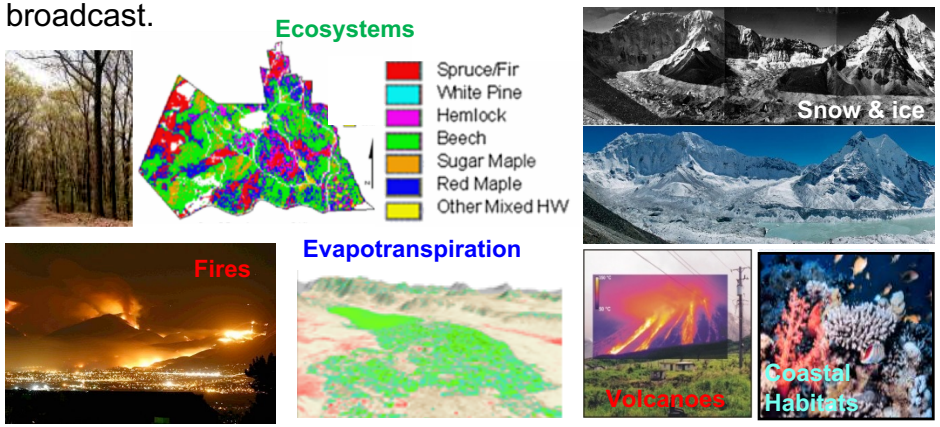
Volcanoes: Eruptions, emissions, regional and *global* impact

Geology and resources: *Global* distributions of surface mineral resources and improved understanding of geology and related hazards

Applications: Disasters, EcoForecasting, Water, Health/AQ

Mission Urgency

The HyspIRI science and applications objectives are critical today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct broadcast.



Measurement

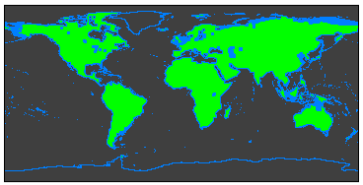
Imaging Spectrometer (VSWIR)

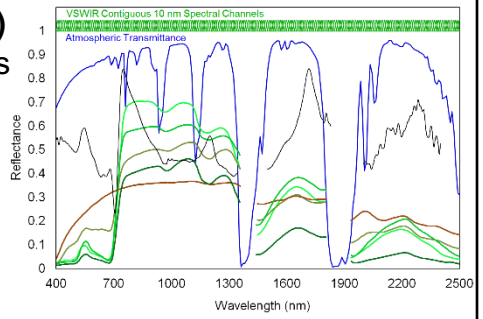
- 380 to 2500nm in ≤10nm bands
- 60 m spatial sampling*
- 19 days revisit*
- Global land and shallow water

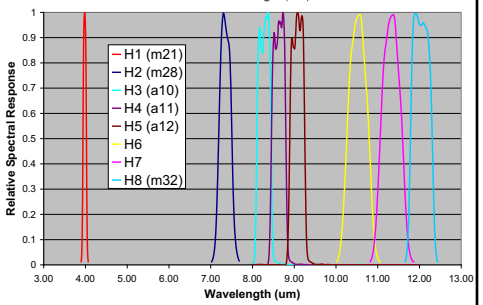
Thermal Infrared (TIR):

- 8 bands between 4-12 µm
- 60 m spatial sampling
- 5 days revisit; day/night
- Global land and shallow water

IPM-Low Latency data subsets







Mission Concept Status

Level 1 Measurement Requirements: Vetted by community and stable

Payload: VSWIR Imaging Spectrometer, **TIR** Multi-spectral Radiometer, and **Intelligent Payload Module (IPM)**

Full Mission original option: Mature

Separate Small Mission option: Pegasus-based solutions identified and studied

***SLI Support:** HyspIRI VSWIR evolving to 30m at 185km swath

ECOSTRESS TIR: Selected EVI for ISS

VSWIR Dyson Option: Technology/Science ISS Demonstration

Summary: The HyspIRI mission measurement requirements and baseline instruments approach are mature and stable with good heritage, low risk and modest cost. Now exploring a range of instrument and data options to save cost, per guidance letter.