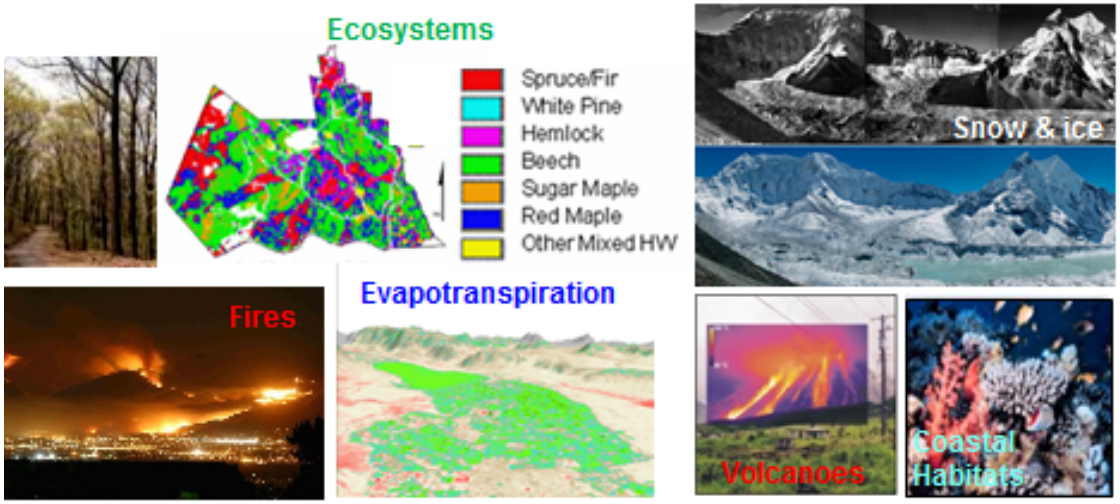
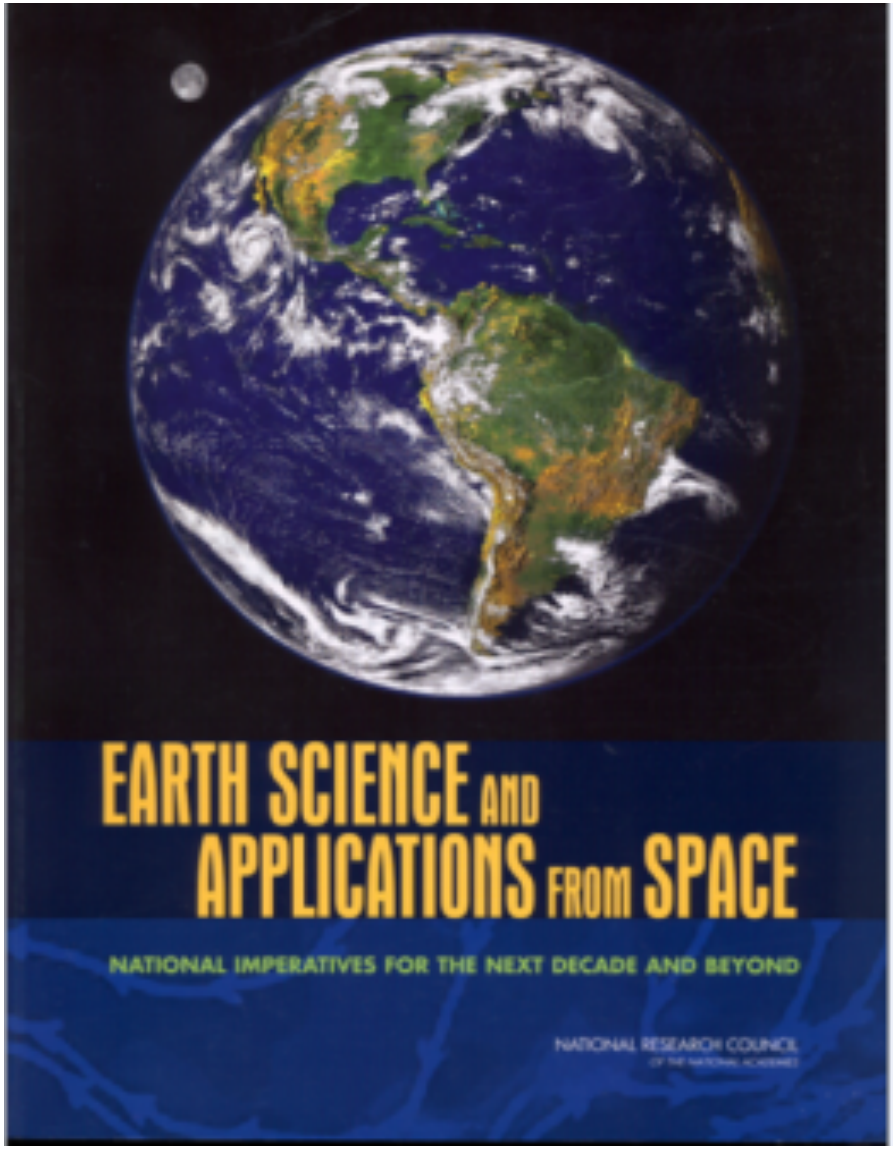


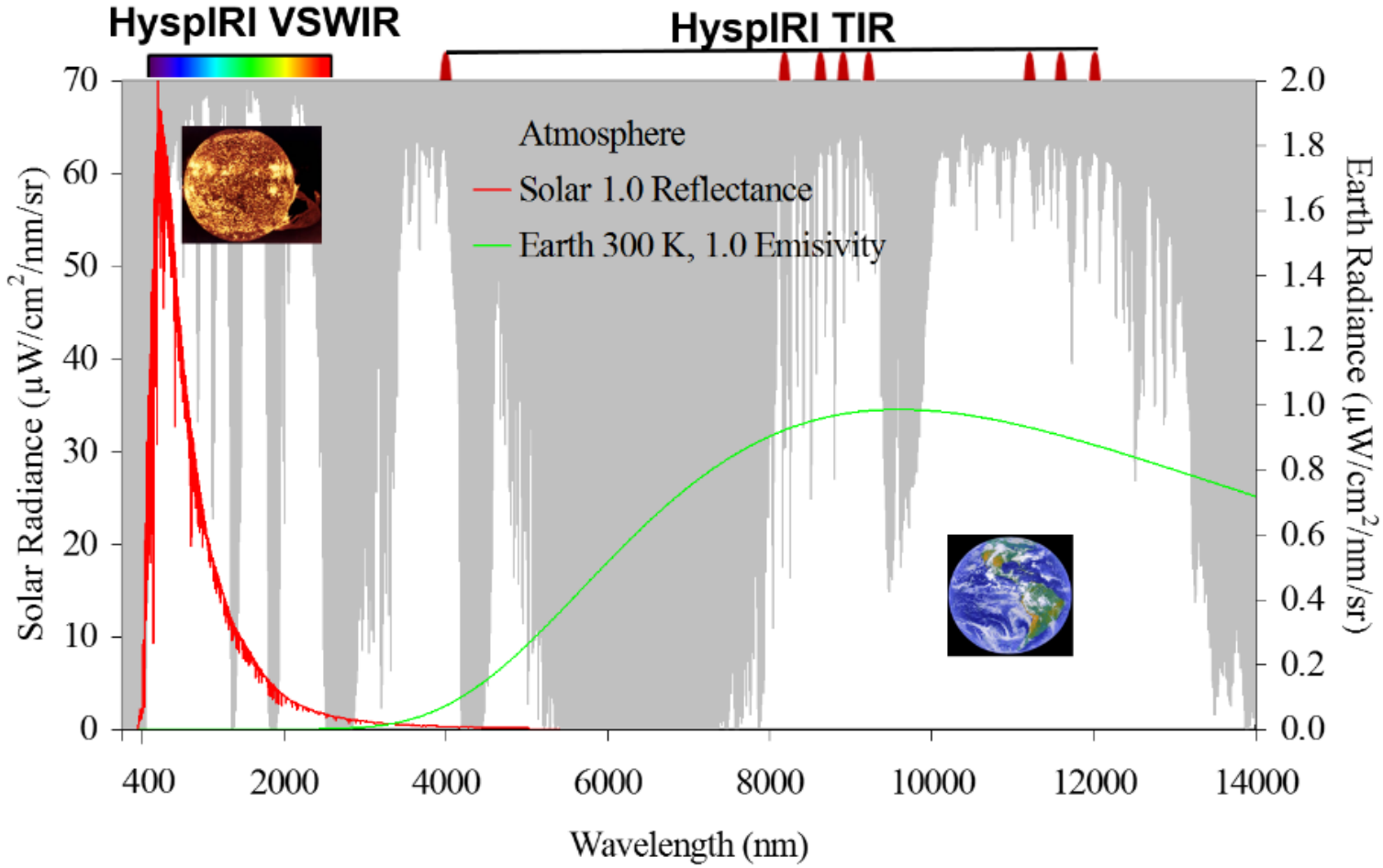
Status of the HyspIRI Mission Concept

Robert Green, Simon Hook, Betsy Middleton and The HyspIRI Community


EARTH SCIENCE AND APPLICATIONS FROM SPACE
NATIONAL IMPERATIVES FOR THE NEXT DECADE AND BEYOND
NATIONAL RESEARCH COUNCIL

HysplRI Measurements

- Global terrestrial and coastal VSWIR spectroscopy at 30 m, 16 days and multispectral TIR at and 60 m, 4 days with real-time downlink of selected products.



HysplRI Objectives and Approach

Key Global Science and Applications Research

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

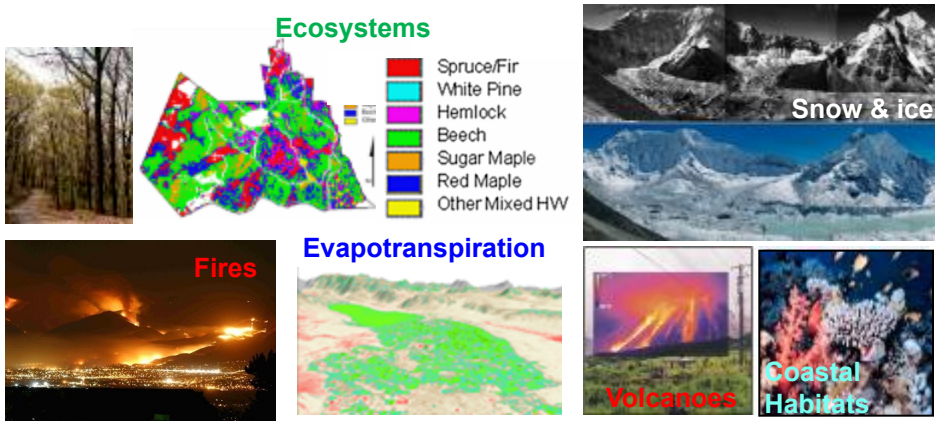
Volcanoes: Eruptions, emissions, regional and *global* impacts

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

Applications: Disasters, EcoForecasting, Health/AQ, Water

Global Mission Urgency

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



Measurement

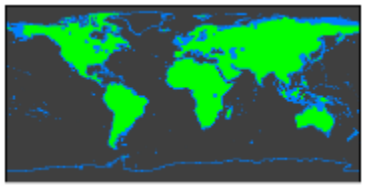
Imaging Spectrometer (VSWIR)

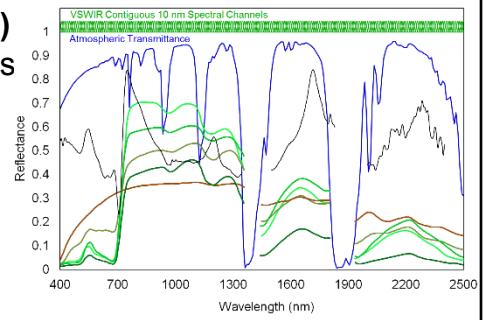
- 380 to 2510nm in ≤10nm bands
- 30 m spatial sampling
- 16 days revisit
- Global land and shallow water

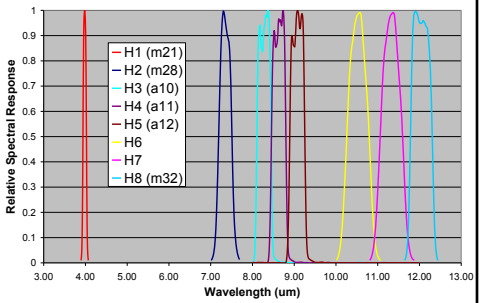
Thermal Infrared (TIR)

- 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 at workshops and in literature (many refereed journal articles)

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

Original 60 m option: Mature

ISS options: VSWIR & TIR Mature, ECOSTRESS EVI selected

Separate Smallsat Mission option: VSWIR and TIR solutions developed with TEAM I/X

2016 Option: HysplRI VSWIR evolved to 30 m and 16 day global revisit. Requires F/1.8 Dyson spectrometer architecture and other current technologies.

Preparatory airborne campaigns: Measurements used to advance and refine science, applications, algorithms, and processing

Current Decadal Survey: >25 HysplRI-related Dec. Sur. RFIs

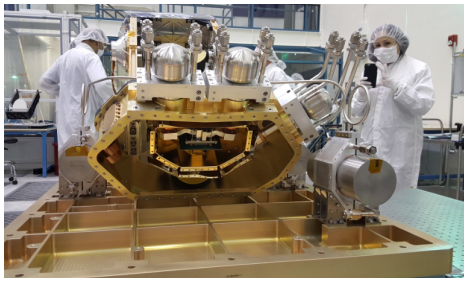
Overall FY16 Progress
2016 Guidance Memo Actions Completed

Guidance Memo Actions	Status	Summary of Actions Taken
1. Continue to build broad community understanding and support by conducting science and applications workshops and data product symposia.		Symposium held in June at GSFC Workshop and Airborne Meeting in October at Caltech Two oral sessions, 38 abstracts received for AGU session in December 2016 >15 HyspIRI-related Decadal Survey RFI2 inputs
2. Continue to conduct HyspIRI data product generation and benchmarking with airborne and satellite data.		Completed 4th year Western US HyspIRI data set; Algorithms advancing Routinely generating L1 and L2 from VSWIR and TIR data FY16 start of Volcano and Coral Reef campaign in Hawaii Small aircraft tests: IPM/spectrometer data throughput (GSFC)
3. Continue to carry out instrument mission trade studies, including smallsat and ISS opportunities, to provide lower cost and more adaptable instrument and/or mission approaches, including risk reduction concepts.		Refined and updated ISS and smallsat options Full 2016 HyspIRI baseline mission study with VSWIR (30m/16 day revisit), TIR (60m/5 day revisit), and IPM; Informed by ECOSTRESS and VSWIR studies
4. Continue to explore options to ensure the HyspIRI VSWIR and TIR instruments meet the Sustainable Land Imaging measurement requirements, including compatibility with heritage data product resolutions.		Evolved VSWIR concept to 30 m sampling and 16 day revisit HyspIRI airborne VSWIR convolved to Landsat bands ECOSTRESS demonstrating TIR for SLI VSWIR-Dyson F/1.8 meets SLI requirements (Mouroulis et al. journal article)
5.Utilize the ECOSTRESS mission development for HyspIRI risk reduction.		Using ECOSTRESS to advance the TRL of key components of the HyspIRI baseline: optics, detector, cryocoolers and science algorithms; TIR related airborne and ground validation efforts including use of HyTES for TIR validation
6.Continue to engage potential international and domestic partners in addressing opportunities to lower the cost of a potential mission while maintaining Level 1 mission requirements.		AVIRIS-NG campaign in India with possibilities for future partnerships Participation in EnMAP science advisory group Participation in International Space Science Institute (ISSI) Workshop on Imaging Spectroscopy
7. Prepare materials updating the National Research Council's 2017 Earth Science Decadal Survey effort on the status and value of a HyspIRI mission and provide the NRC with options for accomplishing the mission.		Web-based HyspIRI comprehensive development report Participation in Decadal Survey November white papers and May RFI 12 White papers, November 2015 >15 RFI2 responses, May 2016
8. Refine and update the HyspIRI comprehensive development report that documents and provides broad access for the NRC and others to the work completed by the HyspIRI team.		The comprehensive development report has been updated The HyspIRI website has been updated to support NASA and NRC efforts

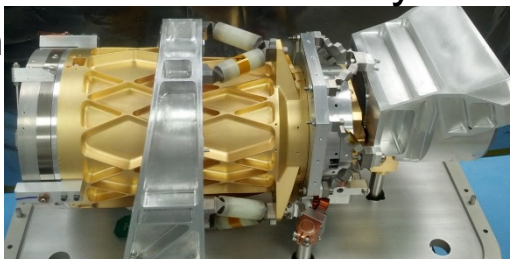
Technical Progress in FY2016

- Refined and benchmarked atmospheric correction and cal/val algorithms
- VSWIR-Dyson F/1.8 prototype has been running at cryogenic temperatures for 9 months; it can be scaled to support 30 m and 16 day revisit; full characterization, calibration and acquisition of relevant spectra achieved
- Tracking ECOSTRESS development and identifying those components that advance the HyspIRI TRL and those components requiring further work for HyspIRI
- Updated full HyspIRI concept with Team-X study for combined VSWIR, TIR, and IPM at VSWIR 30 m and 16 day revisit; TIR uses ECOSTRESS maturing technology; Ka band and lossless compression (4x for VSWIR/3x for TIR) with cloud screening allows downlink of all VSWIR and TIR data
- Testing VSWIR and TIR with latest lossless compression algorithm; now a Consultative Committee for Space Data Systems (CCSDS) standard
- IPM demonstrated 4.8 Gbps composite ingest rate on 8 Low Voltage Differential Signal (LVDS) lines, which is likely method to tap data from SWIR; 1.7 Gbps throughput for Level 1 Radiometric (L1R) correction previously demonstrated, but should shortly demonstrate 4.8 Gbps L1R and L1 Geometric Correction
- Comprehensive report summarizing multi-year effort of HyspIRI concept study team reviewed and made available for web distribution through the HyspIRI website: http://hyspiri.jpl.nasa.gov/comprehensive-development-report

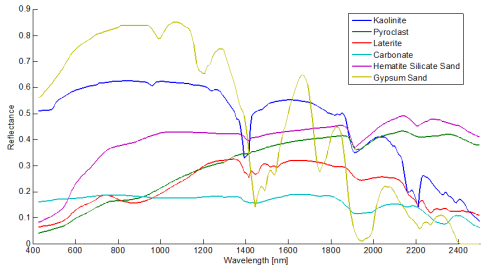
ECOSTRESS



VSWIR-Dyson



VSWIR-Dyson Test Lab Spectra



HyspIRI Comprehensive Development Report

Comprehensive Report

- Comprehensive Development Report

HyspIRI Mission TRL Assessment

- Comprehensive Development Report

Appendix

Reports and Whitepapers

- Compiled Reports and Whitepapers from 2008-2014

Individual Report files

- 2014 HyspIRI Separate Platforms Whitepaper
- 2014 PHyTIR Test Results
- 2012 Workshop Report
- 2012 TIR Band Study Report
- 2011 Workshop Report
- 2011 Symposium Report
- 2011 Sun Glint Report
- 2011 High Temperature Saturation Report
- 2010 Workshop Report
- 2009 Workshop Report
- 2008 Whitepaper and Workshop Report
- TRL Assessment Report

HyspIRI Workshop Material

- 2014 Compiled Workshop
- 2013 Compiled Workshop
- 2012 Compiled Workshop
- 2011 Compiled Workshop
- 2010 Compiled Workshop
- 2009 Compiled Workshop
- 2008 Compiled Workshop

Individual Workshop files

- 2014 Workshop Agenda and Presentations
- 2013 Workshop Agenda and Presentations
- 2012 Workshop Agenda and Presentations
- 2011 Workshop Agenda and Presentations
- 2010 Workshop Agenda and Presentations
- 2009 Workshop Agenda and Presentations
- 2008 Workshop Agenda and Presentations

HyspIRI Symposium Material

- 2014 Compiled Symposium
- 2013 Compiled Symposium
- 2012 Compiled Symposium
- 2011 Compiled Symposium
- 2010 Compiled Symposium

Individual Workshop files

- 2014 Symposium Agenda and Presentations
- 2013 Symposium Agenda and Presentations
- 2012 Symposium Agenda and Presentations
- 2011 Symposium Agenda and Presentations
- 2010 Symposium Agenda and Presentations

TeamX ISS Accommodation Studies

- VSWIR ISS Study
- TIR ISS Study

2014 Small Spacecraft Vendor Presentation

Algorithm Theoretical Basis Documents (ATBDs)

- TIR Level 2 Surface Radiance
- TIR Level 2 Surface Temperature and Emissivity
- TIR Cloud Mask
- VSWIR Level 2 Water Leaving Reflectance
- VSWIR Level 2 Land Surface Reflectance

Science Application Summaries

- Disasters
- Water resources
- Health and Air Quality

Science Application White Papers

- Hyspiri Volcanoes
- Public Health

http://hyspiri.jpl.nasa.gov/comprehensive-development-report

Data Products Symposium at GSFC

Science and Applications Workshop at Caltech

Key Science and Applications Accomplishments for 2016

- Mission and Products Symposium June 3rd - 5th 2016 at GSFC
- Science and Applications Workshop October 18th to 20th at Caltech (+21st Volcano/Coral meeting)
- 38 abstracts for the Fall AGU session Dec 2016 assuring strong science community connection
- >50 HyspIRI related journal articles published in past two years
- Single season acquisition of California HyspIRI target areas; All data processed and made available; Support Student Airborne Research Program (SARP) with HyspIRI-type measurements
- AVIRIS-NG data collections of 57 sites in India in collaboration with ISRO
- Forest Service is using HyspIRI airborne data to track drought effects in Sierra Nevada
- Planning for 2017 Hawaii volcano and coral reef campaign to further advance HyspIRI science and applications research and data processing capability in these important communities
- HyspIRI Aquatic Studies Group (ASG)
  - HyspIRI Town Hall at Ocean Sciences 2016 in New Orleans, LA - 23 Feb 2016.
  - 4th Annual Aquatic Forum at GSFC - 3 June 2016.
  - HyspIRI Town Hall at Ocean Optics XXIII in Victory, BC - 27 Oct 2016 (objective to collect community input for Decadal Survey).
  - HyspIRI ASG continues to interface with NASA aquatic missions: PACE/HyspIRI/GEO-CAPE.

June 2016 Data Products Symposium at GSFC

October 2015 Science and Applications Workshop at Caltech

Nature Plants 2016

PUBLISHED: 2 MARCH 2016 | ARTICLE NUMBER: 16024 | DOI: 10.1038/NPLANTS.2016.24

comment

Monitoring plant functional diversity from space

The world's ecosystems are losing biodiversity fast. A satellite mission designed to track changes in plant functional diversity around the globe could deepen our understanding of the pace and consequences of this change, and how to manage it.

Walter Jetz, Jeannine Cavender-Bares, Ryan Pavlick, David Schimel, Frank W. Davis, Gregory P. Asner, Robert Guralnick, Jens Kattge, Andrew M. Latimer, Paul Moorcroft, Michael E. Schaepman, Mark P. Schildhauer, Fabian D. Schneider, Franziska Schrodt, Ulrike Stahl and Susan L. Ustin

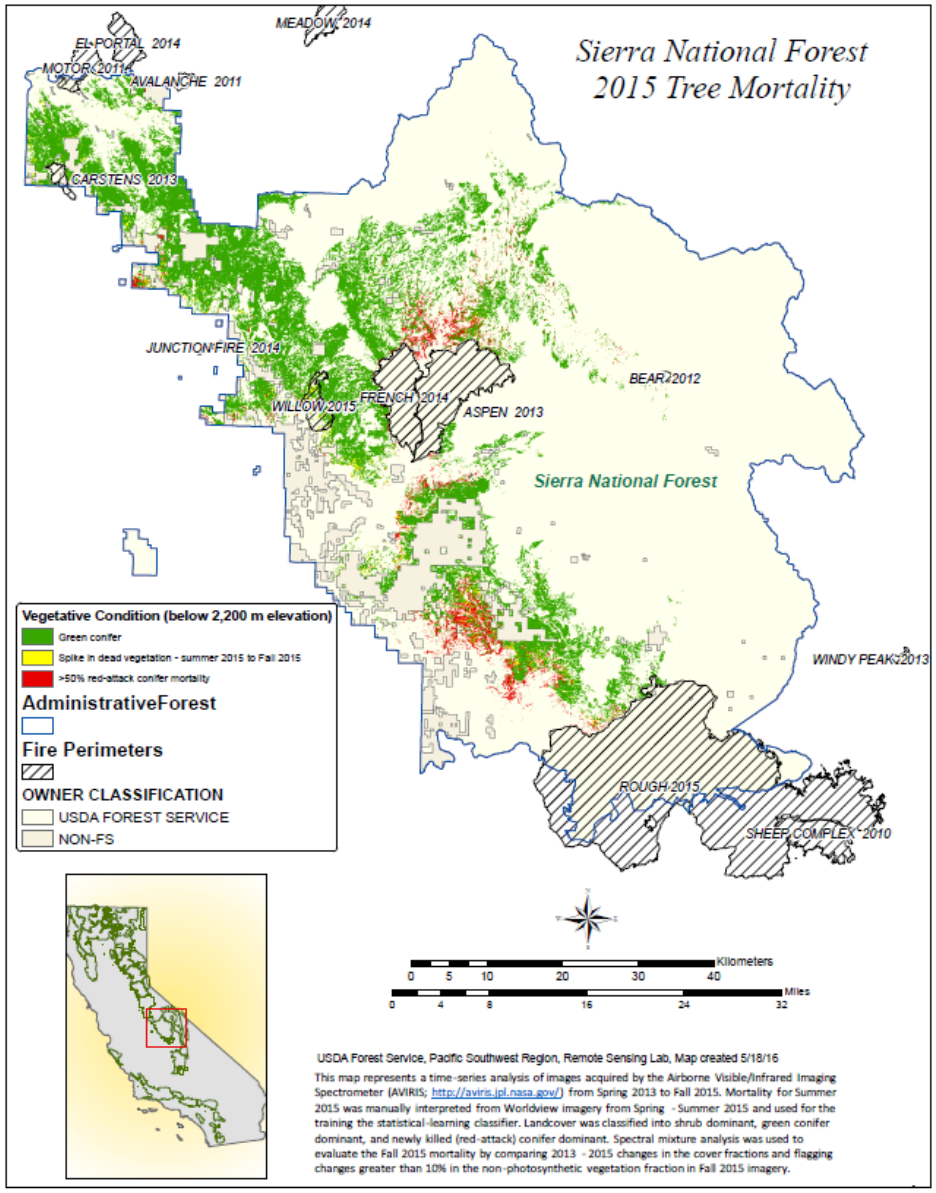
The ability to view Earth's vegetation from space is a hallmark of the Space Age. Yet decades of satellite measurements have provided relatively

time that such a mission would provide has the potential to transform basic and applied science on diversity and function, and to pave the way to a more mechanistically

mass to leaf area. These attributes are related functionally to the uptake, allocation and use of resources such as carbon and nutrients within the plant, and to the defence against

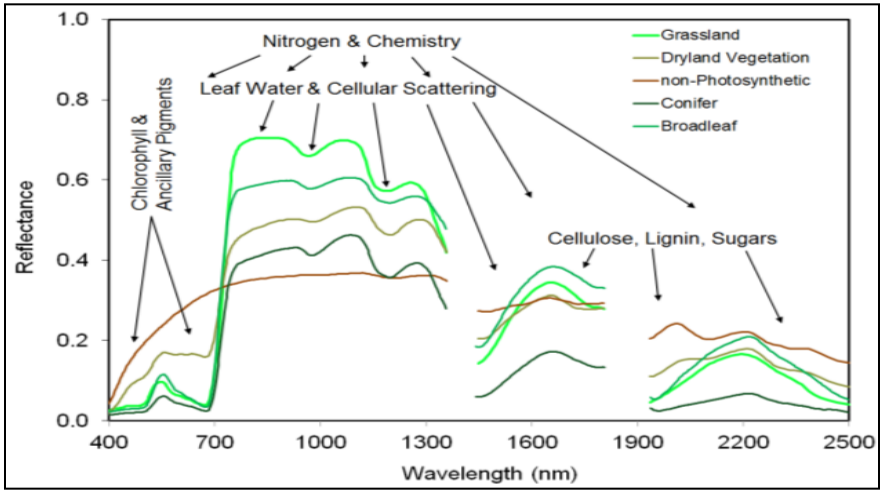
Measurement of Non-Photosynthetic Vegetation

Recent Applications Result from HyspIRI Airborne Campaign



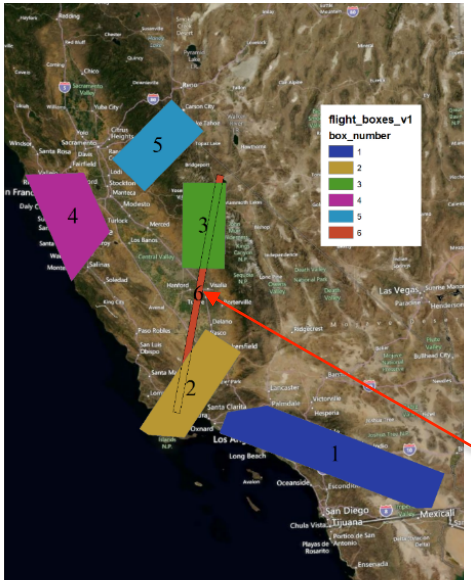
USDA Forest Service, Pacific Southwest Region, Remote Sensing Lab, Map created 5/18/16

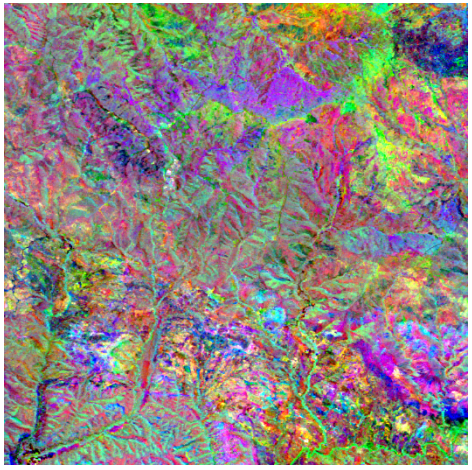
This map represents a time-series analysis of images acquired by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS; http://aviris.jpl.nasa.gov/) from Spring 2013 to Fall 2015. Mortality for Summer 2015 was manually interpreted from Worldview imagery from Spring - Summer 2015 and used for the training the statistical-learning classifier. Landcover was classified into shrub dominant, green conifer dominant, and newly killed (red-attack) conifer dominant. Spectral mixture analysis was used to evaluate the Fall 2015 mortality by comparing 2013 - 2015 changes in the cover fractions and flagging changes greater than 10% in the non-photosynthetic vegetation fraction in Fall 2015 imagery.



Dimensionality of the Earth System Captured with Imaging Spectroscopy

NASA HyspIRI
Preparatory Campaign



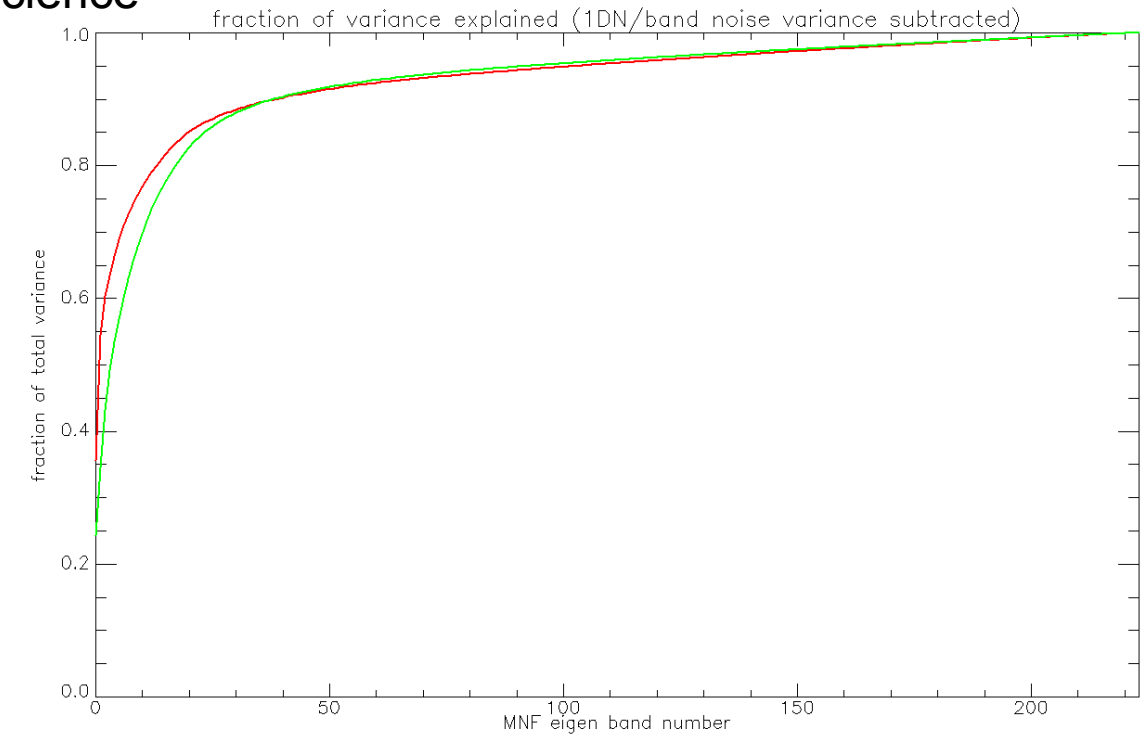


AVIRIS Flight line from Mono Lake to Santa Barbara, CA

A single HyspIRI airborne campaign flight line has 50 content rich eigen images.

A single scene show up to 30 content rich eigen images.

This demonstrates huge dimensionality available for access with imaging spectroscopy for new Earth system science



Carbon Emissions from Biomass Burning

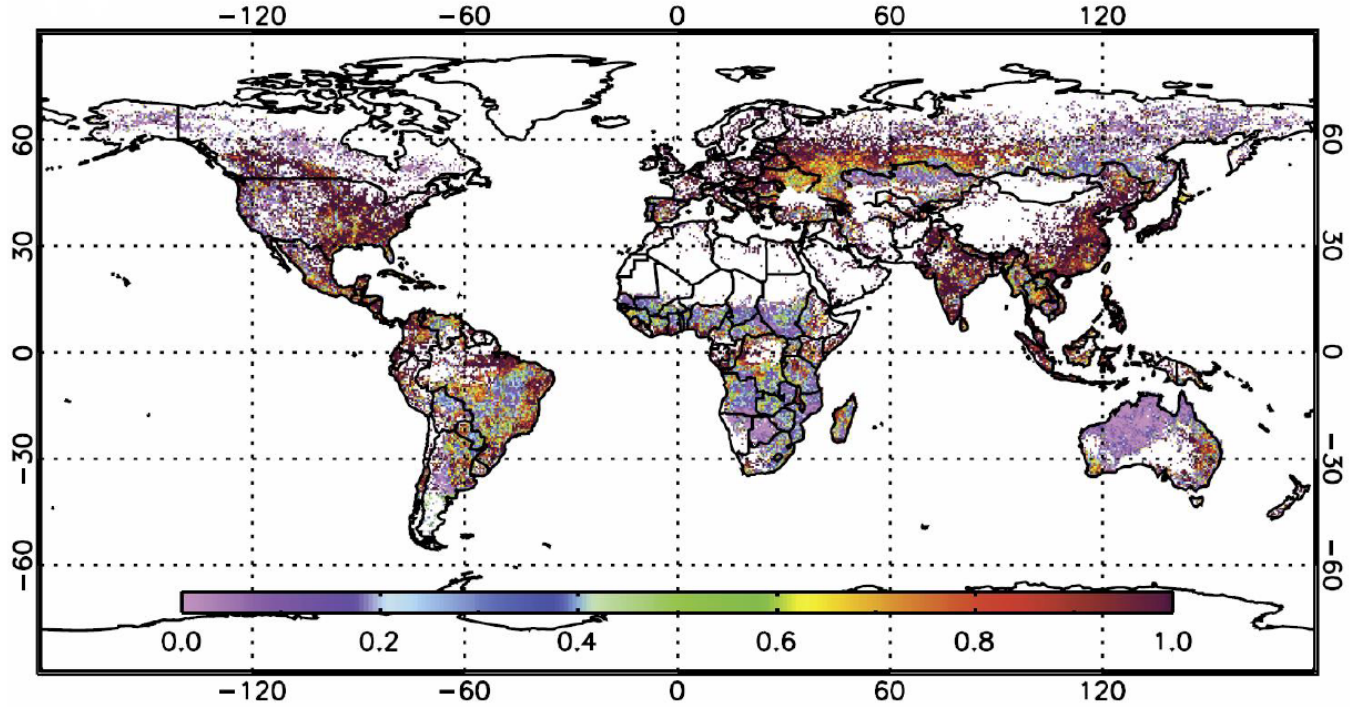


Figure 1 Small fire fraction of total burned area (Randerson et al. 2013). Red and yellows highlight areas where many smaller fires were detected.

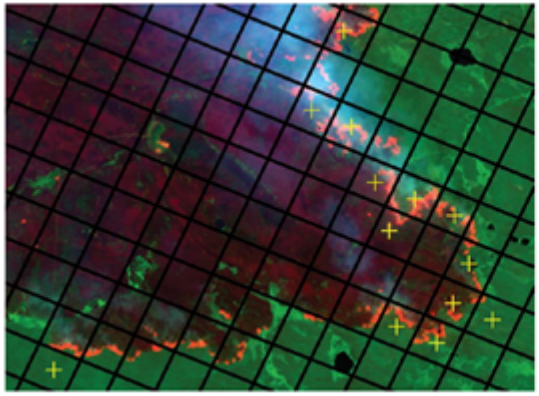


Figure 2. Simultaneous higher resolution 90-m ASTER image with black boxes overlaid corresponding to 1-km MODIS imagery. Yellow crosses represent MODIS pixels where fires were detected. Notice that many pixels where fire is clearly visible in the ASTER image remain undetected in the MODIS image.

PREDICTING CHANGES IN THE BEHAVIOR OF ERUPTING VOLCANOES, AND REDUCING THE UNCERTAINTIES ASSOCIATED WITH THEIR IMPACT ON SOCIETY AND THE ENVIRONMENT

- Gas emissions:
- Low temperature thermal anomalies:
- The color, temperature, and size of crater lakes:
- Lava effusion rate:
- Temperature and cooling rate of active lavas:
- Spatio-temporal variations in the amount and concentration of ash in the atmosphere:
- The spatio-temporal distribution of H2SO4 aerosol:

Figure 3. SO_2 column abundance calculated from Terra ASTER data at Kilauea volcano (source: https://hyspiri.jpl.nasa.gov/downloads/2013_Workshop/day1/18_HyspIRI_VJR_2013.pdf)

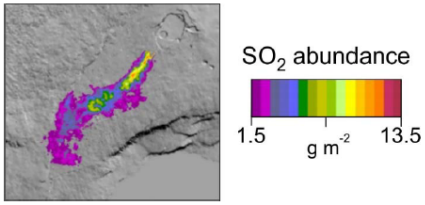


Figure 1. Distribution of Earth's active and potentially active volcanoes (source: Sigurdsson, H. (2015). *Encyclopedia of volcanoes*, 2nd edition. San Diego: Academic Press.

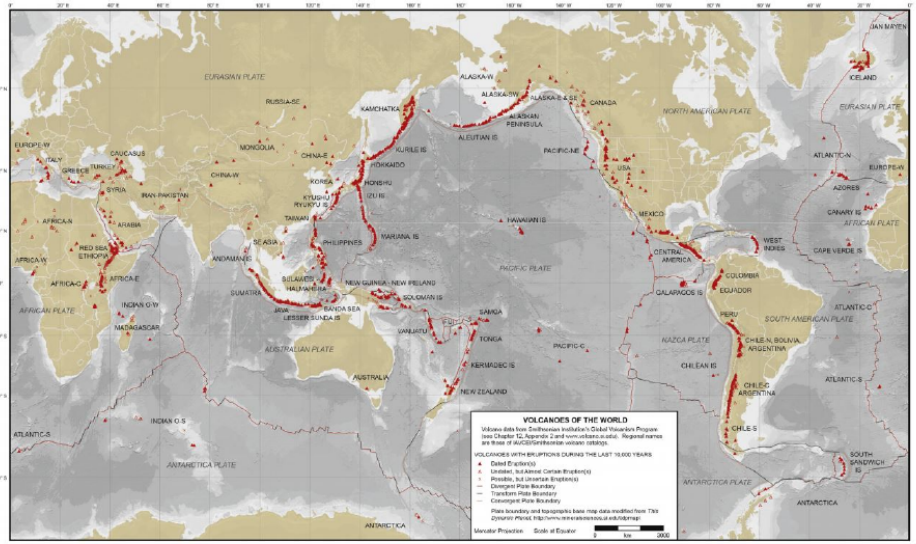
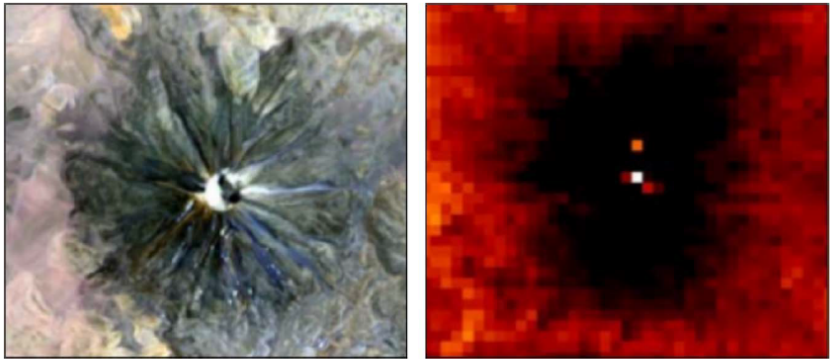


Figure 5. Left: Reflective false color composite of Chiliques Volcano, Chile, obtained by Terra ASTER. Right: thermal infrared night-time image of the same volcano showing subtle thermal anomaly at the summit (source: Pieri, D.C., and Abrams, M. (2004). ASTER watches the world's volcanoes: a new paradigm for volcanological observations from orbit. *J. Volcanol. Geotherm. Res.*, 135, 13-28).



HyspIRI Related Decadal Survey RFI *2* Inputs

Luvall	Jeffrey	A Thermodynamic Paradigm For Using Satellite Based Geophysical Measurements For Public Health Applications
Heidi	Dierssen	Assessing Transient Threats and Disasters in the Coastal Zone with Airborne Portable Sensors
Ryan	Pavlick	Biodiversity
Simon	Hook	Carbon Emissions from Biomass Burning
Eric	Hochberg	Coral Reefs: Living on the Edge
Wendy	Calvin	Earth Surface Geochemistry and Mineralogy: Processes, Hazards, Soils, and Resources
Joshua	Fisher	Evapotranspiration: A Critical Variable Linking Ecosystem Functioning, Carbon and Climate Feedbacks, Agricultural Management, and Water Resources
Tamlin	Pavelsky	From the Mountains to the Sea: Interdisciplinary Science and Applications Driven by the Flow of Water, Sediment, and Carbon II
Philip	Dennison	Global Measurement of Non-Photosynthetic Vegetation
Kevin	Turpie	Global Observations of Coastal and Inland Aquatic Habitats
Philip	Townsend	Global Terrestrial Ecosystem Functioning and Biogeochemical Processes
Dale	Quattrochi	High Spatial, Temporal, and Spectral Resolution Instrument for Modeling/Monitoring Land Cover, Biophysical, and Societal Changes in Urban Environments
Steve	Greb	Inland Waters
Natalie	Mahowald	Measuring the Earth's Surface Mineral Dust Source Composition for Radiative Forcing and Related Earth System Impacts
Frank	Muller-Karger	Monitoring Coastal and Wetland Biodiversity from Space
Robert	Wright	Predicting Changes in the Behavior of Erupting Volcanoes, and Reducing the Uncertainties Associated with their Impact on Society and the Environment
Robert	Green	Science and Application Targets Addressed with the 2007 Decadal Survey HyspIRI Mission Current Baseline
Natasha	Stavros	The role of fire in the Earth System
Riley	Duren	Understanding anthropogenic methane and carbon dioxide point source emissions
Thomas	Painter	Understanding the controls on cryospheric albedo, energy balance, and melting in a changing world

38 Abstracts Submitted to AGU Session

- Two oral sessions allocated by AGU

AGU FALL MEETING

San Francisco | 12–16 December 2016

SEARCH KEYWORDS

SEARCH SECTIONS AND FOCUS GROUPS

SEARCH CONVENER/AUTHOR NAME

LOGIN

GC029:
Earth Science Results from New Imaging Spectroscopy Measurements around the Globe

Session ID#: 13023
Session Description:
In 2015/16, advanced airborne imaging spectrometers operated by NASA and other agencies pursued science campaigns spanning new and diverse environments worldwide. Regions included Greenland, India, the Southern Ocean, the South Pacific, United States, Europe and elsewhere. This session will present salient new results from these diverse investigations. It will highlight algorithmic advances, challenges and opportunities related to regional diversity, preparing for new capabilities from orbital imaging spectrometers such as EnMAP and future missions with full global coverage. Submissions will demonstrate new measurements for land, ocean, cryosphere, and atmosphere science. Examples include: terrestrial ecosystem function, health, and biodiversity; ocean, coastal, benthic and inland water properties; urban land cover condition; snow and ice climate and water resource factors; measurement of the atmosphere including local methane sources; and surface geology related to resources, soils, and hazards. We will also examine calibration, algorithms, and field methodology ensuring continued consistency in global Earth system science.

Primary Convener:
David R Thompson, Jet Propulsion >Laboratory, California Institute of Technology, Pasadena, CA, United States
Conveners:
Robert O Green, Jet Propulsion Laboratory, Pasadena, CA, United States, **Elizabeth Middleton**, NASA Goddard Space Flight Cen., Greenbelt, MD, United States and **Thomas H Painter**, NASA Jet Propulsion Laboratory, Pasadena, CA, United States

Cross-Listed:
A - Atmospheric Sciences
B - Biogeosciences
C - Cryosphere
OS - Ocean Sciences

Index Terms:

0410 Biodiversity [BIOGEOSCIENCES]
1615 Biogeochemical cycles, processes, and modeling [GLOBAL CHANGE]
1632 Land cover change [GLOBAL CHANGE]
1635 Oceans [GLOBAL CHANGE]

Status of Significant Programmatic Products/Events

- Partnership Discussions
  - There are options for partnerships to pursue, if guided (India, Europe, etc.)

- Plan developed to support HyspIRI TIR science and applications through ECOSTRESS measurements and thereby reduce TIR risk
  - Hardware validation to TRL9 of key components e.g.: detector, algorithm validation and partial science validation

- The EVS CORAL mission is benefiting HyspIRI VSWIR aquatic algorithms and understanding by measuring ~2% of the Earth's coral reefs

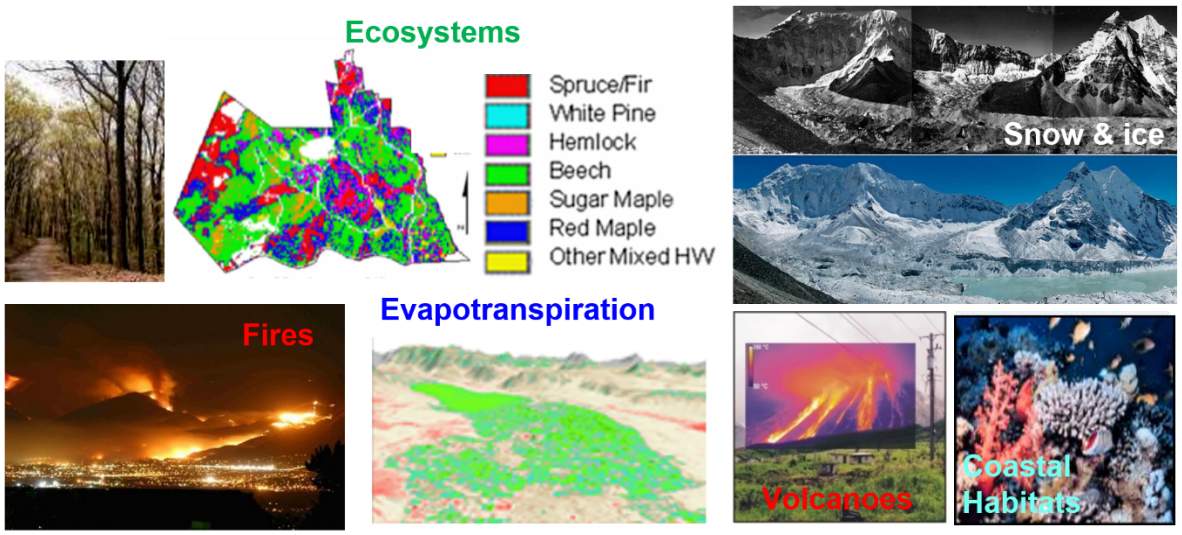
- Processing the diverse environment measurements from the AVIRIS-NG deployment to India is advancing the VSWIR L1 and L2 algorithms

- FY16 over guide activities: HyTES ER-2 flights planned for Fall 2016

- Technology Readiness Assessment
  - HyspIRI technology is TRL 6 or greater
  - There are engineering testbed tasks that make sense to increase maturity and reduce risk (TIR fire band, VSWIR detector and data rates, IPM real-time rates, etc.)

Issues and Challenges

- There is a broad community ready to use HyspIRI measurements to achieve unique and urgent NASA science and applications objectives
- 2017 Airborne Campaign over Hawaii, in conjunction with the CORAL project and ASG activities, will focus on the challenges of coastal aquatic remote sensing with inclusion of HyTES for volcano research
- Engineering elements of the HyspIRI concept, VSWIR, TIR (beyond ECOSTRESS) should continue to be matured; e.g.: ECOSTRESS electronics are for 6 bands not 8, ECOSTRESS does not include fire band
- Potential to use ECOSTRESS data for elements of early HyspIRI TIR science and applications

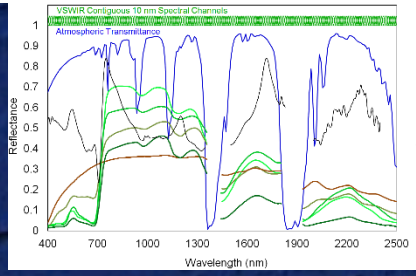


HyspIRI Volcano and Coral Reef Airborne Campaign

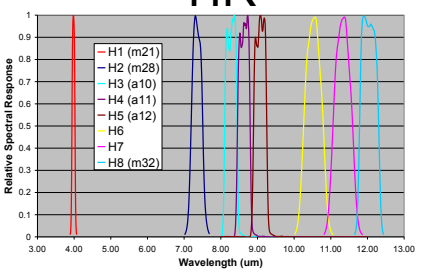
HyspIRI Preparatory Airborne Activities and Associated Science: Coral Reef and Volcano Research

- 10 investigations selected
- Data acquisition in 2017
- Test Level 1 and 2 products for VSWIR and TIR HyspIRI-type measurement
- Advance maturity of higher level products and related algorithms

VSWIR



TIR



Critical Take Aways

- HyspIRI-enabled science and applications are unique and urgent in this period of climate change.
- The technologies are ready for HyspIRI now.
  - ECOSTRESS is maturing the TIR capability for a subset of HyspIRI-TIR bands.
  - The F/1.8 VSWIR-Dyson is maturing the VSWIR solution for 30 m and 16 day revisit.
- The HyspIRI mission concept team and science study group is supporting the current Decadal Survey.
- There are potential international partnership opportunities at multiple levels.
- The JPL and GSFC HyspIRI Mission Concept team has performed exceptionally well. The team is committed to supporting NASA in FY17 and in the future as appropriate to achieve the HyspIRI science and applications research objectives.
- There is a broad science and applications community ready to use the global spectroscopy and TIR measurements that are unique to the HyspIRI Mission

THANK YOU