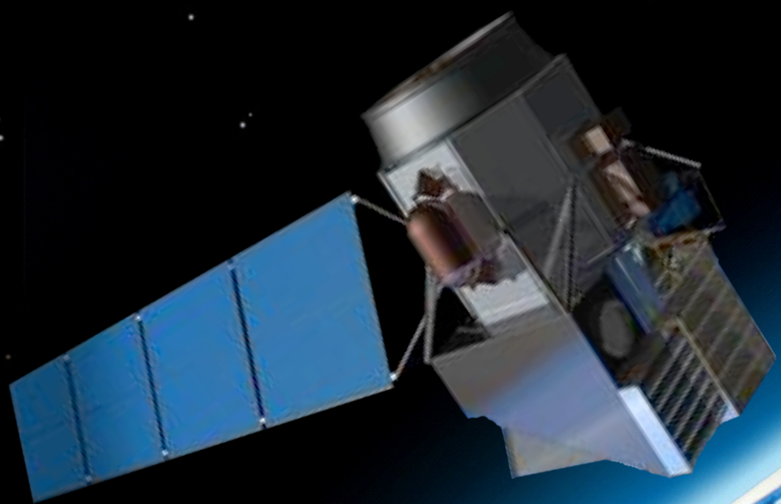
Review: HyspIRI Data Products

August 2018



Elizabeth M. Middleton

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EO-1 Mission Scientist
and the
GSFC HyspIRI Team
Biospheric Sciences Laboratory
NASA GSFC

HyspIRI/SBG Workshop
Washington DC
August 2018

19 Essential Climate Variables

A key TOPC activity is to identify measurable terrestrial key variables that control the physical, biological and chemical processes affecting climate and are indicators of climate change.

Biological/Ecological (6)

- Land cover
- FAPAR
- Leaf area index
- Above ground biomass
- Soil carbon
- Fire disturbance

Hydrological (5)

- River discharge
- Water use
- Ground water
- Lakes
- Soil moisture

Cryospheric (4)

- Snow cover
- Glaciers ~~and ice caps~~
- Ice sheets and ice shelves
- Permafrost

Surface Properties (4)

- Albedo
- Land surface temperature
- Energy fluxes
- Anthropogenic greenhouse gases

New GCOS Terrestrial ECVs

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New GCOS Terrestrial ECVs

HyspIRI Science Questions

HyspIRI has three top-level science questions called out in the NRC 2007 DS:

1. Ecosystem function and composition

-- *What is the global distribution and status of terrestrial and coastal-aquatic ecosystems and how are they changing?*

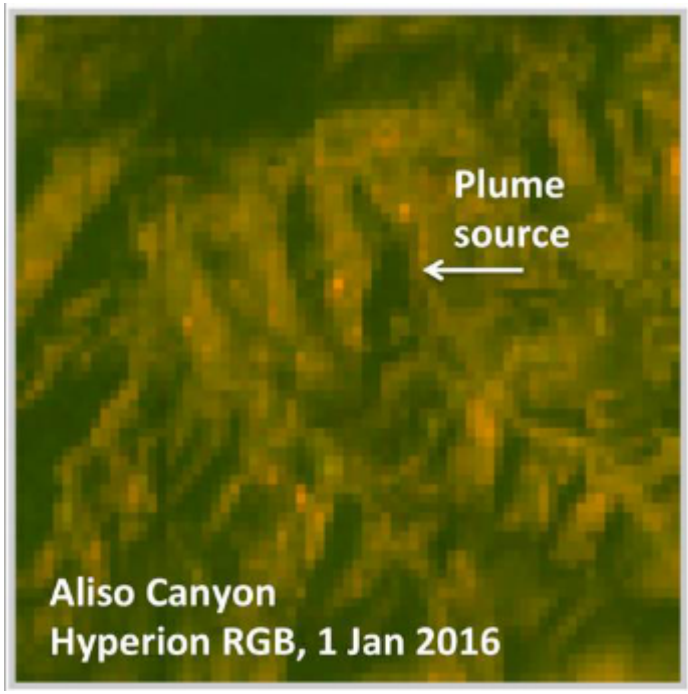
2. Volcanoes and natural hazards

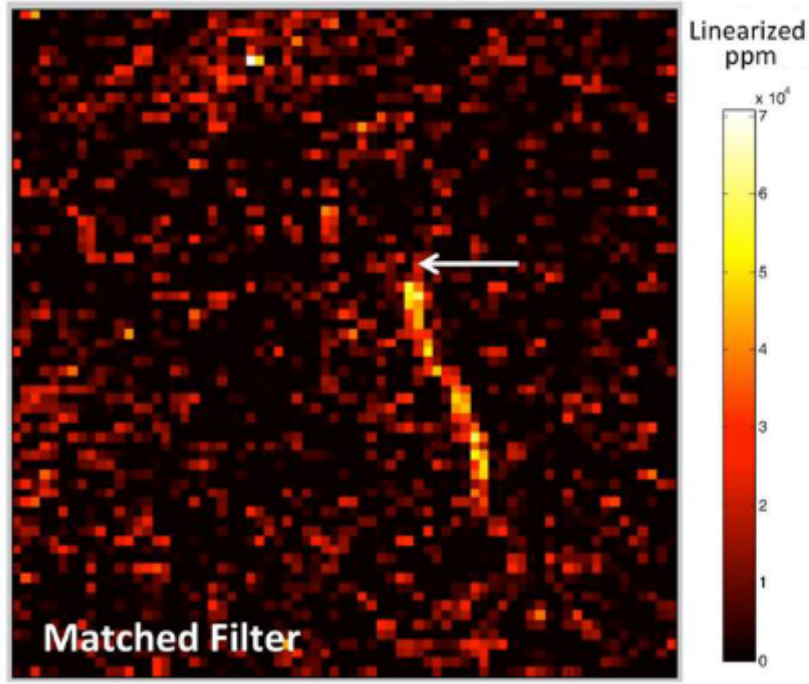
-- *How do volcanoes, fires and other natural hazards behave and do they provide precursor signals that can be used to predict future activity?*

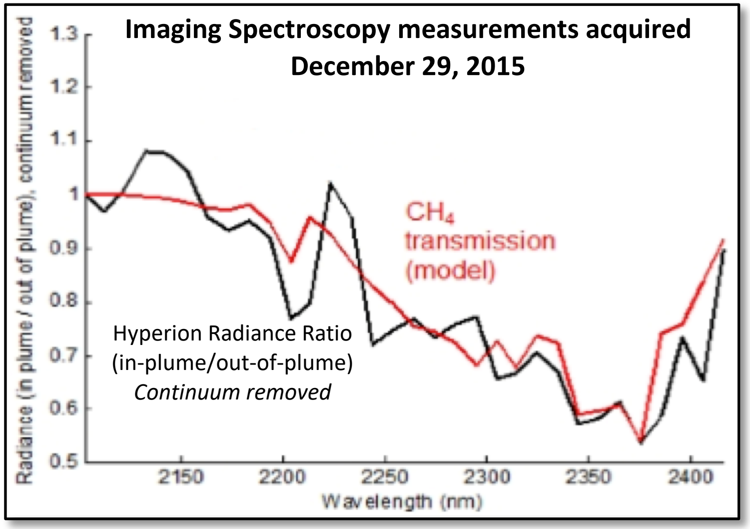
3. Surface composition and the sustainable management of natural resources

-- *What is the composition of the land surface and coastal shallow water regions and how can they be managed to support natural and human-induced change?*

Hyperion Detects the California Methane Leak







On January 1, 2016, Hyperion imaged the massive methane leak in the Aliso Canyon region of California. David Thompson's (JPL) algorithm detected the methane leak within the Hyperion data and showed a pronounced plume trending to the south. Since then, six additional acquisitions have been made, thanks to EO-1's ability to rapidly schedule, reorient satellite attitude, and quickly process and distribute the data.

Hyperion Matched Filter Detection Technique Provided by
D. Thompson, A. Thorpe, R.O. Green and The Imaging Spectroscopy Team, JPL, CalTech

HyspIRI and 2017 DS Science Questions

Matching HyspIRI's three top-level 2007 science questions to DS 2017 science questions relevant for SBG:

1. Ecosystem function and composition
-- What is the global distribution and status of terrestrial and coastal-aquatic ecosystems and how are they changing?

2017 E-1 STRUCTURE, FUNCTION, AND BIODIVERSITY: What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space? *[Objectives: **MI, VI**, and **I** (2)]*

2017 E-2 FLUXES: What are the fluxes (of carbon, water, nutrients, and energy) ***between*** ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing? *[Objectives: **MI CH_4,** and **I** (2)]*

2017 E-3 FLUXES: What are the fluxes (of carbon, water, nutrients, and energy) ***within*** ecosystems, and how and why are they changing? *[Objectives: **MI, VI**, and **I** (2)]*

2. Volcanoes and natural hazards
-- How do volcanoes, fires and other natural hazards behave and do they provide precursor signals that can be used to predict future activity?

***2017 S-*1** HAZARDS: How can large-scale geological hazards be accurately forecast in a socially relevant timeframe? *[Objectives: **MI** volcanoes (2), **VI** land slides]*

20017 S-2 DISASTERS: How do geological disasters directly impact the Earth system and society following an event? [*Objectives: MI*, ***VI*** *(2)]*

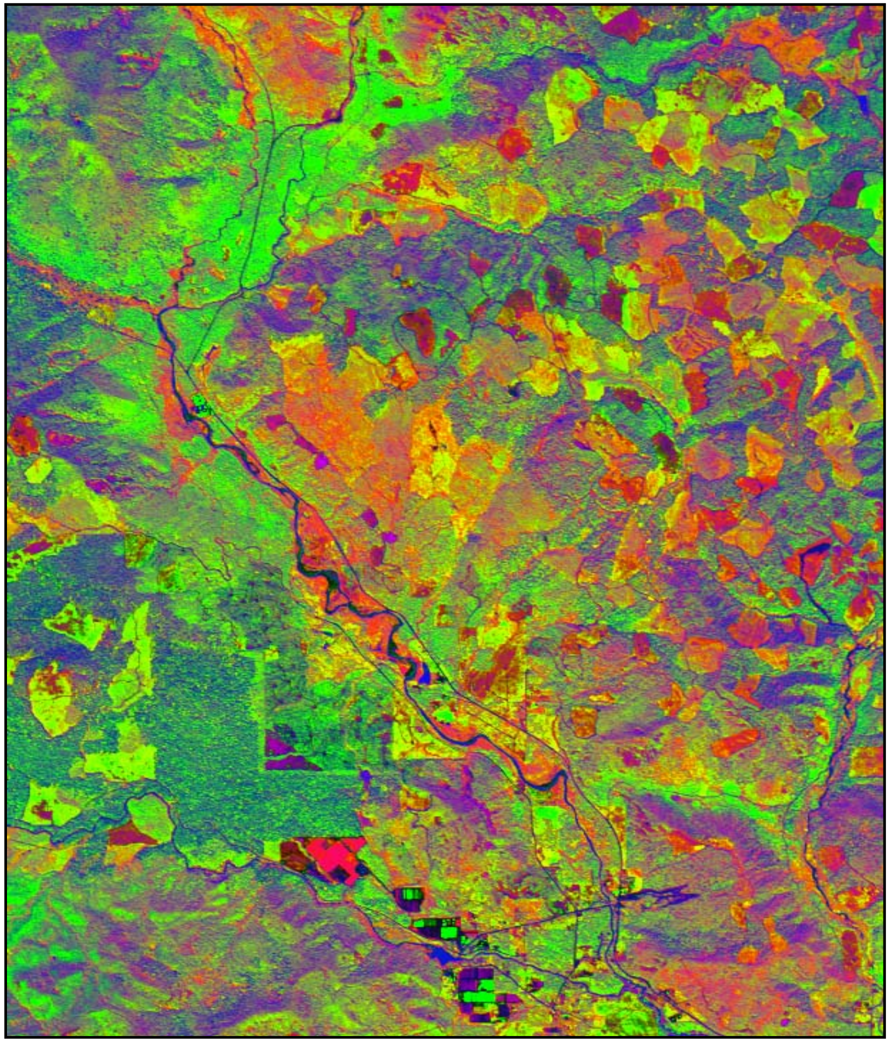
3. Surface composition and the sustainable management of natural resources
-- What is the composition of the land surface and coastal shallow water regions and how can they be managed to support natural and human-induced change?

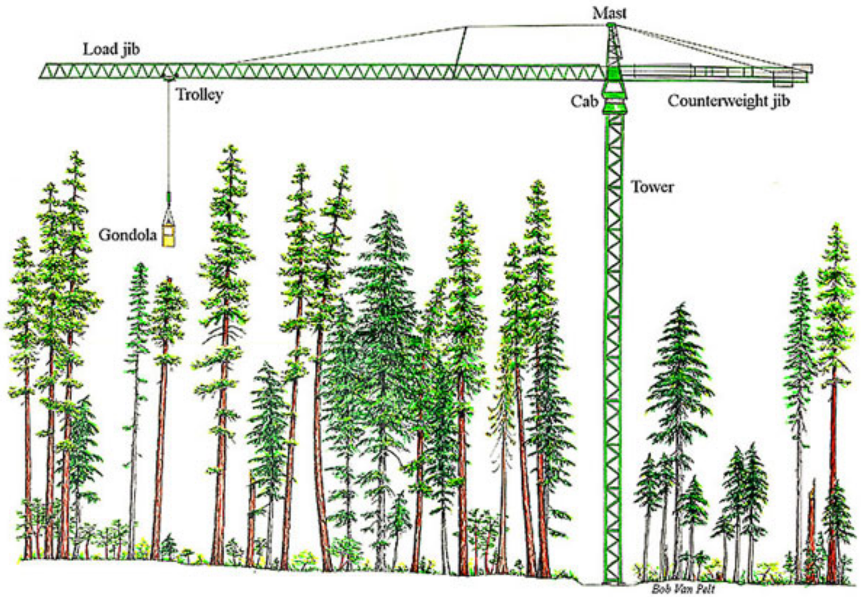
2017 S-4 LAND SURFACE: What processes and interactions determine the rates of landscape change? *[Objectives: **MI**]*

HyspIRI Science Questions

VQ1: 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 [DS2007 195]?

Reflectance Changes with Age Class & Species Mixtures





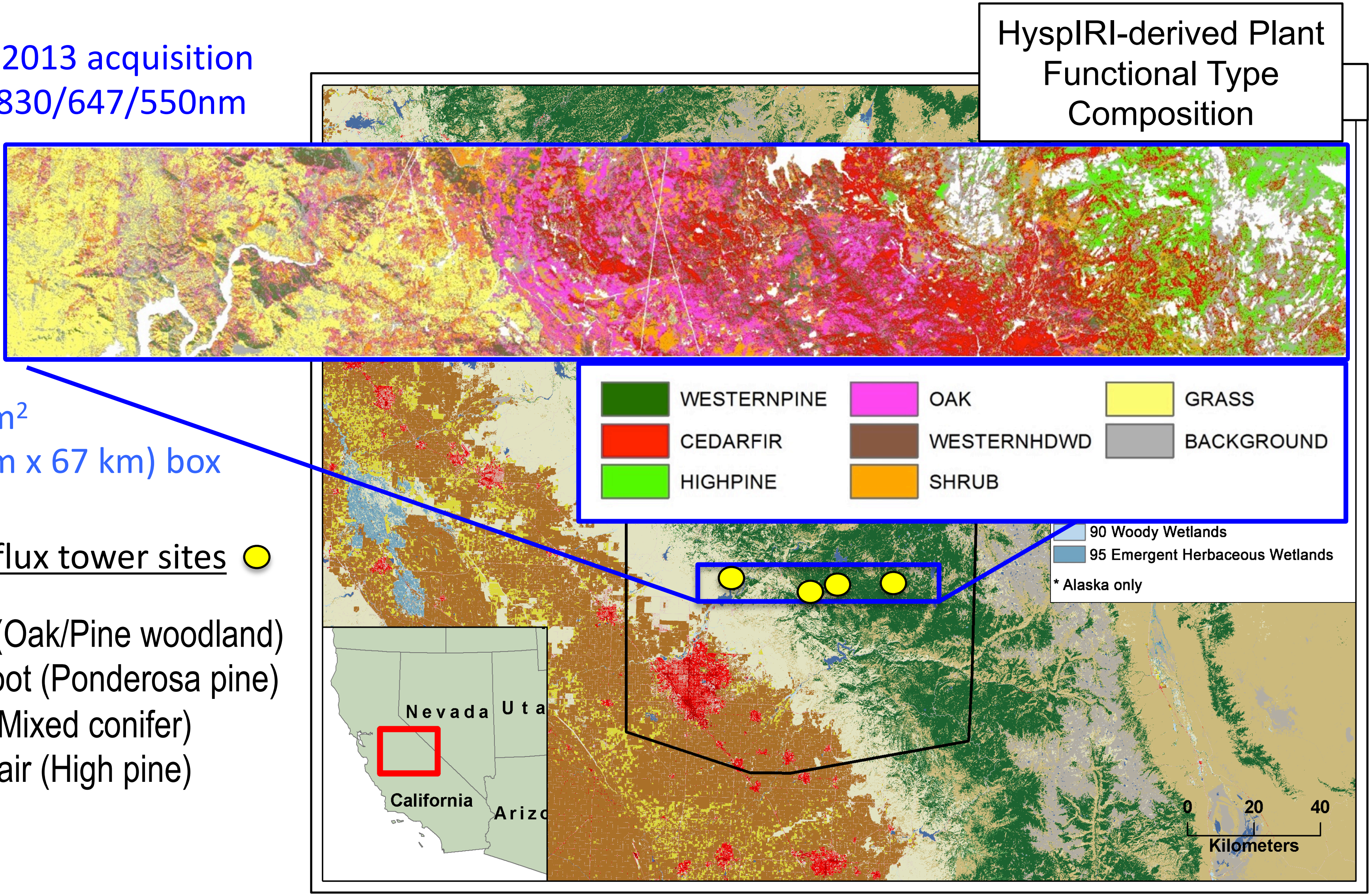
HyspIRI-Derived Composition Estimates for the Yosemite/NEON Flight Box (CA)

June 2013 acquisition
RGB 830/647/550nm

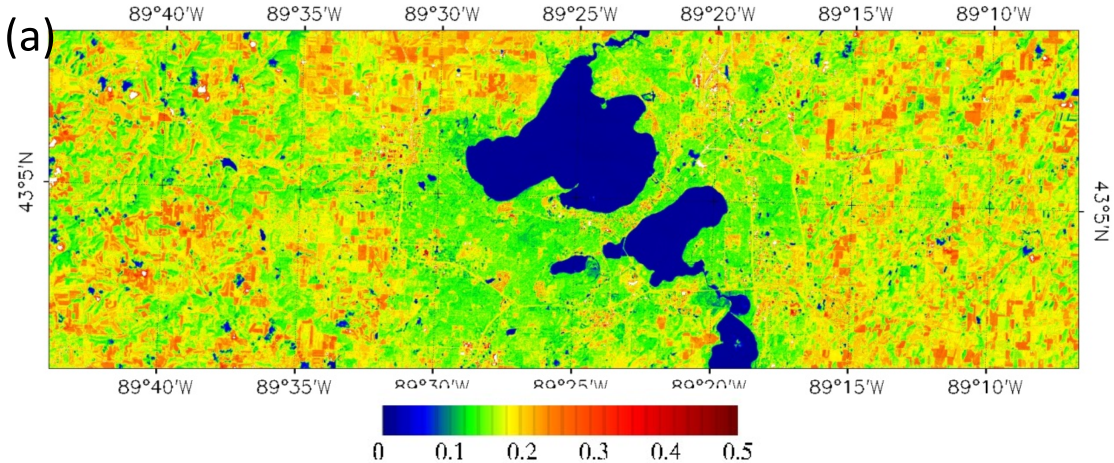
$737 km^2$
(11 km x 67 km) box

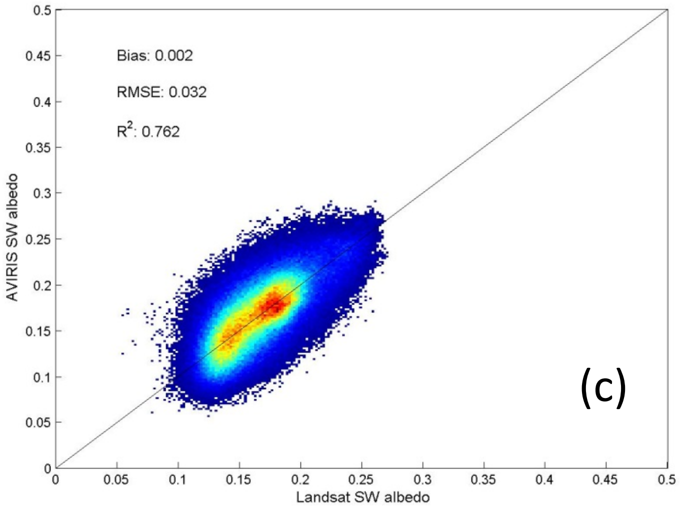
CZO flux tower sites

SJER (Oak/Pine woodland)
Soaproot (Ponderosa pine)
P301 (Mixed conifer)
Shorthair (High pine)

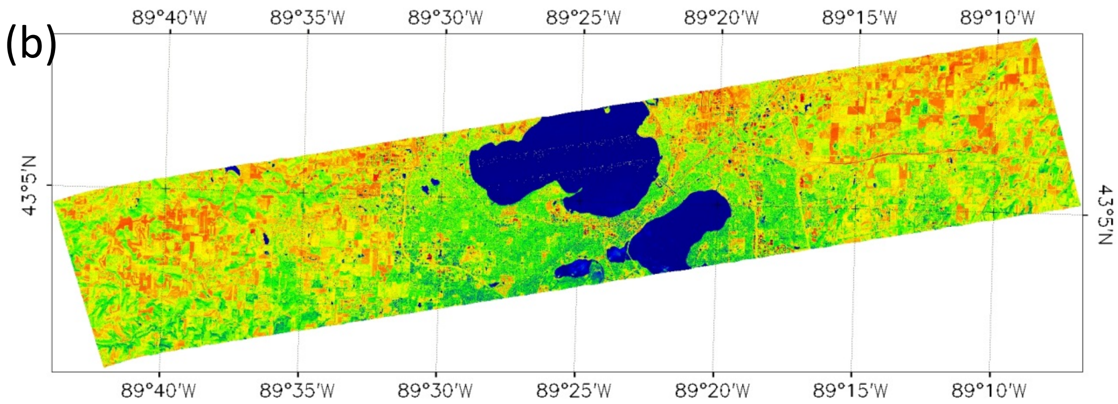


Mapping Surface Albedo: AVIRIS vs. Landsat





Landsat SW Albedo



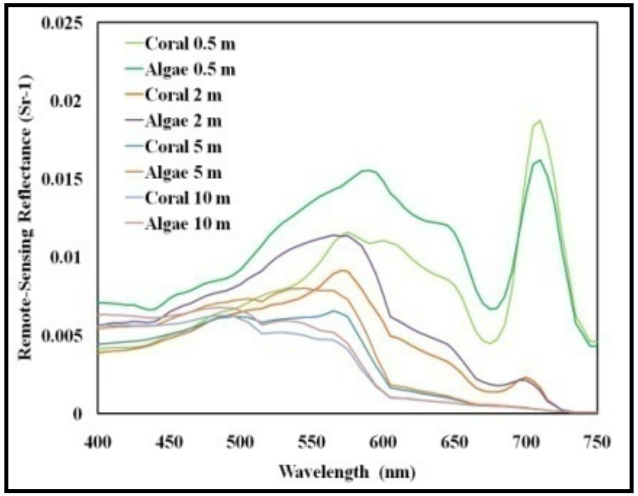
Shortwave albedo estimations from:

(a) Landsat TM on Aug 18th, 2010;
(b) AVIRIS on Aug 26th, 2010 using the stepwise regression algorithm; and
(c) scatter plot.

Image is centered on in Madison, WI, USA [43.08° N, 89.41° W]

He et al. 2013

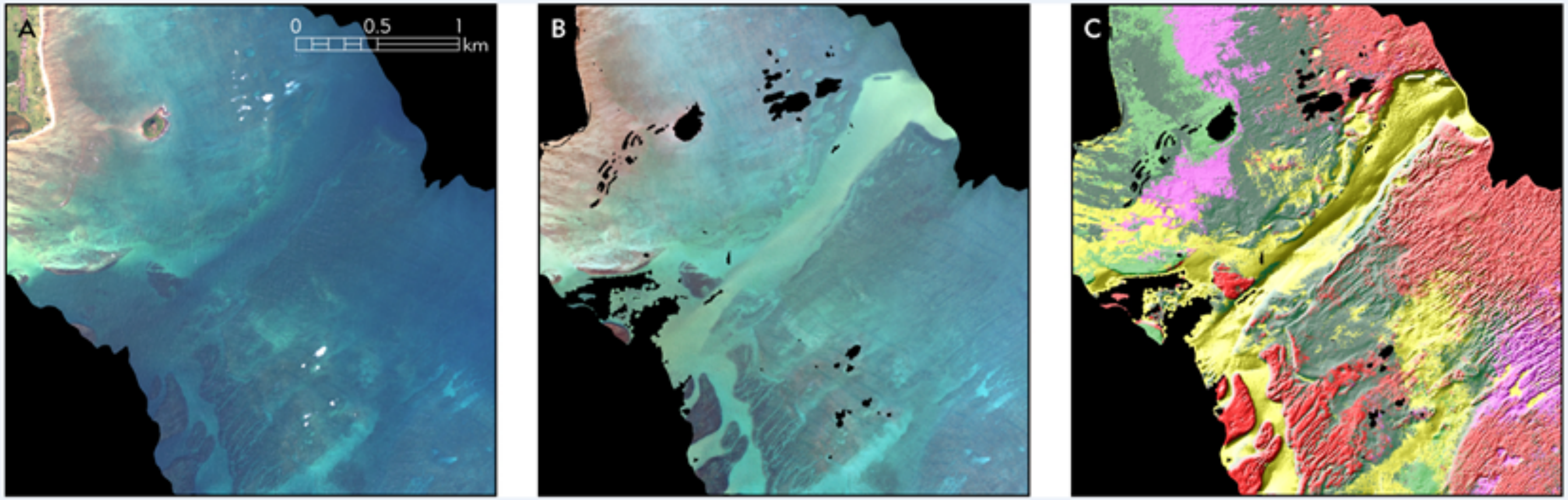
Coral Spectroscopy Measurements



- Composition
- Condition
- Productivity
- Bathymetry
- Water quality

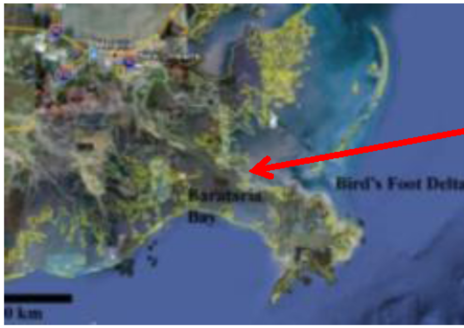
AVIRIS Image of Kaneohe Bay, HI

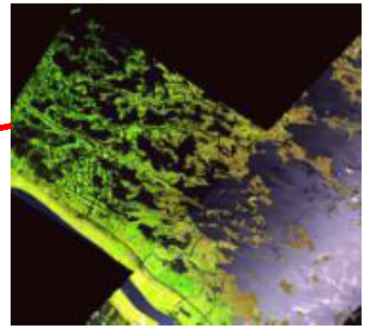
Classification of the bottom of coastal zones and coral reef types

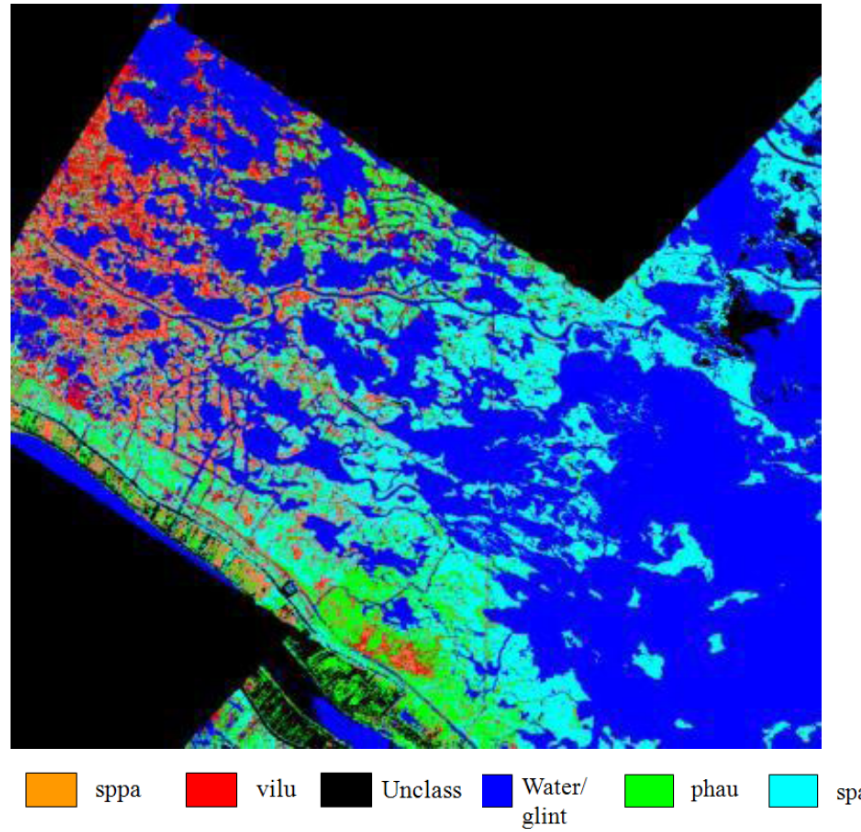


Imaging Spectroscopy
Measuring Species Type in Marshlands

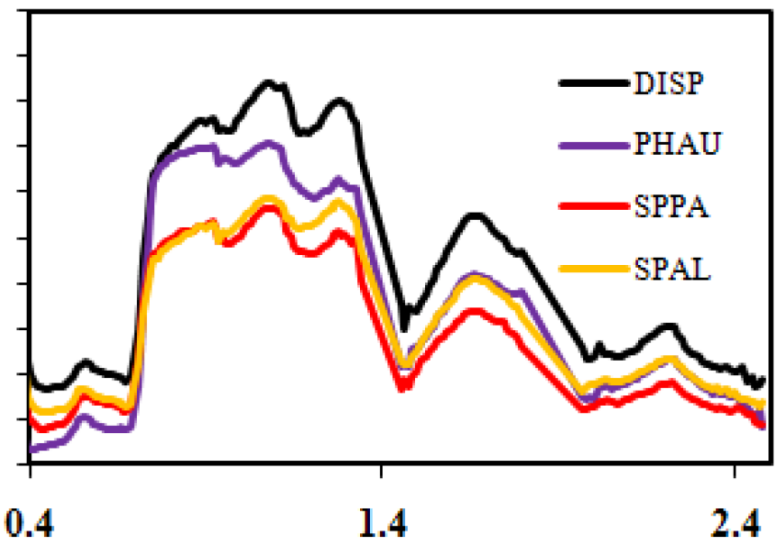
D. Roberts, UCSB

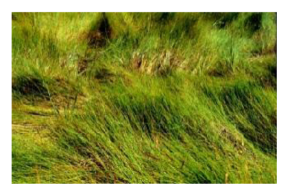






AVIRIS Vegetation Spectra





Vegetation mapped cleanly across scene boundaries

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

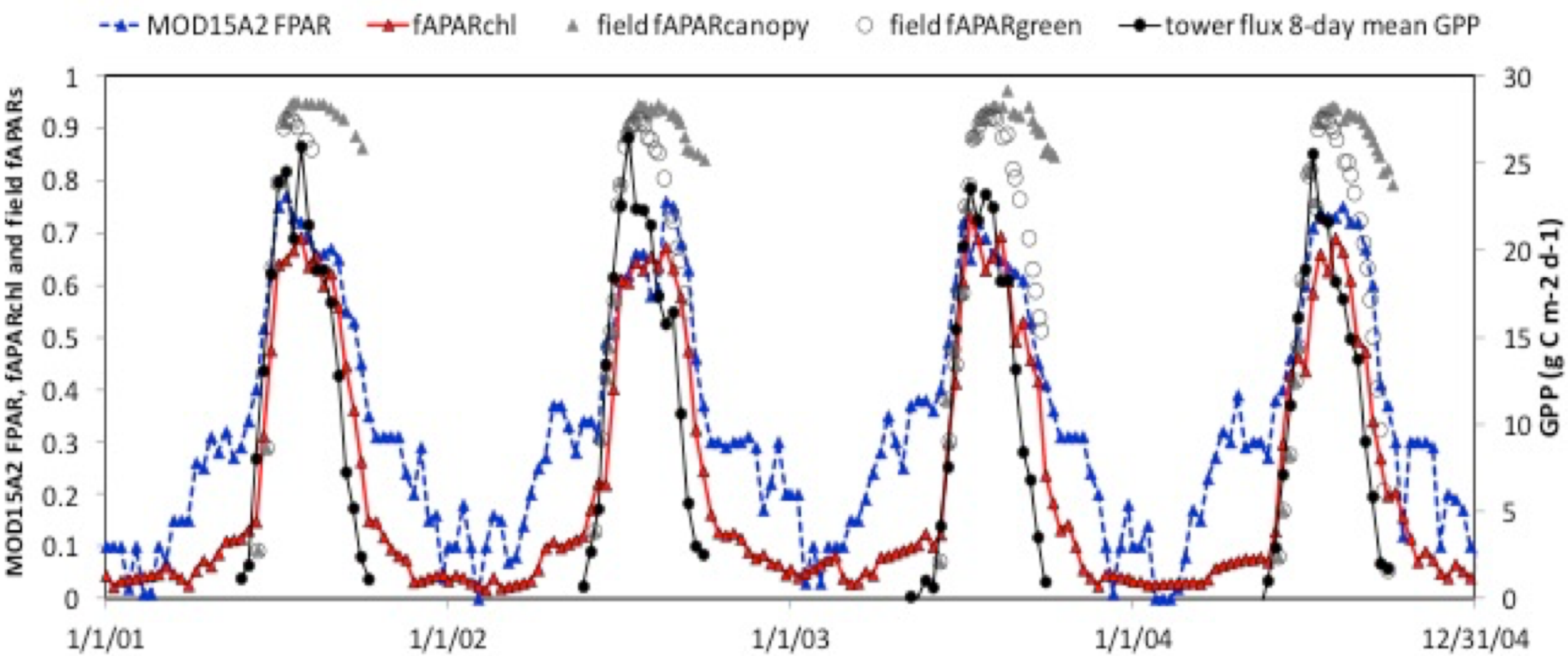
True "Remote Measurement" with Spectral-Shape [Chemistry]

HyspIRI Science Questions

VQ2: Ecosystem Function, Physiology and Seasonal Activity. 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]

US-Ne1: Field Measurements, RTM Retrievals, and Tower GPP

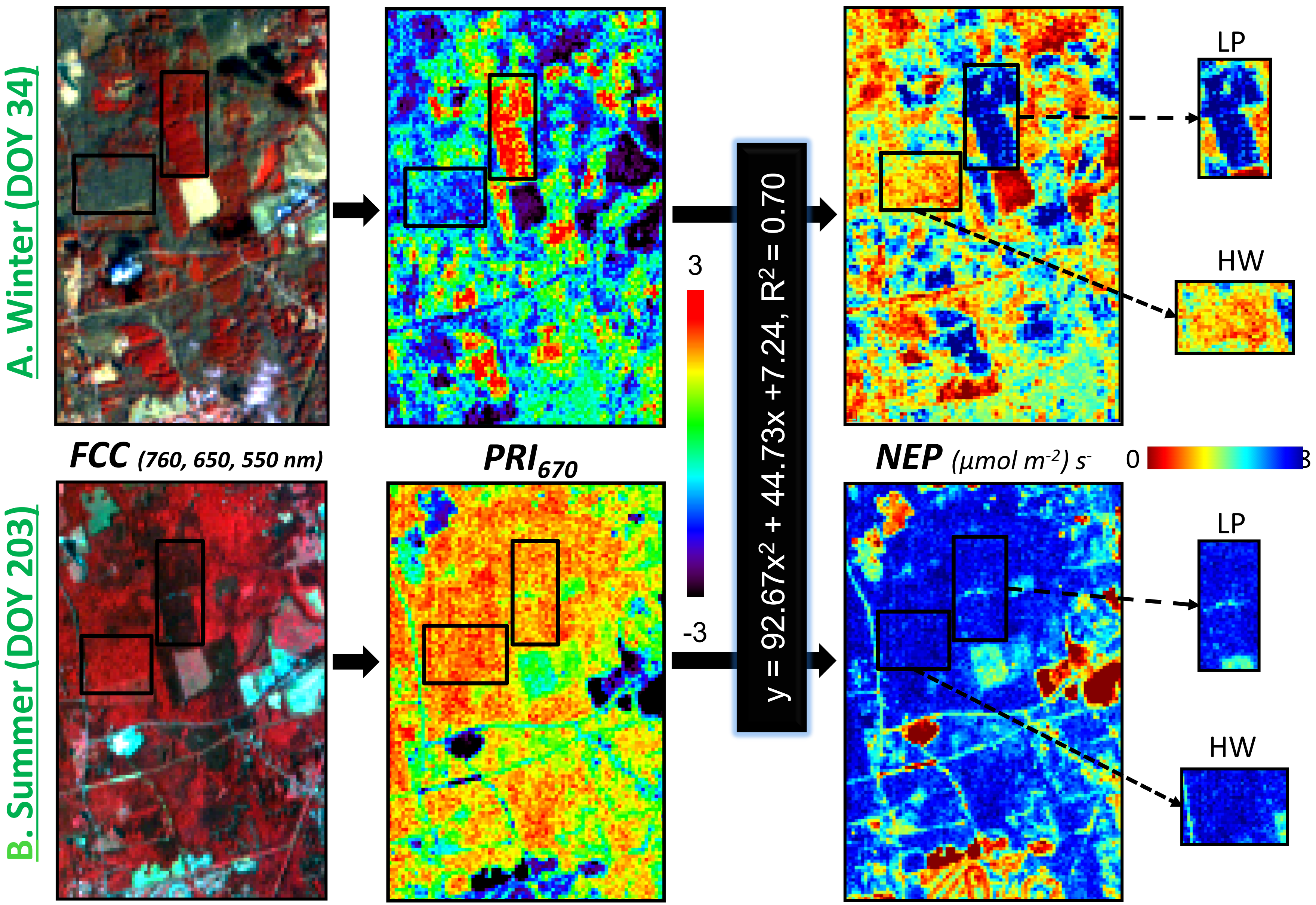
2001-2004



- Retrieved $fAPAR_{chl}$ [--Δ--] matches well with tower GPP but MOD15A2 FPAR [--Δ--] does not.
- MOD15A2 FPAR has too early green-up/too late fall-off, compared to tower GPP.

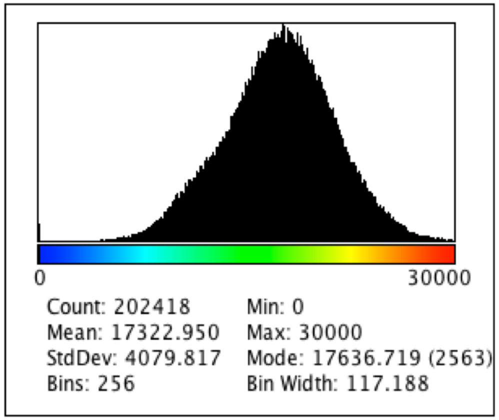
Courtesy of Q. Zhang

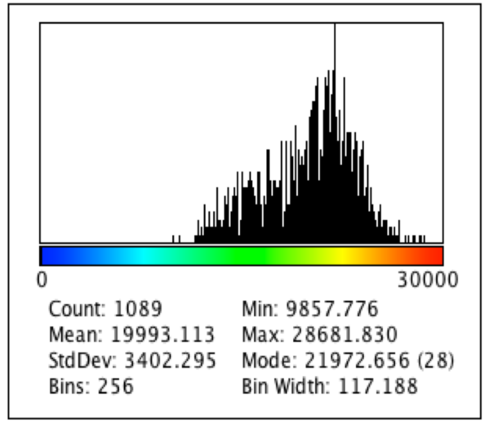
Duke Forest – PRI & NEP

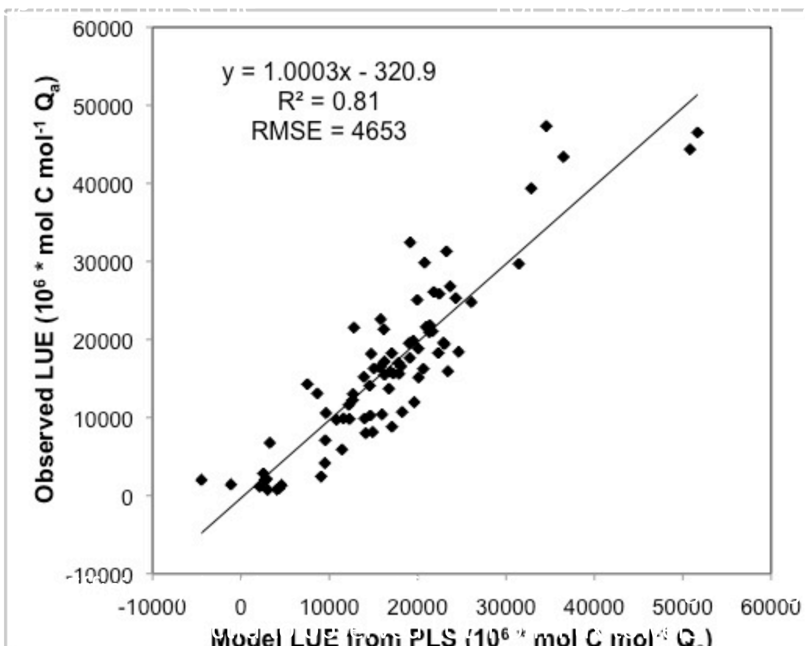


Remote Sensing of Fluxes: Hyperion and Fluxnet

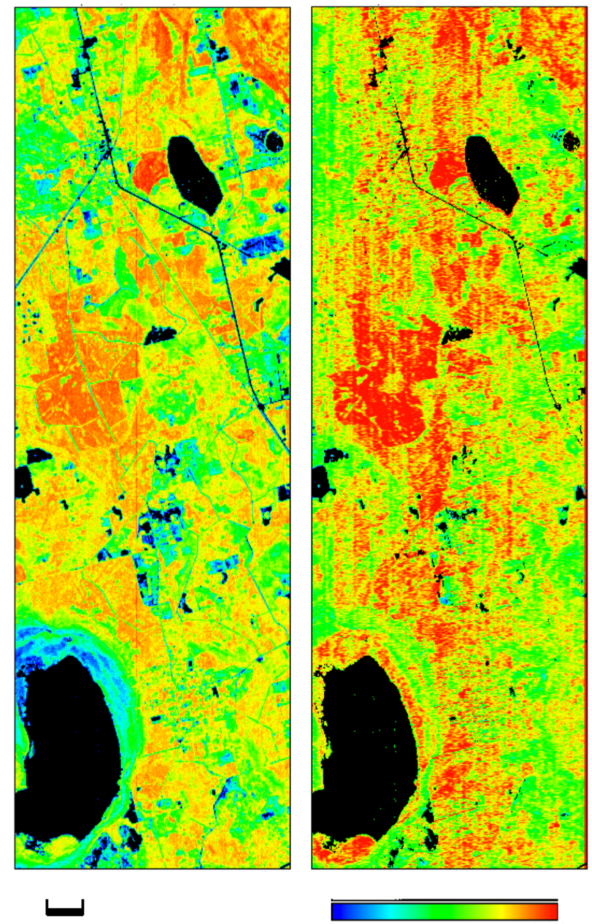
Using matched flux data from LaThuile Fluxnet Synthesis with Hyperion imagery for 33 globally distributed flux tower sites







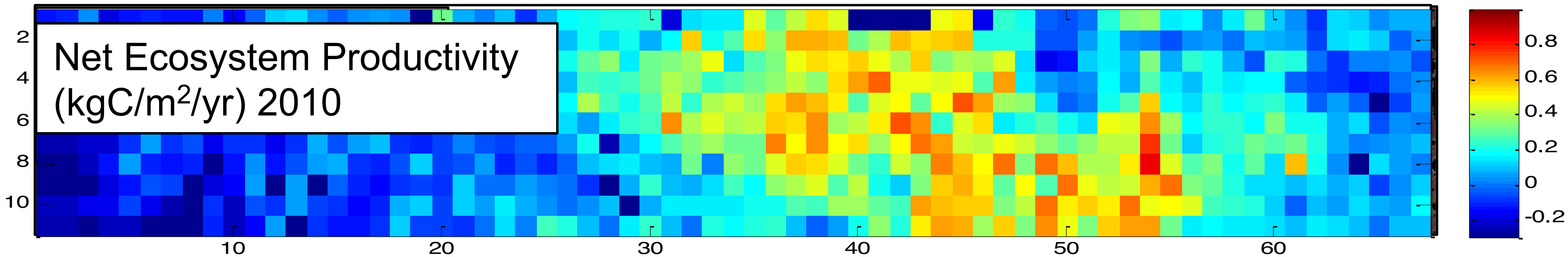
Florida Slashpine



Huemmrich, Campbell & Middleton, RSE submitted

HyspIRI-Derived Composition Estimates for the Yosemite/NEON Flight Box

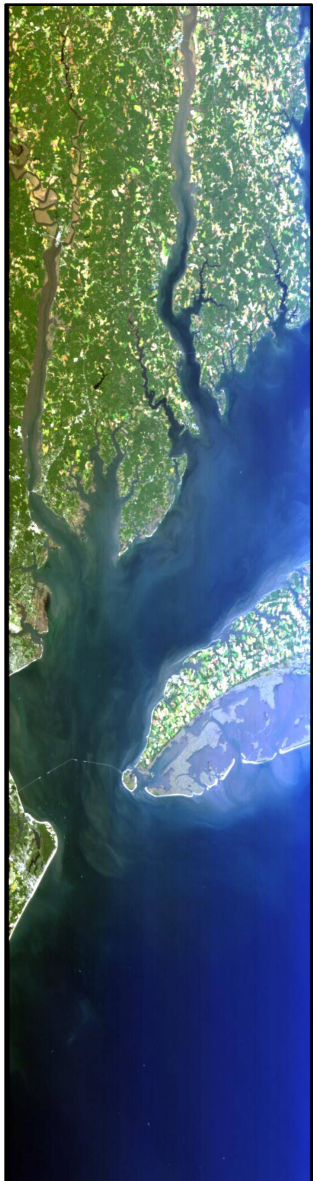
- HyspIRI imaging spectrometry measurements can provide spatially-resolved estimates of plant functional type composition, which provide an important constraint on terrestrial biosphere model predictions of carbon, water and energy fluxes.



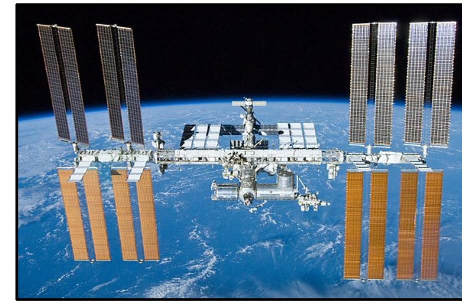
- Imaging spectrometry-constrained terrestrial carbon flux estimates for the Yosemite/NEON flight box indicate that:
  - prior to the recent drought, mid-elevation (1000m-2000m) ecosystems had the highest rates of carbon storage
  - following the onset of the drought in 2012, carbon uptake in mid-elevation forests declined markedly, and lowland ecosystems became a net carbon source.

- <u>Next Steps</u> - Extend to entire Yosemite/Neon Box.
  - Explore resolution sensitivity.

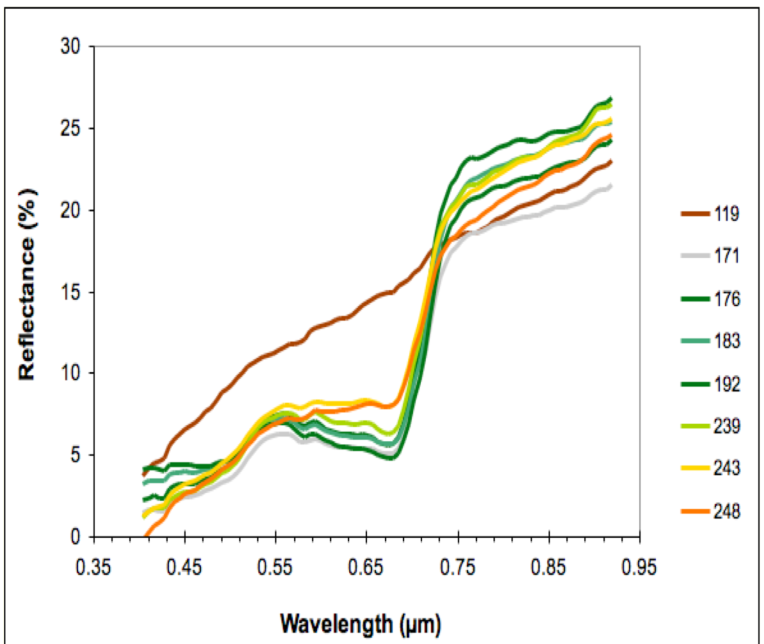
HICO Image Processing

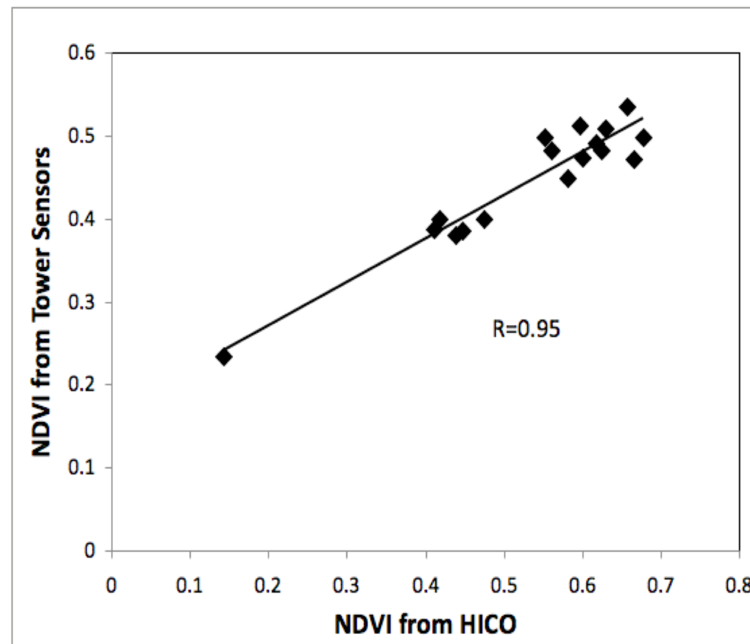


GSD: ~100 m, Image size: 42 x 192 km
Spectral range: 398 - 920 nm used
(HICO, 352 – 1089 nm), 5.7 nm bins



- Atmospherically corrected using ATREM
  - NDVI from HICO compares well with NDVI from tower-mounted radiance sensors





http://www.nasa.gov/mission_pages/station/science/experiments/HREP-HICO.html

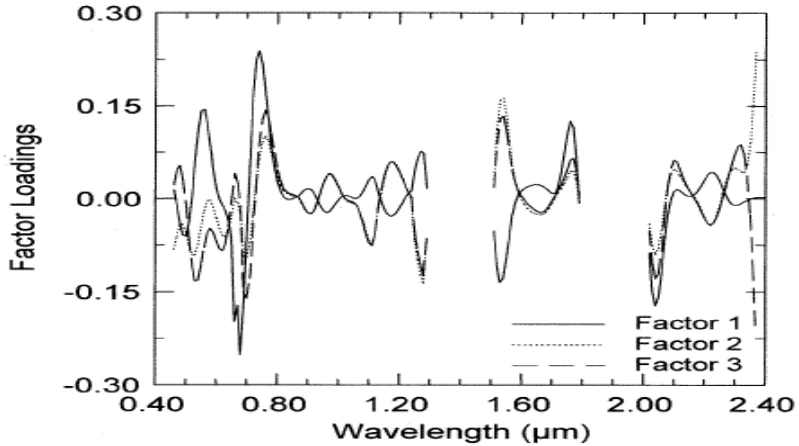
HyspIRI Science Questions

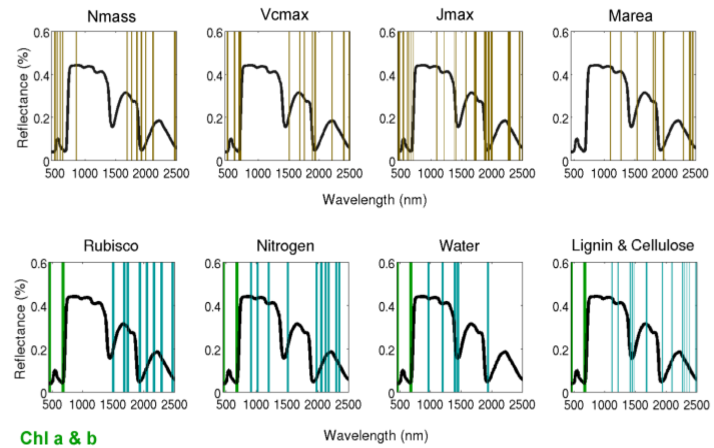
VQ3. How are the biogeochemical cycles that sustain life on Earth being altered/disrupted by natural and human-induced environmental change? How do these changes affect the composition and health of ecosystems and what are the feedbacks with other components of the Earth system?

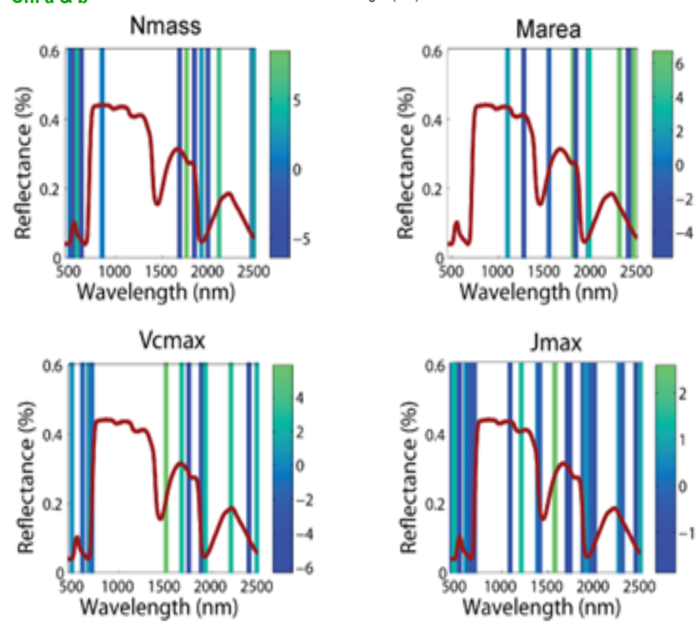
Ecosystem Measurements for Climate Feedbacks

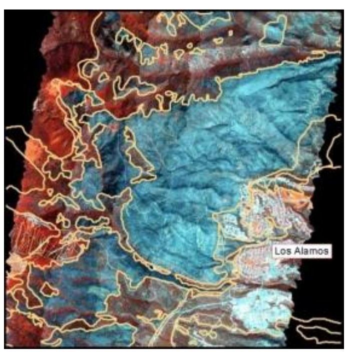
Full spectrum is required for species/functional-type, biogeochemistry and physiological condition

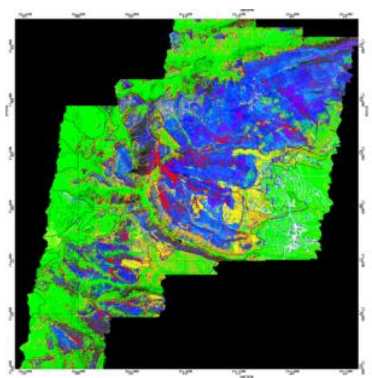
PLSR weighting

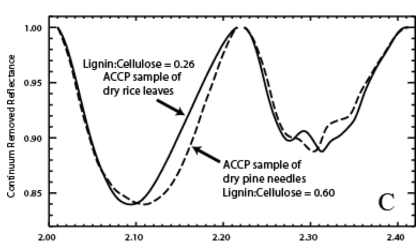


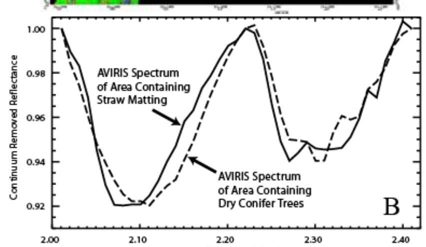








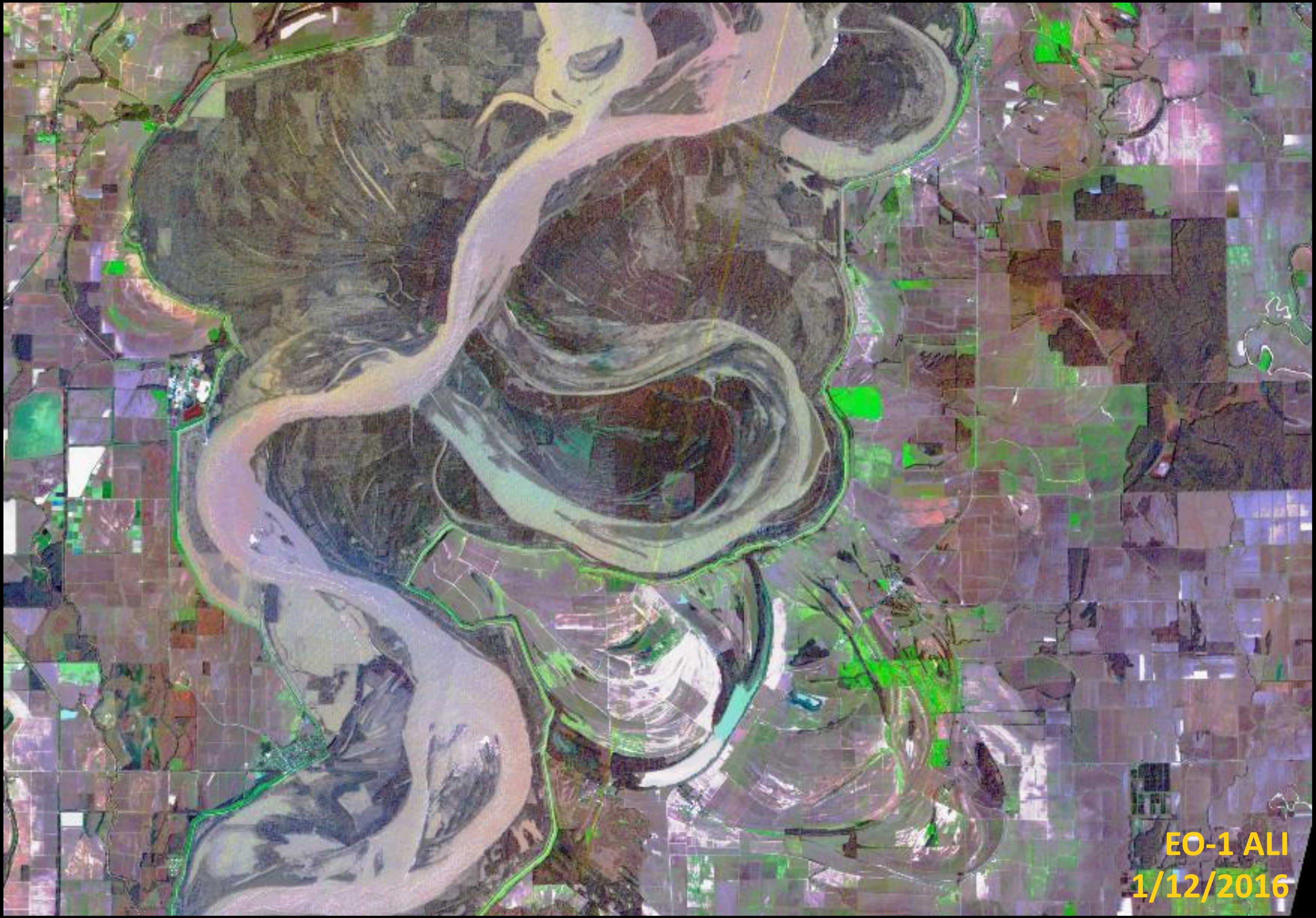




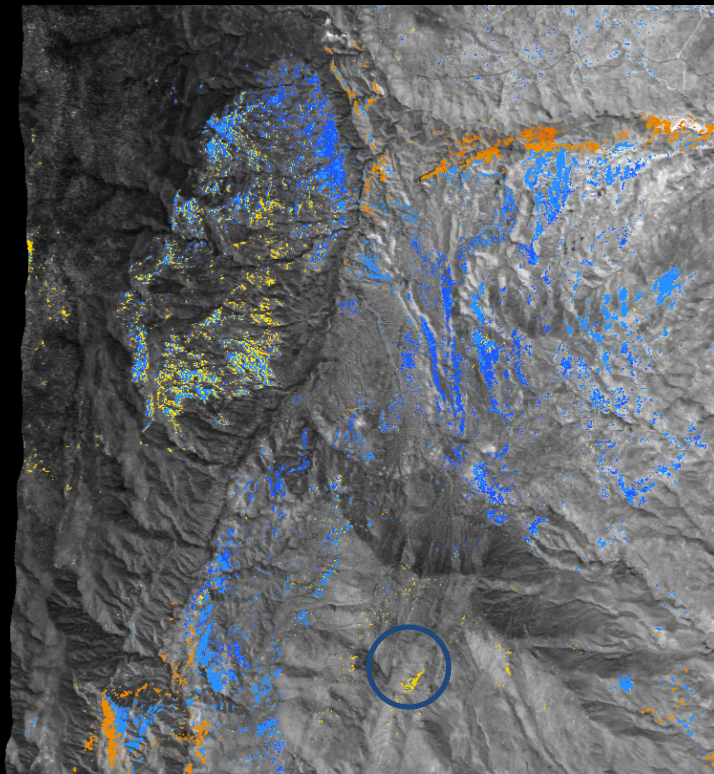
HyspIRI Science Questions

VQ4: How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?

2016 Flooding on the Mississippi River



AVIRIS-ng Hyperspectral Detection of Landslides



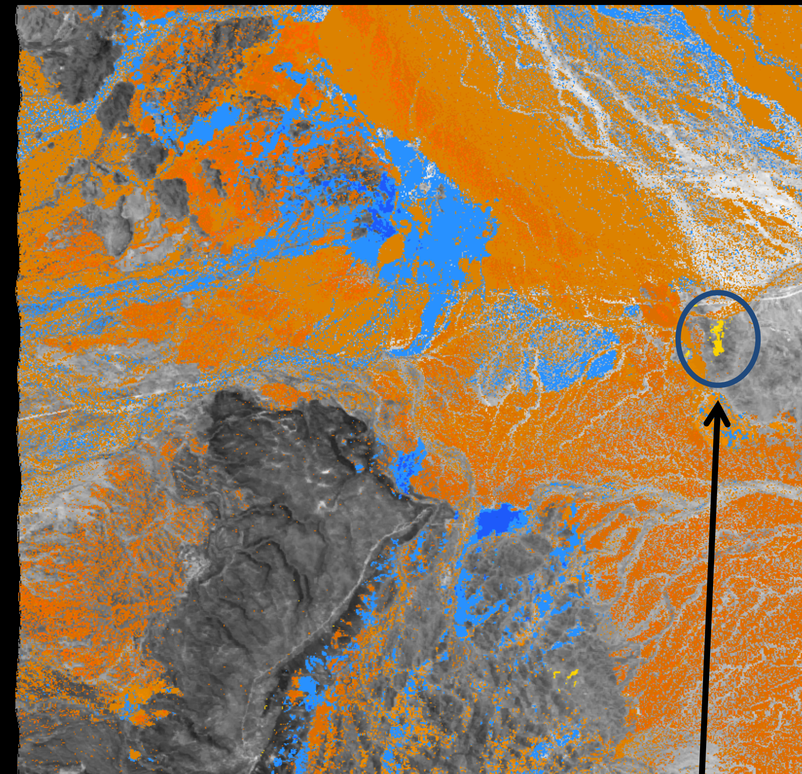
MICA 2-micron minerals:

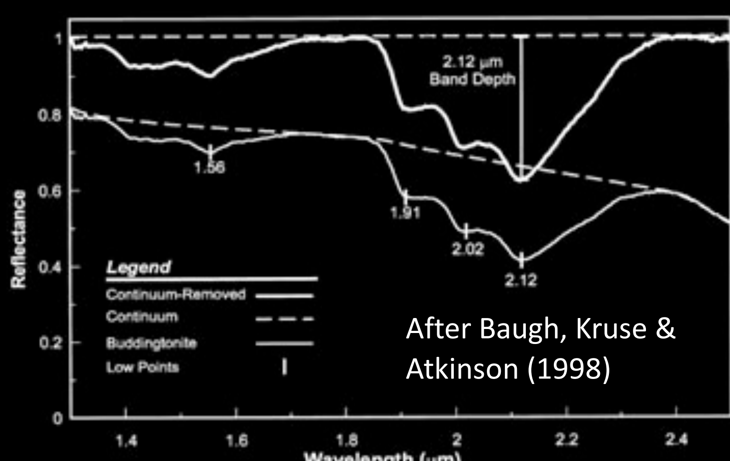
Yellow = Buddingtonite & its mixtures

Orange = Muscovite & Illite mixtures

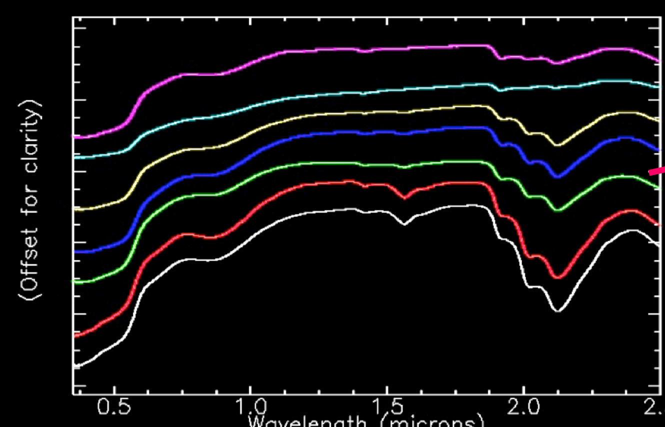
Blue = Kaolinite-dominated mixtures

2 km





After Baugh, Kruse & Atkinson (1998)

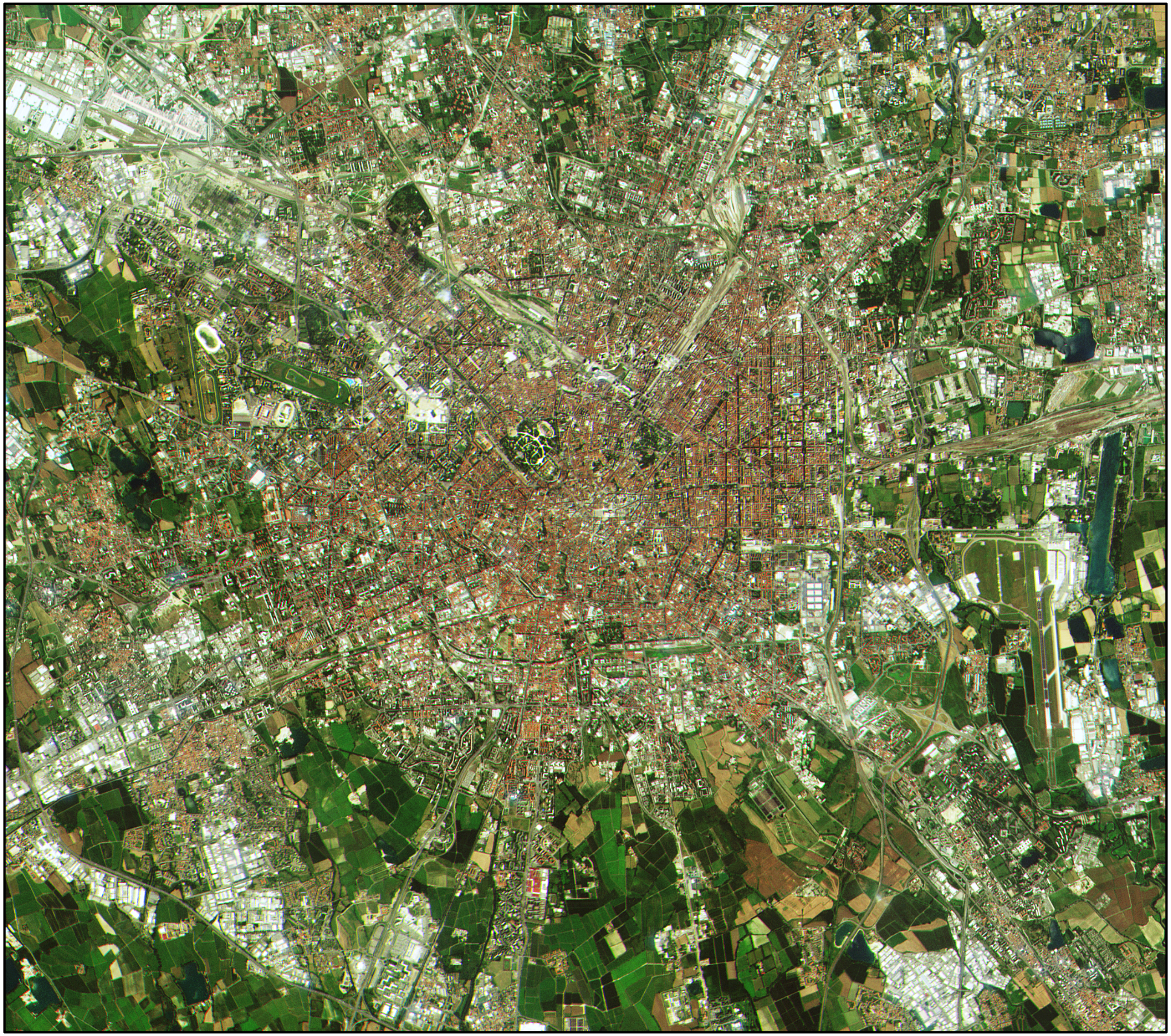


HyspIRI Science Questions

VQ5: How do changes in ecosystem composition and function affect human health, resource use, and resource management? (DS 152-153)

2015 EO-1 Image of Milan, Italy

2015 Sentinel-2A Image of Milan, Italy



ALI Imagery of Toxic Sludge in Hungary

October 9, 2010
True-Color Image from ALI
Toxic Sludge in Hungary

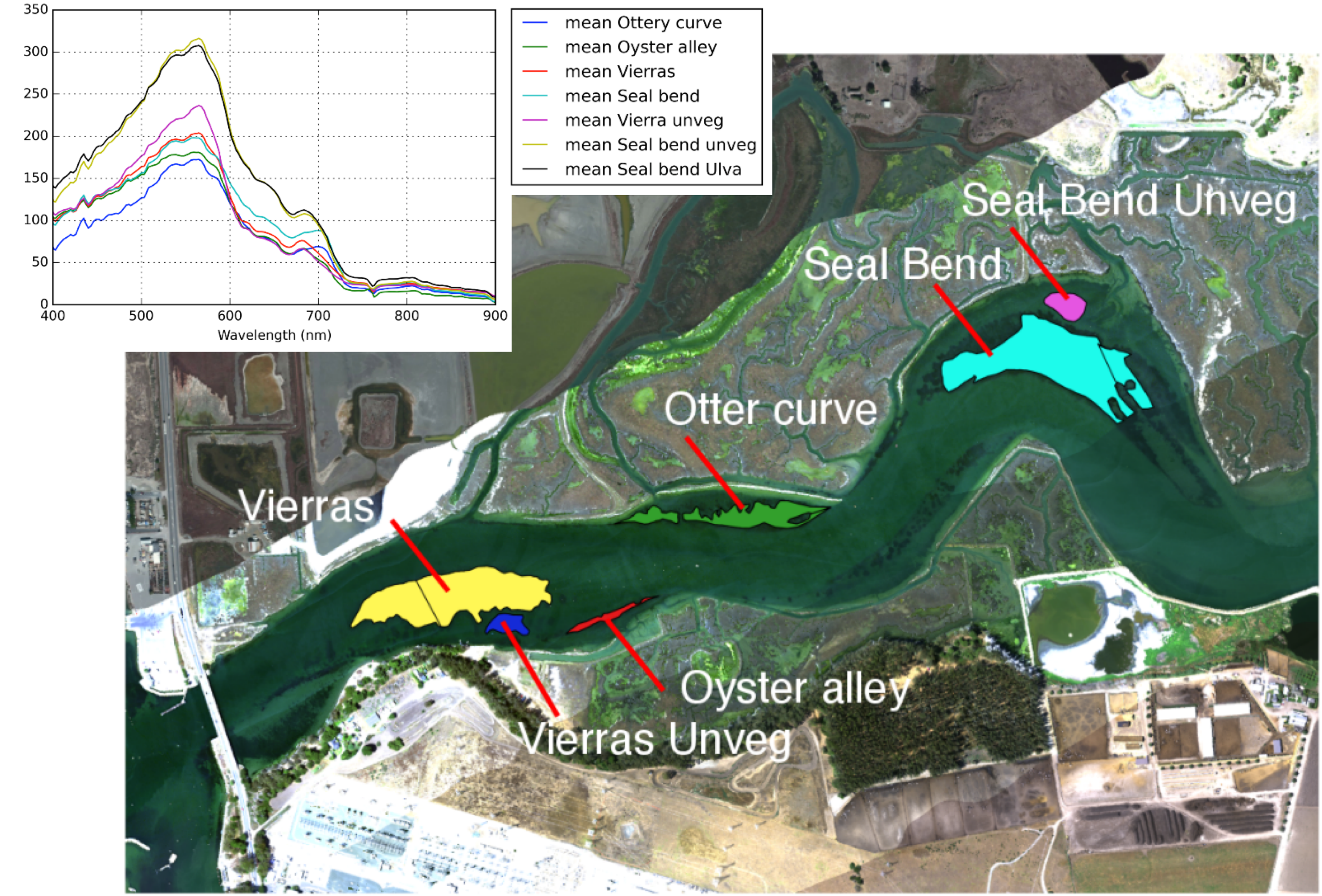
On October 4, 2010, an accident occurred at the Ajkai Timföldgyár aluminum oxide plant in Hungary. A corner wall of a waste-retaining pond broke, releasing a torrent of toxic red sludge down a local stream. Several nearby towns were inundated where the sludge was 2 meters deep in places. A dozen people were killed immediately and dozens more hospitalized for chemical burns.

The plant appears along the right edge of both images, including both bright blue and brick red reservoirs. The breach of the retaining wall is clearly visible, where sludge cut through the NW corner and spread onto nearby fields. The sludge forms a red-orange streak running west from the plant. The wide-area view shows the spill thinning but remaining discernible for several kilometers to the west. Authorities were pouring plaster into the Marcal River in hopes of preventing the sludge from reaching the Danube River.

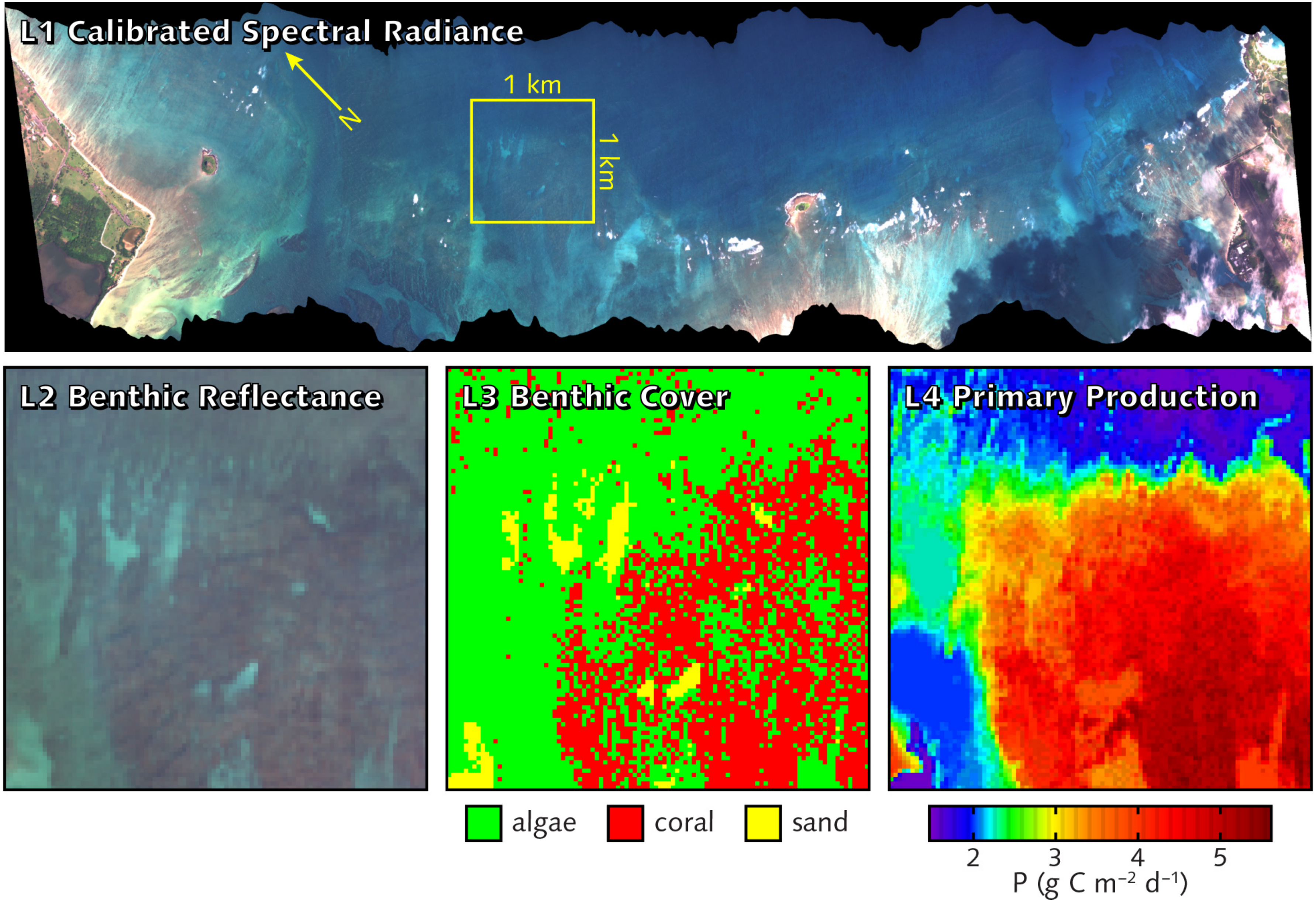
HyspIRI Science Questions

VQ6: Earth Surface and Shallow Water Substrate. What is the land surface soil/rock and shallow water substrate composition?

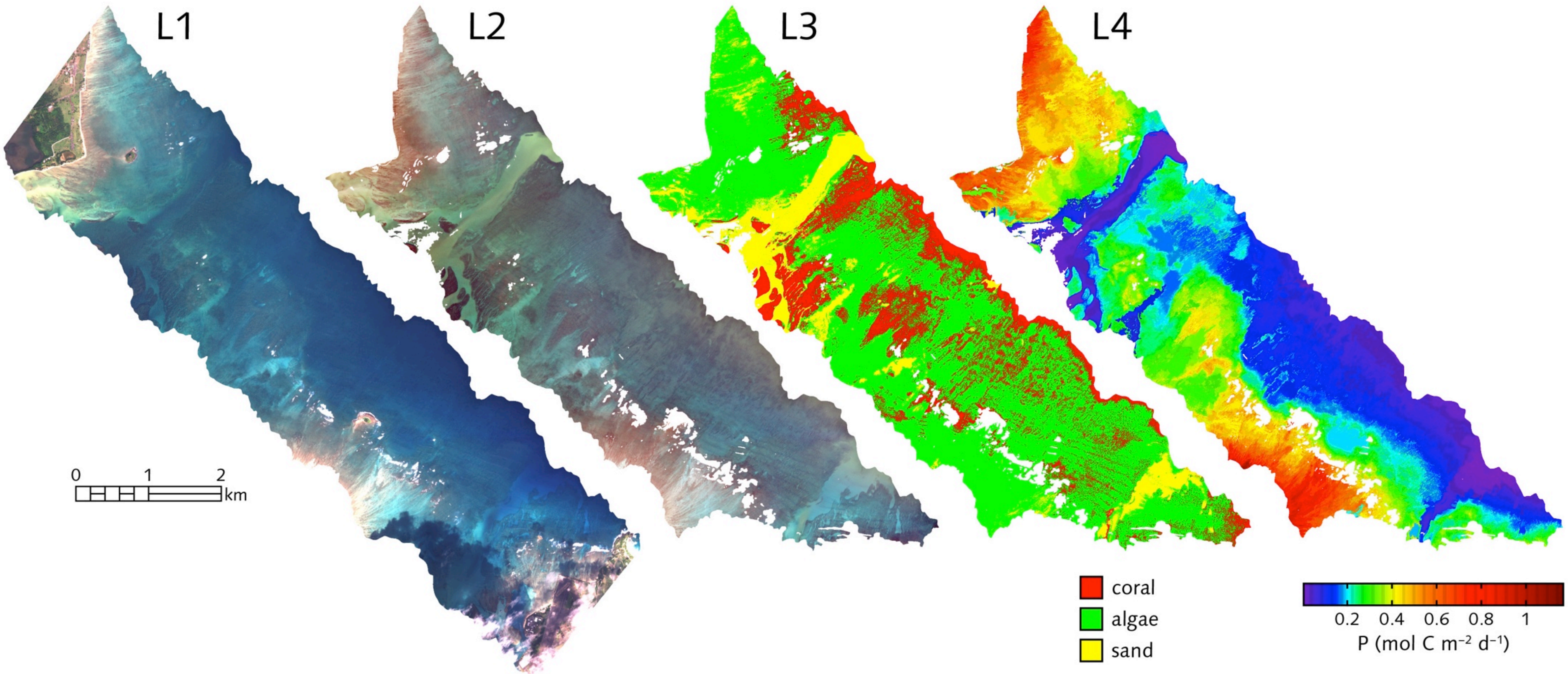
Remote Sensing of Sea Grasses



Observing Reef Conditions



CORAL Reef Data Products

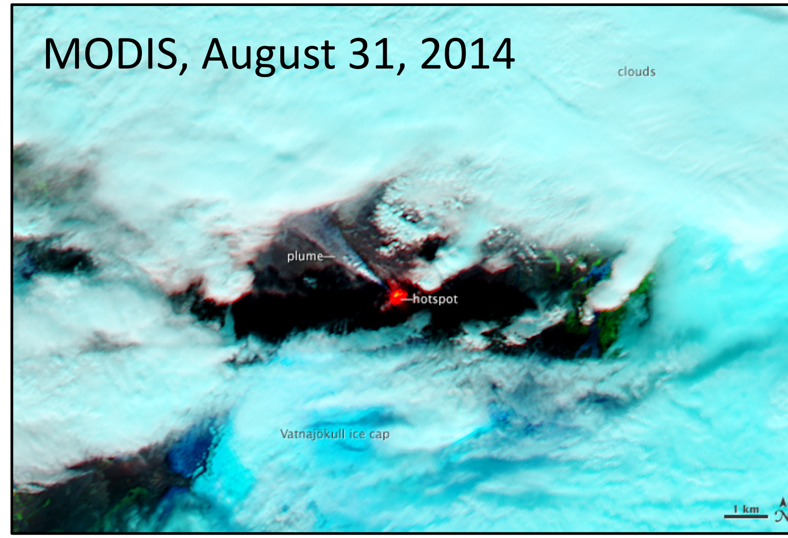


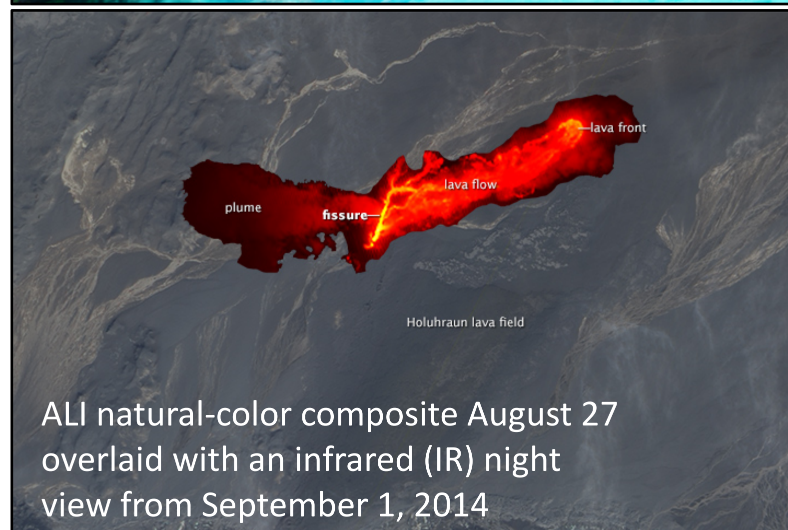
HyspIRI Science Questions

TQ1: Volcanoes. How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

EO-1 Complimenting Landsat 8 and MODIS

EO-1 ALI complementing OLI. When the Villarrica Volcano erupted, EO-1 was able to acquire an image on March 5, 2015 – **five days before** the next Landsat 8 overpass.



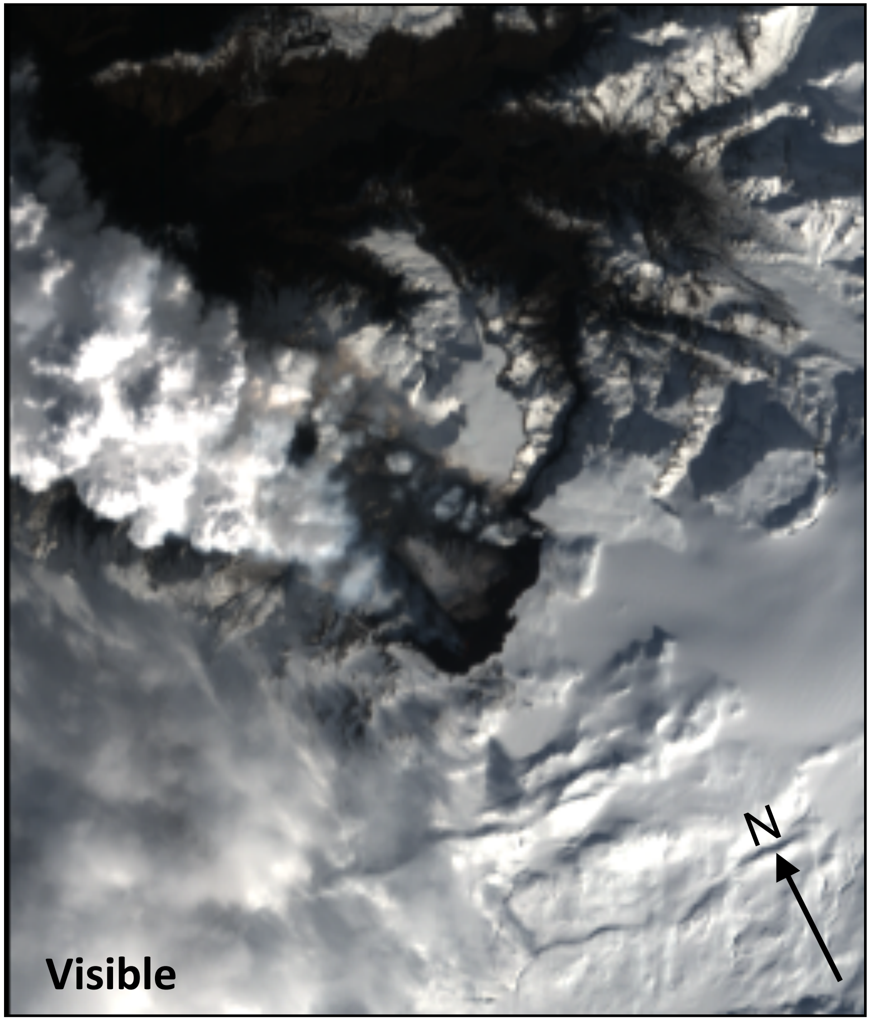


EO-1 ALI night-time image of the Vatnajokull volcano complementing MODIS (top).

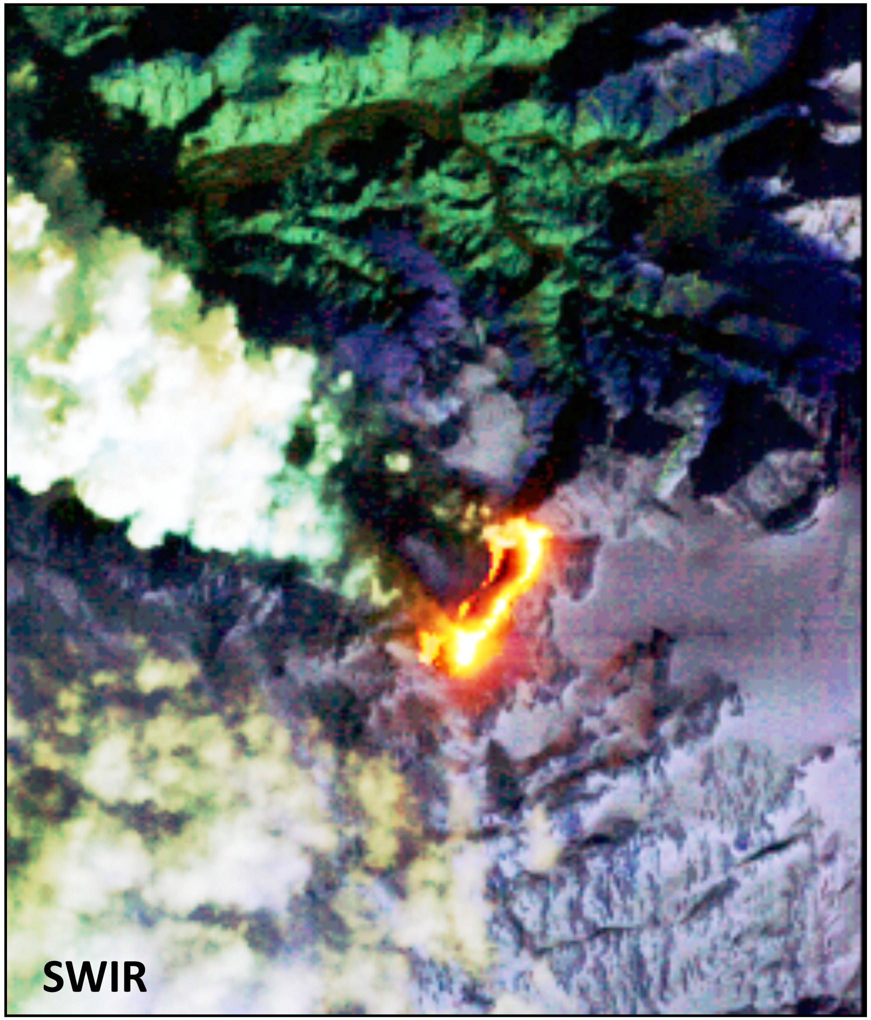
EARTH OBSERVATORY
Where every day is Earth Day

Eyjafjallajökull Volcano, Iceland

24 March, 2010



7.7 km



EO1H2180152010083110KF - Hyperion

Davies *et al.* (2013) JGR

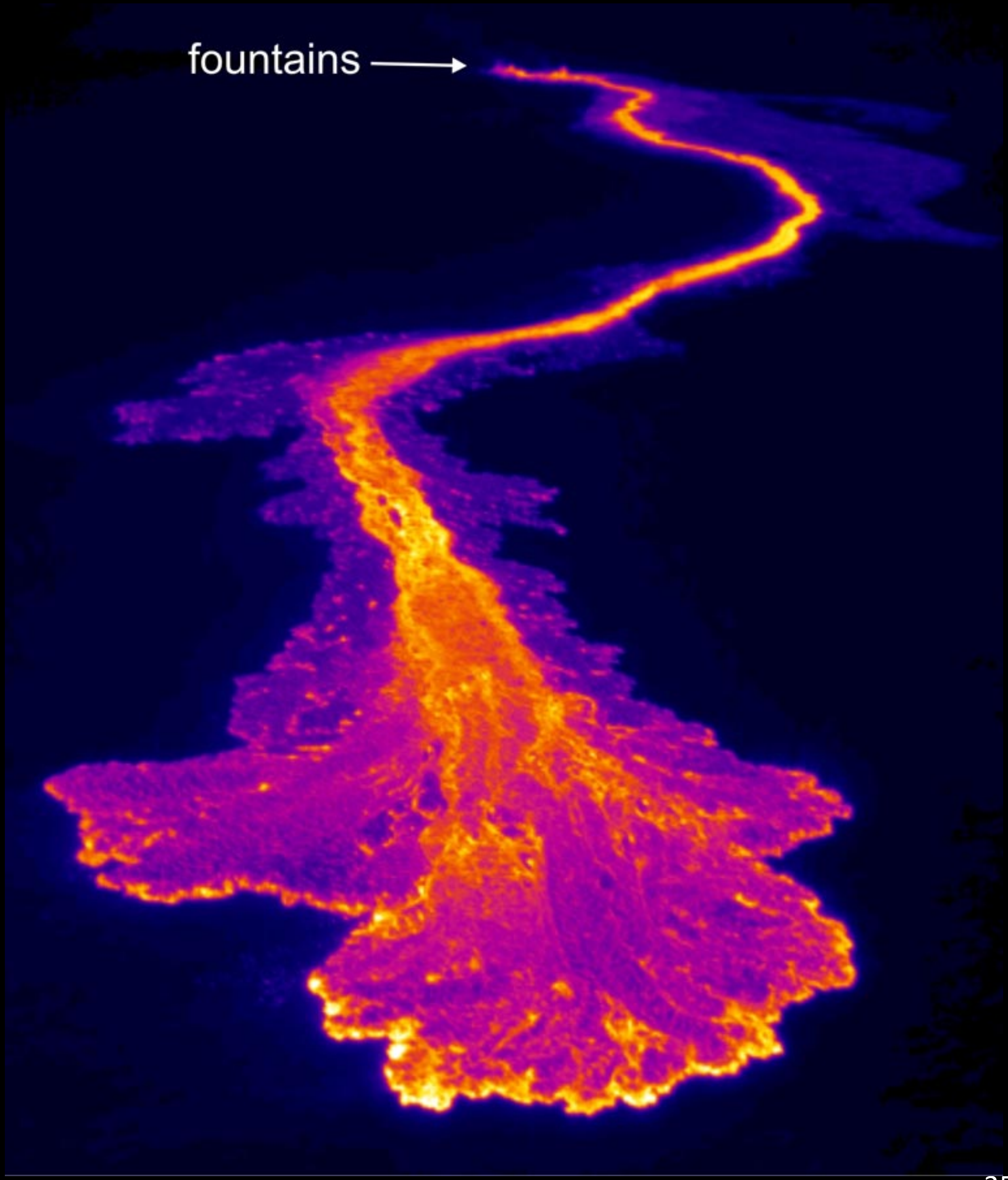
Quantifying Active Volcanic Processes and Mitigating their Hazards with HyspIRI Data

Michael Ramsey, University of Pittsburgh

Andrew Harris, Univesité Blaise Pascal (France)

I. Matthew Watson, University of Bristol (UK)

Matthew Patrick, USGS Hawaiian Volcano Observatory



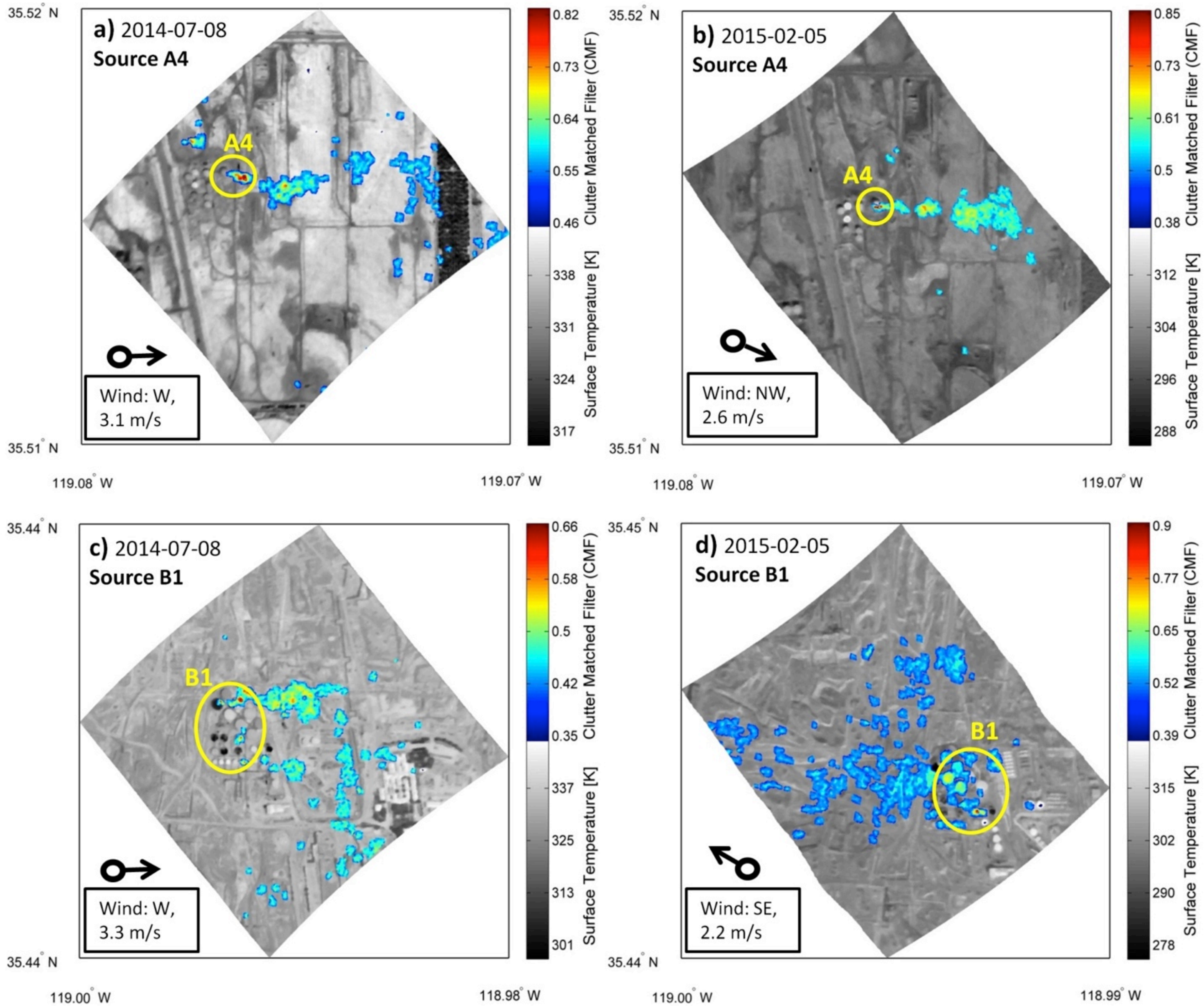
IR image of Kilauea flow: Matt Patrick (HVO)

HyspIRI Science Questions

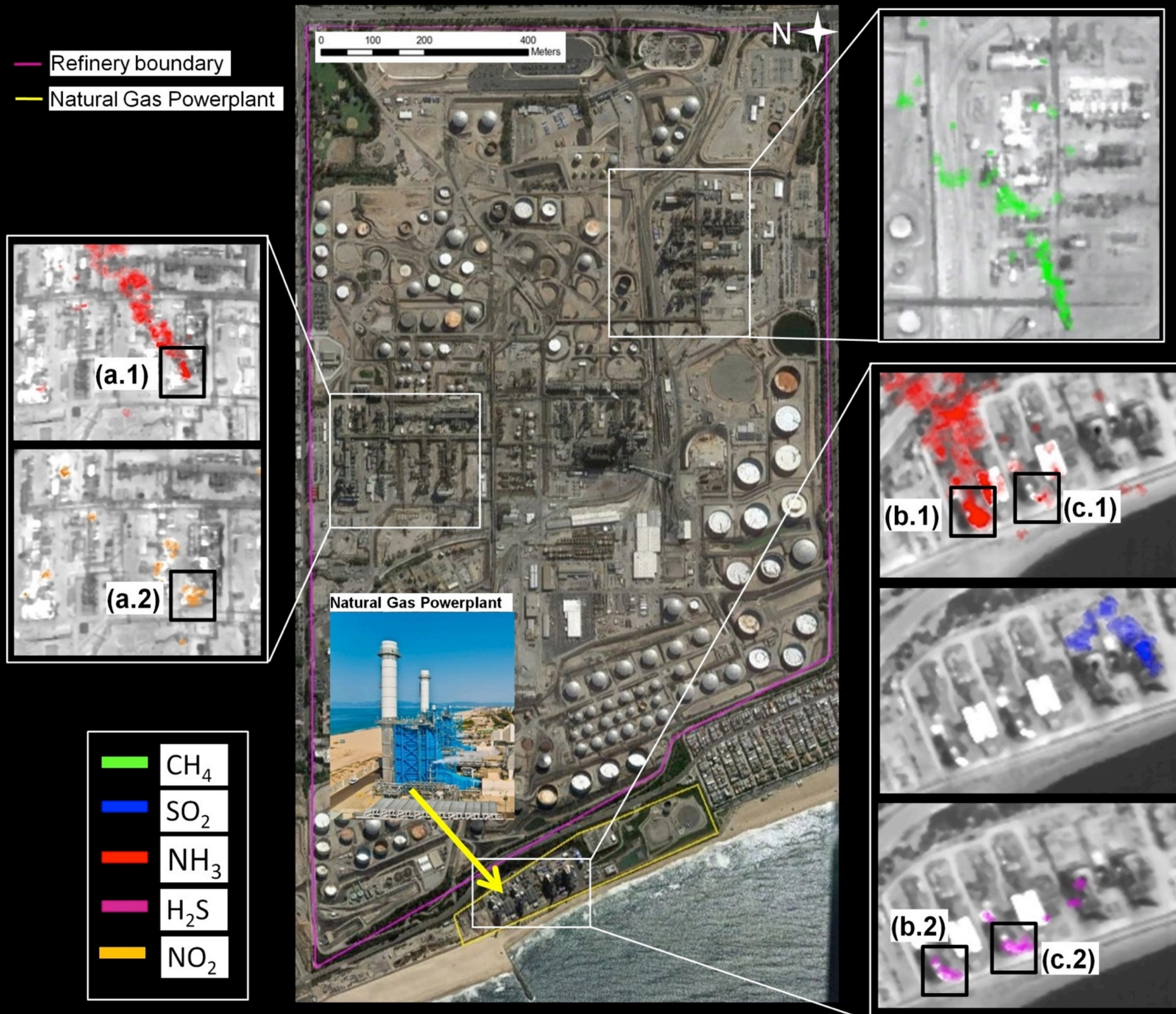
TQ4: Human Health and Urbanization. How does urbanization affect the local, regional, and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

HyTES Science Highlights (2014-2016)

Majority of emissions are from large infrastructure (storage, processing, distribution), not the active well heads themselves.



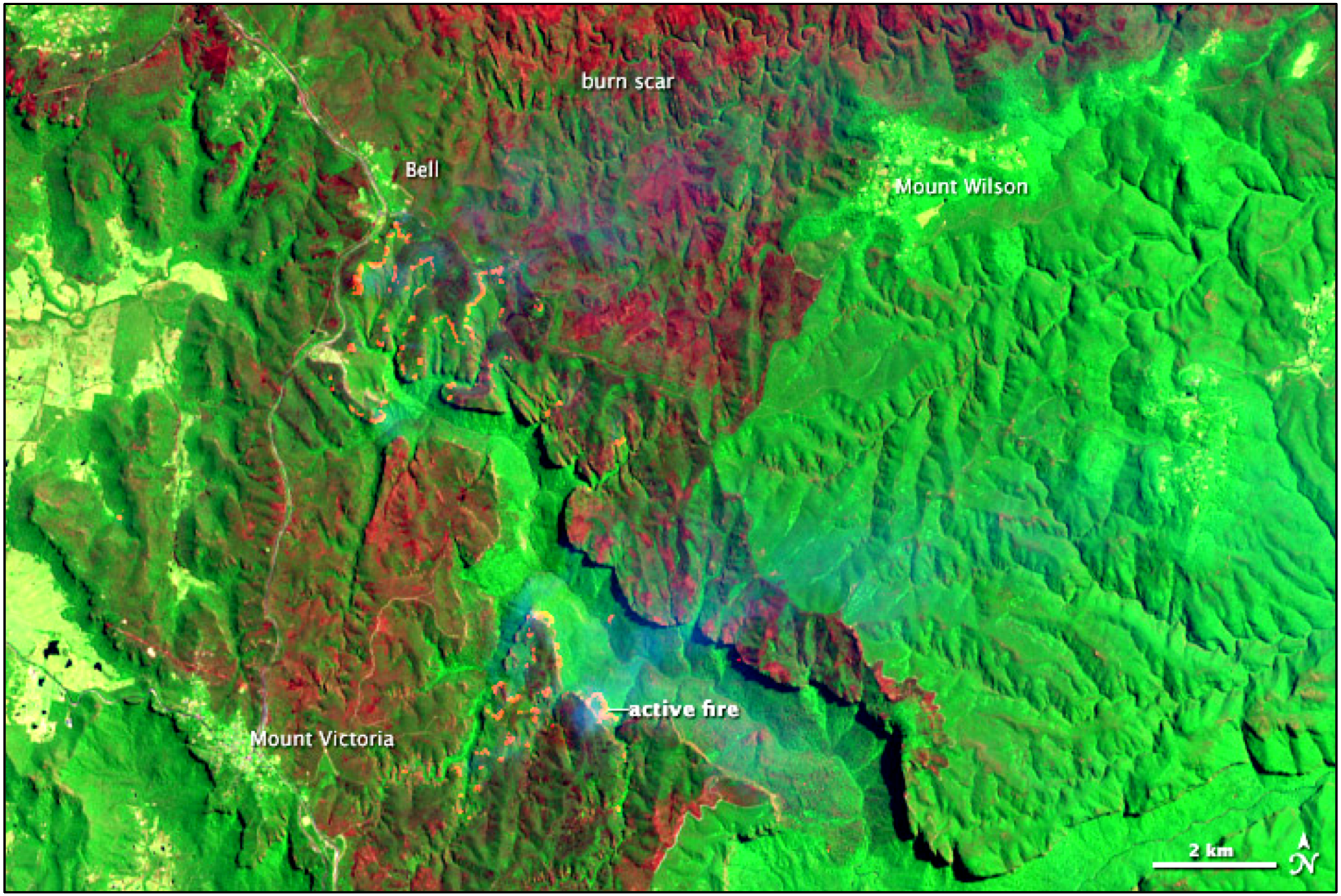
HyTES: Detecting Trace Gases from Power Plants



HyspIRI Science Questions

CQ2: Wildfires. How are fires and vegetation composition coupled?

EO-1 Image of Fires in Australia



October 26, 2013
False-Color Image from EO-1
New South Wales, Australia

HyspIRI Science Questions

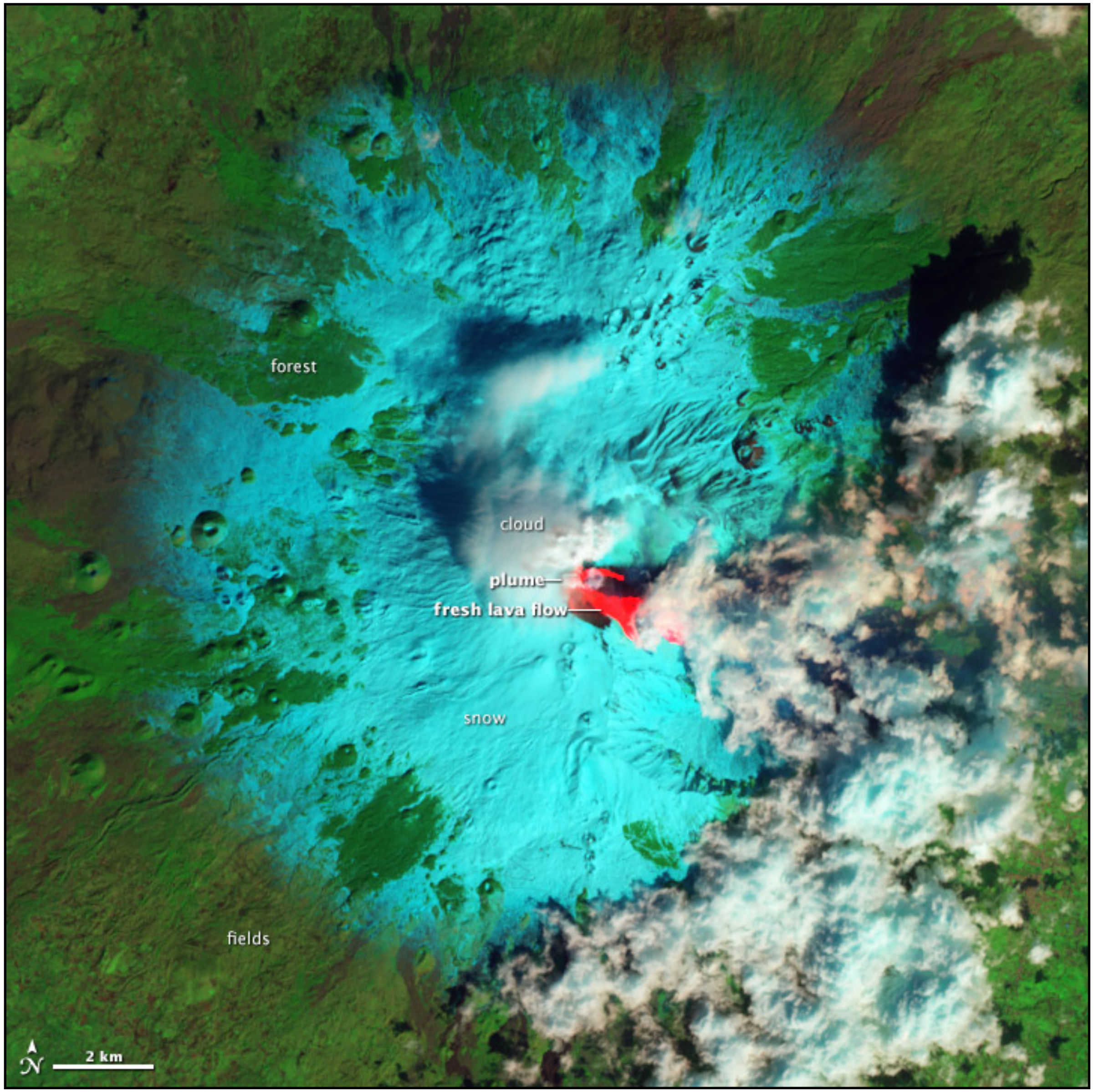
CQ3: Volcanoes. Do volcanoes signal impending eruptions through changes in the temperature of the ground, rates of gas and aerosol emission, temperature and composition of crater lakes, or health and extent of vegetation cover?

ALI Imagery of Mount Etna Boiling Over

February 20, 2013
False-Color Image from ALI
Mount Etna Boils Over

After maintaining a low simmer for ten months, Italy's Etna volcano boiled over on February 19-20, 2013, with three outbursts in 36 hours. This false-color image combines shortwave infrared, near-infrared, and green light in the red, green, and blue channels of an RGB picture. This combination makes it easier to differentiate between fresh lava, snow, clouds, and forest.

In the image, fresh lava is bright red, as the hot surface emits enough energy to saturate the instrument's shortwave infrared detectors but is dark in near-infrared and green light. Snow is blue-green because it absorbs shortwave infrared light, but reflects near-infrared and green light. Clouds made of water droplets (not ice crystals) reflect all three wavelengths of light similarly and appear white. Forests and other vegetation reflect near-infrared more strongly than shortwave infrared and green, and so appear green. Dark gray areas are lightly vegetated lava flows, 30 to 350 years old.



HyspIRI Science Questions

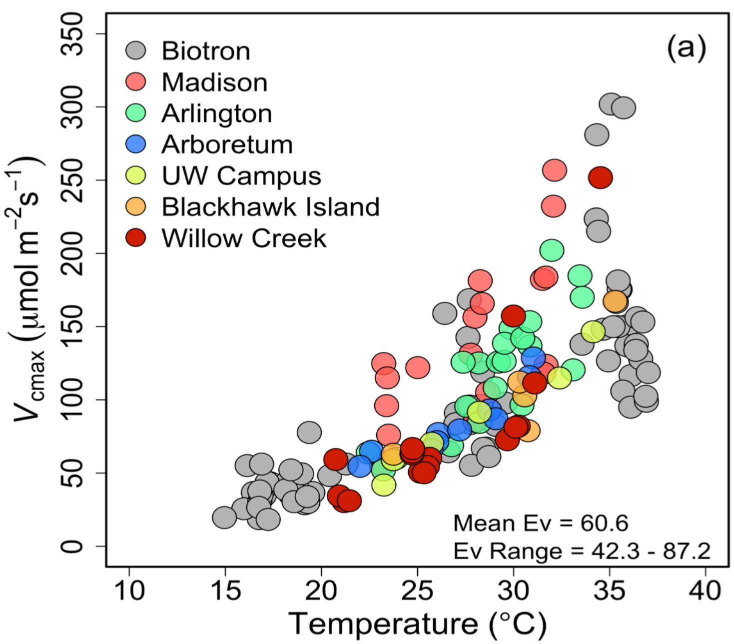
CQ4: Ecosystem Function and Diversity. How do species, functional type, and biodiversity composition within ecosystems influence the energy, water and biogeochemical cycles under varying climatic conditions?

Photosynthetic Capacity using VSWIR and TIR

Proposed RT Approach (P. Townsend)
The case for Thermal IR and Hyperspectral Together

Vegetation photosynthetic capacity (Amax) can be estimated from LUT, or as a *f*(%N) or LMA\), and *at a standardized temperature.*

Photosynthetic Capacity (V_{cmax}, µmolm^{-2}s^{-1})



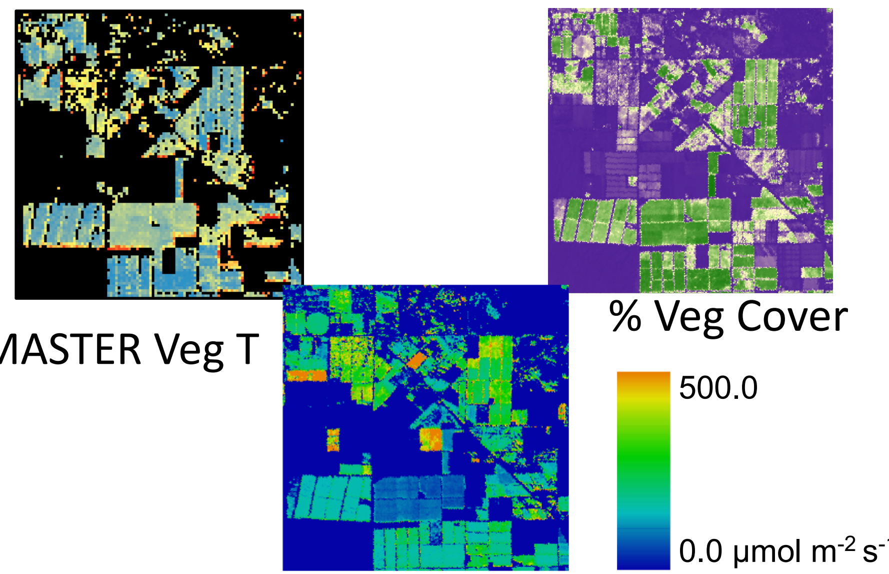
Vegetation Temperature (°C)

- **%N and LMA can be estimated from VSWIR imagery.**

However, Amax varies with leaf temperature.

- **Leaf temperature can be estimated from TIR imagery.**

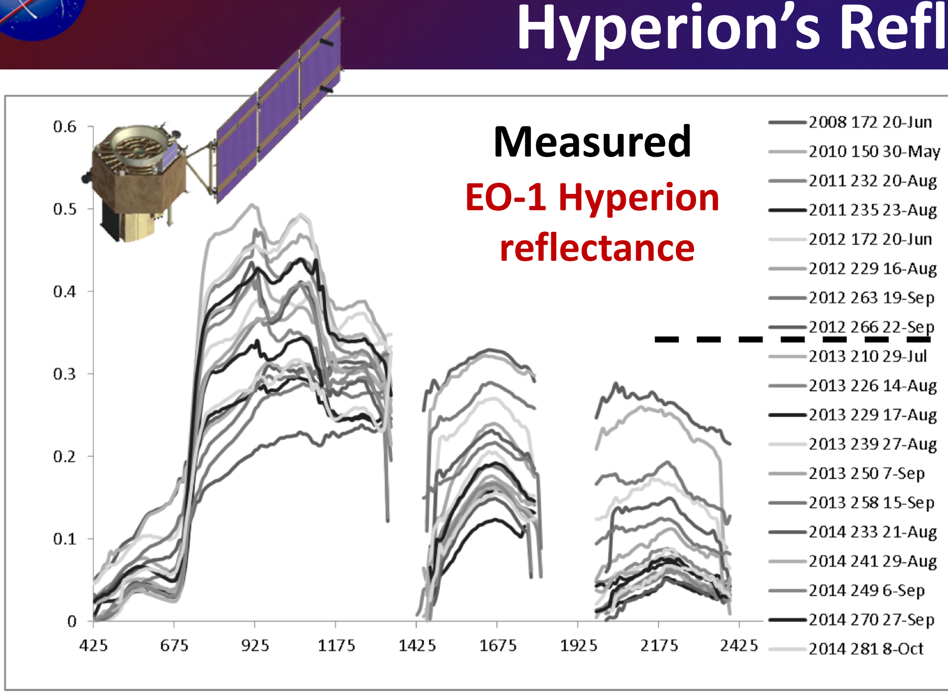
Consequently, combined TIR and VSWIR can be used to measure/map instantaneous Amax.

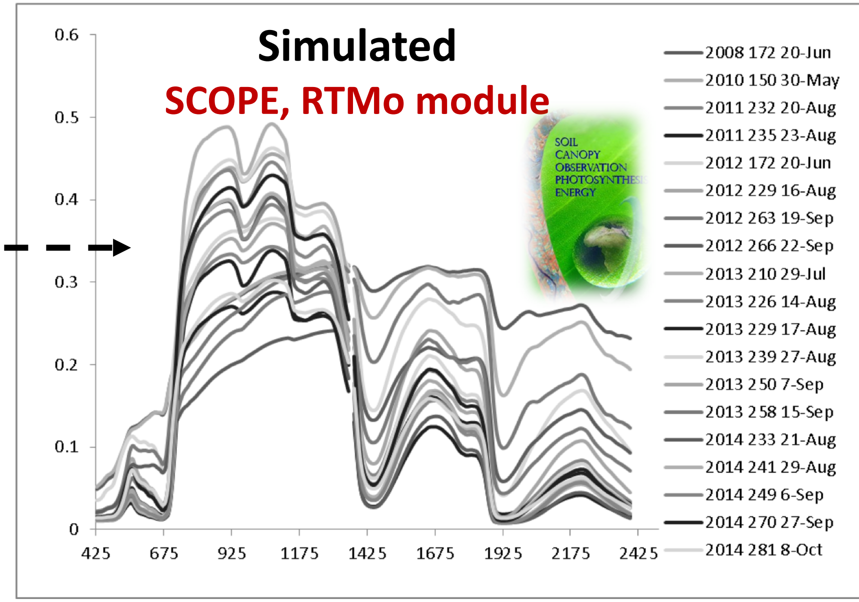


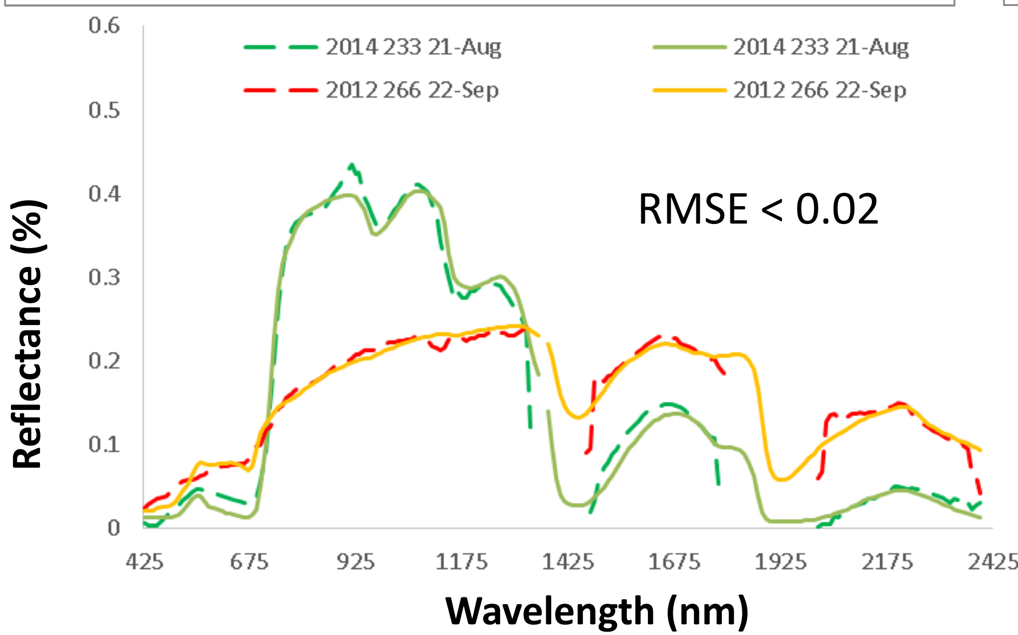
Photosynthetic capacity at ambient temp

Left figure courtesy of Shawn Serbin
Right figures from Phil Townsend

Modeling Canopy Bio-physical Parameters Hyperion's Reflectance and RTMo







RTMo (part of SCOPE) includes:

- ***4SAIL - radiative transfer***
- ***Fluspect' - leaf optical***
- ***GSV - soil reflectance***

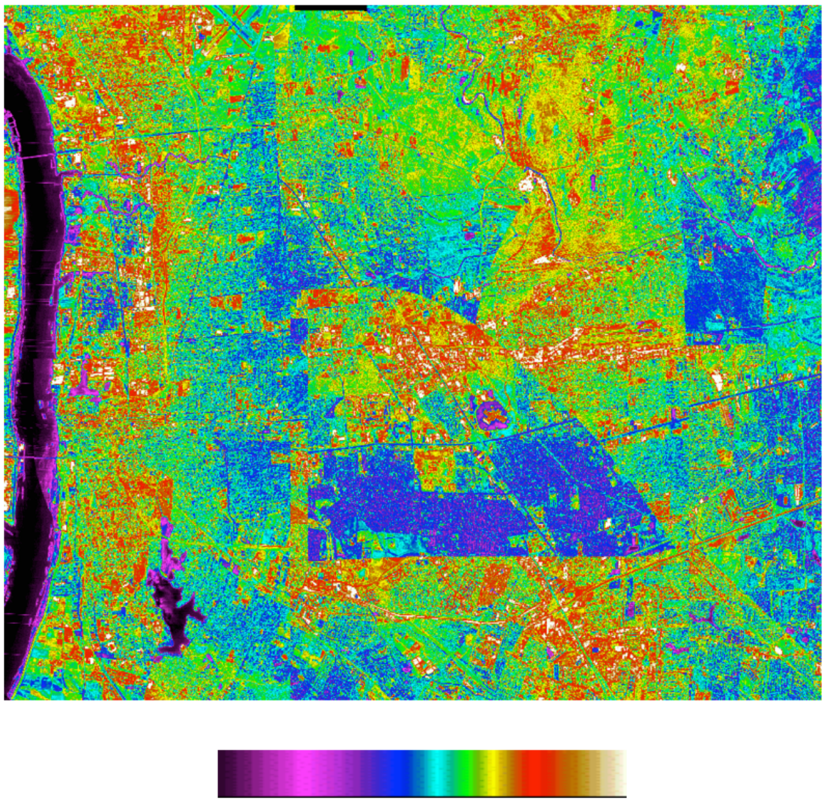
HyspIRI Science Questions

CQ6: Human Health and Urbanization. How do patterns of human environmental and infectious diseases respond to leading environmental changes, particularly to urban growth and change and associated impacts of urbanization?

Urban Heat Island

Baton Rouge

Albedo - May 11, 1998

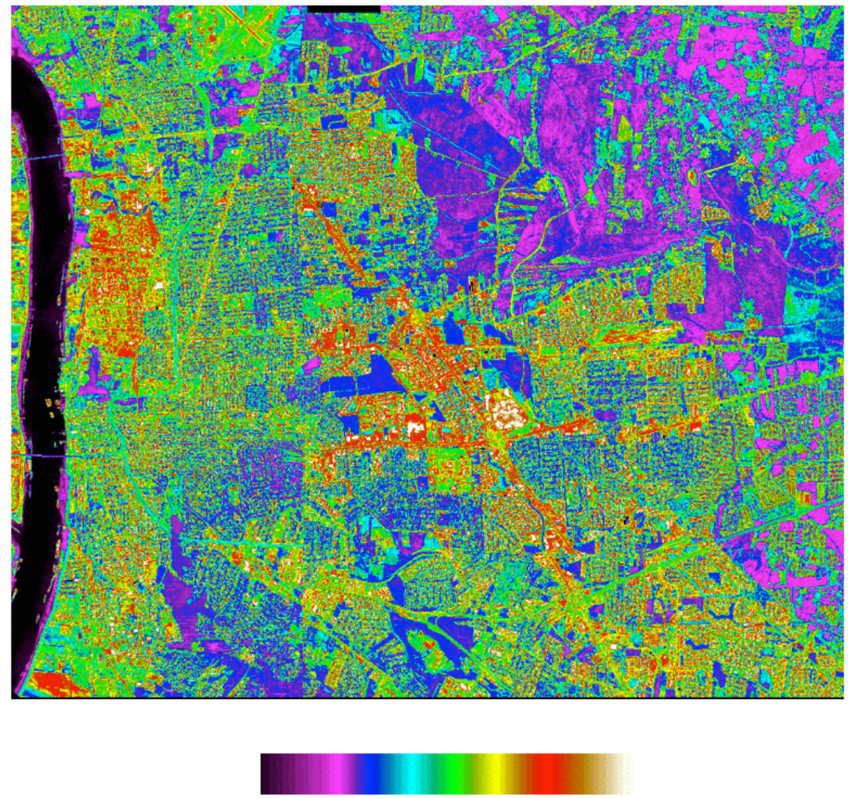


0.07 0.11 0.19 0.23 0.26 0.30 0.35 0.50

Albedo

Baton Rouge

Temperature - May 11, 1998

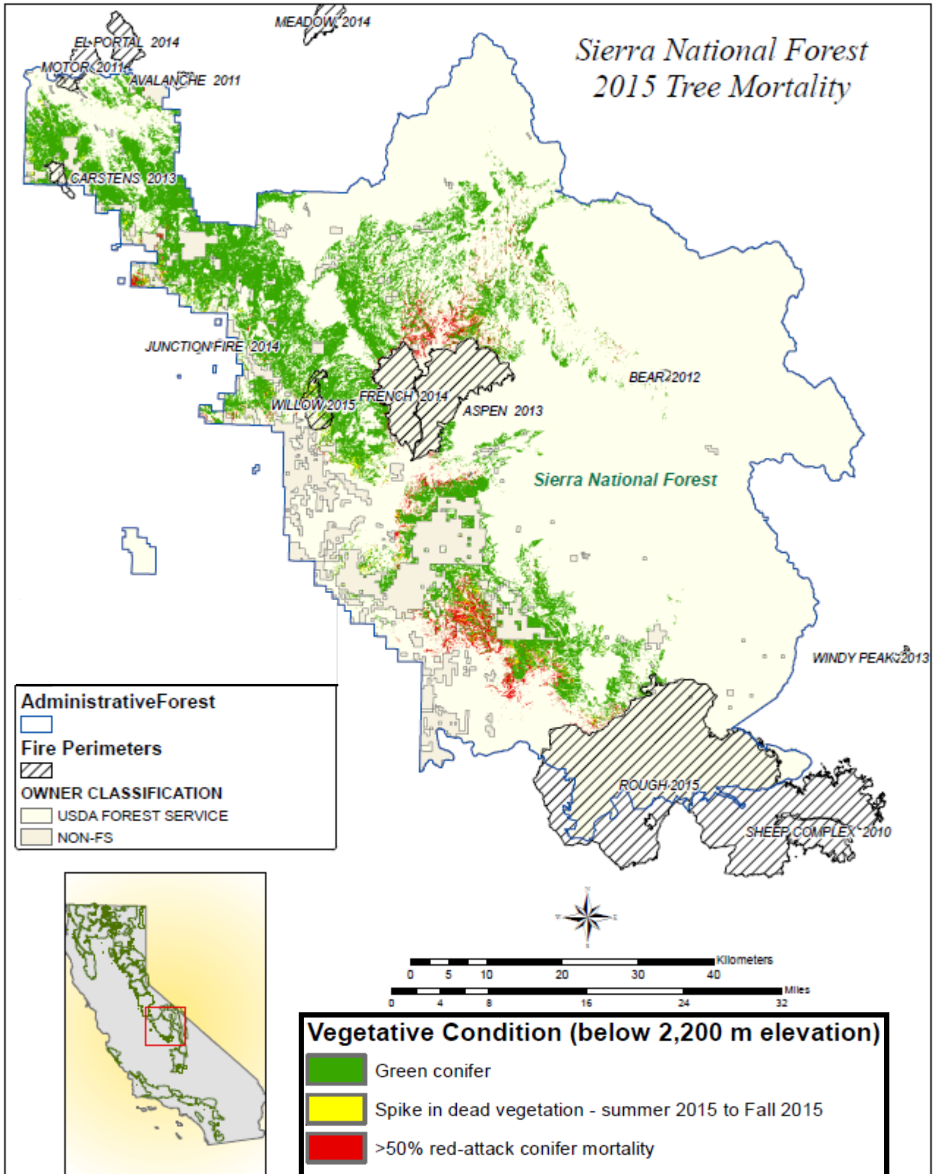


21 30 33 38 41 48 52 63

Temperature oC

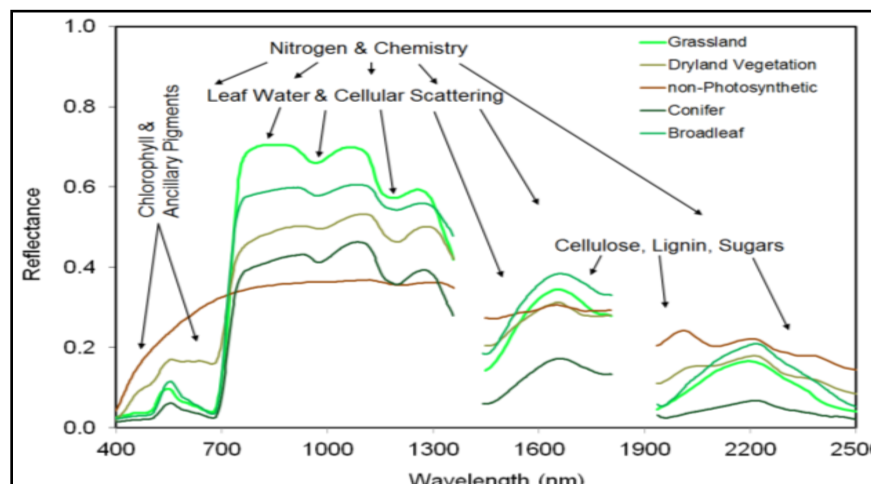
APPLICATIONS

Forest Service use of Measurements from HyspIRI Airborne Campaign

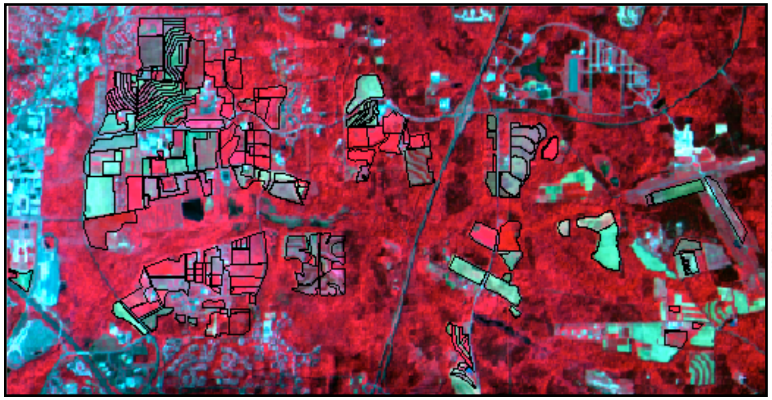


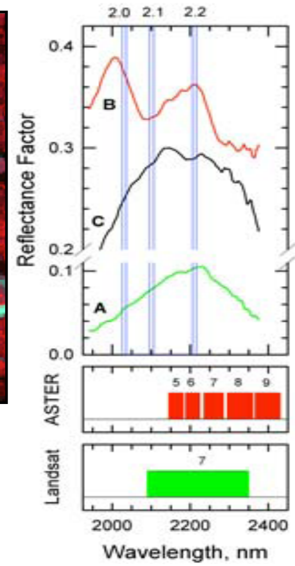
USDA Forest Service, Pacific Southwest Region, Remote Sensing Lab, Map created 5/18/16

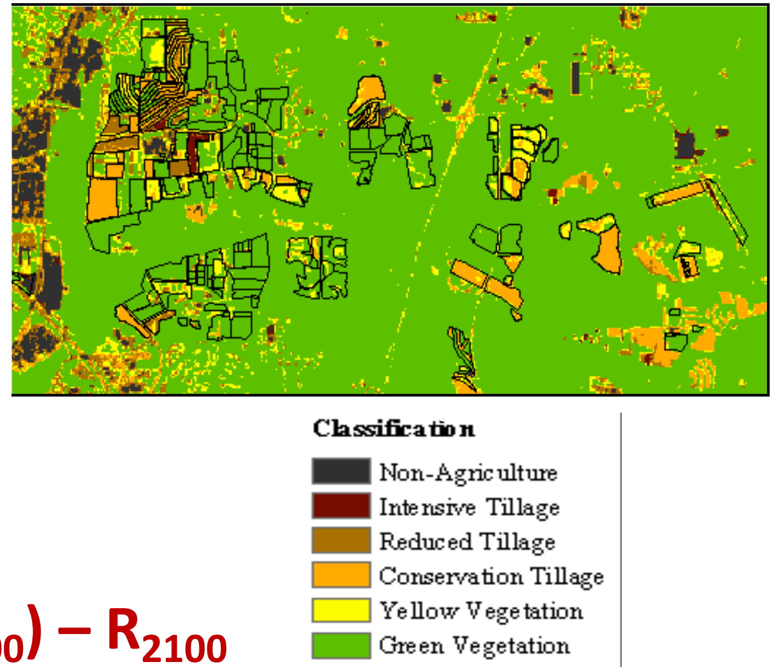
This map represents a time-series analysis of images acquired by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS; http://aviris.jpl.nasa.gov/) from Spring 2013 to Fall 2015. Mortality for Summer 2015 was manually interpreted from Worldview imagery from Spring - Summer 2015 and used for the 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.



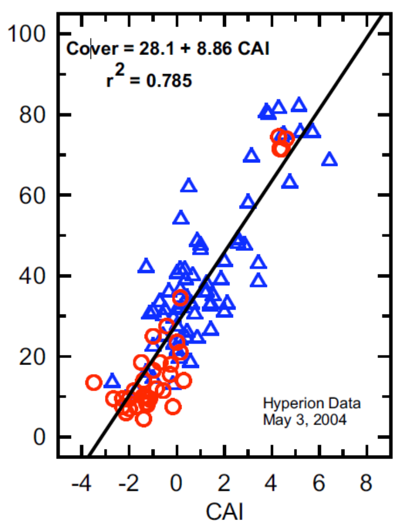
Spectroscopy and Agriculture

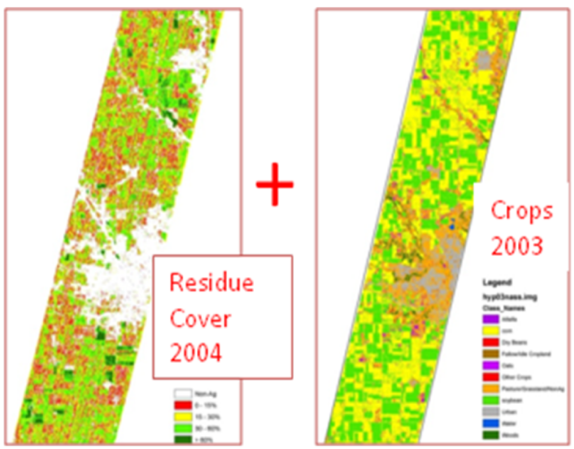






$$CAI = 0.5(R_{2000} + R_{2200}) - R_{2100}$$





For dry and moist conditions CAI is adequate for assessing crop residue cover in Iowa -- from EO-1/Hyperion

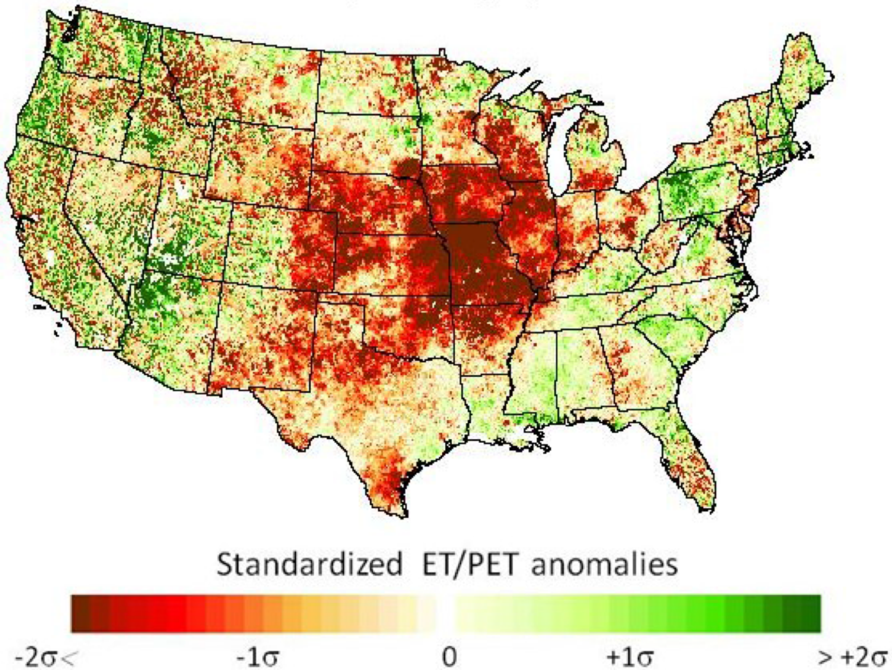
HyspIRI Mission Applications

Eco-Forecast

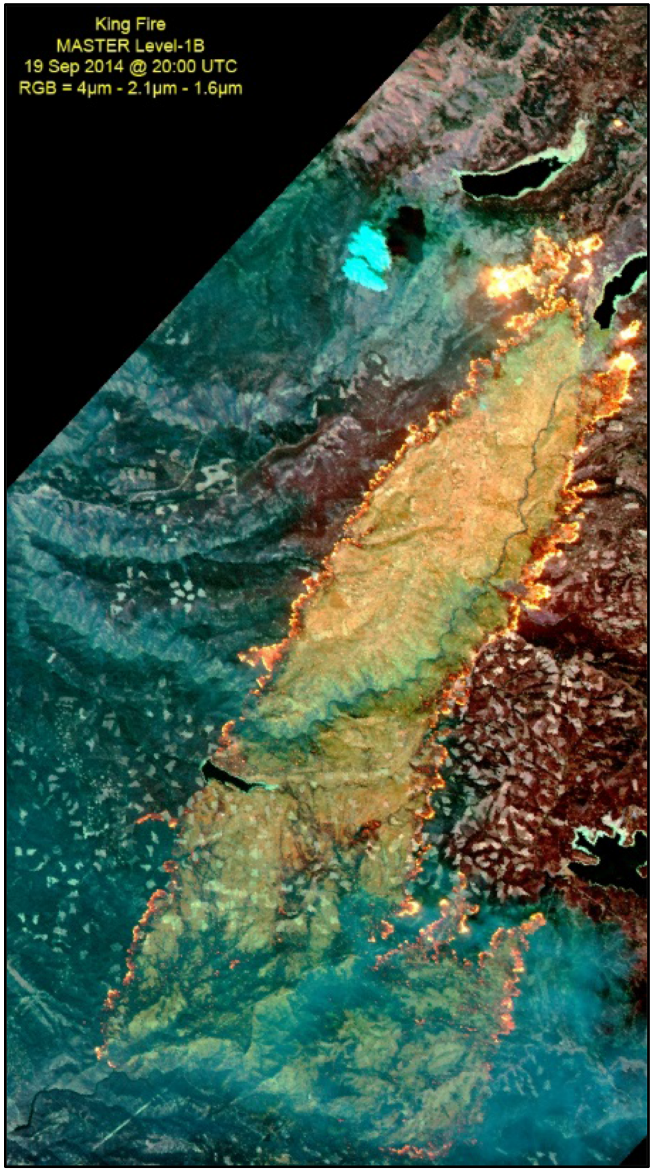
Ecological Forecasting

Evaporative Stress Index

1 month composite ending September 5, 2012

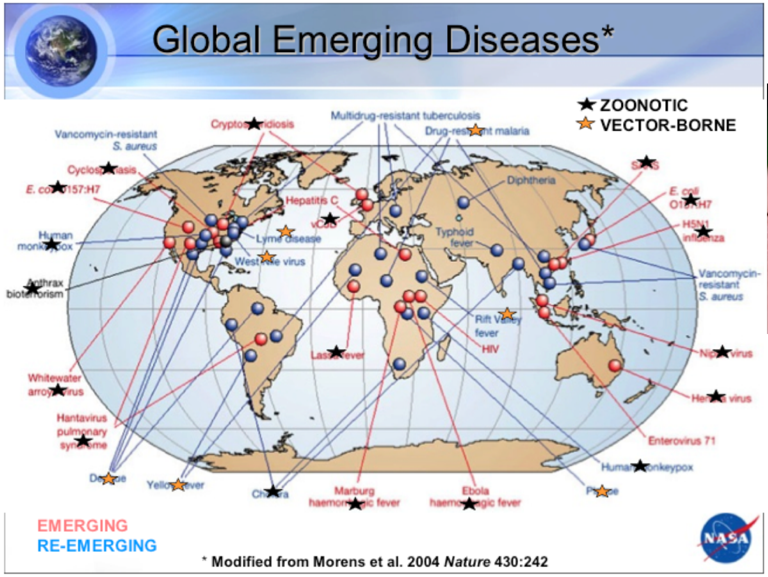


Fire Behavior

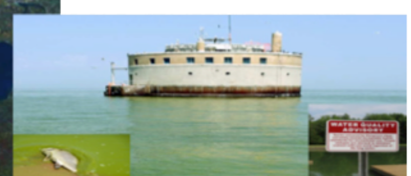


HyspIRI Mission Applications

Vector Borne Diseases



Harmful Algal Blooms



Dust

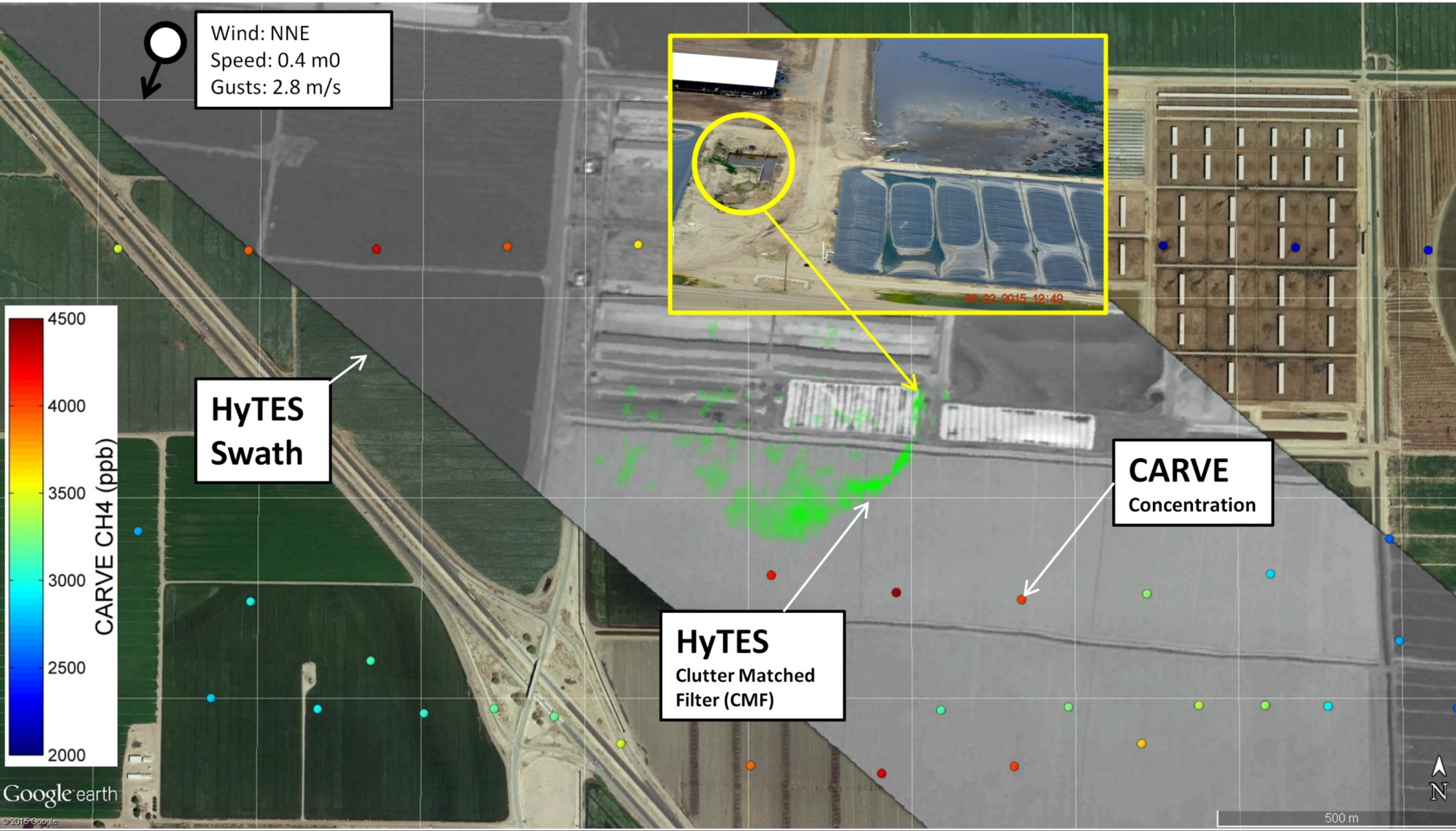
Middle East Dust – Trace Composition

Links between selected elements and some known lung function conditions and diseases

	Desert Dust <10 µm	Desert Dust 20-40 µm
Mn (ppm)	450	331.98
Fe (ppm)	25500	18111.61
Co (ppm)	11.72	8.24
Pb (ppm)	17.22	9.45
Cu (ppm)	220	152.64
Cd (ppm)	1.24	0.70
Mg (ppm)	13230.49	10572.70
Al (ppm)	15912.39	13154.60
Ca (ppm)	139577.64	140250.15
Na (ppm)	1098.28	1476.86
Cr (ppm) [but species critical]	181.32	187.36
Zn (ppm)	105.18	72.30
Ni (ppm)	93.28	60.44
Ti (ppm)	1095.52	539.81

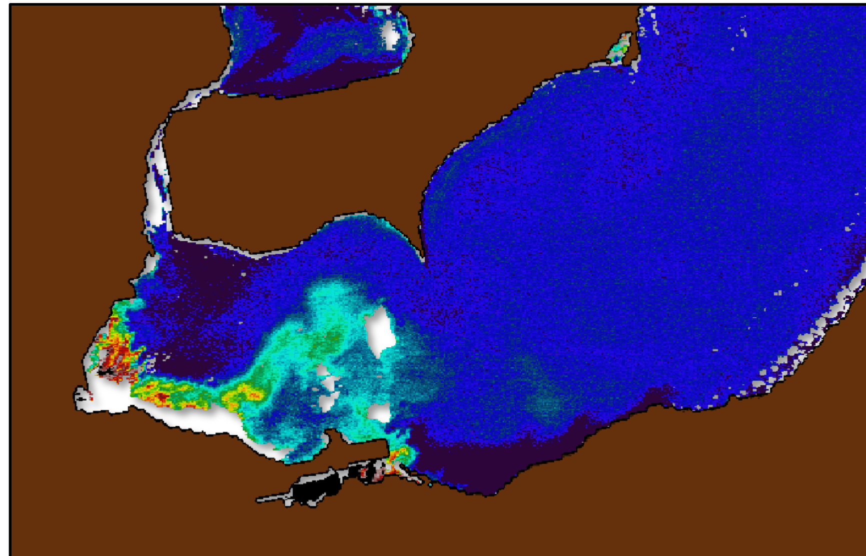
Cancer | Cancer suspected | Cancer & asthma | Emphysema | Asthma

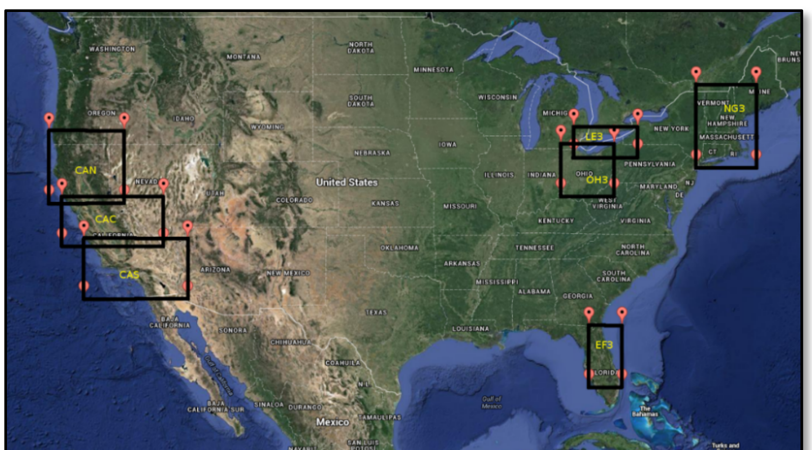
Managed Agricultural Systems – Bakersfield Dairies



CYAN Cyanobacteria Assessment

- Preliminary versions of NOAA cyanobacteria algorithms implemented into NASA standard processing software
  - Joint evaluation with NOAA ongoing
  - First vetted implementation expected in Spring 2016
  - To be made publicly available via SeaDAS (seadas.gsfc.nasa.gov)





- MERIS regional extracts identified & produced
  - CA, OH, FL, New England, plus Great Lakes (not shown to left)
  - Example products available to stakeholders in Spring 2016
  - Full mission time-series available in Summer 2016
  - Reprocessing(s) anticipated following algorithm refinements

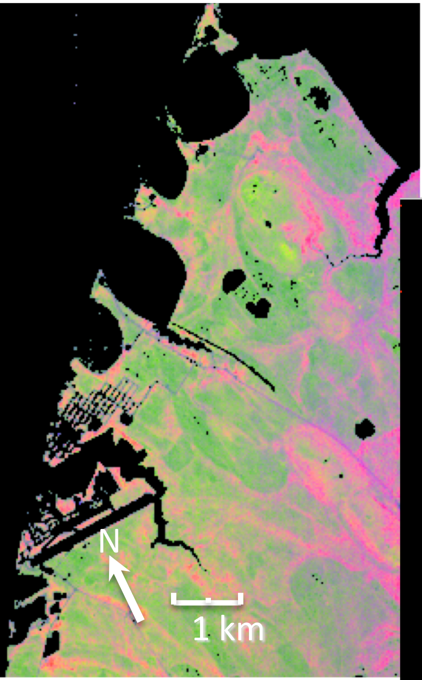
NASA Corn Maze
Mars Rover
Cornbelly's
in Lehi, Utah

THANK YOU!

HyspIRI Studies of Ecosystem Processes and Characteristics: near Barrow, AK

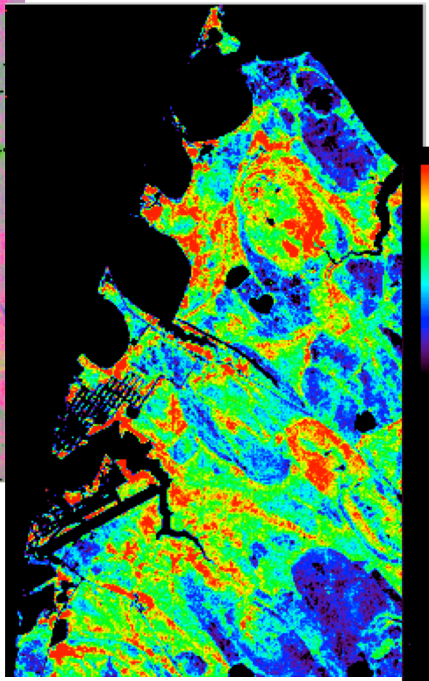
Biodiversity

Addressing questions of terrestrial ecosystem diversity, biochemistry,and function



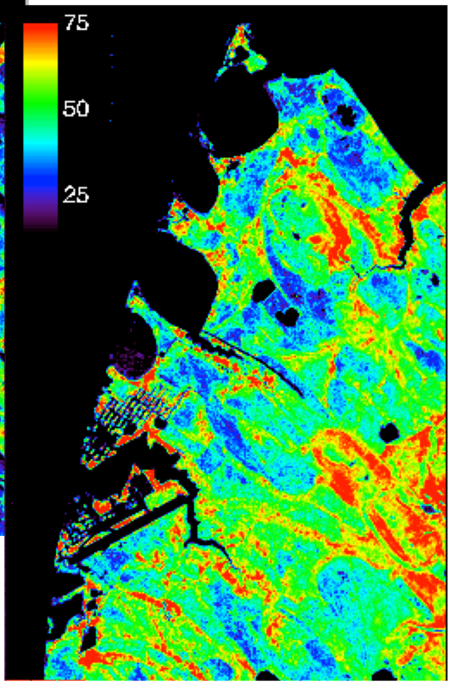
Tundra plant cover type fractions
R-Vascular Plants
G-Moss
B-Lichen

Biochemistry



Chlorophyll Index

Ecosystem Function



Photosynthetic light use efficiency (mol C mol^{-1} absorbed quanta X 1000)

Hyperion image of tundra near Barrow, AK, USA, July 20, 2009
Huemmrich et al. JSTARS 2013

– Plant type distribution affects ecosystem processes and response to climate change

– Biochemistry is diagnostic of responses to environmental conditions, e.g. soil nutrients, water availability

– Ecosystem function shows the spatial patterns in productivity over an area considered a single vegetation type in models