HyspIRI Products Symposium on HyspIRI Products for Societal Benefit Areas (SBAs) and Aquatic Studies

NASA/GSFC, May 29 and 30, 2013
Building 34, Conference room W150

Wireless internet connection:
Choose "guest" network

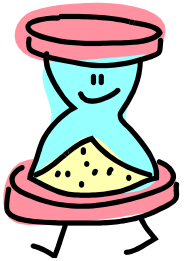
GSFC EO-1/HyspIRI Team

Betsy Middleton, NASA
Steve Ungar, UMBC

Petya Campbell, UMBC
Kevin Turpie, UMBC
Lisa Henderson, Sigma Space

David Landis, Sigma Space
Larry Corp, Sigma Space
Lawrence Ong, SSAI
Dan Mandl, NASA
Pat Cappelaere, Vightel Corp
Fred Huemmrich, UMBC
Ben Cheng, ERT
Qingyuan Zhang, USRA

Wed/Thurs Lunches: Pay at Registration Desk
Wednesday Dinner: Sign up



HyspIRI Symposium Goals

The Symposium's sessions are closely aligned with NASA's Applied Sciences program elements and the Earth Science Technology priorities:

1. Ecological Forecasting and Public Health, including Terrestrial and Coastal/Inland Aquatic Ecosystems;
2. Disasters/Natural Hazards and Water Management; and
3. Automated, Rapid Processing for Low Latency Data Products.

We will review recent accomplishments in these areas and identify the primary data products compatible with the technology to be provided by HyspIRI.

DAY 1 (May 29): Morning Agenda

8:00 Registration/ Posters Up in Room W120B/ Coffee

8:30 Symposium Opening, Goals and Agenda, W150 [*Chair: Elizabeth Middleton NASA/GSFC*]

8:40 Current status of HyspIRI mission [*Woody Turner, NASA/HQ Co-Program Scientist*]

8:55 The NASA Applied Sciences Program and the US Group on Earth Observations SBAs: Earth Sciences Serving Society [*Lawrence Friedl, NASA/HQ Associate Director for Applied Sciences*]

9:10 Aircraft campaign – status update, sites, and flight plans [*Woody Turner*]

9:25 Instruments concept (IC-1): introducing VSWIR & TIR instruments on separate platforms [*Rob Green & Simon Hook, NASA/JPL*]

9:35 - 10:00 Coffee Break

10:00 Ecological Forecasting for Terrestrial and Aquatic Ecosystems, W150 [*Chair: Susan Ustin, UC Davis*]

10:00 Improving ecological forecasting with hyperspectral data: A data assimilation system for the Community Land Model [*Andrew Fox, NEON*]

10:20 Evapotranspiration estimation with simulated HyspIRI data over arid lands [*Andrew French, USDA*]

10:40 HyspIRI data products for plant functional types [*Susan Ustin, UCD*]

11:00 Determining leaf dry matter content using the normalized dry matter index and its possible application for estimating fuel moisture content [*Raymond Hunt, USDA*]

11:20 Data fusion techniques for mapping daily water use at field scales [*Martha Anderson, USDA*]

11:40 The Matsu System for Rapid Analysis of Large Volumes of Data [*Bob Grossman, U Chicago*]

12:00 – 13:00 Lunch

DAY 1 (May 29): Afternoon Agenda #1

12:20 Aquatic Data Products Breakout, W150

12:20 Angular dependence on sand density of the spectral BRDF [*Bill Philpot, Cornell*]

12:40 Photosynthetic condition of giant Kelp (*Macrocystis pyrifera*) in the Santa Barbara Channel [*Thomas Bell, UC St. Barbara*]

13:00 Coastal & Inland Aquatic Data Products Topical Areas, W150 [*Chair: Kevin Turpie, UMBC*]

13:00 Coral reef products for HyspIRI [*Eric Hochberg, BIOS*]

13:20 Use of HyspIRI Observations to get Phytoplankton Functional Groups [*John Moisan, NASA/WFF*]

13:40 Improved Absorption and Taxonomic Composition Estimates with HyspIRI [*Tiffany Moisan, NASA/WFF*]

14:00 Impacts of Spatial and Spectral Resolution on Hyperspectral Remote Sensing of Aquatic Vegetation [*Richard Zimmerman, Old Dominion University*]

14:20 Using hyperspectral airborne PRISM imagery to map vulnerable coastal salt marsh and sea grass habitats [*Heidi Dierssen, University of Connecticut*]

14:40 Hyperspectral Imager for Coastal Ocean (HICO) [*Bo-Cai Gao, Naval Research Lab*]

15:00 – 15:20 Coffee Break

15:20 Special Topics 1, W150 [*Chair: Stephen Ungar NASA/GSFC*]

15:20 HyspIRI Aircraft campaign: science goals, project overviews & data sharing [*Rob Green & Simon Hook*]

15:35 Initial science results of the NASA/MAGI airborne instrument at the Salton Sea, CA: implications for environmental studies using HyspIRI data [*David Tratt, Aerospace Corp.*]

DAY 1 (May 29): Afternoon Agenda #2

15:50 Parallel Discussion Sessions: Charge, Goals and Anticipated Outcome [*Elizabeth Middleton*]

W150 Coastal/inland aquatic products: issues, products & requirements [*Kevin Turpie*]

16:00 Aquatic studies with HyspIRI preparatory airborne campaign [*Sherry Palacios, UC Santa Cruz*]

16:20 HyspIRI aquatic data products report [*Kevin Turpie, UMBC*]

1. *HyspIRI's potential contributions to wetland studies [Kevin Turpie, UMBC]*
2. *Potential applications of HyspIRI for land/water/ice Geomorphology. [Young-Heon Jo University of Deleware]*
3. *Detecting and quantifying water surface features using hyperspectral remote sensing: Strengths and limitations of HyspIRI [Chuanmin Hu, University of South Florida]*
4. *Water-column retrievals [Emmanuel Devred, Université Laval]*
5. *Bathymetry from hyperspectral remote sensing [ZhongPing Lee, University of Massachusetts Boston]*
6. *Benthic data products [Eric Hochberg, BIOS]*

17:00 Aquatic data products discussion [Chair: *Kevin Turpie, UMBC*]

1. *Discussion on candidate suite of data products*
2. *Availability of data for product development (HICO, air campaign data, ISS HICO follow-on / HyspIRI concept instrument)*
3. *Seed questions regarding data product generation*
4. *Potential issues regarding data product generation*
   - *Atmospheric correction techniques: are further developments required for HyspIRI aquatic data products? (e.g., NO2)*
   - *Spatial resolution changes from 60m to 1km for depth > 50m. Resolution can be commanded for an in situ study. Is this sufficient for observations such as water surface features or ice-edge phenomena?*
   - *Separation of the VSWIR and Thermal instruments*

W120A Ecological forecasting: products, requirements & issues [*Susan Ustin*]

W305 Instruments concept (IC-2): discussing benefits and concerns from having VSWIR & TIR on separate platforms [*Simon Hook & Rob Green*]

17:30 Adjourn

6:30pm Happy Hour & Dinner [Ruby Tuesday]

DAY 2 (May 30): Morning Agenda

8:00 Registration/ Posters in Room W120B/ Coffee

8:30 Environmental & Human Impacts including Disasters, Natural Hazards, Water Management and Public Health, W150 [*Chair: Jeff Luvall, NASA/MSFC*]

8:30 Traceability matrix, HyspIRI products in support of SBA requirements [*Jeff Luvall, NASA/MSFC*]

8:50 Ecologic niche models for neglected tropical diseases (NTD) in data-scarce landscapes based on environmental suitability and poverty-related risk factors at the census tract level used for operational community-based intervention programs [*John Malone, Louisiana State University*]

9:10 Volcanic CO_2 measurements from hyperspectral data [*Fabrizia Buongiorno, INGV*]

9:30 The feasibility of systematic inland water quality monitoring with HyspIRI [*Arnold Dekker, CSIRO*]

9:50 Discussion [*Chair: Jeff Luvall*]

10:10-10:30 Coffee Break

10:30 Automated, Rapid Processing for Low Latency Data Products, W150 [*Chair: Dan Mandl, NASA/GSFC*]

10:30 IPM Update and Preliminary Low Latency User Requirements [*Dan Mandl, NASA/GSFC*]

10:45 An open GeoSocial API to meet societal needs [*Pat Cappelaere, Vightel Co.*]

11:00 Rapid Co-Registration with Landsat GLS [*Maria Sazama, NASA/GSFC*]

11:15 Geo-correction for Airborne Platforms [*Vuong Ly, NASA/GSFC*]

11:30 EDOS high-rate data capture and delivery of low-latency HyspIRI level-zero data [*Bruce Mclemore, Honeywell*]

11:45 Discussion [*Chair: Dan Mandl*]

12:00 – 13:00 Lunch

***DEMO*:** ENVI Services Engine for Web-Accessible HSI Applications, W120A *[Thomas Harris]*

DAY 2 (May 30): Afternoon Agenda

13:00 Special Topics, W150 [*Chair: Stephen Ungar*]

13:00 Current and future hyperspectral instruments [*Michael Abrams, NASA/JPL*]

13:20 HyspIRI Spectral Library: concept, status and requirements [*Simon Hook*]

13:40 Role of imaging spectrometer data for model-based cross-calibration of imaging sensors [*Kurt Thome, NASA/GSFC*]

14:00 Spectral time series for the study of ecosystem function, using EO-1 Hyperion [*Petya Campbell, UMBC*]

14:20 Linking terrestrial biosphere models with imaging spectrometry measurements of ecosystem composition, structure and function [*Paul Moorcroft, Harvard*]

14:40 Discussion Synopsis: Ecological Forecasting for Terrestrial and Aquatic Ecosystems [*Susan Ustin*]

14:50-15:15 Coffee Break

15:15 Interactive Poster Presentations, W150 [*1 slide/poster, 2 min/each*]

16:00 HyspIRI products in support of Societal Benefit Areas: *Synopsis from Discussion Sessions and Open Discussions, W150* [*Chairs: Woody Turner & Elizabeth Middleton*]

16:00 Coastal and Inland Aquatic Data Products Break-Out *[Kevin Turpie]*

16:10 Environmental & Human Impacts *[Jeff Luvall]*

16:20 Rapid Processing for Low Latency *[Dan Mandl]*

16:30 Instruments concept: impacts on higher level products from placing VSWIR & TIR instruments on separate platforms *[Rob Green & Simon Hook]*

16:40 Open Discussions

17:00 (W150) Summary and review of report outline [*Elizabeth Middleton & Petya Campbell*]

17:30 Adjourn

NASA Decadal Survey HysplRI

HysplRI Status Update

HysplRI 2013 Products Symposium, NASA GSFC Bldg. 34, Rm W150

Woody Turner

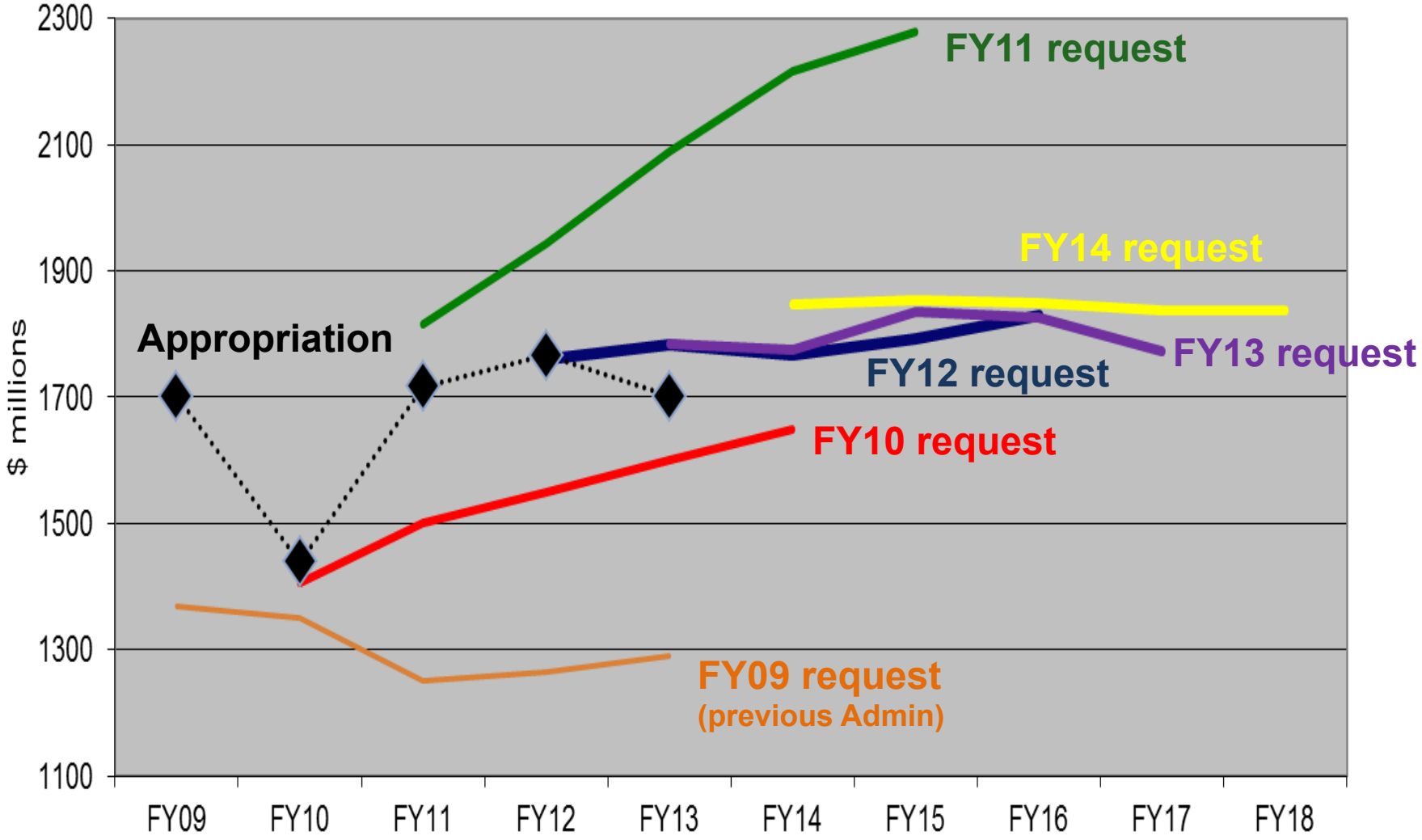
HysplRI Co-Program Scientist

Earth Science Division

NASA Headquarters

May 29, 2013

Earth Science Budget FY 14 Request



Marching Orders for FY2013

(Per 12/20/2012 Guidance Memo from Steve Volz)

1. Continue broad community support via workshops/symposia

2. Draft science objectives whitepaper specifying value of individual science measurements & potential science return of instruments on separate platforms

3. Use airborne activities to define instrument capabilities & data product development & utilization related to hyperspectral instrument

4. Examine instrument trades toward defining lower cost & more adaptable instrument &/or measurement approaches (IDL/Team I with ESTO, ESM SEWG)

5. Participate in Applied Sciences-led data latency study

6. Support cross-mission studies of possible ISS instrumentation options for advanced instrument demonstrations (ESM Program Office)

7. Provide a schedule detailing implementation of FY13 tasks

Past Year

- 5th HyspIRI Science Workshop in October 2012
- Pre-Formulation Workshop in November 2012
  - *"For a Tier II Decadal Survey mission, the HyspIRI concept is relatively mature and would address compelling research needs within multiple Earth science disciplines, however a dedicated HyspIRI mission is not in the near term program budget. Consequently the team should* ***discontinue mission-level concept studies*** *and* ***focus on the instrument and data management/data product development activities****. The team is to be commended for its excellent community coordination and on its steady progress on instrument definition and data compression techniques. The airborne campaigns, both past and planned, continue to provide excellent data sets for your study activities. The value of leveraging the R&A budget to enable the study activities and of the Independent Cost Estimate (ICE) conducted by the Aerospace Corporation in support of the HyspIRI mission is also recognized."* – Steve Volz
  - Current launch date still after 2020
  - Explore partnerships to accelerate launch of elements of the HyspIRI mission
- HyspIRI Preparatory Airborne Activities Mission started in April 2013 with 14 investigations
- Steering Committee, Science Study Group (SSG), and International Science Group calls
- HyspIRI Mission Applications Reps: JPL/Simon Hook, MSFC/Jeff Luvall
- AVIRISng and HyTES flying, PHyTIR development
- Prepare for opportunities!

Land Imaging in FY 2014 President's Budget

In FY14 NASA will initiate the definition of a sustained, space-based, global land imaging capability for the nation, ensuring continuity following LDCM. Near-term activities led by NASA, in cooperation with USGS, will focus on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives. Evaluations and design activities will include consideration of stand-alone new instruments and satellites, as well as potential international partnerships. It is expected that NASA will support the overall system design, flight system implementation, and launch of future missions, while USGS will continue to fund ground system development, post-launch operations, and data processing, archiving, and distribution.

- President's FY2014 Budget release

- **NASA Earth Science Division has responsibility for first studying and then implementing a "*sustained, space-based, global land imaging capability for the nation*"**
  - **$20M (FY14) proposed in NASA budget to study options**
- **NASA will lead this activity, supported by the USGS**
  - **ESD flight, R&A and Applied Sciences are working with USGS**
- **The remainder of FY13 is a planning period, as NASA and USGS work out the details of the study and the cooperative relationship, and initiate study activities**
  - **The study will be led by NASA HQ in close coordination with USGS**
  - **The study "*will include consideration of stand-alone new instruments and satellites, as well as potential international partnerships*"**

HyspIRI Preparatory Airborne Mission Update

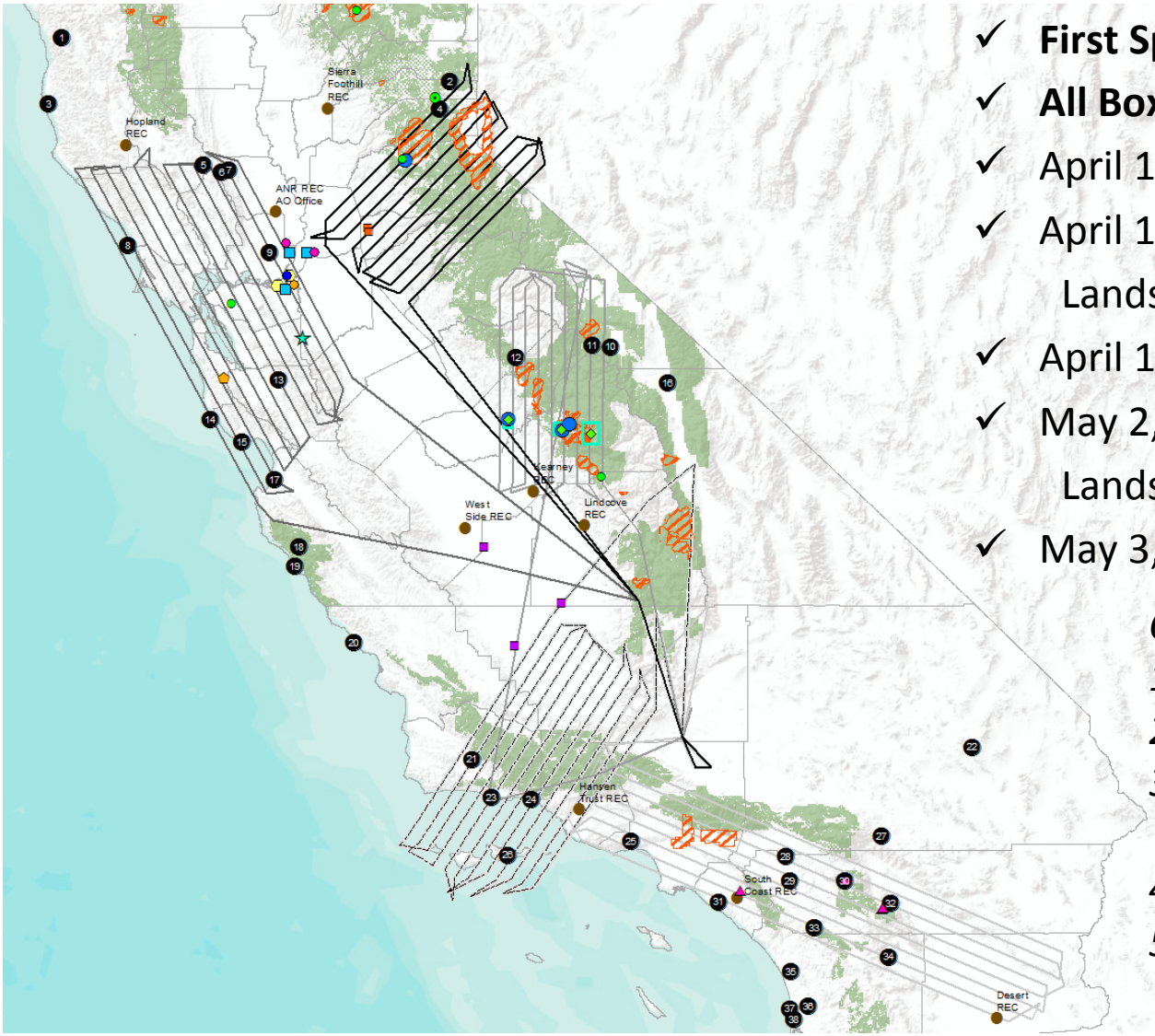
HyspIRI 2013 Products Symposium, NASA GSFC Bldg. 34, Rm W150

Woody Turner
HyspIRI Co-Program Scientist
Earth Science Division
NASA Headquarters

May 29, 2013

(Slides Provided by JPL/Ian McCubbin)

HyspIRI Airborne Preparatory Mission



- ✓ **First Spring Collection Success**
- ✓ **All Boxes Collected**
- ✓ April 10, 2013 – San Francisco Bay
- ✓ April 11, 2013 – Santa Barbara Box
  Landsat 8 Under-flight over LA
- ✓ April 19, 2013 – Southern California
- ✓ May 2, 2013 – Lake Tahoe Box
  Landsat 8 Under-flight over SF Bay
- ✓ May 3, 2013 Yosemite and NEON Box

Current Status:

1. *Level 1a Data being Processed*
2. *Level 2 Pipeline being Finalized*
3. *Mosaic Pipeline of Large Datasets is in final stages*
4. *Next set of flights start May 22*
5. *Flights with NEON Airborne Observatory June 8-11, 2013*
6. *More field work by PI Teams*

Charts by JPL/Ian McCubbin

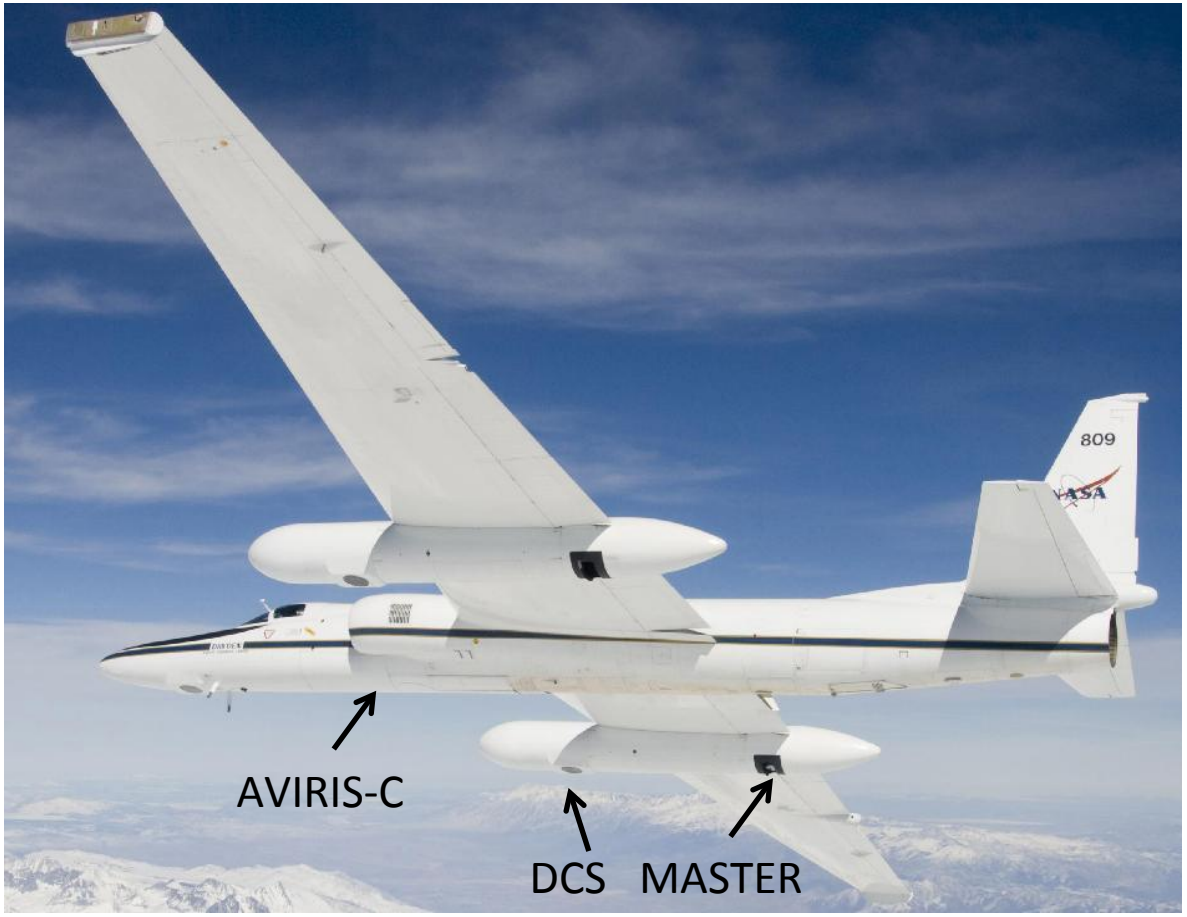
HyspIRI Airborne Preparatory Mission

AVIRIS and MASTER on ER-2 with 3 Seasonal Flights in 2013 and 2014

Datasets to Simulate Future HyspIRI Satellite

Flights Over California Based from NASA Dryden

ER-2	*AVIRIS*	*AVIRIS*	*MASTER*	*MASTER*
Altitude	*Resolution*	*Swath*	*Resolution*	*Swath*
65,000 ft	*20 m*	*12 km*	*50 m*	*35 km*



2013 Dates:

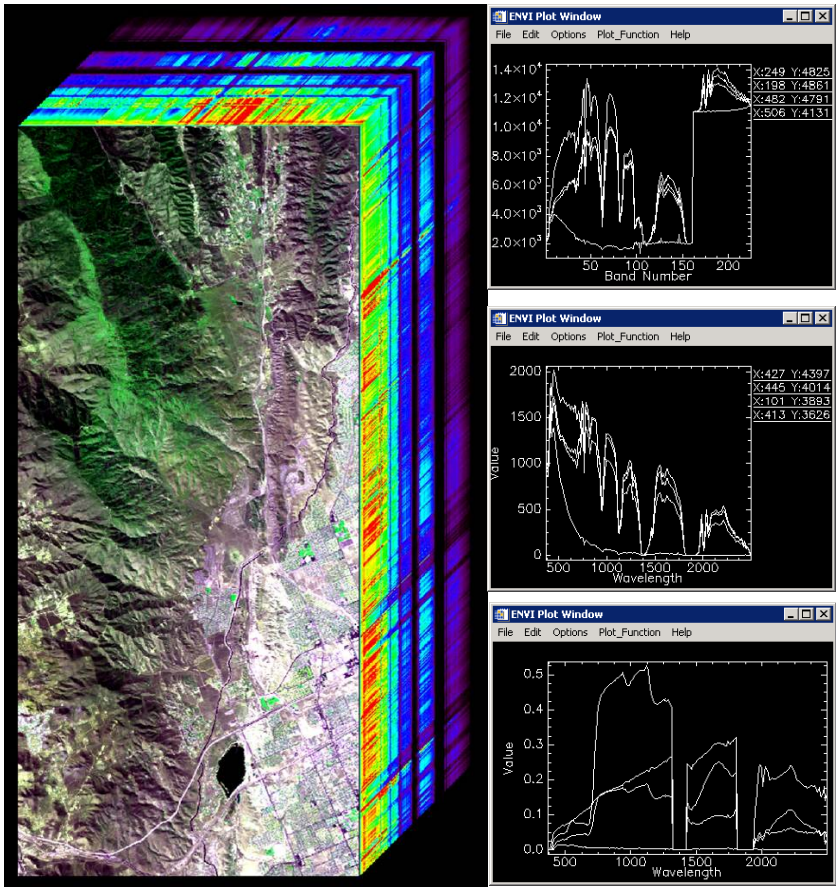
- ✓ Mar 20 - April 22
2. May 22 - June 10
3. Fall Flights
   - A. Aug 15 – 29
   - B. Sept 9 – 20
   - C. Oct 7 – 18

PI TEAM:
Wendy Calvin/University of Nevada - Reno
Matthew Clark/Sonoma State University
Bo-Cai Gao/Naval Research Laboratory
Bernard Hubbard/U. S. Geological Survey
George Jenerette/University of California Riverside
Thomas Kampe/National Ecological Observatory Network Incorporation
Raphael Kudela/University of California Santa Cruz
Ira Leifer/University of California, Santa Barbara
Shunlin Liang/University of Maryland
Paul Moorcroft/Harvard University
Dar Roberts/University of California, Santa Barbara
Philip Townsend/University of Wisconsin-Madison
Susan Ustin/University of California, Davis
Jan van Aardt/Rochester Institute of Technology

HyspIRI Airborne Preparatory Mission

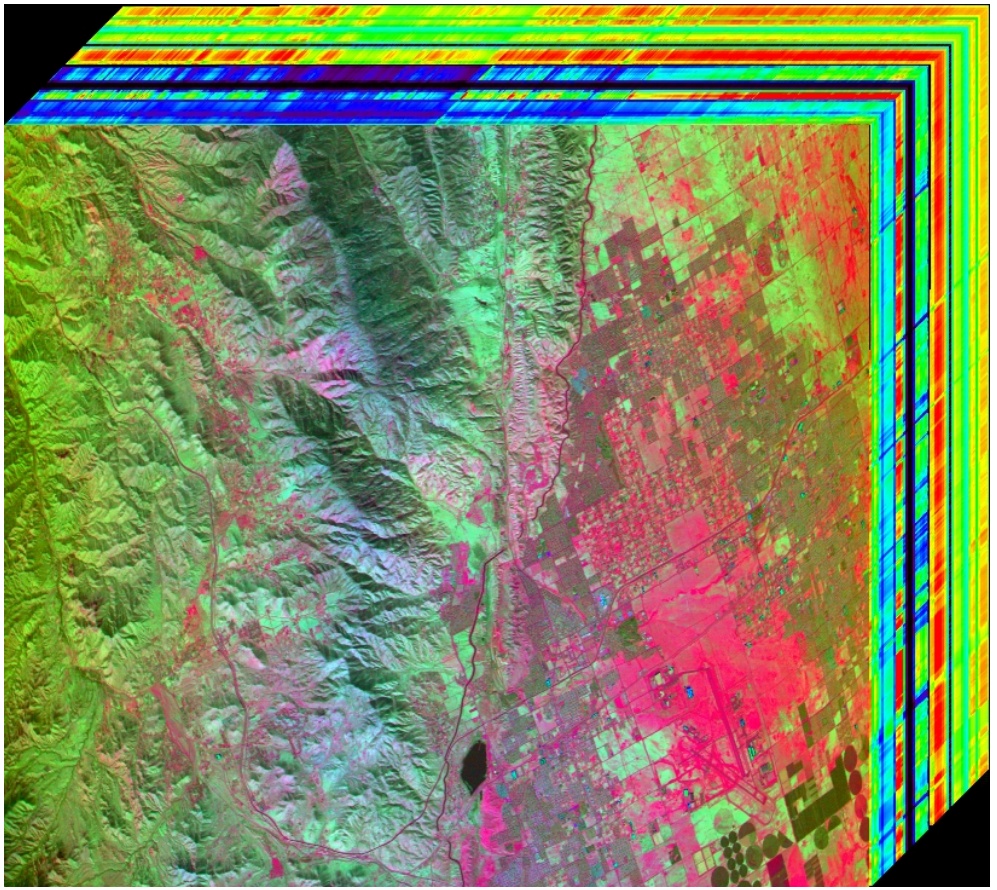
First HyspIRI Test Flights March 29, 2013, Palmdale CA

AVIRIS



AVIRIS image cube and Level 1a, 1b and 2 spectra. The reflectance spectra (L2) will be used to address the full range of science objectives including ecosystems and climate.

MASTER

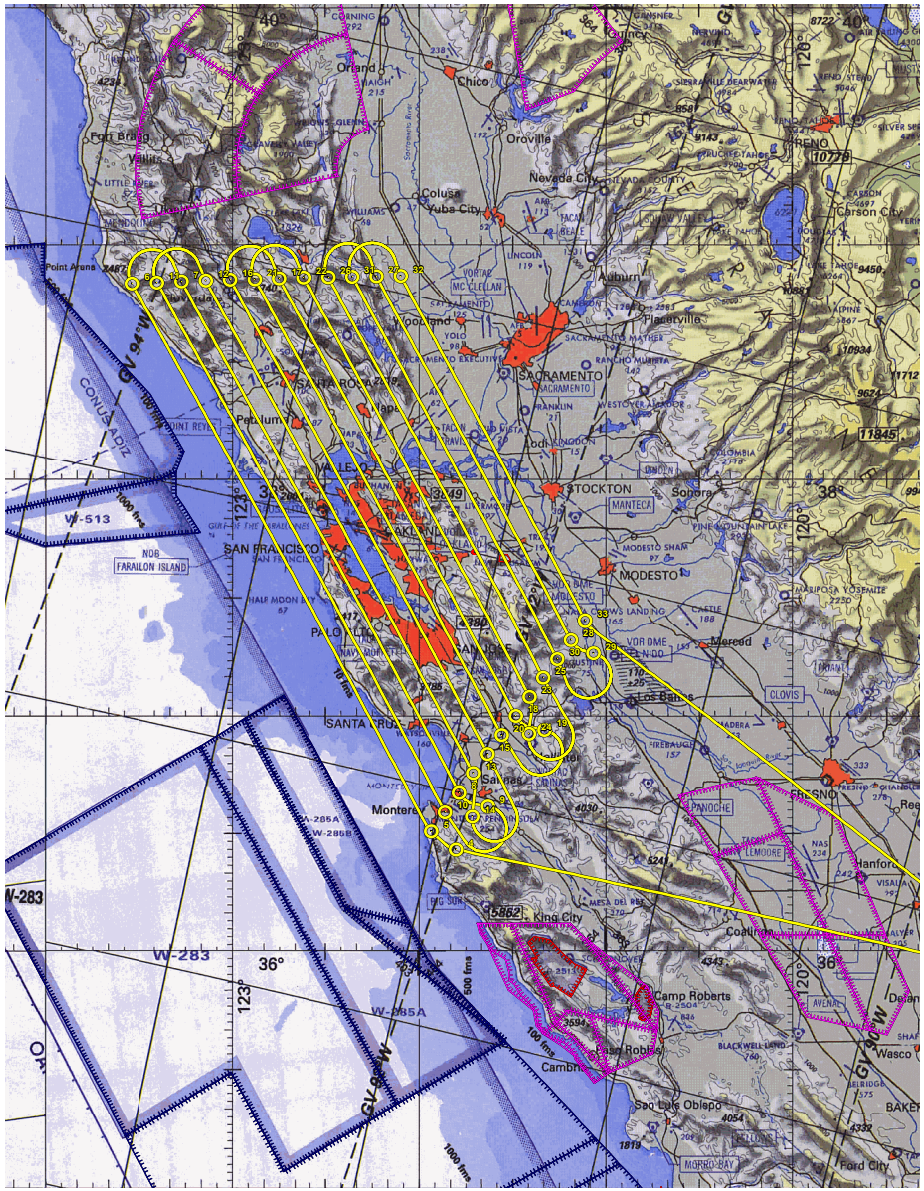


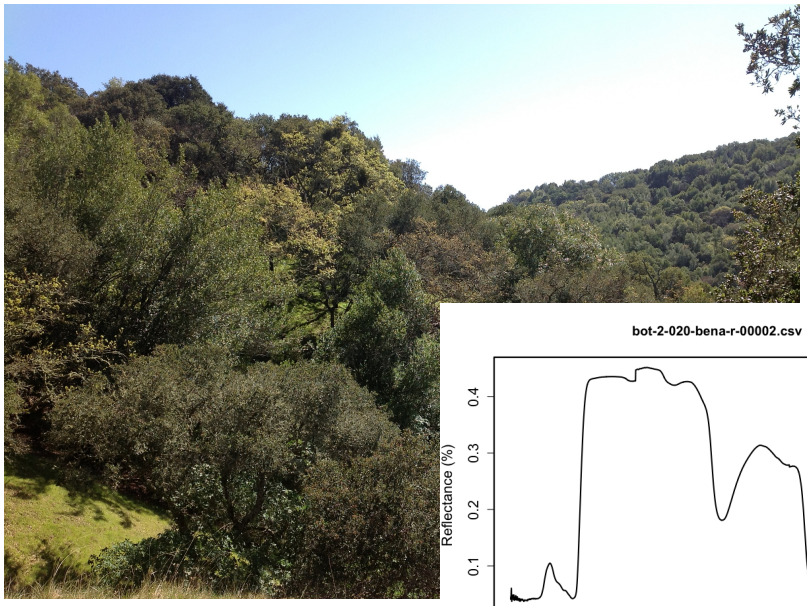
MASTER image cube. Temperature information is shown as color intensity and mimics topography and composition (emissivity) information is shown as color. Red areas are composed of minerals with high silica such as urban areas Water and heavily vegetated areas are dark indicating they are cooler. HyspIRI temperature and composition information are key to addressing a range of objectives.

April 10, 2013 – San Francisco Bay - 6.5 hours

UCSC and Ames Team on R/V Martin in Monterey Bay – Sonoma State in Bay Area

UCD in Sacramento Delta



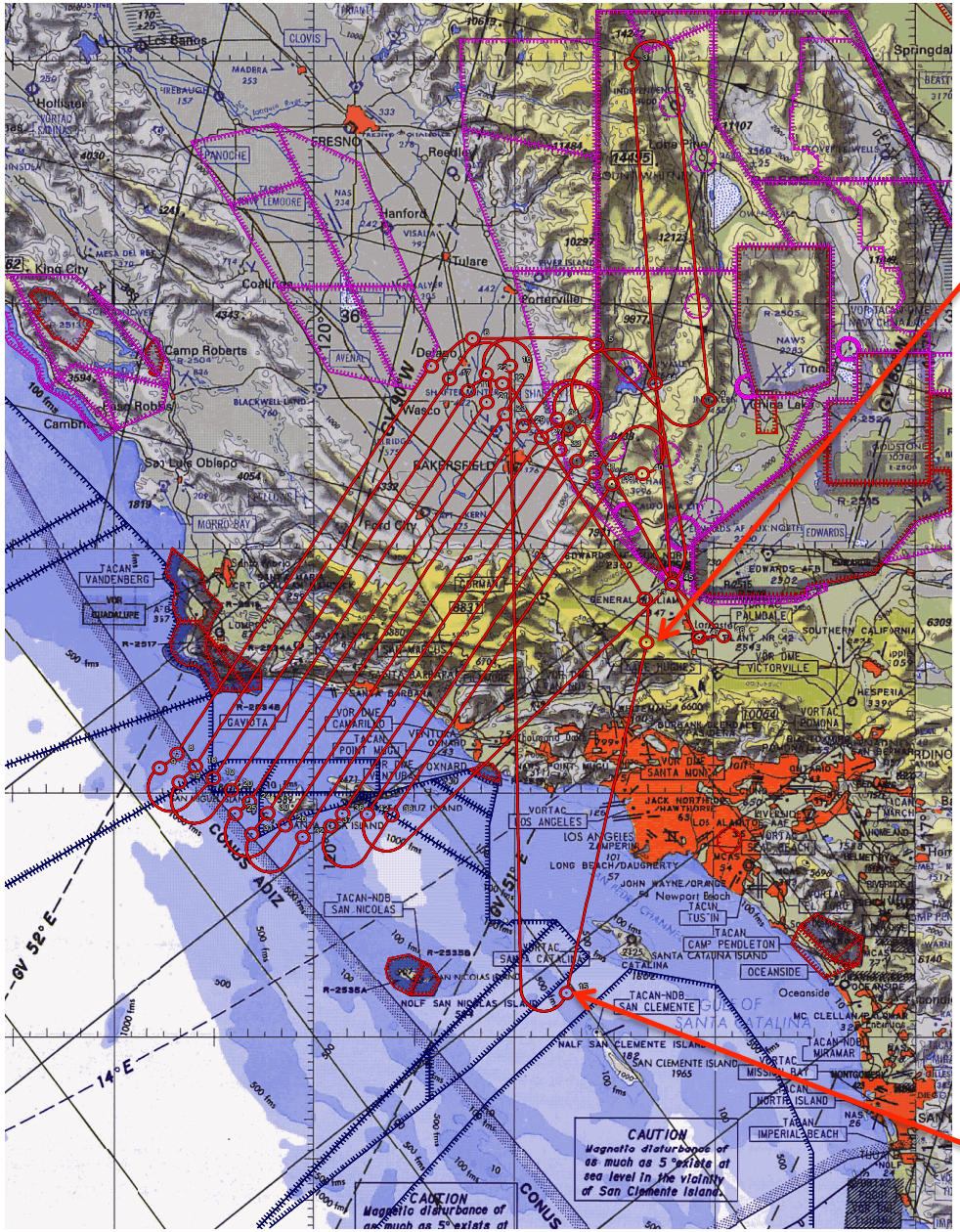


Field Spectra and Photos from Sonoma State and Wisconsin

R/V Martin used by UCSC/Ames Ocean Remote Sensing Team at Monterey Bay

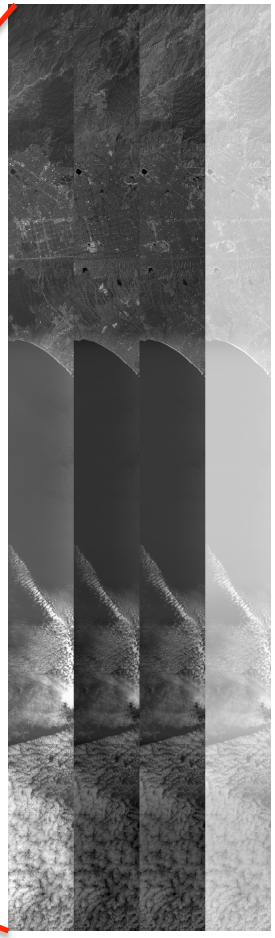
April 11, 2013 – Santa Barbara Box - 4.1 hours

Landsat 8 Under-flight over Los Angeles



NASA/NOAA UCSB Plumes and Blumes Cruise in SB Channel During Overflight

AVIRIS Data



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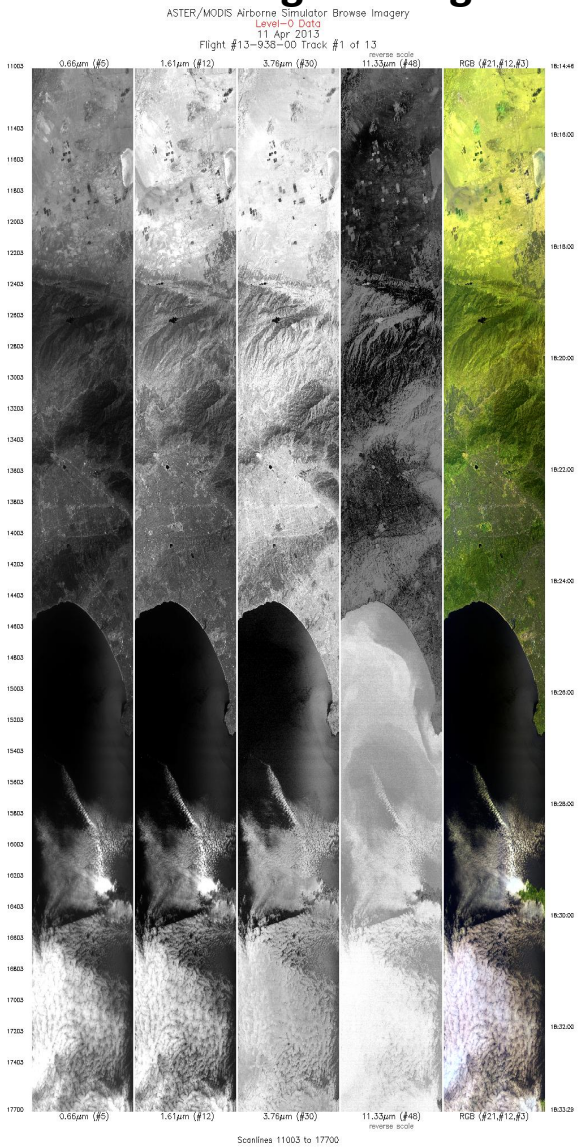
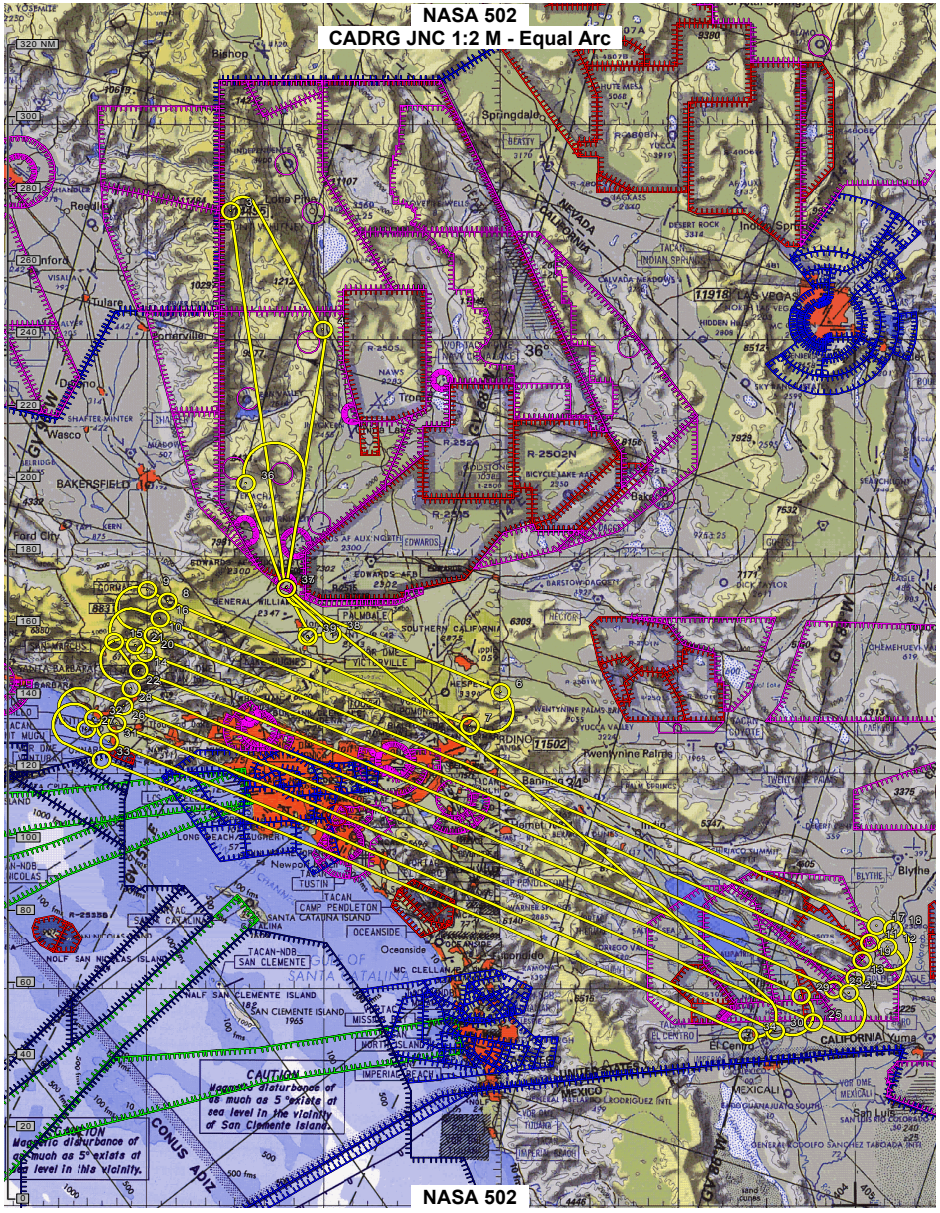


MASTER Data

April 19, 2013 – Southern California Box

7.6 hour Flight Time

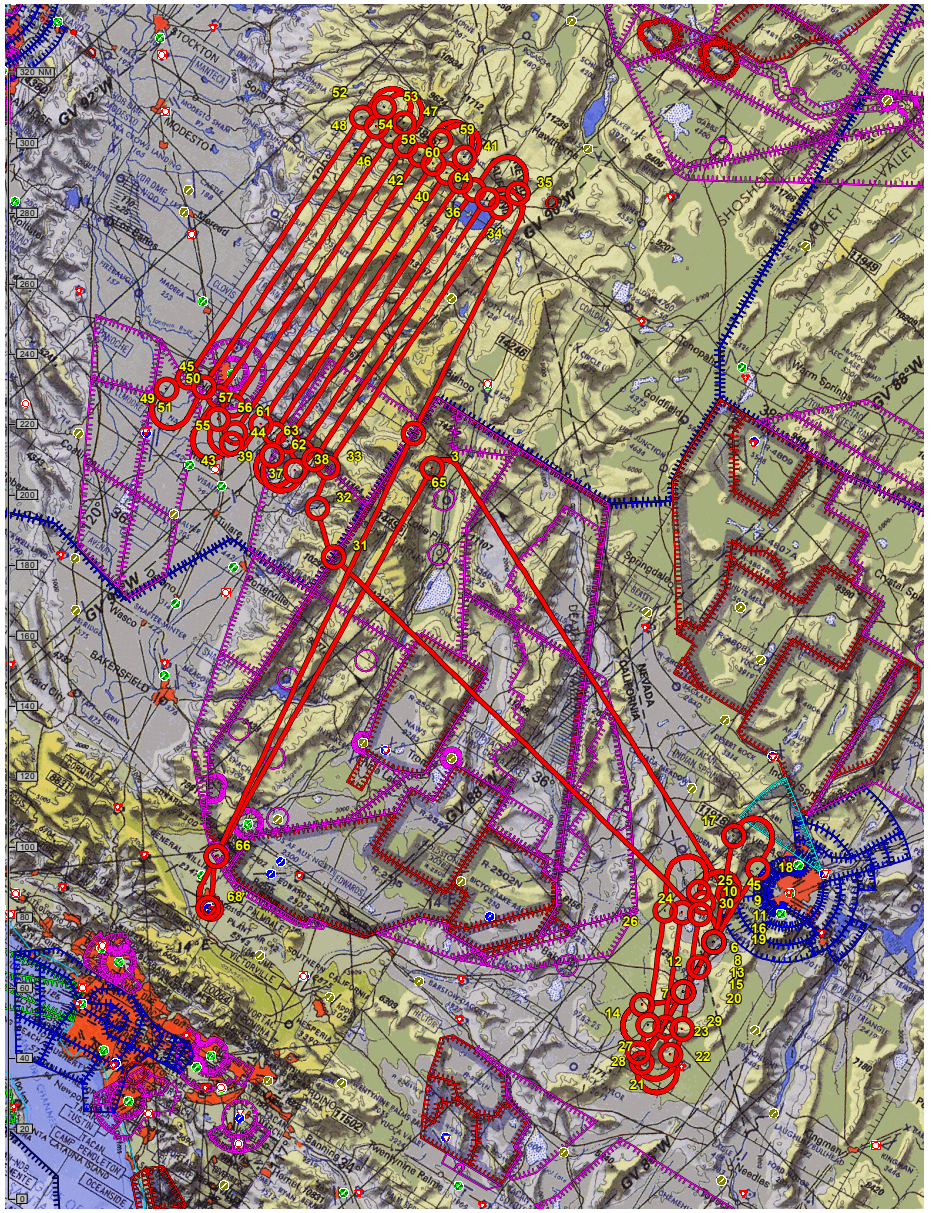
Plus: AirMSPI



May 3, 2013 Yosemite and NEON Box

4.3 hours of Flight Time and ASO Overflight

Plus: NAST-I, SHIS, AirMSPI, & NAST-M



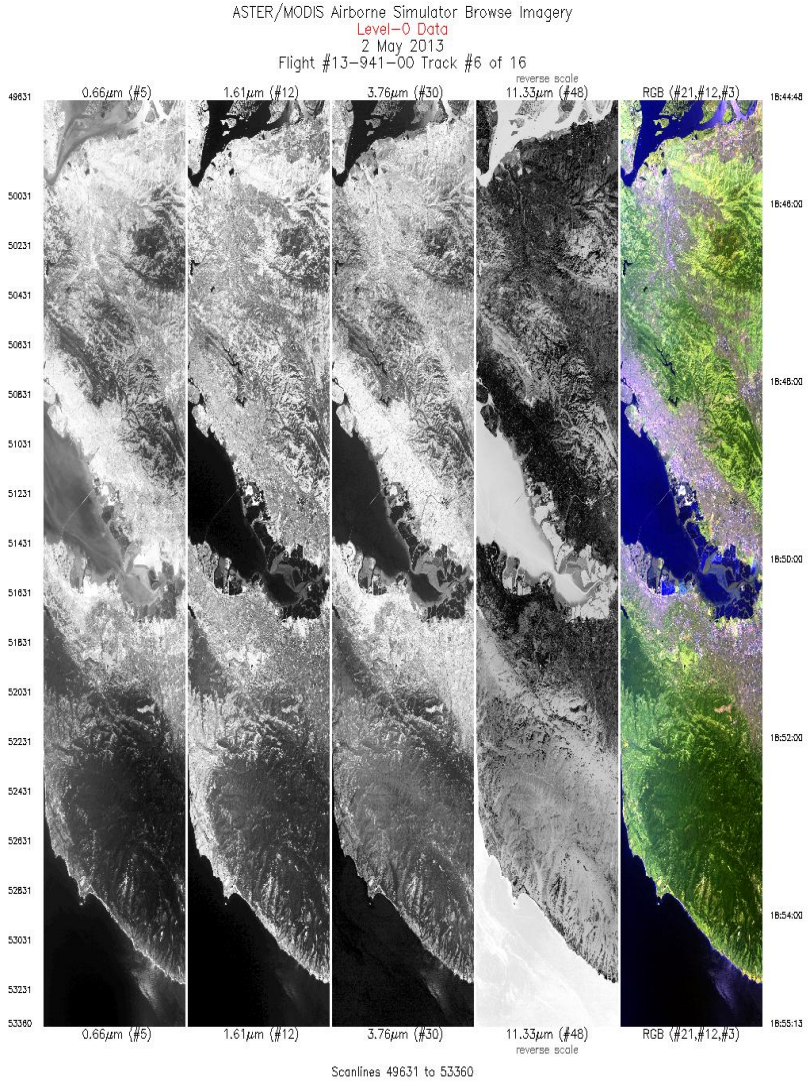
May 2, 2013 – Lake Tahoe Box

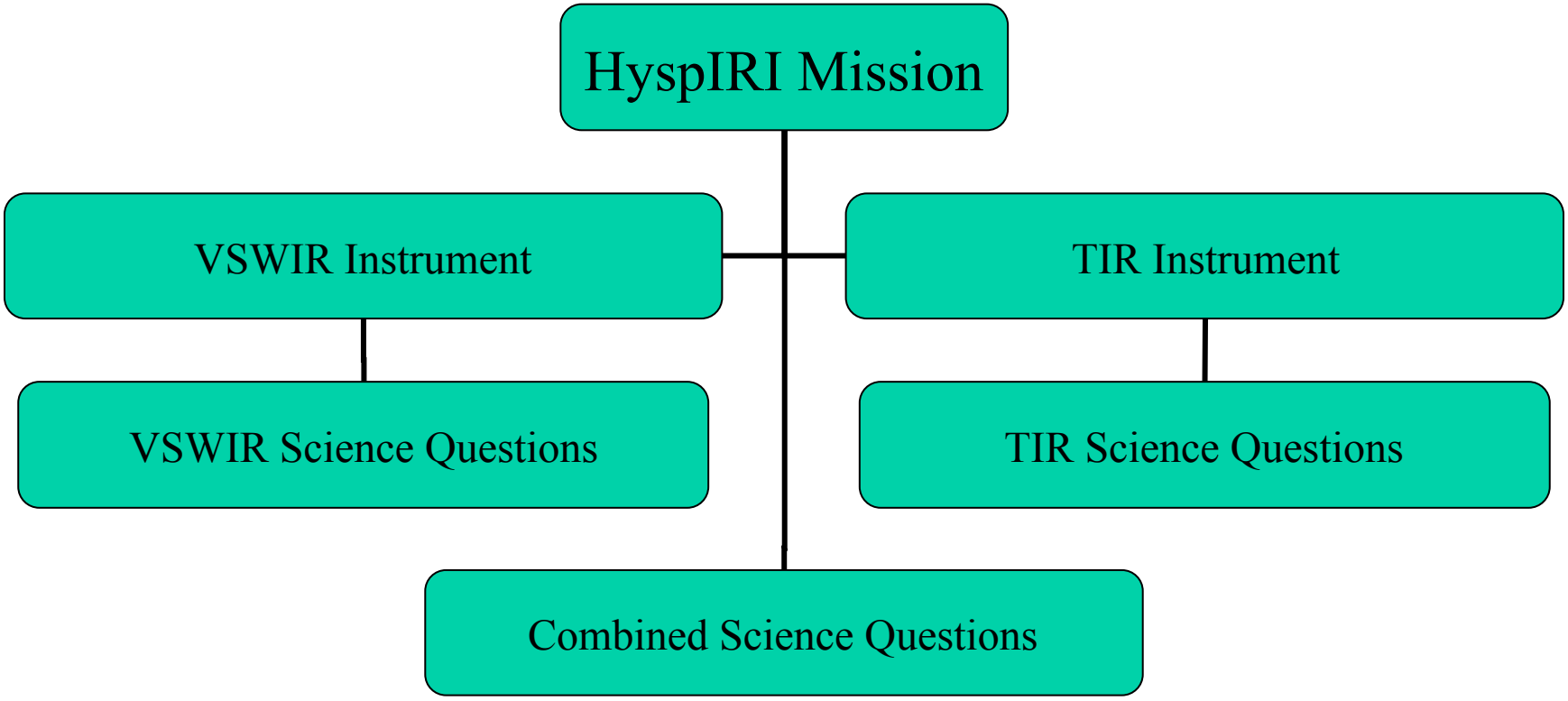
Landsat 8 Under-flight over CA Delta and SF Bay

4.4 hour Flight Plus: NAST-I, SHIS, & AirMSPI

AVIRIS Data

MASTER Data




HyspIRI Mission
VSWIR Instrument
TIR Instrument
VSWIR Science Questions
TIR Science Questions
Combined Science Questions

TIR Overarching Science Questions

•TQ1. Volcanoes and Earthquakes
– How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?
• TQ2. Wildfires
– 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
– 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
– 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
– 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?

Pros and Cons

Question	Description	Together	Separate
TQ1	…		
TQ2	…		
TQ3	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?	Pros: •Coincident VNIR data for calculating ET •Coincident data for calculating cloud-mask during daytime Cons: •VNIR data do not cover full swath	Pros: •VNIR data do not need to be coincident for ET calculation •Alternate VNIR source could be full swath (better for cloud detection) Cons: •Alternate VNIR source must be sufficiently close in time to TIR data
TQ4	…		
TQ5	…		

Leads and Co-Leads for Questions

- VQ1 – Pattern and Spatial Distribution of Ecosystems and their Components
- VQ2 – Ecosystem Function, Physiology and Seasonal Activity
- VQ3 – Biogeochemical Cycles
- VQ4 – Changes in and Responses to Disturbance
- VQ5 – Ecosystems and Human Well-being
- VQ6 – Earth Surface, Snow/Ice, and Shallow Water Benthic Composition
- TQ1 – Volcanoes and Earthquakes
- TQ2 – Wildfire temperature and emissions
- TQ3 – Water Use and Availability
- TQ4 – Urbanization and Human Health
- TQ5 – Surface composition and Change
- CQ1 – Coastal, ocean, and inland aquatic environments
- CQ2 – Wildfire, fuel, and recovery
- CQ3 – Volcanoes and hazards
- CQ4 – Ecosystem Function and Diversity
- CQ5 – Land surface composition and change
- CQ6 – Human Health and Urbanization

VSWIR Science Questions

VSWIR Overarching Science Questions

- VQ1. Pattern and Spatial Distribution of Ecosystems and their Components
  - What is the global spatial pattern of ecosystems and diversity distributions and how do ecosystems differ in their composition or biodiversity?
- 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?
- VQ3. Biogeochemical Cycles
  - 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
  - How are disturbance regimes changing, and how do these changes affect the ecosystem processes that support life on Earth?
- VQ5. Ecosystem and Human Health
  - How do changes in ecosystem composition and function affect human health, resource use, and resource management?
- VQ6. Earth Surface, Snow/Ice, and Shallow-Water Benthic Composition
  - What are the land surface soil/rock and shallow-water benthic compositions?

VQ1. Pattern and Spatial Distribution of Ecosystems and their Components

- How are ecosystems organized within different biomes associated with temperate, tropical, and boreal zones, and how are these changing?
- How do similar ecosystems differ in size, species composition, fractional cover and biodiversity across terrestrial and shallow aquatic biomes?
- 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?
- What are the extent and impact of invasive species in terrestrial and shallow aquatic ecosystems?
- What are the spatial structure and species distribution in observable phytoplankton blooms?
- How do changes in coastal morphology and surface composition impact coastal ecosystem composition, diversity and function?

VQ2. Ecosystem Function, Physiology and Seasonal Activity

- 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?

- How do seasonal changes affect productivity, carbon sequestration, and hydrological processes across ecosystems and agriculture?

- How do environmental stresses affect the physiological function of water and carbon exchanges at the seasonal time scale within ecosystems (including agriculture)?

- What is the environmental impact of aquatic plants and coral in inland and coastal water environments at the seasonal time scale?

VQ3. Biogeochemical Cycles

- How do changes in climate and atmospheric processes affect the physiology and biogeochemistry of ecosystems?
- 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?
- What are the consequences of increasing nitrogen deposition for carbon cycling and biodiversity in terrestrial and coastal ecosystems?
- How do changes in hydrology, pollutant inputs and sediment transport affect freshwater and coastal marine ecosystems?
- How do changing water balances affect carbon storage by terrestrial ecosystems?
- What are the key interactions between biogeochemical cycles and the composition and diversity of ecosystems?
- How do changes in biogeochemical processes feed back to climate and other components of the Earth system?

VQ4. Changes in and Responses to Disturbance

- 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?
- 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?
- - What are the effects of disturbances on productivity, water resources, and other ecosystem functions and services?
- How do changes in human uses of ecosystems affect their vulnerability to disturbance and extreme events?

VQ5. Ecosystem and Human Health

- How do changes in ecosystem composition and function affect the spread of infectious diseases and the organisms that transmit them?
- 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?
- What are the impacts of flooding and sea-level rise on ecosystems, human health, and security?

VQ6. Earth Surface, Snow/Ice, and Shallow Water Benthic Composition

- What is the distribution of the primary minerals and mineral groups on the exposed terrestrial surface?
- 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?
- What changes in bottom substrate occur in shallow coastal and inland aquatic environments?
- What impact do desert dust and black carbon have on critical water resources through the acceleration of snow and glacier melt?
- What is the impact of climate change on the reflectivity of snow and ice in the Earth's polar regions?
- How can measurements of rock and soil composition be used to understand and mitigate hazards?

TIR Science Questions

TIR Overarching Science Questions

•TQ1. Volcanoes and Earthquakes
– How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?
• TQ2. Wildfires
– 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
– 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
– 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
– 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

- Do volcanoes signal impending eruptions through changes in surface temperature or gas emission rates and are such changes unique to specific types of eruptions?
- 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?
- What are the characteristic dispersal patterns and residence times for volcanic ash clouds and how long do such clouds remain a threat to aviation?
- What do the transient thermal anomalies that may precede earthquakes tell us about changes in the geophysical properties of the crust?
- Can the energy released by the periodic recharge of magma chambers be used to predict future eruptions?

TQ2. Wildfires

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

TQ3. Water Use and Availability

- How is climate variability (and ENSO) impacting the evaporative component of the global water cycle over natural and managed landscapes?
- What are relationships between spatial and temporal variation in evapotranspiration and land-use/land-cover and freshwater resource management?
- Can we improve early detection, mitigation, and impact assessment of droughts at local to regional scales anywhere on the globe?
- 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?
- 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?

TQ4. Human Health and Urbanization

- How do changes in local and regional land cover and land use, in particular urbanization affect surface energy balance characteristics that impact human welfare?
- 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?
- How can the factors influencing heat stress on humans be better resolved and measured?
- How can the characteristics associated with environmentally related health effects, that affect vector-borne and animal-borne diseases, be better resolved and measured?
- How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems, and urbanization?

TQ5. Earth Surface Composition and Change

- What is the spectrally observable mineralogy of the Earth's surface and how does this relate to geochemical and surficial processes?
- 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?
- 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?
- 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?

Combined Science Questions

Combined Overarching Questions

- CQ1. Coastal Ocean, and Inland Aquatic Environments
  - 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. Wildfire, Fuel and Recovery
  - How are fires and vegetation composition coupled?
- CQ3. Volcanoes and Related Signatures
  - 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
  - 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
  - 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
  - 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 Water Environments

- 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?

CQ2. Wildfire, Fuel and Recovery

- 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?
- 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?

CQ3. Volcanoes and Surface Signatures

- What do comparisons of thermal flux and SO2 emission rates tell us about the volcanic mass fluxes and the dynamics of magma ascent?
- 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?
- Can measurements of the rate at which lava flows cool allow us to improve forecasts of lava flow hazards?
- Does the temperature and composition of volcanic crater lakes change prior to eruptions?
- Do changes in the health and extent of vegetation cover indicate changes in the release of heat and gas from crater regions?

CQ4. Ecosystem Function and Diversity

- How can we enhance phenological & stress characterization through synergy between reflective and emitted radiation with higher frequency temporal sampling?
- 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?
- How is physiological function affecting water and carbon exchange expressed at the ecosystem scale, especially seasonal down-regulation due to environmental stress factors?
- 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?
- 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?
- How do climate-induced temperature and moisture changes impact the distribution and spread of invasive and native species?

CQ5. Surface Composition and Change

- What is the composition of the exposed terrestrial surface of the Earth?
- How does the surface mineralogy and soil composition relate to the plant physiology and function on the terrestrial surface of the Earth?
- How is the composition of exposed terrestrial surface responding to anthropogenic and non anthropogenic drivers (desertification, weathering, disturbance e.g. logging, mining)?
- 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?
- 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?

CQ6. Human Health and Urbanization

- 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?

- What changes can be observed and measured in emissivity's of urban surfaces and how do emissivity's change for different cities around the world as they impact the urban heat island and associated land-atmosphere energy balance characteristics?

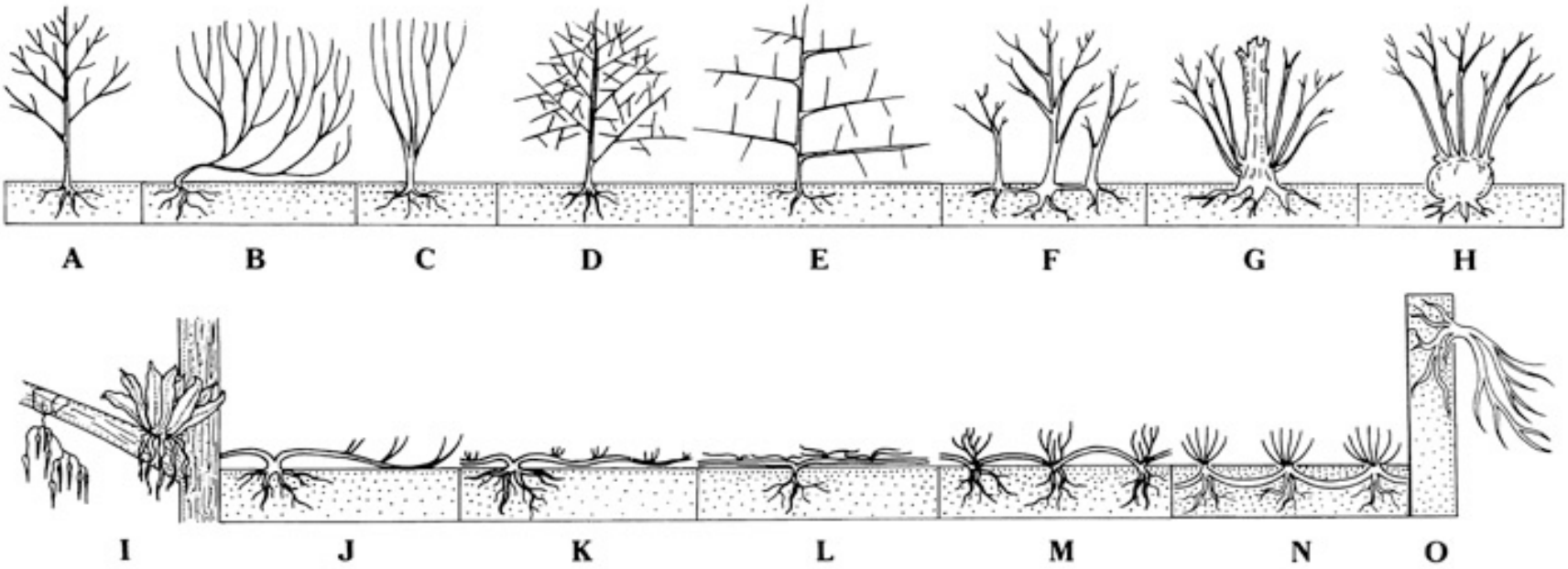
- How does the distribution of urban and peri-urban impervious surfaces affect regional energy balance fluxes, hydrologic processes, biogeochemical fluxes, and what is the response of ecosystems to these changes?

- What is the status and availability of freshwater resources including snow and ice and how is this related to climate variability, land-use, and population growth?

Ecological Forecasting for Terrestrial and Aquatic Ecosystems Session

Plant Growth Forms

Susan L. Ustin
U. California Davis

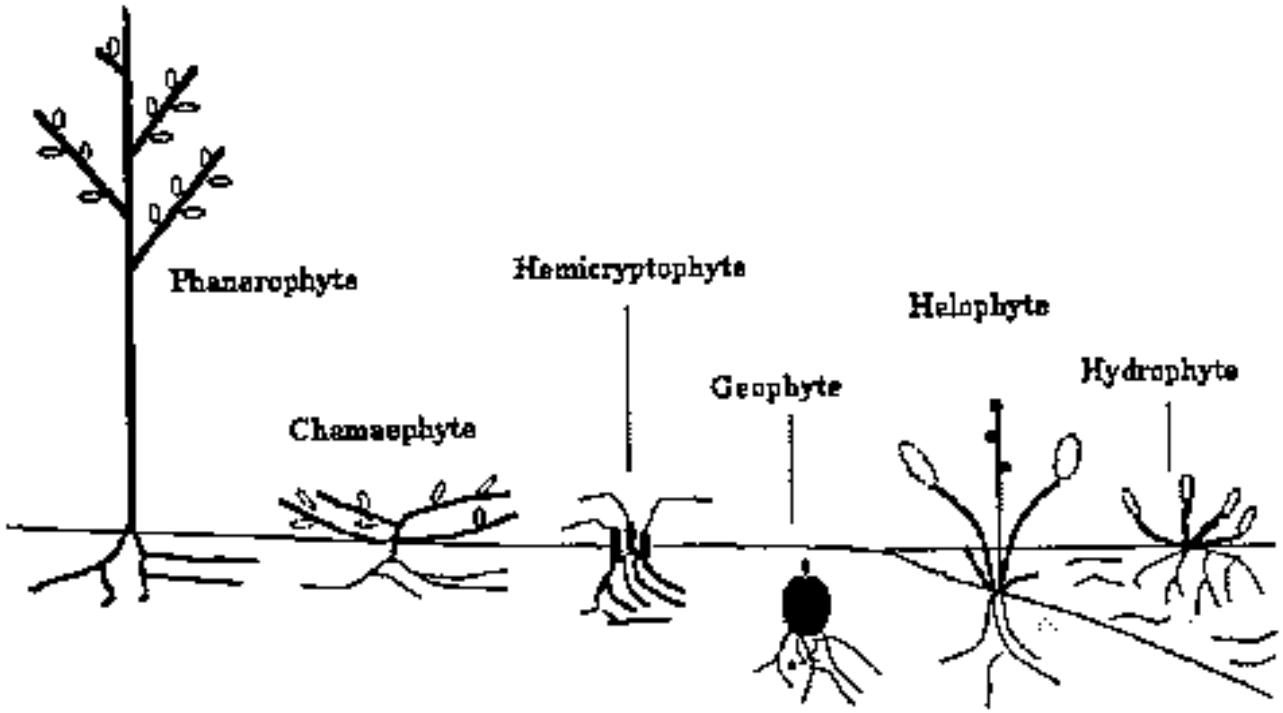


slustin@ucdavis.edu

How do Botanists Classify Plants with similar Traits?

Many Definitions of Plant Functional Types

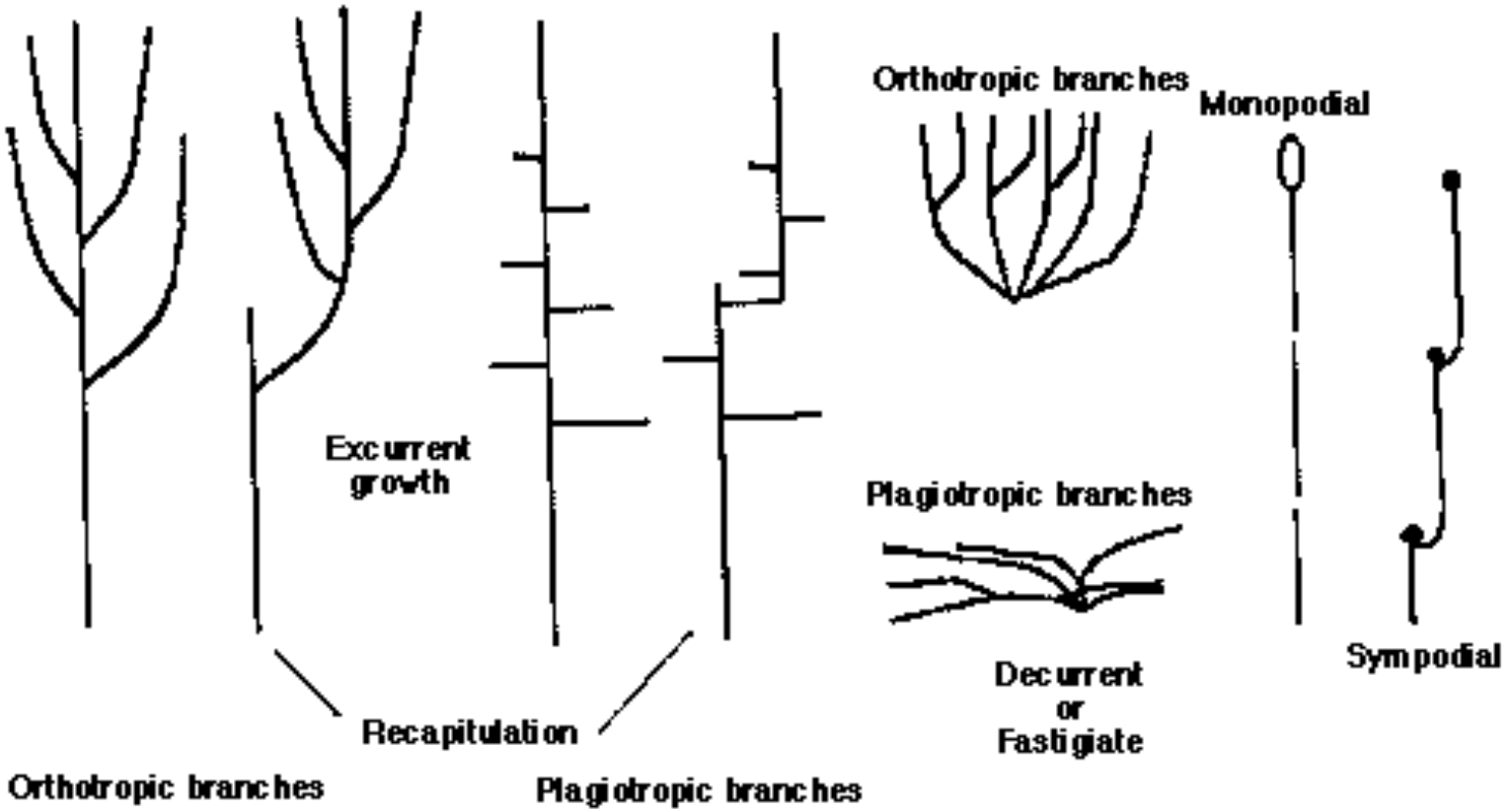
1. Location of pernnating (overwintering) organs



How do Botanists Classify Plants with similar Traits?

Many Definitions of Plant Functional Types

2. Branching architectures



Remote Sensing PFTs Developed from GCM Parameterizations

SiB2	BATS	IGBP DISCover
Broadleaf evergreen tree	Broadleaf evergreen tree	Broadleaf evergreen forest
Broadleaf deciduous tree	Broadleaf deciduous tree	Broadleaf deciduous forest
Broadleaf & needleaf tree	Mixed woodland	Mixed forest
Needleleaf evergreen tree	Needleleaf evergreen tree	Needleleaf evergreen forest
Needleleaf deciduous tree	Needleleaf deciduous tree	Needleleaf deciduous forest
Broadleaf shrub	Evergreen shrub	Closed shrubland
Dwarf trees & shrubs	Deciduous shrub	Open shrubland
Agriculture C3 grassland	Tall grass (savanna)	Woody savanna
Short vegetation C4 grassland	Short grass	Savanna
	tundra	Grassland
	desert	Cropland
	Semidesert	Crop & other vegetation
	Cropland	Barren or Sparse
	Irrigated Crop	Wetland
	Wetland	Snow & Ice
	Glacier	

IGBP DISCover, International Geosphere-Biosphere Programme Data and Information System Global 1 km Land Cover Data Set (Loveland et al., 2000)

Remote Sensing PFTs Developed from GCM Parameterizations

Climate Rules →

Remote Sensing Data Products	Plant Functional Types
Needleleaf evergreen tree	Temperate Boreal
Needleleaf deciduous tree	Boreal
Broadleaf evergreen tree	Tropical Temperate
Broadleaf deciduous tree	Tropical Temperate Boreal
Shrub	Broadleaf evergreen temperate Broadleaf deciduous temperate Broadleaf deciduous boreal
Grass	C3 C3 arctic C4
Crop	Crop 1 (e.g., corn) Crop 2 (e.g., wheat)

PFT Databases:

1 km U MD tree cover
- Needleleaf, Broadleaf
- Evergreen, Deciduous

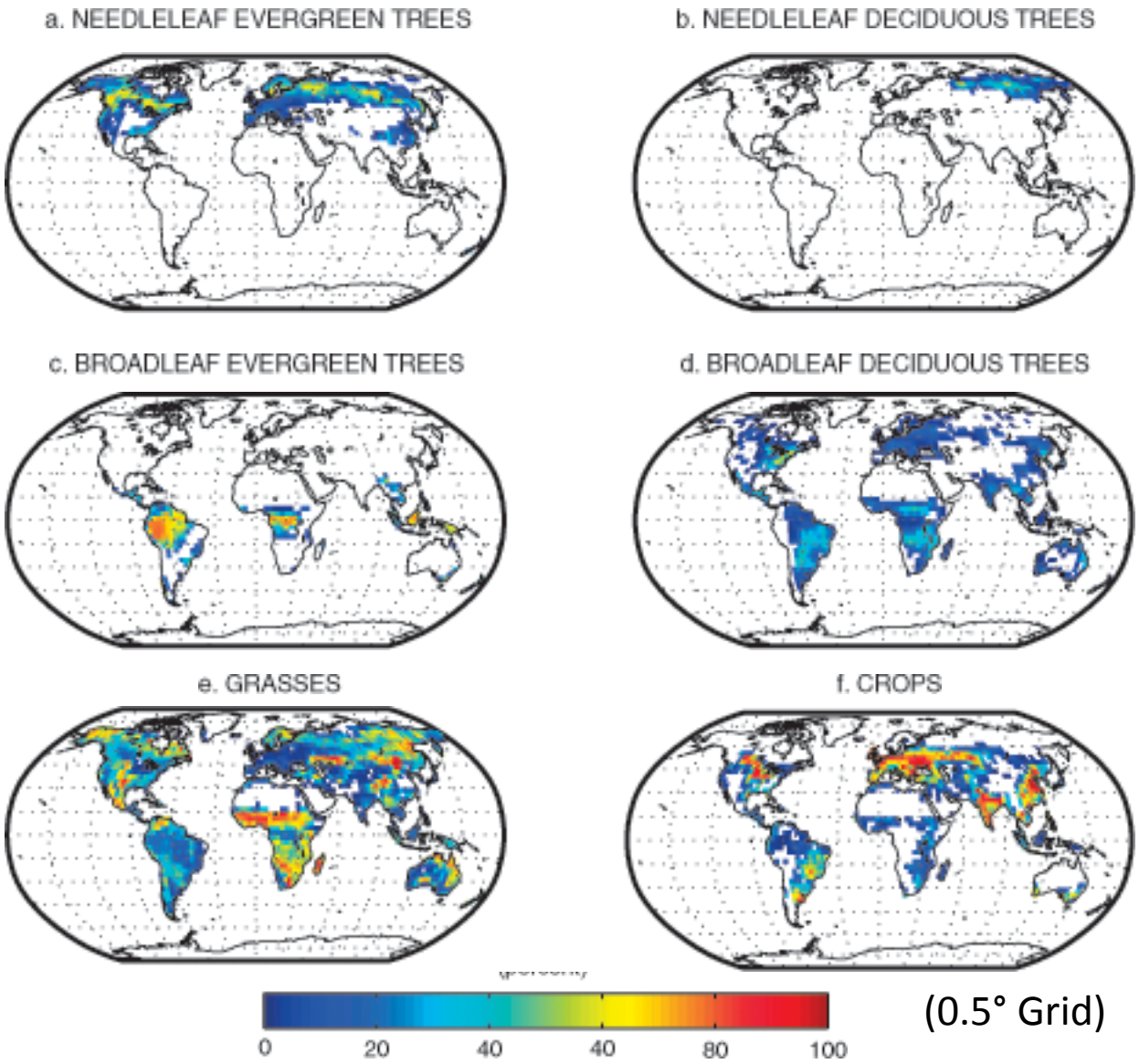
1 km IGBP DISCover
- Shrub, Grass, Crop

Monthly Leaf Area

- 1 km AVHRR R, NIR
- April 1992 to March 1993
- NDVI 200km x 200km grid
- Ave NDVI for 1 km pixel, w/ PFT > 60%

Oleson and Bonan (2000)

Distribution of PFTs Used in CLM model



(0.5° Grid)

Bonan et al. 2002. Global Biogeochemical Cycles

Optical properties for plant functional types

Plant Functional Type	Leaf Angle ❹	Leaf Reflectance VIS ❸	Leaf Reflectance NIR ❸	Stem Reflectance VIS ❷	Stem Reflectance NIR ❷	Leaf Transmittance VIS ❷	Leaf Transmittance NIR ❷	Stem Transmittance VIS ❷	Stem Transmittance NIR ❷
NET temperate	0.01	0.07	0.35	0.16	0.39	0.05	0.10	0.001	0.001
NET boreal	0.01	0.07	0.35	0.16	0.39	0.05	0.10	0.001	0.001
NDT boreal	0.01	0.07	0.35	0.16	0.39	0.05	0.10	0.001	0.001
BET tropical	0.10	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
BET temperate	0.10	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
BDT tropical	0.01	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
BDT temperate	0.25	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
BDT boreal	0.25	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
BES temperate	0.01	0.07	0.35	0.16	0.39	0.05	0.10	0.001	0.001
BDS temperate	0.25	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
BDS boreal	0.25	0.10	0.45	0.16	0.39	0.05	0.25	0.001	0.001
C_3 grass arctic	-0.30	0.11	0.58	0.36	0.58	0.07	0.25	0.220	0.380
C_3 grass	-0.30	0.11	0.58	0.36	0.58	0.07	0.25	0.220	0.380
C_4 grass	-0.30	0.11	0.58	0.36	0.58	0.07	0.25	0.220	0.380
Crop1	-0.30	0.11	0.58	0.36	0.58	0.07	0.25	0.220	0.380
Crop2	-	-	-	-	-	-	-	-	-

different values in database

Morphological Characteristics

Plant Functional Type	Leaf Dimension (m) ❶	Roughness Length ❸	Displacement Height ❷	Root Distribution a ❸	Root Distribution B ❹
NET temperate	0.04	0.055	0.67	7.0	2.0
NET boreal	0.04	0.055	0.67	7.0	2.0
NDT boreal	0.04	0.055	0.67	7.0	2.0
BET tropical	0.04	0.075	0.67	7.0	1.0
BET temperate	0.04	0.075	0.67	7.0	1.0
BDT tropical	0.04	0.055	0.67	6.0	2.0
BDT temperate	0.04	0.055	0.67	6.0	2.0
BDT boreal	0.04	0.055	0.67	6.0	2.0
BES temperate	0.04	0.120	0.68	7.0	1.5
BDS temperate	0.04	0.120	0.68	7.0	1.5
BDS boreal	0.04	0.120	0.68	7.0	1.5
C_3 grass arctic	0.04	0.120	0.68	11.0	2.0
C_3 grass	0.04	0.120	0.68	11.0	2.0
C_4 grass	0.04	0.120	0.68	11.0	2.0
Crop1	0.04	0.120	0.68	6.0	3.0
Crop2	-	-	-	-	-

different values in database

Photosynthetic parameters

Plant Functional Type	Path ❷	V_{max25} ❽	A ❷	m ❸
NET temperate	C_3	51	0.06	6
NET boreal	C_3	43	0.06	6
NDT boreal	C_3	43	0.06	6
BET tropical	C_3	75	0.06	9
BET temperate	C_3	69	0.06	9
BDT tropical	C_3	40	0.06	9
BDT temperate	C_3	51	0.06	9
BDT boreal	C_3	51	0.06	9
BES temperate	C_3	17	0.06	9
BDS temperate	C_3	17	0.06	9
BDS boreal	C_3	33	0.06	9
C_3 grass arctic	C_3	43	0.06	9
C_3 grass	C_3	43	0.06	9
C_4 grass	C_4	24	0.04	5
Crop1	C_3	50	0.06	9
Crop2	-	-	-	-

different values in database

Does classification by growth form categories denote physiological functioning?

Daintree Biosphere Reserve, Queensland, Australia

Tropical Forest in West Sumatra, Indonesia

Growth Form Differences Relate to Adaptations for Resource Conditions

Coast Redwood
Sequoia sempervirens

Sierra "Big Tree"Redwood
Sequoiadendron giganea

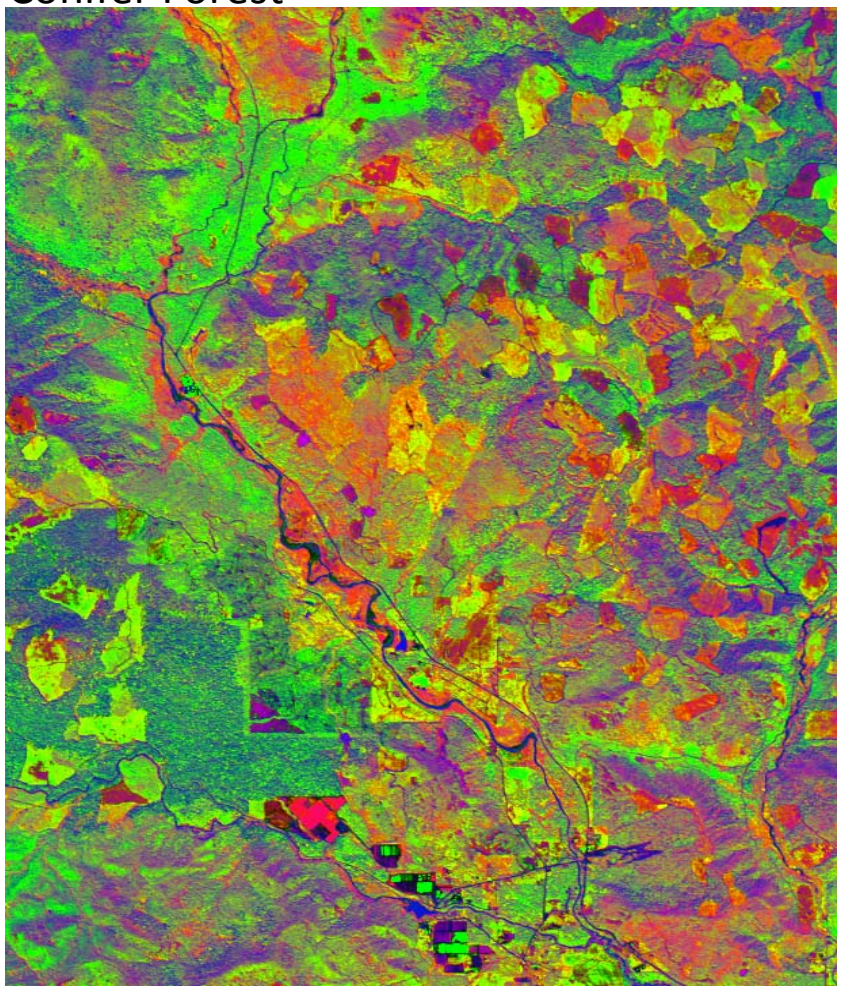
Diffuse Light
Moderate Sum/Win Temperatures
High soil moisture & Relative humidity
Closed canopy forests

Direct Light
Lower winter temperatures
Low summer soil moisture & Relative Humidity
Open canopy forests

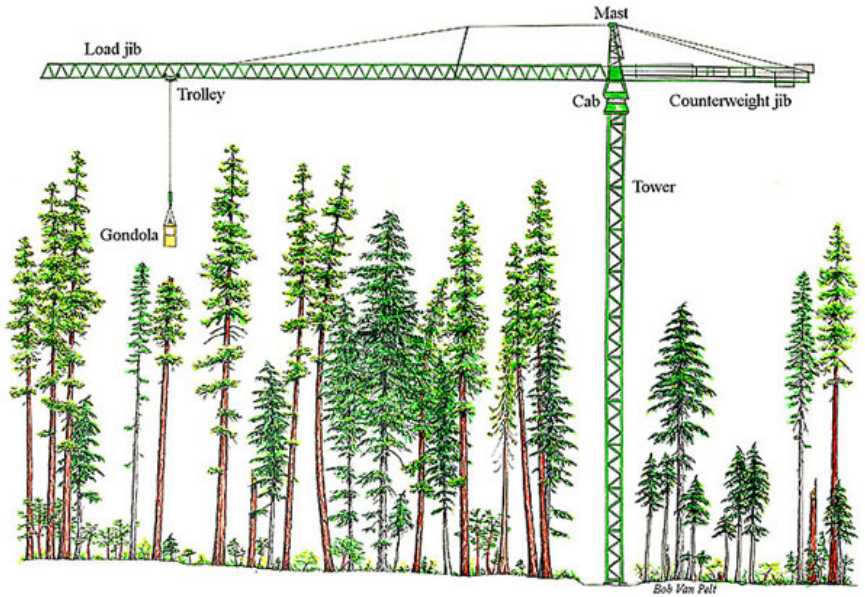
Reflectance Changes with Age Class & Species Mixtures

Wind River Canopy Crane Site, Carson, WA

Age class distributions from newly harvested to 500+ yr “old growth” Conifer Forest

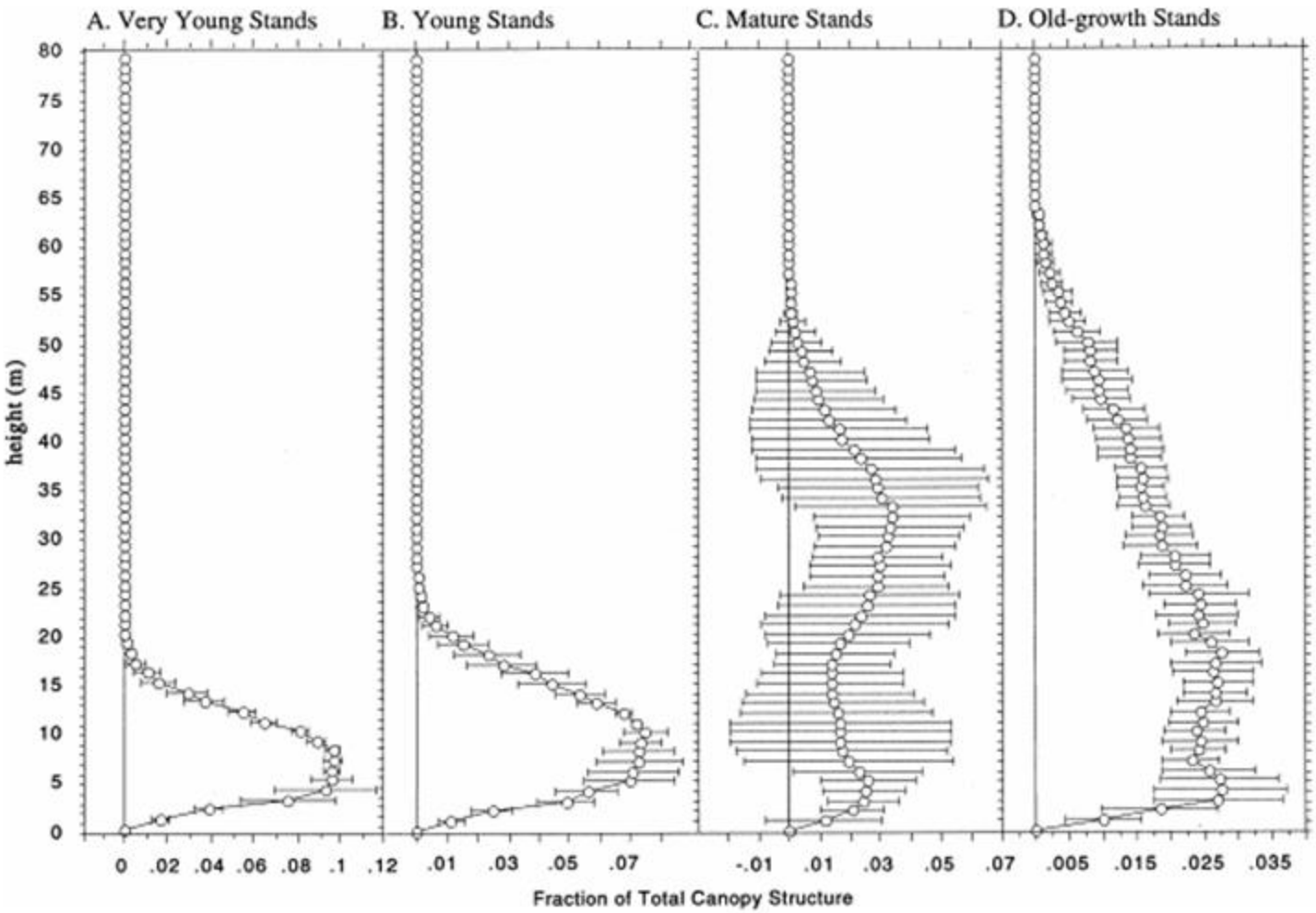


R= soil, G=vegetation, B=shade



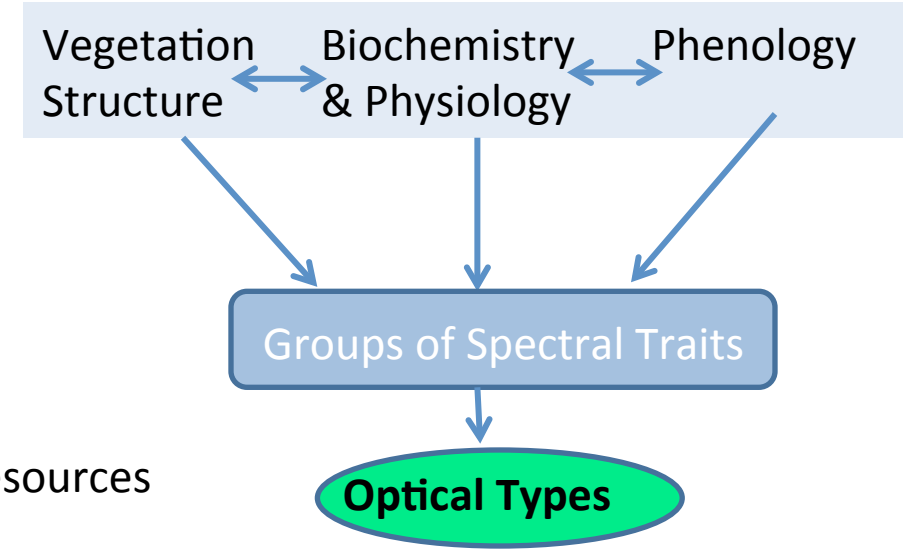
Remnants of the Southern Gondwana Flora in Australia & New Zealand

Distribution of Canopy Cover with Height at Canopy Crane Site: Changing Light Conditions



The Concept of Mapping Leaf Optical Types: An Alternative to Mapping Functional Types

- Assumes a Limited Range of Optimizing Strategies to Respond to Environmental Conditions
- Based on Theory of Functional Convergence



Ustin & Gamon, 2010 New Phytol.

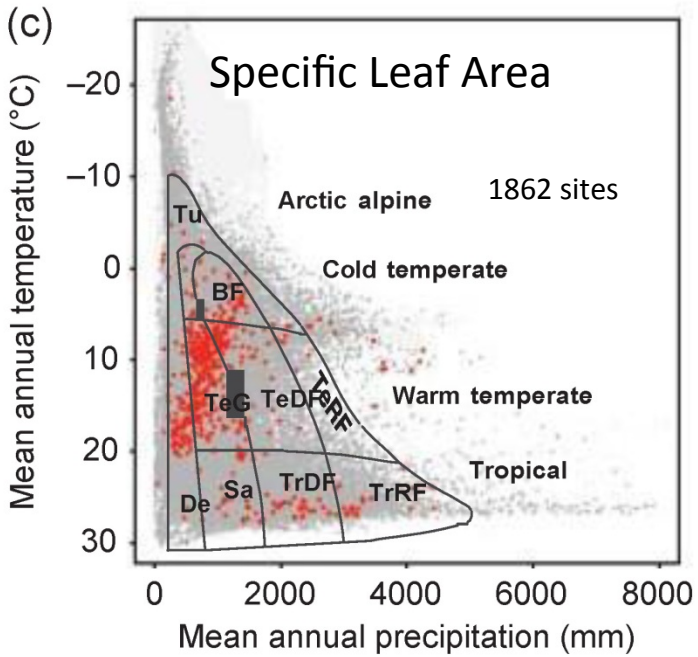
Optimize: Light harvesting, water and nutrient resources for given climate conditions

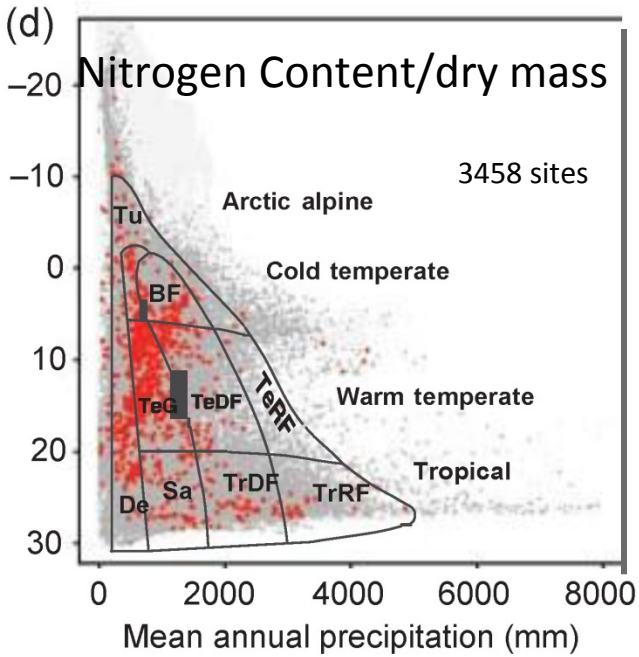
Detectable Optical Properties Using Imaging Spectroscopy

Leaf area index
Leaf Mass Area (=1/SLA)
Chlorophyll and Carotenoid Pigments
Canopy Water Content
Xanthophyll pigments
Leaf Longevity
Leaf Nitrogen
Ligno-cellulose

These Optical Properties are consistent with Generalized Leaf Trait Literature developed over the past decade.

Relationships between Climate Space and Specific Leaf Area (SLA) and N Content/dry mass





Whittaker Biome Types:

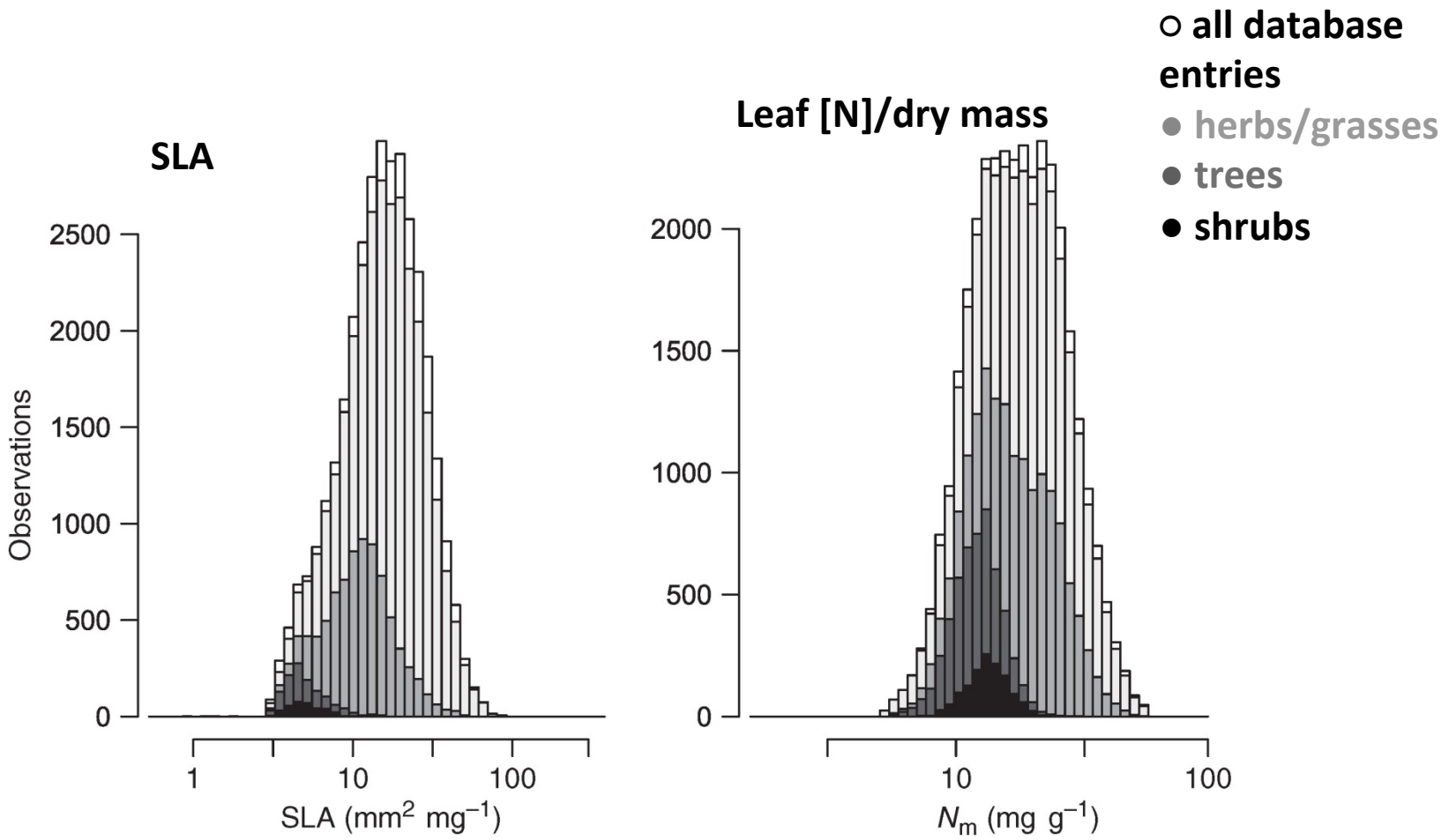
Tu: Tundra
BF: Boreal Forest
TeG: Temperate Grassland
TeDF: Temp. Deciduous Forest
TeRF: Temp. Rain Forest
TrDF: Tropical Deciduous Forest
TrRF: Tropical Rain Forest
Sa: Savanna
De: Desert

- Georeferenced in TRY Database (**69,296 species; 93 traits**)
- Global Biodiversity Information Facility Database

Note: SLA = 1/LMA

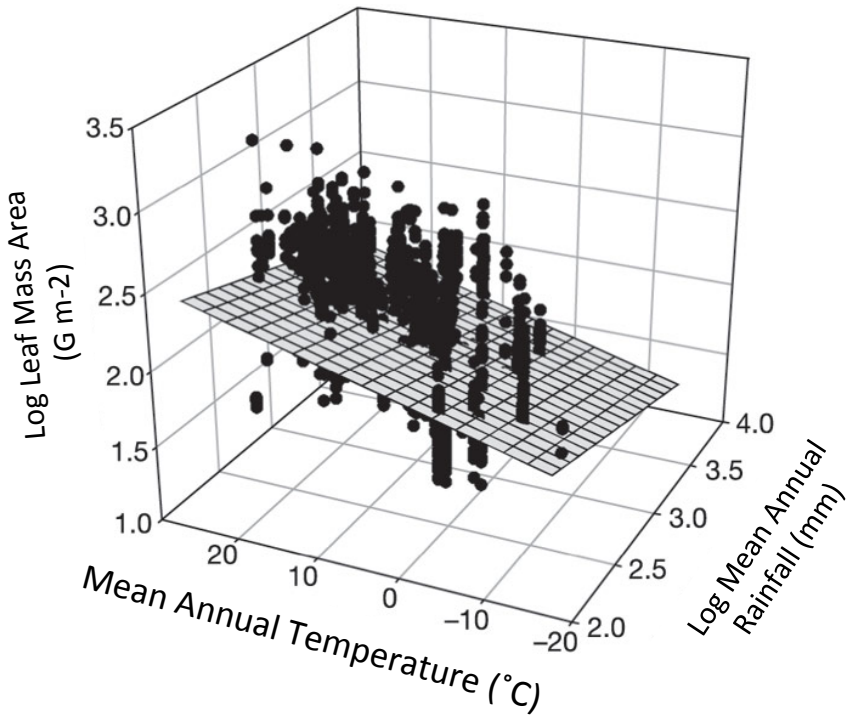
J . KATTGE & 134 others, 2011. TRY – A Global Database of Plant Traits. Global Change Biology (2011) 17, 2905–2935

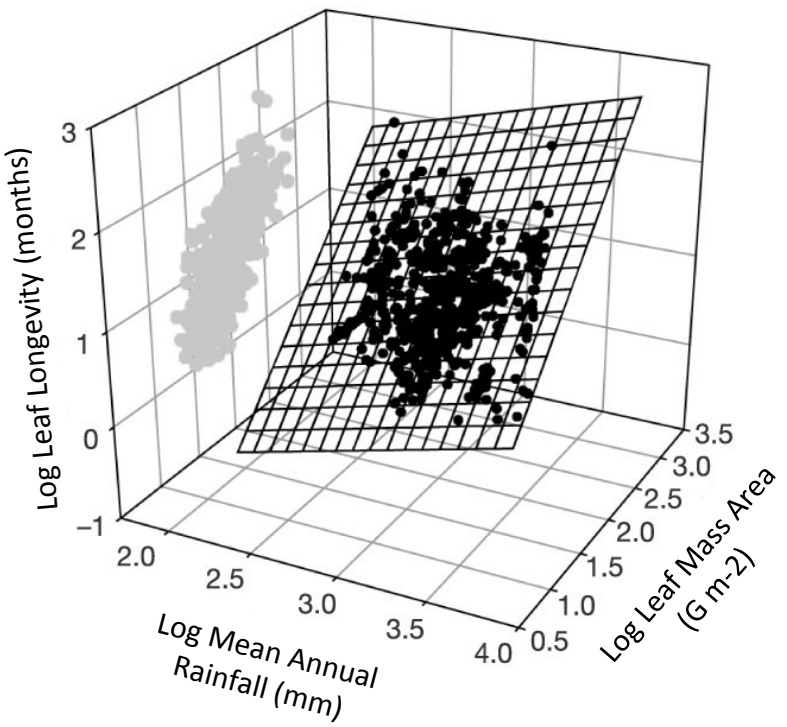
Trait Frequency Distributions for Specific Leaf Area (SLA) and Leaf Nitrogen



J . KATTGE & 134 others, 2011. TRY – A Global Database of Plant Traits. Global Change Biology (2011) 17, 2905–2935

A Global Universal Spectrum of Leaf Economics: Key Co-Varying Structural and Physiological Properties



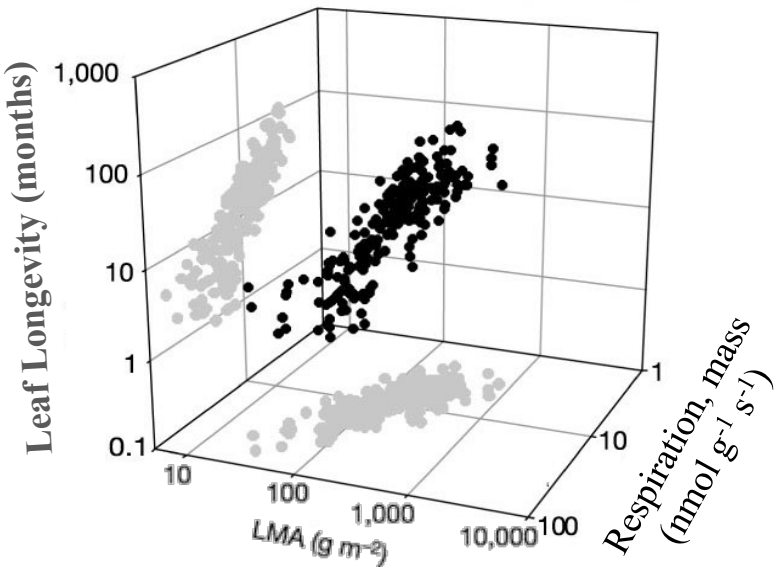


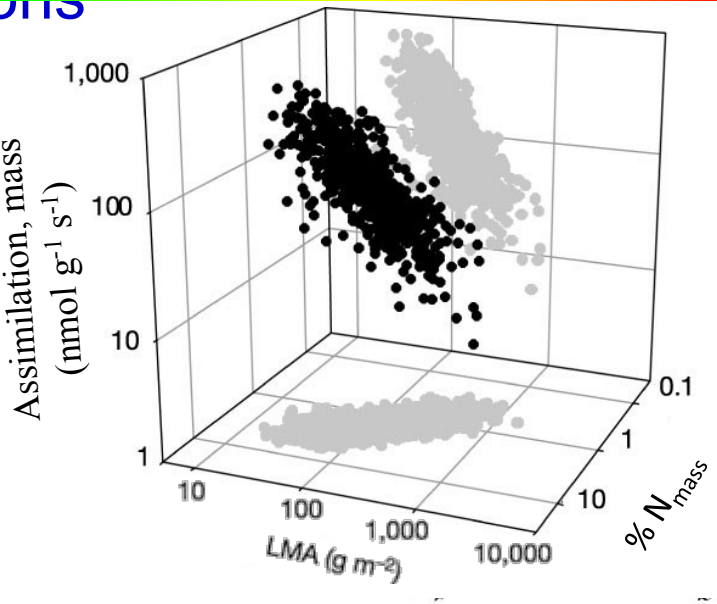
Traits vary from fast to slow return on investments in nutrients and dry mass in leaves, and operate largely independently of growth form, PFT or biome

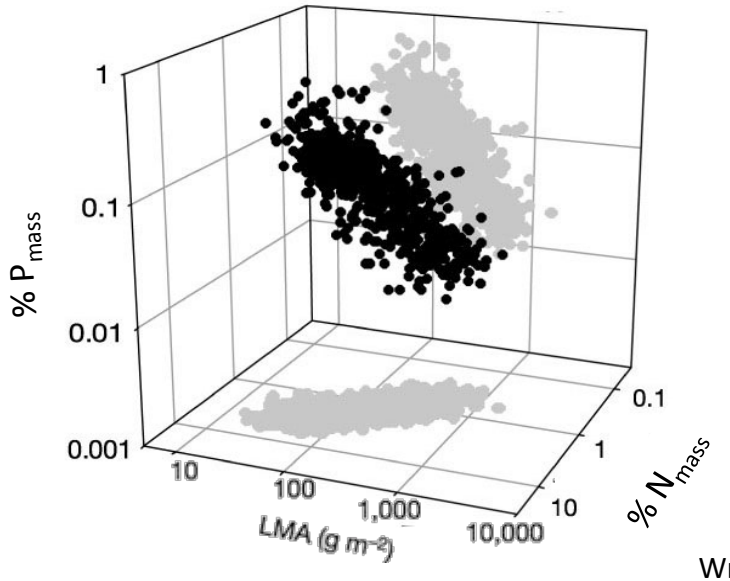
>2500 species from 175 global sites

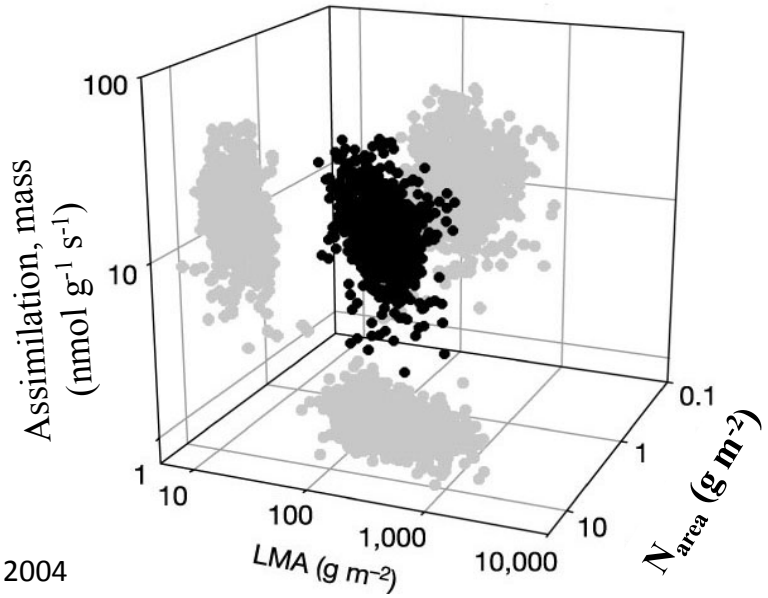
Wright et al. Nature, 2004

Leaf Investment Strategies are Largely Arrayed Along A Single Spectrum, With a Globally Consistent Pattern of Trait Correlations



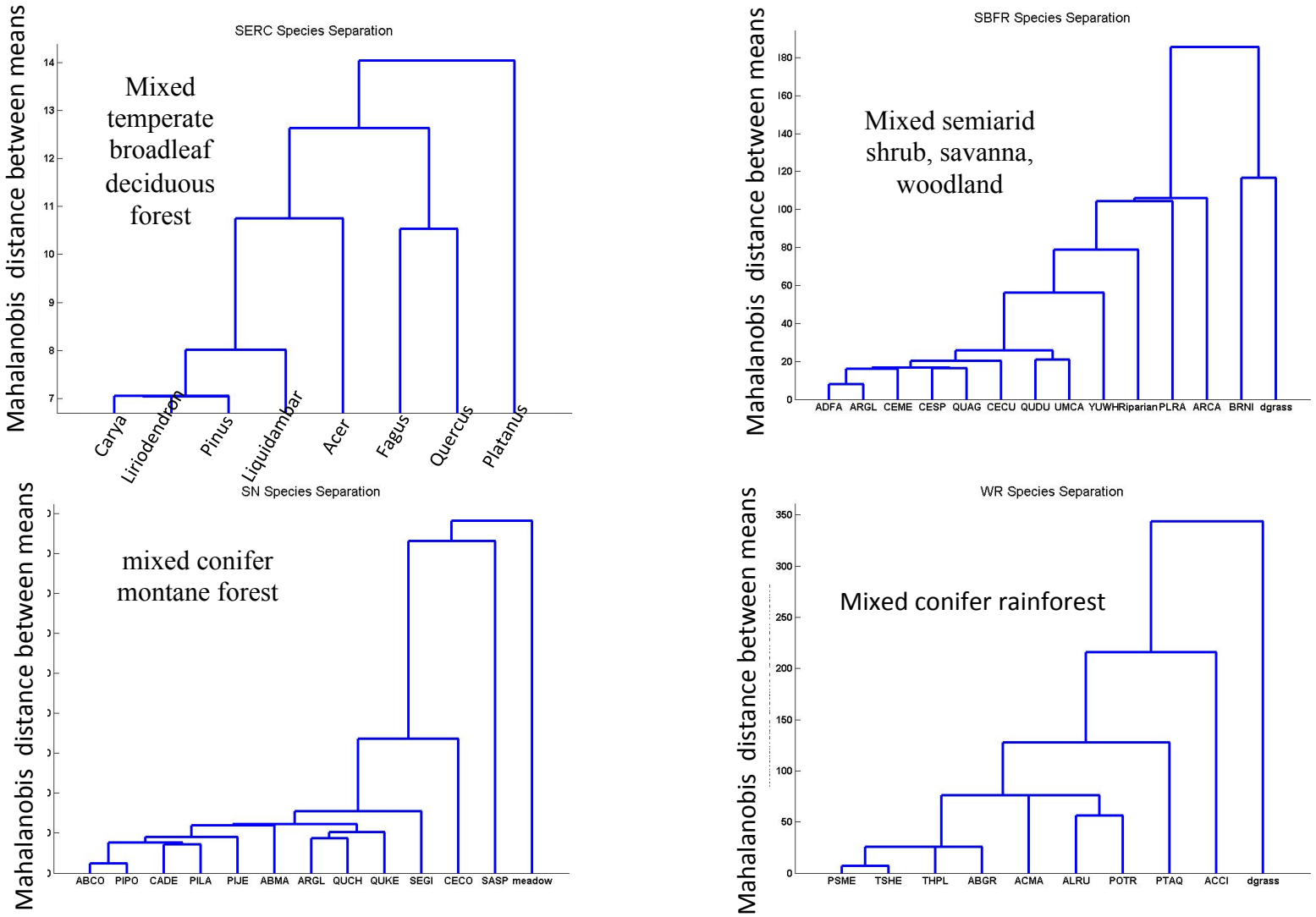






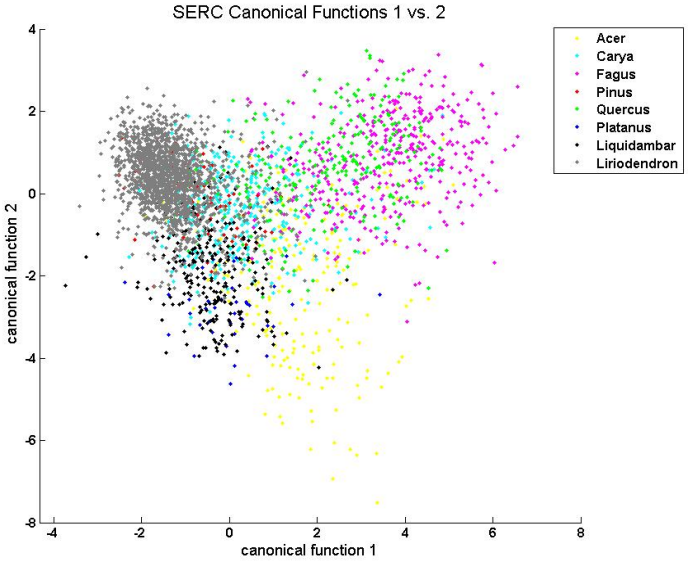
Wright et al. Nature, 2004

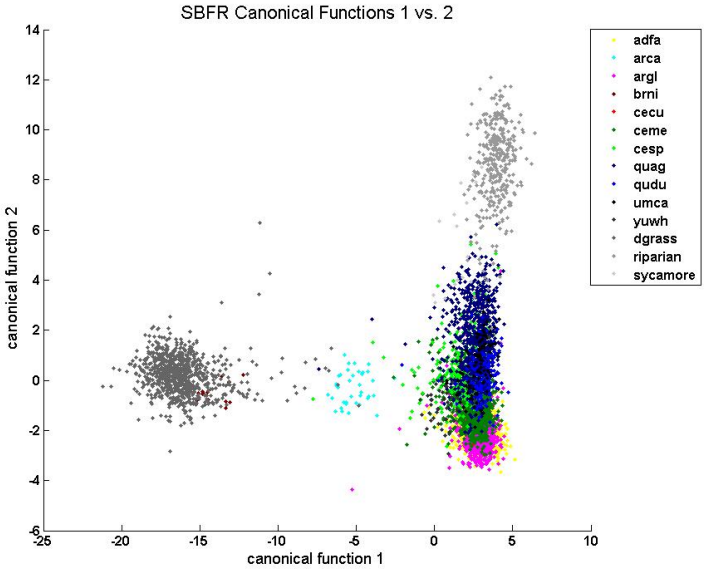
Species Clusters based on Spectral Similarity by Site

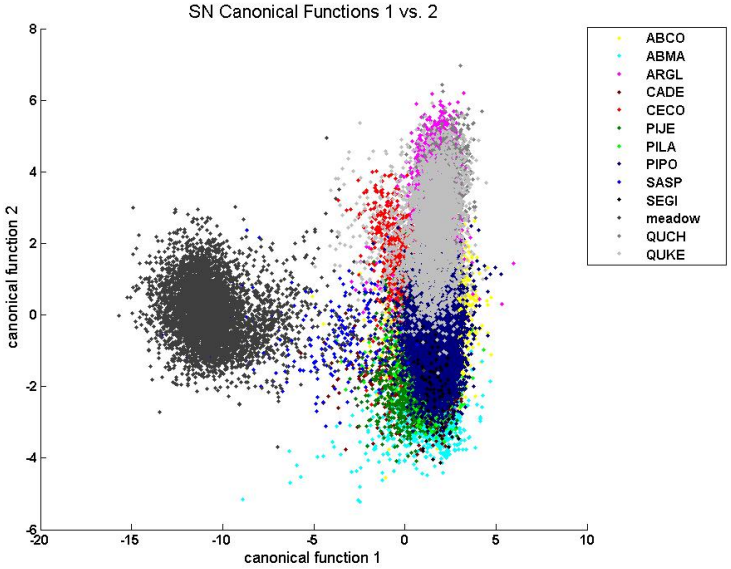


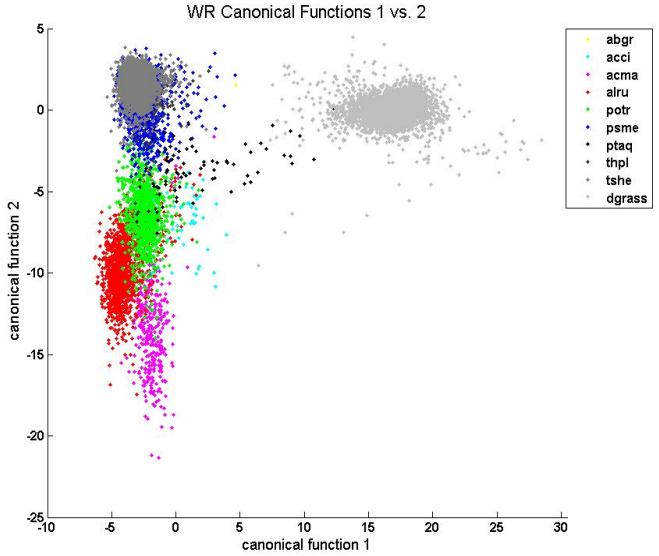
Keely L. Roth, Dar A. Roberts, Philip E. Dennison, and Michael Alonzo, IGARSS 2012

Canonical Discriminant Analysis Results



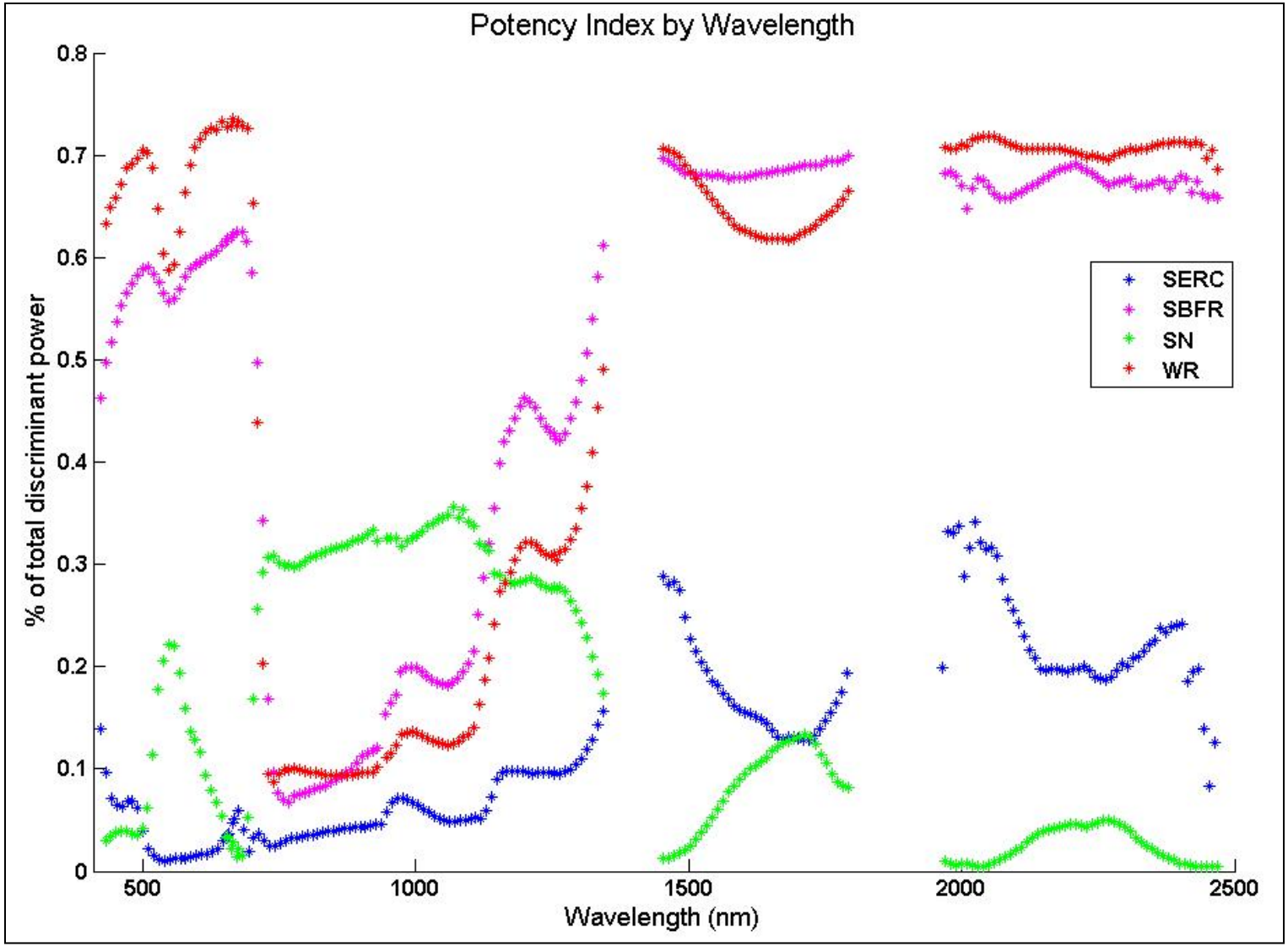






Roth, K.L., Roberts, D.A., Dennison, P.E. and Alonzo, M. (2012, July). *Discriminating plant species across diverse ecosystems with imaging spectroscopy*. Paper presented at the IEEE International Geoscience and Remote Sensing Symposium, Munich, Germany.

Canonical Discriminant Analysis Potency Index



Keely L. Roth, Dar A. Roberts, Philip E. Dennison, and Michael Alonzo, IGARSS 2012

Questions?

Model of Proposed HyspIRI Satellite

IMPROVING ECOLOGICAL FORECASTING WITH HYPERSPECTRAL DATA: A DATA ASSIMILATION SYSTEM FOR THE COMMUNITY LAND MODEL

Andy Fox[1], Tim Hoar[2] & Dave Schimel[3]

1. National Ecological Observatory Network
2. National Center for Atmospheric Research
3. Jet Propulsion Laboratory

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Ecological forecasting

1. **Predicting the most likely future state of an ecological system**
   i. Relevant for short-term forecasts
   ii. Systems own dynamics most strongly govern change over time
   iii. i.e. forecasting the likely spread of invasive species

2. **Predicting the most likely future state, given a decision today**
   i. Relevant when alternate management actions or scenarios are considered
   ii. i.e. forecasting likely impacts on biodiversity from alternate wildfire mitigation schemes

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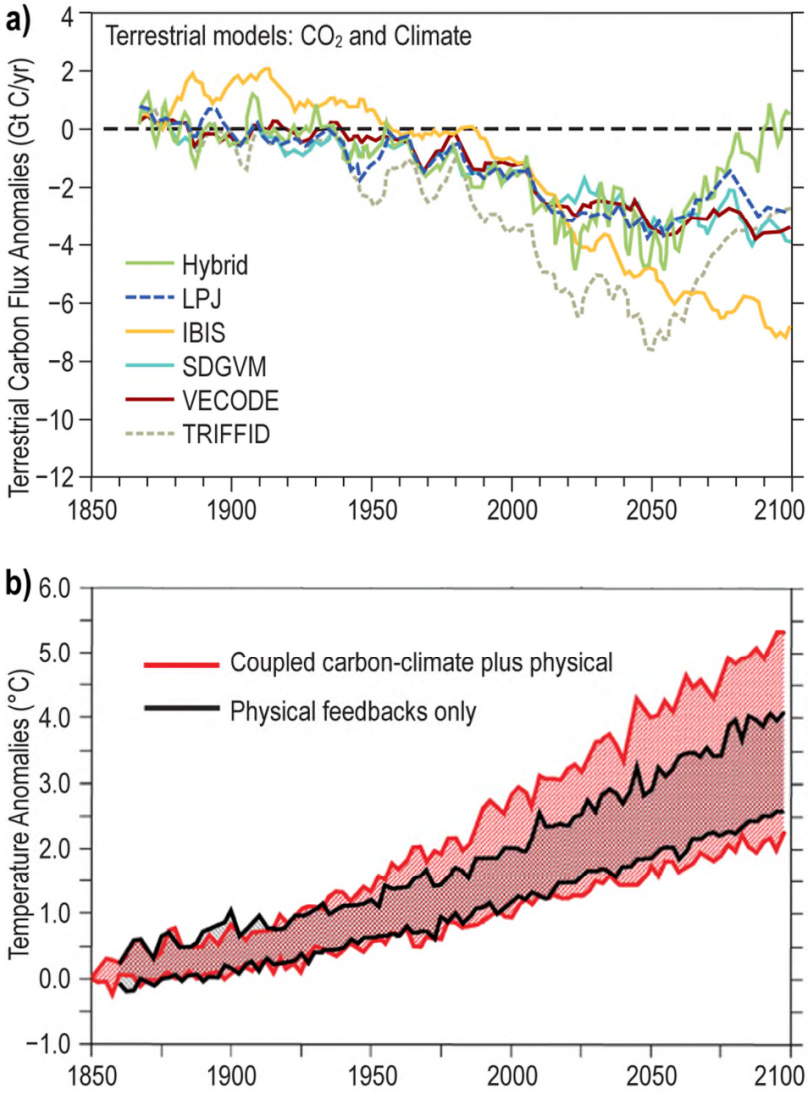
Coupled carbon-climate models

- Uncertainty in carbon cycle feedbacks roughly doubles climate uncertainty for any given emission pathway
- Most of this uncertainty is associated with responses of the terrestrial biosphere

- This uncertainty stems from
  - i. **Structural uncertainty**
  - ii. **Parameter uncertainty**
  - iii. **Initial conditions uncertainty**
  - iv. **Boundary conditions uncertainty**



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Is biodiversity of vegetation a problem?

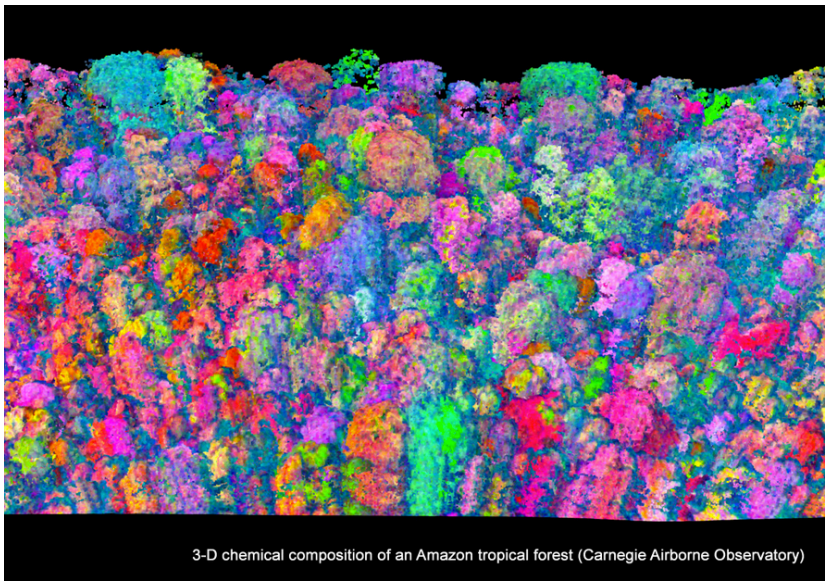
- The c. 300,000 vascular plant species represented by c. 20 plant functional types (PFTs)
- Hyperspectral remote sensing allows us to potentially classify many thousands of vegetation categories
- Reveals the detailed biological, functional and structural diversity

i. **Leaf nitrogen** – nutrient status and photosynthetic potential

ii. **Specific leaf area** – fundamental tradeoff in leaf construction and light interception

iii. **Lignin/Cellulose** – Foliar recalcitrance, decomposability and nutrient cycling

iv. $\mathbf{V_{cmax}}$ – photosynthetic capacity of vegetation



3-D chemical composition of an Amazon tropical forest (Carnegie Airborne Observatory)

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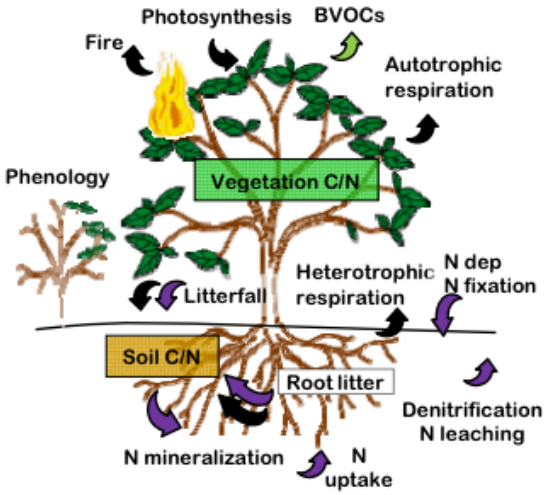
Canopy parameters control biogeochemistry

Photosynthesis

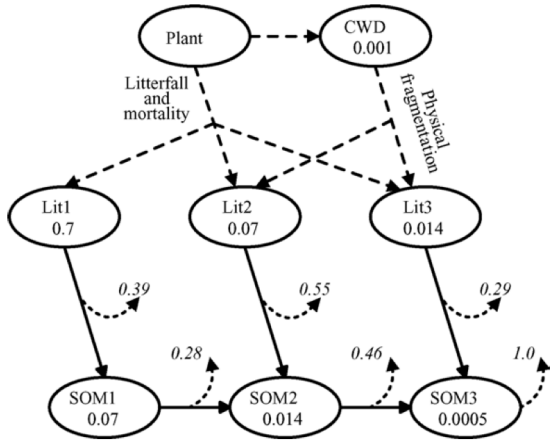
$$V_{cmax} = f(N_a F_{LNR})$$
$$N_a = f(CN_L SLA)$$

- N_a - Leaf nitrogen concentration
- F_{lnr}– Fraction of leaf N in rubisco
- CN_L – Leaf C:N ratio
- SLA – Specific leaf area: top of canopy



Respiration

- 3 litter pools, 3 soil organic matter pools and coarse wood debris pool in converging cascade
- Approximate labile, cellulose and lignin
- LF_{flig} – leaf litter lignin fraction
- LF_{fcel} – leaf litter cellulose fraction



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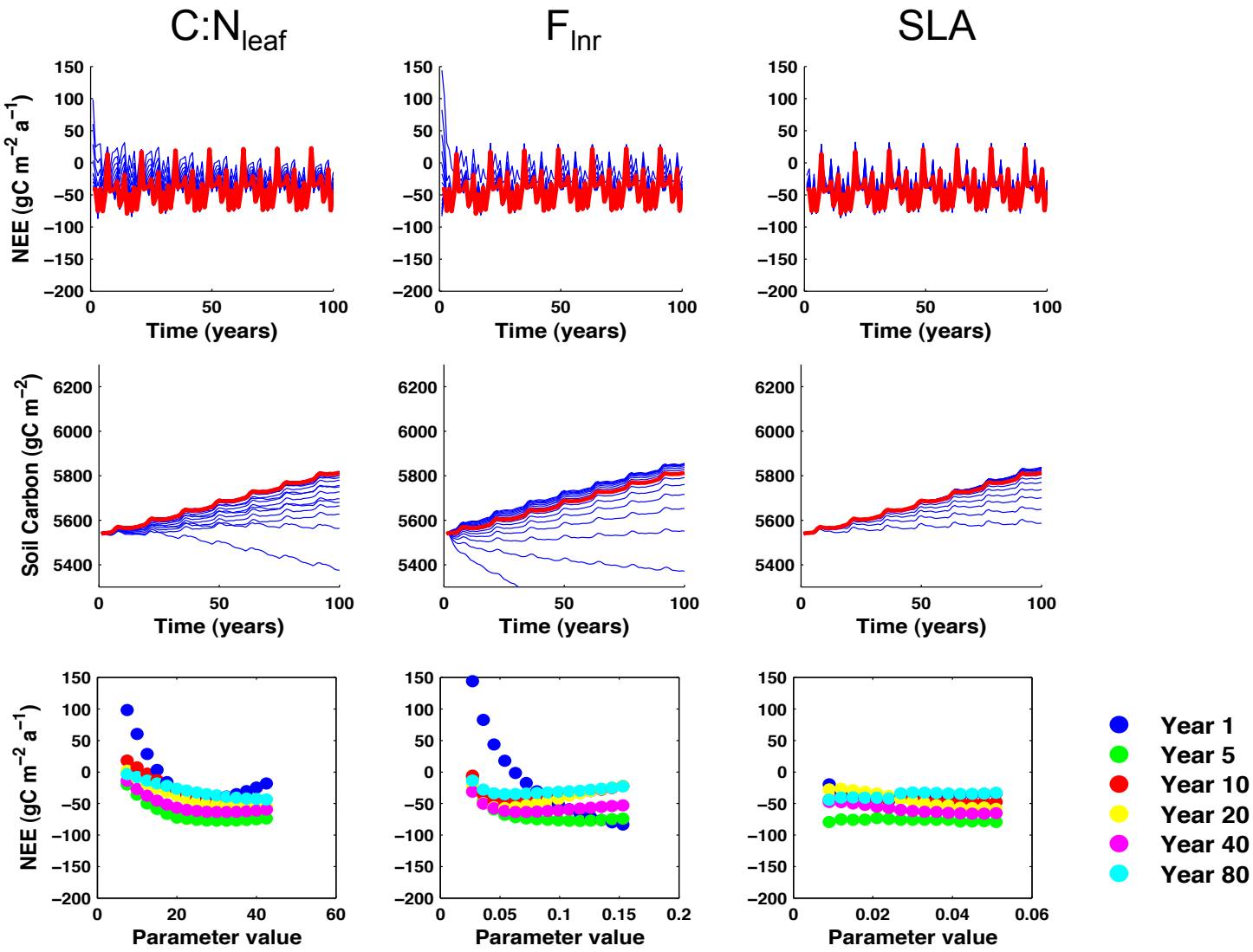
Sensitivity to canopy chemistry parameters



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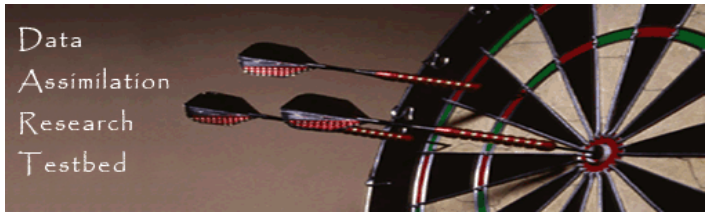
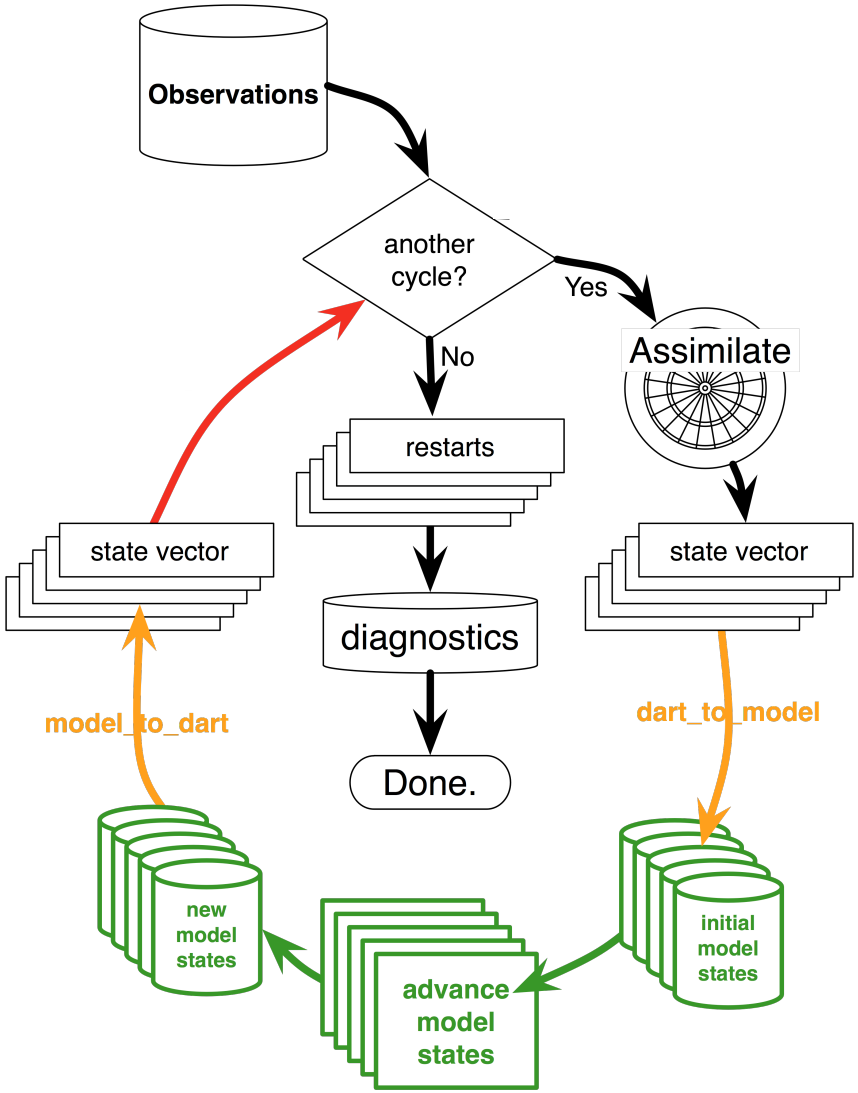
Data Assimilation Research Testbed (DART)

- DART is a community facility for ensemble DA
- Uses a variety of flavors of filters
  - Ensemble Adjustment Kalman Filter
- Many enhancements to basic filtering algorithms
  - Adaptive inflation
  - Localization
- Uses new multi-instance capability within CESM





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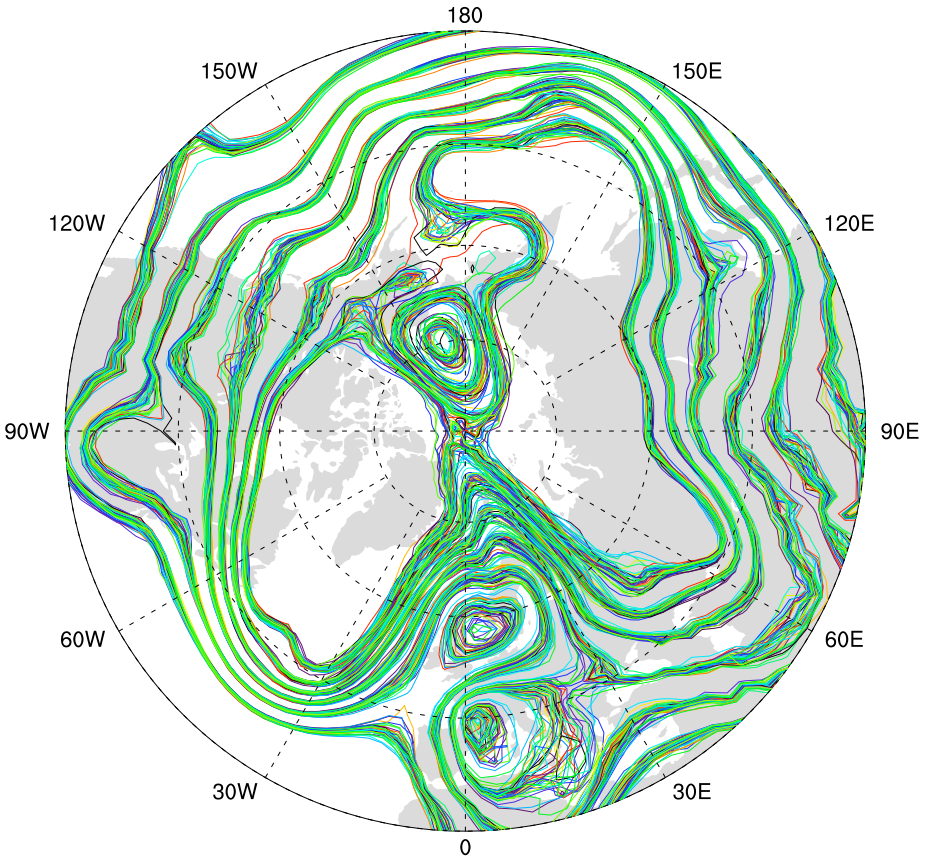
Observing system simulation experiment

- 80 member, 6 hourly climate reanalysis available, 1998 – 2010
- Each forces separate CLM ensemble member at 1° x 1°
- Generates spread in the land model states
- At 60 NEON sites observe:

i. **Leaf area index**
ii. **Leaf nitrogen concentration**
iii. **Net Ecosystem Productivity**
iv. **Evapotranspiration**

- **175,000 observations a month**



500 hPa GPH
Feb 17 2003

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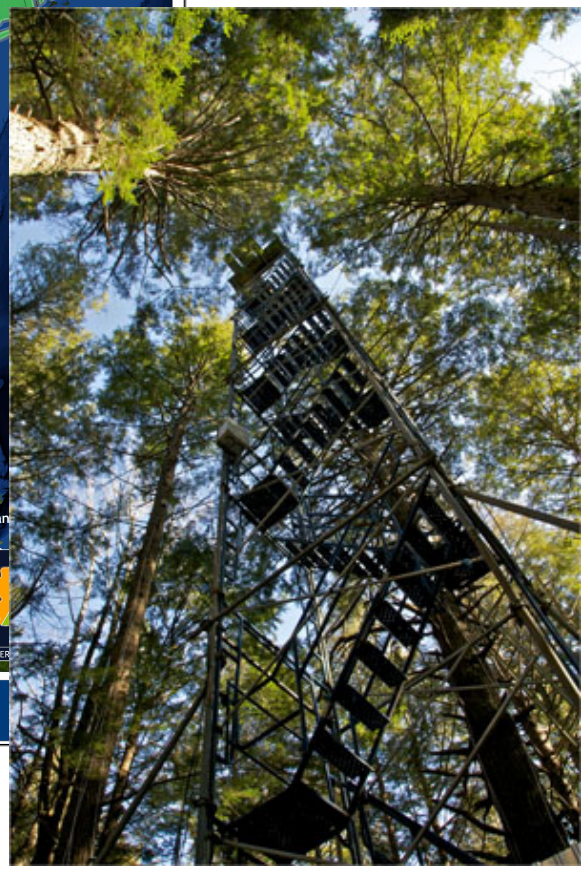
NEON sites and Harvard forest flux tower



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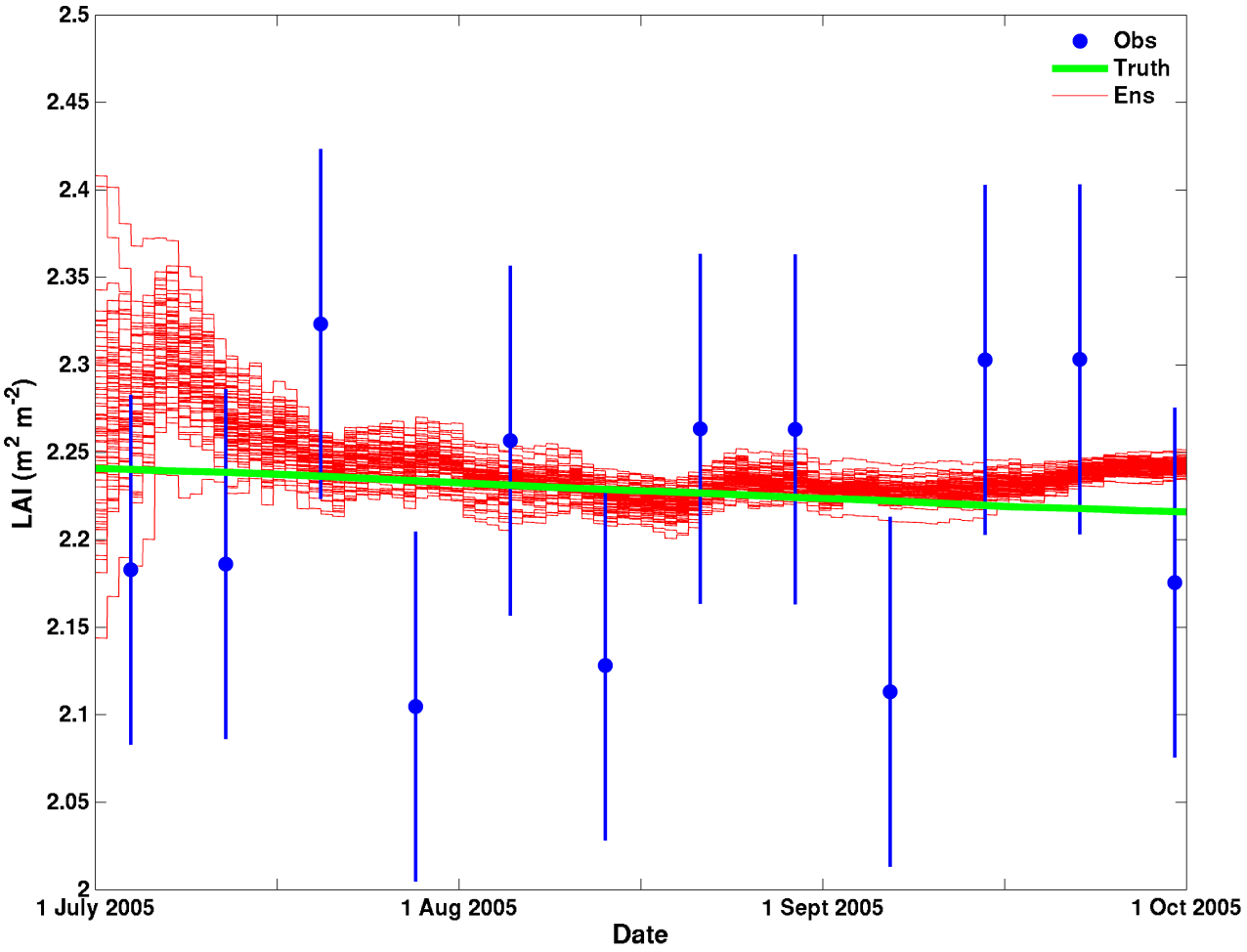
LAI – observations every 8 days



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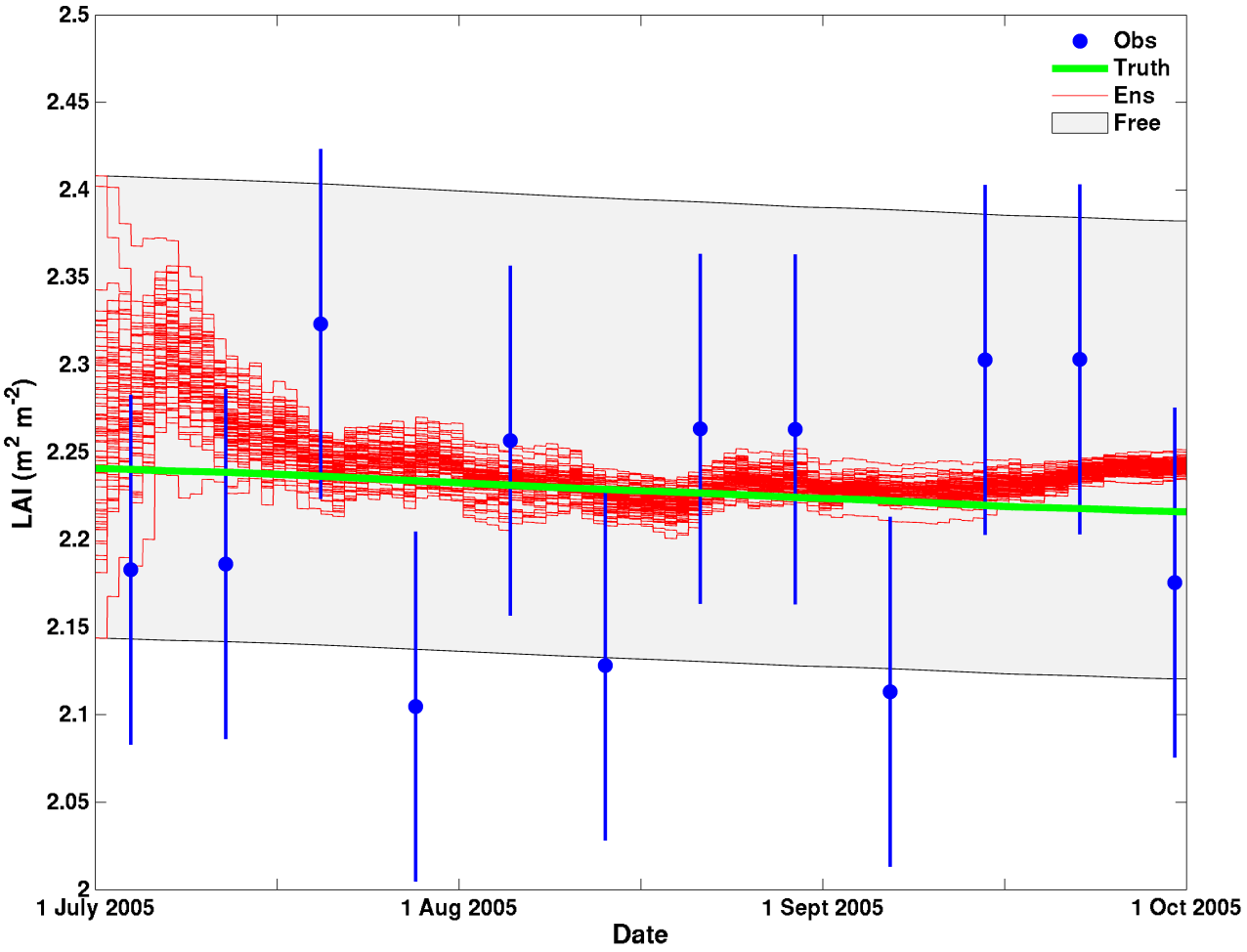
LAI – observations every 8 days



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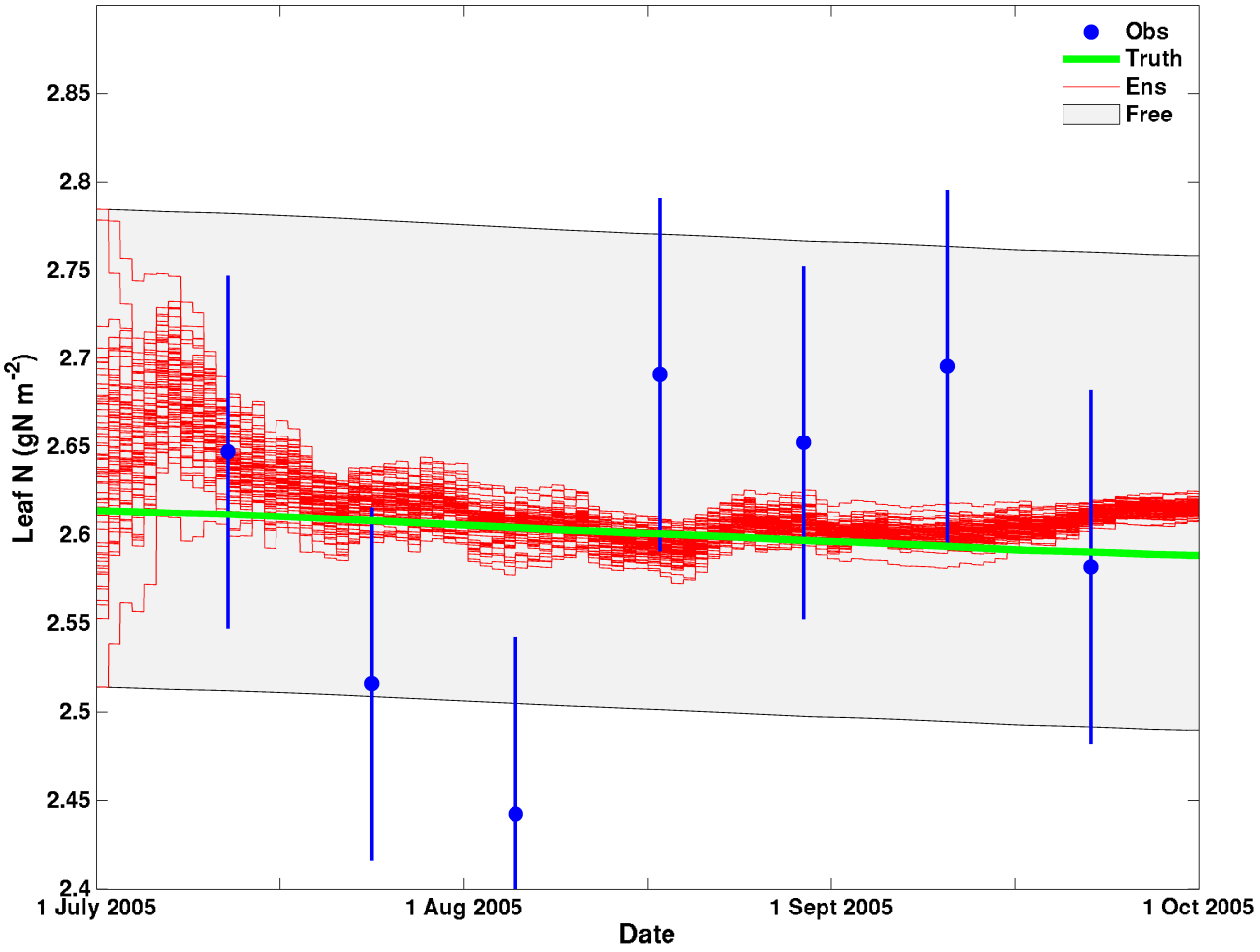
Leaf Nitrogen – observations every 12 days



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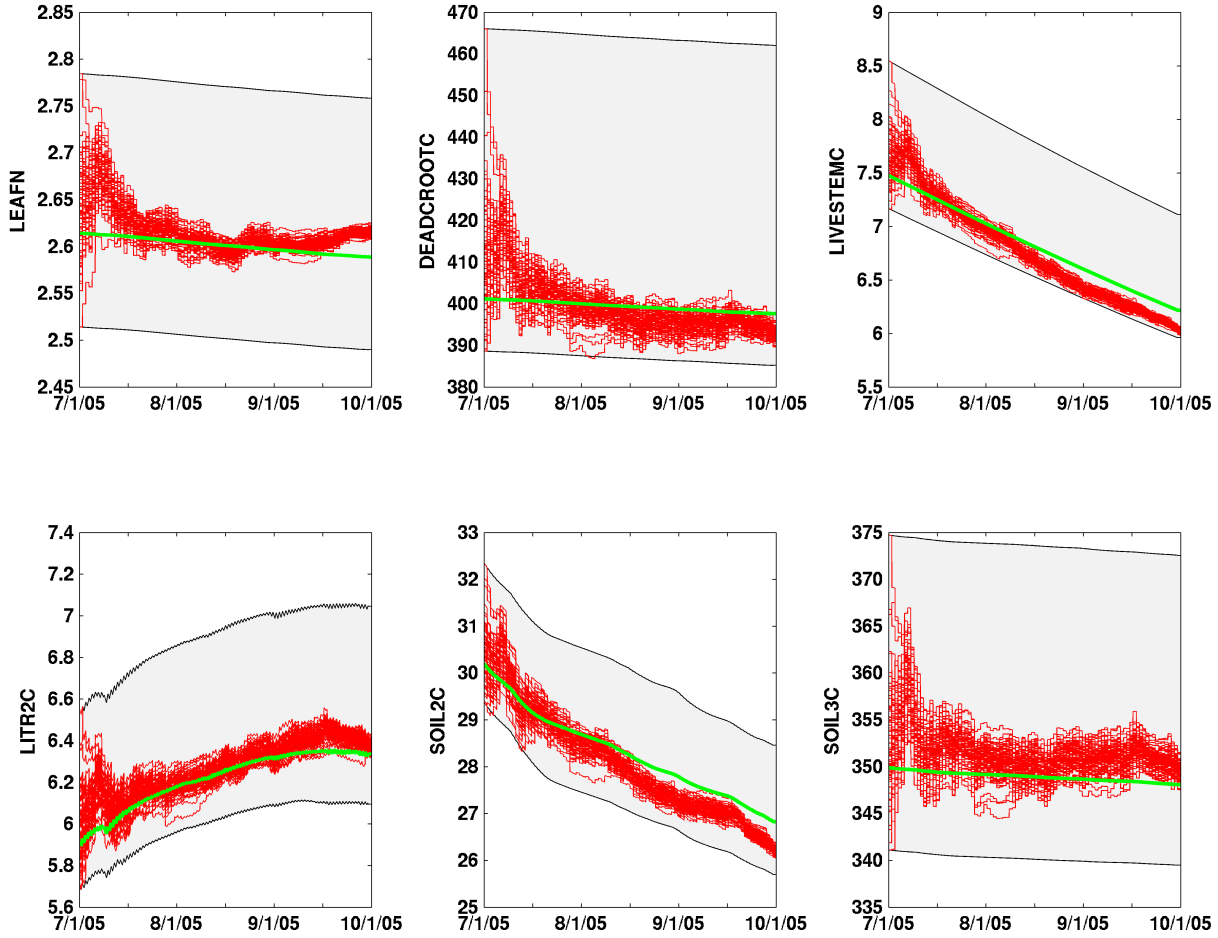
Examples of other N and C pools- unobserved



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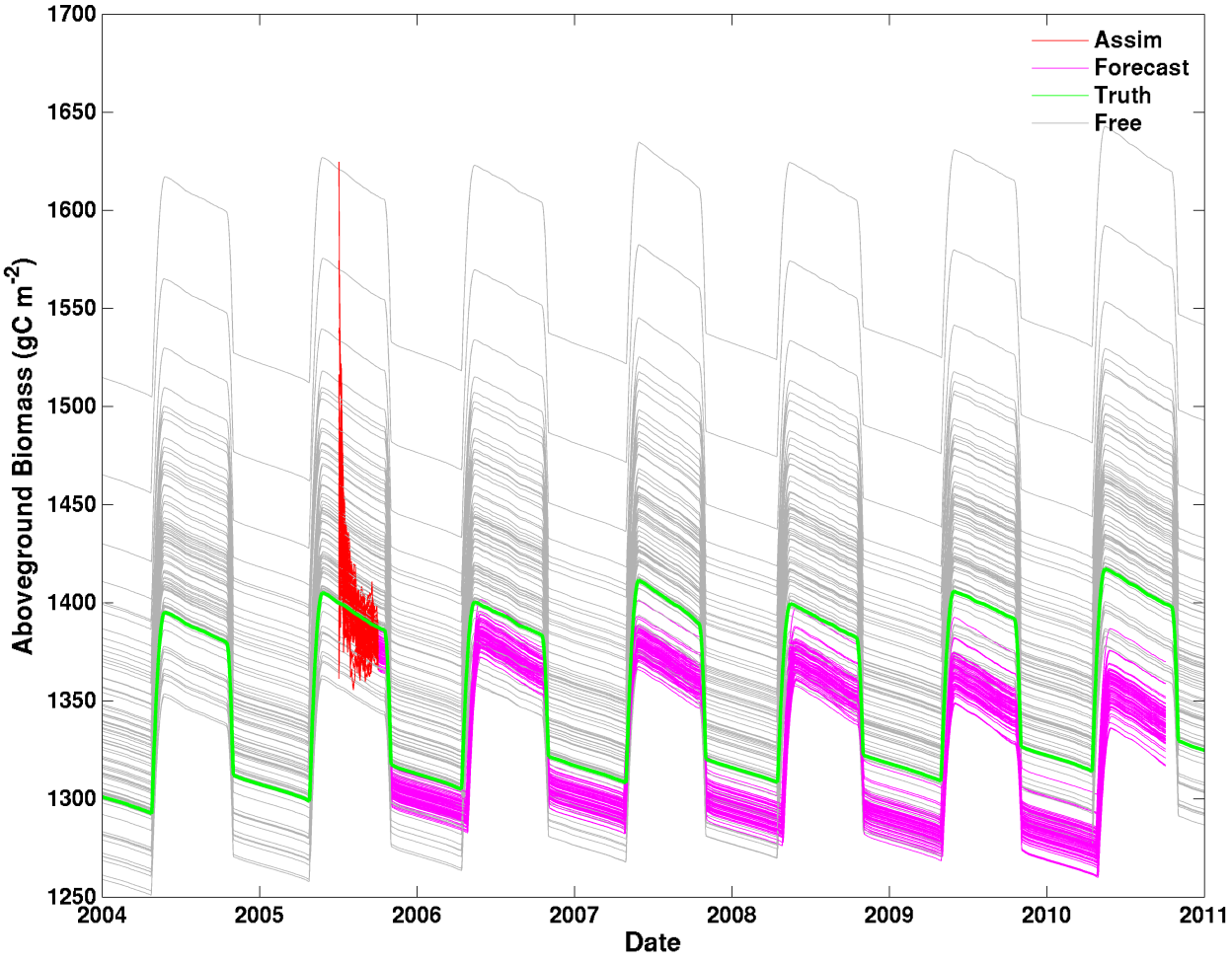
Impact on forecast - biomass



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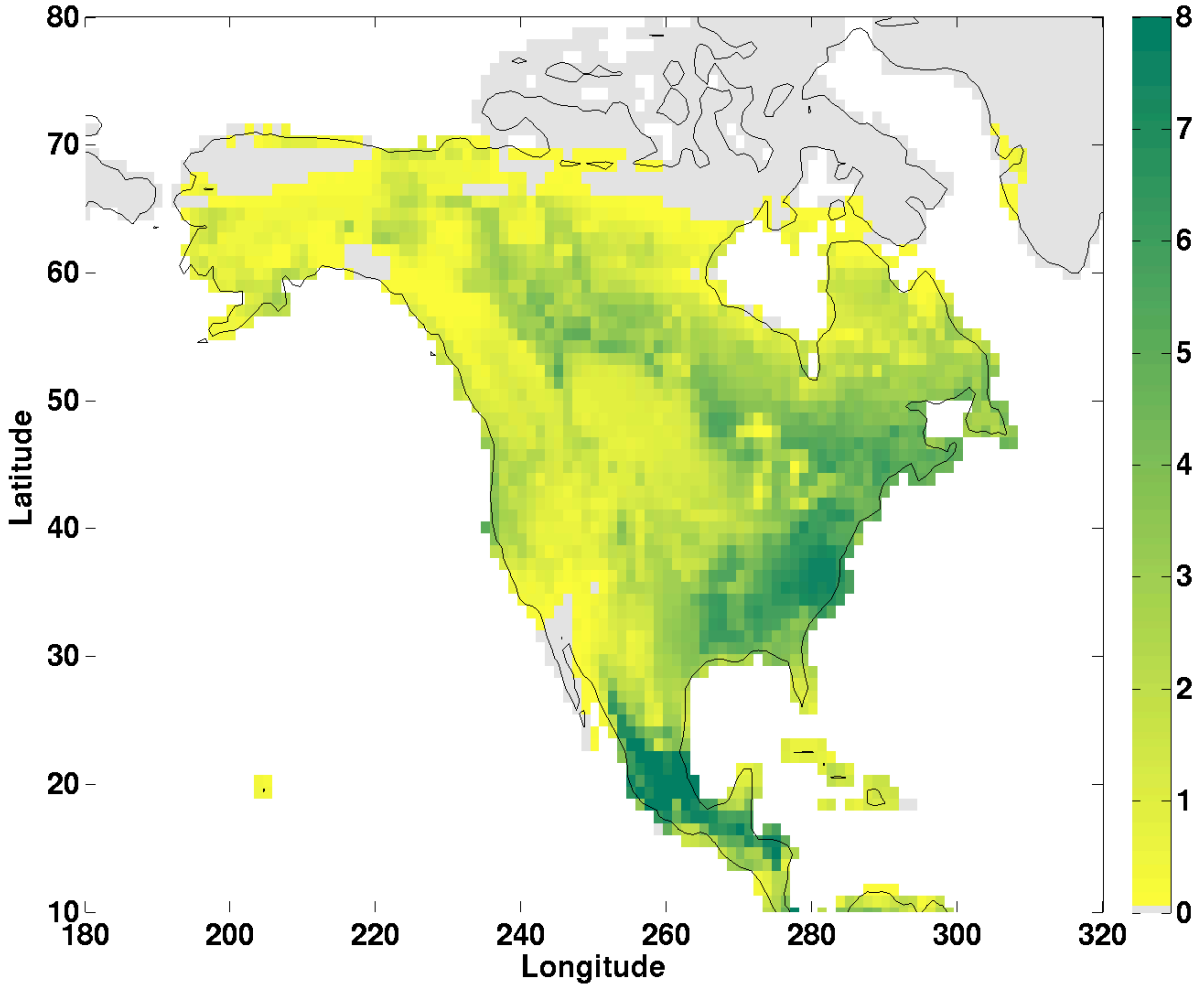
Mean LAI from 80 ensemble members



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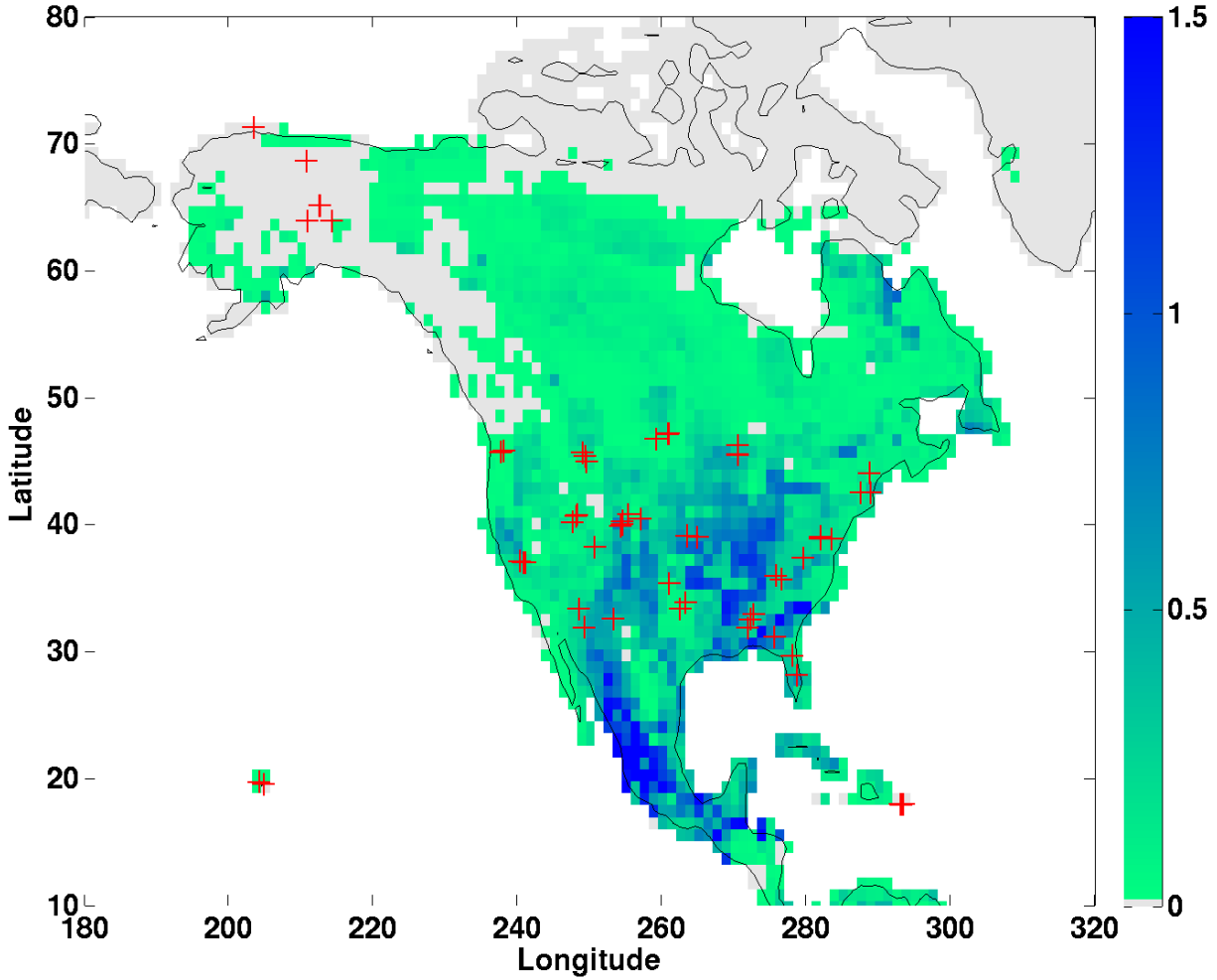
LAI spread from 80 ensemble members



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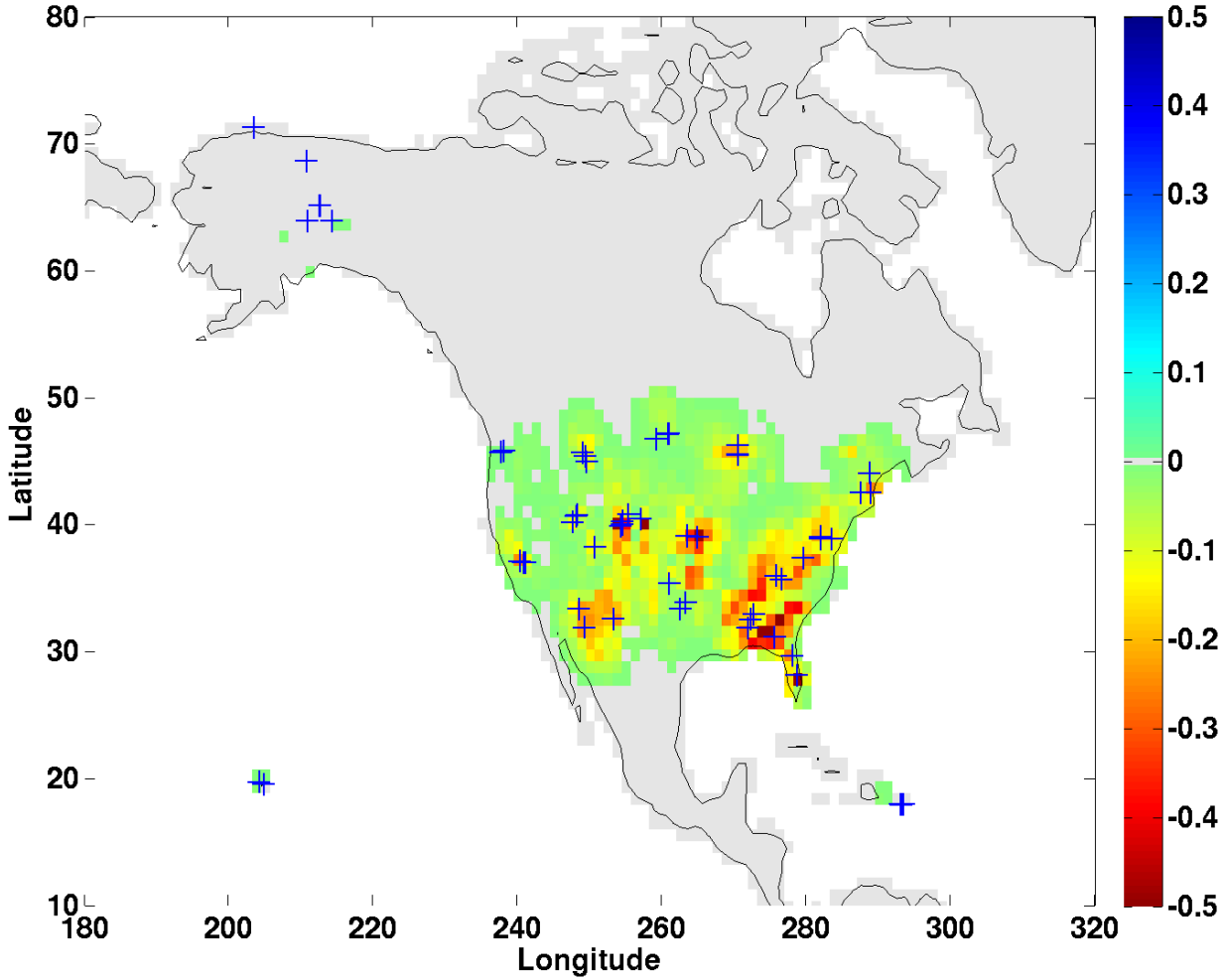
Reduction in LAI ensemble spread



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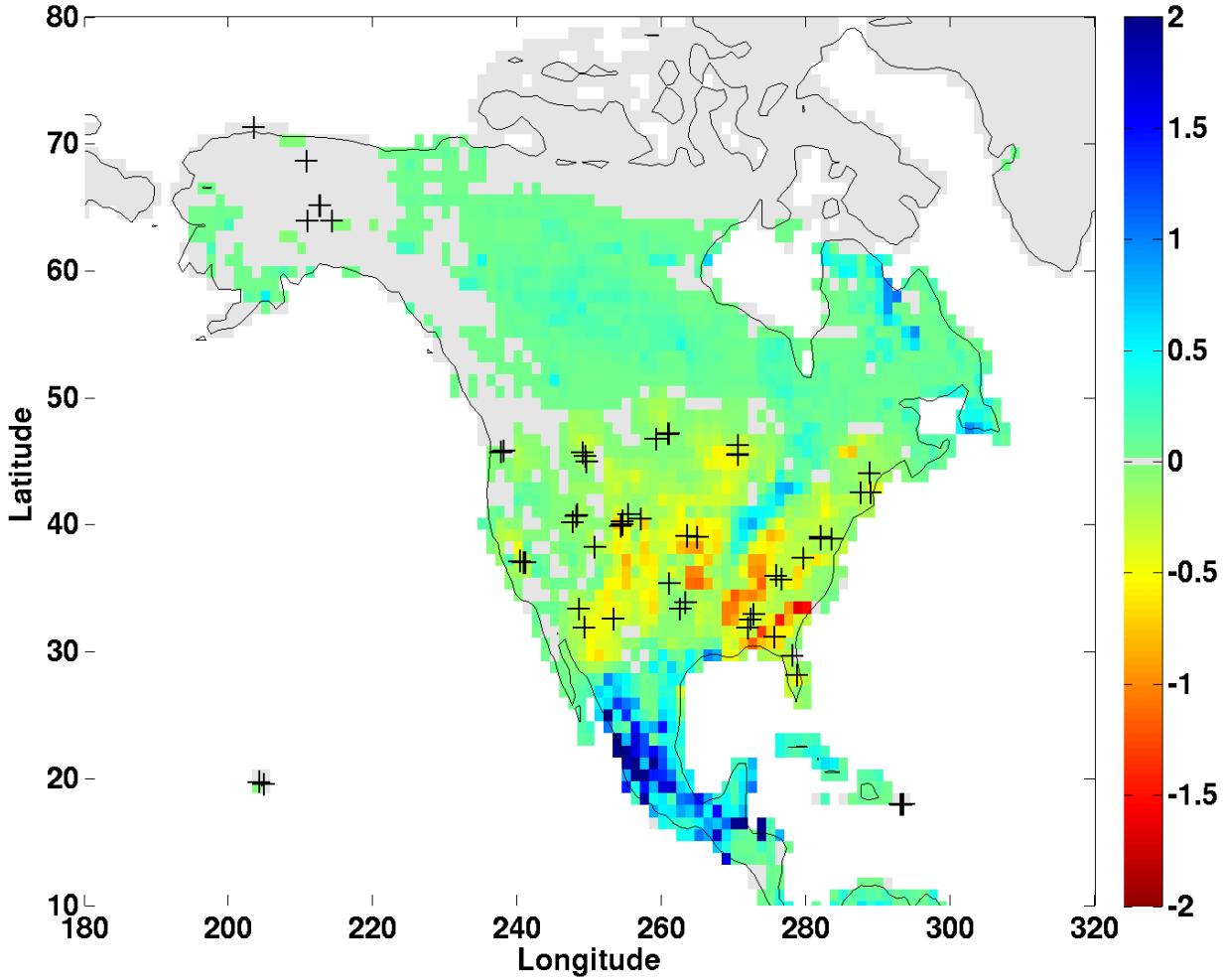
Reduction in LAI ensemble spread



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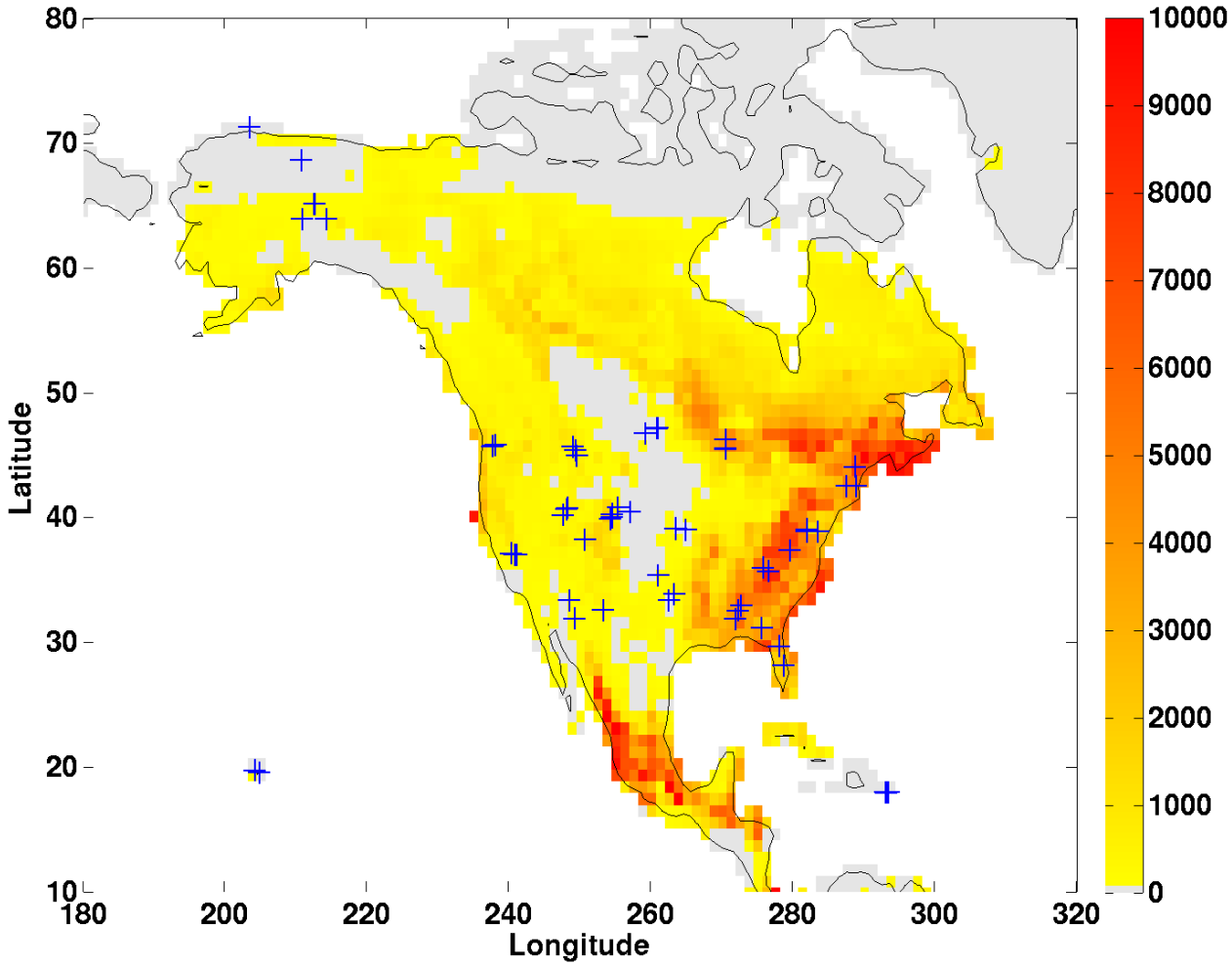
Mean biomass from 80 ensemble members



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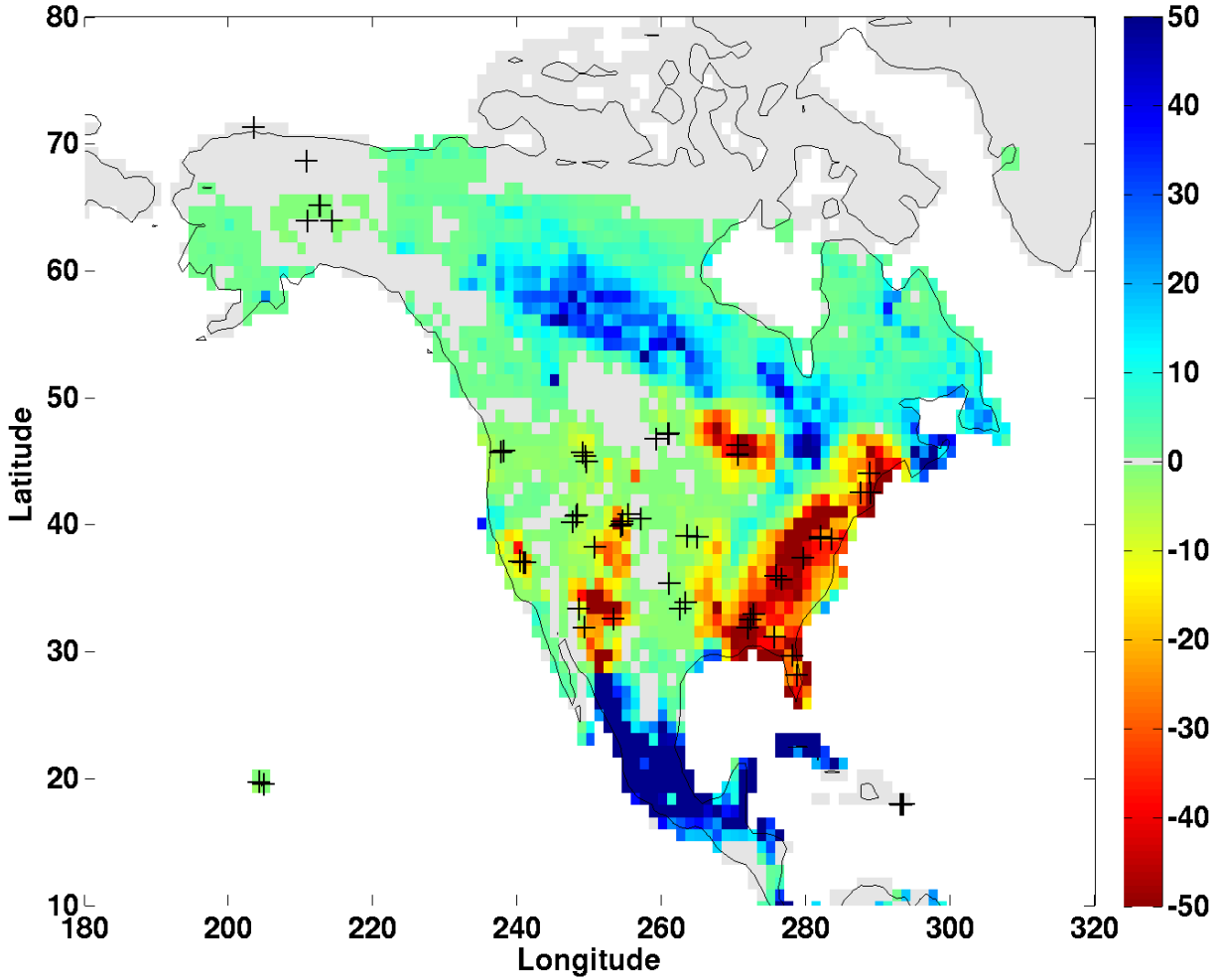
Change in biomass ensemble spread



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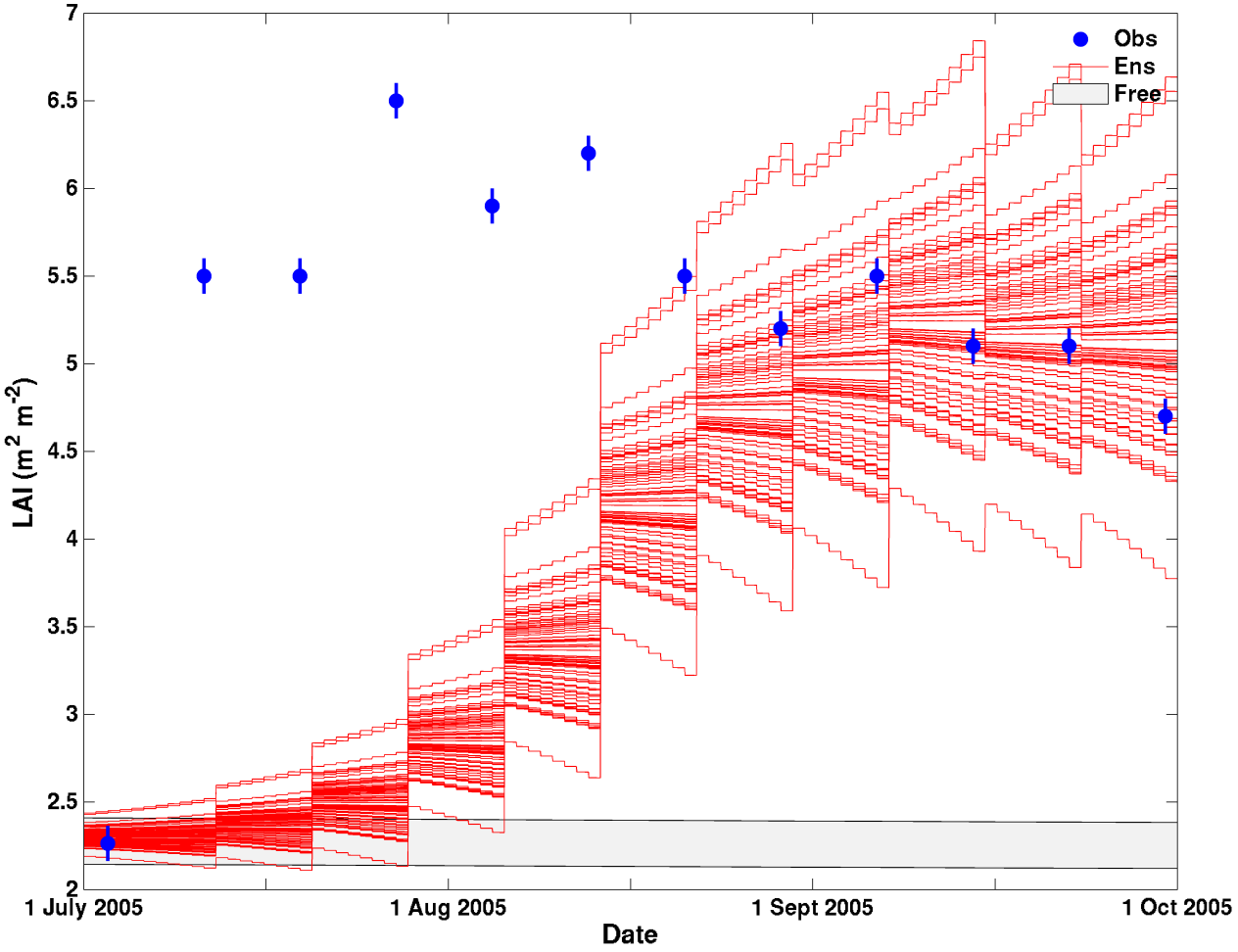
“Real observations” - MODIS LAI



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Summary

- Ecological forecasting is essential to advancing scientific understanding and is a useful societal application of knowledge
- Ecological forecasting requires deterministic knowledge of process, but forecasts should be probabilistic and provide and estimate of uncertainty on future state
- Hyperspectral remote sensing provides detailed biological, functional and structural diversity
- It can classify vegetation, but also provides key information about these categories
- But using this information in complex BGC models is challenging. “Direct replacement” is unlikely to work
- Ensemble data assimilation can account for uncertainties in model and observations, providing probabilistic estimates of future states
- But need to make sure the models are ready for the data

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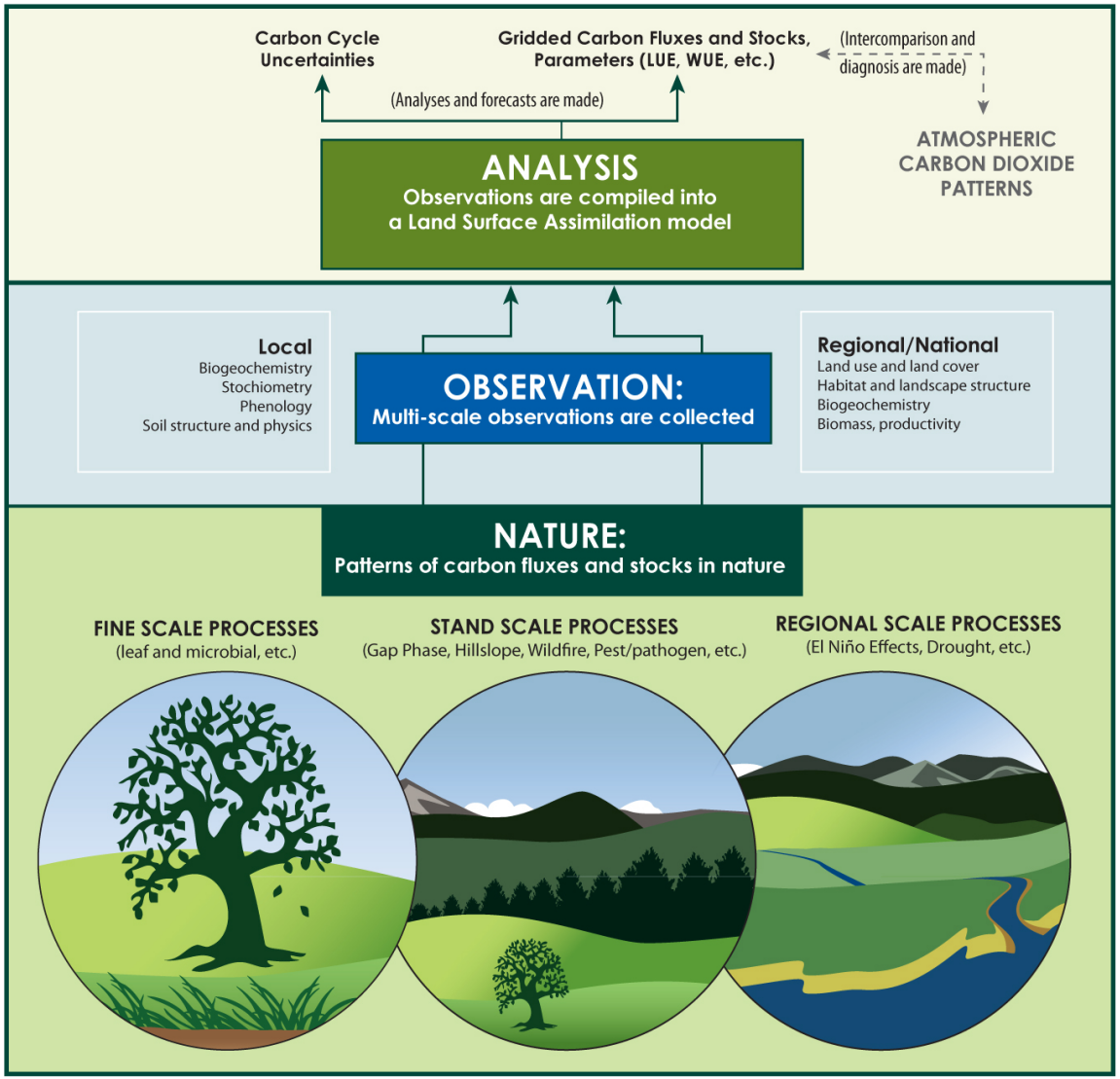
Integrating observations with models



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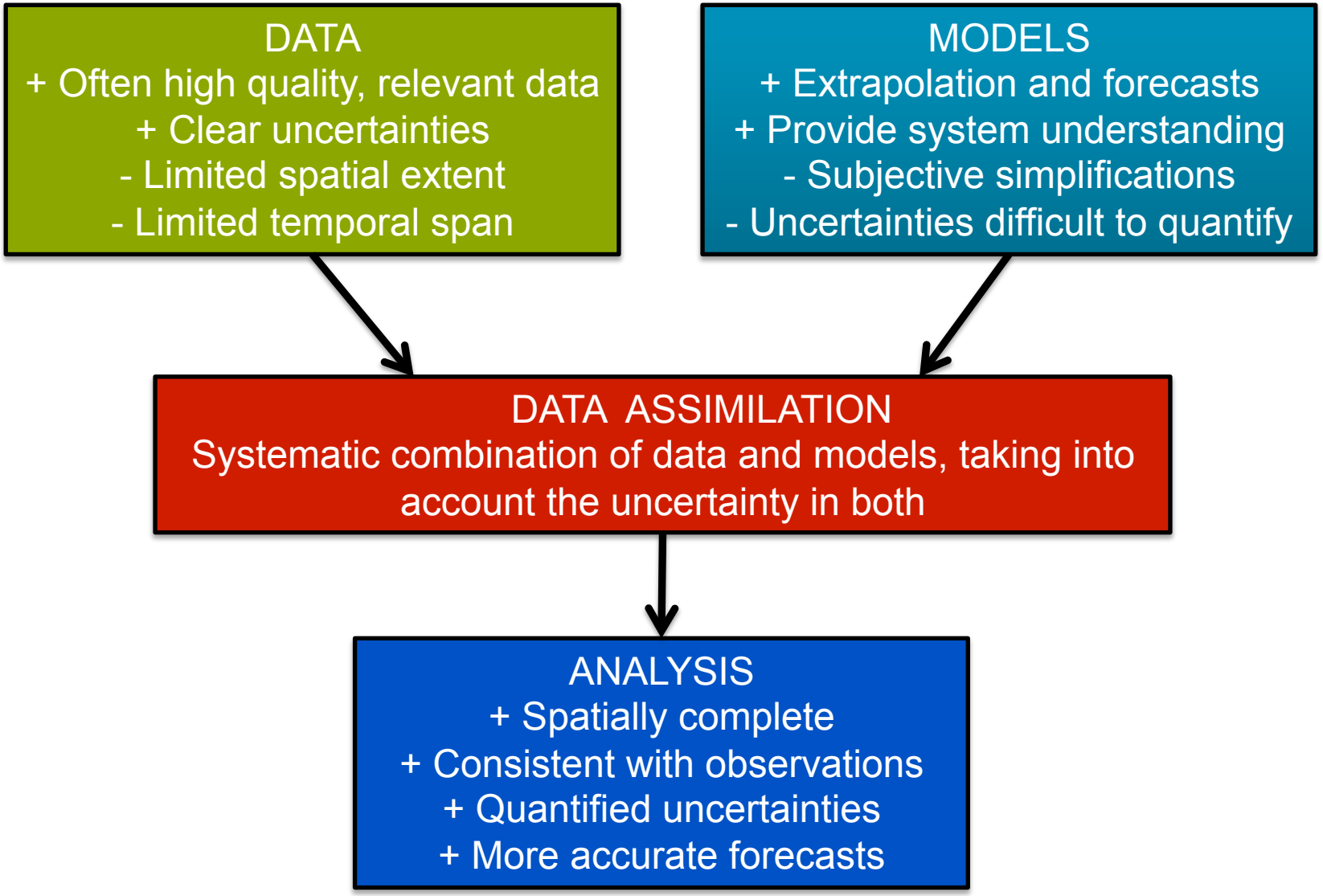
Data Assimilation



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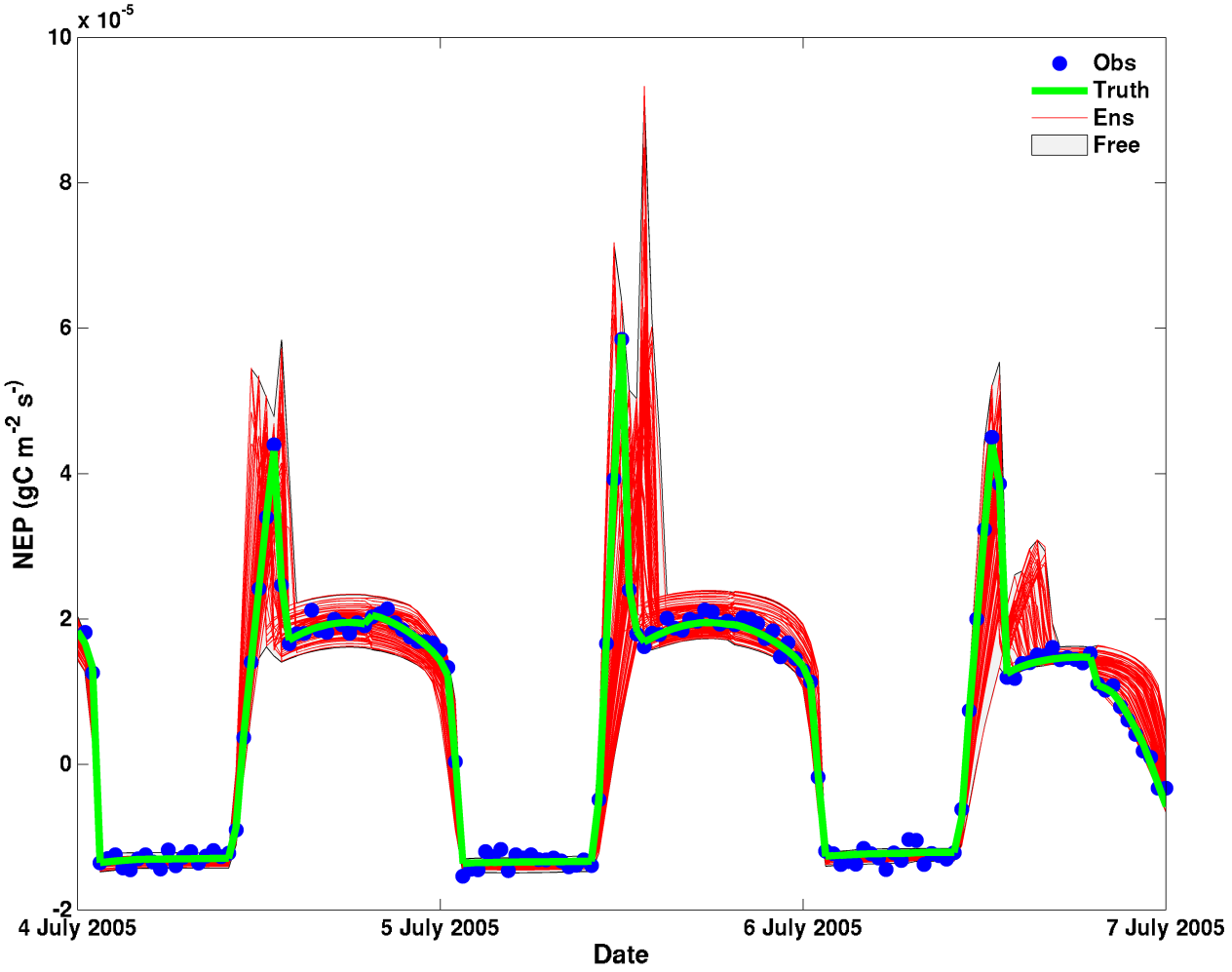
NEP – observations every 30 minutes



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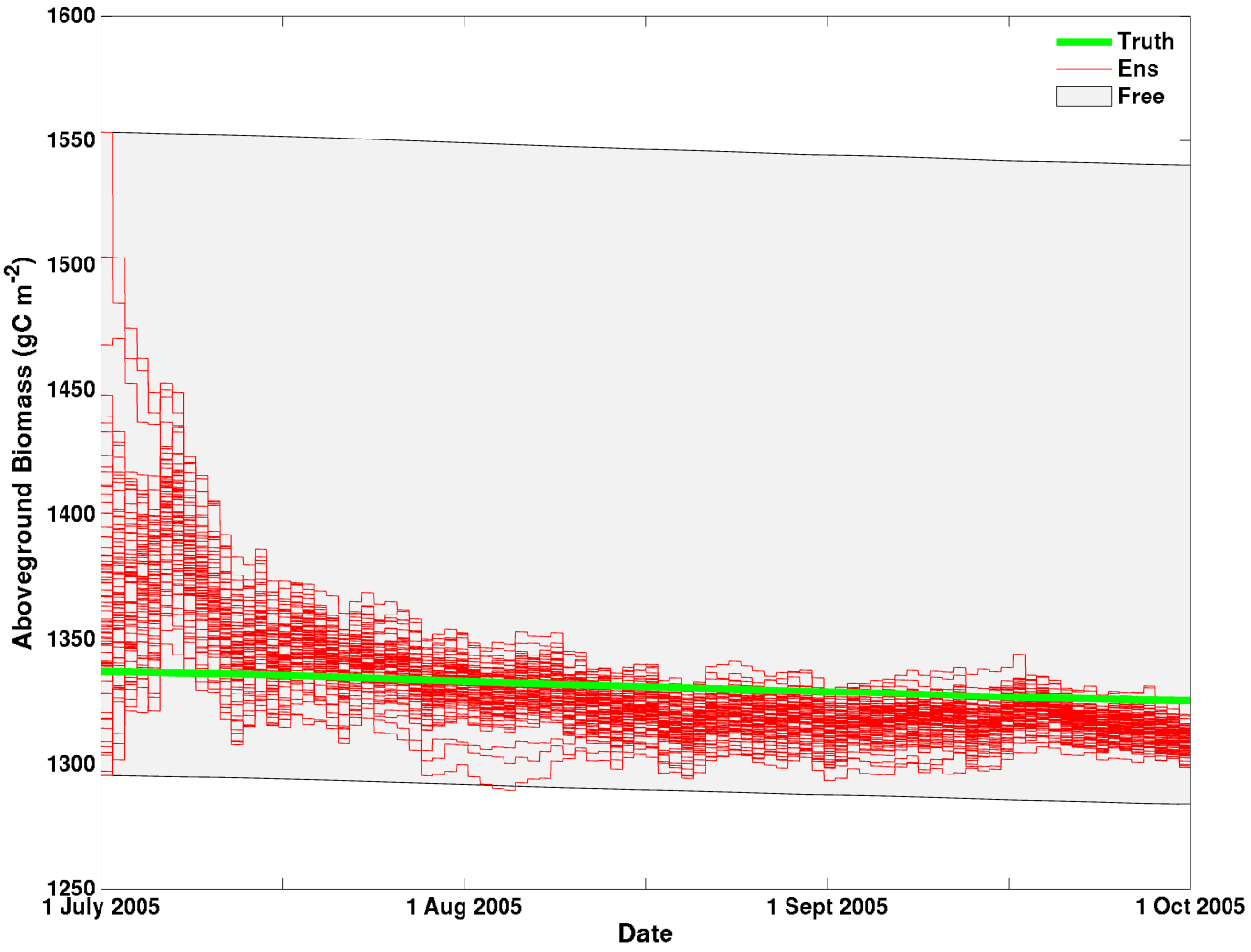
Above ground biomass - unobserved



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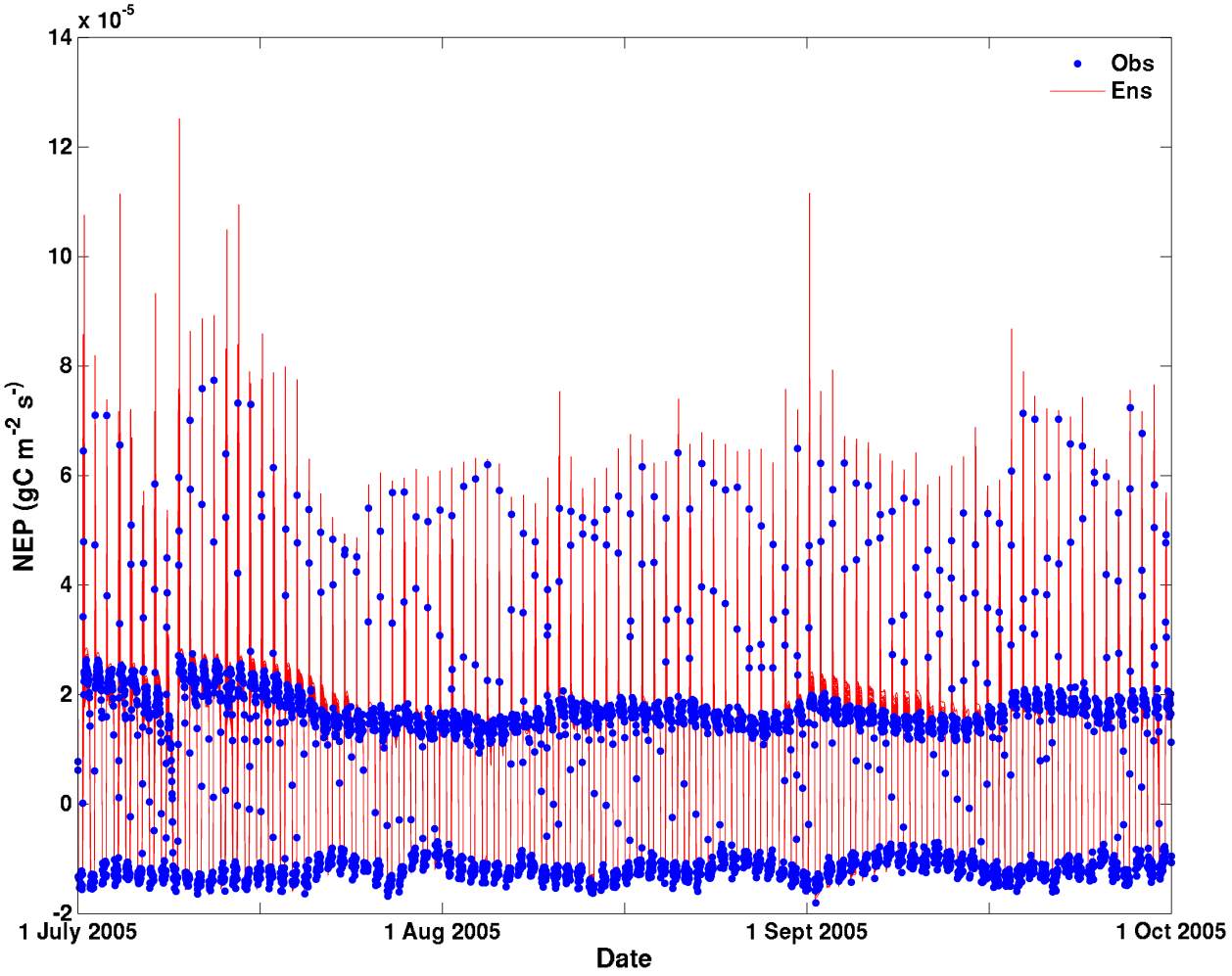
NEP – observations every 30 minutes



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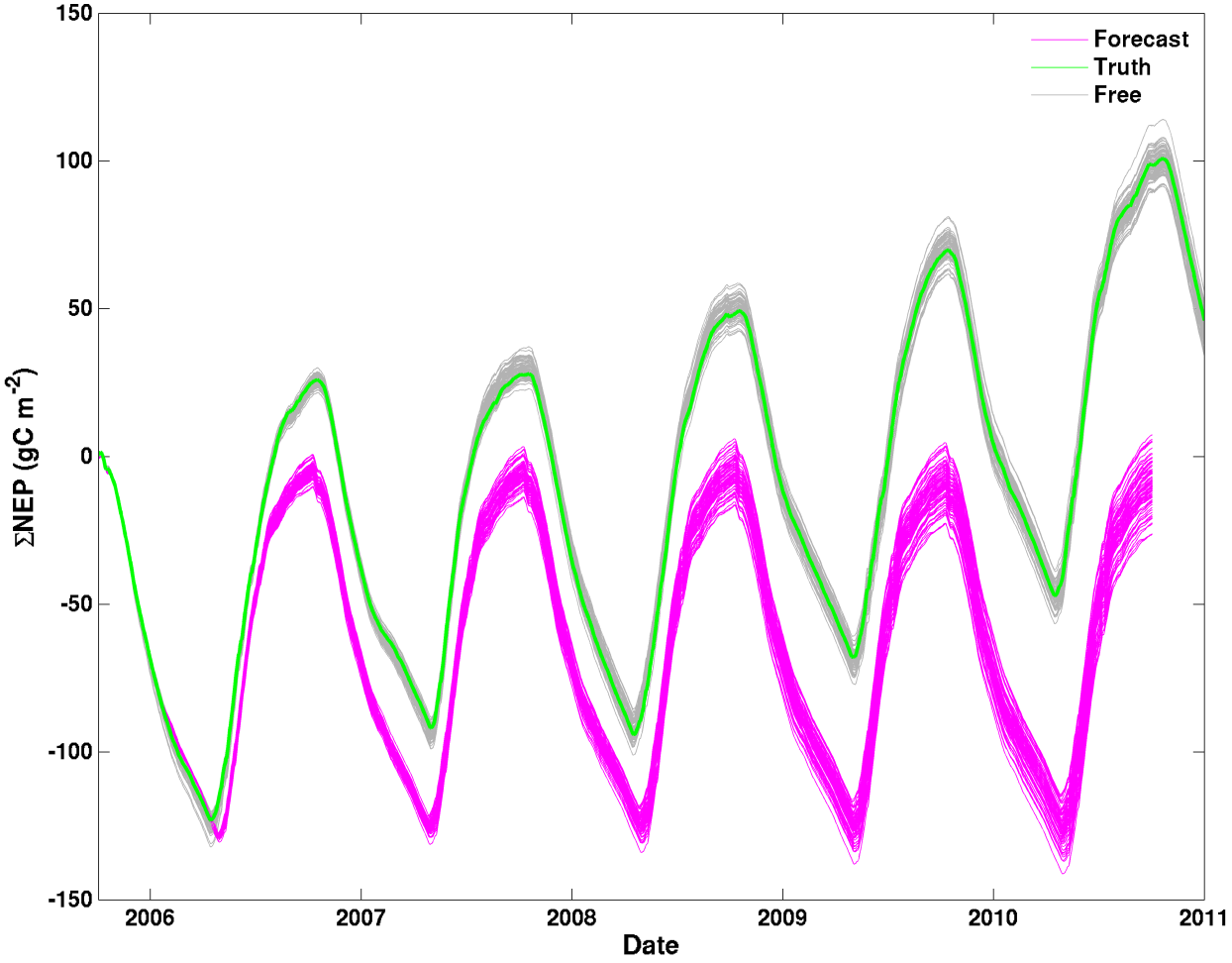
Impact on forecast - ΣNEP



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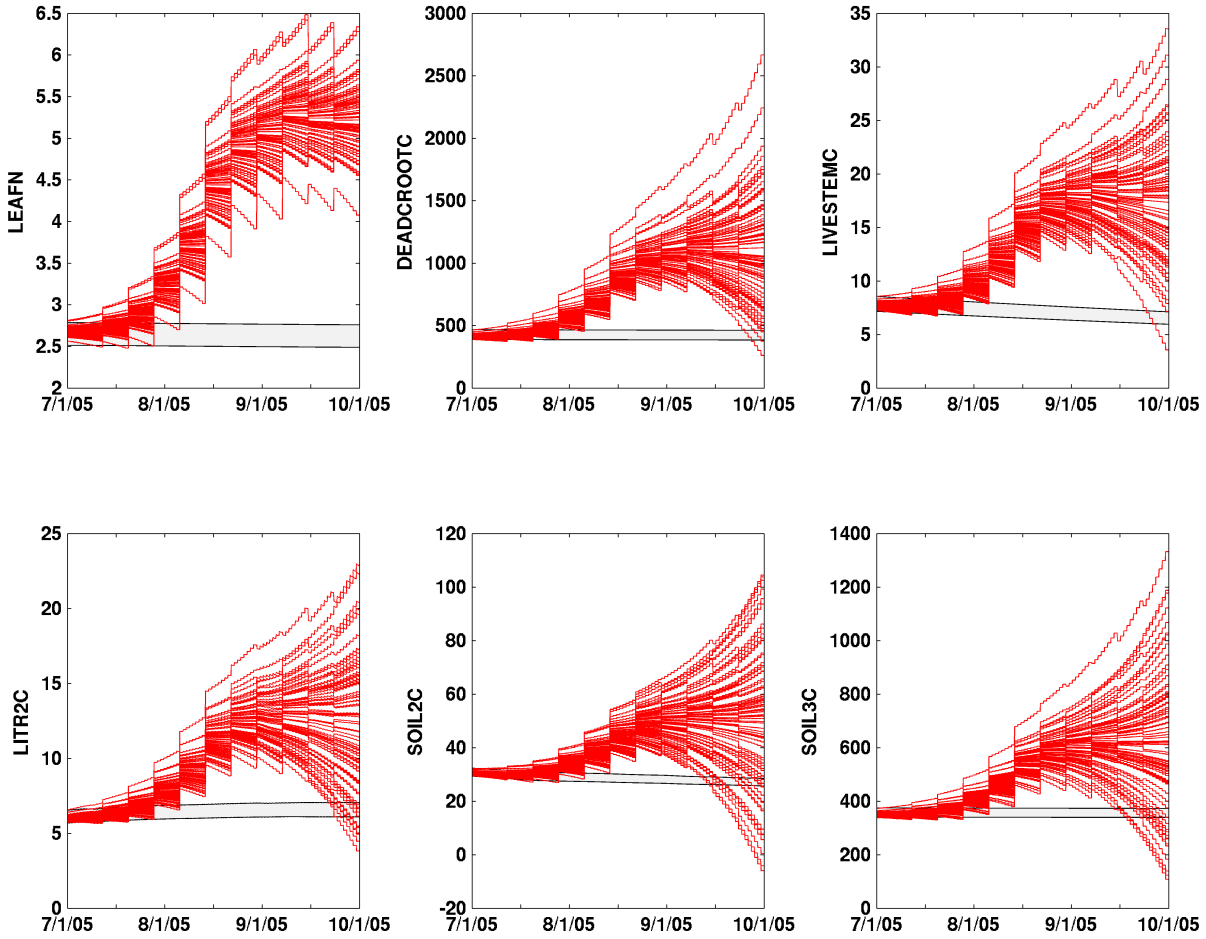
Examples of N and C pools - unobserved



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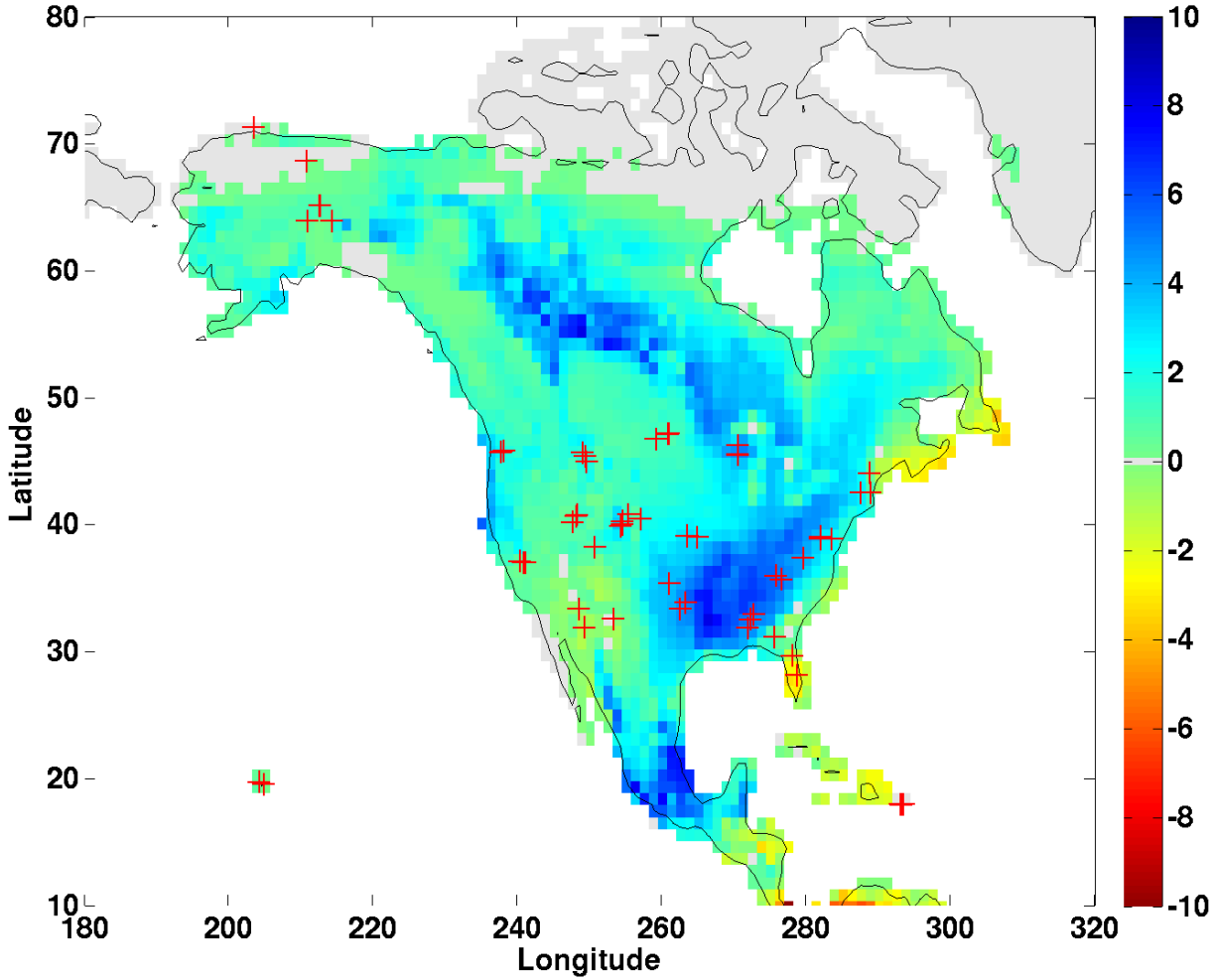
Mean NEP from 80 ensemble members



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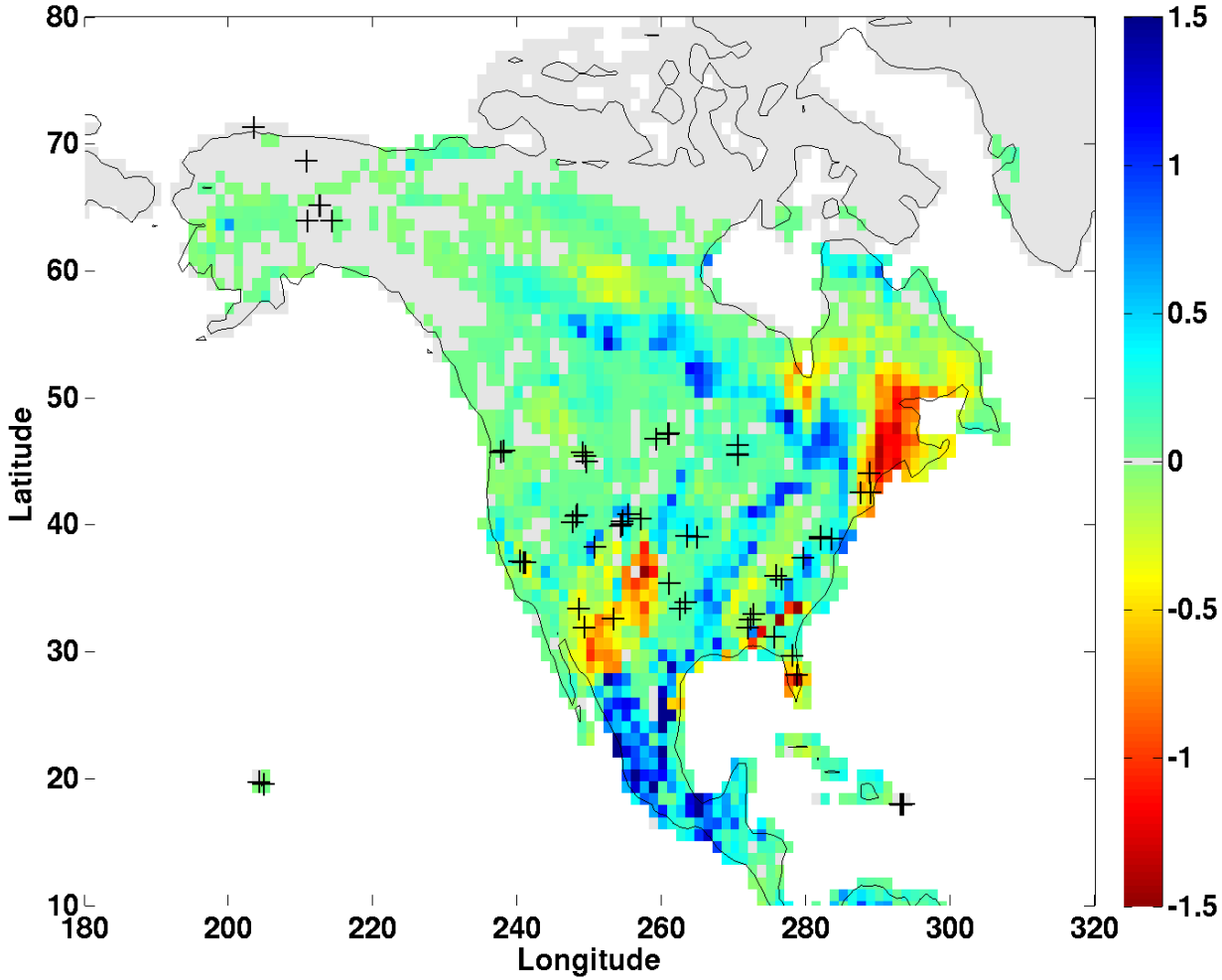
Change in NEP ensemble spread



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Evapotranspiration Estimation with Simulated HyspIRI Data over Arid Lands

Andrew N. French [1], Juan Manuel Sanchez [2], Vicente Garcia-Santos [3], Kelly Thorp[1]

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2. University of Castilla-La Mancha, Albacete, Spain

3.University of Valencia, Valencia, Spain

United States Department Of Agriculture
Agricultural Research Service

Need for Remote Sensing Evapotranspiration Research Over Arid Lands

- Population increases to 7 Billion+
- Increasing living standards increases demand for water
- Drought and climate change exacerbating water availability
- Food production needs to increase & this requires large increases in water availability
- Food production from irrigated agriculture especially important: 53% of market value on 17% of crop land (Clemmens et al., 2008)
- Conflicting demands upon arid lands: increased agricultural production, urbanization, preservation of wild lands
- Remote sensing is the only way to provide global to local scale decision and management support

Water Management & Decision Support

- Rangeland:
  - Effect of drought on vegetation health and livestock carrying capacity
  - Controlling invasive species
  - Determining effective and ineffective management practices
  - Remote sensing provides annual to decadal scale views of water needs and vegetation patterns
- Irrigated Lands:
  - Irrigation district decisions: infrastructure, water costs, water priority rights
  - Competition with urban users
  - Competition between tree crops and annual cropping systems
  - **Agronomy:**
    - **Responses to stress are fast & slow (stomata, roots)**
    - **Flash events: frost, heat wave**
    - **Detection of water stress critically dependent on phenology**
    - **Survival of severe stress not important**
    - **Genetics and climate change means water use patterns will change**

Objectives

- Show that remote sensing with a HyspIRI-like platform can assist with water problems
  - Rangeland assessment of vegetation and water use
  - Irrigated land monitoring
- Highlight some attributes of HyspIRI that are especially helpful:
  - Spatial resolution
  - Hyperspectral VSWIIR
  - Multispectral TIR
  - Overpass frequency

ET Estimation

- Vegetation Index
  - Empirical estimates based on standard green plant water use
  - Multiple sources of remote sensing data at <100m resolutions
  - Standardized ET results, stress detection difficult

- Surface energy balance
  - Physically based, uses land surface temperature to estimate evaporation and is an indicator for stomatal control
  - Remote sensing data less readily available, analysis more difficult than VI
  - Potentially rapid detection of plant stress

Surface Energy Balance Approaches

Two-Source Energy Balance:

- Considers differences in energy transfer between air, soil and vegetation.
- More physically realistic representation of the ET processes
- Sensitive to LST and air temperature uncertainties

METRIC/SEBAL:

- Internally calibrated LST based on scene context to estimate ET
- Less sensitive to LST and air temperature uncertainties.

$$LE = \frac{\Delta}{\Delta + \gamma}[R_n - G] + \frac{\gamma}{\Delta + \gamma}\rho c_p [e^* - e_a]/r_a$$

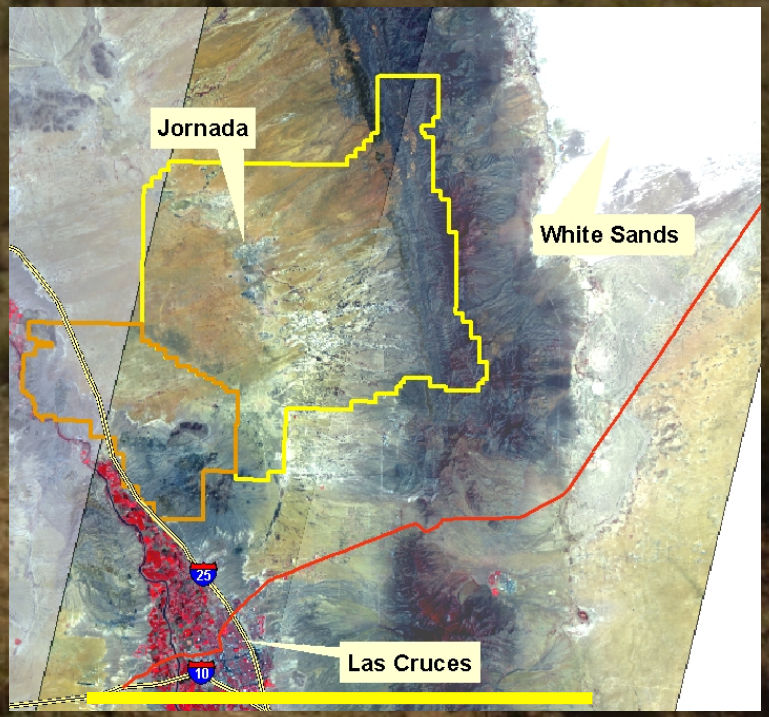
$$LE_C = f_g \alpha \left[\frac{\Delta}{\Delta + \gamma}\right] R_{n,C}$$

1. Transpiration (ET of vegetation): first gues
2. Sensible heat component from LST
3. Evaporation (ET of soil): key part of TSEB
4. Transpiration if LST canopy known.

The Jornada Study Site

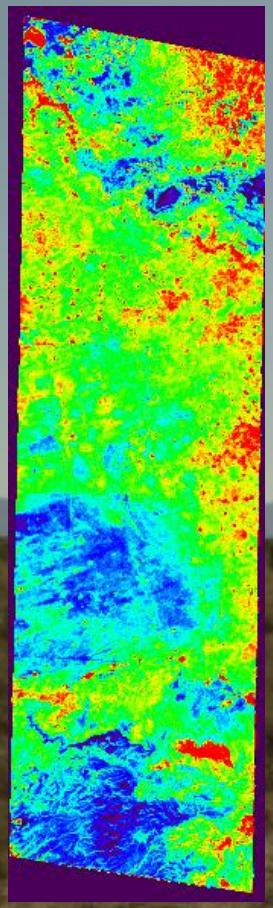
LTER (1990) & USDA Research Rangeland site since 1912. Desertification causes and trends.

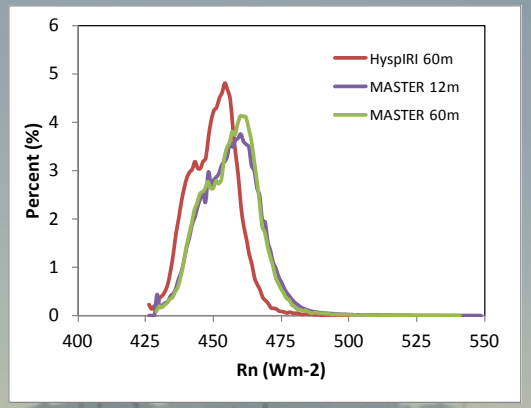
MASTER data collected 1998-2010 on 8 sorties. 3-12m resolution
AVIRIS data collected 1998-2002. 89+ scenes collected , georegistered, corrected and modeled.

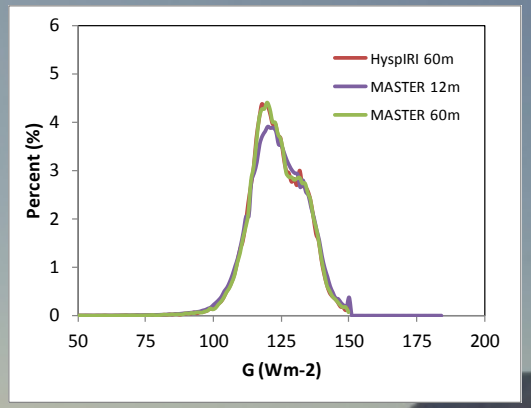


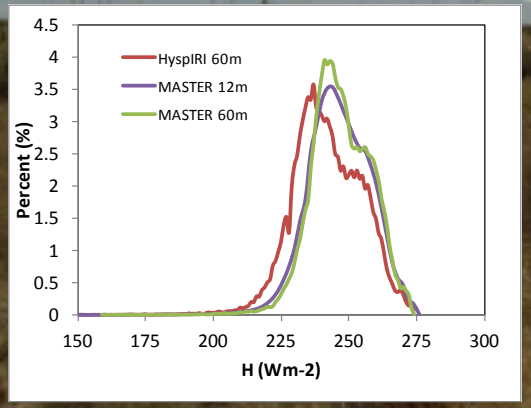
JORNADA

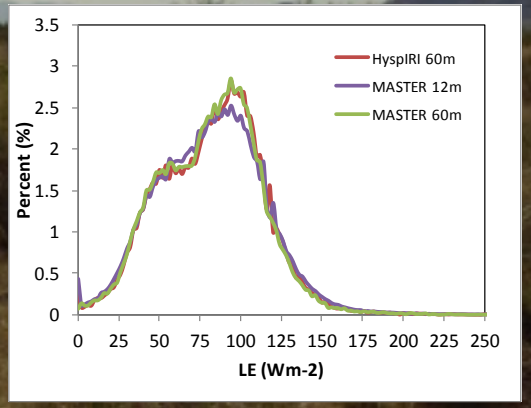
HyspIRI Simulations with MASTER
N-S transect over key grassland and mesquite dune sites







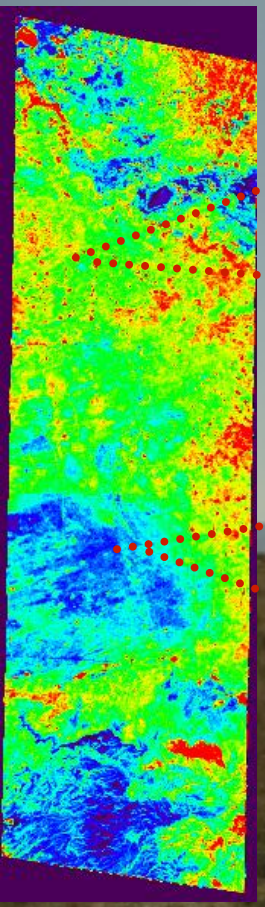




HYSPIRI/MASTER (60m)	Bias	RMSE
Rn	-4	5
G	-0.09	0.6
H	-5	5
LE	0.8	1.9

	MASTER 12m		MASTER 60m		HYSPIRI 60m
	Mean	SD	Mean	SD	Mean
Rn	456	11	456	10	452
G	124	11	124	10	124
H	247	12	247	11	242
LE	82	34	82	31	83

Local Validation of ET Modeling at Jornada



3*3 (60 m)

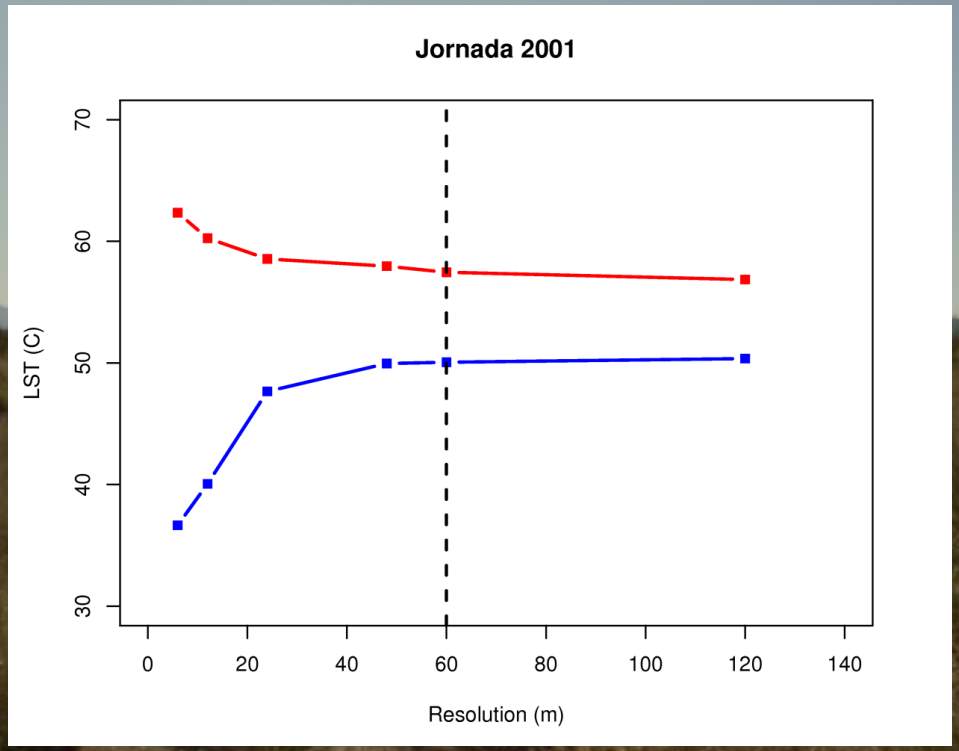
Mesquite

3*3 (60 m)

Grass

Date	Time	Grass/Mesquite	Rn			G		H			LE		
			Observed	Predicted	Diff.	Observed	Predicted	Observed	Predicted	Diff.	Observed	Predicted	Diff
20-May-04	17:36	G	562	441	-121	x	124	374	263	-111	31	51	20
	17:53	M	540	460	-80	x	116	364	258	-106	27	82	55
	18:42	G	564	441	-123	x	135	392	257	-135	30	45	15
	18:42	M	610	452	-158	x	123	348	241	-107	34	85	51
4-Oct-07	17:19	M	457	407	-50	x	91	280	175	-105	28	139	111
22-Oct-08	17:45	G	424	380	-44	x	92	224	231	7	26	55	29
	18:52	G	386	357	-29	x	84	214	253	39	24	17	-7
Mean/Bias			*506*	*420*	*-86*		*109*	*314*	*240*	*-74*	*29*	*68*	*39*
RMSE				**97**					**97**			**53**	
%				**19**					**31**			**185**	

Effect of Spatial Resolution on ET Estimates

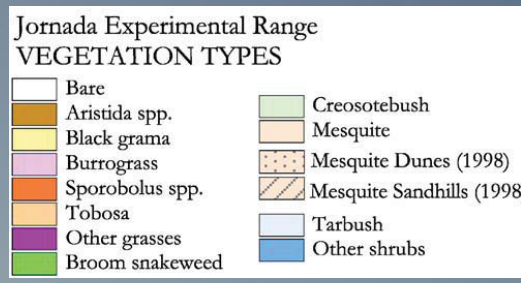


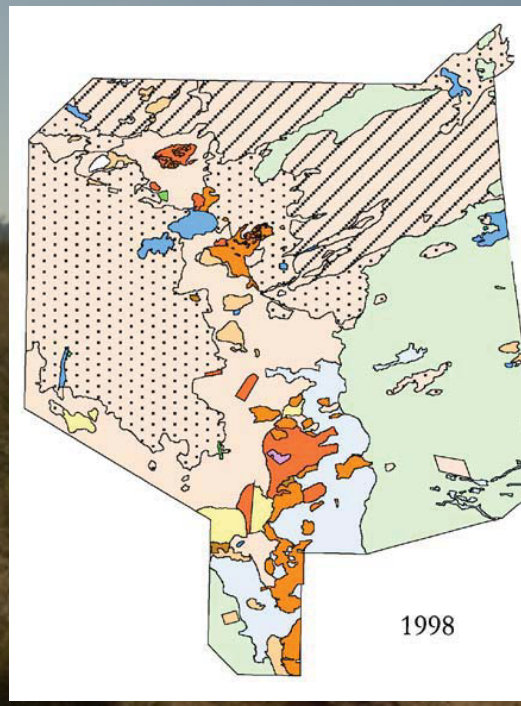
Shrub level heterogeneity at Jornada is less than 10 m
However landscape scale ET homogeneous at 60 m

MESMA Results: Spectral Resolution Overcomes Limitations with Spatial Resolution

June 15, 2001

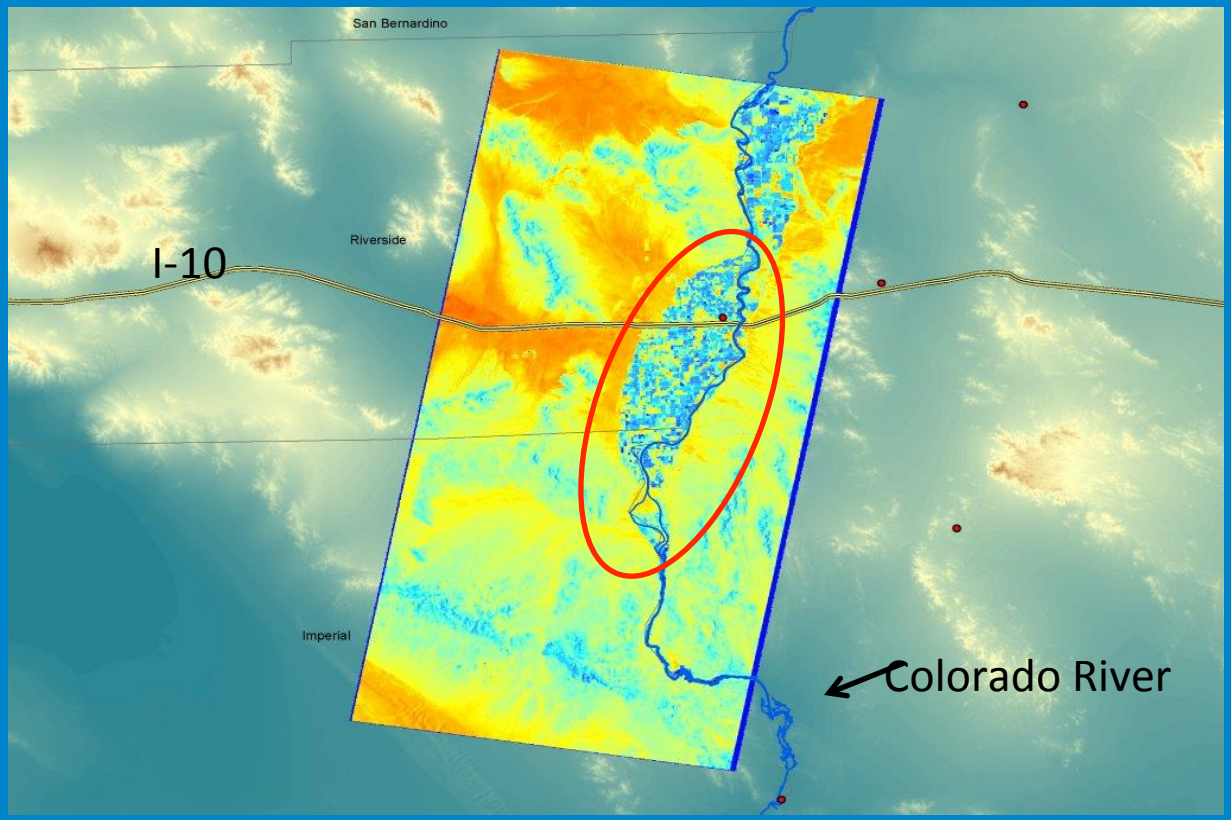
October 9, 2002





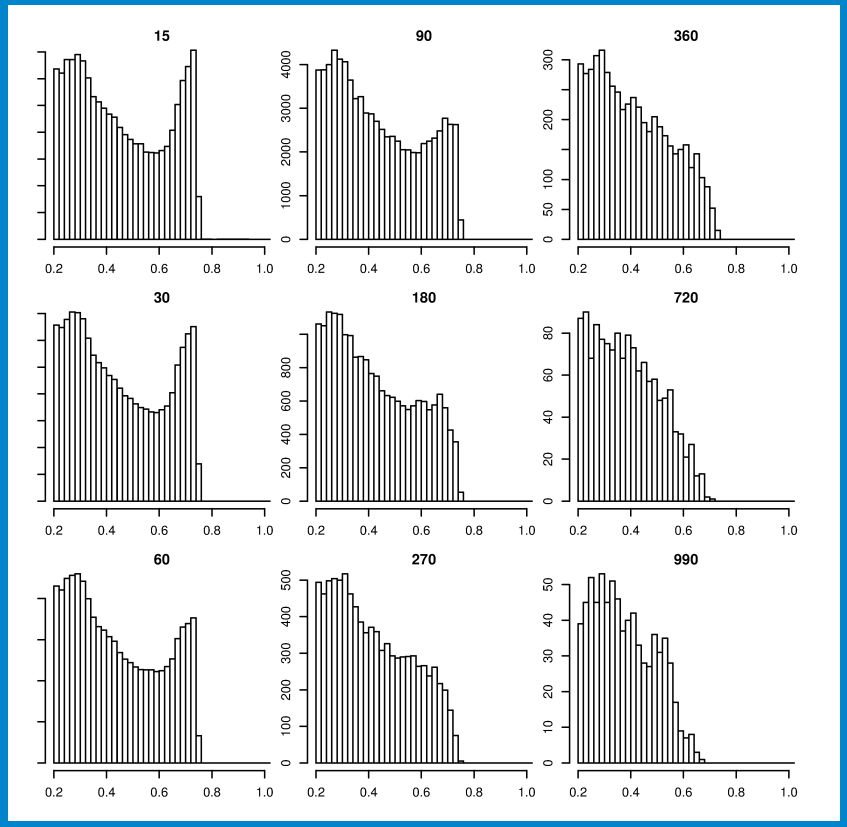
1998
Gibbens et al. (2005)

ET Modeling over Palo Verde Irrigation District, California, June 17, 2007
ASTER LST, Emissivities & NDVI

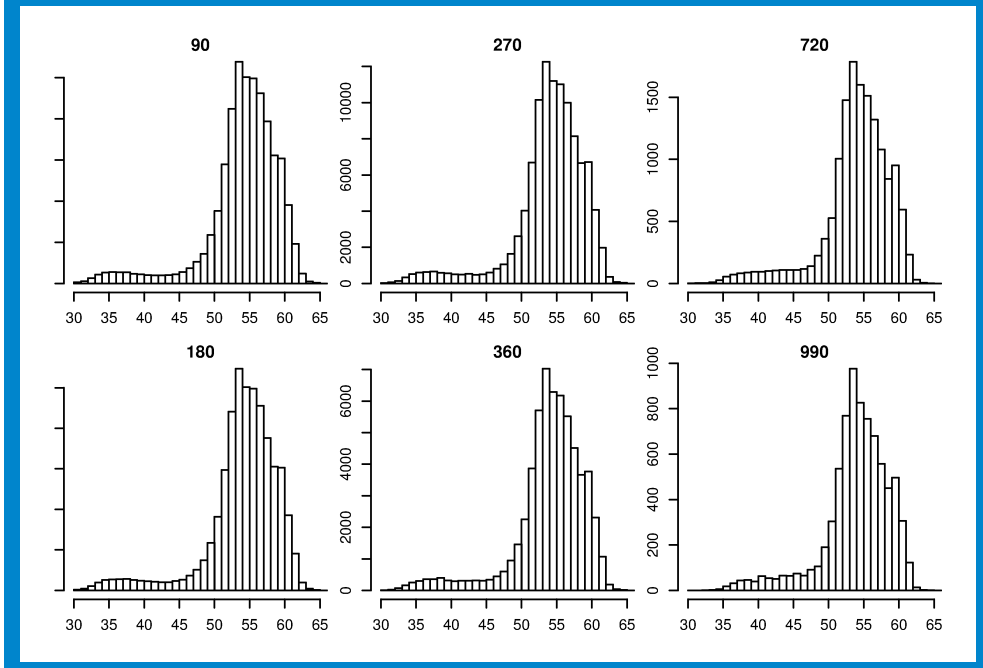


Role of Spatial Resolution for Irrigated Land
Palo Verde Irrigation District

Bi-Modal Distributions
Where two modes disappear indicates critical resolution
At PVID that scale is 200-300 m



NDVI



LST

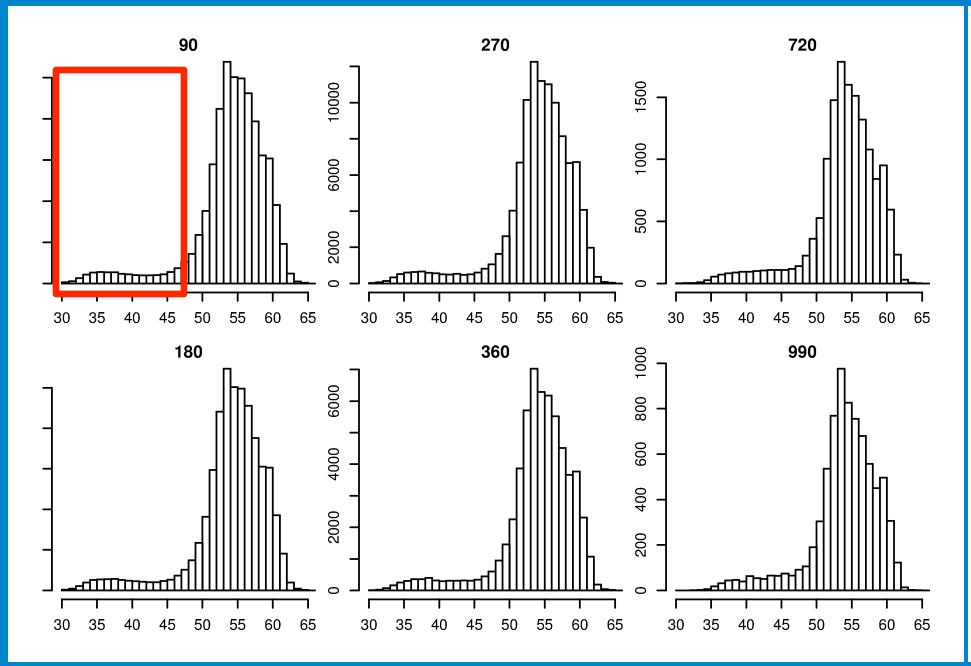
Spatial Scaling of Land Surface Temperatures at PVID

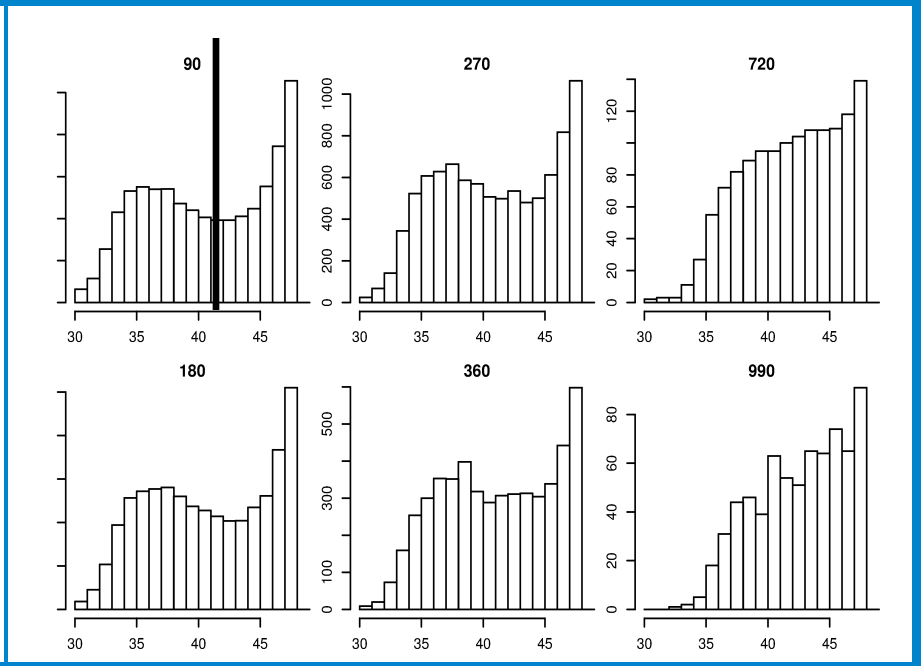
Crops 30-42 C; Desert >45 C
Critical scale ~ 300 m

90 m

270 m

720 m



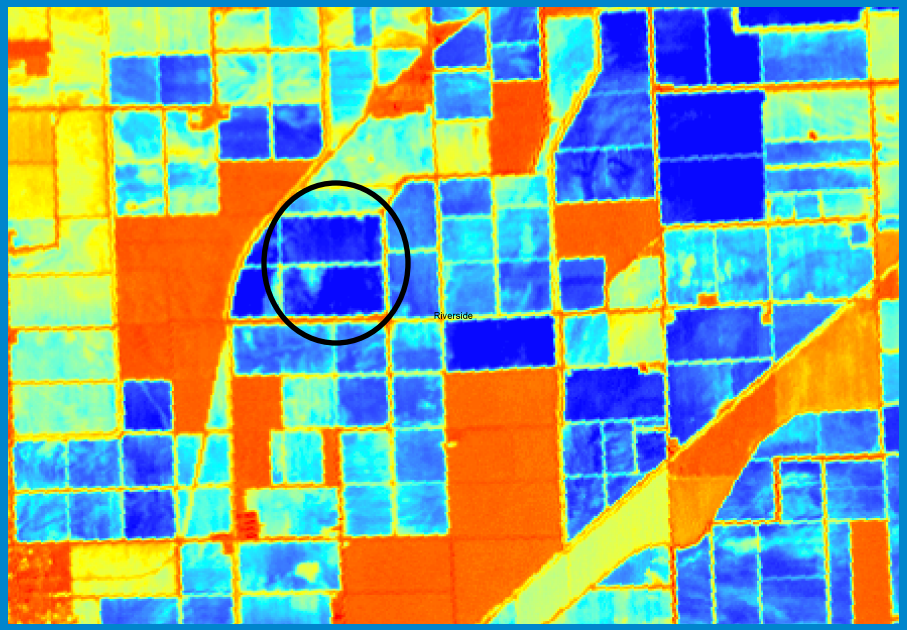


180 m

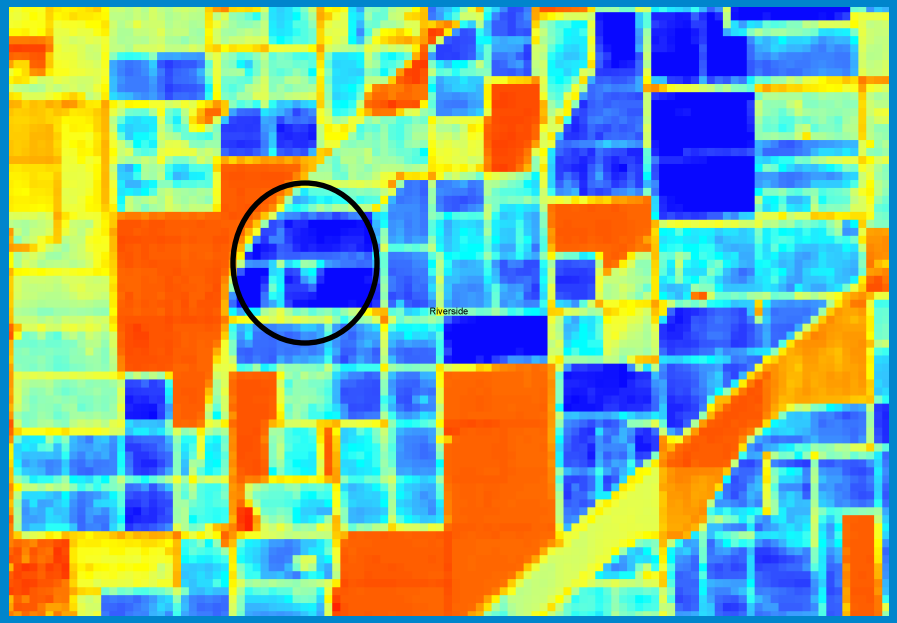
360 m

990 m

NDVI at Palo Verde
Sub-Field Scale Variability Observed at 60 m

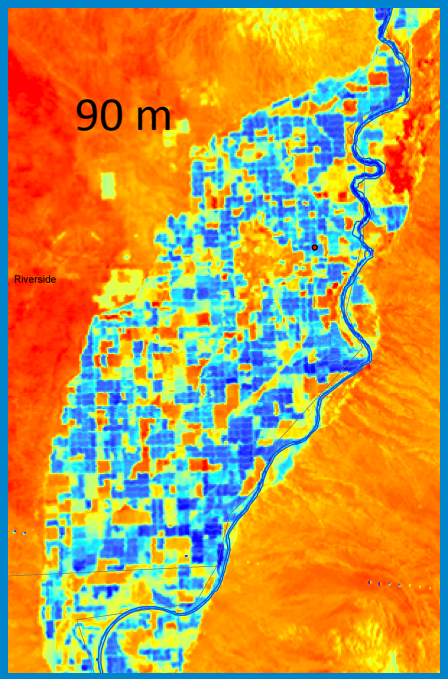


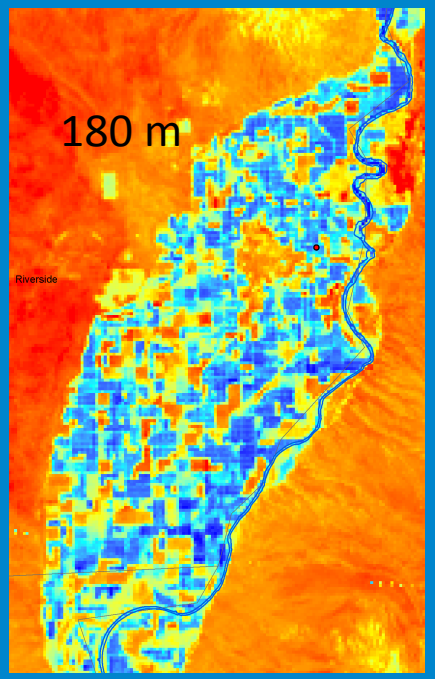
15 m

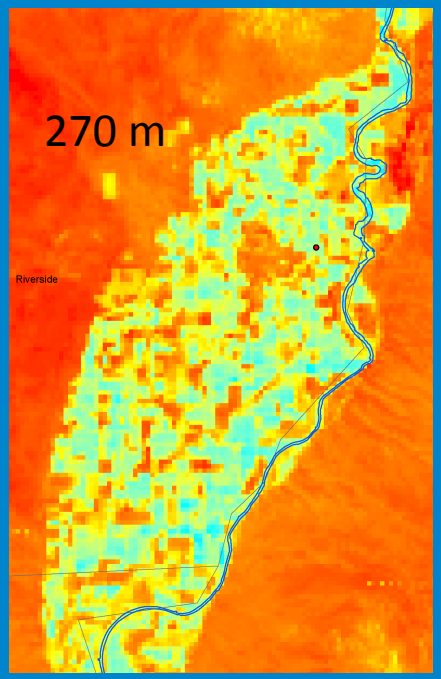


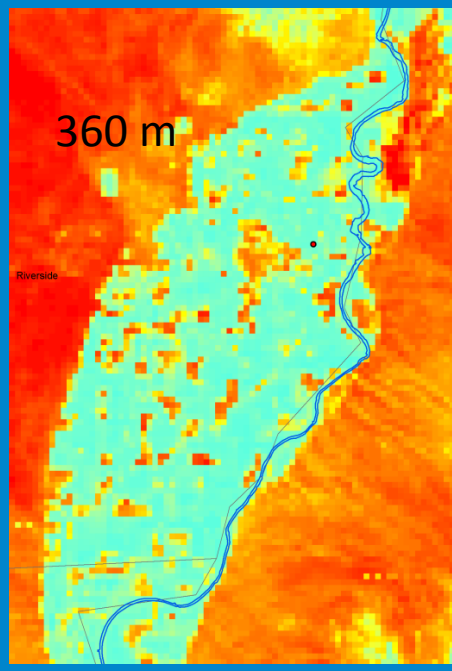
60 m

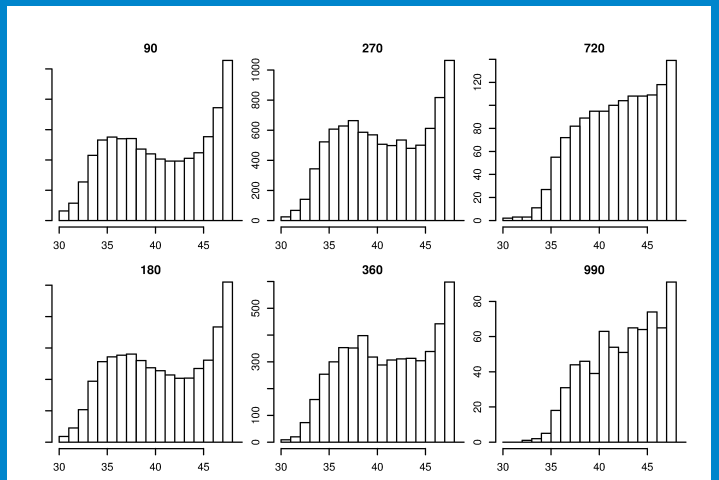
Effect of Spatial Resolution on ET Estimation At Palo Verde Irrigation District







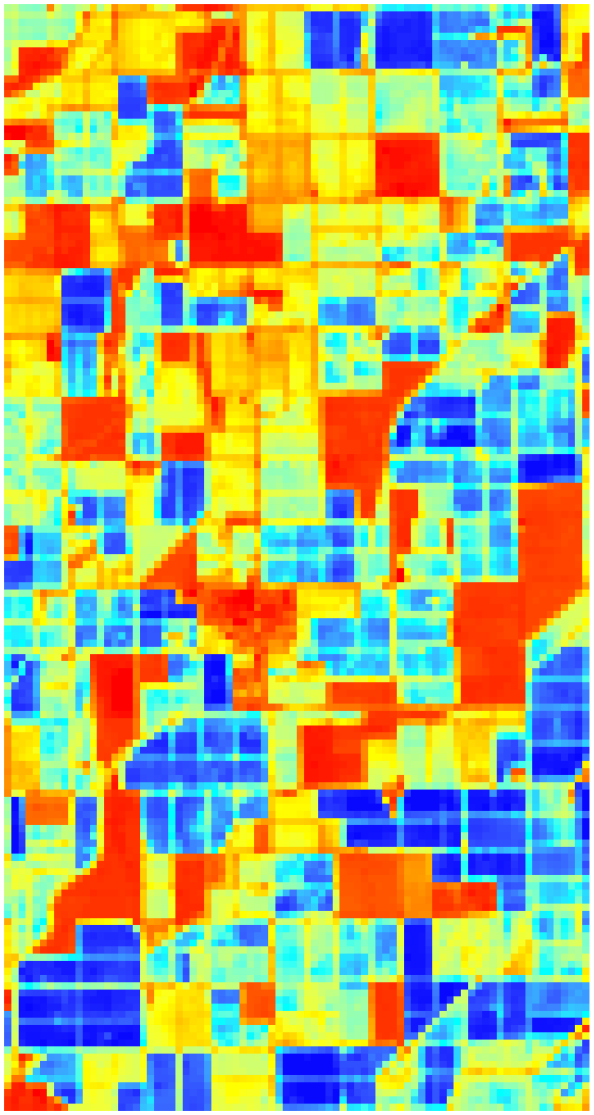




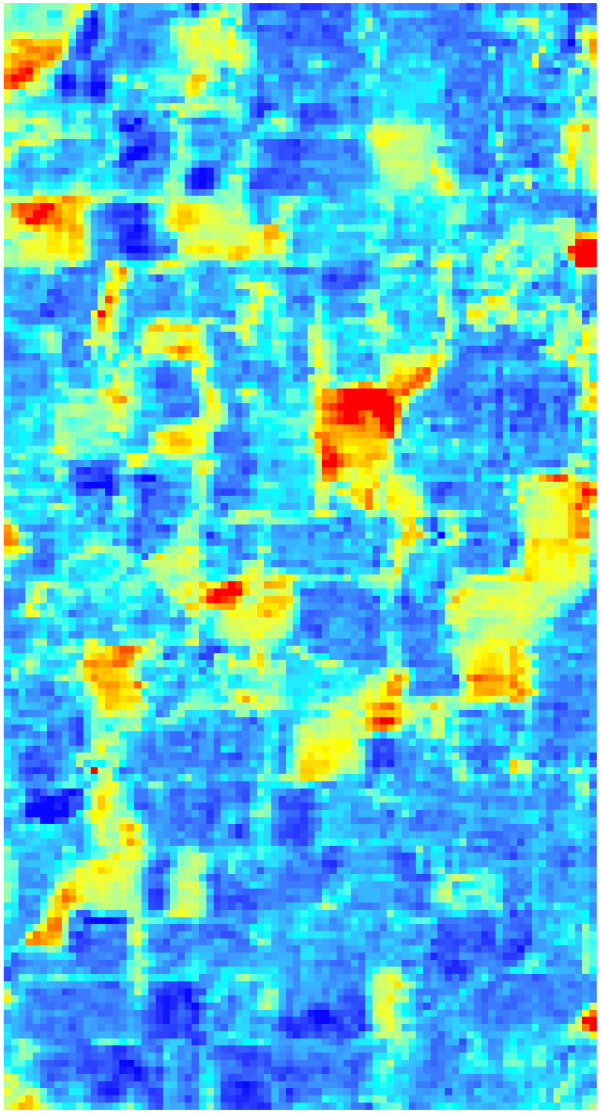
Large systematic changes in LE Flux distributions > 200 m

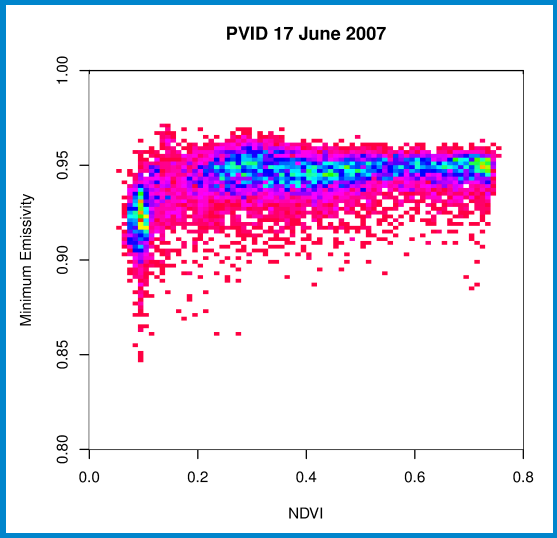
Multispectral TIR: Potential Surface Soil Moisture Indicator

NDVI

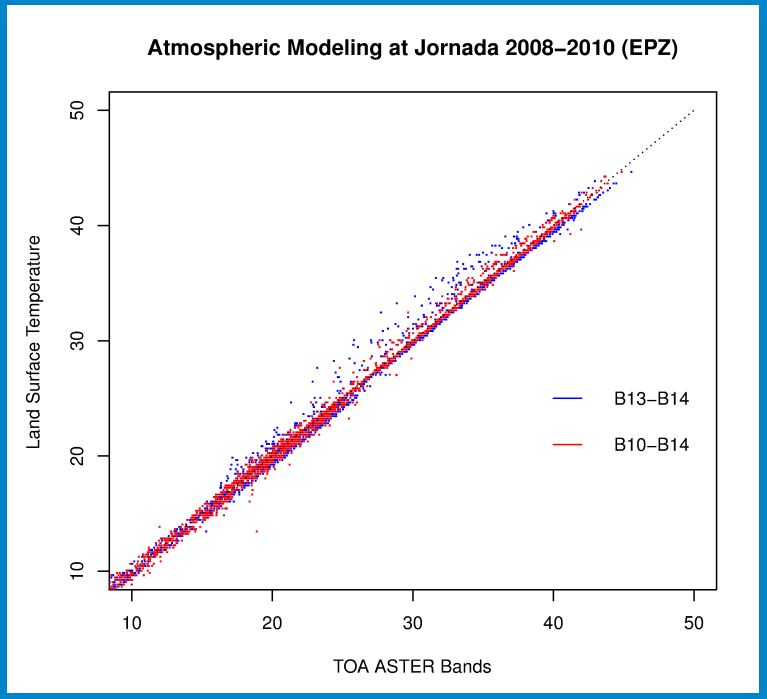


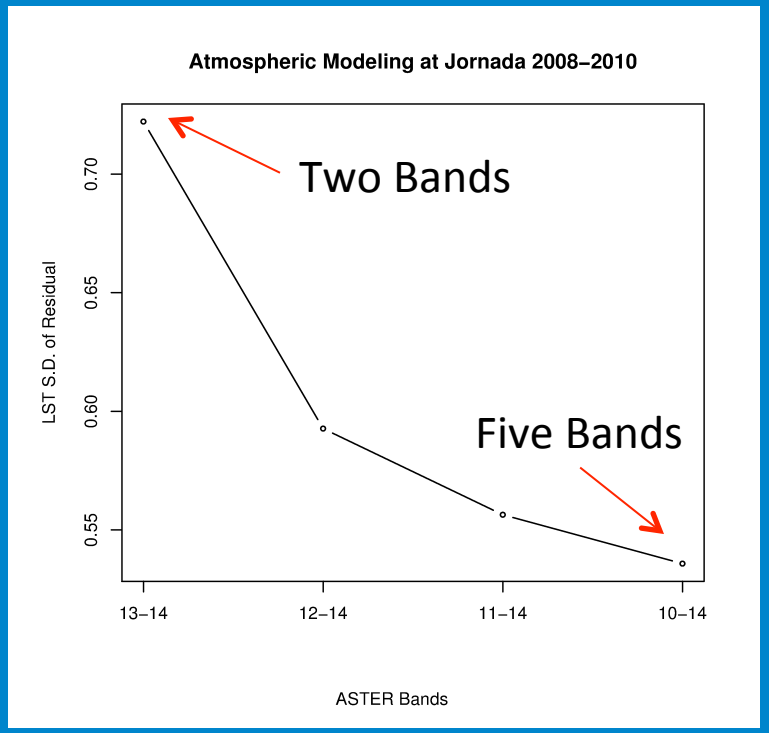
Emissivity Contrast

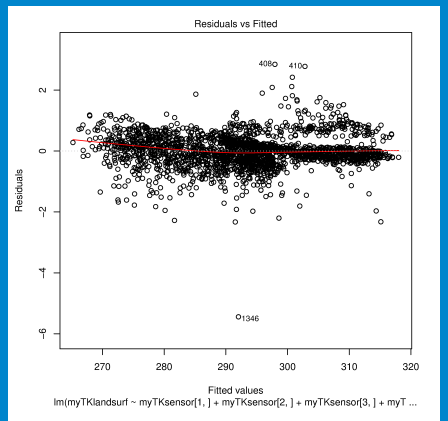


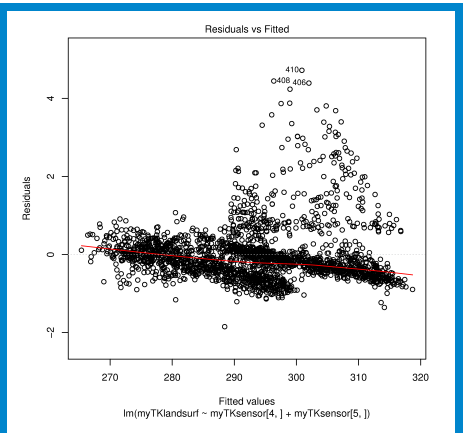


Multiple Thermal Bands Improve Surface Temperature Estimates









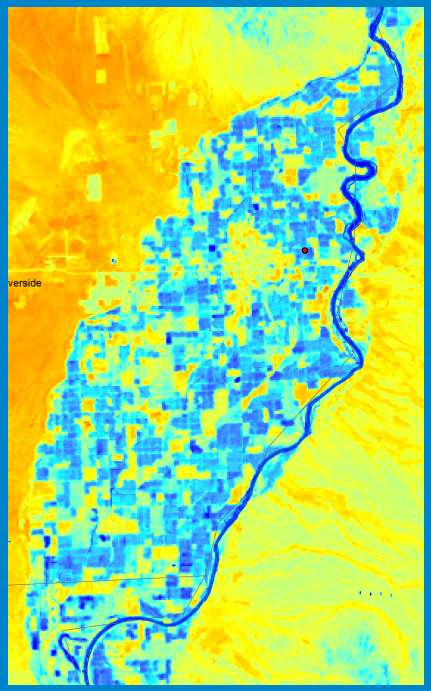
Conclusions

- HyspIRI design offers substantial benefits for ET mapping in arid lands
- For rangeland can reasonably estimate low ET values while discriminating shrubs, grasses, senescent vegetation
- For irrigated lands can map ET at sub-field scales
- Multispectral thermal can improve LST estimation and discriminate wet and dry soils
- 5-day periodicity helps address agronomic needs for stress detection

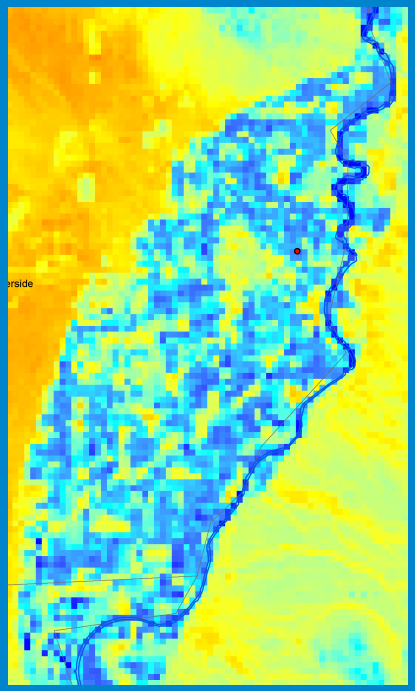
Effect of Spatial Resolution on ET Estimation At Palo Verde Irrigation District

Large systematic changes in LE Flux distributions > 200 m

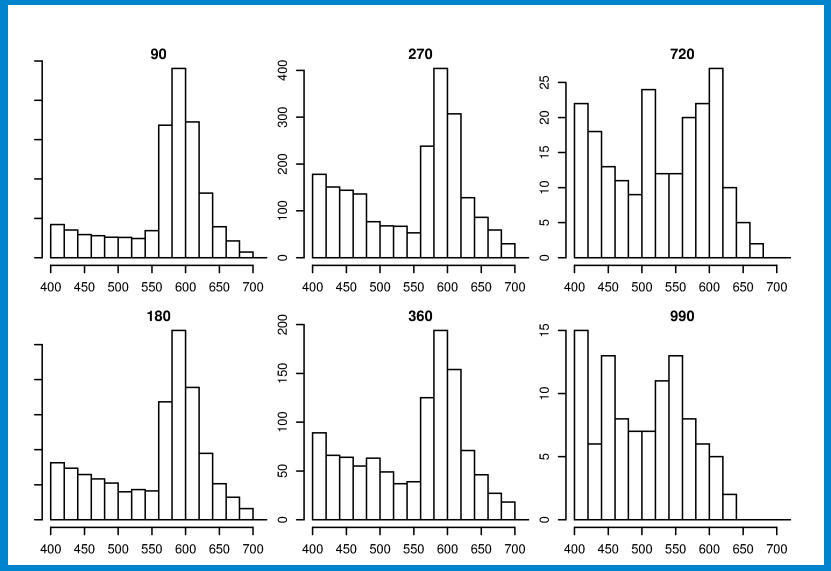
LE Flux

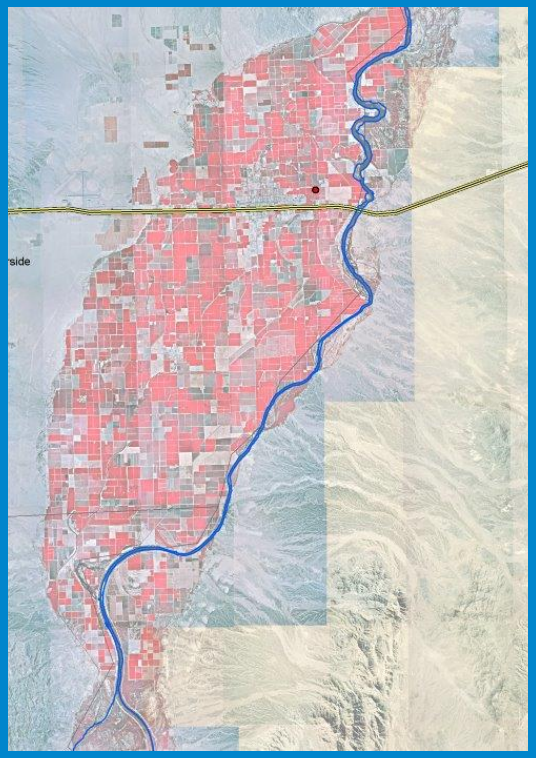


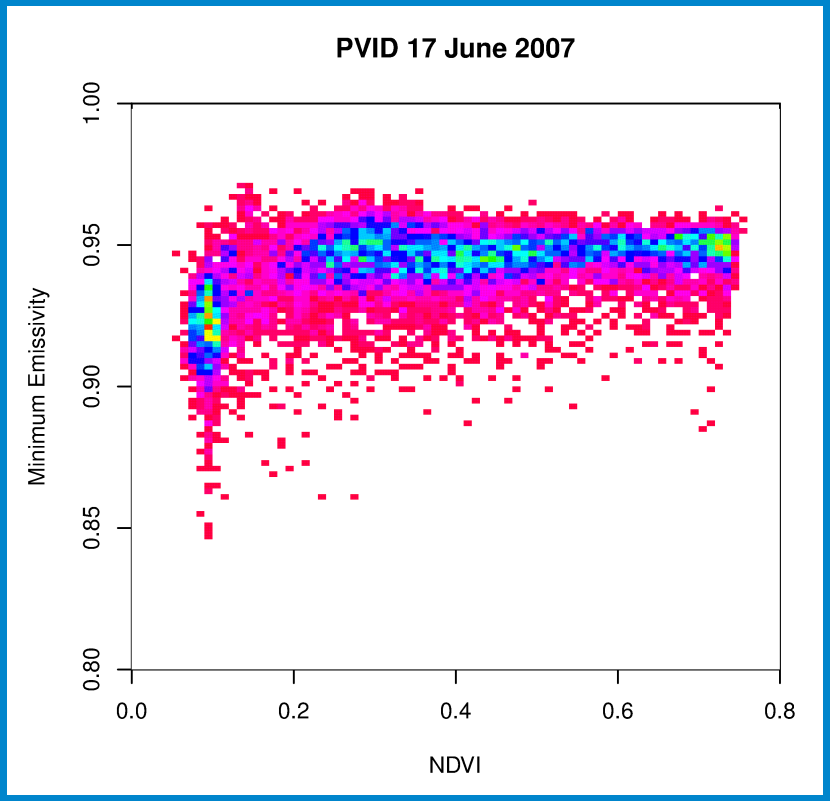
90 m



360 m






PVID 17 June 2007
Minimum Emissivity
1.00
0.95
0.90
0.85
0.80
0.0
0.2
0.4
0.6
0.8
NDVI

Determining leaf dry matter content using the Normalized Dry Matter Index and its possible application for estimating fuel moisture content

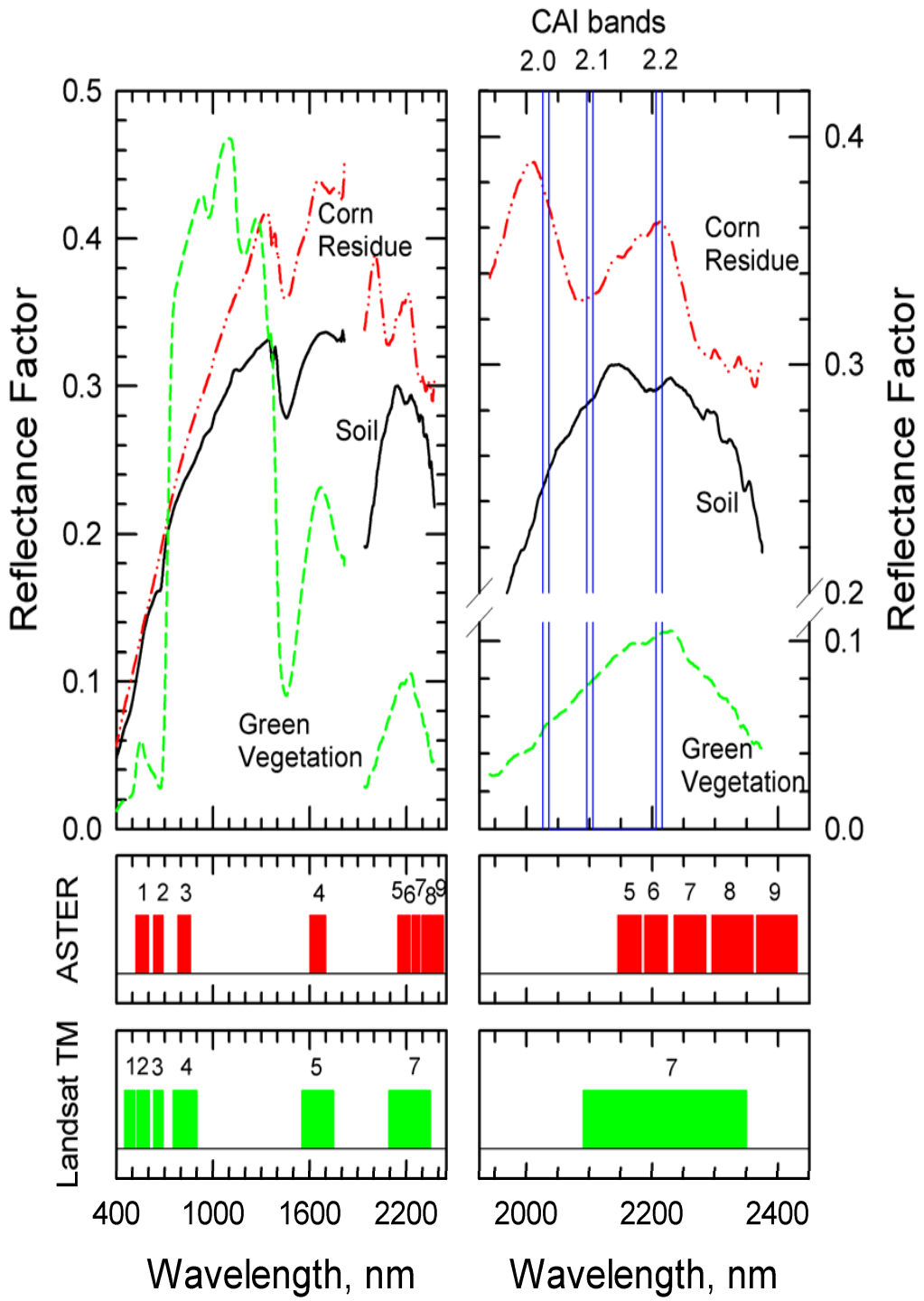
E. Raymond Hunt Jr., Tao Cheng, David Riaño, Susan L. Ustin, Lingli Wang, Xianjun Hao, John J. Qu, and Craig S. T. Daughtry,

USDA-ARS HRSL
Hydrology & Remote Sensing Lab
Beltsville, Maryland, USA

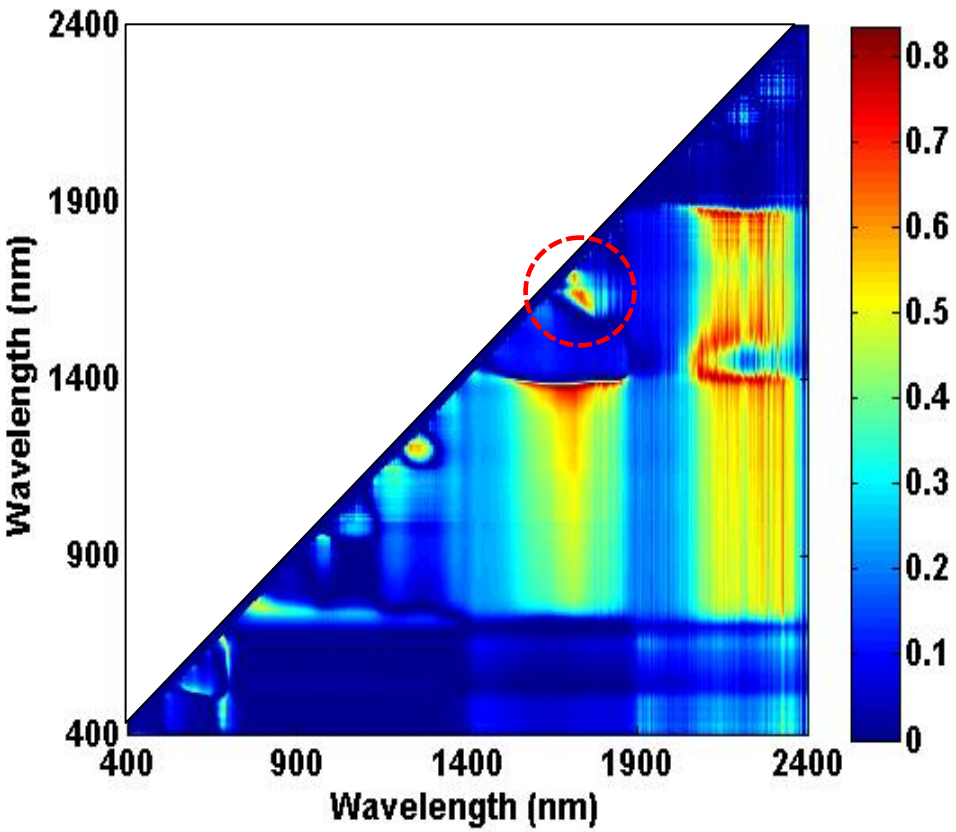
STARS
CENTER FOR SPATIAL TECHNOLOGIES AND REMOTE SENSING
DEPT. OF LAND, AIR AND WATER RESOURCES

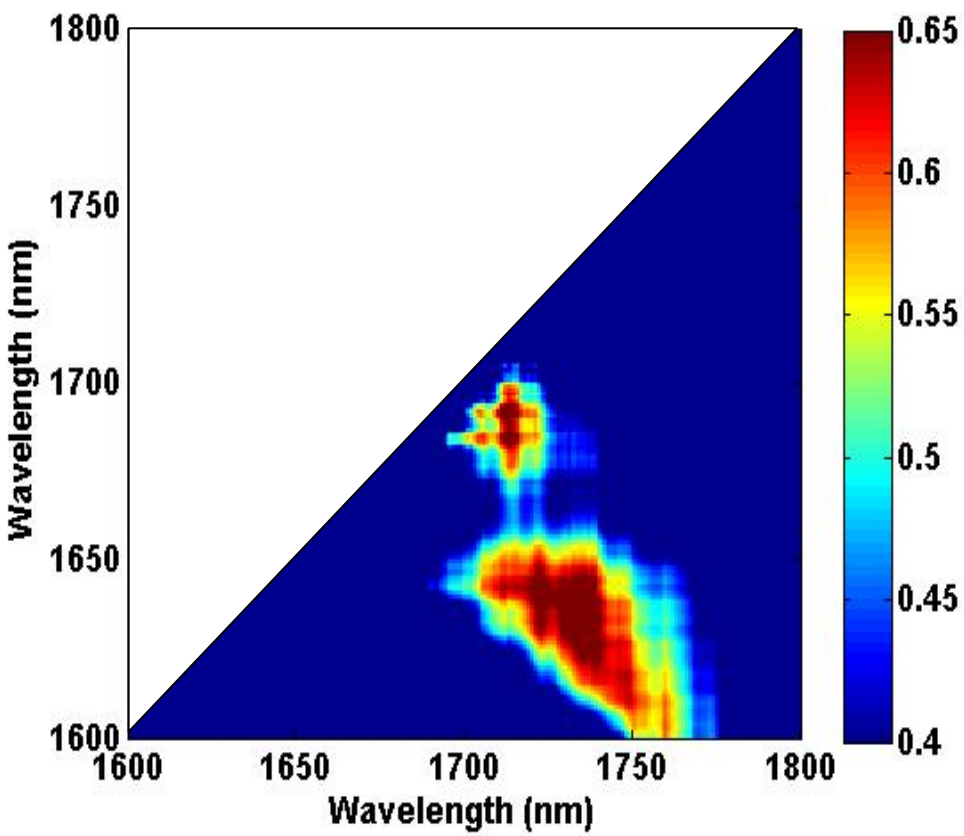
GEORGE MASON UNIVERSITY

Fuel Moisture Content (FMC) is a critical parameter to determine wildfire ignition and spread



A number of spectral indices were developed for crop residue cover based on absorption features of plant dry matter (Cellulose Absorption Index – CAI).



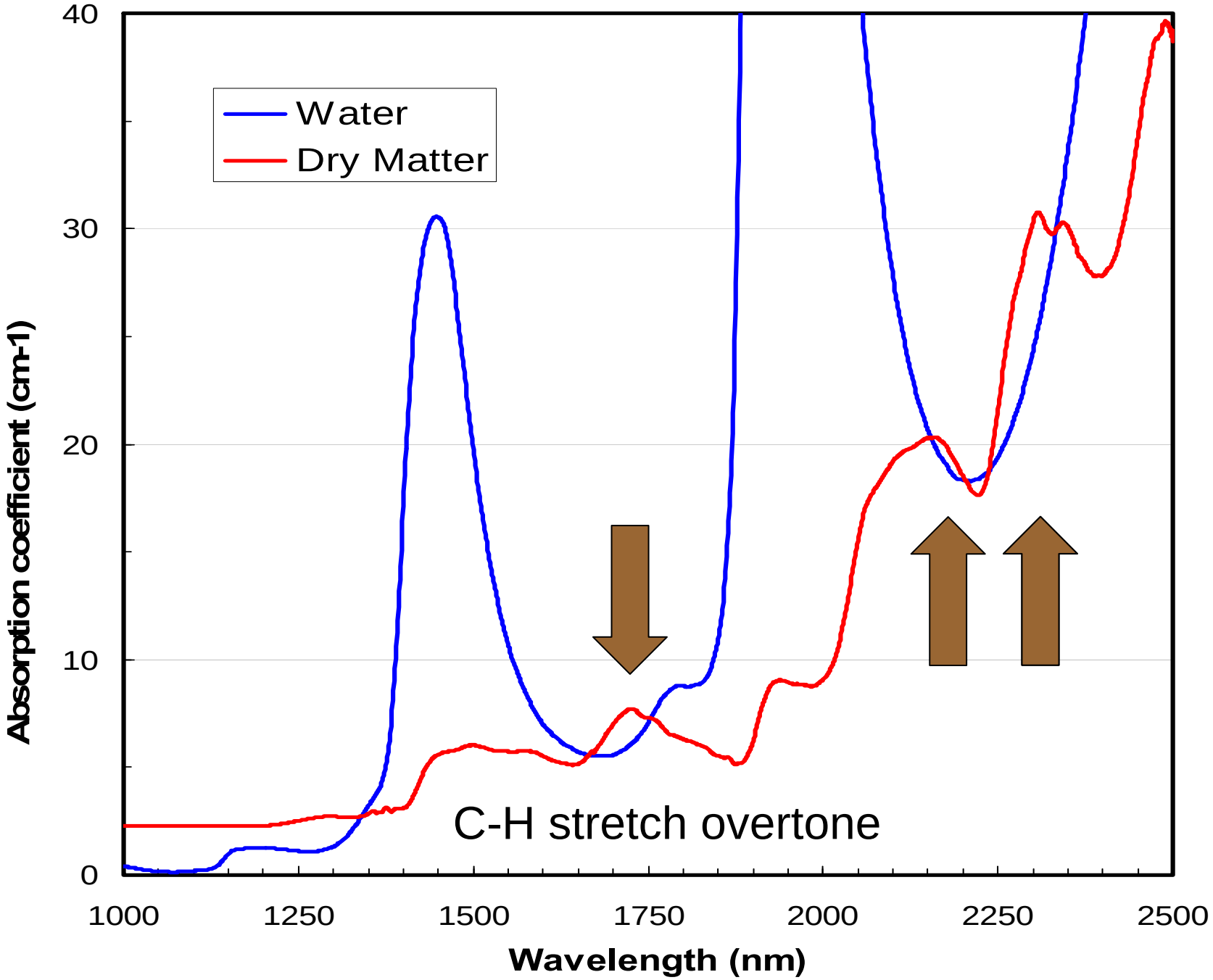


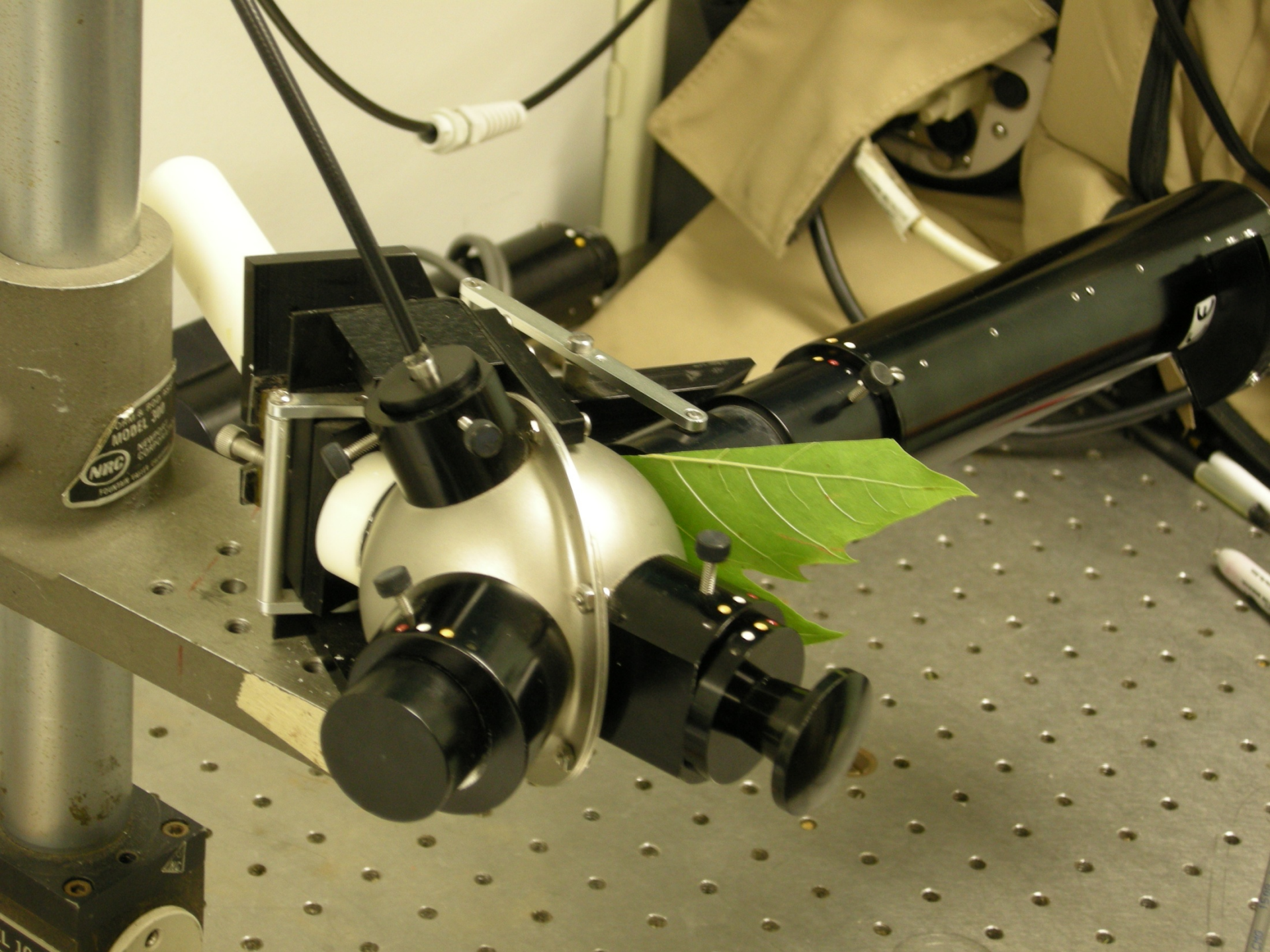
Normalized Difference = (Band 1 – Band 2)/(Band 1 – Band 2)

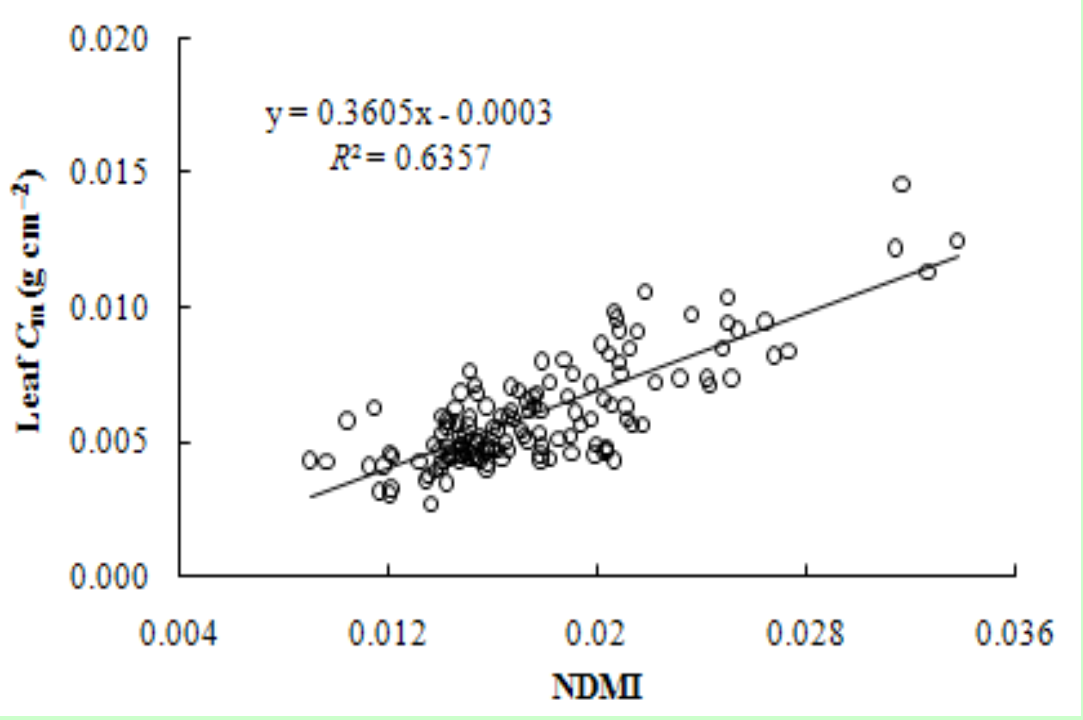
Band 1 (y-axis), Band 2 (x-axis)

Highest correlations: Band 1 - 1649 nm, Band 2 - 1722 nm

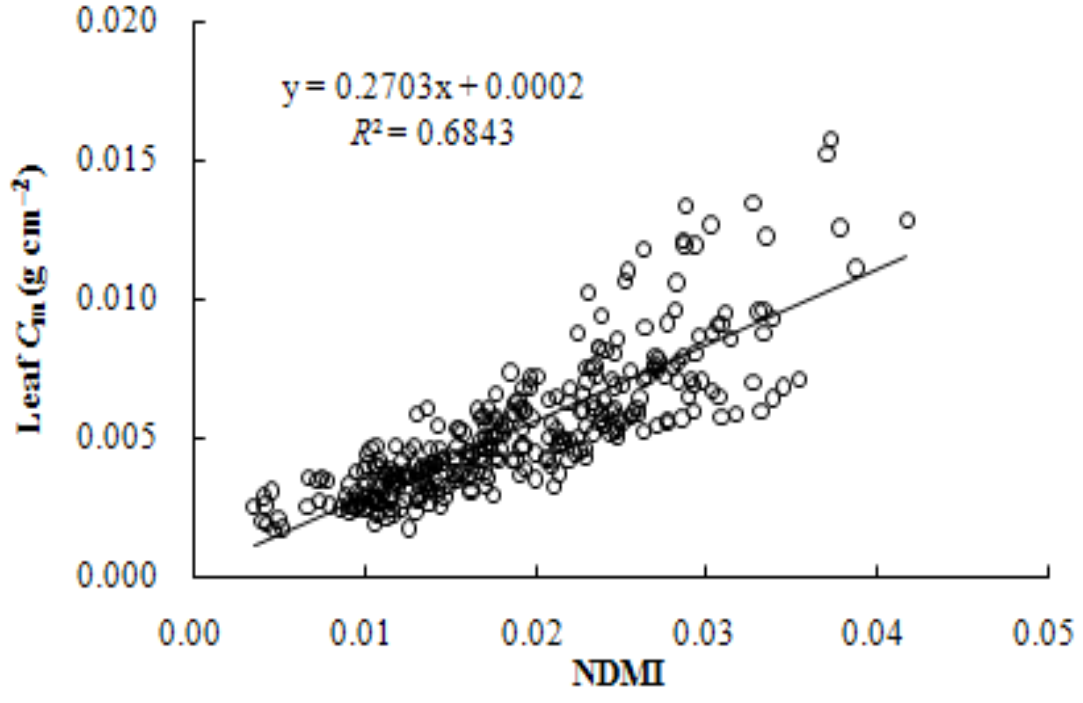
Called Normalized Dry Matter Index (NDMI)


Water
Dry Matter
C-H stretch overtone
Absorption coefficient (cm-1)
Wavelength (nm)
0
10
20
30
40
1000
1250
1500
1750
2000
2250
2500

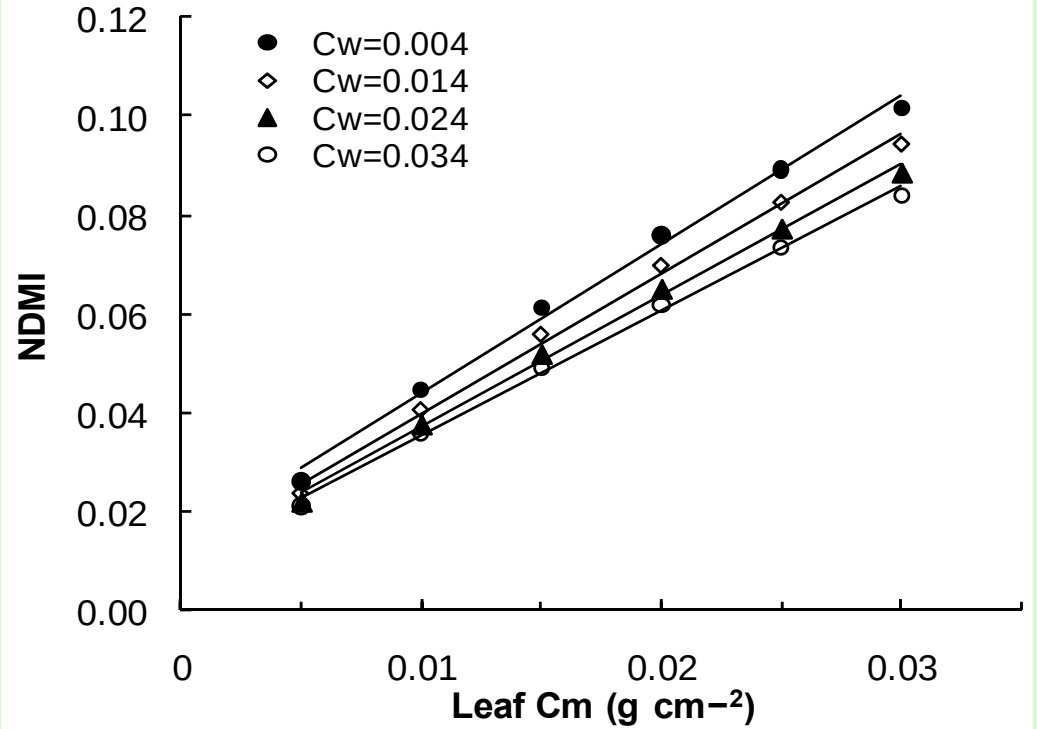




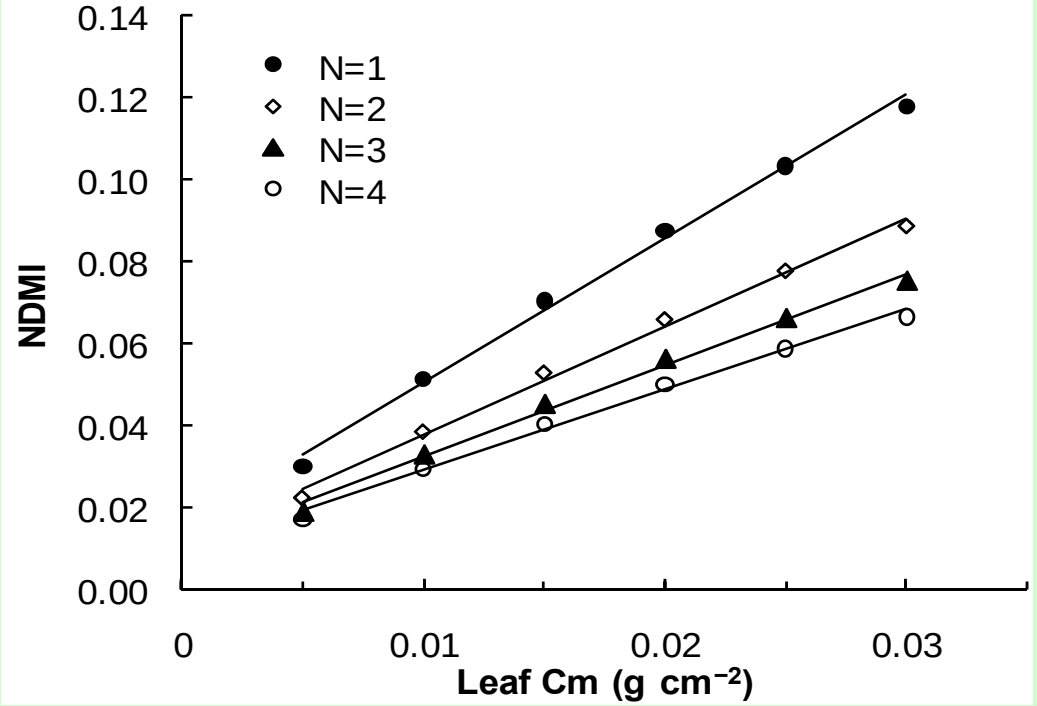
Validation
Leaf spectral reflectance of various species



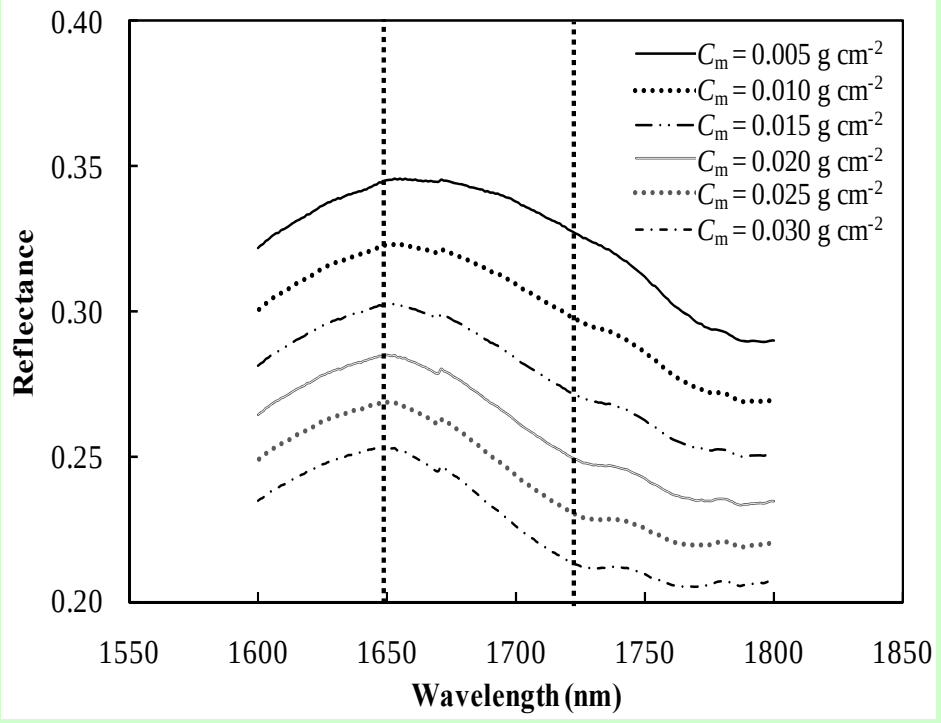
Validation
LOPEX data

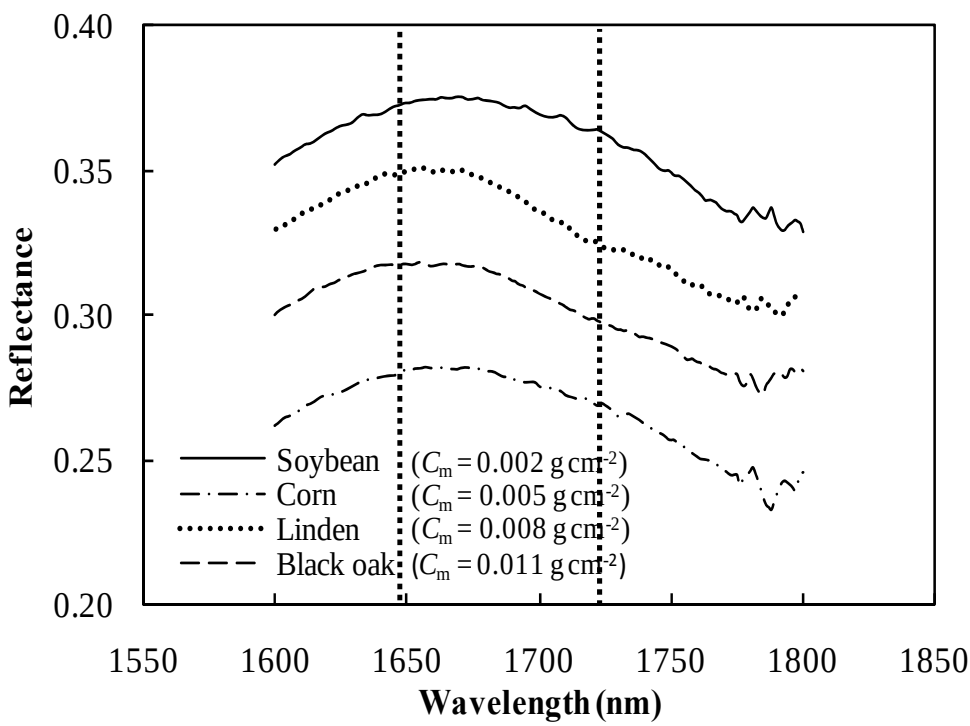


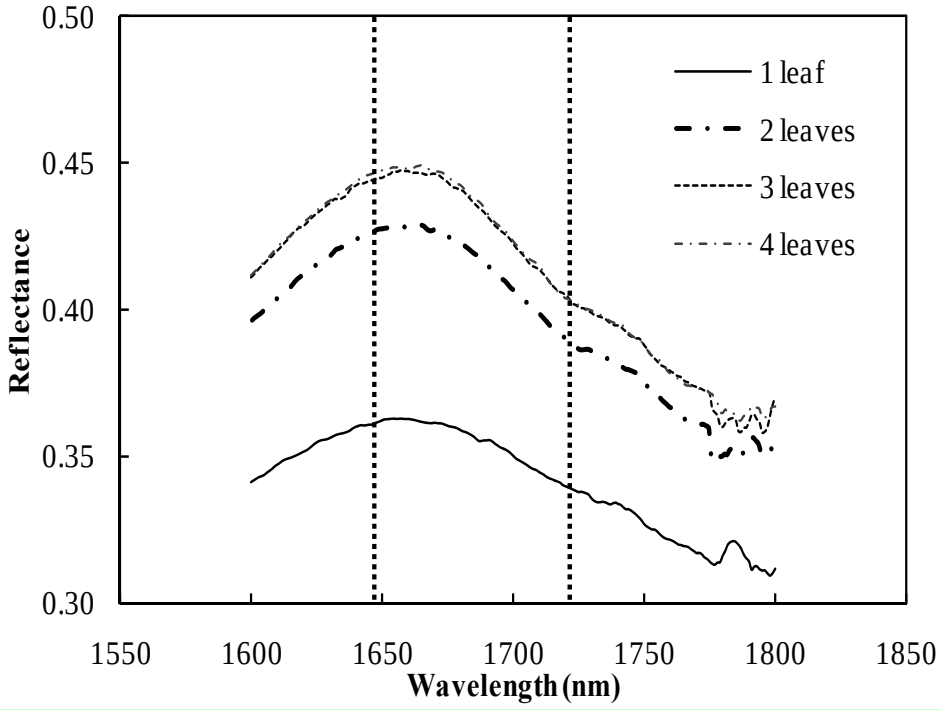
PROSPECT
Sensitivity to leaf water content (Cw)



PROSPECT
Sensitivity to leaf structure parameter (N)



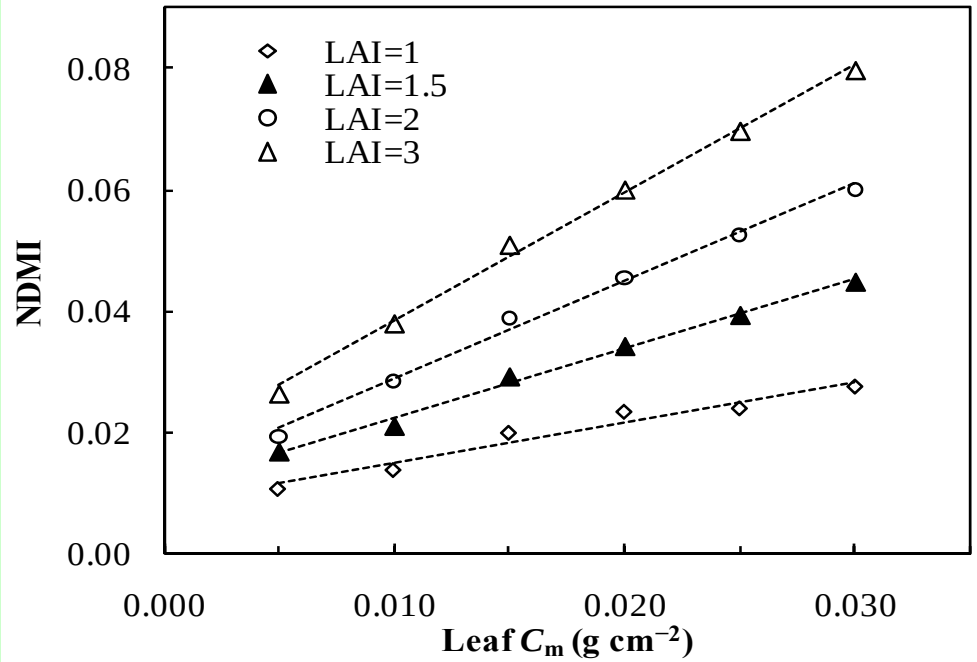




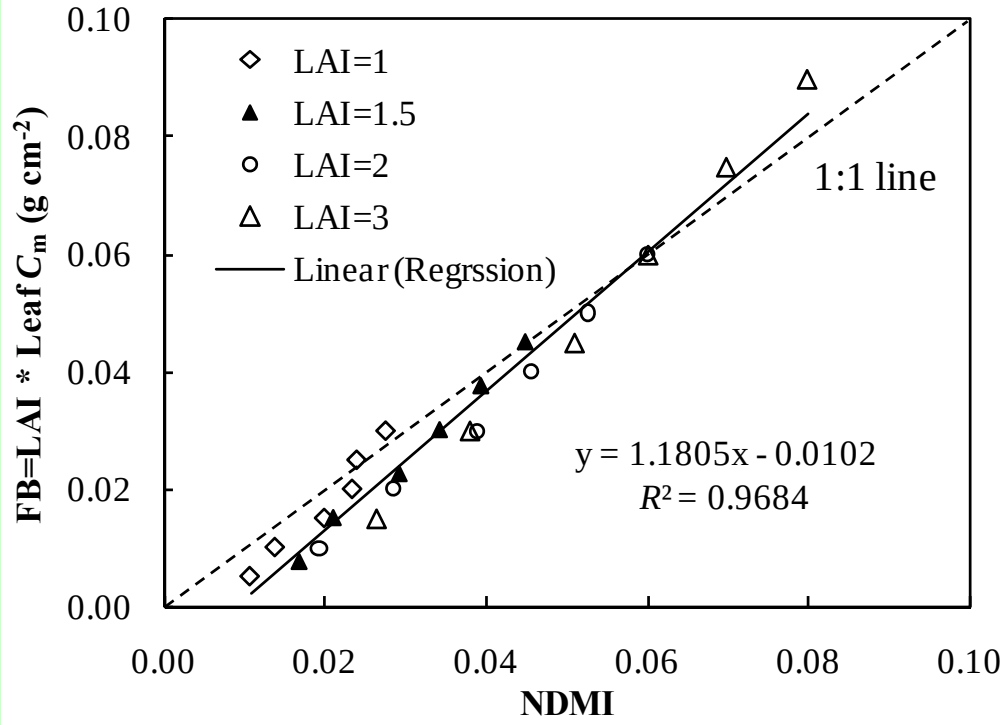
Leaf reflectances

PROSPECT simulations

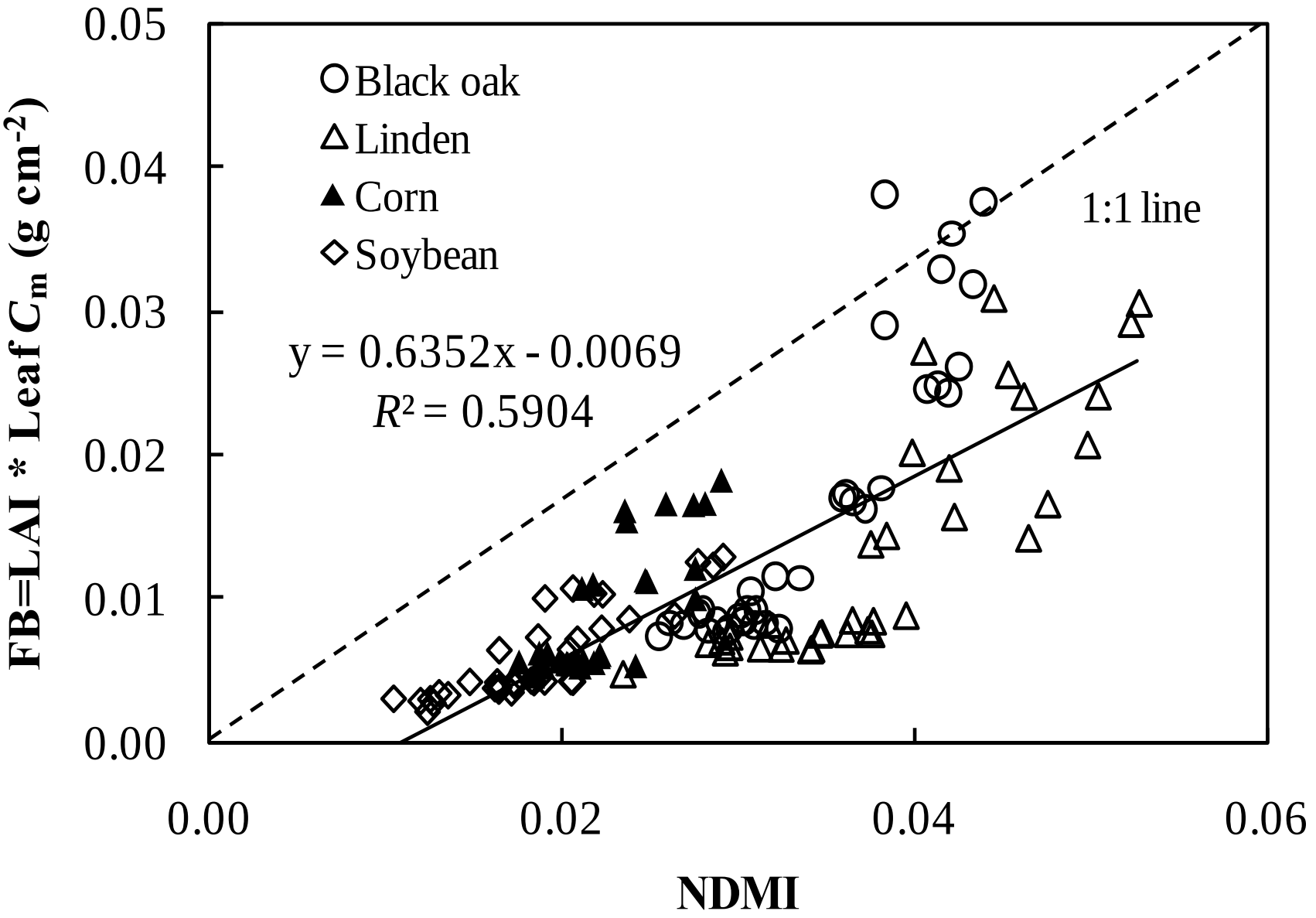
Stacked *Tilia* leaves



SAIL
Sensitivity to LAI



SAIL
Canopy dry mater content
= LAI * Cm

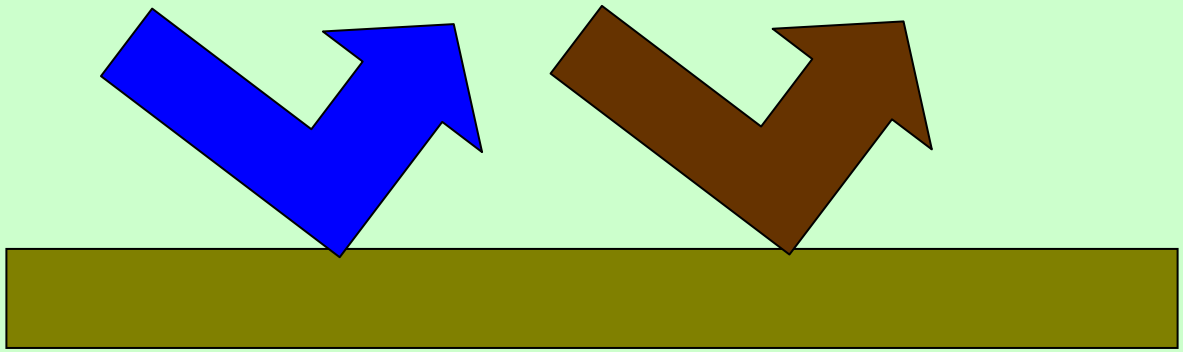


Spectral reflectances of stacked leaves were used to show that NDMI may predict total dry matter content of canopies

• Fuel moisture content (FMC) is the ratio of leaf water content to leaf dry-matter content

• Also, it is the ratio of canopy water content to canopy dry matter content, because leaf area cancels out

- We hypothesized that FMC could be remotely sensed using a ratio of a leaf/canopy water index to a leaf/canopy dry-matter index
- With a ratio of two indices, leaf area and other canopy factors may cancel out, so a ratio of two indices would be more accurate than either index alone.
- What indices to use?



Dry Matter Indices	Abbreviation	Equation
Normalized Dry Matter Index	NDMI	$(\rho_{1649} - \rho_{1722}) / (\rho_{1649} + \rho_{1722})$
Normalized Difference Tillage Index	NDTI	$(\rho_{1650} - \rho_{2215}) / (\rho_{1650} + \rho_{2215})$
Cellulose Absorption Index	CAI	$0.5\ (\rho_{2031} - \rho_{2211}) - \rho_{2101}$
Normalized Difference Lignin Index	NDLI	$[\log(1/\rho_{1754}) - \log(1/\rho_{1680})]/$ $[\log(1/\rho_{1754}) + \log(1/\rho_{1680})]$
Normalized Difference Nitrogen Index	NDNI	$[\log(1/\rho_{1510}) - \log(1/\rho_{1680})]/$ $[\log(1/\rho_{1510}) + \log(1/\rho_{1680})]$
Ligno-Cellulose Absorption Index	LCA	$2\ \rho_{2205} - (\rho_{2165} + \rho_{2330})$
Shortwave Infrared Normalized Difference Residue Index	SINDRI	$(\rho_{2210} - \rho_{2260}) / (\rho_{2210} + \rho_{2260})$
Dry Matter Content Index (NEW)	DMCI	$(\rho_{2305} - \rho_{1495}) / (\rho_{2305} + \rho_{1495})$

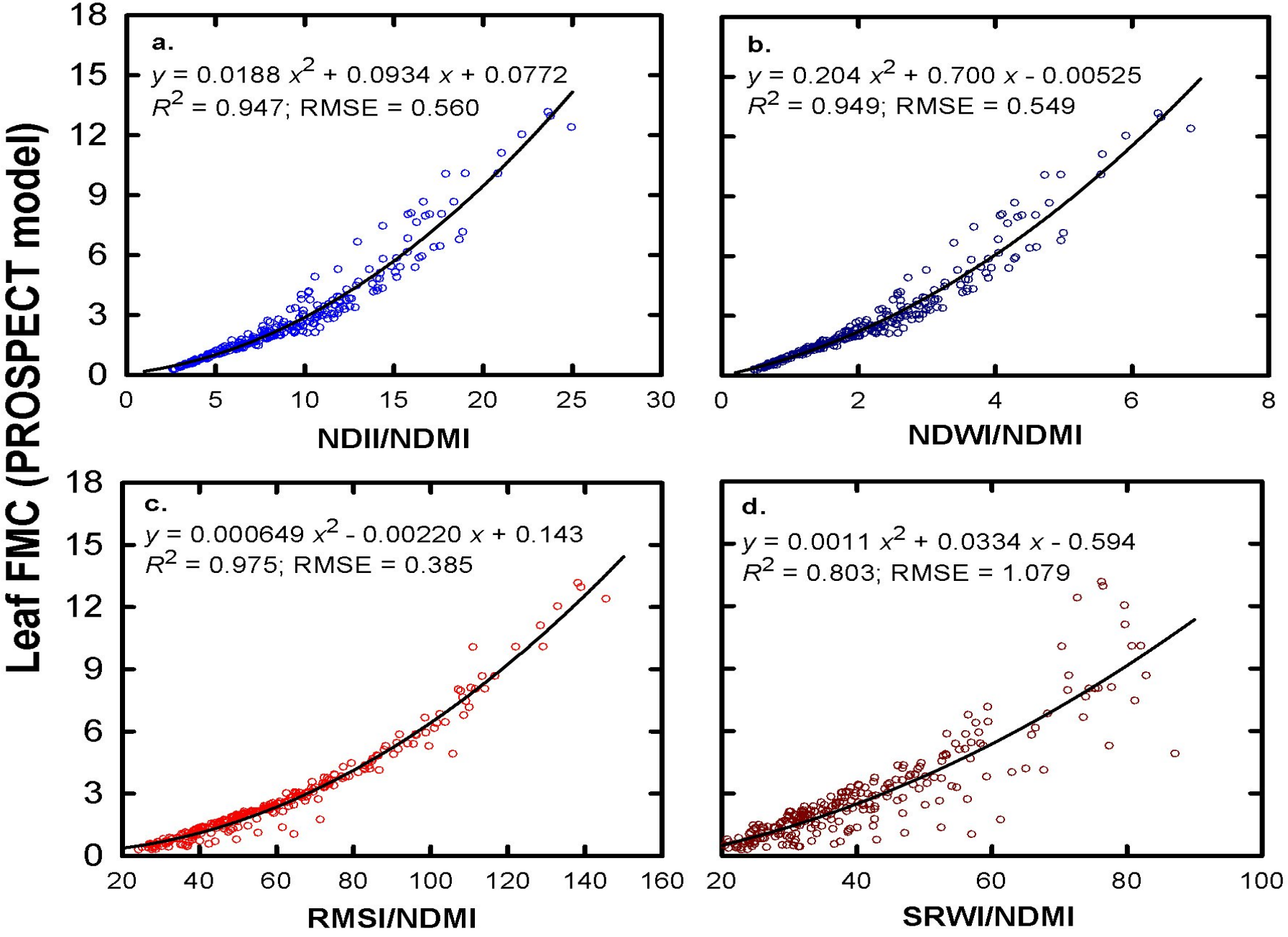
Canopy Water Indices	Abbreviation	Equation
Normalized Difference Infrared Index	NDII	$(\rho_{860} - \rho_{1650})/(\rho_{860} + \rho_{1650})$
Reciprocal of Moisture Stress Index	RMSI	ρ_{860}/ρ_{1650}
Normalized Difference Water Index	NDWI	$(\rho_{860} - \rho_{1240})/(\rho_{860} + \rho_{1240})$
Simple Ratio Water Index	SRWI	ρ_{860}/ρ_{1240}

PROSPECT simulations for dry-matter and water indices

Index	Leaf structure parameter (N)	Dry matter content (C_m)	Water content (C_w)	Fuel moisture content (FMC)
NDMI	-0.326	0.897	-0.0349	-0.599
NDTI	-0.500	0.279	0.792	0.274
CAI	-0.306	0.458	0.119	-0.119
NDLI	0.287	0.112	0.902	0.456
NDNI	0.121	-0.287	0.897	0.684
LCA	0.759	-0.100	-0.626	-0.268
SINDRI	0.0794	0.531	-0.832	-0.808
DMCI	0.394	-0.847	0.102	0.589
NDII	-0.381	0.0628	0.919	0.478
RMSI	-0.406	0.0496	0.899	0.476
NDWI	-0.382	-0.106	0.927	0.593
SWRI	-0.386	-0.108	0.923	0.595

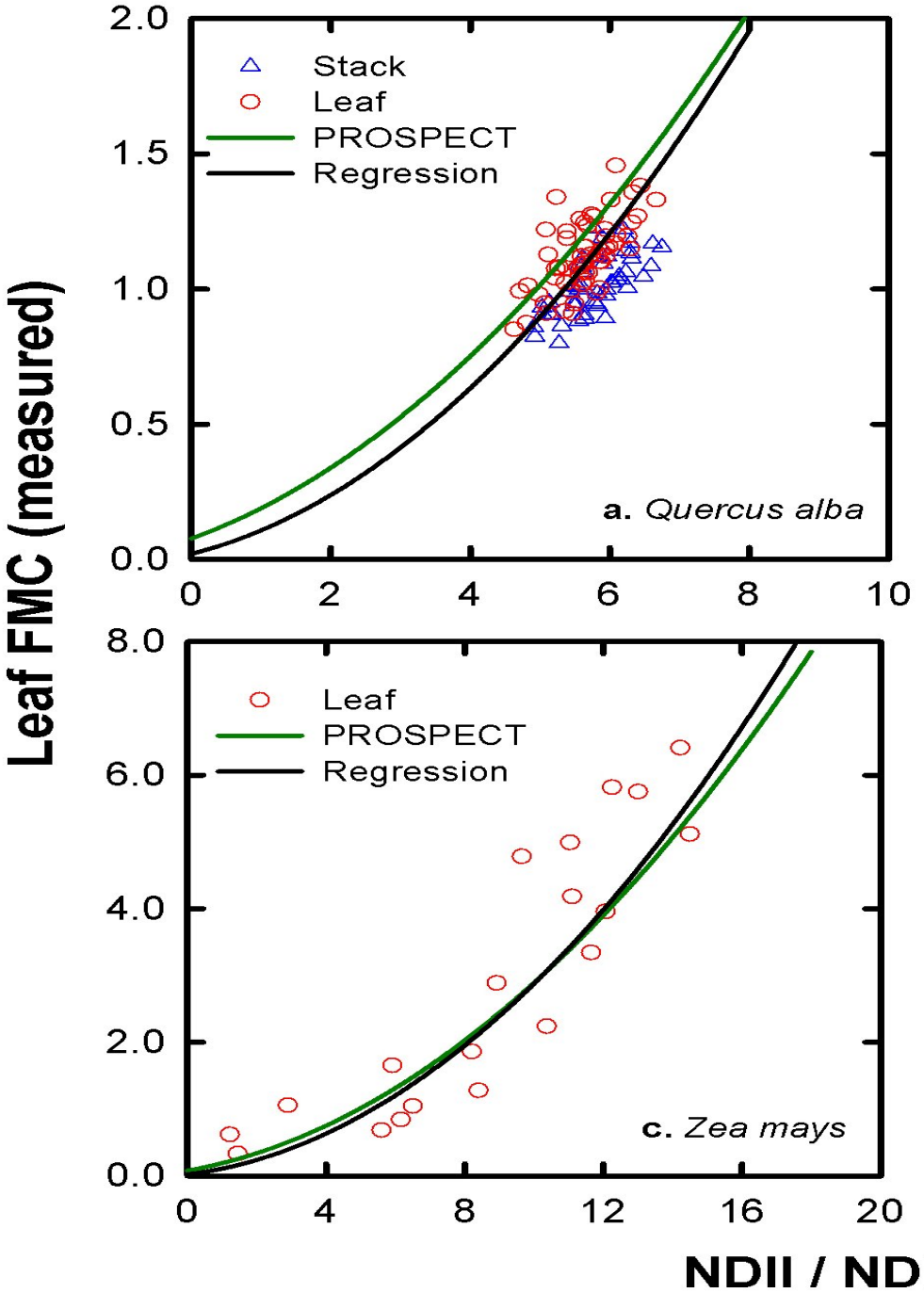
PROSPECT simulations water/dry-matter index

Dry-matter index	Water index			
	NDWI	NDII	SWRI	RMSI
NDMI	0.966	0.961	0.716	0.899
NDTI	0.809	0.734	-0.207	0.064
CAI	-0.097	-0.091	-0.083	-0.087
NDLI	0.523	0.356	-0.335	0.010
NDNI	0.166	-0.126	-0.537	-0.478
LCA	0.369	0.308	0.256	0.279
SINDRI	0.048	0.049	0.046	0.047
DMCI	-0.922	-0.903	-0.689	-0.882


Leaf FMC (PROSPECT model)
a.
y = 0.0188 x2 + 0.0934 x + 0.0772
R2 = 0.947; RMSE = 0.560
NDII/NDMI
b.
y = 0.204 x2 + 0.700 x - 0.00525
R2 = 0.949; RMSE = 0.549
NDWI/NDMI
c.
y = 0.000649 x2 - 0.00220 x + 0.143
R2 = 0.975; RMSE = 0.385
RMSI/NDMI
d.
y = 0.0011 x2 + 0.0334 x - 0.594
R2 = 0.803; RMSE = 1.079
SRWI/NDMI

Leaf spectral reflectance data water/dry-matter index ratio

Dry-matter index	Water index			
	NDWI	NDII	SWRI	RMSI
NDMI	0.732	0.890	0.674	0.775
NDTI	0.232	-0.064	-0.003	-0.036
CAI	-0.367	-0.174	-0.360	-0.270
NDLI	0.282	0.199	-0.041	0.047
NDNI	0.079	0.044	-0.058	0.057
LCA	0.403	0.205	0.408	0.323
SINDRI	0.498	0.469	0.478	0.474
DMCI	-0.539	-0.486	-0.500	-0.505

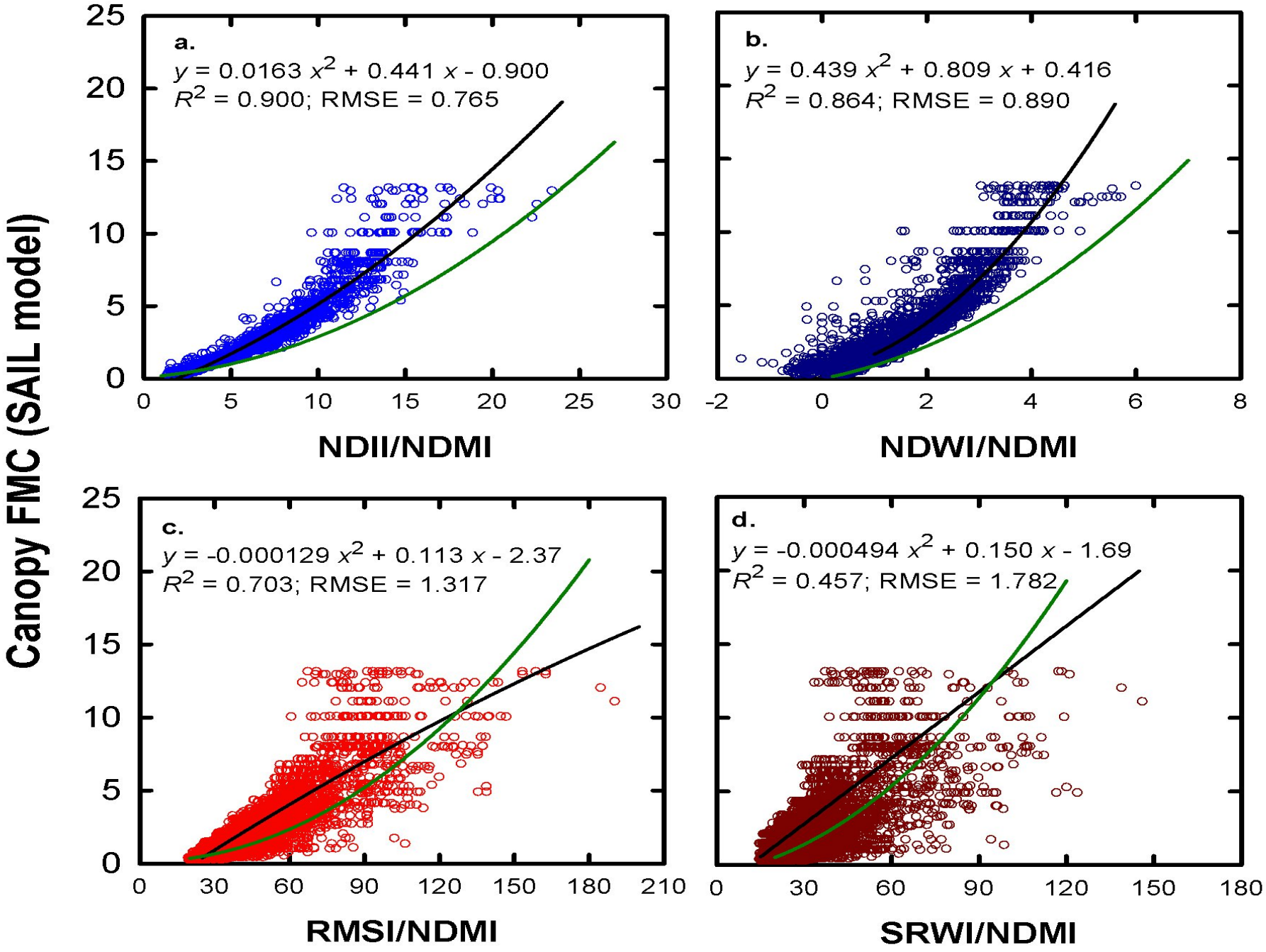


Leaves and leaf stacks were air-dried over a few Hours

Regression equation was for all data pooled, not a fit to each species

SAIL model simulations water/dry-matter index ratio

Dry-matter index	Water index			
	NDWI	NDII	SWRI	RMSI
NDMI	0.706	0.952	0.760	0.950
NDTI	0.467	0.568	0.142	0.684
CAI	-0.327	-0.228	-0.199	-0.239
NDLI	0.426	0.366	0.109	0.413
NDNI	0.456	0.359	0.400	0.397
LCA	0.403	0.350	0.353	0.360
SINDRI	0.518	0.254	0.173	0.210
DMCI	-0.597	-0.755	-0.445	-0.691


Canopy FMC (SAIL model)
a.
y = 0.0163 x2 + 0.441 x - 0.900
R2 = 0.900; RMSE = 0.765
NDII/NDMI
b.
y = 0.439 x2 + 0.809 x + 0.416
R2 = 0.864; RMSE = 0.890
NDWI/NDMI
c.
y = -0.000129 x2 + 0.113 x - 2.37
R2 = 0.703; RMSE = 1.317
RMSI/NDMI
d.
y = -0.000494 x2 + 0.150 x - 1.69
R2 = 0.457; RMSE = 1.782
SRWI/NDMI

Airborne Visible Infrared Imaging Spectrometer (AVIRIS)

High altitude 20-m pixels

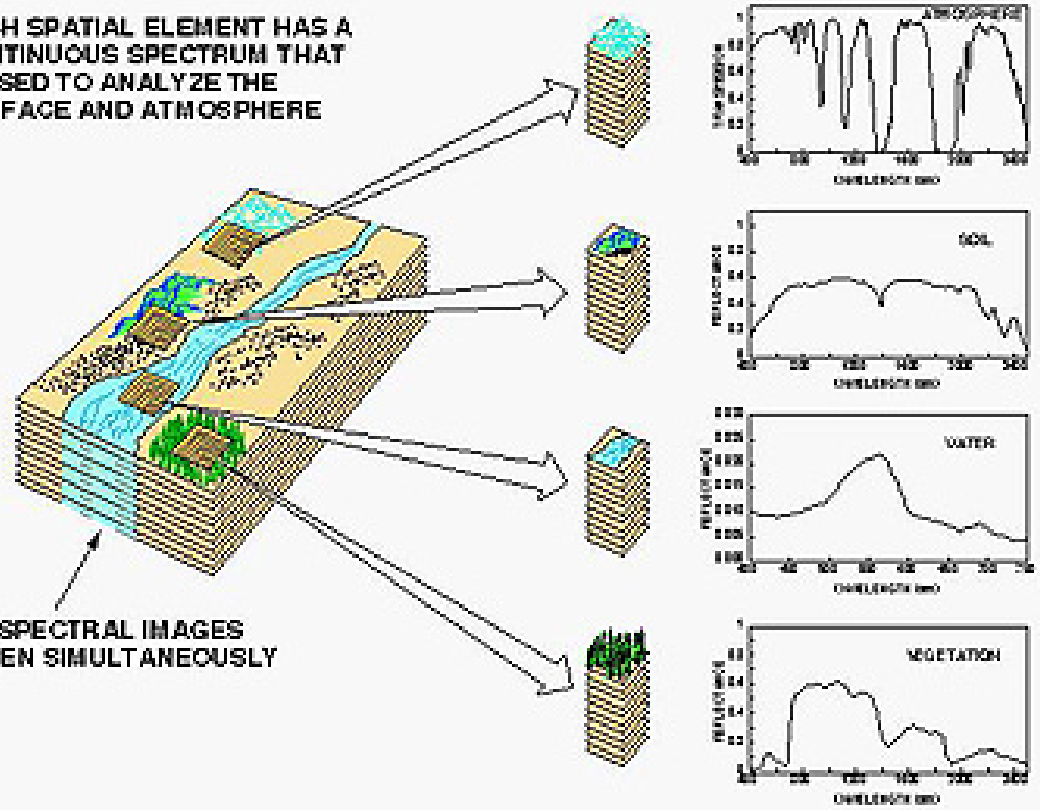
Required viewgraph for describing imaging spectroscopy

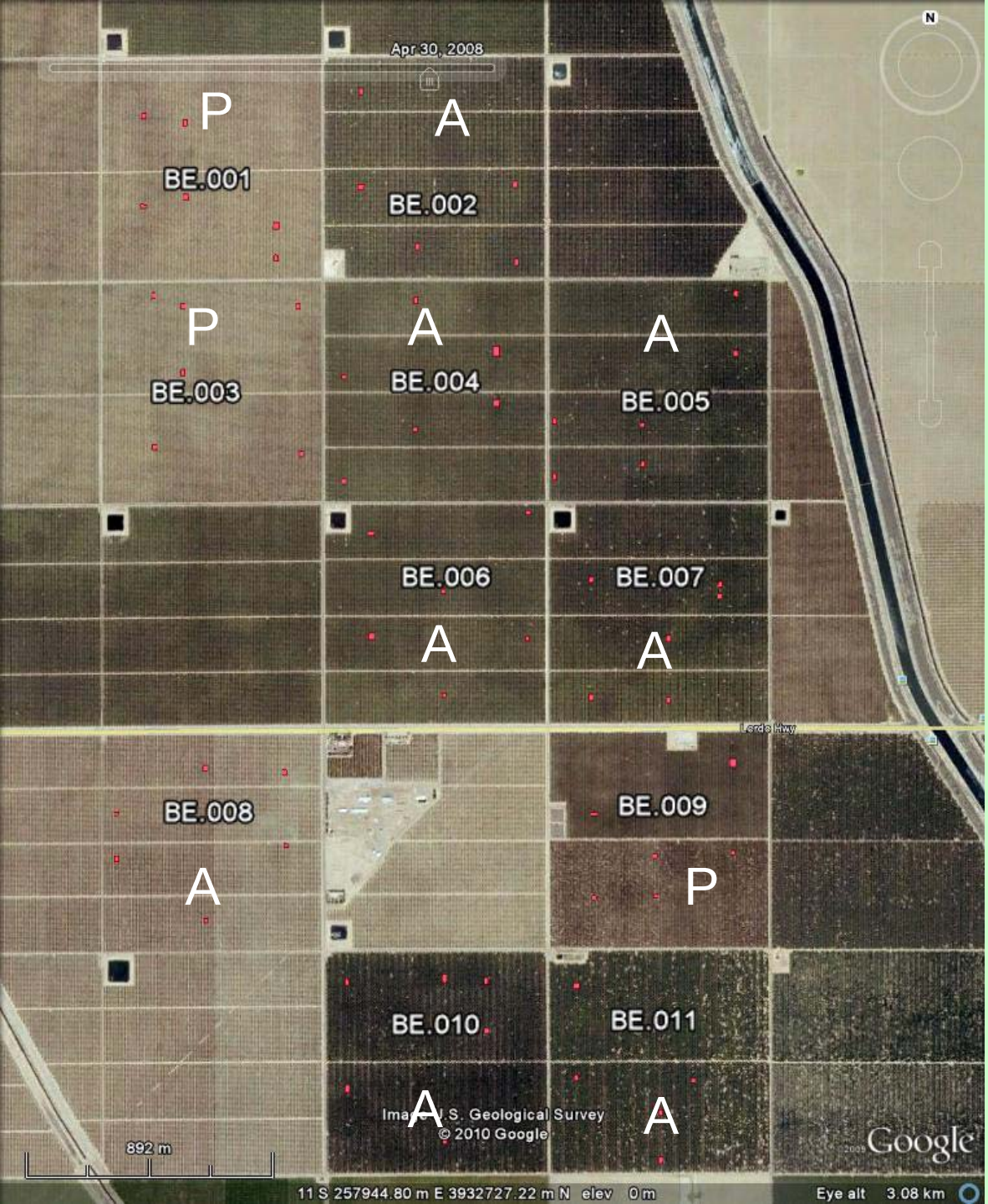
JPL

AVIRIS CONCEPT

EACH SPATIAL ELEMENT HAS A CONTINUOUS SPECTRUM THAT IS USED TO ANALYZE THE SURFACE AND ATMOSPHERE

224 SPECTRAL IMAGES TAKEN SIMULTANEOUSLY





Remote sensing Orchard Water Stress (ROWS)

Paramount Farms Belridge District,

Lost Hills, California

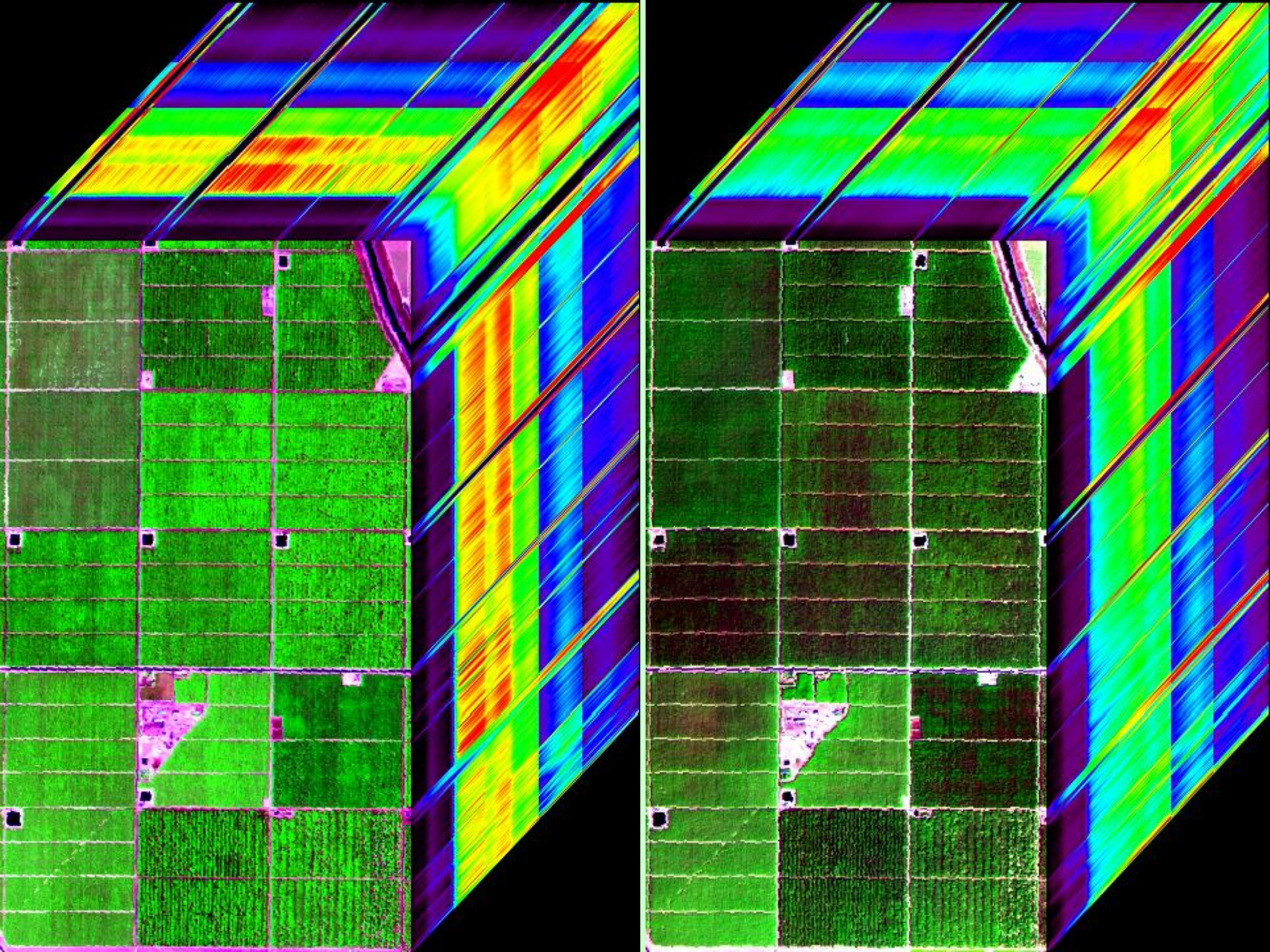
AVIRIS ER-2 overflights

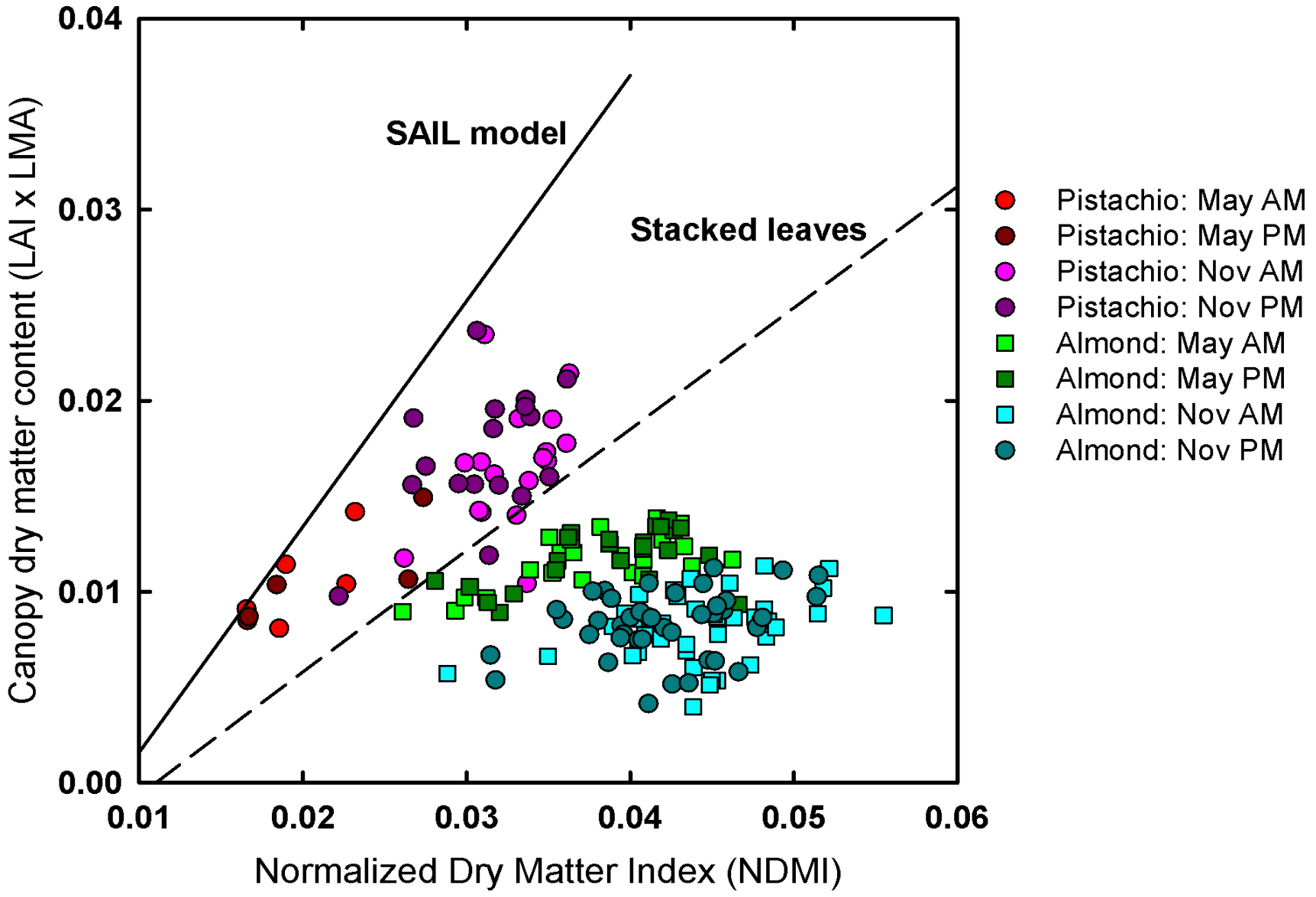
May 20, 2011

11 AM and 3 PM

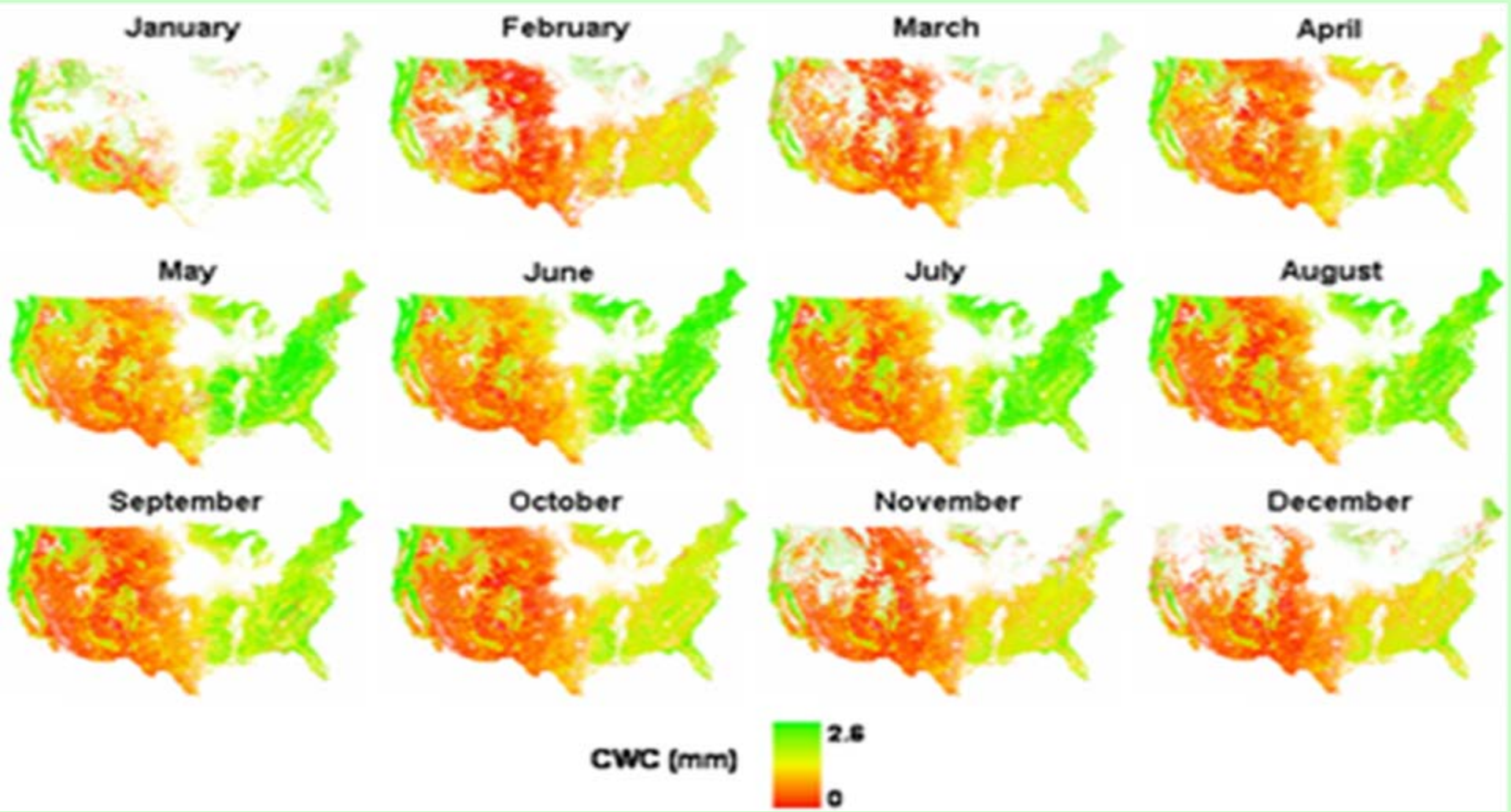
Nov. 2, 2011

11 AM and 3 PM




0.04
0.03
0.02
0.01
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Canopy dry matter content (LAI x LMA)
Normalized Dry Matter Index (NDMI)
SAIL model
Stacked leaves
Pistachio: May AM
Pistachio: May PM
Pistachio: Nov AM
Pistachio: Nov PM
Almond: May AM
Almond: May PM
Almond: Nov AM
Almond: Nov PM

HyspIRI will have a 19-day repeat frequency, so the temporal resolution will not be sufficient to monitor FMC



MODIS and VIIRS have high temporal frequency for monitoring canopy water content, but don’t have bands for dry-matter content

At the leaf scale, FMC from NDII/NDMI seems to be independent of plant functional type/species, so an index ratio cancels out leaf properties.

At the canopy scale, particularly for AVIRIS data, FMC from NDII/NDMI may be highly dependent on plant species.

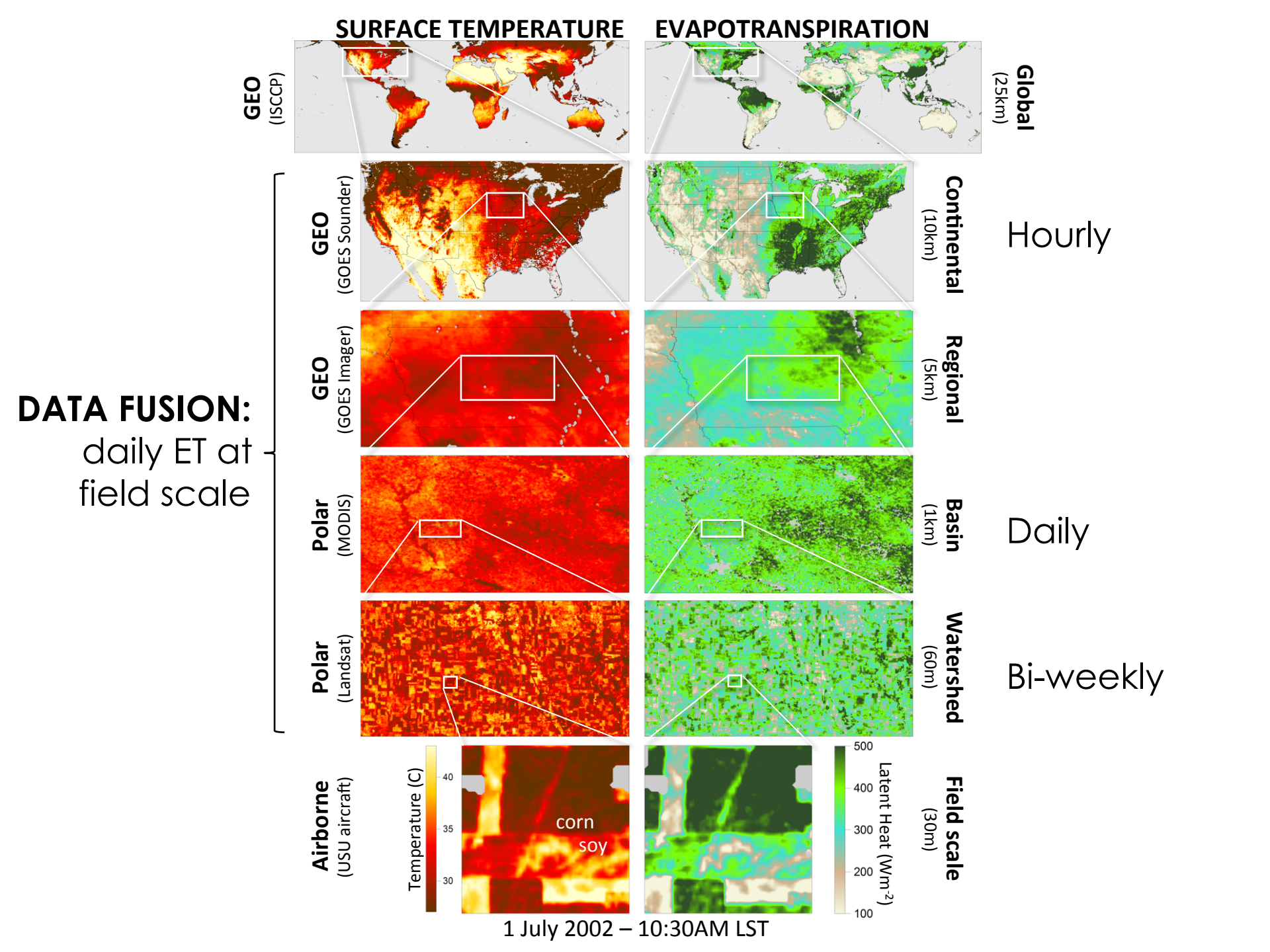
Monitoring FMC by satellite will probably require two satellite sensors:

- Imaging spectrometer (HyspIRI)
  - Dry matter content
  - Regional calibration of FMC

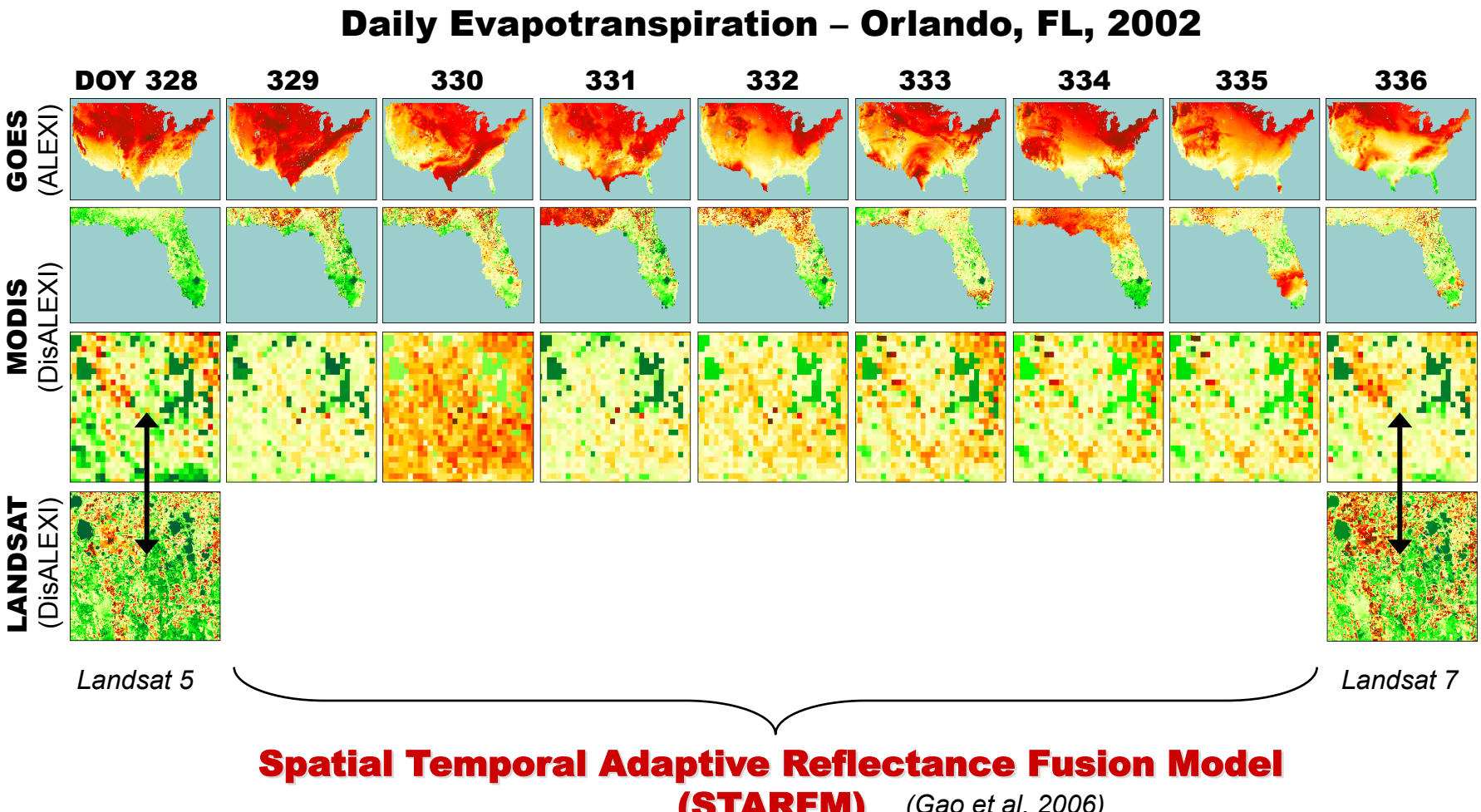
- Environmental satellites (VIIRS, MODIS)
  - Water content

Data Fusion Techniques for Mapping Daily Water Use at Field Scales

Martha C. Anderson
Carmelo Cammalleri
Feng Gao
Mitchell Schull
USDA-Agricultural Research Service
Hydrology and Remote Sensing Laboratory
Beltsville, MD

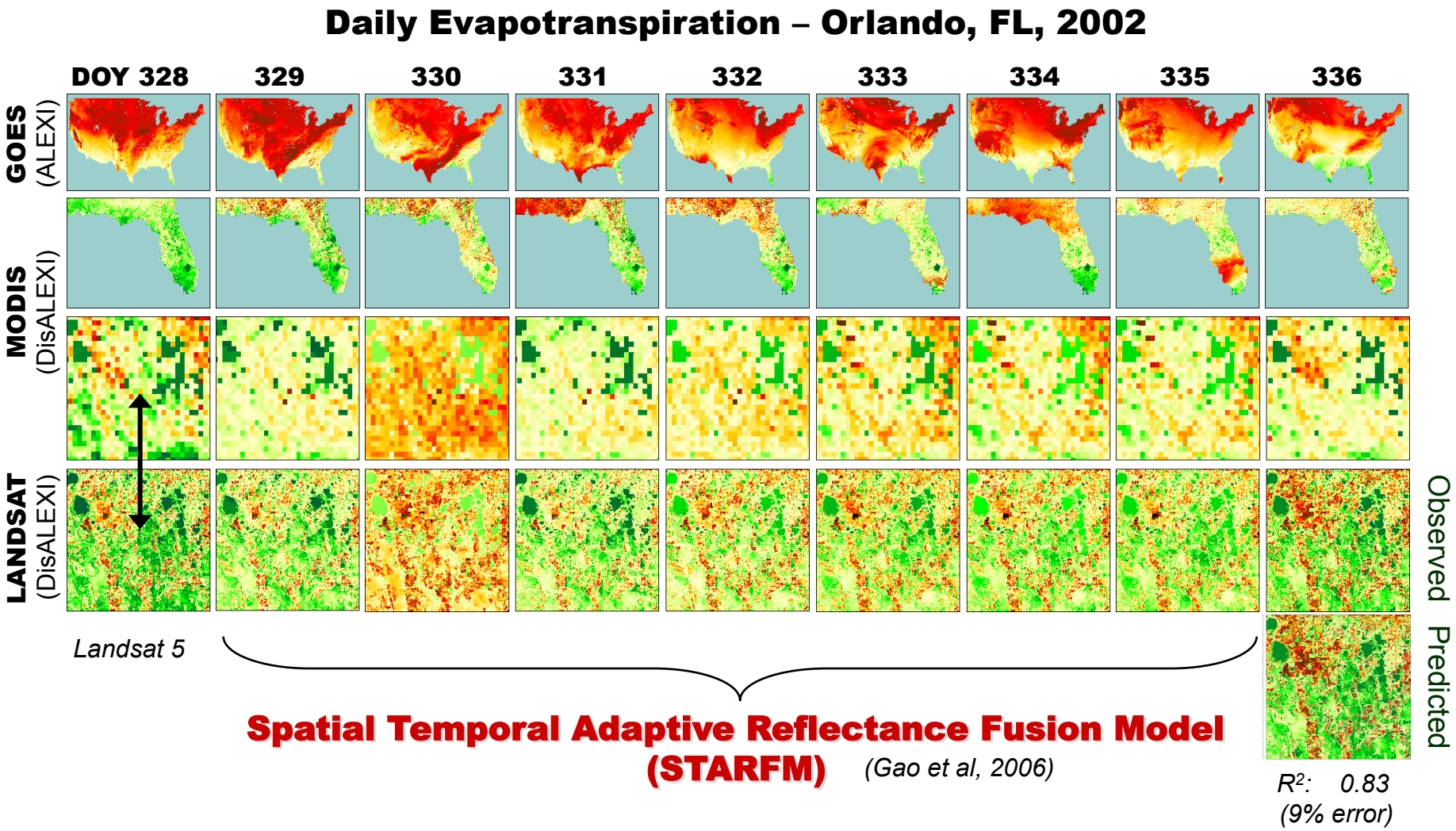

SURFACE TEMPERATURE
EVAPOTRANSPIRATION
GEO (ISCCP)
Global (25km)
GEO (GOES Sounder)
Continental (10km)
Hourly
GEO (GOES Imager)
Regional (5km)
DATA FUSION:
daily ET at field scale
Polar (MODIS)
Basin (1km)
Daily
Polar (Landsat)
Watershed (60m)
Bi-weekly
Airborne (USU aircraft)
Temperature (C)
40
35
30
corn
soy
Latent Heat (Wm-2)
500
400
300
200
100
Field scale (30m)
1 July 2002 – 10:30AM LST

GOES/MODIS/Landsat FUSION

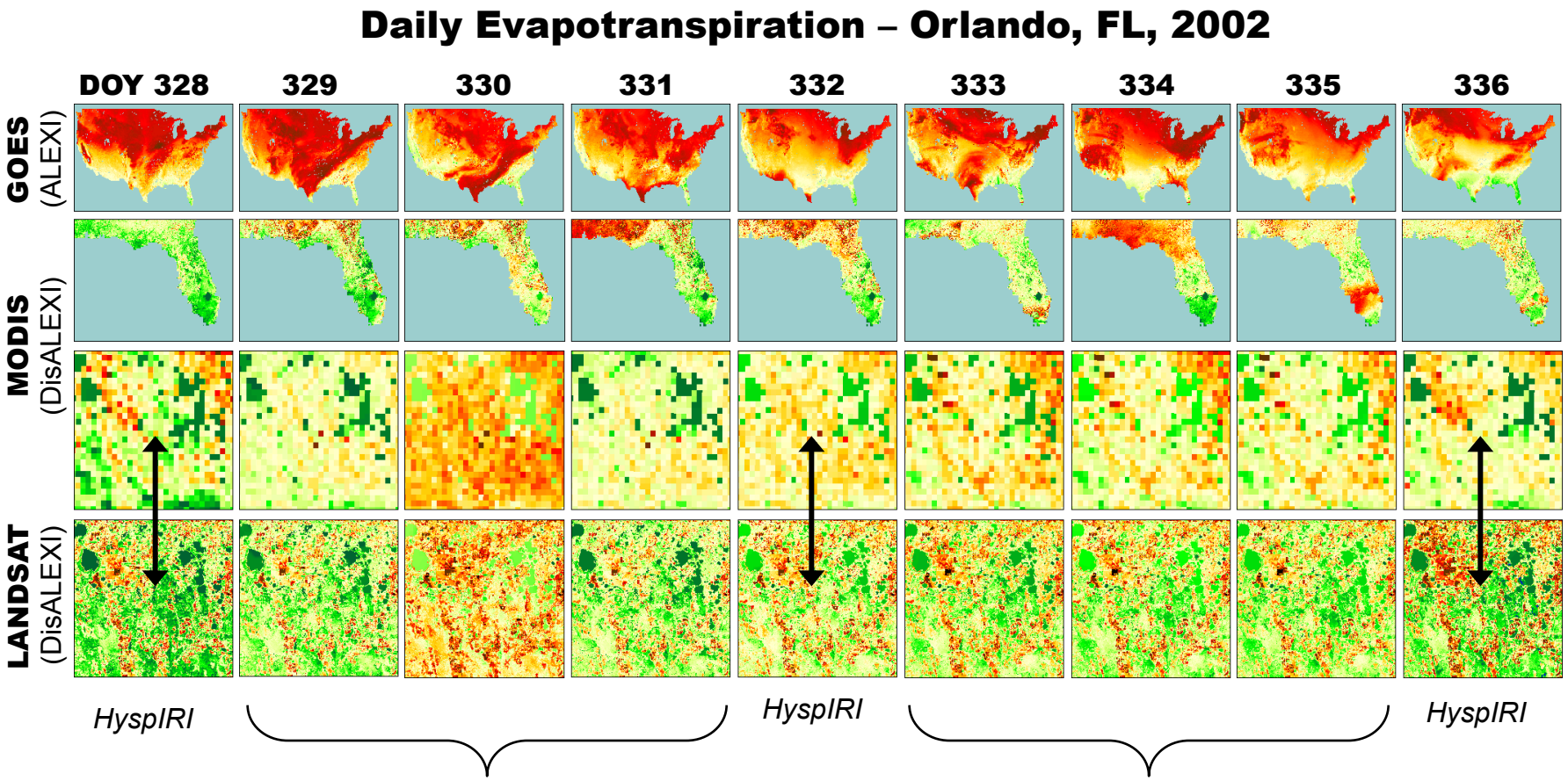


Spatial Temporal Adaptive Reflectance Fusion Model (STARFM) *(Gao et al, 2006)*

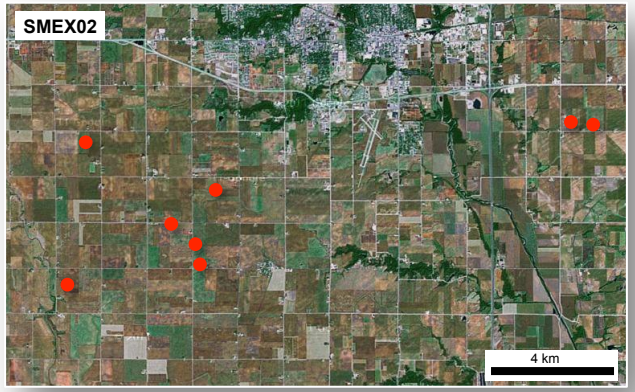
GOES/MODIS/Landsat FUSION



GOES/MODIS/HyspIRI FUSION

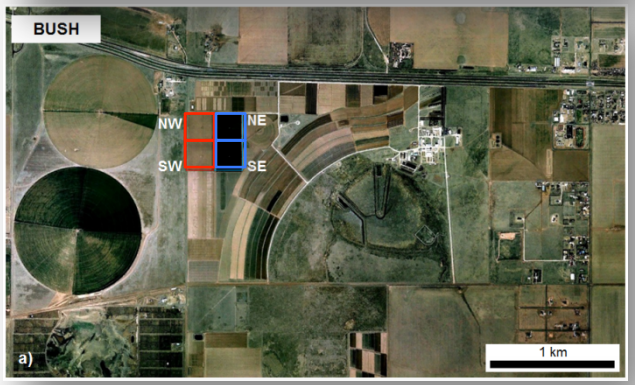


Spatial Temporal Adaptive Reflectance Fusion Model (STARFM) *(Gao et al, 2006)*



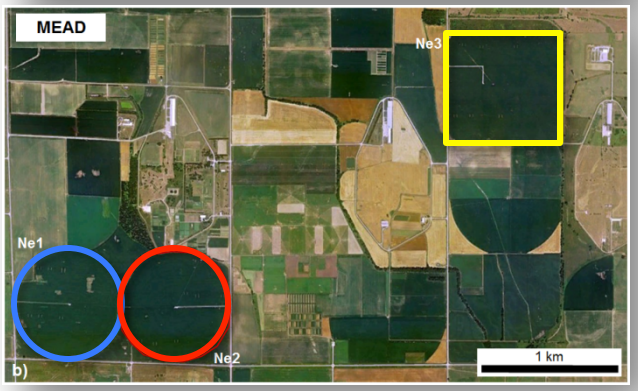
SMEX02

Soil Moisture Experiment 2002
Ames, Iowa
Rainfed corn and soybean



BEAREX08

Bushland ET and Remote sensing Experiment 2008
Bushland, Texas
Rainfed and irrigated cotton

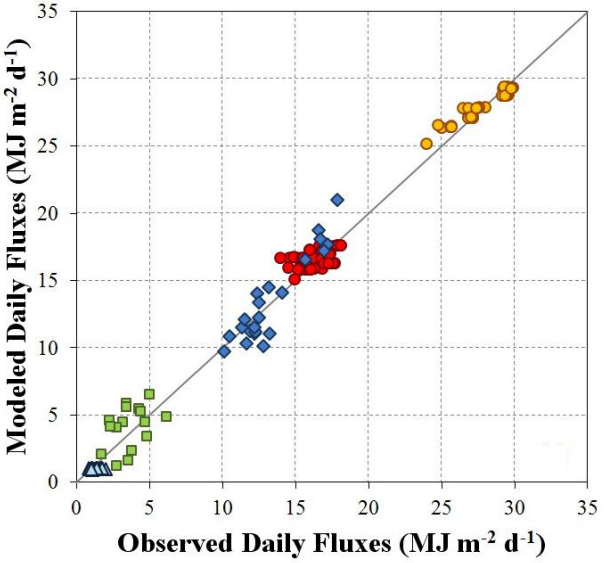


MEAD

Ameriflux site (S. Verma)
Mead, NE
Rainfed and irrigation corn and soybean

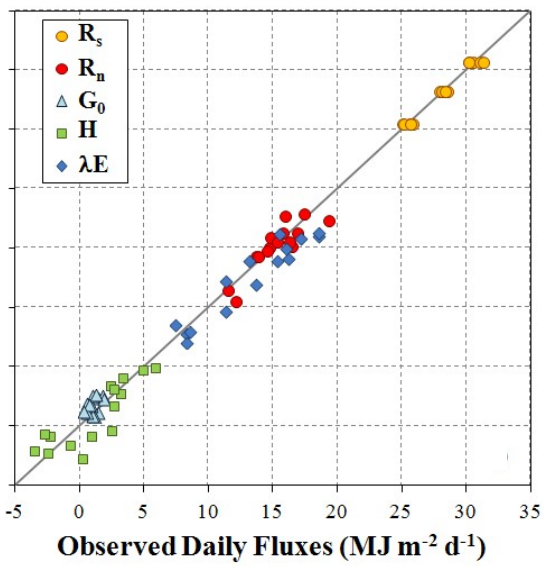
Model performance on Landsat dates

SMEX02



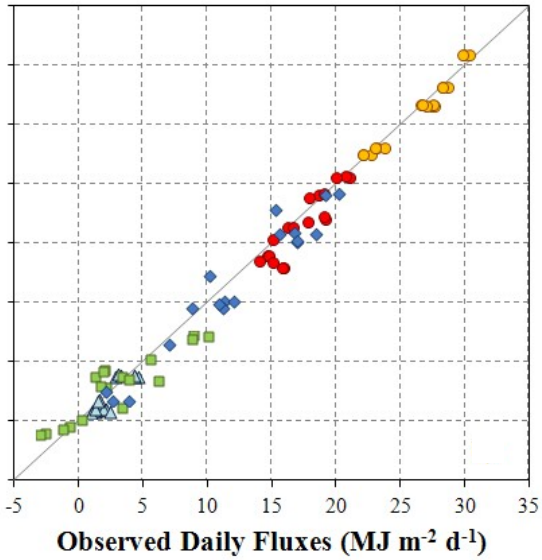
MAE: 1.08 MJ m^{-2} d^{-1}
RE: 8%

BEAREX08



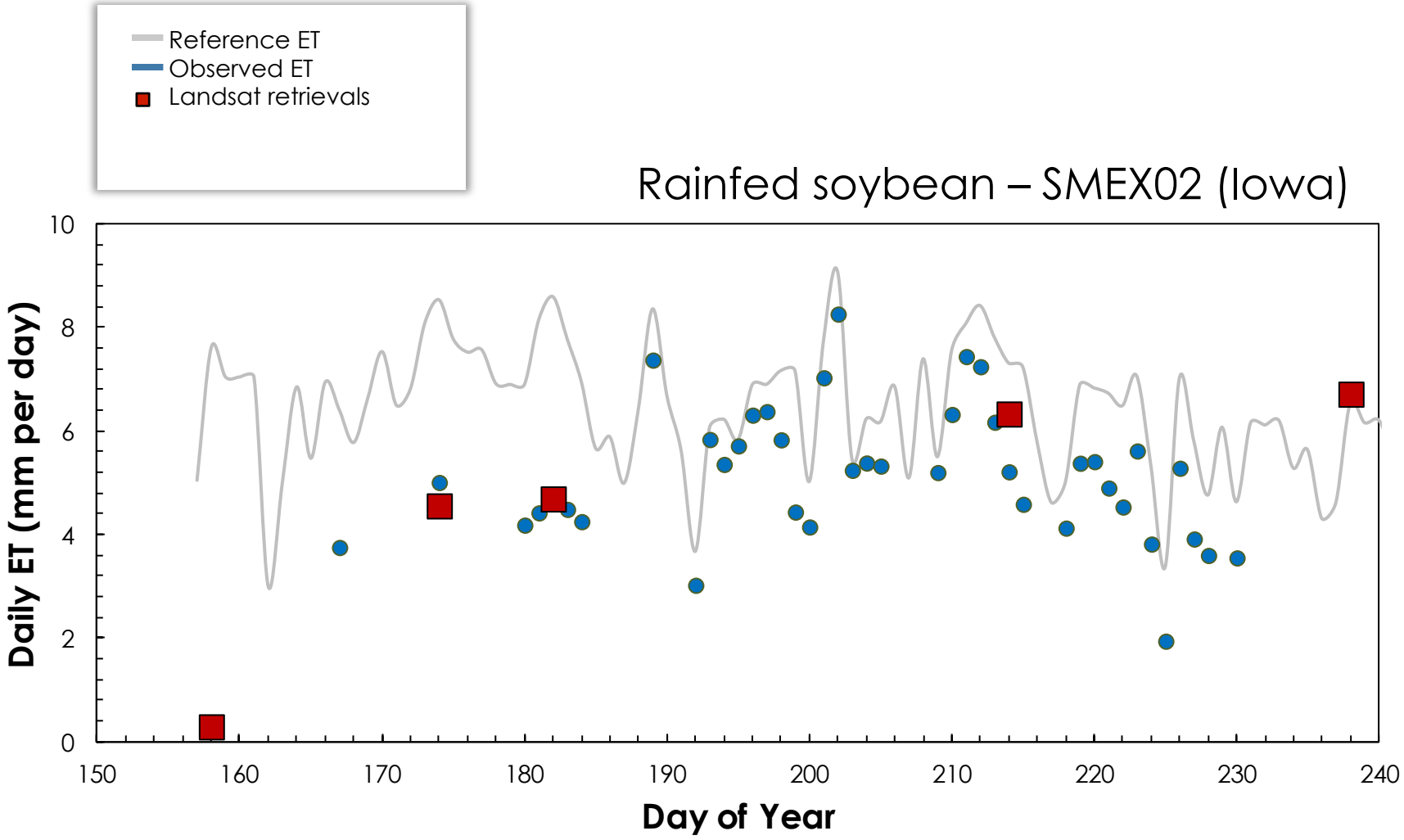
1.3 MJ m^{-2} d^{-1}
10%

MEAD

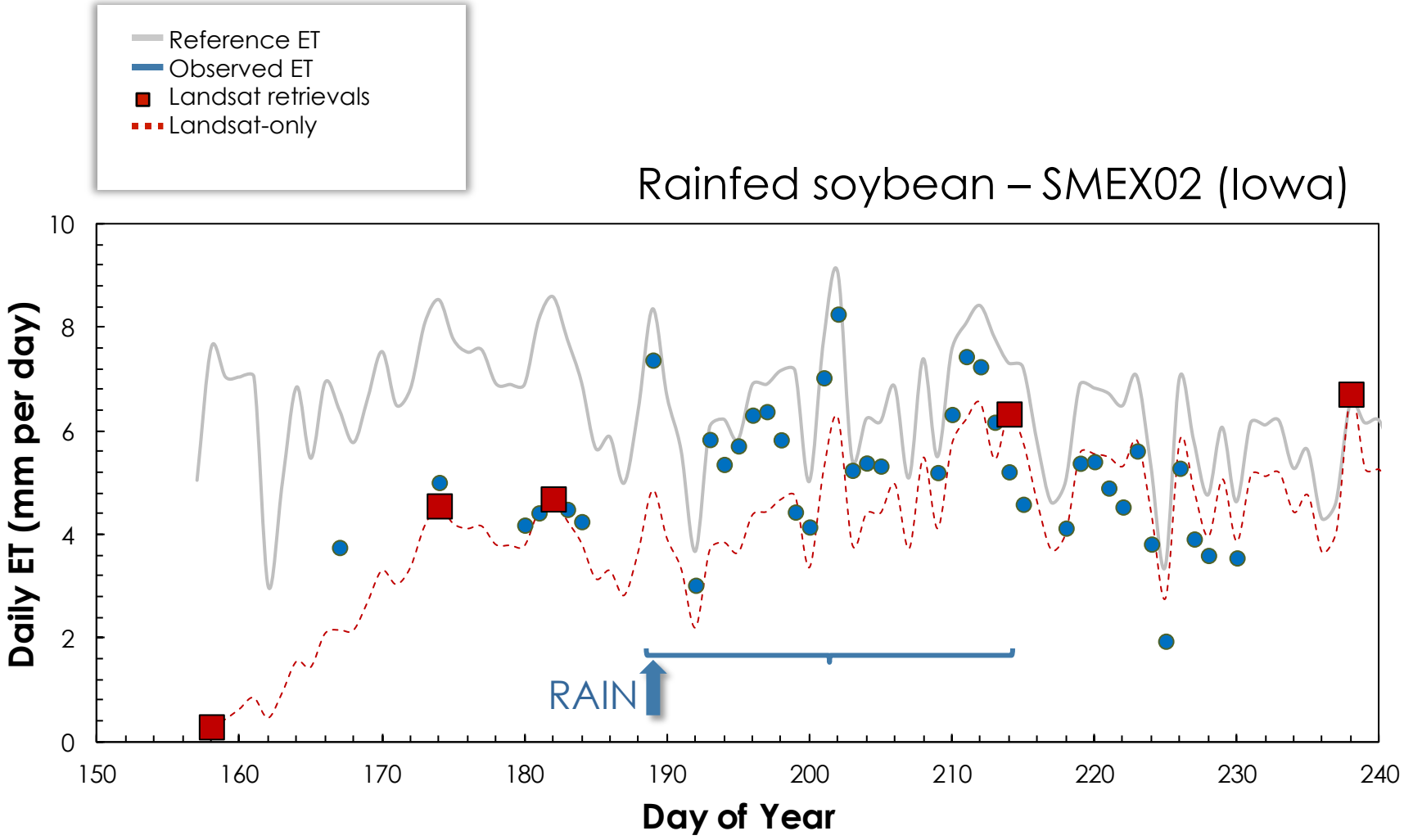


1.3 MJ m^{-2} d^{-1}
11%

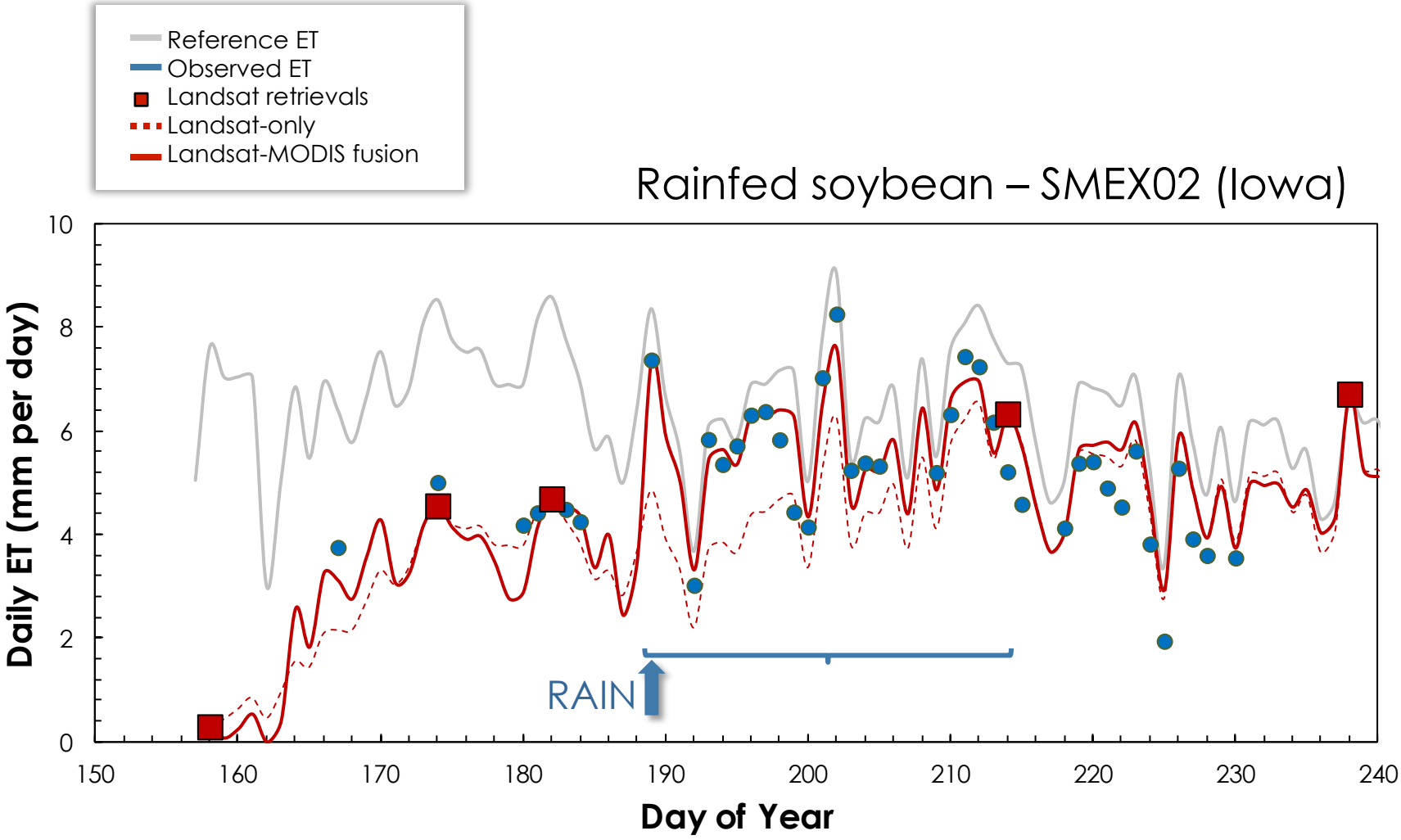
Validation using flux tower data



Validation using flux tower data

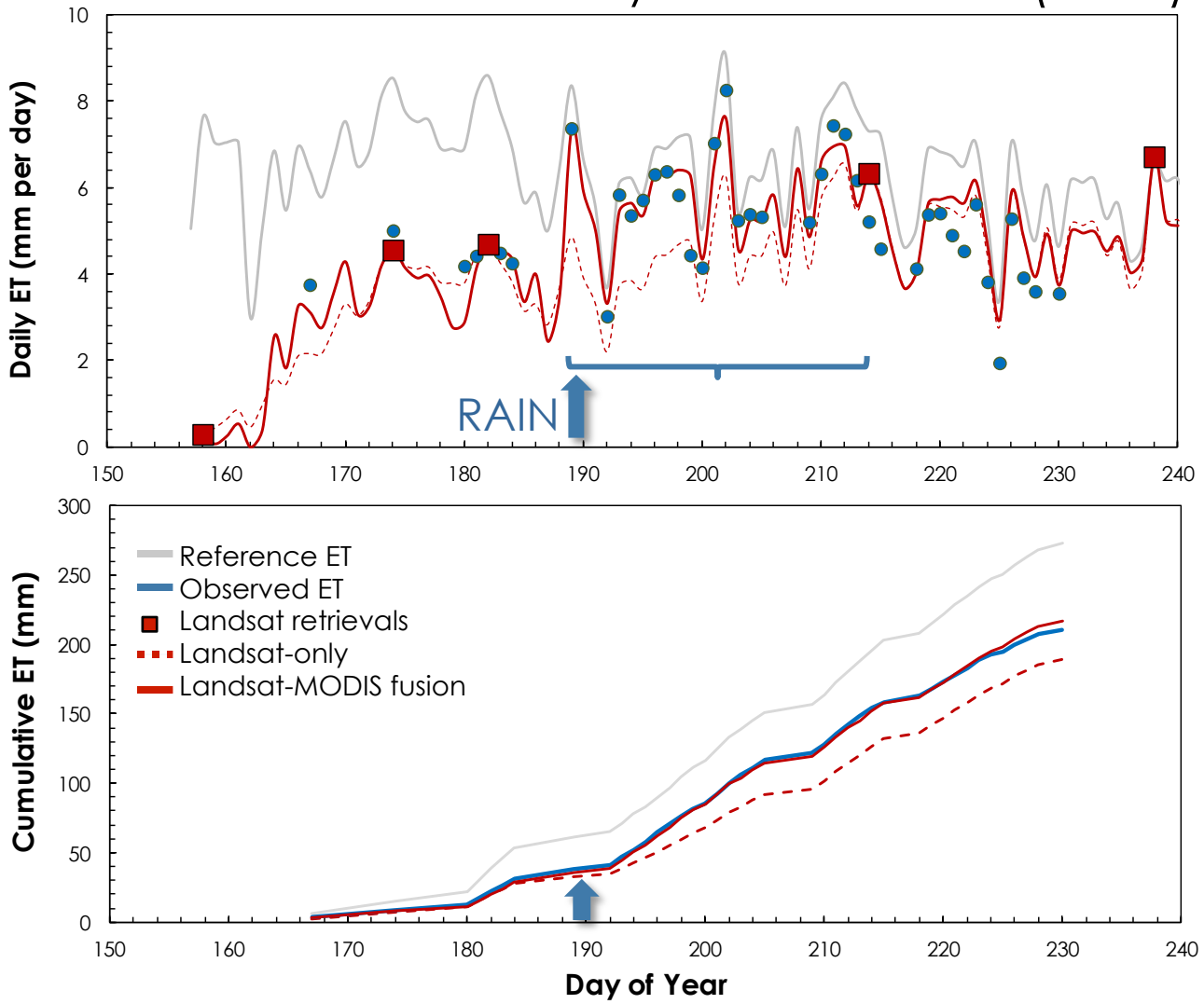


Validation using flux tower data

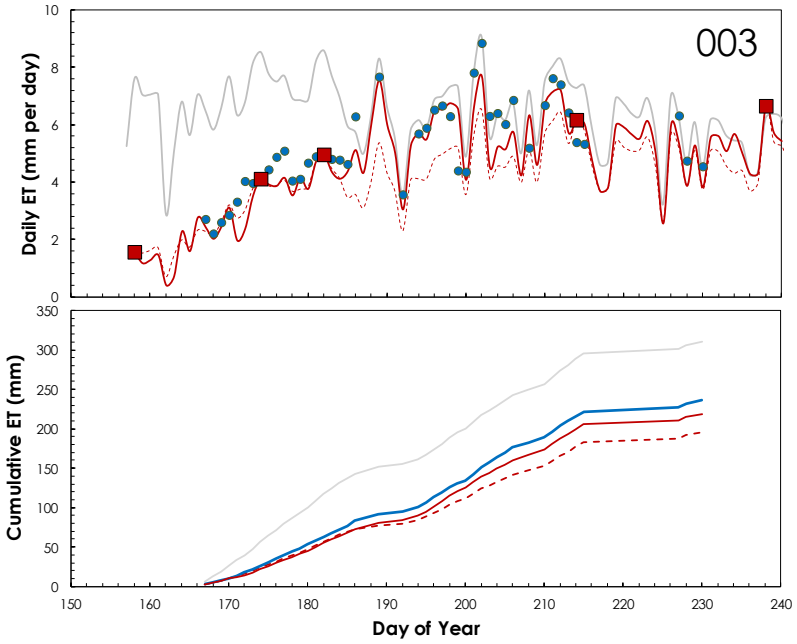


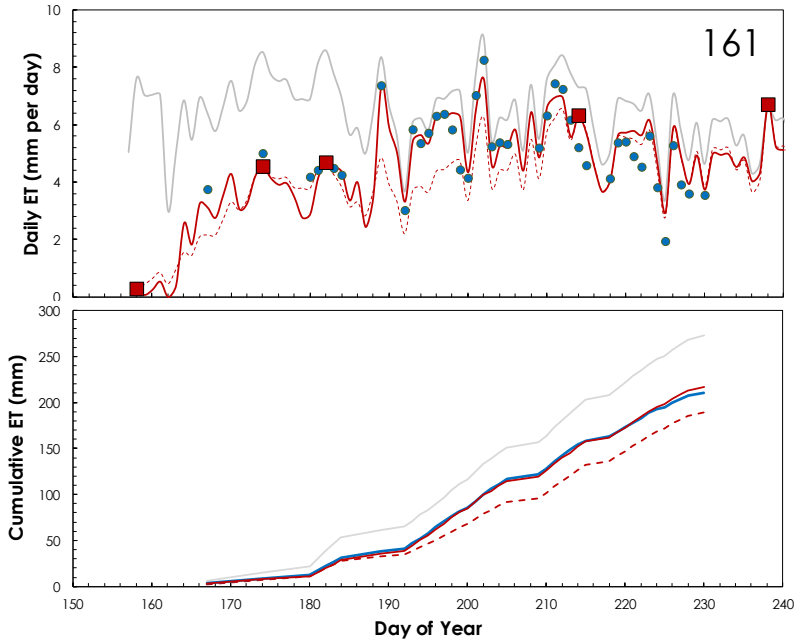
Validation using flux tower data

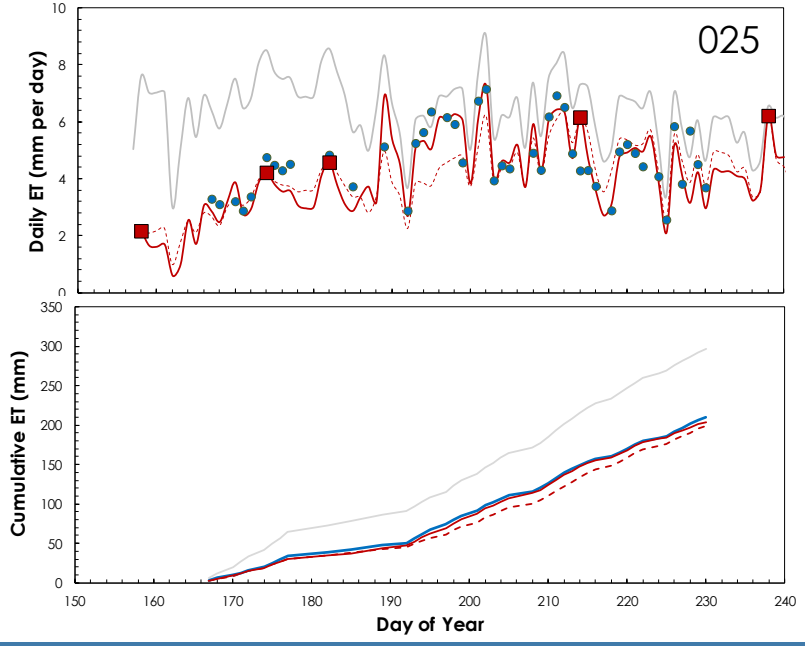
Rainfed soybean – SMEX02 (Iowa)

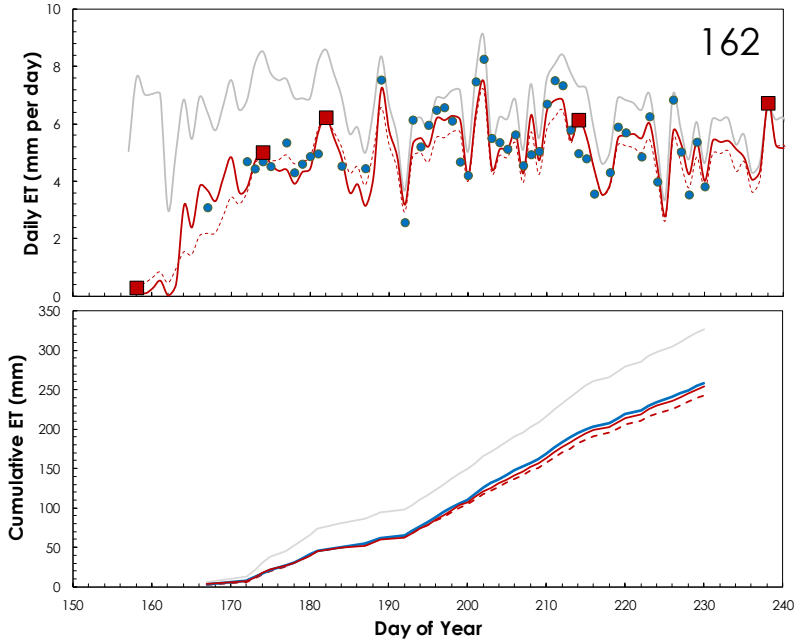


SMEX02: soybean and stunted corn

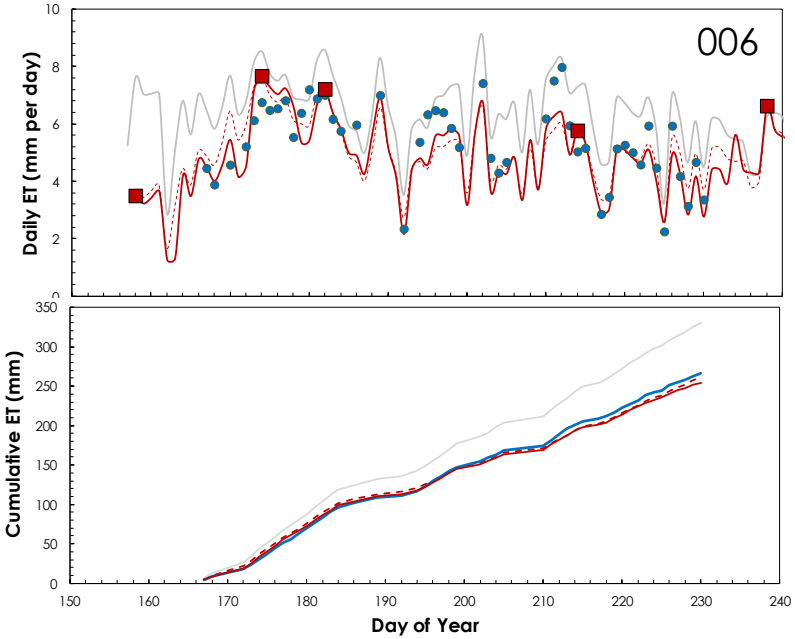


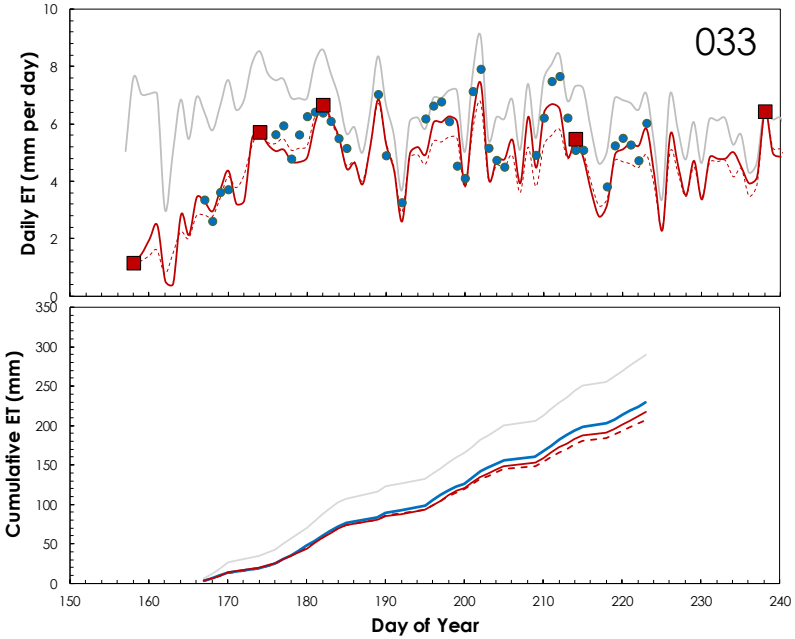


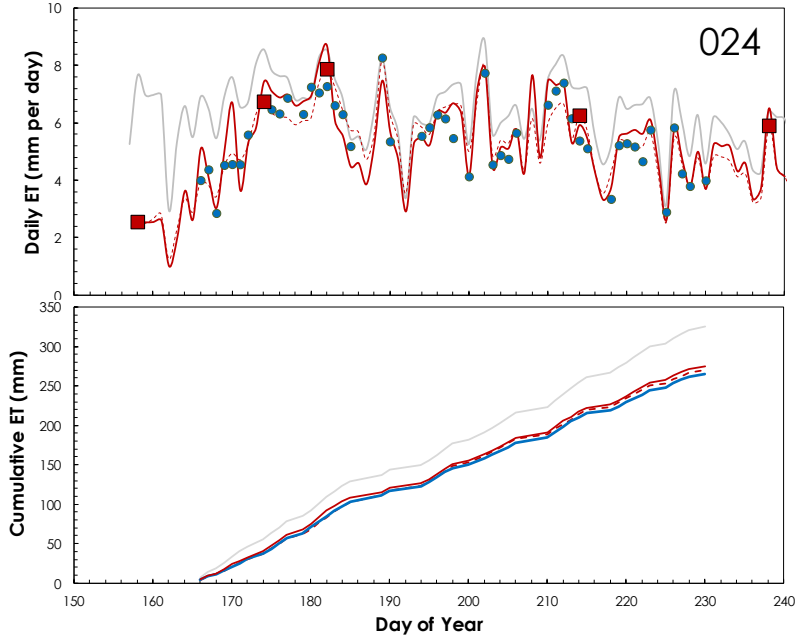


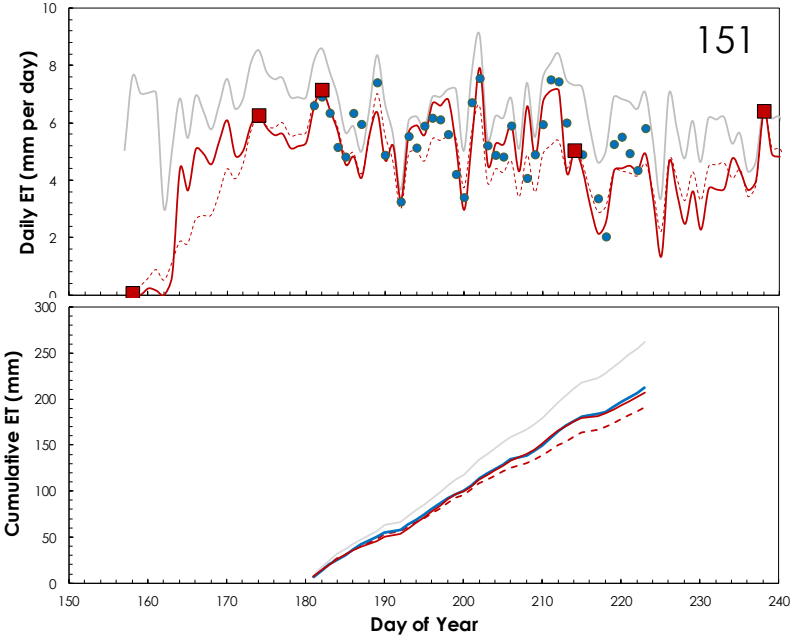


SMEX02: healthy corn

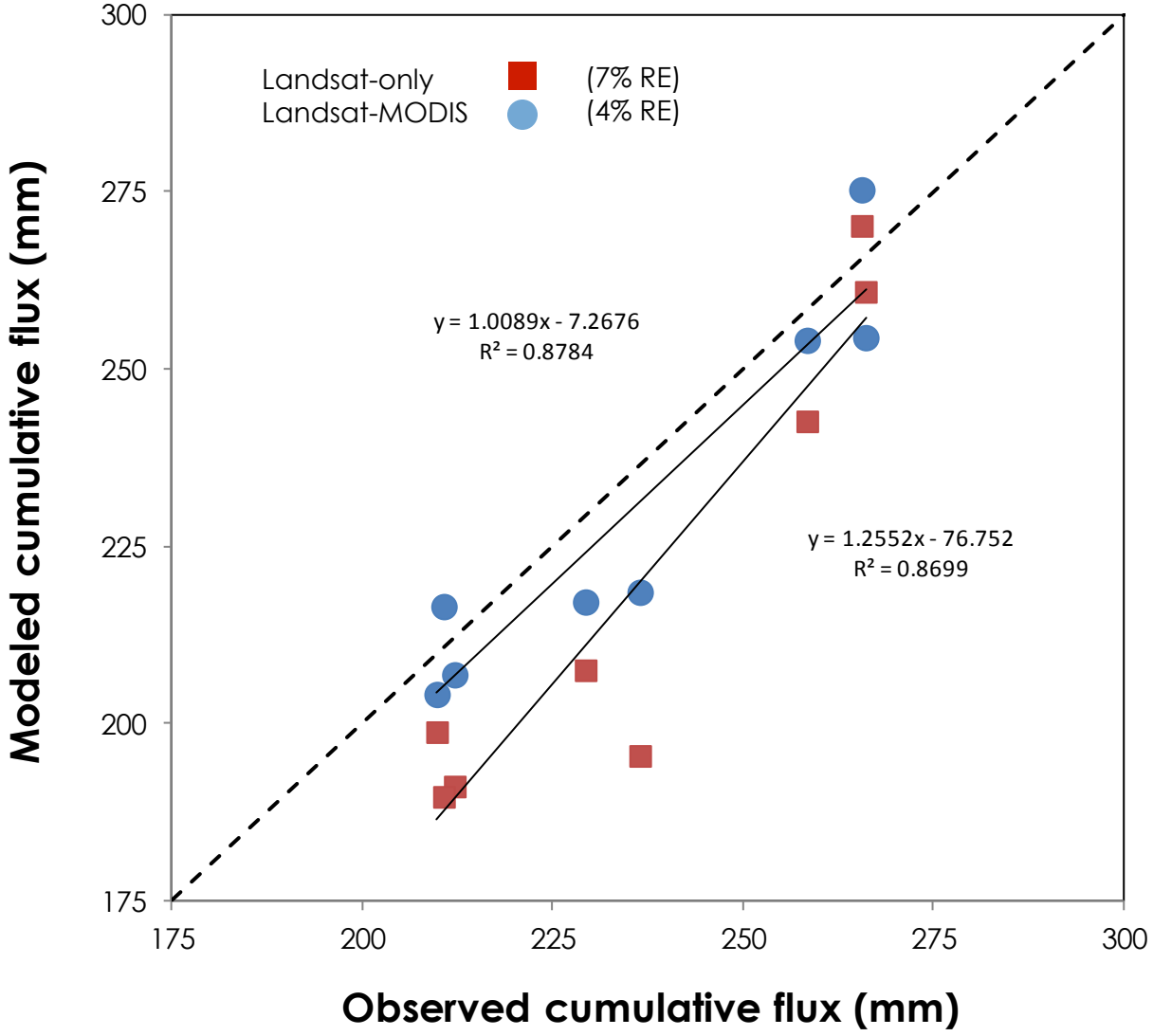




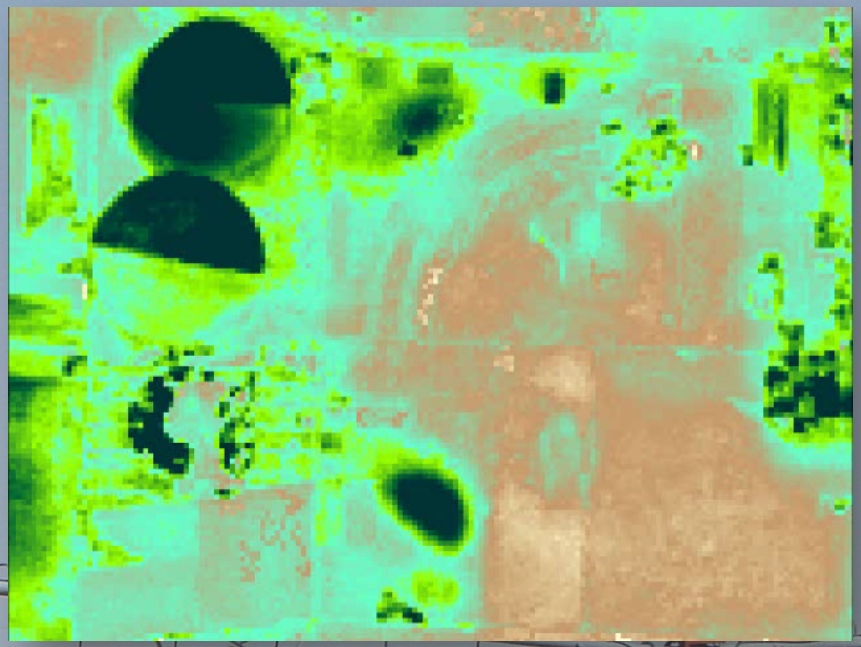




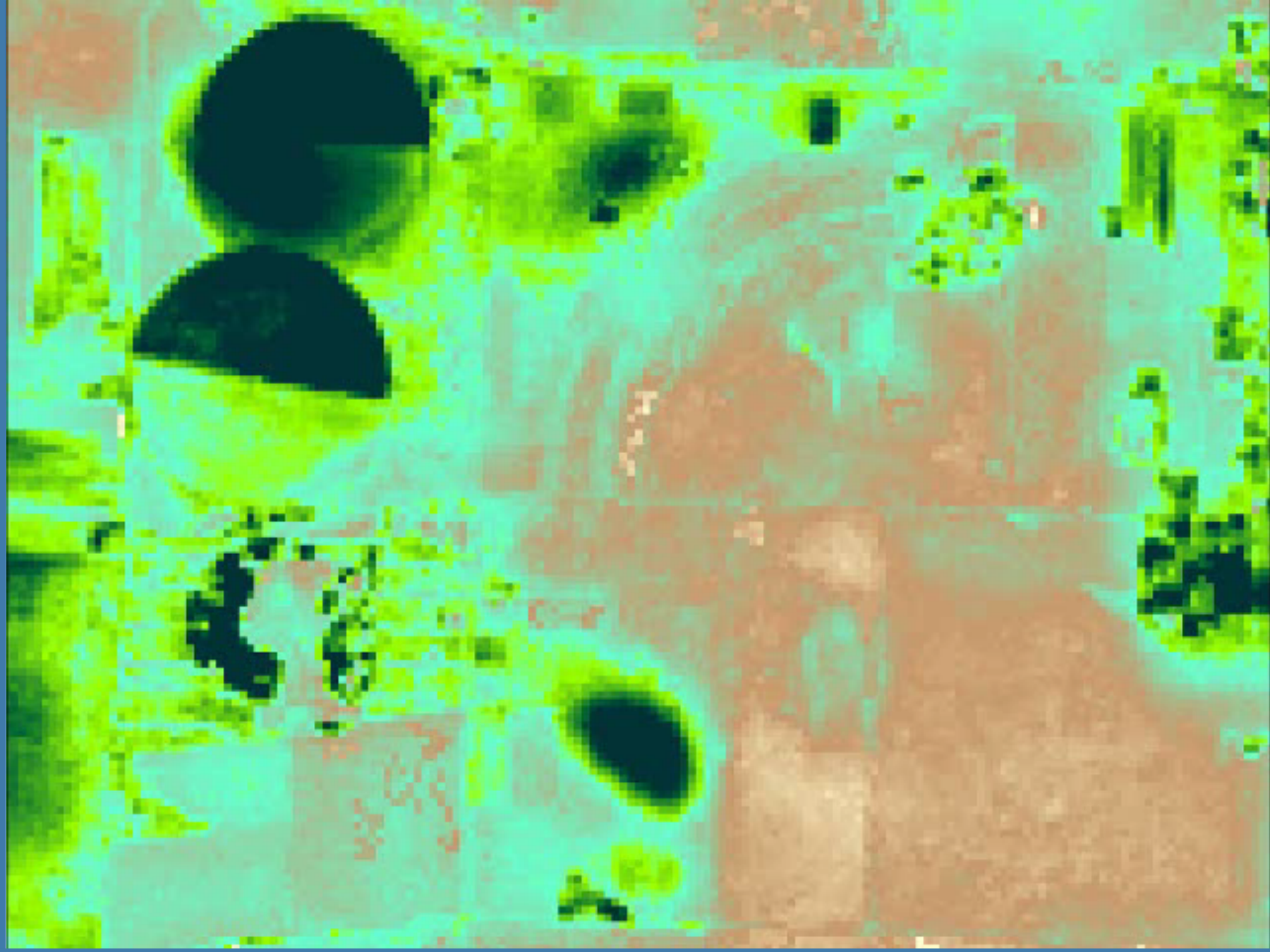
SMEX02 cumulative fluxes



BEAREX08

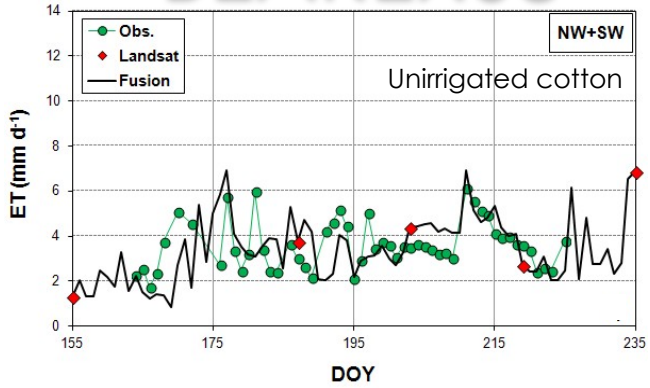


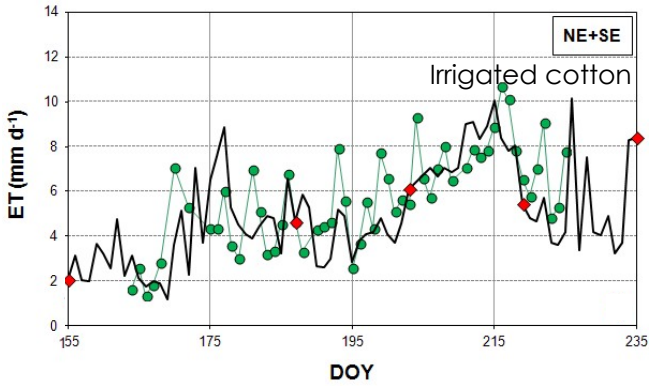
Daily ET at field scale (Landsat+MODIS)

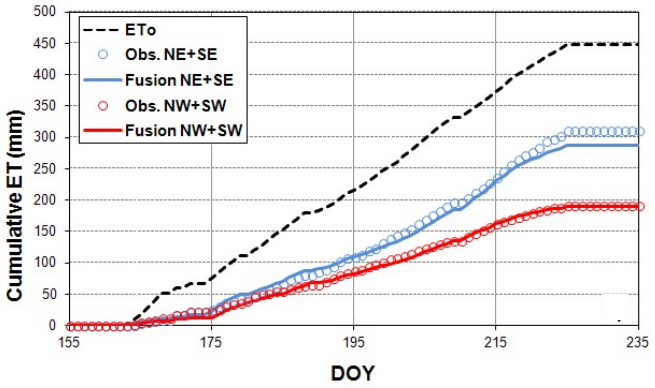


BEAREX08 and MEAD

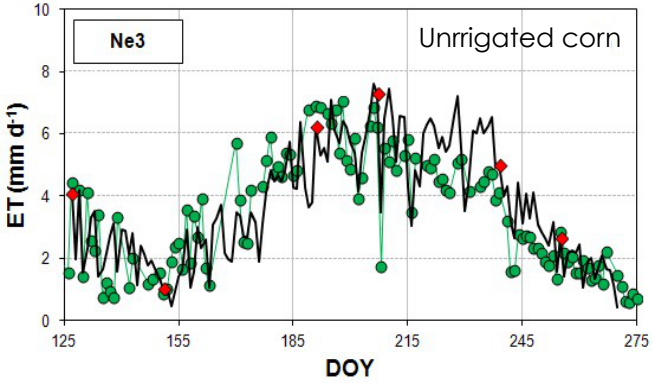
BEAREX08

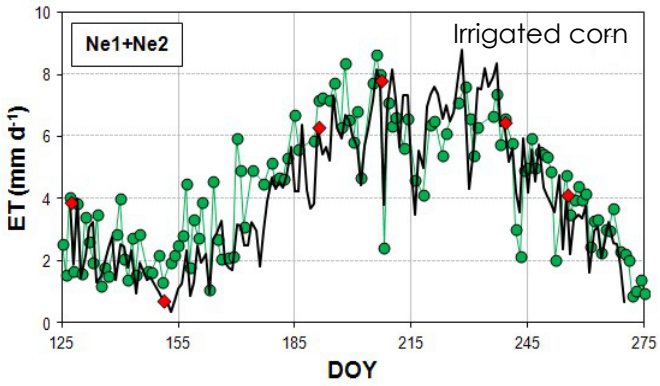


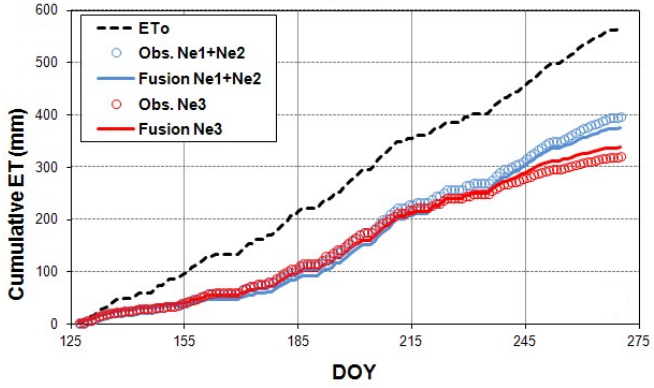




MEAD







WATER MANAGEMENT

DROUGHT MONITORING

FOOD AND WATER SECURITY

APPLICATIONS FOR SATELLITE ET

… *Monitoring Drought*

Realtime Drought Monitoring

Firefox

(109 unread) - ec... | Topics in Science... | Evaporative Stres... | Downloads | University Resear... | LTAR Network In... | Problem loading ... | Typhoon Bolave... | 2012 AMS Inform...

hrsl.arsusda.gov/drought

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USDA

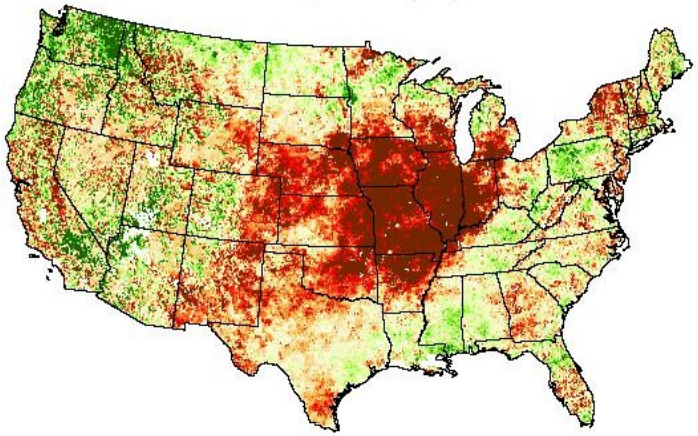
Evaporative Stress Index

USDA-ARS HRSL

Hydrology & Remote Sensing Lab
Beltsville, Maryland, USA

Evaporative Stress Index

1 month composite ending August 27, 2012



Standardized ET/PET anomalies

-2σ< | -1σ | 0 | +1σ | > +2σ

Download

Description

The Evaporative Stress Index (ESI) describes temporal anomalies in evapotranspiration (ET), highlighting areas with anomalously high or low rates of water use across the land surface. Here, ET is retrieved via energy balance using remotely sensed land-surface temperature (LST) time-change signals. LST is a fast-response variable, providing proxy information regarding rapidly evolving surface soil moisture and crop stress conditions at relatively high spatial resolution. The ESI also demonstrates capability for capturing early signals of "flash drought", brought on by extended periods of hot, dry and windy conditions leading to rapid soil moisture depletion.

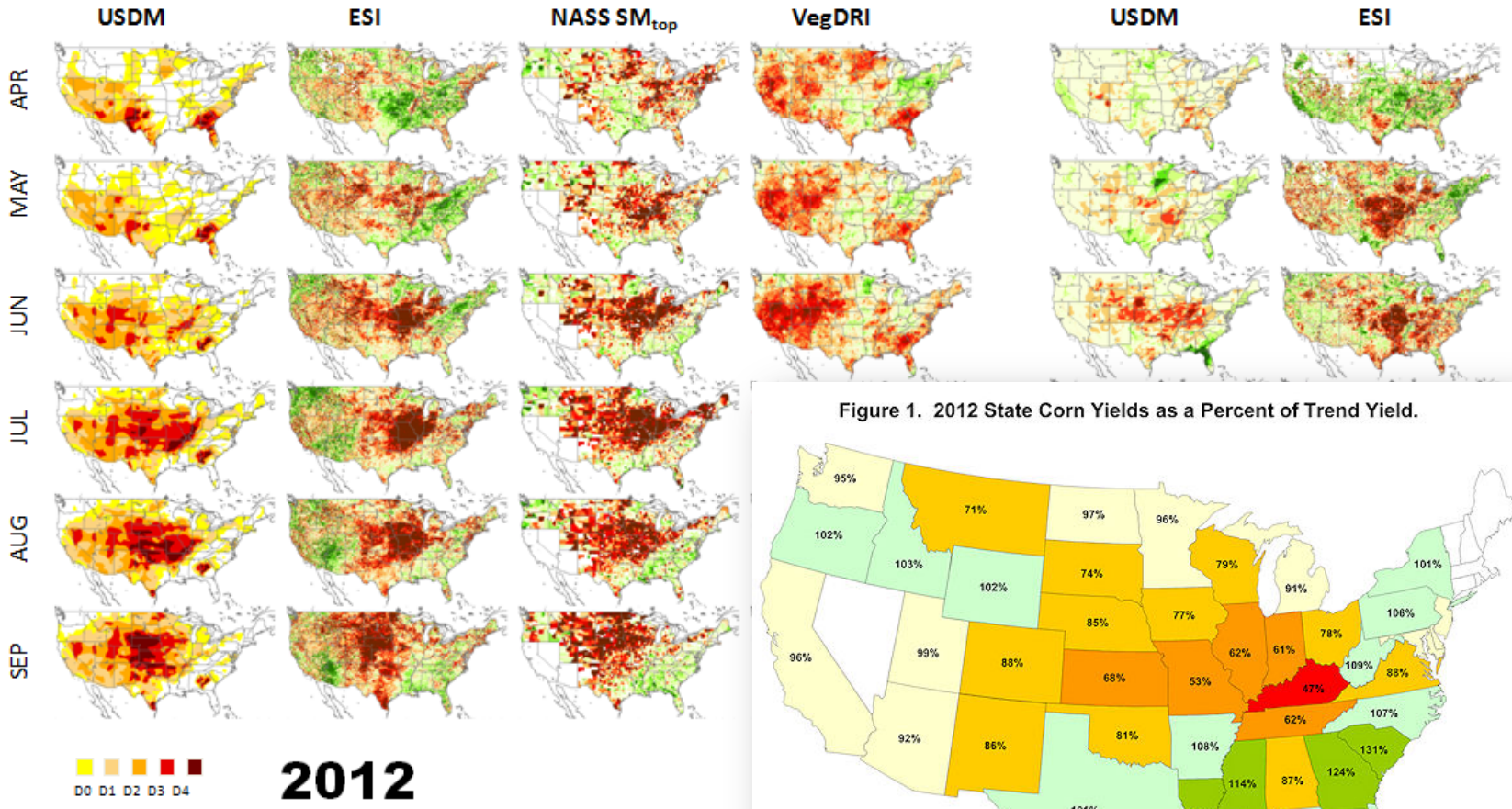
Coverage

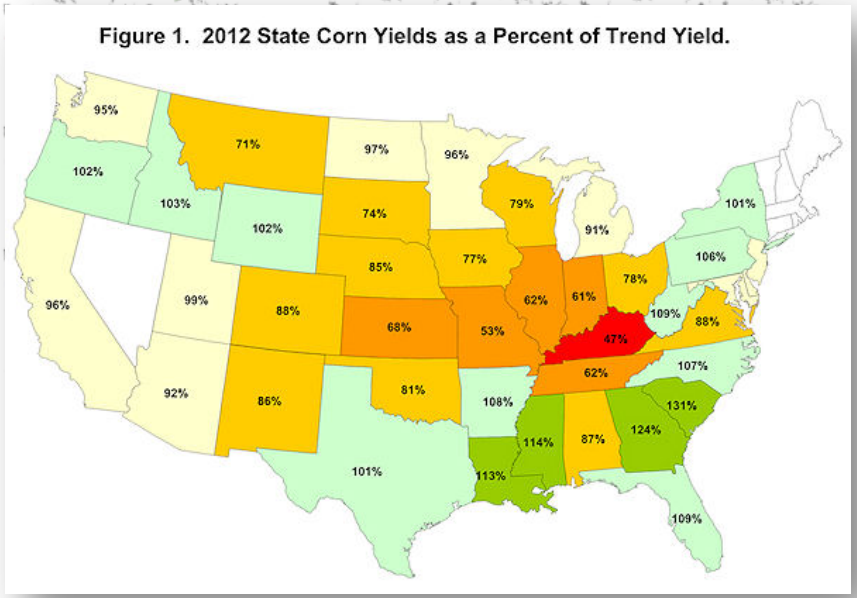
Current Conditions

Hydrology and Remote Sensing Laboratory | 10300 Baltimore Avenue | Beltsville, MD 20705 | Contact Us
Version 2.1.2

hrsl.arsusda.gov/drought/index.php

2012 FLASH DROUGHT

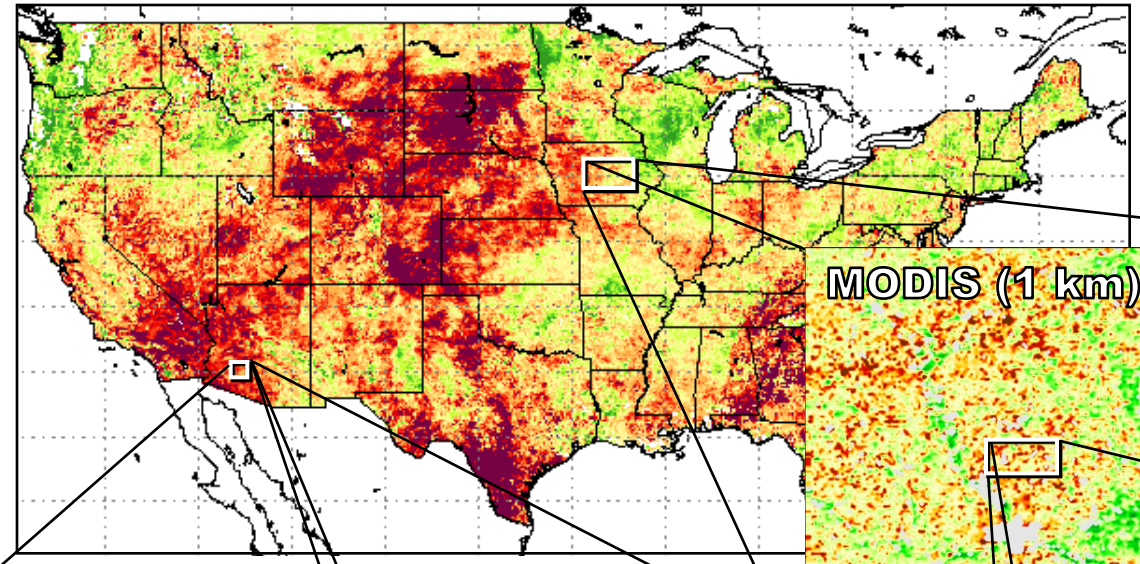


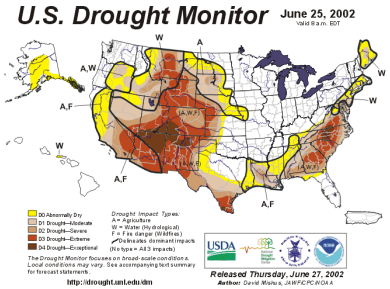


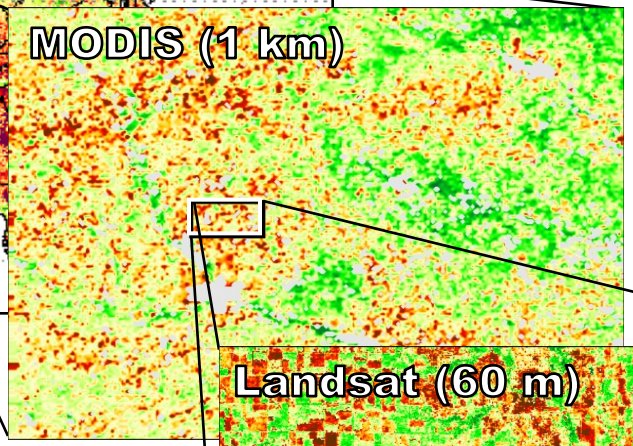
Multiscale Drought/Stress Monitoring

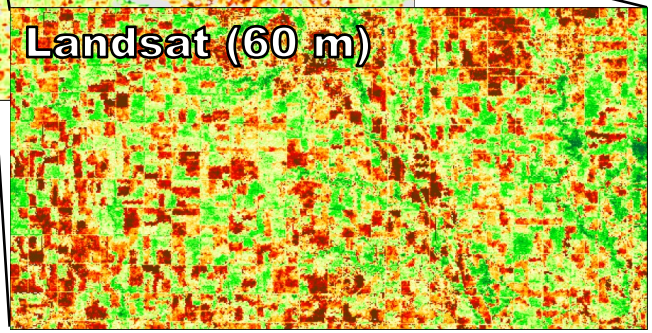
GOES Evaporative Stress Index

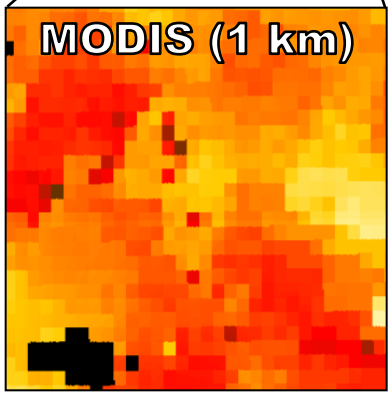
JUNE 2002

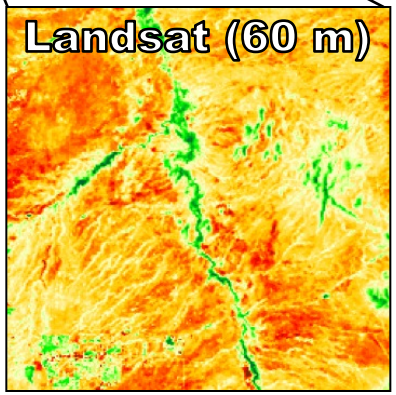








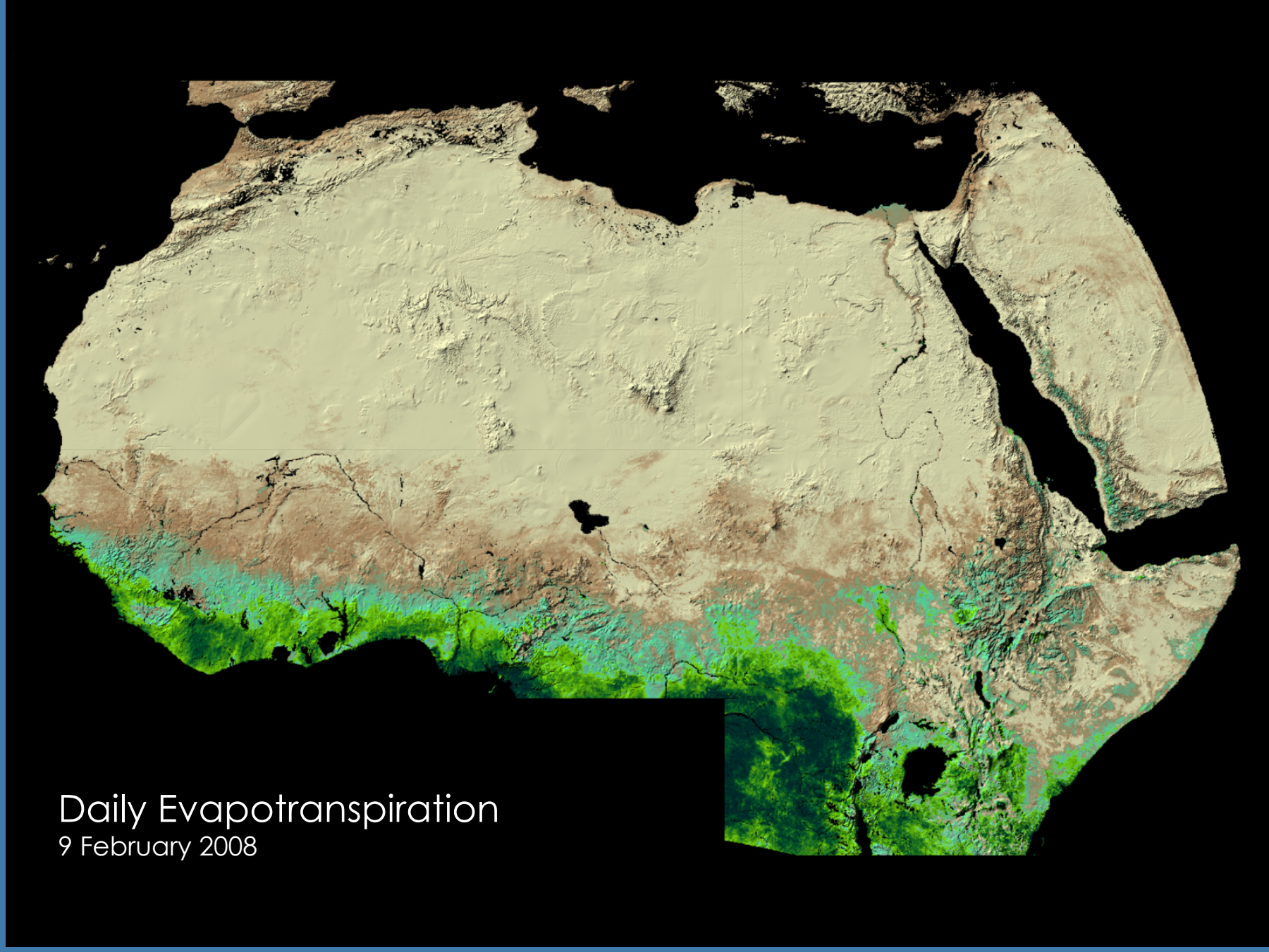




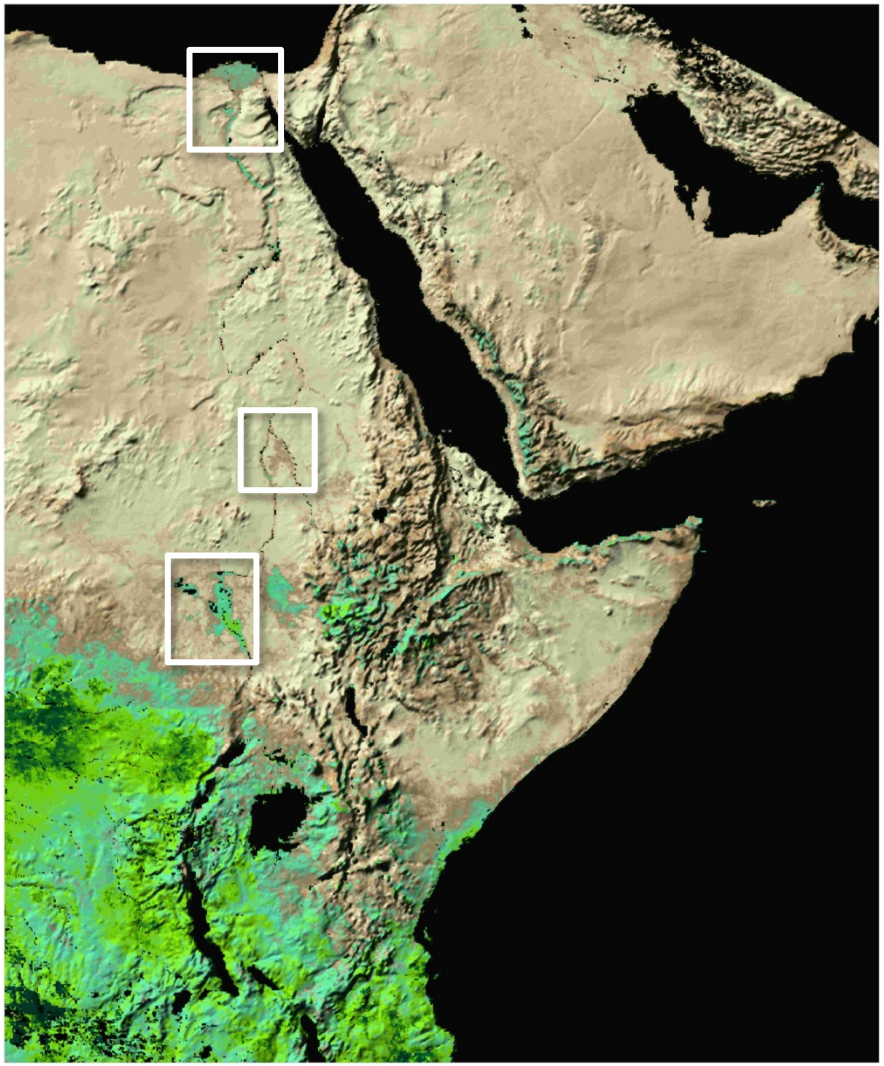
APPLICATIONS FOR SATELLITE ET

… Food and Water Security

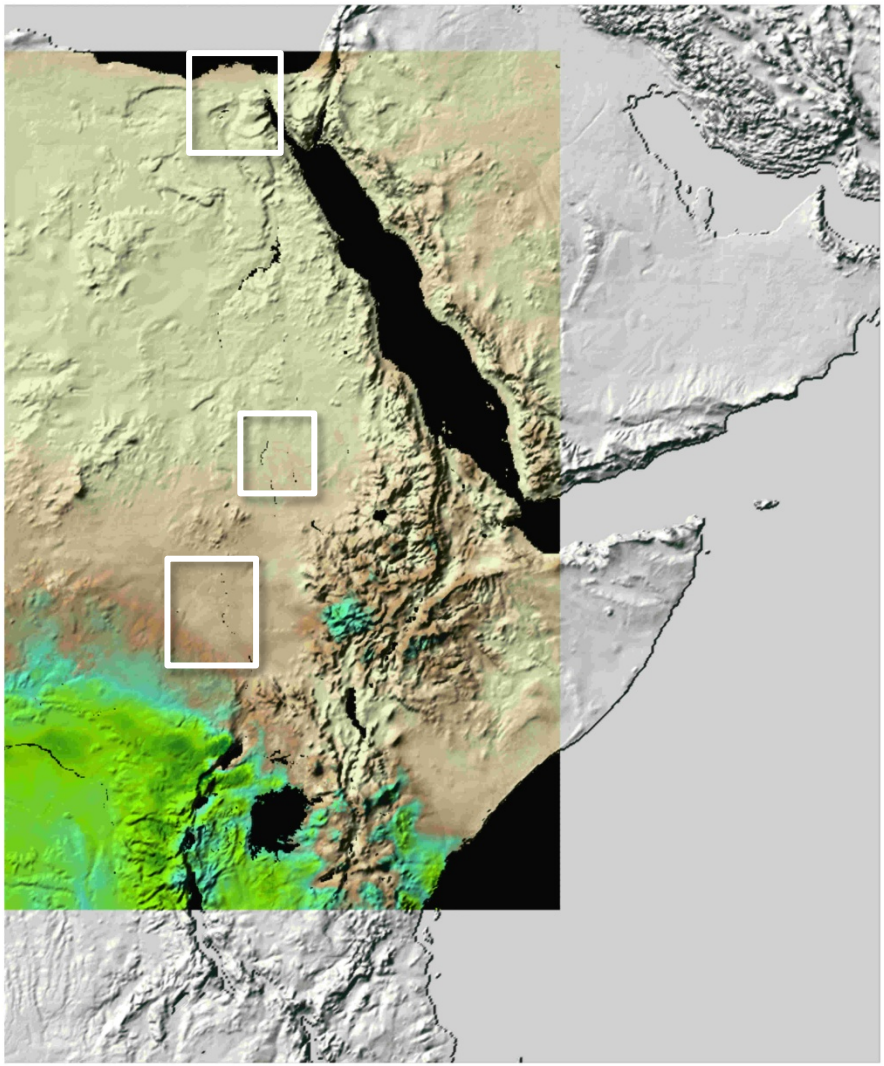
ALEXI ET over MENA Region



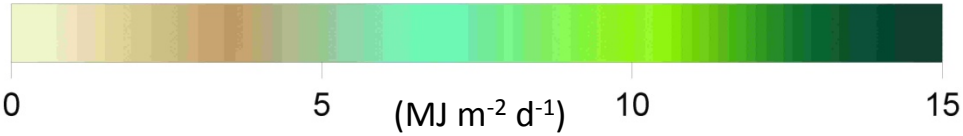
2009 FEBRUARY



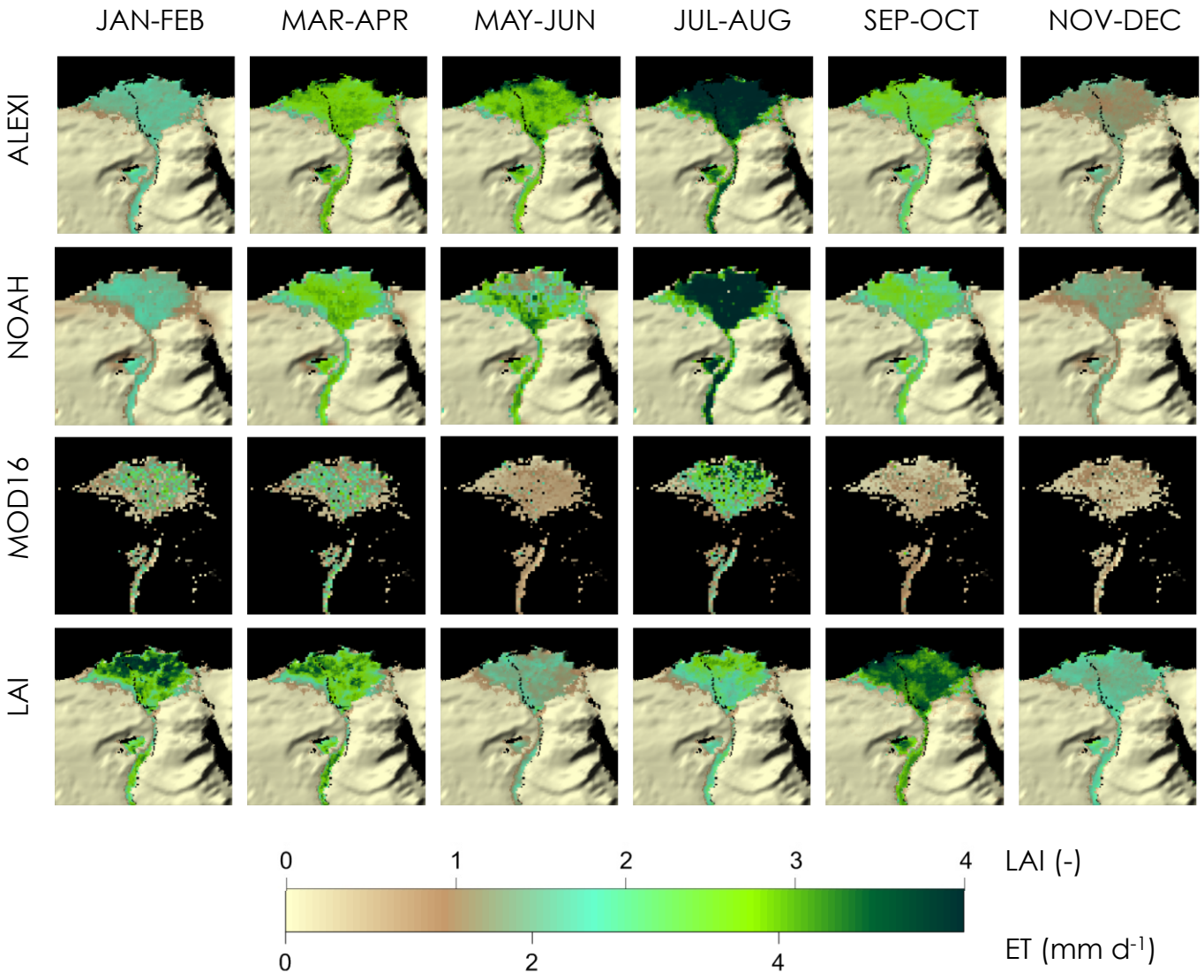
Average ALEXI ET



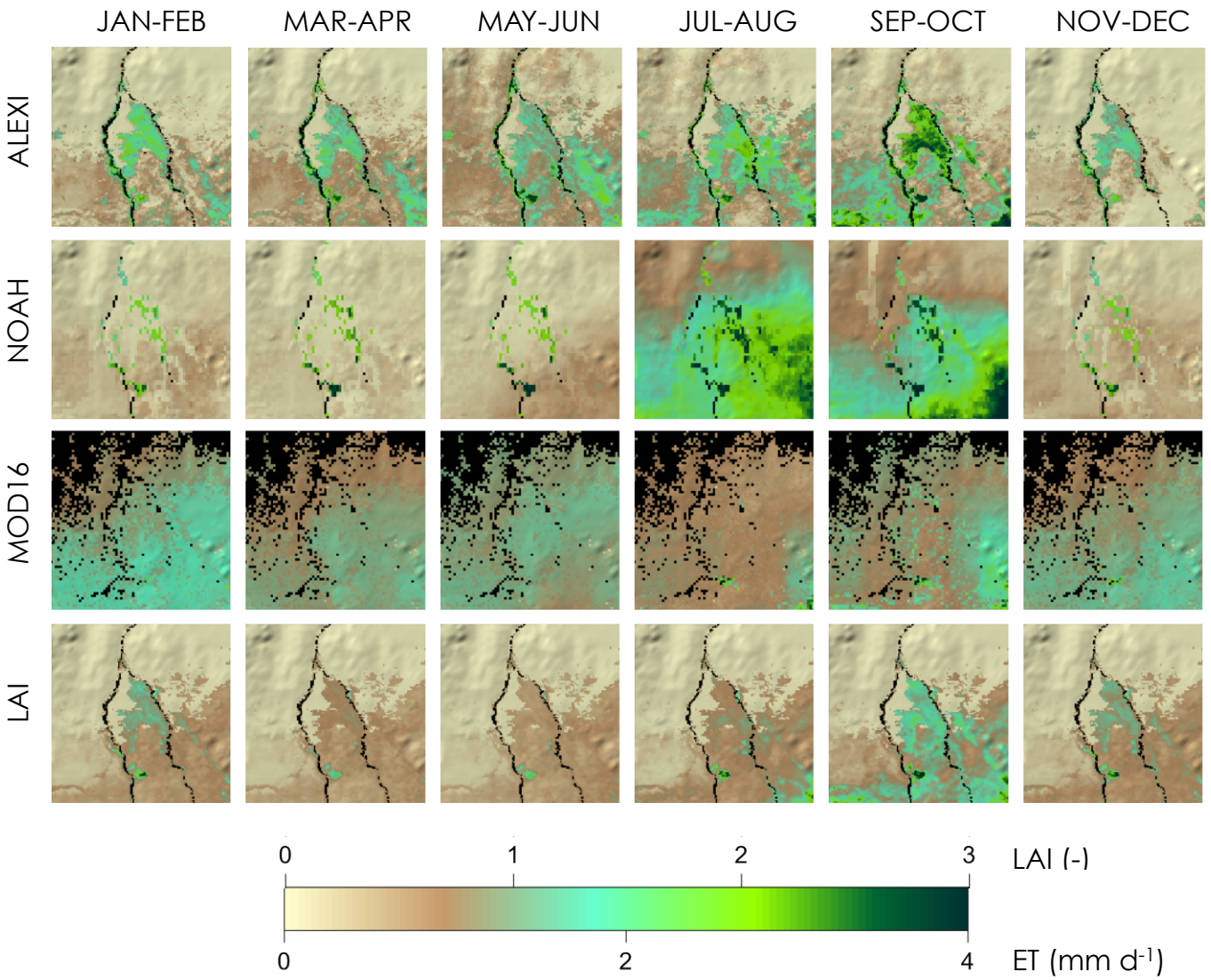
Average Noah ET



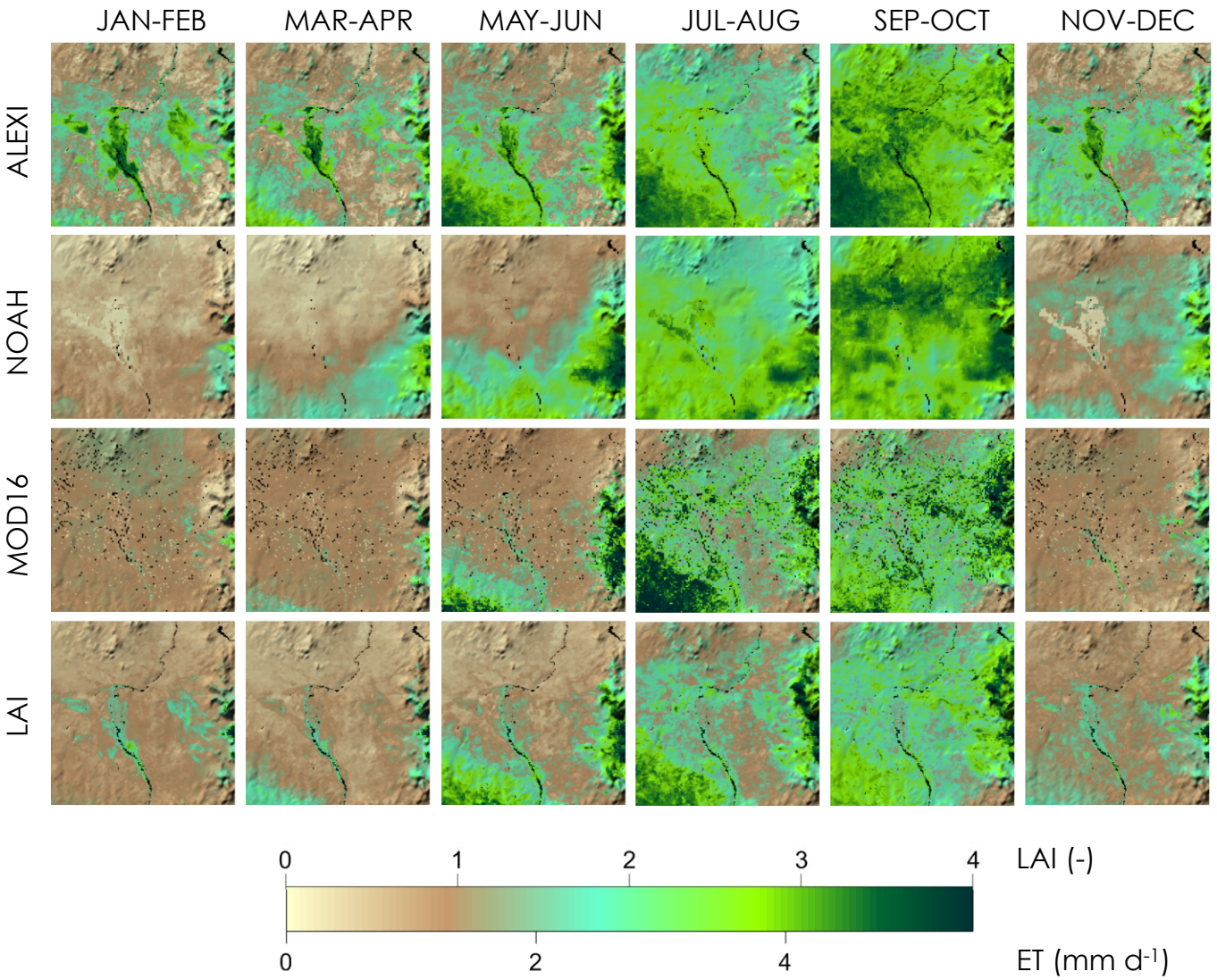
NILE DELTA

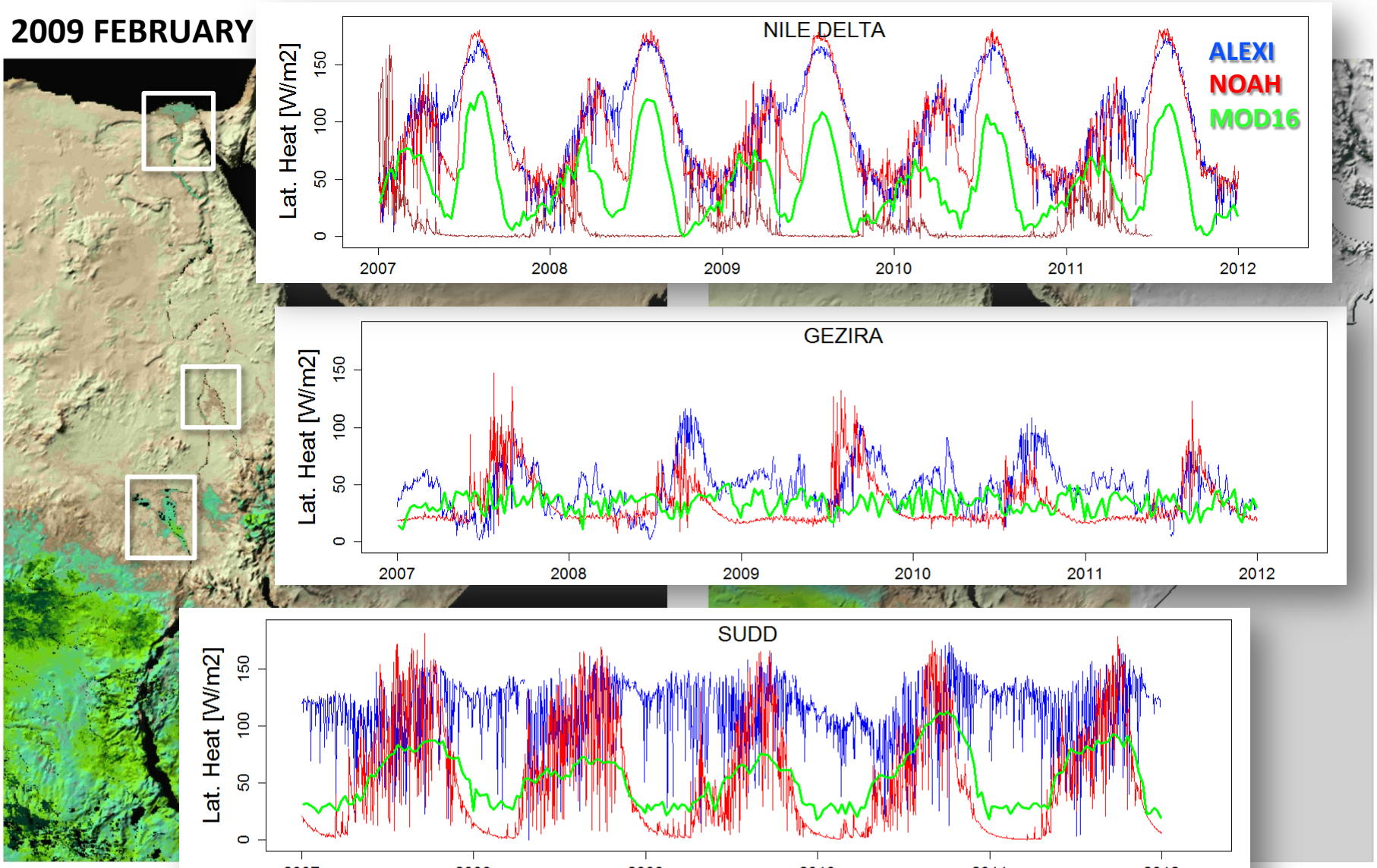

JAN-FEB
MAR-APR
MAY-JUN
JUL-AUG
SEP-OCT
NOV-DEC
ALEXI
NOAH
MOD16
LAI
0
1
2
3
4
LAI (-)
0
2
4
ET (mm d-1)

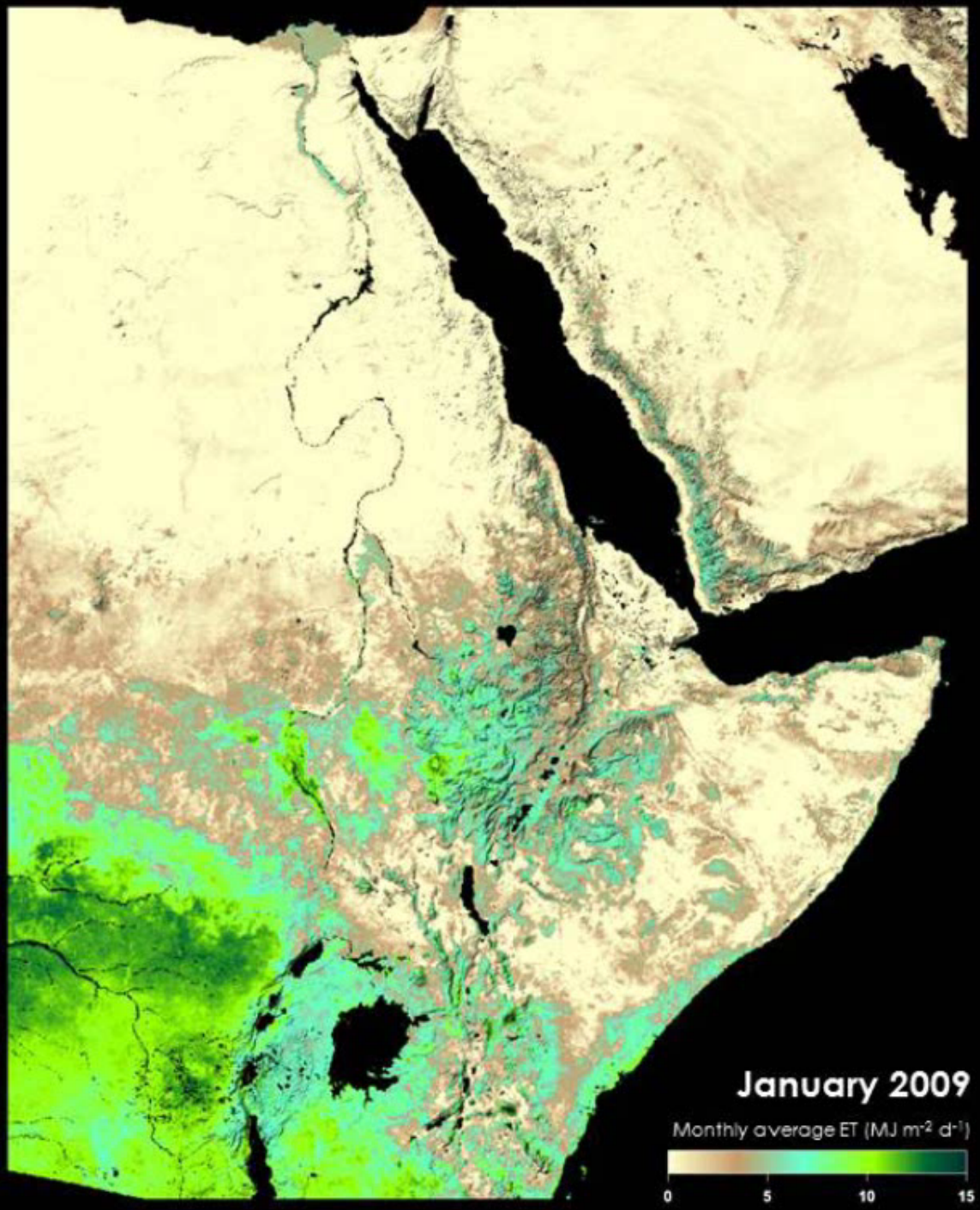
GEZIRA IRRIGATION SCHEME



SUDD WETLAND




2009 FEBRUARY
NILE DELTA
Lat. Heat [W/m2]
0
50
100
150
2007
2008
2009
2010
2011
2012
ALEXI
NOAH
MOD16
GEZIRA
Lat. Heat [W/m2]
SUDD
Lat. Heat [W/m2]
Average ALEXI ET
Average Noah ET
0
5
10
15
(MJ m-2 d-1)


January 2009
Monthly average ET (MJ m-2 d-1)
0
5
10
15

Satellite Evapotranspiration

- Monitoring water use at field to continental scales
- Land-surface temperature conveys early warning of vegetation stress
- Independent check on precipitation-based drought indices
- Applications in global water and food security

We can't manage what we can't measure …

Conclusions

USDA is an equal opportunity provider and employer.

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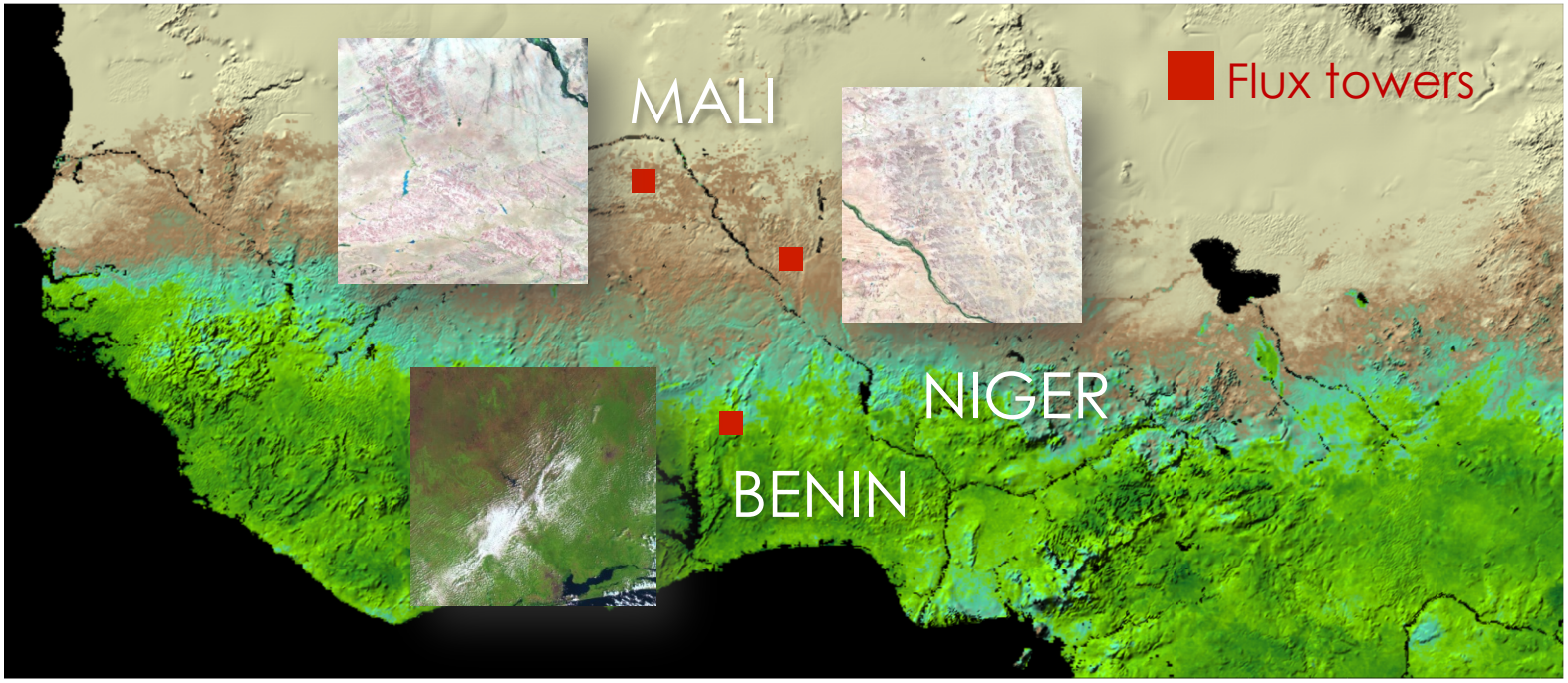
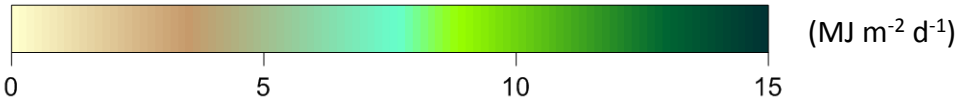
African Monsoon Project

ALMIP AMMA Land Surface Model Intercomparison Project

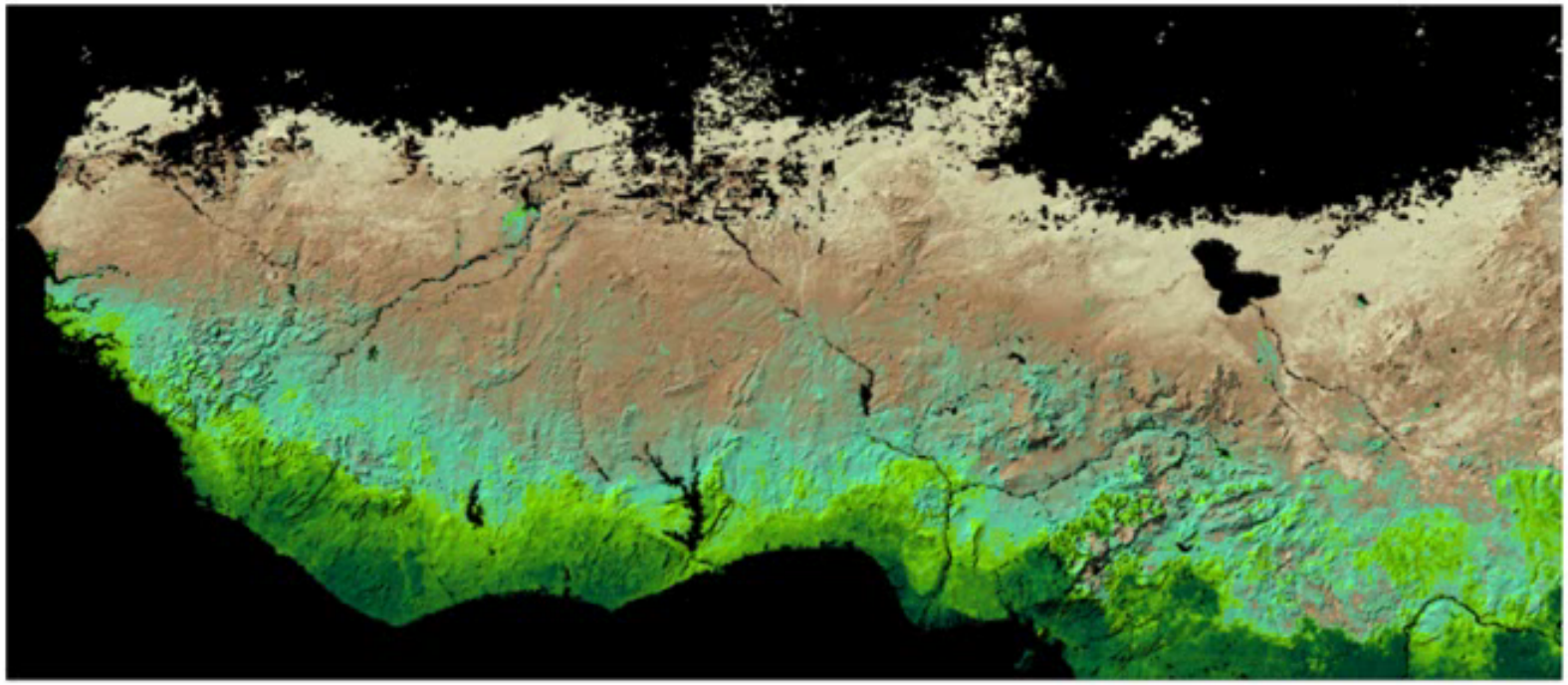


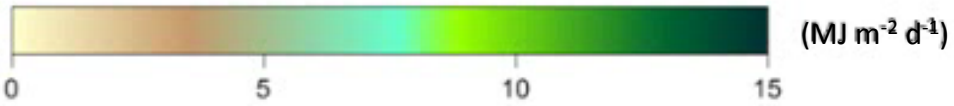
African Monsoon Multidisciplinary Analysis (CNRM, CESBIO)



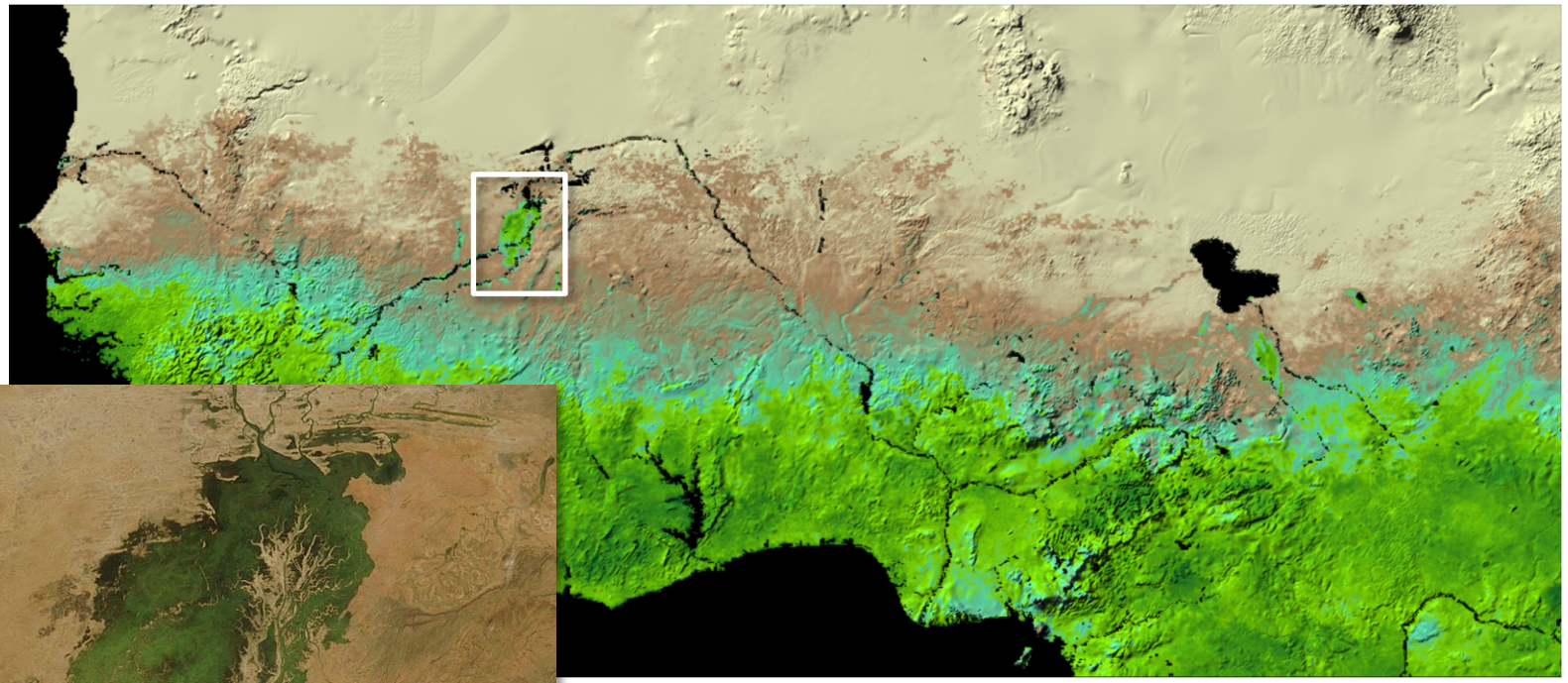
2007 JANUARY

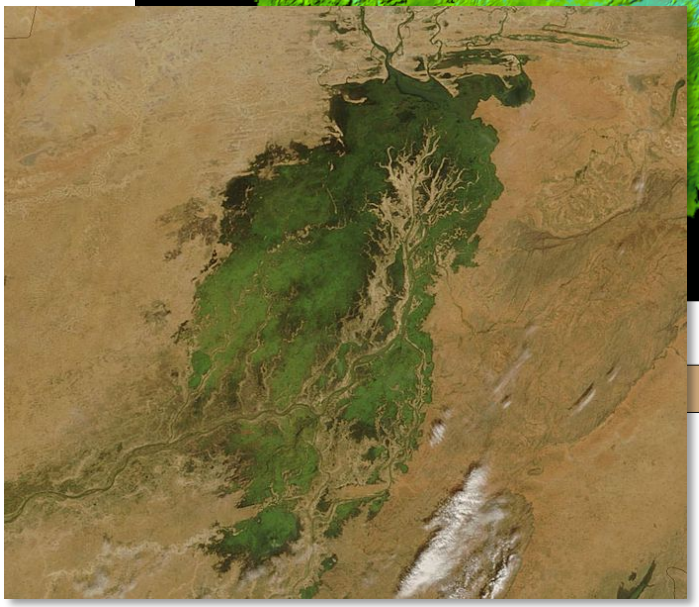
MONTHLY AVERAGE LATENT HEAT





2007 NOVEMBER

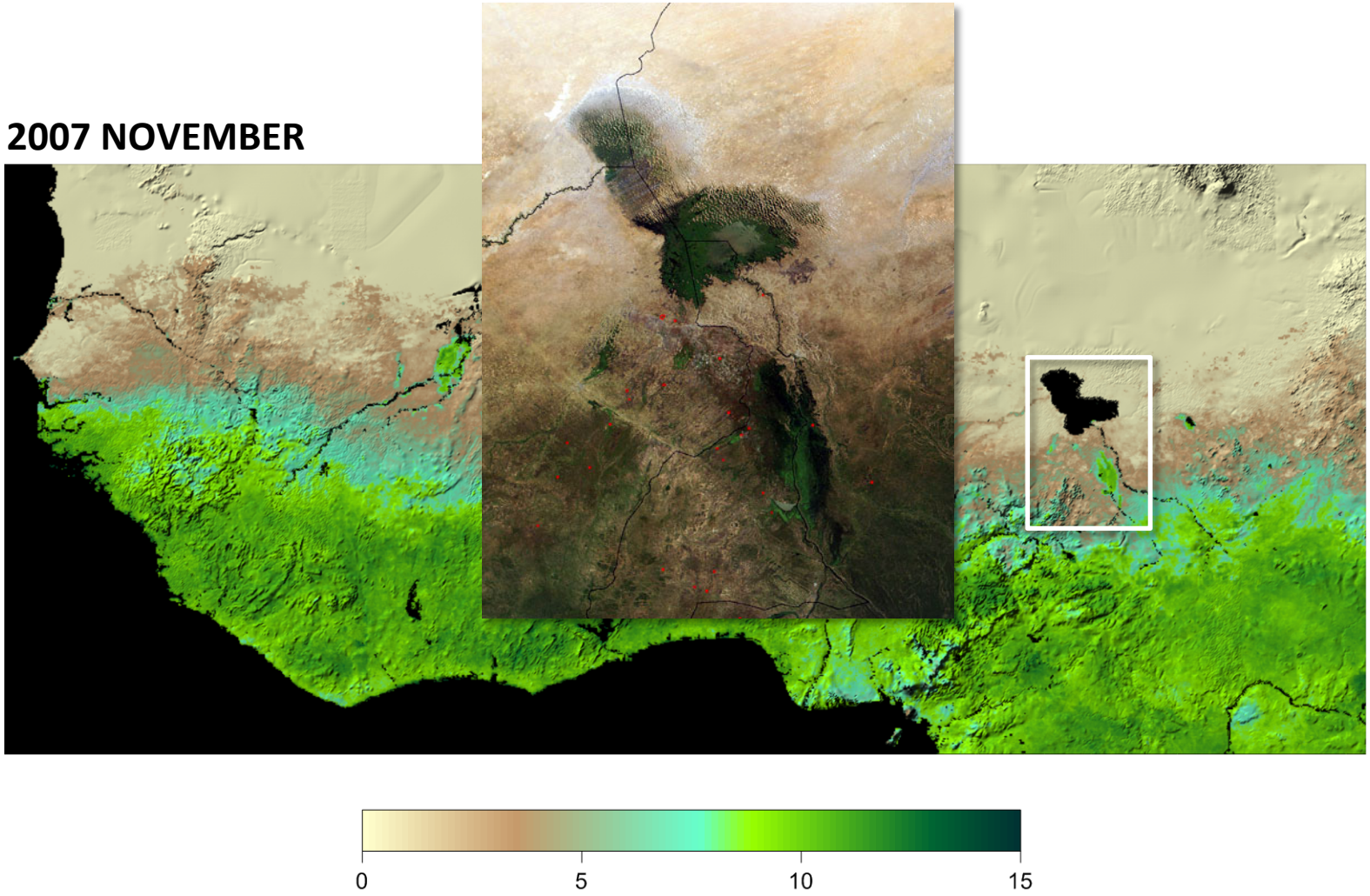




Inland Niger Delta, MODIS

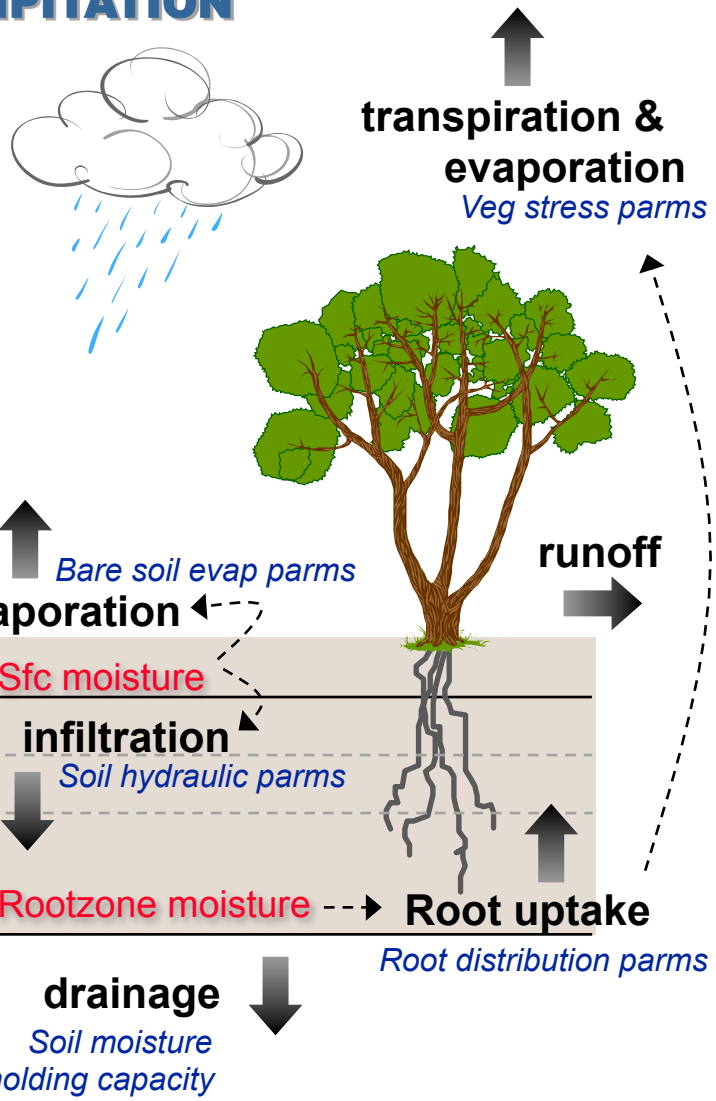
Lake Chad and Logone floodplain, MODIS

2007 NOVEMBER



Technical approach to mapping ET

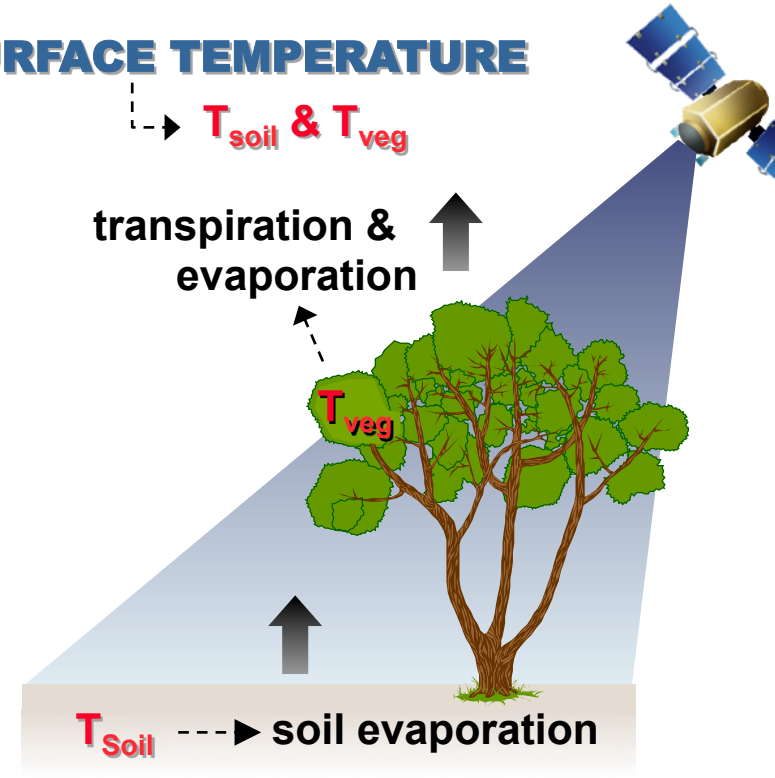
PRECIPITATION



WATER BALANCE APPROACH

(prognostic modeling)

SURFACE TEMPERATURE

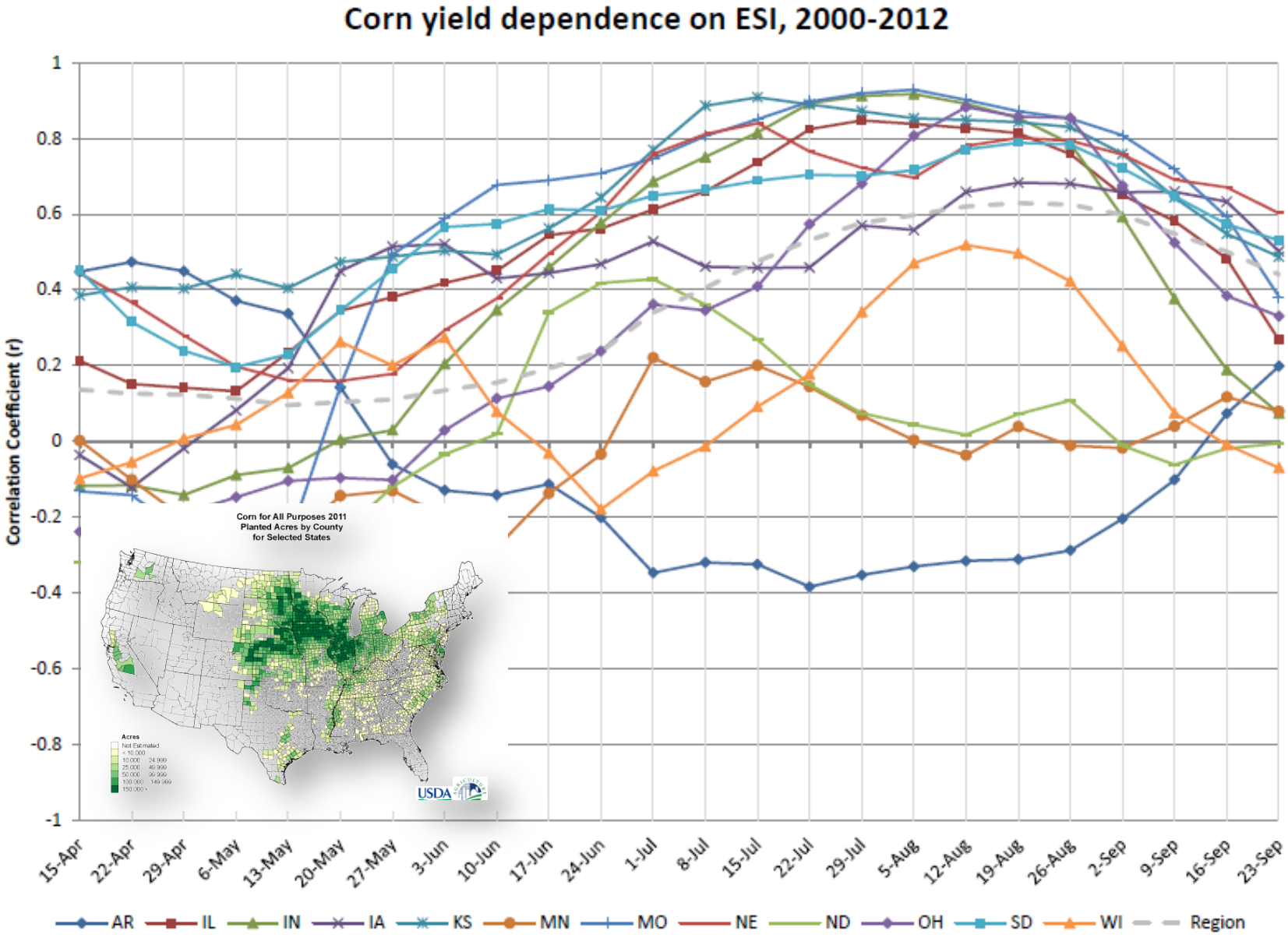


Given known radiative energy inputs, how much water loss is required to keep the soil and vegetation at the observed temperatures?

ENERGY BALANCE APPROACH

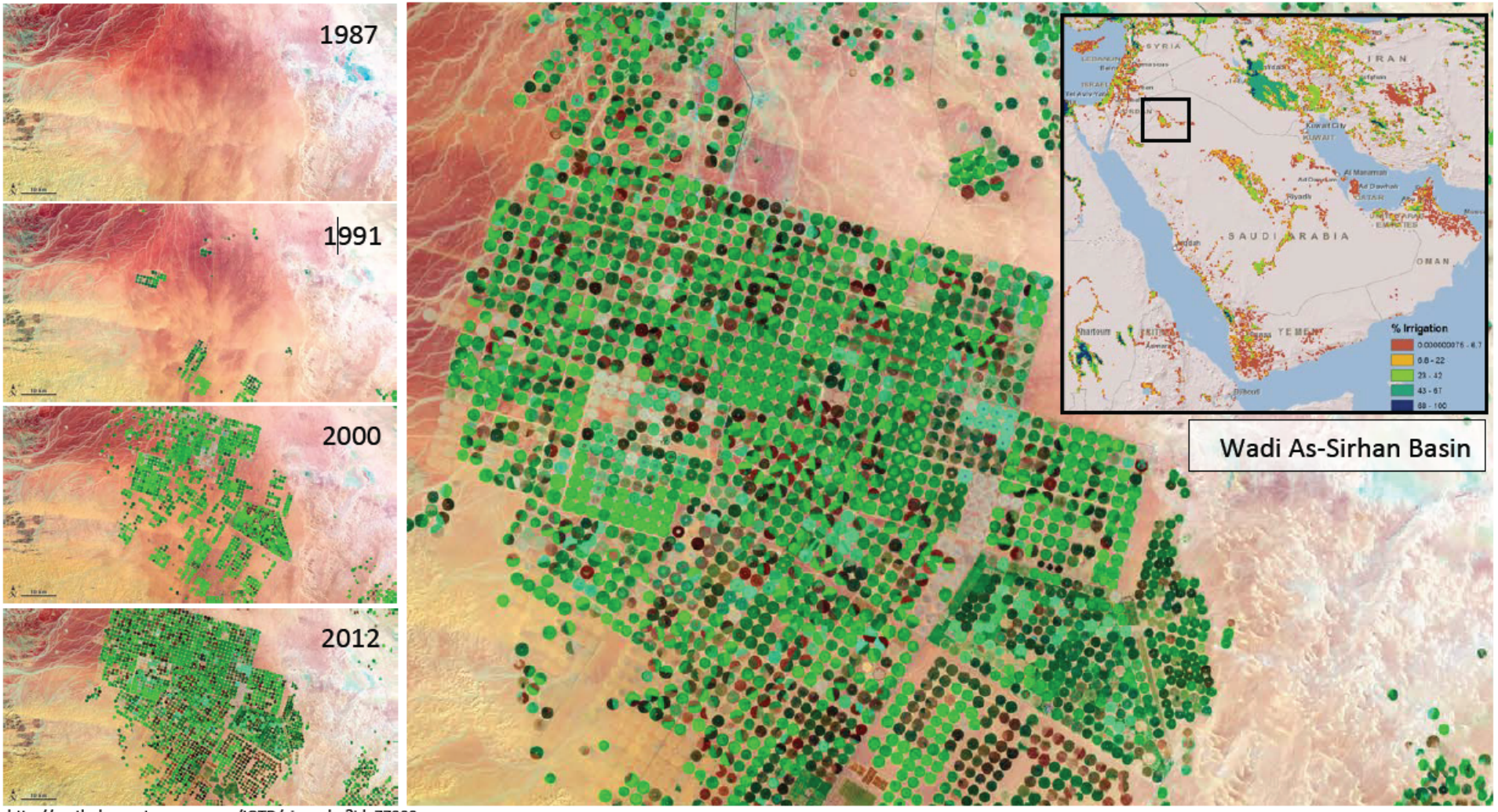
(diagnostic modeling)

Correlations of ESI with corn yield



(Dave Johnson, NASS)

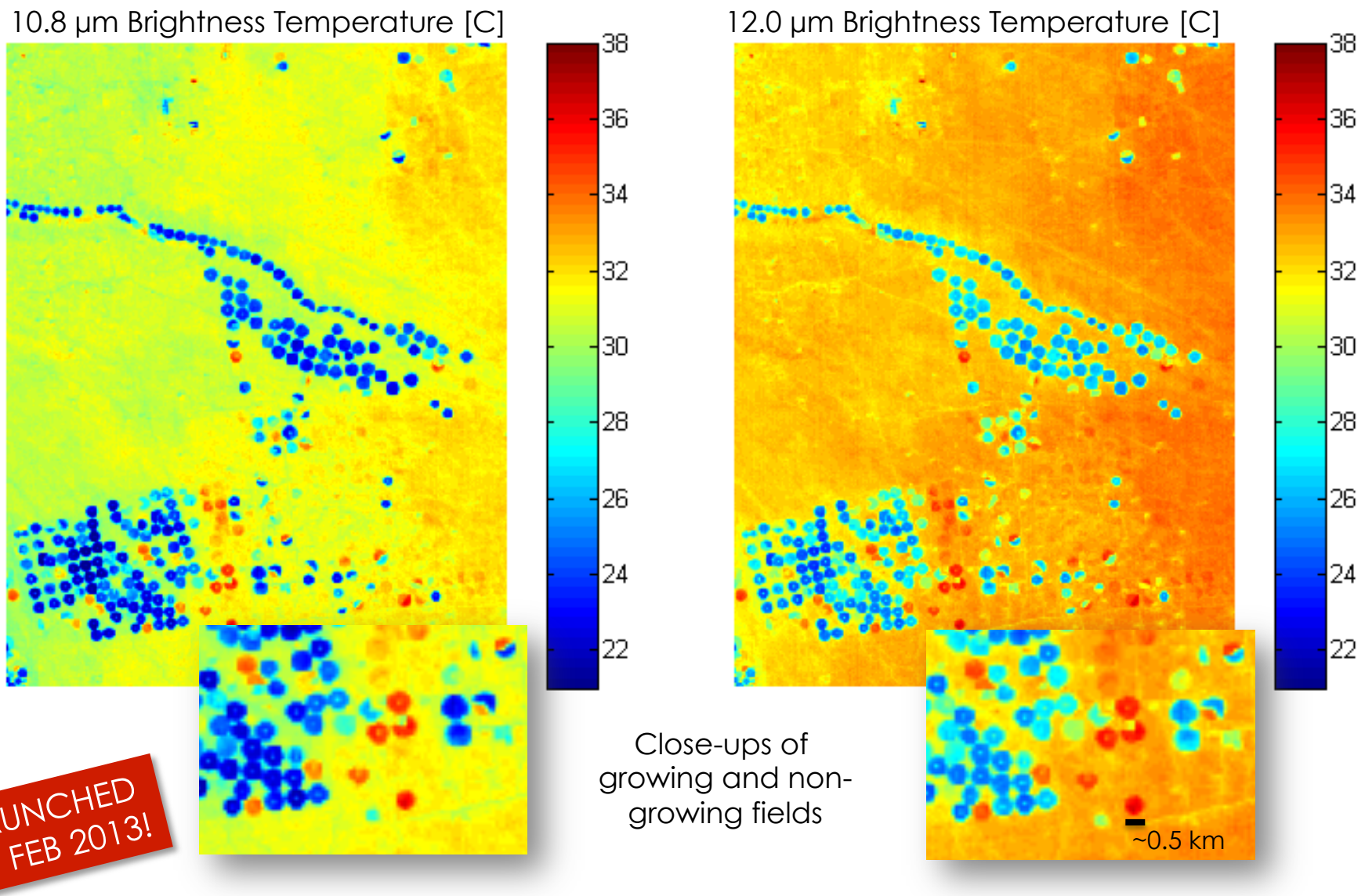
EXPANSION of IRRIGATION



http://earthobservatory.nasa.gov/IOTD/view.php?id=77900

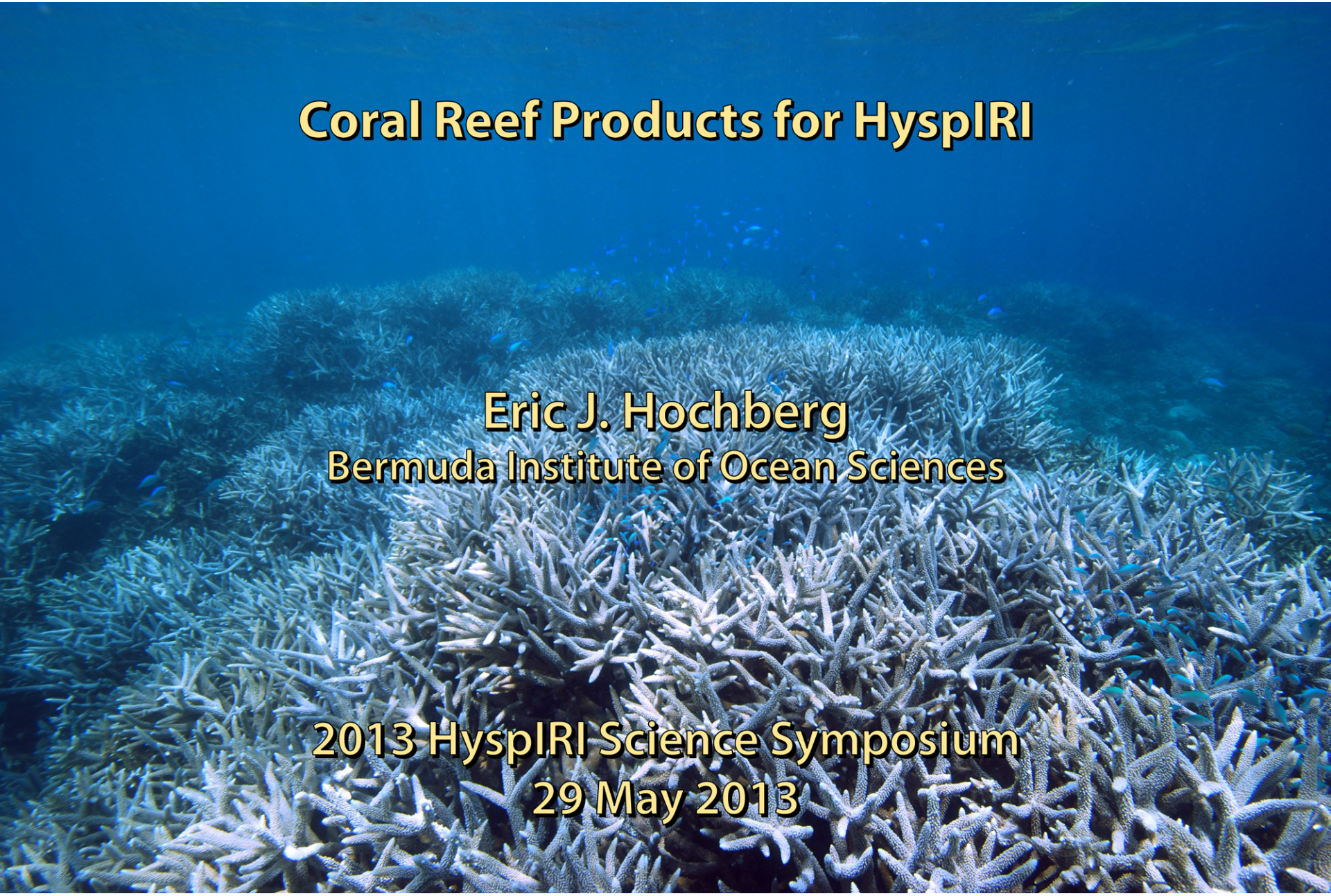
Landsats 4,5,7 – visible, near infrared bands: vegetation amount

CONSUMPTIVE WATER USE



LAUNCHED 11 FEB 2013!

Landsat 8 – thermal infrared bands: vegetation status and water use

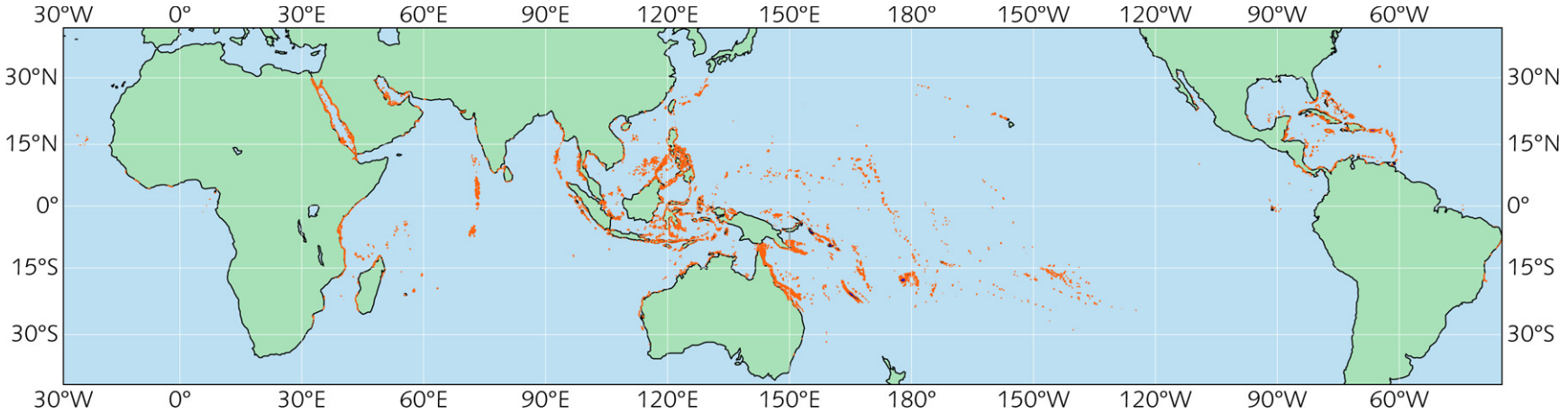


Coral Reef Products for HyspIRI

Eric J. Hochberg
Bermuda Institute of Ocean Sciences

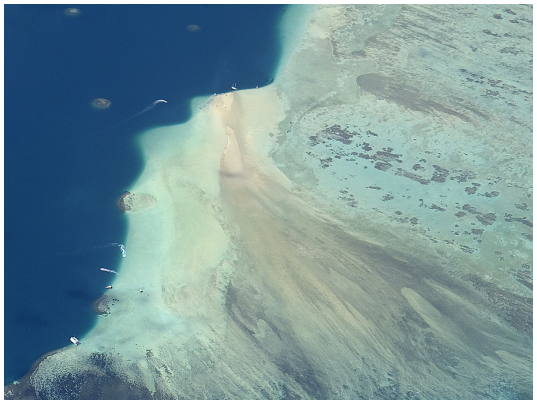
2013 HyspIRI Science Symposium
29 May 2013

Coral Reefs: Global Distribution and Importance



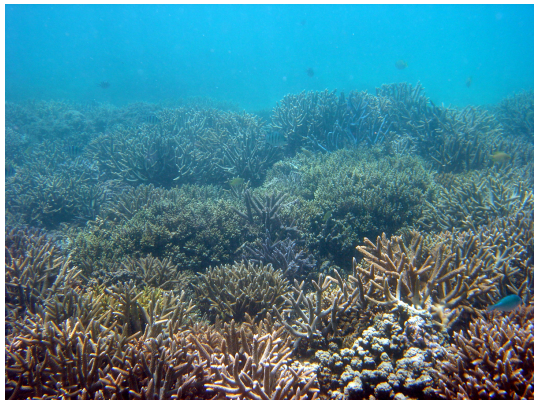
Focus for traditional culture and food source for innumerable small subsistence economies

Protection to shorelines from storm and wave damage and barriers that provide safe passage for shipping



Superlative recreational resource and the foundation of a multibillion dollar tourist industry worldwide

Major locus of global biodiversity, providing an ecological reserve of genetic complexity

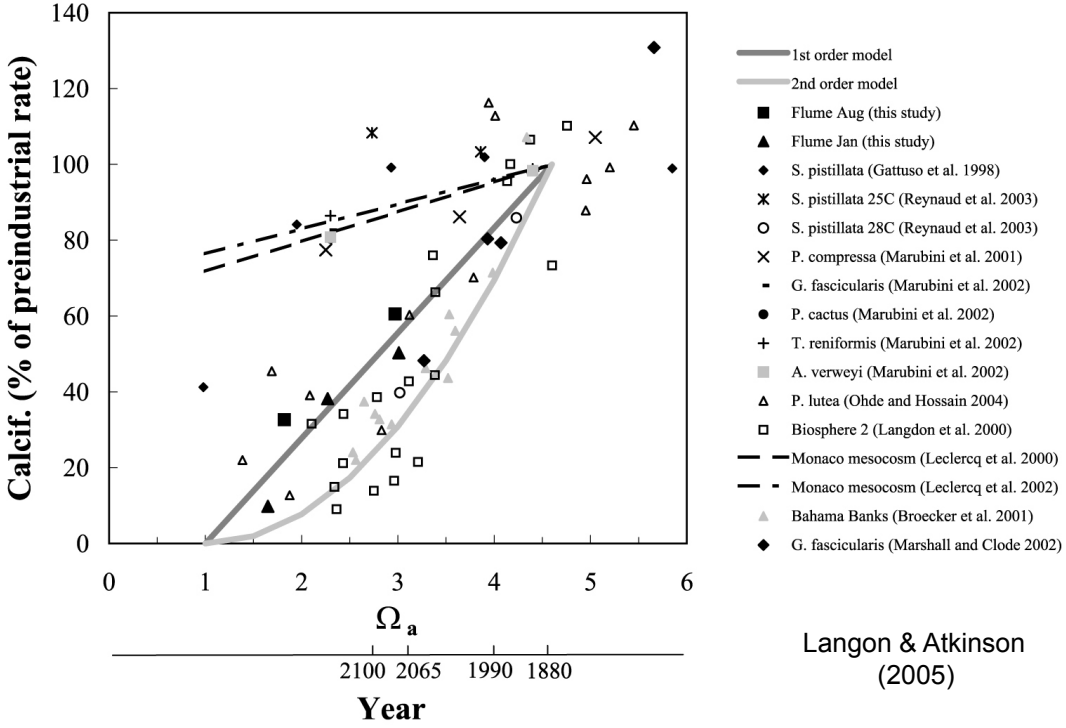


Global Stresses to Reefs

SST: Increased Coral Bleaching

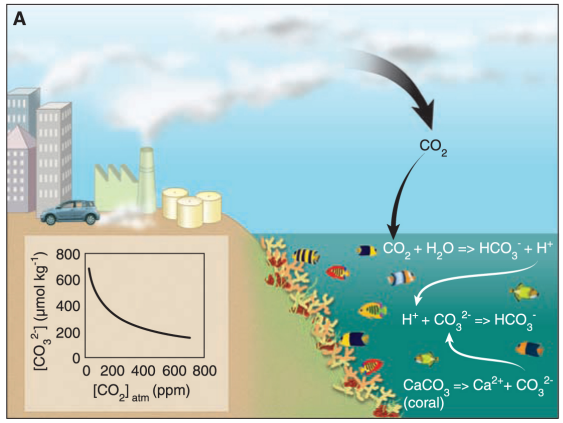
SST: increased Coral Disease

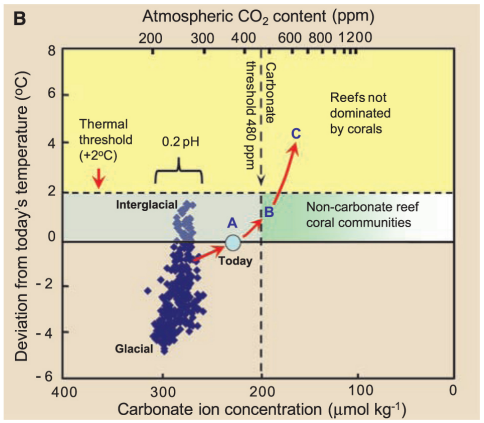
Ocean Acidification: Decreases in Calcification Rates



Langon & Atkinson (2005)

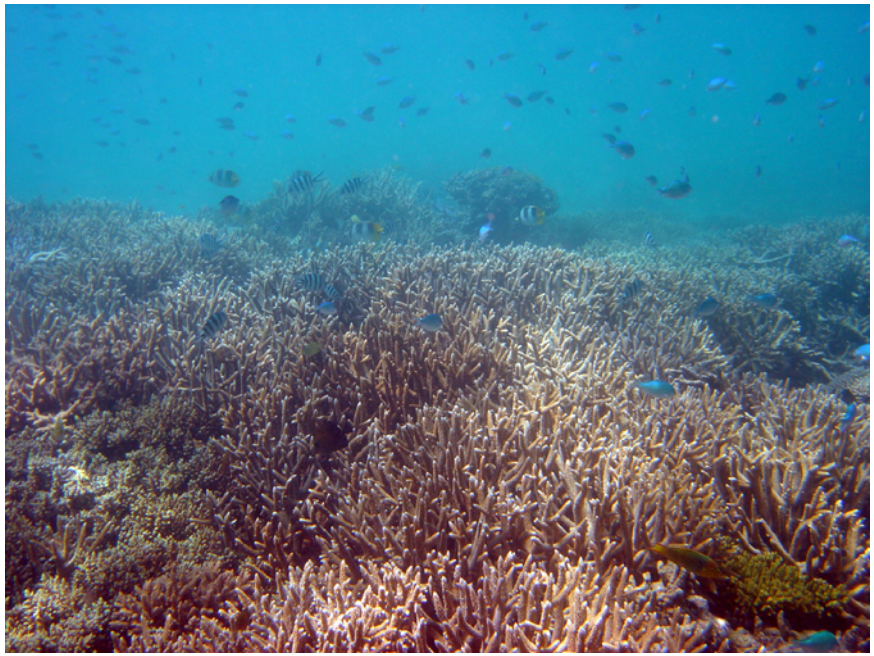
Synergistic Effects



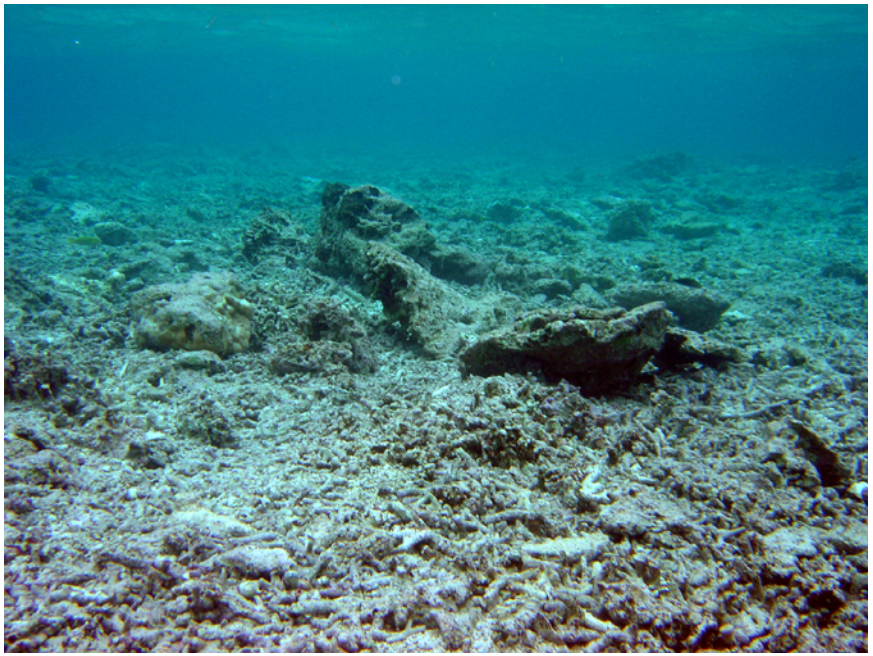


Hoegh-Gulberg et al. (2007)

The Primary Coral Reef Problem:
Phase Shifts from Coral-Dominated to Algae-Dominated

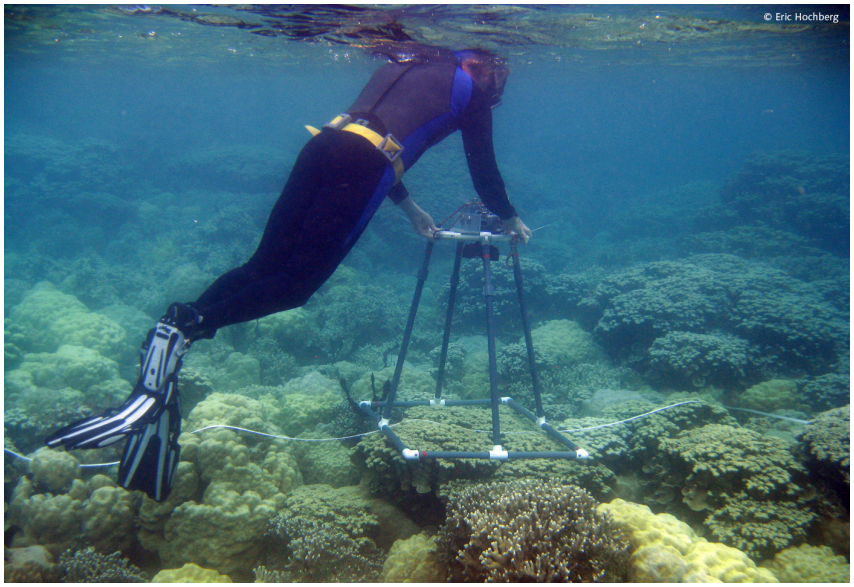


- Rough
- High productivity/calcification
- “Healthy”



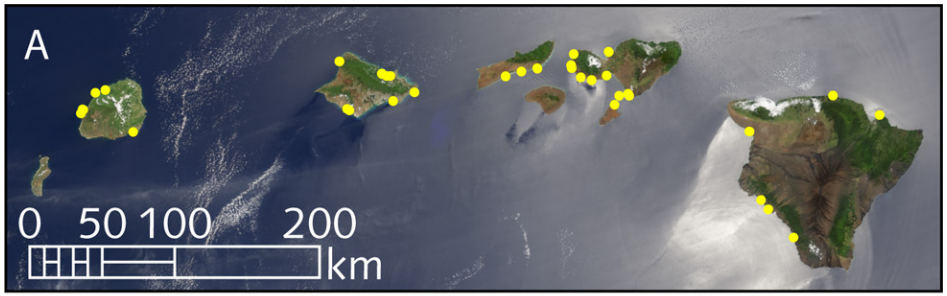
- Smooth
- Low productivity/calcification
- Not “healthy”

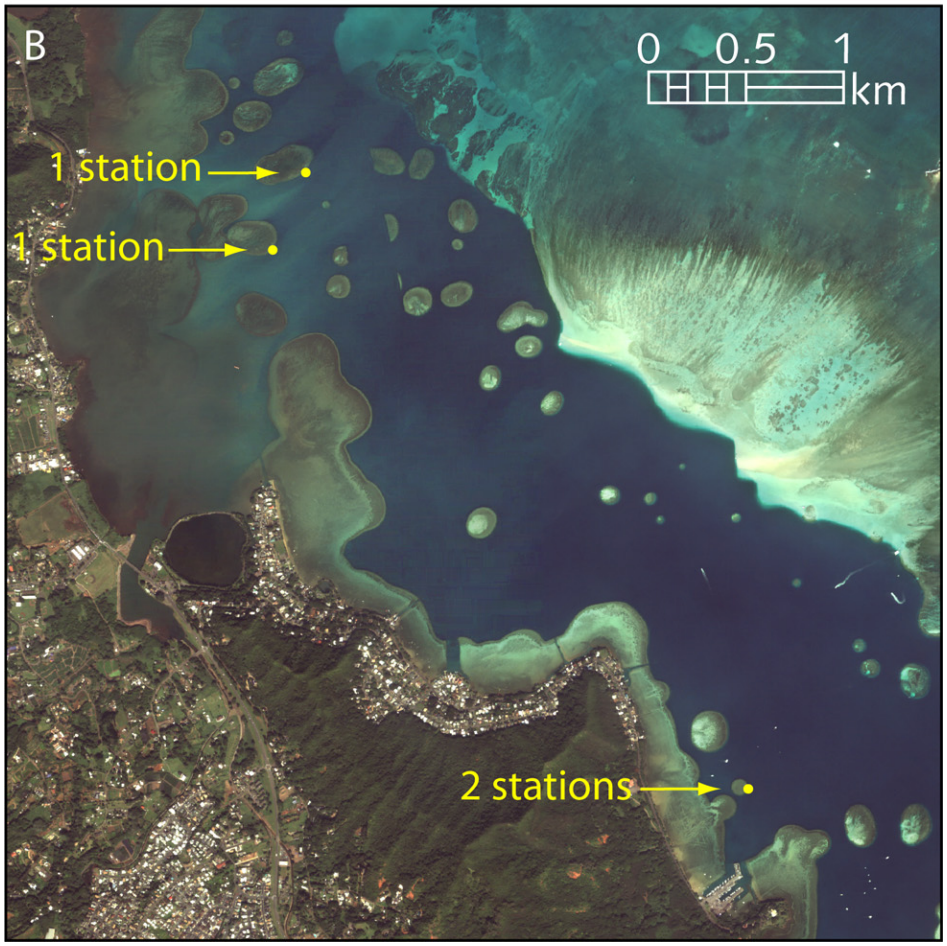
State of the Art in Coral Reef Assessment



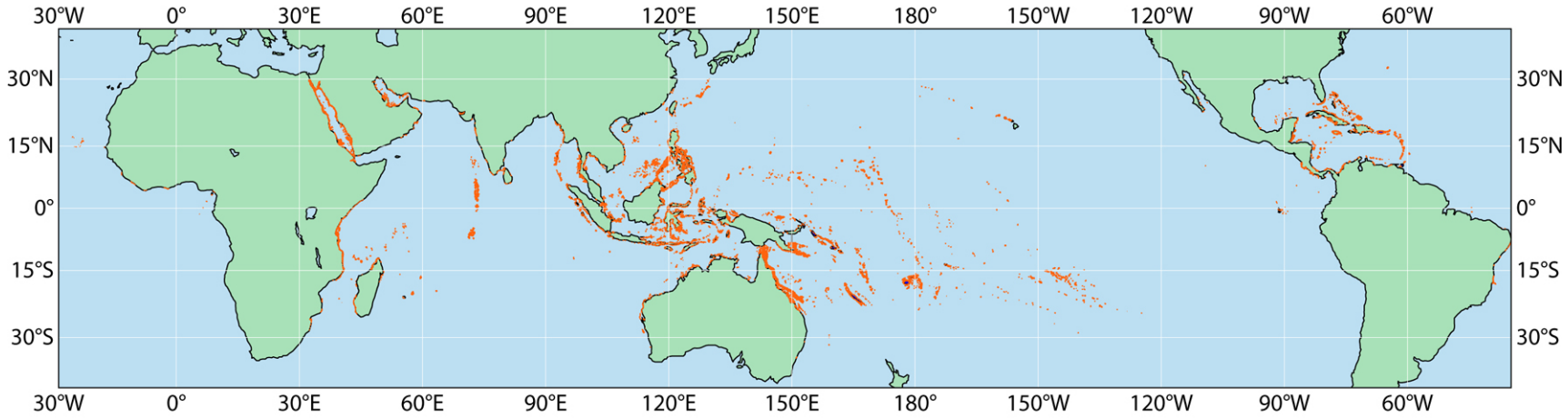
Photoquadrat Transects: detailed laborious, small footprint

“Manta-Tows”: quick, semi-quantitative, larger footprint

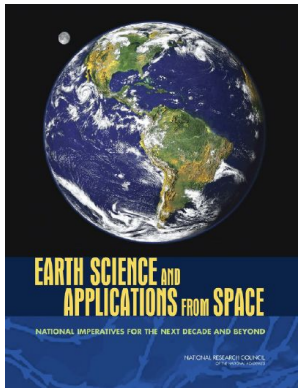




Coral Reefs: Sampling Problem



- ~9,000 reefs in the world, covering 500,000 km^2
- spread across 200,000,000 km^2 of ocean
- Quantitative in situ surveys cover only 10s to 100s of km^2 worldwide
- *Current estimates of reef loss are based on direct observation of only 0.01–0.1% of the world's reef area*
- **Only satellite remote sensing can provide the uniform data set required for assessment of the global status of coral reefs**

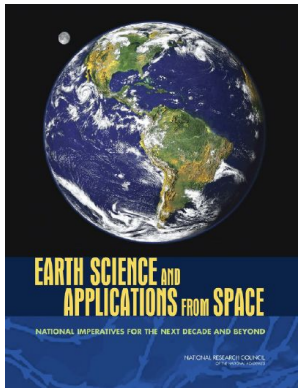


HyspIRI MISSION

p. 113 “A capability to detect such changes provides possibilities for early warning of detrimental ecosystem changes, such as drought, reduced agricultural yields, invasive species, reduced biodiversity, fire susceptibility, altered habitats of disease vectors, and changes in the health and extent of coral reefs.”

p. 114 “**Background**...Requirements for ecosystem studies include information on canopy water content, vegetation stress and nutrient content, primary productivity, ecosystem type, invasive species, fire fuel load and moisture content, and such disturbances as fire and insect damage. In coastal areas, measurements of the extent and health of coral reefs are important.”

p. 114 “**Science Objectives**...Observations can also detect changes in the health and extent of coral reefs, a bellwether of climate change. Those capabilities have been demonstrated in space-borne imaging spectrometer observations but have not been possible globally with existing multispectral sensors.



LAND-USE CHANGE, ECOSYSTEM DYNAMICS, AND BIODIVERSITY

p. 191 "*Mission to observe distribution and changes in ecosystem function.* An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity."

BOX 7.3 ECOSYSTEM PROPERTIES FOR WHICH SATELLITE DATA ARE REQUIRED

Terrestrial Ecosystems	Coastal and Open-Ocean Ecosystems
Distribution and changes in key species and functional groups of organisms	Coral-reef health and extent
Disturbance patterns	Photosynthesis
Vegetation stress	Sediment fluxes
Vegetation nutrient status	Phytoplankton community structure
Primary productivity	Algal blooms
Vegetation cover	CO_2 concentration
Standing biomass	
Vegetation height and canopy structure	
Habitat structure	
Human infrastructure	
Atmospheric CO_2 and CO concentration	

TABLE 7.1 Land-Use Change and Ecosystem Dynamics Panel Priority New Missions

Summary of Mission Focus	Variables	Type of Sensor	Coverage	Spatial Resolution	Frequency	Synergies with Other Panels	Related Planned or Integrated Missions
Ecosystem function: climate and land-use impacts on terrestrial and coastal ecosystems	*Terrestrial:* Distribution and changes in key species and functional groups of organisms, disturbance patterns, vegetation stress, vegetation nutrient status, primary productivity, vegetation cover *Coastal:* coral-reef health and extent	Hyperspectral	Global, pointable	50-75 m	30 day, pointable to daily	Climate Health Solid Earth	HyspIRI

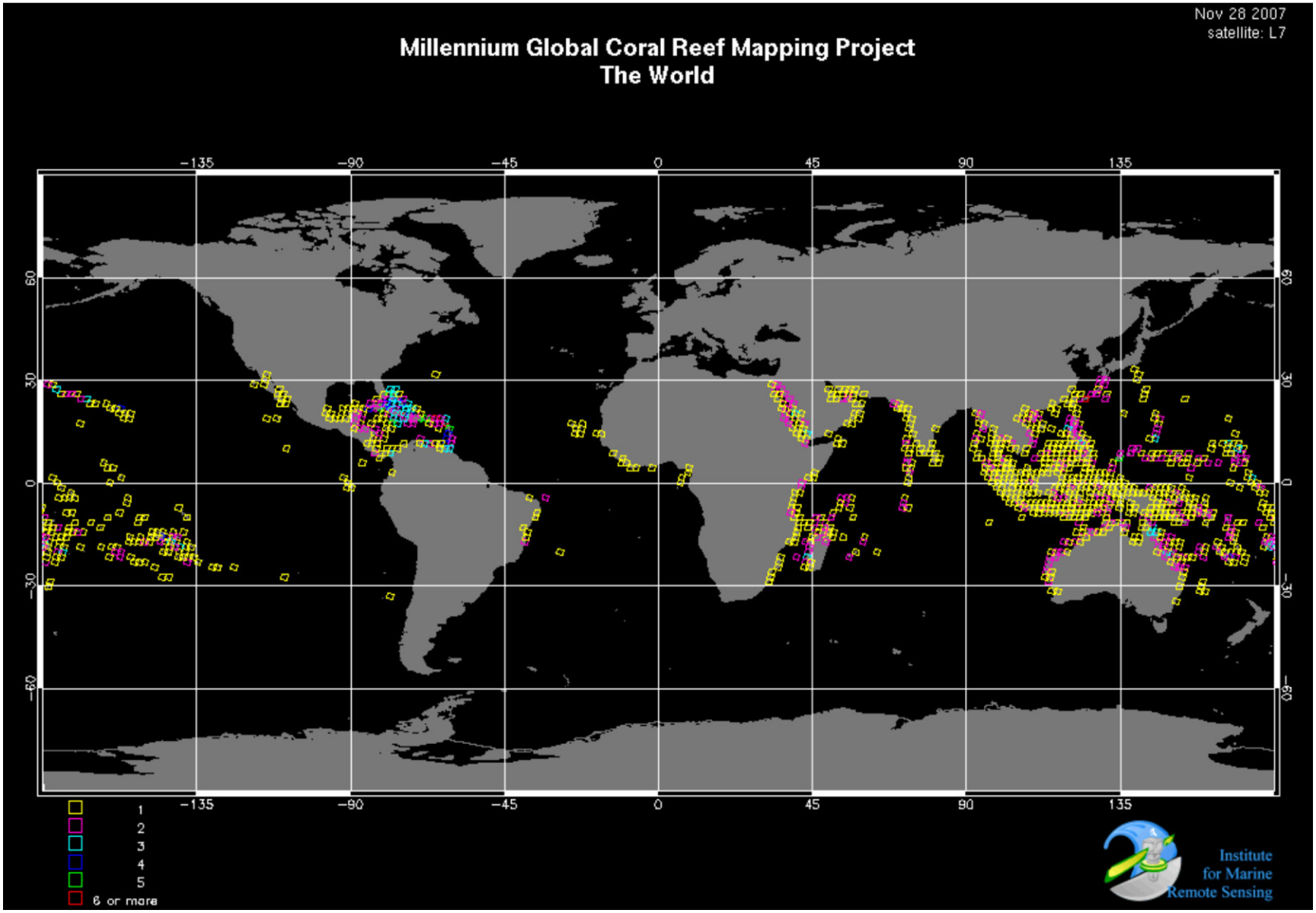
Ecosystem Function

Mission Summary—Ecosystem Function

Variables:	Distribution and changes in key species and functional groups of organisms; disturbance patterns; vegetation stress; vegetation nutrient status; primary productivity; vegetation cover; coral-reef health and extent
Sensor(s):	Hyperspectral
Orbit/coverage:	LEO/global-pointable
Panel synergies:	Climate, Health, Solid Earth
New science:	Land ecosystem chemistry, diversity, leaf water stress; coral reef health and extent
Applications:	Ecosystem interactions with changing climate, agriculture, invasive species, disturbance, management, urbanization

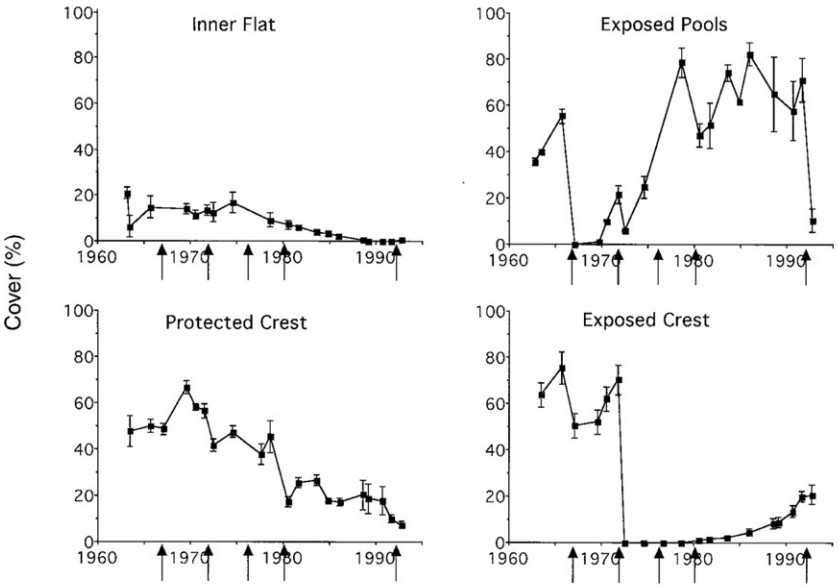
Ecosystem function, the first mission concept listed in Table 7.1, is aimed at detecting a suite of functional responses of ecosystems to direct human and climate impacts and providing detailed information for improved management of ecosystems. This mission builds on legacy remote sensing measurements of chlorophyll and visible reflectance and will use direct and inferential techniques for observing the spatial pattern of additional key functional properties of ecosystems. The properties targeted reveal ecosystem responses critical for understanding the effects of climate, land use, and resource use. Key properties are listed in Box 7.3 and include indexes of ecosystem composition (distribution of and changes in key species or functional groups of organisms and disturbance patterns) and ecosystem health and dynamics (leaf water stress and energy-water-carbon-nutrient fluxes). The mission focuses on terrestrial ecosystems but would also address coral-reef health and extent.

Coral Reef Extent — A Good Start

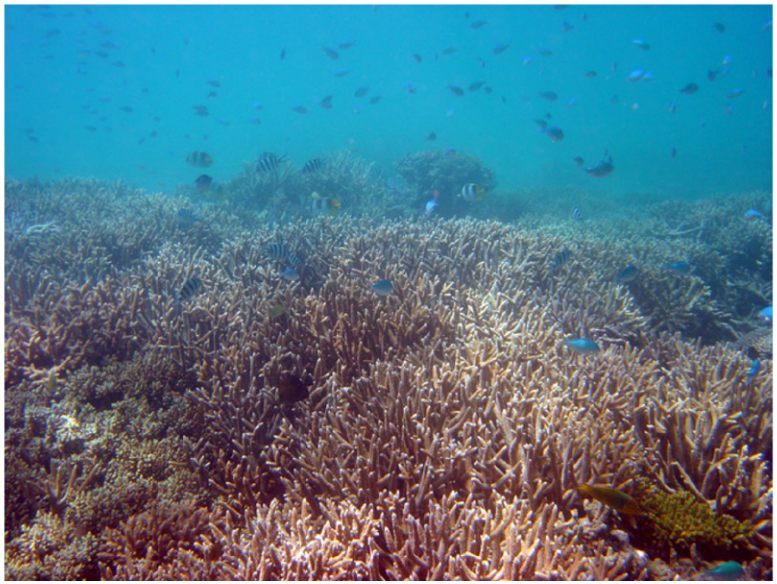


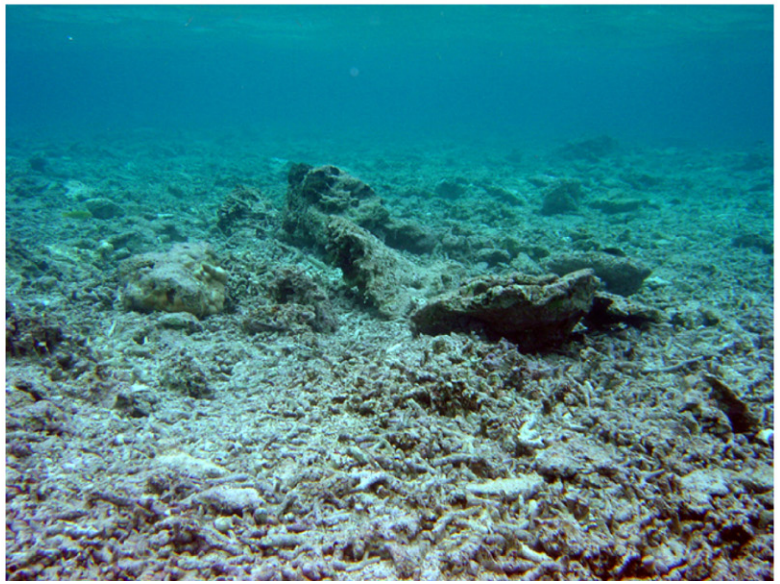
Coral Reef Health — Reducible to a quantitative measure

Connell et al. (1997)



- When corals die their skeletons are rapidly colonized by algae
- Healthy reefs usually increase coral coverage during recovery from stress
- Degraded reefs gradually become dominated by algae and rubble
- With the loss of reef-builders, the carbonate structure erodes, ultimately becoming a flat bottom with shifting rubble and sand
- **A key quantitative parameter to assess the health of a reef is the distribution of living coral, algae and sand**
- **Such a quantitative index can be effectively utilized to evaluate the relative impacts of natural phenomena and human activities to reef communities**

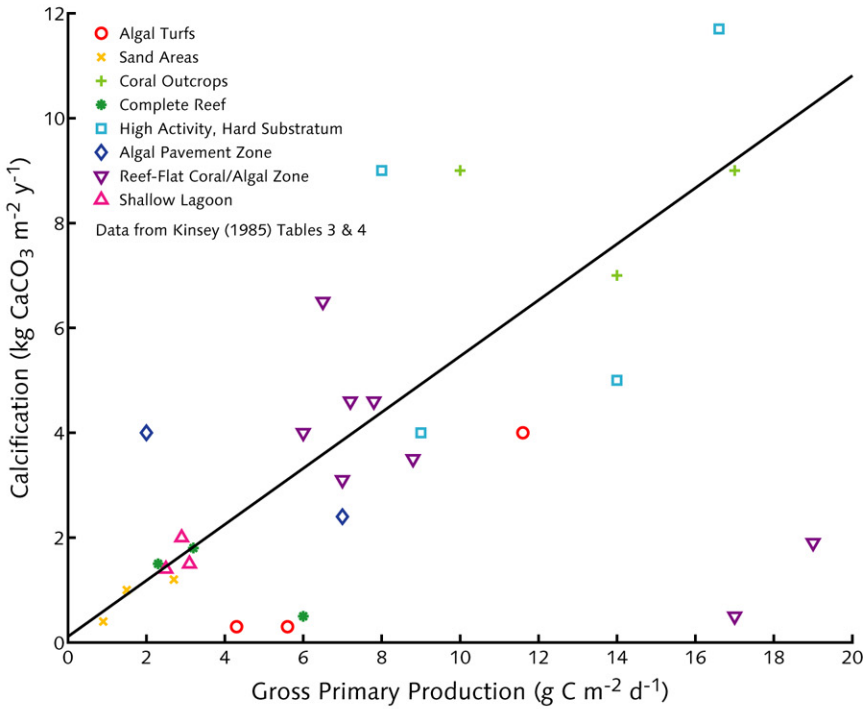




Coral Reef Function

Published values for specific biotopes in coral reef environments (after Kinsey 1984)

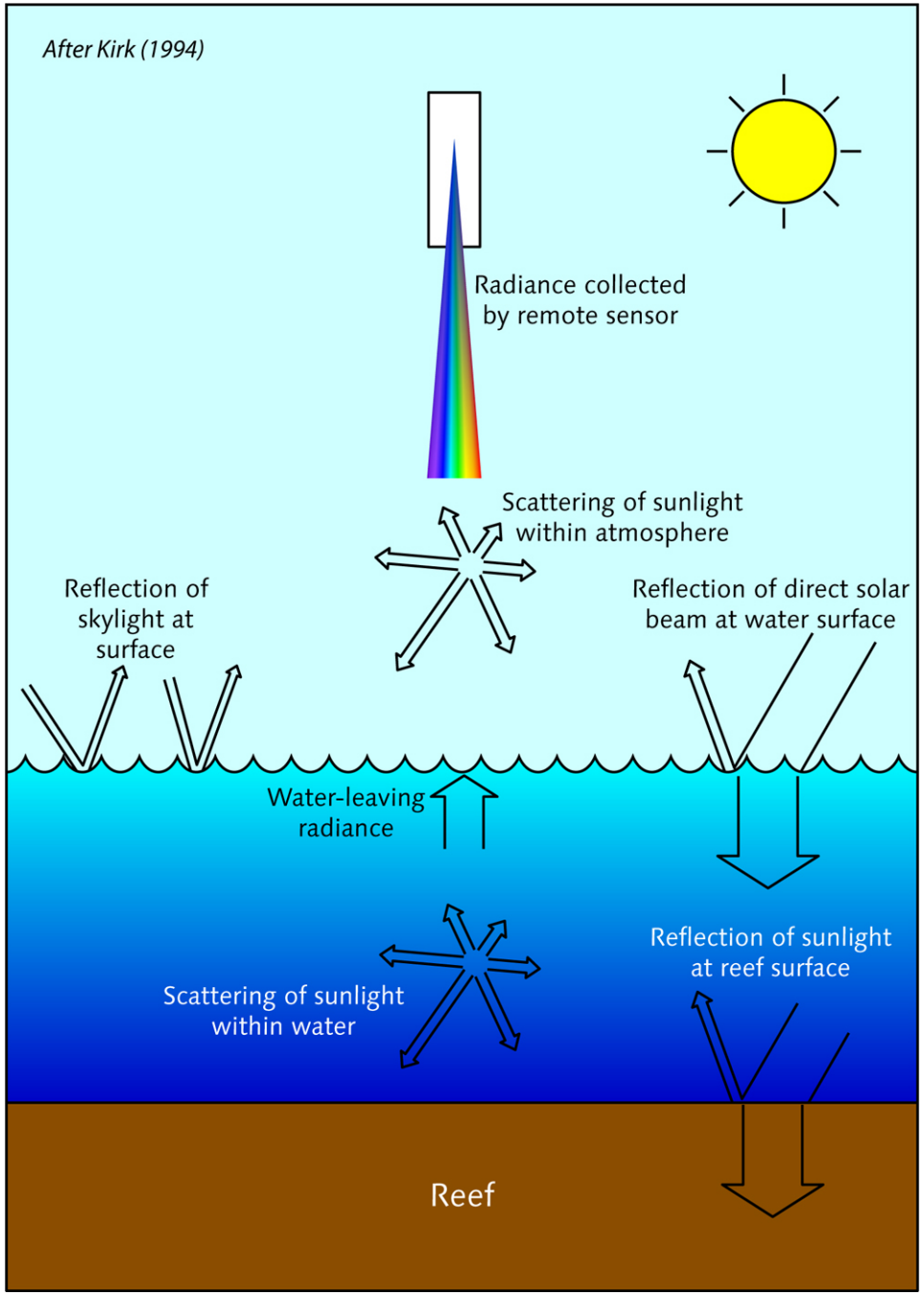
Reference	Location	P (mol O_2 m^{-2} d^{-1})
Algal turfs & algal/sand flats		
Smith (1973)	Enewetak	0.97
Smith & Marsh (1973)	Enewetak	0.87
Kinsey (1979)	Lizard Island	0.36
"	Kaneohe Bay	0.47
Hargraves (1982)	Carrie Bow Key	~1.67
Sorokin (1982)	Various Indo-Pacific	0.17-0.33
Vooren (1981)	Curacao	0.16
Hawkins & Lewis (1982)	Barbados	0.08
Rogers & Salesky (1981)	St. Croix (turf)	0.25
	" (macroalgae)	1.23
Coralline encrusting algae		
Vooren (1981)	Curacao	0.08
Hawkins & Lewis (1982)	Barbados	0.07
"Sand" areas		
Sournia (1976)	Takapoto	~0.17
Sorokin (1982)	Various Indo-Pacific	0.05-0.11
Kinsey (1977)	One Tree Island	0.08
Kinsey (1979)	Kaneohe Bay	0.23
Kinsey (1979)	One Tree Island	0.13
Coral outcrops		
Kinsey (1979)	6 sites GBR	1.42-3.08
"	*Leptoria phrygia* patch	0.67
"	*Acropora pulchra* patch	1.5
"	*Porites andrewsi* patch	1.17
Atkinson & Grigg (1984)	French Frigate Shoals	
	Porites compressa/lobata	~0.83



- The relative distribution of coral, algae and sand also allows for straightforward estimates of productivity using concepts of standard metabolic rates for reef community types
- Higher-order models are under development
- Calcification is correlated with productivity

Five sources of light received by a remote sensor pointed at a coral reef.

Only light reflected at the reef surface can provide information about the reef.



Hochberg & Atkinson (2003)

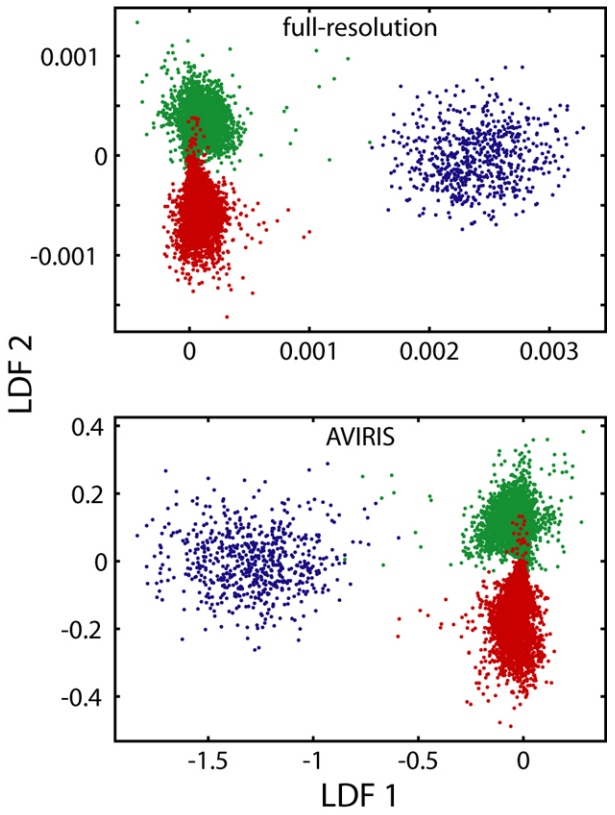
Table 1
Classification error matrices for in situ spectral reflectances of three coral reef classes: coral, algae, and carbonate sand

(A) Full-resolution: overall accuracy = 98%

		Actual class		
		Algae	Coral	Sand
Predicted class	Algae	2726 (99.2)	75 (3.3)	1 (0.3)
	Coral	23 (0.8)	2168 (96.6)	0 (0.0)
	Sand	0 (0.0)	1 (0.0)	320 (99.7)

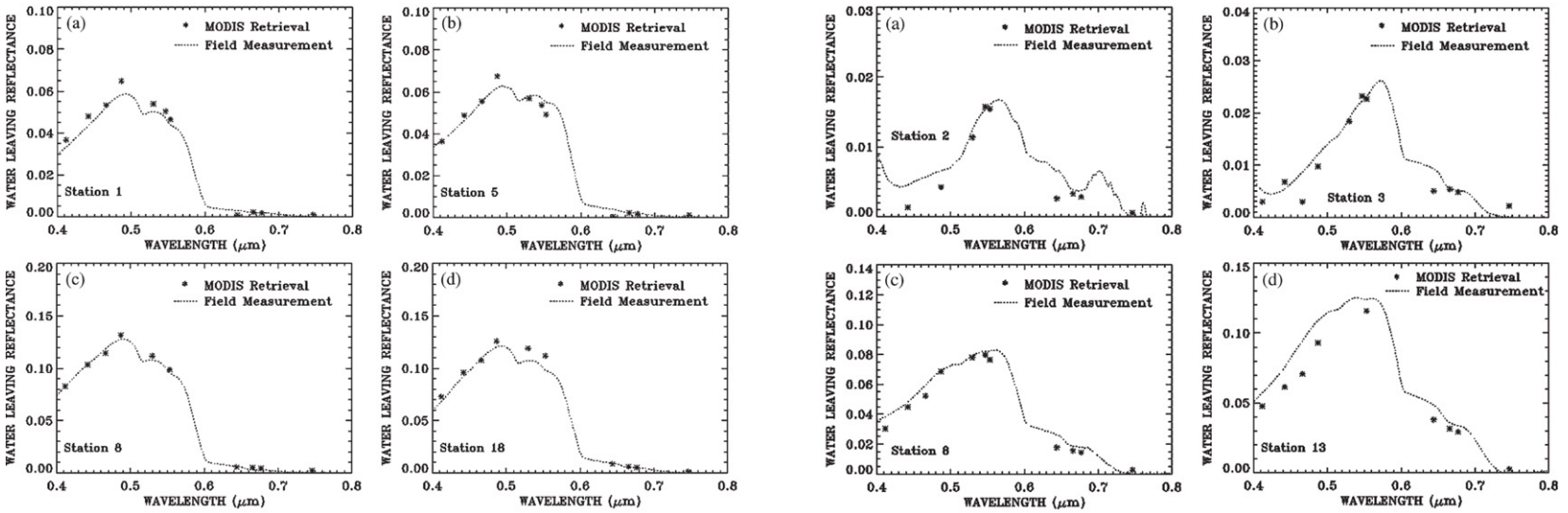
(C) AVIRIS: overall accuracy = 98%

		Actual class		
		Algae	Coral	Sand
Predicted class	Algae	2725 (99.1)	74 (3.3)	1 (0.3)
	Coral	24 (0.9)	2170 (96.7)	0 (0.0)
	Sand	0 (0.0)	0 (0.0)	320 (99.7)



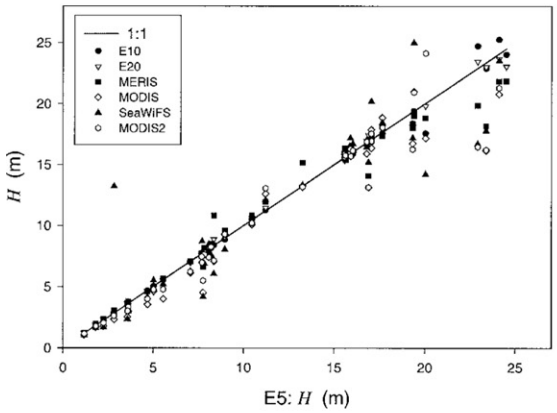
Conclusion: Contiguous, 10-nm-wide wavebands over range 400–700 nm provides excellent spectral discrimination between coral, algae, and sand

Gao et al. (2007)

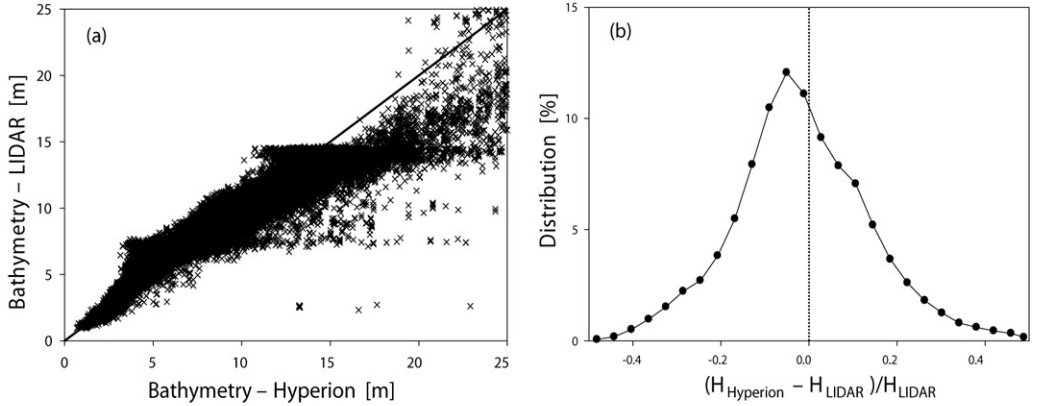


Conclusion: Combined wavebands across both NIR and SWIR (i.e., 0.865, 1.04, 1.24, 1.64, and 2.25 μm) provide very good atmospheric correction

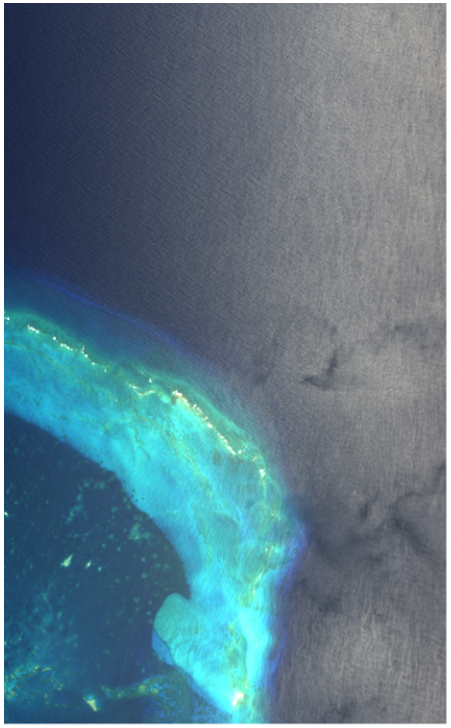
Lee & Carder (2002)

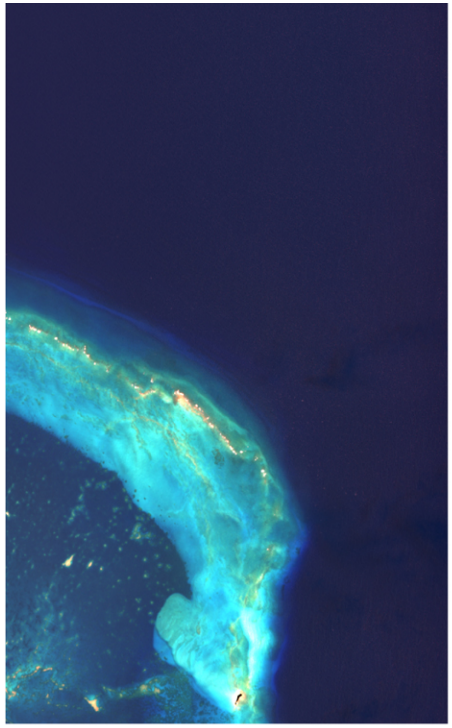


Lee et al. (2007)



Conclusion: Contiguous, 10-nm-wide wavebands over range 400–800 nm is excellent band set for retrieval of shallow water bathymetry

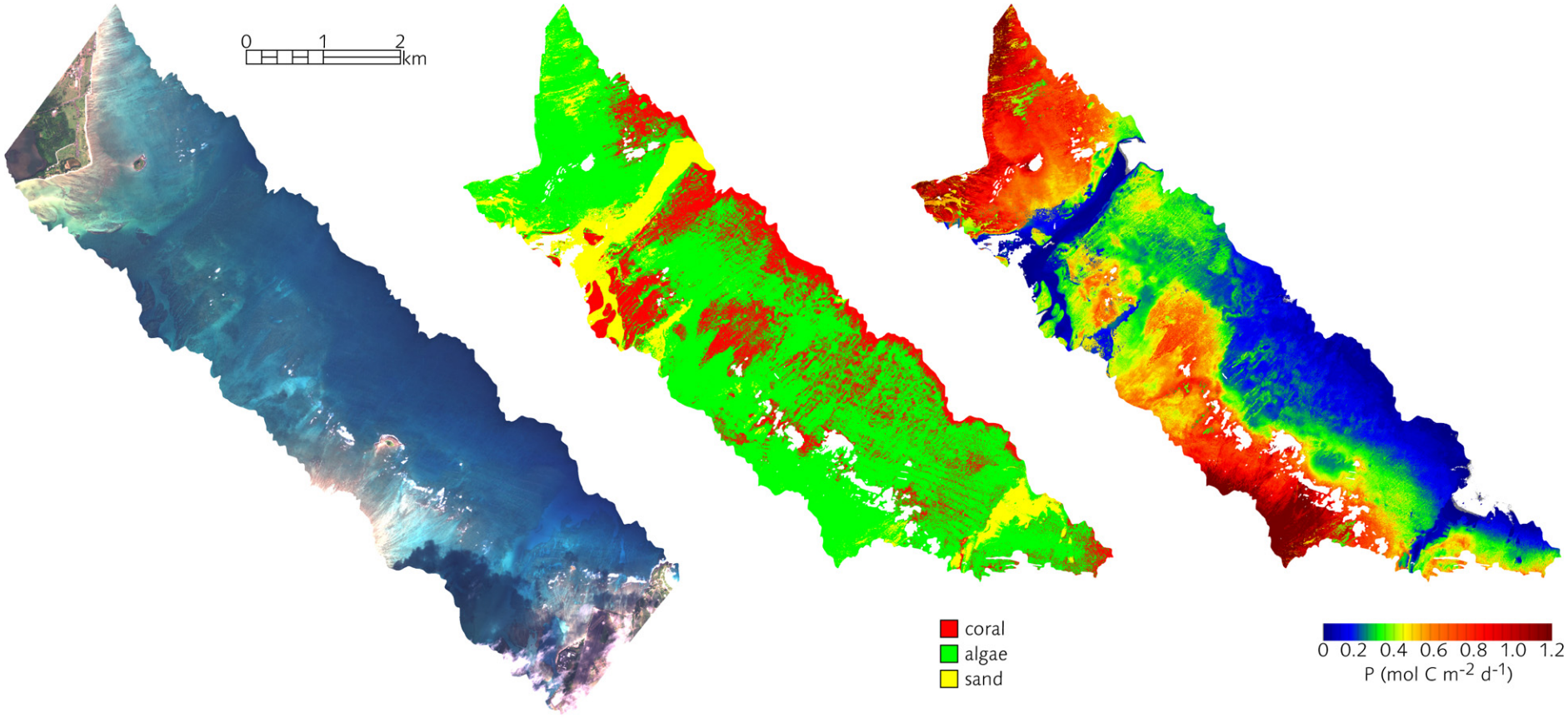




Various Workers & HyspIRI Sun Glint Subgroup

Conclusion: Glint is readily correctable, provided (1) suitable reference waveband(s) at wavelengths > 900 nm and (2) good atmospheric correction

Coral Reef Products



Pseudo-true-color picture

Map of bottom-types

Map of productivity

HyspIRI Coral Reef Science

Data products will be used to answer specific environmental questions on the ratios of coral, algae and sand with respect to geographical limits, regional oceanography, reef morphology, seasonality and human use patterns and impacts.

- Determine the coral/algae/sand ratios in pristine reefs versus human impacted reefs.
- Determine how coral/algae/sand ratios vary with reef morphology, underlying geology, latitude, seasonality, disturbance events, and oceanographic conditions of wind, waves, and nutrients.
- Determine the spatial scales of responses in coral/algae/sand ratios to environmental changes.
- Develop appropriate indices for these ratios to help regional and local monitoring efforts.
- Determine how coral/algae/sand ratios interact with centers of coral diversity.
- Advise managers, locally and internationally, regarding how to respond to regional and local changes in reef composition.
- Show how global space-based data can alter local perception of problems and help with management efforts.
- Identify how series of regional reefs add to regional productivity and recruitment to fisheries.
- Identify reefs that are suitable for more intensive monitoring and scientific investigation.
- Determine how coral/algae/sand is distributed in response to impacts from localized sedimentation, runoff and nutrients.
- Provide input to hydrodynamic and biogeochemical models for reef function, and aid existing monitoring programs.
- Identify specific, abnormal reef environments, either by reef morphology or coral/algae/sand index ratios.
- Support many small scale existing studies. Available data will allow local scale studies to be put in a larger context through large data-base.

Using HyspIRI at the Land/Sea Interface to Identify Phytoplankton Functional Types

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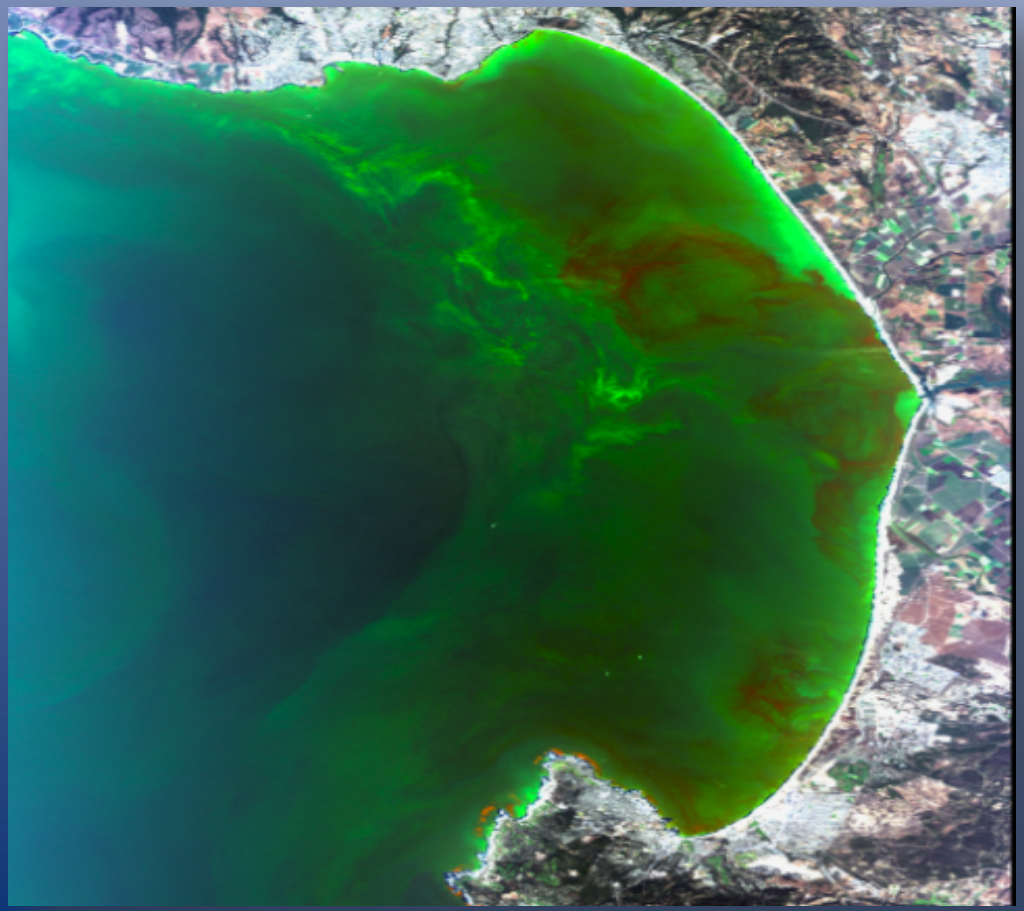
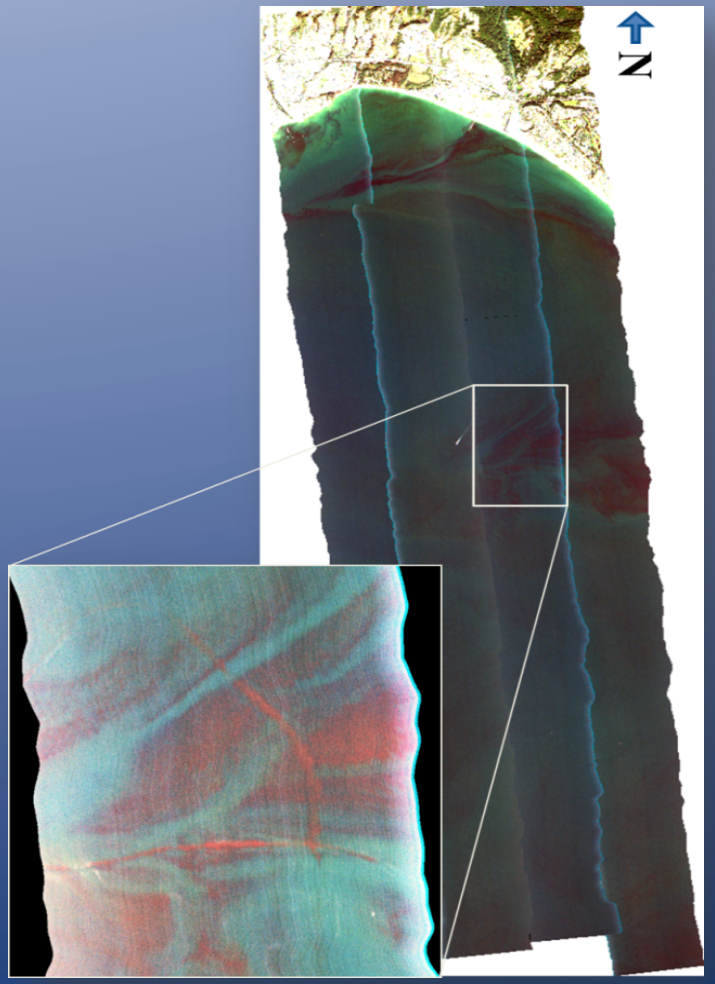
Liane Guild (co-PI), NASA Ames Research Center, Moffett Field, CA
Sherry Palacios (post-doc), NASA Ames
Kendra Hayashi, Jennifer Broughton, UCSC





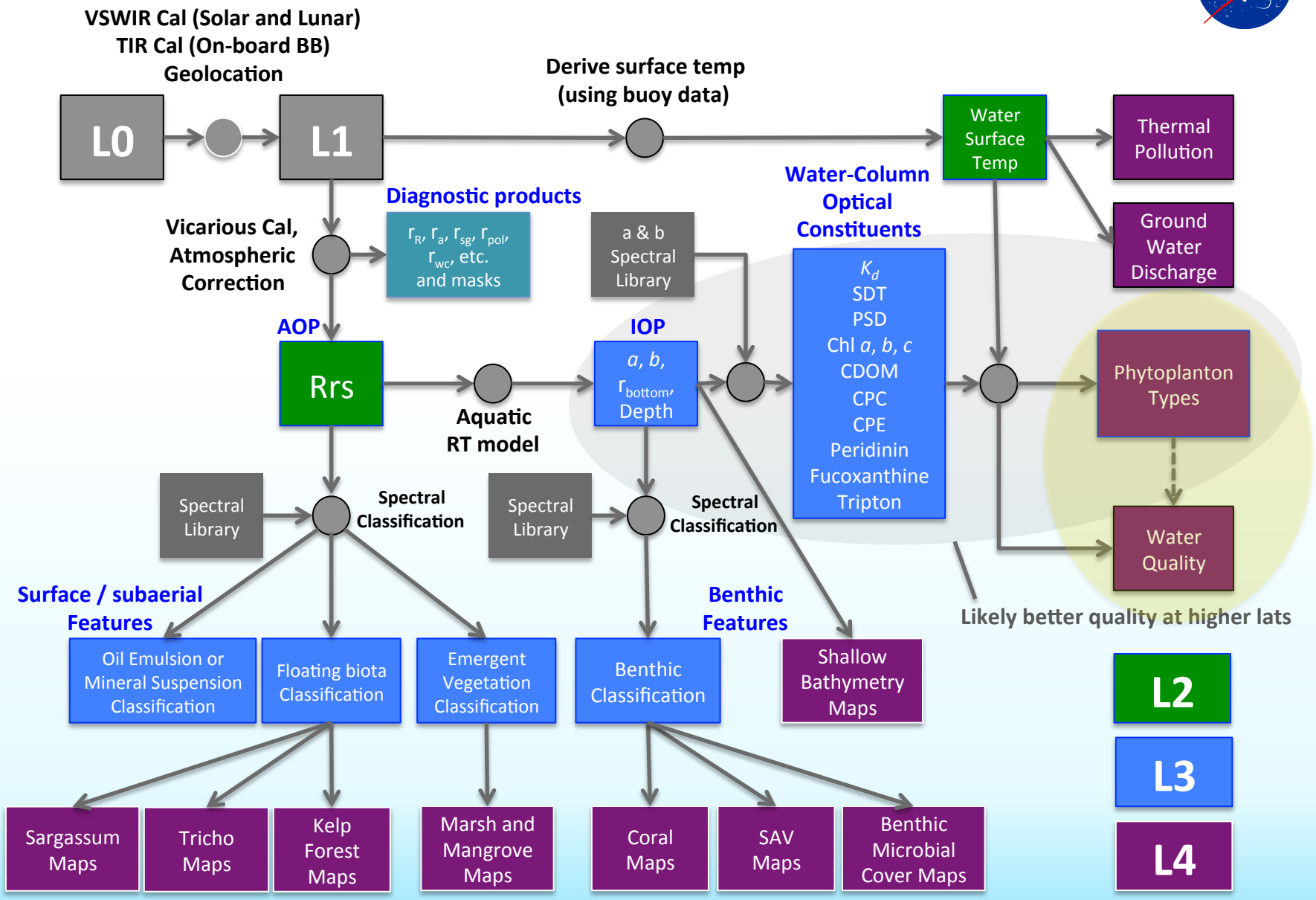
Contact: kudela@ucsc.edu, liane.s.guild@nasa.gov, sherry.l.palacios@nasa.gov

Objectives/Significance

- **Our primary goal is to demonstrate the utility of an airborne HyspIRI simulation to address the biological properties of coastal California, within the context of the long-term monitoring programs ongoing in the area**

1) The development and improvement of algorithms and models for the detection and prediction of HABs
2) Provide PFTs for inland water bodies such as lakes and reservoirs
3) Provide PFTs for the coastal ocean to assess ecosystem health and water quality (focusing on HABs and red tides)

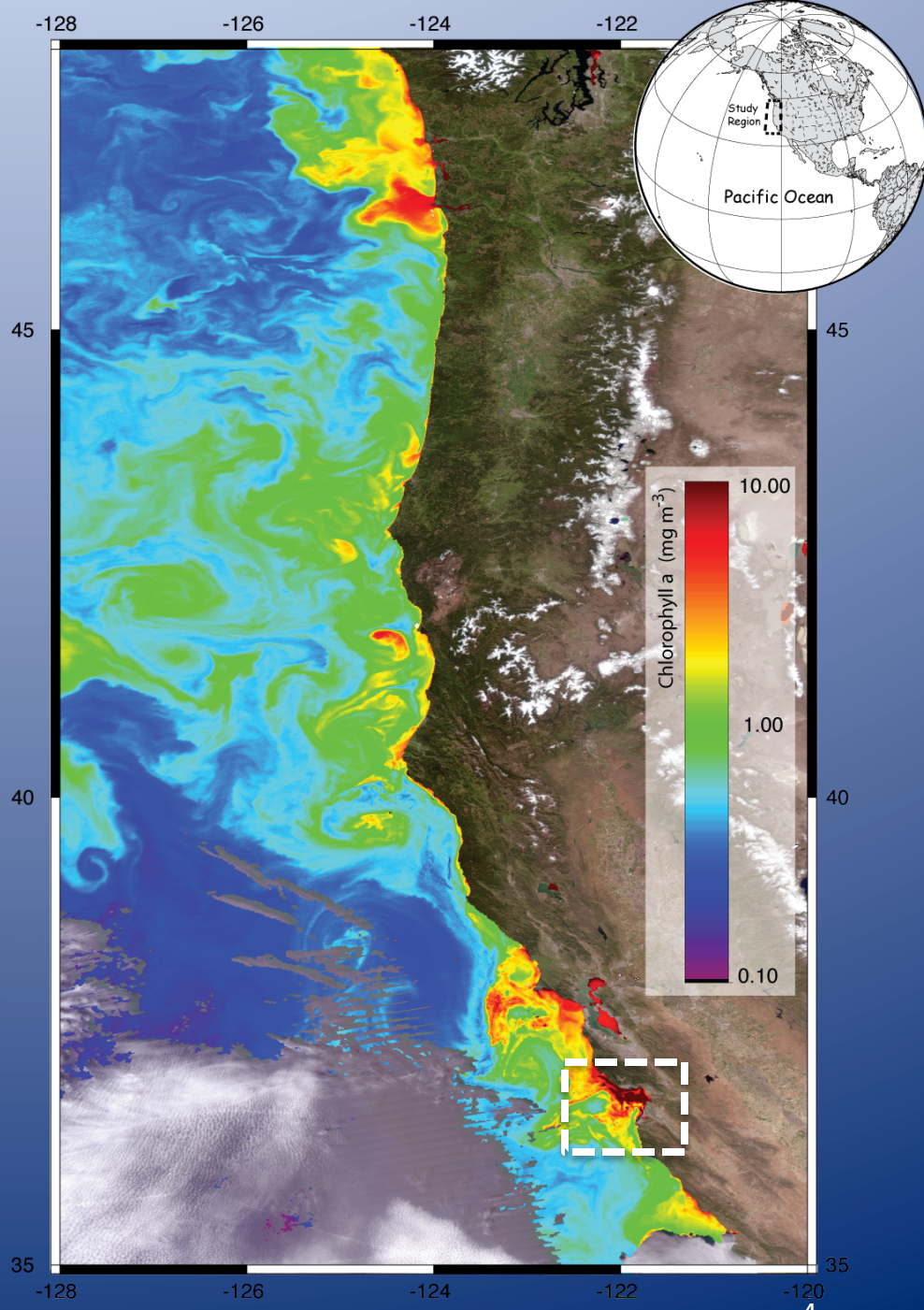
Aquatic Applications and Product Hierarchy



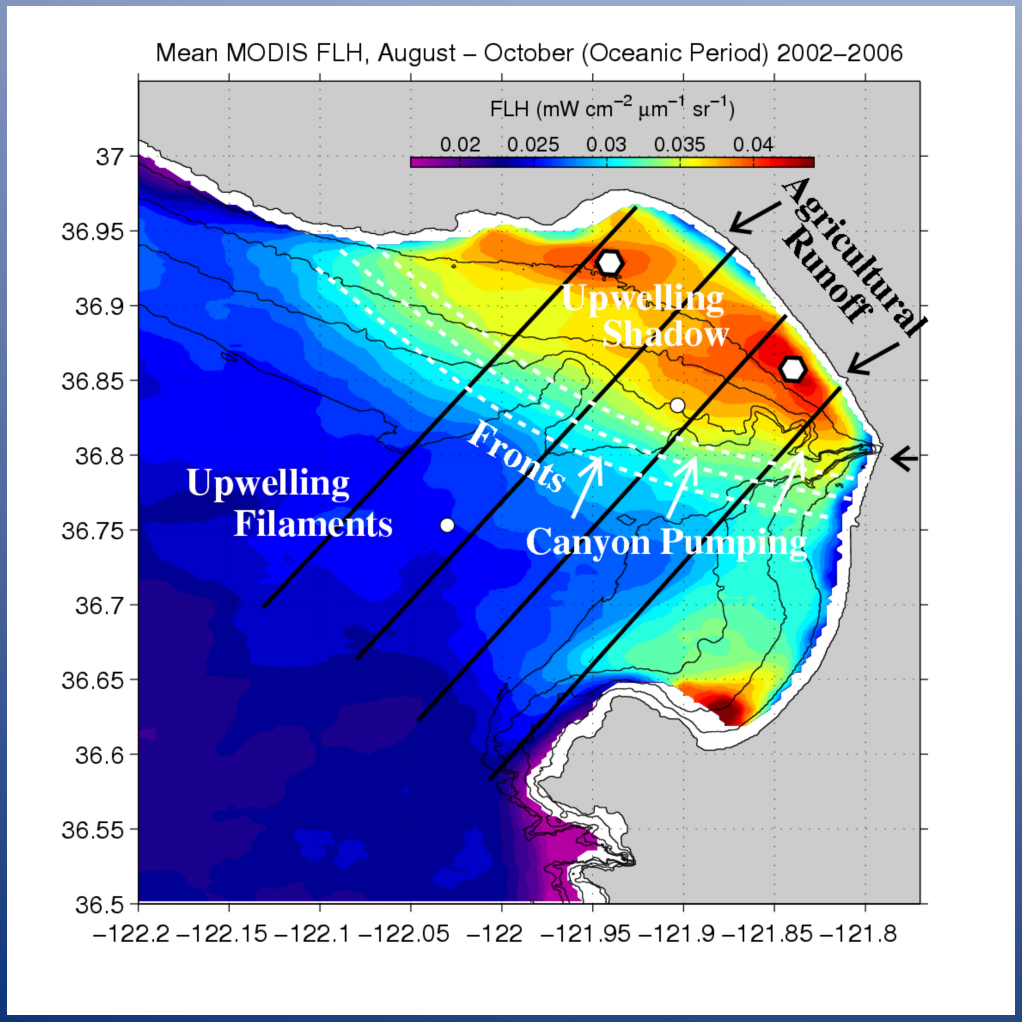
Kevin's Slide

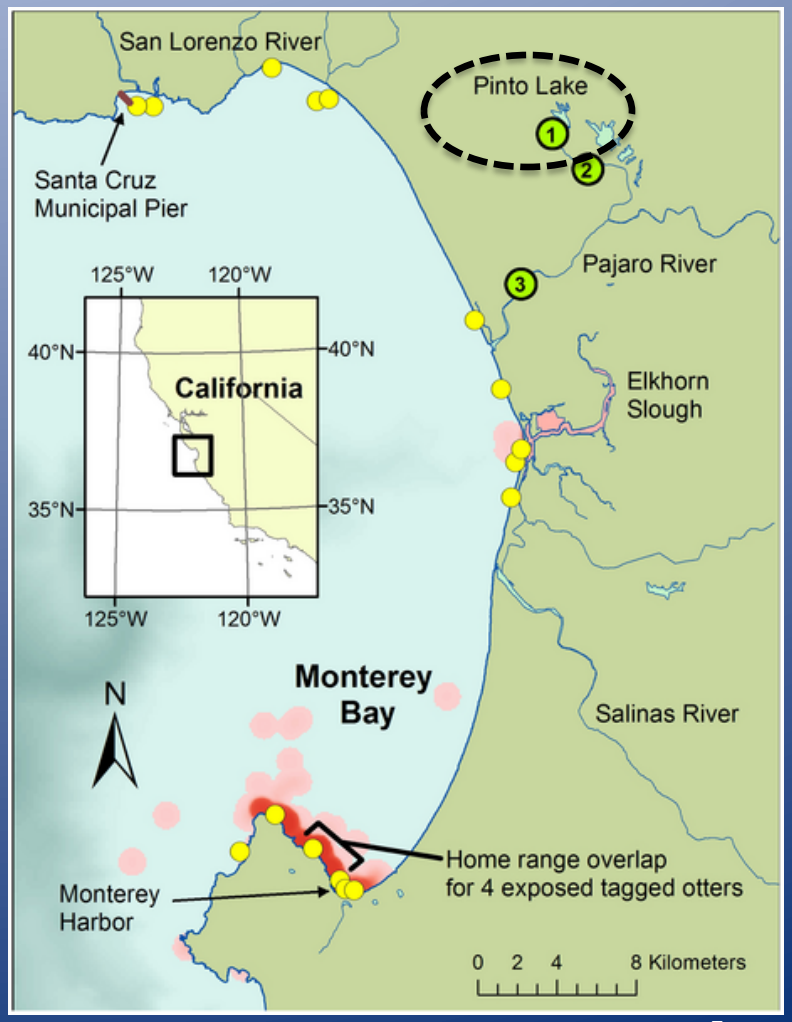
Monterey Bay as a Testbed

- Monterey Bay has been used for COAST 2006 (PHILLS 2 sensor), COAST-HOPE 2011 (Headwall and C-AIR sensors), PRISM (2012), SARP (MASTER, 2010), and GLIMMER (2012) as well as numerous AVIRIS overflights
- Ongoing time-series by UCSC, MLML, MBARI, with moorings and shore stations
- Features include Elkhorn Slough, Case 1 & 2 waters, red tides, kelp beds, river plumes

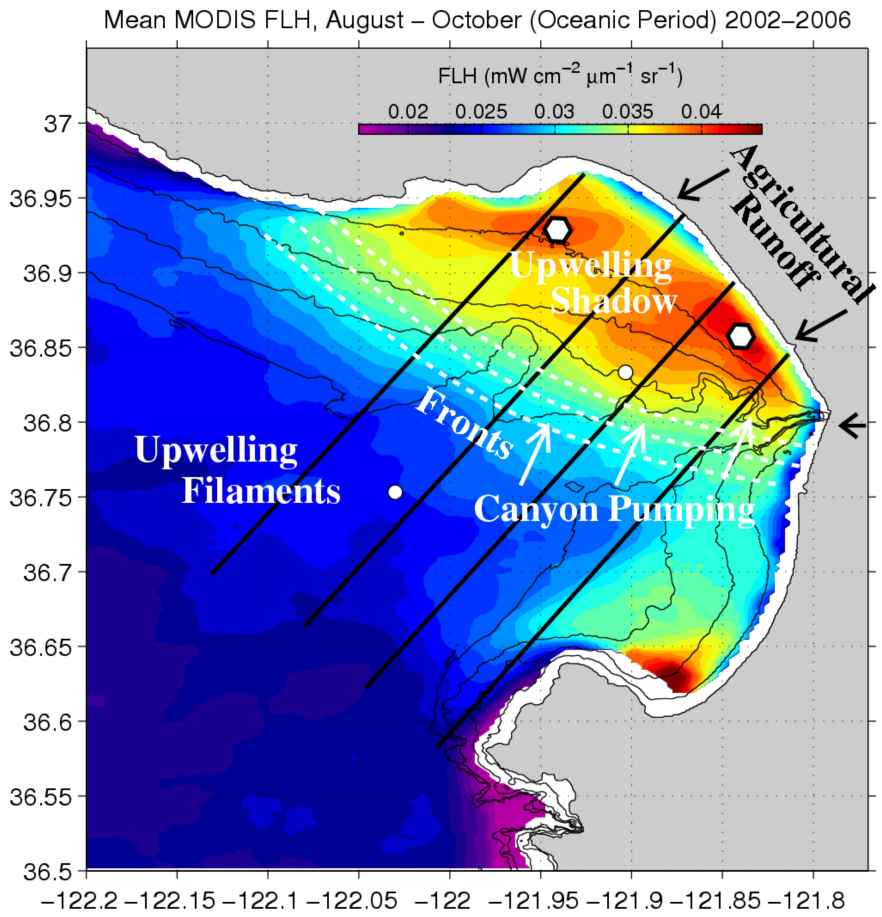


Field Sites


Mean MODIS FLH, August – October (Oceanic Period) 2002–2006
FLH (mW cm^{-2} µm^{-1} sr^{-1})
0.02 0.025 0.03 0.035 0.04
Agricultural Runoff
Upwelling Shadow
Fronts
Upwelling Filaments
Canyon Pumping
37
36.95
36.9
36.85
36.8
36.75
36.7
36.65
36.6
36.55
36.5
−122.2 −122.15 −122.1 −122.05 −122 −121.95 −121.9 −121.85 −121.8


San Lorenzo River
Pinto Lake
1
2
Santa Cruz Municipal Pier
3
Pajaro River
125°W 120°W
40°N
40°N
California
35°N
35°N
125°W 120°W
Elkhorn Slough
N
Monterey Bay
Salinas River
Home range overlap for 4 exposed tagged otters
Monterey Harbor
0 2 4 8 Kilometers

Field Sites – Flight Timing



Spring (March), Summer (July), and Fall (October) maximize the likelihood of data collection days, minimize cloud cover (for collection of satellite data), and provide a range of scientifically interesting features, including tidal exchange with Elkhorn Slough, red tides, fall transition, upwelling versus oceanic conditions, and, potentially, a "first flush" rain event.

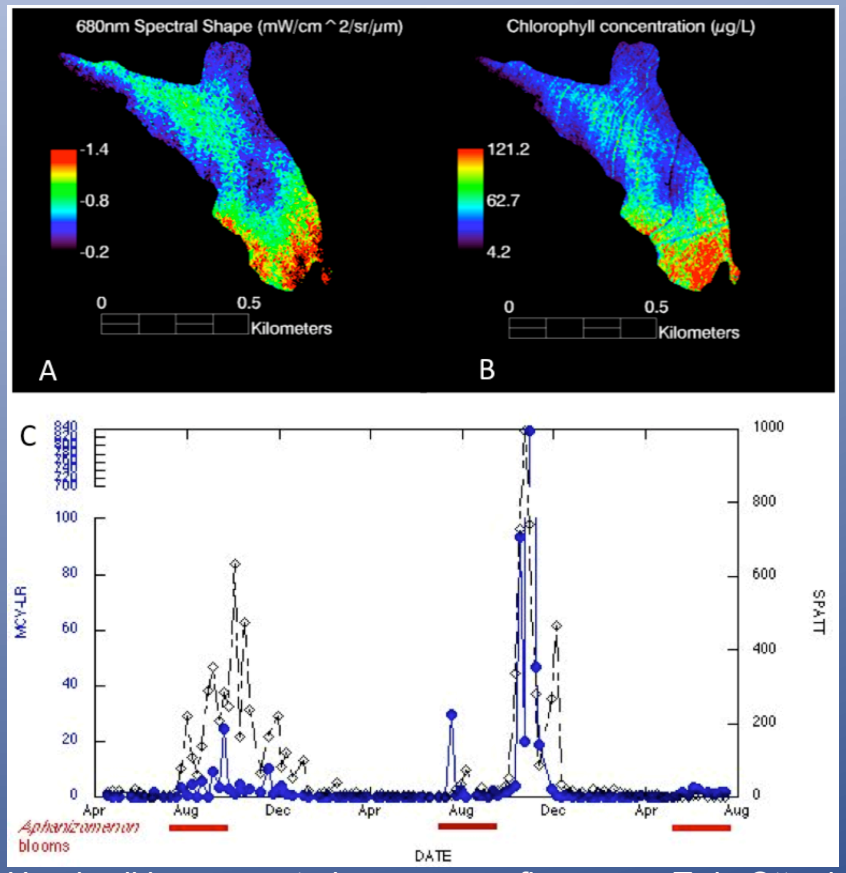
Seasonality in Monterey Bay can be delineated by

- upwelling (April-August),
- oceanic (September-October), and
- Davidson (November-March) seasons.

Having up to three AVIRIS overflights may enable capturing some of this seasonality.

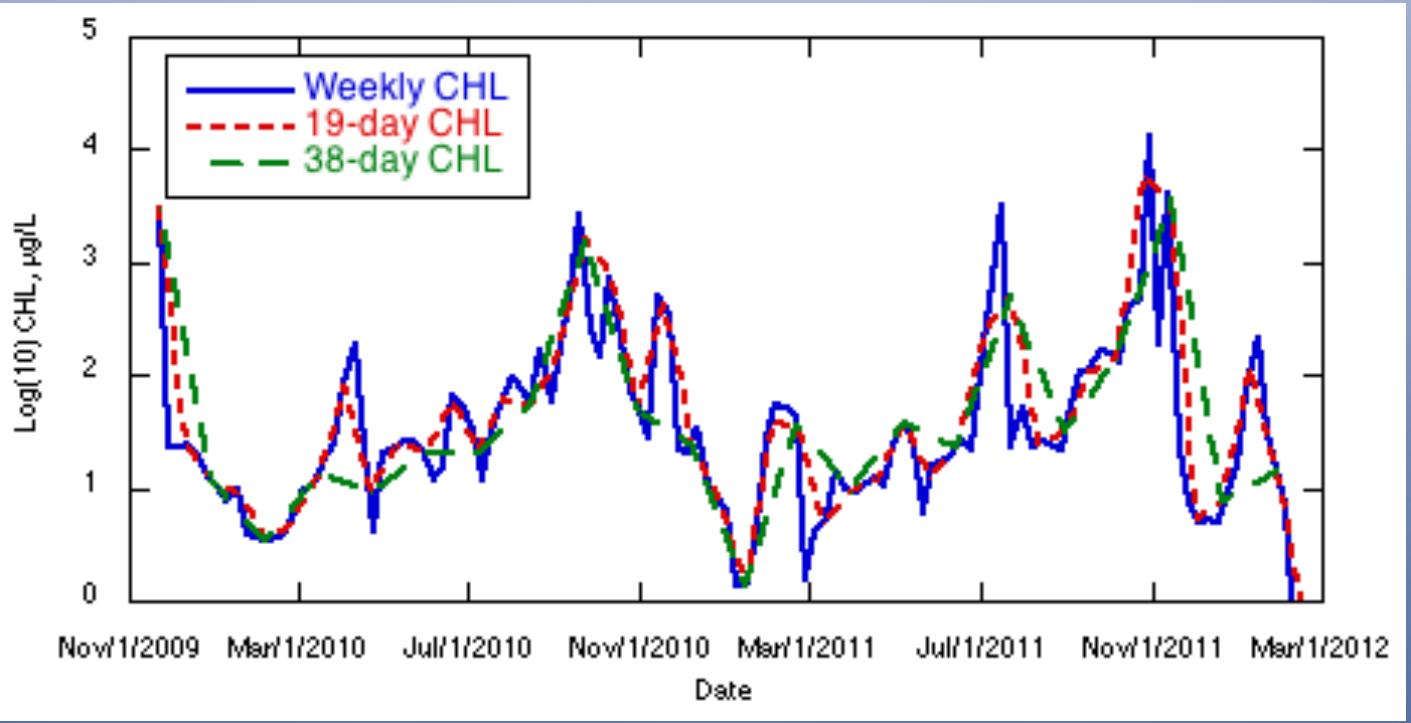
Pinto Lake

Meso-eutrophic lake, dominated by cyanos in summer with clear seasonal species succession



A Headwall hyperspectral sensor was flown on a Twin Otter in October 2010 over Pinto Lake. A spectral shape algorithm (A) and a band-ratio chlorophyll *a* algorithm (B) were applied. Sampling confirmed the presence of an extensive *Microcystis* bloom (with extremely elevated toxin levels) and chlorophyll concentrations. Toxin data from grab and time-integrated (SPATT) samples are shown (C) for 2010–2012. A separate spectral shape algorithm applied to HICO data in 2011 (not shown) successfully identified blooms dominated by *Aphanizomenon* (indicated with red bars) versus *Microcystis* from in-water spectra and HICO data.

Pinto Lake



Chlorophyll (and toxin) samples have been collected weekly for ~3 years from Pinto Lake, CA. Weekly CHL data are plotted after degrading to 19- and 38-day repeat cycles.

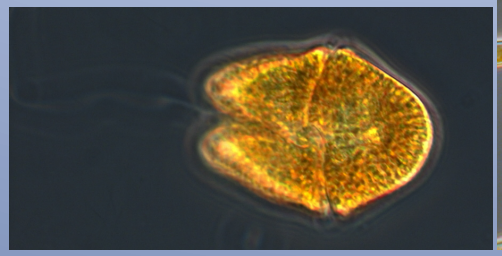
Pinto Lake has also been used as a site for airborne data collection in 2010, 2011, 2012, and 2013, and there are historical bio-optical and reflectance data available for comparison

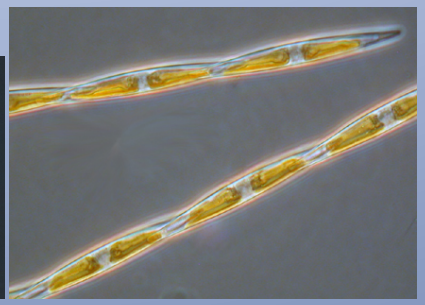
Phytoplankton Functional Types (PFTs)

- For oceanic waters, using PHYDOTax (Palacios 2012). This is an inversion model based on signature spectra (similar approach to CHEMTAX, but uses reflectance data). Solves for 6 functional types. Signature library developed using large-volume cultures (a, bb, c) and HydroLight
- For Pinto Lake, we have been using spectral shape algorithms with Headwall, MASTER, and HICO

PHYDOTax – Signature Library Taxa

dinoflagellate





diatom

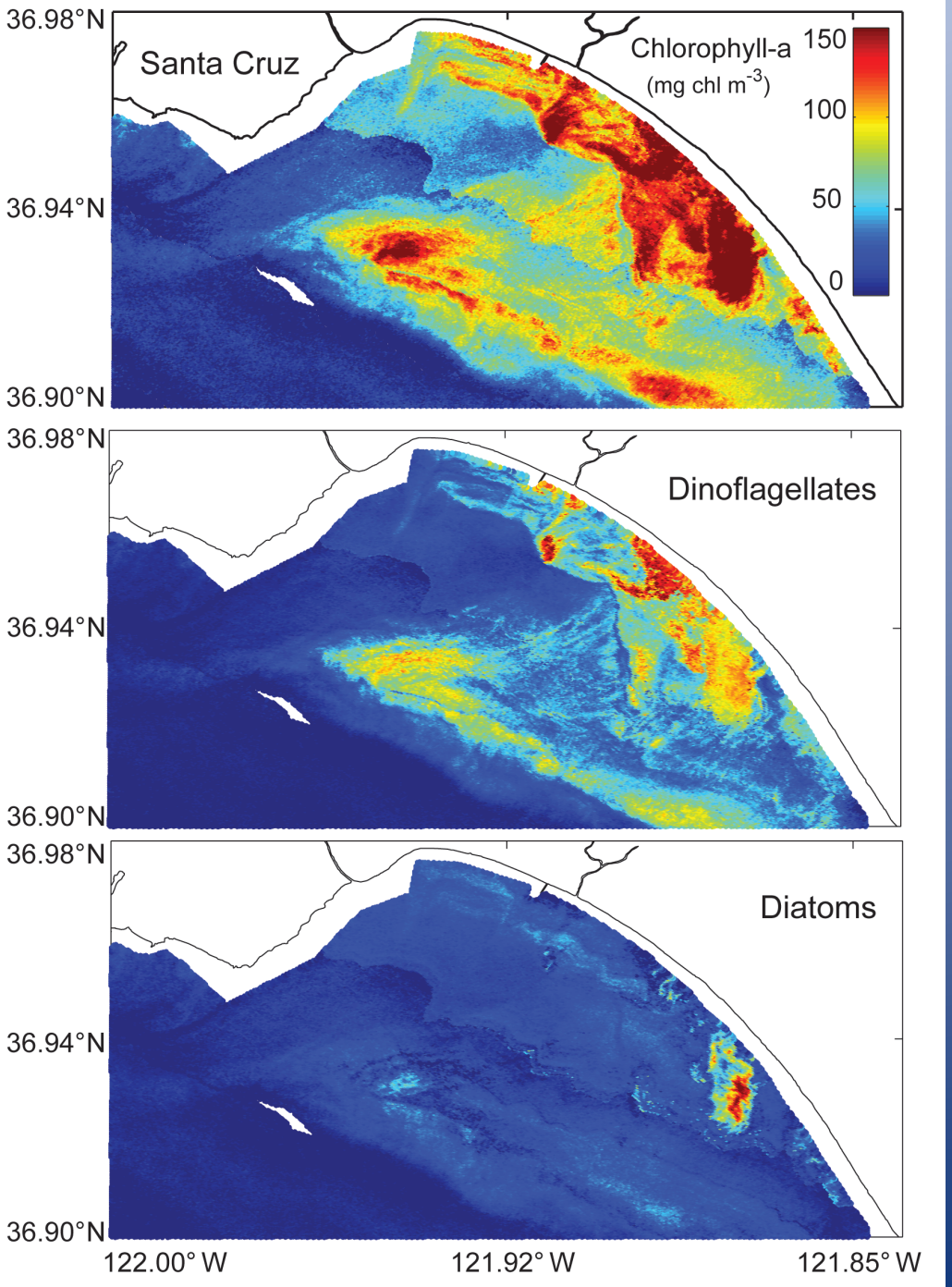
cryptophyte

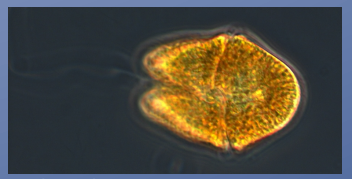
haptophyte

chlorophyte

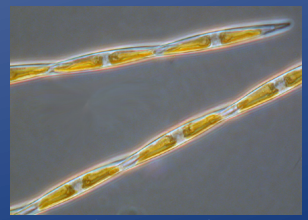
cyanobacterium

PHYDOTax Predictions





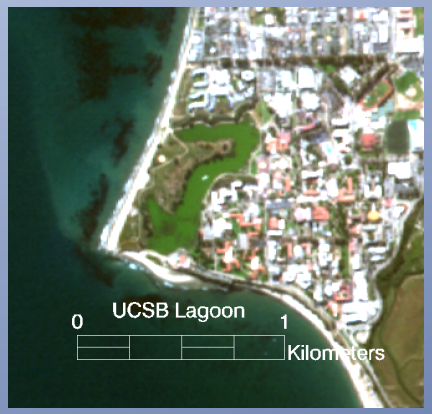
Akashiwo sanguinea

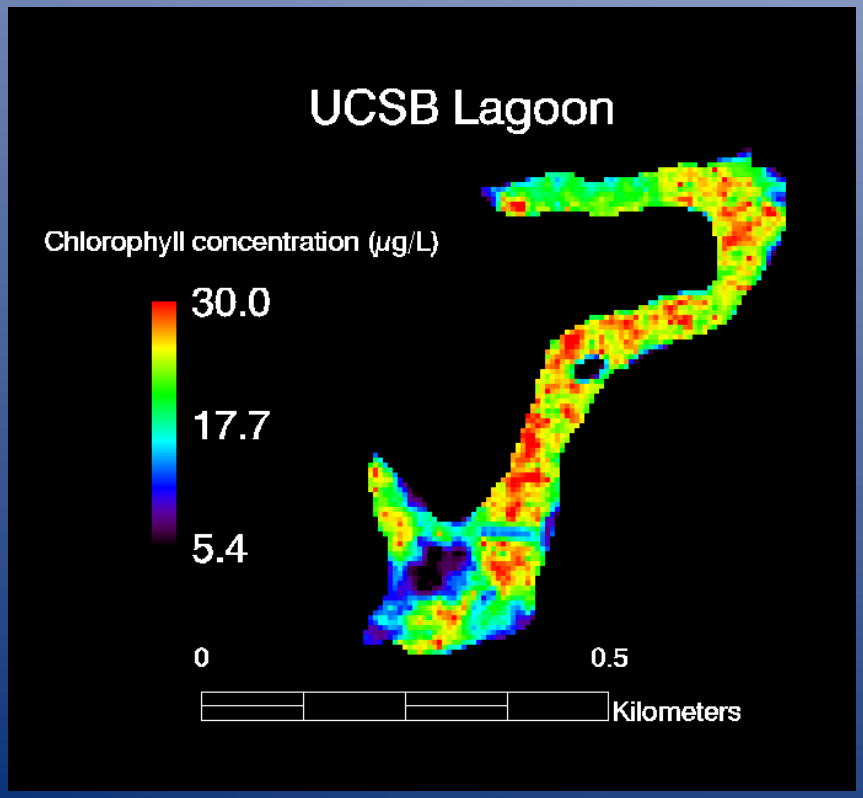


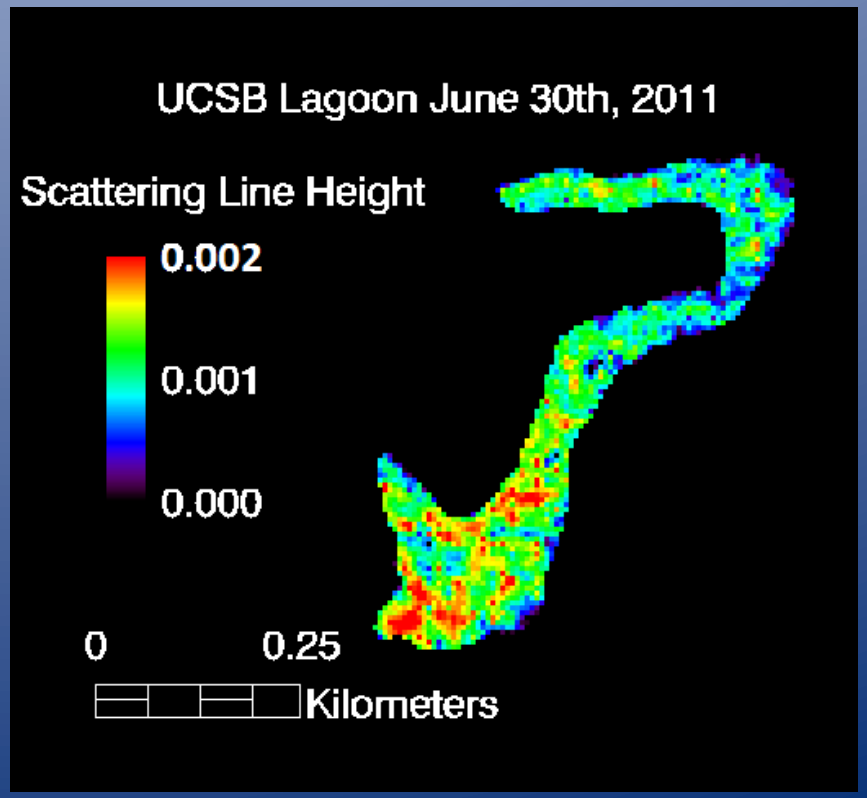
Pseudonitzschia sp.

MSLH – Index to detect the cyanobacterium *Microcystis*

- Vessicles in *Microcystis* exhibit unique scattering characteristics
- Index similar to FLH
- MSLH=MASTER Scattering Line Height



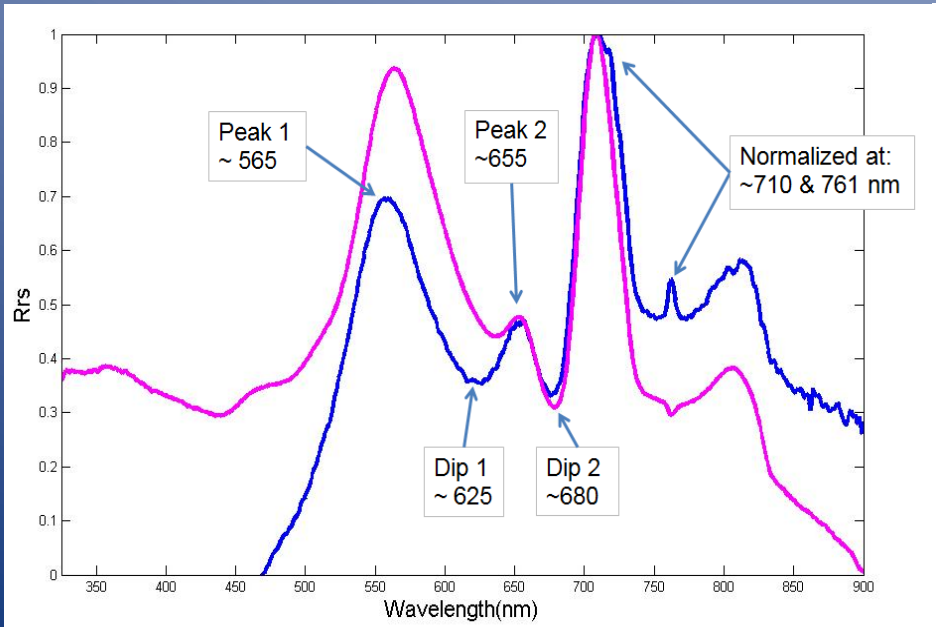


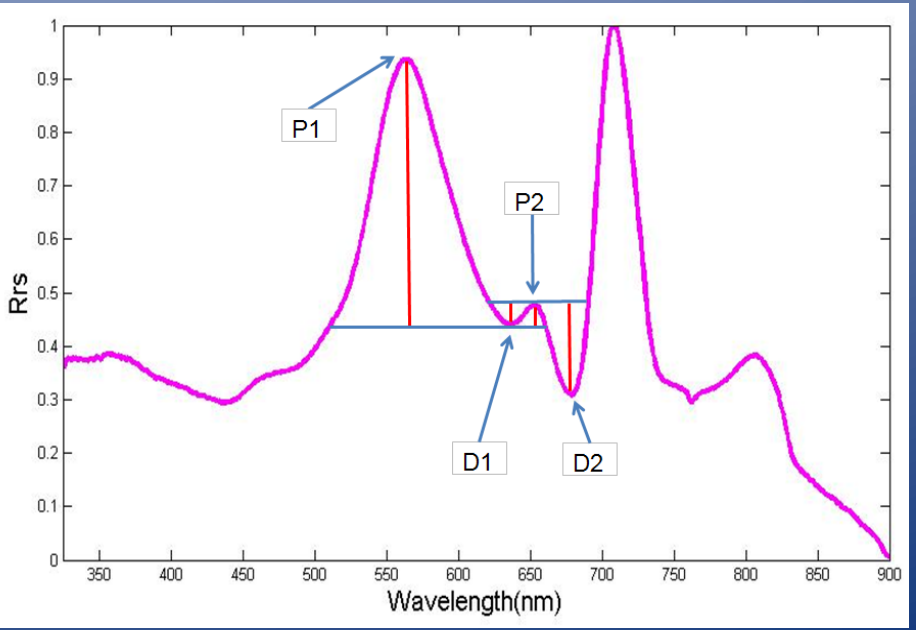


Santa Barbara 2011 MSLH, David Austerberry

Creation of indices & use on library species

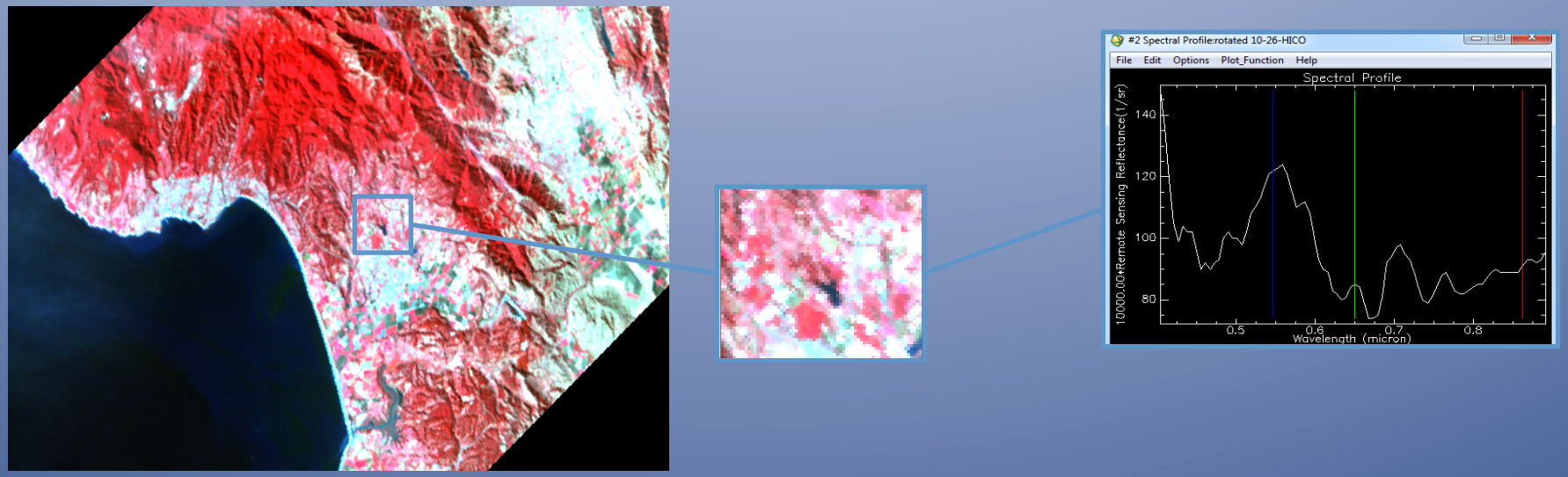
- Identification of key spectral features
- Feature x-value, y-value, height, width, area
- Ex. index, (peak 1 height/peak 2 height) = $\frac{(R565 - R625)}{(R655 - R625)}$





Pinto Lake 2012, Spectral Shape, Emma Accorsi

Indices applied to HICO match field data



- Indices applied 10/26/2011 HICO data suggest high biomass mixed bloom, consistent with 10/23 and 10/29 field data

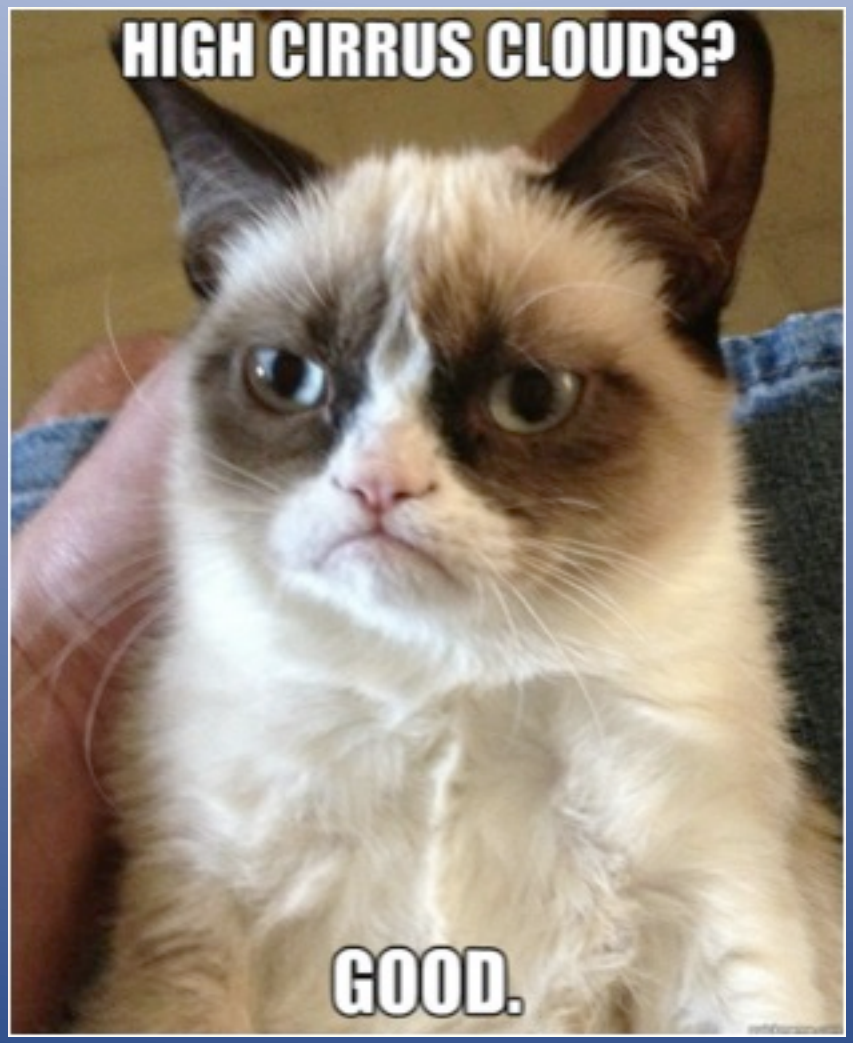
HyspIRI Airborne Flight Planning
Science Requirements – Coastal Ocean

- **Goal: Demonstrate the utility of an airborne HyspIRI simulation to address the biological properties of coastal California, within the context of the long-term monitoring programs ongoing in the area.**

1) Dates: March, July, October are best weather windows
2) Sun elevation of 30-45 deg is optimal along with flying into and out of the sun to avoid sun glint
3) Flight line timing over water to meet best weather and sun elevation will vary through the seasons (Spring, Summer, Fall)
4) Repeat flight lines at varying sun elevations will be a nice test of sun glint algorithms
5) Recommend use of HyspIRI look angle from AVIRIS to simulate HyspIRI, another good test for algorithms
6) Request that SB and Monterey Bay flights are not scheduled on consecutive days so that field teams and instruments can participate in field activities for both sites

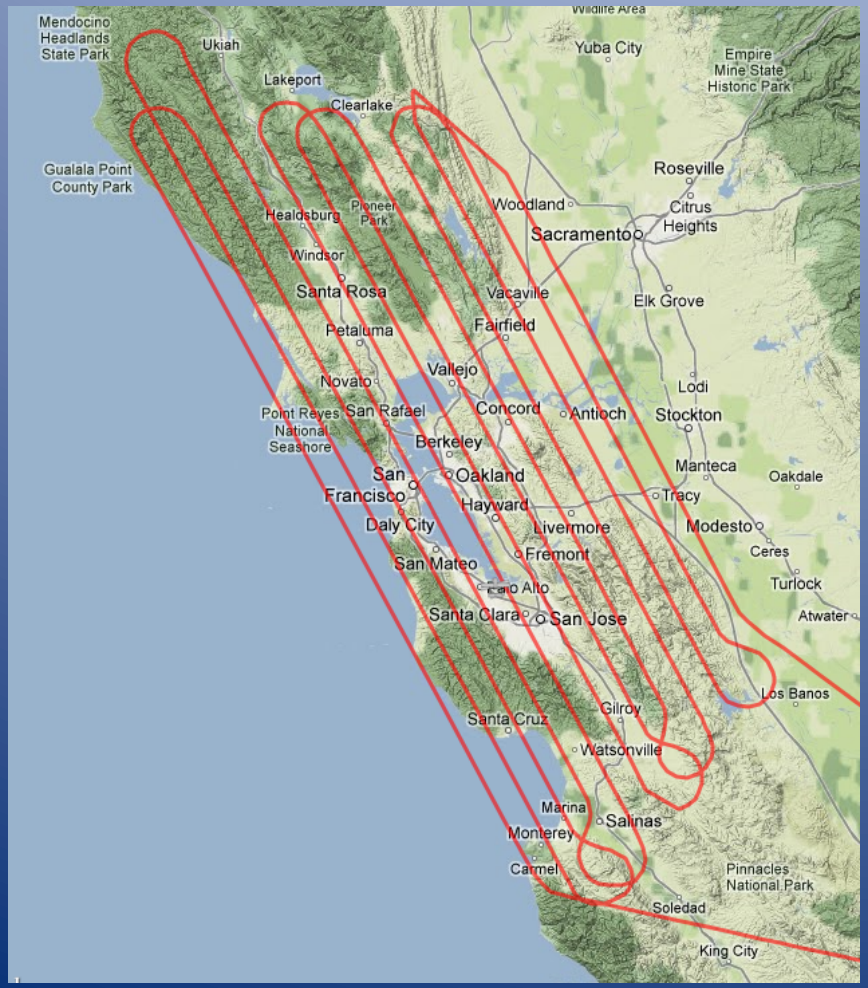
Spring 2013 Overflights

Ian McCubbin Deserves an Award!

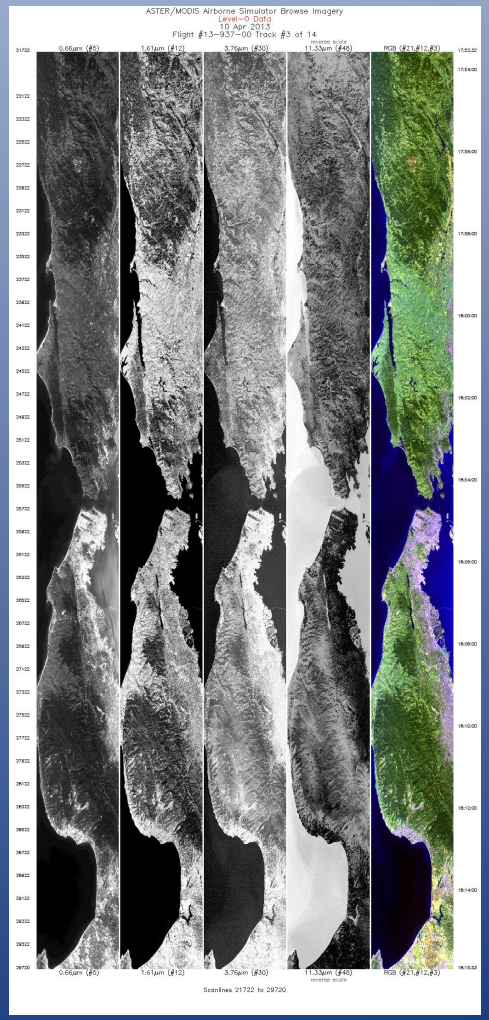

HIGH CIRRUS CLOUDS?
GOOD.

San Francisco Bay Over-flights
10 April 2013

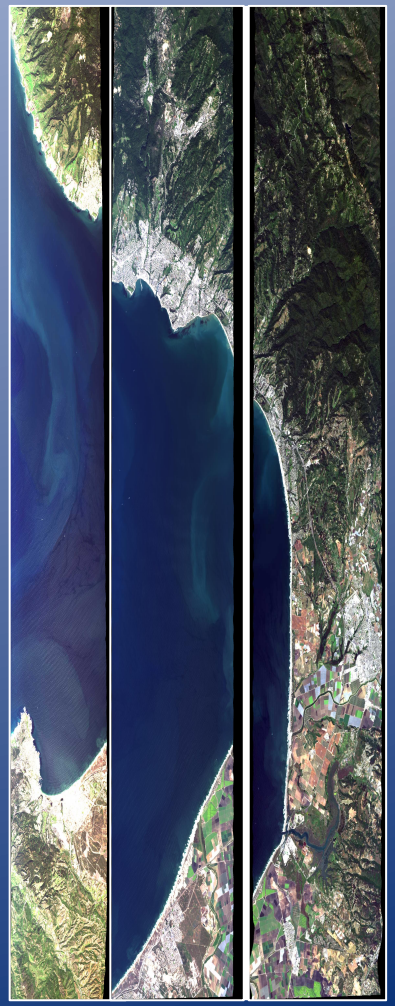
Flight Lines



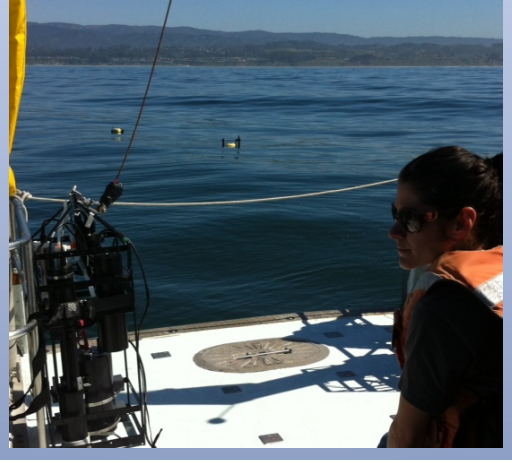
MASTER



AVIRIS (subset)



Field Collection 10 April 2013



Data Products?

Ship-based Measurements

- Underway T, S, Fluorescence
- At each station:
  - Size fractionated chlorophyll
  - CDOM, absorption spectra, nutrients
  - Satlantic HyperPro cast
    - Water-leaving radiance, profile data
  - Backscattering/ac-s casts
  - ASD surface reflectance

When will the data be available?

- Awaiting AVIRIS imagery from JPL
- Timeline for ground-truth data
  - 2013: data collection, processing, cataloging
  - 2014 & 2015: processing, analysis, distribution
- Data distribution – SeaBASS and CoastColour.org

What about sun glint?

HysplRI Airborne Flight Planning
Science Requirements – Coastal Ocean

- **Goal: Demonstrate the utility of an airborne HysplRI simulation to address the biological properties of coastal California, within the context of the long-term monitoring programs ongoing in the area.**

1) Dates: March, July, October are best weather windows for capturing biological variability
2) Sun elevation of 30-45 deg is optimal along with flying into and out of the sun to avoid sun glint
3) Flight line timing over water to meet best weather and sun elevation will vary through the seasons (Spring, Summer, Fall)
4) Repeat flight lines at varying sun elevations will be a nice test of sun glint algorithms
5) Recommend use of HysplRI look angle from AVIRIS to simulate HysplRI, another good test for algorithms
6) Request that SB and Monterey Bay flights are not scheduled on consecutive days so that field teams and instruments can participate in field activities for both sites

Impacts of Spatial and Spectral Resolution on Hyperspectral Remote Sensing of Aquatic Vegetation

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Paul Bissett
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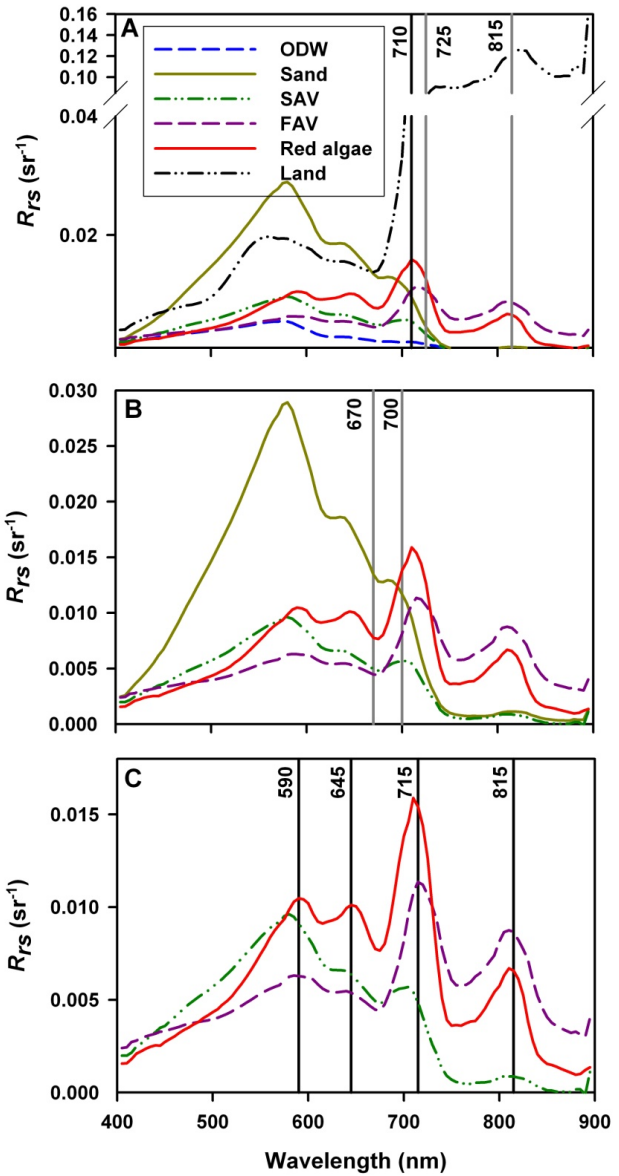
David Kohler
Weo-Geo, Inc.
Portland OR

Motivation for Remote Sensing of Coastal Environments

- Highly valuable, highly visible
- Very productive
  - Biogeochemistry
  - Carbon flux
  - Fisheries
- Shoreline protection
  - Flooding, storm inundation
  - Erosion
- Esthetic
  - Recreation, tourism
- Heavily impacted
  - Water quality
  - Flow patterns
  - Erosion
  - Loss of habitat
  - Climate change
    - Sea level rise
    - Storm intensity
    - Ocean warming
    - Ocean acidification

Challenges for Remote Sensing of Coastal Environments

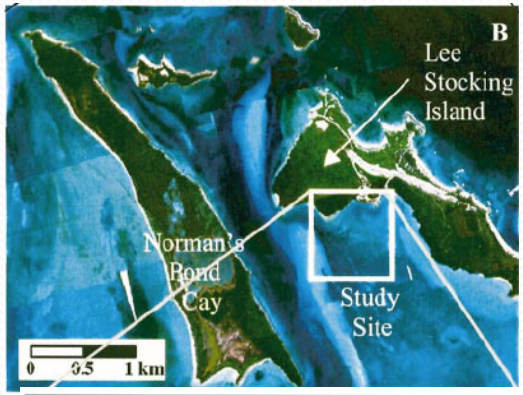
- Dark water targets in close proximity to bright land
- Spatial heterogeneity requires high spatial resolution
- Submerged habitats represent unique optical targets
  - Darker than land
  - Brighter than optically deep water
  - Unique range of spectral signatures
    - Bare sand and mud
    - Green seagrass meadows
    - Red, brown and green seaweeds
    - Corals
  - Affected by water depth, transparency and color
- Atmospheric correction is critical

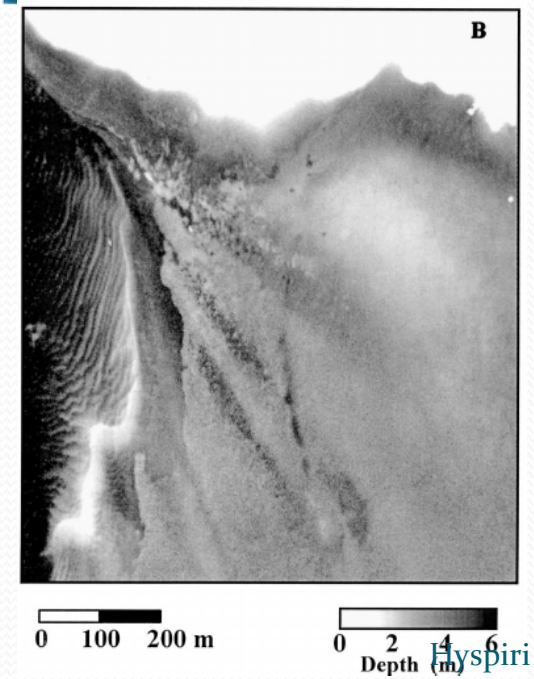


The Aquatic Macrophyte Opportunities:

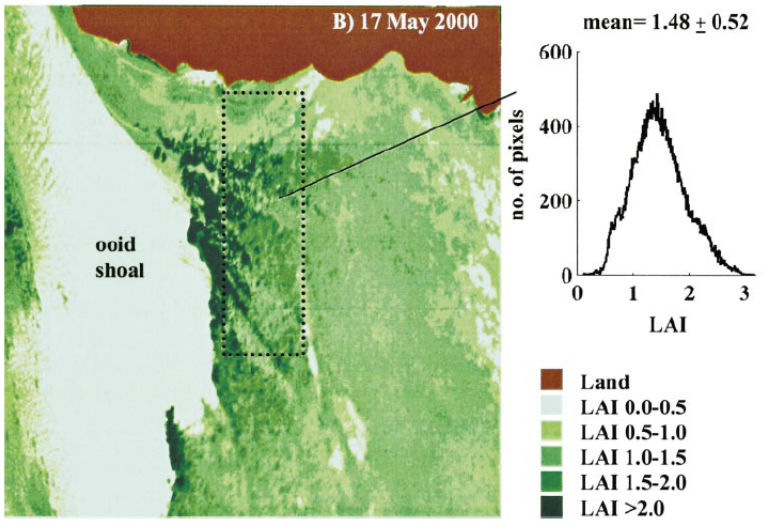
- Floating canopies provides a strong reflecting target
  - No overlying water column
  - California kelp forests
    - *Macrocystis pyrifera*
    - *Nereocystis luetkeana*
  - Gulf Of Mexico and Gulf Stream
    - *Sargassum fluitans*
- Seagrasses grow in optically shallow water – within the visible range of remote sensing

In clear, blue Bahamian waters, past experiments demonstrated utility of HS imagery for mapping

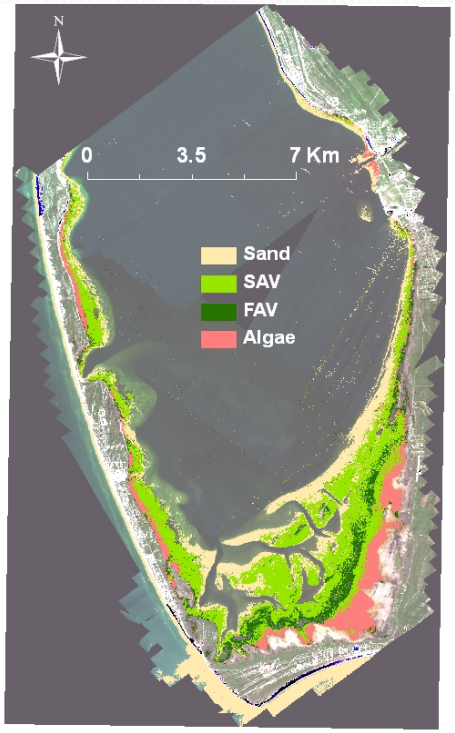




- Bathymetry
- Sand & seagrass distribution
- Seagrass abundance



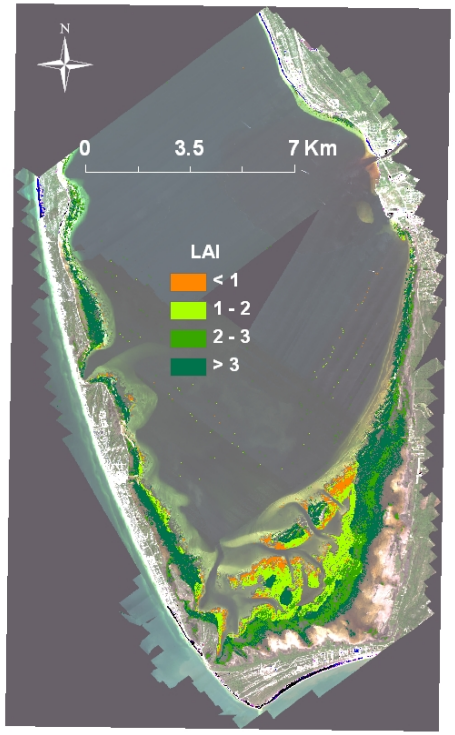
In more complex waters of coastal Florida Past experiments demonstrated utility of HS imagery for mapping:



- Sand
- Submerged seagrass
- Floating seagrass
- Benthic algae

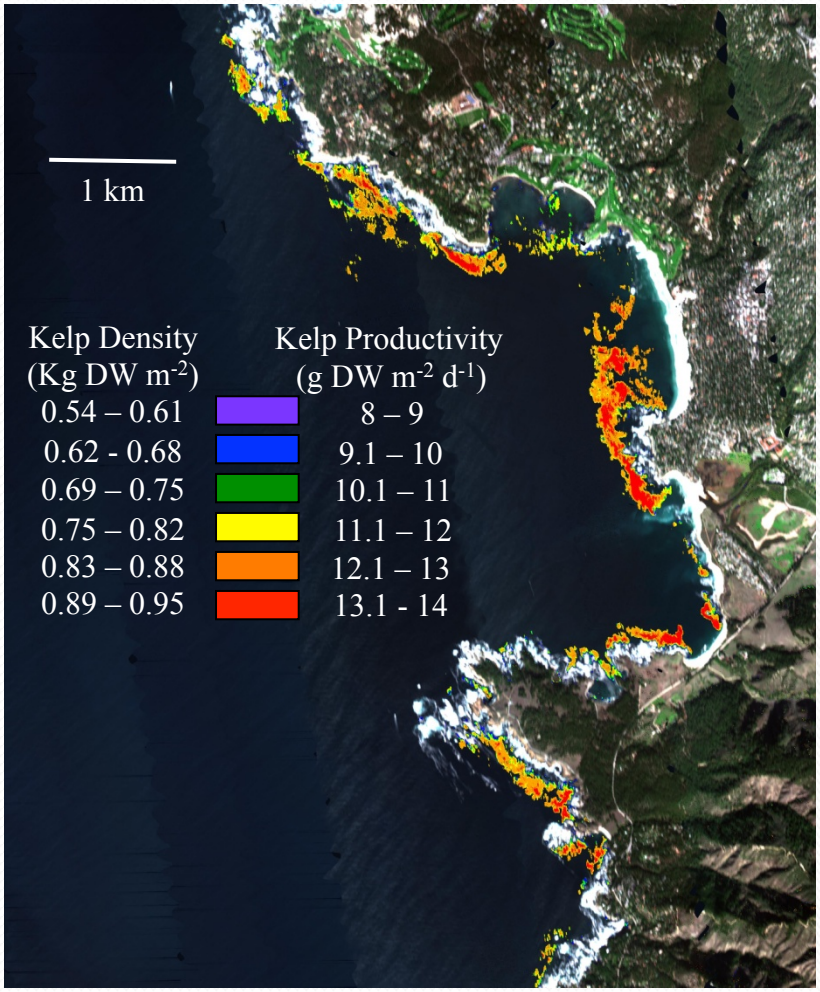
And for quantifying

- Abundance of submerged seagrass



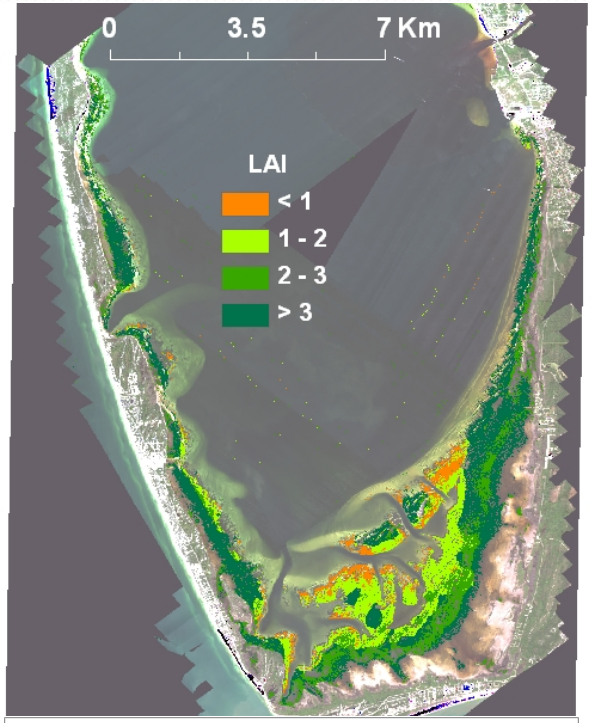
But bathymetry is problematic

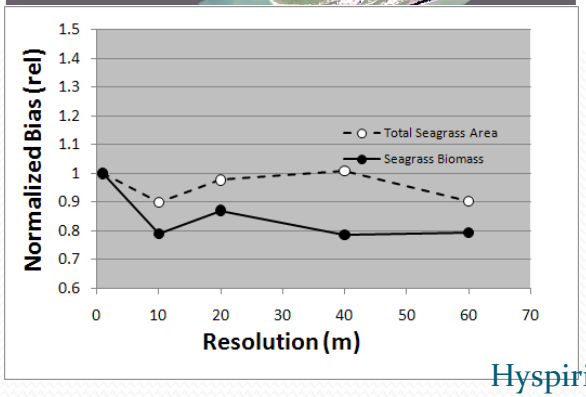
In more complex waters of coastal California past experiments demonstrated utility of HS imagery for mapping giant kelp



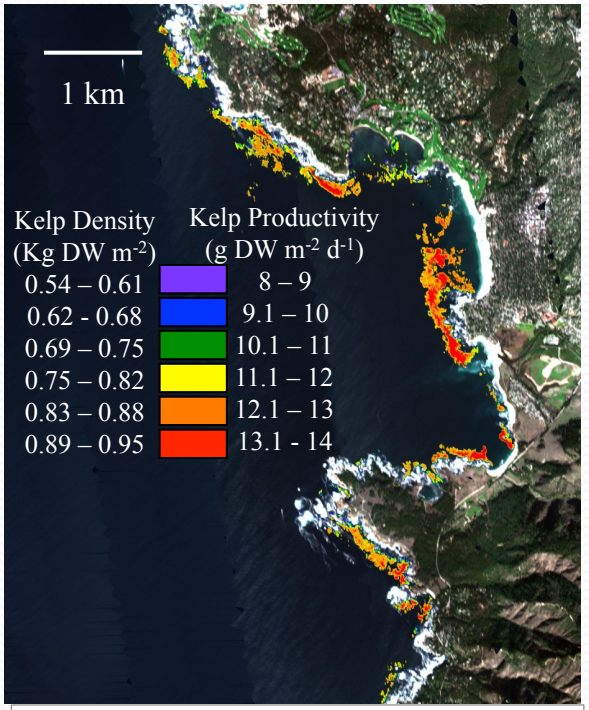
- Distribution
- Abundance
- Productivity
- However, the results are sensitive to spatial resolution of the imagery

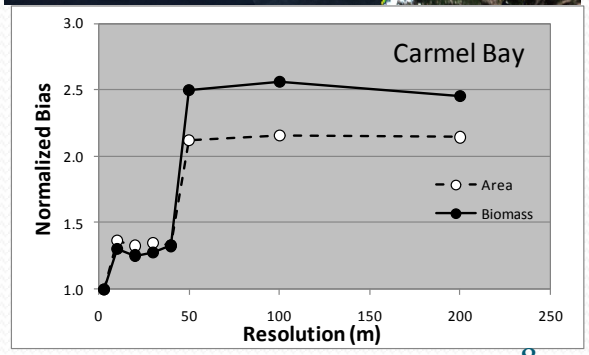
Size matters….



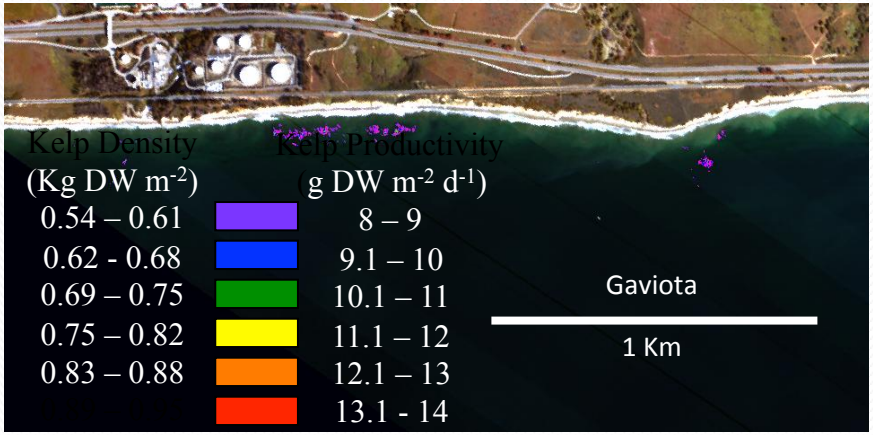


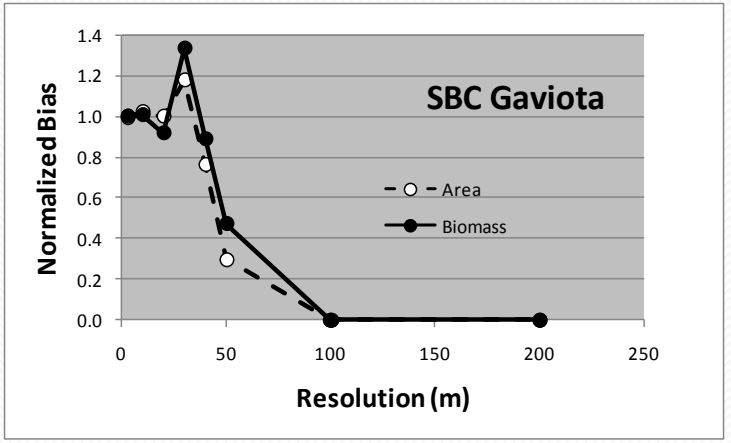
- Retrieval accuracy decreases with pixel resolution
- Error appears consistent within a scene
- But not across scenes

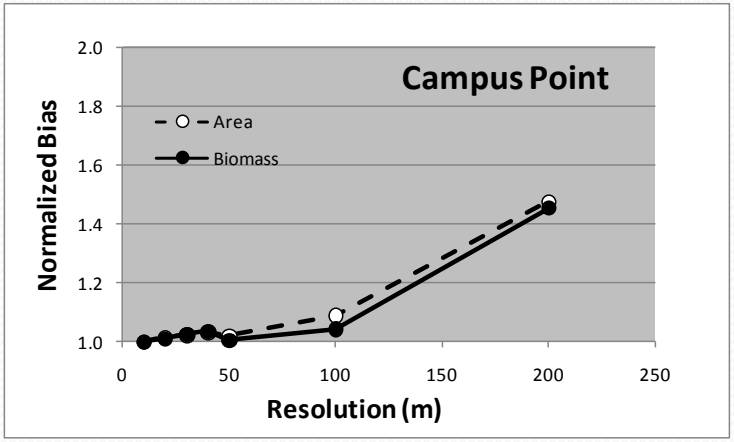




Size matters….



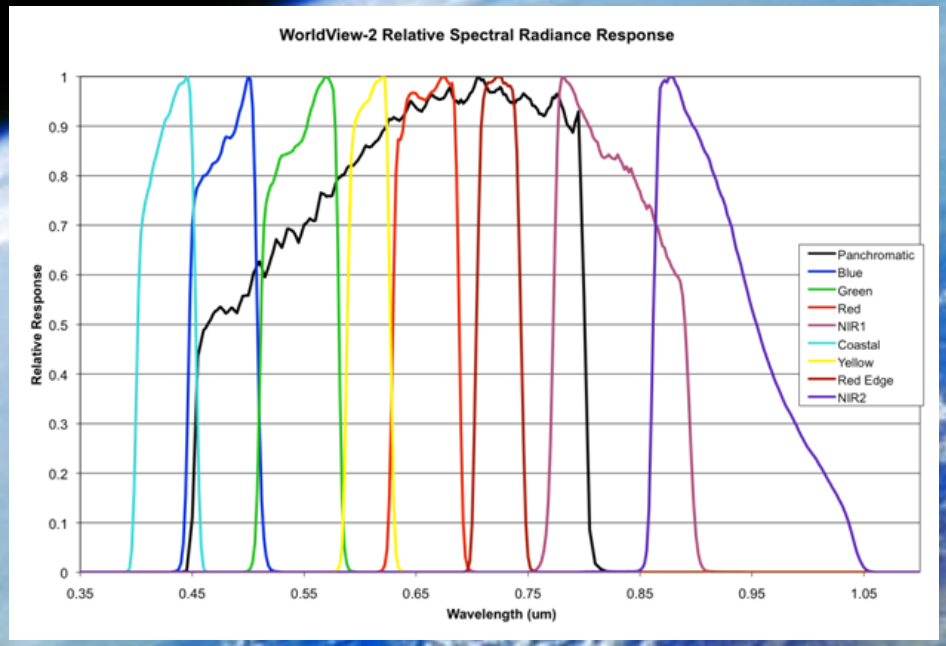




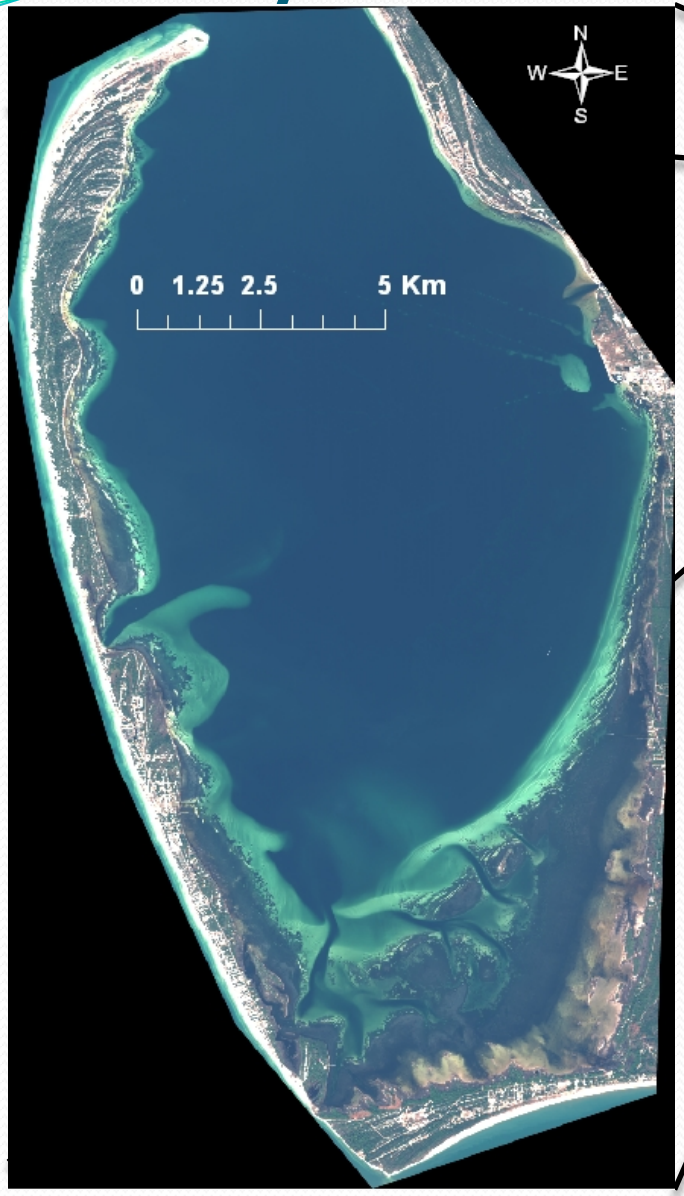
- Retrieval accuracy decreases with pixel resolution
- Error appears consistent within a scene
- But not across scenes

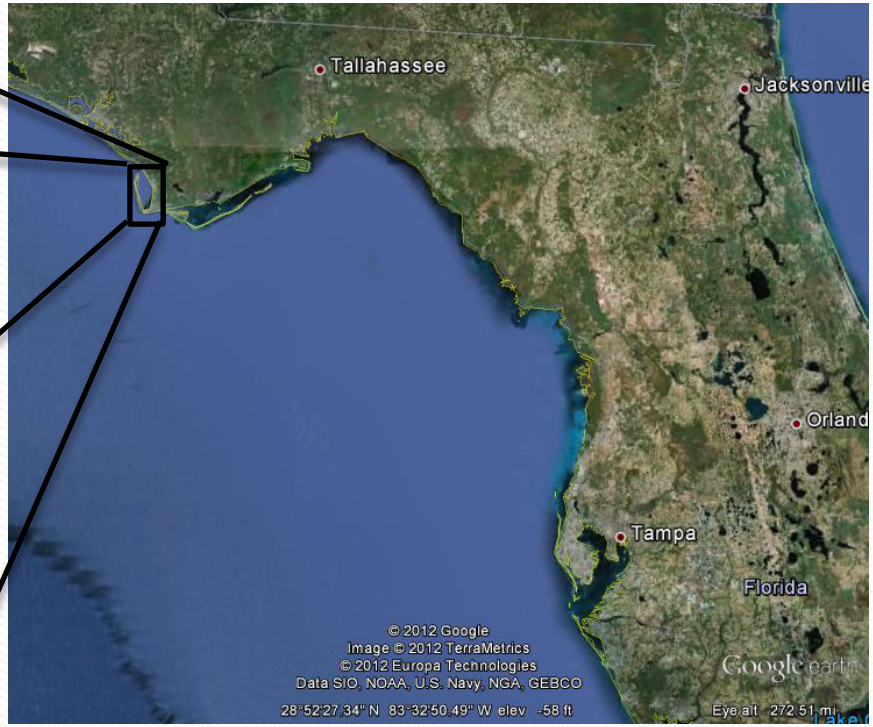
So, how does spectral resolution affect our retrievals?

- WorldView-2
  - Operated by Digital Globe, Inc
  - 8 multispectral bands
  - 3 m resolution (0.5 m pan)
  - 12 bit dynamic range
  - Pointing capability
    - Optimize view angle
    - Avoid glint



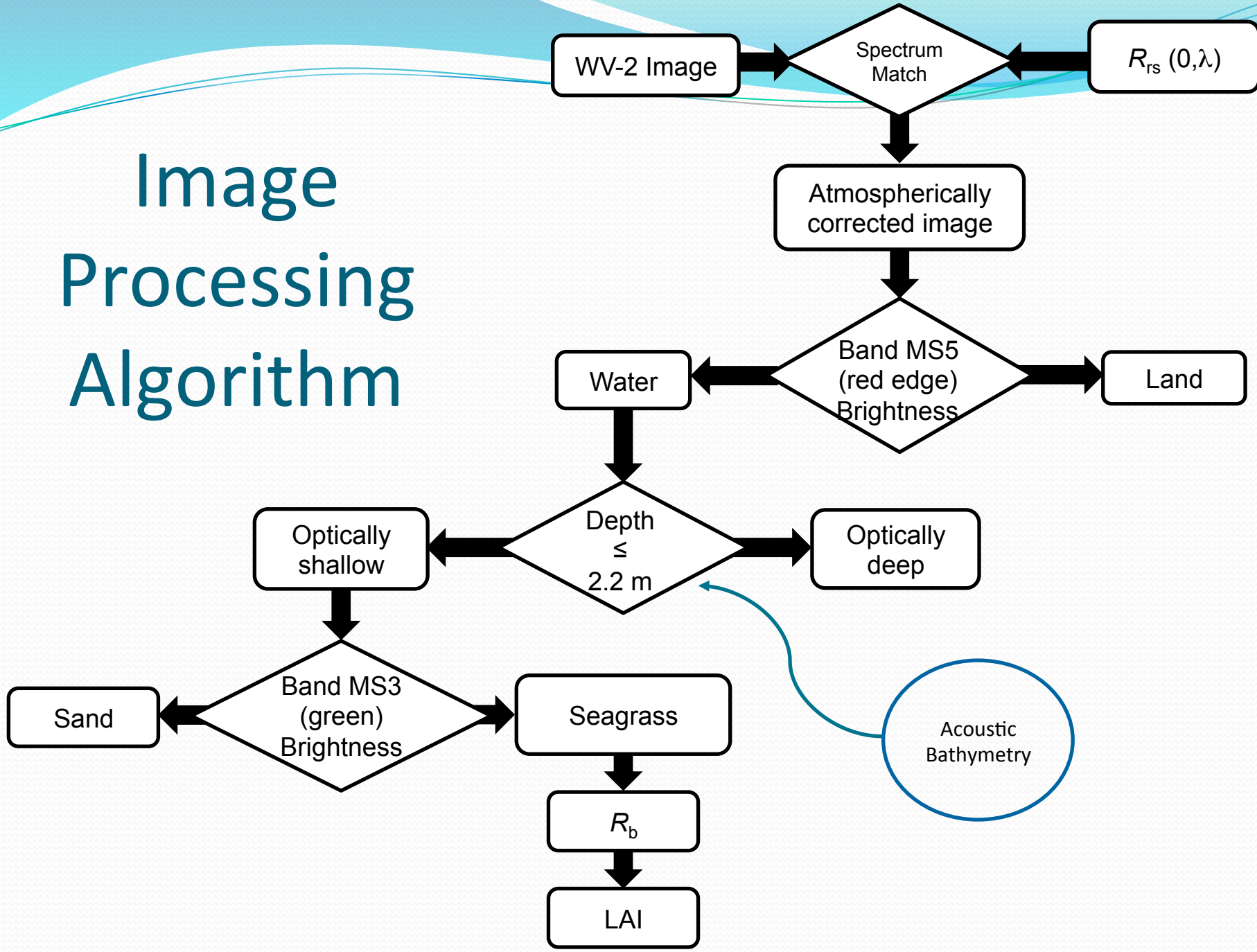
Study Site: St Joseph's Bay, FL, USA





- Optically deep basin (>3 m)
- Shallow fringe (<2 m) consisting of
  - Bare sand
  - Seagrass meadows
  - Benthic algae
- Highly colored water column
  - CDOM
  - Phytoplankton
  - Detritus/Sediment

Image Processing Algorithm

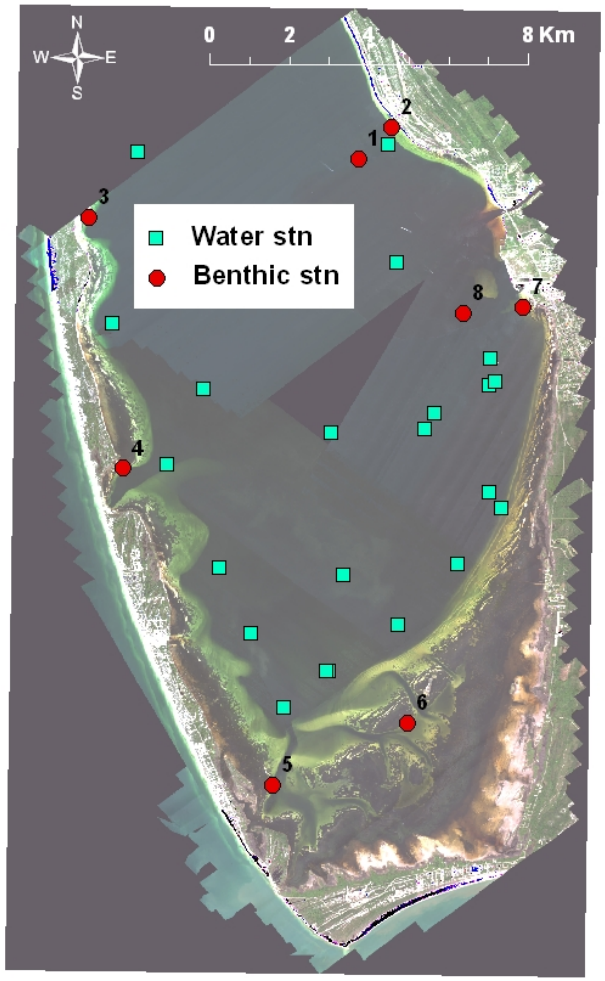


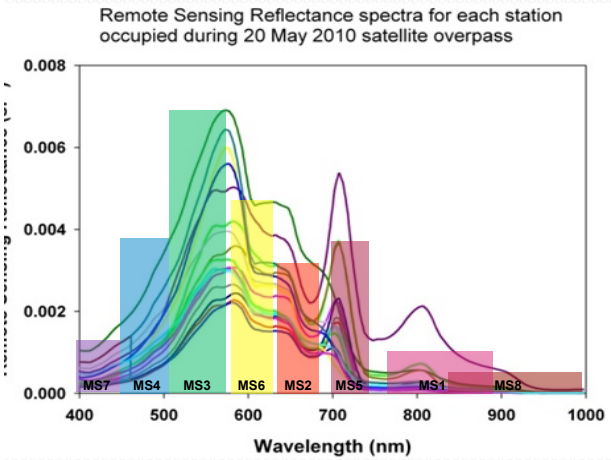
Step 1: Atmospheric Correction

WV-2 Image → Spectrum Matching ← Measured $R_{rs}(0,\lambda)$

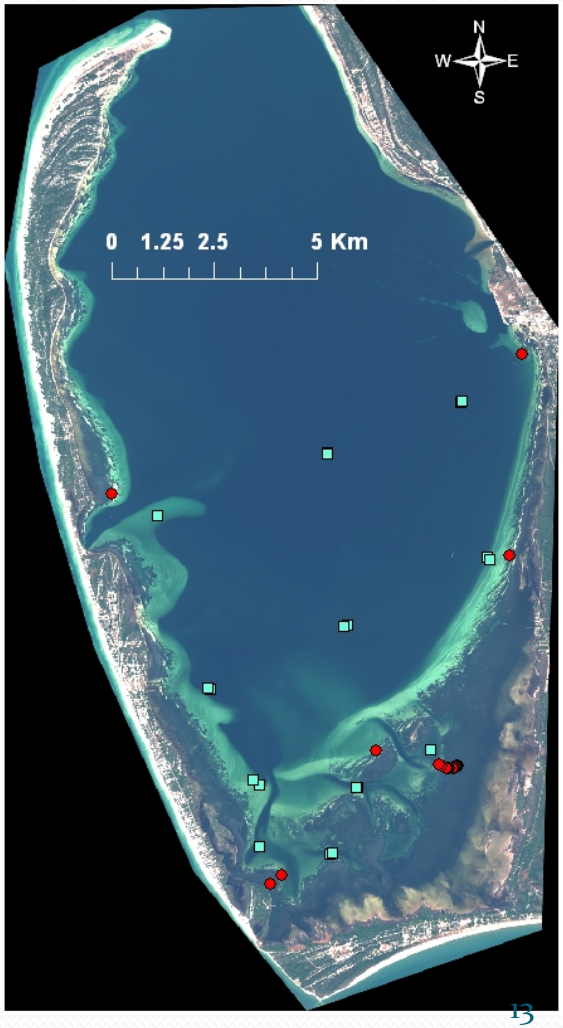
Spectrum Matching → Atmospherically corrected image

2006 SAMSON HS Image

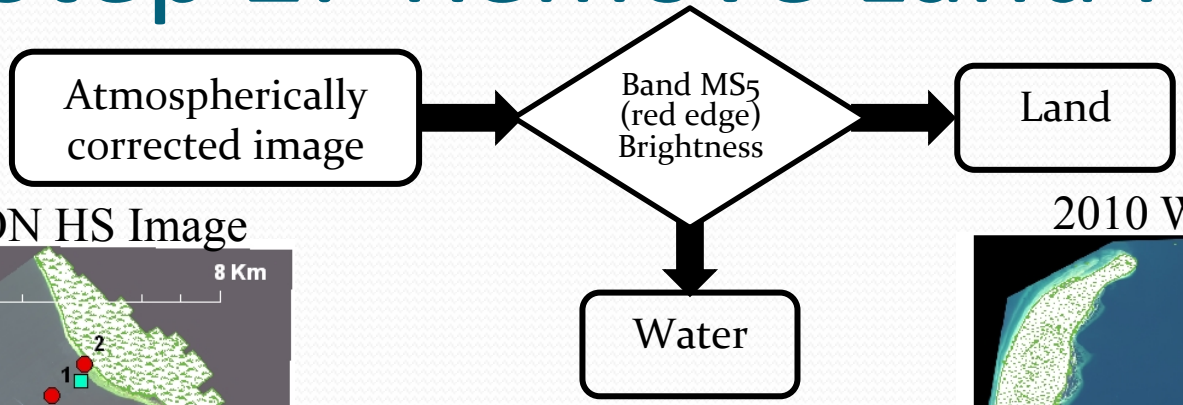




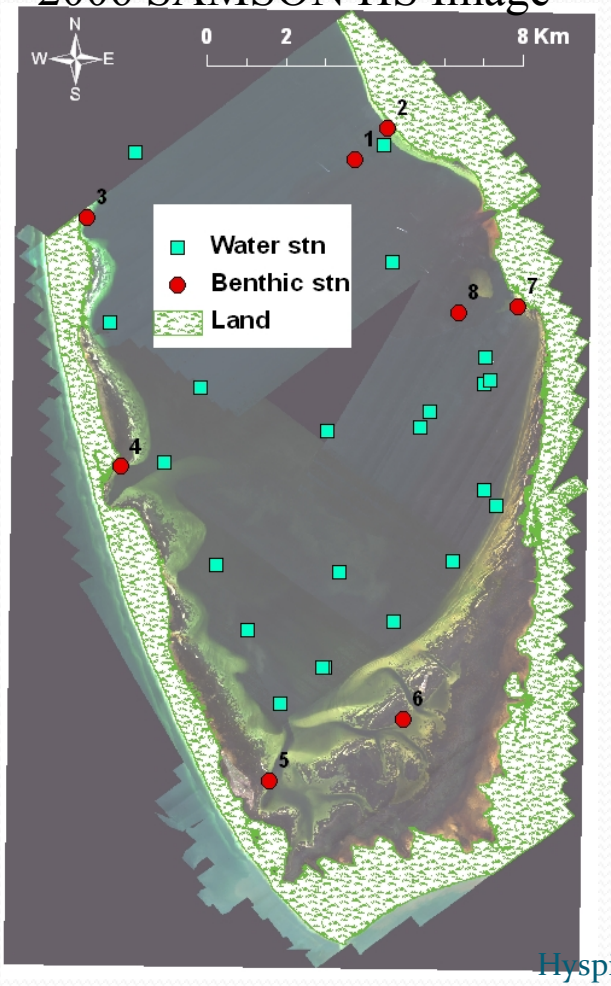
2010 WV-2 MS Image

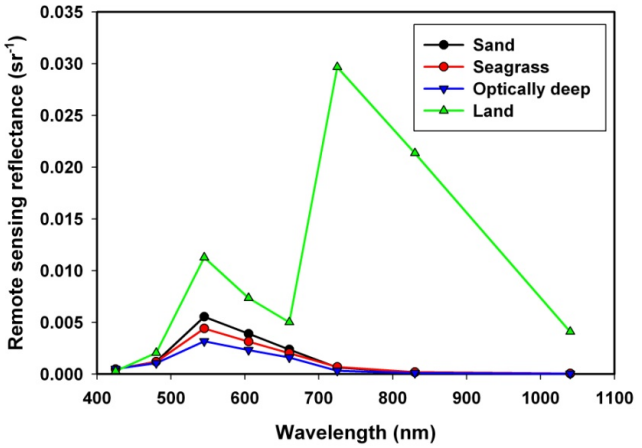


Step 2: Remove Land Pixels

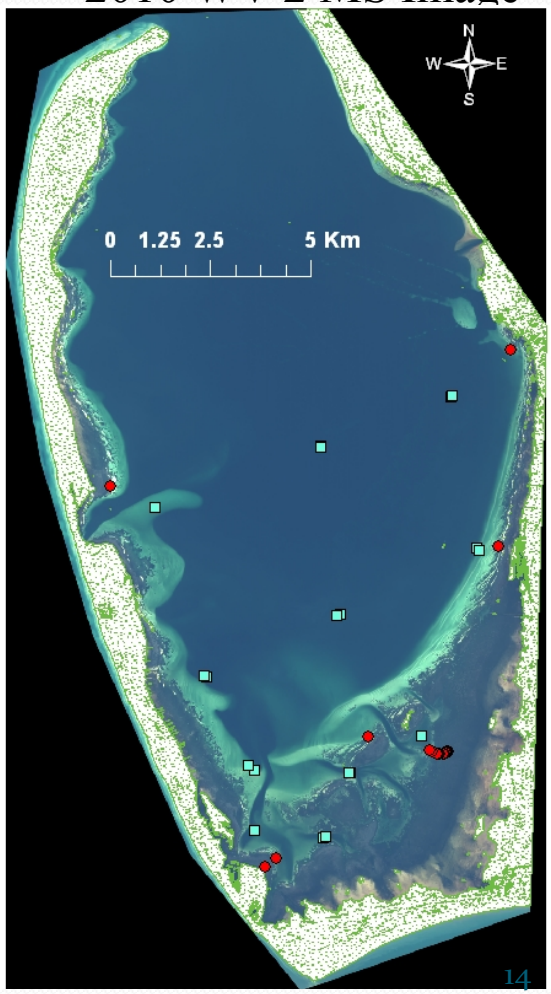


2006 SAMSON HS Image

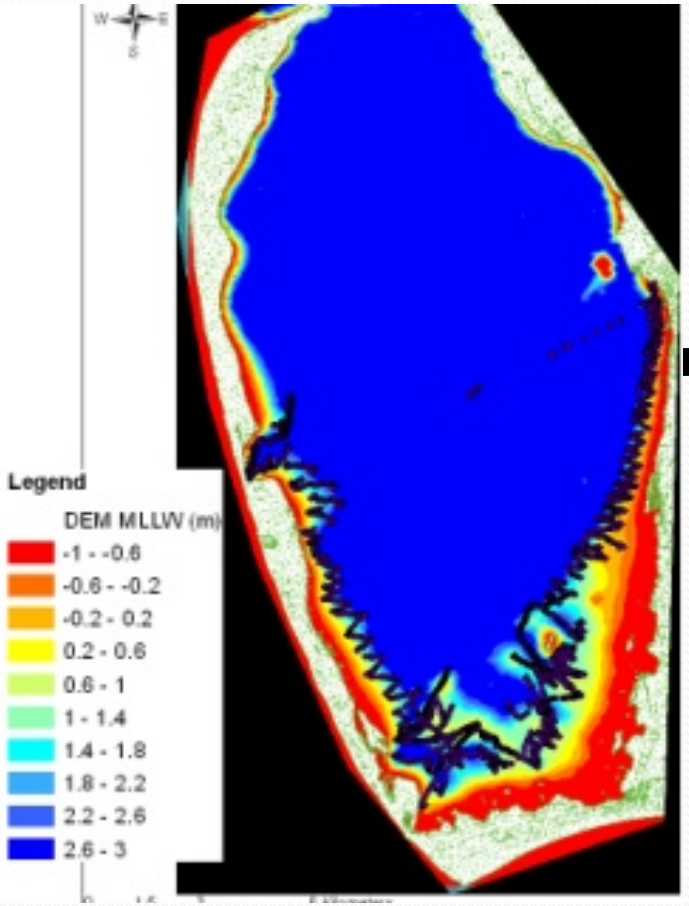


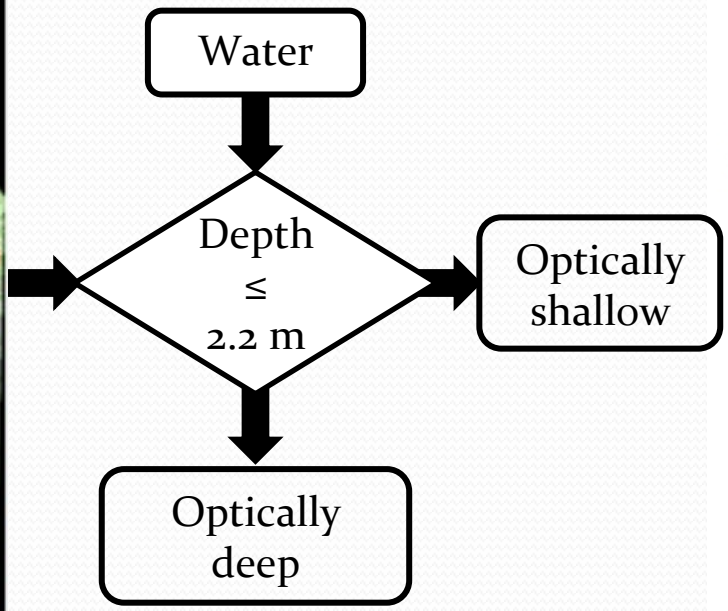


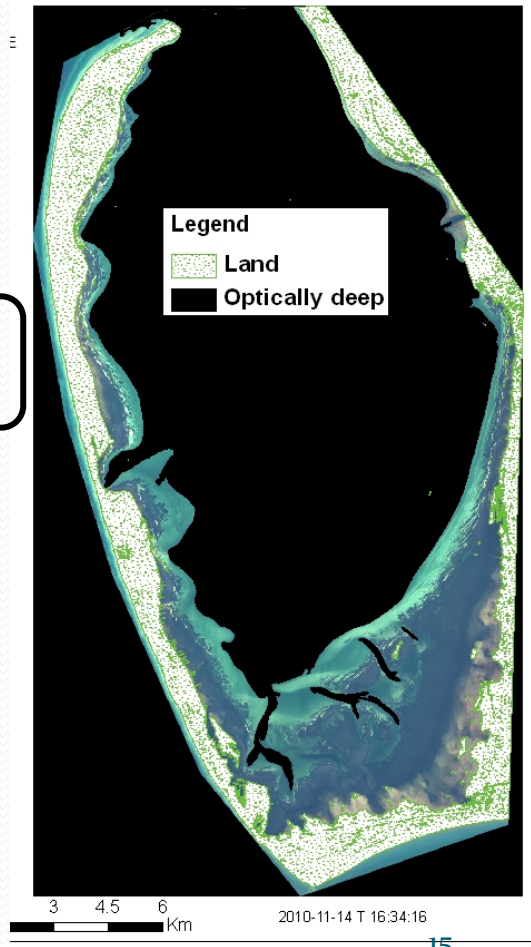
2010 WV-2 MS Image



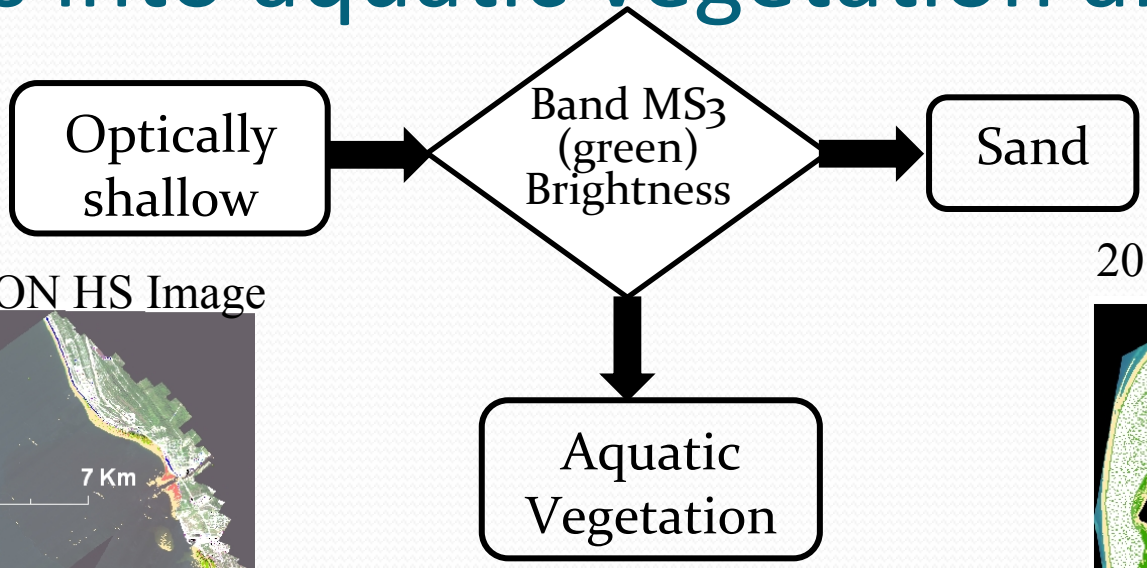
Step 3: Remove optically deep water pixels using acoustic DEM:



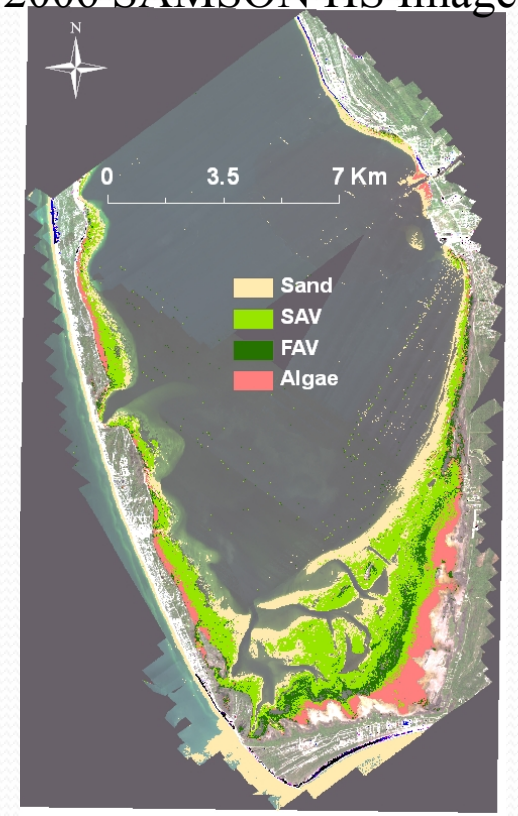




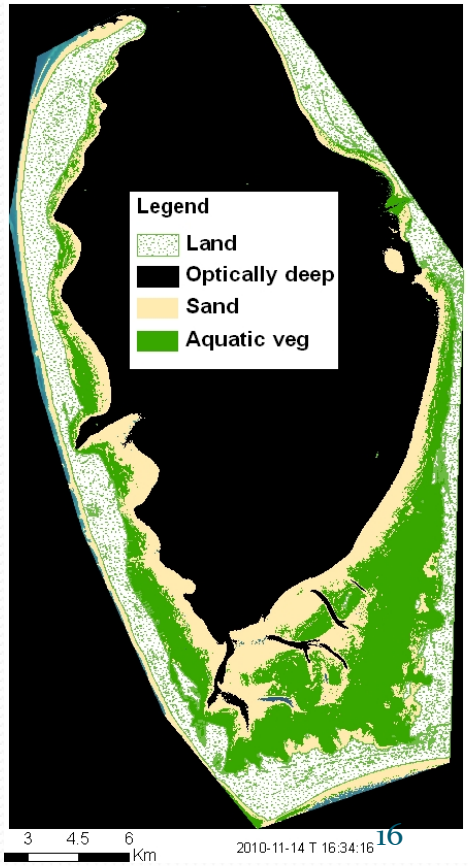
Step 4: Separate optically shallow pixels into aquatic vegetation and sand



2006 SAMSON HS Image



2010 WV-2 MS Image



Step 5: Retrieve R_b for seagrass pixels

Acoustic Bathymetry

+

Seagrass

+

IOPs

- R_{rs} from WV-2 imagery
- $Q_b = E_u(z_b)/L_u(z_b) = \pi$
- K_{Lu} & K_d from *Hydrolight* using measured IOPs

$$R_b = \frac{R_{rs} Q_b}{t} \frac{\exp\left[-K_{Lu} z_b\right]}{\exp\left(K_d z_b\right)}$$

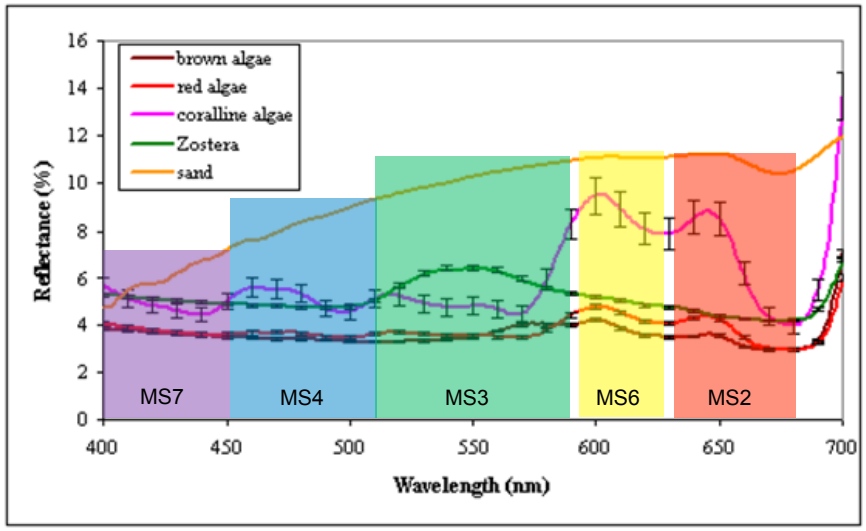
- z_b – bottom depth from acoustic survey
- t – air/sea transmittance of $L_u(0.54)$

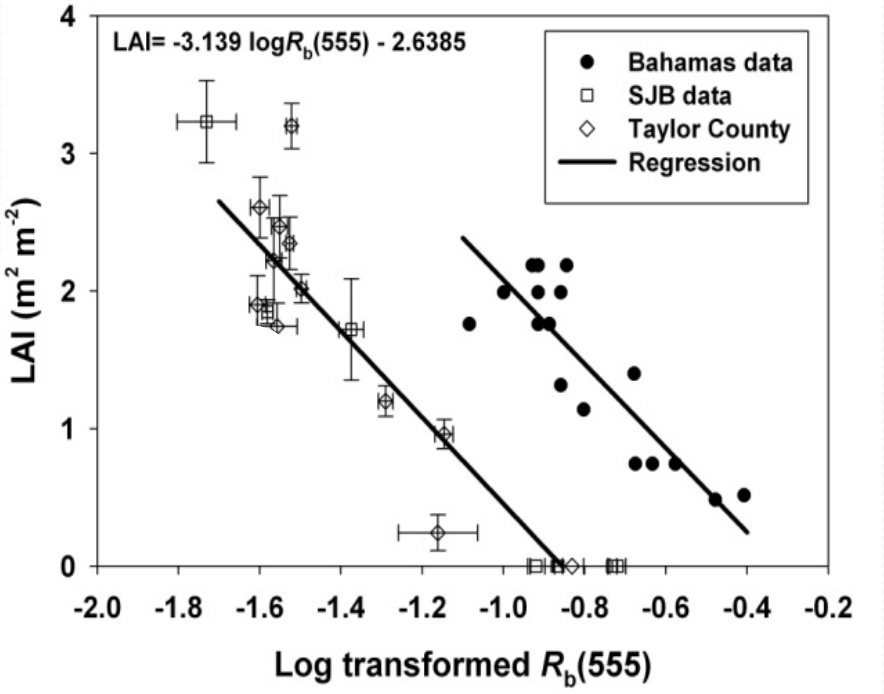
Dierssen, H., R. Zimmerman, R. Leathers, T. Downes, and C. Davis. 2003. Remote sensing of seagrass and bathymetry in the Bahamas Banks using high resolution airborne imagery. Limnol. Oceangr. **48: 444-455.**

$$R_b = \frac{R_{rs} Q_b}{t} \frac{\exp\left[-K_{Lu} z_b\right]}{\exp\left(K_d z_b\right)}$$

LAI

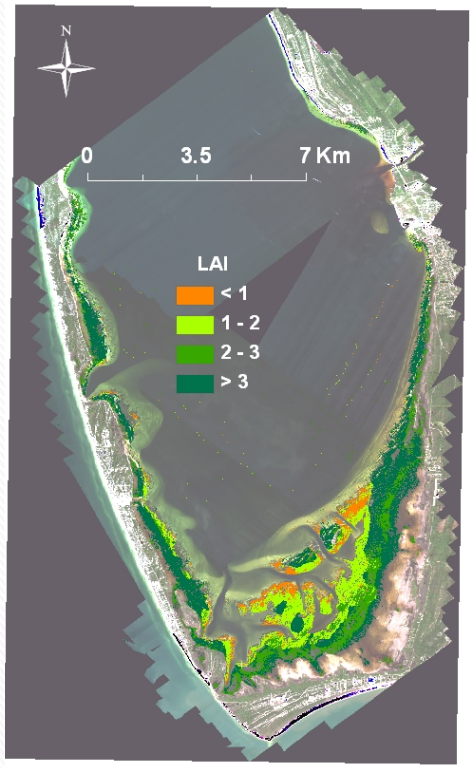
- Log R_b(555) predicts LAI
- Florida and Bahamas slopes consistent
- X-intercept results from brightness of sand bottom (siliclastic vs. carbonate)
- Benthic algae are seen as seagrass
  - Spectral band resolution did not permit optical differentiation of seagrasses from benthic algae





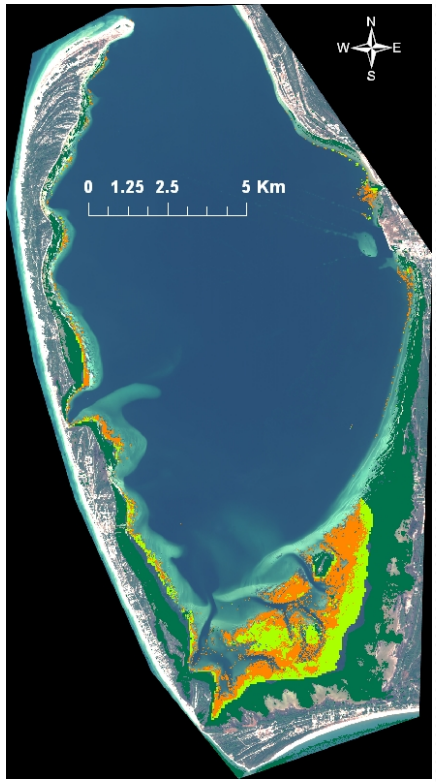
Quantifying the Abundance of Submerged Aquatic Vegetation in Nearshore Coastal Environments

2006 SAMSON HS Image

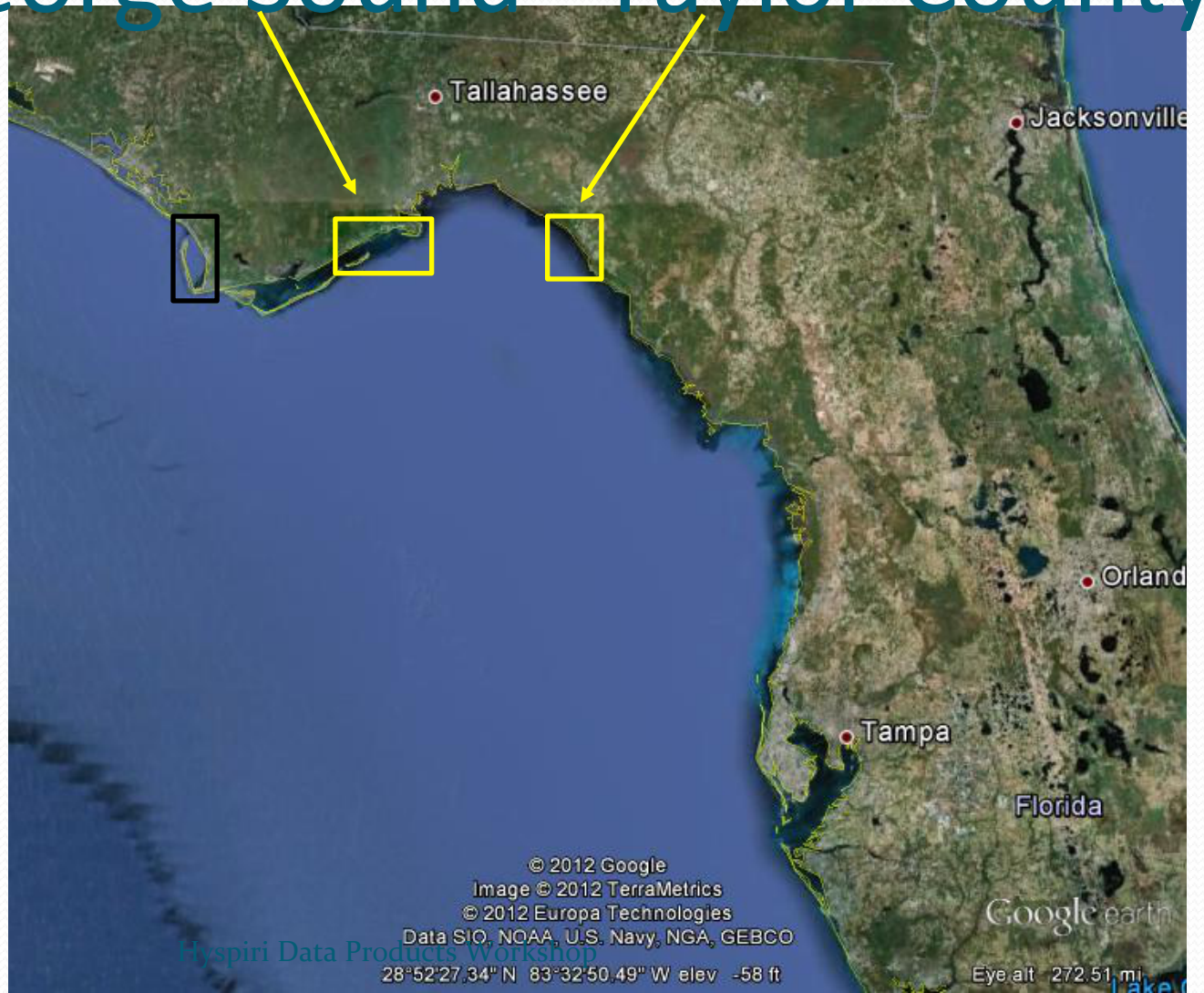


Target	2006 Hyperspectral	2010 Multispectral	Difference (%)
Water depth at overpass (rel MLW)	0.4	-0.5	
Total Area Covered	149	184	0
Benthic Classification Accuracy	100%	100%	0
Optically Shallow Area (km^2)	37	57	34
Bare Sand Area (km^2)	14	27	49
Benthic Vegetation Area (km^2)	24	30	21
SAV Area (km^2)	15	11	-35
FAV Area (km^2)	3	19	82
Benthic Algae	5	N.A.	

2010 WV-2 MS Image

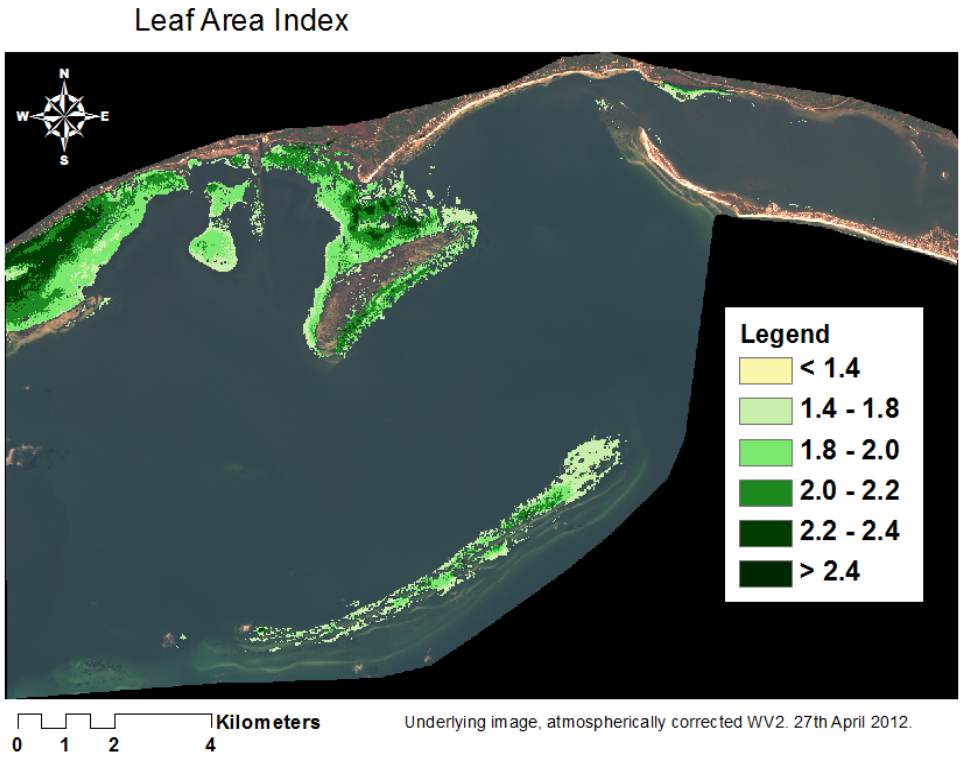


Two additional sites –
St. George Sound Taylor County, Fl

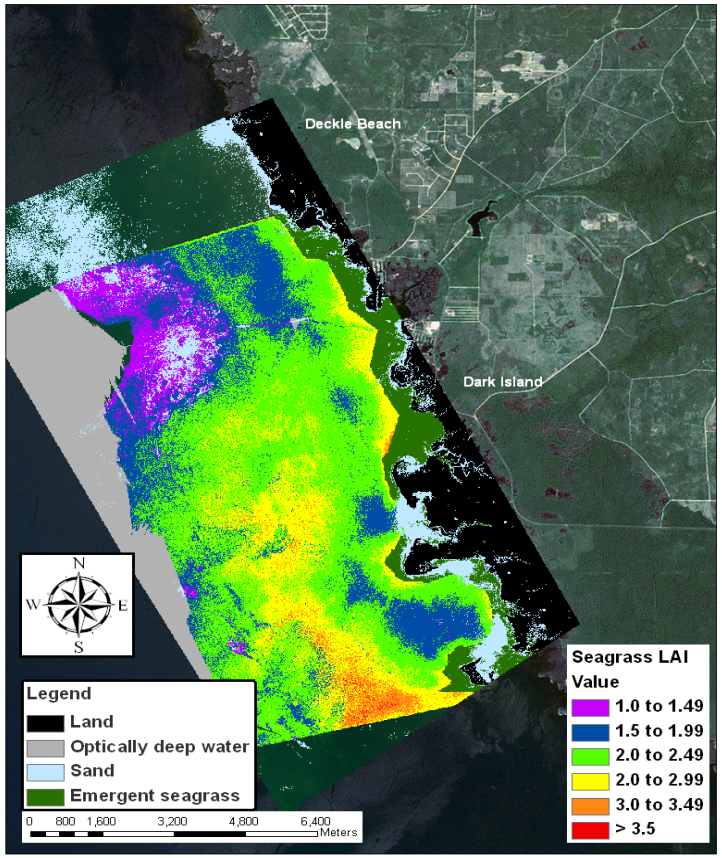


Quantifying the Abundance of Submerged Aquatic Vegetation in Nearshore Coastal Environments

2012 WV-2 MS Image
St George Sound, FL



2010 WV-2 MS Image
Taylor County, FL



Conclusions

- Aquatic macrophyte abundance readily quantified from imaging spectroscopy
- Spatial resolution affects retrieval statistics
  - Loss of texture and patch detail
  - Over-estimates size of large patches
  - Small patches disappear
  - Largest effects between 10 and 50 m resolution
- Spectral resolution affects resolution of plant functional types
  - MS imagery easily discriminates between vegetated areas and sand
    - Sufficient for quantifying seagrass abundance in coastal waters
  - Discrimination among vegetation functional types not possible
    - Optically deep green water looks like SAV
    - Seagrasses and seaweeds not separable
- Bathymetry is essential; optical retrieval unreliable
  - LIDAR bathymetry library growing
  - Once obtained, likely to be valid for considerable time in most areas

Future Work

- The glint issue can be tested experimentally
  - Hyspiri Discussion Group 2009-2010
    - Not a serious problem for classifying seagrass and bright sand in clear (blue) waters
    - Ability degrades with turbidity & depth
    - Need to assess impacts of glint
      - in turbid or colored coastal waters
      - on biomass estimates
- MS-sharpening as a way to increase spatial resolution of HS image?
- Analogous to pan-sharpening of MS imagery
- Could be tested by co-ordinated imaging of same region from 2 sensors
    - E.g. HICO and WV2

Using hyperspectral airborne PRISM imagery to map vulnerable coastal salt marsh and seagrass habitats

Dr. Heidi Dierssen

UCONN Professor

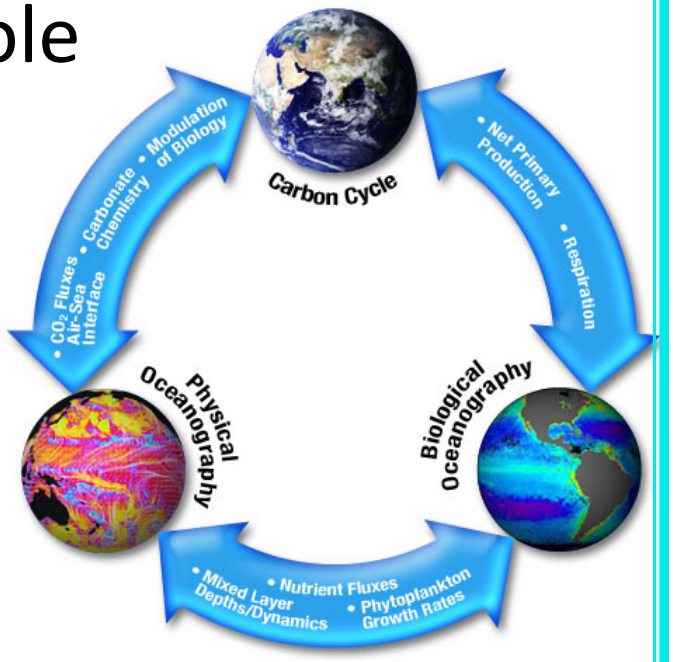
Marine Sciences/Geography

Acknowledgements

- UCONN COLORS Lab- Eric Heupel (photographs), Kelley Bostrom, Brandon Russell
- NASA JPL
- Naval Research Lab
  - Gao for atmospheric correction
- Field Validation team for PRISM
  - NASA Ames
  - University of Santa Cruz
  - Moss Landing Marine Labs
  - Monterey Bay Aquarium Research Institute
- Richard Zimmerman, Old Dominion University

Why seagrasses and salt marshes?

- Improved understanding of role of shallow banks and bays on carbon cycle and climate

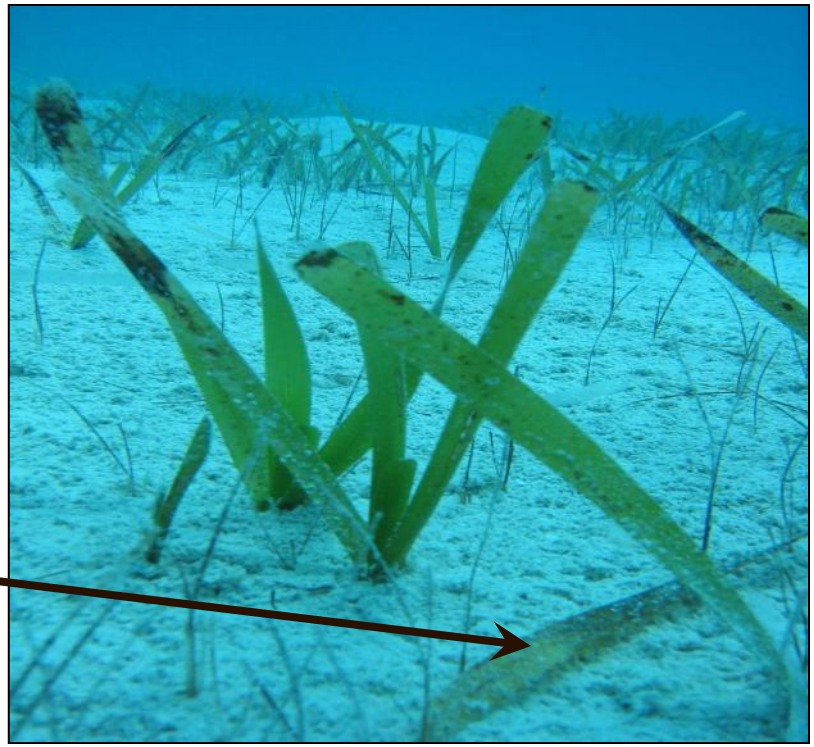


- ***BLUE*** Carbon
  - Coastal vegetation sequesters carbon more effectively than terrestrial ecosystems

Questions regarding fate of carbon

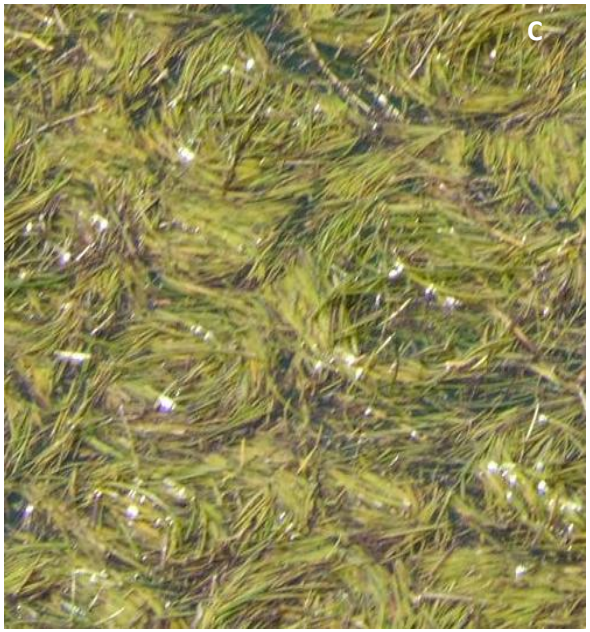
- Different seagrass species play different ecological roles

- Turtlegrass leaves decompose in the beds



Manateegrass

- Buoyant leaves, exported carbon



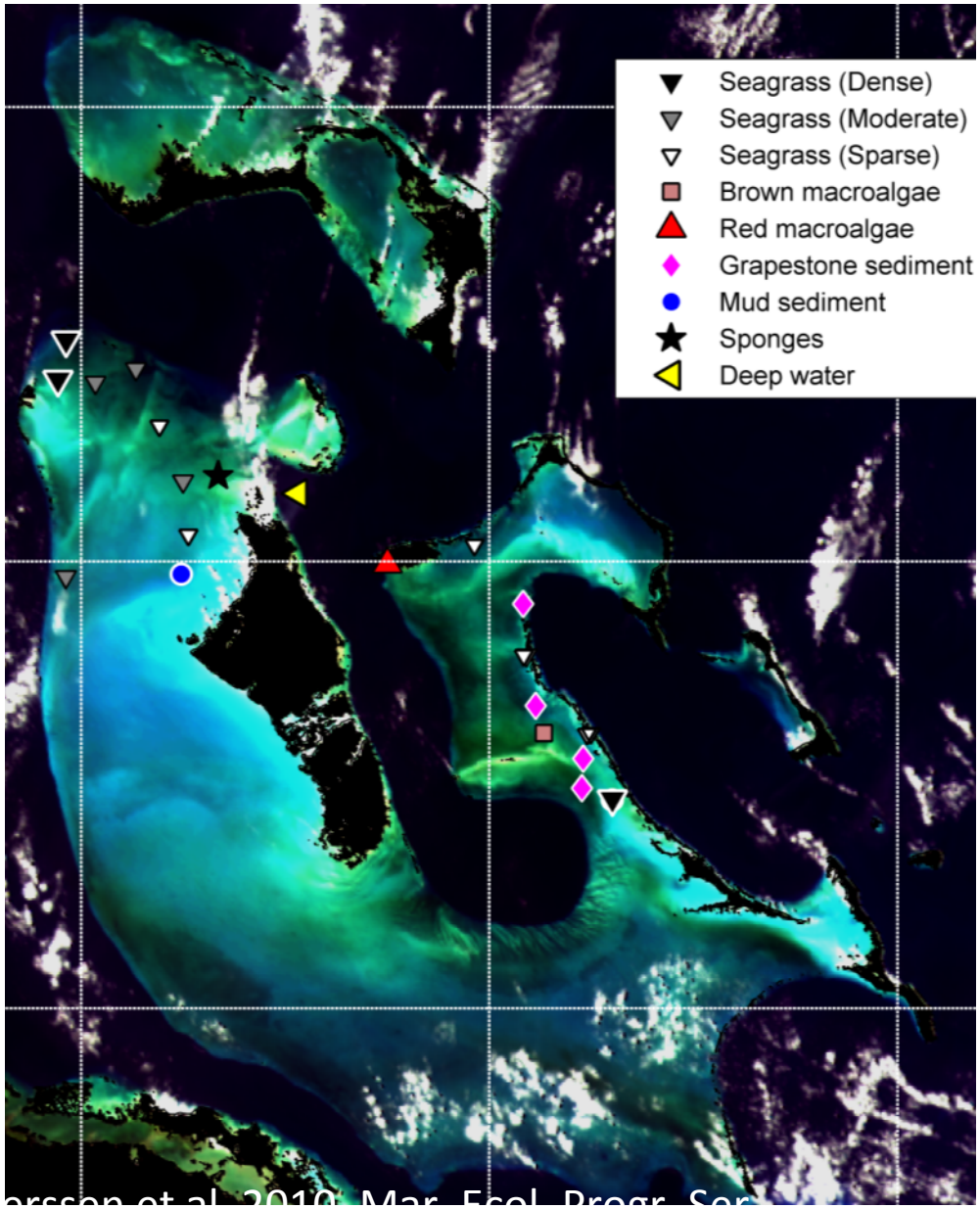
FL Bay seagrass beds have little debris
Export Carbon out of system

Seagrass serves as critical habitat

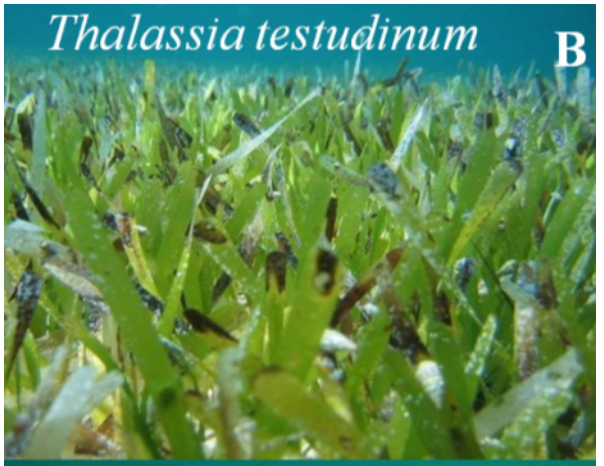
>150 species small invertebrates
100 species algae
Fish

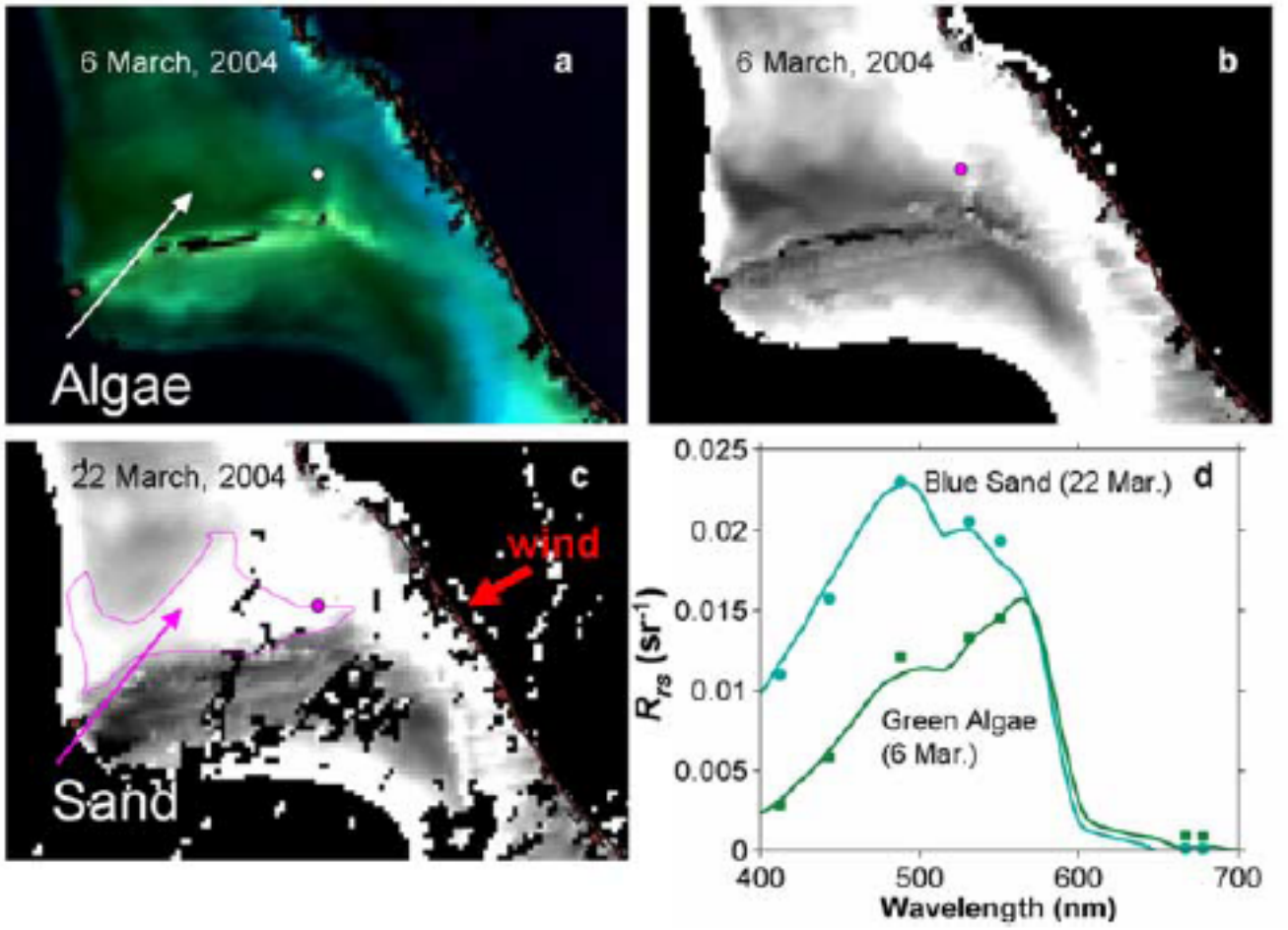
Seagrass as Habitat for Other Organisms

5
4
3
2
1



erssen et al. 2010. Mar. Ecol. Progr. Ser.





Pulsed export of >7 x10^{10} g of carbon directly to seafloor (negatively buoyant). This is equivalent to the daily carbon flux of phytoplankton biomass in the pelagic tropical North Atlantic and 0.2–0.8% of daily carbon flux from the global ocean.

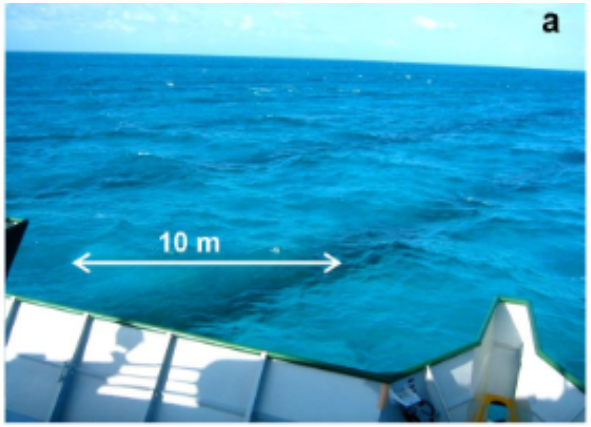
Dierssen et al. 2009. Geophys. Res. Lett.

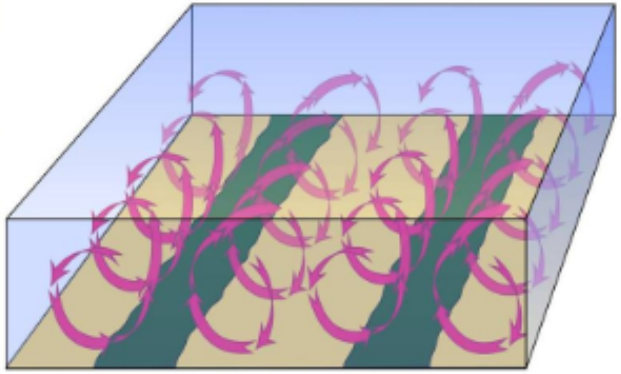
GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L04602, doi:10.1029/2008GL036188, 2009

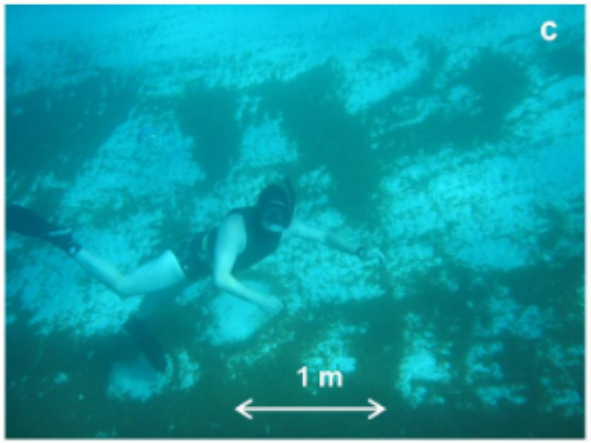
Click Here for Full Article

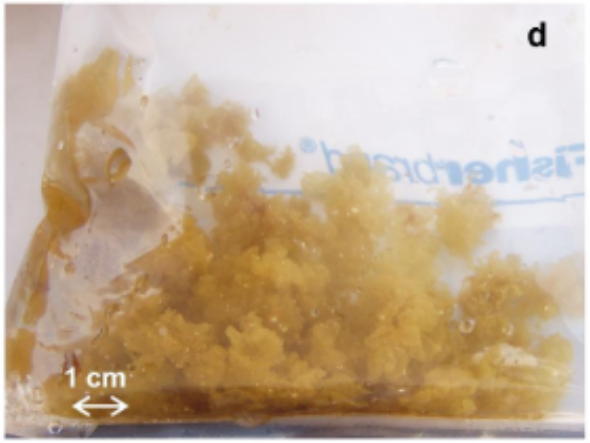
Potential export of unattached benthic macroalgae to the deep sea through wind-driven Langmuir circulation

H. M. Dierssen,[1] R. C. Zimmerman,[2] L. A. Drake,[2,3] and D. J. Burdige[2]





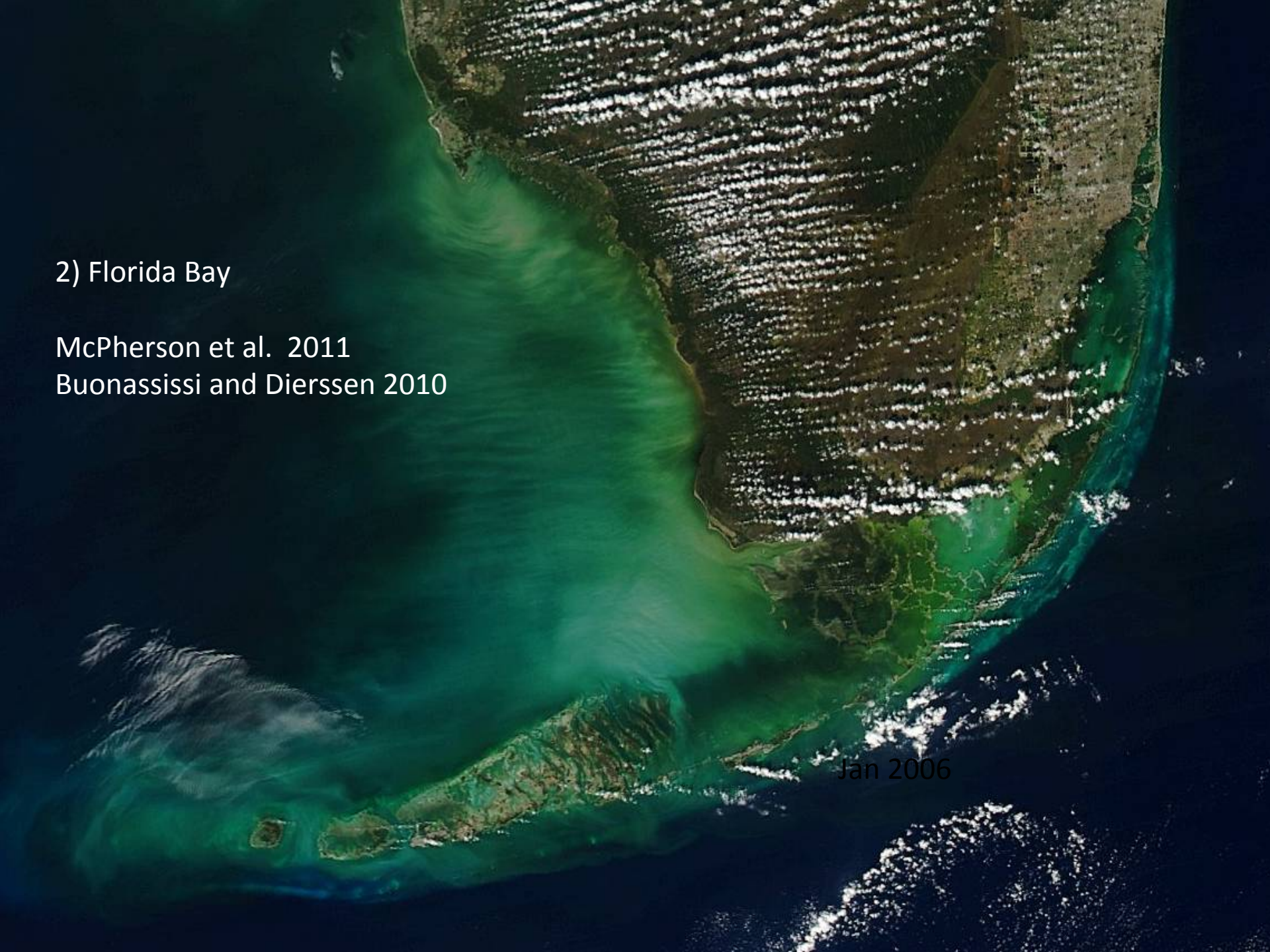




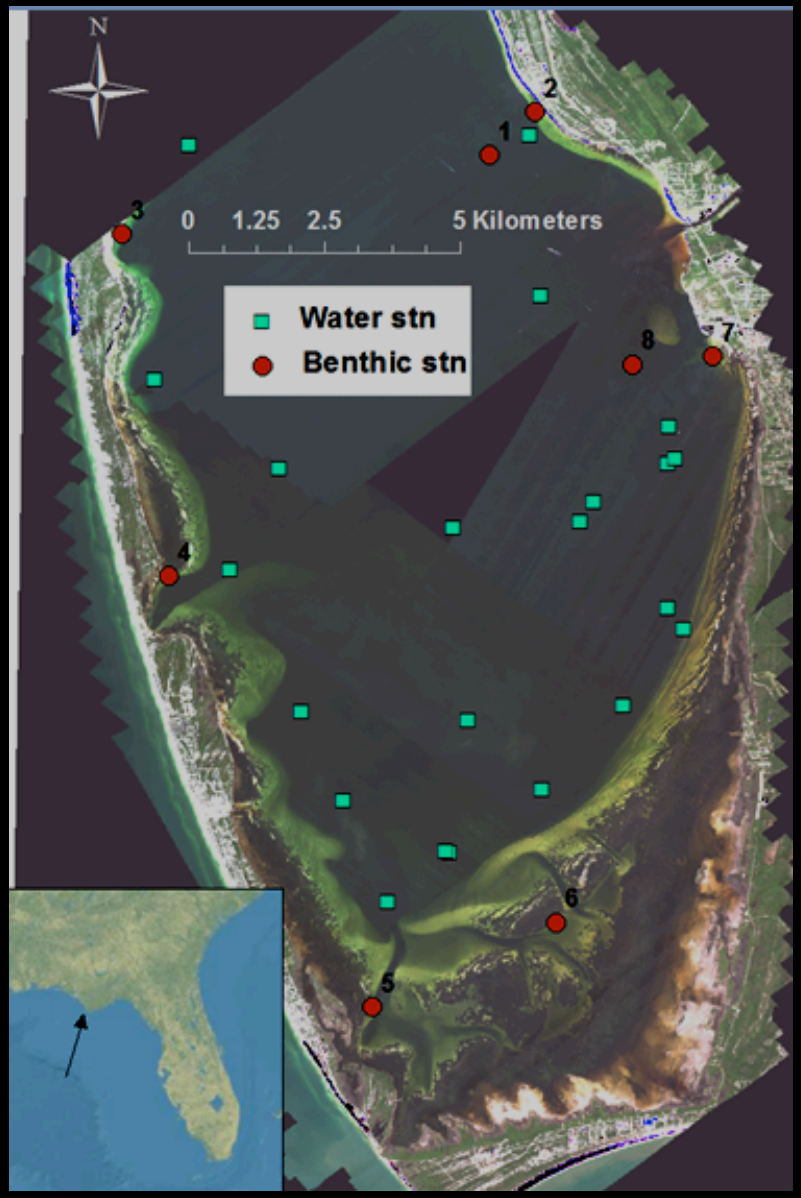
Optics and remote sensing of Bahamian carbonate sediment whitings and potential relationship to wind-driven Langmuir circulation

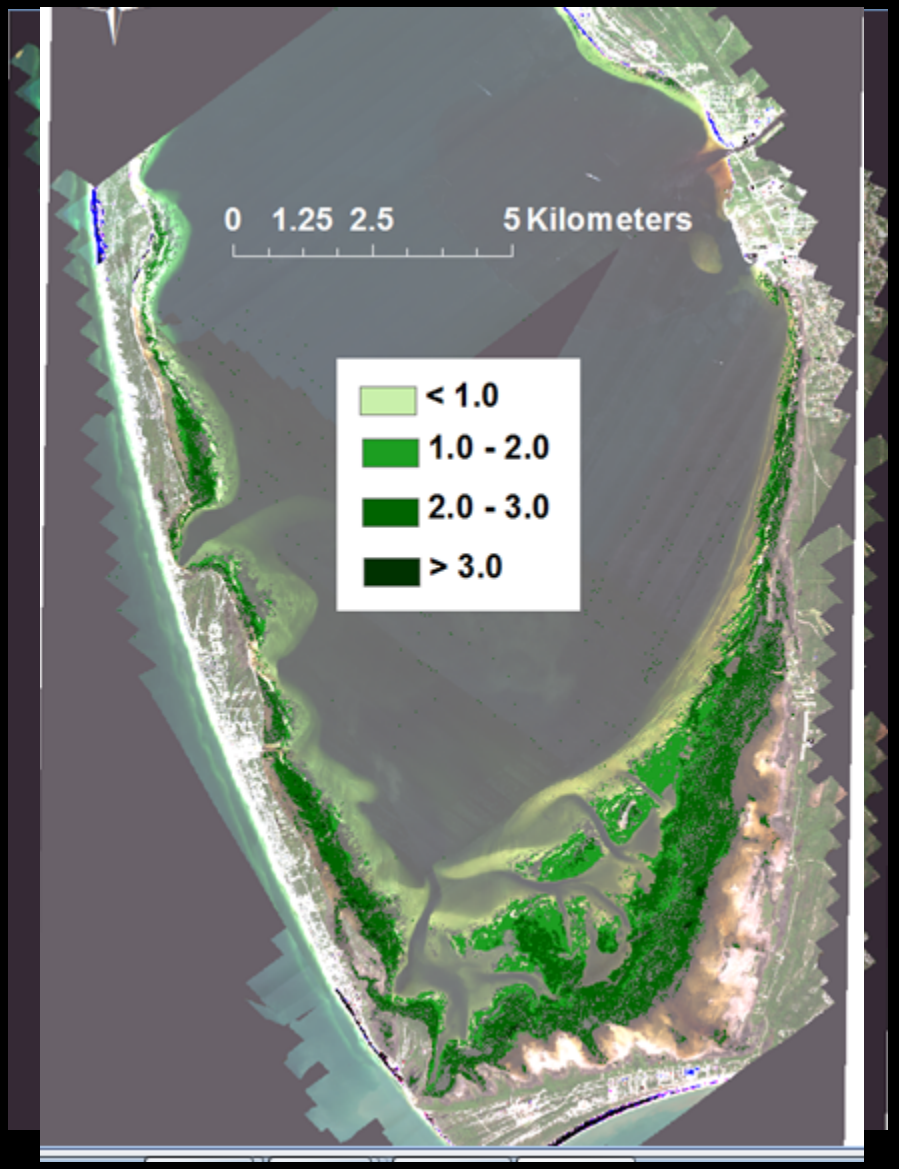
Biogeosciences, 6, 1–14, 2009
www.biogeosciences.net/6/1/2009/

H. M. Dierssen[1], R. C. Zimmerman[2], and D. J. Burdige[2]


2) Florida Bay
McPherson et al. 2011
Buonassissi and Dierssen 2010
Jan 2006

St. Joseph Bay, Florida

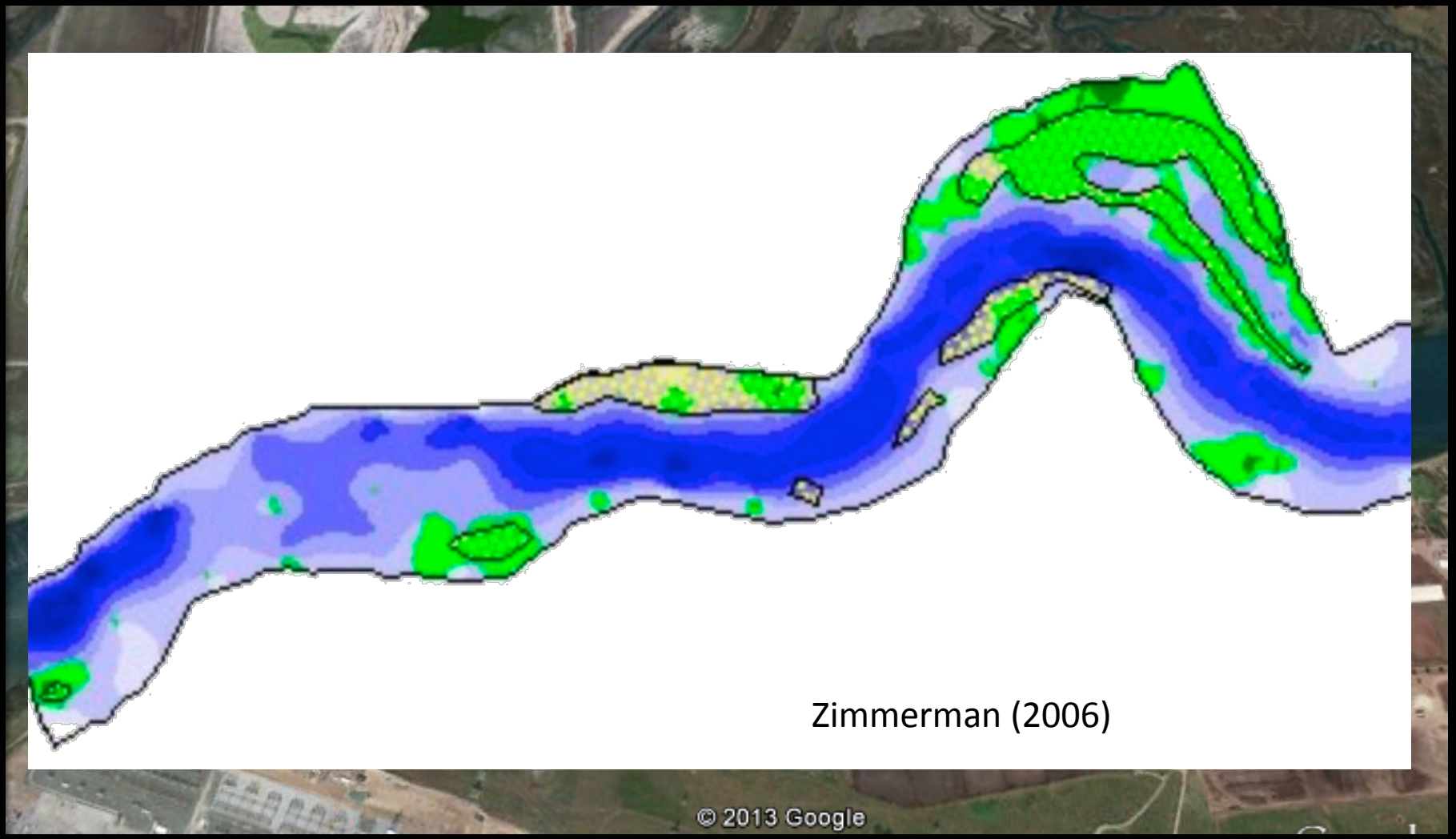


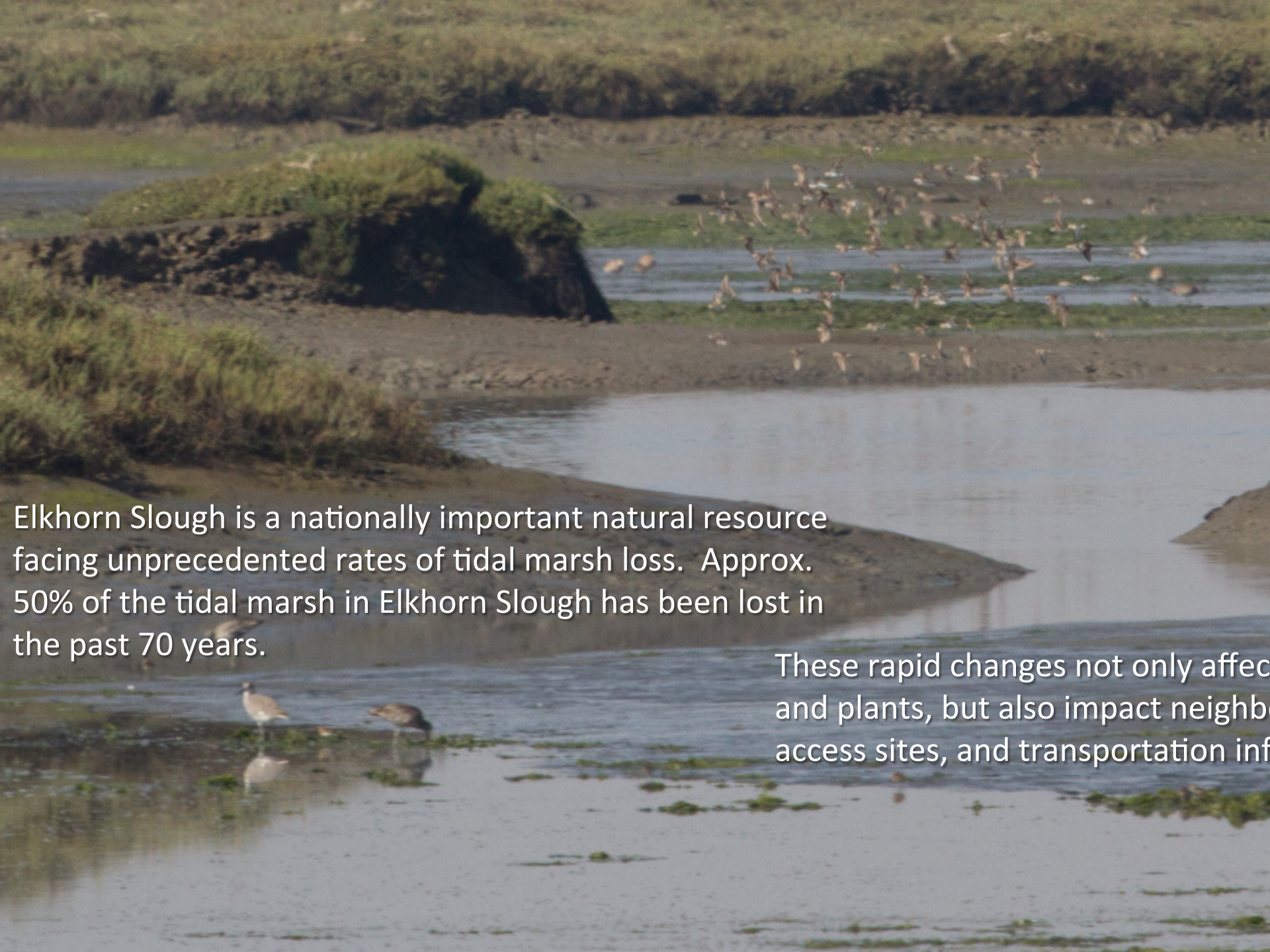


Hill et al. submitted, Est. and Coasts

4) Port Aransas, TX

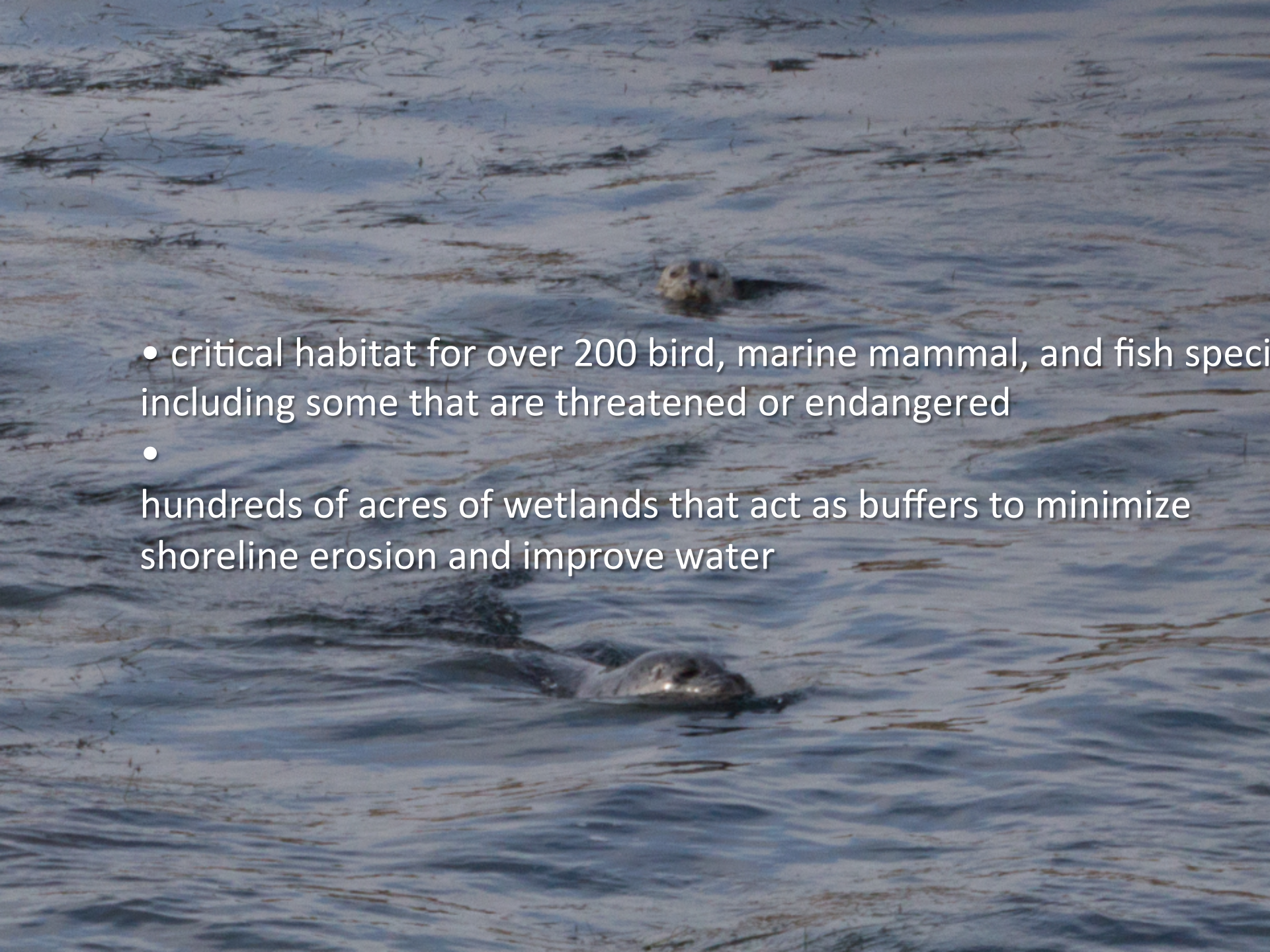
5) Elkhorn Slough, California





Elkhorn Slough is a nationally important natural resource facing unprecedented rates of tidal marsh loss. Approx. 50% of the tidal marsh in Elkhorn Slough has been lost in the past 70 years.

These rapid changes not only affec
and plants, but also impact neighb
access sites, and transportation inf



- critical habitat for over 200 bird, marine mammal, and fish speci
including some that are threatened or endangered
-
hundreds of acres of wetlands that act as buffers to minimize shoreline erosion and improve water

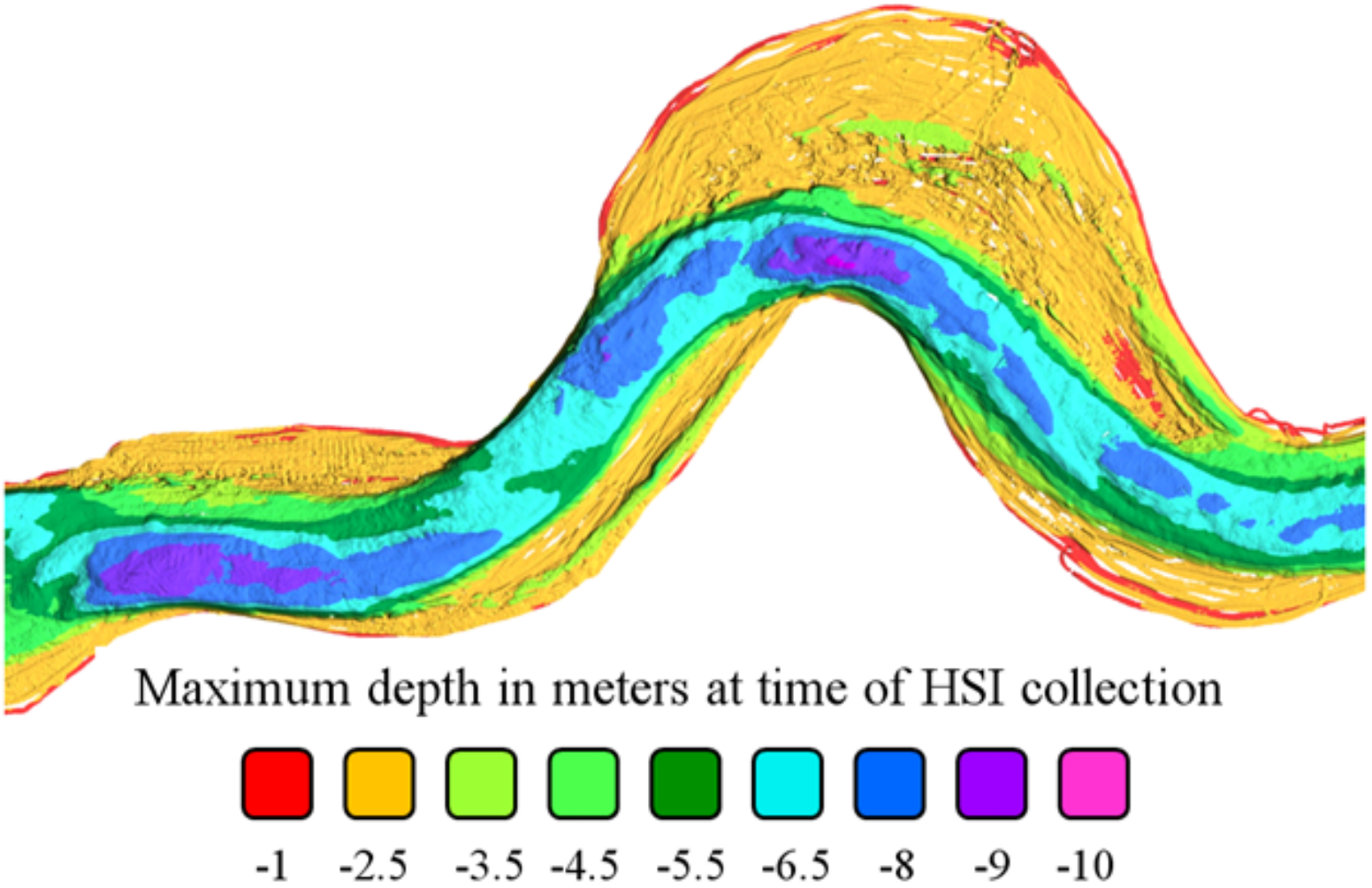


Figure 24 Bathymetry of Elkhorn Slough

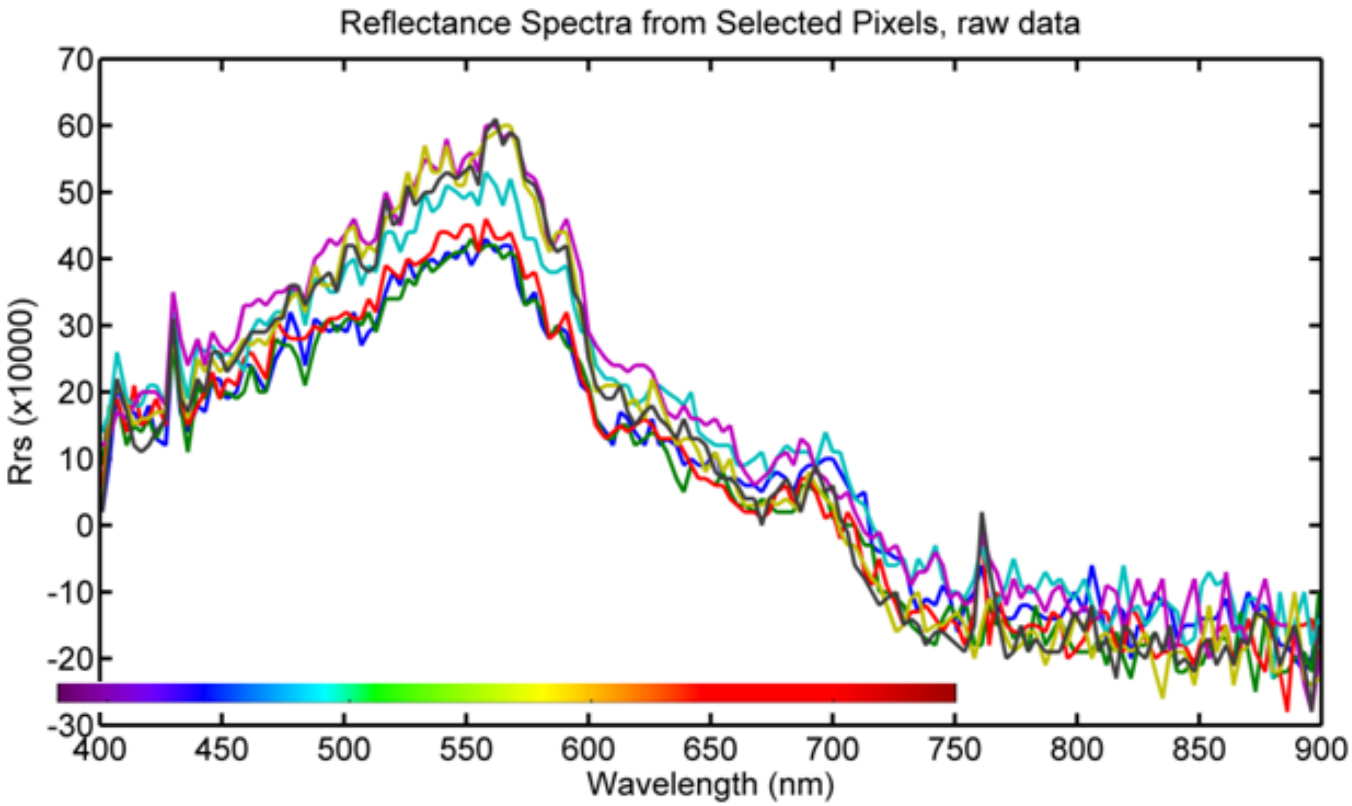
Bostrom, 2012, M.S. thesis

Figure 36 Glint visible in the hyperspectral imagery

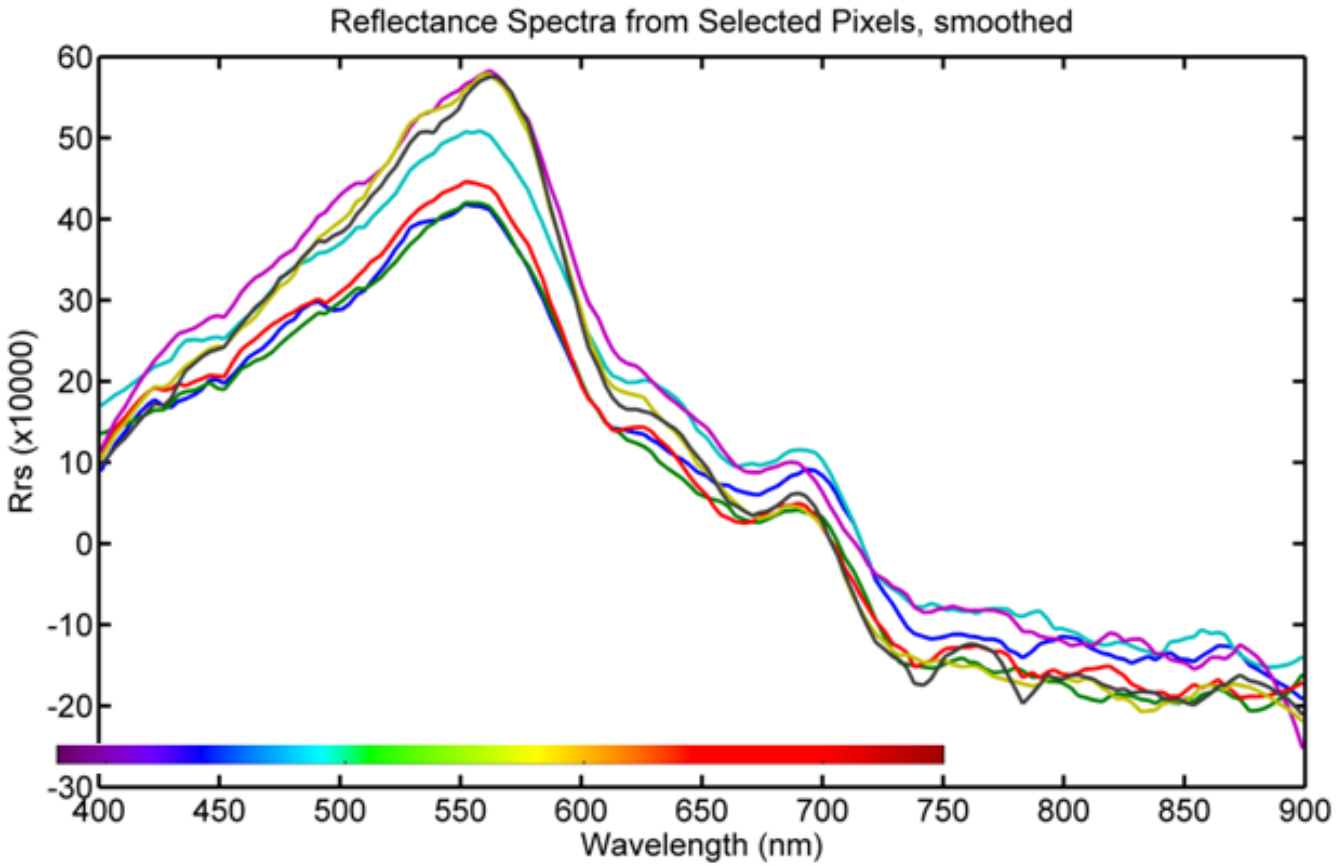
A pseudo true color image of the study location from the SAMSON imagery shows differences in the magnitude of reflected light due to sun glint between the NE/SW flight track lines (arrows).

Heritage sensor: SAMSON

R_{rs} Spectra from Image



R_{rs} Spectra from Image, filtered



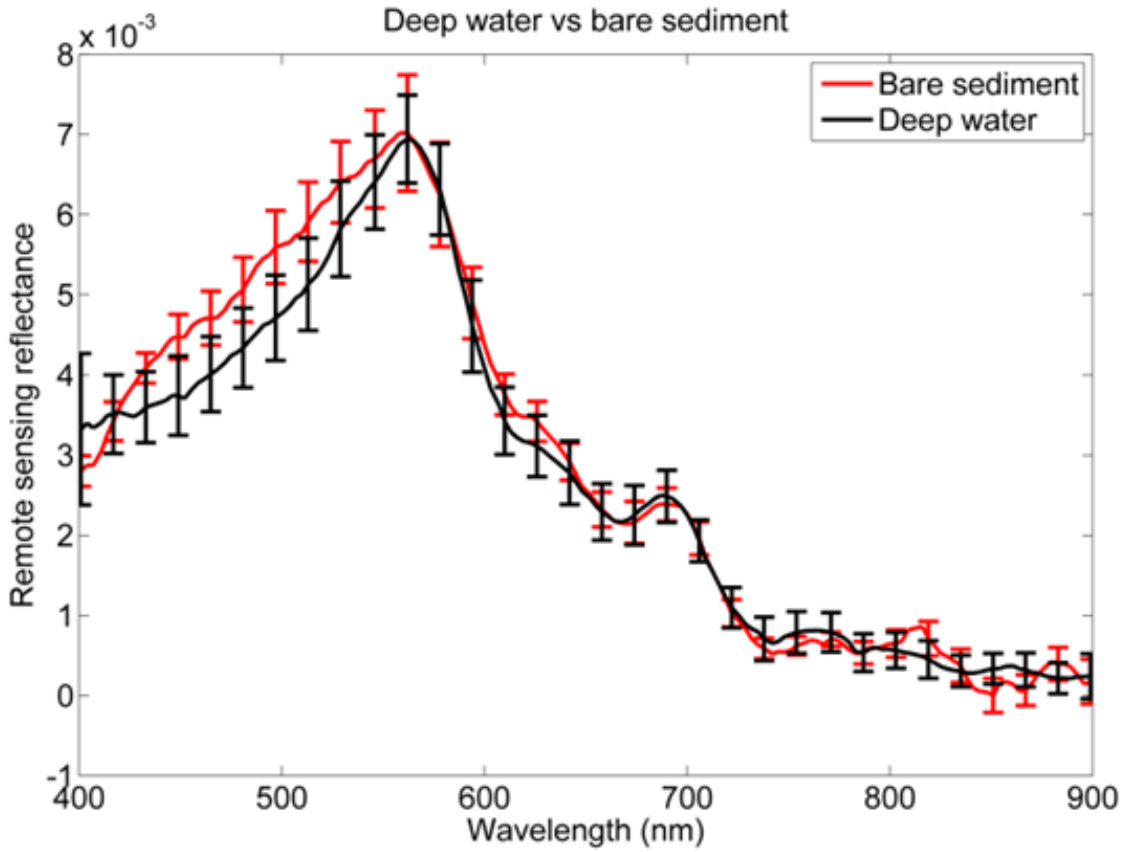
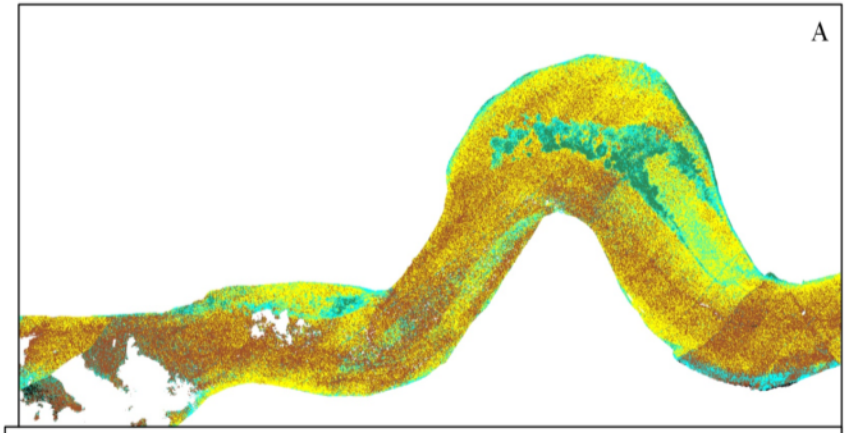
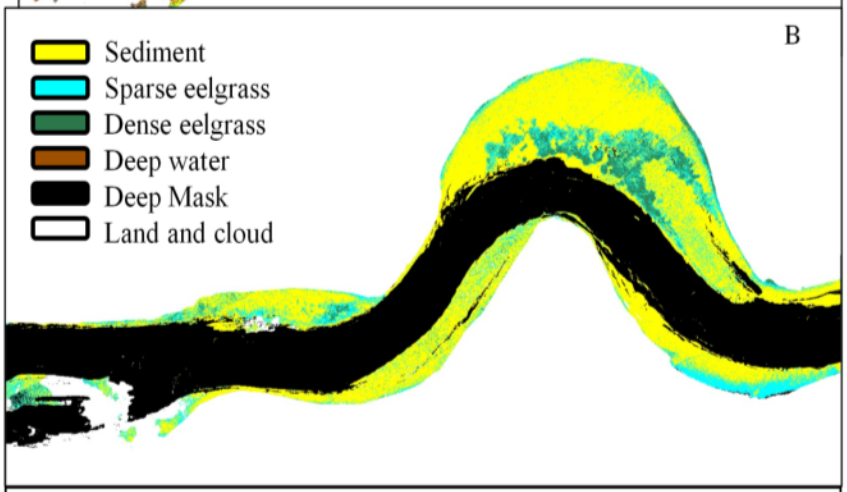


Figure 32 Standard errors in sediment and deep water spectra

The average Remote Sensing Reflectance (sr^{-1}) spectrum with one standard error for all field stations containing bare sediment on the seafloor (<3 m water depth) compared to a similar number of deep water (>5.5 m water depth) pixels. The overlap of error bars across the visible spectrum indicate no significant difference between the two spectra and show that deep water and sediment cannot be spectrally distinguished.



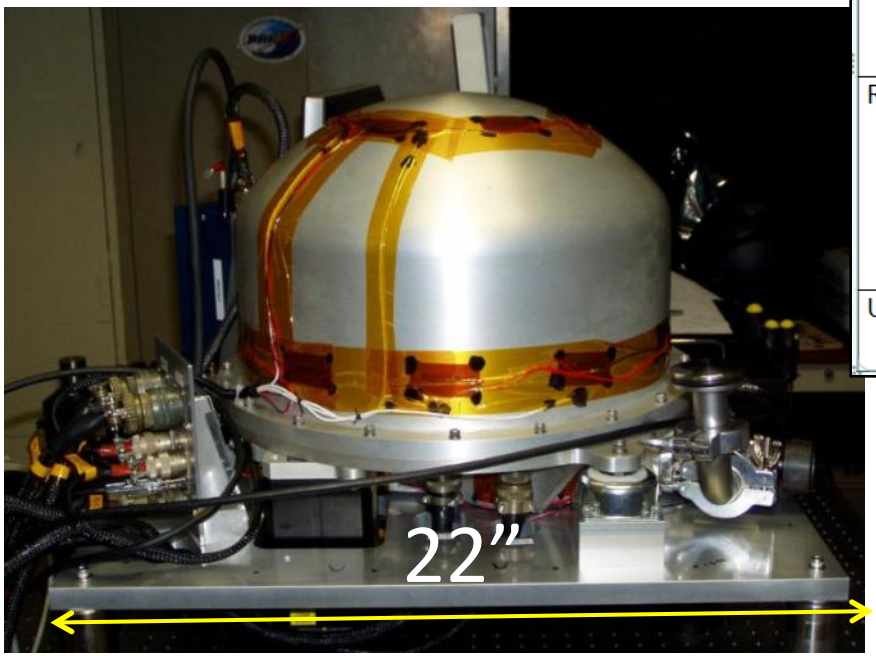


C

Field Measurement	Remotely Sensed Product: Dense eelgrass	Sparse Eelgrass	Bare Sediment	Total
Dense eelgrass	**5**	0	0	5
Sparse Eelgrass	3	**2**	2	7
Bare Sediment	2	0	**4**	6
Total	10	2	6	**18**

Portable Remote Imaging SpectroMeter (PRISM): NASA Coastal Applications

Spectral	Range	**350-1050 nm**
	Sampling	**2.85 nm**
	Resolution (FWHM)	3.5 nm
	Calibration uncertainty	< 0.1nm
Spatial	Field of view	30.7°
	Instantaneous FOV sampling	0.882 mrad
	IFOV resolution (FWHM)	0.97 mrad
	Cross-track spatial pixels	608
	Ground resolution	**0.35 – 20 m**
Radiometric	Range	0 to max. beach R
	Sampling	**14 bit**
	Stability	>99%
	Calibration uncertainty	<2%
	SNR	**2000 @450 nm***
	Polarization variation:	**< 1%**
Uniformity	Spectral cross-track uniformity	**>95%**
	Spectral IFOV mixing uniformity	**>95%**

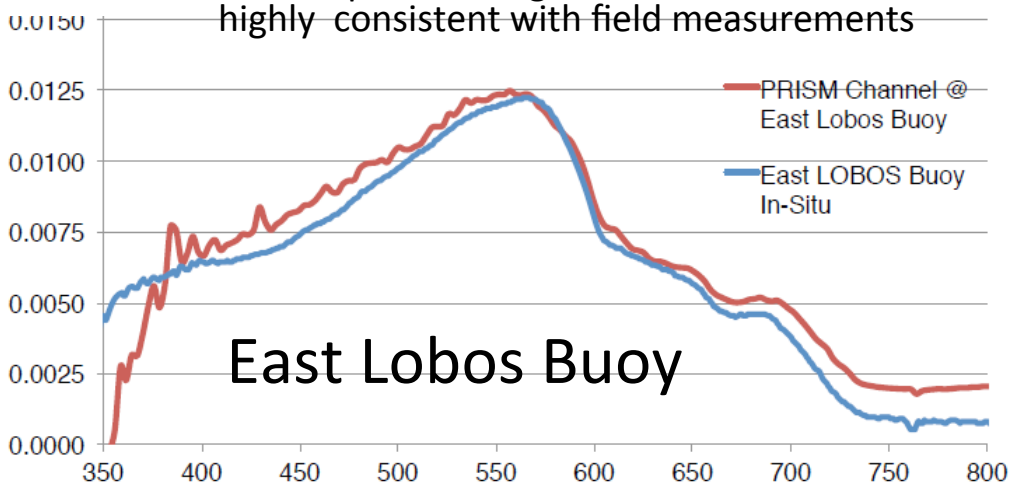


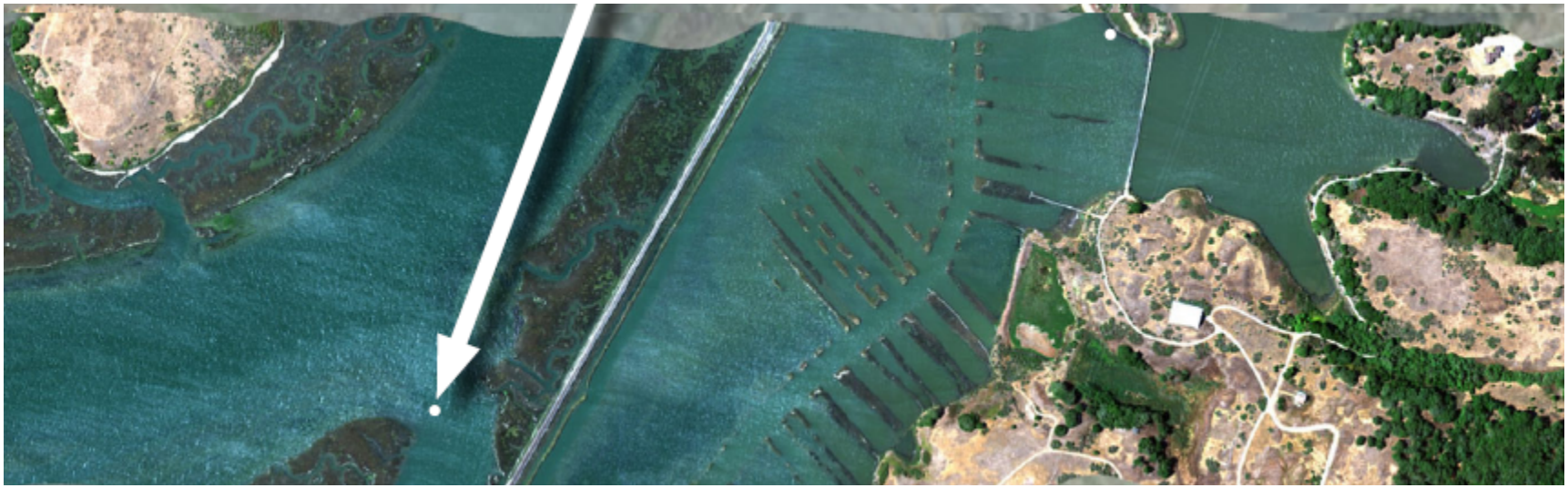
Built in 2012 by NASA JPL funded by NASA Ocean Biology and Biogeochemistry to address challenges of coastal remote sensing. Integrated on Twin Otter Platform.

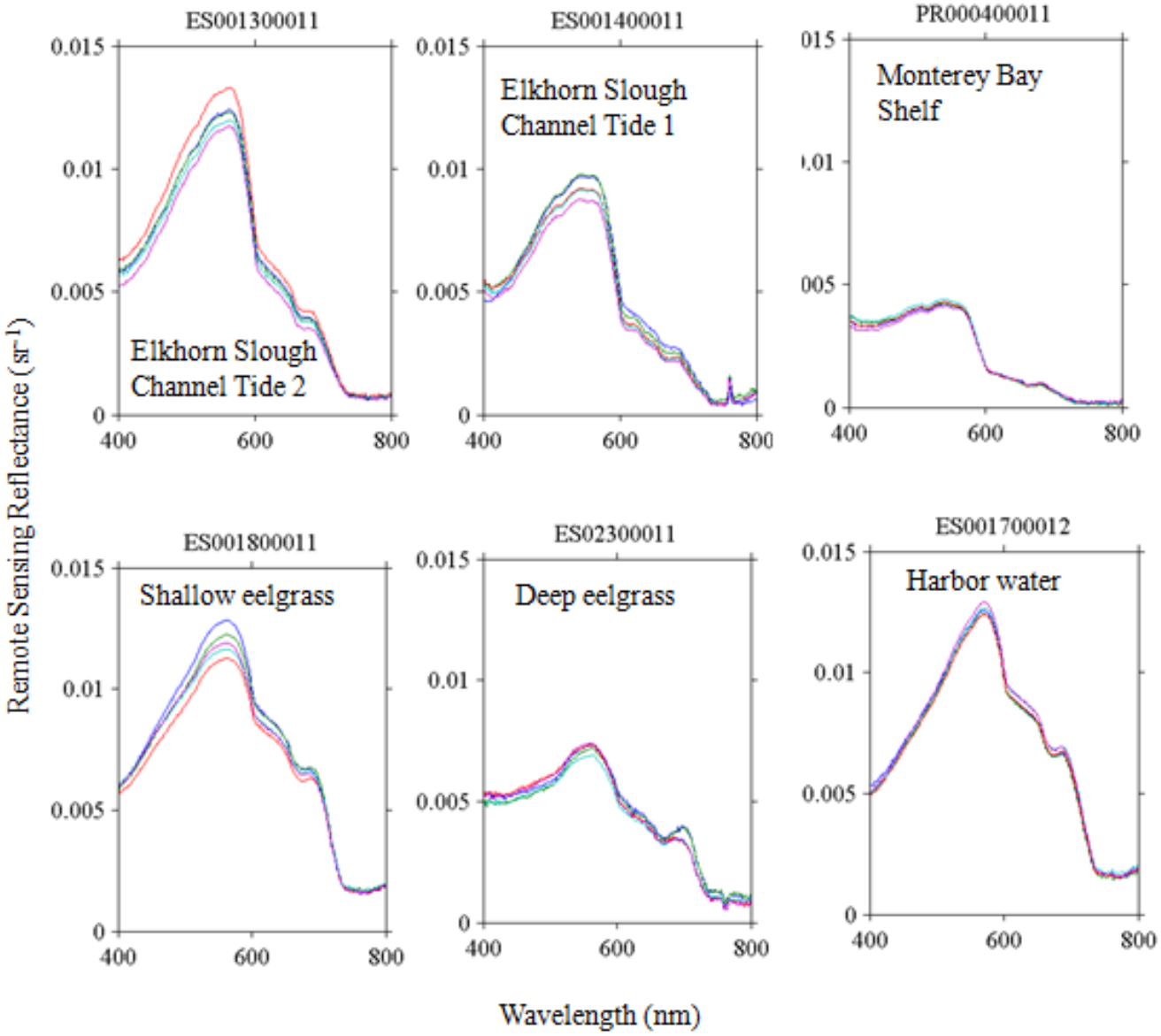
PRISM Field Validation

First PRISM overflight
July 17-28 2012

Initial atmospheric and glint correction shows data highly consistent with field measurements



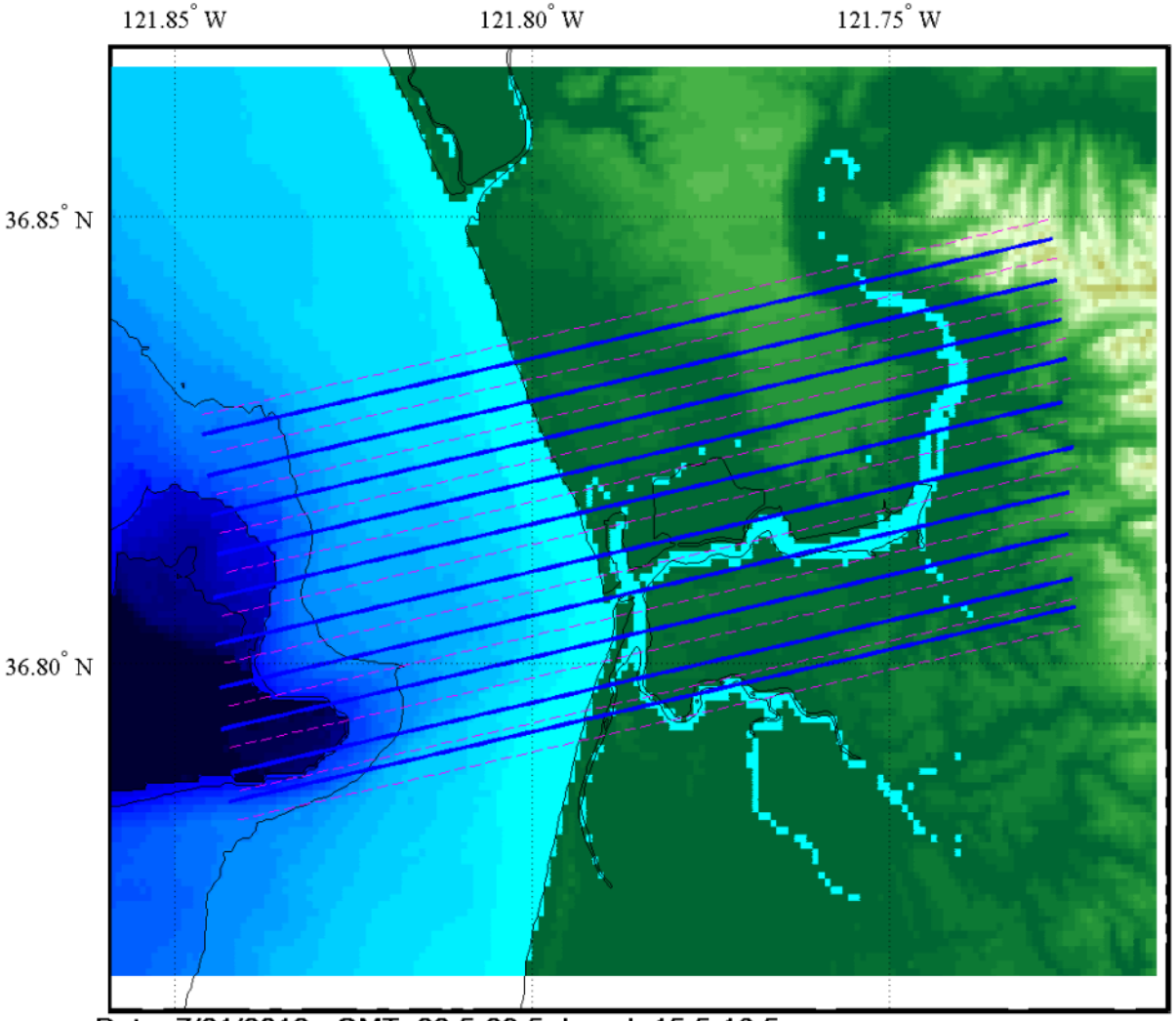



ES001300011
Elkhorn Slough
Channel Tide 2
ES001400011
Elkhorn Slough
Channel Tide 1
PR000400011
Monterey Bay
Shelf
ES001800011
Shallow eelgrass
ES02300011
Deep eelgrass
ES001700012
Harbor water
Remote Sensing Reflectance (sr-1)
Wavelength (nm)
0.015
0.01
0.005
0
400
600
800

Select

Quasi True Color

Chlorophyll



Date: 7/21/2012; GMT: 22.5-23.5; Local: 15.5-16.5

Line 1: [36.8475N, -121.7272W] to [36.8256N, -121.8461W]; 10.86 km; Time 0.098 hr

Line 2: [36.8428N, -121.7266W] to [36.821N, -121.8453W]; 10.84 km; Time 0.098 hr

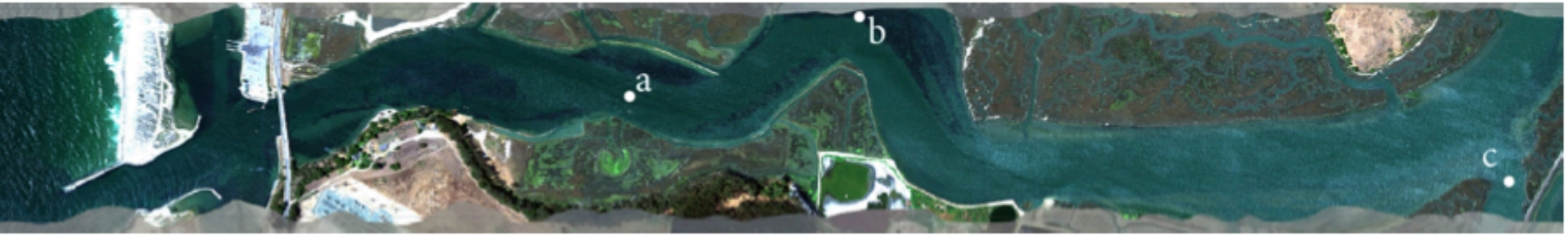
Line 3: [36.8385N, -121.726W] to [36.8166N, -121.8448W]; 10.85 km; Time 0.098 hr

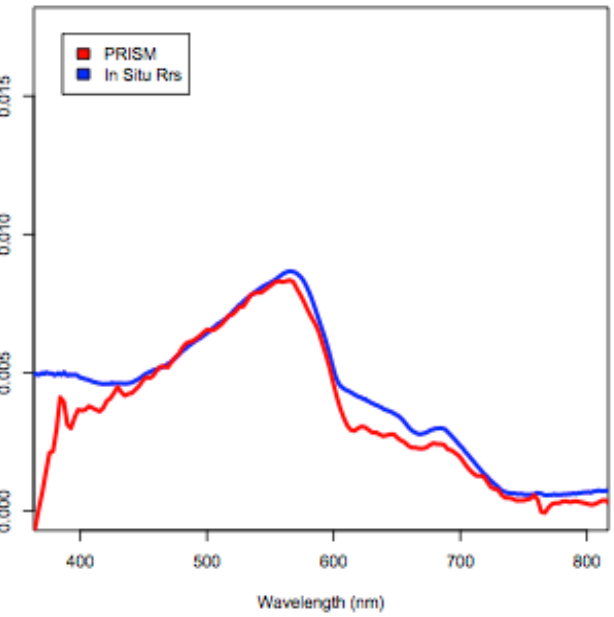
Line 4: [36.834N, -121.7252W] to [36.8122N, -121.8439W]; 10.84 km; Time 0.098 hr

Line 5: [36.8292N, -121.7258W] to [36.8073N, -121.8445W]; 10.84 km; Time 0.098 hr

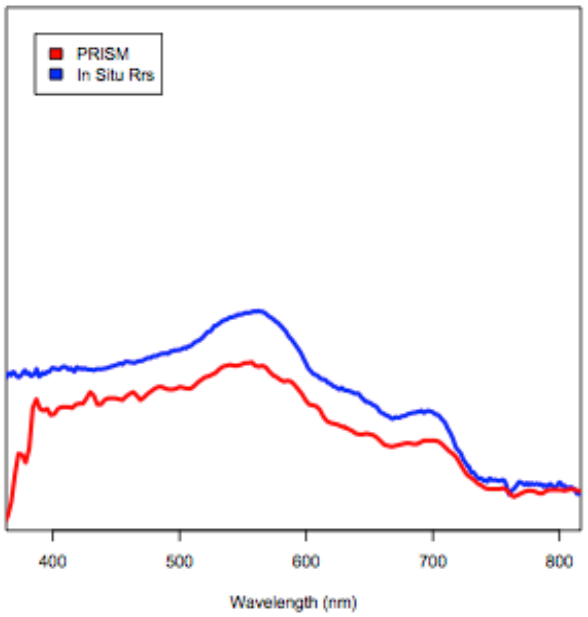
Line 6: [36.8242N, -121.7242W] to [36.802N, -121.8442W]; 10.96 km; Time 0.099 hr

Line 7: [36.8191N, -121.7249W] to [36.7972N, -121.8437W]; 10.85 km; Time 0.098 hr

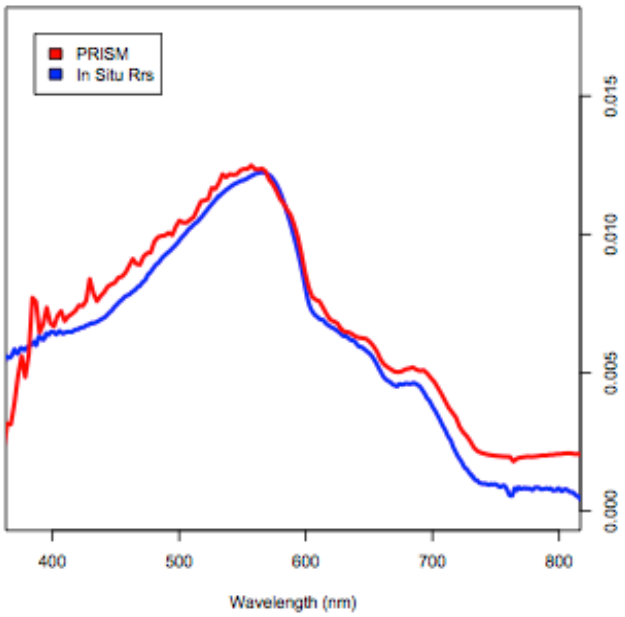




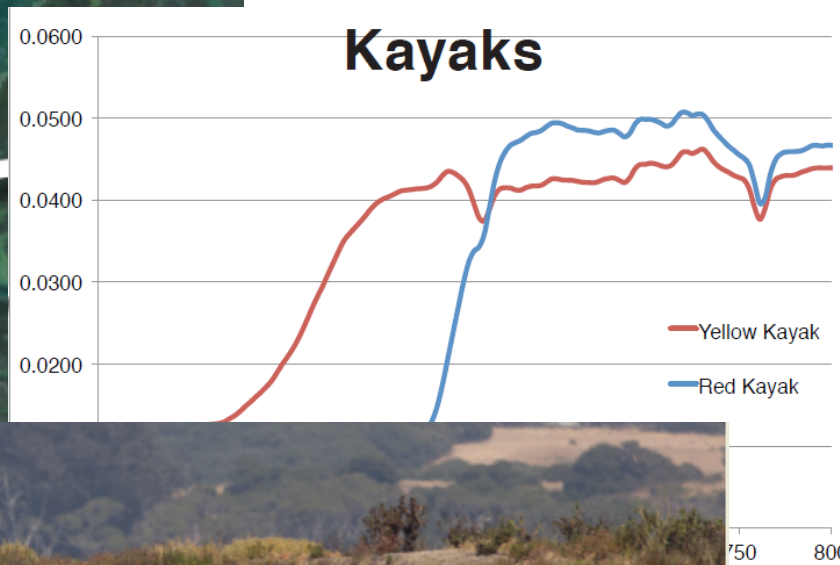
(a) West LOBO Buoy



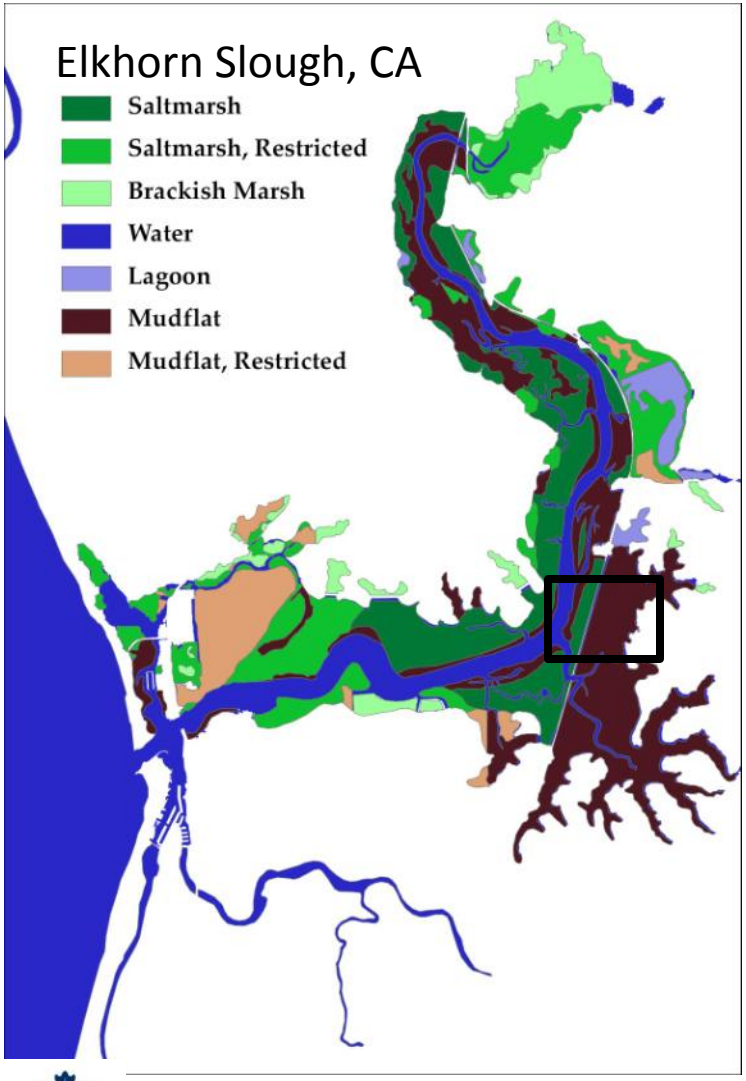
(b) Seal Bend Dense Eelgrass

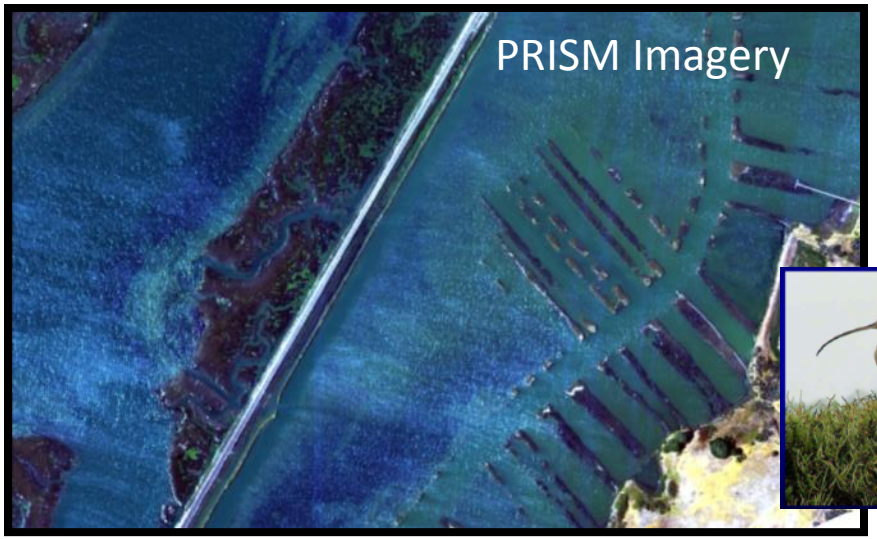


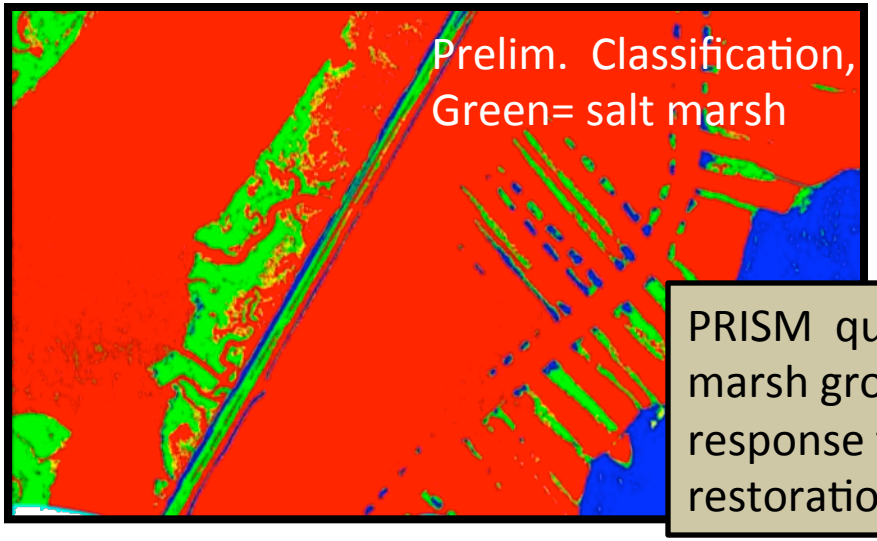
(c) East LOBO Buoy


Kayaks
0.0600
0.0500
0.0400
0.0300
0.0200
Yellow Kayak
Red Kayak
750
800

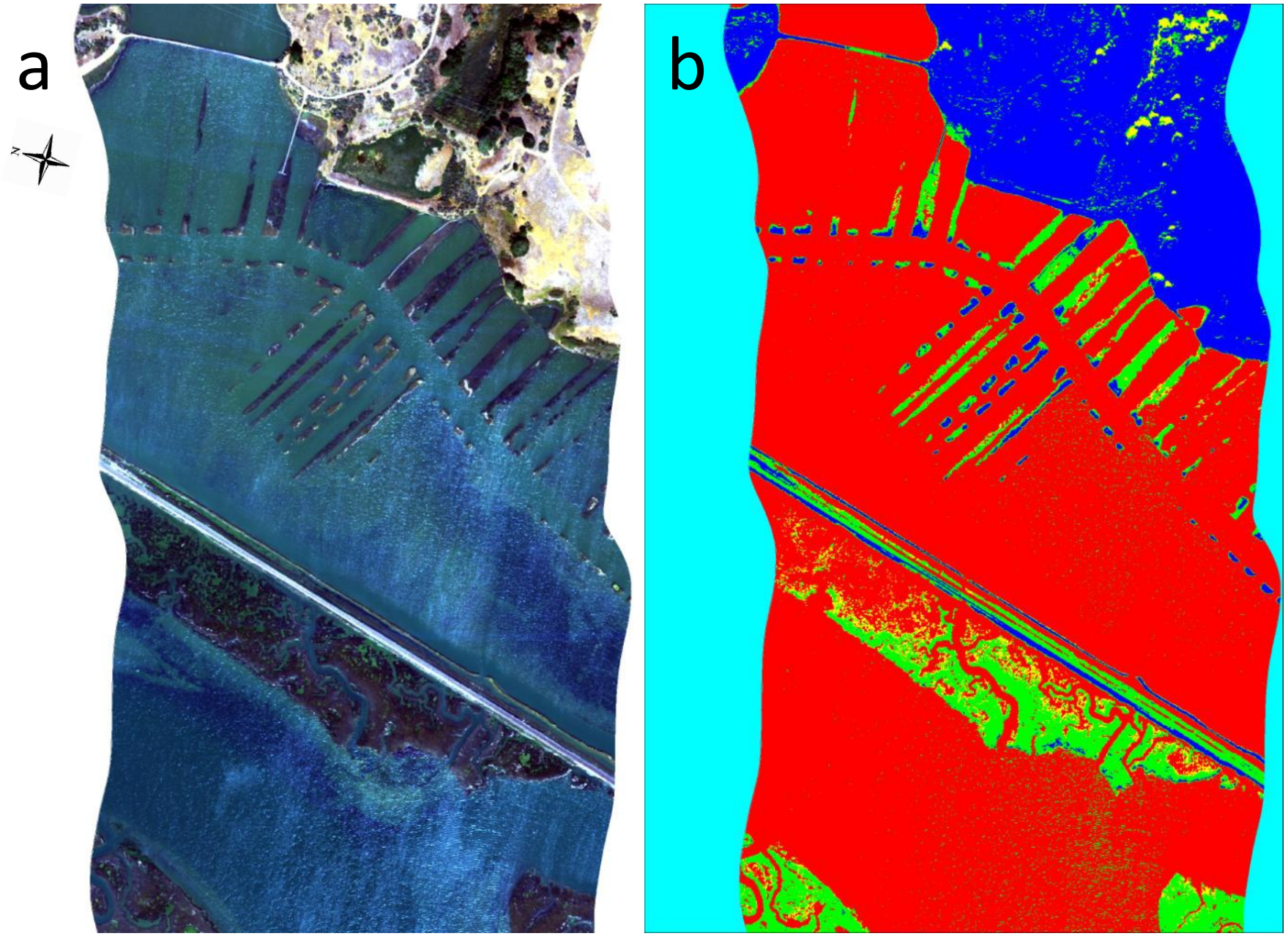
PRISM Science: Mapping Coastal Habitats **Salt Marsh Restoration**





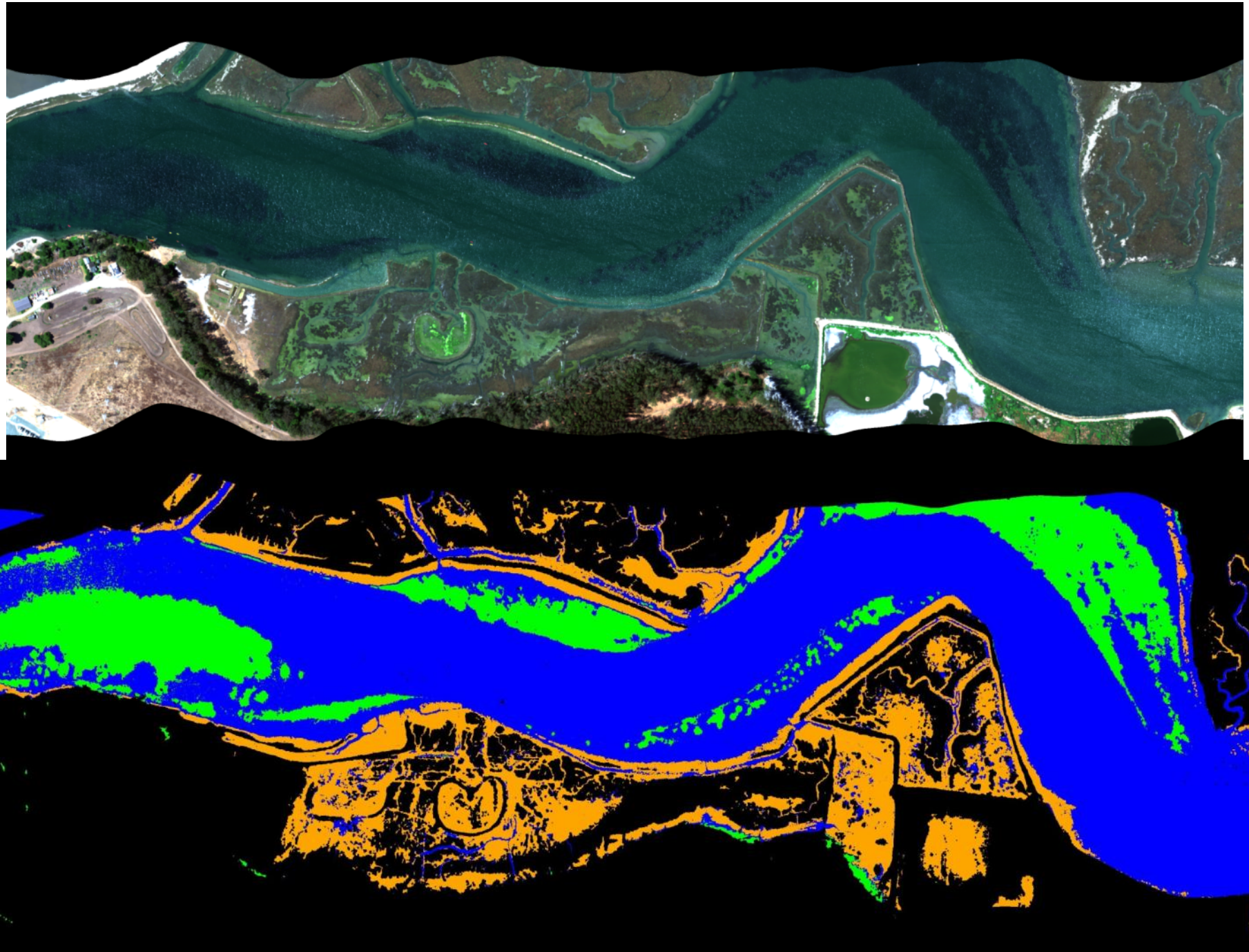


PRISM quantifies marsh growth in response to restoration efforts


a
b

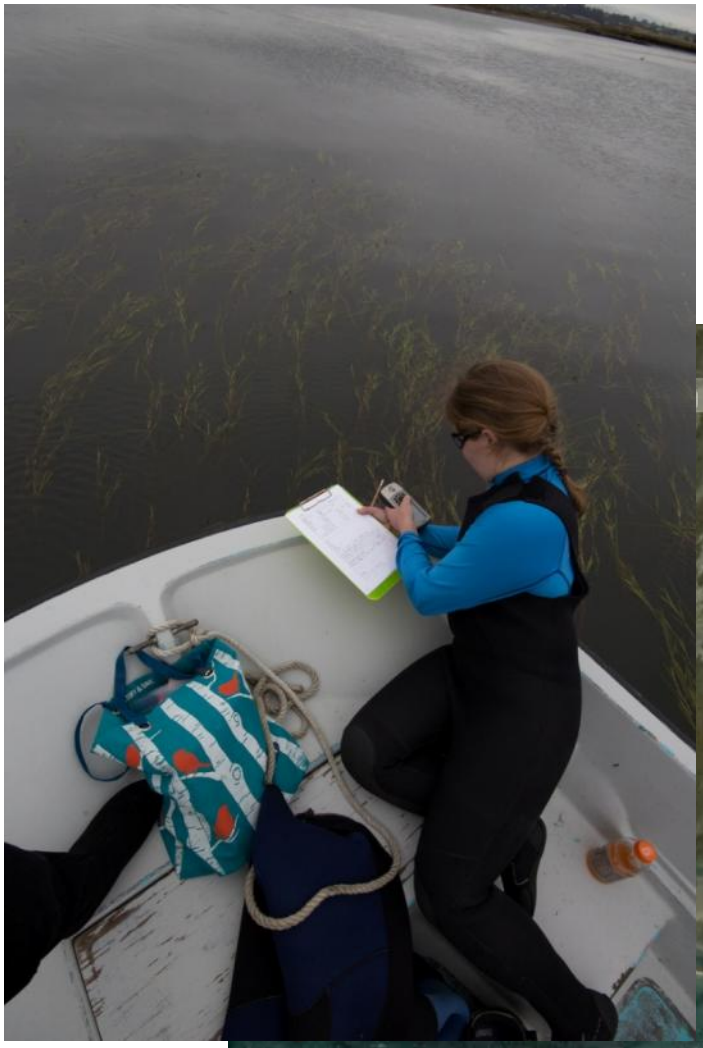
PINNACLE

Eelgrass Beds in Turbid Water



Pauls Island
© 2013 Google

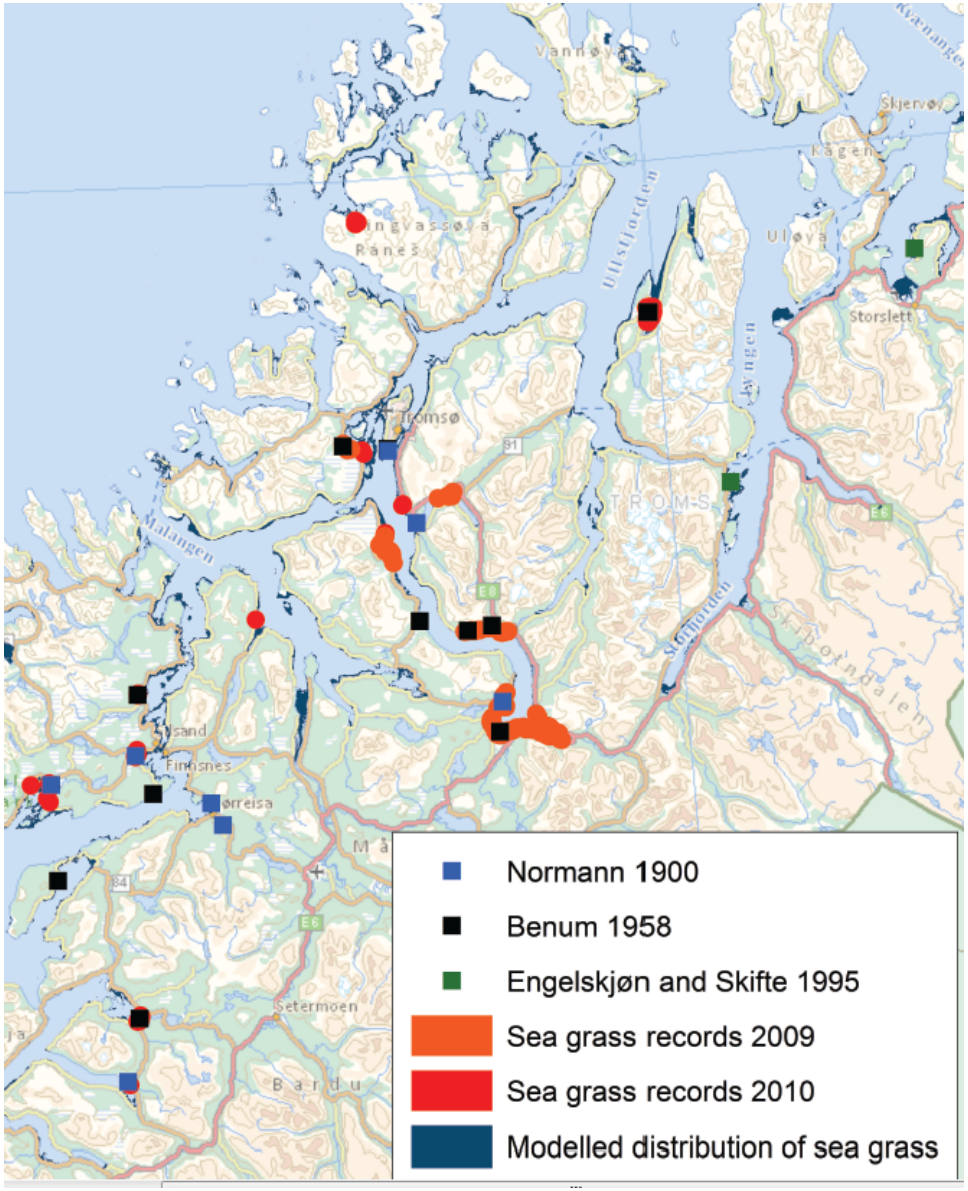
Validation Points



Next HyspIRI Study Site: Eelgrass in Clear Waters

Nina Mari Jørgensen, Akvaplan-niva, FRAM – High North Research Centre on Climate and the Environment, 9296 Tromsø.

Seagrass at 70ºN



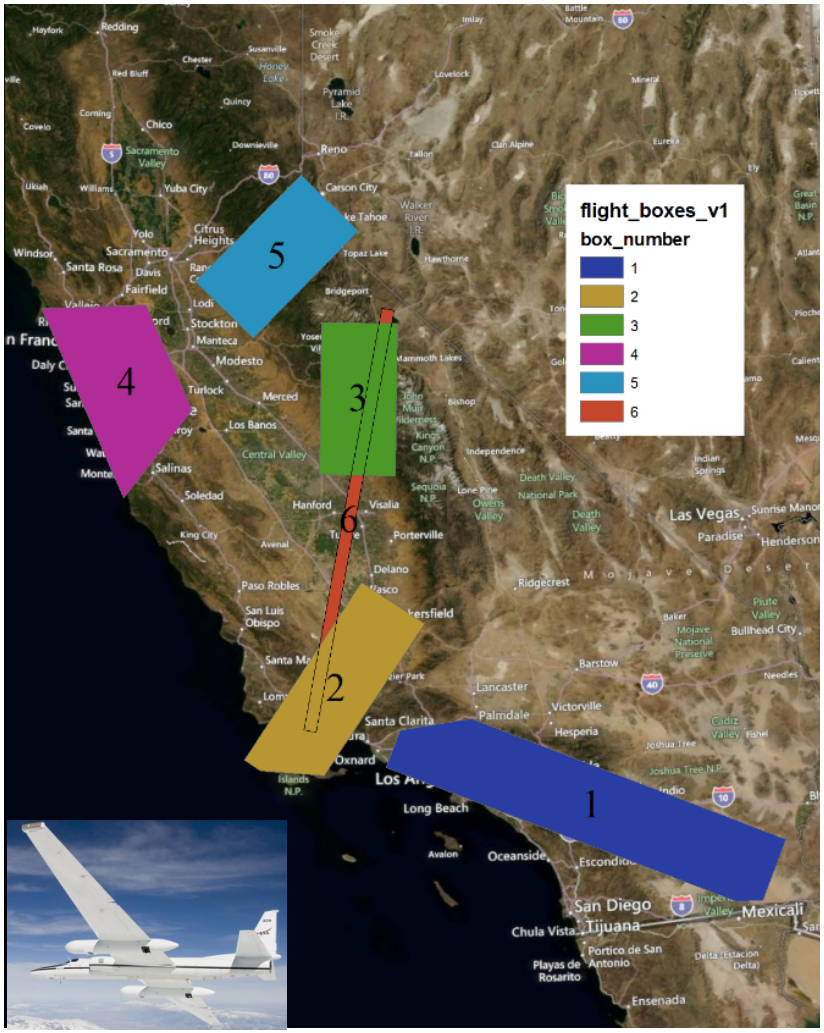
The largest eelgrass meadow in Troms was 324,000 m^2 found in Balsfjorden, first discovered in 1884 (Normann 1900).

Troms
Tromso
Balsfjord, Troms, Norway
© 2013 Google
Image IBCAO

HyspIRI Aircraft campaign: science goals, project overviews & data sharing

[*Rob Green & Simon Hook*]

HyspIRI Preparatory Airborne Science (Ecosystems, Seasonal, Climate, Coastal, Urban, Resources)



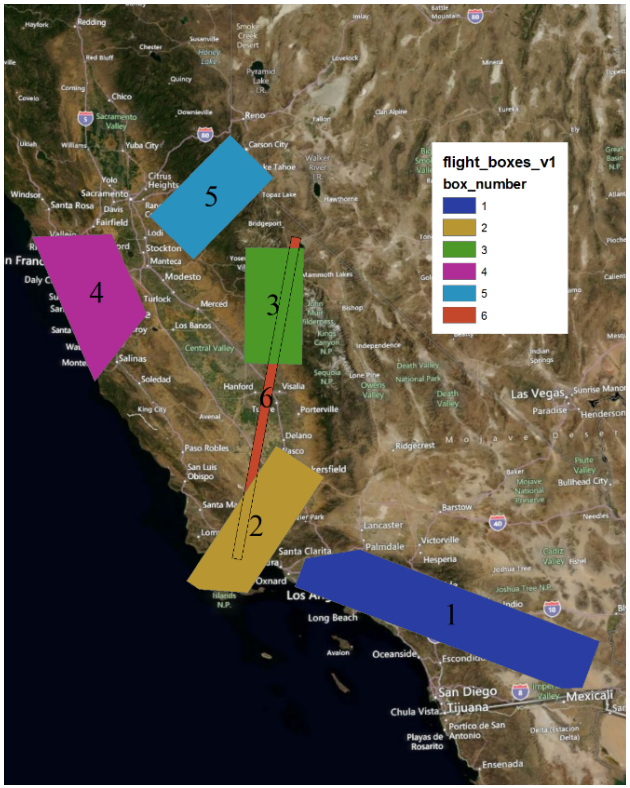
- 6 zones, 3 seasons, 2 years
- Objective: Advance HyspIRI Mission Science Readiness
  - Ecosystem composition, function, biochemistry, seasonality, structure, and modeling
  - Coastal ocean phytoplankton functional types, habitat
  - Urban land cover, temperature, transpiration
  - Surface energy balance
  - Atmospheric characterization and local methane sources
  - Surface geology, resources, soils, hazards

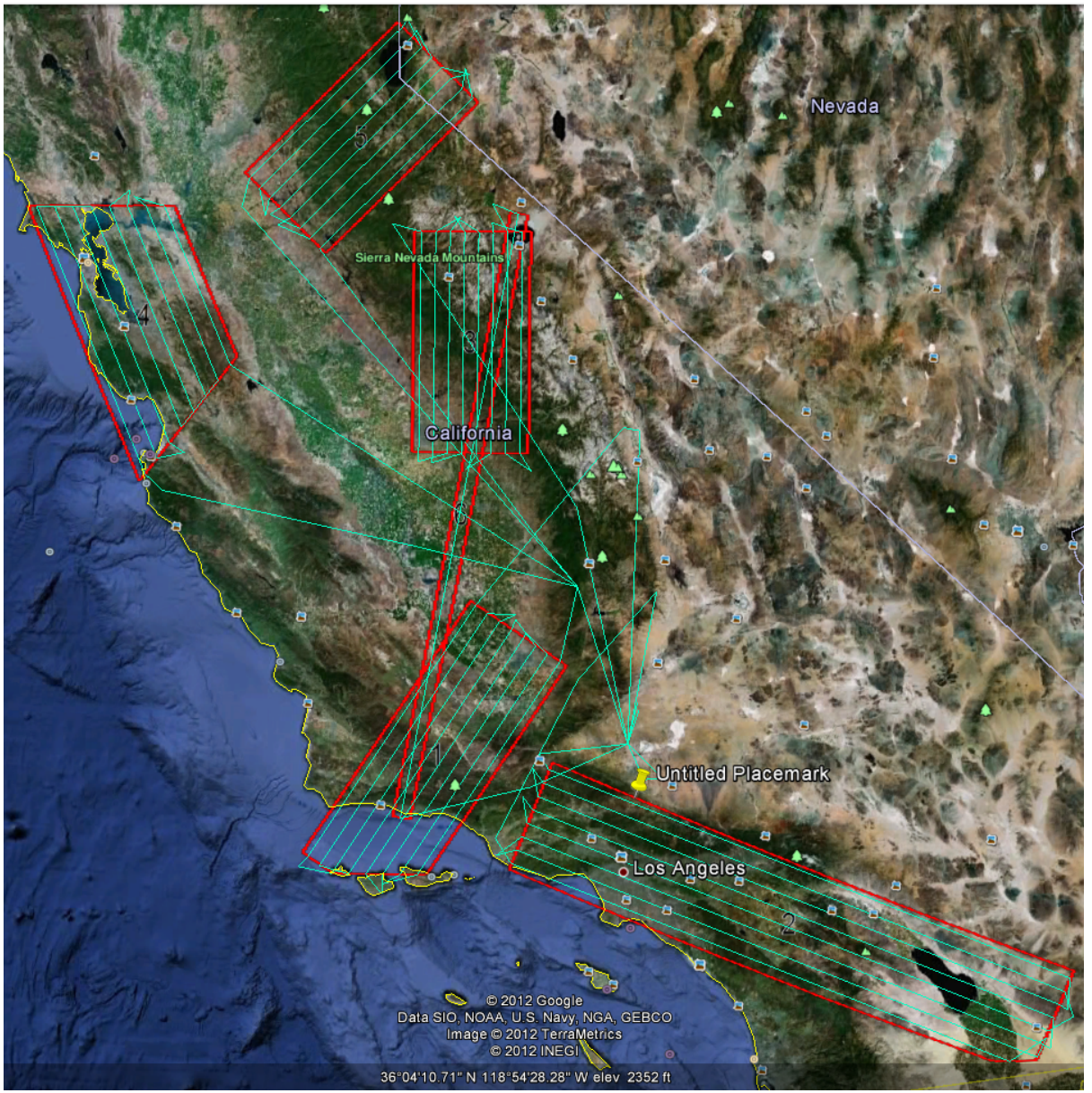
AVIRIS and MASTER on ER-2

HyspIRI Preparatory Airborne Activities Projects

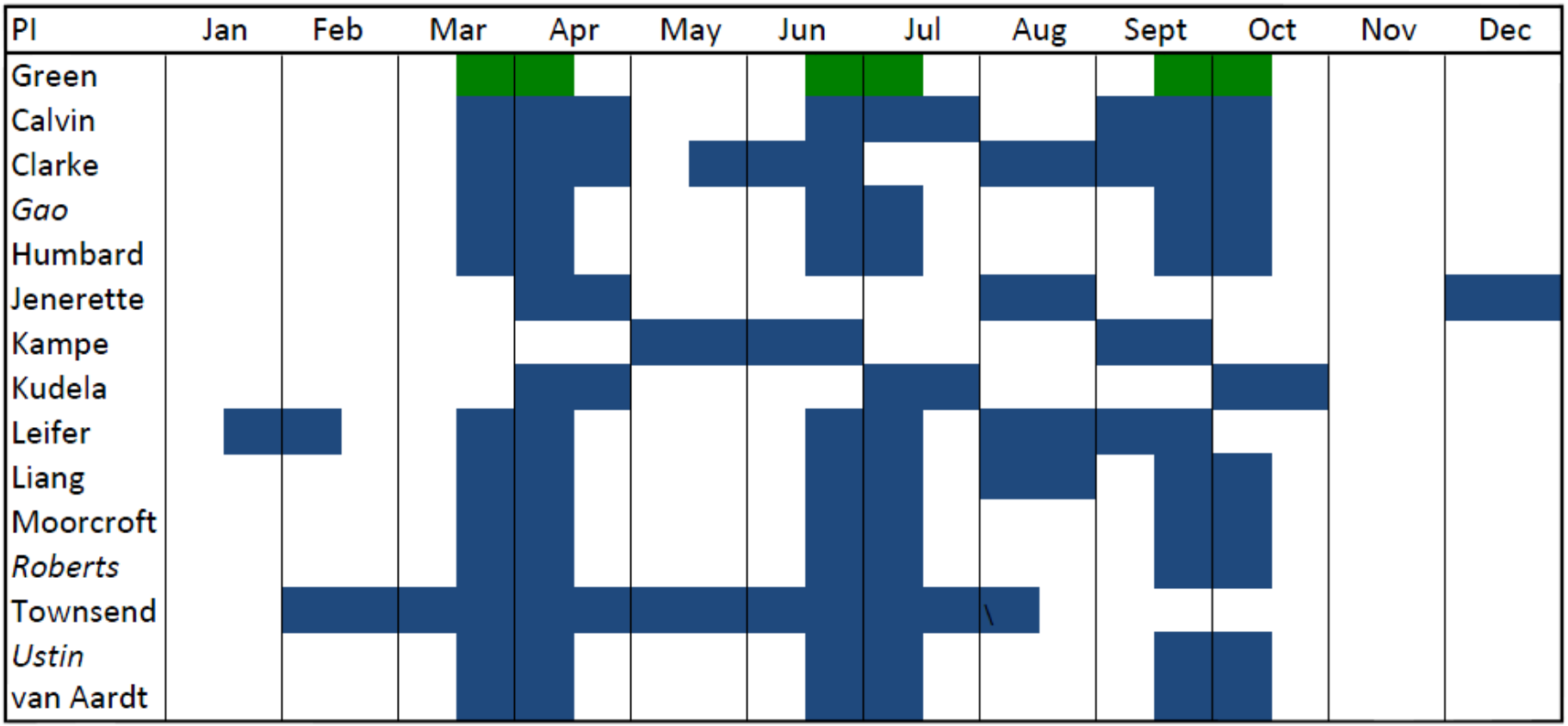
- Harvard/Paul Moorcroft - Linking Terrestrial Biosphere Models with Imaging Spectrometry Measurements of Ecosystem Composition, Structure, and Function
- UC Santa Barbara/Dar Roberts - HyspIRI discrimination of plant species and functional types along a strong environmental-temperature gradient
- UWI/Philip Townsend - Measurement of ecosystem metabolism across climatic and vegetation gradients in California for the 2013-2014 NASA AVIRIS/MASTER airborne campaign
- UC Davis/Susan Ustin - Identification of Plant Functional Types By Characterization of Canopy Chemistry Using an Automated Advanced Canopy Radiative Transfer Model
- Sonoma State/Matthew Clark - Spectral and temporal discrimination of vegetation cover across California with simulated HyspIRI imagery
- NRL/Bo-Cai Gao - Characterization and Atmospheric Corrections to the AVIRIS-Classic and AVIRISng Data to Support the HyspIRI Preparatory Airborne Activities
- USGS/Bernard Hubbard - Using simulated HyspIRI data for soil mineral mapping, relative dating and flood hazard assessment of alluvial fans in the Salton Sea basin, Southern California
- UC Riverside/George Jenerette - Assessing Relationships Between Urban Land Cover, Surface Temperature, and Transpiration Along a Coastal to Desert Climate Gradient
- NEON/Thomas Kampe - Synergistic high-resolution airborne measurements of ecosystem structure and process at NEON sites in California
- UC Santa Cruz/Raphael Kudela - Using HyspIRI at the Land/Sea Interface to Identify Phytoplankton Functional Types
- Bubbleology/Ira Leifer - Hyperspectral imaging spectroscopic investigation of California natural and anthropogenic fossil methane emissions in the short-wave and thermal infrared
- UMD/Shunlin Liang - Characterizing surface energy budget of different surface types under varying climatic conditions from AVIRIS and MASTER data
- RIT/Jan van Aardt - Investigating the impact of spatially-explicit sub-pixel structural variation on the assessment of vegetation structure from HyspIRI data
- UNV/Wendy Calvin - Energy and Mineral Resources: Surface composition mapping that identifies resources and the changes and impacts associated with their development

HyspIRI Preparatory Airborne Science
(Ecosystems, Seasonal, Climate, Coastal, Urban, Resources)

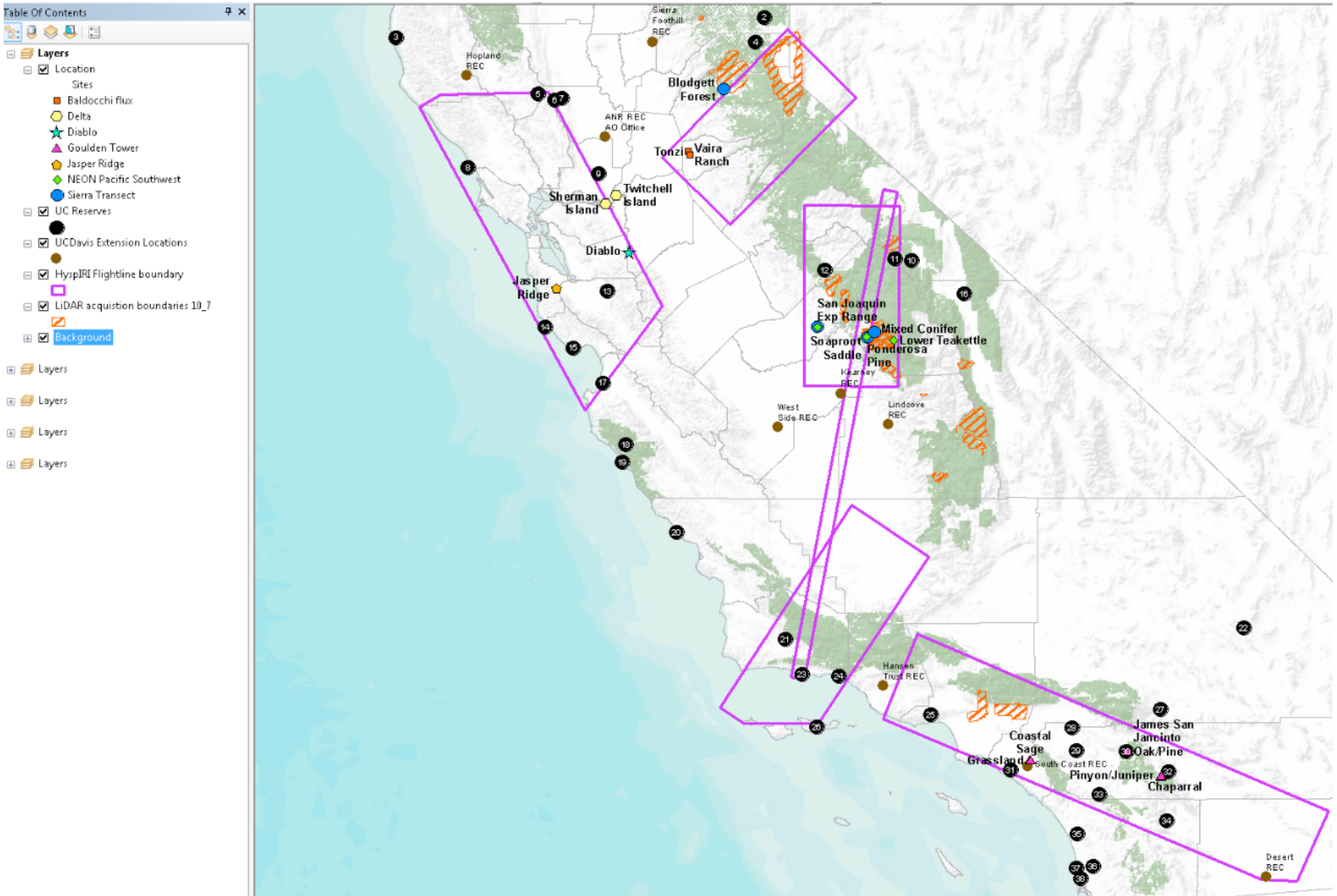




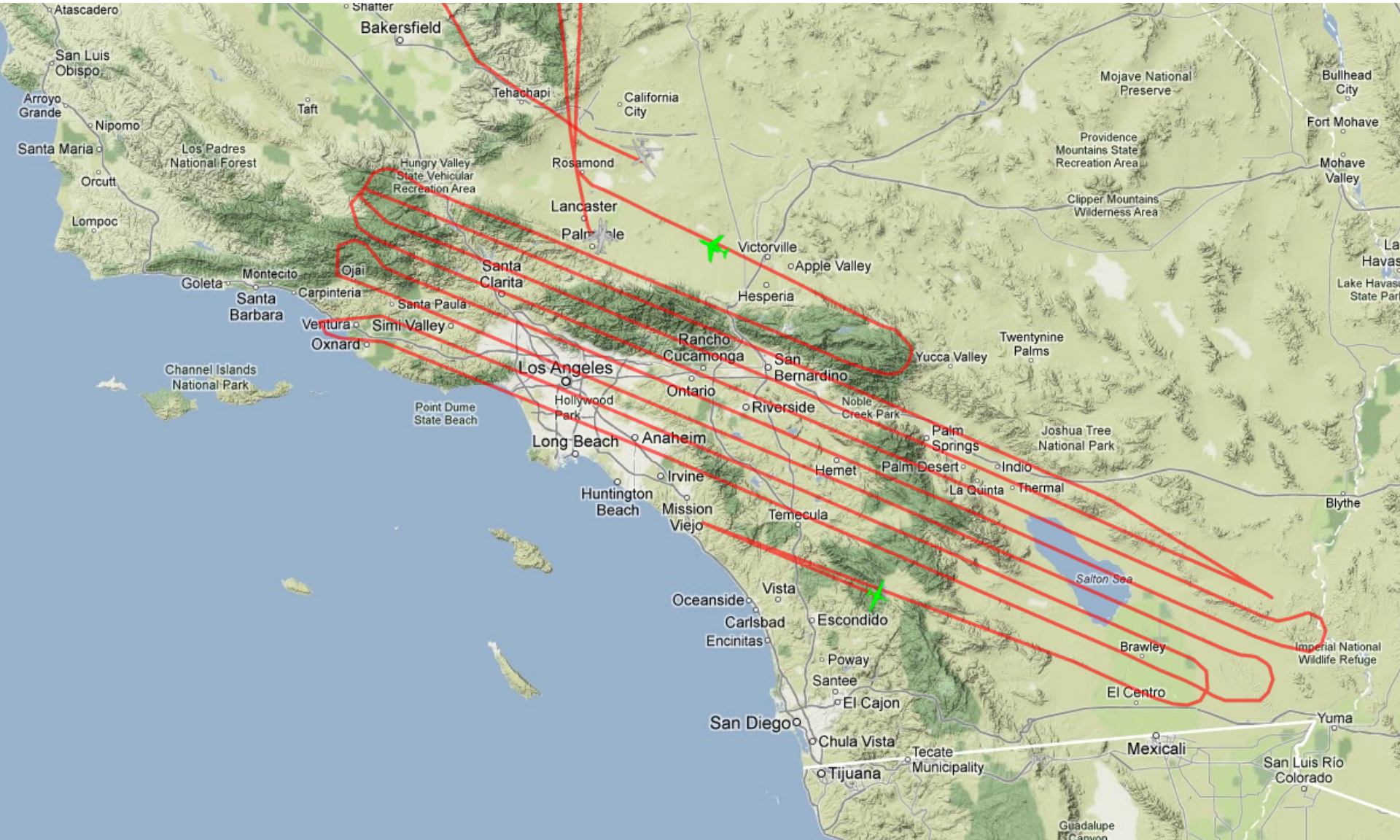
Approximate Timing



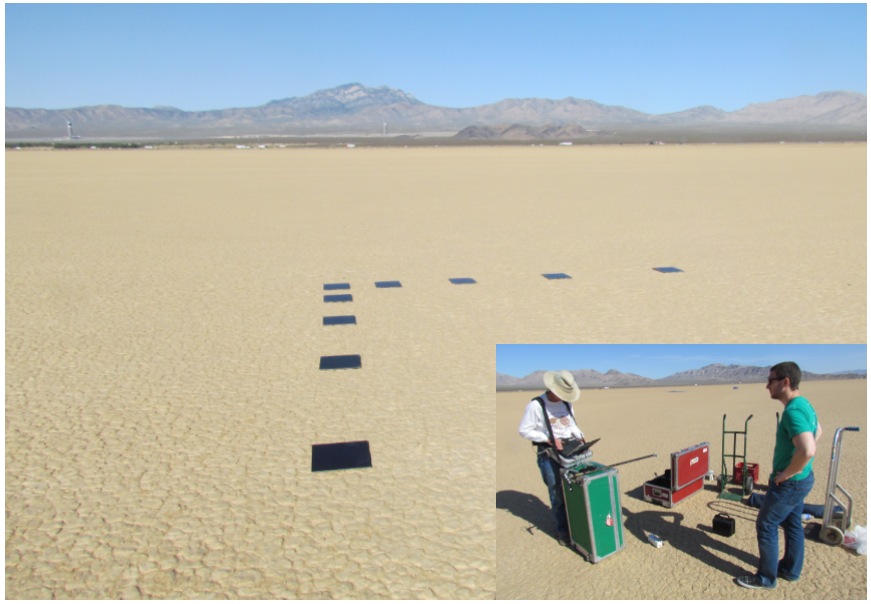
Infrastructure location



HyspIRI Preparatory Science
Flight 22 May 2013

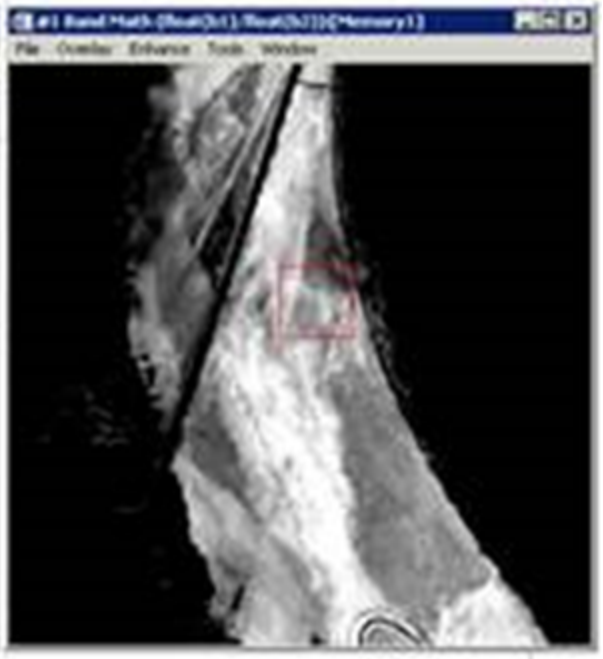


Example AVIRIS Calibration Validation Experiment
Ivanpah Playa Calibration Site 2012

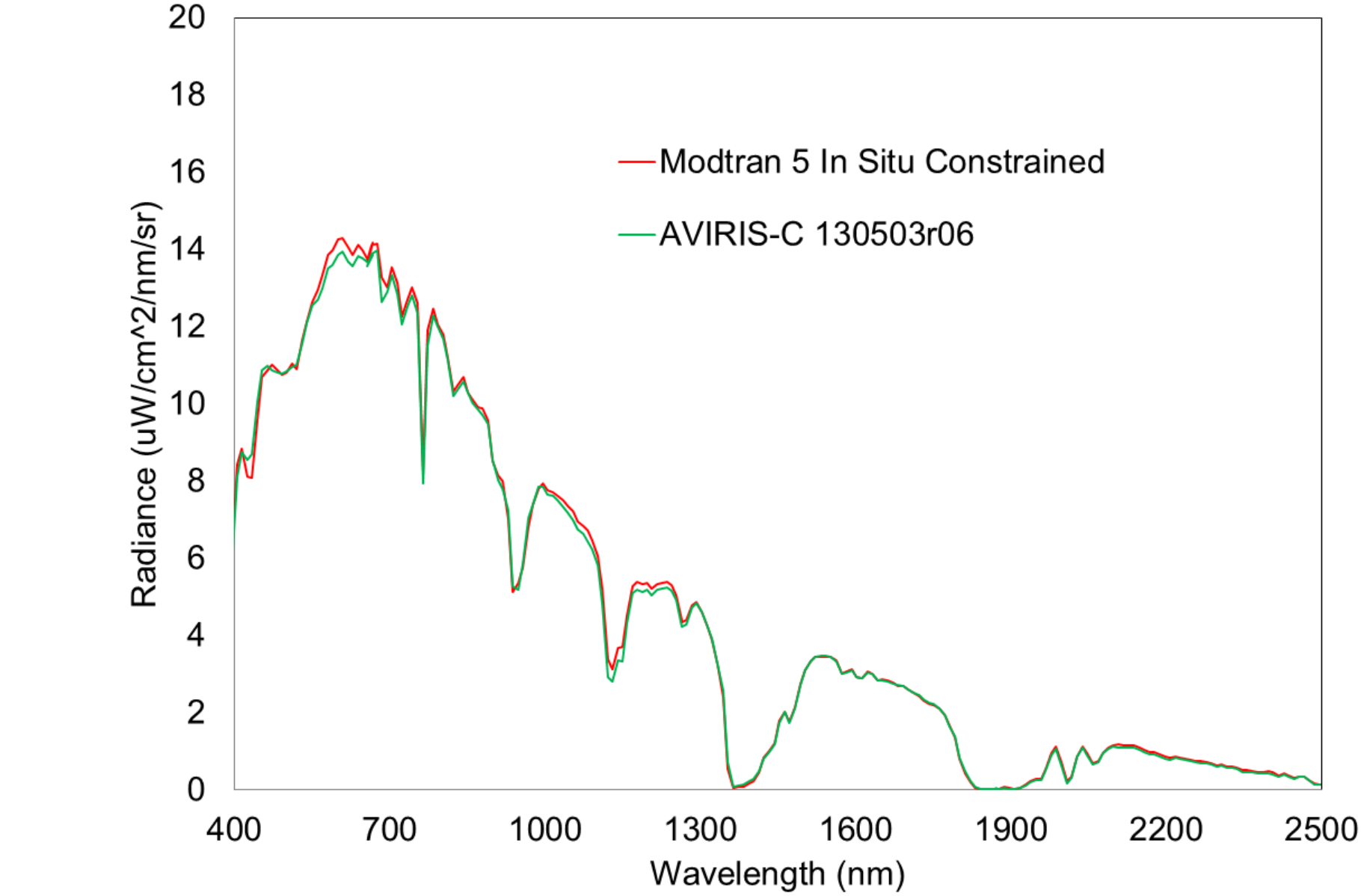


AVIRIS-C Calibration Experiment 3 May 2013

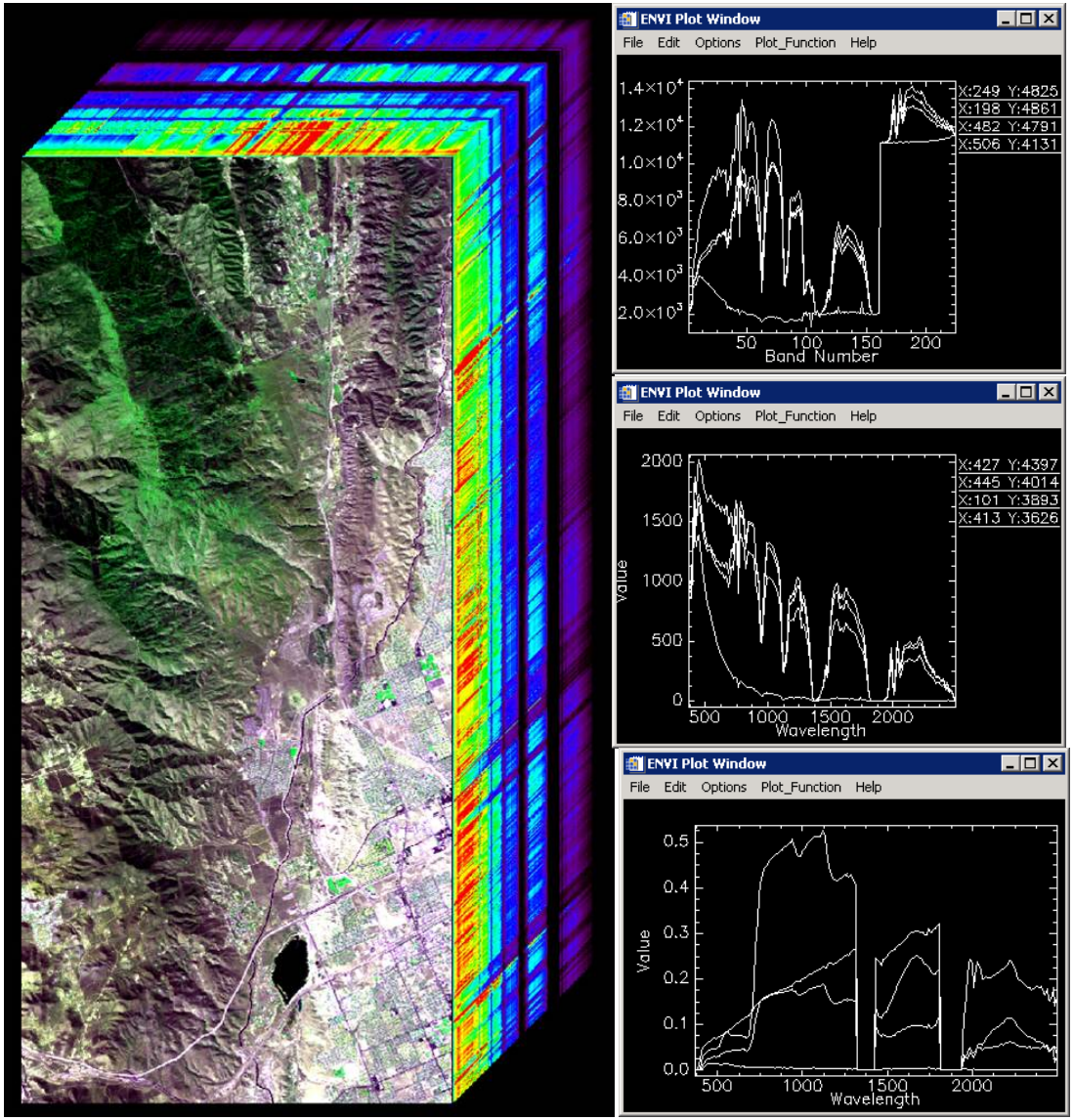
Ivanpah Tarp Location 130503



Preliminary Results 3 May 2013 HyspIRI Preparatory Campaign



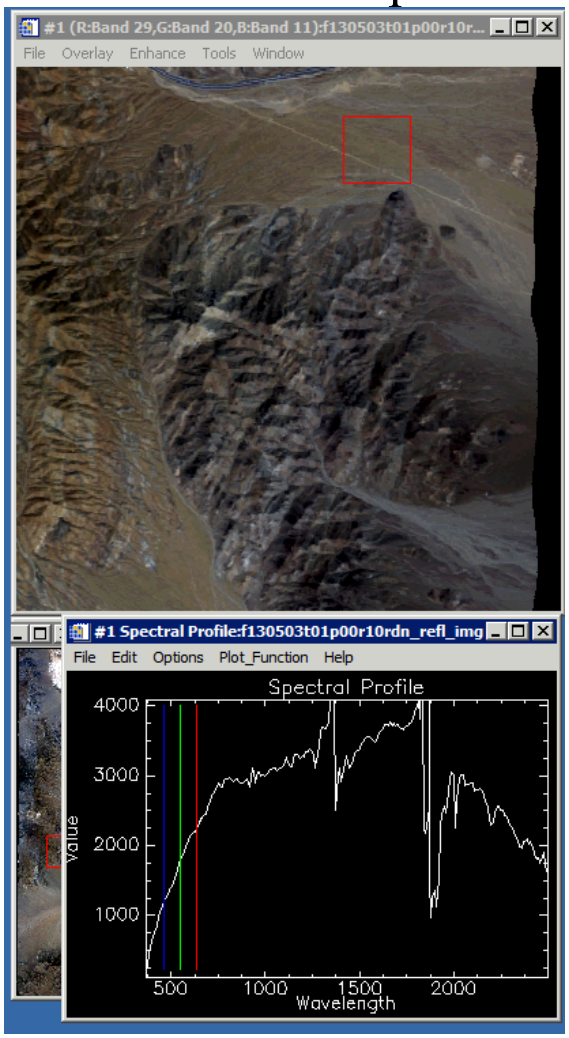
HyspIRI Airborne Campaign – First Flights March 29, 2013, Palmdale CA



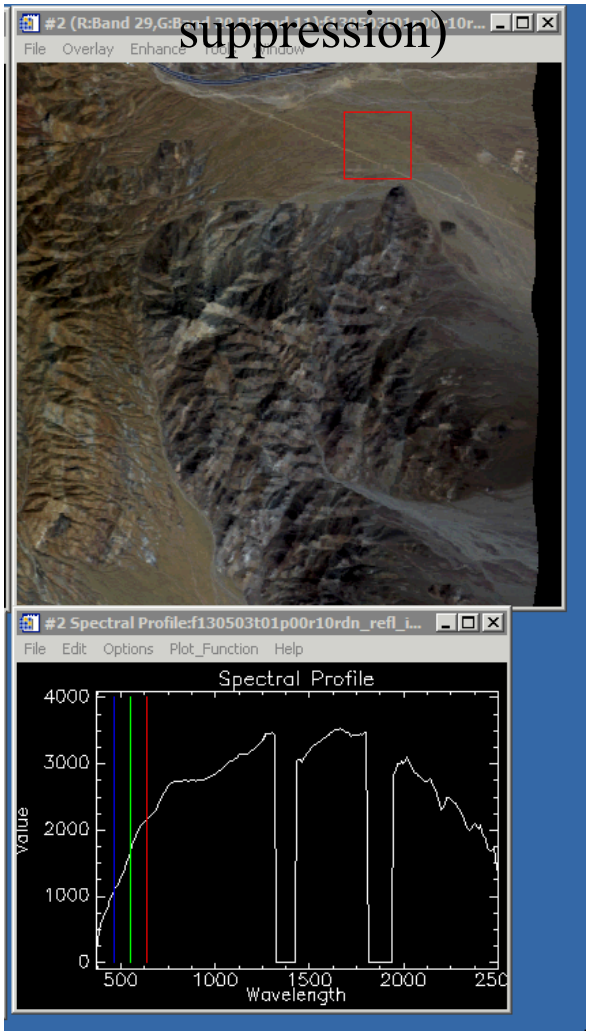
AVIRIS image cube and Level 1a, 1b and 2 spectra. The reflectance spectra (L2) will be used to address the full range of science objectives including ecosystems and climate.

F130503t01p00r10 (typical spectrum)

ATREM output

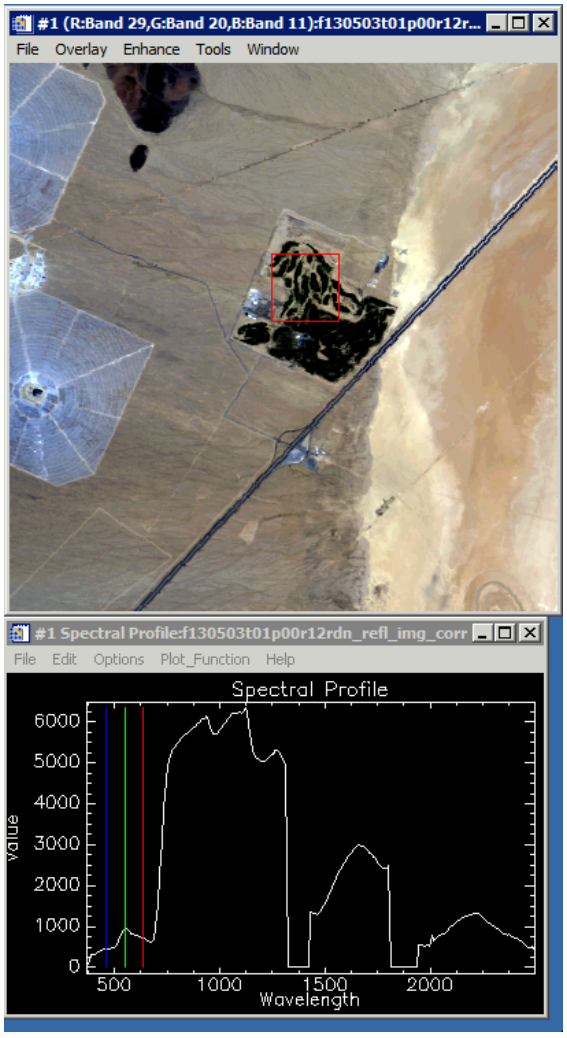


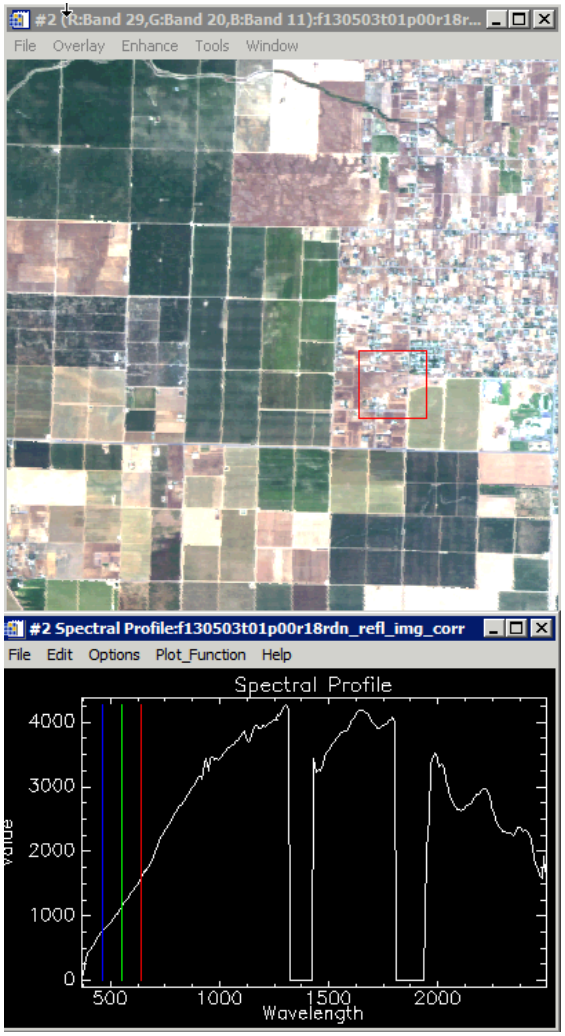
Final L2 product (after residual suppression)

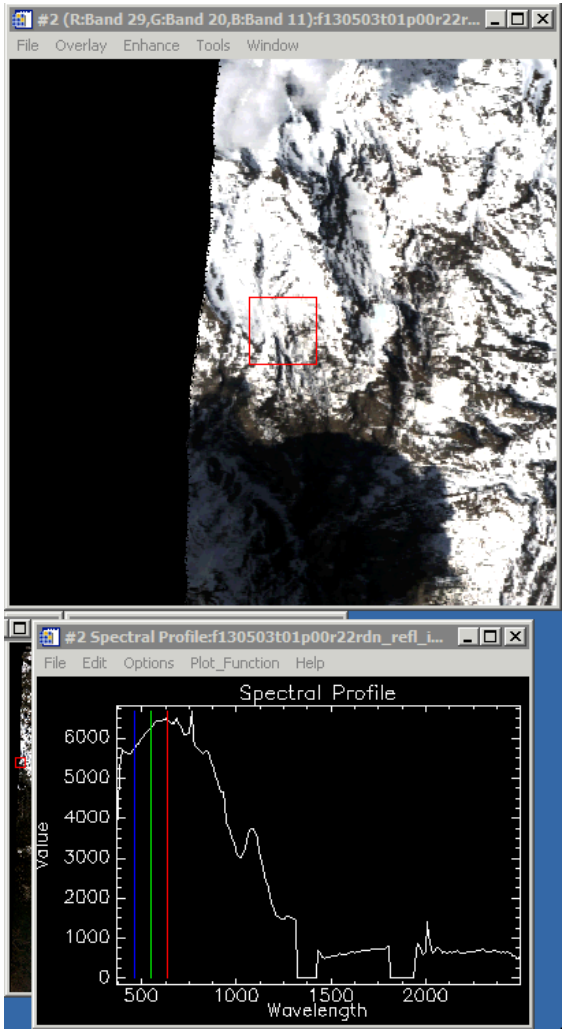


Vegetation (f130503t01p00r12)

Final L2 product (after residual suppression)

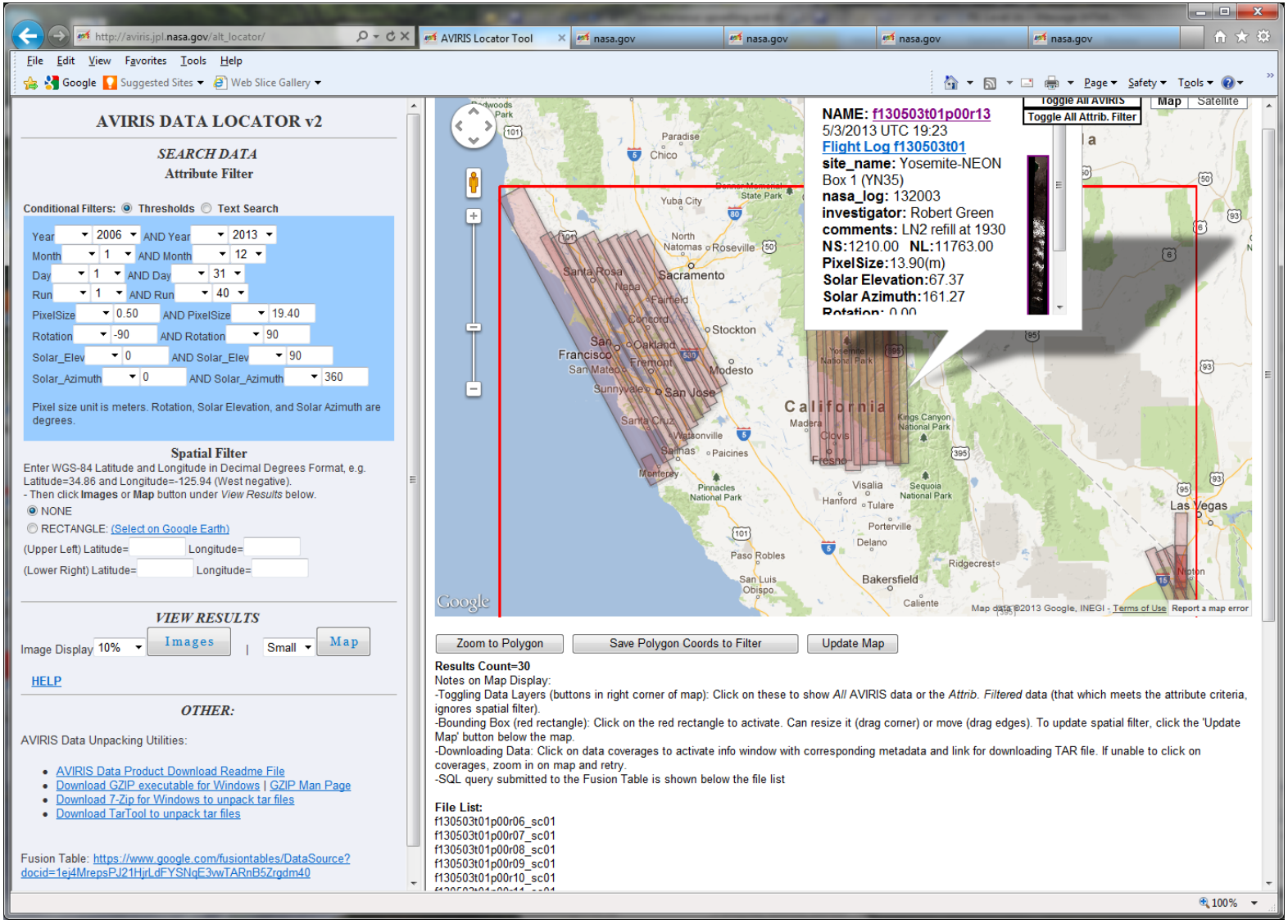




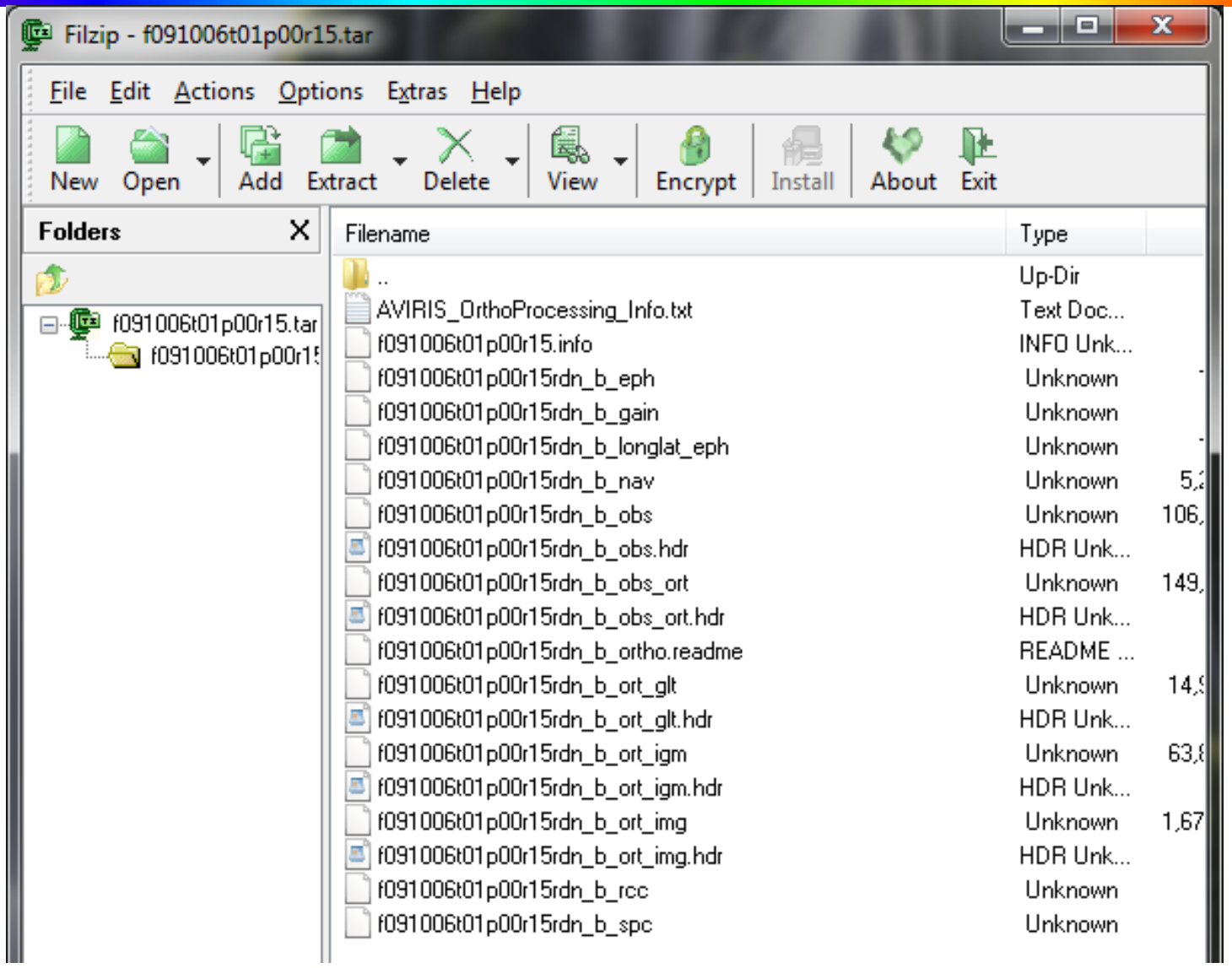


AVIRIS Locator/Download Tool
L1b Radiance

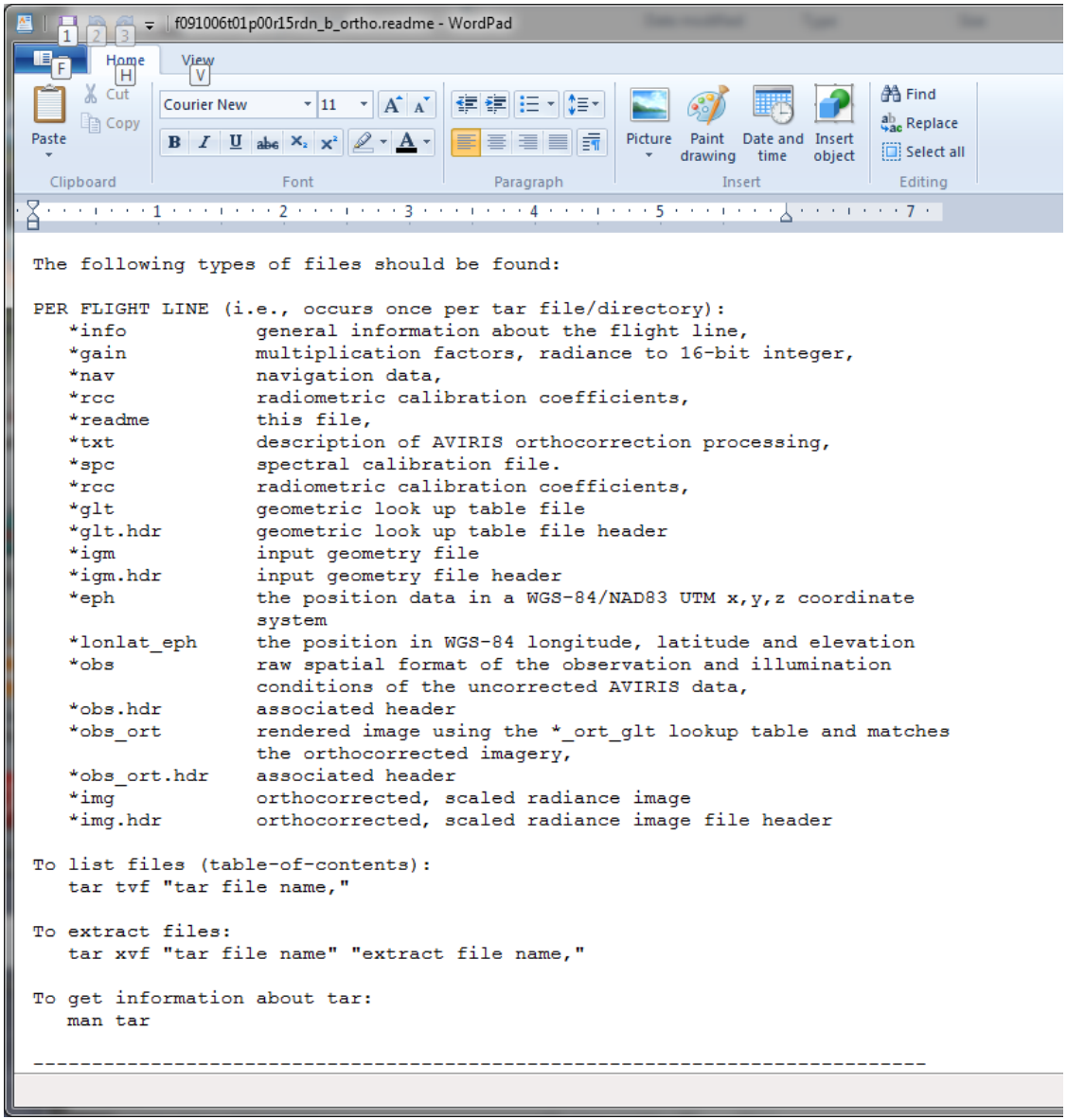
- http://aviris.jpl.nasa.gov/alt_locator



Contents of an AVIRIS tar file

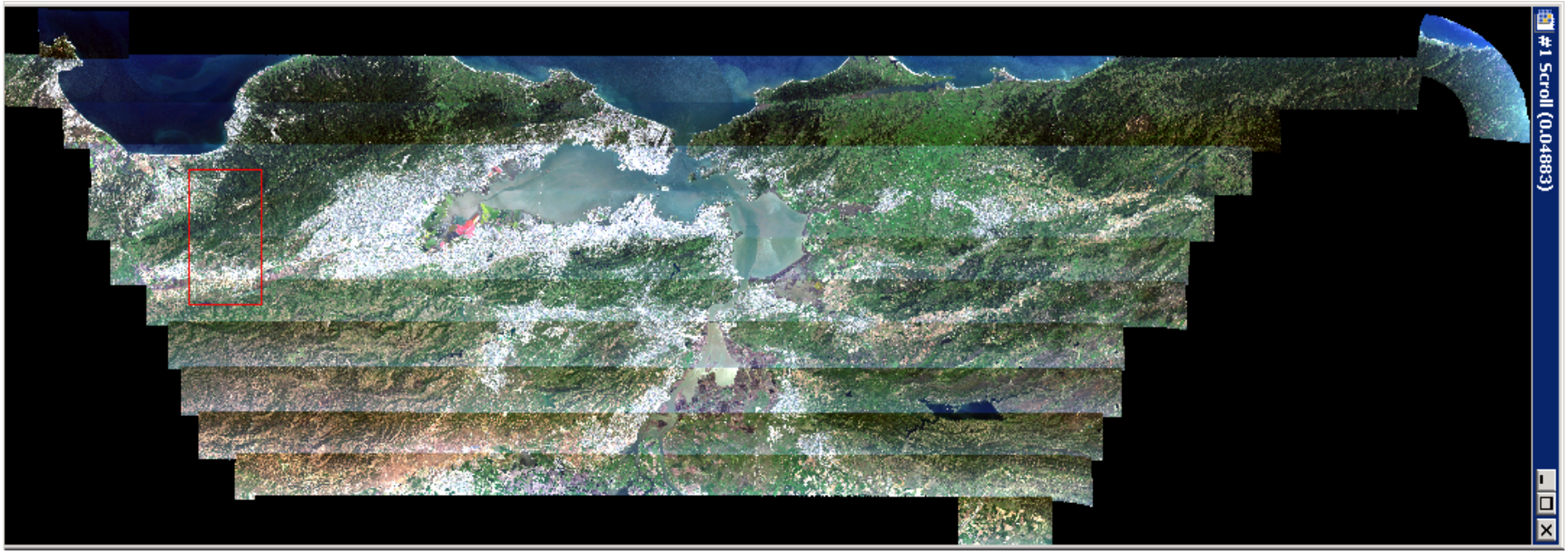


Readme File

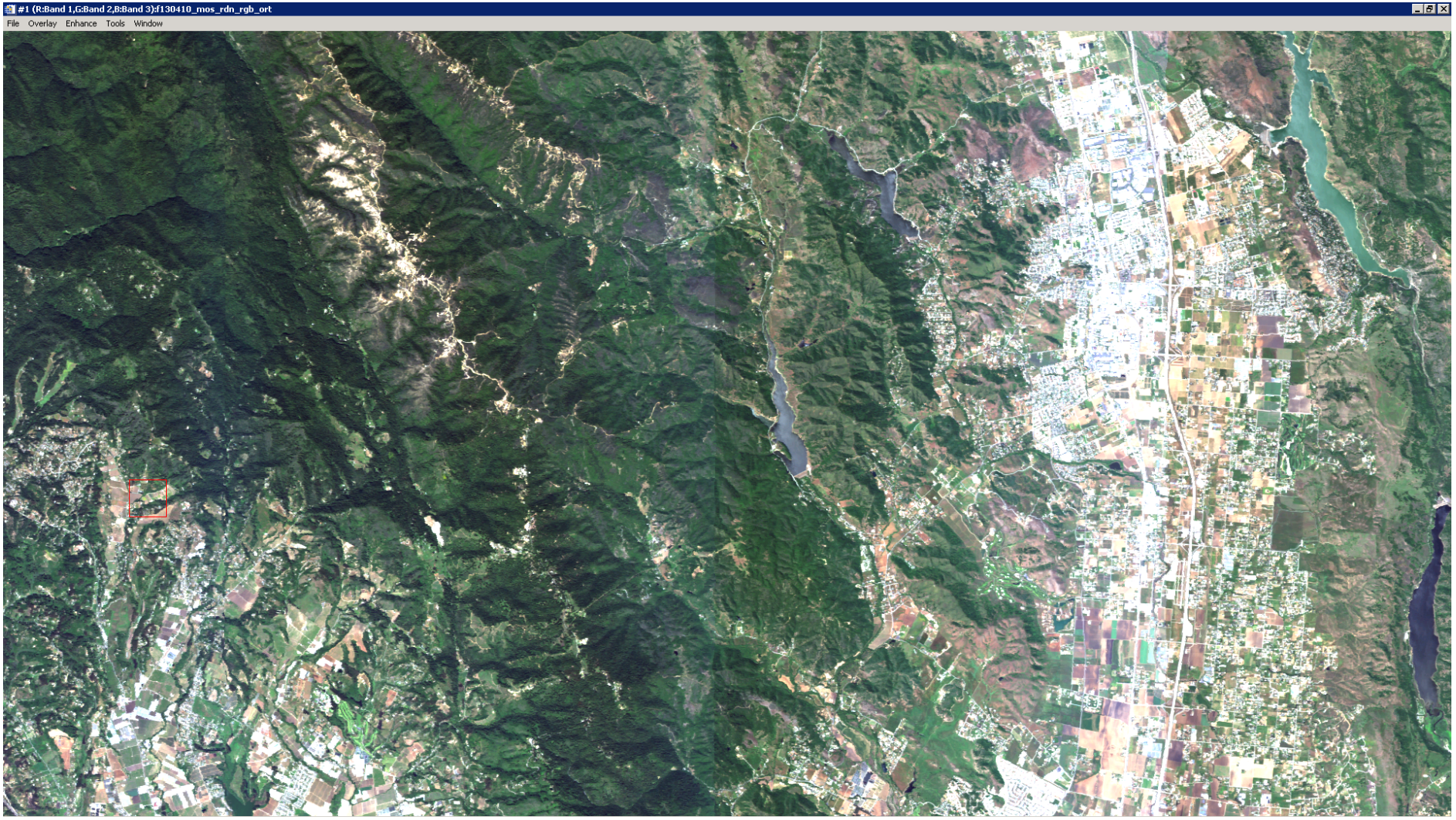



```
The following types of files should be found:

PER FLIGHT LINE (i.e., occurs once per tar file/directory):
   *info           general information about the flight line,
   *gain           multiplication factors, radiance to 16-bit integer,
   *nav            navigation data,
   *rcc            radiometric calibration coefficients,
   *readme         this file,
   *txt            description of AVIRIS orthocorrection processing,
   *spc            spectral calibration file.
   *rcc            radiometric calibration coefficients,
   *glt            geometric look up table file
   *glt.hdr        geometric look up table file header
   *igm            input geometry file
   *igm.hdr        input geometry file header
   *eph            the position data in a WGS-84/NAD83 UTM x,y,z coordinate
                   system
   *lonlat_eph     the position in WGS-84 longitude, latitude and elevation
   *obs            raw spatial format of the observation and illumination
                   conditions of the uncorrected AVIRIS data,
   *obs.hdr        associated header
   *obs_ort        rendered image using the *_ort_glt lookup table and matches
                   the orthocorrected imagery,
   *obs_ort.hdr    associated header
   *img            orthocorrected, scaled radiance image
   *img.hdr        orthocorrected, scaled radiance image file header

To list files (table-of-contents):
   tar tvf "tar file name,"

To extract files:
   tar xvf "tar file name" "extract file name,"

To get information about tar:
   man tar

--------------------------------------------------------------------------------
```

Mosaic Tool



Portion of a Mosaic



AVIRIS-C Summary

- Successful collection the first season of the HyspIRI preparatory airborne campaign
- A calibration/validation experiment was held on the 3rd of May
- Level 1b data are being loaded into the AVIRIS locator/download tool
- Test Level 2 data well be added to the tool starting next week
- We replaced the on-board calibrator bulb on AVIRIS yesterday
  - It should last for 2-3 years
- Summer season AVIRIS measurements for the HyspIRI preparatory airborne campaign have begun.

Initial science results of the NASA MAGI airborne instrument: Implications for environmental studies using HysplRI data

[1]Ramsey, M.S., [2]Tratt, D.M., [2]Hall, J.L., and [1]Reath, K.A.

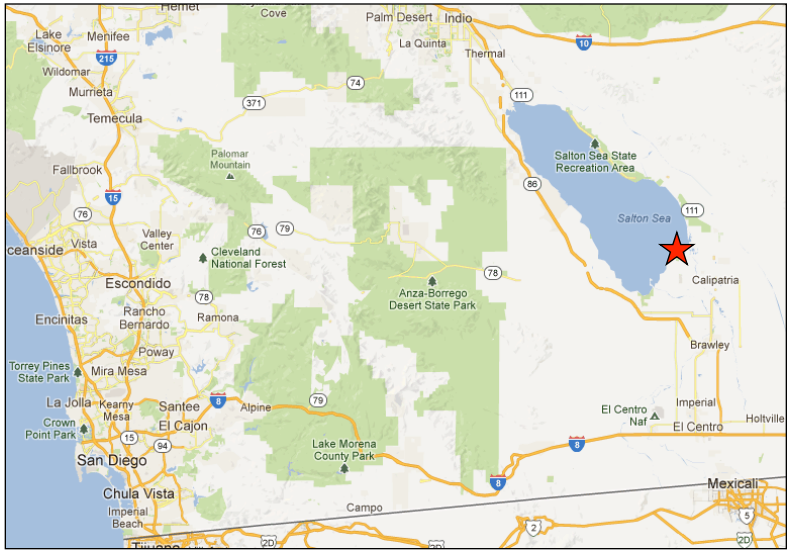
[1]Department. of Geology and Planetary Science
University of Pittsburgh, Pittsburgh, PA, USA

[2]Space Science Applications Laboratory
The Aerospace Corporation, Los Angeles, CA, USA

2013 HysplRI Science Symposium
GSFC, MD (29 – 30 May 2013)

Overview

- **Salton Sea Geothermal Field (SSGF)**
  - geology and geothermal presence
  - prior TIR remote sensing results
- **MAGI Instrument**
  - brief background/specification
- **Data/Results**
  - data processing flow
  - Anomalies observed in the data
  - mineral identification at recently-exposed geothermal sites
- **Summary**
  - implications for environmental conditions and geothermal prospecting in the future with HysplRI



Salton Sea Geothermal Field

- **Rationale**
  - prime geologic, thermal and logistical target
    - mineralogical diversity
    - exposed geothermal targets
    - accessibility
  - environmental target
    - lowering of the water level >1m in the last decade
      - exposed high saline deposits
      - fish die offs
      - potential airborne particulates
        - » *impose respiratory health issues*

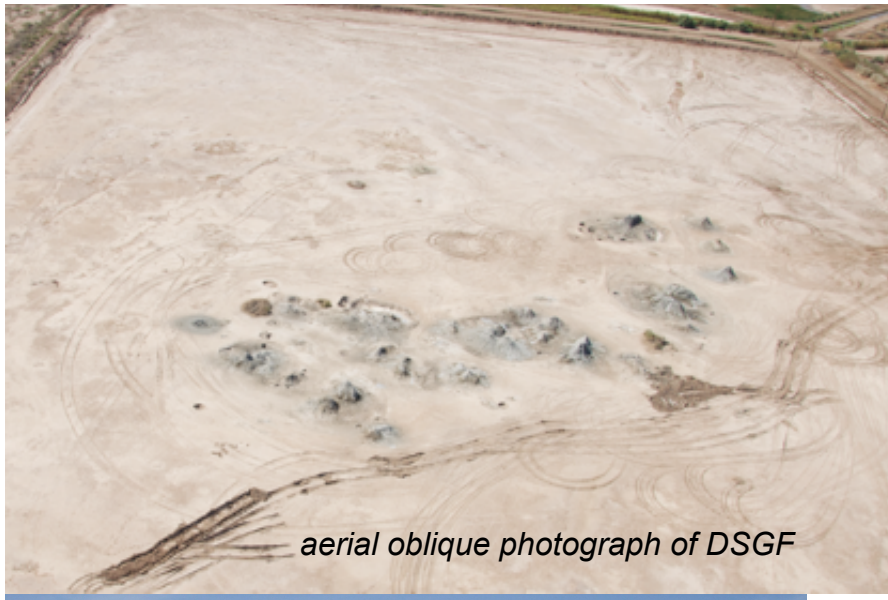
dead fish are common along the shoreline

Previous Work

- **Davis-Schrimpf Geothermal Field (DSGF)**
  - inland, lower temperatures and surface activity
    - ➢ mainly small mud volcanoes (gryphons) and warm springs
    - ➢ target of mineral mapping using SEBASS data
      - able to document subtle changes in sulfate mineralogy
      - precursory study for MAGI data

[Reath, 2011]

[Reath & Ramsey, 2013]

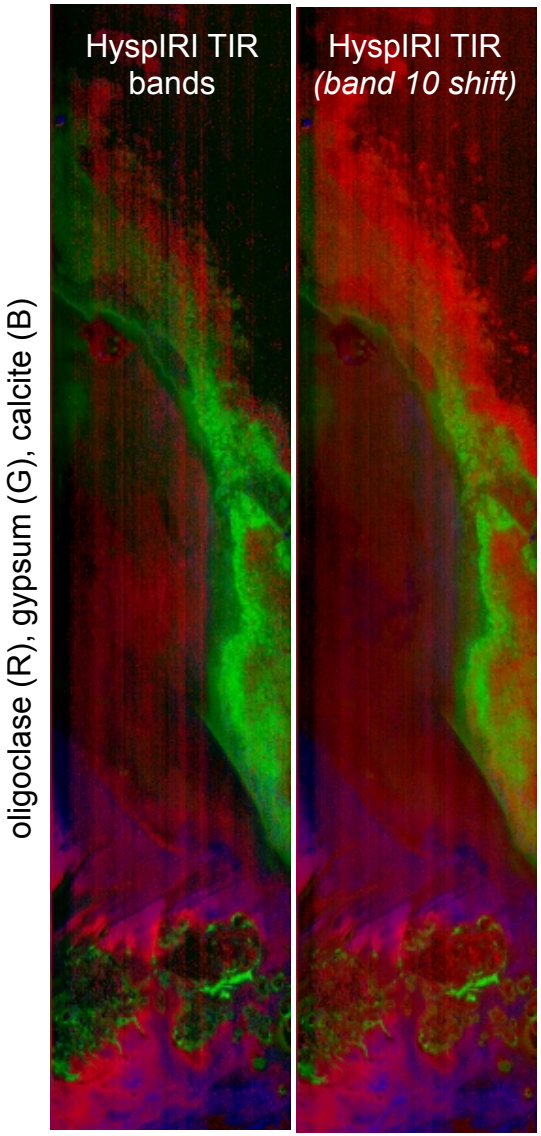


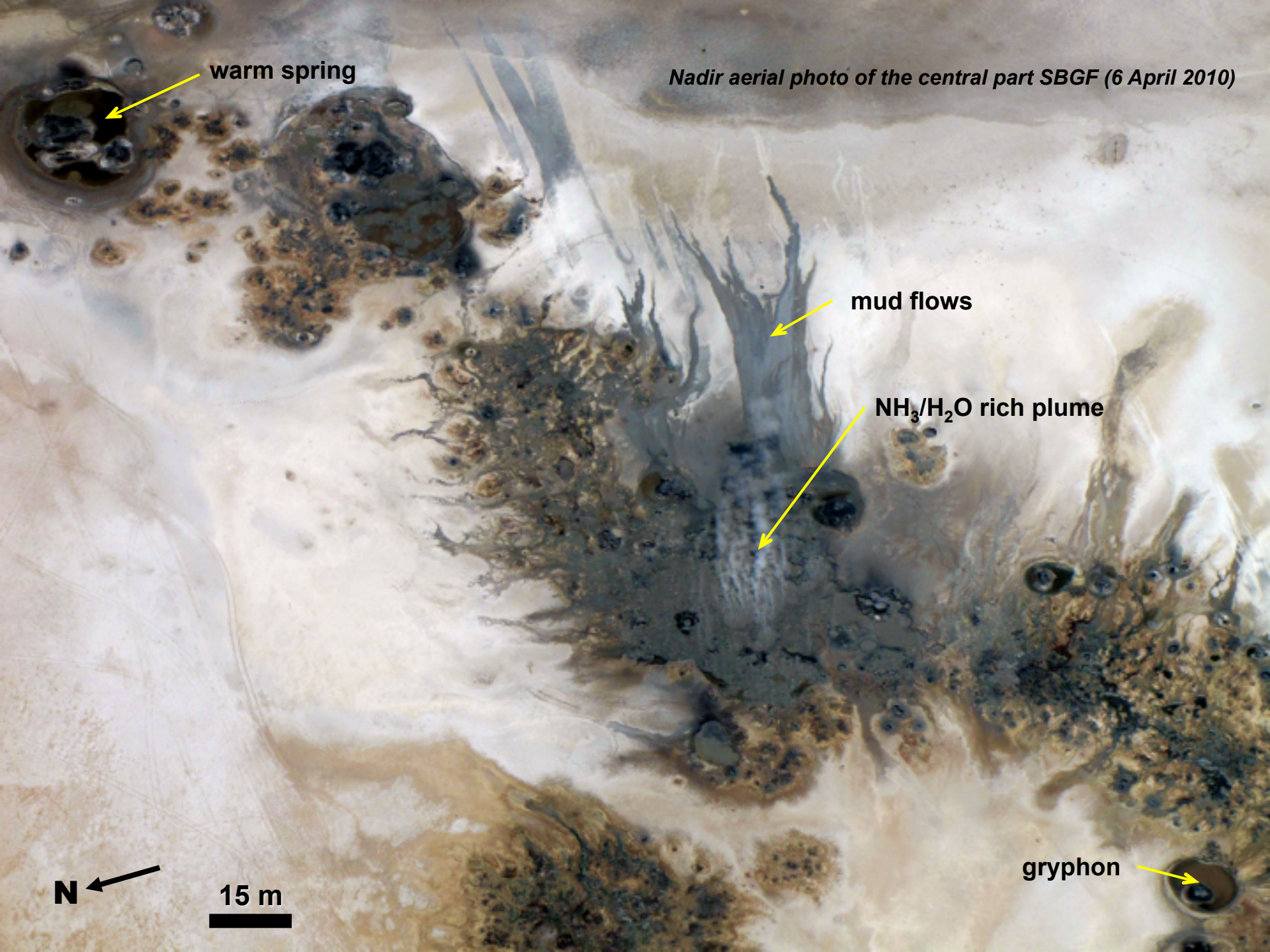
aerial oblique photograph of DSGF

gryphon and warm spring (K. Reath)

Previous Work

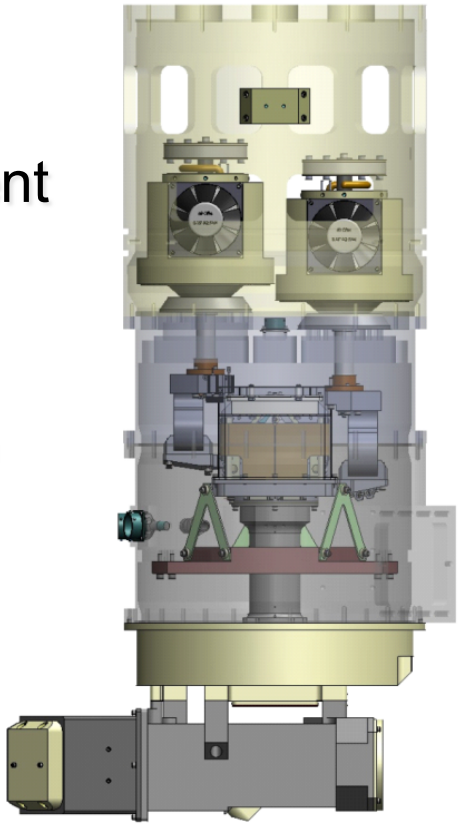
- **Sandbar Geothermal Field (SBGF)**
  - subaqueous in the past
  - recently exposed with lowering sea levels
  - higher temperatures and surface activity
    - ➢ vigorous gryphons, mud flows and warm springs
    - ➢ target of SEBASS mineral mapping
      - study effects of moving HyspIRI TIR band positions *[Ramsey, 2012]*




warm spring
Nadir aerial photo of the central part SBGF (6 April 2010)
mud flows
NH_3/H_2O rich plume
gryphon
N
15 m

Instrument Details

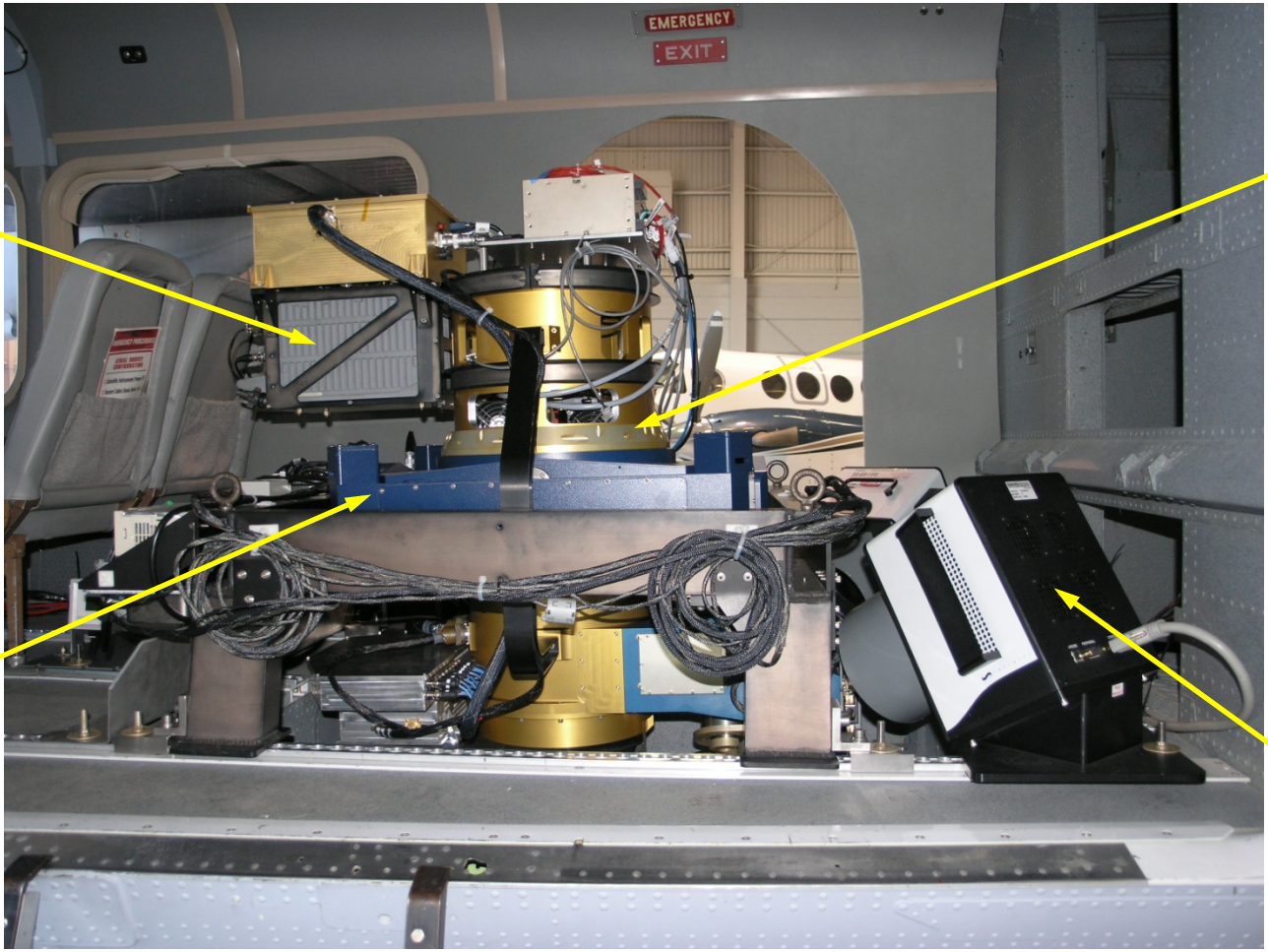
- **MAGI (Mineral And Gas Identifier) ***
  - airborne demonstrator sensor designed to support post-HyspIRI technology development
    - PI: Jeff Hall (Aerospace)
  - one of two airborne Instrument Incubator Program (IIP) IR instruments funded in 2009
  - thermal IR region (7.1 – 12.7 micron)
    - 32 spectral channels
  - 2m ground sampling from 12,000 ft AGL
  - five validation targets occurred in Dec. 2011
    - *included Coso (CA), Cuprite (NV), Salton Sea (CA), San Joaquin Valley (CA)*



CAD model of the MAGI sensor core showing the components

** see poster by Hall et al. for more details*

MAGI On The Twin Otter



Inertial Navigation System

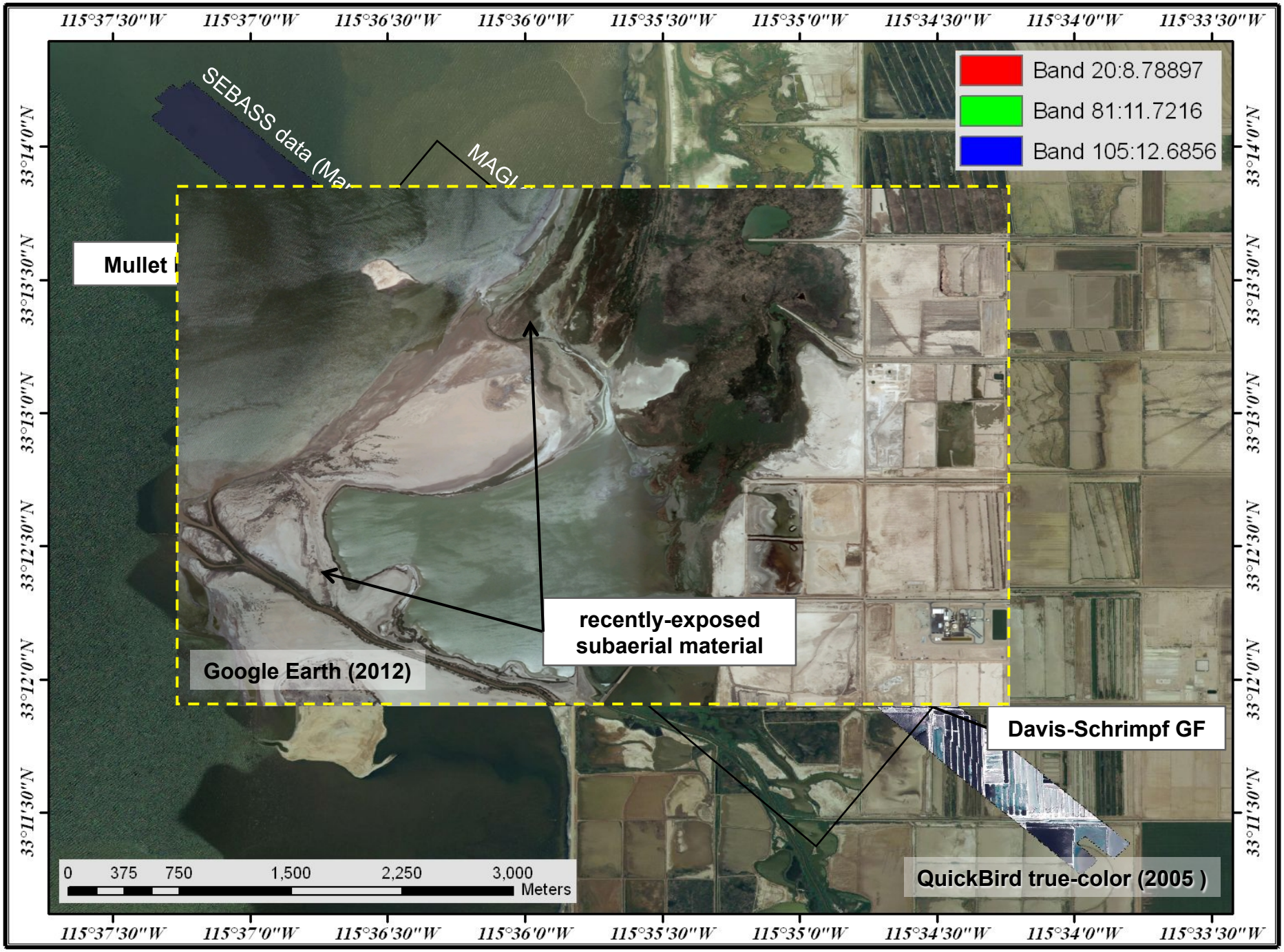
Three-Axis Stabilization Platform

Sensor

Calibration Blackbody

MAGI Flights

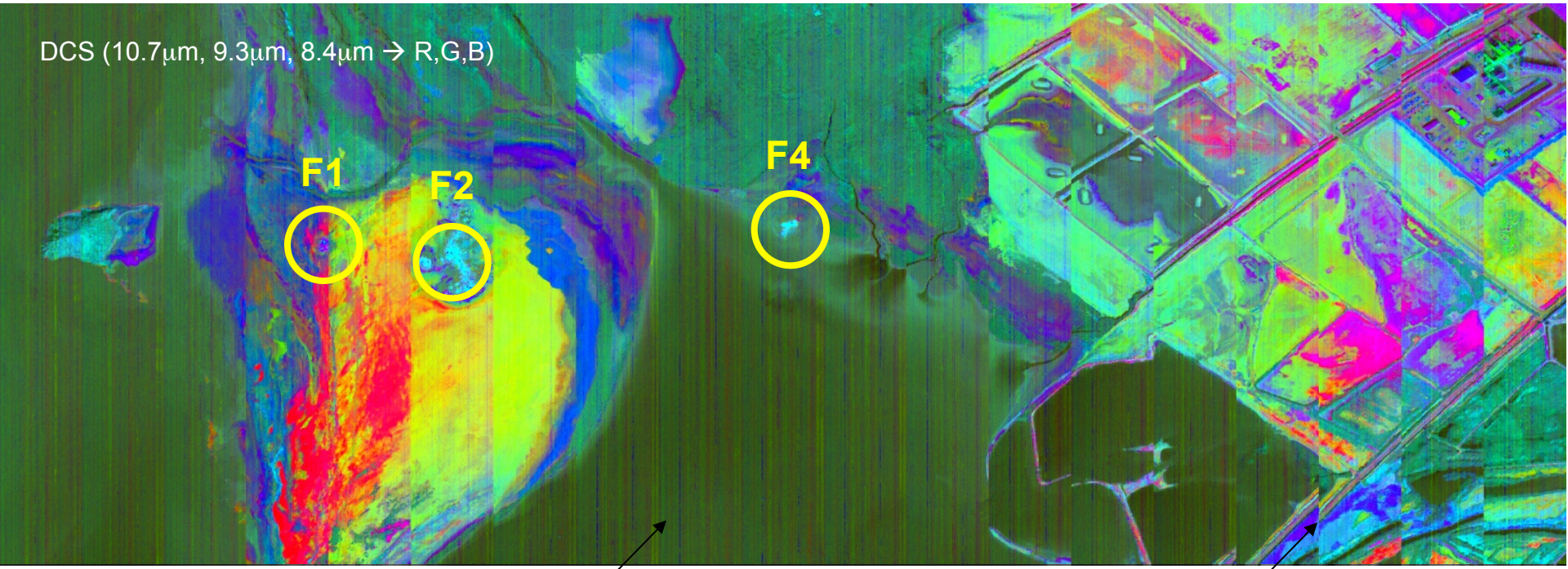
- **Salton Sea Geothermal Field**
  - 9 December 2011 at 13:44 local time
  - 10,000 ft (3 km) AGL → GSD ~ 1.6 m
  - post-processing
    - each whisk calibrated to radiance-at-sensor *(μW/cm^2/sr/μm)*
    - whisks mosaiced together
      - no corrections for whisk to whisk misregistration
    - atmospherically corrected using the In-Scene Atmospheric Compensation (ISAC) procedure *[Young et al., 2002]*
    - TE separation → emissivity normalization
    - spectral deconvolution → laboratory end-members
    - detectable scan line and bad pixel noise present
      - no corrections have been attempted for these as of yet


115°37'30"W
115°37'0"W
115°36'30"W
115°36'0"W
115°35'30"W
115°35'0"W
115°34'30"W
115°34'0"W
115°33'30"W
33°14'0"N
33°13'30"N
33°13'0"N
33°12'30"N
33°12'0"N
33°11'30"N
SEBASS data (Ma
MAGI
Band 20:8.78897
Band 81:11.7216
Band 105:12.6856
Mullet
recently-exposed subaerial material
Google Earth (2012)
Davis-Schrimpf GF
QuickBird true-color (2005)
0 375 750 1,500 2,250 3,000
Meters

MAGI data (Dec, 2011)
F1
F2
F4
sub-aerially exposed thermally-elevated zones (nomenclature of Lynch et al., 2013)

Mosaic Data

- T_{max} = 89.1°C (F2), 74.9°C (F4), 60.3°C (F1)
- decorrelation stretch (DCS) in general highlights
  - quartz-rich minerals (red), evaporite-rich minerals (green), clay-rich minerals (blue)

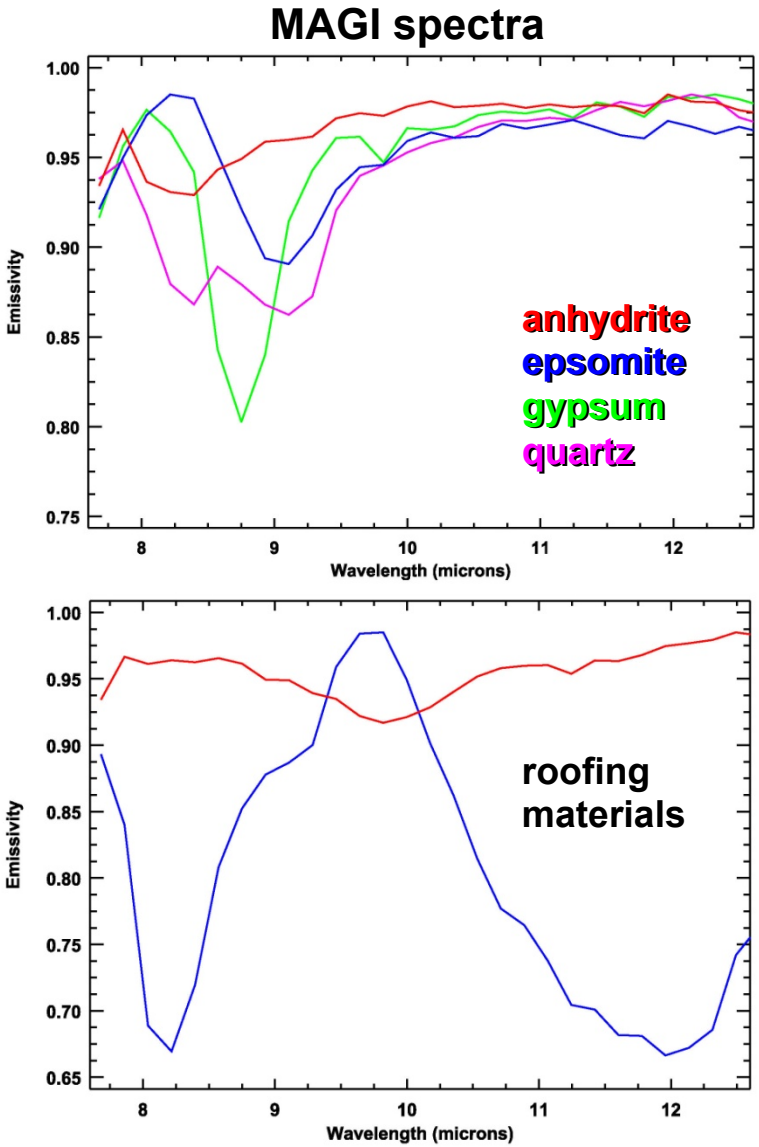


scan line noise accentuated by the DCS

whisk mosaic misregistration

Methods

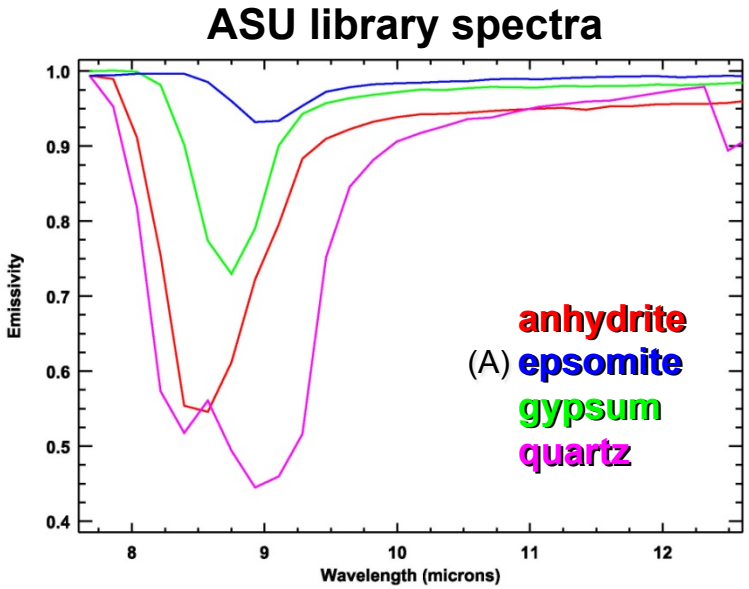
- **MAGI Emissivity Data**
  - spectral end-members identified visually and using ENVI's pixel purity index (PPI)
  - noted ~11 end-members that corresponded to known minerals:
    - evaporites: *anhydrite, calcite, gypsum, epsomite*
    - phyllosilicates: *talc, hectorite, Na-montmorillonite, nontronite*
    - silicates: *microcline, oligoclase, quartz*
  - several other unique signatures
    - roofing and industrial materials at geothermal power plant



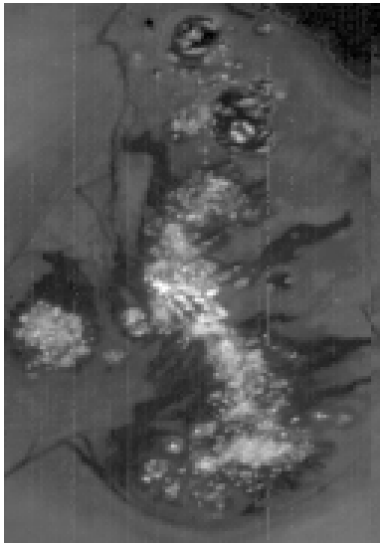
Methods

- **Mineral Identification**
  - spectral deconvolution approach

    [Ramsey and Christensen, 1998]
  - examined both image and library-based spectral end-members
    - work presented here is using library-based end-members

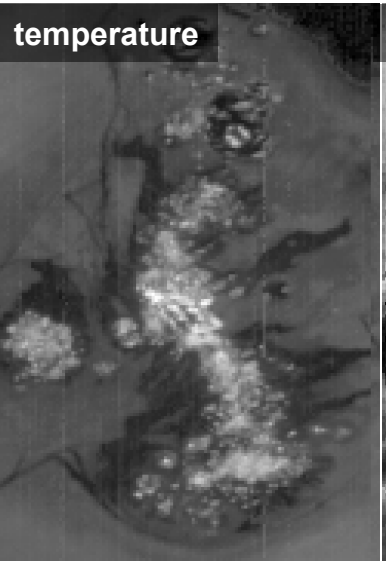


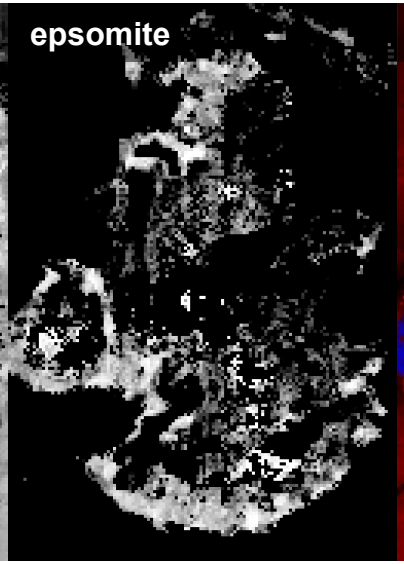
- **Temperature**
  - temperatures of the fumarole fields compared to mineral identification

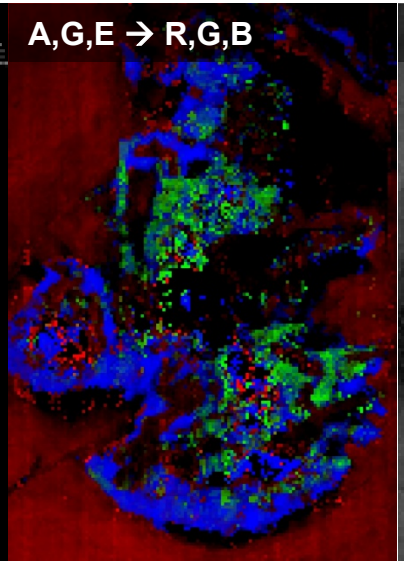


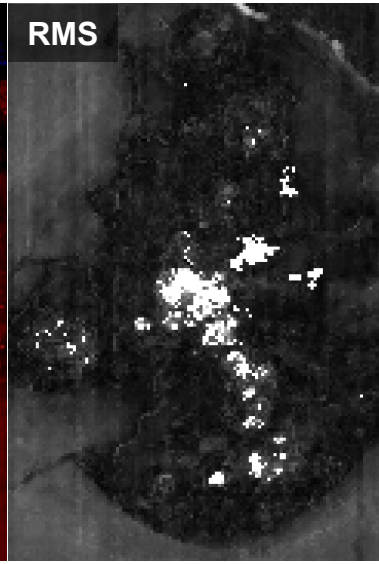
Initial Results

- **F2 Site**
  - "cores" of the active thermal features suffered from sub-pixel thermal mixing making identification difficult
  - progression of gypsum, epsomite, anhydrite from center to edges of the thermal features
    - ➢ indicate formation temperature ± dehydration reactions
      - e.g., gypsum dehydrates > 50°C

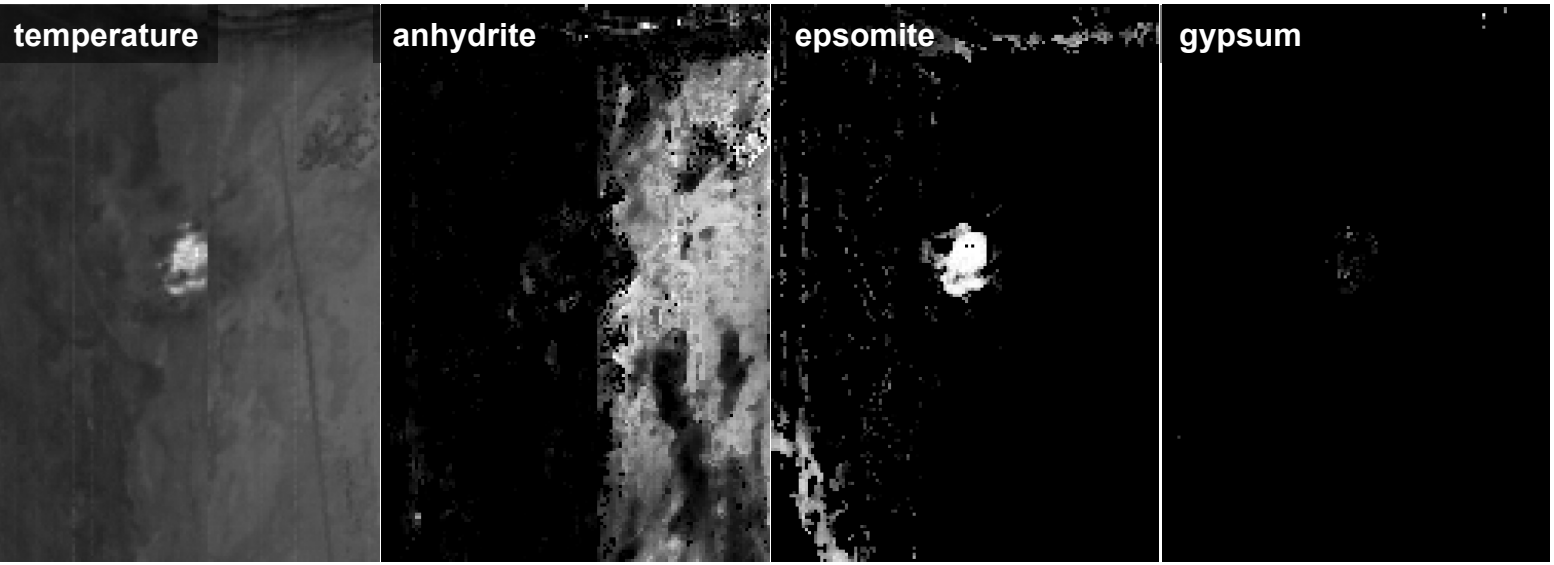




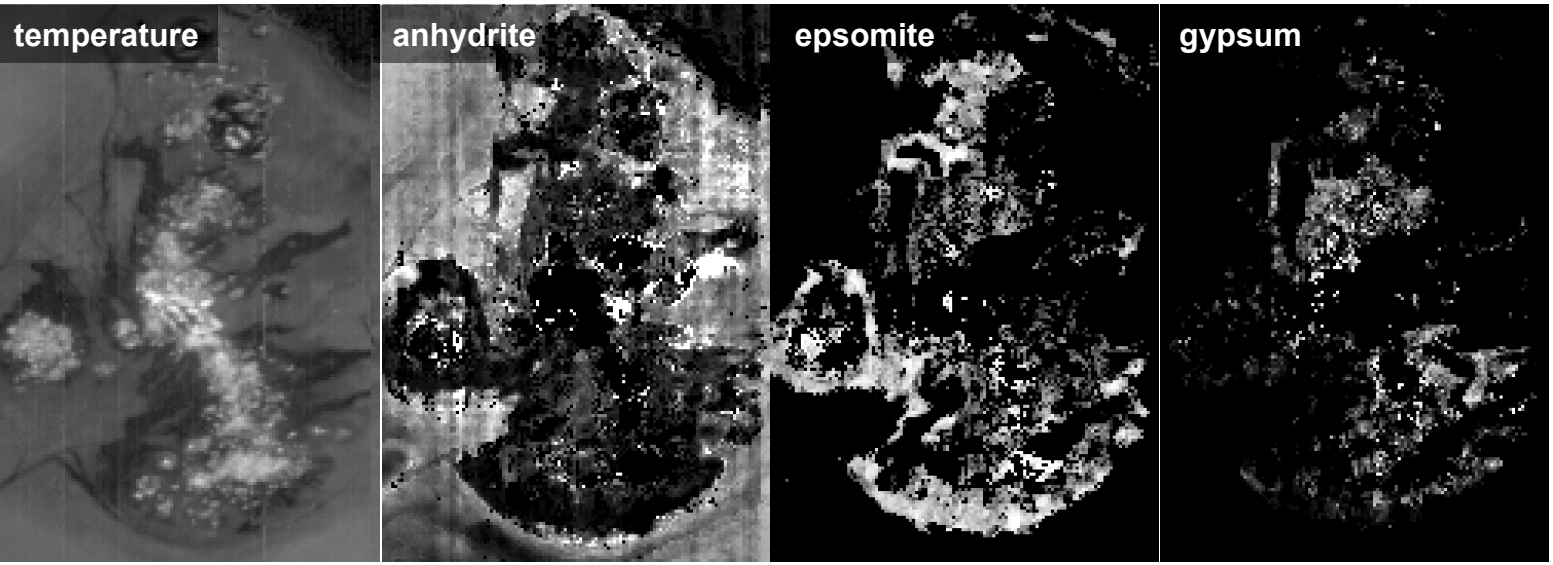




Initial Results



- **F1 site:**
  - T_{max} = 60.3 °C
  - ↓ gypsum
  - max = 31.9%
  - ↑ epsomite
  - max = 98.4%



- **F2 site:**
  - T_{max} = 89.1 °C
  - ↑ gypsum
  - max = 78.5%
  - ↓ epsomite
  - max = 49.1%

surface mineralogy moving away from F2 site *(left → right)*
(general progression from gypsum to epsomite to anhydrite to quartz/clay)

Conclusions

- **MAGI Data**
  - proving to be a well-calibrated dataset
  - spectral resolution sufficient for surface mineralogy
  - also identified NH_3 plumes *[see Hall et al. poster]*
  - noise clean up and whisk registration tools still required
  - other data sets currently under analysis

- **Salton Sea Geothermal Field (SSGF)**
  - diversity of thermal/compositional targets
  - general correlation of fumarole temperature and mineral formation temperature
  - lower sea level has exposed large land areas
    - mix of finer-grained quartz, clay, and evaporite minerals
      - could be easily mobilized by the wind

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Mapping and Modeling Neglected Tropical Diseases and Poverty in Brazil, Bolivia and Colombia

JB Malone, P Nieto, P Mischler, M Martins, JC McCarroll

Louisiana State University, USA

Penelope Vounatsou, Ronaldo Scholte

Swiss TPH, Switzerland

ME Bavia

Universidade Federal da Bahia, Brazil

HyspIRI Symposium, NASA Goddard Space Flight Center , May 29-30, 2013

Pan American Health Organization
Regional Office of the World Health Organization

Swiss TPH
Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

LSU

UFBA
UNIVERSIDADE NOVA

Objectives

- Data Portal – A resource data base accessible by FTP was developed for 6 NTD in Brazil, Bolivia and Colombia (Chagas disease, Leishmaniasis, Schistosomiasis, Leprosy, Lymphatic Filariasis and Soil-Transmitted Helminths), with relevant climatic, environmental, population and poverty data

- Risk Modeling – Maximum Entropy, Bayesian and GIS methodologies were used to map and model environmental and socioeconomic risk of 6 NTD

- Course Development – A 4-day short course was developed for training use by PAHO on data portal access and geospatial analysis using ArcGIS 9.3.1, Maximum Entropy (Maxent) and Bayesian modeling

Data Portal

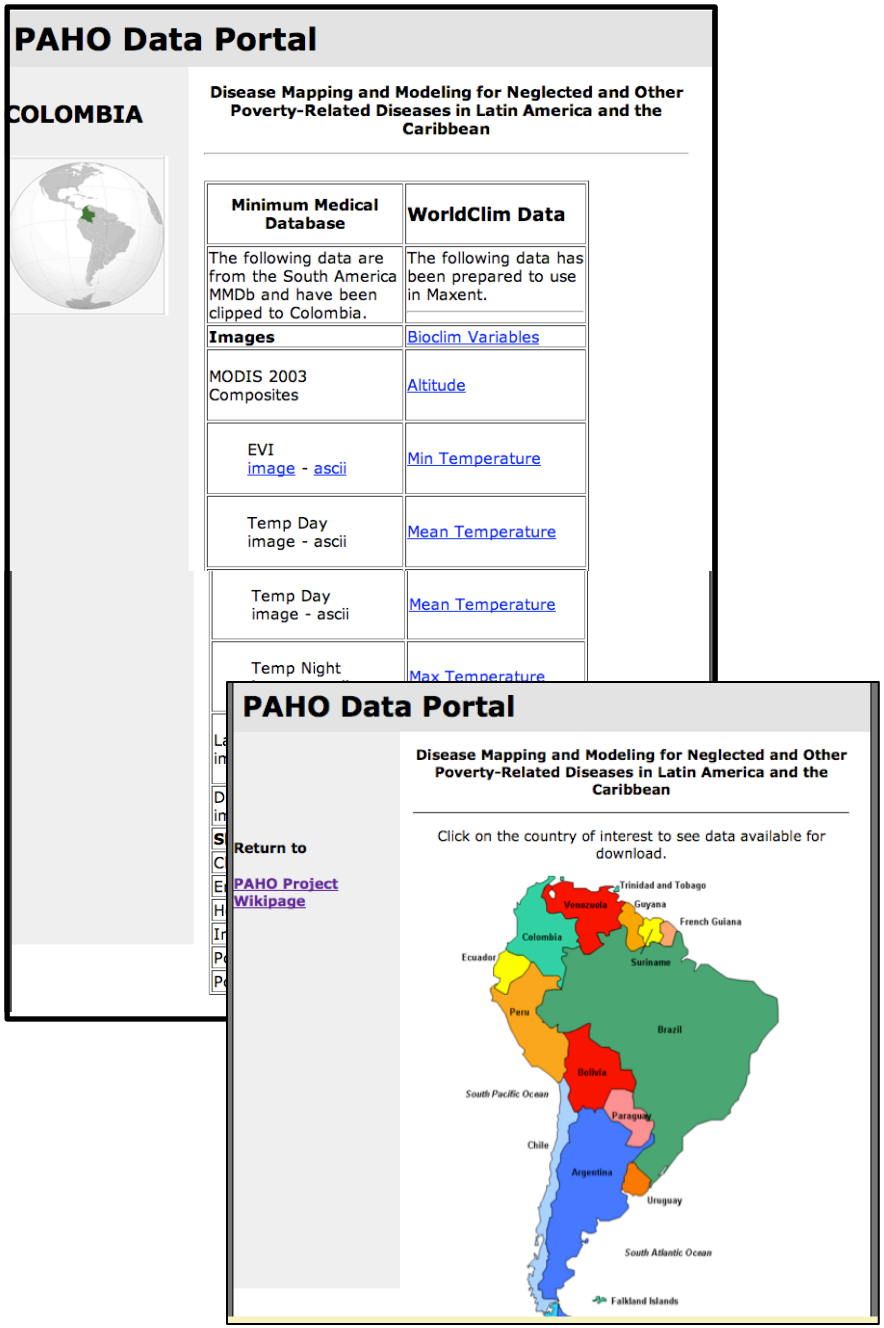
All data clipped to the country boundary; WGS84 projection, 1 km spatial resolution; in ASCII format for Maxent or Bayesian modeling

This example shows the data available for Colombia

Worldclim (global coverage, Ikm resolution) used for ecological Niche modeling and by the climate change community

MODIS EVI, LST annual composites for 2005-2009

Socioeconomic Data at the Municipality level



Worldclim Global Climate Data

Tmin, Tmax, Precip, SRTM, Bioclim – 1 km resolution

Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in ecological niche modeling (e.g., BIOCLIM, GARP).

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (P2/P7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (P5-P6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

Contents of Data Portal/FTP Site

MODIS

Mean annual composites for 2005-2009:
Enhanced Vegetation index (EVI), Normalized difference Vegetation Index (NDVI)
Land surface temperature (LST) day and night and dT

Climate GRID

Long term normal (LTN) climate grid (18x18 km cell size) – Precip, Tmax, Tmin, PET, PPE

Environmental

World Wildlife Fund Ecoregions
Locations of springs, dams, rivers, small streams

Health Data

Bolivia: Ministerio de Salud y Deportes/ Sistema Nacional de información en Salud
Brazil: Ministerio da Saude, SINAN
Colombia: Instituto Nacional de salud/Estadísticas de la Vigilancia en Salud Pública Ministerios de la protección Social (SIVIGILA) , literature reports.

Infrastructure

Roads, airfields/airports, rail road lines layer, utility lines

Political Boundaries

Counties, major cities, States/Departments, Municipalities

Socioeconomical Variables at Municipality Level Used for Risk Analysis of NTDs in Colombia

Area of municipality	Floors: carpet, marmol, hardwood, tablet	Garbage: in the river, stream, lake, lagoon
Displacement (just COL)	Floors: carpet, brick , vinyl,	Garbage: in another way
Population	Floors: cement	Drinking water from: running water service
Extension Km2	Floors: tough wood, other vegetal material	Drinking water from: well, pump
Human development index	Floors: soil, sand	Drinking water: rain fall
Unsatisfied basic needs * UBN	Walls: block, brick, stones, hardwood	Drinking water: public tank
Miseria (2 or more *UBN)	Walls: adobe, bahareque	Drinking water: car-tank
Un adequate housing * UBN	Walls: rough wood	Drinking water from: river, stream, lake , lagoon
Unsatisfied services* UBN	Wall: pre fabricated walls	Drinking water from: bottles, bag
Overcrowding * UBN	Walls: cane, bamboo, vegetal material	Infant mortality
Educational needs* UBN	Walls: zinc, fabric, cardboard, plastic	Life expectancy
Economical dependency*UBN	No walls	Attendance educational institution YES
Sewage	Electricity: yes	Attendance /educational institution NO
Running water	Electricity: no	
Toilet connected to sewage	Garbage collection services	
Toilet connected to septic tank	Burrow the garbage	
Latrine	Burn the garbage	
No sanitary service	Garbage: patio, back yard, ditch	

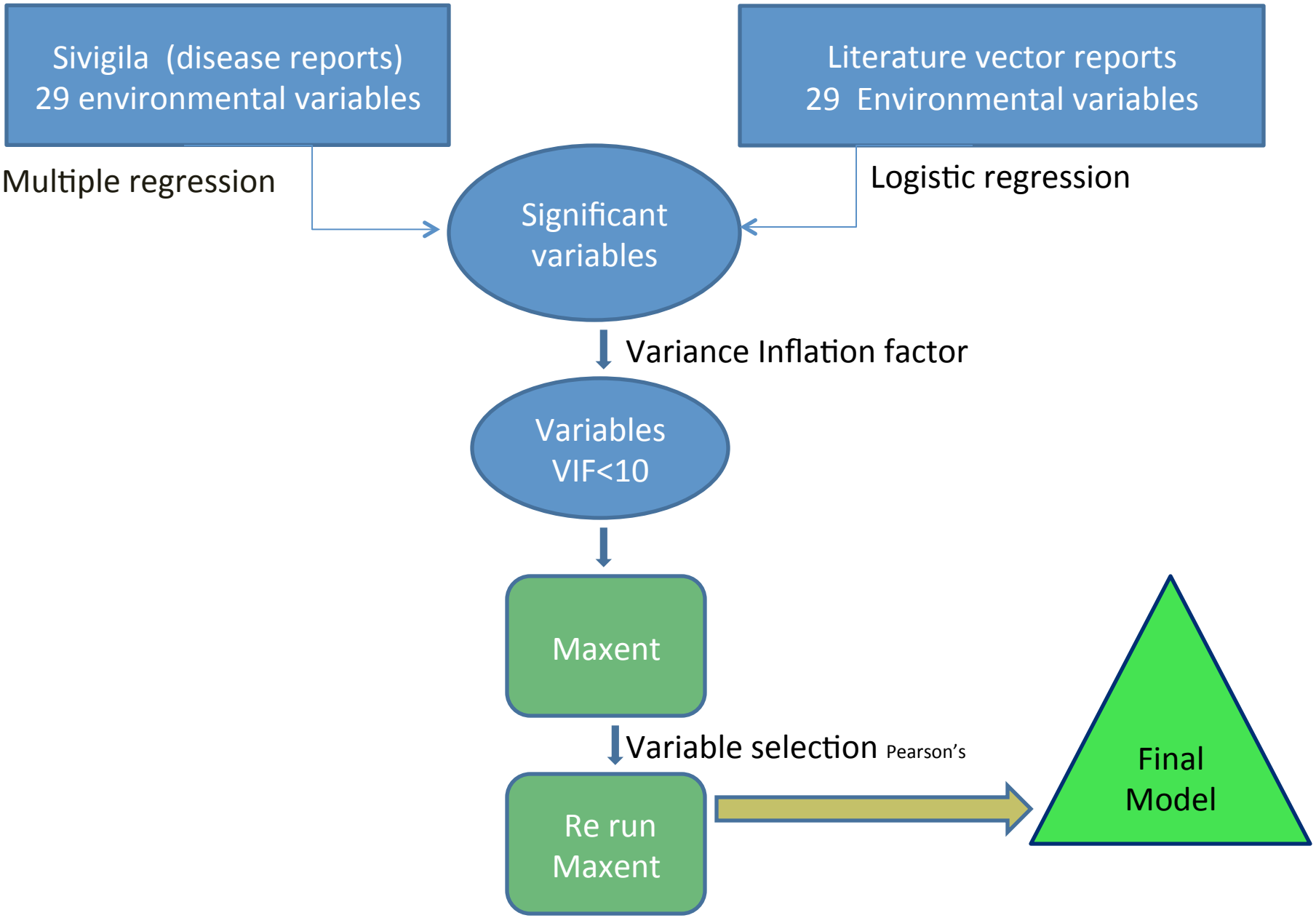
Table 1. Socioeconomical variables (47) selected for risk analysis of NTDs in Colombia
***UBN:** http://www.dane.gov.co/files/investigaciones/boletines/censo/Bol_nbi_censo_2005.pdf

Opennlp.maxent package is a mature Java package for training and using maximum entropy models.

Check out the Sourceforge page for Maxent for the latest news. You can also ask questions and join in discussions on the forums.
Download the latest version of Maxent.

Steven J. Phillips, Robert P. Anderson, Robert E. Schapire.
Maximum entropy modeling of species geographic distributions.
Ecological Modelling, 190:231-259, 2006.

Environmental Models



Chagas Disease

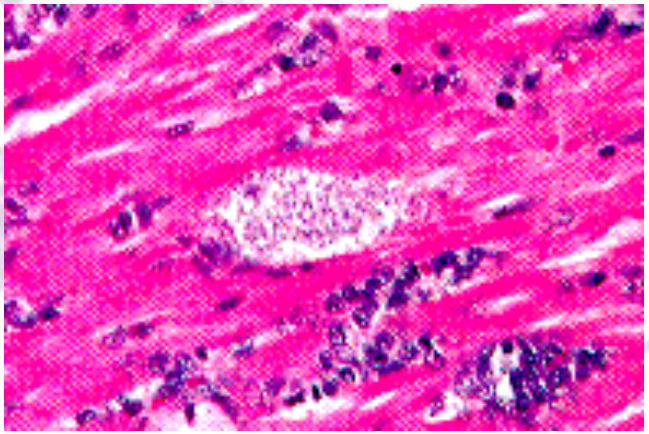
Trypanosoma cruzi - 20 million infected in the Americas - Chronic Cardiomyopathy

Circulating Trypomastigote and Tissue Amastigote forms in mammals

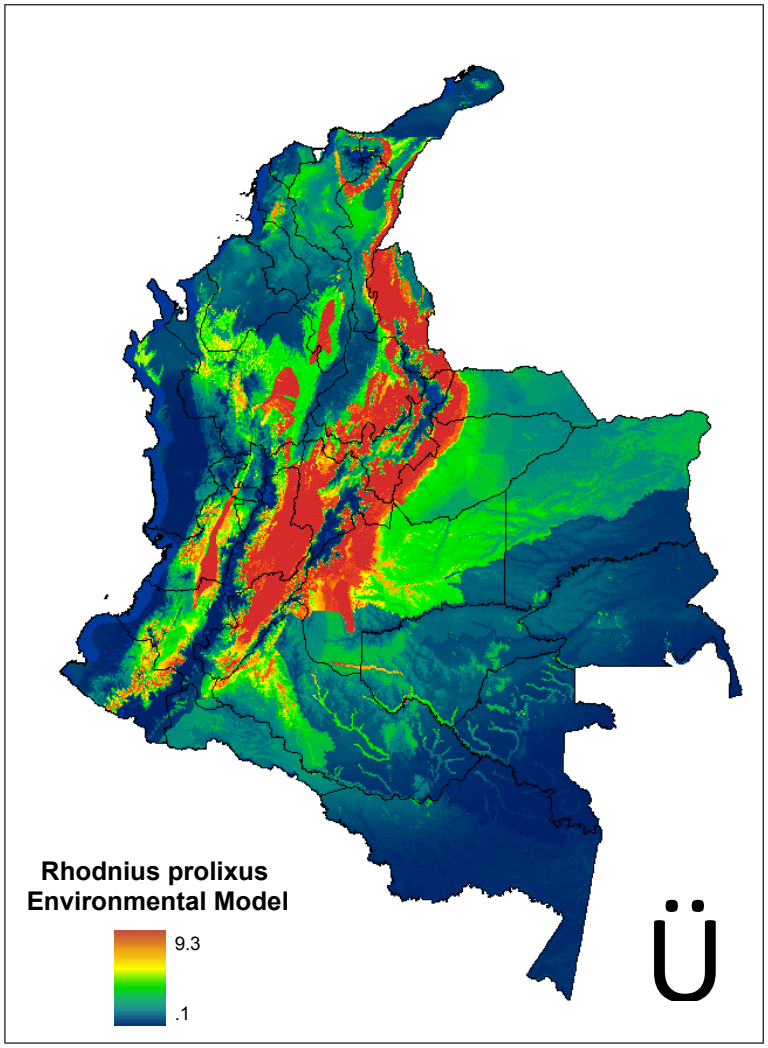
Triatomid 'kissing' bug vectors

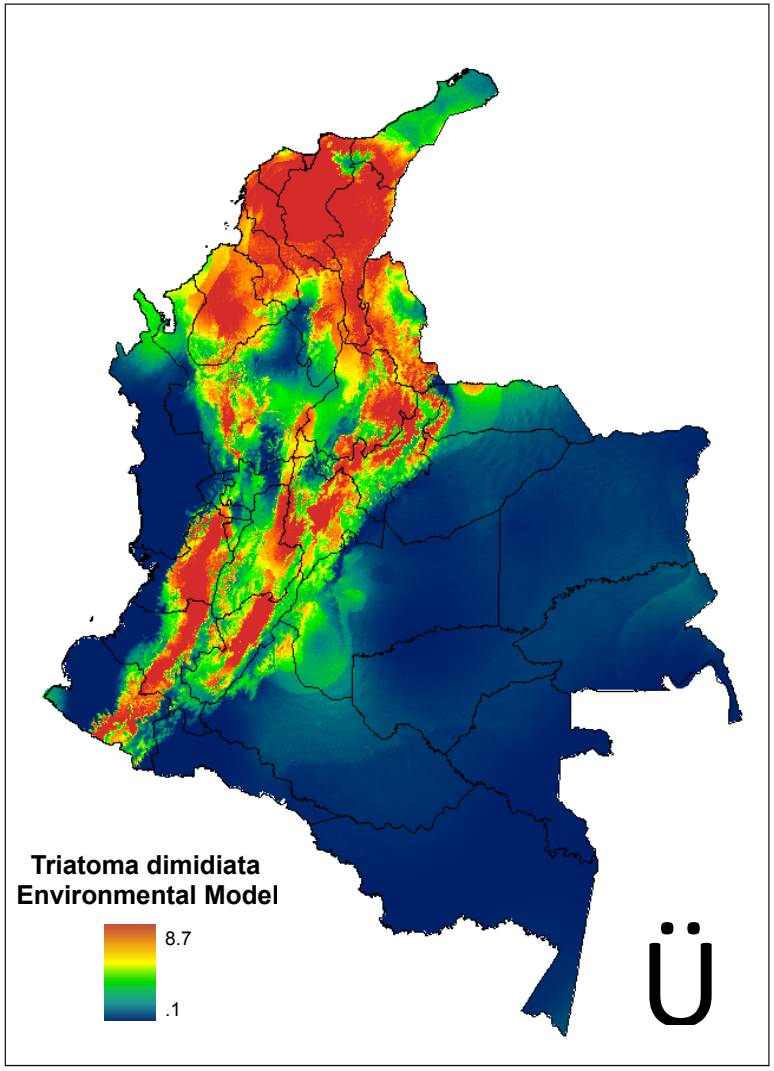
Romana's Sign

Tissue amastigote form

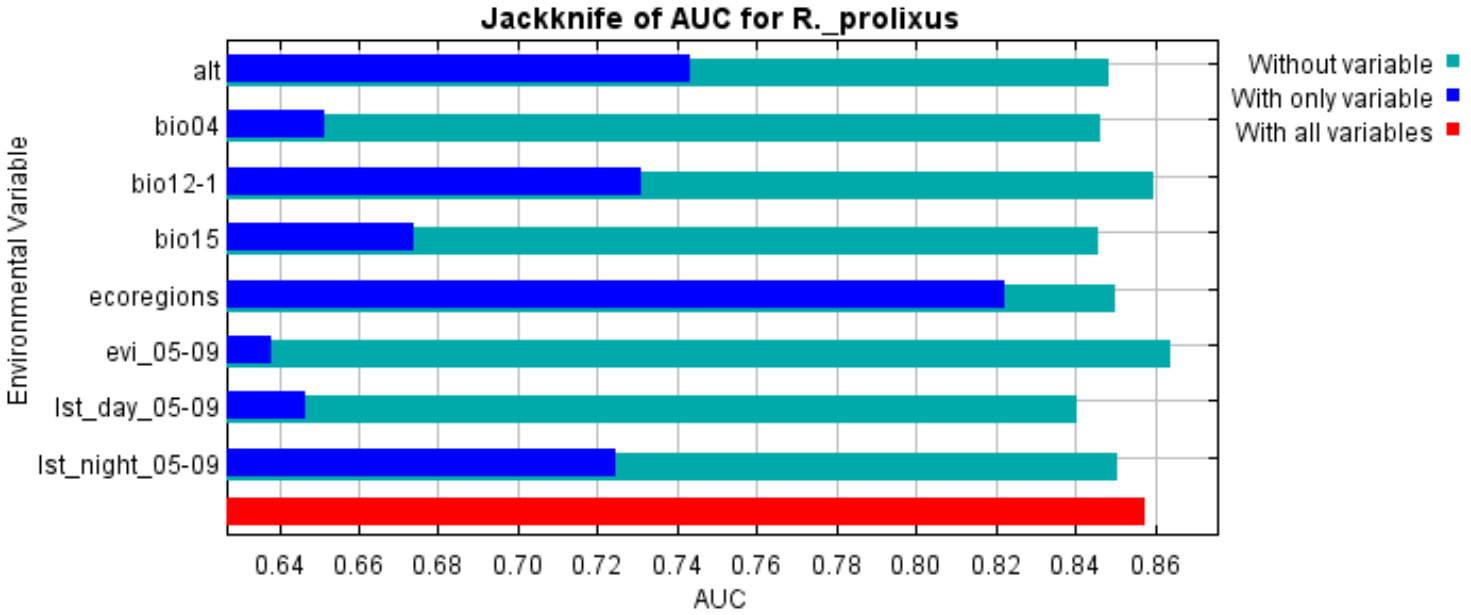


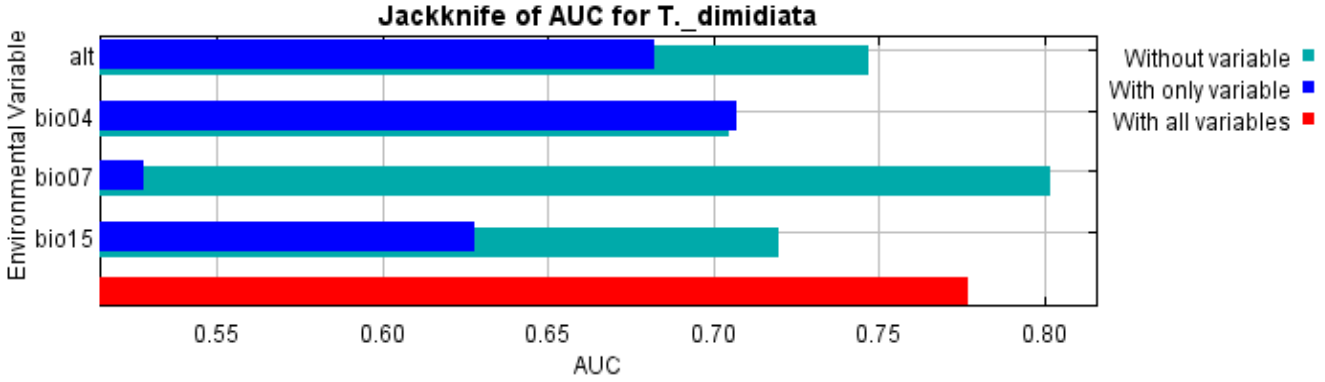
Chagas Vector Distribution



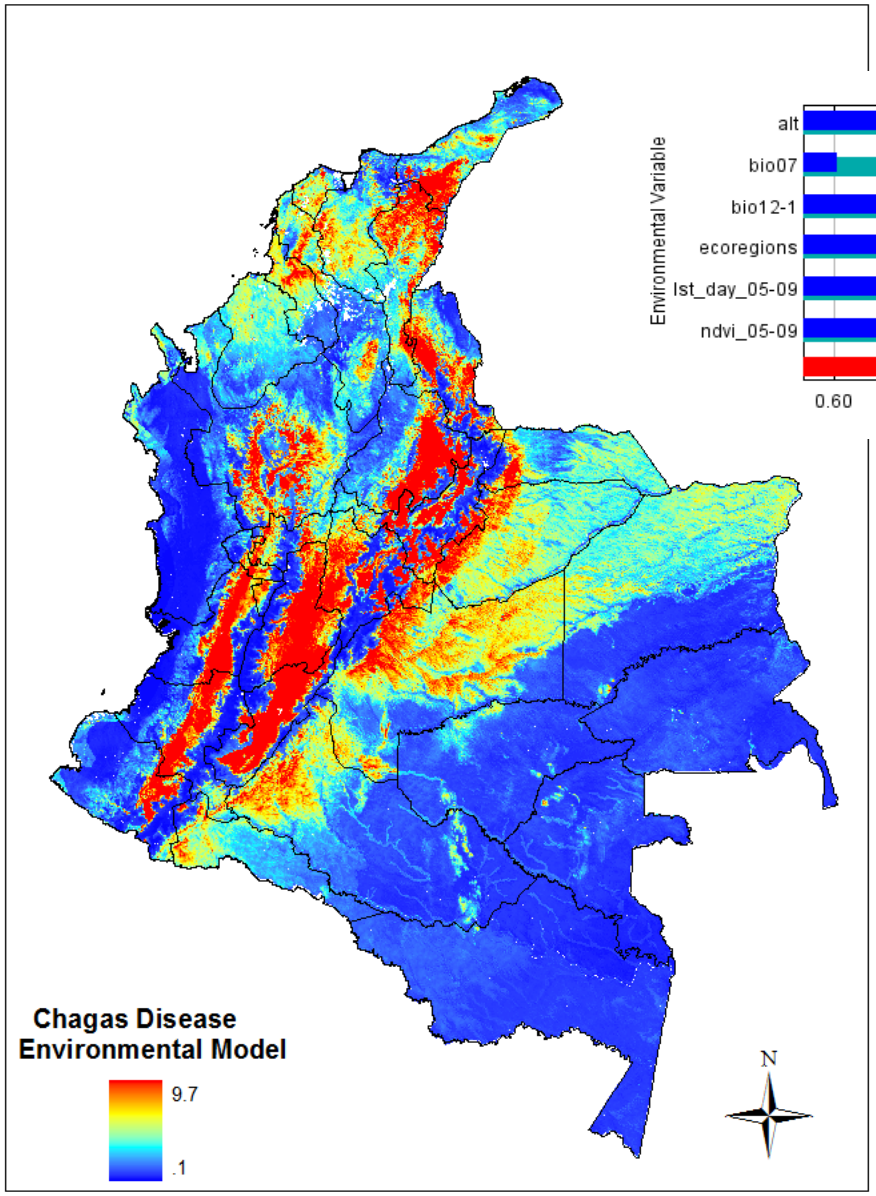


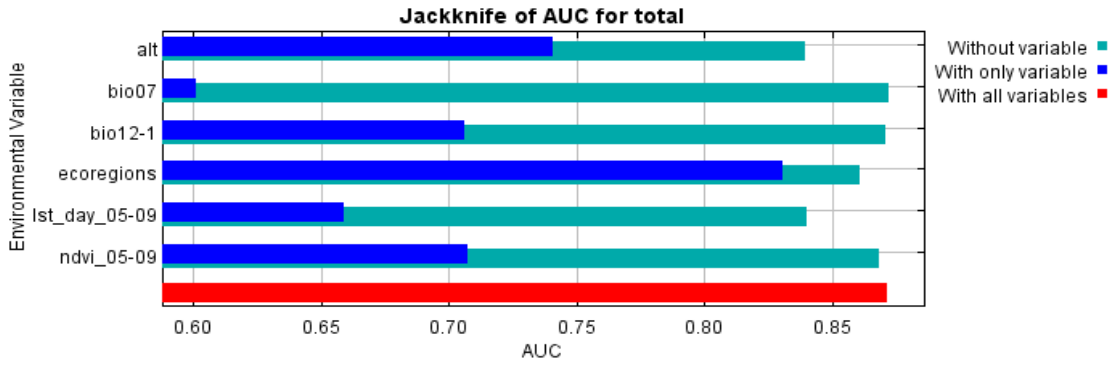
Chagas vectors - Environmental Niche model





Chagas Environmental Niche Model





Socio-Economical Model

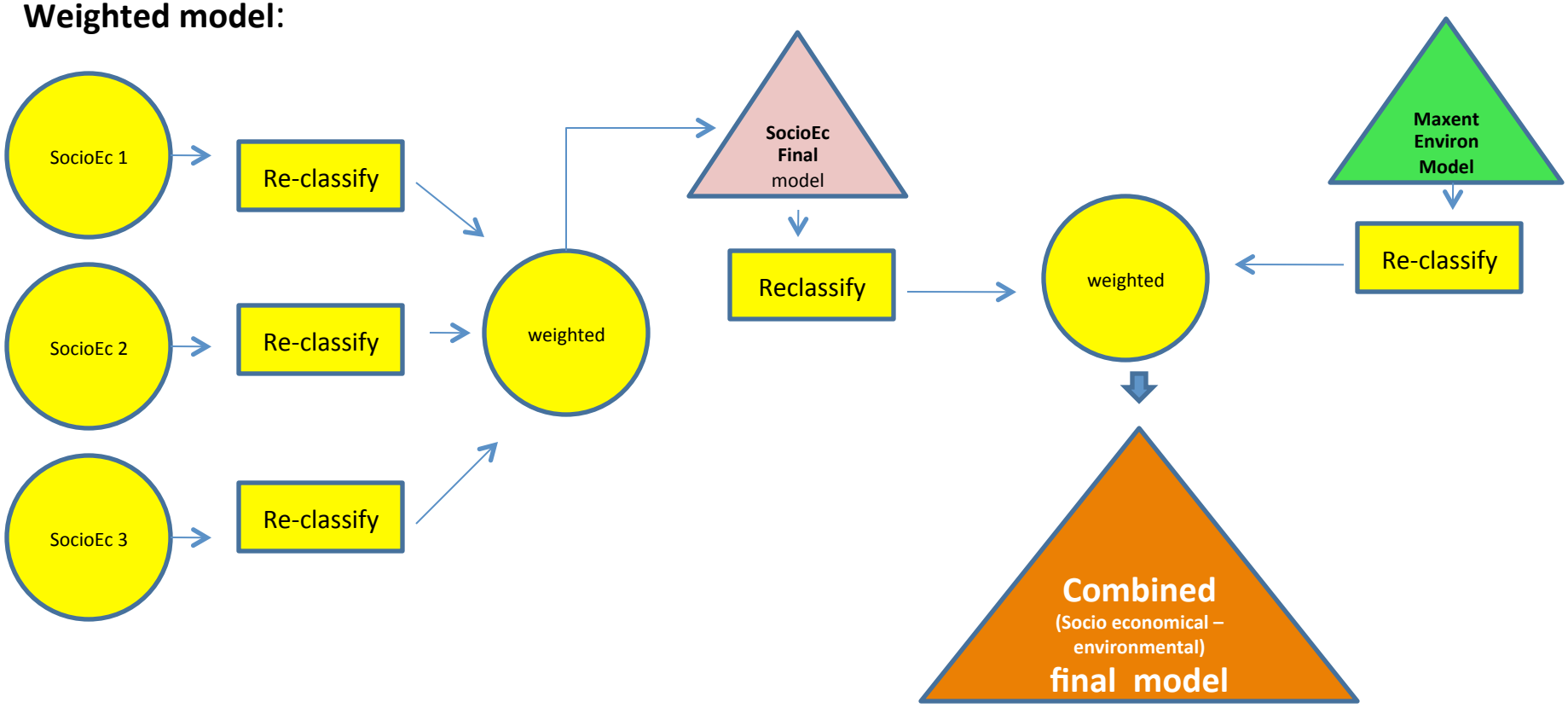
Hdi, ubn, disp Ifm , epz	Mis, viv, ser, hac, ins, dep	Acd, poz, llu, pub , tan, queb, bot	Acu, slu, ase, acl	Ino, let, nos, insp,	Ent, que, pat, rio	Mar,bal, cem,mad,tier,	blo, tap, tan, pref, veg, zin

41 socio economical variables divided in 8 groups

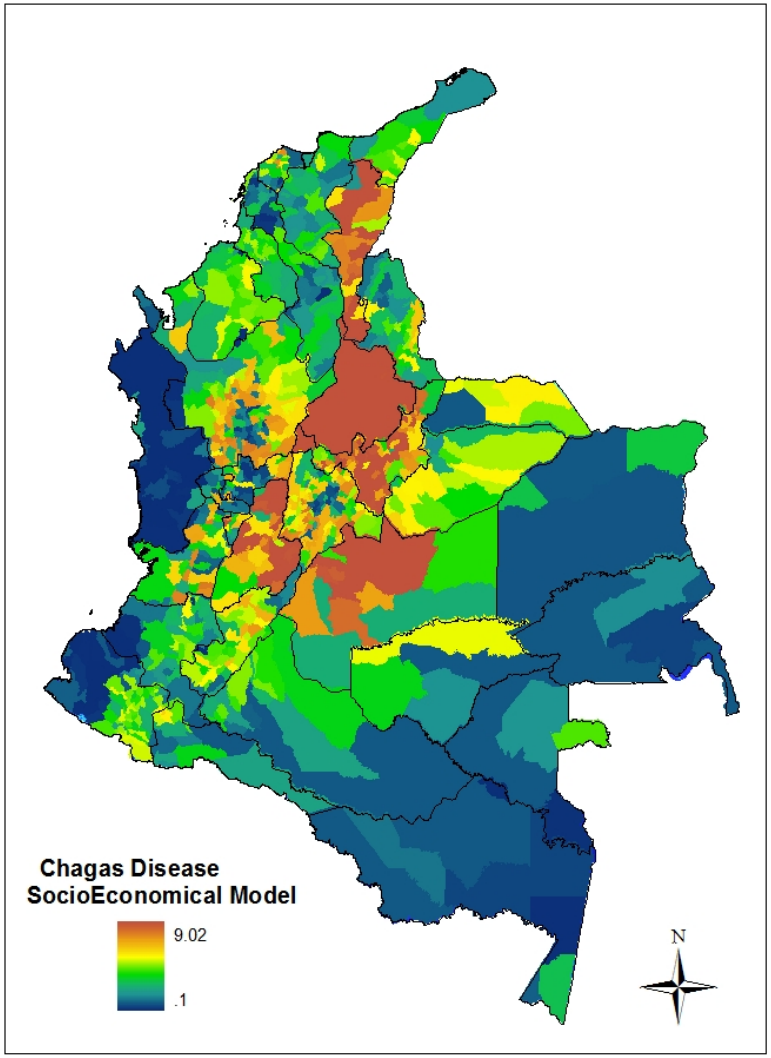
Multiple Regression and VIF

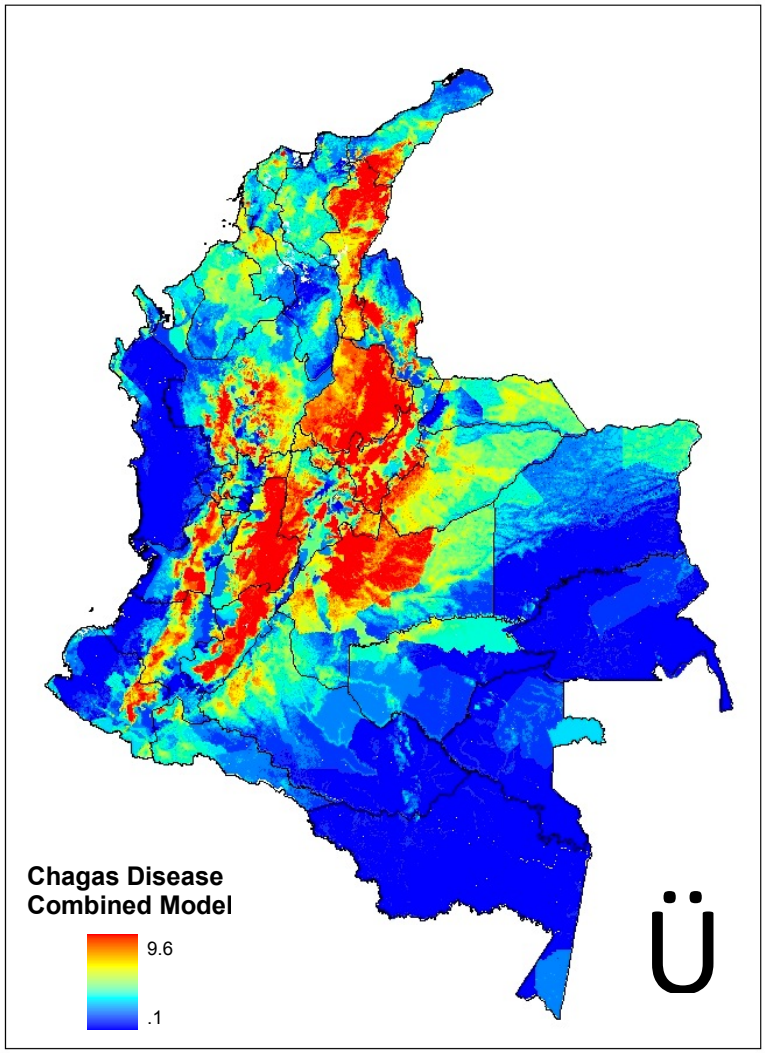
Choose variables for weighted models

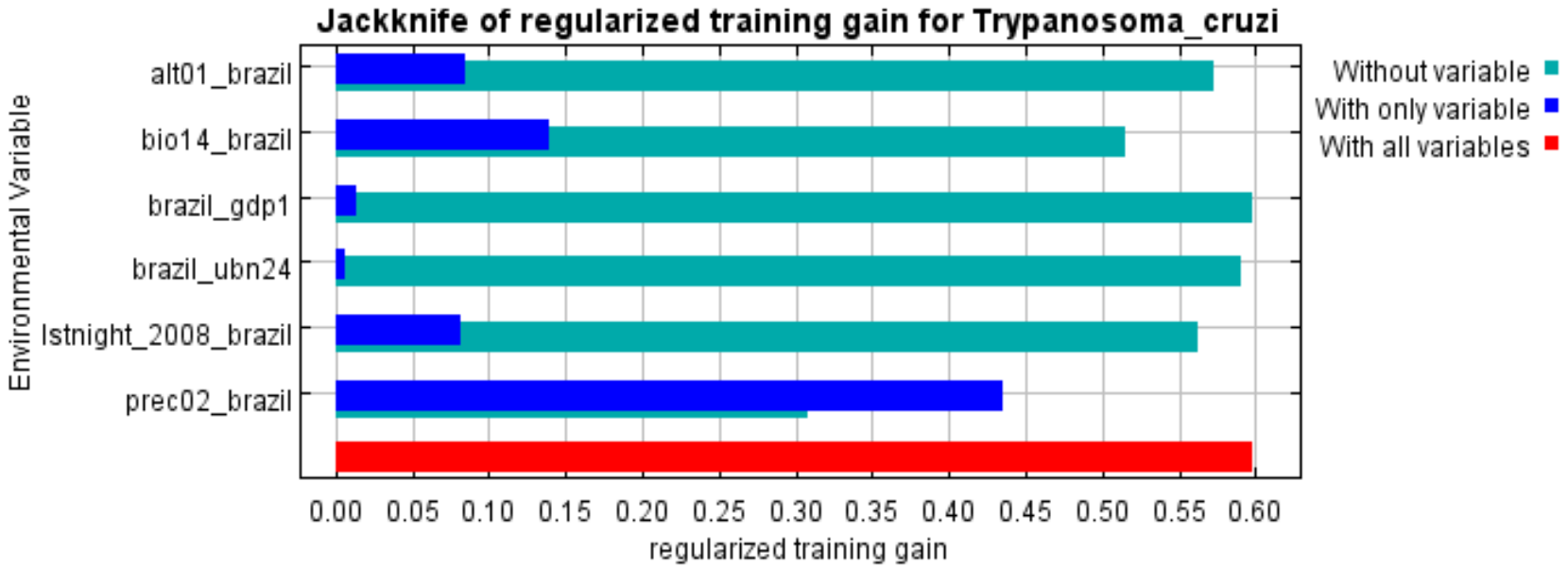
Weighted model:



Socioeconomic Factors – Municipality level





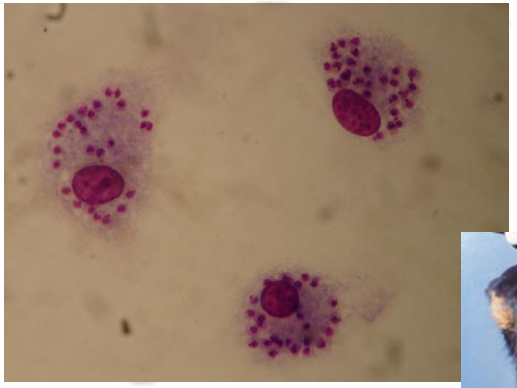


Variable	Percent contribution
prec02_brazil	75.3
bio14_brazil	13.1
alt01_brazil	5.4
lstnight_2008_brazil	4.5
brazil_ubn24	1.1
brazil_gdp1	0.7

Visceral Leishmaniasis

Caused by protozoans of the genus *Leishmania*

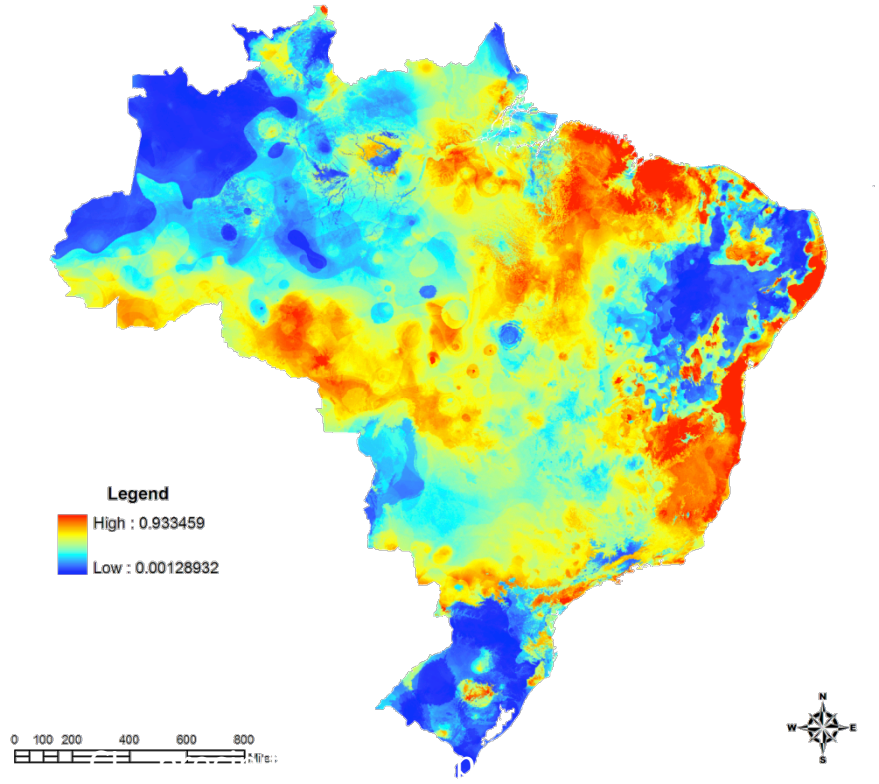
- Amastigote form – mammals
- Promastigote form – arthropod vector



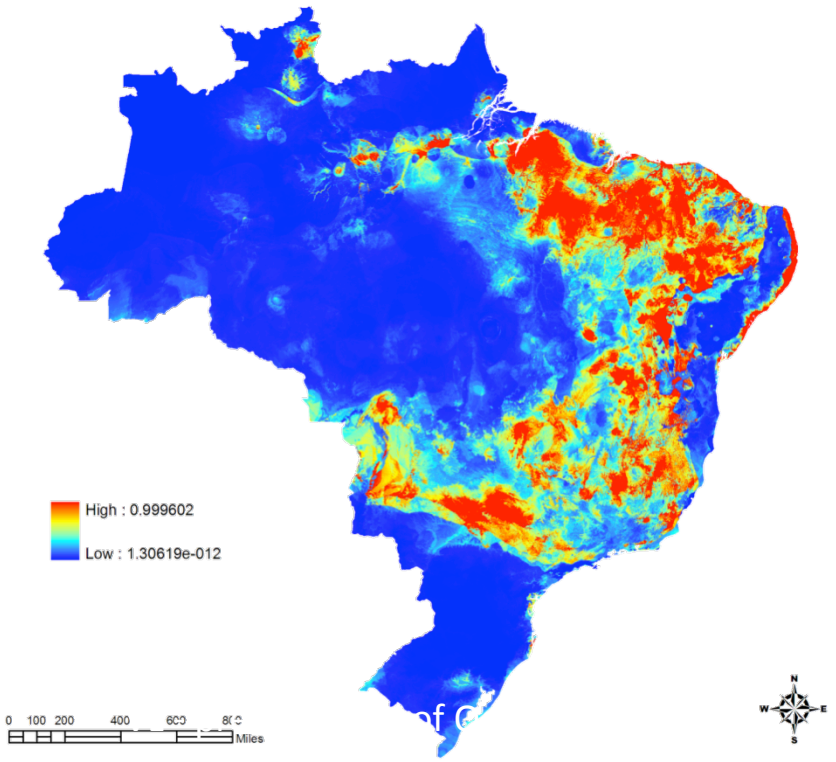
Sandfly vector (*Lutzomyia*)

Leishmaniasis – Visceral and Cutaneous

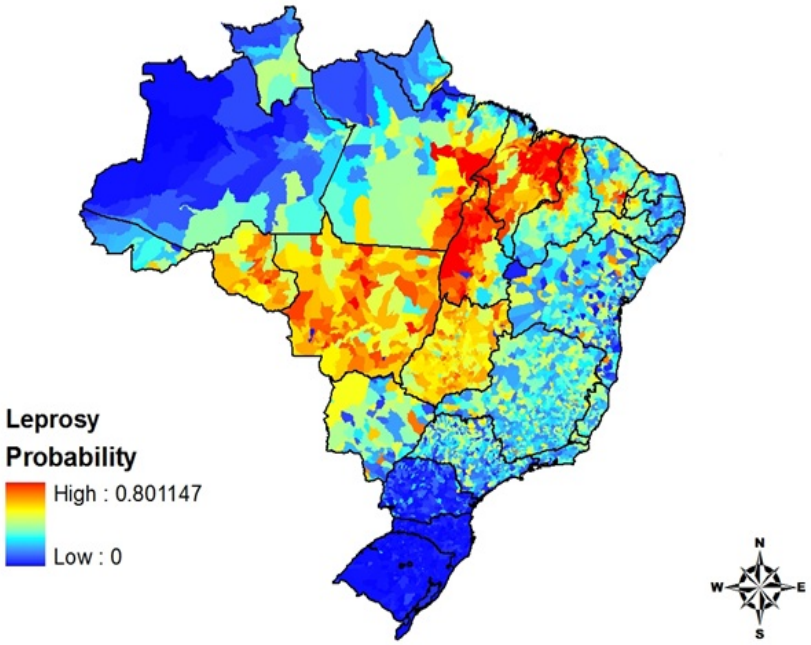
Maxent Environmental Model using Worldclim data
Cutaneous Leishmaniasis



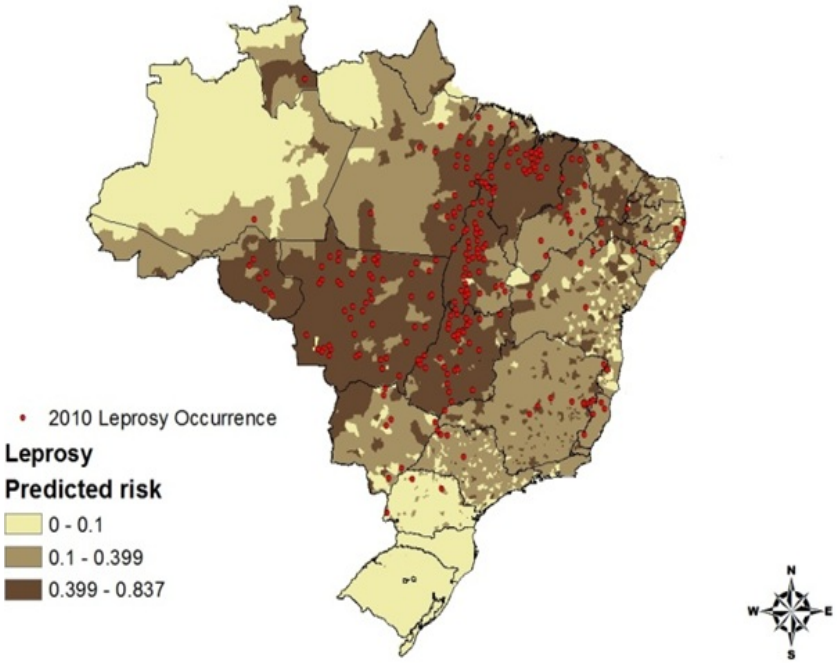
Maxent Environmental Model using Worldclim data
Visceral Leishmaniasis



Leprosy in Brazil

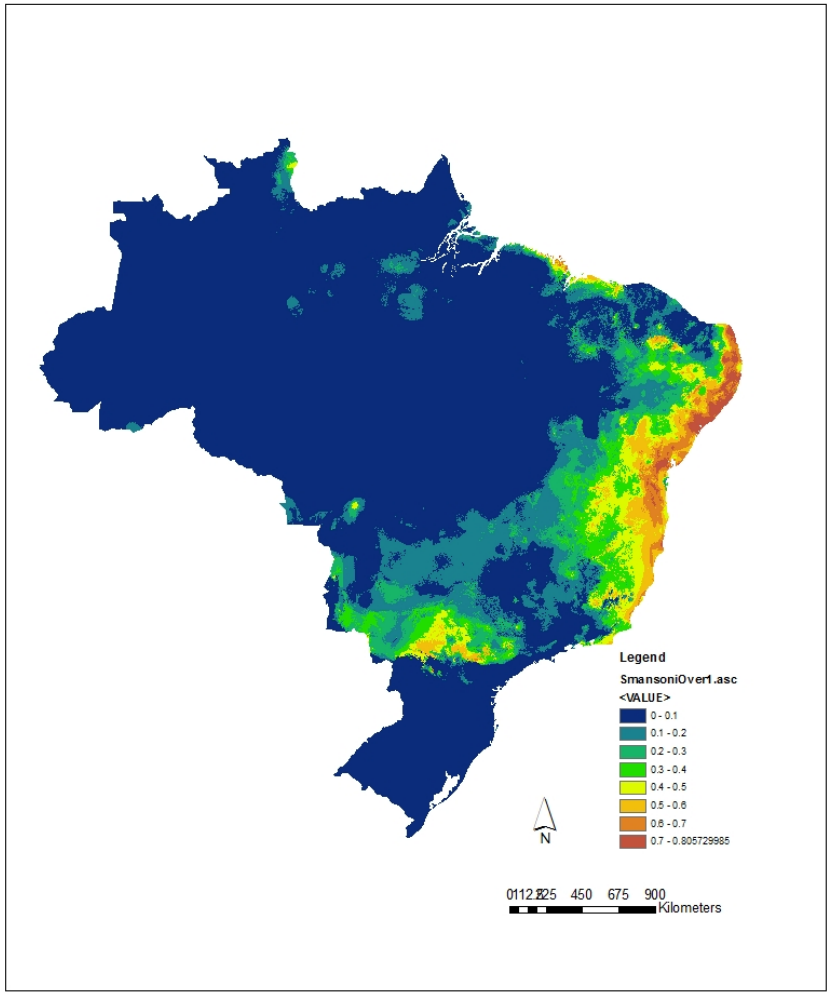


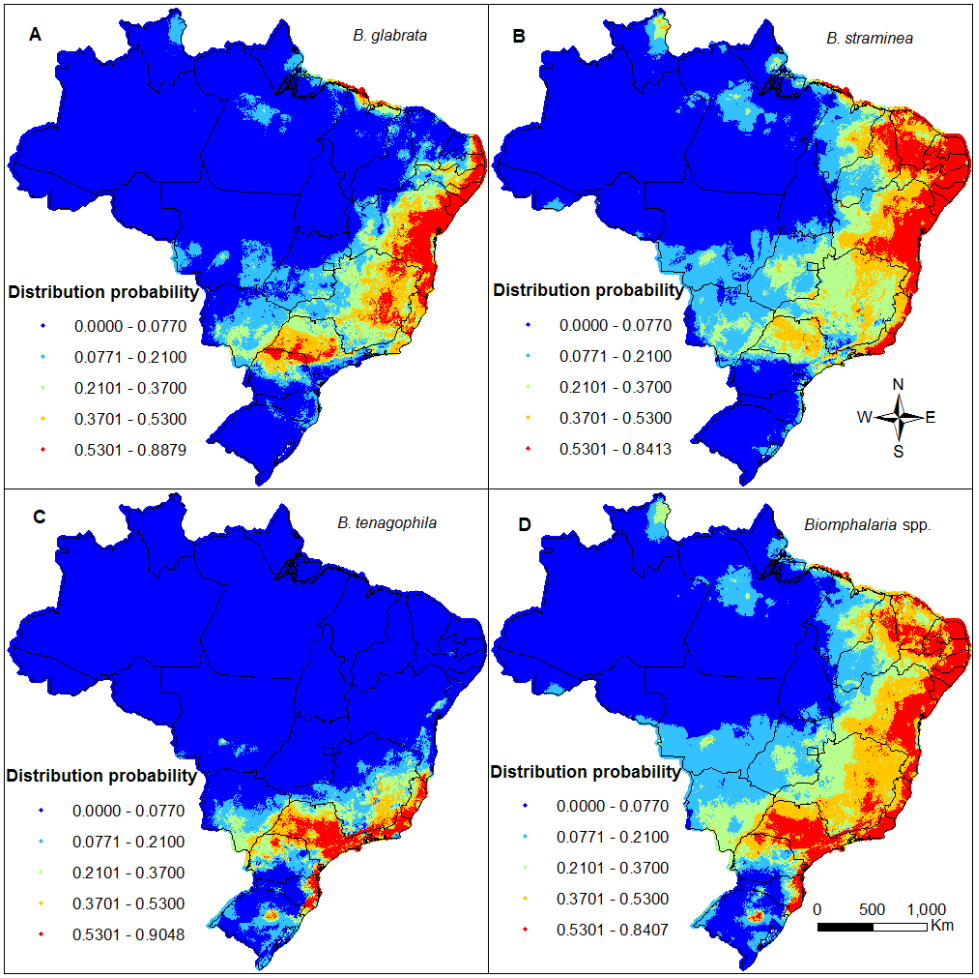
Maxent predictive model showing the distribution probability of leprosy occurrence. Red indicates a higher probability of occurrence, while blue indicates a low probability of occurrence.



The predicted risk map of leprosy overlaid with 2010 leprosy occurrence data.

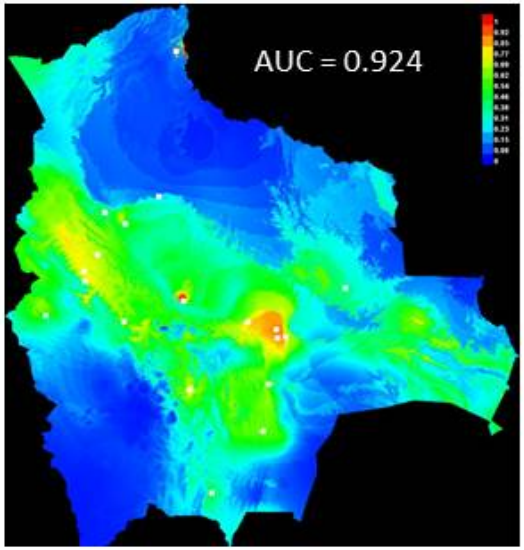
Schistosomiasis





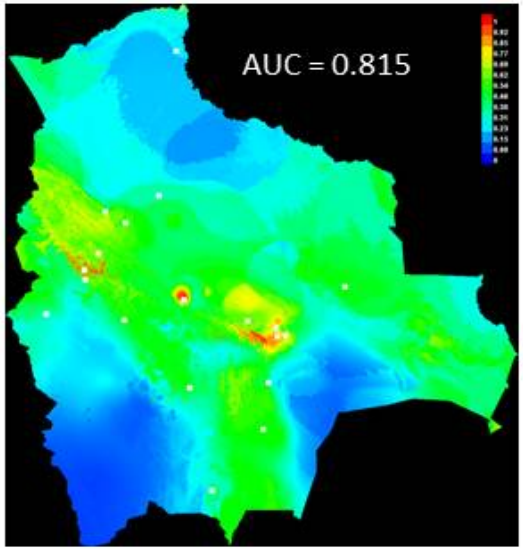
Hookworm in Bolivia

Worldclim Model



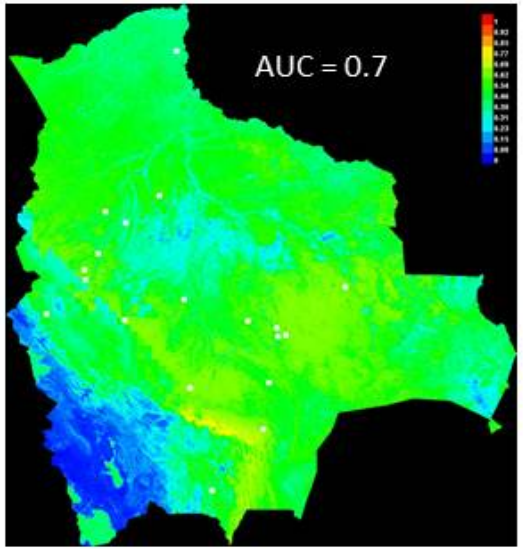
Variable	% Contribution
tmax06	28.2
prec01	18.4
prec08	13.3
tmax04	9.5
tmin05	8.9
tmin04	7.1
tmin03	3.9
prec03	3.0
prec04	2.0
prec05	1.8
prec09	1.7

Bioclim Model



Variable	% Contribution
Bio13 - Precipitation wettest month	37.2
Bio15 - Precipitation Seasonality	29.4
Bio03 - Isothermality	13.0
Bio09 - Mean temperature driest quarter	11.5
Bio01 - Annual mean temperature	6.3
Bio02 - Mean diurnal range	2.1
Bio07 - Temperature annual range	0.3
Bio12 - Annual precipitation	0.2

MODIS Model

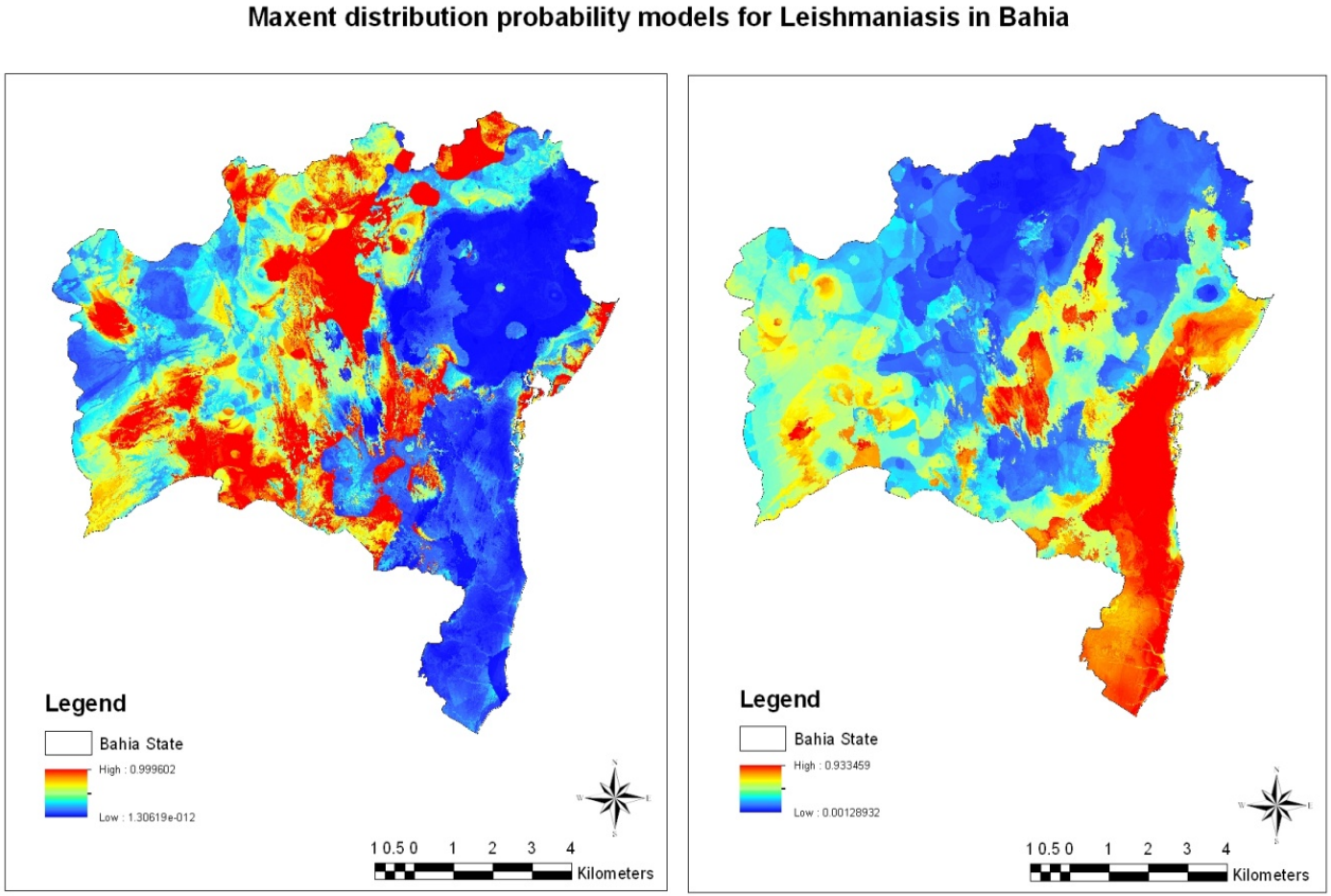


Variable	% Contribution
GDD/WB Gradient	44.3
LST day	21.8
LST night	20.3
Temperature Difference (dT)	12.8
Enhanced Vegetation Index	0.7

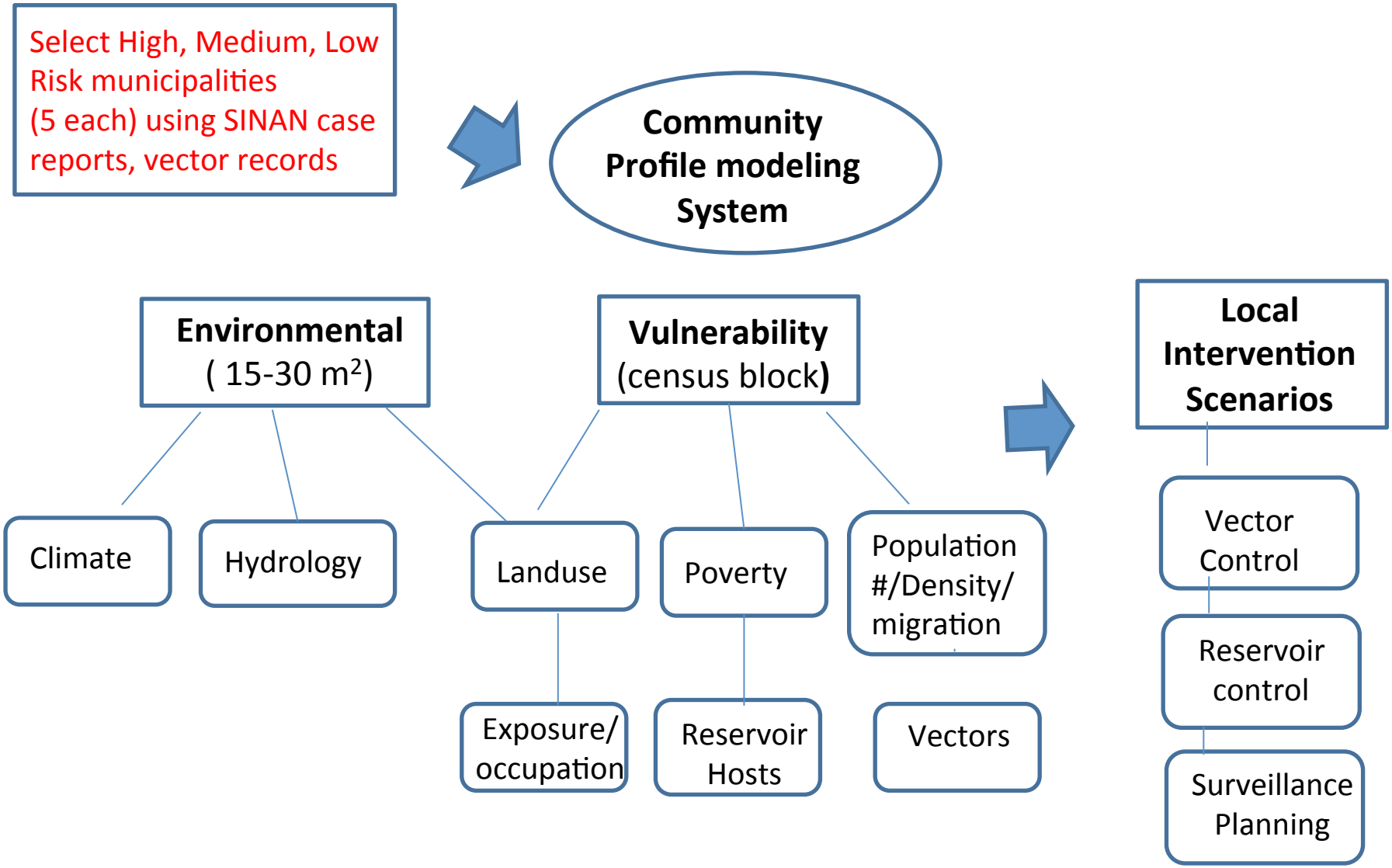
Conclusions and Recommendations

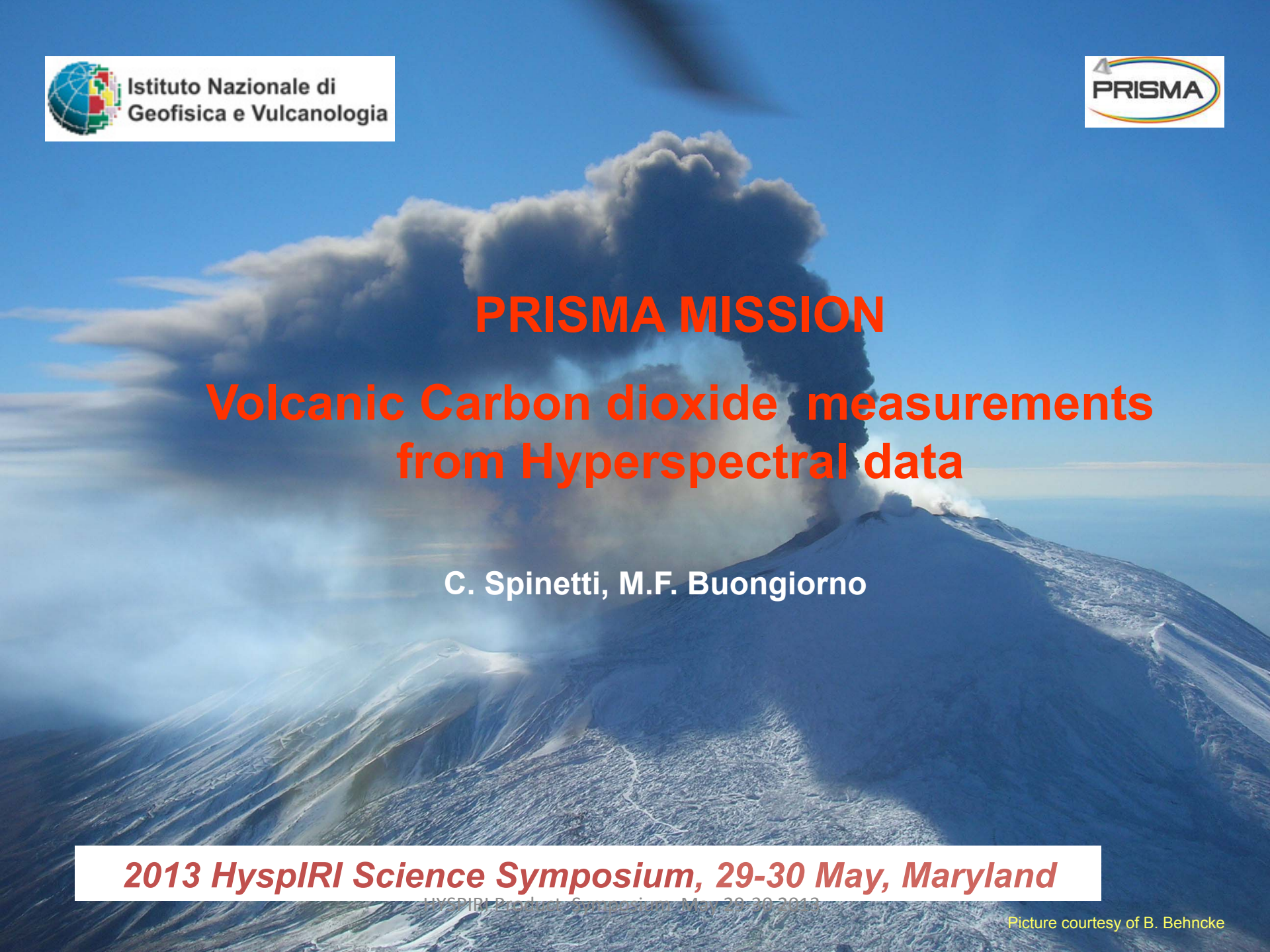
1. Maxent Ecological Niche Modeling is a useful tool to guide surveillance and control programs for NTD, particularly where health surveillance data are scarce
2. Extrapolation of risk surfaces is of limited validity where representative survey data are absent in a given ecosystem
3. Socioeconomic data or poverty indicators should be at the census tract level; Municipality level data is typically too heterogeneous
4. Results of Maxent ecologic niche mapping and modeling should be validated by alternative methods eg. biology based GDDxWB climate models

Future Work



Maxent generated risk surfaces extracted for Bahia from national scale maps on visceral leishmaniasis (a) and cutaneous leishmaniasis (b) using MODIS environmental satellite annual composite data on vegetation index (EVI) and land surface temperature (LST).


Select High, Medium, Low Risk municipalities (5 each) using SINAN case reports, vector records
Community Profile modeling System
Environmental (15-30 m2)
Vulnerability (census block)
Local Intervention Scenarios
Climate
Hydrology
Landuse
Poverty
Population #/Density/ migration
Exposure/ occupation
Reservoir Hosts
Vectors
Vector Control
Reservoir control
Surveillance Planning



Istituto Nazionale di Geofisica e Vulcanologia

PRISMA

PRISMA MISSION

Volcanic Carbon dioxide measurements from Hyperspectral data

C. Spinetti, M.F. Buongiorno

2013 HysplRI Science Symposium, 29-30 May, Maryland

Picture courtesy of B. Behncke

summary

- PRISMA MISSION OVERVIEW
- ASI-AGI PROJECT PRODUCTS TO FOR VOLCANIC APPLICATIONS
- CO2 RETRIEVAL LGORITHM REVIEW
- CONCLUSION
- PRISMA AND HYSPIRI MISSION MUTUAL BENEFITS

PRISMA MISSION OVERVIEW AND DEVELOPMENT STATE

PRISMA (PRecursore IperSpettrale della Missione Applicativa) Hyperspectral Payload is an Electro-Optical instrument composed of a high spectral resolution spectrometer optically integrated with a medium resolution panchromatic camera.

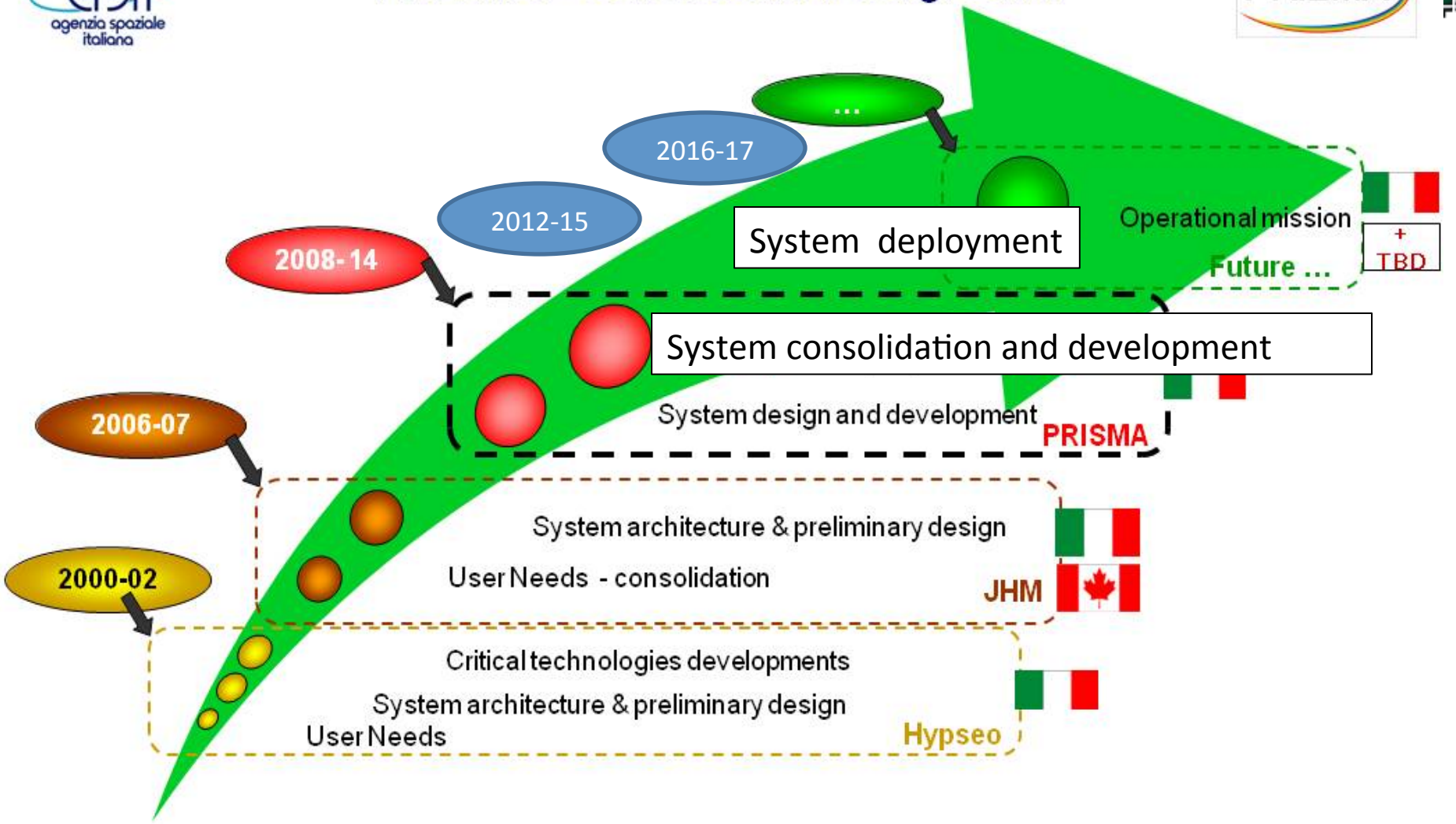
The instrument is the focus of the Earth Observation PRISMA mission, fully funded by ASI (Agenzia Spaziale Italiana) and developed by a consortium of Italian companies, lead by CGS as S/C responsible. PRISMA is: "a pre-operative small Italian hyperspectral mission, aiming to qualify the technology, contribute to develop applications and provide products to institutional and scientific users for environmental observation and risk management …"

In this context SELEX Galileo has the full responsibility of the Electro-Optical Payload (**Hyperspectral and Pancromatic cameras**); in addition, SELEX Galileo provides the following items: a) PhotoVoltaic Assembly (PVA); b) Power Control & Distribution Unit (PCDU) for the S/C; c) AA-STR Autonomous Star Tracker for S/C attitude control and is also responsible of Data Products management (Level 0 and Level 1).

PRISMA Mission is based on previous experiences carried out by SELEX Galileo under ASI studies for Earth Observation, namely the programs **HypSEO** phase B (first study) and **JHM** (Joint Hyperspectral Mission) phase A (mission and instruments refinement).

The launcher baseline (which will be provided by the Agency) is **VEGA**, but the Mission design will be compatible also with other launchers to maintain the maximum flexibility.

PRISMA - context and background



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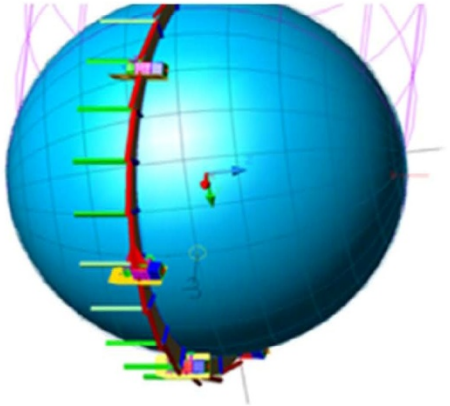
PRISMA MISSION OVERVIEW (Courtesy of SELEX-GALILEO)

SELEX GALILEO
A Finmeccanica Company

PRISMA

PRISMA Mission Overview

Orbit	sun synchronous
Orbital Altitude	615 Km
Inclination	97.851°
LTDN	10:30 a.m.
Orbital period	about 97 min (5819.7 sec)
Average eclipse duration	about 34 min (2048sec)
Beta Angle	from 16.1 to 26.6 deg
Repeat cycle	29 days (430 orbits)
Relook time	7 days
Area Of Interest (AoI)	longitude from 10°W to 50°E, latitude from 30°N to 70°N
Outside AoI	40° latitude window per orbit at every latitude in the range 70°N – 60°S
Swath / GSD	30 Km / 30m
Off- Nadir	18.2°
AoI access duration	Average Duration 8.44 min Maximum Duration 11.19 min
Lifetime	5 years



Primary area of interest

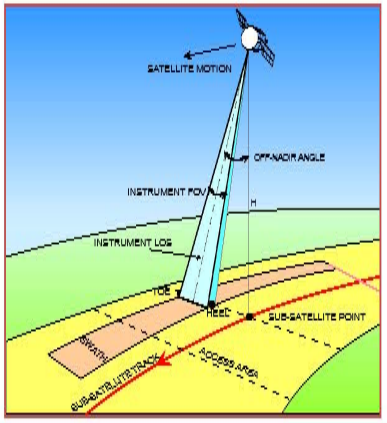
PRISMA Payload features

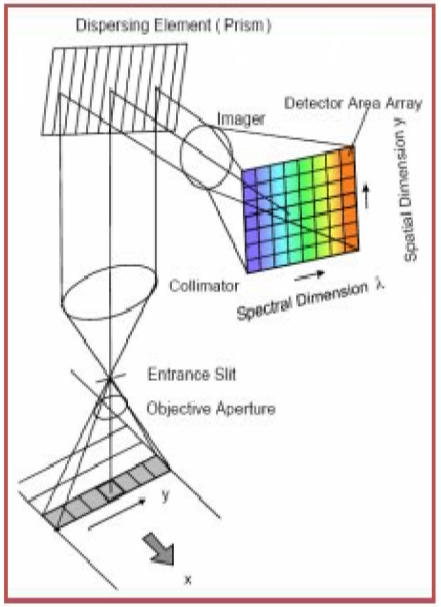
The PRISMA hyperspectral camera utilizes a prism to obtain the dispersion of incoming radiation on a 2-D matrix detector. At each shot, a full across track line is imaged.

The "instantaneous" spectral and spatial dimension (across track) of the spectral cube are given directly by the 2-D detector, while the "temporal" dimension (along track) is given by the satellite motion. This image scanning concept is defined as "**Pushbroom**"; the advantages of this concept being: a uniform spatial resolution, a good geo-reference, no scanning mechanism need, availability of a long pixel integration time.

The key PRISMA Payload technical features are:

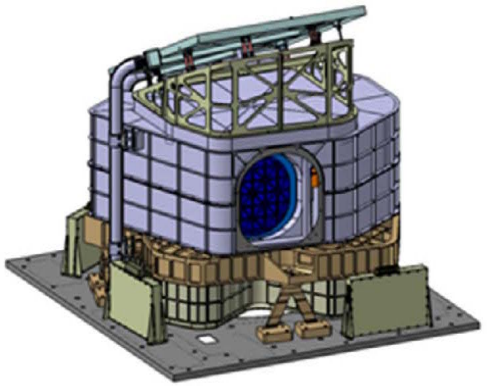
- Spatial GSD: **30 m (Hyper)** / **5m (PAN)**;
- Swath width: **30 km**;
- Daily data collection: > 100.000 km^2 ;
- Uninterrupted acquisition: up to 1800 km ;
- Spectral range: 0.4-2.5 µm (Hyp) / 0.4-0.7 µm (PAN);
- Continuous coverage of spectral range with spectral bands of **12 nm** width;
- Absolute radiometric accuracy better than 5%.





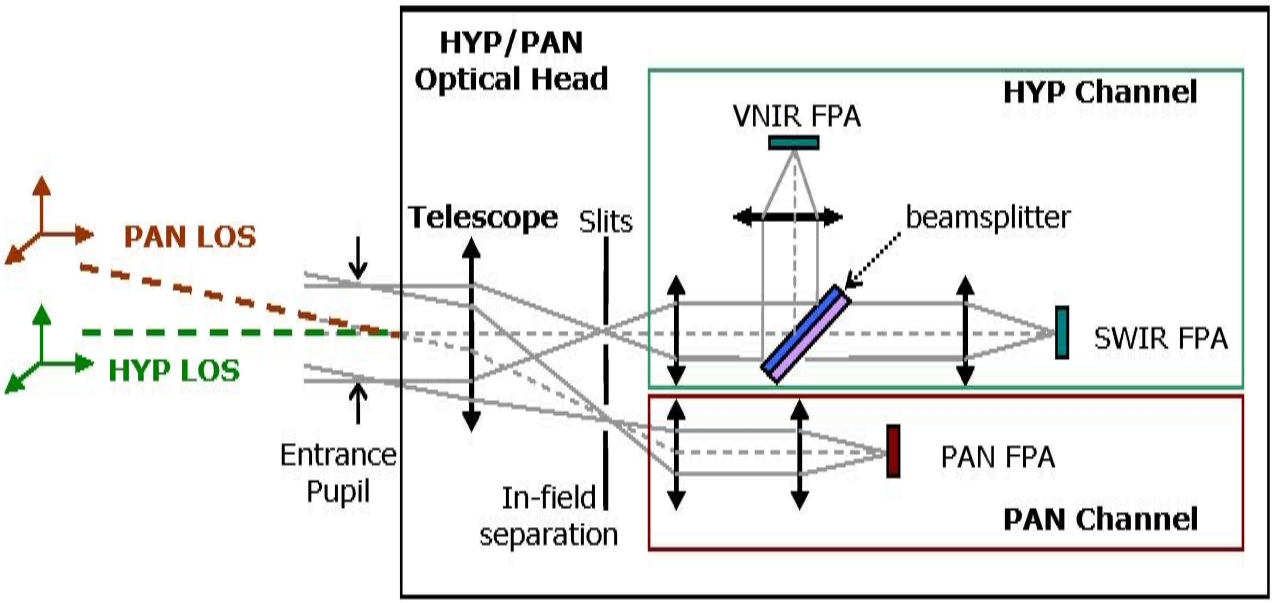
PRISMA Payload Overview

Reference Orbit Altitude	615 Km
Swath / FOV	30 Km / 2.77°
GSD	Hyperspectral: 30 m PAN: 5 m
Spatial Pixels	Hyperspectral: 1000 PAN: 6000
Pixel Size	Hyperspectral: 30x30 µm PAN: 6.5x6.5 µm
Spectral Range	VNIR: 400 – 1010 nm SWIR: 920 – 2500 nm
Spectral Sampling Interval (SSI)	≤ 11 nm
Spectral Width	≤ 12 nm
Cross-Track Variation of Centre Wavelength (Smile)	< +/- 0.1 SSI
Spatial registration of spectral sampling (incl. Keystone)	≤ 0.1 pixel
Spectral Calibration Accuracy	+/-0.1 nm
Radiometric Quantization	12 bit
VNIR SNR	> 200:1 on 400 – 1000 nm > 600:1 @ 650 nm
SWIR SNR	> 200:1 on 1000 – 1750 nm > 400:1 @ 1550 nm > 100:1 on 1950 – 2350 nm > 200:1 @ 2100 nm
PAN SNR	> 240:1
Absolute Radiometric Accuracy	Better than 5%
Aperture Diameter	210 mm
MTF	VNIR @ Nyquist Frequency > 0.3 SWIR @ Nyquist Frequency > 0.3 PAN @ Nyquist Frequency > 0.2
Cooling System	Passive Radiator
Lifetime	5 years



View of the Optical Head

- Three mirror anastigmat (TMA) telescope common to all channels.
- Prism based VNIR and SWIR Spectrometers.
- Three mirror design Panchromatic Camera.
- Internal Calibration Unit optical relay, with high reflectance integrating sphere and parabolic mirror to image Sun light and spectral lamps.

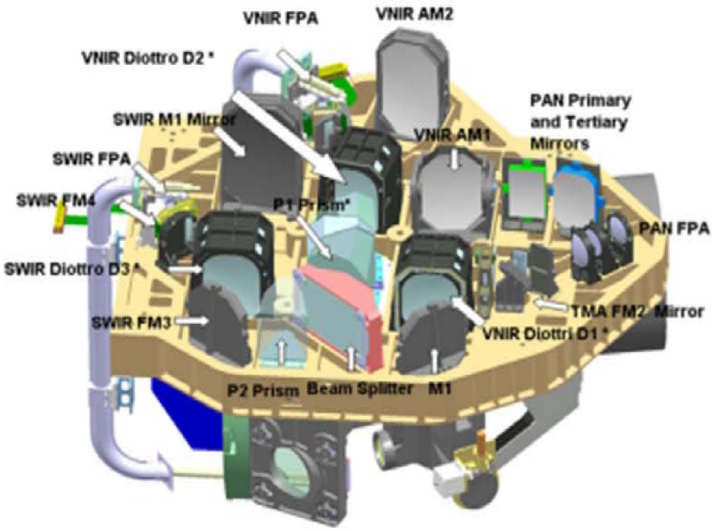


The overall instrument spectral radiation (400-2505nm) is split into **two channels** (VNIR and SWIR), adopting two different focal plane arrays:

- the VNIR , range [400nm - 1010nm] with 66 spectral bands
- the SWIR, range [920nm- 2505nm] with 171 spectral bands.

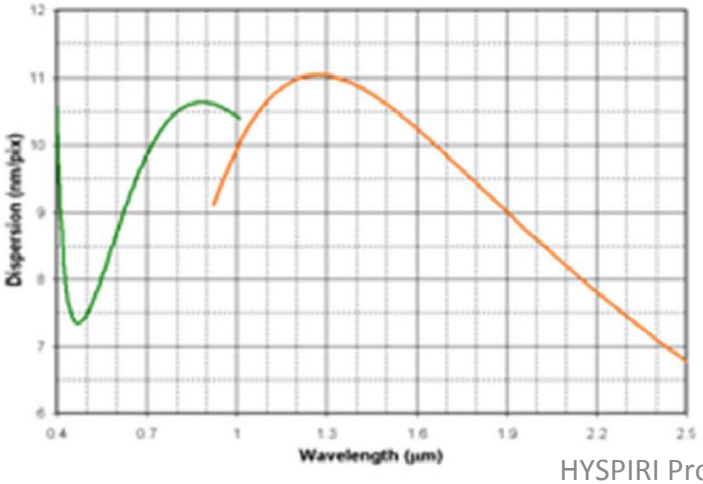
The spectral dispersion is achieved by prisms placed in parallel beams and designed in order to optimize the spectral dispersion. The advantages of this solution are:

- Excellent optical quality, in terms of PSF, Smile and Keystone effects;
- High flexibility of arrangement;
- Large clearance around focal planes;
- High optical transmission to achieve high SNR ratio while assuring required maximum spectral dispersion.

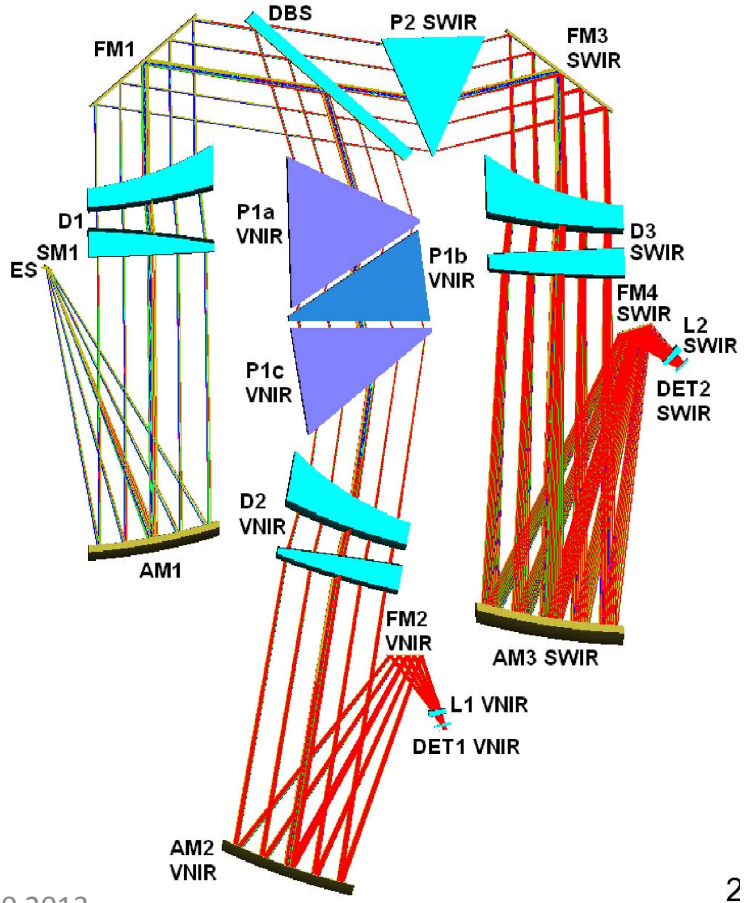


The selected design layout for the Spectrometer is the band separation, obtained with dichroic beam splitter (DBS). The main advantages of this configuration are the same field of view for both VNIR and SWIR channel (i.e. same entrance slit) and the use of several common optical elements for both channels.

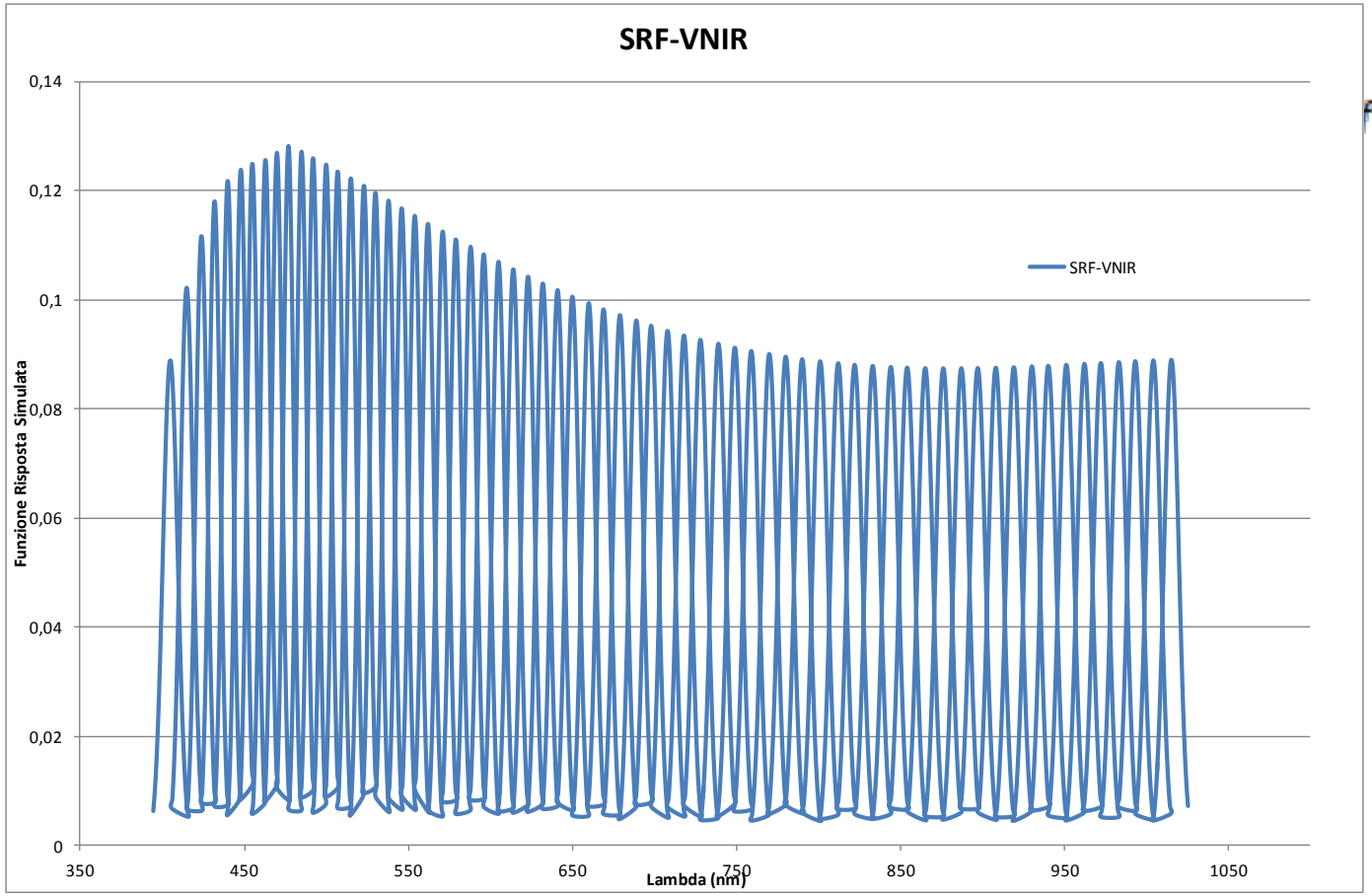
- Smile and the Keystone effects are contained within 10% of the pixel, for both VNIR and SWIR bands.
- Each VNIR and SWIR spectrometer channel has a magnification such to match the detector pixel.
- Detectors: 1000x256 pixels, with pixel size of 30x30 µm – working temperature 185 K (passive cooling).
- Spectrometer entrance slit: 30 mm x 30 µm.



Total spectral dispersion



PRISMA Response function simulation VNIR 66 bands

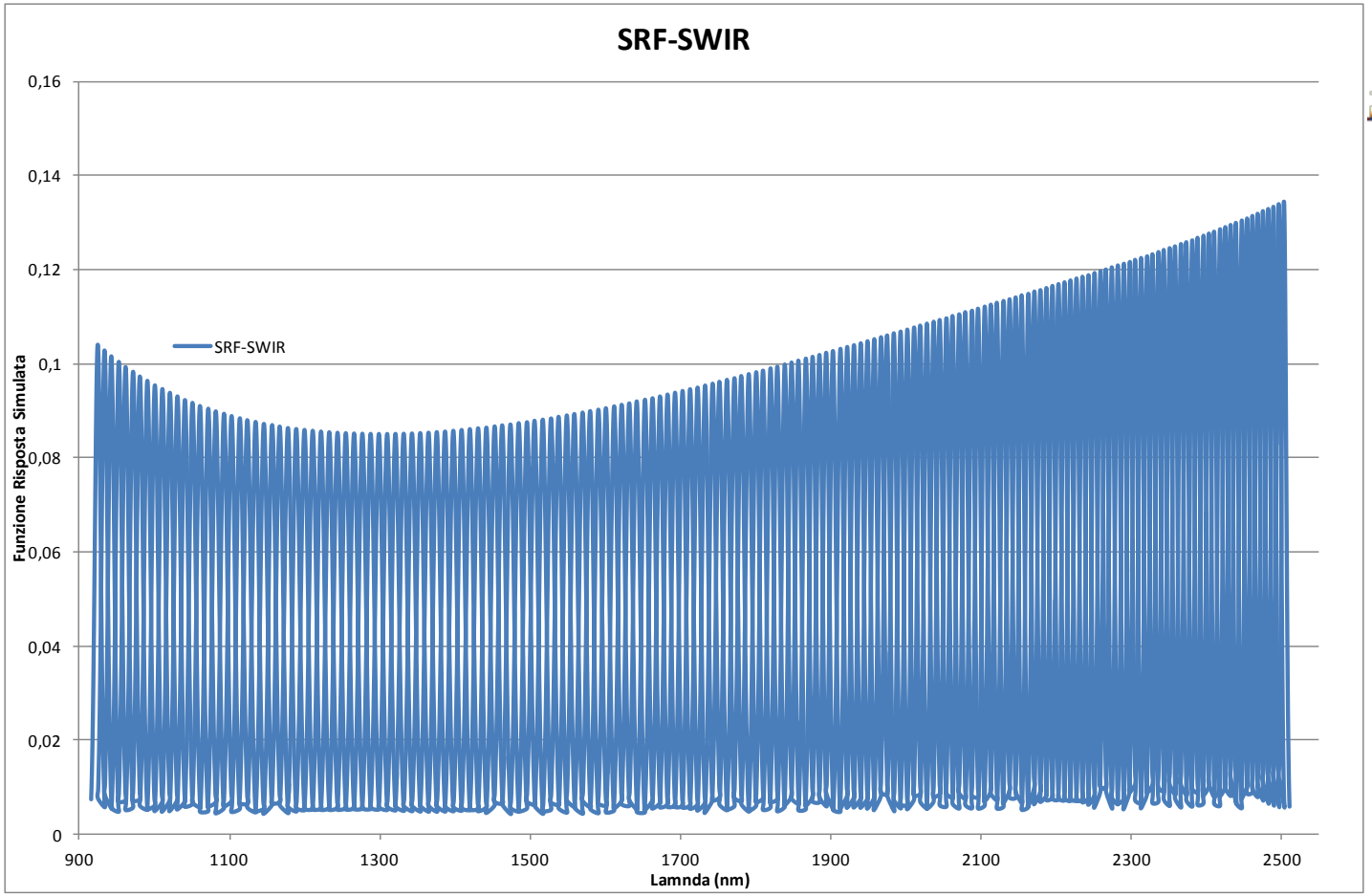


$$f(x) = \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{\frac{(x-x_j)^2}{2\sigma_j^2}}$$

$$\sigma_j = \frac{FWHM_j}{2(2Ln2)^{1/2}}$$

Con FWHM le ampiezze delle singole bande

PRISMA RESPONSE FUNCTION FOR SWIR 171 bands

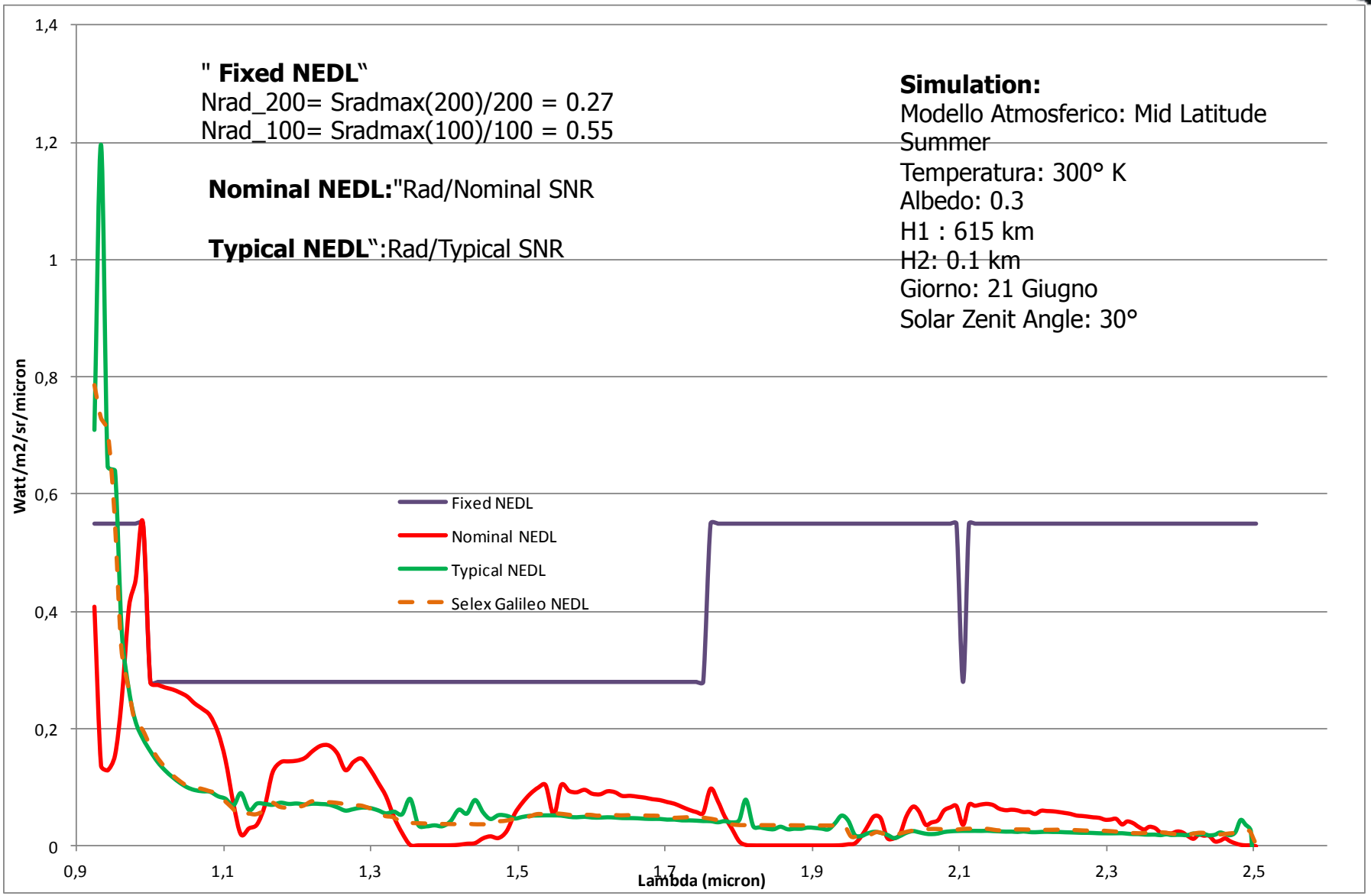


$$f(x) = \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{\frac{(x-x_j)^2}{2\sigma_j^2}}$$

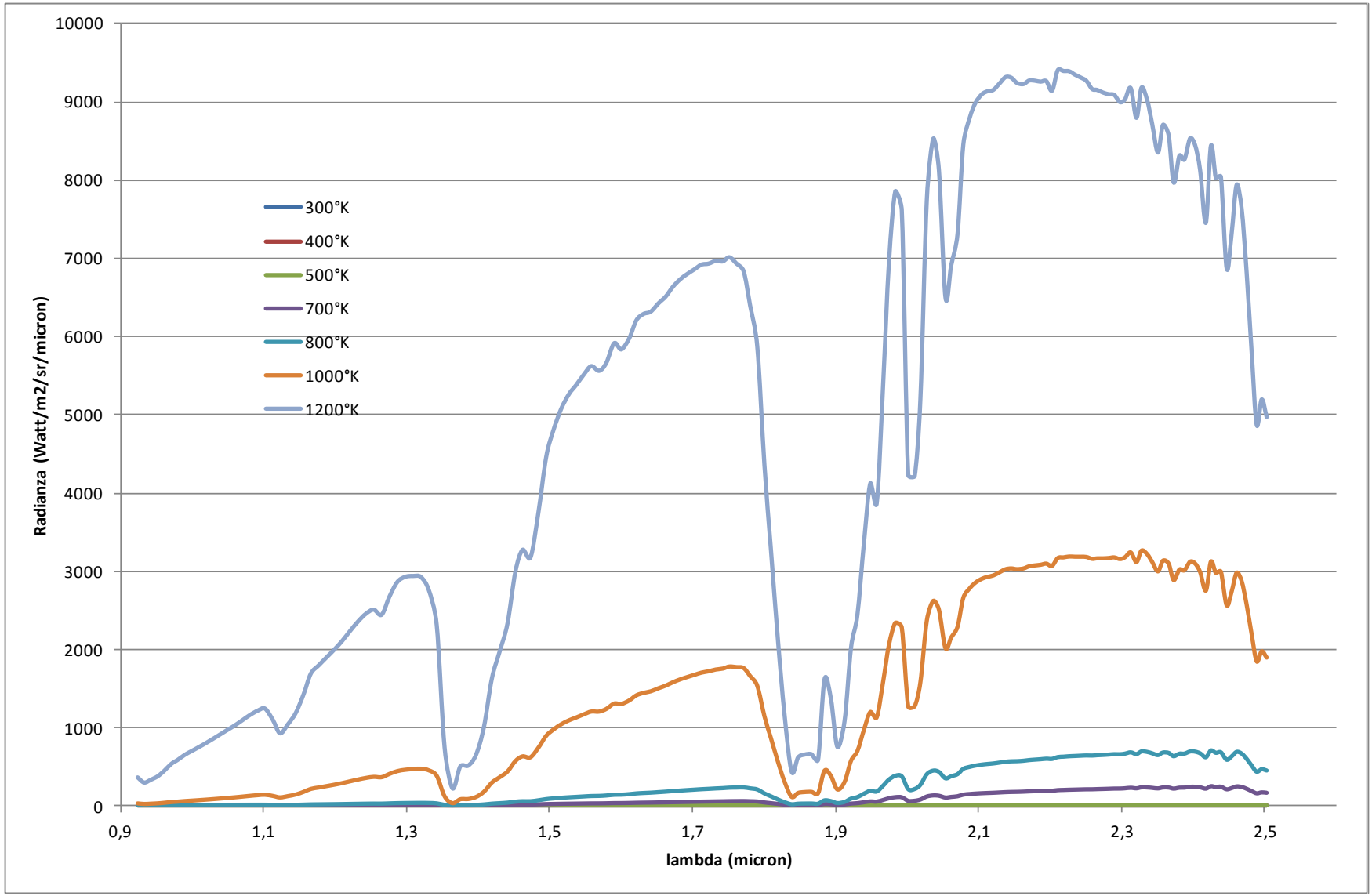
$$\sigma_j = \frac{FWHM_j}{2(2Ln2)^{1/2}}$$

Con FWHM le ampiezze delle singole bande

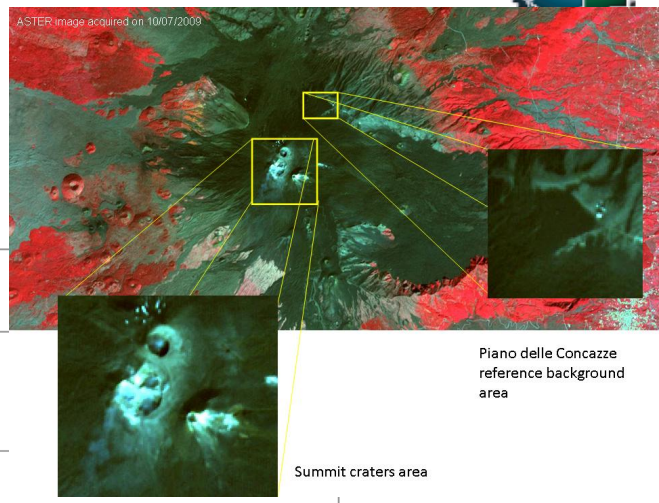
SIMULATED NDL FOR PRISMA

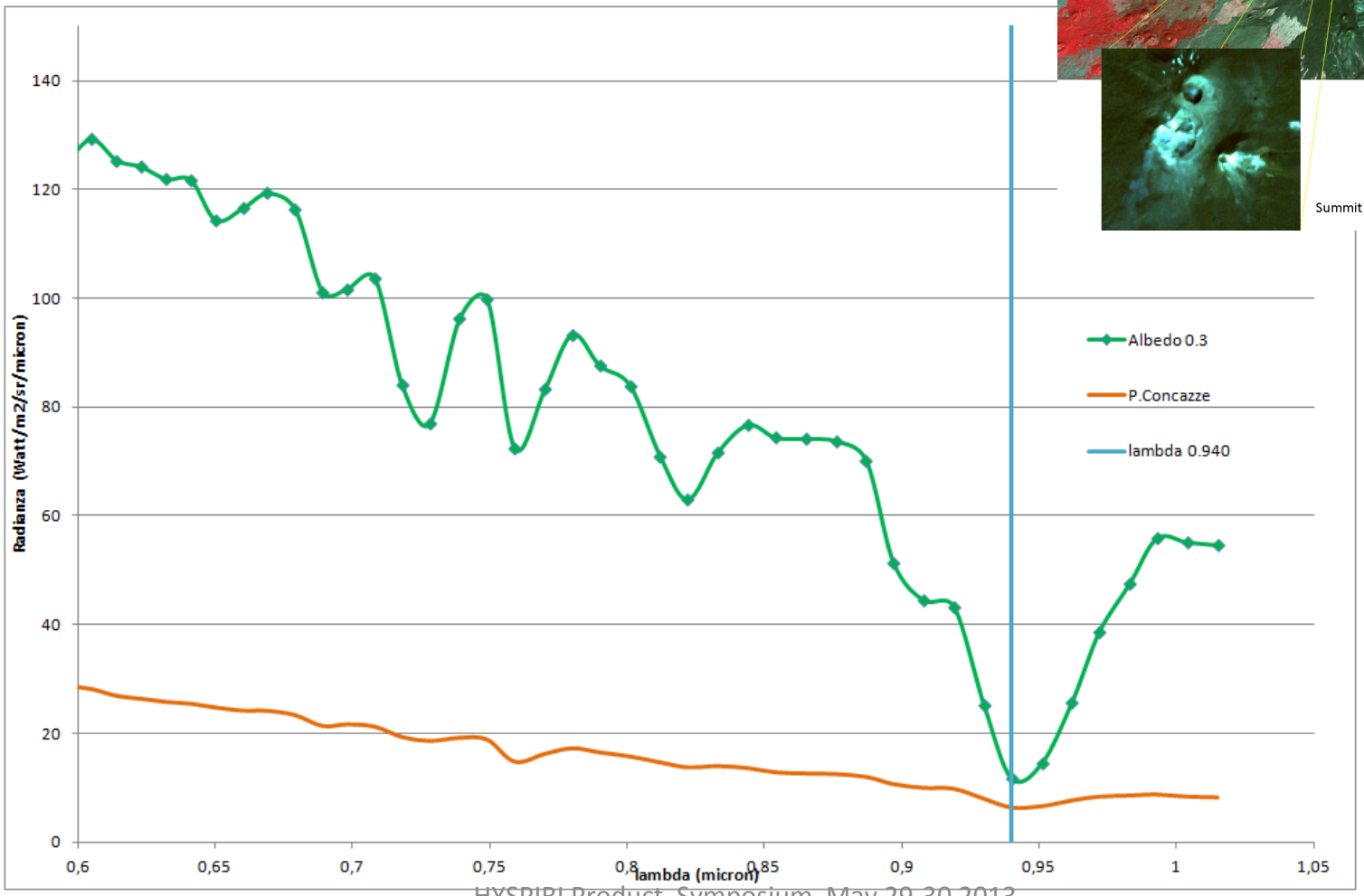


SIMULATION OF RADIANCES FOR DIFFERENT MATERIALS AND TEMPERATURE

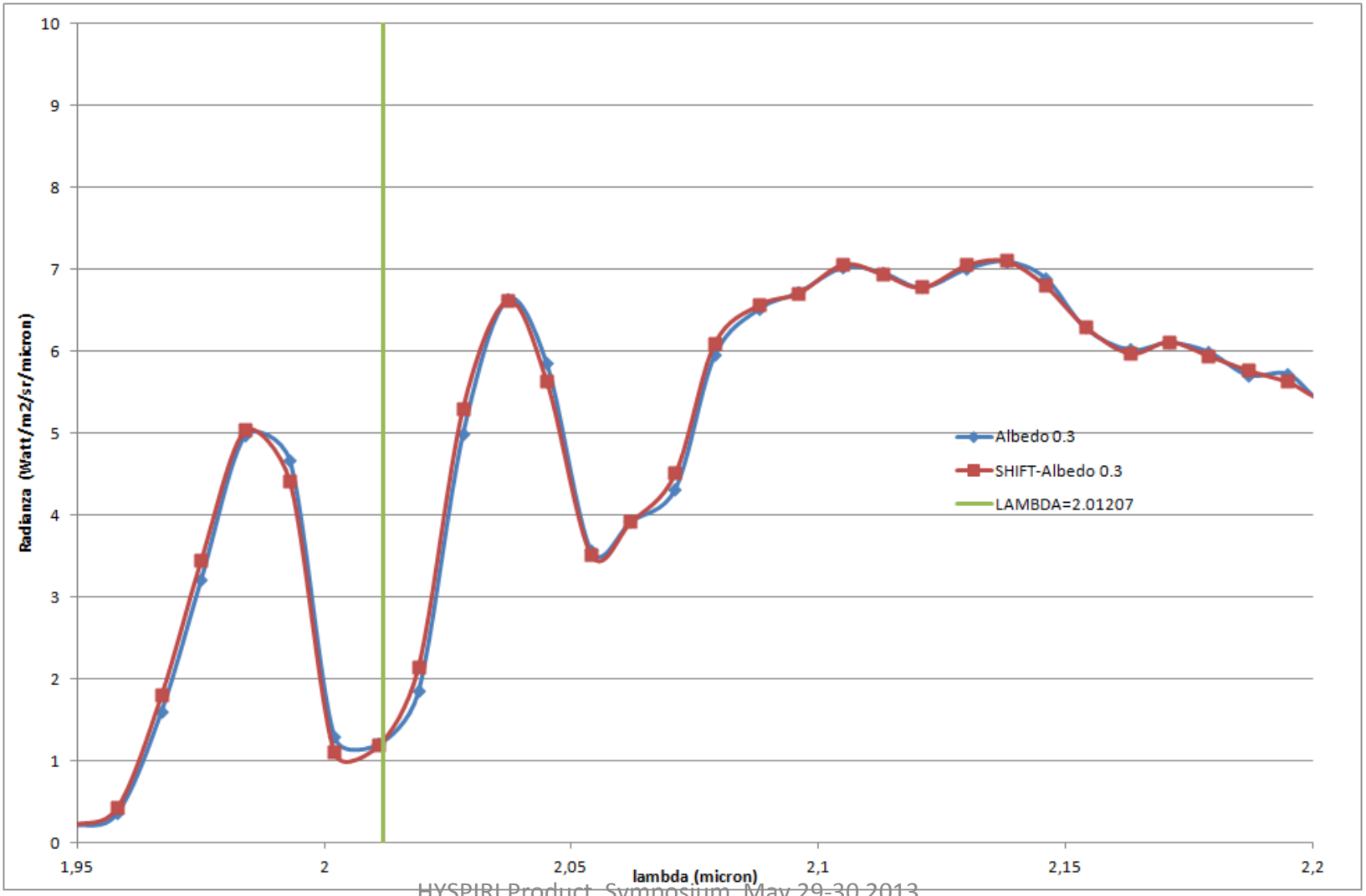


Water absorption at 940 nm

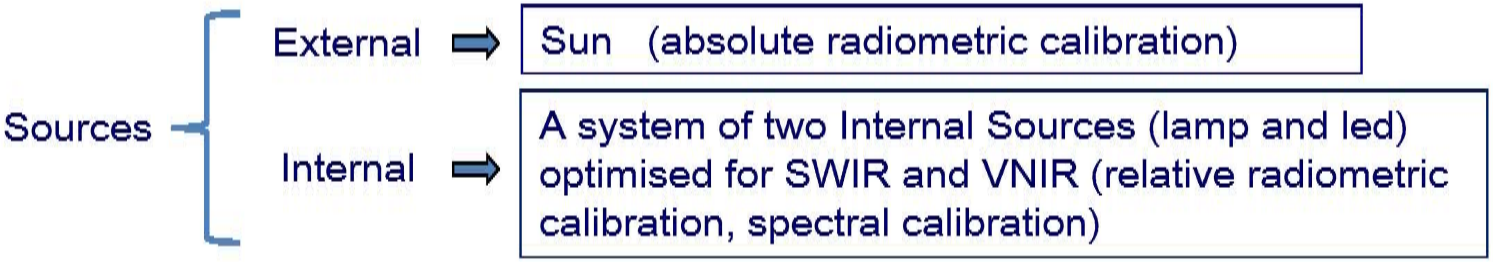




CO2 SWIR absorption 2.01207 micron

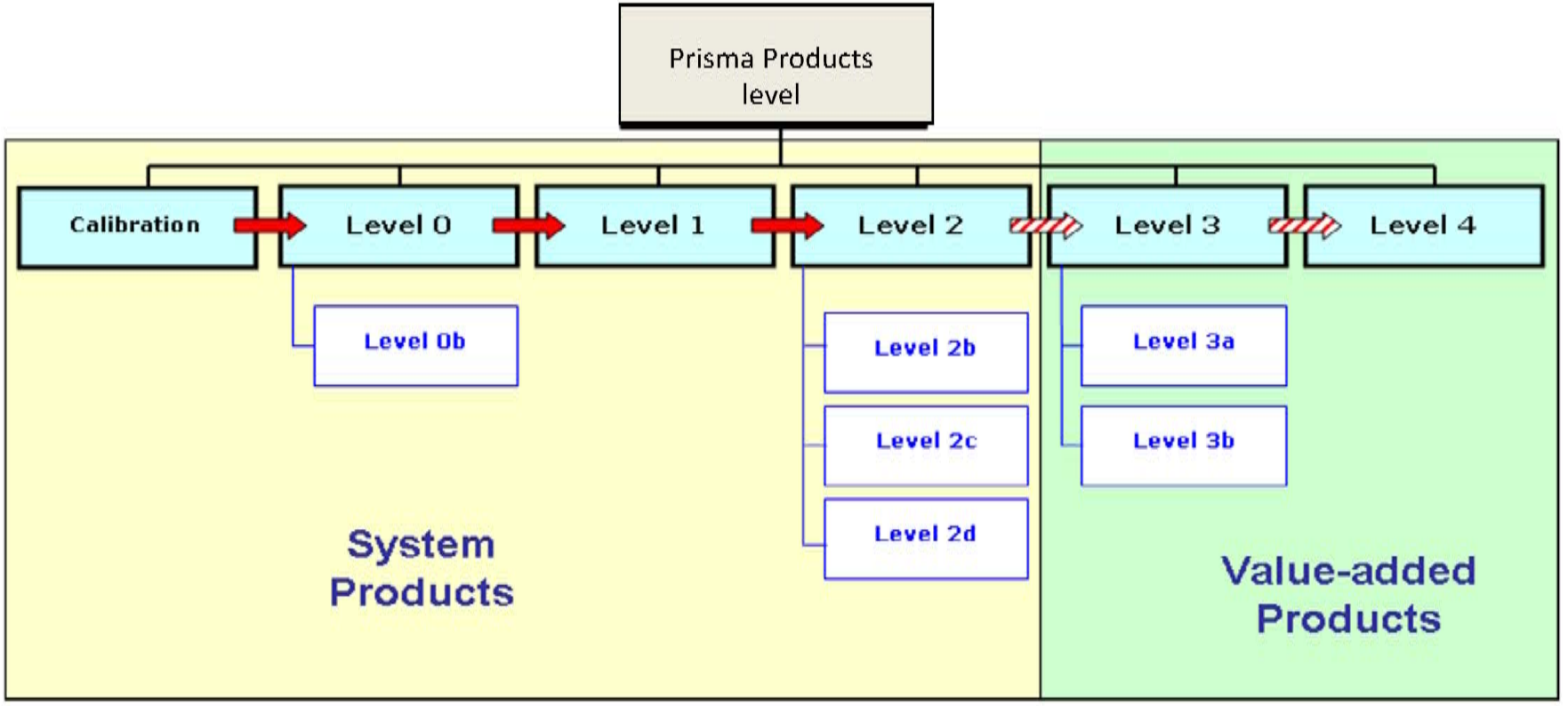


In-Flight Calibration



- Goal: maintain PRISMA calibration accuracies throughout the whole mission operational lifetime (**5 years**), by using Internal Calibration Unit (ICU) for quantifying calibration uncertainty and updating the Key Data Parameters (KDP) set.
- Strategy: systematic measurements of the reference radiance from the **internal sources** (lamp, led) and the **Sun**. These activities doesn't impact on the Satellite manoeuvring and they can be executed with a high repetition frequency.
- Additional in-flight calibration reference sources: External Flat-Field, Earth Specific Targets and Moon Observation (Specific S/C manoeuvres - more rarely execution respect to the ICU's one).
- Monitored ICU degradation by Moon radiance acquired periodically; independent measurement of the ICU transmittance degradation (KDP ITF updating).

Products are classified as **"System Products"**, generated within IDHS facility and **"Value-Added Products"**, playing a key role in the applications definition.



TITLE	Name of the institute	
Development of algorithms and products for applications in agriculture and land monitoring to support the PRISMA mission (SAP 4 PRISMA)	Istituto di Metodologie per l'Analisi Ambientale IMAA CNR	Vincenzo Cuomo
Singergistic use of PRISMA products with high resolution meteo-chemistry simulations and their validation from ground and satellites (PRIMES)	CETEMPS - Univ. de L'Aquila	Guido Visconti
Hyperspectral systems analisys for integrated geophysical applications (ASI-AGI)	Istituto Nazionale di Geofisica e Vulcanologia (INGV)	Fabrizia Buongiorno
Advanced methodologies for analysis, integration and optimization of PRISMA level 1 and 2 products - OPTIMA -	Istituto di Fisica Applicata Nello Carrara (IFAC -CNR)	Ivan Pippi
Coasts and Lake Assessment and Monitoring by PRISMA HYperspectral Mission (CLAM PHYM)	Institute of Marine Sciences (ISMAR - CNR)	Luigi Alberotanza

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please contact
the ASI Program Manager

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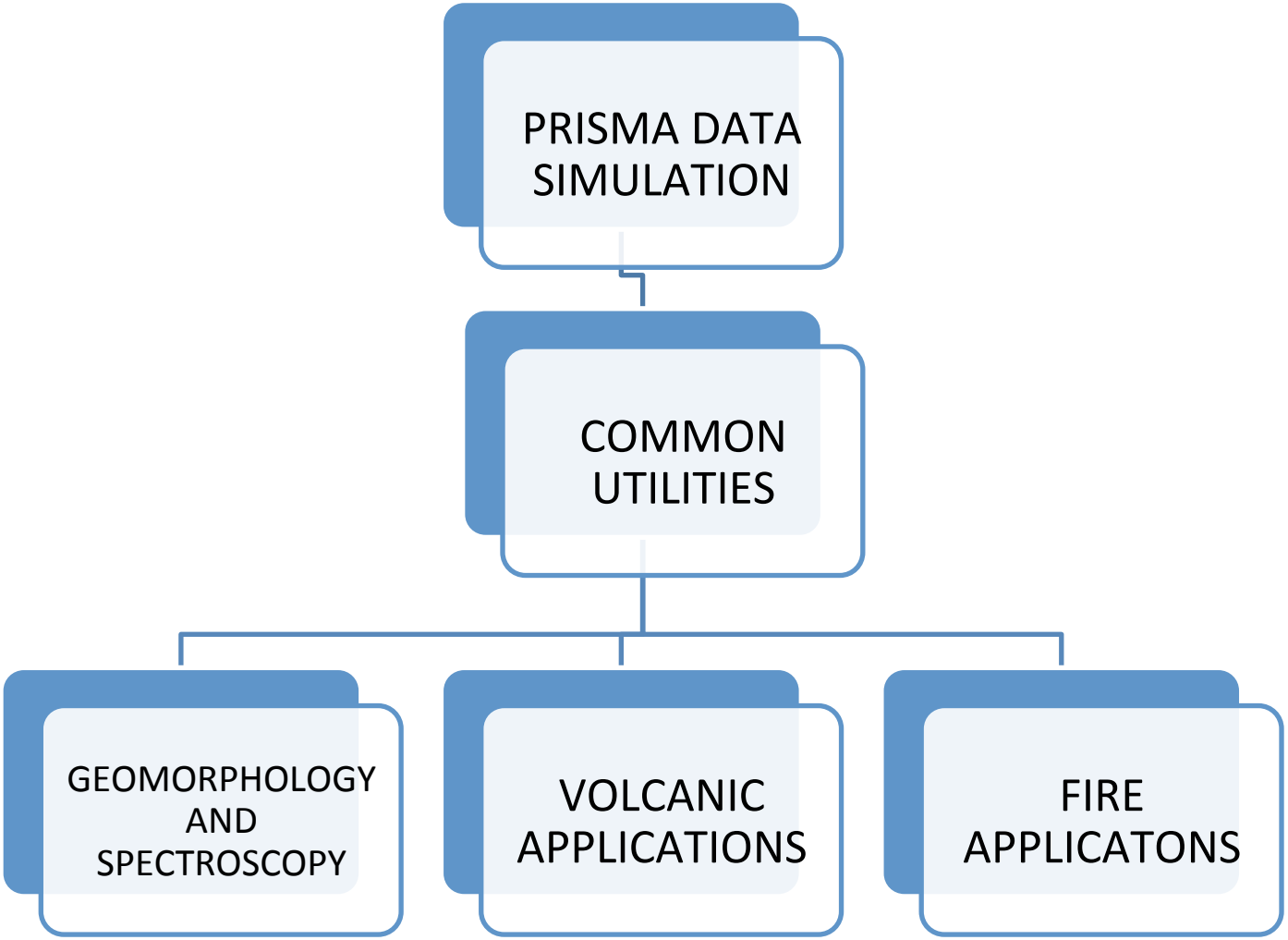
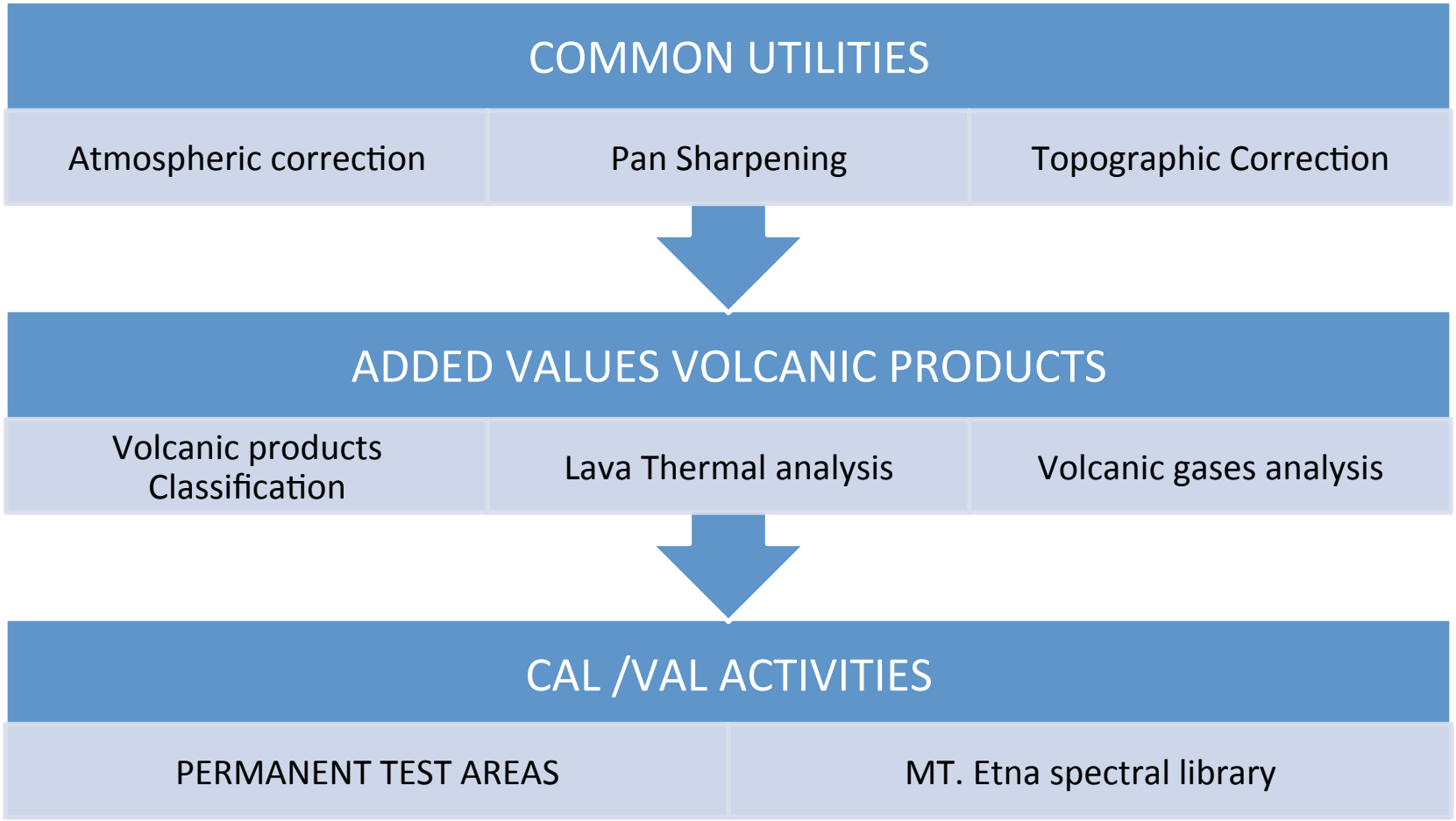
For any further information on the scientific studies
please contact

cristina.ananasso@asi.it

PRISMA GEOPHYSICAL APPLICATION PRODUCTS (ASI-AGI)



PRODUCTS DEVELOPMENT APPROACH



Product description portfolio
Heritage from GMES projects

Service WP 30210 Volcanoes (E&V) Services		
Providers identification *(In previous projects)*		INGV
Providers identification *(In SAFER)*		INGV
General Service Description		The following products have been selected and will be delivered taking into account that objectives of SAFER project aimed to the crisis phase. • **HTE (high temperature events)** • **ASH detection** • **SO2 concentration and flux** • **Ash Dispersion models** • **Sineruptive maps** All the products will be delivered to the EU and Non EU focal point and they will be in the appropriate standard format according to the OGC requirements and to the INSPIRE indications
Targeted Users *(In previous projects and now)*		
Spatial coverage *(In previous projects)*		
Technical validation *(achieved in previous projects)*	Validation dossier reference	
	Technical validation content *(short summary: volume of tests done, purpose of the tests, conclusions etc)*	
Operational validation *(achieved in previous projects)*	Volume of products delivered	
	End users' feedback	
Product description *(In case more than one product is delivered by the service, please describe each product)*		
1. Product		
2. Product		
3. Product		
...		

Service WP 30210 Volcanoes (E&V) Services	
Are all products delivered per activation? Can single products be chosen? *(only to be answered by those service providers who offer more than one product)*	
Delivery Format Please indicate the format *(e.g. jpg, tiff, shp ...)*	
Map	
Analyses data (Vector/Raster)	
kml	
Online service	
Others	
1. Sustainability **Required Input Data/Software:** 1. EO-Data	VHR, HR, MR, LR optical data VHR, HR radar data
2. Non EO-Data	GPS
3. List of used Software for the processing	ITT platform (ENVI/IDL)+ GAMMA + home made SW,
Is there a sustainable supply of relevant EO- and non EO-data for the provided product (GSCDA quota and sensor availability ensured)	All the product will be generated trough the ensured data provided by ESA.
Is a support of the used software ensured (and how)?	Yes it is
2. Transferability Risk Areas covered by the product/service	Etna all events that will occur during the lifetime of the project Piton de la Fournaise all events that will occur during the lifetime of the project World Wide test Service on demand for events in the South America or South Pacific area
Transferability of the product t o other areas	World Wide test Service on demand for events in the South America or South Pacific area
In which scale range can the product be used?	From 1:50000 up to 1:250000

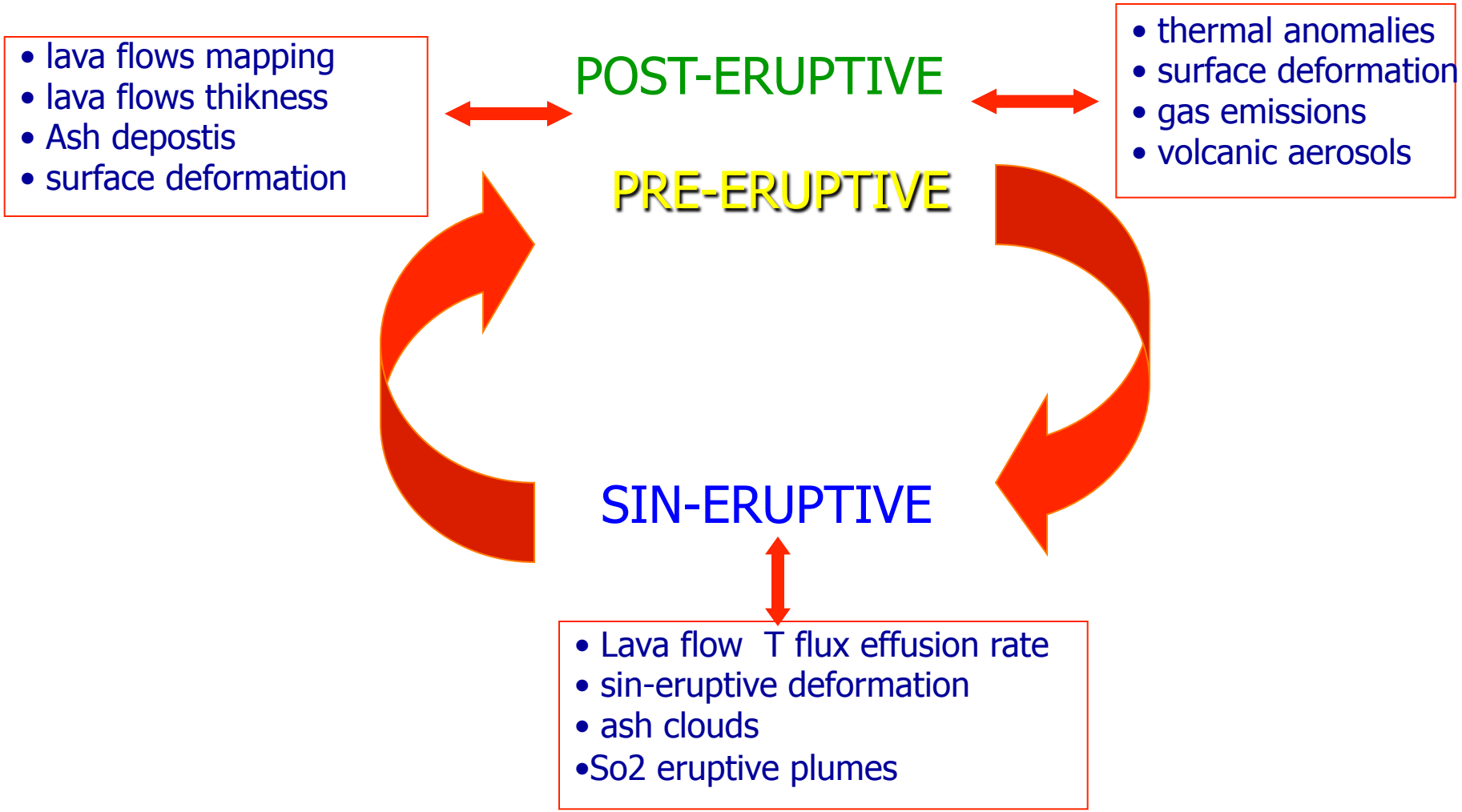
Products for volcano monitoring

LOCATION OF ITALIAN

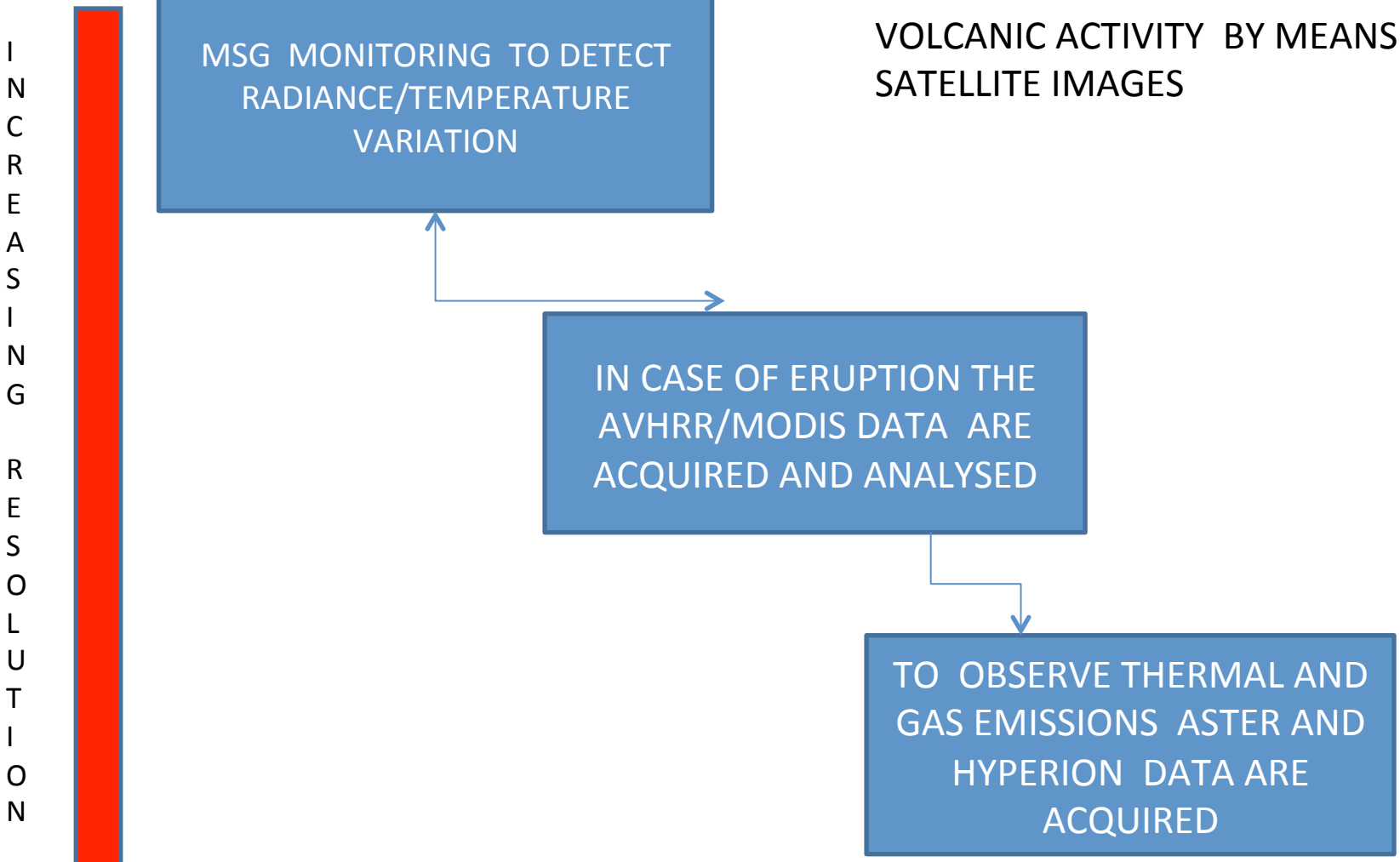
ACTIVE VLOCANOES

(in red)

products related to Volcanic Risk Phases



WORKFLOW SCHEME TO MONITOR VOLCANIC ACTIVITY BY MEANS OF SATELLITE IMAGES



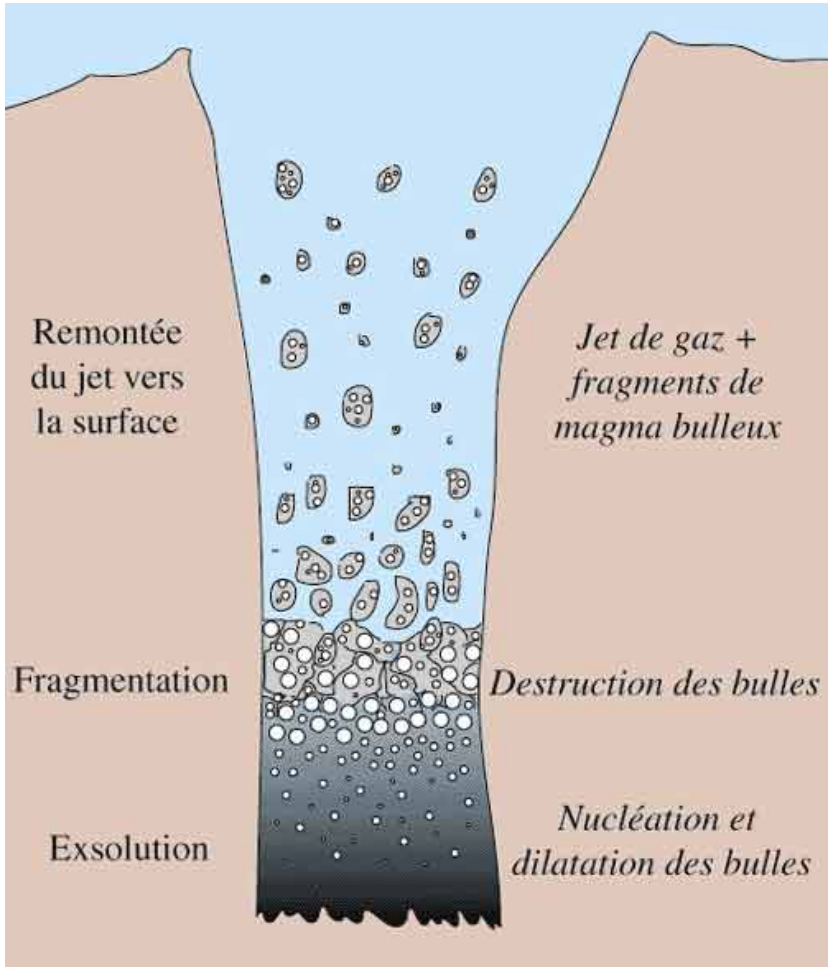
VOCANIC GAS EMISSIONS PRODUCTS FROM PRISMA

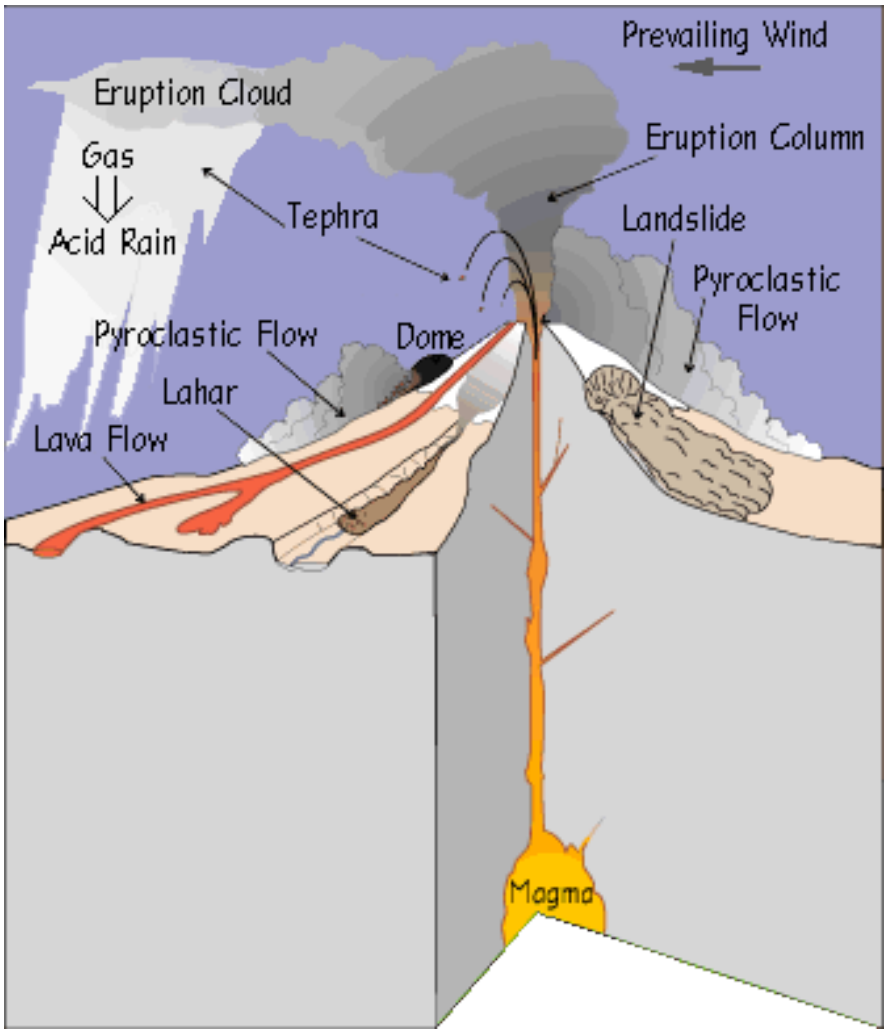
Algorithms: Review of the CBRW modified algorithm development of new algorithm LIR based on hyperspectral sensors data in the SWIR range

Objective: Analysis of the absorption bands of CO2 and CH4 in volcanic plumes and degassing cold fumaroles

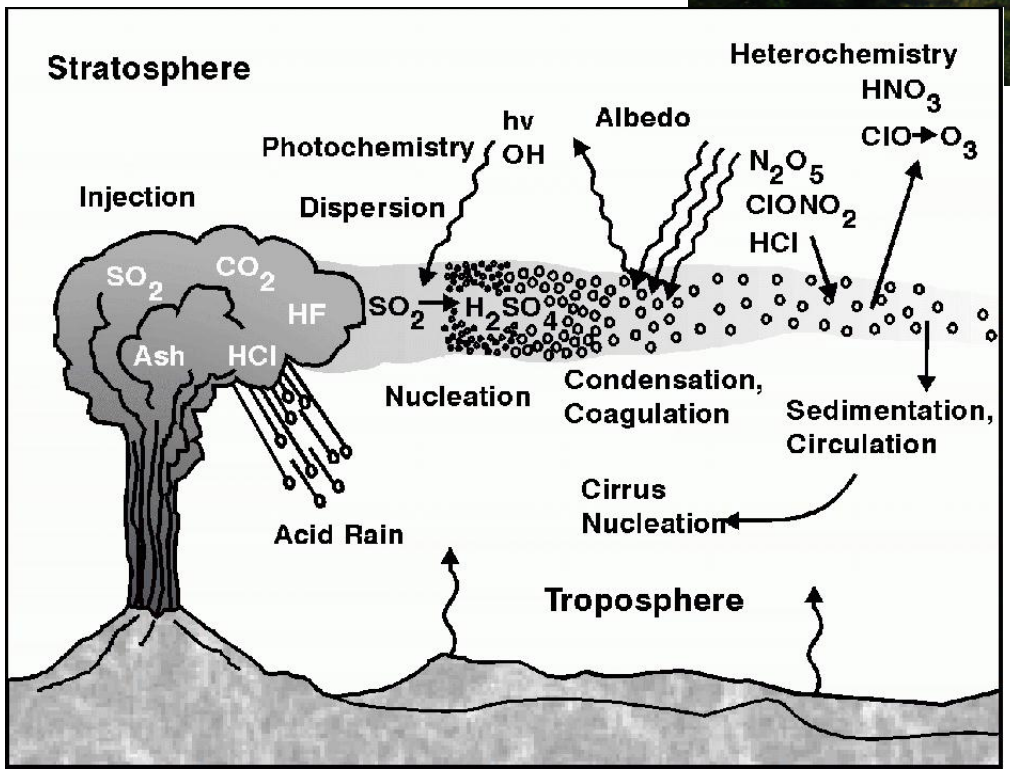
Products: maps to show degassing areas in volcanic zones CO2 concentration and flux in volcanic plumes

Volcanic emissions in atmosphere





Volcanic plume



- ✓ Volcanoes inject in the troposphere H2O, CO2, SO2, H2, CO and in lower quantities H2S, HCl, HF, He, …
- ✓ Those gases can be responsible of acid rains, pollution of aquifers, ….
- ✓ More globally, the volcanic plumes have an impact on the climate.
- ✓ Some historical eruptions are known to have induced colder climate during some years

Volcanic gases flux (1975-1995)

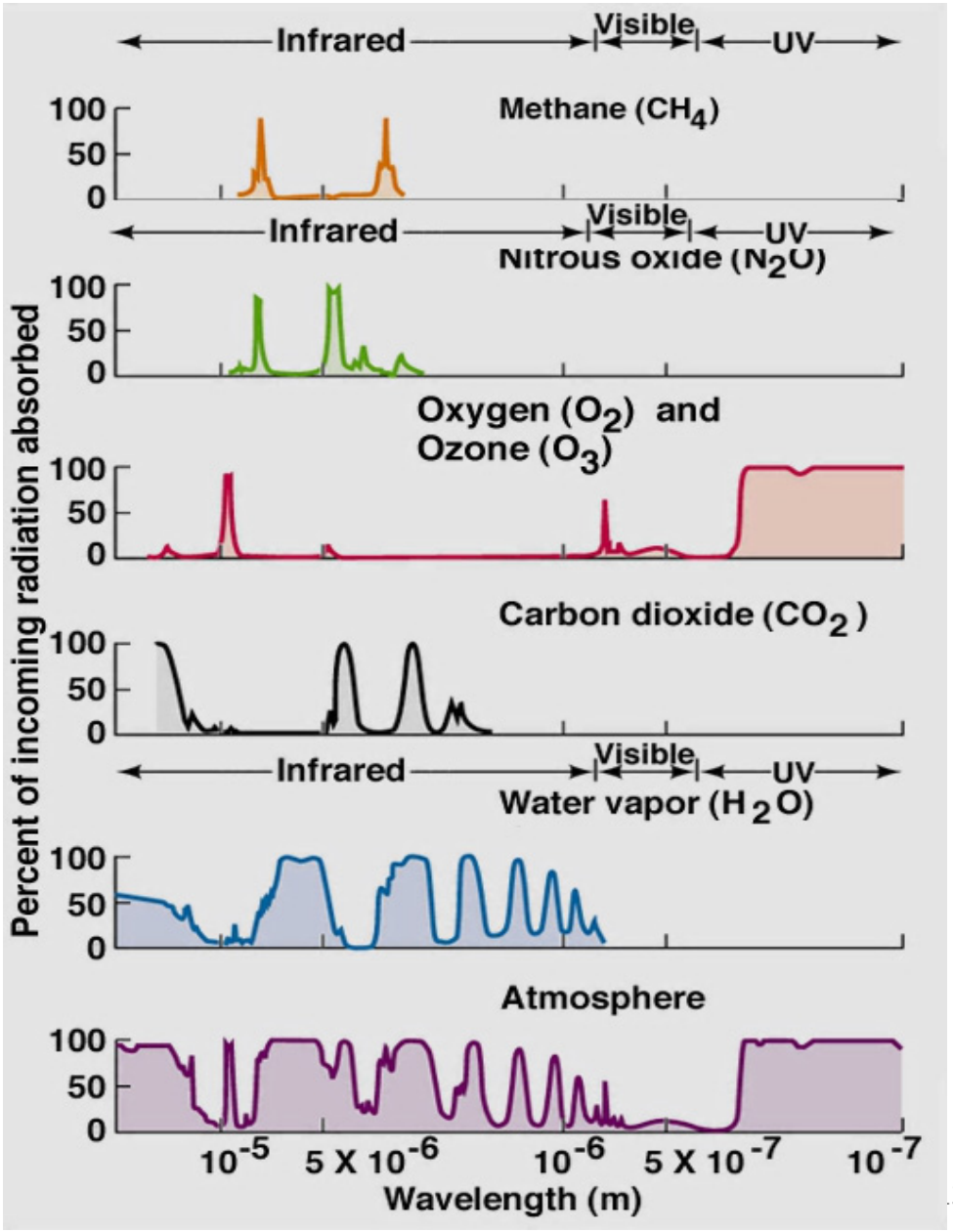
Species	***Global Volcanism (Gg/yr)***	***Etna/Global Volcanism***
H_2O	$5.0 \cdot 10^6$	10%
CO_2	$(8\text{-}20) \cdot 10^4$	(7-16)%
SO_2	$1.3 \cdot 10^4$	11%
HCL	$(4\text{-}110) \cdot 10^2$	9%
HF	60-6000	8%
Br	77	2.6%
Zn	9.6	51%
Cu	9.4	5.9%
Mn	42	0.6%
Pb	3.3	4.5%

Volcanic CO_2 emissions

Volcano	***CO_2 (T/d)***
Mt. Etna	11000-70000
Popocatepetl	6400-40000
Oldoinyo Lengai	7200
Augustine	6000
Mt. St. Helens	4800
Stromboli	3000
Kilauea	2800
White Island	2600
Erebus	1850
Redoubt	1800
Grimsvotn	360
Vulcano	270

DATA SOURCE:

Symonds et al., 1994; Gerlach et al., 1997; Allard et al., 1998; Varley et al., 1998; Delagdo et al., 1998; Kopenick et al., 1996; Allard et al., 1991; Wardell and Kyle, 1998; Brantley et al., 1993; O'Keefe, 1994

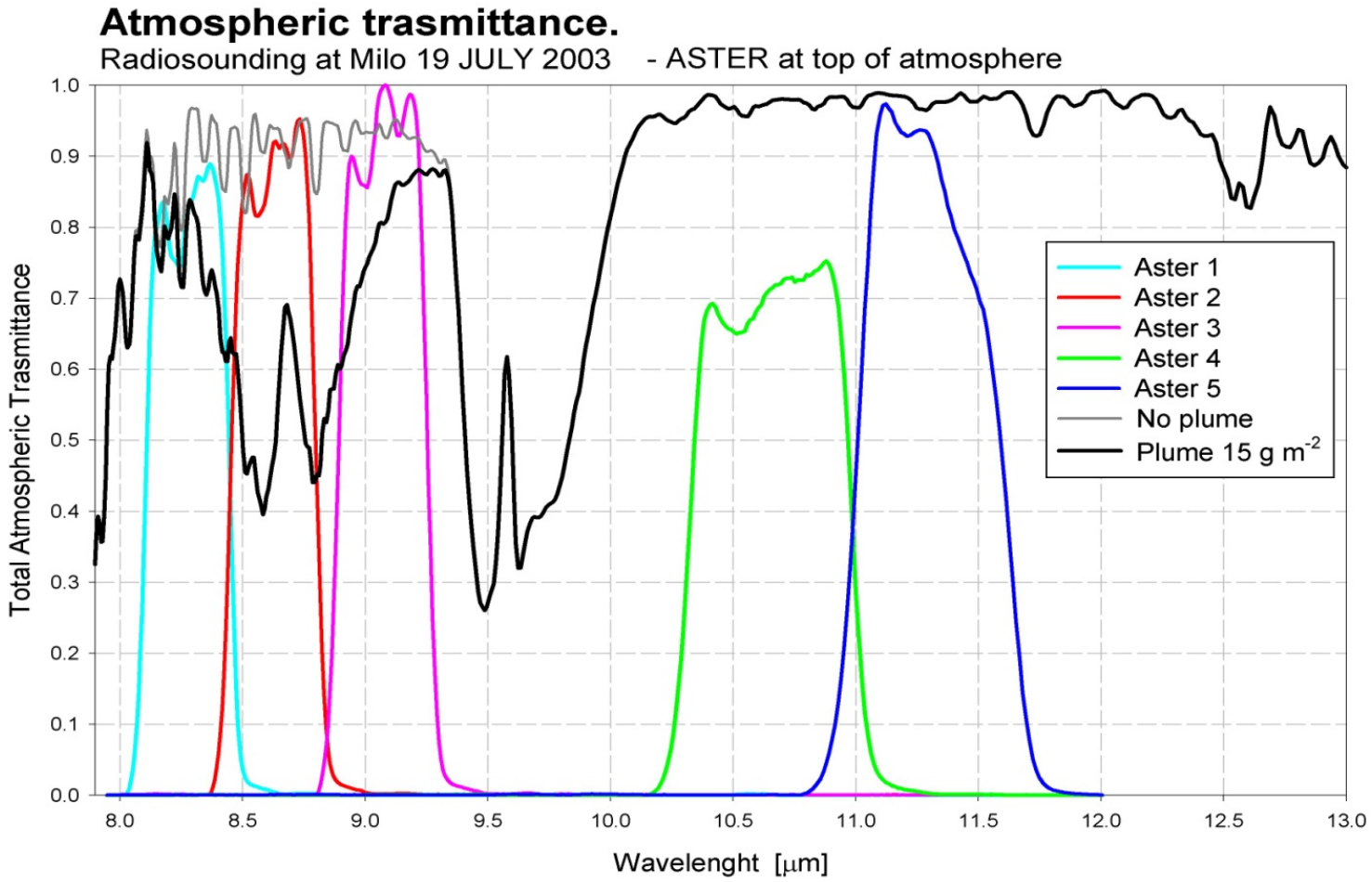


atmospheric absorption features

volcanic

volcanic

VOLCANIC SO2

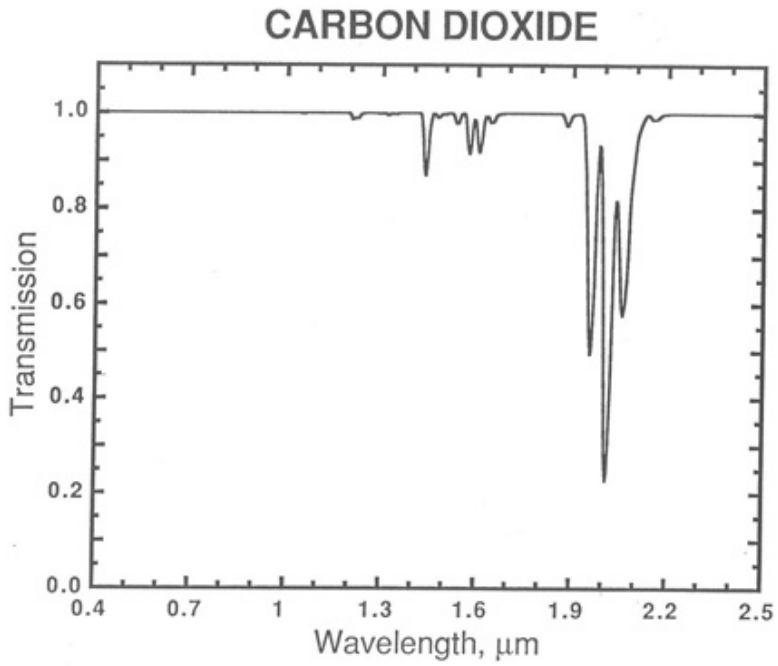


Volcanic Carbon Dioxide Retrieval

CO_2 absorption lines are present in the spectral range of hyperspectral imaging spectroradiometer VNIR-SWIR

weak absorption 1270 nm and 1610 nm

strong absorption 1950 nm and 2100 nm



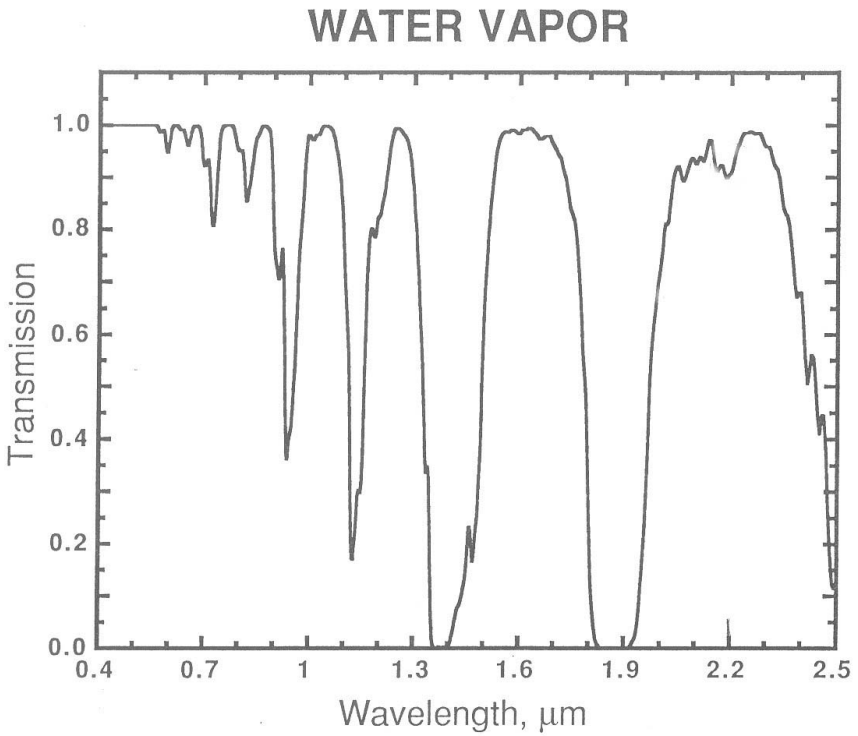
Atmospheric transmisson simulated using Modtran with the only presence of CO_2 in standard condition with 10 nm of spectral resolution

Water Vapour absorptions in the VNIR-SWIR spectral range

Water Vapour Absorption lines are present in the spectral range of hyperspectral imaging spectroradiometer:

weak absorption
940 e 1125 nm

very strong absorption
1350 e 1900 nm



Atmospheric transmisson simulated using Modtran with the only presence of water vapour in standard condition

The CIBRW retrieval alghoritm

In order to retrieve the tropospheric volcanic plume Carbon Dioxide abundance, an inversion technique has been developed for remote sensing hyperspectral data (*Spinetti et al., 2008, RSE*). The algorithm is based on the assumption that there is a relationship between the dip in the atmospheric spectrum curve, due to the gas absorption, and the gas concentration in the atmospheric column. The retrieval is based on solving the equation:

$$CIBRW = \exp(-\alpha(w) \cdot [CO_2]^{\beta(w)})$$

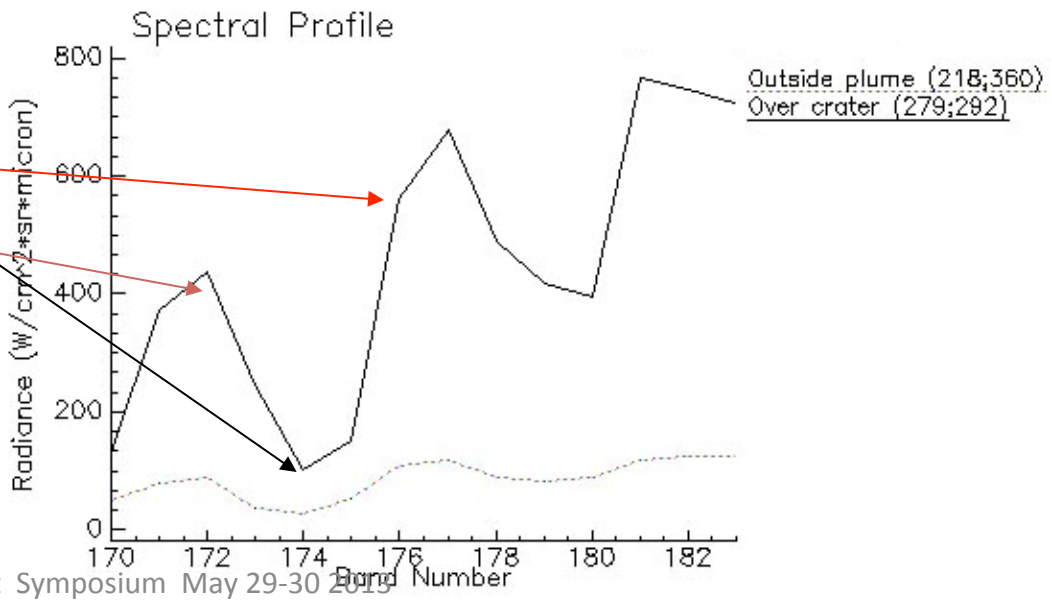
- $[CO_2]$ is the unknown carbon dioxide columnar abundance ($kg \cdot m^{-2}$);

- α e β parameters related to the model variables, volcanic water vapor abundance and volcanic aerosol presence;

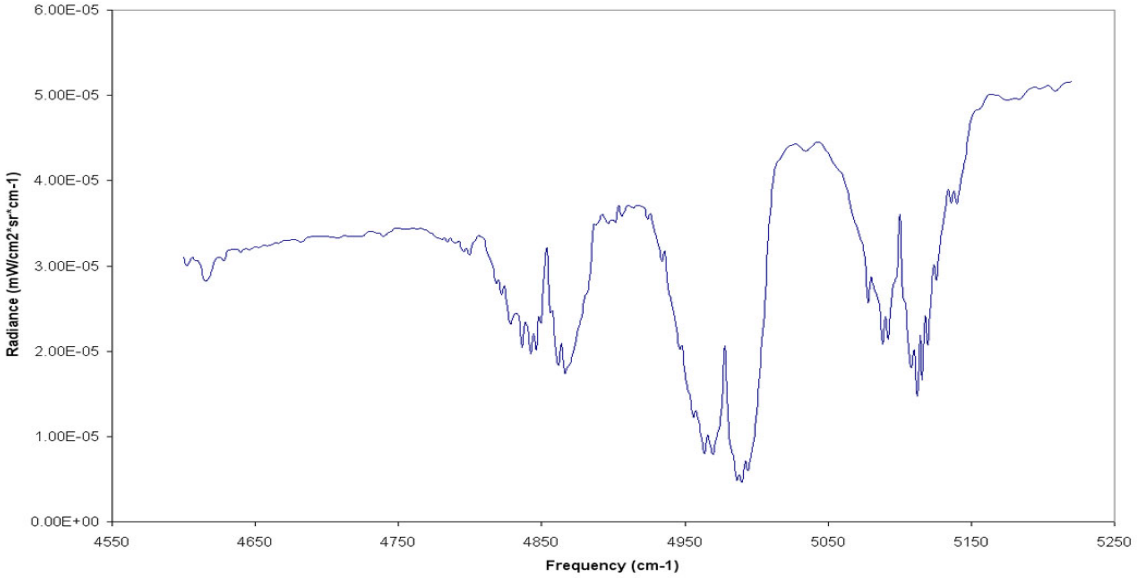
- CIBR is given by the following ratio:

$$CIBR = \frac{R_a}{A \cdot R_1 + B \cdot R_2}$$

- R_a is the radiance corresponding to the minimum of absorption
- A and B are the weighting constants
- R_1 and R_2 are the radiances of the continuum

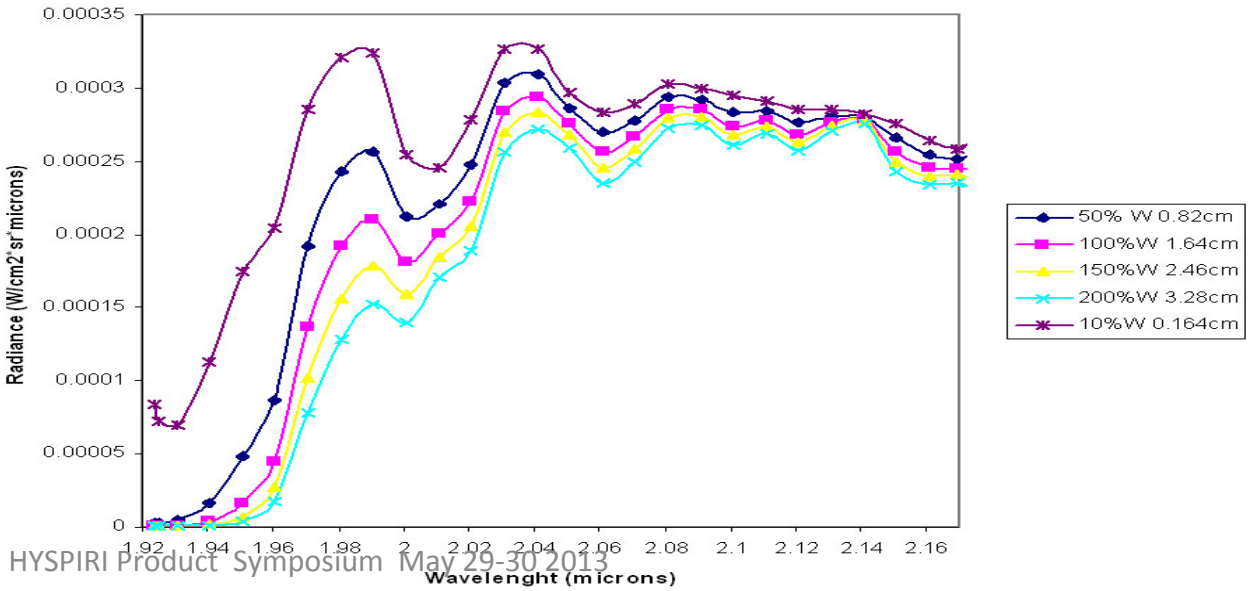


The water vapour influence



Considering 10 nm of spectral resolution, CO2 lines partially overlap with the water vapor lines. The presence of water vapor influences the CO2 absorption bands cancelling the signal of the first CO2 absorption band and modifying the other two bands depending on the amount of water vapor.

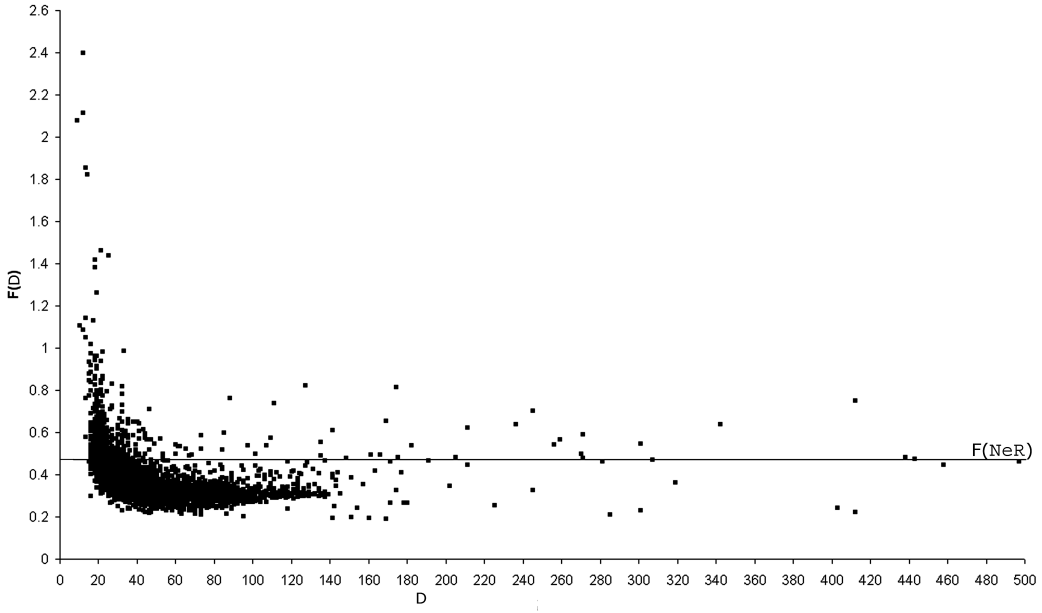
Modtran Radiance simulation at standard atmospheric conditions with the atmospheric concentration of CO2 and the presence of different values of water vapour in the atmospheric column.



Signal Sensitivity Analysis

In order to quantify the signal sensitivity with respect to the CO2 absorption line variations, a sensitivity function F(D) has been defined:

$$F(D) = \left| \frac{D(\lambda)\,|_{\lambda=\lambda_m}}{D(\lambda)\,|_{\lambda=\lambda_{C1}} + D(\lambda)\,|_{\lambda=\lambda_{C2}}} \right|$$



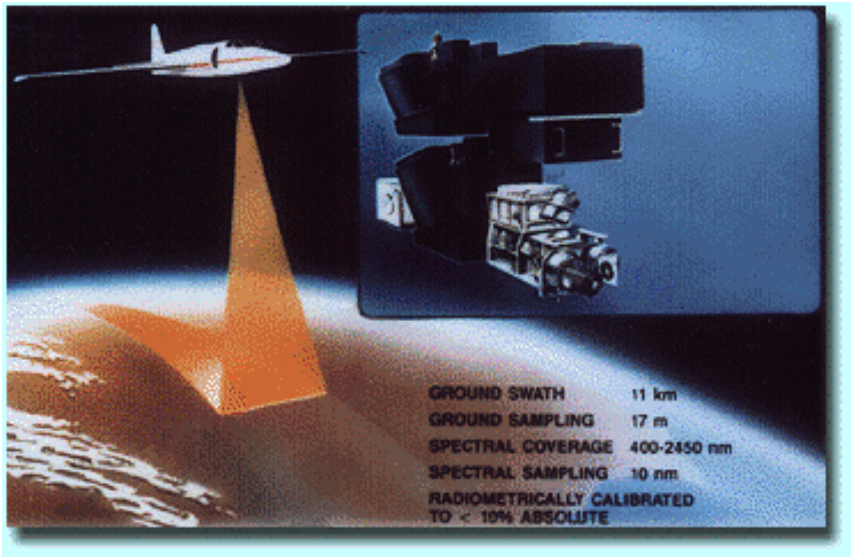
λ_m= 2011nm is the CO2 absorption channel; λ_{c1} = 1981nm and λ_{c2} = 2031nm are channels in the continuum;
$D = (R_{Plume} - R_{Atm})$ where R_{Plume} is the volcanic plume radiance and R_{Atm} is the atmospheric radiance outside the plume

The CO2 retrieval is possible only if the signal contains the information on volcanic CO2 above the atmospheric background, i.e. where F(D) assumes values greater than the noise equivalent radiance:

$$F(D) > F(NeR)$$

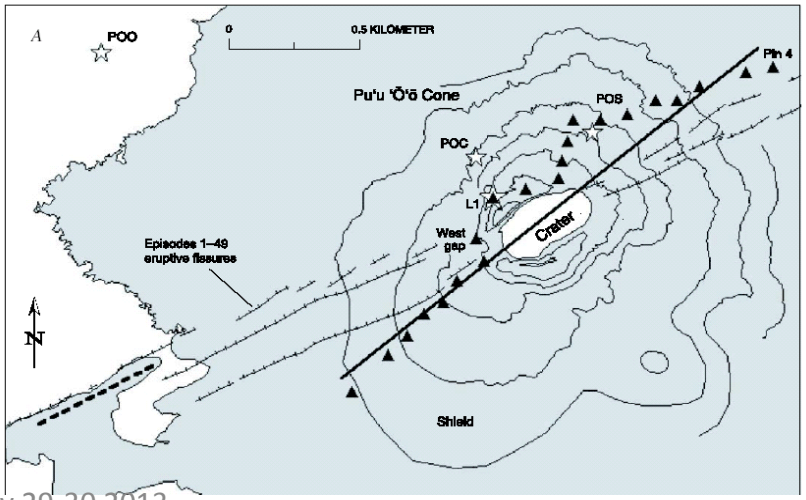
AVIRIS

Airborne Visible/InfraRed Imaging Spectrometer



"Whisk broom" scanning

Spectral coverage	**400-2450 nm**
Spectral sampling interval	**9.6-9.9 nm**
Spectral channel width	**9.8 12.5 nm**
Number of spectral channel	**224**
Number of pixel scan line	**614**
Number sca/sec	**12**
IFOV	**1.0 mrad**
Rad. Calib. accuracy	**6%**
In-flight stability	**1%**
Spectral calib.accuracy	**2+- nm**



Water vapour abundance map of Pu'o'O Vent plume at Kilauea volcano

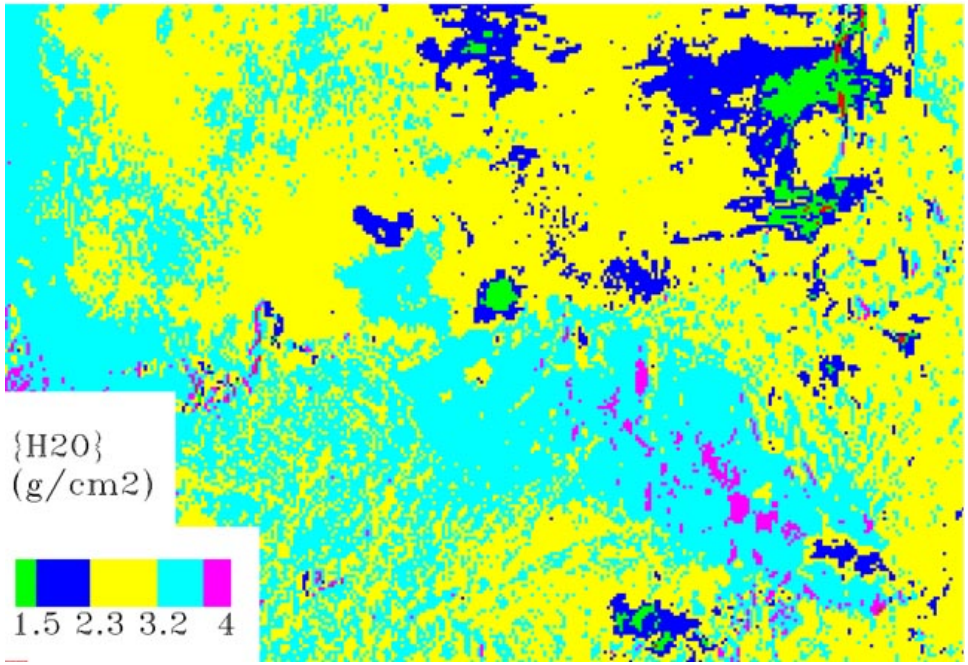
AVIRIS campaign April 26th 2000

Pixel dim.

20x20 m^2 @ crater

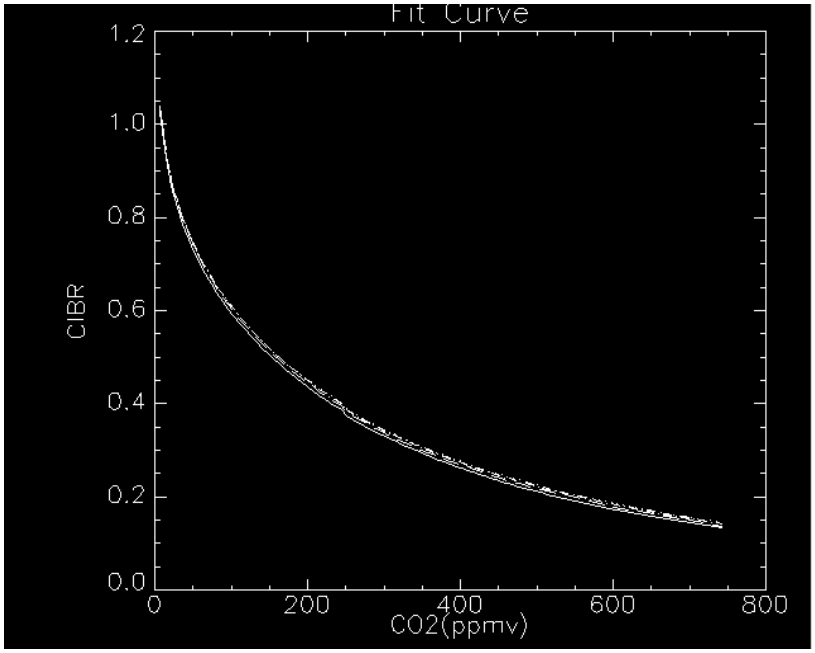
R 676.31± 0.11nm
G 529.43 ± 0.11nm
B 452.08 ± 0.11nm

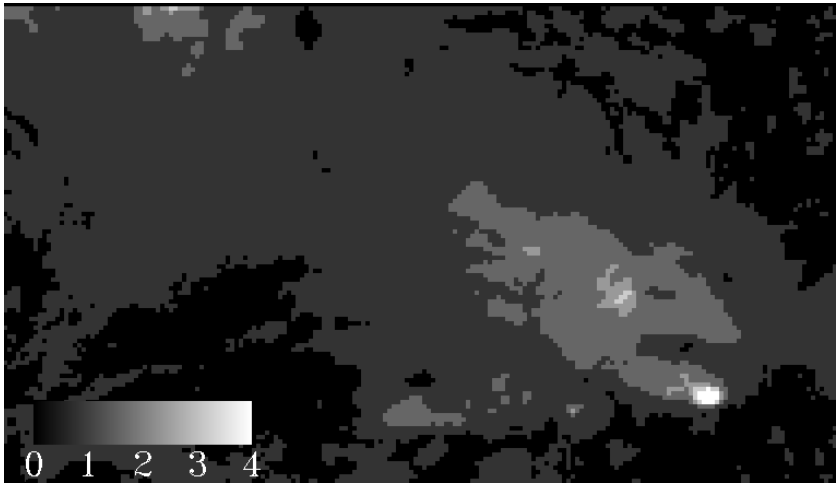
Water vapour map retrieved using 940 nm absorption band



Spinetti and Buongiorno 2004, IEEE Trans

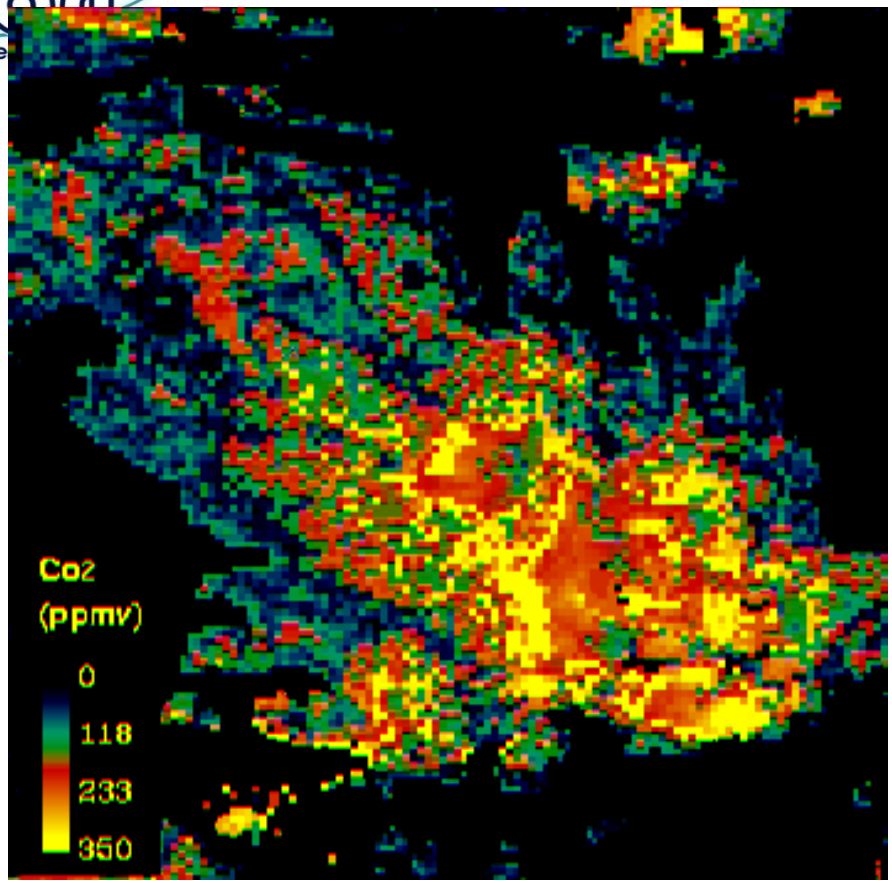
Paramaters α and β depending on water vapour content



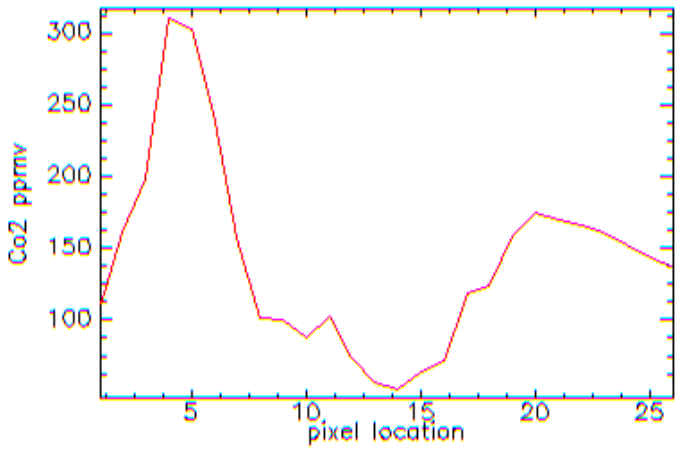


Index	W (g/cm2)	α(w)	β(w)	Correlation fit (R^2)
0	2.3	0.0160669	0.740992	0.989785
1	2.8	0.0141277	0.759783	0.986303
2	3.2	0.0133723	0.766998	0.984544
3	3.4	0.0135917	0.763602	0.984492
4	4	0.0141354	0.756234	0.985672

Map of CO_2 abundance in the Pu'o'O Vent plume



26-4-00



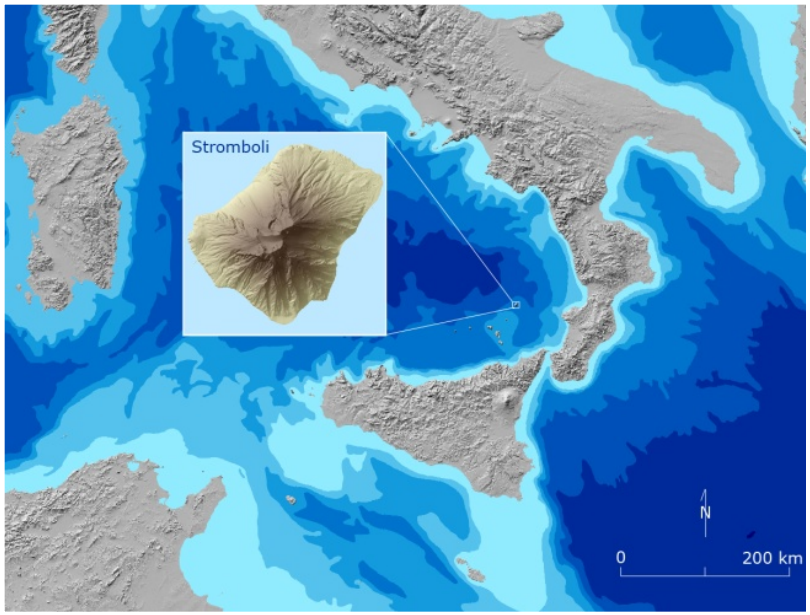
$\Phi_{CO2} = 396 \pm 138$ t d^{-1}

Accordance with ground sampling data

Figure 13. Lava from crater of Pu'u 'Ō'ō flows through west gap in cone. View eastward; photograph by J.P. Kauahikaua, taken October 20, 1997.

Figure 14. Crater of Pu'u 'Ō'ō. Fume rises from several vents on crater floor, which is covered with pāhoehoe erupted in 2002. View westward; photograph taken April 11, 2002.

The Stromboli Volcano

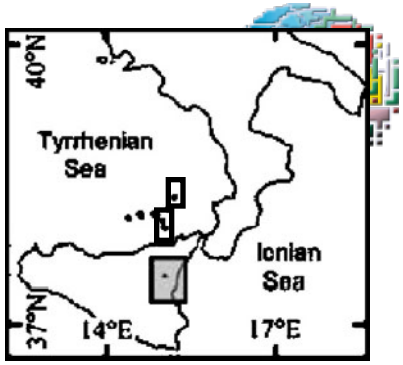


Located on the north-eastern part of the eolian arcipelago Stromboli is an open-conduit volcano active from more then 1,000 years.

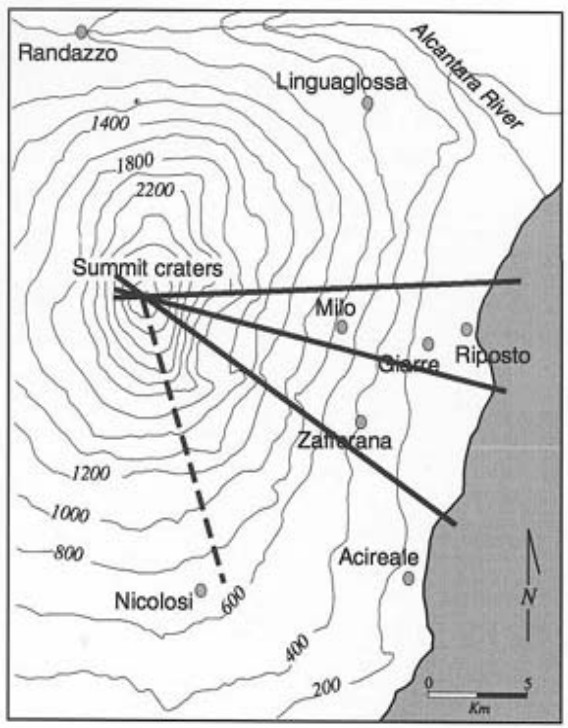
The typical activity is characterized by regular explosions emitting small volumes of lava spatter and pyroclasts up to 50–100 m above the craters every 15–20 min. Whilst activity of Stromboli volcano is mainly of *low intensity*, Strombolian explosions are occasionally interrupted by *major explosions, paroxysmal events, effusive activity as lava flow and landslides*.

When such events happen, the risk level of the vicinity of the volcano poses a serious hazard for people on the volcano especially in the crater area.

Airborne Measurement Campaigns MIVIS on Etna, Vulcano e Stromboli

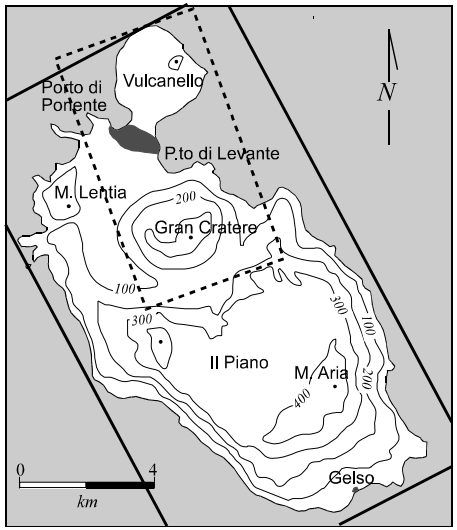


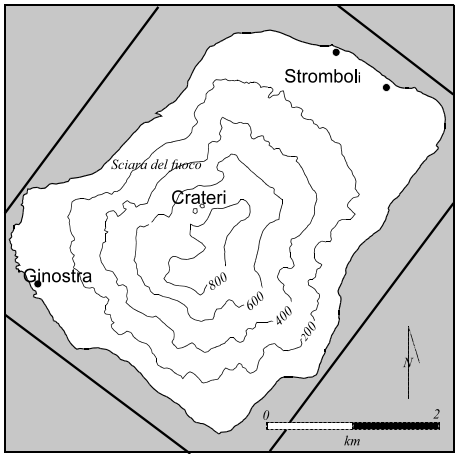
July 1994



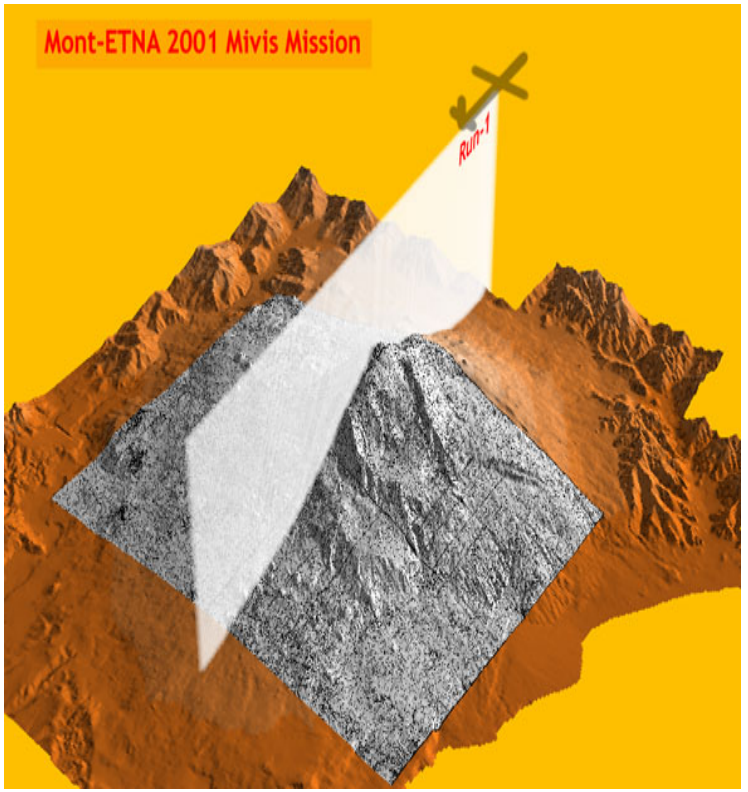
"MVRRS Campaign: MIVIS Mission on Sicilian Volcanoes and Ground Measurements" 1999 Publication of Quaderni di Geofisica

June 1997





July 2001

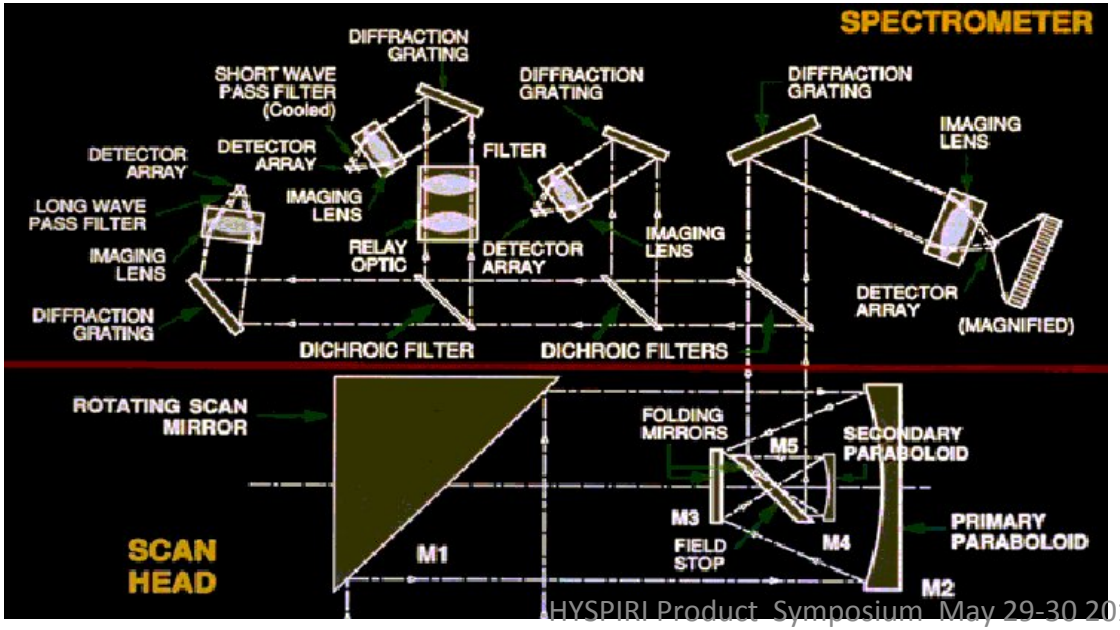


Daedalus AA5000 MIVIS
Multispectral Infared and Visible Imaging Spectrometer

102 spectral bands simultaneously sampled and recorded

Optical port	Spectral Range	Number of channels	Spectral resolution
1 (VIS)	431-833 nm	20	20 nm
2 (NIR)	1.150-1.550 μm	8	50 nm
3(SWIR)	1.985-2.479 μm	64	9 nm
4 (TIR)	8.210-12.700 μm	10	340-540 nm

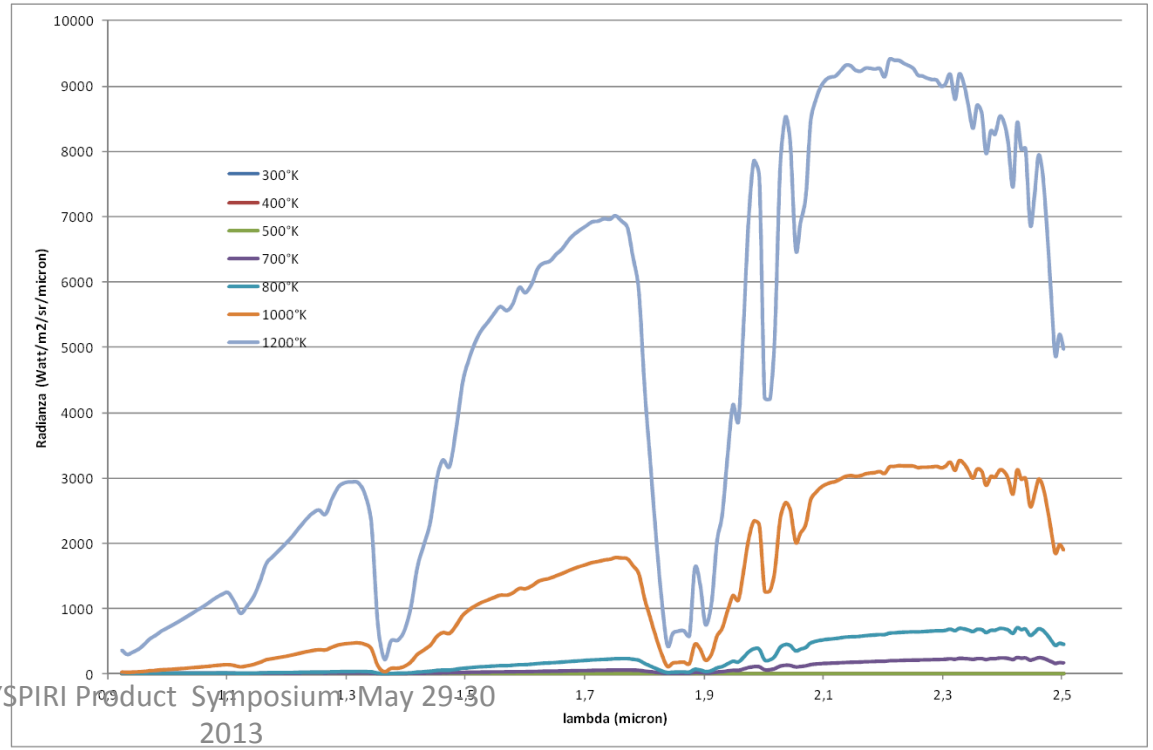
MIVIS Scan Head and Spectrometer



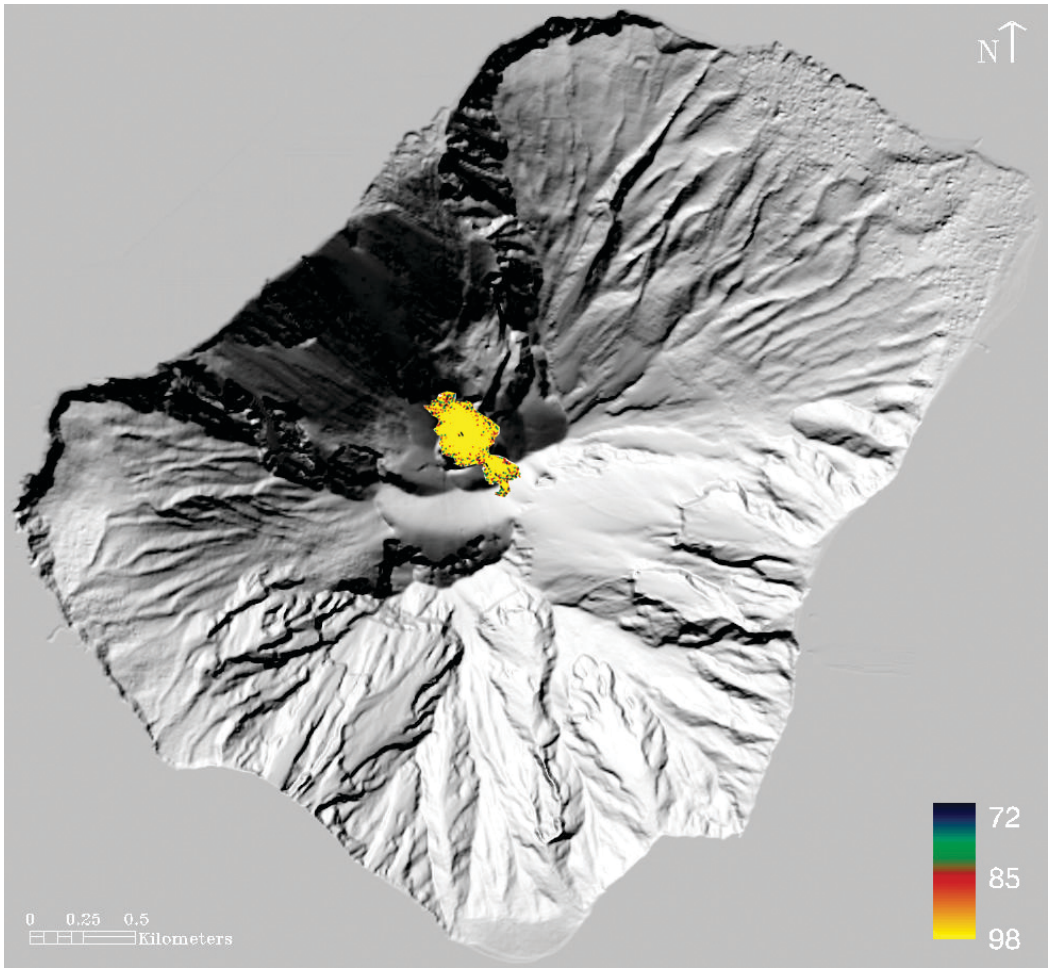
LARA System

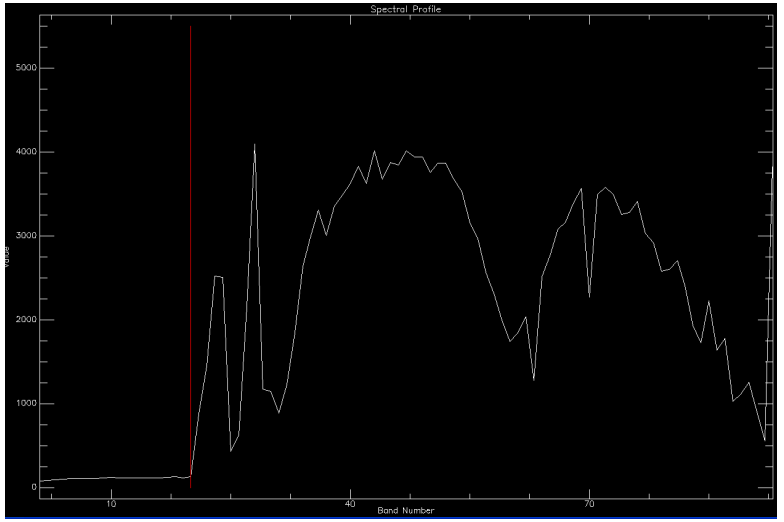
Radiating source

The radiating source is represented by an hot spot in a scene. The radiance shows an increment in the CO2 lines. This appends during Strombolian explosions. Temperature has been derived using the plank equation applied to radiance data. The temperature of the plume has been used as input in the Modtran simulations.



CO_2 map (ppm) retrieved from MIVIS data July 97





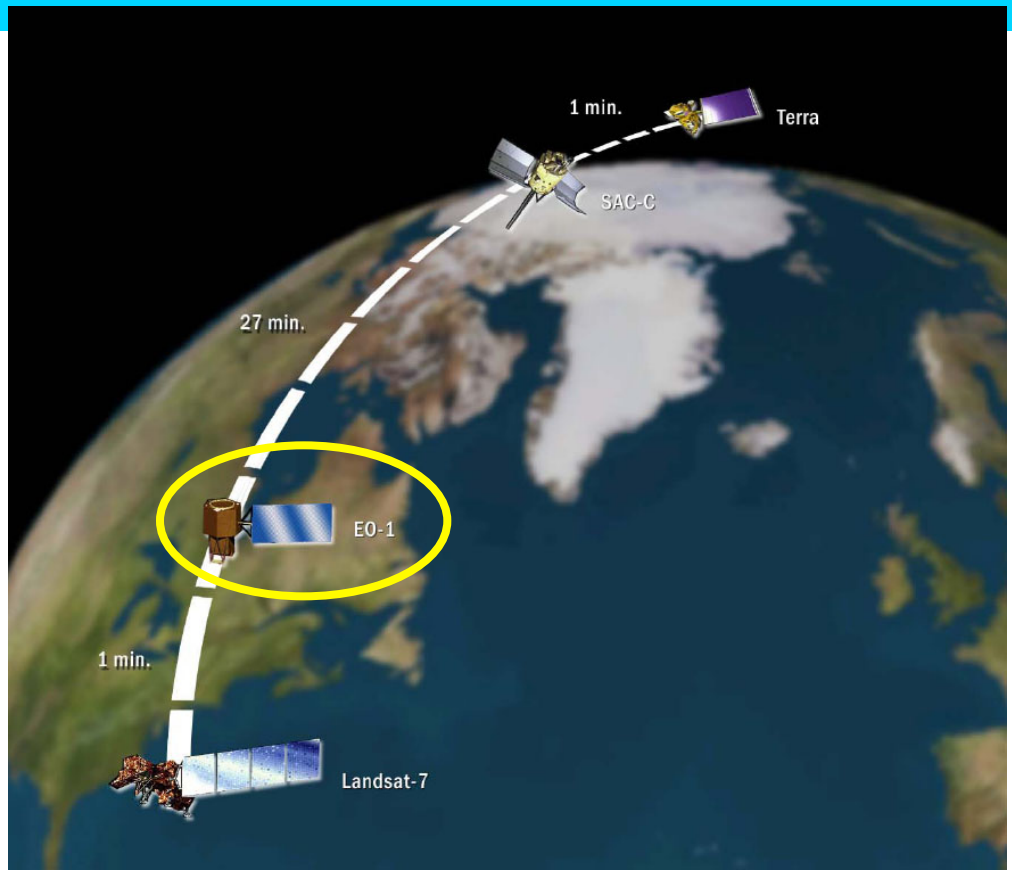
CO2 map @ 3 m res

Flight level 11500 ft 3.5 km

Spinetti et al., 2012

HYPERION

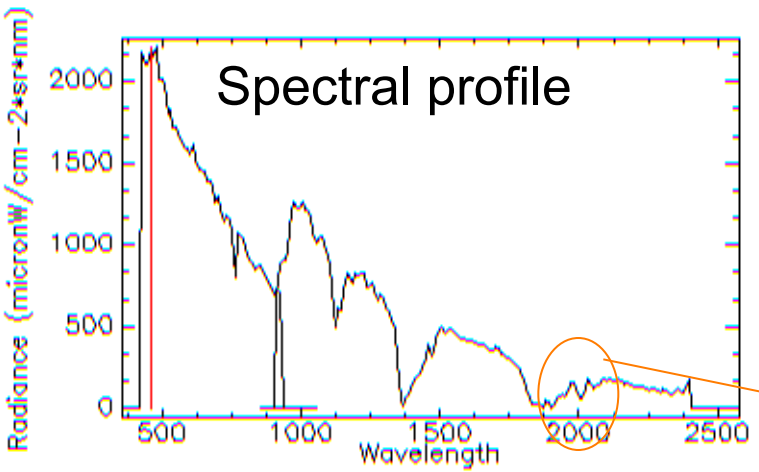
hyperspectral spaceborne imaging spectrometer



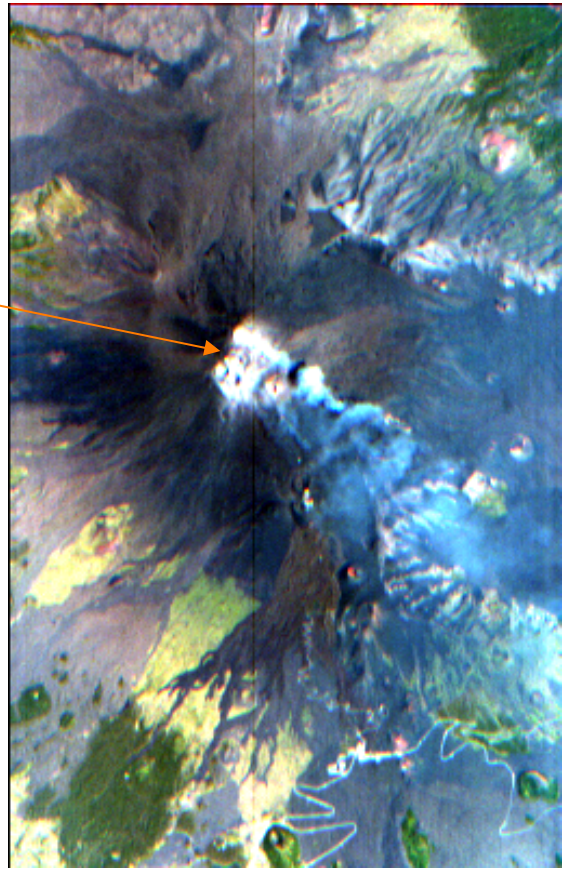
Morning constellation
709 km orbit
EO-1 launched on 2000

“Push broom” scanning
242 channels 400 – 2500 nm. 10 nm nominal channel bandwidth.
224 Hz frame rate. 12 bit data encoding.
0.61 degrees total field of view. 42.4 microrad Instantaneous Field of View.
On-board Accuracy Radiometry 3.40% VNIR SNR (550 - 700nm) 140- 190 SWIR SNR (~ 1225nm) 96 SWIR SNR (~ 2125nm) 38

Hyperion data analysis



Mt. Etna volcano



R
G
B

Pixel dim.
30*30 m^2

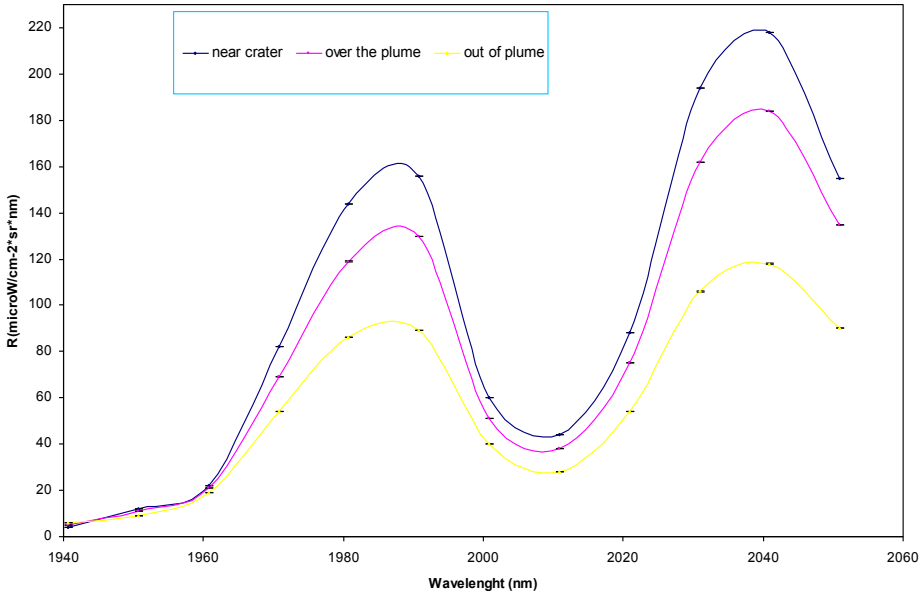
Hyperion 19-7-03

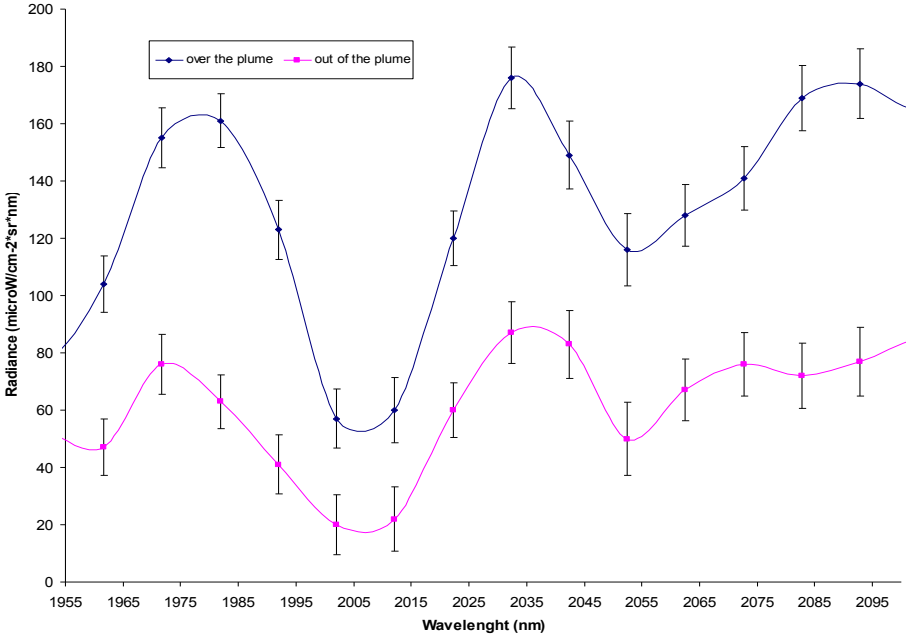
Mt. Etna N-E crater picture

Signal Sensitivity Analysis

Sensitivity function

$$F = \frac{|(R_{Plume} - R_{Atm})|_{ch174}|}{|(R_{Plume} - R_{Atm})|_{ch172} + (R_{Plume} - R_{Atm})|_{ch176}|}$$





F(min) ≥ NeΔR

Hyperion data have a very limited sensitivity compared to Aviris

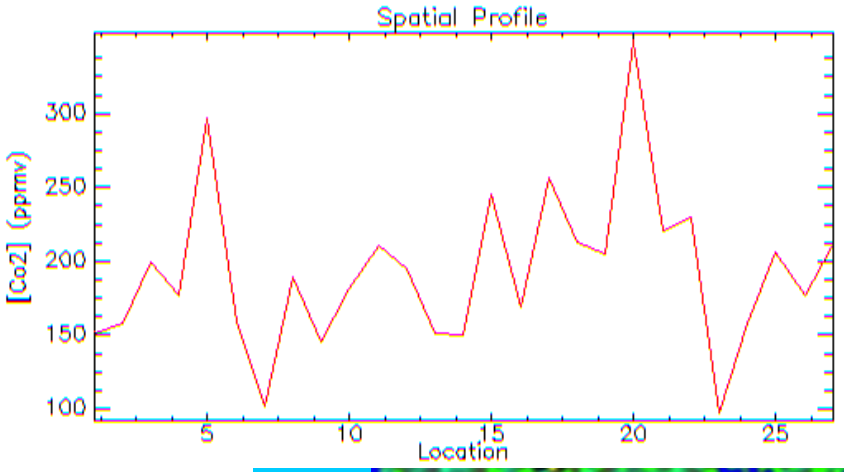
Signal to Noise Ratio

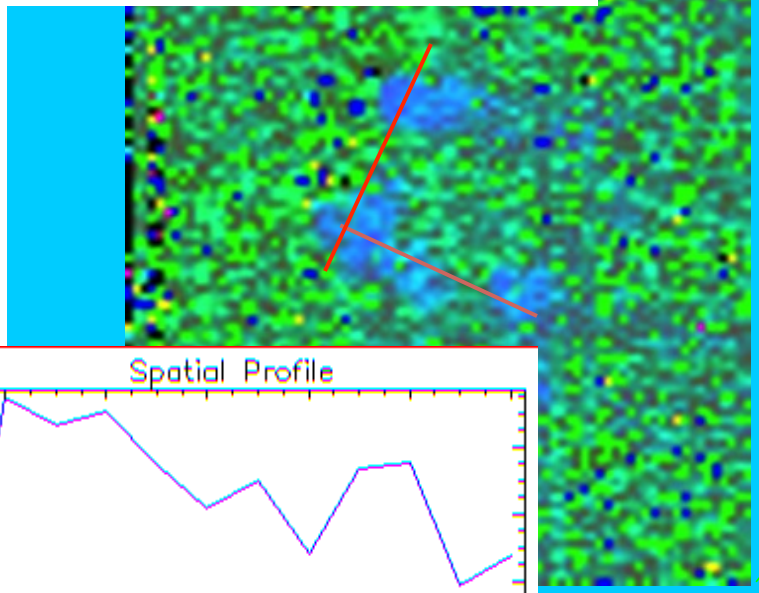
Gao and Homogeneus area methods

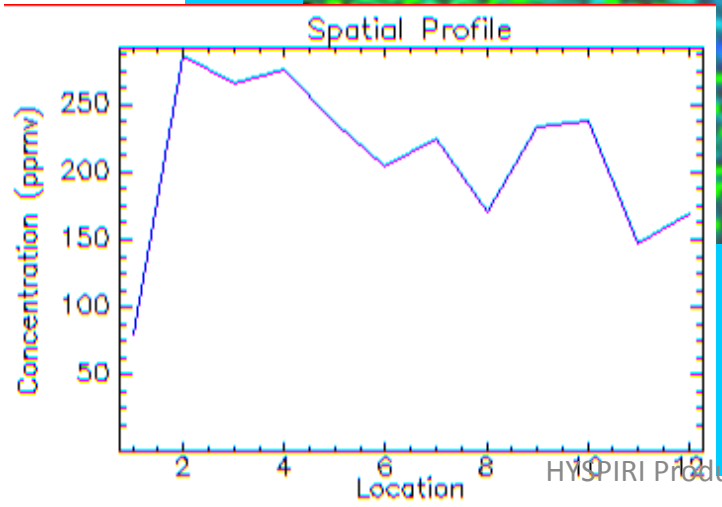
Data	Water vapour absorption bands	Carbon dioxide absorption bands
AVIRIS 2000	940nm SNR>>10	2.005 μm SNR>>10
Hyperion 2001	1.125μm SNR>10	2.005 μm SNR≥10
Hyperion 2003	1.125μm SNR>10	2.005 μm SNR≈10

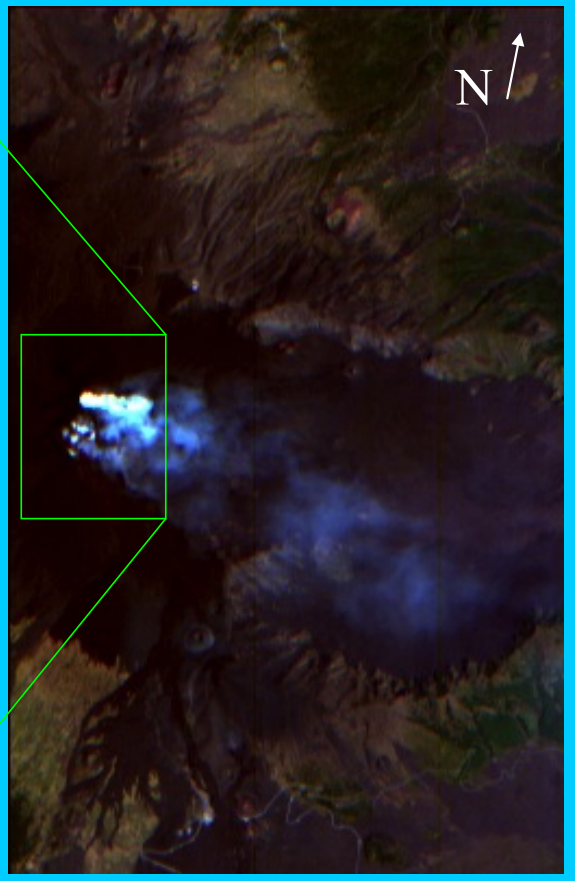
Mt. Etna CO_2 plume

For the end of August 2001 the CO2 map detecting two of the degassing crater after an intense period of eruption. After 2 month another intense eruptive activity started at Mt. Etna 2002-2003 eruption.



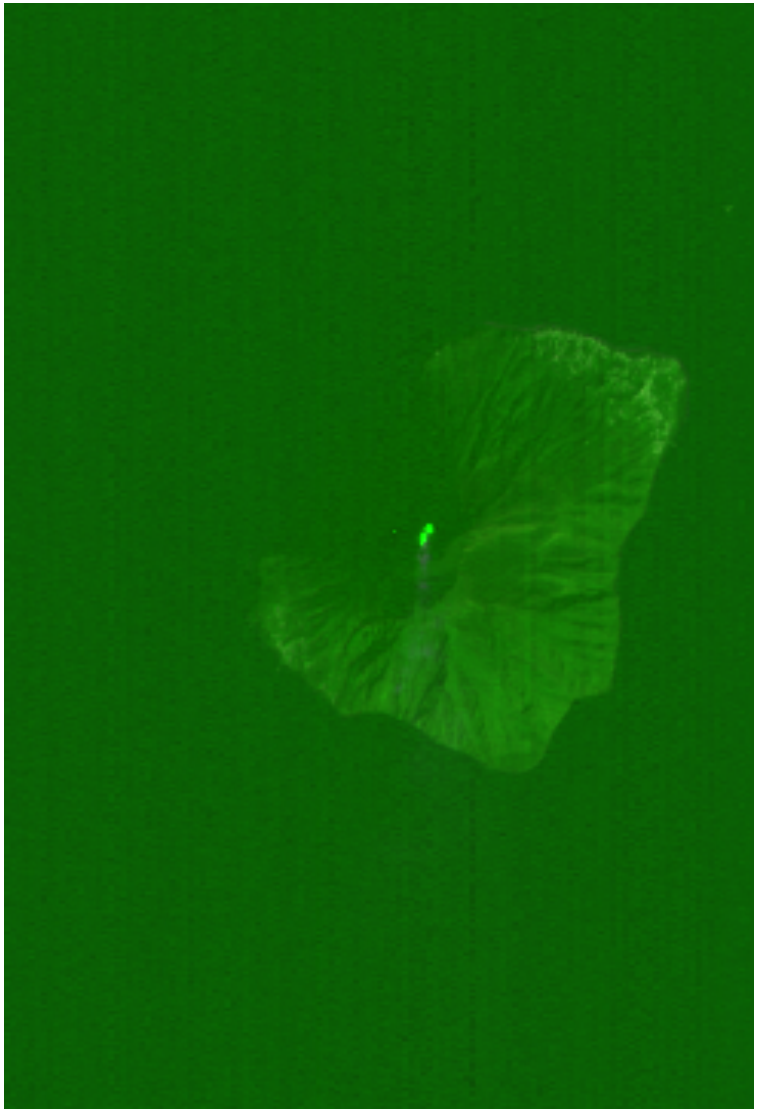


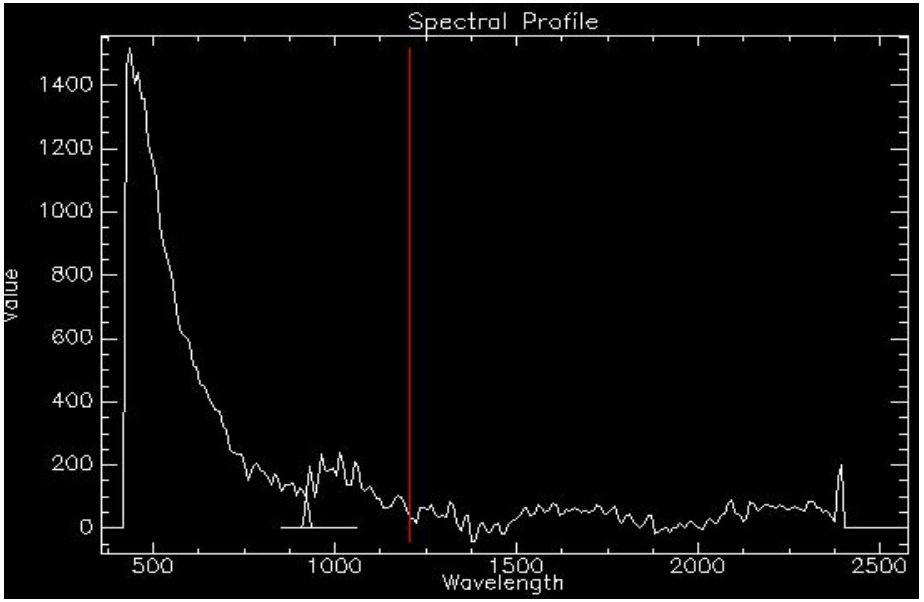


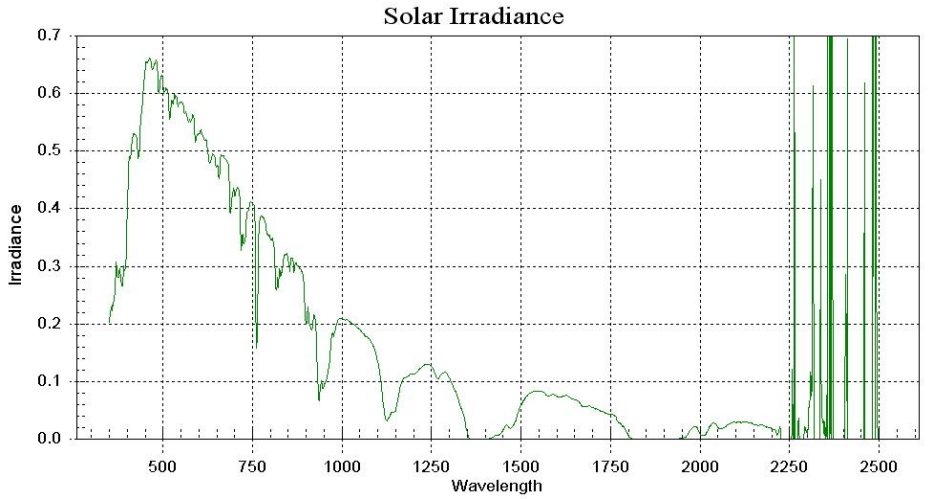


Hyperion 30-8-2001

Volcanic plume CO2 test retrieval using EO-1 Hyperion data







F(min) >> NeDR

The condition is not satisfied for Hyperion data over Stromboli

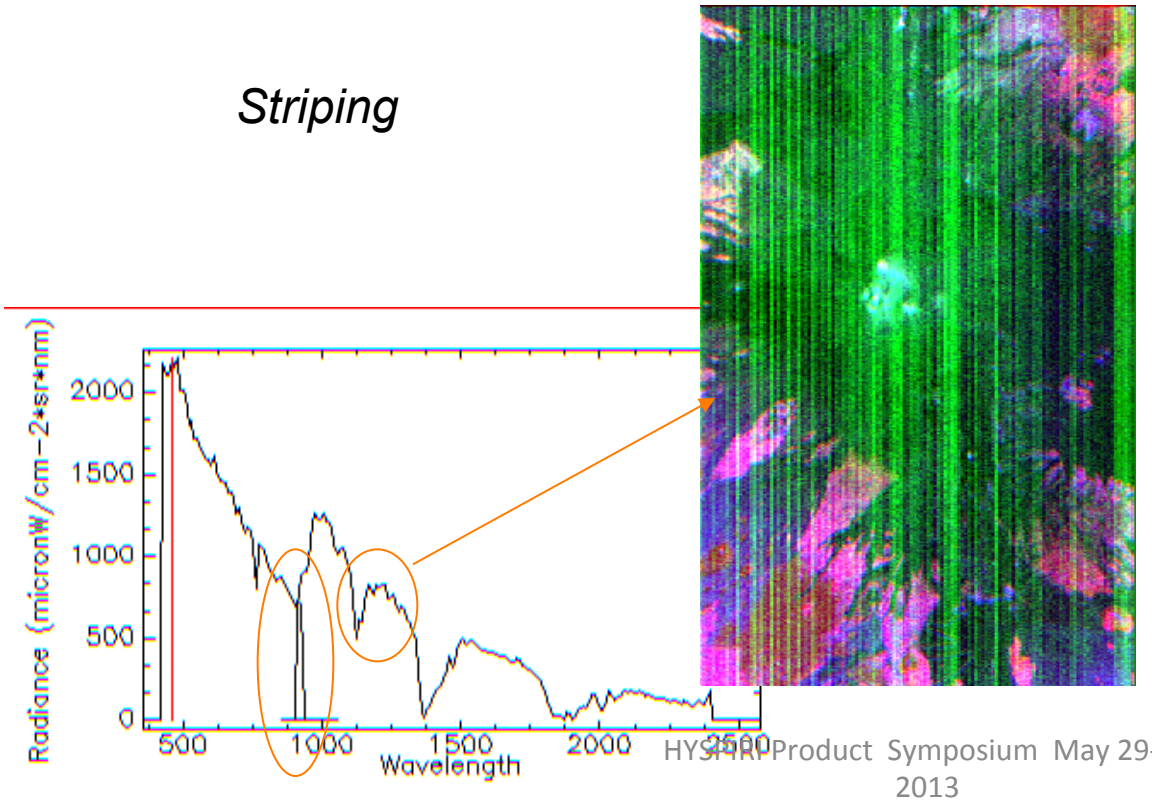
Hyperion data anlysis to retrieve H_2O e CO_2

The absoprtion band at 940 nm is located in and overlap zone between two spectrometers which gives a lower sensitivity

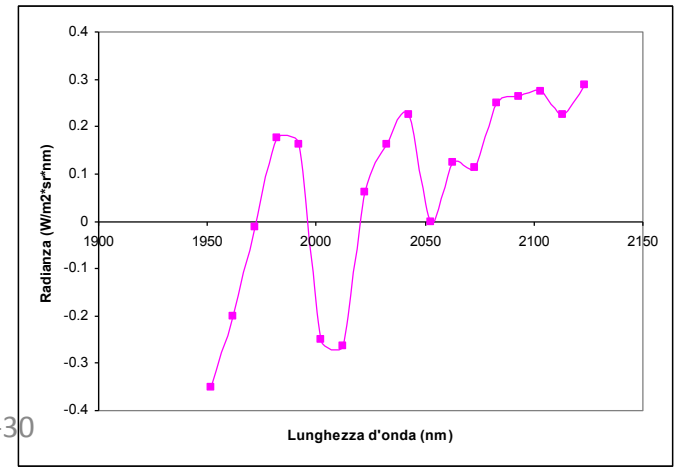
A strong Striping is visible when the albedo <5% and atmospheric transmittance <10%

We observed on calibrated data pixels with radiances <0

Striping



Radiometric calibration



Conclusions

- PRISMA mission should ensure appropriate products for geophysical application starting from levl0-1 up to level 2-3 products
- To detect and estimate volcanic emitted CO2 by means of hyperspectral imager is necessary high spectral resolution and high radiometric accuracy and calibration considering that volcanic areas have generally a very low albedo (as basalts)
- The developed algorithm needs an instrument capable to measure water vapor and aerosol content which make the hyperspectral imagers the best choice if they improve the radiometric accuracy and band location for water and CO2.
- At the moment only AVIRIS has fulfilled the algorithms requirements to retrieve CO2 concentration from volcanic plumes
- The test performed on HYPERION showed its limitation in terms of SNR and lack of usable 940 nm band for water content retrieval

Prisma And Hyspiri Mission Mutual Benefits

- PRISMA is composed by an hyperspectral imager VIS-SWIR range and a pancromatic camera for data fusion and pansharpening
the ground resolution is 30 m and 5m (pancromatic) and swath is 30 km

- HYSPIRI i s composed by an hyperspectral camera VIS-SWIR and a MIR-TIR multispectral imager the ground resolution is 60 m and swath 145(VIS-SWIR)-600 km (MIR-TIR)

- it could be very desirable to have increase the cooperation between the two missions in terms of opportune orbital characteristics and instruments calibration

- for volcanic applications the HYSPIRI configuration would be the most desirable since both co2 and so2 could be retrieved. Moreover SWIR-TIR spectral region assure a more precise thermal analysis for lava flows, lava lake and fire

Thank
you
Istituto Nazionale di
Geofisica e Vulcanologia
F.Doumaz 2012 ©

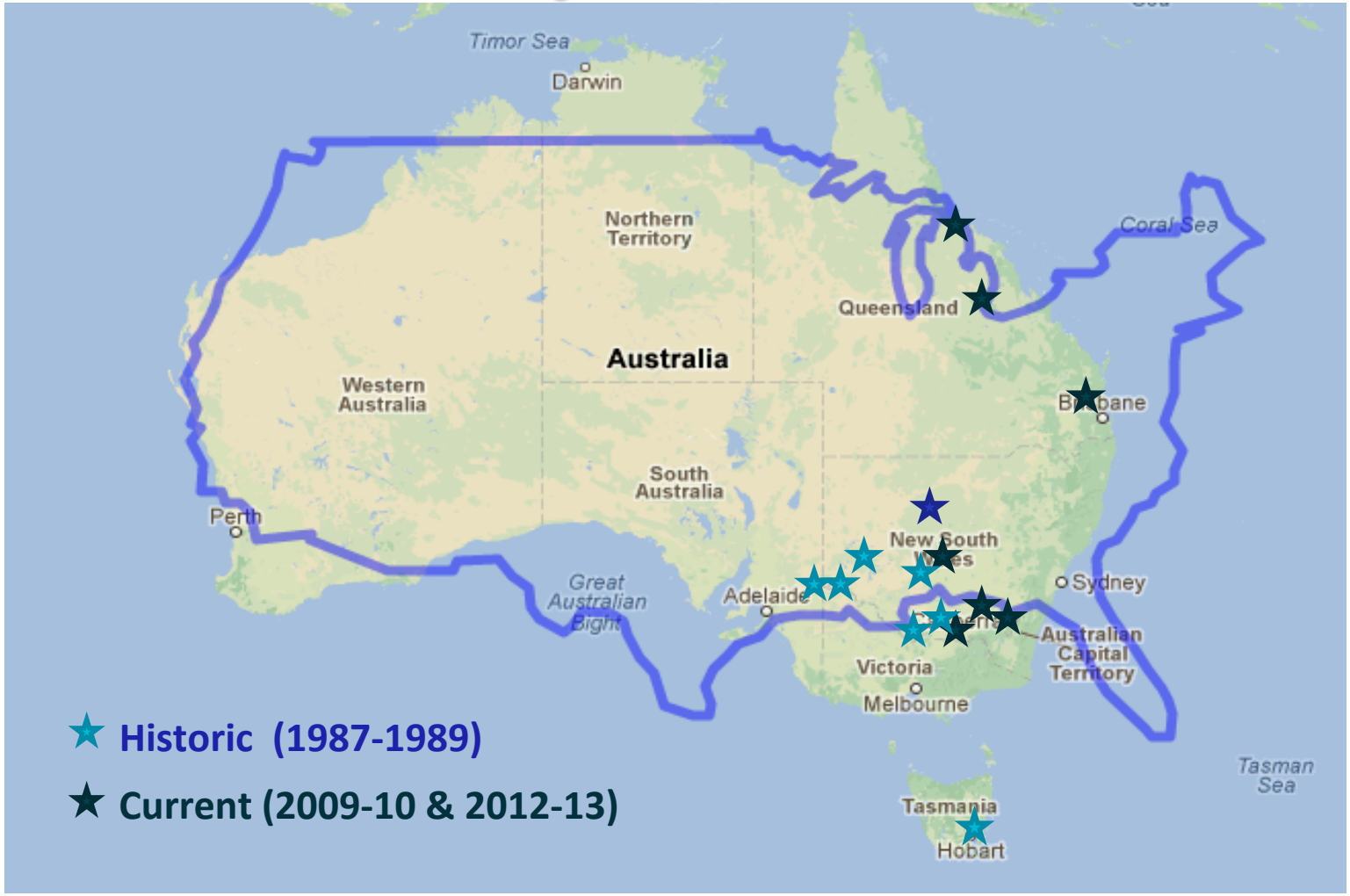
water quality monitoring: the role of HyspIRI

Arnold Dekker, Tim Malthus, Erin Hestir
Earth Observation & Informatics -Transformational Capability Platform
29th May 2013 NASA GSFC

DIVISION OF LAND AND WATER & WATER FOR A HEALTHY COUNTRY
www.csiro.au

CSIRO

In situ bio-optical observations



Drivers for our EO of water quality research

- Legislation:
  - National Plan for Environmental Information
  - State of Environment
- Algorithms
- New Technologies
- Ecosystem science
  - Climate change and variability
  - Drivers of water quality
  - Resilience
  - Prediction

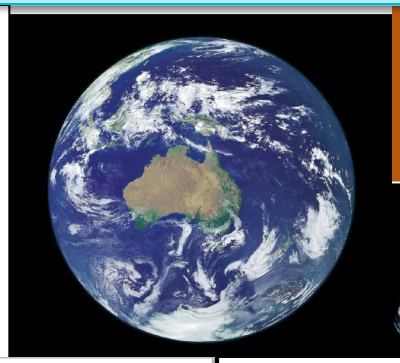
2013

2020

The Senate

Standing Committee on Economics

Lost in Space? Setting a new direction for Australia's space science and industry sector



Australian Government
Geoscience Australia

A National Space Policy:
Views from the Earth Observation Community

Australian Government
Department of Innovation, Industry, Science and Research

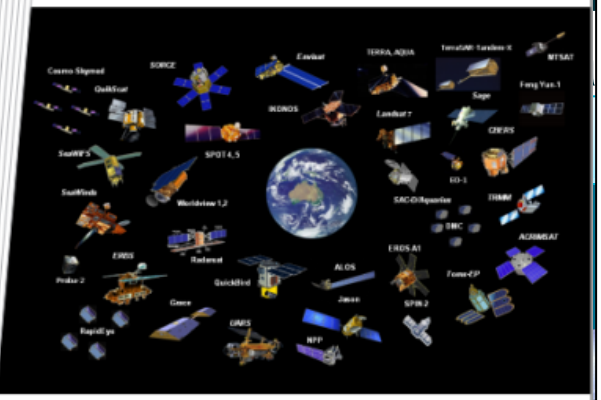
ANALYSIS OF AUSTRALIAN GOVERNMENT SPACE ACTIVITIES

MAY 2010

The economic value of earth observation from space

A review of the value to Australia of Earth observation from space

CSIRO



Continuity of Earth Observation Data for Australia:
Research and Development Dependencies to 2020

January 2012

Australian Government

"..certainty and strategic direction for satellite technology users"

National Space Policy

"..better domestic co-ordination and focused international engagement"

"...giving priority to Earth observations from space.."

Australian Government

National Earth Observations from Space Infrastructure Plan

"CSIRO is Australia's lead R&D Agency"

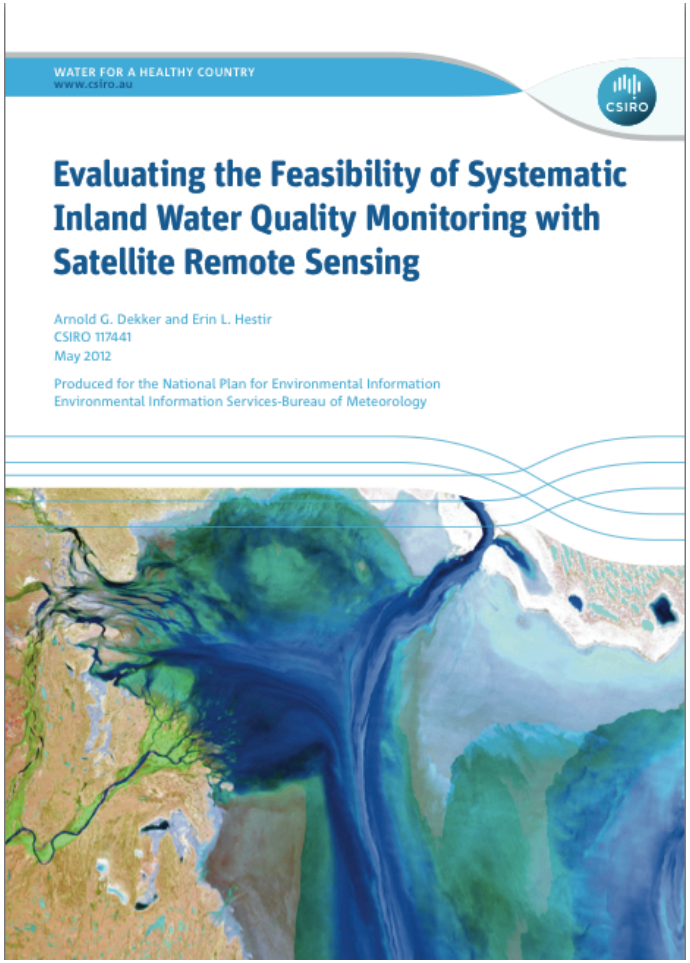
Australian Context for Water Quality

- **The Challenge: Ongoing monitoring of Australia's inland water quality**
- Australia's water quality is poor and is negatively trending
- But water quality data are scarce, potentially declining and with poor temporal coverage
- We need rapid, cost-effective assessments of water quality to assess baseline conditions and study responses to existing and potential environmental stressors
- Such assessments are needed across a range of scales
- Includes from continuous in situ measurements to satellite remote sensing, the latter overcoming some of the costs of remote sampling

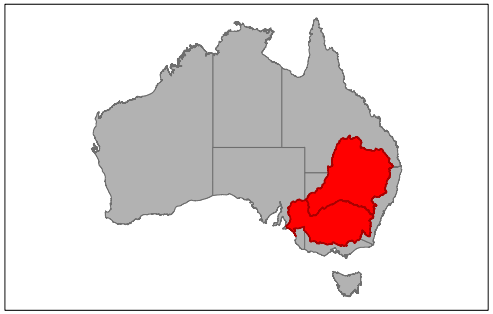
The potential solution

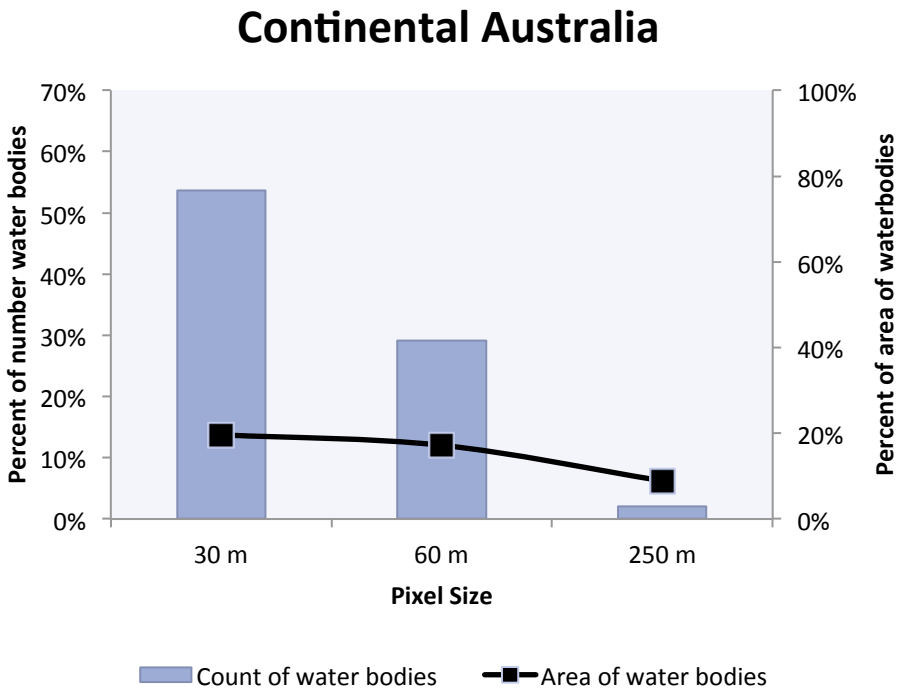
: http://www.clw.csiro.au/publications/waterforahealthycountry/#reports

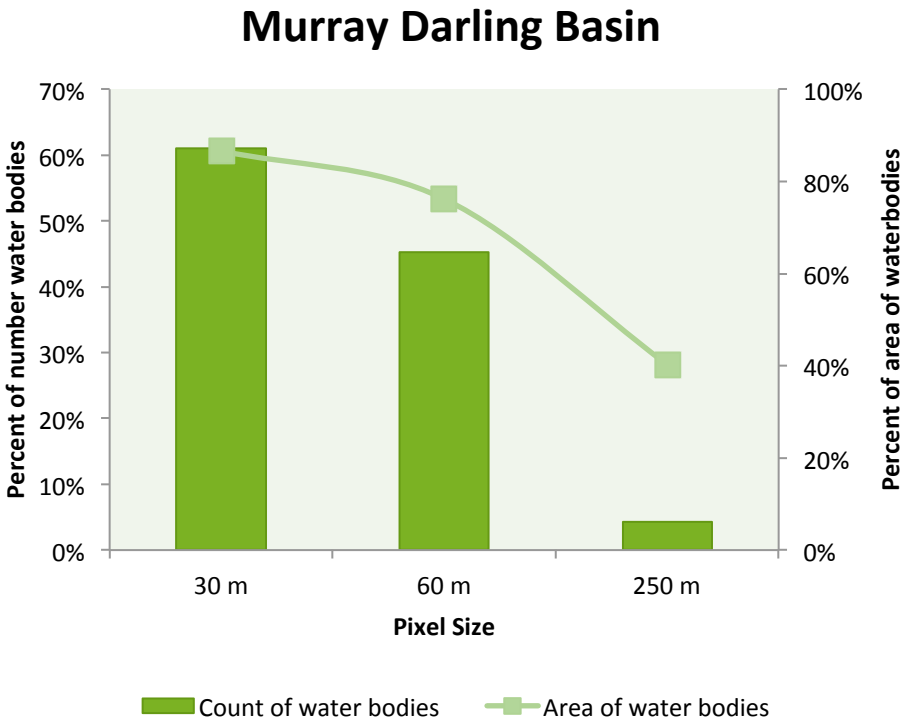
- **Satellite remote sensing**
  - Provides an objective, high frequency and spatially continuous measurement tool to overcome these challenges
  - But for a limited set of water quality parameters
  - Using inversion approaches
  - Will need calibration and validation over low reflecting targets



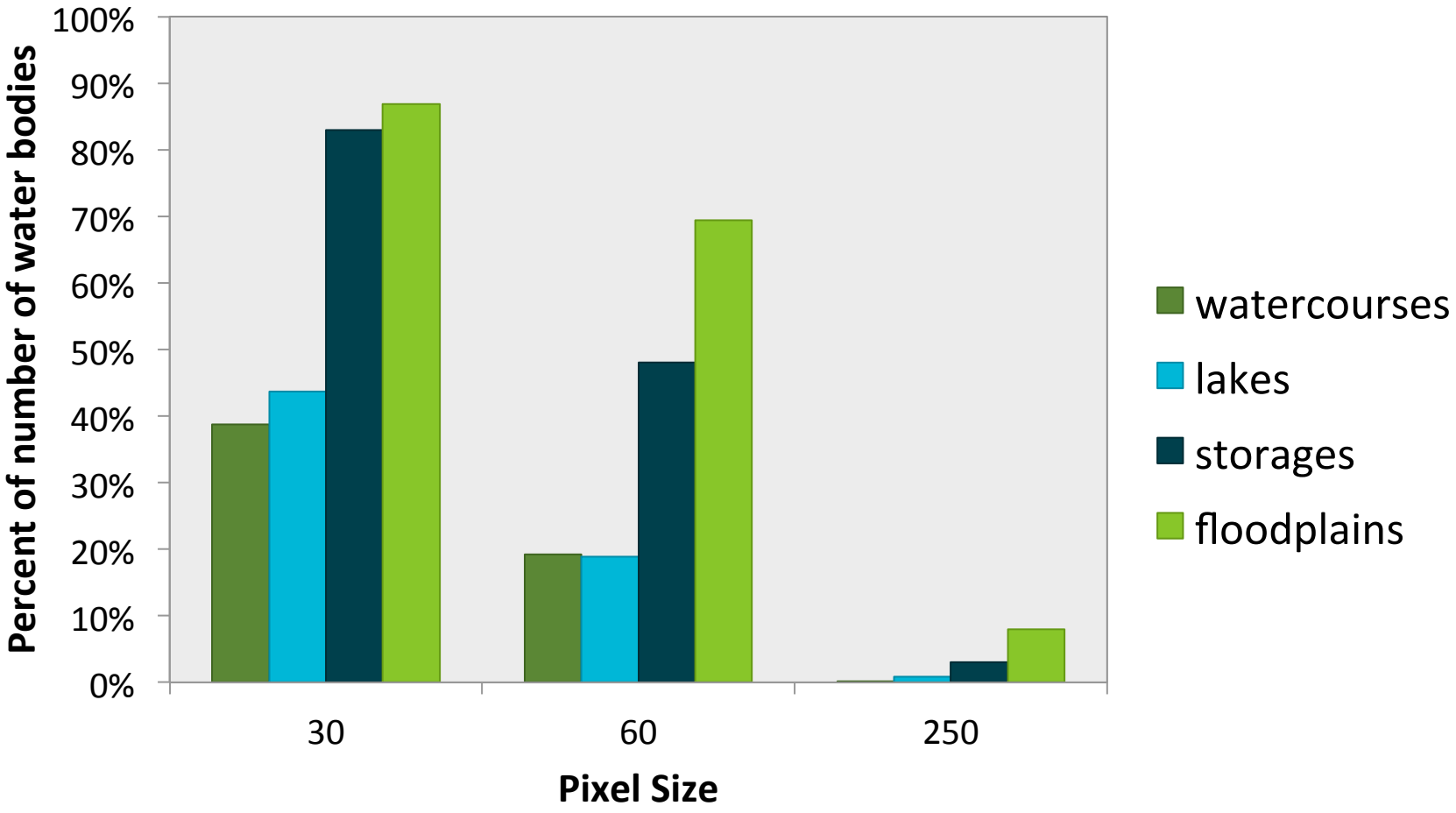
EO-resolvable water bodies in Australia







EO-resolvable water bodies in Australia



Dekker & Hestir 2012, CSIRO

Relative capability for wq retrieval using free satellite data

	Pixel Size (m)	Bands (400-900 nm)	Revisit cycle	CHL	CYP	TSM	CDOM	SD	K_d
Low res.									
MODIS	1000	9	Daily	●	●	●	●	●	●
MODIS	500	2	Daily	●	●	●	●	●	●
MODIS	250	2	Daily	●	●	●	●	●	●
MERIS	300	15	2-3 days	●	●	●	●	●	●
VIIRS	750	7	2x/day	●	●	●	●	●	●
Med res.									
Landsat	30	4	16	●	●	●	●	●	●
Future									
Sentinel-3	300	21	Daily	●	●	●	●	●	●
LDCM	30	5	16	●	●	●	●	●	●
Sentinel-2	10-60	10	3-5 days	●	●	●	●	●	●
HySpIRI	60	60	19 days	●	●	●	●	●	●

● **Highly suited,** ● **Suited,** ● **Potential,** ● **Not suited**

- *Adapted from: Dekker and Hestir (2012). Evaluating the Feasibility of Systematic Inland Water Quality Monitoring with Satellite Remote Sensing, CSIRO*

Water quality variables from remote sensing e.g. WV-2

Chlorophyll

Colored dissolved organic matter

Cyano-pigments

Total suspended matter

Water column optically active components

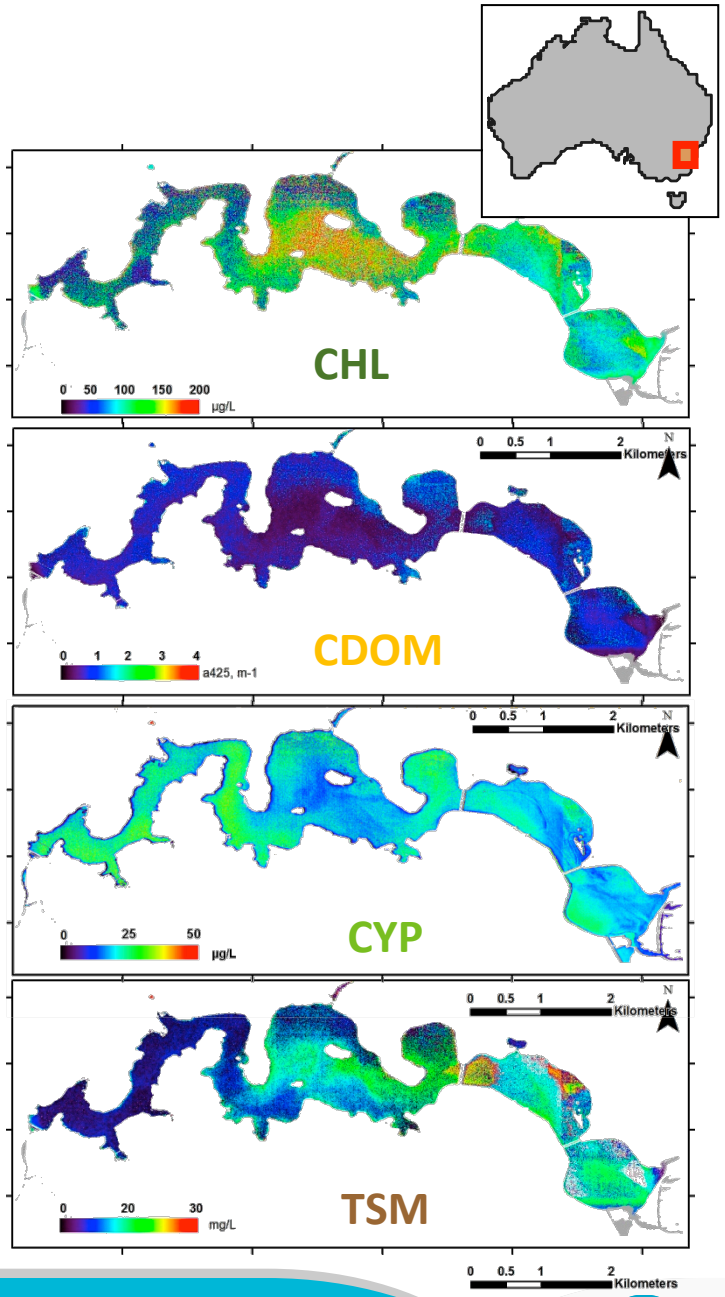
Vertical attenuation of light

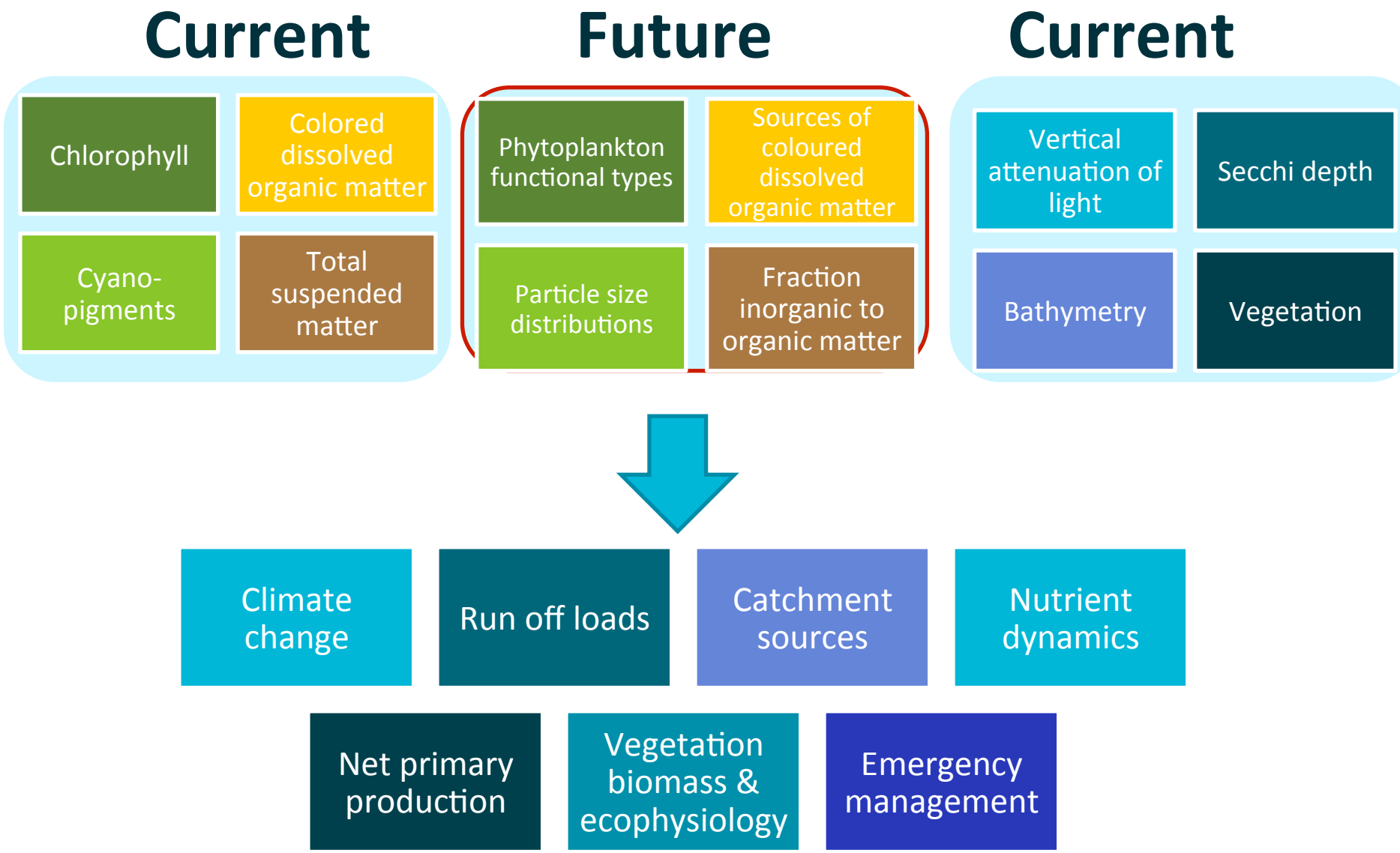
Secchi depth

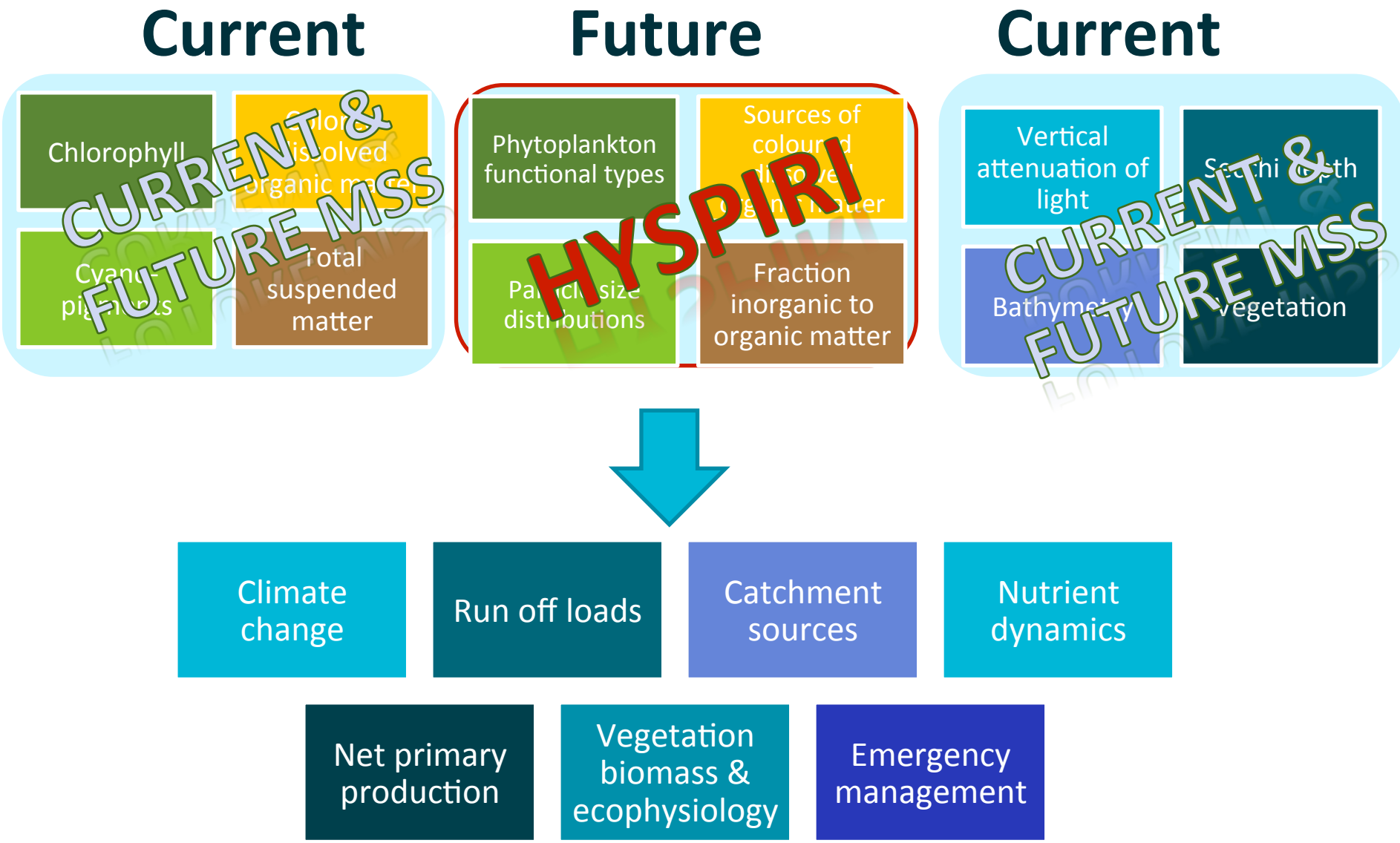
Bathymetry

Vegetation

Estimated from water column properties



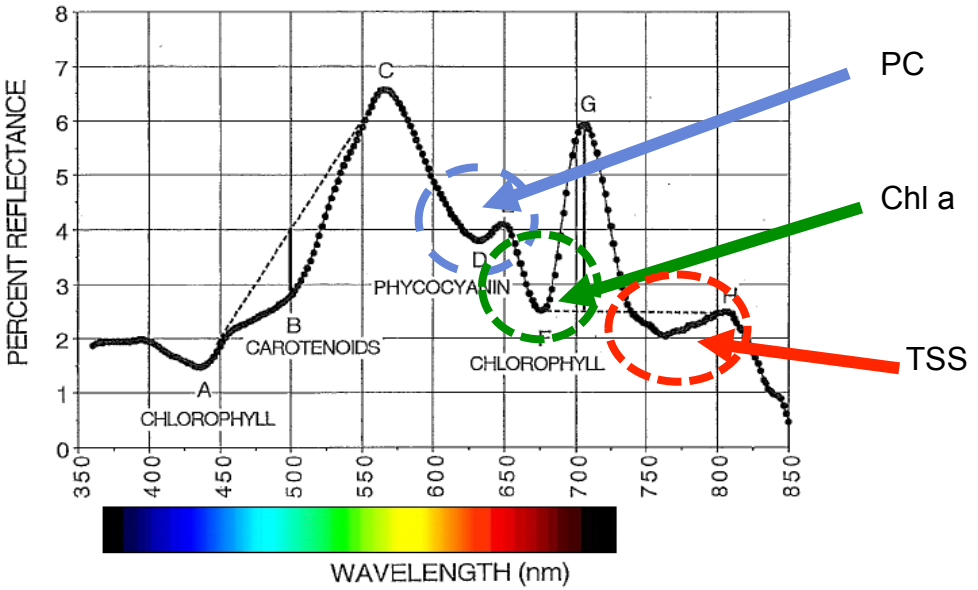

Current
Chlorophyll
Colored dissolved organic matter
Cyano-pigments
Total suspended matter
Future
Phytoplankton functional types
Sources of coloured dissolved organic matter
Particle size distributions
Fraction inorganic to organic matter
Current
Vertical attenuation of light
Secchi depth
Bathymetry
Vegetation
Climate change
Run off loads
Catchment sources
Nutrient dynamics
Net primary production
Vegetation biomass & ecophysiology
Emergency management


Current
Future
Current
Chlorophyll
Total suspended matter
CURRENT & FUTURE MSS
Phytoplankton functional types
Fraction inorganic to organic matter
HYSPIRI
Vertical attenuation of light
Vegetation
CURRENT & FUTURE MSS
Climate change
Run off loads
Catchment sources
Nutrient dynamics
Net primary production
Vegetation biomass & ecophysiology
Emergency management

Pigment signals in spectral reflectance

Spectral resolution:

- Detect significant spectral features
- Discriminate different wq parameter signals



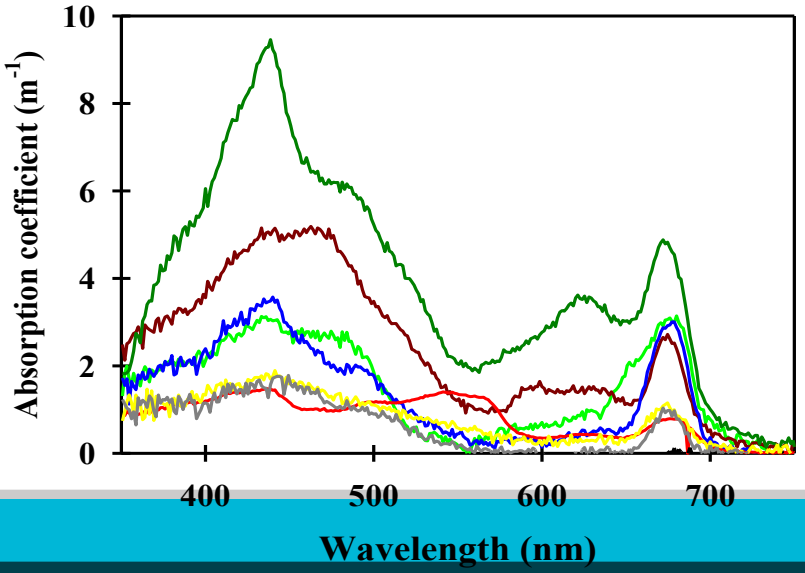
Schalles a

Colouring Material:Pigments in phytoplankton cultures: their light absorption and scattering

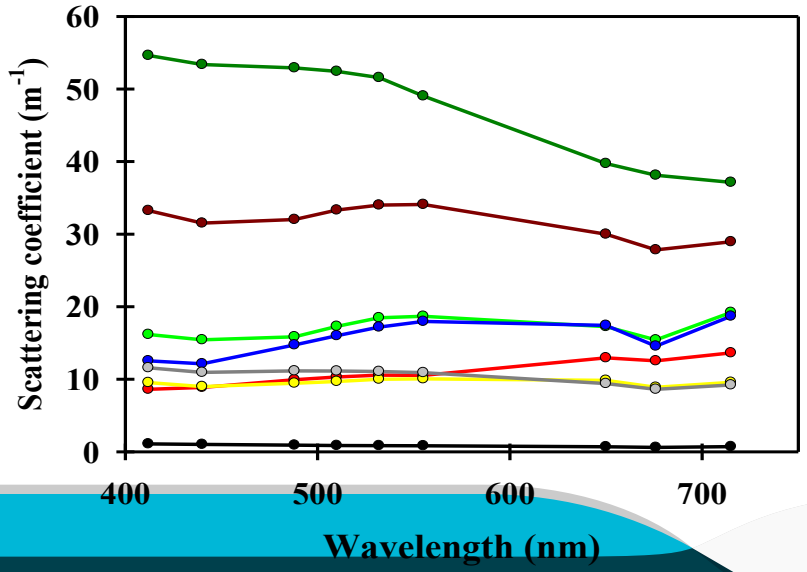
From left to right on the photo:

- Dunaliella tertiolecta
- Emiliania huxleyi
- Pavlova lutheri
- Porphyridium cruentum
- Synechococcus sp.
- Gymnodinium catenatum
- Thalassiosira pseudonana
- Chaetoceros socialis

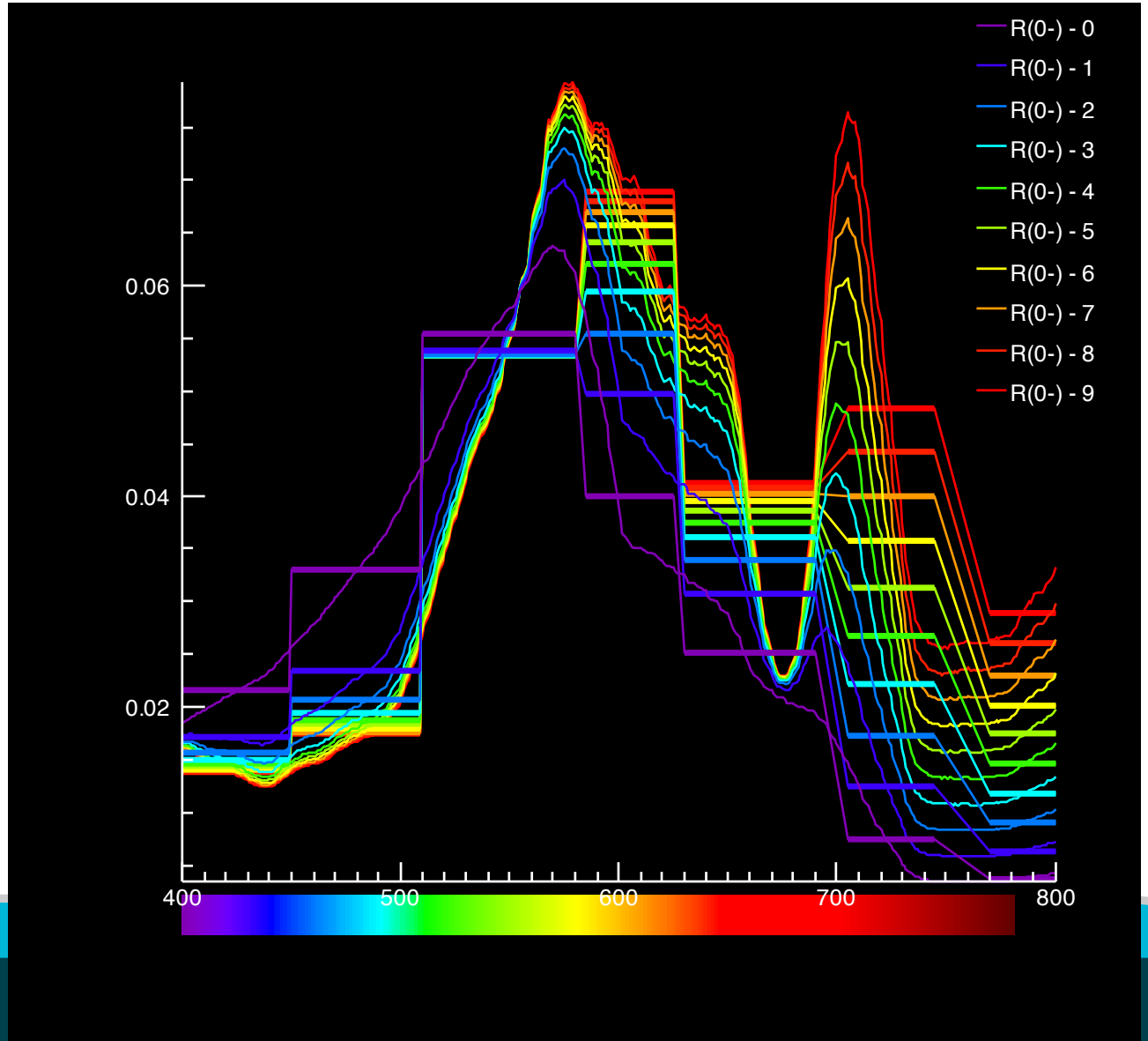
Phytoplankton absorption



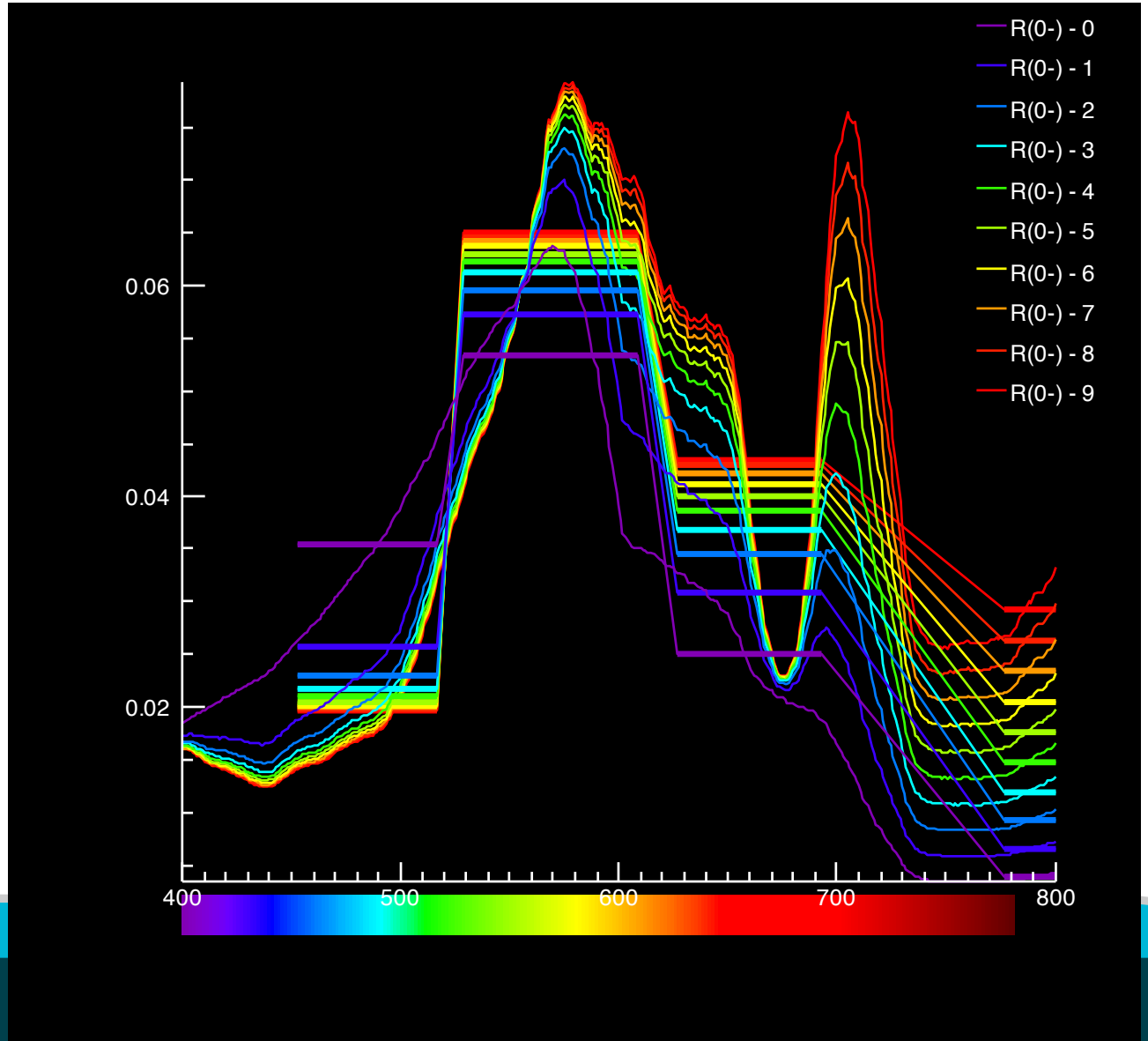
Phytoplankton scattering



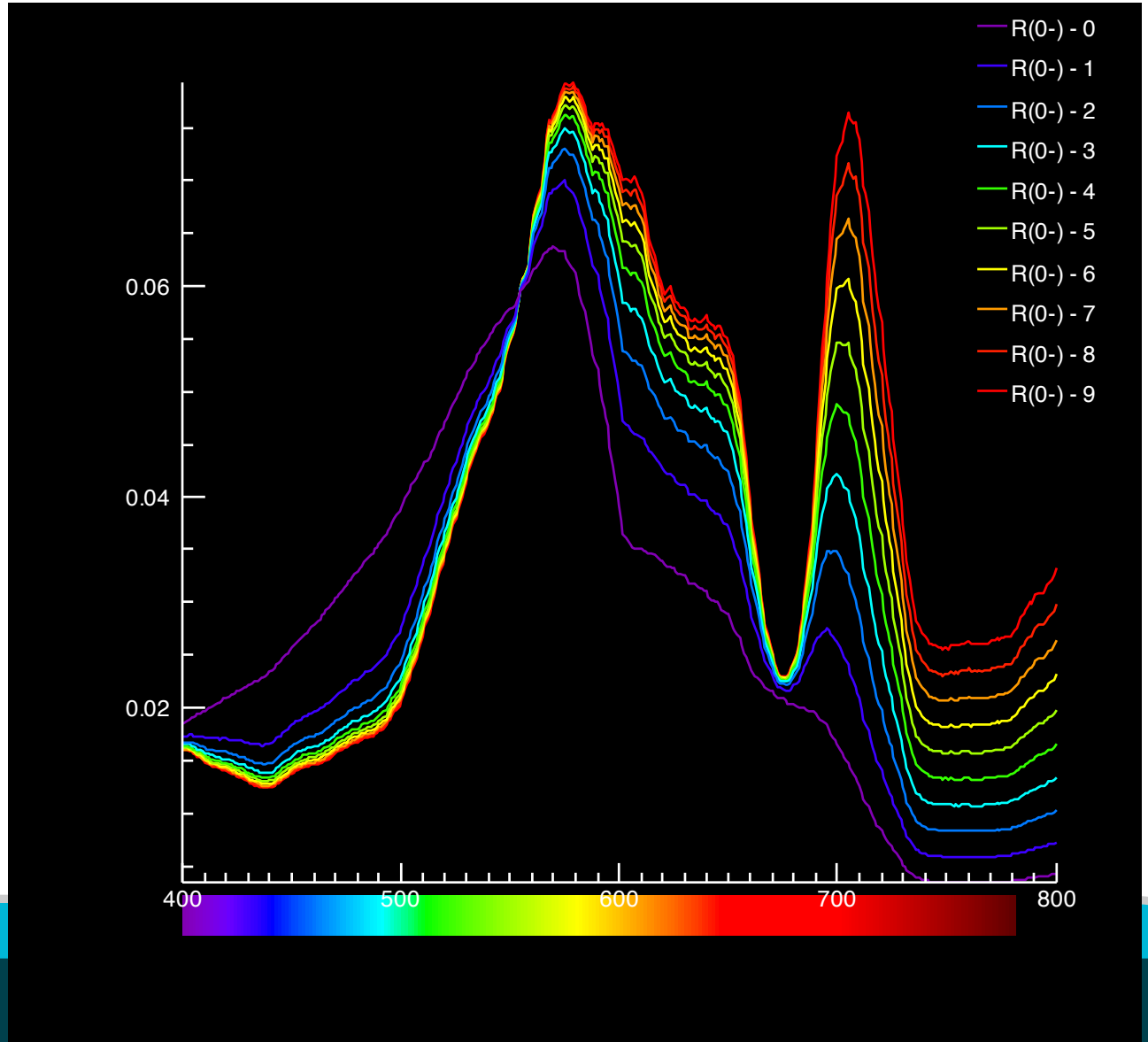
Algal bloom as seen by WorldView-2 2m



Algal bloom as seen by Landsat 30 m

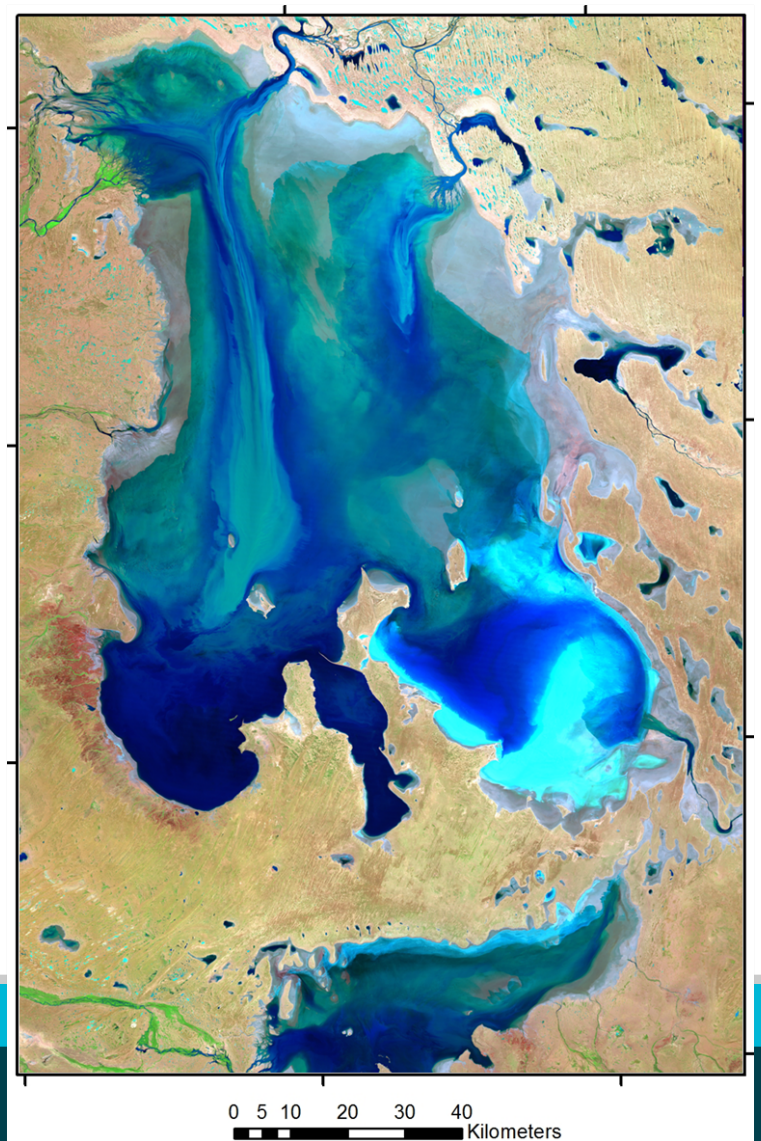


Algal bloom reflectance simulation~ HyspIRI 60m

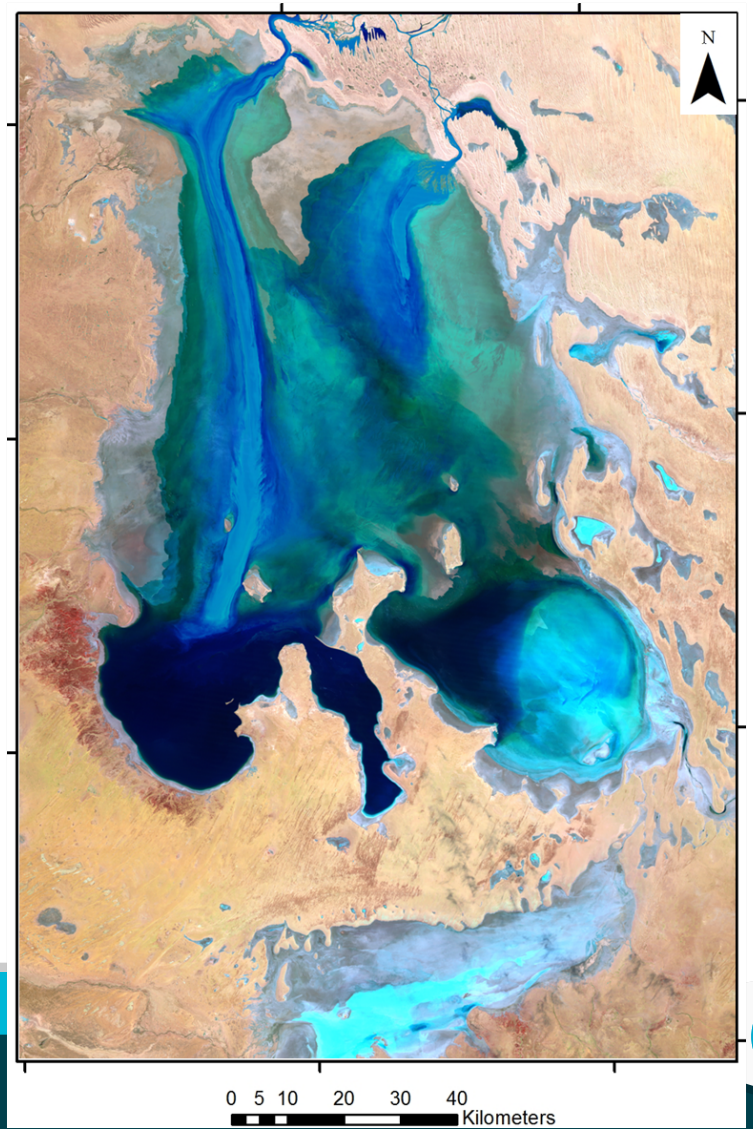


Needs bio-optical parameterisation of algorithm to estimate water quality or hyperspectral from space

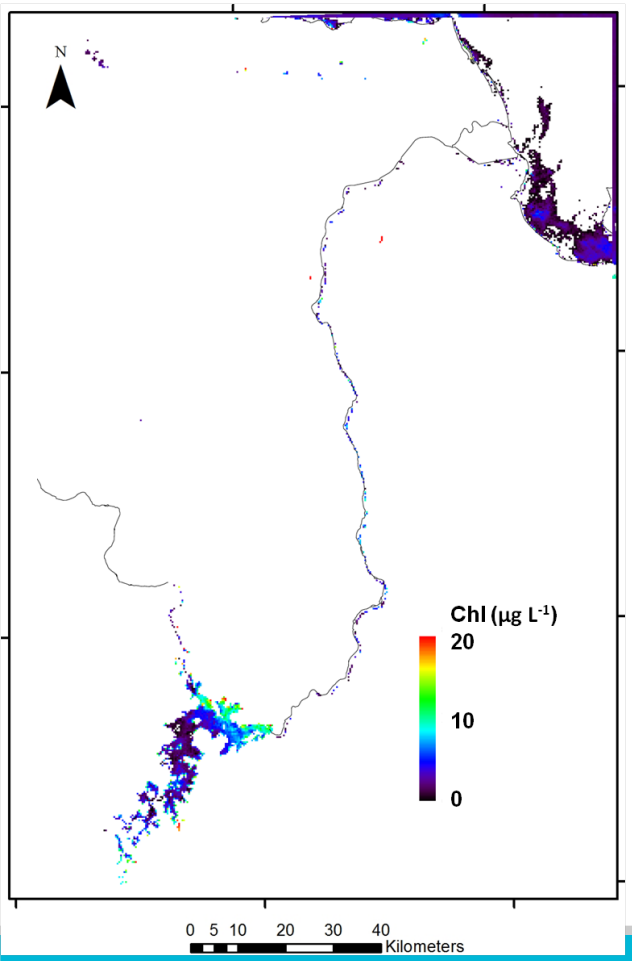
9th May 2009

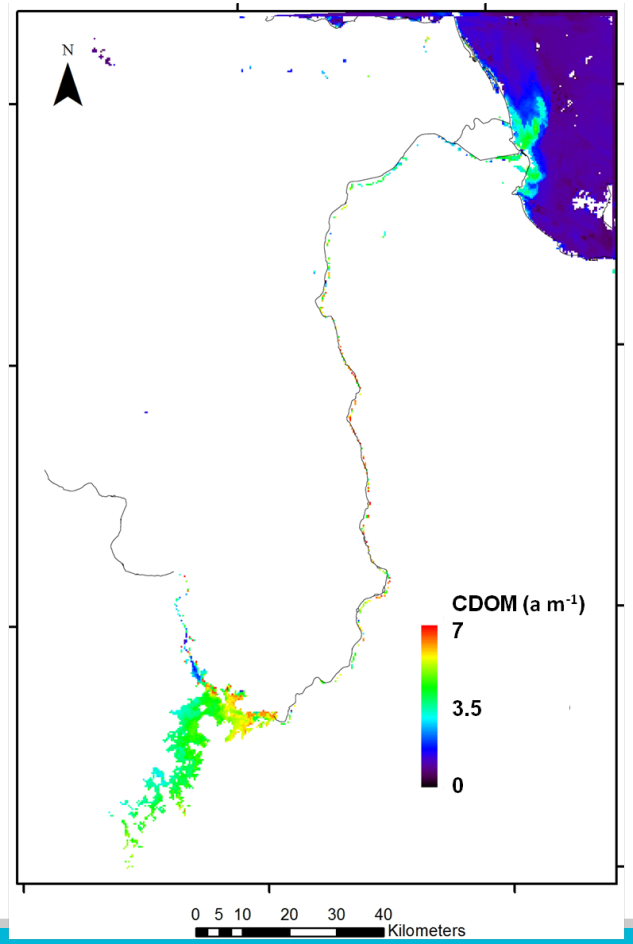


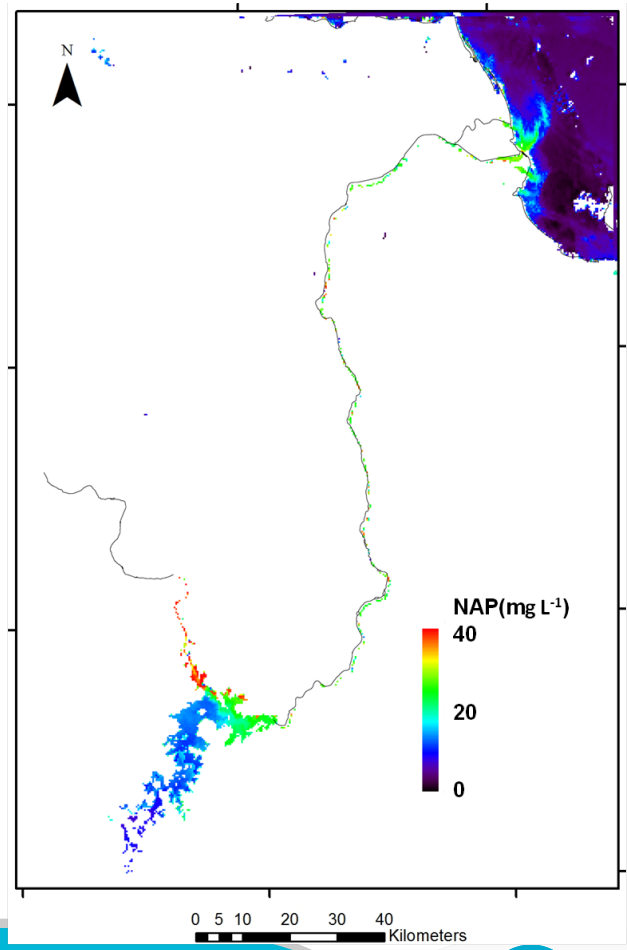
28th March 2011



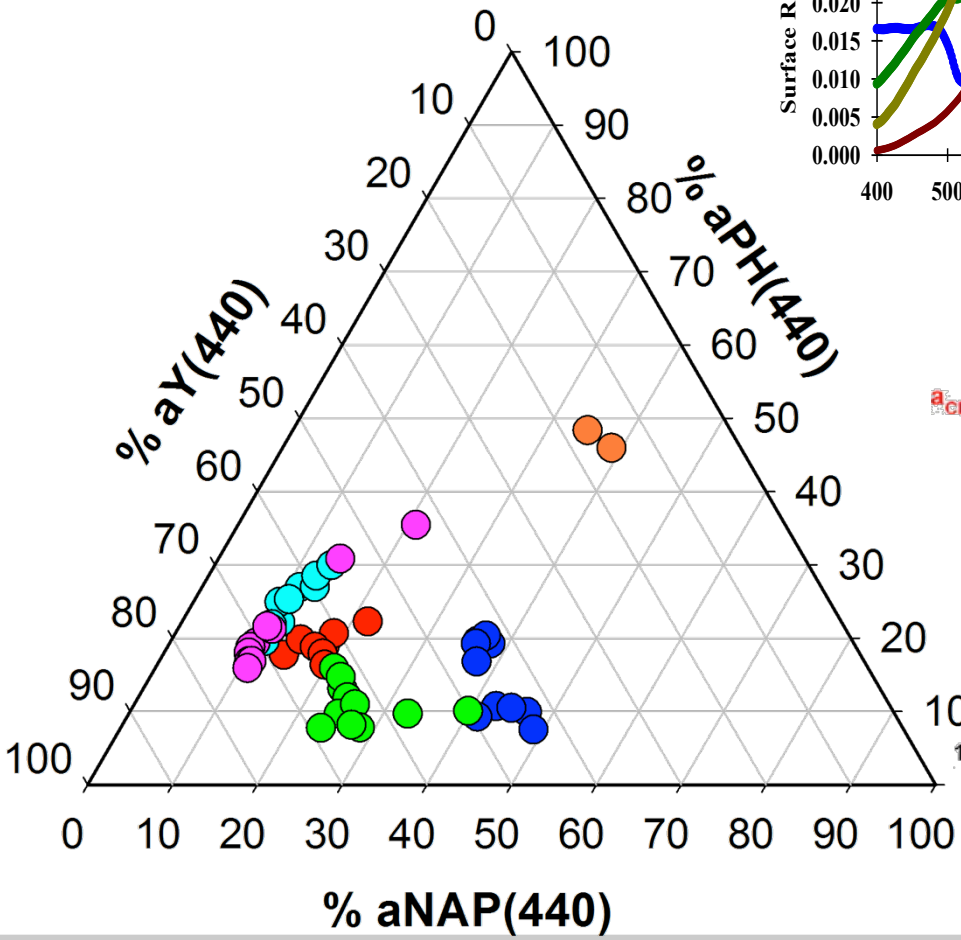
MERIS inland –coastal water example (from G. Campbell USQ)
Burdekin Falls Dam and Burdekin to GBR
MERIS : every two days a scene @ 300 m resolution

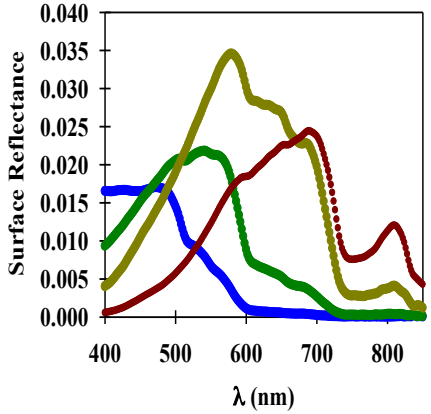


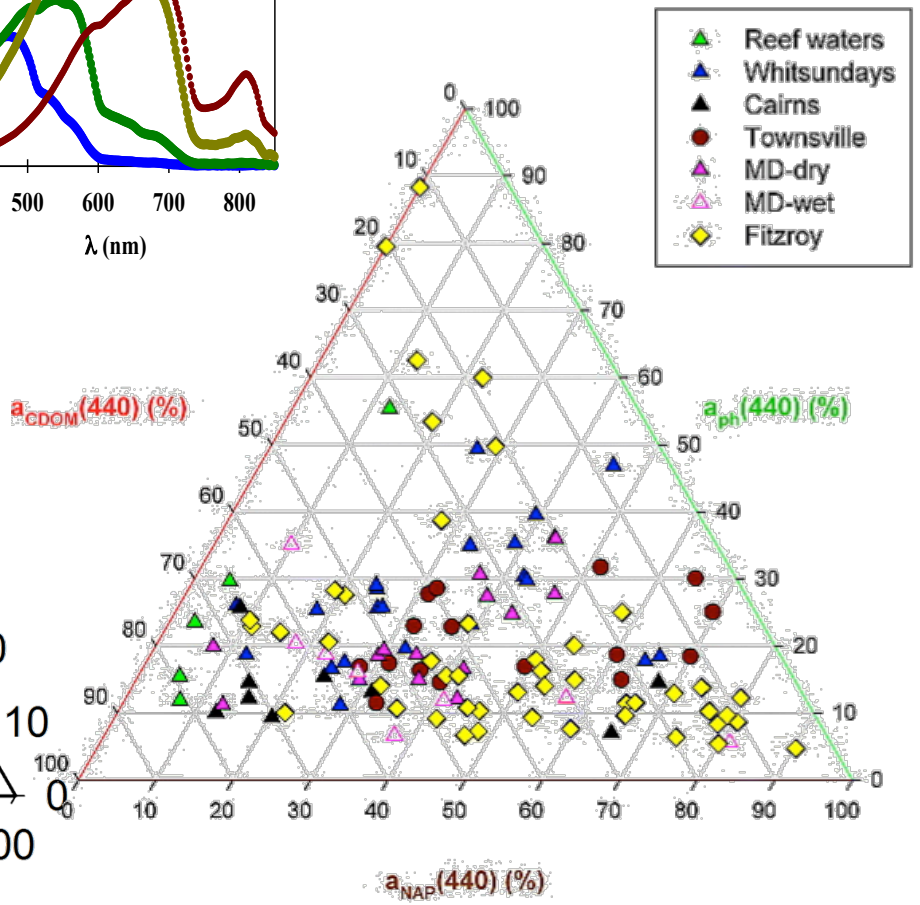


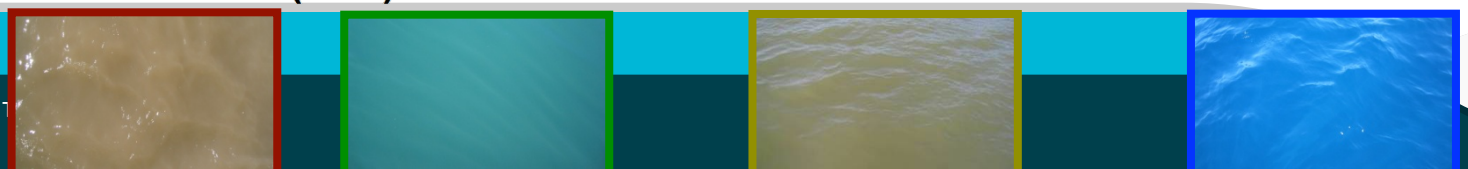


Inland waters->->->->->->->->Coastal Waters









Semi-analytical approaches: the forward problem

Index of refraction, distribution, particle size and properties of all constituents

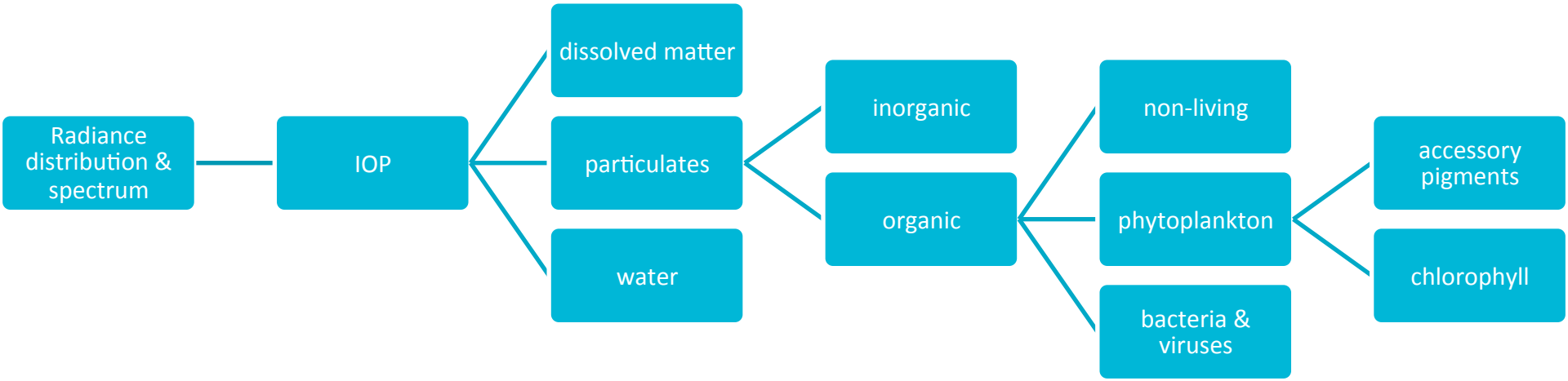
Inherent Optical Properties (IOPs)

Remote Sensing Reflectance

$$\cos\theta \frac{dL(z,\theta,\phi,\lambda)}{dz} = \ldots$$

HYDROLIGHT

Semi-analytical approaches: the inverse problem



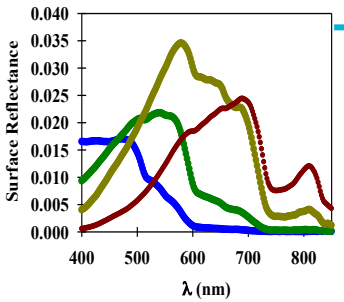
$$R_{rs}(\lambda) = f\,[a(\lambda), b_b(\lambda), \rho(\lambda), H, \Theta_w, \Theta_v, \psi]$$

IOCCG Report Number 5 (2006): *Remote Sensing of Inherent Optical Properties: Fundamentals, Tests of Algorithms, and Applications.*

Solution: The adaptive Linear Matrix inversion (a-LMI) hyperspectral parameterisation-EO sensor agnostic

Loop RTE inversion over candidate model parameter sets

r_{rs}



$SIOP_k$ = Candidate model parameter set k

$[a^*_{phy}(\lambda), S_{CDOM}, a^*_{NAP}(440), S_{NAP}, b^*_{bphy}(555), Y_{phy}, b^*_{NAP}(555), Y_{NAP}]_k$

$[C_{CHL}, C_{CDOM}, C_{NAP}]_k = f(r_{rs}^{input}, SIOP_k)$

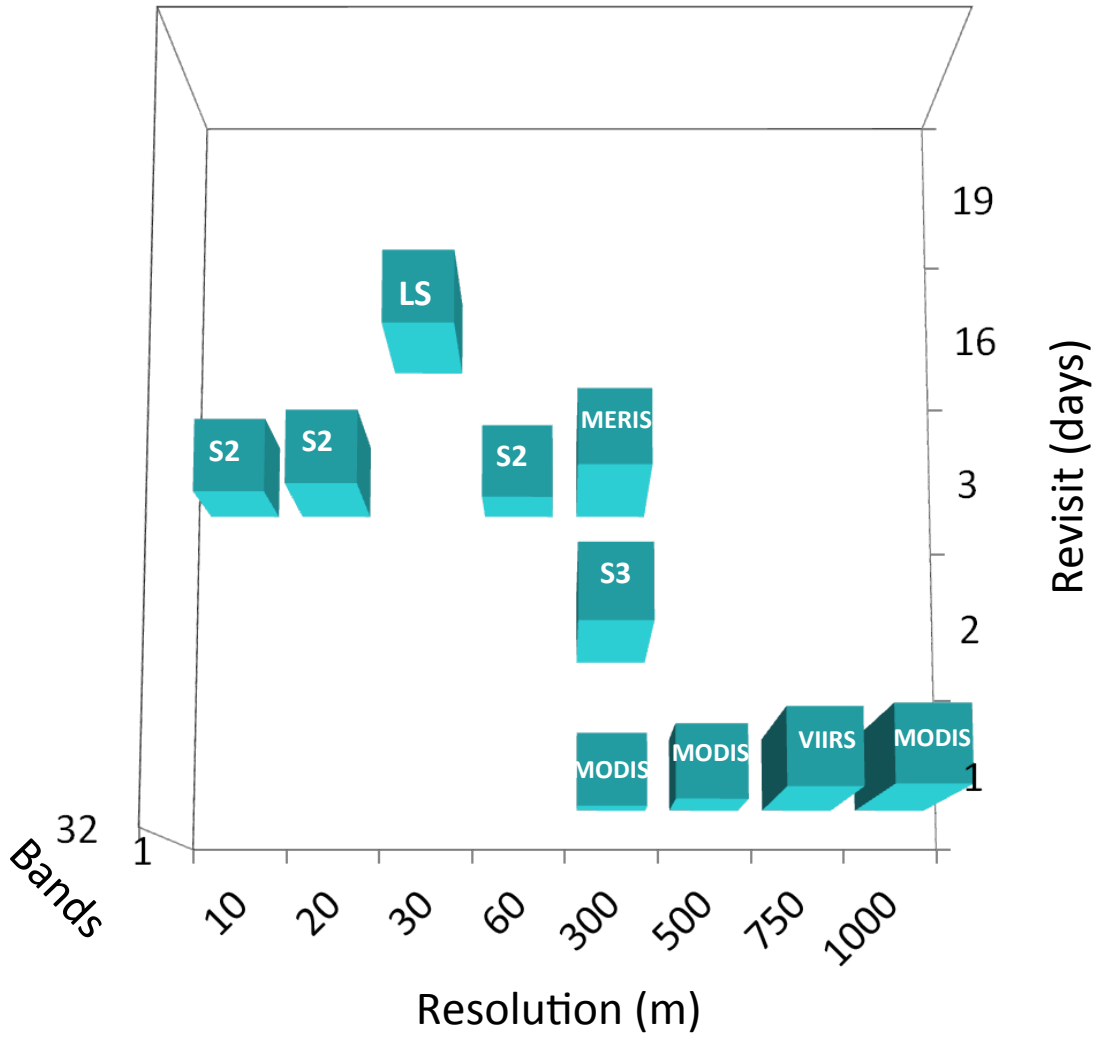
$\Delta k = \Delta(r_{rs}^{input}, r_{rs}^{model}{}_k)$

C_{CHL}
C_{CDOM}
C_{NAP}

a_{phy}
a_{CDOM}
a_{NAP}
b_{bphy}
b_{bNAP}

Brando et al, 2012, Applied Optics

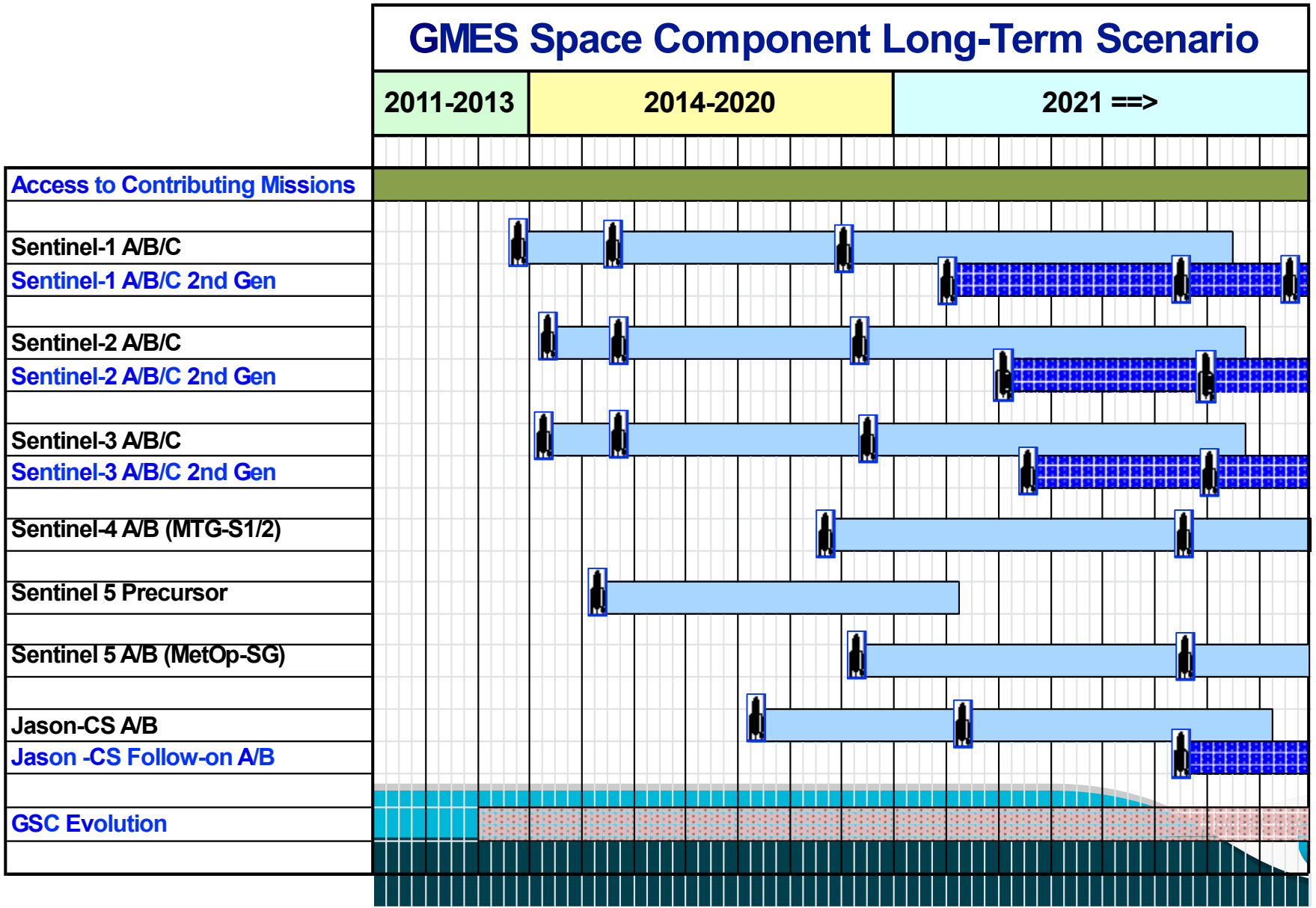
Current & pending global mapping capabilities



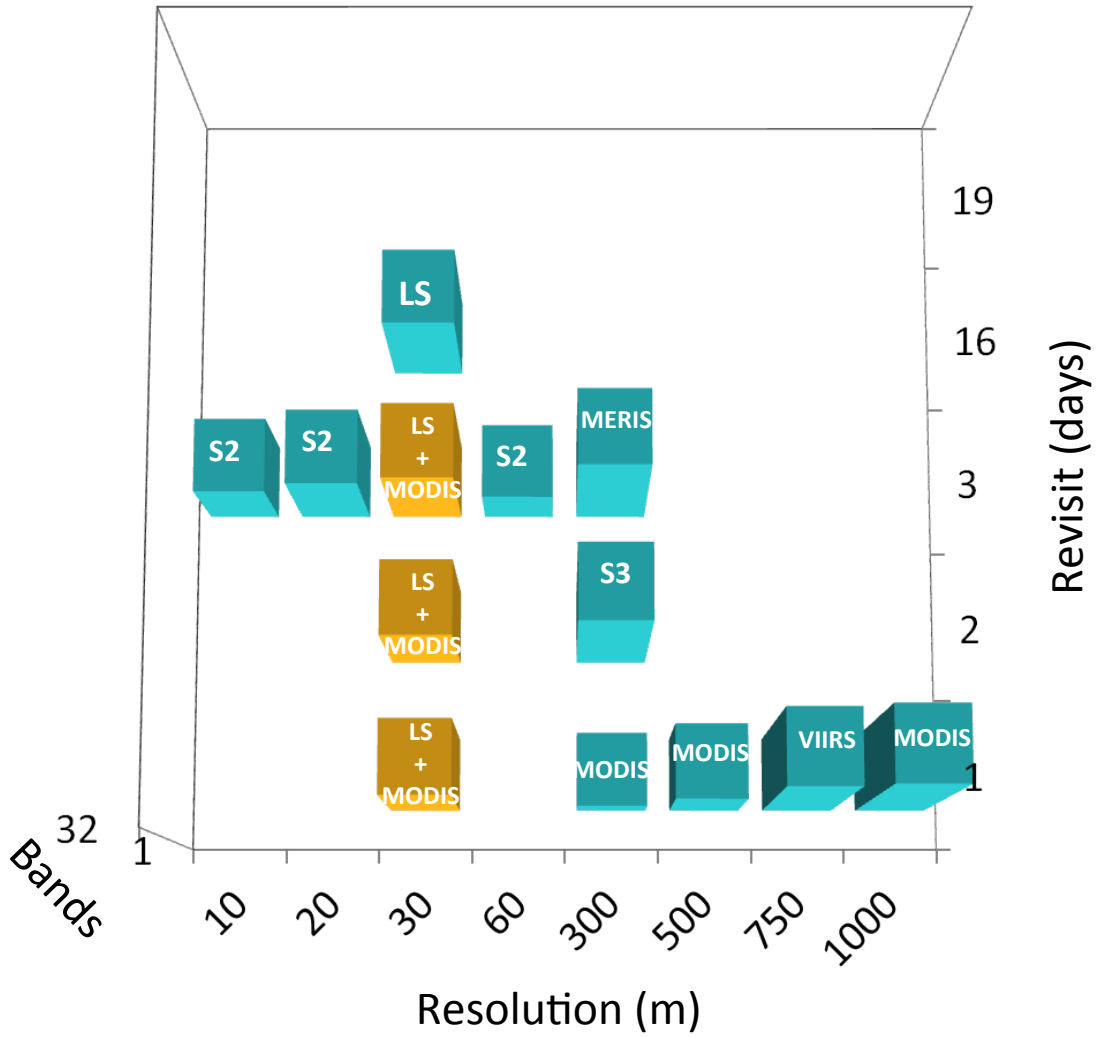
Sentinel-2 as an Optically Deep Water Sensor

Band	Spatial	Spectral	From	To	Optically Deep Water
Nr	Resolution (m)	width (nm)	λ	λ	
1	60	20	433	453	Chlorophyll, CDOM, NAP, Kd + Turb + SD
2	10	65	458	523	Carotenoids, zeaxanthine, CDOM, TSM,Kd + Turb + SD
3	10	35	543	578	Cyanophyco-erythrin, TSM, CDOM, Kd + Turb + SD
4	10	30	650	680	Chlorophylls, TSM, Kd + Turb + SD
5	20	15	698	713	TSM, Kd + Turb + SD, floating algal layers & macro-algae
6	20	15	733	748	TSM, Sunglint,floating algal layers & macro-algae
7	20	20	773	793	TSM, Sunglint,floating algal layers & macro-algae
8	10	115	785	900	TSM, Sunglint
8a	20	20	855	875	ATCOR, Sunglint
9	60	20	935	955	ATCOR, Sunglint
10	60	30	1360	1390	ATCOR
11	20	90	1565	1655	
12	20	180	2100	2280	

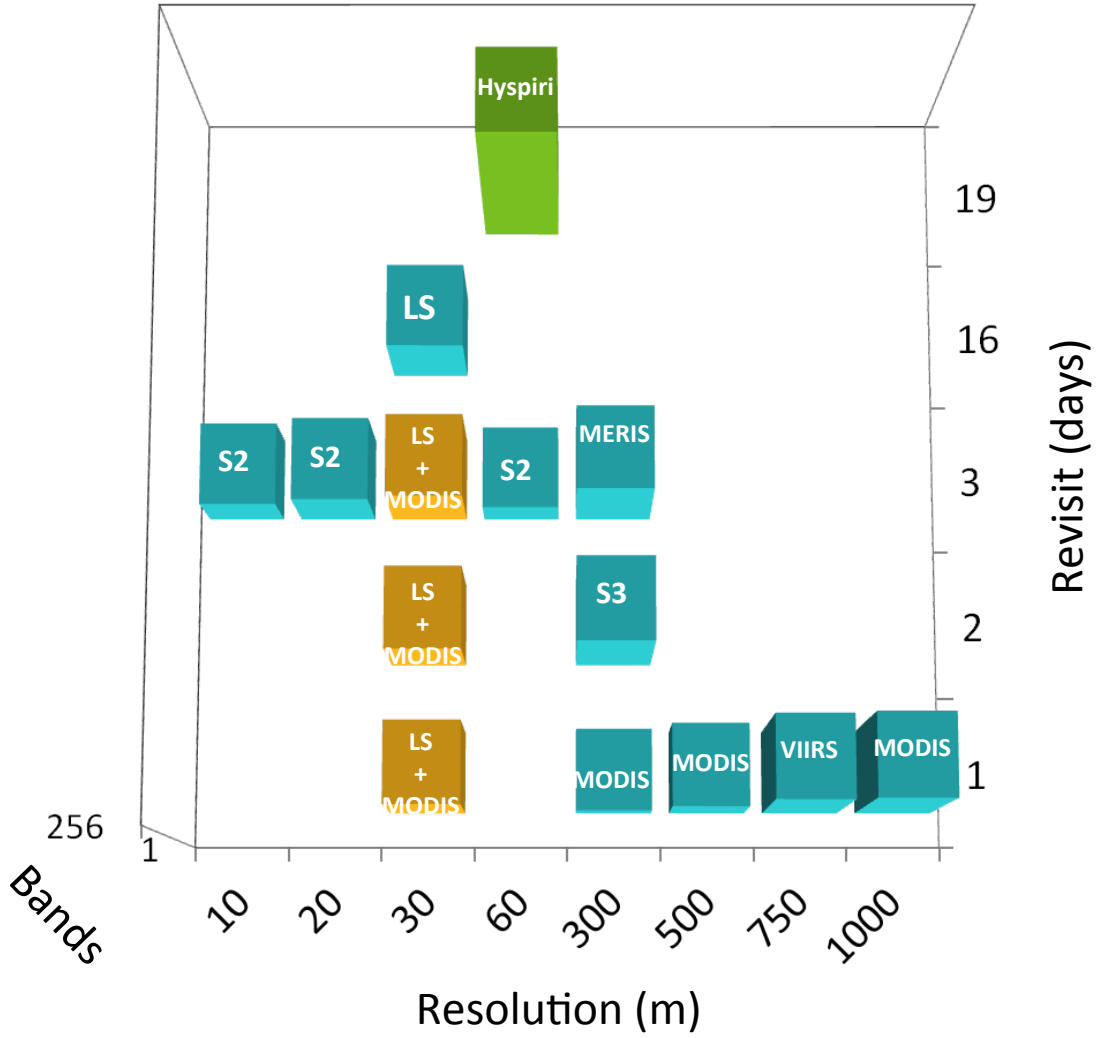
Users need decade-long term perspectives



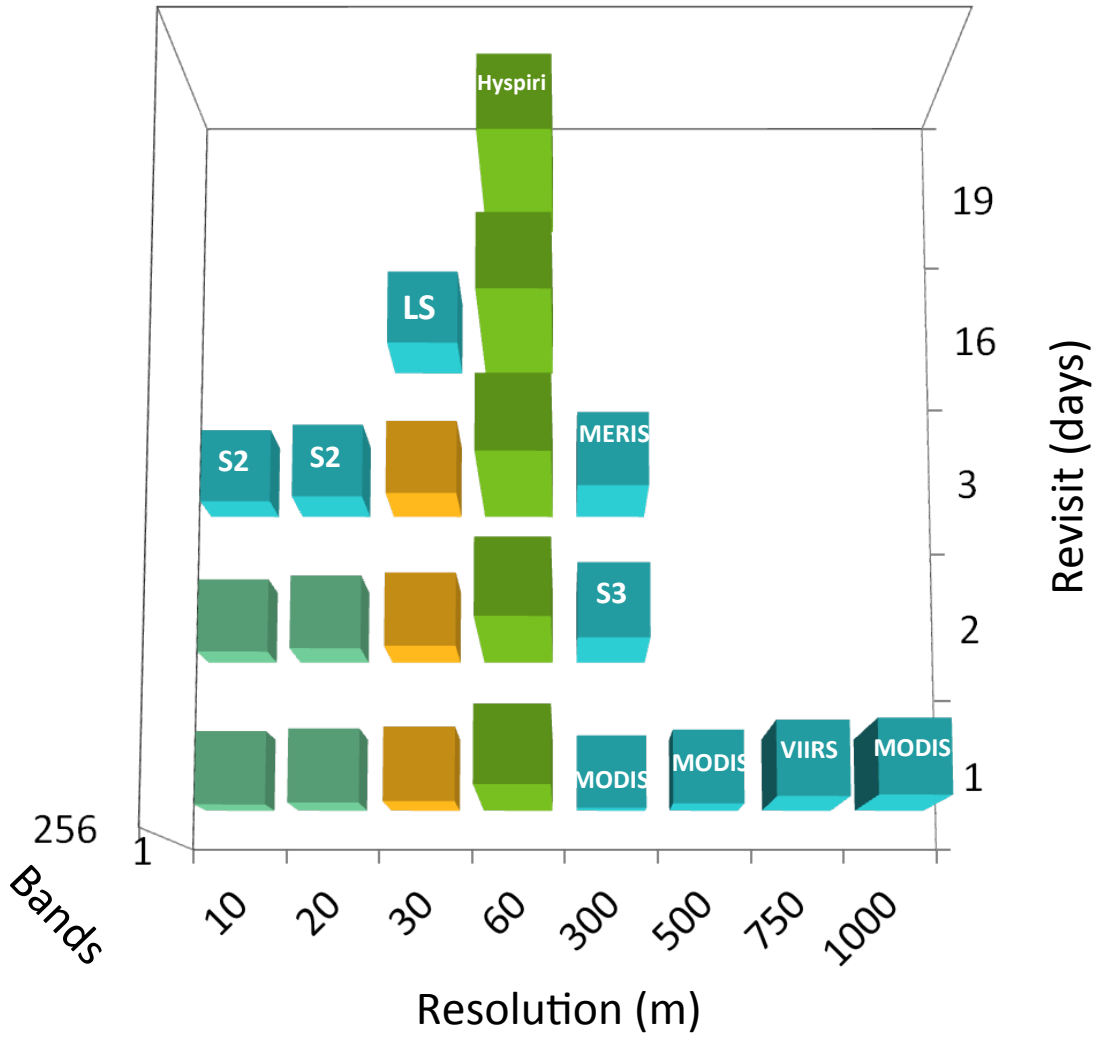
Current blending opportunities



Hyspiri's contribution to global mapping

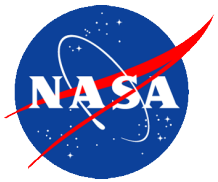


Future blending potential



Towards an Aquatic Earth Observation System: using tools such as hydrodynamic and biogeochemical models, in situ observations and multi-and hyperspectral earth observation to:

- Eutrophication- Nutrients Fluxes & Budgets
  - Inland waters, bays and estuaries: water quality, macrophytes & habitat
- Carbon Fluxes & Budgets
  - Land to inland water body to sea: fluxes and reservoirs
- Climate Change
  - Retrospective time series analyses for trend and anomaly detection (including areas in Australia where nothing has been measured previously)
- Shoreline erosion and flooding
  - Effect of land-use changes on run-off
  - Riparian and flood plain
  - Bathymetry and DEM
- National Environmental Accounts
  - Habitat status, State of Environment reporting
- Emergency management
  - Potentially harmful algal blooms
  - Oil & Chemical Spill Response;

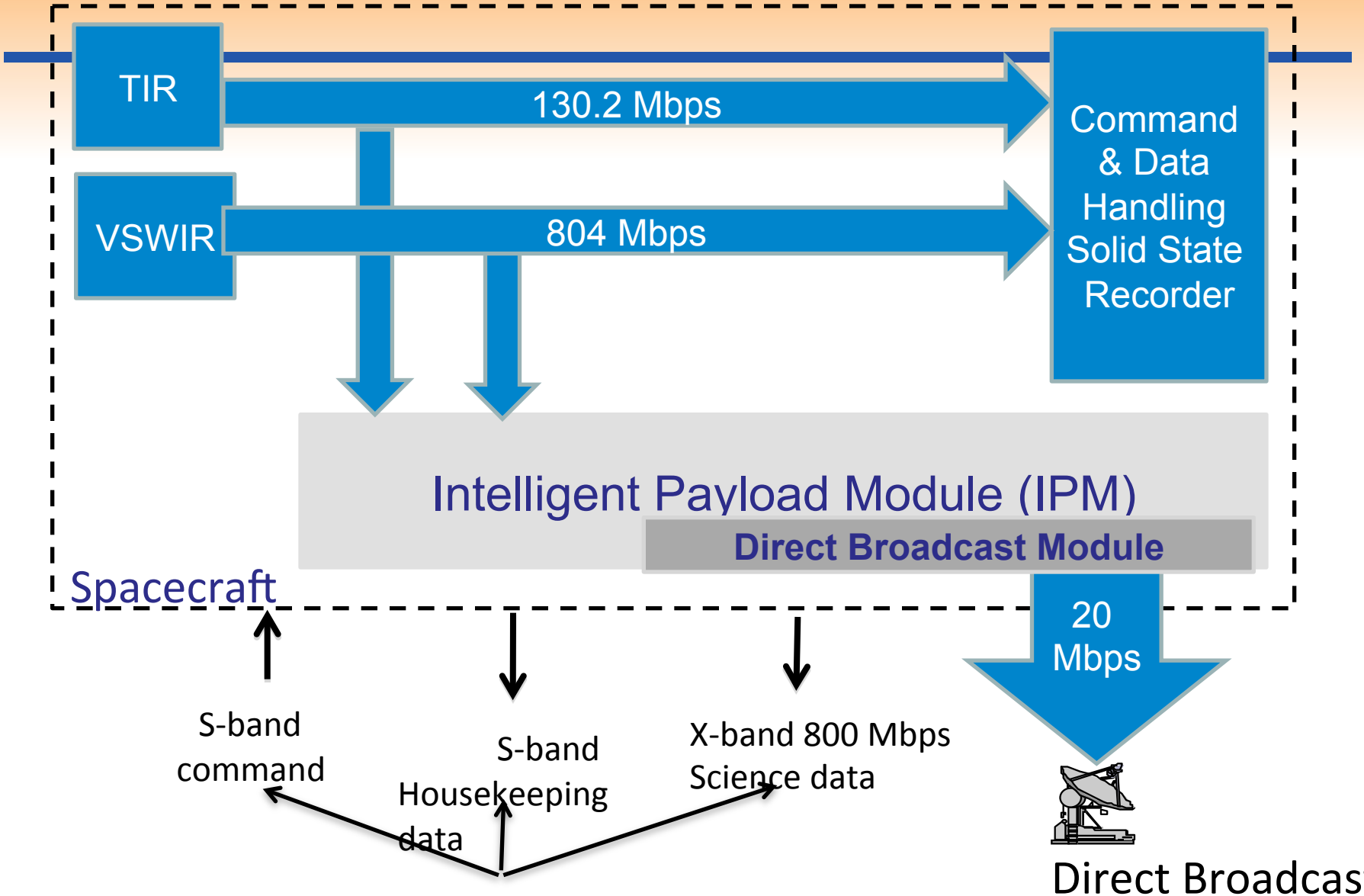


IPM and Low Latency Ops Concept Status

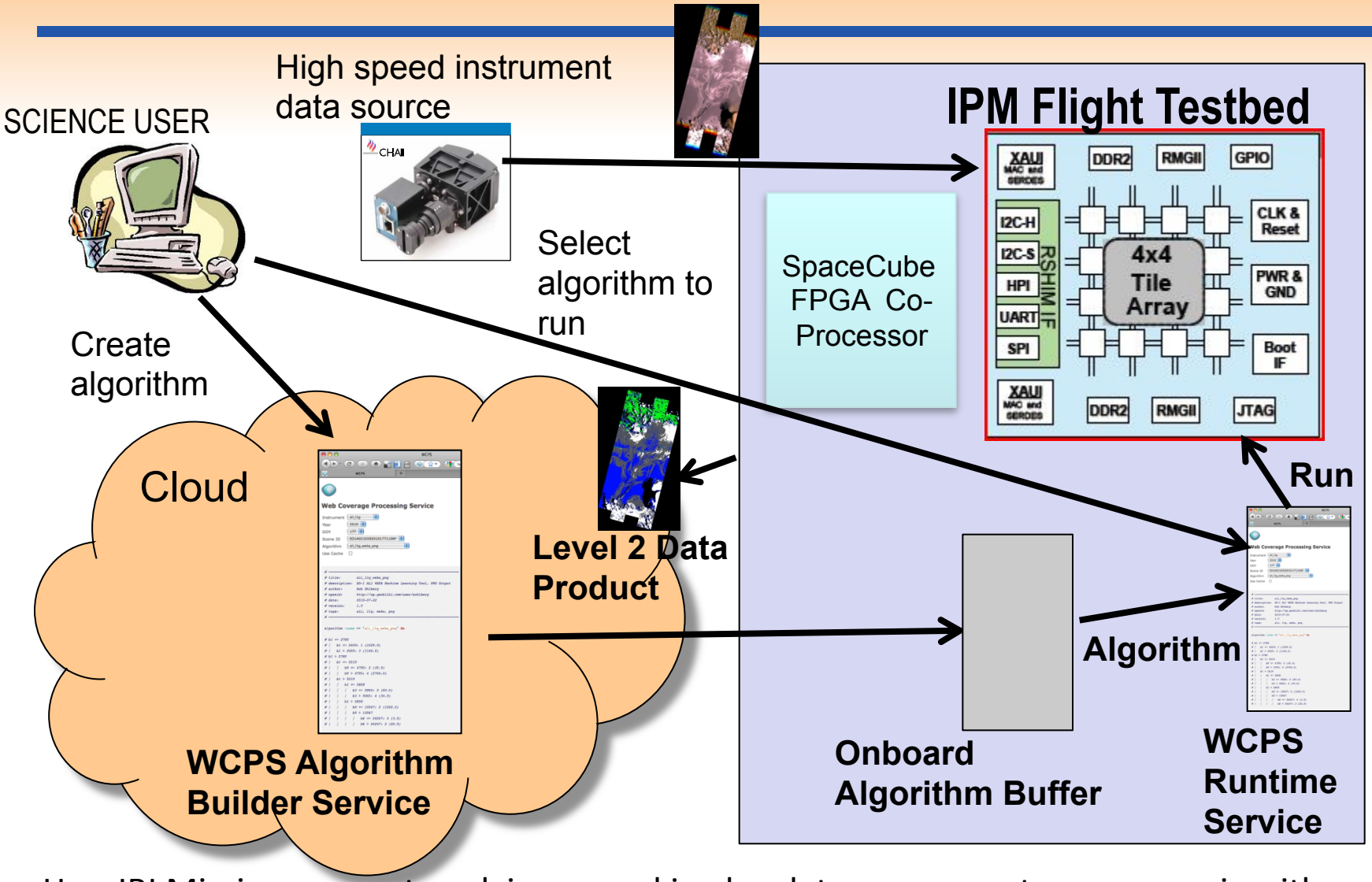
Dan Mandl

HysplRI Symposium
May 30, 2013

Original HysplRI Low Latency Data Flow Operations Concept (Intelligent Payload Module)



Revised Low Latency Ops Concept



HyspIRI Mission concept evolving so making low latency concept more generic with some combination of ground cloud computing and onboard multicore processor.

EO-1 Cloud Computing Functionality

Technologists
NASA Investigators
Disaster Responders

Matsu Cloud

http server

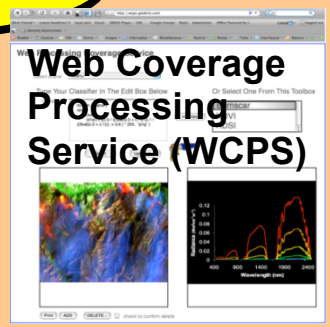
Level 1R and Level 1G Processing for ALI & Hyperion

Co-registration with Landsat GLS

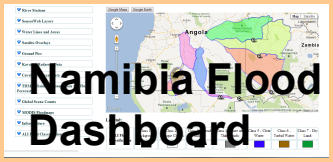
Starlight 100 Gigabit Ethernet Exchange

Hyperion and ALI Level 0 Processed data from GSFC, building 3 server

Web Coverage Processing Service (WCPS)



Atmospheric Correction for ALI & Hyperion

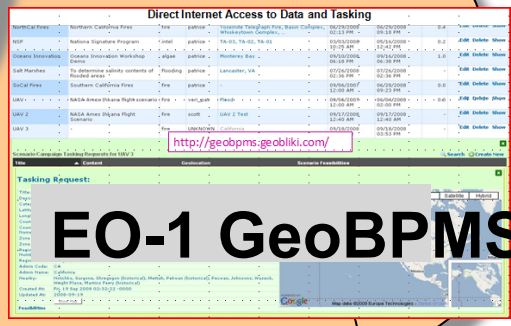


Namibia Flood Dashboard

Multi year data product archive

Matsu Cloud
- Eucalyptus/Open Stack-based Elastic Cloud SW
- 300+ core processors
- 500+ Tbytes of storage
- 10 Gbps connection to GSFC
  - being upgraded to 100 Gbps (Part of OCC)
- Hadoop Tiling/MapReduce/Accumulo
- Supplied by Open Cloud Consortium
- Open Science Data Cloud Virtual Machines & HTTP server to VM's

Joyent Cloud



EO-1 GeoBPMS

EO-1 GeoBliki

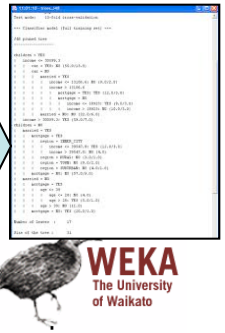
Joyent Cloud
- Ruby on Rails
- 3 processors
- 3 Tbytes of storage

Experimental Intelligent Payload Module Quick Load/Quick Look Ops Con

Web Coverage Processing Service (WCPS)-Client Uploads to Various Environments

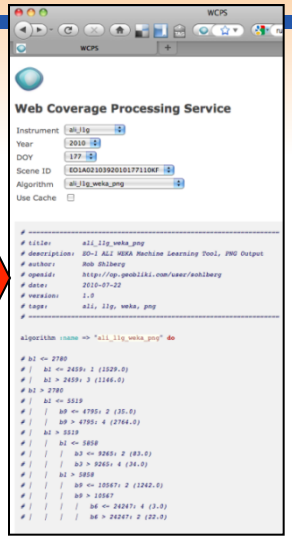
Create Custom Algorithm

SCIENCE USER



Machine Learning Supervised Classifier (Regression Tree) Refined Offline

Custom Algorithm



Quick algorithm upload

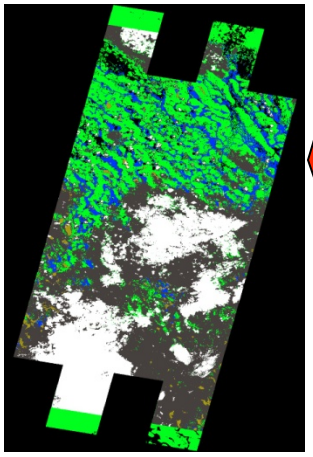
HyspIRI

Cessna , helicopter, etc.

Lua Scripts

Compute Cloud Infrastructure As A Service

WCPS-Runtime Executes Algorithm Against Selected Sensor Data

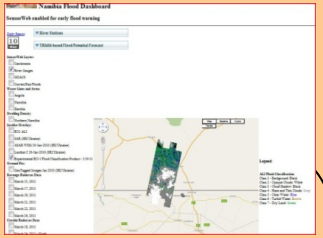


Custom Data Product (KMZ, PNG…)

Notification to user

Quick look data products

Cloud



Roadmap for IPM Flight Opportunities

2013-2014

Mini UAV Helicopter

2020+ HyspIRI/HSI+ Thermal

Maestro-lite

2013 GliHT Flight

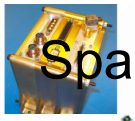
Headwall

SpaceCube

TileraPro

2013/2014 Bussmann Helicopter

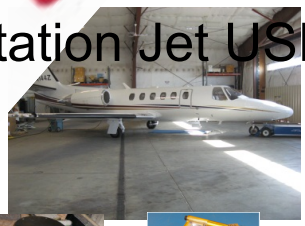
SpaceCube



TileraPro

Chai 640

2013 Citation Jet USFS

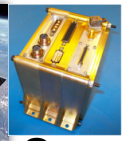


AMS

SpaceCube

TileraPro

2008



SpaceCube Xilinx FPGA

Flight & Ground Architecture Using Operational SW Components

CASPER

WCPS

TlmOut

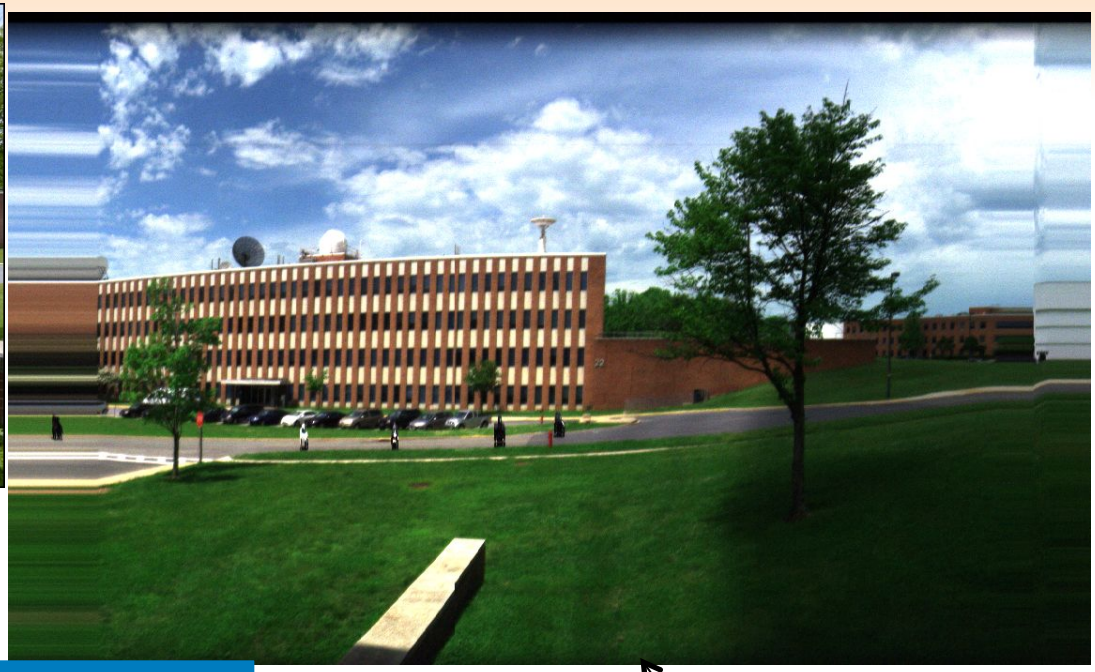
CmdIn

CFDP

ASIST

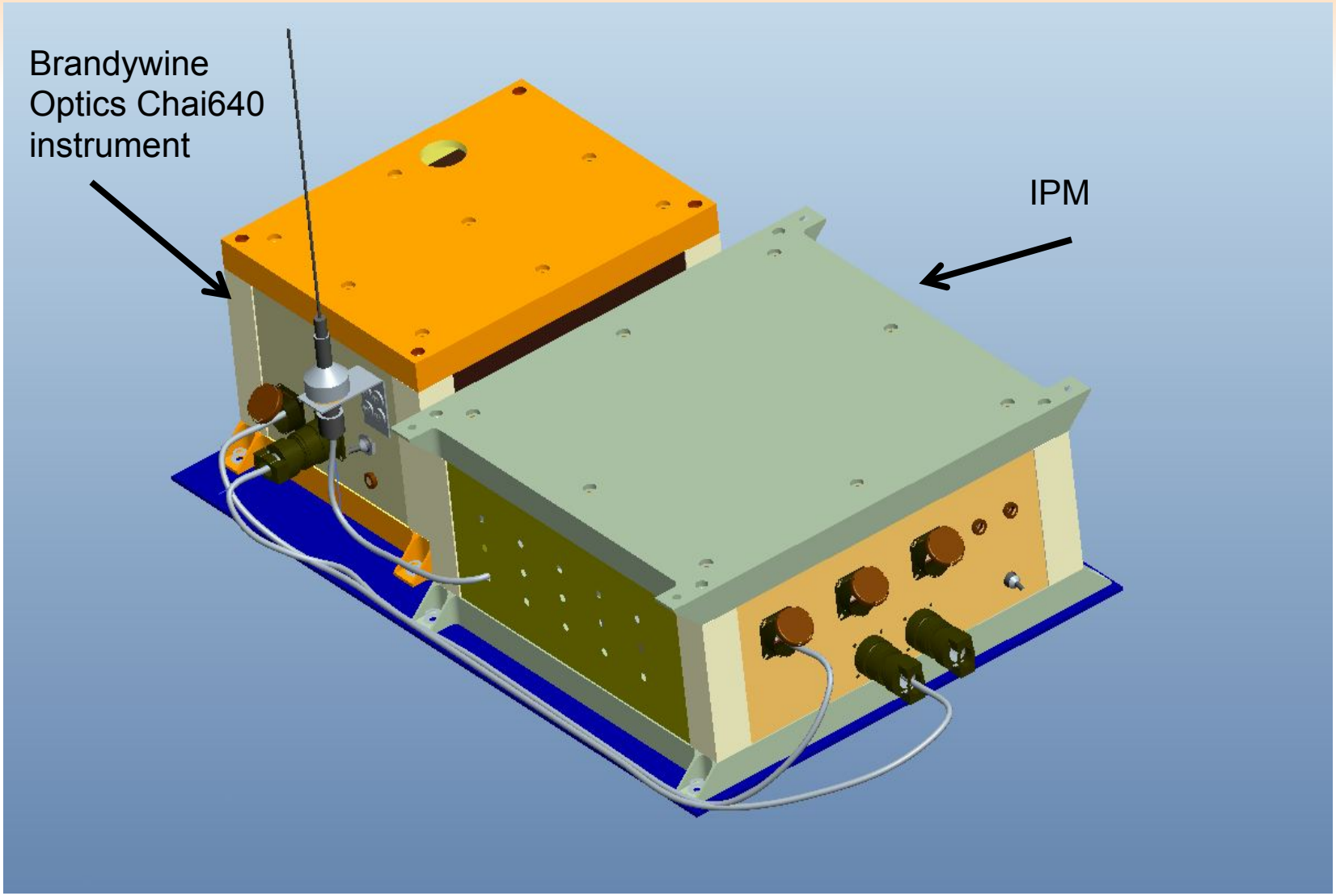
WCPS – Web Coverage Processing Service
CmdIn – Command Ingest
TlmOut – Telemetry Output
CASPER - Continuous Activity Scheduling Planning Execution and Replanning system
CFDP - CCSDS File Delivery Protocol
ASIST - Advanced Spacecraft Integration and System Test Software

First Calibration Test with Chai V640 Imaging Spectrometer Instrument (5/16/13)



Visible image constructed from test data

Intelligent Payload Module Assembly with Chai640



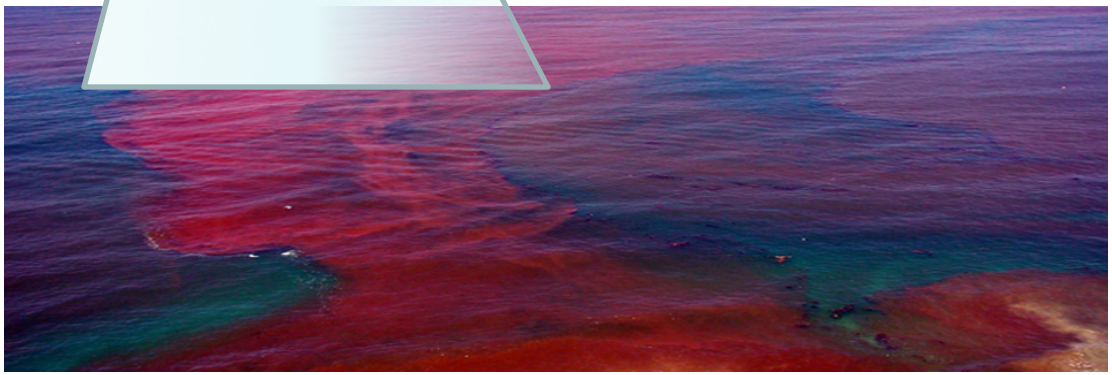
Beginning Integration Process on Helicopter

Sample Operational Scenario: Detection of Harmful Algal Blooms with Rapid Map Downlinked to Validation Team on Ground

Realtime map with following processing steps:
- ✓Radiance to reflectance conversion
- ✓Atmospheric Correction
- ✓Geocorrection/Co-registration
- ✓Classification

Downlink to Ipad

Validation team in boat being directed to location by rapid map product



Harmful Algal Bloom

Unmanned Aerial System Jellyfish Monitoring Mission with IPM (Univ. of Catalunya)

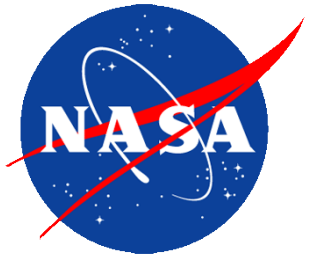
Area of interest: Delta del Ebre south of Barcelona. Multiple Australian jellyfish being increasingly detected.

First test mission: Late summer 2012

Initial low-altitude mid-altitude images successfully acquired.

http://www.youtube.com/watch?v=Uam7-thvM80

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH


NASA

GEOSS

SensorWeb

May 30, 2013

Enabling Information Discovery and Sharing To Foster Citizen Science And Support Societal Needs

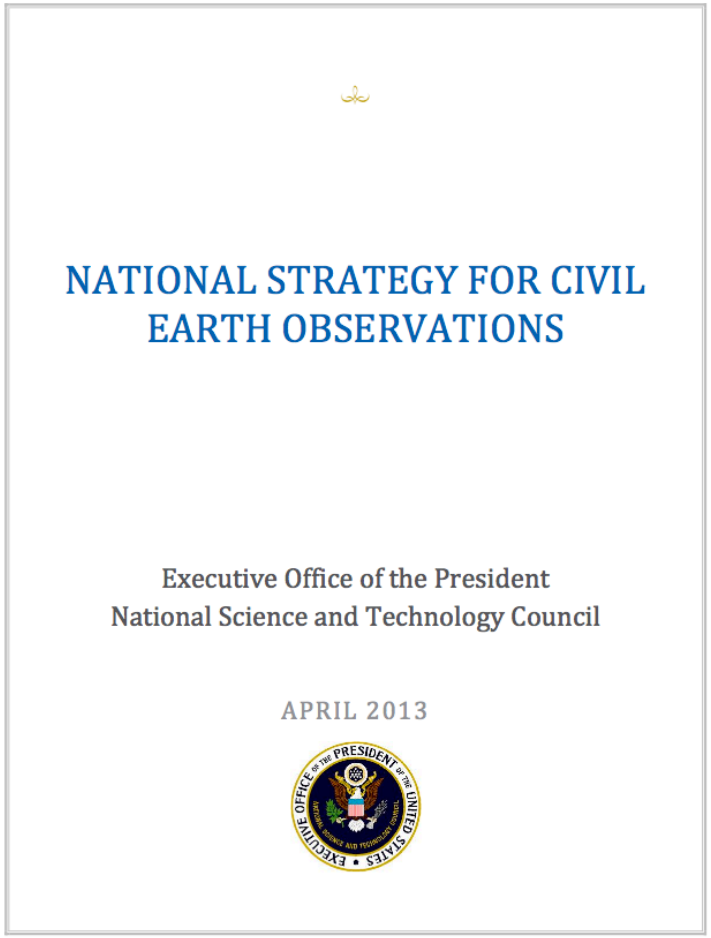
HysplRI Symposium – Greenbelt MD

Open GeoSocial

Dan **Mandl**
Stu **Frye**
Pat **Cappelaere**

Who Has Heard of This?

- NSCEO



Before NSCEO

Earth Sciences From Space

Mission Priority

After NSCEO

Earth Sciences From Space

GEOSS

Mission Priority

Problem Statement For GEOSS End-Users

- Hard To **Discover** Data [From Multiple Sources]
- Hard To **Process** It Into Actionable Information
- Hard To **Distribute** To Other End-Users
- Hard To **Validate** and Improve

GEOSS Users Do Not Care About Data
They Want Products they can put on a map

Vision

END-USER FOCUS

Push Information To The Last Mile

Science Data/Assets Available For **Societal Benefits**

- Turning Big Data Into Actionable Information ("Products")
- Leverage Citizen To Improve Science Products

- **Partners**
  - World Bank Global Facility For Disaster Risk Management
  - Humanitarian OpenStreetMap
  - SERVIR
  - Universities: Dartmouth, MD, Kansas…
  - ESA ESSI-Labs
  - RASOR (FP7)…
- **GEOSS Architecture Implementation Flood Pilots**
  - Caribbean
  - Namibia
  - New Interests: [Mozambique, Malawi, Nepal, MENA…]

A Higher Level Approach

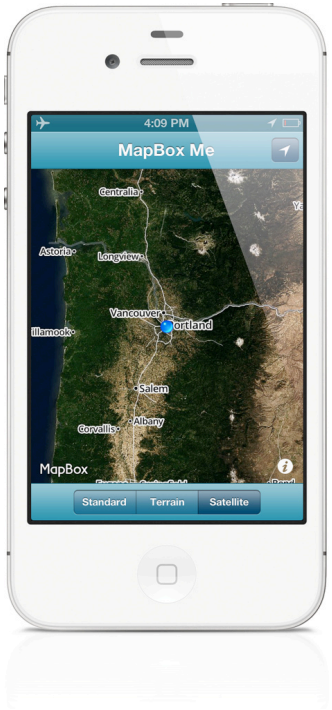
- Server Publishes
  - **Products** (Not Data, Resources nor Services)
  - **Behaviors** (Activity Sequences to Generate Products)
    - Write Once (on Server), Runs Every time (on Client).

- Client Specifies
  - AOI
  - Societal Benefit Area
  - Product Type

"I want a Flood Map for Haiti"

Products are queried, generated and acquired form multiple sources

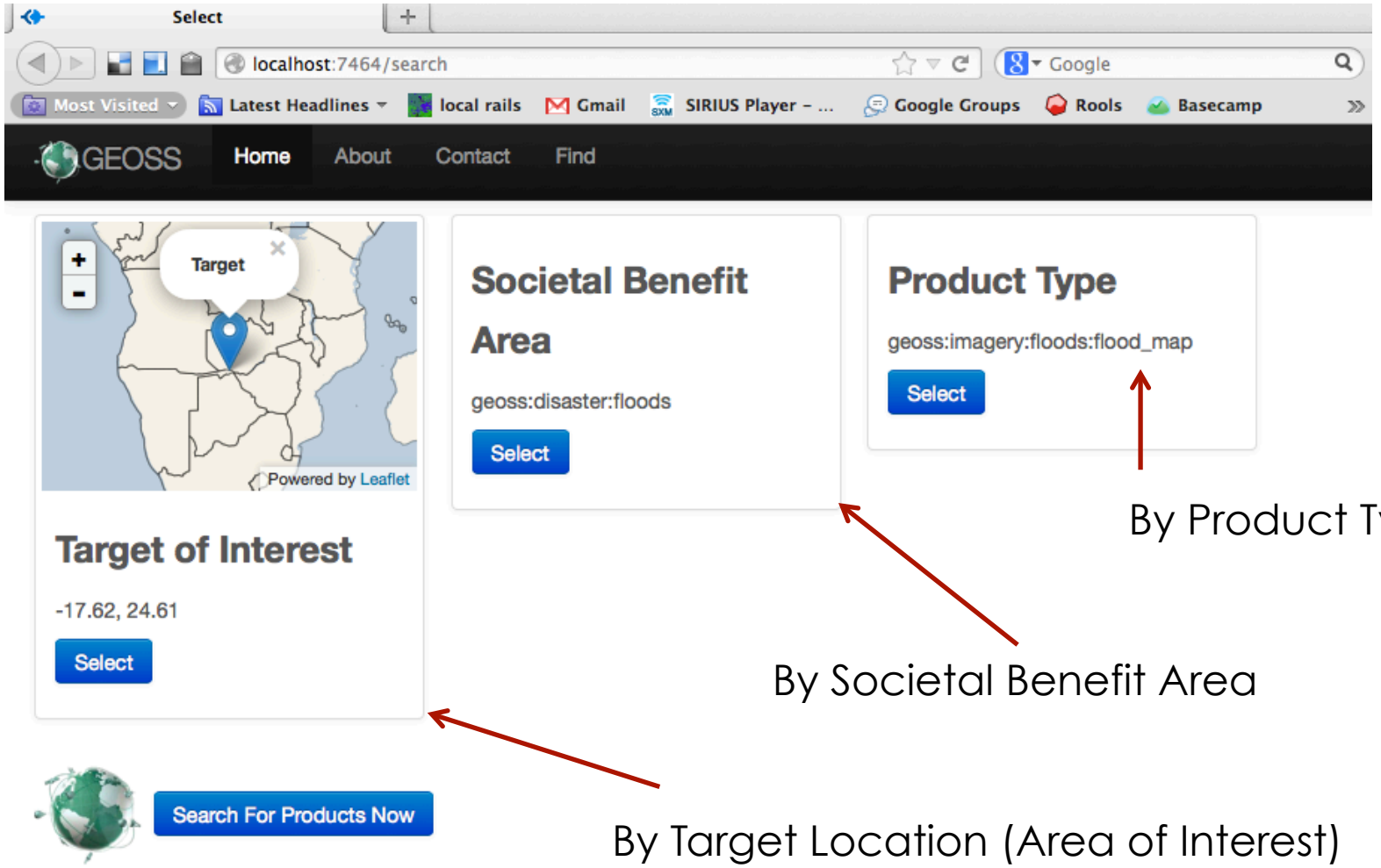
And Runs On These Platforms…



Actionable Information on the Client Side…

Search Products Page

Keep It Simple



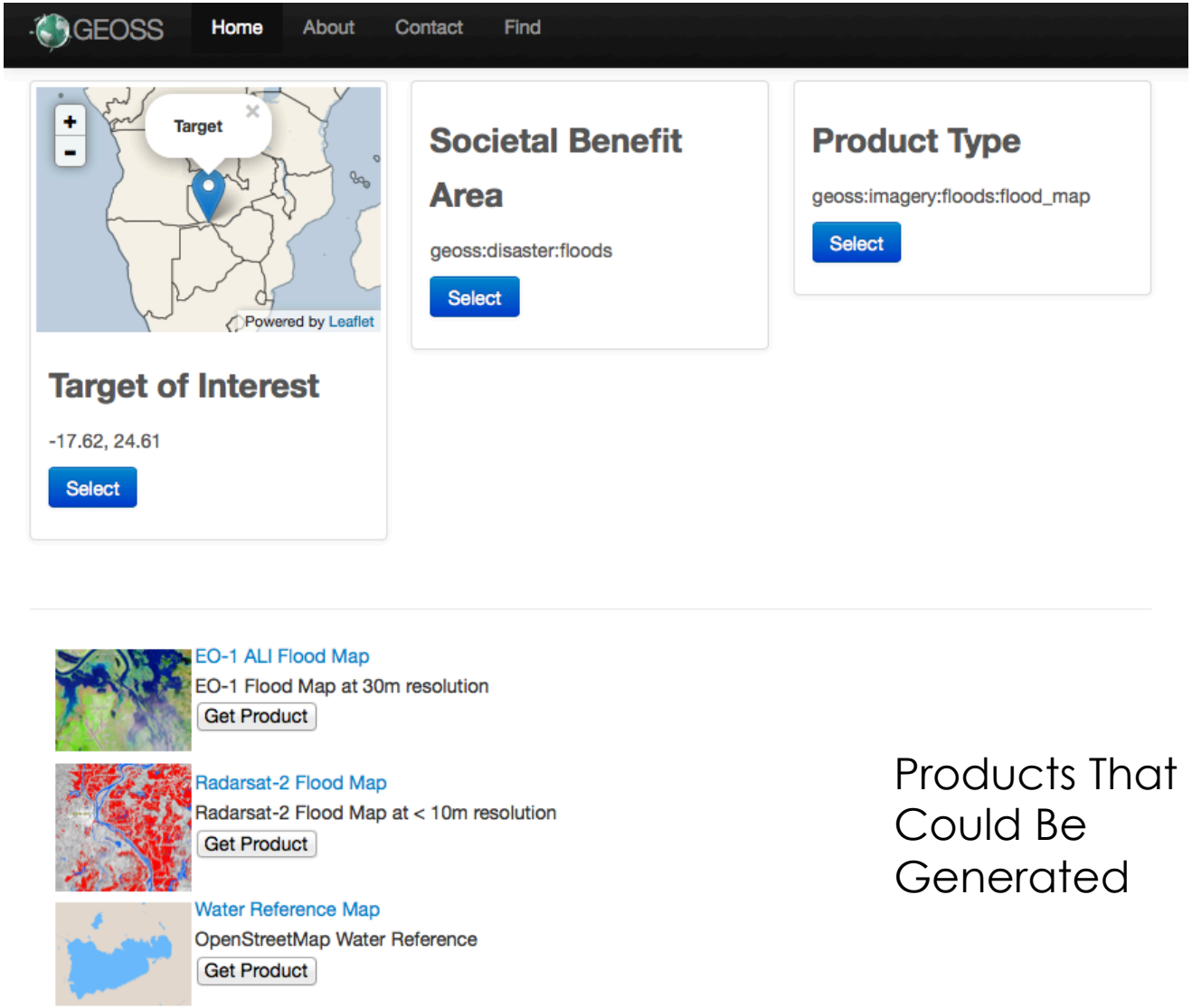
By Product Type

By Societal Benefit Area

By Target Location (Area of Interest)

© Vightel, 2013

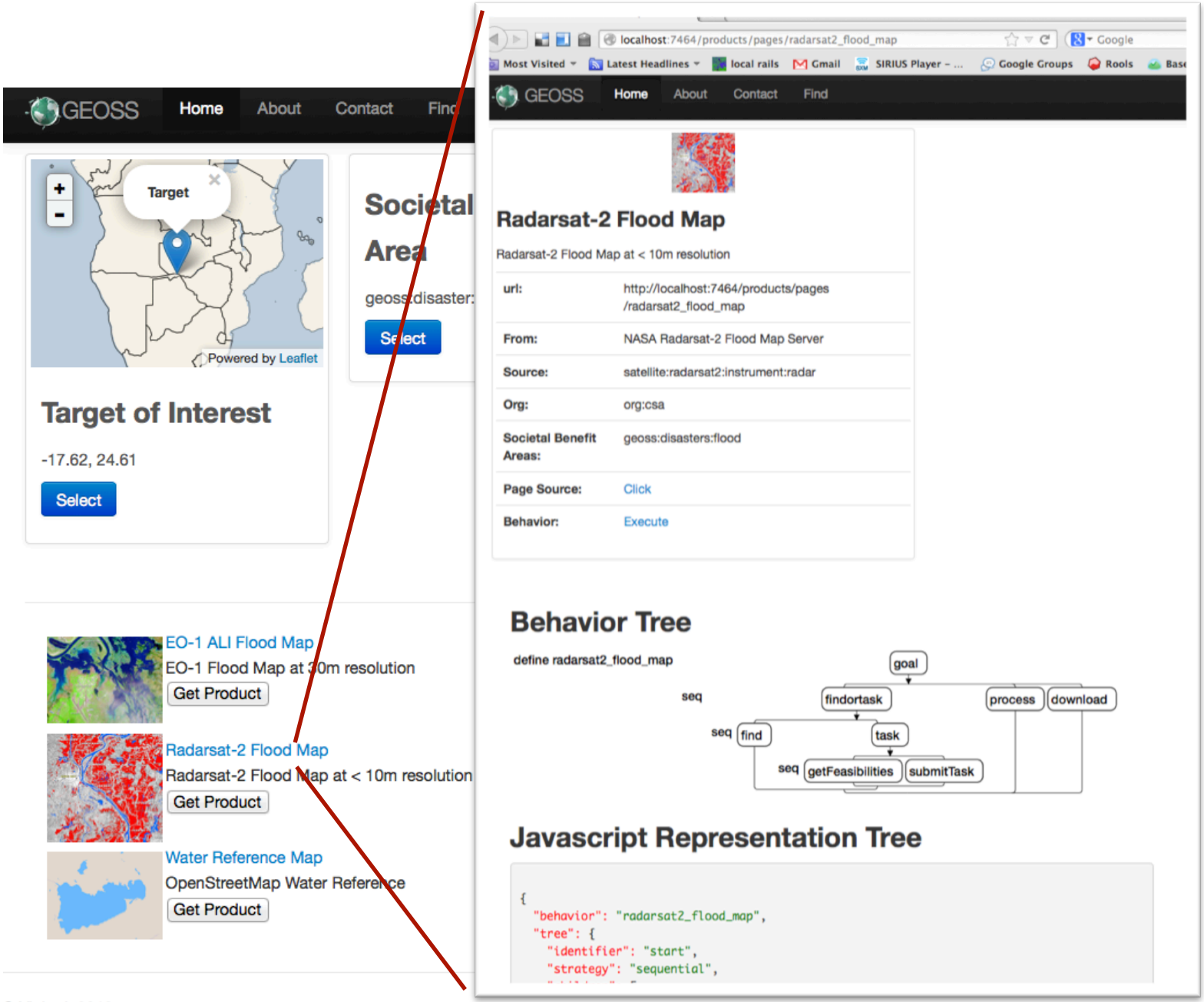
Potential Products Matching Constraints…



Products That Could Be Generated

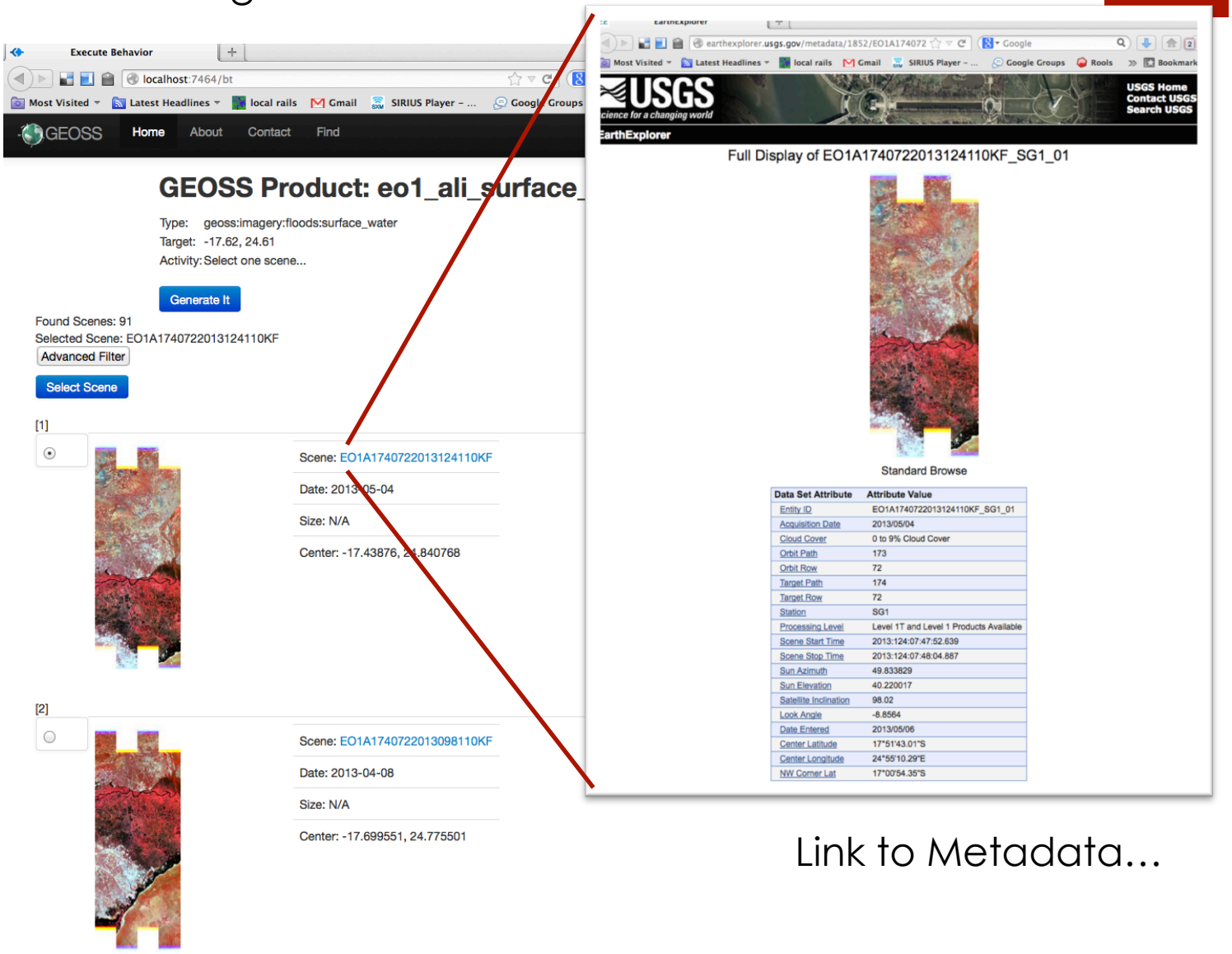
© Vightel, 2013

Checkout the Behavior…



© Vightel, 2013

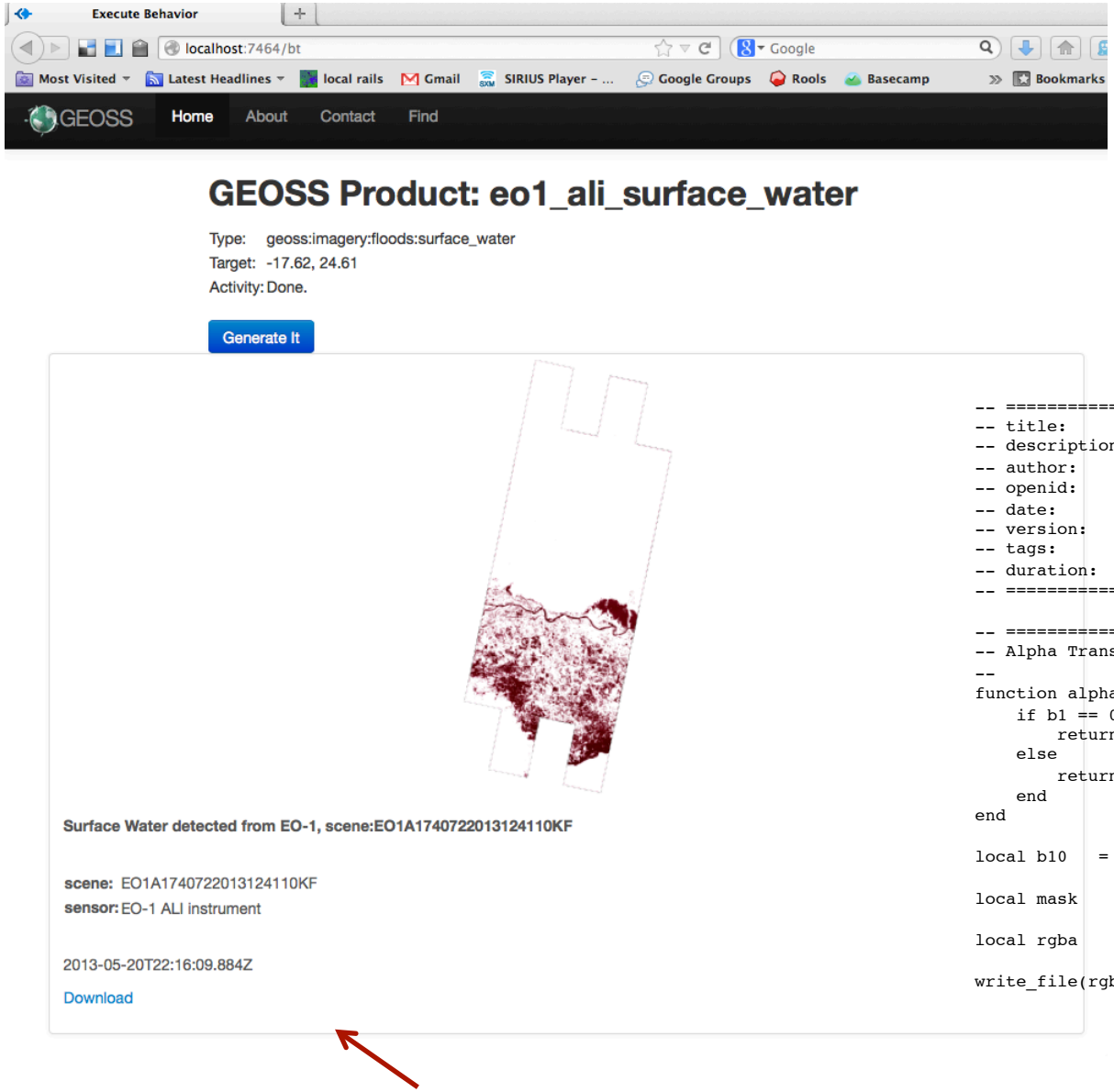
Select Matching Scene…



Link to Metadata…

Product Generated By WCPS… Download Here!

Still No Coding…



WCPS Algorithm

```
-- ========================================
-- title:        b10_density_slice
-- description:  Water Detection
-- author:
-- openid:       http://op.geobliki.com/cappelaere
-- date:         2012-02-05
-- version:      1.0
-- tags:         ali_l1t, 9
-- duration:      10s
-- ====================================

-- ======================
-- Alpha Transparency Mask
--
function alpha_mask(b1)
    if b1 == 0  or b1 > 800 then
        return 0
    else
        return 255
    end
end

local b10   = band(10)

local mask          = process_mask_function( alpha_mask, {b1=b10})

local rgba          = colorize( b10, "red_purple", mask )

write_file(rgba)
```

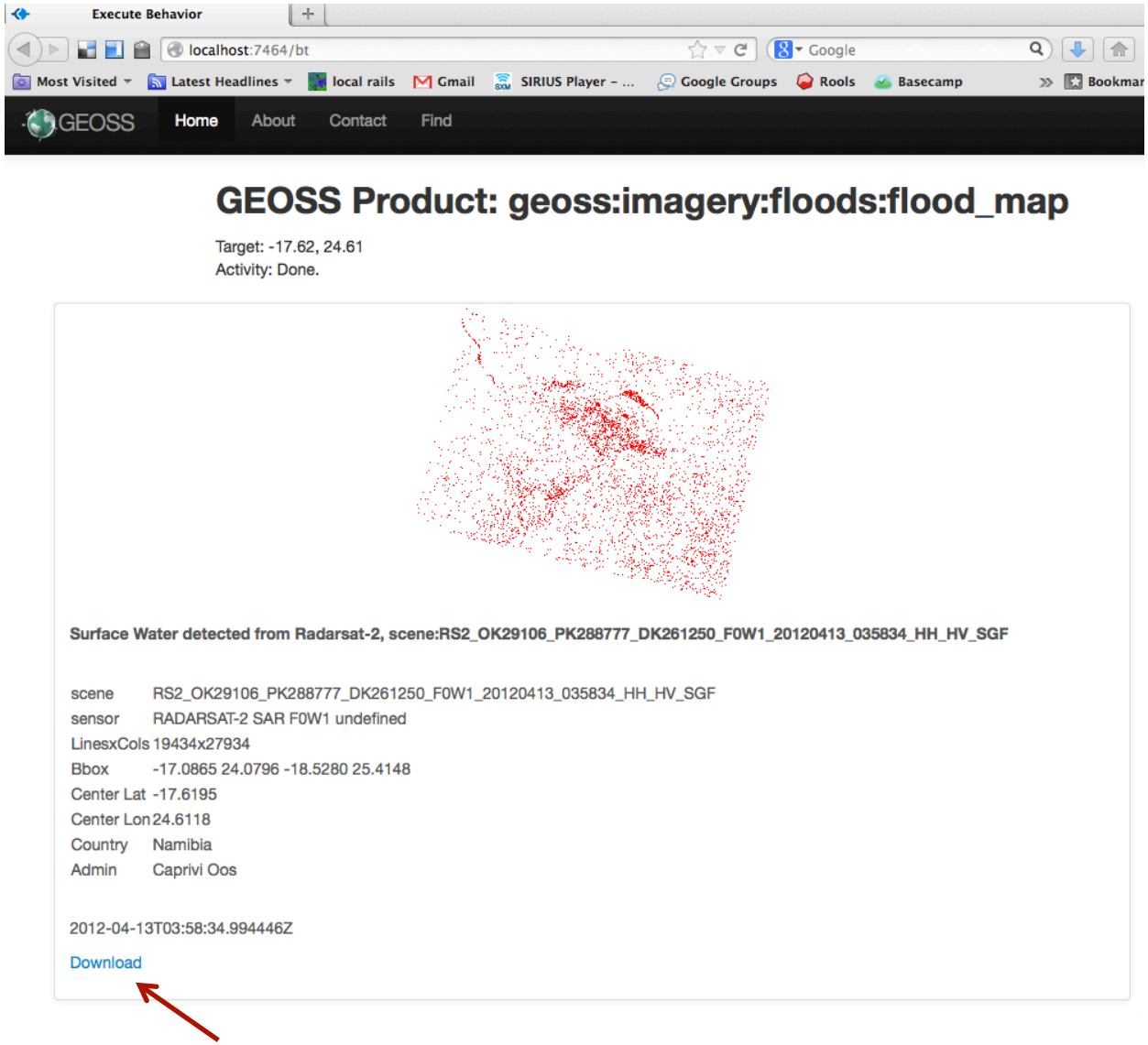
Surface Water detected from Modis tile:020E010S

MODIS tile 020E010S
sensor MODIS

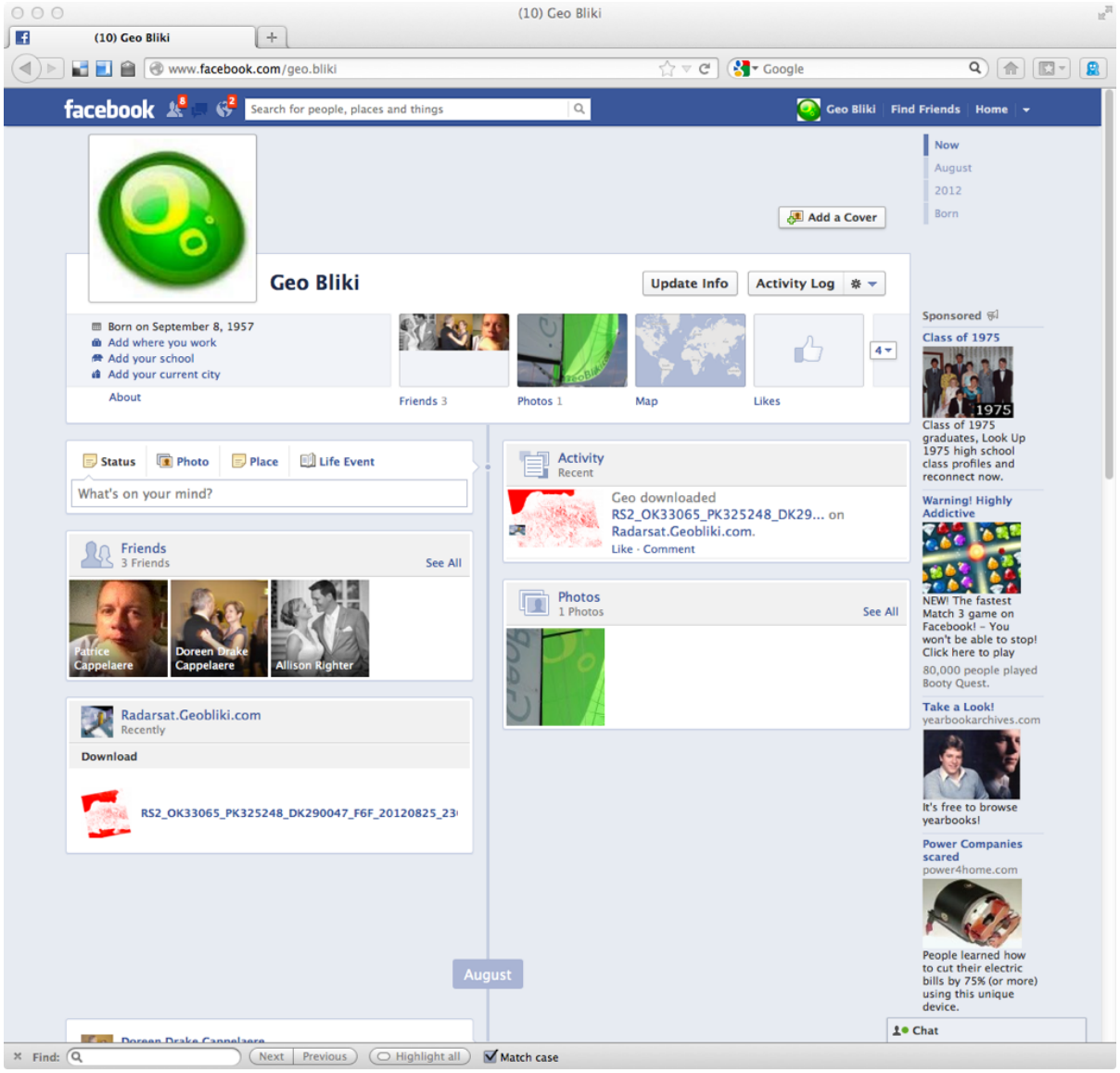
2013-05-20

Download

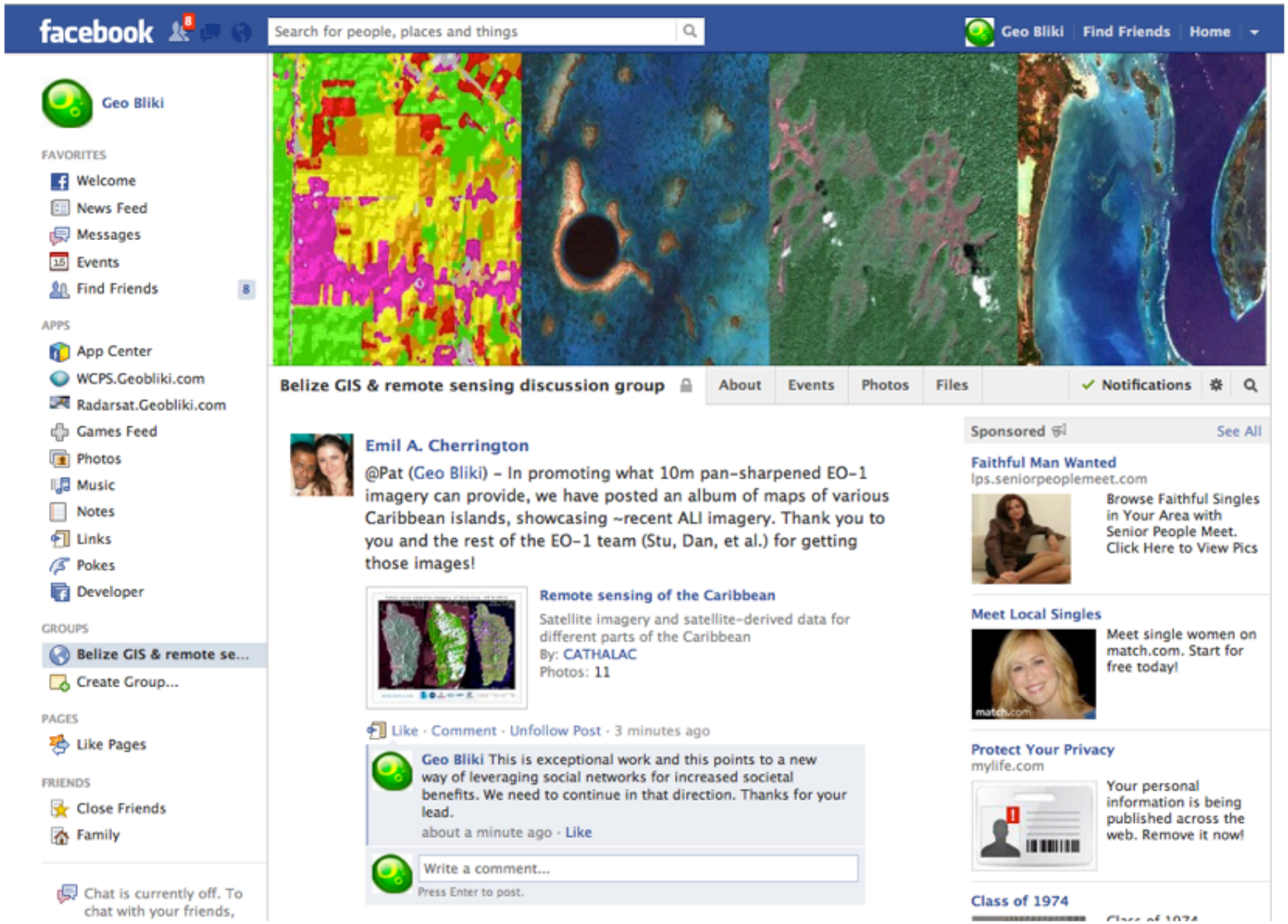
Flood Map Returned As Product… Download Here!



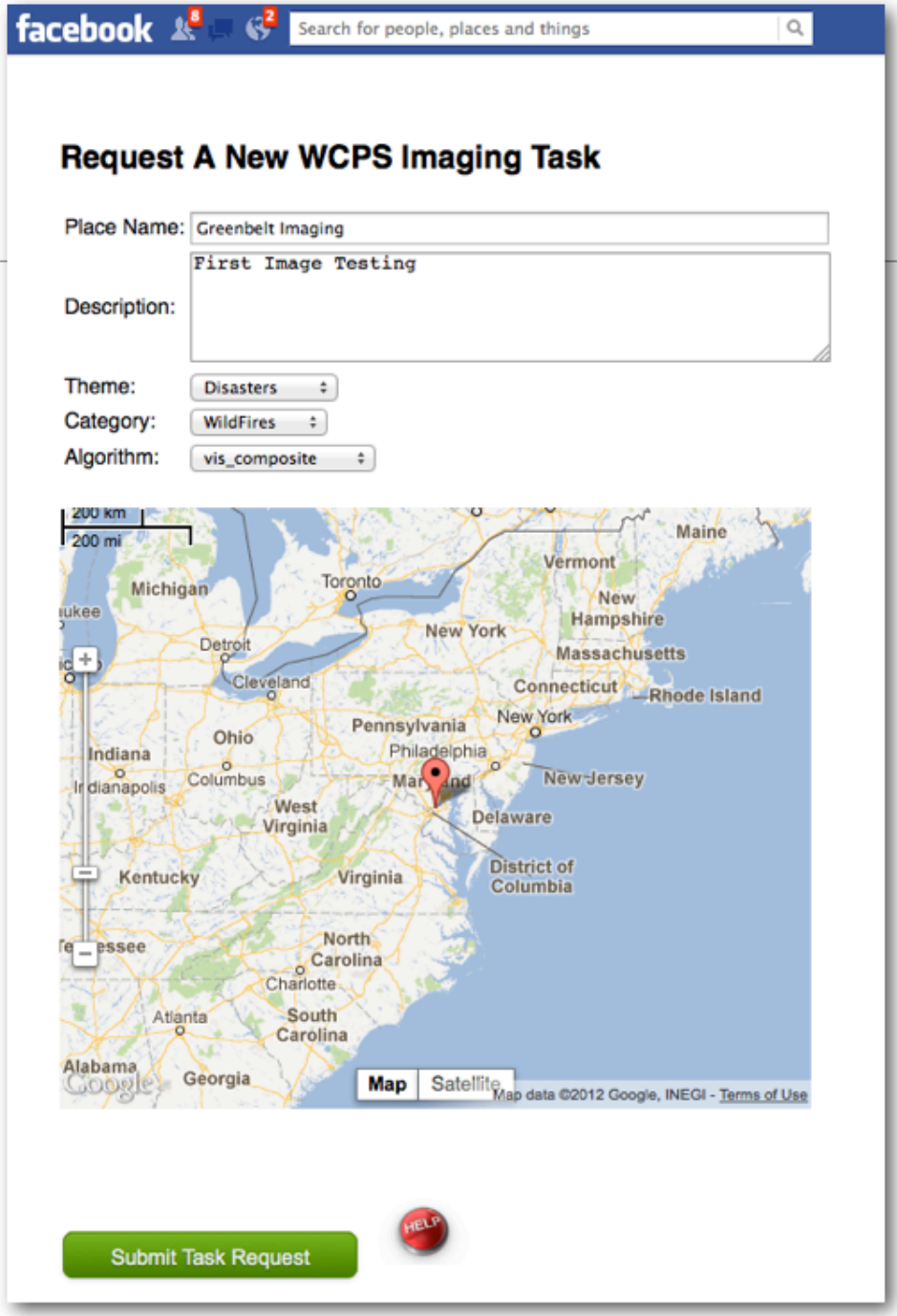
Activities Appear On User Timeline for Discovery as Stories…
With Links to Allow Mimicking…



Community Involvement



IPM Tasking


facebook
Search for people, places and things
Request A New WCPS Imaging Task
Place Name:
Greenbelt Imaging
Description:
First Image Testing
Theme:
Disasters
Category:
WildFires
Algorithm:
vis_composite
200 km
200 mi
Maine
Vermont
New Hampshire
Massachusetts
Rhode Island
Connecticut
New York
Pennsylvania
Philadelphia
New Jersey
Delaware
District of Columbia
Virginia
West Virginia
Ohio
Indiana
Columbus
Kentucky
North Carolina
Charlotte
South Carolina
Atlanta
Georgia
Alabama
Michigan
Toronto
Detroit
Cleveland
Map
Satellite
Map data ©2012 Google, INEGI - Terms of Use
Submit Task Request
HELP

Benefits

- Increase Speed of Acquisition, Data Processing and Distribution Using Ubiquitous Social Tools
- Increase Science Collaboration Around The Data At Lower Cost
- Leverage Cognitive Surplus Available on The Web to Solve Big Science Problem
- Increase Potential For More Science Applications & Research
- Increase Societal Benefits of Science Data At Lower Cost to Science Mission
- Provide Societal Benefits Analytics

Thank You

- Contact
  - pat@cappelaere.com
  - skype: patrice_cappelaere
  - http://twitter.com/cappelaere
  - http://github.com/cappelaere
  - http://www.linkedin.com/pub/pat-cappelaere/0/163/236/
  - http://www.slideshare.net/cappelaere

Automatic Registration for On Ground and On Board Processing

Patricia Sazama, University of Maryland

Dan Mandl, GSFC Code 581

Jacqueline Le Moigne, GSFC Code 580

Image Registration

Definition

“Exact pixel-to-pixel matching of two different images or matching of one image to a map”

Navigation or Model-Based Systematic Correction

Orbital, Attitude, Platform/Sensor Geometric Relationship, Sensor Characteristics, Earth Model, etc.

Image Registration/Feature-Based Precision Correction

Navigation within a Few Pixels Accuracy

Image Registration Using Selected Features (or Control Points) to Refine Geo-Location Accuracy

Image Registration as a Post-Processing or as a Feedback to Navigation Model

Role of Image Registration in Remotely Sensed Data

- Essential for spatial and radiometric calibration of multitemporal measurements for creating long-term phenomenon tracking data
- Used for accurate change detection
- Basis for extrapolating data throughout several scales for multi-scale phenomena (distinguish between natural and human-induced)

Challenges in Image Registration

Navigation Error (or varying “Initial Conditions”)

- Historical satellites (e.g., Landsat-5 compared to Landsat-7)
- Following a maneuver (e.g., star tracking)

Needs:

- Sub-pixel accuracy
- Robustness to recurring use
- Speed and High-Level of Autonomy (Near- or Near-real time applications, e.g., disaster management)
- On the ground or On Board Processing

Image Registration Components

0 Pre-Processing
- Cloud Detection, Region of Interest Masking, …

1 Feature Extraction (“Control Points”)
- Gray Levels, Salient Points (e.g., Edges, Edge-like such as Wavelet Coefficients, Corners), Lines, Contours, Regions, Scale Invariant Feature Transform (SIFT), etc.

2 Feature Matching
- Choice of Spatial Transformation (**function f**: a-priori knowledge)
- Choice of Search Strategy :
  - Global vs Local, Multi-Resolution, Optimization, ...
- Choice of Similarity Metrics
  - L2-Norm, Normalized Cross-Correlation, Mutual Information, Hausdorff Distance, …

3 Remapping/Resampling (**function g**: if necessary)

Global Land Survey Maps

- A collection of Landsat-type satellite images from USGS
  - Near complete global coverage
  - Orthorectified
  - Each image has cloud cover of less than 10%
  - Four versions: 1970, 1990, 2000, and 2005
- Ground truth for the registration programs was drawn from the GLS 2000 and can be updated when the GLS 2010 is completed
- http://landsat.usgs.gov/science_GLS.php

Image Registration

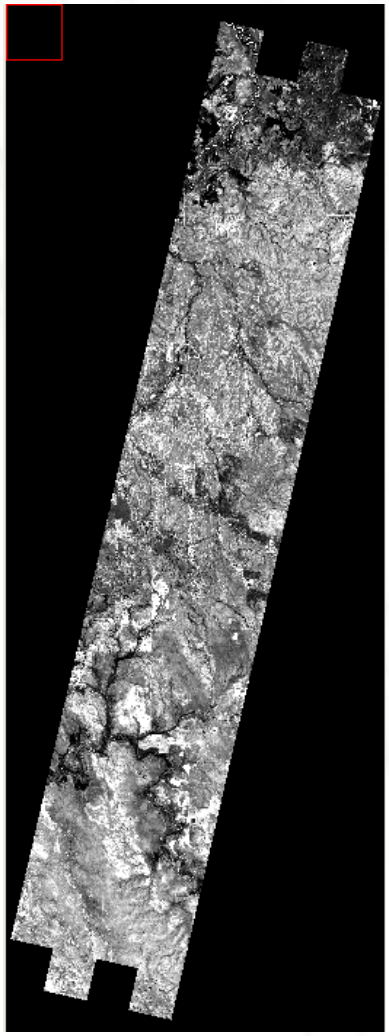
- First Method: Co-register 2 full size images
  - Compares image with a previously geo-corrected ground truth image
  - Uses GLS 2000 dataset stored on the cloud

Step 1) Script automatically selects a GLS map for the EO1 scene using scene metadata

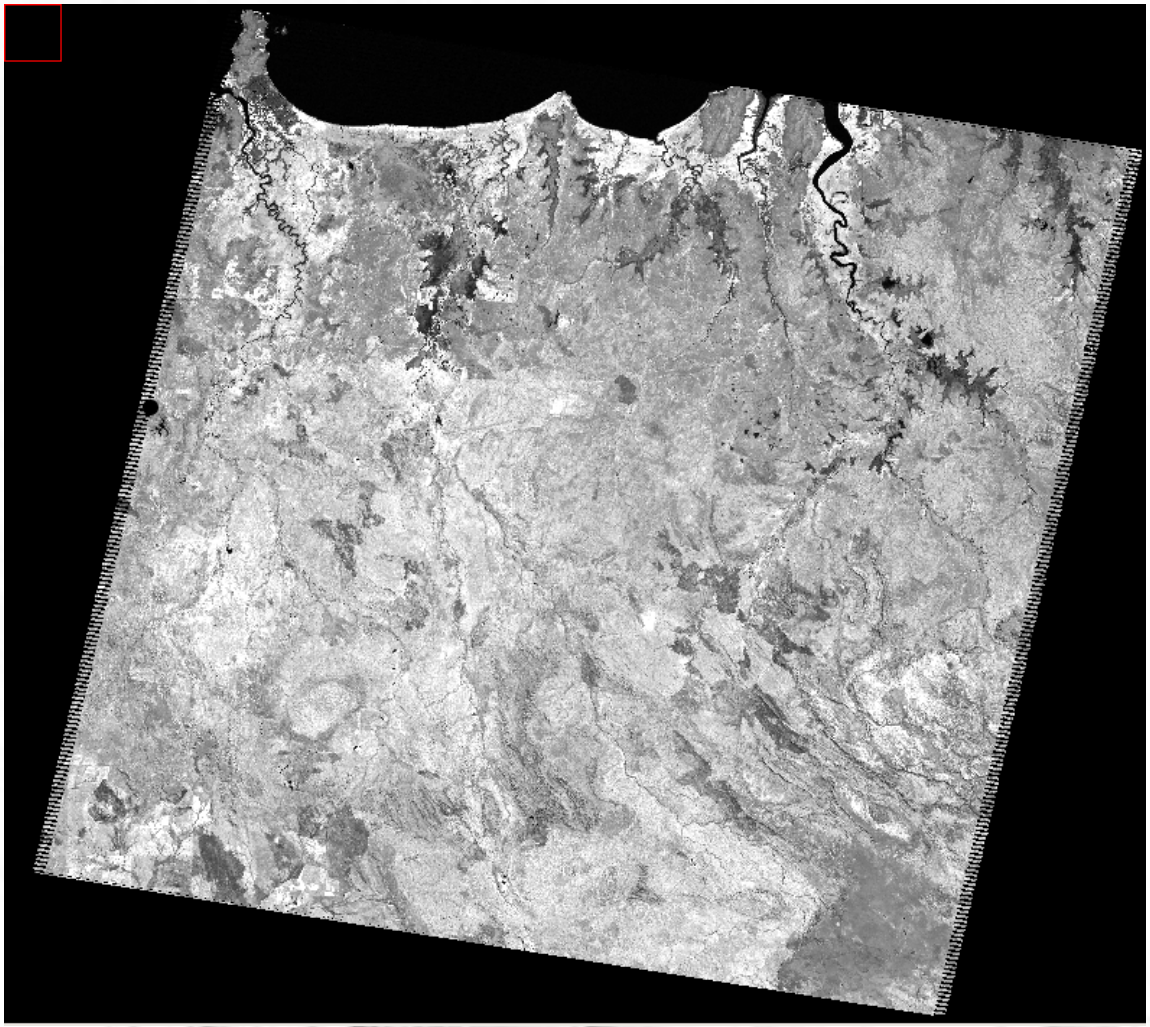
Step 2) Registration program automatically selects ground control points and finds the transformation between the two images

GLS Co-registration

- Step 1: EO1 scene and selected GLS map



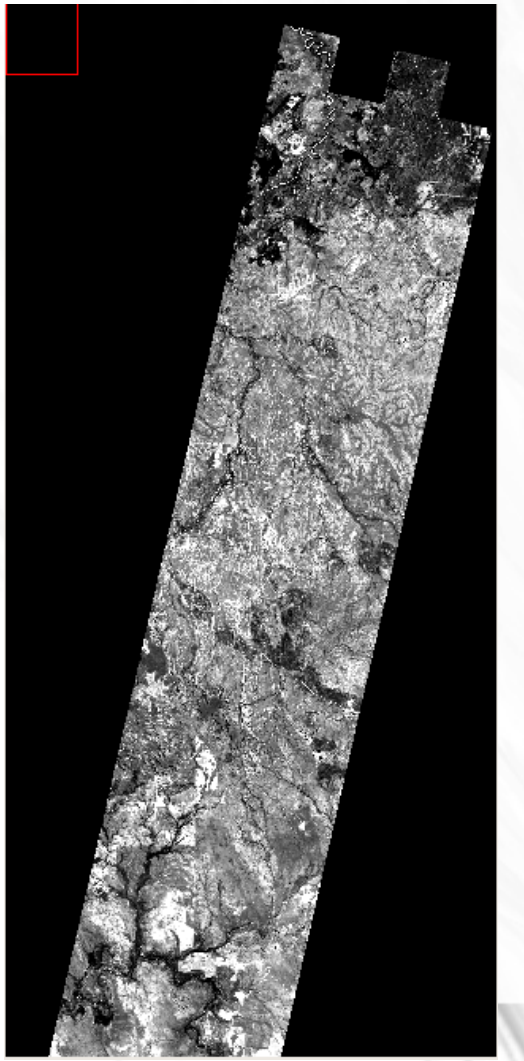
EO1 Scene



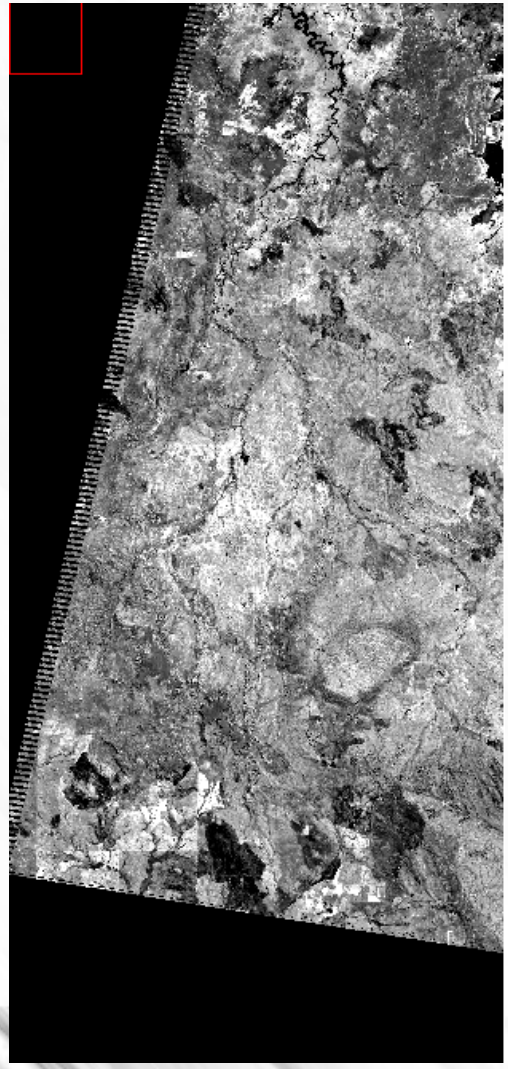
Corresponding GLS map of area

GLS Co-registration

- Step 2: Crop scenes to overlapping region



Cropped EO1 Scene



Cropped GLS map

GLS Co-registration

Step 3: Extract features over multiple passes

Step 4: Compute best transformation between these features

- Returns transform to align image:

TransX = 11.0 px

TransY = -.851 px

Rotation = -0.0007 deg

- Manual Results:

TransX = 11 px

TransY = -1 px

Rotation = 0 deg

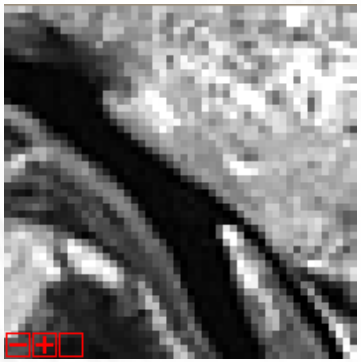
Registration with Chips

- Second Method: Co-register many regions of an image with “chips”
  - A lighter, faster method of registration
  - Using our database of chips from all over the world generated from the GLS 2000 maps

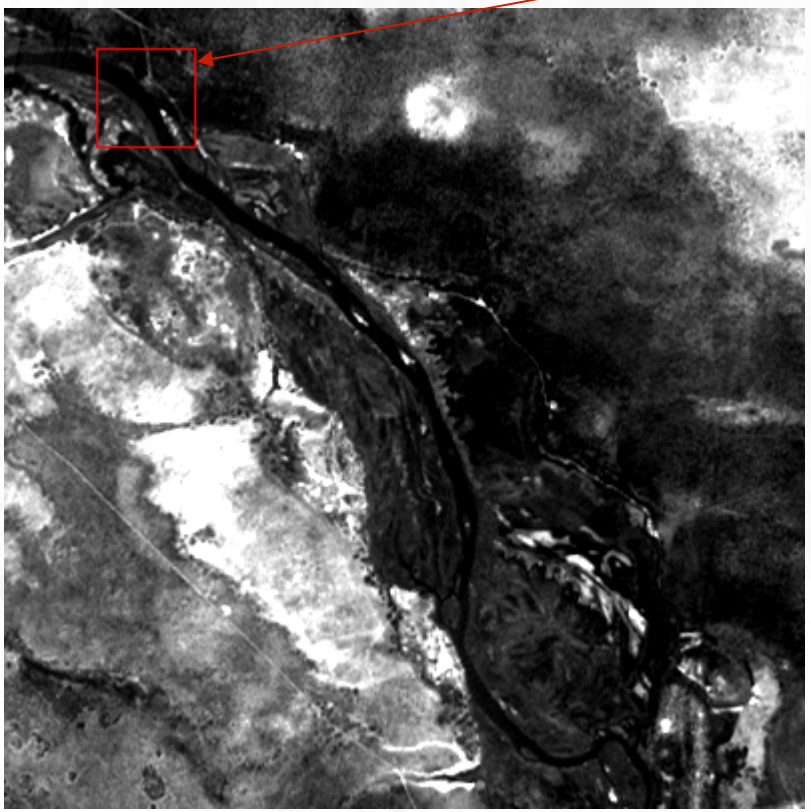
Step 1) Using basic information about where the EO1 scene was taken, the program finds chips that overlap the scene

Step 2) Co-registers these smaller areas and combines their local transformations to get the global transformation

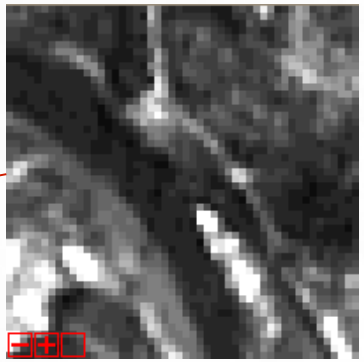
Chip Registration



Overlapping chip from database



Area in EO1 scene where chip was extracted



Chip extracted from EO1 scene

Initial Results

- Initial testing has been performed on approximately 10 scenes for each method
- Full Scene Registration results:
  - Worst case overall error was 2-pixel, several tests gave results with subpixel accuracy
  - Uses a large amount of memory and time so best for use on ground with previously captured images
- Chip Registration results:
  - On current test chips performs much faster and with much less memory
  - Takes a matter of seconds
  - Initial results are on par with the first method

Future Directions: On Board Registration

- The chip-based method is much faster and less resource-demanding, so is ideal for on board image registration
- In the future, the method can be parallelized by doing the independent chip co-registration on separate threads
  - This can be done using AESOP and can then be used on SpaceCube or the future MAESTRO
- So close to or real time image registration can be achieved on board, eliminating a large amount of post-processing

Geocorrection for Airborne Platforms (GCAP) , Web Coverage Processing Service (WCPS) and Atmospheric Correction Status

Vuong Ly

HysplRI Symposium
May 30, 2013

EO-1 Cloud Computing Functionality

Technologists
NASA Investigators
Disaster Responders

Matsu Cloud

http server

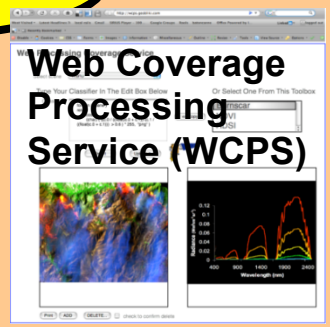
Level 1R and Level 1G Processing for ALI & Hyperion

Co-registration with Landsat GLS

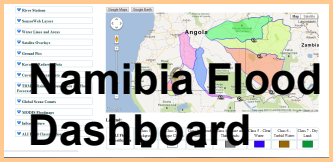
Starlight 100 Gigabit Ethernet Exchange

Hyperion and ALI Level 0 Processed data from GSFC, building 3 server

Web Coverage Processing Service (WCPS)



Atmospheric Correction for ALI & Hyperion

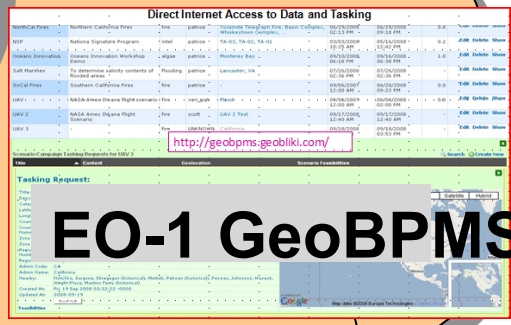


Namibia Flood Dashboard

Multi year data product archive

Matsu Cloud
- Eucalyptus/Open Stack-based Elastic Cloud SW
- 300+ core processors
- 500+ Tbytes of storage
- 10 Gbps connection to GSFC
  - being upgraded to 100 Gbps (Part of OCC)
- Hadoop Tiling/MapReduce/Accumulo
- Supplied by Open Cloud Consortium
- Open Science Data Cloud Virtual Machines & HTTP server to VM's

Joyent Cloud

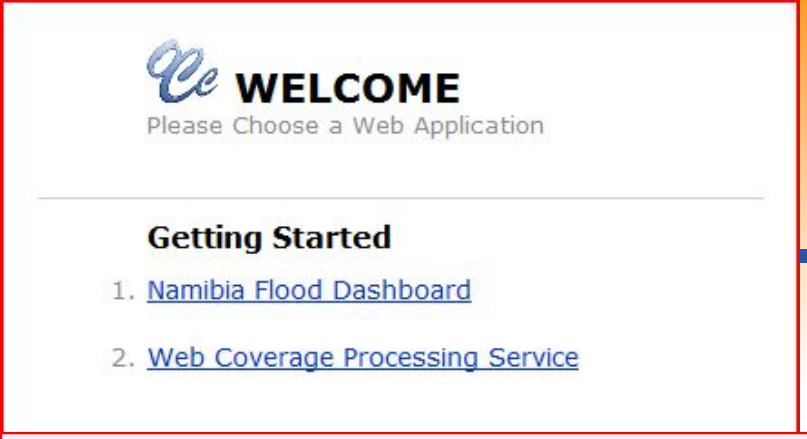


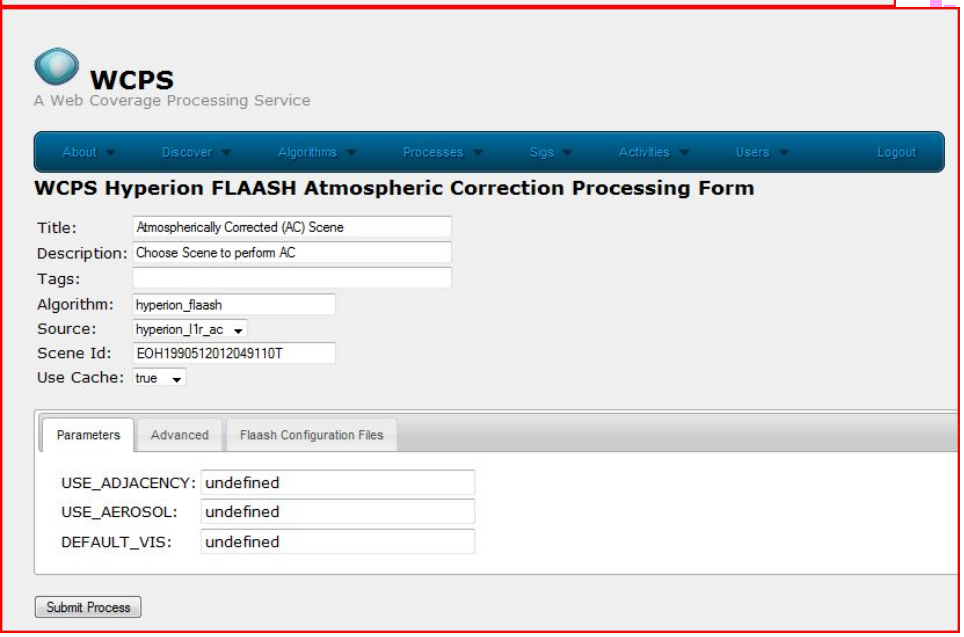
EO-1 GeoBPMS

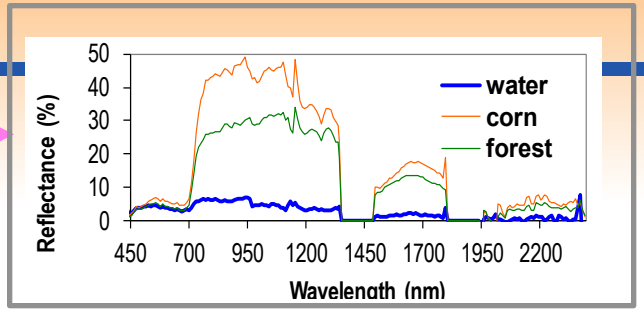
EO-1 GeoBliki

Joyent Cloud
- Ruby on Rails
- 3 processors
- 3 Tbytes of storage

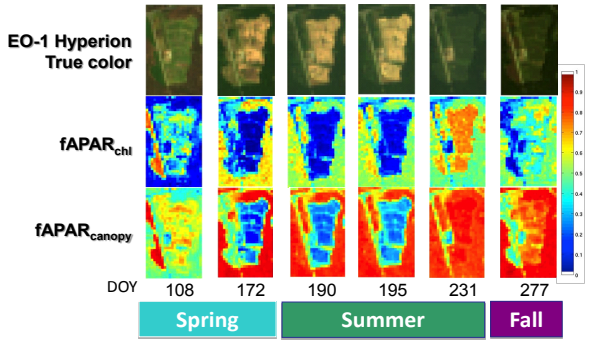
Web Coverage Processing Service
Atmospheric Correction Status





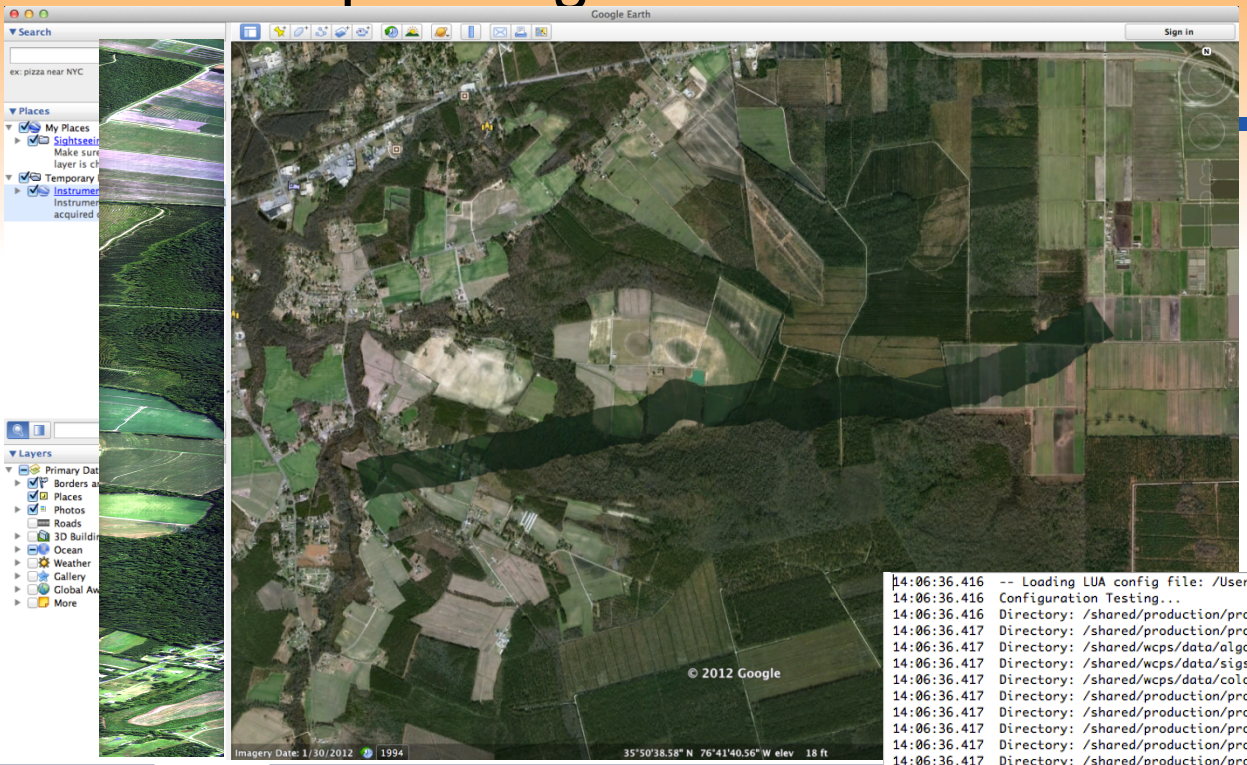


Selected scene with applied algorithms including atmospheric correction



EO-1 Product Prototypes: **albedo, water content, derivatives, fAPAR, chlorophyll, N …..**

Geo-Correction for Airborne Platforms (GCAP) Operating on G-LiHT Airborne Data



Headwall imaging spectrometer

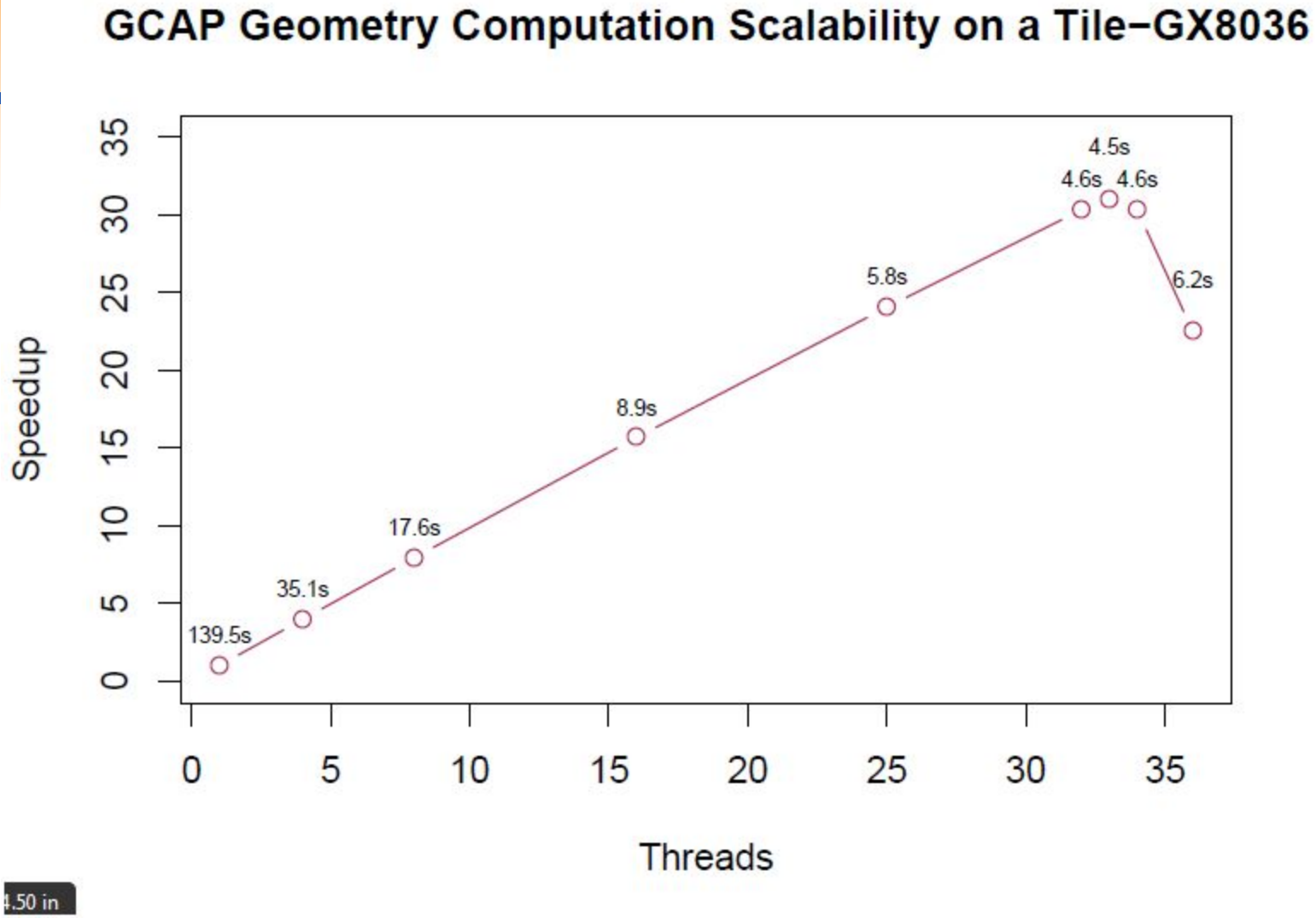
```
<terminated> gcap [C/C++ Application] /Users/imvuong/Documents/code/gcap/src/.libs/gcap (10/15/12 2:05 PM)
config.c:32: INPUT_FILENAME = /Users/imvuong/Documents/code/gcap/data/input/Parker-Track1.bin
config.c:32: IMU_POSITION_FILE = /Users/imvuong/Documents/code/gcap/data/input/110728_132454.pos
config.c:32: INSTR_TIMESTAMP_FILE = /Users/imvuong/Documents/code/gcap/data/input/Parker-Track1.asc
config.c:32: BAND = 40 80 160
config.c:32: OUTPUT_DIR = /shared/production/proddata/gliht_l1g/Parker-Track1/
config.c:57: ROLL_OFFSET = 0.000000
config.c:57: PITCH_OFFSET = 0.000000
config.c:57: ALTITUDE_OFFSET = 0.000000
config.c:57: HEADING_OFFSET = 0.000000
config.c:57: INSTR_TIMESTAMP_OFFSET = -0.460000
config.c:57: INSTR_VIEW_ANGLE = 53.000000
main.c:213: Input image size: 1004x5465x402.
gcap.c:166: UL: 35.851659867857456732,-76.730605800650906190
gcap.c:167: UR: 35.851659867857456732,-76.658554548188419631
gcap.c:168: LL: 35.836418930876448030,-76.730605800650906190
gcap.c:169: LR: 35.836418930876448030,-76.658554548188419631
main.c:218: Output image size: 6494x1695x402.
main.c:234: Writing file: /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1-B040.tif.
main.c:234: Writing file: /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1-B080.tif.
main.c:234: Writing file: /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1-B160.tif.
main.c:143: UL: 35.851659867857456732,-76.730605800650906190
main.c:144: UR: 35.851659867857456732,-76.658554548188419631
main.c:145: LL: 35.836418930876448030,-76.730605800650906190
main.c:146: LR: 35.836418930876448030,-76.658554548188419631
main.c:148: Writing file: /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1.meta.
```

Run GCAP

```
14:06:36.416  -- Loading LUA config file: /Users/imvuong/Documents/code/wcps/data/wcps.frodo.lua
14:06:36.416  Configuration Testing...
14:06:36.416  Directory: /shared/production/proddata exists
14:06:36.417  Directory: /shared/production/proddata/wcps exists
14:06:36.417  Directory: /shared/wcps/data/algos exists
14:06:36.417  Directory: /shared/wcps/data/sigs exists
14:06:36.417  Directory: /shared/wcps/data/colormaps exists
14:06:36.417  Directory: /shared/production/proddata/ams_l1g exists
14:06:36.417  Directory: /shared/production/proddata/ams_l2 exists
14:06:36.417  Directory: /shared/production/proddata/gliht_l1g exists
14:06:36.417  Directory: /shared/production/proddata/gliht_l2 exists
14:06:36.417  Directory: /shared/production/proddata/ali_l1g exists
14:06:36.417  Directory: /shared/production/proddata/ali_l1g_ac exists
14:06:36.417  Directory: /shared/production/proddata/ali_l2 exists
14:06:36.417  Directory: /shared/production/proddata/hyperion_l1r exists
14:06:36.417  Directory: /shared/production/proddata/hyperion_l1r_ac exists
14:06:36.417  Directory: /shared/production/proddata/hyperion_l1g exists
14:06:36.418  Directory: /shared/production/proddata/hyperion_l1g_ac exists
14:06:36.418  Directory: /shared/production/proddata/hyperion_l2 exists
14:06:36.418  wcps init  1
14:06:36.418  WCPS Execute vis_composite gliht_l1g Parker-Track1 0 1 NA  init 1
14:06:36.418  WCPS Execute vis_composite gliht_l1g Parker-Track1 0 1 NA
14:06:36.418  WCPS Execute algo:vis_composite inst:gliht data:l1g scene:Parker-Track1 cache:0 userid:1 sig:NA...
14:06:36.418  Execute file: /shared/wcps/data/algos/gliht_l1g/vis_composite.lua
14:06:36.419  Creating Atom file /shared/production/proddata/gliht_l2/gliht_l1g/Parker-Track1/vis_composite.atom...
14:06:36.419  get band for instrument: gliht data: l1g
14:06:36.420  get band 160 - file /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1-B160.tif
 min:0.000000 mean:30.582403 stdev:76.606514 max:3142.000000  zeroes:8943407 positive:2063923
14:06:36.492  get band for instrument: gliht data: l1g
14:06:36.492  get band 80 - file /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1-B080.tif
 min:0.000000 mean:59.534584 stdev:135.201553 max:4063.000000  zeroes:8943407 positive:2063923
14:06:36.549  get band for instrument: gliht data: l1g
14:06:36.549  get band 40 - file /shared/production/proddata/gliht_l1g/Parker-Track1/Parker-Track1-B040.tif
 min:0.000000 mean:35.607391 stdev:84.499809 max:3577.000000  zeroes:8943407 positive:2063923
14:06:37.165  write_file:/shared/production/proddata/gliht_l2/gliht_l1g/Parker-Track1/vis_composite.png
14:06:39.119  Making kmz
14:06:39.120  Creating doc file: /shared/production/proddata/gliht_l2/gliht_l1g/Parker-Track1/doc.kml
14:06:39.129  Output filesize: 4174419 and tiling is set to 1
14:06:39.307  Making thumnail
14:06:39.660  Making atom entry
14:06:39.661  closed Atom file /shared/production/proddata/gliht_l2/gliht_l1g/Parker-Track1/vis_composite.atom
execute result:0
14:06:39.682  Done.
```

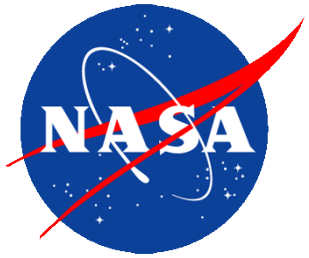
Run WCPS

Developing IPM software



Note that performance falls when adding tiles 34 and 35 to assist in processing of GCAP . This is because the Tilera operating system resides in two of the tiles and when those tiles assist in the actual calculation, the total performance goes down.

Performance Metrics


NASA

EOS Data and Operations System (EDOS)

"EDOS High-Rate Data Capture and Delivery
of
Low-Latency HyspIRI Level-Zero Data"

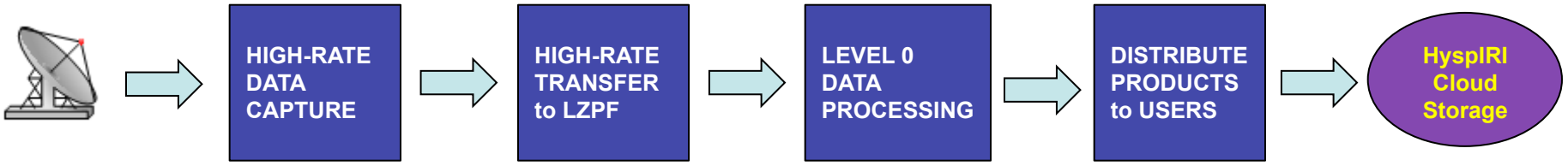
GSFC Code 428

Bruce McLemore

Honeywell Technology Solutions, Inc.

EDOS Overview

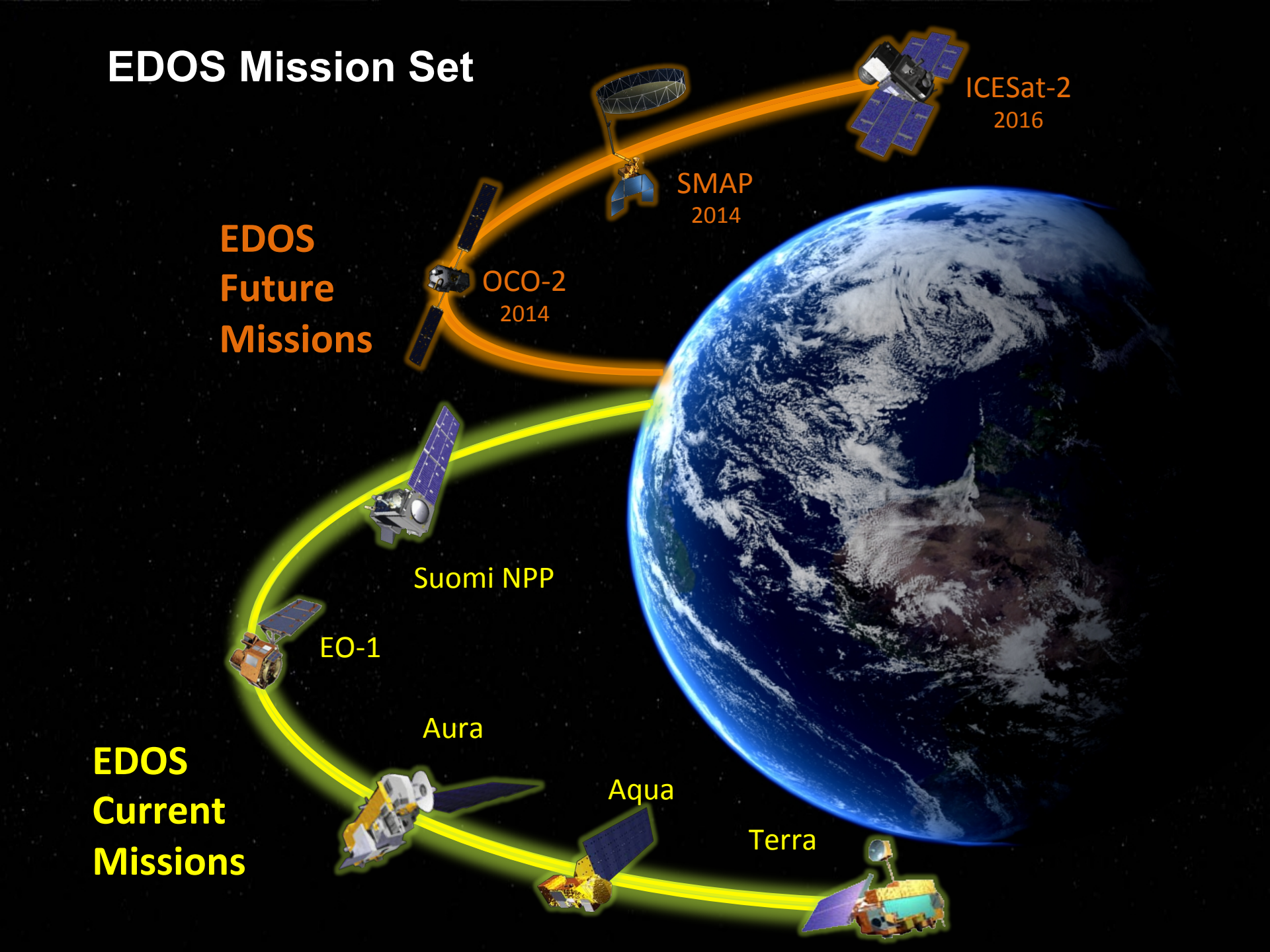
- **EDOS is NASA's high-rate, multi-mission science data system that:**
  - Autonomously captures science data at remote ground stations
    - ❖ EDOS capture systems are located at 6 sites serving 16 antennas
    - ❖ Front-end processing includes demodulation, frame synchronization, and decoding, as needed
  - Transfers science data to GSFC over NASA's closed high-rate network or high-rate open (Internet) networks with increased bandwidth, where available
  - Performs initial level zero science data processing
  - Currently delivers more than 1/2 Terabyte of level-zero products worldwide (20 external customers) in a variety of formats and protocols on a daily basis
  - Can transfer data directly to level 1 science customers (or HyspIRI Cloud storage) from station gateway via open (Internet) networks, where available



EDOS Key Features

- Data-driven system (no schedules or pre-pass setup required)
- Routinely supports spacecraft downlink rates from 150 Mbps to 300 Mbps (capable of 500 Mbps and extendable to higher rates in the future)
- Prioritized data delivery to insure latency requirements are met
- Fully automated system; operation intervention only needed to resolve ground system anomalies
- Experienced 24x7 multi-mission operations and engineering support team
- Modular design permits level zero processing and delivery to be performed at ground station or central site, as needed
- Worldwide customer access to web-based displays providing real-time monitoring of mission data quality
- Evolutionary design enables cost effective support for new missions by leveraging existing NASA infrastructure

EDOS Mission Set



EDOS Background

- In addition to the current and future missions planned, EDOS previously supported ICESat, OCO, and ALOS missions
- Additional infrastructure capacity exists to add new missions
- Ground station support at:
  - SvalSat, Norway
  - Poker Flat, Gilmore Creek and ASF, Alaska
  - White Sands, New Mexico
  - Wallops Island, Virginia
  - TrollSat and McMurdo (via TDRSS), Antarctica
- Data-driven high-rate capture systems switchable between antennas
- Designed to support any mission that is CCSDS compliant
- Delivers selected products with various latencies to MOC or Level 0 science user:
  - *real-time products < 5 seconds*
  - *near real-time products < 1 hour*
  - *non-real-time products < 24 hours*
- Produces time-based products from multiple antenna contact sessions
- Upon request can archive all products for life of mission
- Highly stable system with complete backup level-zero processing facility

EDOS Architectural Models

Centralized Model

- All data captured at the remote site are transferred to the LZPF at GSFC
- The data is transferred via high rate NASA networks or open networks from the stations to GSFC
- EDOS LZPF performs level zero processing and generates and delivers all products from GSFC to science customers worldwide
- Supports time-based products from multiple ground stations

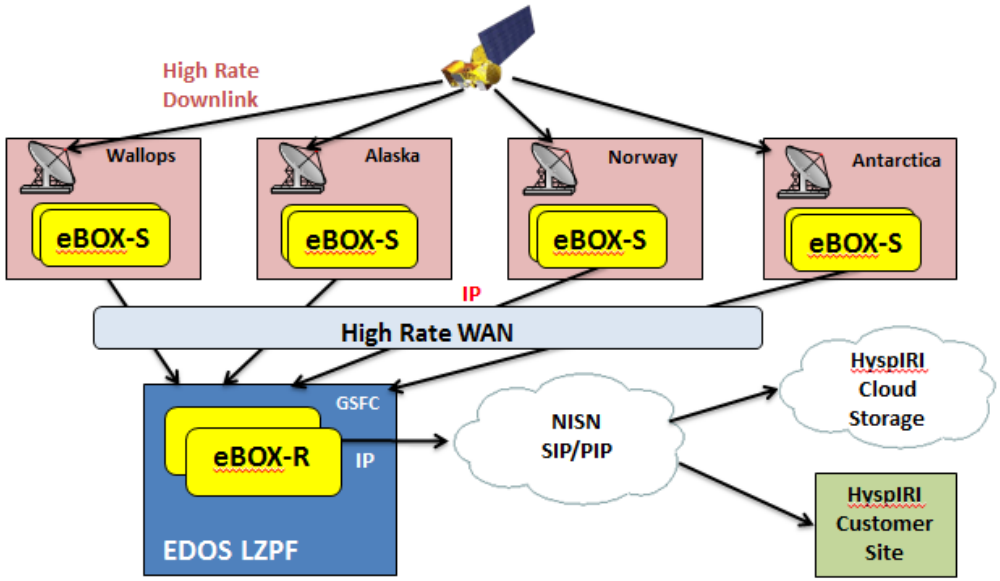


Diagram illustrating the Centralized Model

Remote Site Decentralized Model

- This EDOS architectural model offers the capability of capturing, processing, and delivering level zero data directly to the end-users from the ground site
- This model is useful for high-rate missions and is the model that was used for ALOS
- The EDOS modular design permits level zero processing to be performed at the central or at remote sites as required

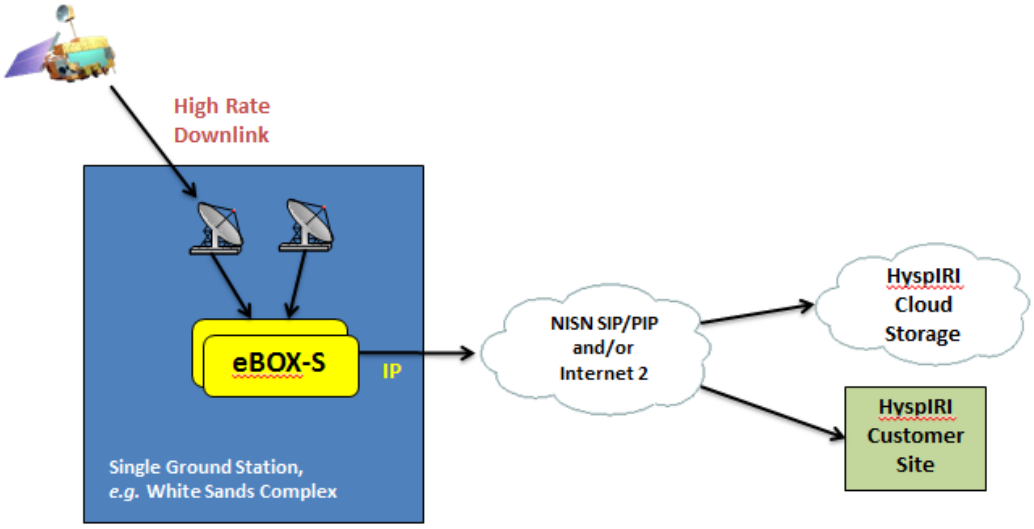
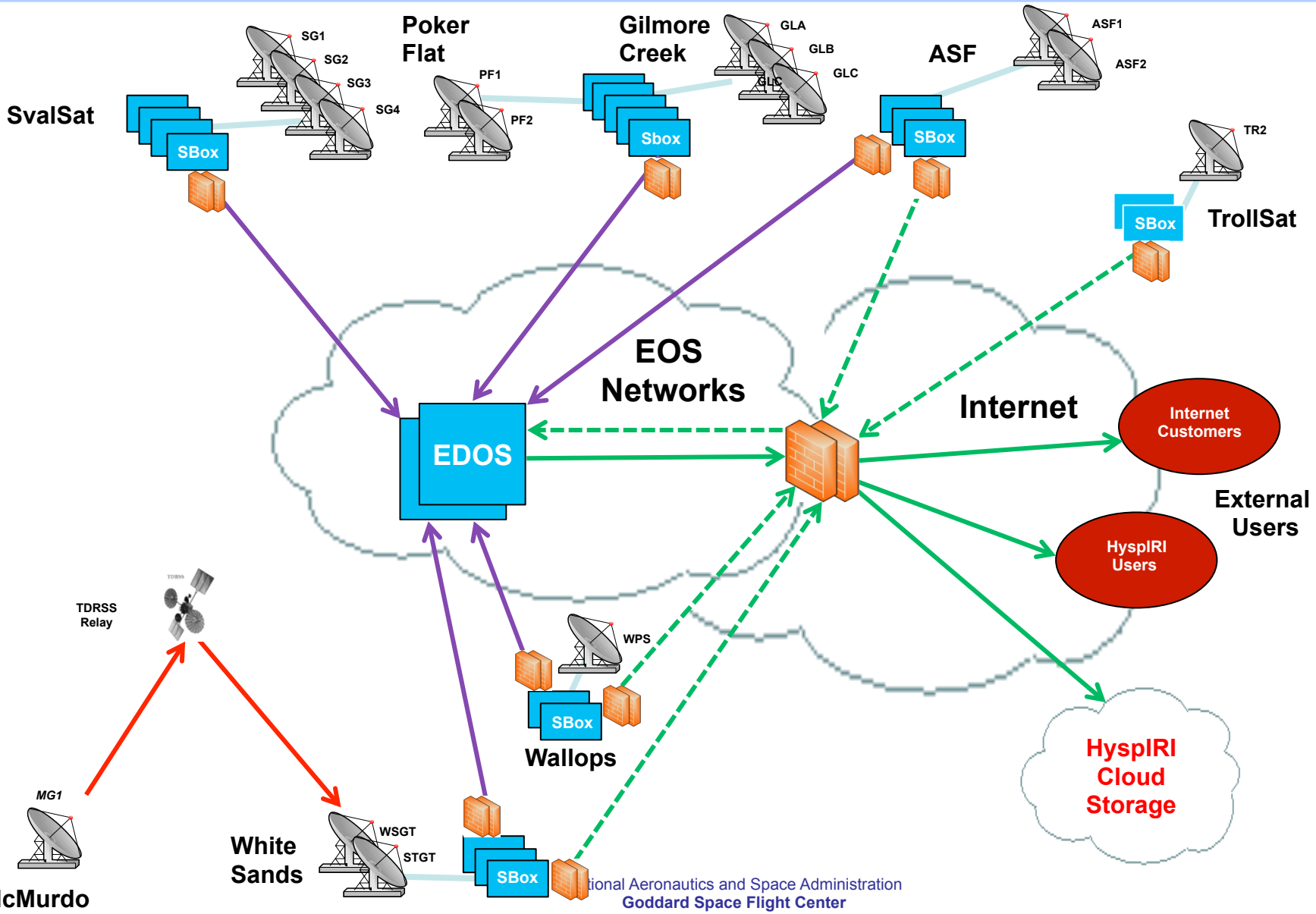


Diagram illustrating the Decentralized Model

EDOS Hybrid Architecture Overview



EDOS Latency Enhancements

- *EDOS strives to keep pace with technology and network advances in order to deliver Level 0 data to the science community as soon as possible*
- *The major focus for EDOS latency enhancements is to maximize WAN throughput from the ground stations*
  1. Enhancements to use the existing network bandwidth more efficiently:
     - Use of "Jumbo Frames" to enhance TCP performance on closed network
     - Prioritized data delivery including prioritized queuing and "Real-time" streaming
     - Lossless data compression to increase network throughput
     - Removal of encoding bits at ground station after forward error correction
     - Replace TCP-based WAN protocol with open-source UDP-based WAN accelerator protocol to overcome long round trip delays
  2. Architectural enhancements to increase the network bandwidth:
     - Use of higher rate open network connections in Hybrid architecture
     - Ongoing effort to add new open network connections with higher bandwidth
- *For high rate missions, the EDOS default minimum latency requirement is the time needed to transfer all data received during a contact (with margin) before the next contact.*

EDOS Goal: Continuously improve WAN transfer rate to keep up with spacecraft downlink rate.

Benefits of EDOS

- 24x7 operations support monitoring all station contacts and product deliveries for all missions and customers
- Additional EDOS capture systems can be easily added at existing (or new) ground stations worldwide as part of a modular, scalable architecture
- No schedule interface is required due to data-driven design assuring 24x7 data capture for any EDOS mission
- Existing integrated high-rate networks provide reduced product latencies
- Proven interface to EOSDIS Distributed Active Archive Centers for product distribution extendable to the HyspIRI Cloud Storage
- High-rate data delivery from remote site or centralized LZPF
- Additional spare capacity exists in existing system. More can be added!
- Reduced project risk to use an existing system for HyspIRI at a fraction of the cost of developing a new system

EDOS is a cost-effective solution for HyspIRI high rate data capture, level zero processing, and low-latency delivery

EXELIS

Visual Information Solutions

ENVI & IDL Services Engine For Web-Accessible Multi- & Hyperspectral Applications

HysplRI Products Symposium

Goddard Space Flight Center
May 30, 2013

IDL

DISCOVER WHAT'S IN YOUR DATA

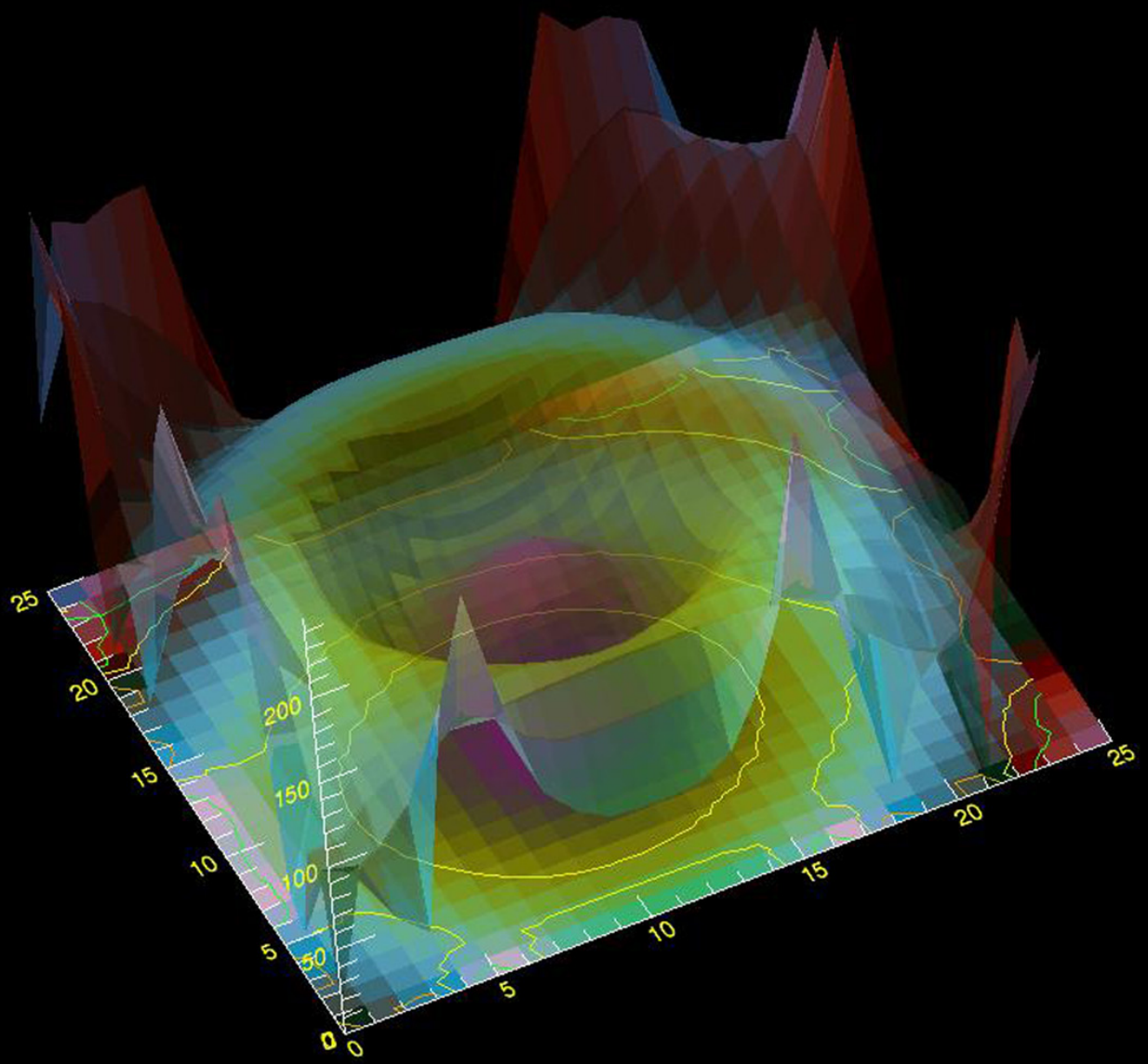
> Language for Analysis, Rules, and Conventions

> Interactive Graphics System

> Development Environment

> Customize ENVI Products with IDL

> Output File Formats



ENVI Platform

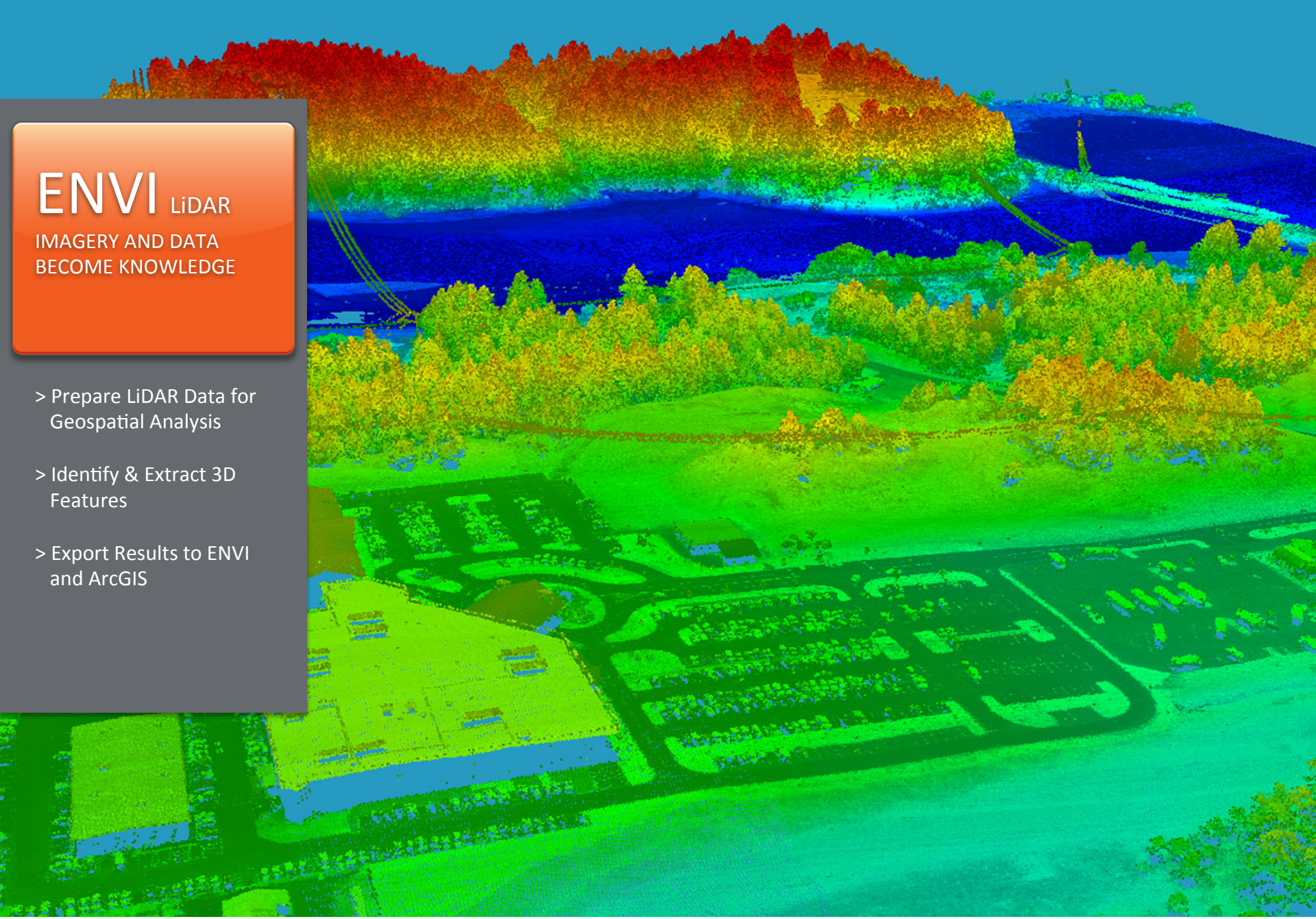
IMAGERY AND DATA
BECOME KNOWLEDGE

> ENVI

> ENVI | LiDAR

> ENVI | SARscape

> ENVI | Services Engine



ENVI LiDAR

IMAGERY AND DATA BECOME KNOWLEDGE

> Prepare LiDAR Data for Geospatial Analysis

> Identify & Extract 3D Features

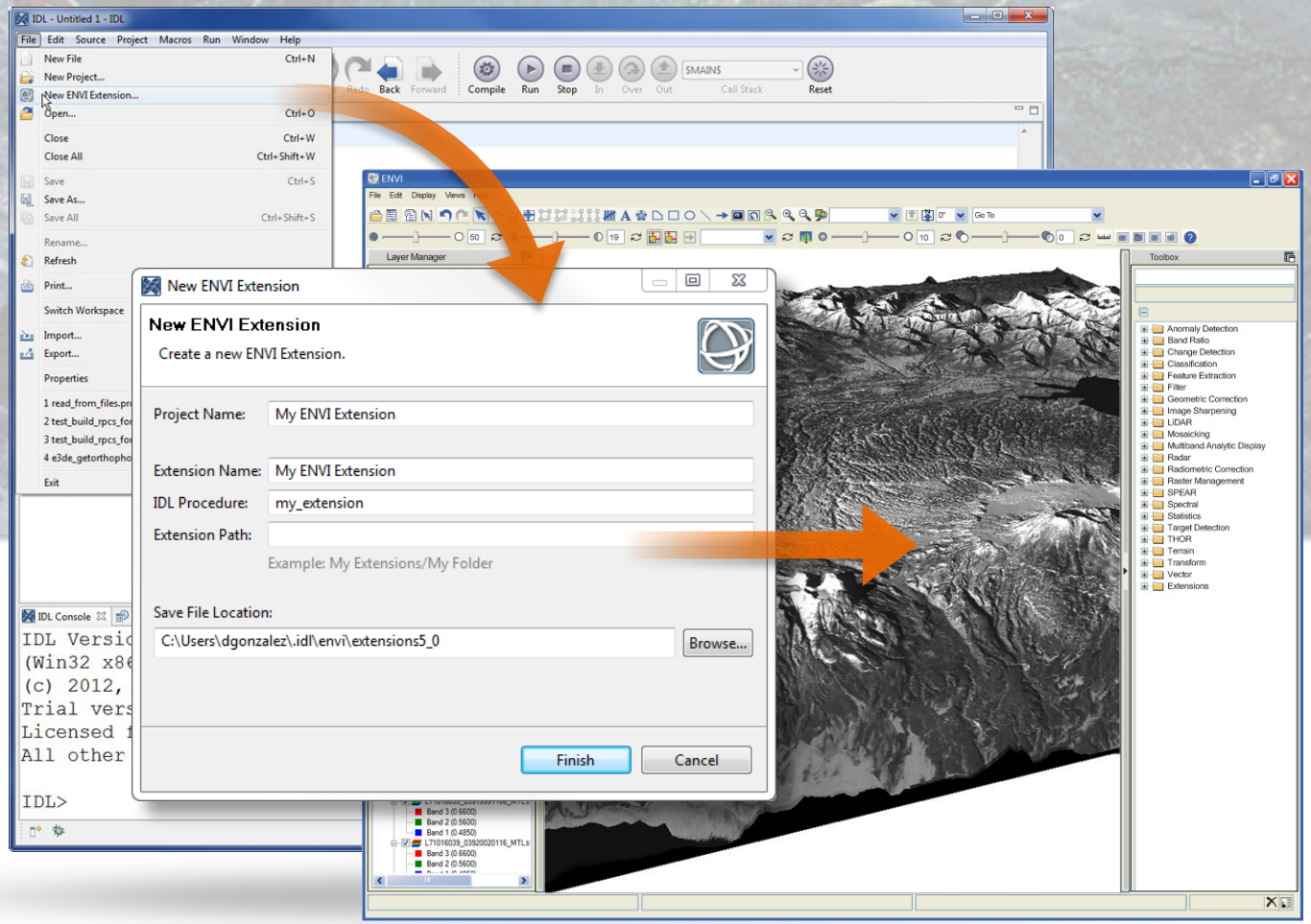
> Export Results to ENVI and ArcGIS

Extending ENVI with IDL
- Custom algorithms
- Batch Processing in IDL using the ENVI API

IDL

DISCOVER WHAT'S IN YOUR DATA

- > Language for Analysis, Rules, and Conventions
- > Interactive Graphics System
- > Development Environment
- > **Customize ENVI Products with IDL**
- > Output File Formats

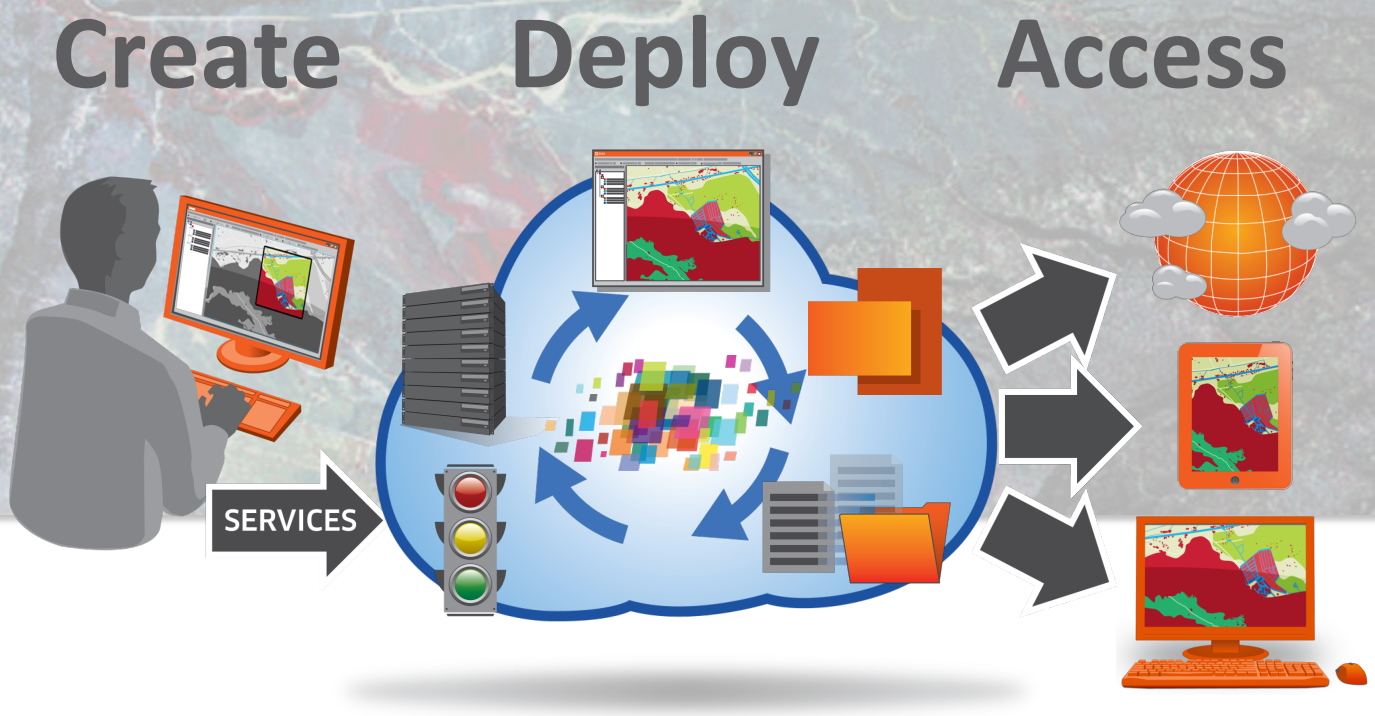


ENVI Services Engine

ENVI Services

ONLINE, ON-DEMAND, GEOSPATIAL AWARENESS

- > Configure seamlessly with your existing infrastructure
- > Create and publish web deployed image analysis tools
- > Consume ENVI from mobile, web, and thin clients
- > Get geospatial imagery where and when you need it



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Configure seamlessly with your existing infrastructure

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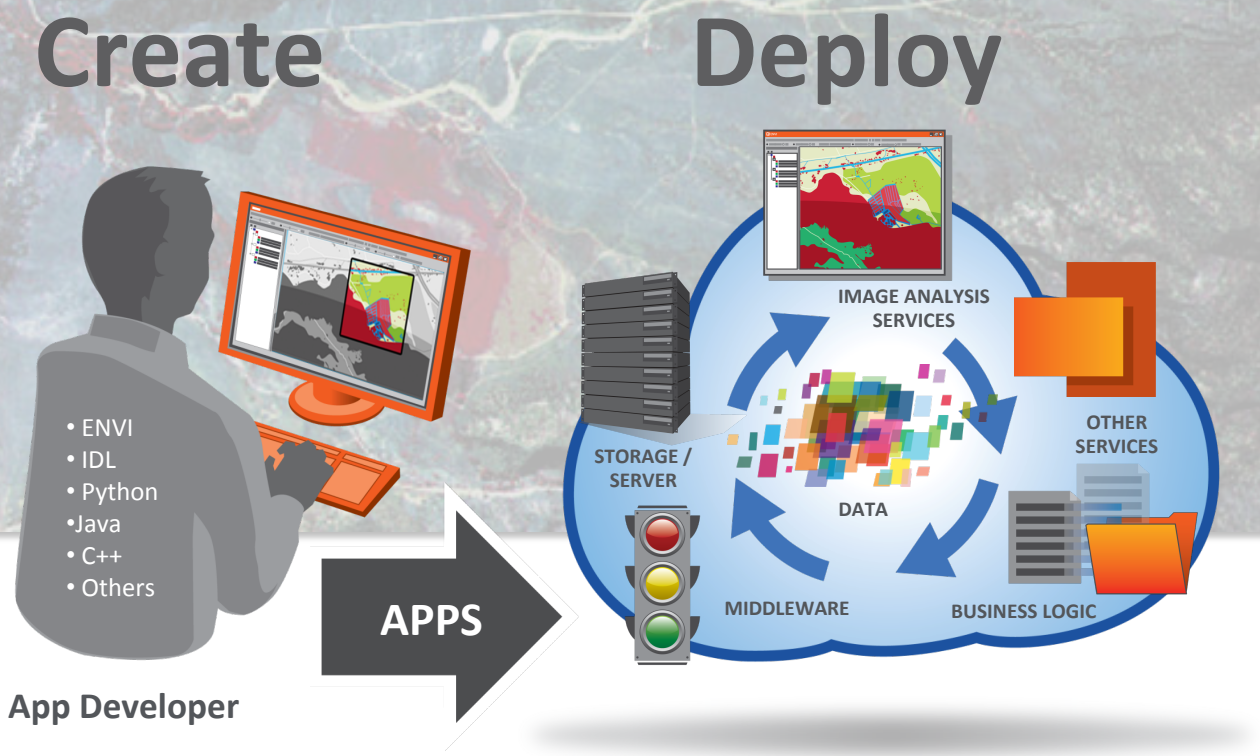
Create and publish web deployed image analysis tools



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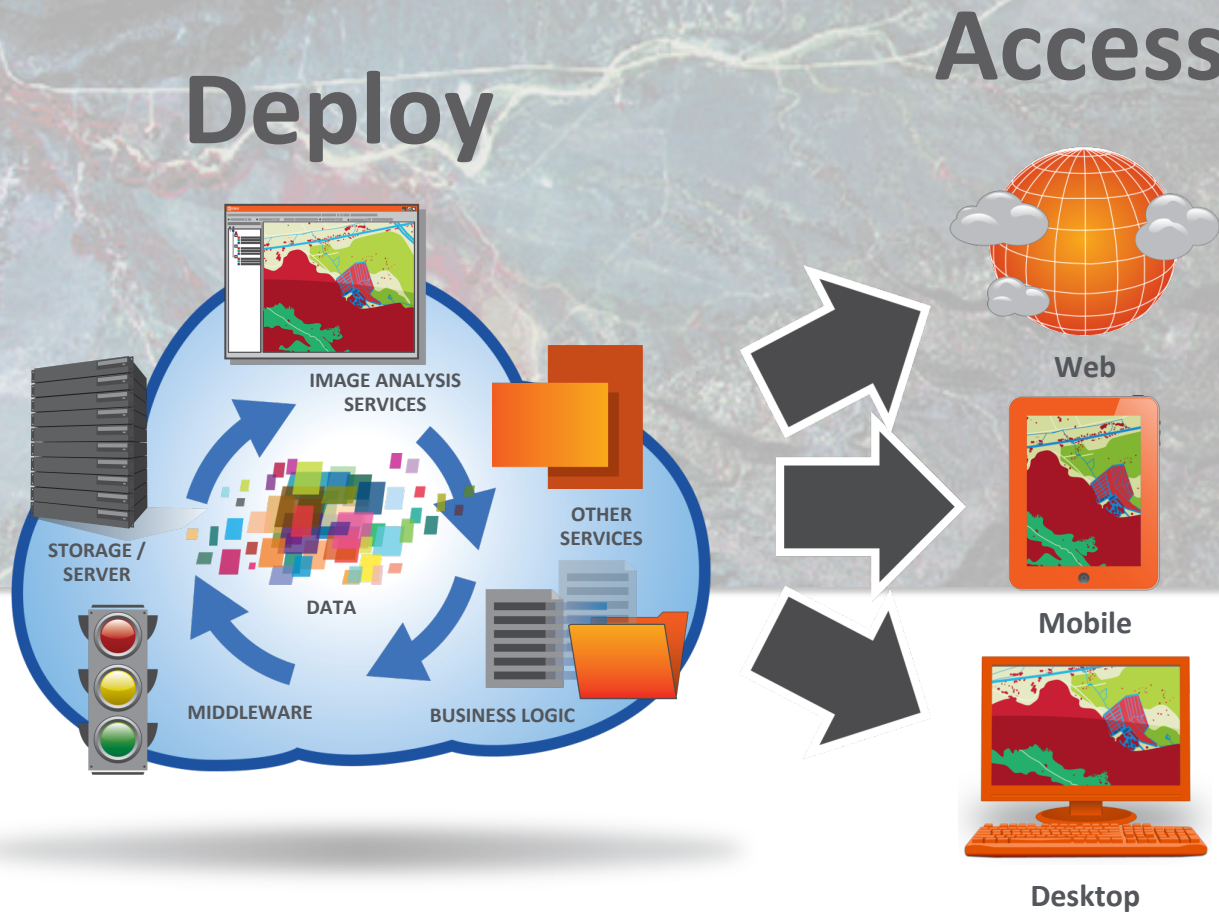
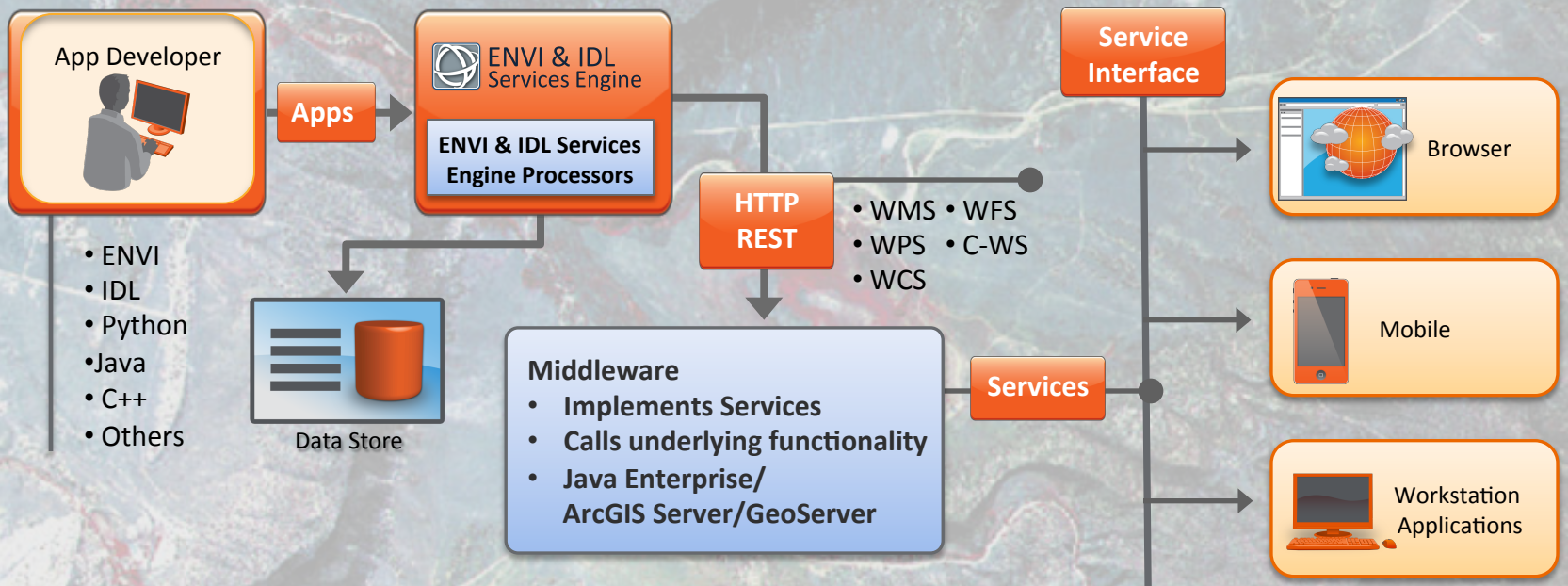
Consume ENVI from mobile, web, and thin clients



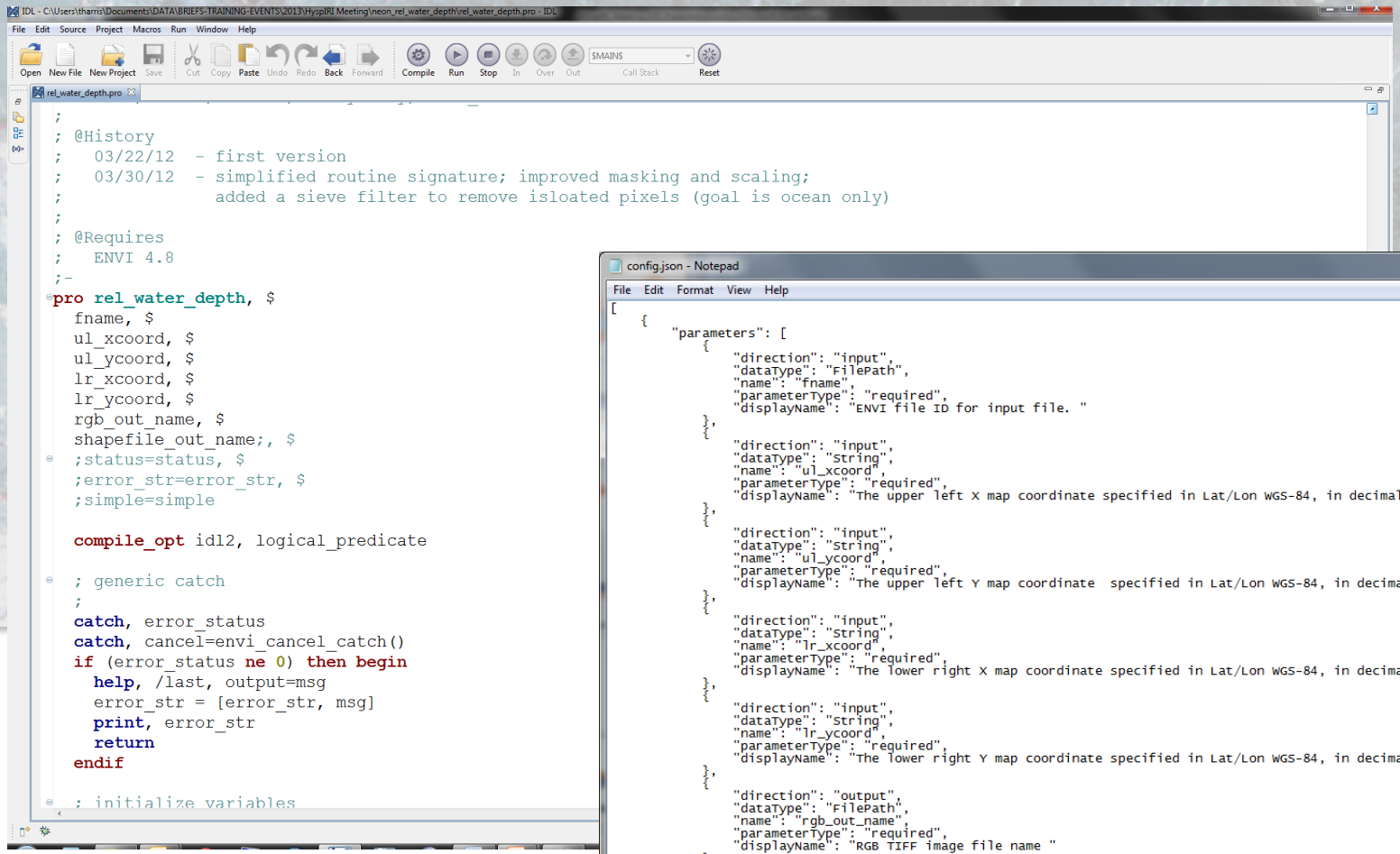
Integrating ENVI Services with GeoServer

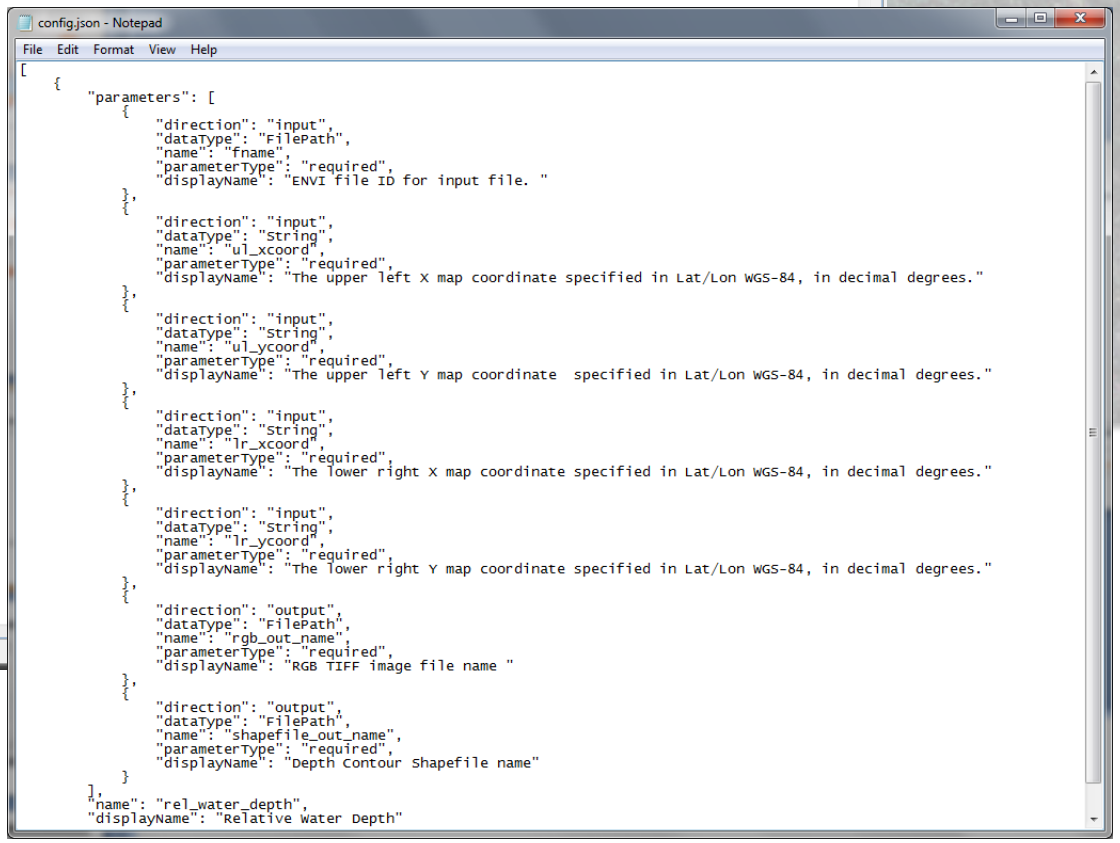
Deployment in the Enterprise

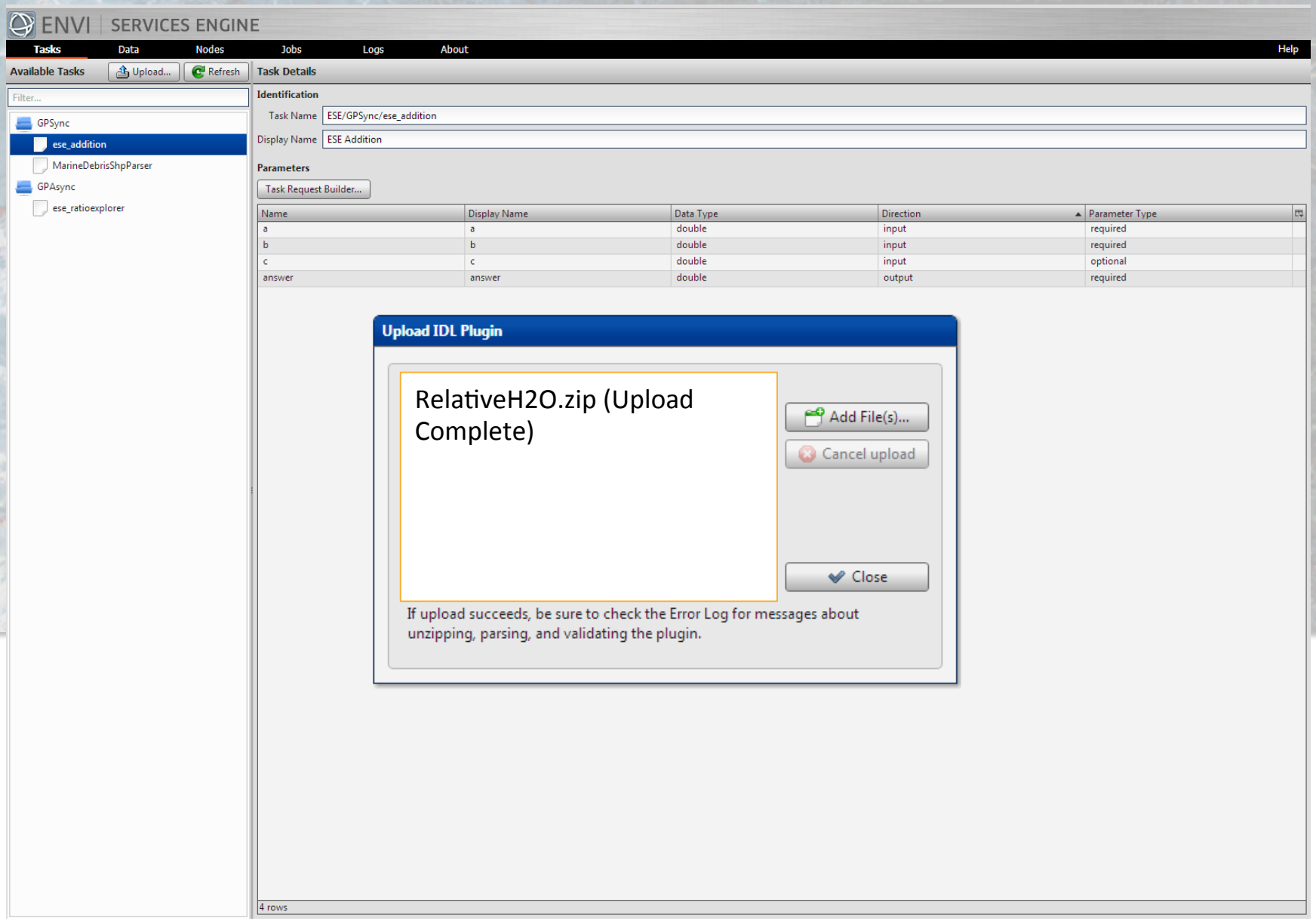


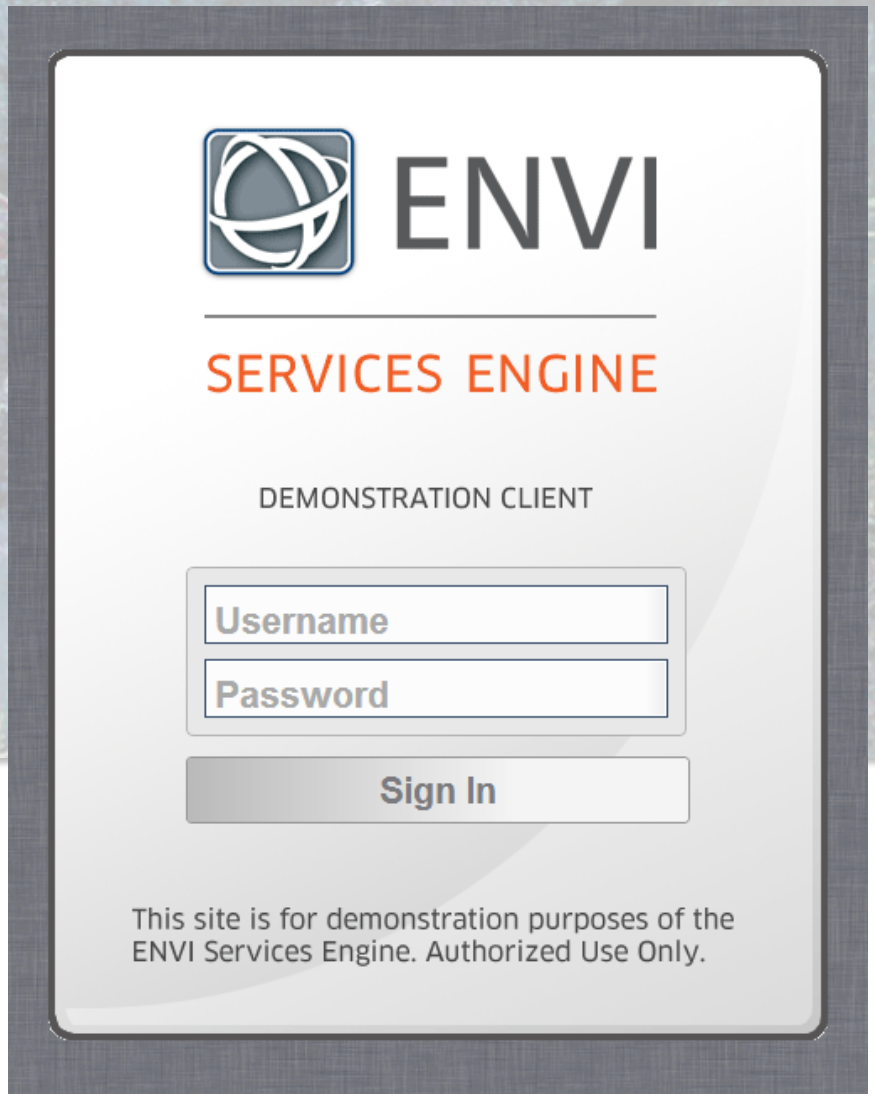
- Developers create apps with ENVI+IDL, Python, or other development tools and publish them to the engine
- Middleware agnostic design integrates through HTTP
- ENVI Services Engine manages ENVI+IDL processes
- End users interact via their interface of choice
- Discrete online apps simplify updates to users

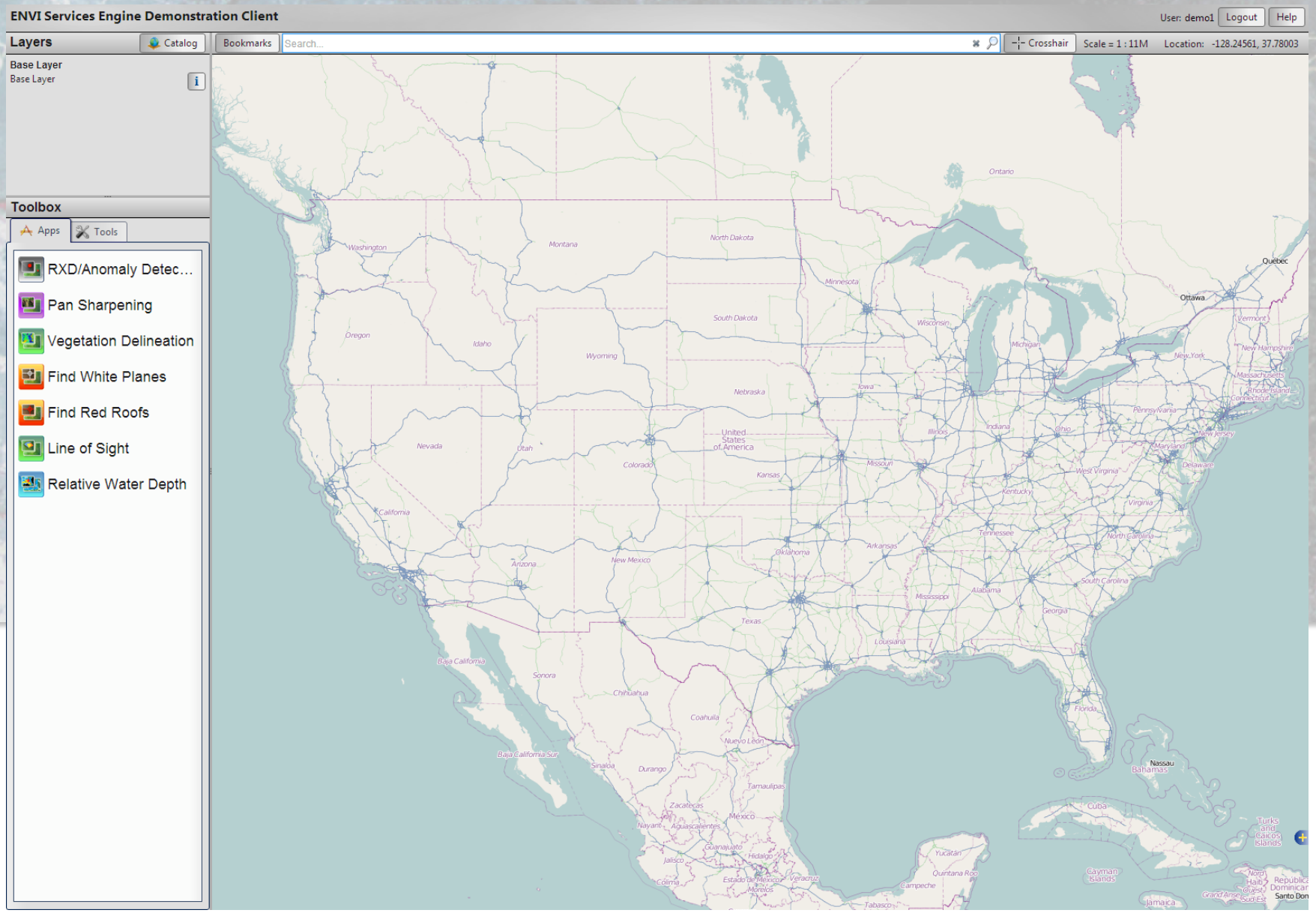
ENVI & IDL Services Engine
IDL Application Deployment Model






ENVI SERVICES ENGINE
Tasks
Data
Nodes
Jobs
Logs
About
Help
Available Tasks
Upload...
Refresh
Task Details
Filter...
GPSync
ese_addition
MarineDebrisShpParser
GPAsync
ese_ratioexplorer
Identification
Task Name
ESE/GPSync/ese_addition
Display Name
ESE Addition
Parameters
Task Request Builder...
Name
Display Name
Data Type
Direction
Parameter Type
a
a
double
input
required
b
b
double
input
required
c
c
double
input
optional
answer
answer
double
output
required
4 rows
Upload IDL Plugin
RelativeH2O.zip (Upload Complete)
Add File(s)...
Cancel upload
Close
If upload succeeds, be sure to check the Error Log for messages about unzipping, parsing, and validating the plugin.


ENVI
SERVICES ENGINE
DEMONSTRATION CLIENT
Username
Password
Sign In
This site is for demonstration purposes of the
ENVI Services Engine. Authorized Use Only.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User: demo1
Logout
Help
Layers
Catalog
Base Layer
Base Layer
Bookmarks
Search...
Crosshair
Scale = 1 : 11M
Location: -128.24561, 37.78003
Toolbox
Apps
Tools
RXD/Anomaly Detec...
Pan Sharpening
Vegetation Delineation
Find White Planes
Find Red Roofs
Line of Sight
Relative Water Depth
Ontario
Quebec
Ottawa
Washington
Montana
North Dakota
Minnesota
South Dakota
Oregon
Idaho
Wyoming
Wisconsin
Michigan
Nebraska
Iowa
Nevada
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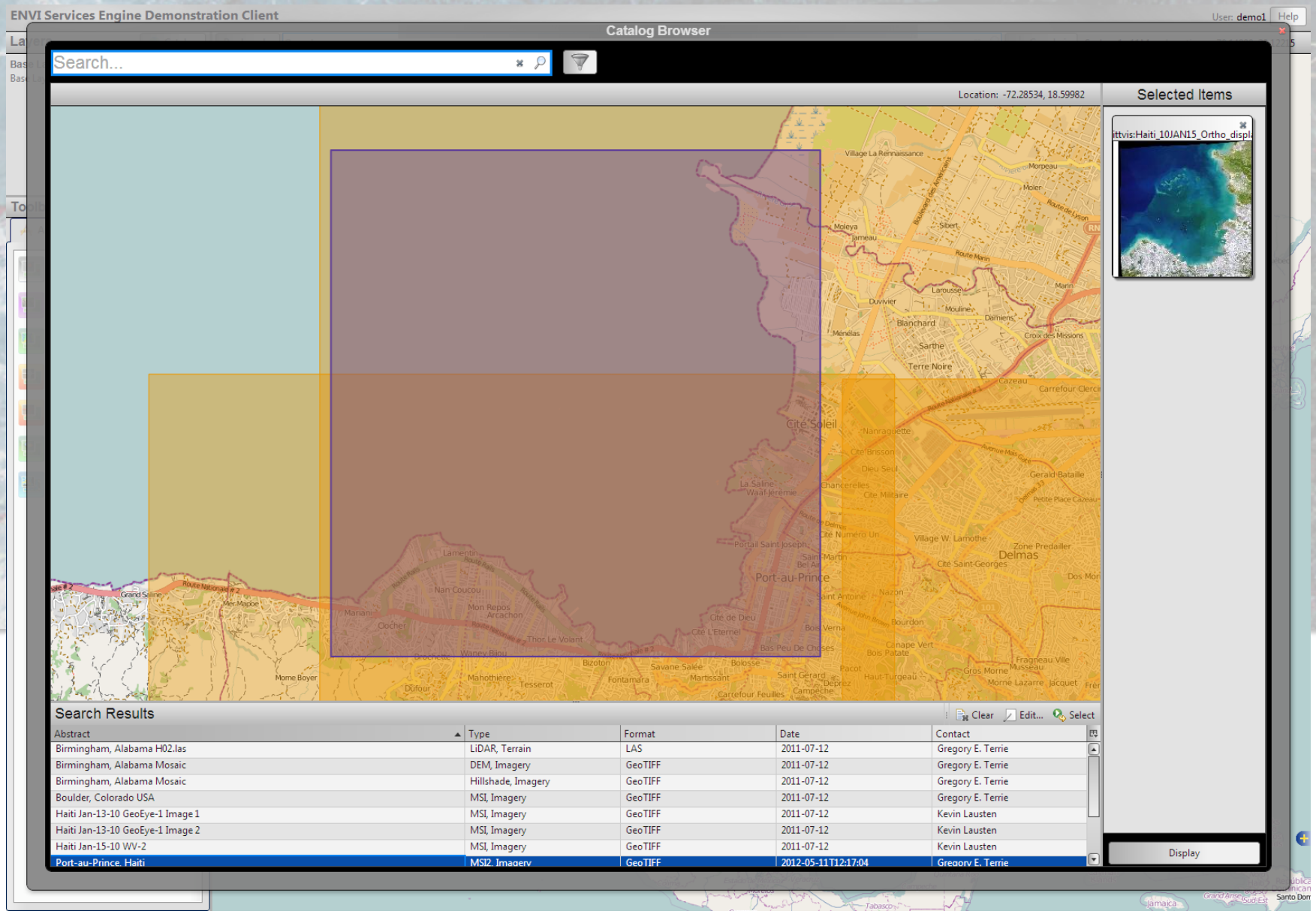
Coahuila
Nuevo Leon
Tamaulipas
Sinaloa
Durango
Zacatecas
Nayarit
Aguascalientes
Jalisco
Guanajuato
Hidalgo
Colima
Estado de Mexico
Morelos
Veracruz
Tabasco
Campeche
Yucatan
Quintana Roo
Cuba
Nassau
Bahamas
Cayman Islands
Jamaica
Haiti
Turks and Caicos Islands
Republica Dominicana
Santo Domingo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Help
Catalog Browser
Search...
Location: -72.28534, 18.59982
Selected Items
ittvis:Haiti_10JAN15_Ortho_displ
Display
Search Results
Clear
Edit...
Select
Abstract
Type
Format
Date
Contact
Birmingham, Alabama H02.las
LiDAR, Terrain
LAS
2011-07-12
Gregory E. Terrie
Birmingham, Alabama Mosaic
DEM, Imagery
GeoTIFF
2011-07-12
Gregory E. Terrie
Birmingham, Alabama Mosaic
Hillshade, Imagery
GeoTIFF
2011-07-12
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Boulder, Colorado USA
MSI, Imagery
GeoTIFF
2011-07-12
Gregory E. Terrie
Haiti Jan-13-10 GeoEye-1 Image 1
MSI, Imagery
GeoTIFF
2011-07-12
Kevin Lausten
Haiti Jan-13-10 GeoEye-1 Image 2
MSI, Imagery
GeoTIFF
2011-07-12
Kevin Lausten
Haiti Jan-15-10 WV-2
MSI, Imagery
GeoTIFF
2011-07-12
Kevin Lausten
Port-au-Prince, Haiti
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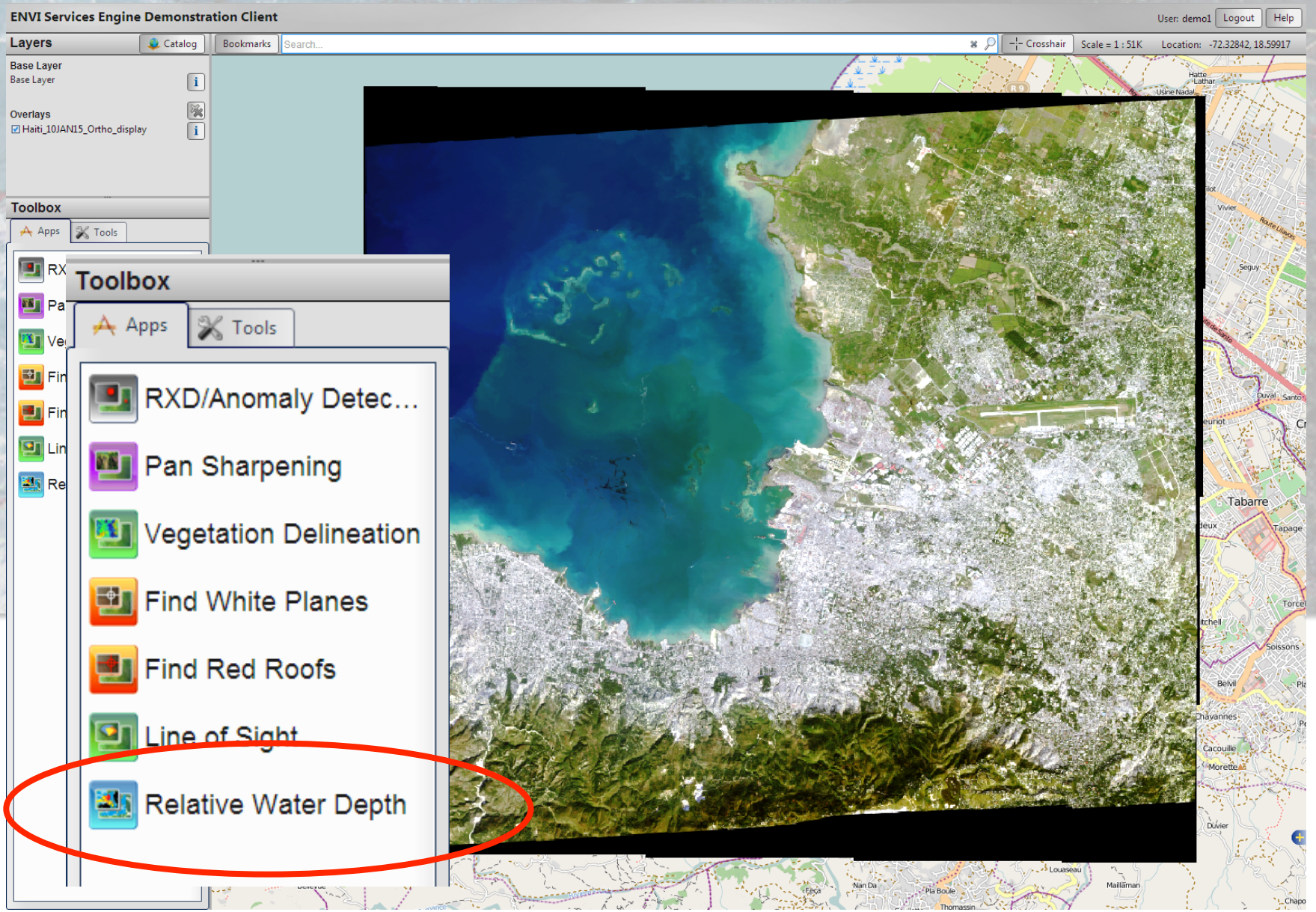
Delmas
Carrefour
Pétion-Ville
Jamaica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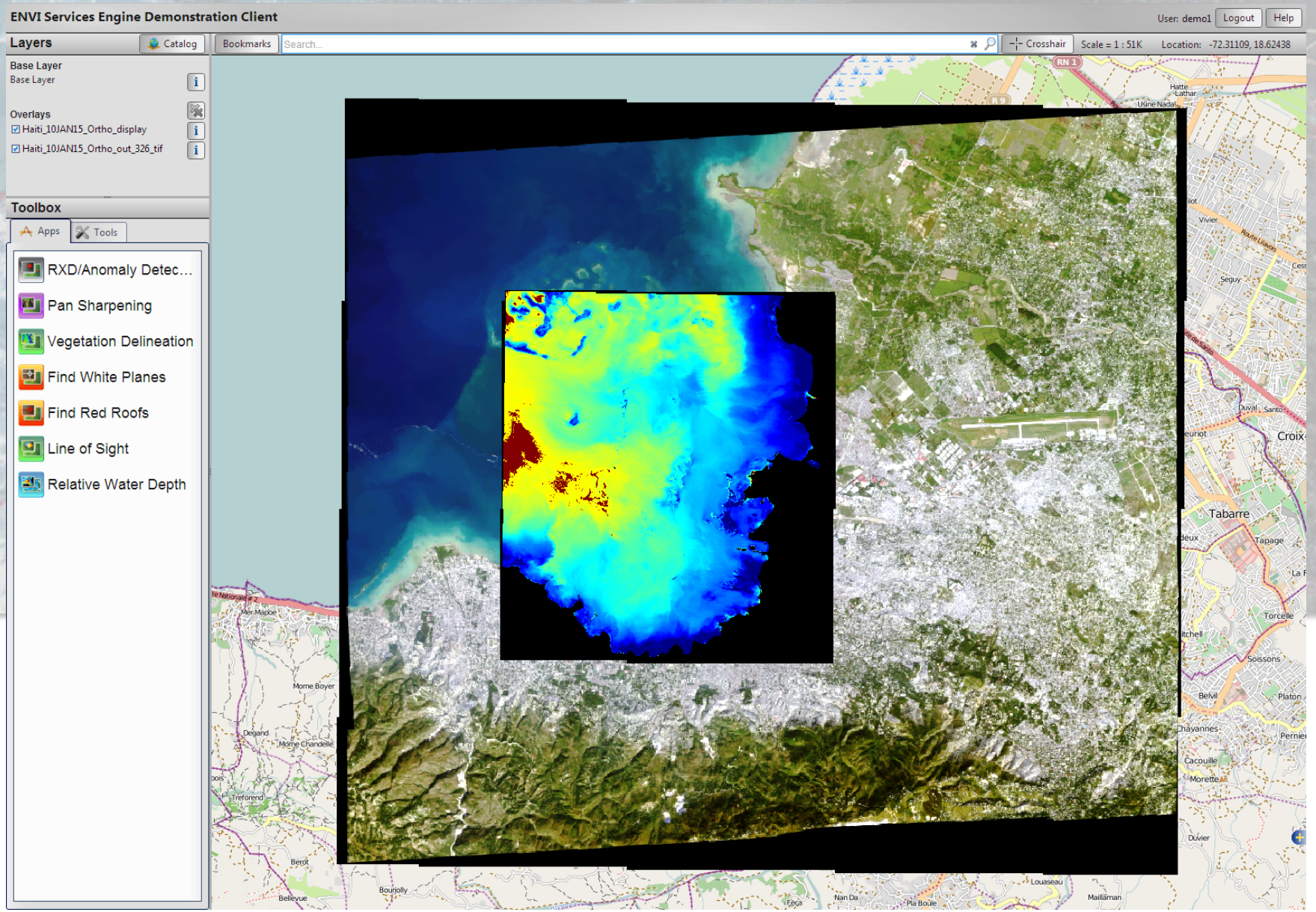
User: demo1
Logout
Help
Layers
Catalog
Bookmarks
Search...
Crosshair
Scale = 1 : 51K
Location: -72.32842, 18.59917
Base Layer
Base Layer
Overlays
Haiti_10JAN15_Ortho_display
Toolbox
Apps
Tools
RXD/Anomaly Detec...
Pan Sharpening
Vegetation Delineation
Find White Planes
Find Red Roofs
Line of Sight
Relative Water Depth
Tabarre


ENVI Services Engine Demonstration Client
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Logout
Help
Layers
Catalog
Bookmarks
Search...
Crosshair
Scale = 1 : 51K
Location: -72.31109, 18.62438
Base Layer
Base Layer
Overlays
Haiti_10JAN15_Ortho_display
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Toolbox
Apps
Tools
RXD/Anomaly Detec...
Pan Sharpening
Vegetation Delineation
Find White Planes
Find Red Roofs
Line of Sight
Relative Water Depth
Tabarre
Croix-
Torcelle
Soissons
Platon
Cacouille
Duvier
Bellevue
Bourjolly
Louaseau
Maillâman
Pla Boûle
Nan Da
Fèca
Morne Boyer
Morne Chandelle
Trefrend
Berot
Degand
Mer Maipoe

Ecosystem Spectral Information System (EcoSIS):

Integration of Spectral Data with Measurements of Vegetation Functional Traits

Alphabetically:

Phil Dennison, University of Utah

John Gamon, University of Alberta, SpecNet

Simon Hook and Rob Green, JPL

Shelley Petroy and Tom Kampe, NEON, Inc.

Dar Roberts, UC-Santa Barbara

Phil Townsend and Shawn Serbin, University of Wisconsin

Susan Ustin, UC-Davis

Art Zygielbaum, University of Nebraska

…..and…..

You!

Why Spectral Libraries?

Tool for discovery.

Document species characteristics and map them.

Characterize the diversity of function and its variability on earth.

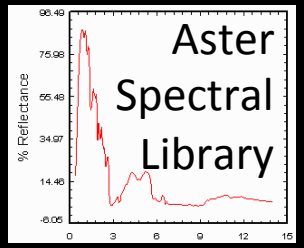
Deliver scientifically vetted data to an international and open community of researchers…

…and metadata to ensure inter-comparability.

Tools to facilitate the synthesis of large data sets by community.

Precedents:

USGS science for a changing world



TERN Terrestrial Ecosystem Research Network

AusCover

RSL SPECCHIO

neon™ National Ecological Observatory Network

CarnegieSpectranomics

SpecNet

Example Contributions

Table 2. Examples of spectral data contributions from the project Principal Investigators.

Site	Veg Type/Species	Vegetation Conditions	Spectral Data	Temporal/Sample Characteristics	Ancillary Data
Missoula, Montana	lodgepole pine, sagebrush	Retained old and emergent new needles, separated into two samples	hemispherical leaf/needle reflectance and transmittance, 350-2500 nm	weekly for 4+ months, 4 sites, 8 samples per site, adaxial and abaxial sides	Time series moisture content, partial biochemical analysis
Missoula, Montana	lodgepole pine, sagebrush	Maturing leaves and needles over field season	branch and canopy field spectra, 350-2500 nm	weekly for 4+ months, 4 sites, approximately 10 areas per site	Time series live fuel moisture
Fivemile, Utah	sagebrush, NPV, soil	Mature sagebrush with declining canopy moisture over time	canopy field spectra, 350-2500 nm	every two weeks for 4 months, 10 canopies per site for 5 sites	Time series live fuel moisture
Range Creek, Utah	desert scrub, NPV, soil		canopy field spectra, 350-2500 nm	field campaign, approximately 15 plant species	
Santa Monica Mountains, California	chaparral, coastal sage scrub, NPV, soil		branch and canopy field spectra, 350-2500 nm	field campaigns 1995-2000, approximately 20 plant species	
Mead, Nebraska	corn, soy crops, row planted	irrigated and non-irrigated fields	350-2500 nm reflectance	weekly through growing season covering ten years, 36 samples per field, 3 fields	pyranometer, quantum sensor, GPS, IRT
				Roughly monthly	

Attribute	Variable
Plot/Sample ID	A06-42
NEON Domain	1
Domain Site	Core
Type	Vegetation
Form	Deciduous Tree
Measurement Scale	Leaf
Estimate - Sample Location on Tree	Mid Canopy - exposed
Measurement Type	Field
Instrumentation	ASD
Spectra Collection Protocol	Plant Probe
Calibration Protocol	Plant Probe Reference
Measurent Protocol	Standard Measurement Sequence
Spectra per Sample	20
Samples per Save	1
Acquisition Conditions	Not recorded
Field Personnel	Nathan Leisso

Example Data – a whole range of data and metadata in different formats

D1373a

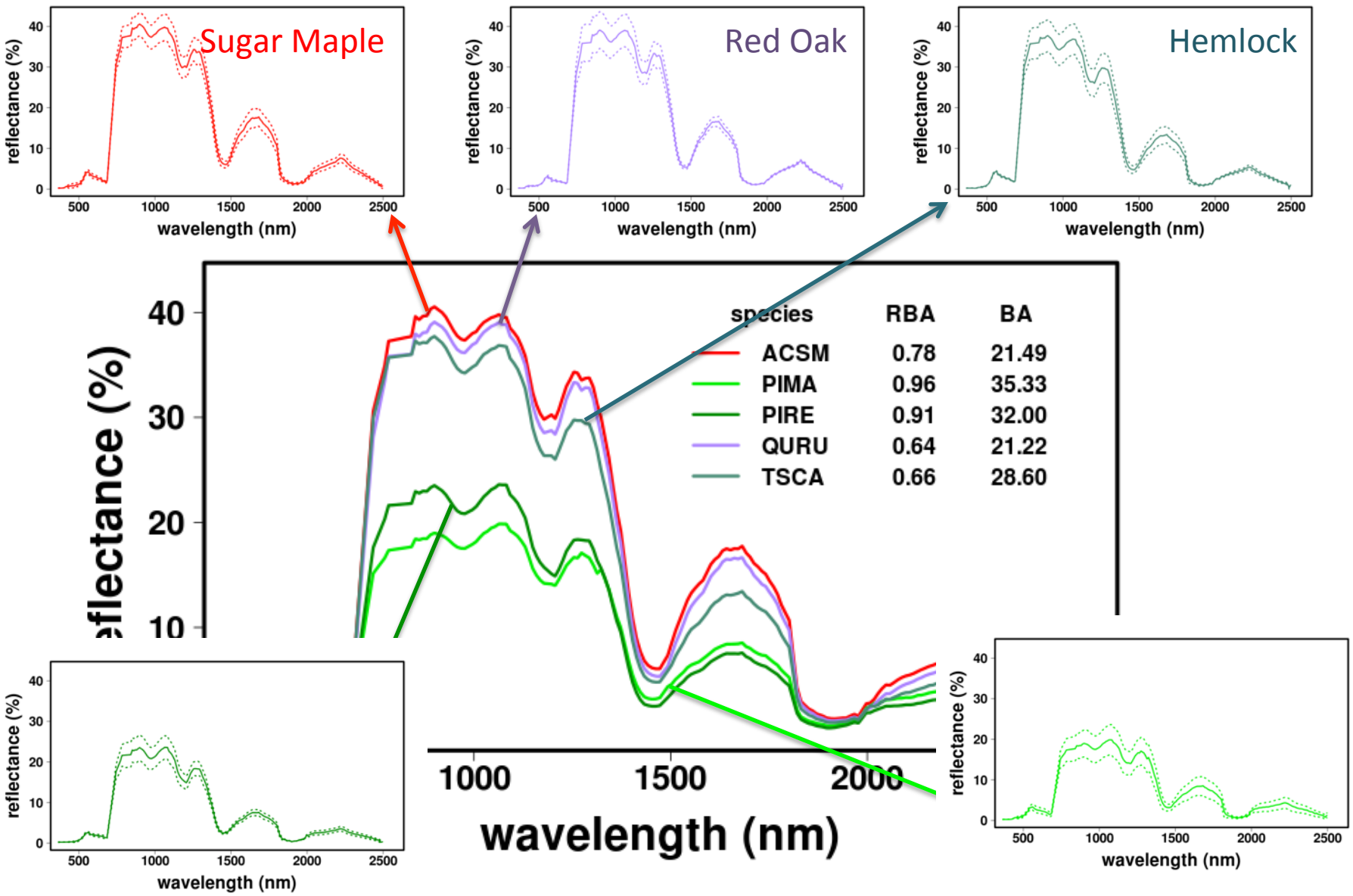
Douglas-fir #1373 sampled from Wind River Crane on Sept 9, 1996, by John Gamon & John Surfus

"Dark-to-Light" reflectance spectra during 10 minute transition from darkness to full sun

For method, see Gamon JA, Surfus JS (1999) Assessing leaf pigment content and activity with a reflectometer. New Phytologist 143:105-117.

Difference Spectrum (duaDIFF, ColumnW) shows delta Reflectance (10 minute - 0 minute of sun), illustrating features due to Xanthophyll pigment conversion and chl fluorescence quenching

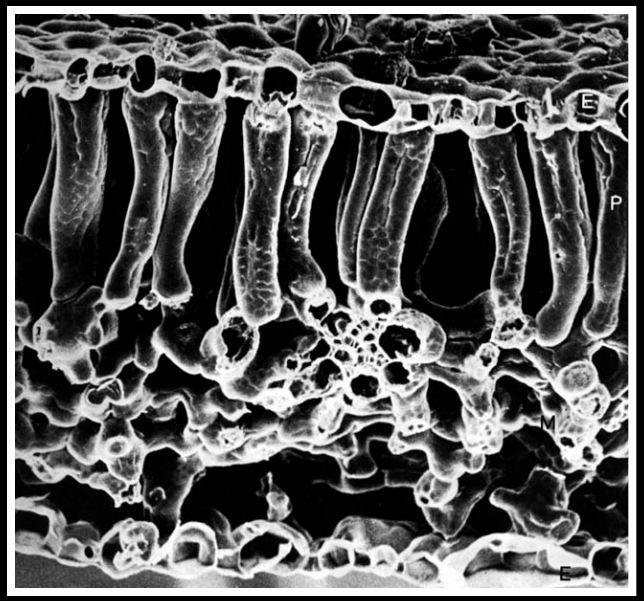
minutes	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
Wavelength	dua00001	dua00002	dua00003	dua00004	dua00005	dua00006	dua00007	dua00008	dua00009	dua00010	dua00011	dua00012	dua00013	dua00014	dua00015	dua00016	dua00017
305.56	0.349091	0.32	0.34545	0.32	0.32364	0.34545	0.33455	0.32364	0.33818	0.34545	0.36727	0.33091	0.34909	0.32364	0.36364	0.32364	0.35273
308.91	0.36619719	0.35563	0.34507	0.33099	0.34155	0.32747	0.34155	0.34155	0.33099	0.35211	0.39789	0.35211	0.33099	0.34507	0.35916	0.35563	0.35916
312.26	0.36824304	0.375	0.34122	0.36486	0.37838	0.33784	0.34797	0.36149	0.35135	0.37838	0.35473	0.38176	0.36486	0.40203	0.36824	0.38176	0.37162
315.61	0.34768208	0.34768	0.36424	0.37417	0.3543	0.36755	0.37748	0.36093	0.3543	0.36755	0.35762	0.37748	0.37417	0.39073	0.35762	0.38411	0.38079
318.95	0.35915487	0.33099	0.33803	0.35915	0.34507	0.35915	0.37676	0.37324	0.38028	0.3662	0.35211	0.35563	0.35563	0.32746	0.37324	0.34155	0.38028
322.3	0.36610165	0.34576	0.3661	0.35254	0.34915	0.3322	0.32881	0.35932	0.35932	0.33559	0.38305	0.34915	0.36271	0.32542	0.3661	0.37288	0.35932



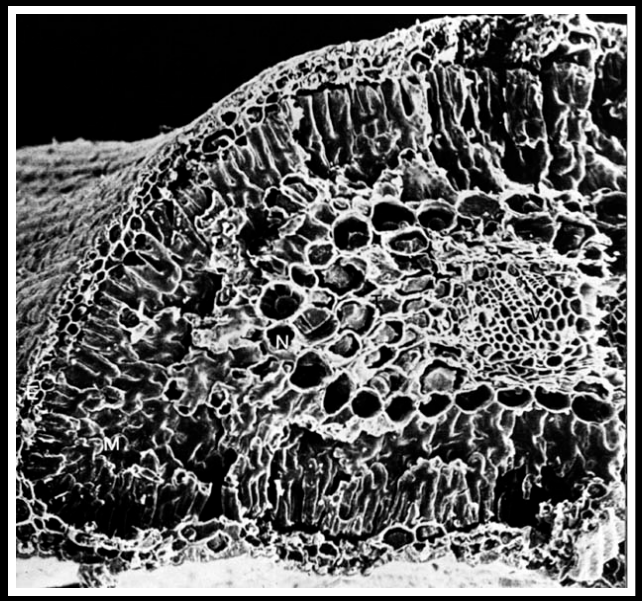
Spectral information can be about about species, differences between species, and geographic variations within a species. It can also be at the canopy and the leaf level.

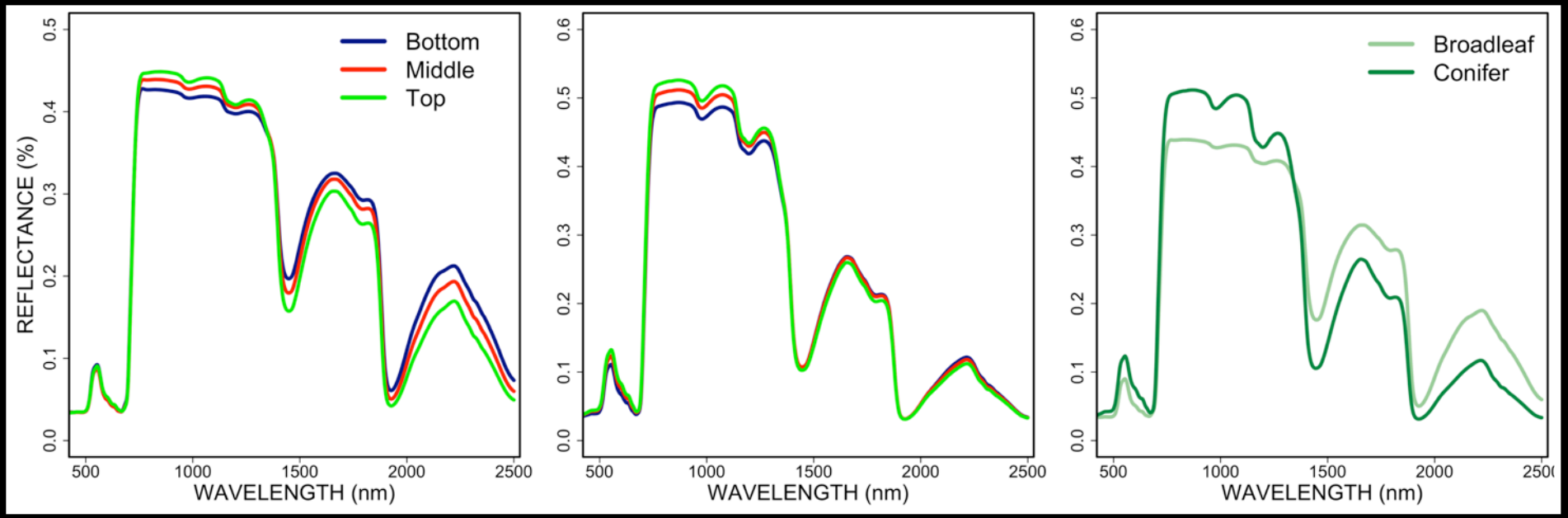
Leaf-level spectra

Maple

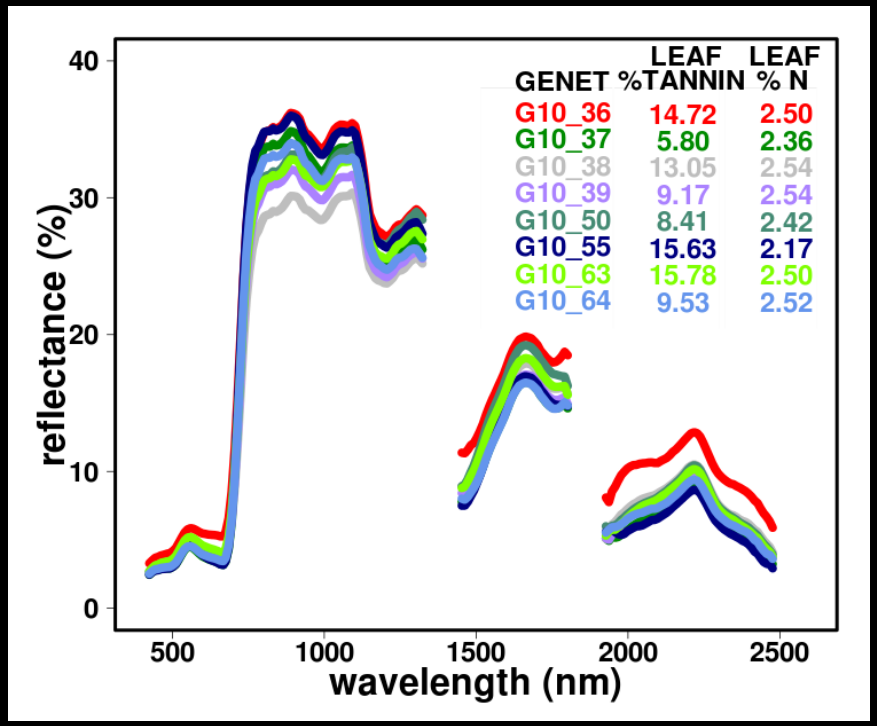


Pine



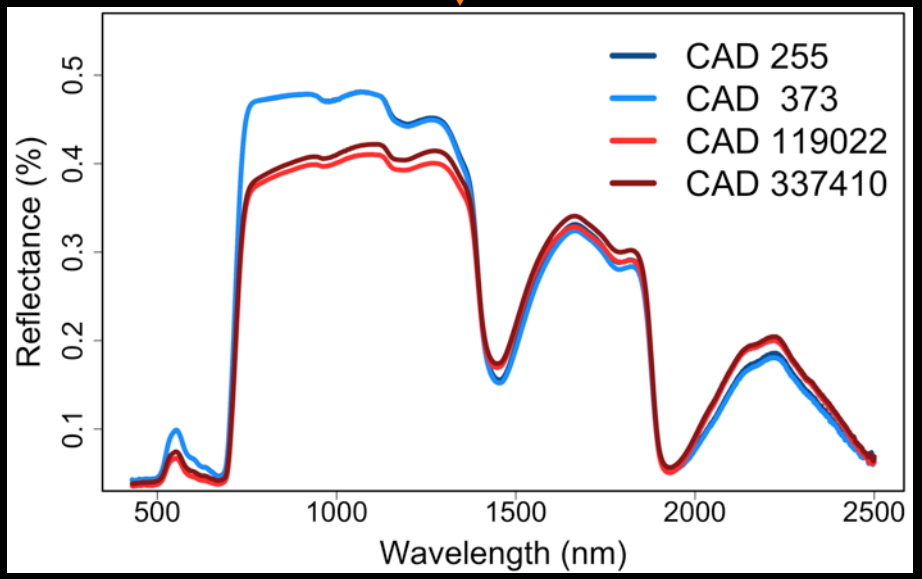


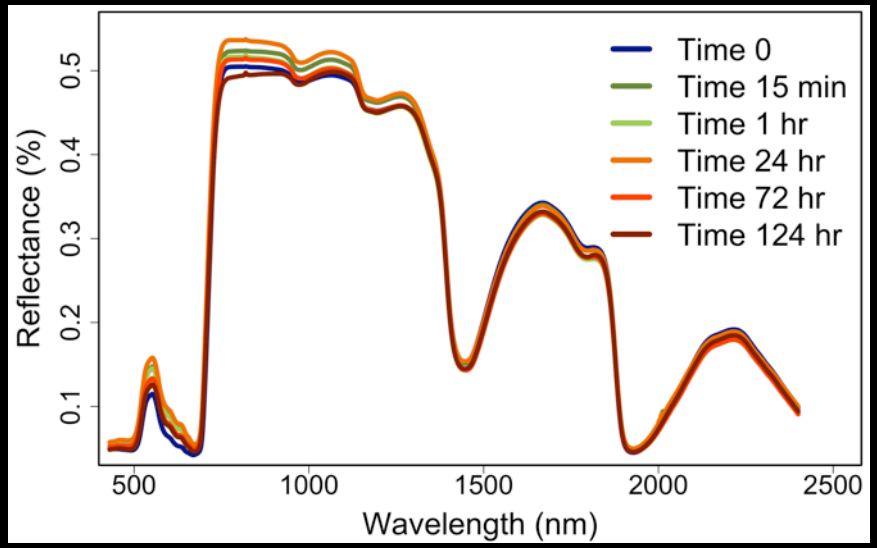
Spectral information can be about differences in reflectance through the canopy of a tree.



Genotypes of aspen.
Different reflectance.
Different chemistry.

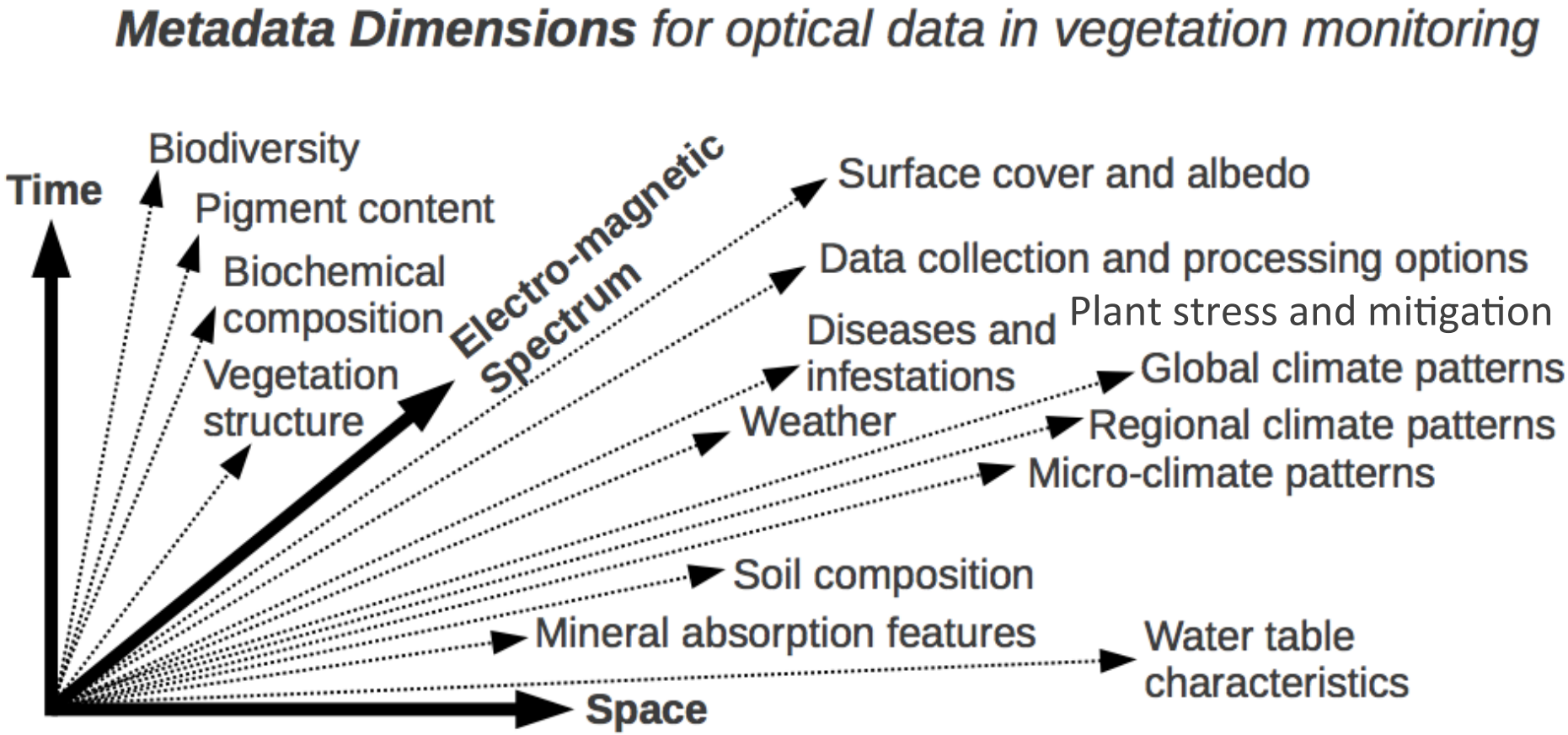
Soybeans: same variety, different levels of pest pressure.





Milkweed.
Rapidly induced chemical defenses to perturbations.

Spectral data serve as “proxy” measurements for all ranges of underlying properties and functions in ecosystems that are costly, impractical, inconvenient or impossible to otherwise characterize at broad spatial and temporal scales.



G. Pastorello and J. Gamon

EcoSIS

EcoSIS Activities
(lead institutions)

- Develop Database Back-End (UC-Davis, JPL)
- Develop EcoSIS User Interface (UC-Davis, JPL, UW)
- Metadata Standards (UW, NEON, Alberta, UNL)
- Best Practices (UCSB, NEON, Alberta, UNL)
- Populate EcoSIS (all members, coordinated by UW)
- QAQC, Error Assessment (UW, JPL)
- EcoSIS Tools (UW, Alberta, community)

Deliverable

EcoSIS Public Database

JPL

- Spectral Library (0.35-13.0 µm)
- Metadata
- Associated measurements (species, chemistry, etc.)

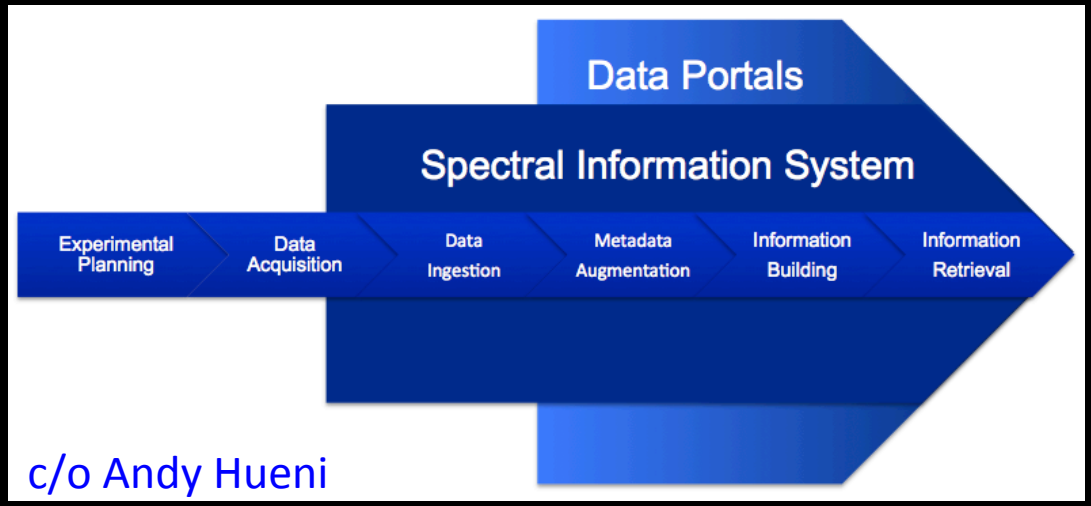
EcoSIS Tools (Open Source)

- Visualization, Query, Discovery

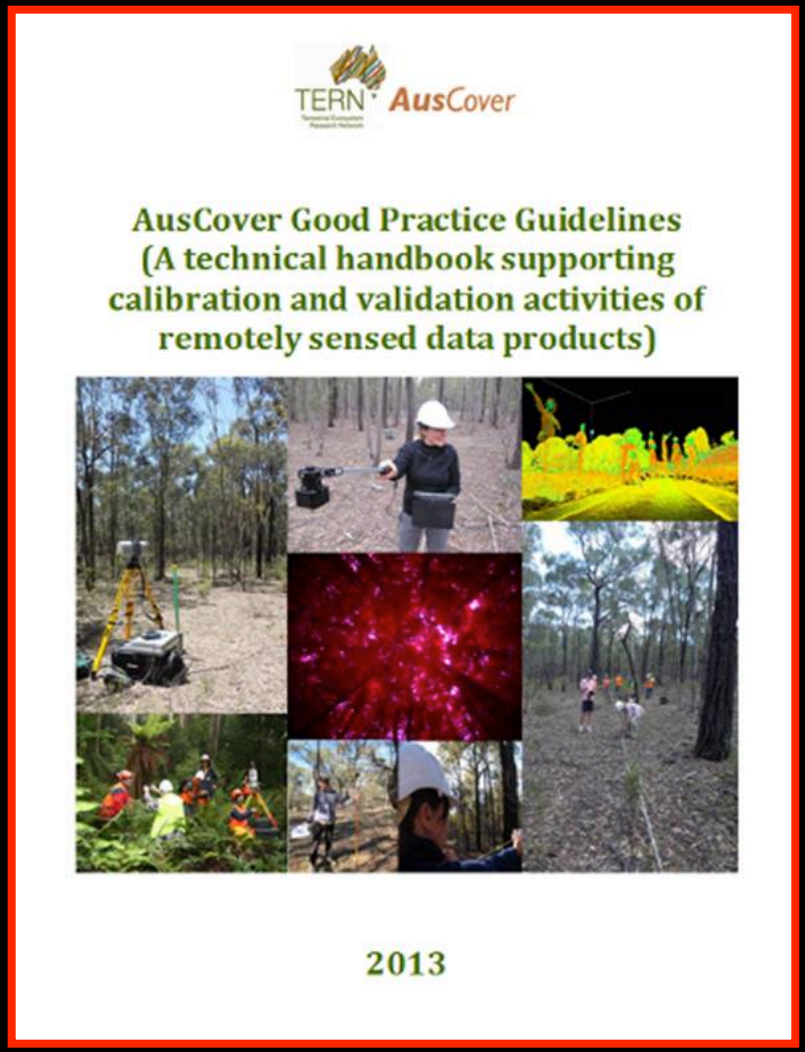
EcoSIS Outcomes
(via community engagement)

- Accommodation of Legacy and New Data Sets
- Evolution of Open-source Tools for Discovery & Analysis
- Synthesis Studies & Meta-Analyses
- Development of a Broader EcoSIS User Community
- Growth of EcoSIS to Reflect Evolving Science Needs

International linkages are important:



c/o Andy Hueni



Moving Forward:

Community participation is essential:

- Decision-making open process
- Review/oversight committee
- Your data contributions to EcoSIS
- Open source data and tools

Virtual meetings, side meetings at AGU, etc.

join-ecosis-community@lists.wisc.edu

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Beyond ASTER: Future VNIR-SWIR and TIR Hyperspectral Instruments

Michael Abrams
Jet Propulsion Laboratory, California Institute of Technology

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California Institute of Technology
Pasadena, California

Outline of Presentation

- Current scanners
- Ready scanners
- Future scanners

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California Institute of Technology
Pasadena, California

Current Scanners

Sensor	**Hyperion**	**CHRIS**	**HySI**	**HJ-1A**	**HICO**
Country and Organization	USA NASA	UK ESA	India ISRO	China CAST	USA NASA/ONR
GSD (m)	30	17/34	506	100	90
Swath at Nadir (km)	7.65	13 (nominal)	129.5	≥50	42
Wavelength Coverage (nm)	357-2576	400-1050	400 - 950	450 - 950	353 - 1081
Number of Bands	242	18/37/6	64	110 - 128	128
Spectral Res. (nm @ FWHM)	10	5.6-32.9	~ 10	5	5.7
Launch Date	2000	2001	2008	2008	2009

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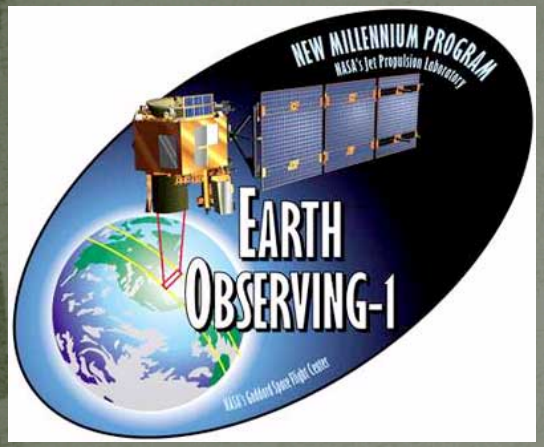
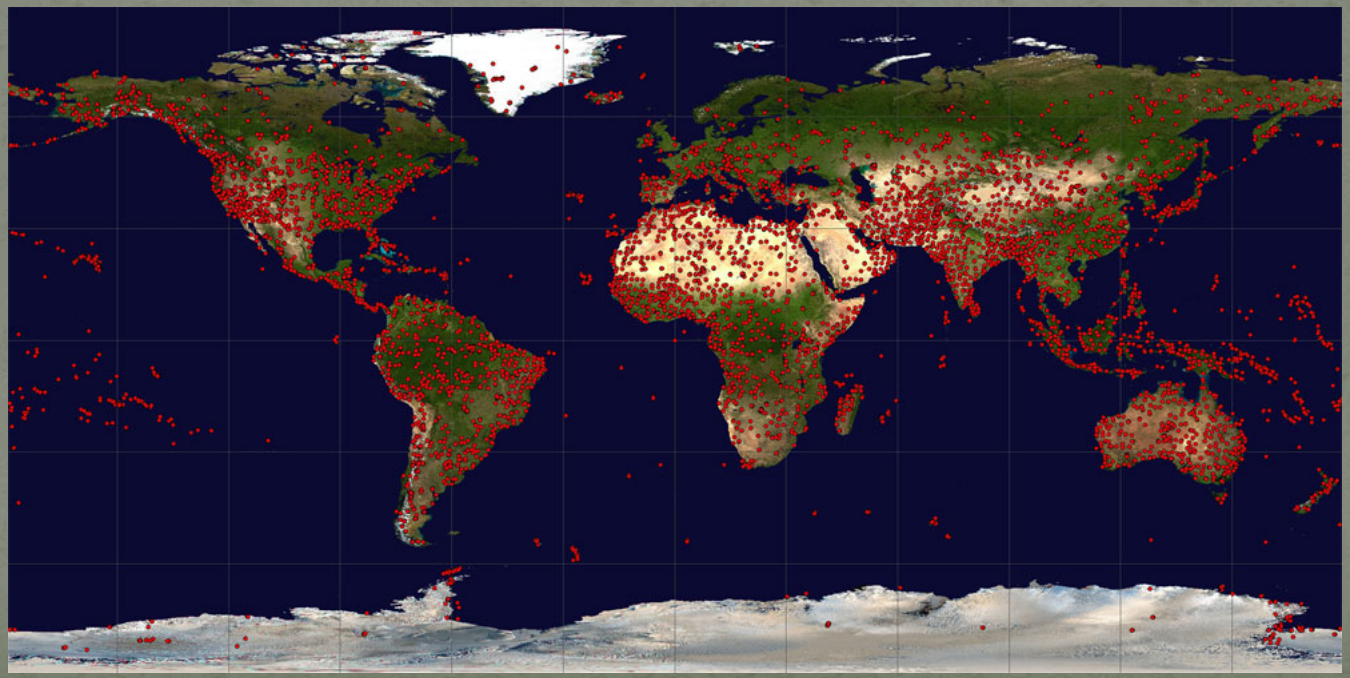
Hyperion



Hyperion operates on NASA's EO-1 spacecraft since 2000. It is a VSWIR hyperspectral scanner, accompanying the ALI multispectral instrument. Hyperion was a technology demonstration, explaining its 7.5 km swath width, and very limited data acquisition capability. Over 11 years, numerous scenes have been acquired, and are available free to users. EO-1 has run out of fuel, and will stop acquiring data soon.



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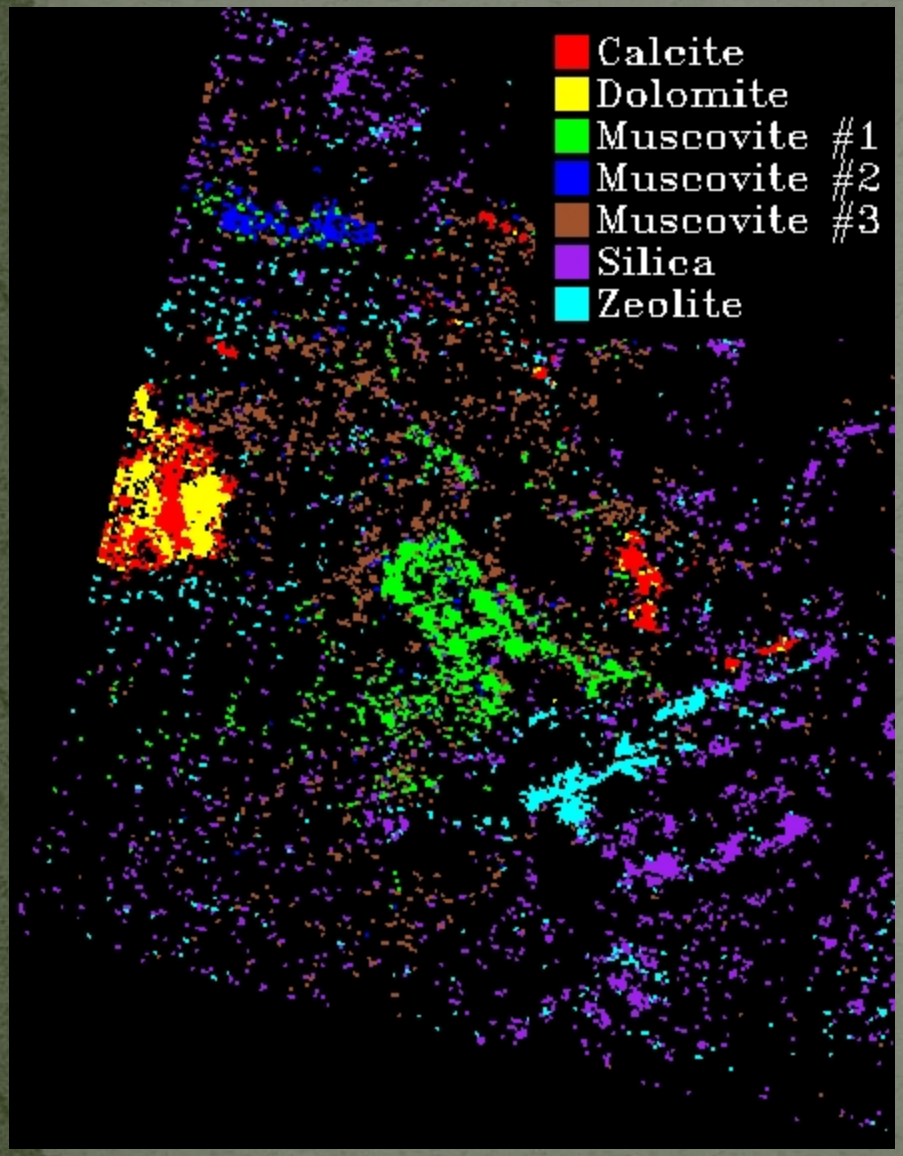
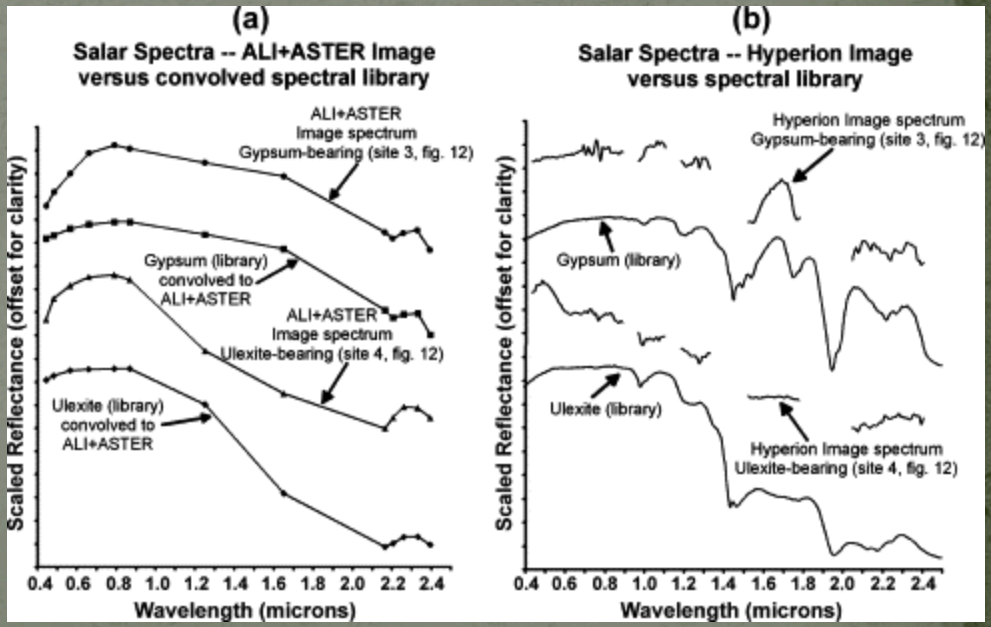
Hyperion



An example of Hyperion's mineral mapping capability relying on full spectrum hyperspectral imaging from 0.4 to 2.45 μm.



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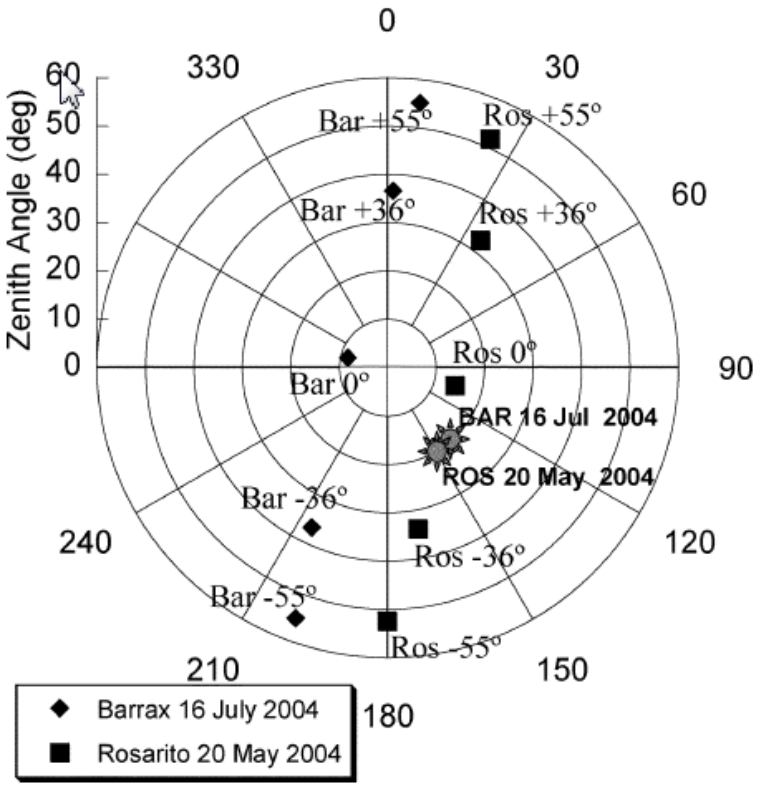
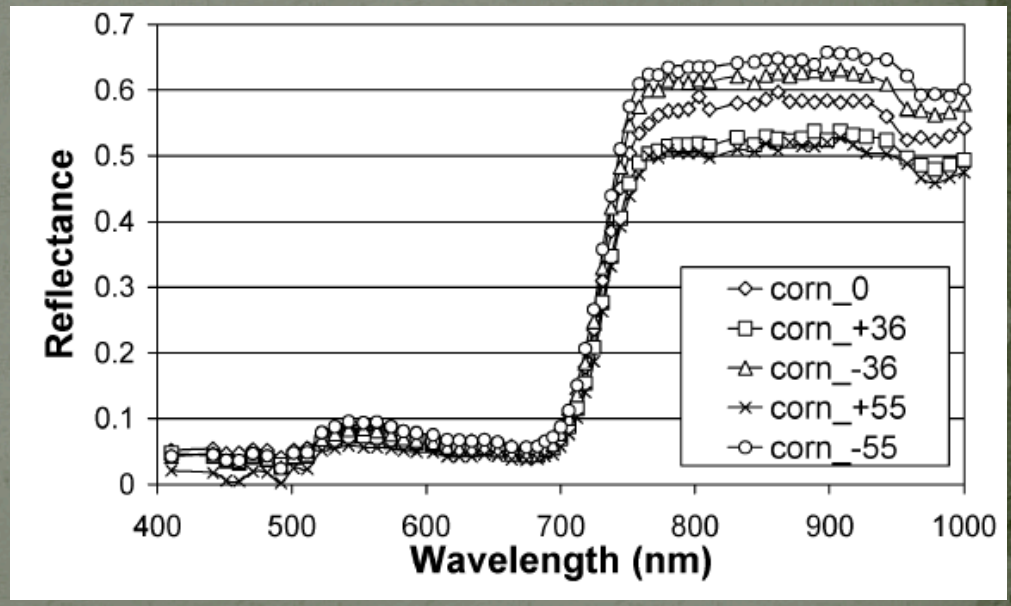
CHRIS
Compact High Resolution Imaging Spectometer on ESA's PROBA platform



CHRIS acquires 13 x 13 km images with 5 different viewing angles for BRDF studies.



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CHRIS

All CHRIS data are available through ESA's online EOLI catalogue.

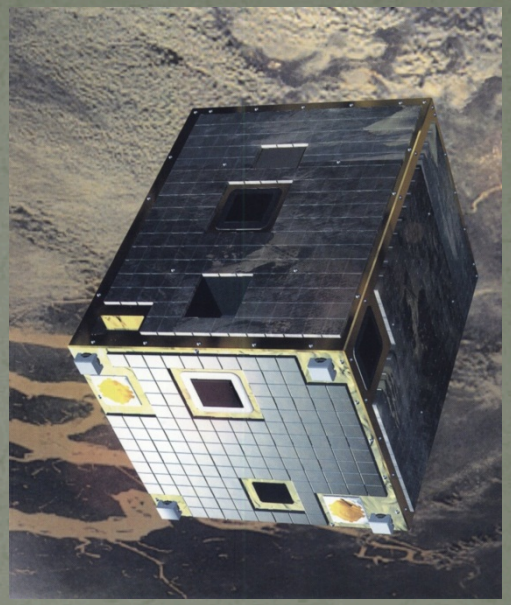
MODE 1: Full swath width, 62 spectral bands, 773nm / 1036nm, nadir ground sampling distance 34m @ 556km

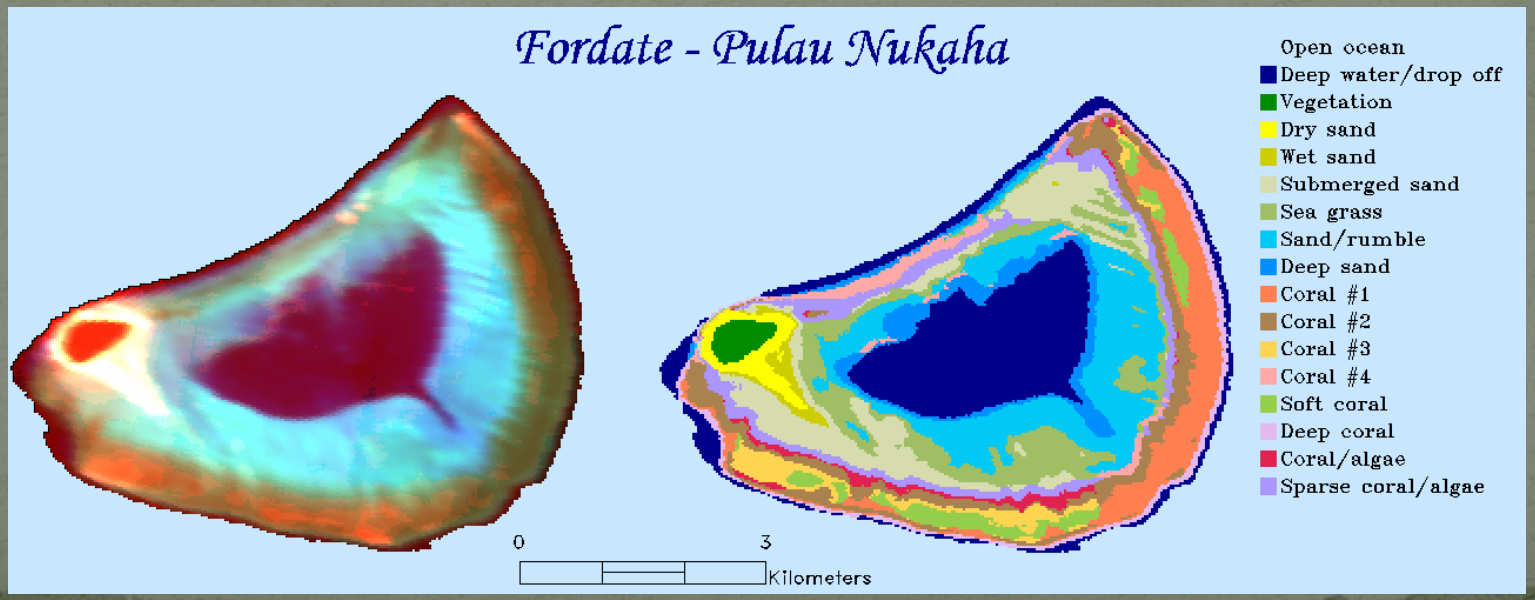
MODE 2 WATER BANDS: Full swath width, 18 spectral bands, nadir ground sampling distance 17m @ 556km

MODE 3 LAND CHANNELS: Full swath width, 18 spectral bands, nadir ground sampling distance 17m @ 556km

MODE 4 CHLOROPHYL BAND SET: Full swath width, 18 spectral bands, nadir ground sampling distance 17m @ 556km

MODE 5 LAND CHANNELS: Half swath width, 37 spectral bands, nadir ground sampling distance 17m @ 556km





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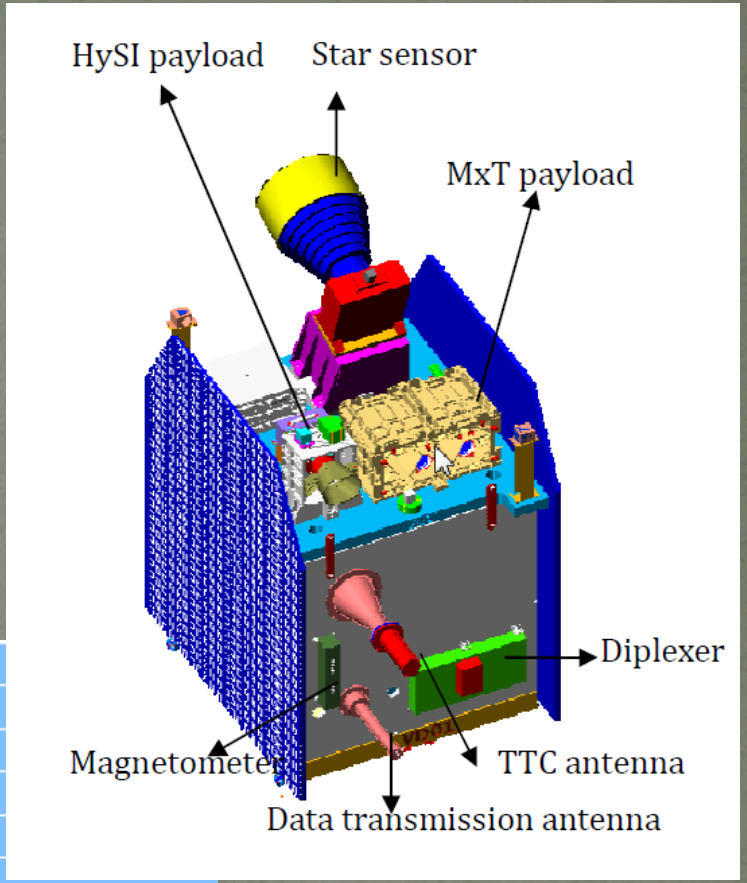
HySI

HySI (Hyperspectral camera), is one of two instruments on IMS-1 (Indian Mini Satellite-1), previously called TWSat (Third World Satellite), a small earth observing satellite developed by Indian Space Research Organization (ISRO). It has about 500m IFOV and 129 km swath. Data are made available to developing countries.



Nation:	India
Type / Application:	Earth Observing
Operator:	ISRO
Contractors:	ISRO
Equipment:	
Configuration:	Microsatellite-SSB (SSB-2)
Propulsion:	?
Power:	2 deployable solar arrays, batteries
Lifetime:	2 years
Mass:	83 kg
Orbit:	630 km × 630 km, 97.9°

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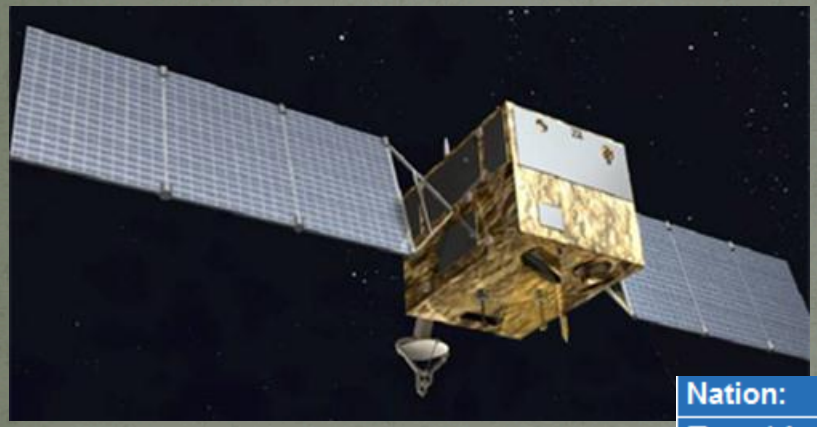
HJ-1A
Huan-Jing (=Environment) Constellation

HJ-1A is also the Small Multi-Mission Satellite (SMMS) of Asia Pacific Space Cooperation Organization (APSCO) and it will be the important data resources of APSCO space application. SMMS is a joint venture payload between China, Iran, South Korea, Mongolia, Pakistan, Thailand and Bangladesh under the Asian-Pacific organization.



Nation:	China
Type / Application:	Earth observation
Operator:	CAST
Contractors:	DFH Satellite Co. Ltd of CAST
Equipment:	
Configuration:	CAST968B Bus
Propulsion:	
Power:	2 deployable solar arrays, batteries
Lifetime:	
Mass:	
Orbit:	

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HJ-1A

Fourier Transform hyperspectral imager

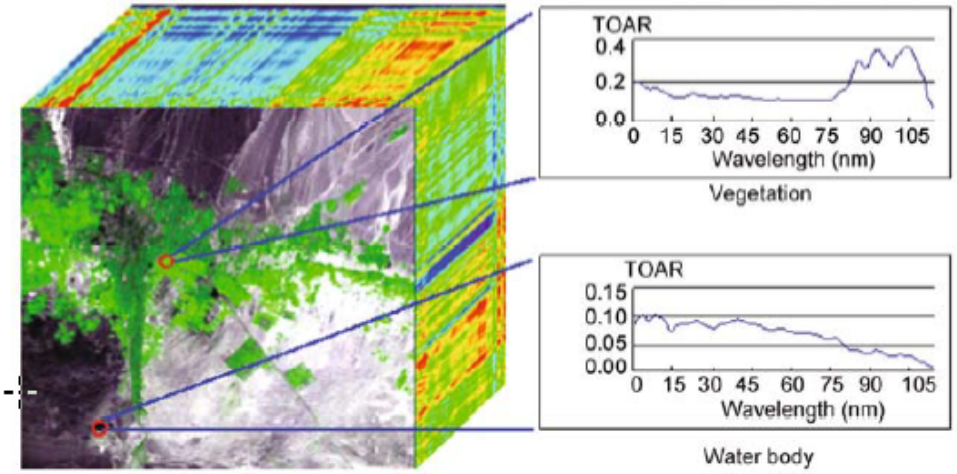

Figure 3 First orbit hyperspectral image of HJ-1A.

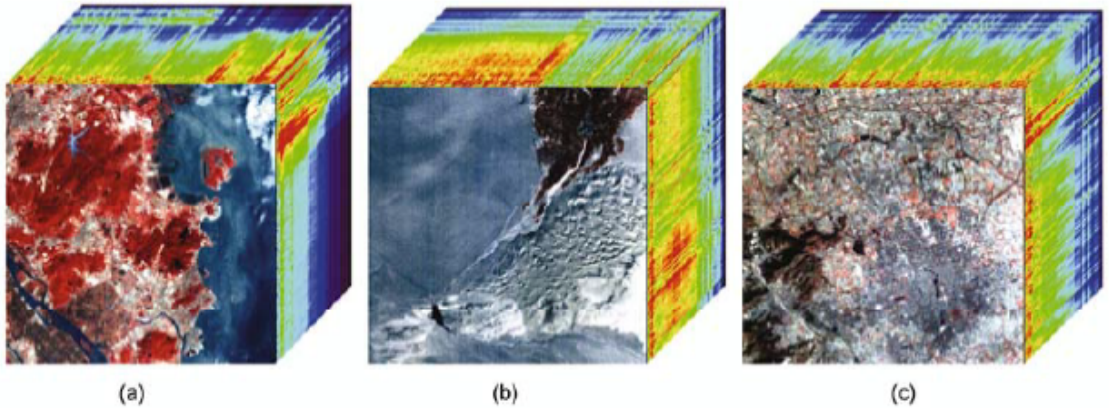

Figure 4 HJ-1A hyperspectral image cubes.

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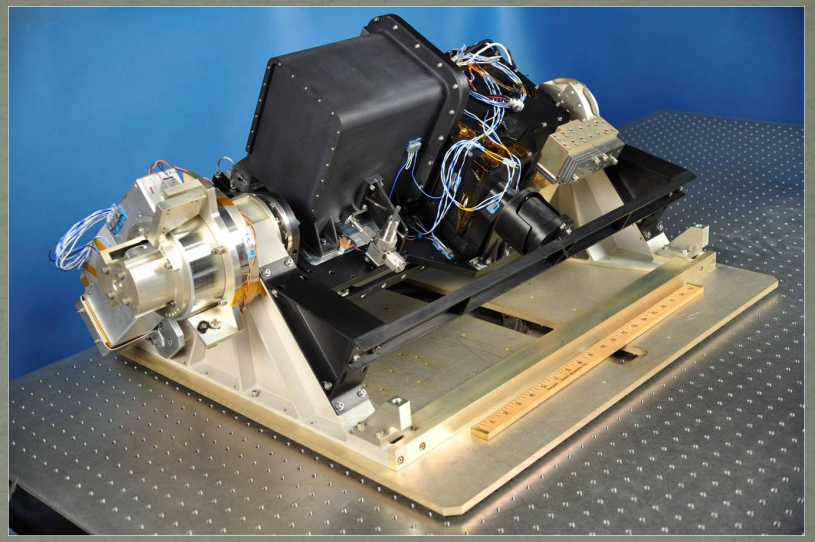
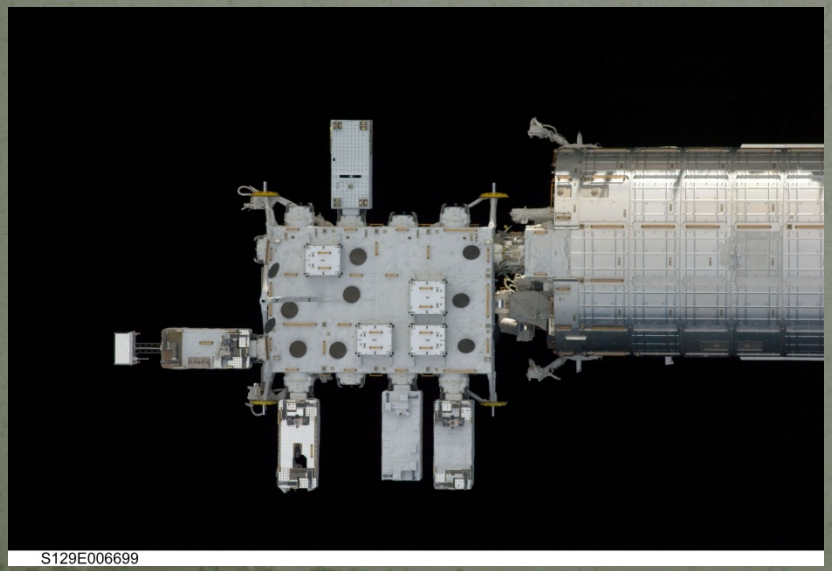
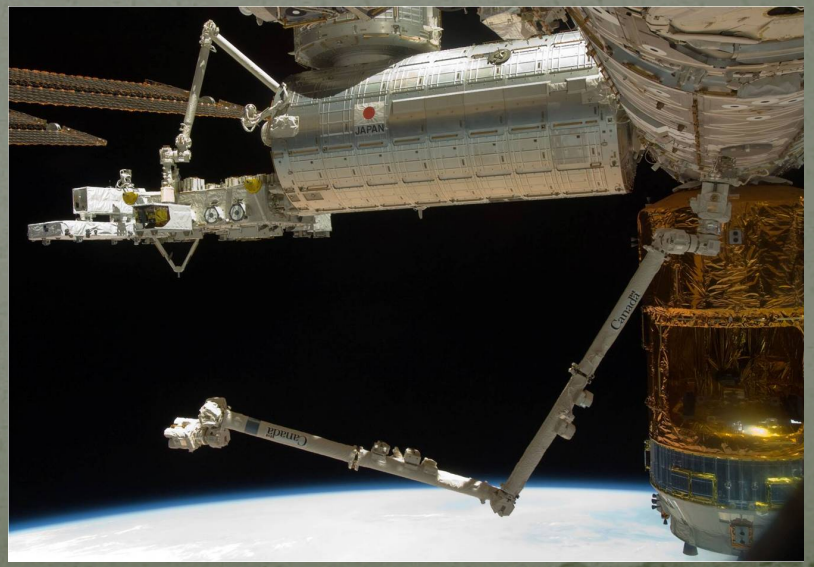
HICO
Hyperspectral Imager for the Coastal Ocean

HICO is operated on the Space Station by the US NASA and Navy. The data system is done by Oregon State University. HICO is designed for ocean observations







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California Institute of Technology
Pasadena, California

HICO
Hyperspectral Imager for the Coastal Ocean

HICO Home

- HICO
  - Design & Heritage
  - Calibration
  - Targets
  - Orbit
- Meet the Team
- Meetings
- Publications & Presentations
- Contact Us

Log In

- Become a HICO Data User

Data

- Search Data
- Schedule
- Data characteristics
- Working with the data
- How to request data
- Subscribe
- Request New Target

Image Galleries

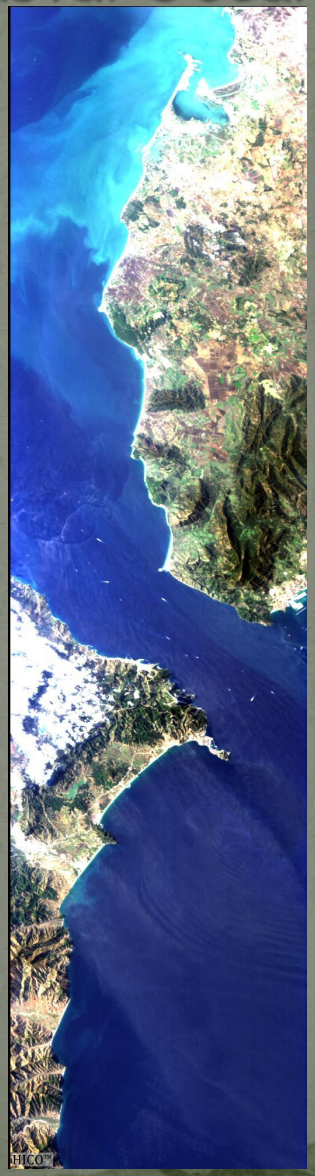
Current Projects

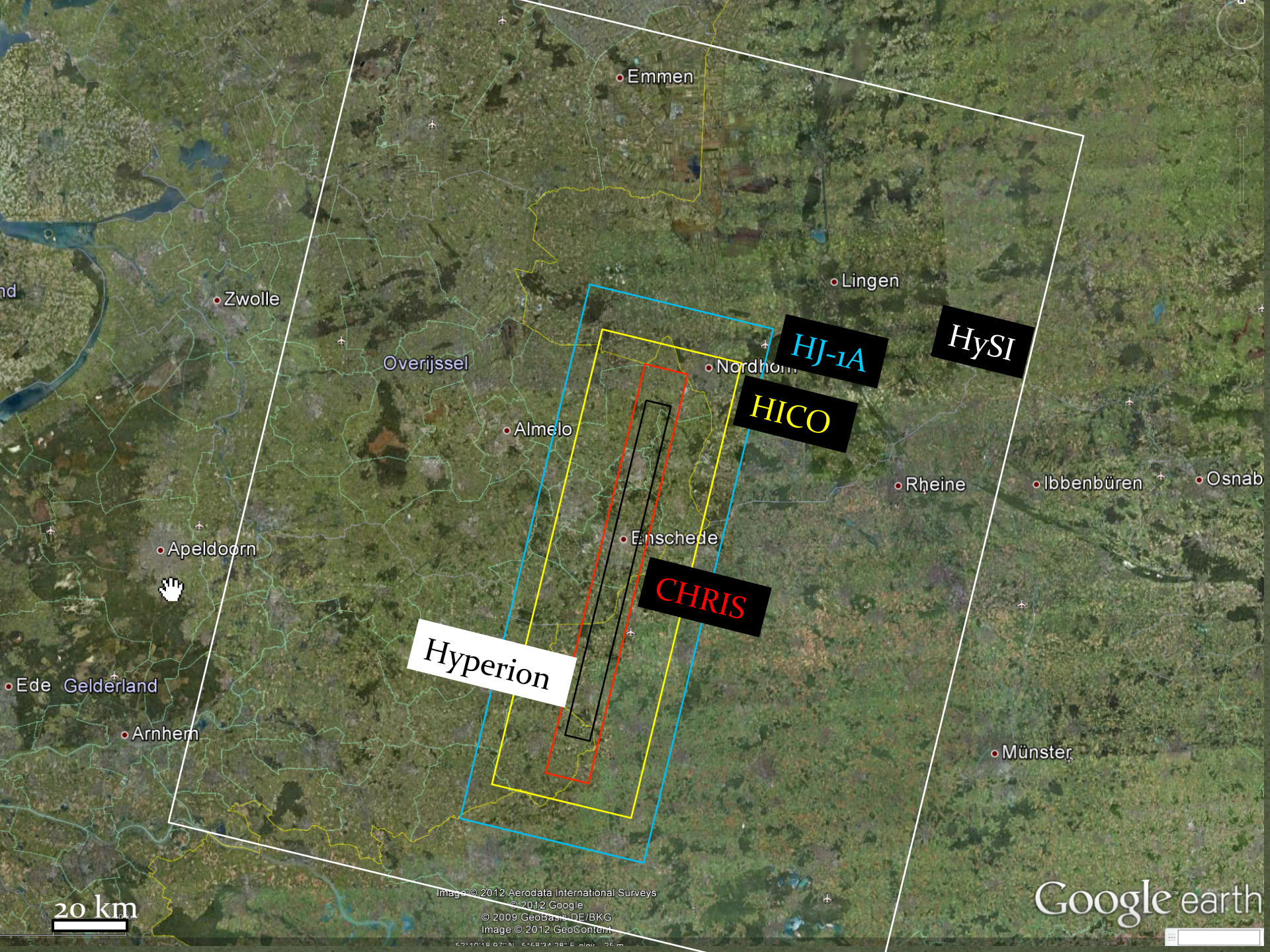
Targets

Targets collected by HICO and distributed through this website are shown below (Google Earth plugin required). Alternatively, the targets may be viewed as a list of target names.

Please see below for more information about the image.

Each target covers an area 50 km wide by 200 km long. The target areas are shown as rectangles on the




Emmen
Zwolle
Lingen
HJ-1A
HySI
Overijssel
Nordhorn
HICO
Almelo
Rheine
Ibbenbüren
Osnab
Enschede
Apeldoorn
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Spectral Coverage

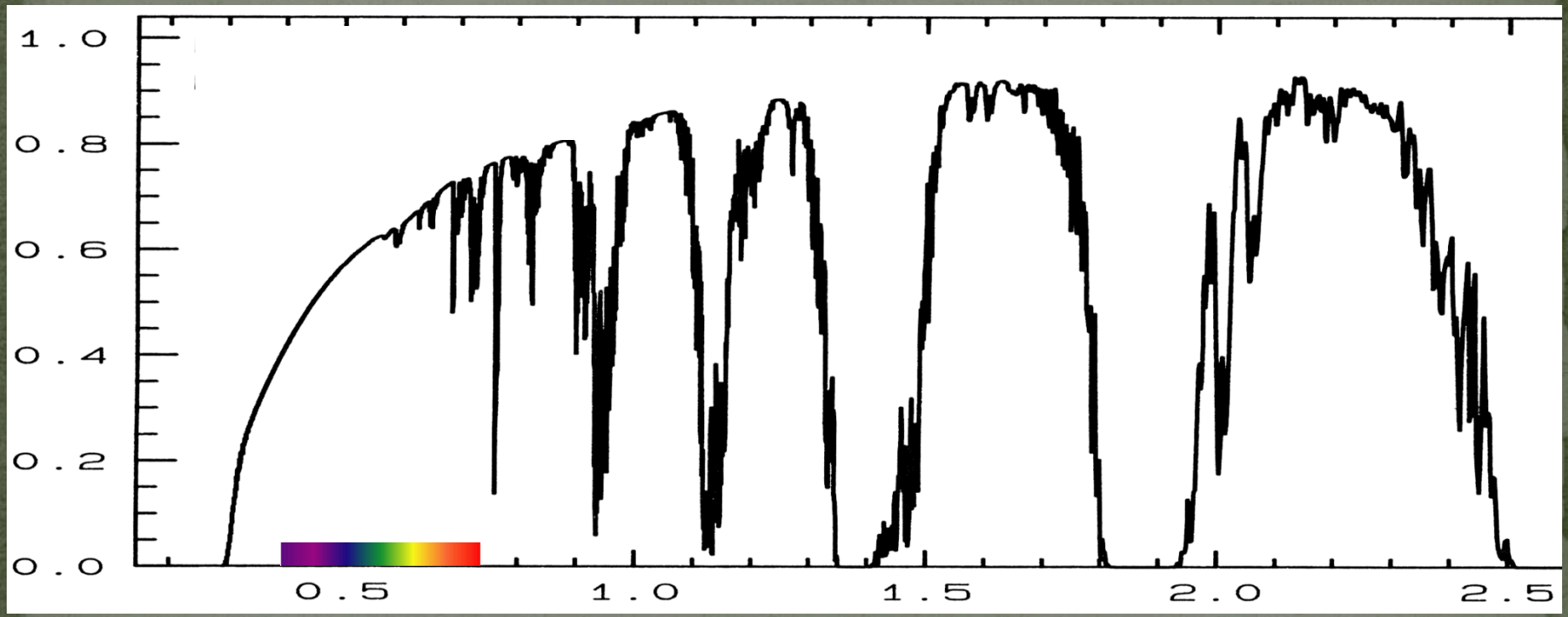
HJ-1A

HySI

Chris

HICO

Hyperion



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Ready Scanners

Sensor	EnMAP	PRISMA	MSMI
Country and Organization	Germany GFZ/DLR	Italy ASI	S. Africa SunSpace
GSD (m)	30	30	~15
Swath at Nadir (km)	30	30	~15
Wavelength Coverage (nm)	420 - 2450	400 - 2500	440 - 2350
Number of Bands	218	237	200
Spectral Res. (nm @ FWHM)	5/10 VNIR 10 SWIR	~12	10
Launch Date	2017	2017	?

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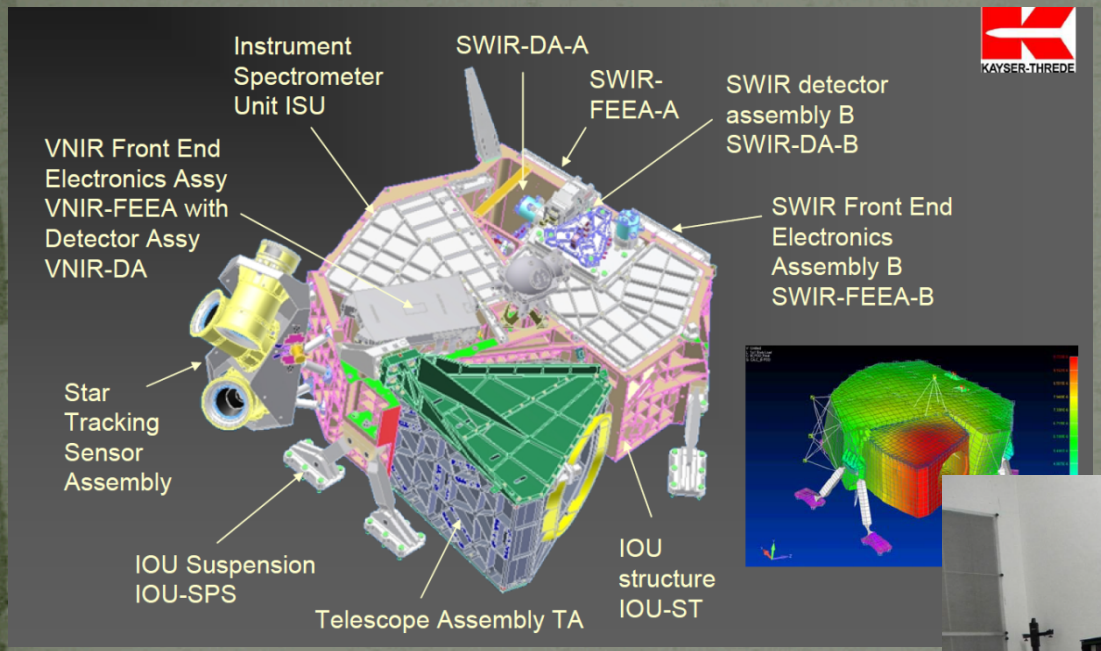
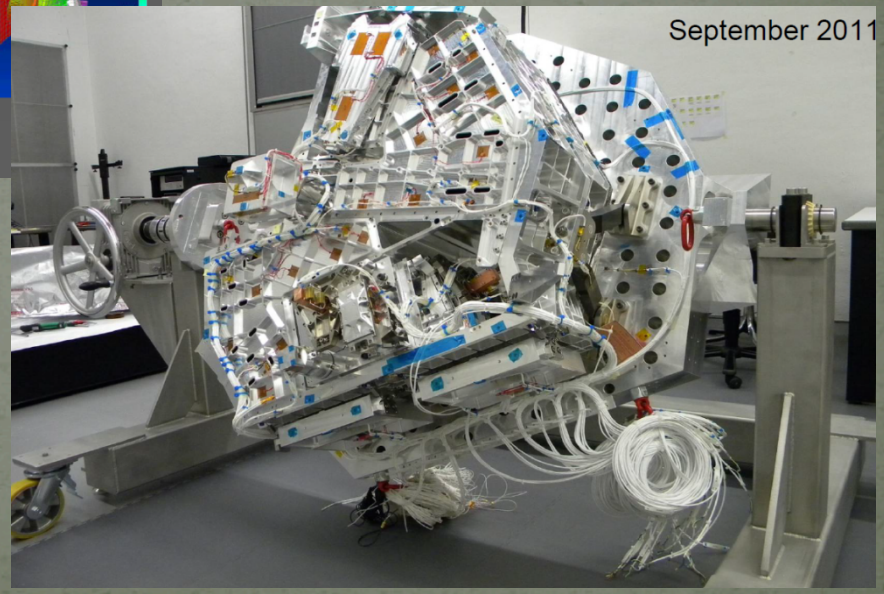
EnMAP Hyperspectral Imager

ENMAP





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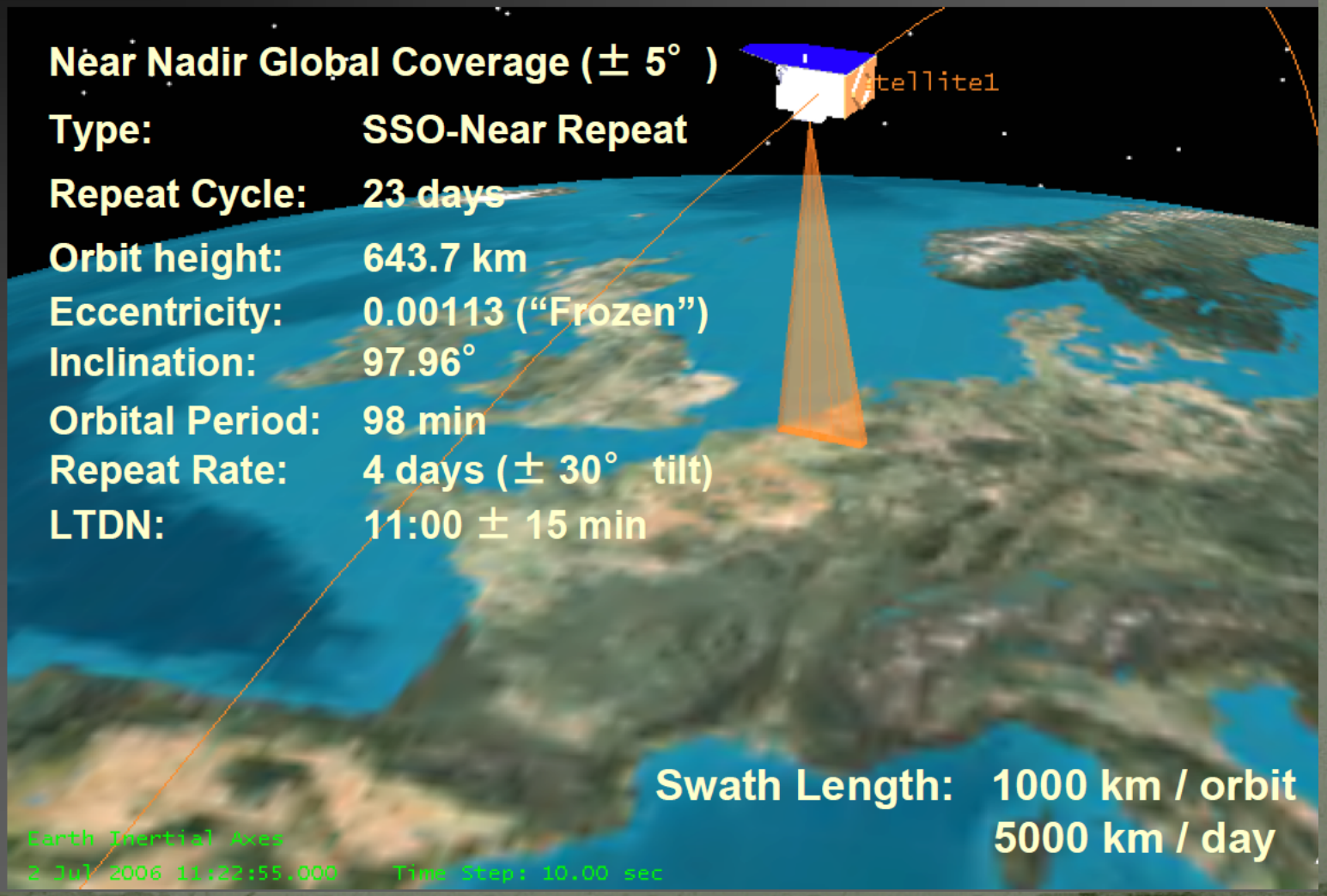
ENMAP

Main Orbit Parameters



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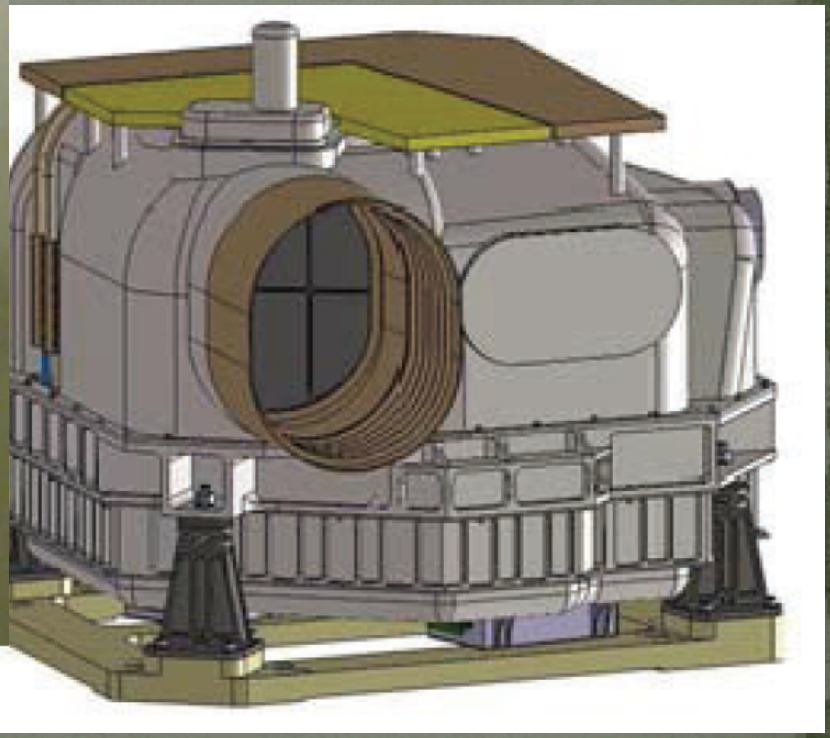
PRISMA

Italian Space Agency: ~2015 launch(?)



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PRISMA
Italian Space Agency: ~2016 launch(?)

1. Development of algorithms and products for applications in agriculture and land monitoring supporting
the PRISMA mission (to be realised by CNR IMAA)
2. Synergic use of PRISMA products with high spatial resolution meteo-chimical simulation and ground
validation (to be realised by CETEMPS)
3. hyperspectral system analysis for integrated geophysical applications (to be realised by INGV)
4. advanced methods for analysis, integration and optimization of level 1 and level 2 PRISMA products (to
be realised by IFAC CNR)
5. Coasts and Lake Assessment and Monitoring by PRISMA HYperspectral Mission (to be realised by
ISMAR CNR).

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Ready Scanners

Multi-Sensor Microsatellite Imager (MSMI)

Sensor	**EnMAP**	**PRISMA**	**MSMI**
Country and Organization	Germany GFZ/DLR	Italy ASI	S. Africa SunSpace
GSD (m)	30	30	~15
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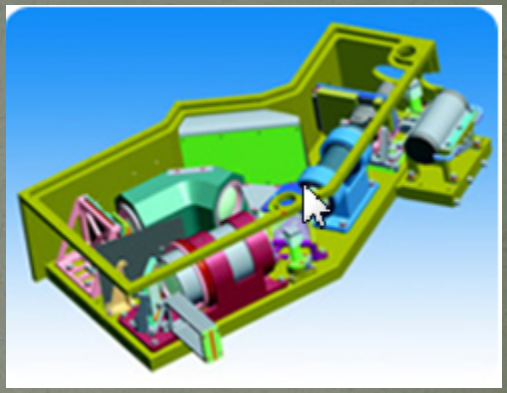
MSMI

Multi-Sensor Microsatellite Imager (*MSMI*)



Optical SpectroMeter Unit (OSMU) is a hyperspectral imaging spectrometer integrated in a South-African Multi-Sensor Microsatellite Imager (MSMI) onboard of the second generation SUNSAT satellite ZASat2. OSMU contains two spectral channels: one in the visible and one in the infrared range. It has a field of view of 1,25° imaged on a detector of 1000 by 400 pixels. About 200 spectral bands are recorded in the wavelength area between 350 and 2350nm, with a spectral resolution of 5-14nm and at a spatial ground resolution of 15m (seen from height of 600km).

South Africa will provide the satellite bus for the first – indeed, probably for both – of the satellites in the recently announced India Brazil South Africa Dialogue Forum (Ibsa) satellite programme.

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Planned Scanners

Sensor	HyspIRI*	HISUI-ALOS-3	HYPXIM CA
Country and Organization	USA JPL, NASA	Japan METI	France CNES
GSD (m)	60	30	15
Swath at nadir (km)	145	15	30
Wavelength Coverage (nm)	380 – 2500	400 - 2500	400 - 2500
Number of bands	> 200	185	> 200
Spectral Res. (nm @ FWHM)	10	10 VNIR 12 SWIR	≤ 14 VIS ≤ 10 NIR/SWIR
Launch Date	Baseline > 2020	>2016	~ 2019

*Proposed instrument –Pre-decisional for planning and discussion purposes only

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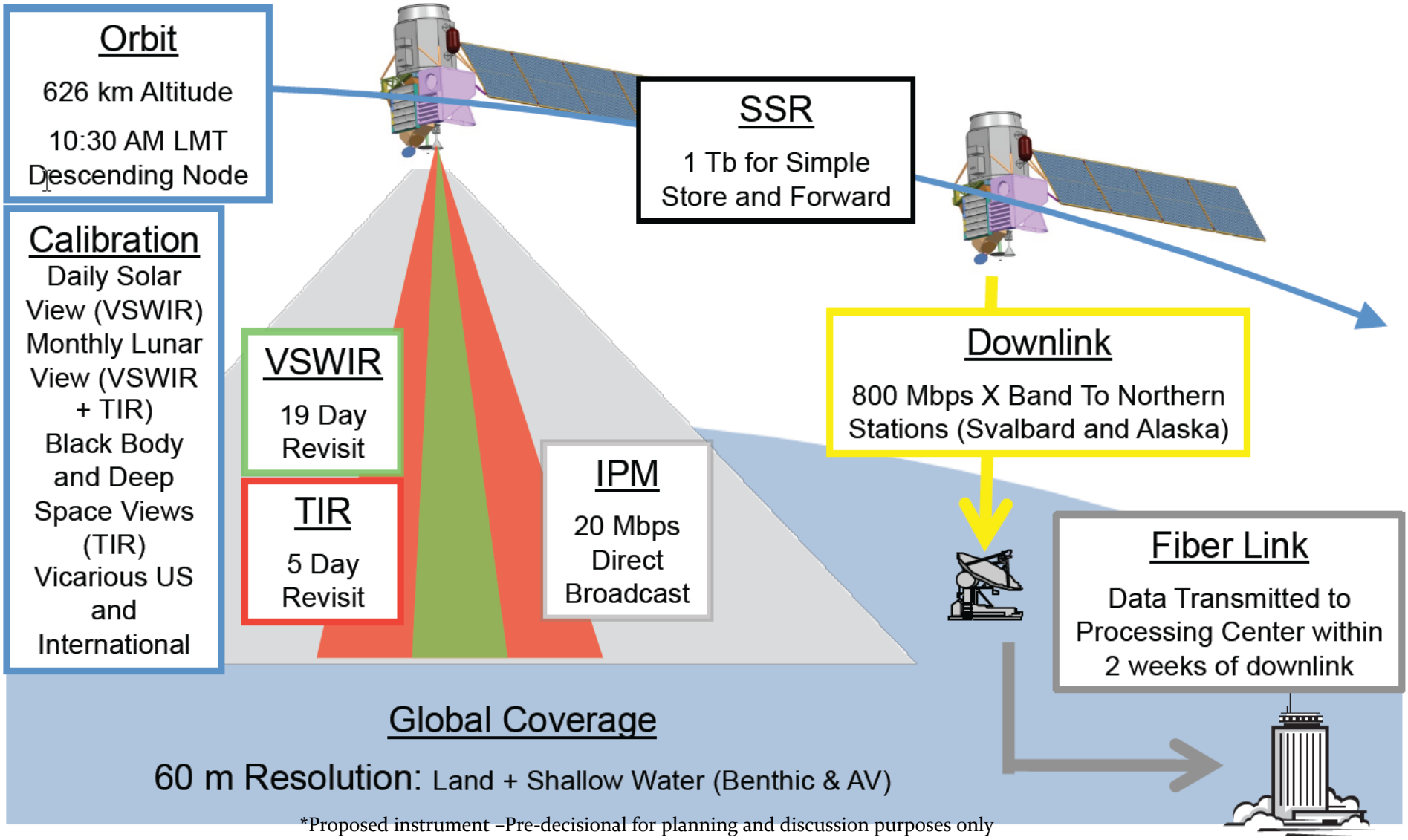
Hyperspectral Infrared Imager - HyspIRI*



*Proposed instrument –Pre-decisional for planning and discussion purposes only

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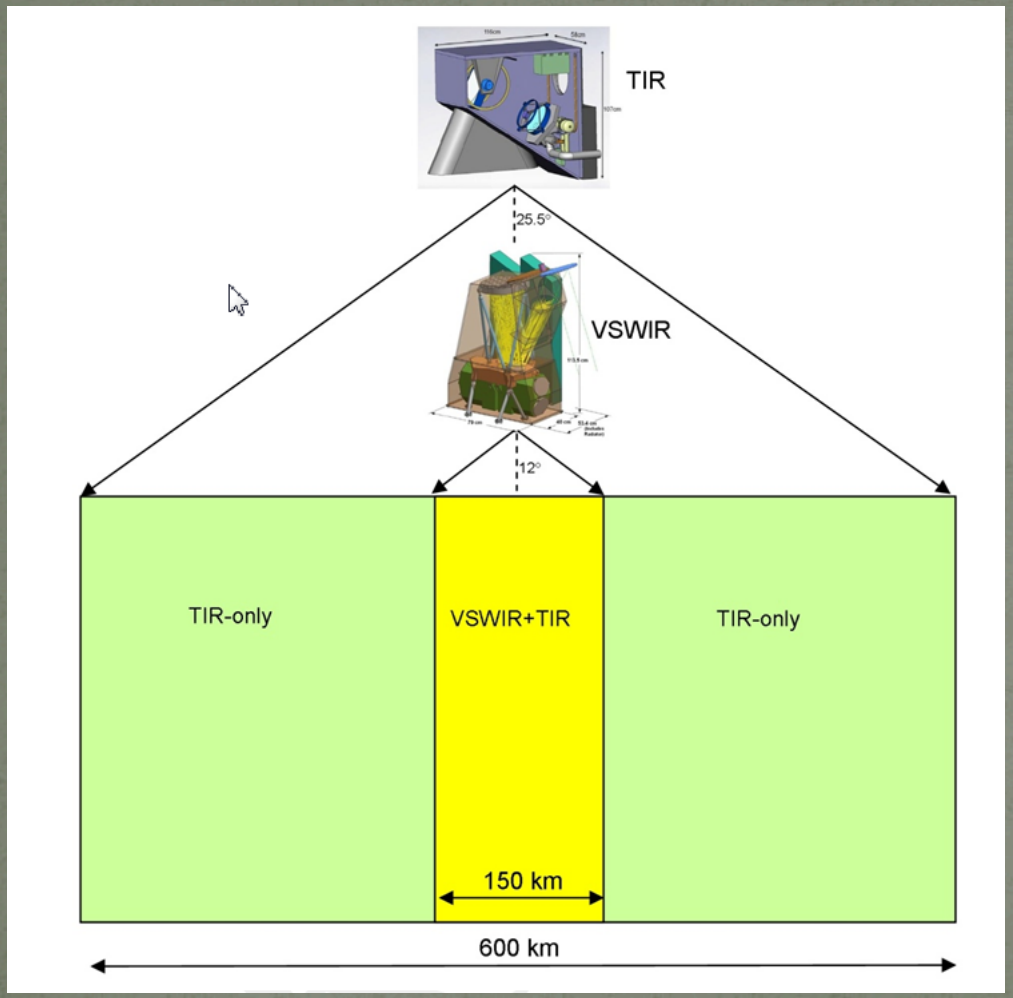
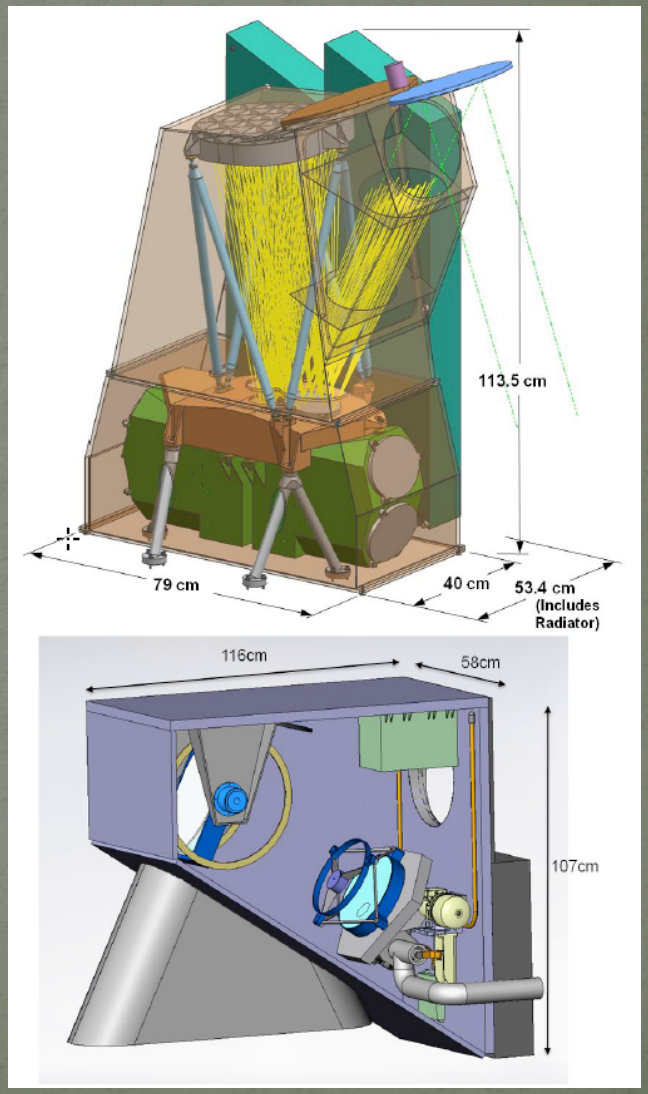
Hyperspectral Infrared Imager - HyspIRI*





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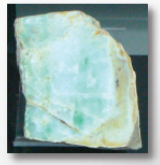
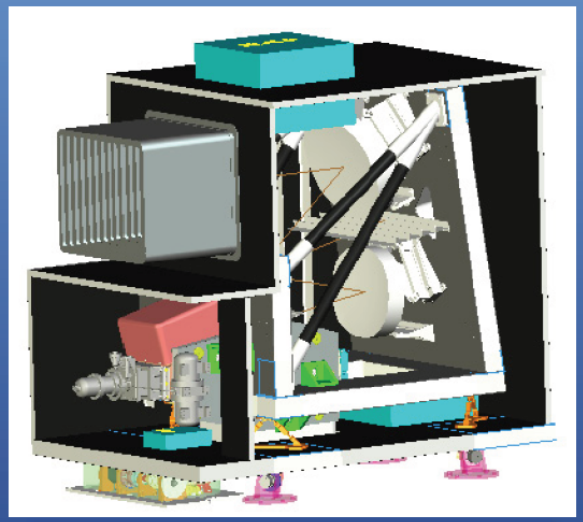
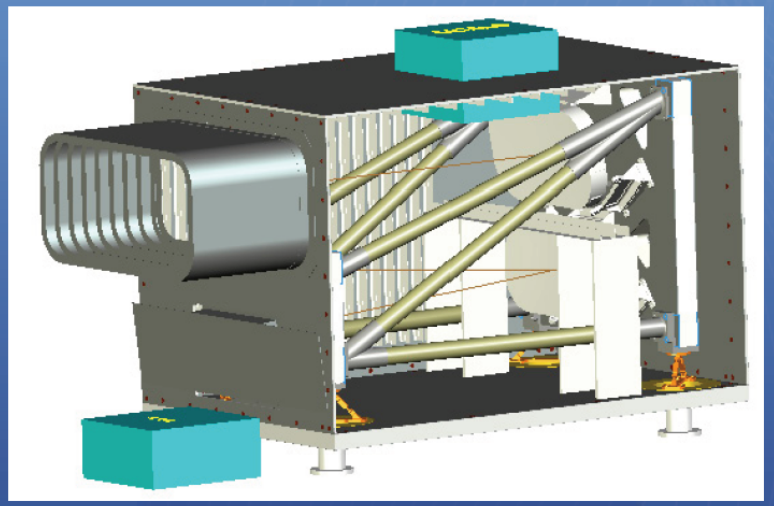
JAXA's ALOS-3 and HISUI (Hyperspectral Imaging Suite)



HISUI



Hyperspectral Imager



Multispectral Imager

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HISUI

Parameter		Requirement
Spatial Resolution and Swath Width		30 m and 30 km
Spectral	Bands	185 (VNIR:57 SWIR:128)
	Range	0.4 - 2.5 μm VNIR:0.4-0.97 μm SWIR:0.9-2.5 μm
	Resolution	10 nm (VNIR), 12.5 nm (SWIR)
Signal to Noise Ratio (30% albedo)		≥ 450 @620 nm ≥ 300 @2100 nm
MTF		≥ 0.2
Dynamic Range		≥ 10 bits (current design=12bit)
Data Compression		Lossless (70%)
Pointing Capability		≈ ±3 ° (±30 km)

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Planned Scanners

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*Proposed instrument –Pre-decisional for planning and discussion purposes only

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HYPXIM

- France's CNES sponsored a mission study to investigate hyperspectral scanners for civilian and military applications
- This resulted in plans for three instrument concepts: HYPXIM-C, HYPXIM-CA and HYPXIM-P Hyper-performance

- HYPXIM-C: 2 satellites, 15 km swath, 15 m resolution, 200 kg weight
- HYPXIM-CA: 30 x 30 km images, 60 kg weight

- HYPXIM-P: 16 km swath, 3-day revisit with pointing, 8 m resolution; 40 bands in TIR with 100 m resolution

SHALOM

Spaceborne Hyperspectral Applicative Land and Ocean Mission

SHALOM is a cooperation between the Italian Space Agency ASI and the Israeli Space Agency ISA based on a satellite carrying a Hyper-spectral Imaging Spectrometer (0,4-2.5 microns), an advanced PRISMA type, and a satellite carrying an infrared camera (8-12 microns).

Phase A study completed early 2013.

Panchromatic

- Swath: 30 km
- Spatial GSD: <2.5 m
- Spectral ranges: 400-700 nm
- SNR = 240

Hyperspectral

- Swath: 30 km
- Spatial GSD: <\0 m
- Spectral ranges (contiguous spectrum):
  - VNIR: 400-1010 nm
  - SWIR: 920-2500 nm
- Spectral resolution: 10 nm
- SNR

  VNIR: 200 (400-1000 nm)
  600 (@650nm)

  SWIR: 200 (1000-1750 nm)
  400 (@1550nm)
  100 (1950-2350 nm)
  200 (@2100nm)

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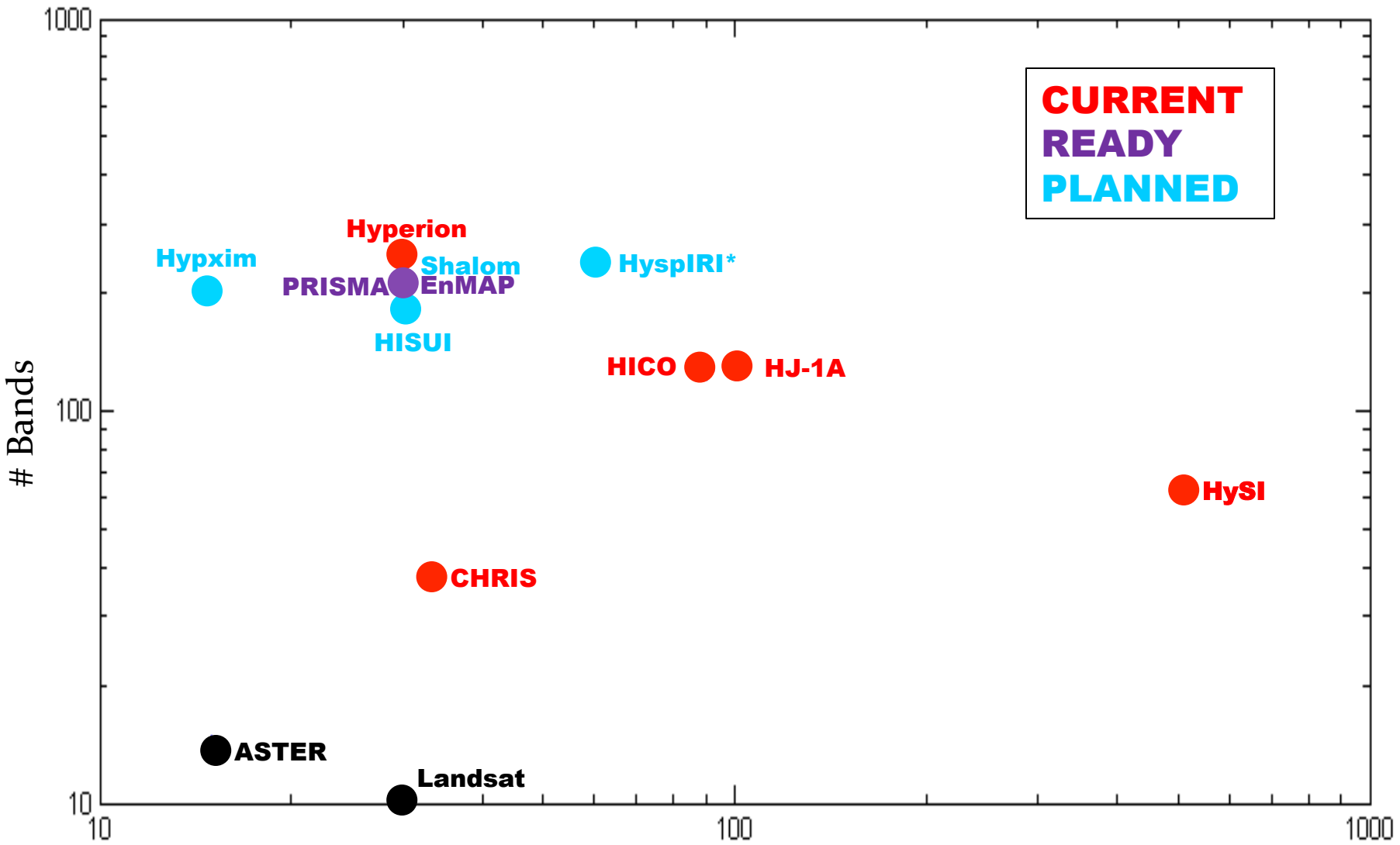
IFOV vs Number Bands



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Spectral Coverage and Swath Width

	VNIR	SWIR	TIR	Swath
Landsat	4	2	1	180
ASTER	3	6	5	60
CHRIS	37			13
HYSI	64			130
Hyperion	85	135		7
HJ-1A	110			50
HICO	128			42
EnMAP	85	135		30
PRISMA	90	145		30
HISUI	85	100		15
HYPXIM-P	65	135	40	30
HyspIRI*	85	135	8	145/600
Shalom	90	145		30

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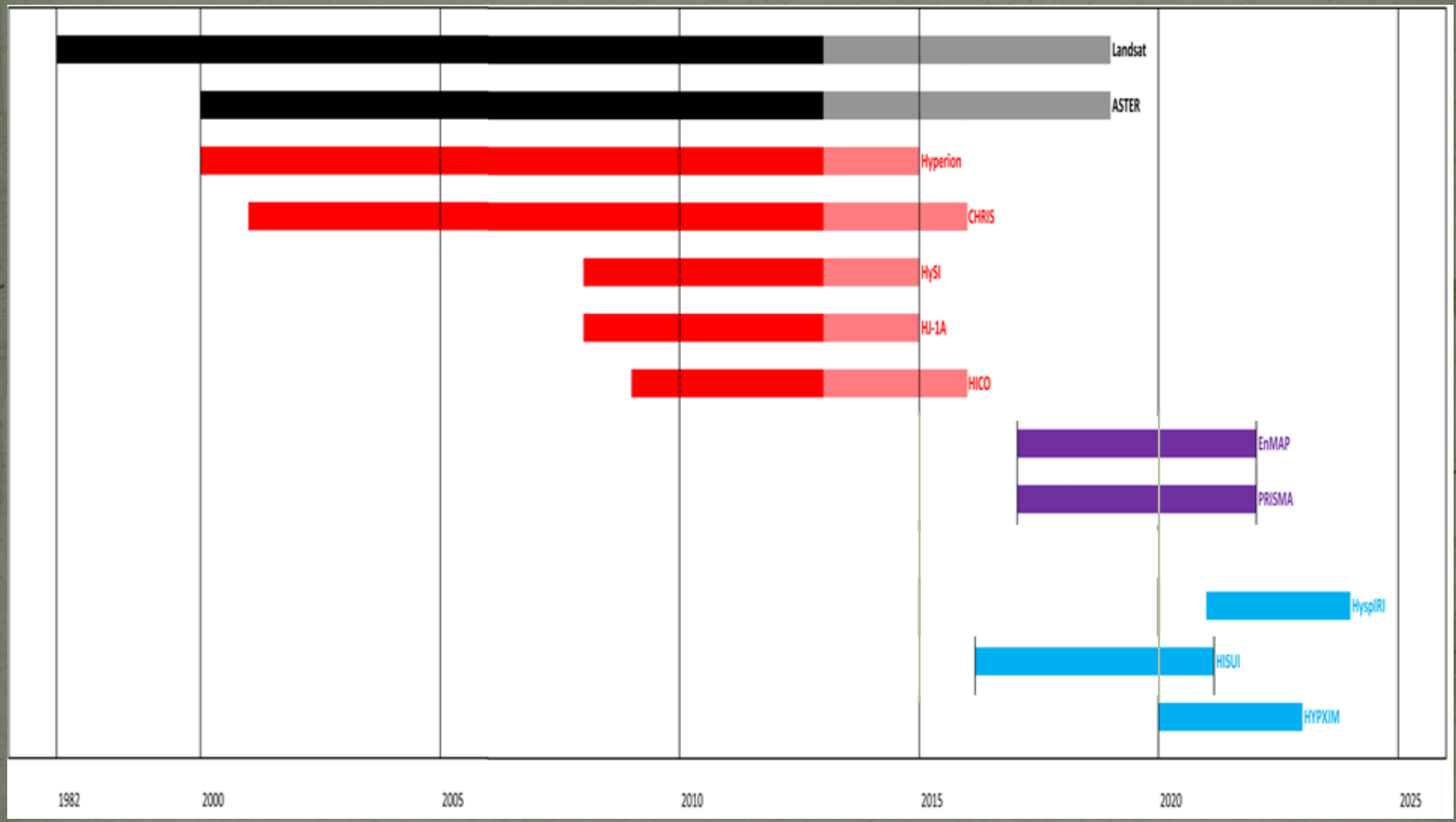
Instrument Lifetimes



Ecosystem Spectral Information System (EcoSIS):

Integration of Spectral Data with Measurements of Vegetation Functional Traits

Alphabetically:

Phil Dennison, University of Utah

John Gamon, University of Alberta, SpecNet

Simon Hook and Rob Green, JPL

Shelley Petroy and Tom Kampe, NEON, Inc.

Dar Roberts, UC-Santa Barbara

Phil Townsend and Shawn Serbin, University of Wisconsin

Susan Ustin, UC-Davis

Art Zygielbaum, University of Nebraska

…..and…..

You!

Why Spectral Libraries?

Tool for discovery.

Document species characteristics and map them.

Characterize the diversity of function and its variability on earth.

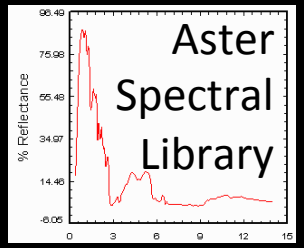
Deliver scientifically vetted data to an international and open community of researchers…

…and metadata to ensure inter-comparability.

Tools to facilitate the synthesis of large data sets by community.

Precedents:

USGS science for a changing world



TERN Terrestrial Ecosystem Research Network

AusCover

RSL SPECCHIO

neon™ National Ecological Observatory Network

CarnegieSpectranomics

SpecNet

Example Contributions

Table 2. Examples of spectral data contributions from the project Principal Investigators.

Site	Veg Type/Species	Vegetation Conditions	Spectral Data	Temporal/Sample Characteristics	Ancillary Data
Missoula, Montana	lodgepole pine, sagebrush	Retained old and emergent new needles, separated into two samples	hemispherical leaf/needle reflectance and transmittance, 350-2500 nm	weekly for 4+ months, 4 sites, 8 samples per site, adaxial and abaxial sides	Time series moisture content, partial biochemical analysis
Missoula, Montana	lodgepole pine, sagebrush	Maturing leaves and needles over field season	branch and canopy field spectra, 350-2500 nm	weekly for 4+ months, 4 sites, approximately 10 areas per site	Time series live fuel moisture
Fivemile, Utah	sagebrush, NPV, soil	Mature sagebrush with declining canopy moisture over time	canopy field spectra, 350-2500 nm	every two weeks for 4 months, 10 canopies per site for 5 sites	Time series live fuel moisture
Range Creek, Utah	desert scrub, NPV, soil		canopy field spectra, 350-2500 nm	field campaign, approximately 15 plant species	
Santa Monica Mountains, California	chaparral, coastal sage scrub, NPV, soil		branch and canopy field spectra, 350-2500 nm	field campaigns 1995-2000, approximately 20 plant species	
Mead, Nebraska	corn, soy crops, row planted	irrigated and non-irrigated fields	350-2500 nm reflectance	weekly through growing season covering ten years, 36 samples per field, 3 fields	pyranometer, quantum sensor, GPS, IRT
				Roughly monthly	

Attribute	Variable
Plot/Sample ID	A06-42
NEON Domain	1
Domain Site	Core
Type	Vegetation
Form	Deciduous Tree
Measurement Scale	Leaf
Estimate - Sample Location on Tree	Mid Canopy - exposed
Measurement Type	Field
Instrumentation	ASD
Spectra Collection Protocol	Plant Probe
Calibration Protocol	Plant Probe Reference
Measurent Protocol	Standard Measurement Sequence
Spectra per Sample	20
Samples per Save	1
Acquisition Conditions	Not recorded
Field Personnel	Nathan Leisso

Example Data – a whole range of data and metadata in different formats

D1373a

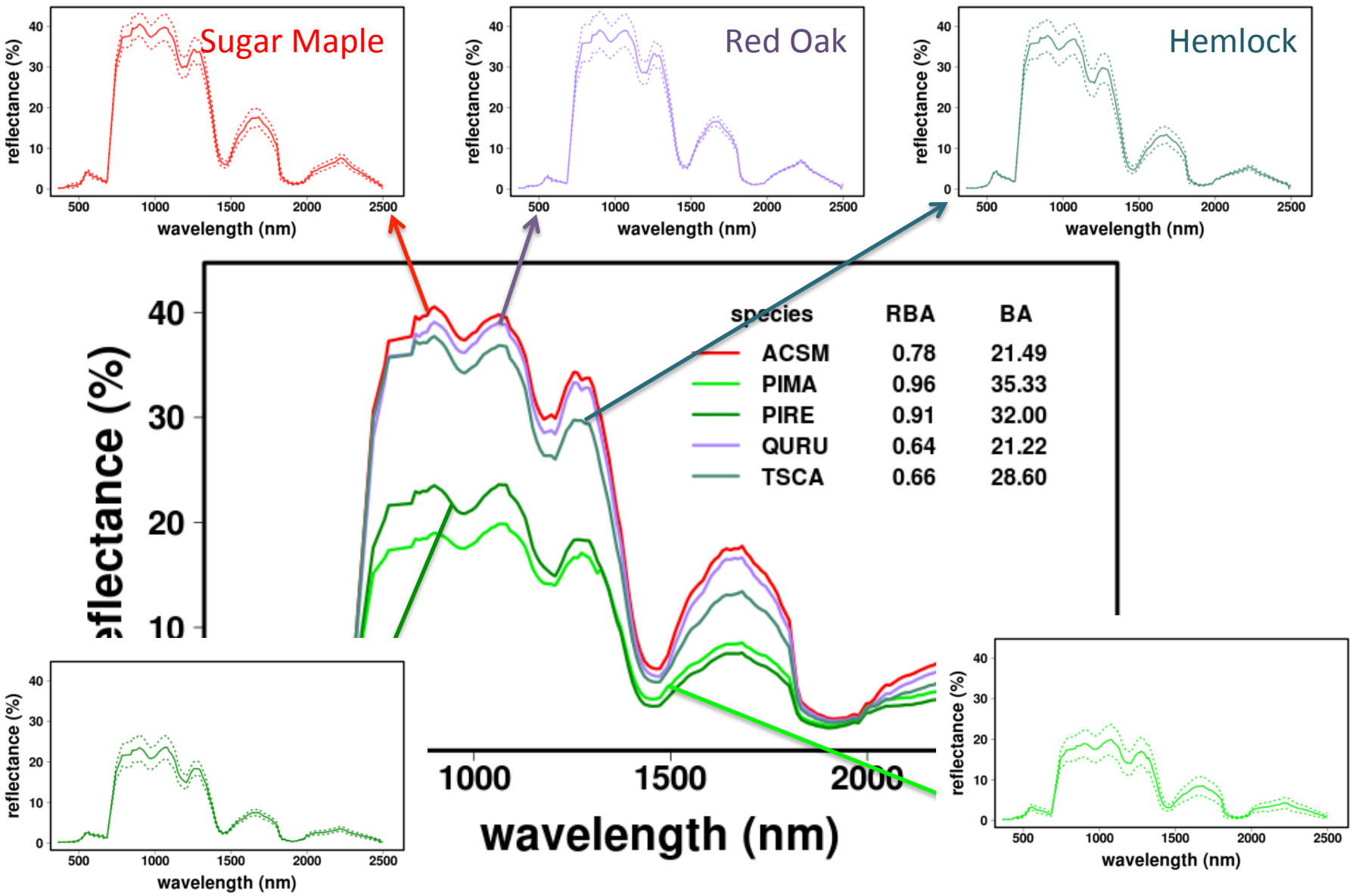
Douglas-fir #1373 sampled from Wind River Crane on Sept 9, 1996, by John Gamon & John Surfus

"Dark-to-Light" reflectance spectra during 10 minute transition from darkness to full sun

For method, see Gamon JA, Surfus JS (1999) Assessing leaf pigment content and activity with a reflectometer. New Phytologist 143:105-117.

Difference Spectrum (duaDIFF, ColumnW) shows delta Reflectance (10 minute - 0 minute of sun), illustrating features due to Xanthophyll pigment conversion and chl fluorescence quenching

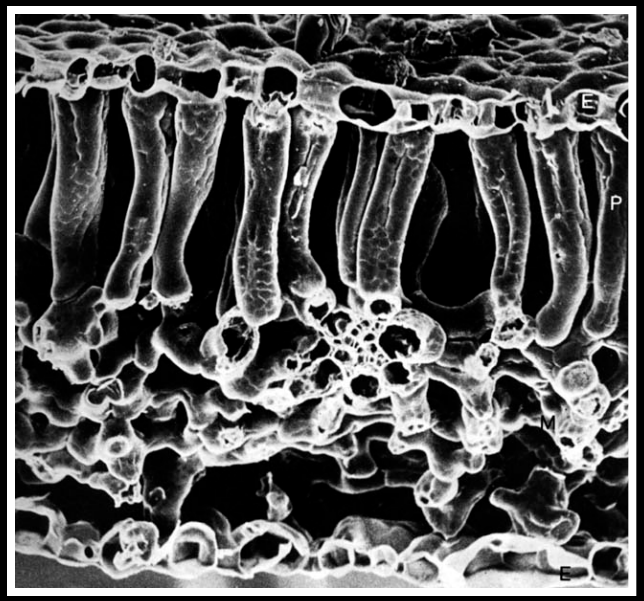
minutes	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
Wavelength	dua00001	dua00002	dua00003	dua00004	dua00005	dua00006	dua00007	dua00008	dua00009	dua00010	dua00011	dua00012	dua00013	dua00014	dua00015	dua00016	dua00017
305.56	0.349091	0.32	0.34545	0.32	0.32364	0.34545	0.33455	0.32364	0.33818	0.34545	0.36727	0.33091	0.34909	0.32364	0.36364	0.32364	0.35273
308.91	0.36619719	0.35563	0.34507	0.33099	0.34155	0.32747	0.34155	0.34155	0.33099	0.35211	0.39789	0.35211	0.33099	0.34507	0.35916	0.35563	0.35916
312.26	0.36824304	0.375	0.34122	0.36486	0.37838	0.33784	0.34797	0.36149	0.35135	0.37838	0.35473	0.38176	0.36486	0.40203	0.36824	0.38176	0.37162
315.61	0.34768208	0.34768	0.36424	0.37417	0.3543	0.36755	0.37748	0.36093	0.3543	0.36755	0.35762	0.37748	0.37417	0.39073	0.35762	0.38411	0.38079
318.95	0.35915487	0.33099	0.33803	0.35915	0.34507	0.35915	0.37676	0.37324	0.38028	0.3662	0.35211	0.35563	0.35563	0.32746	0.37324	0.34155	0.38028
322.3	0.36610165	0.34576	0.3661	0.35254	0.34915	0.3322	0.32881	0.35932	0.35932	0.33559	0.38305	0.34915	0.36271	0.32542	0.3661	0.37288	0.35932



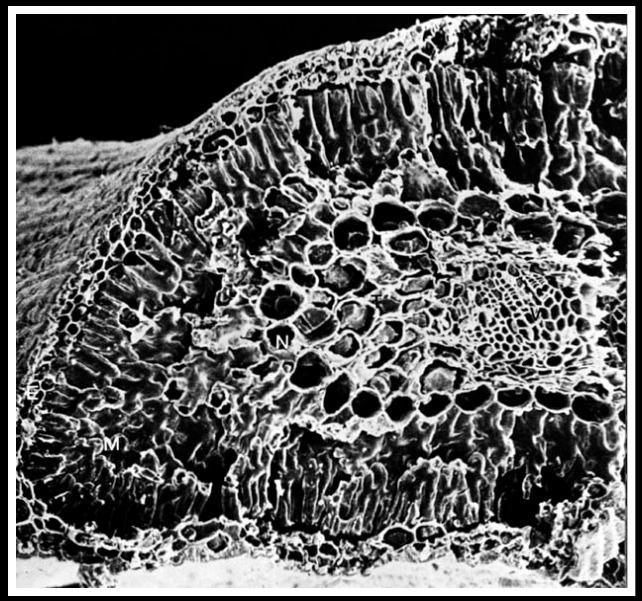
Spectral information can be about about species, differences between species, and geographic variations within a species. It can also be at the canopy and the leaf level.

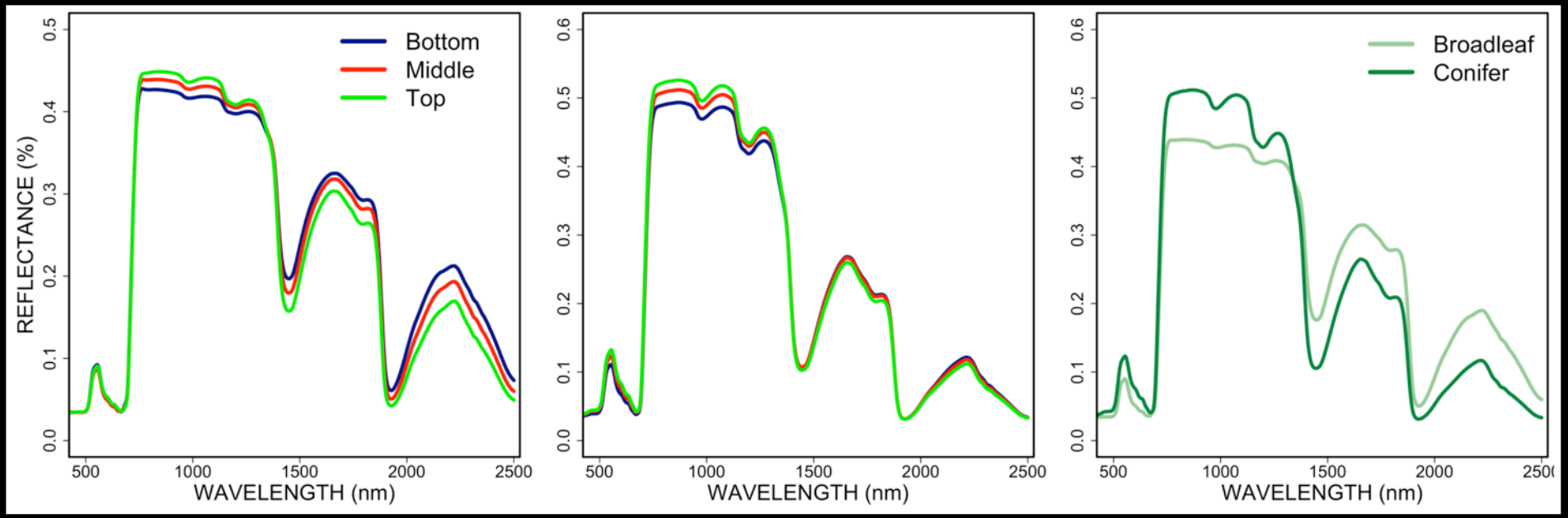
Leaf-level spectra

Maple

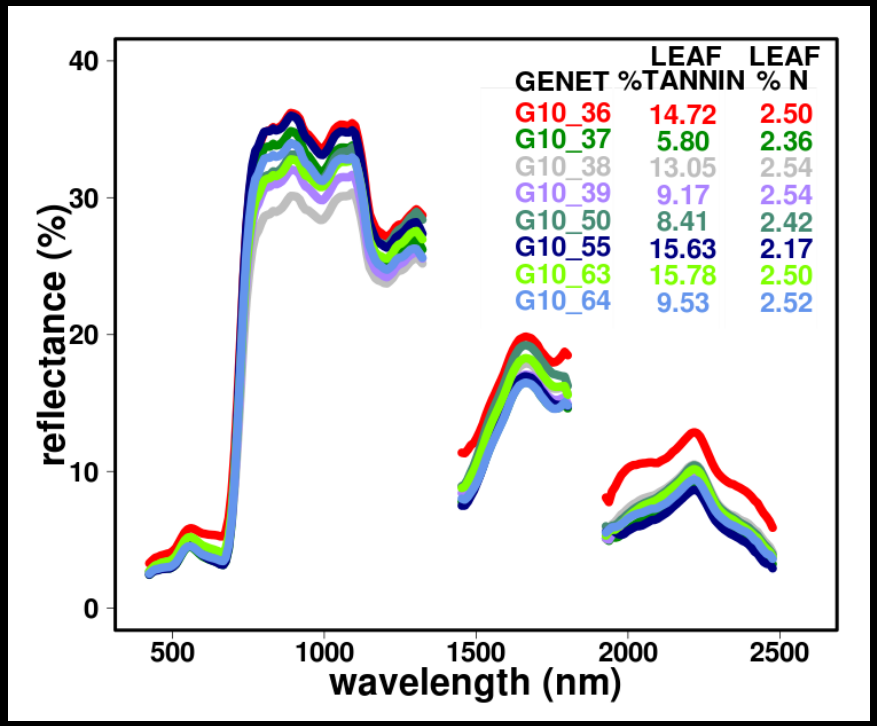


Pine



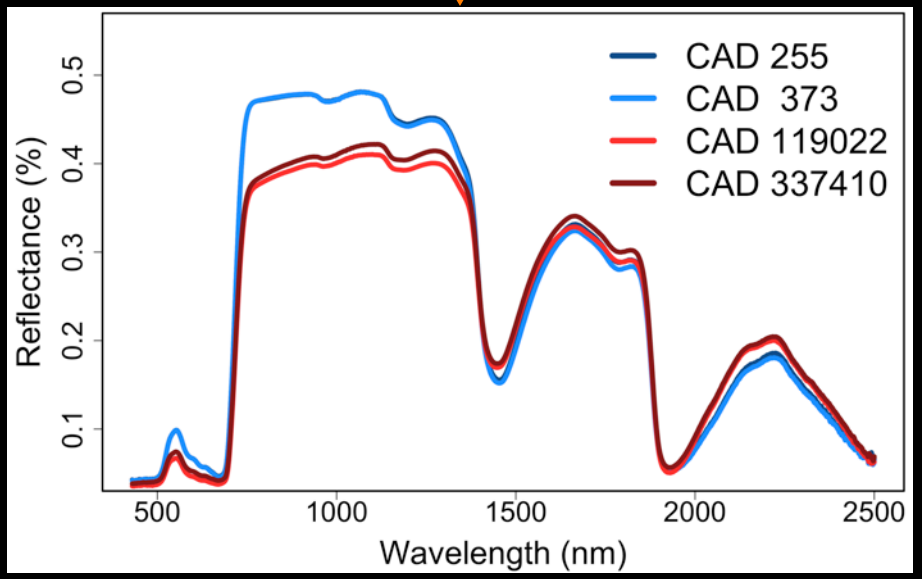


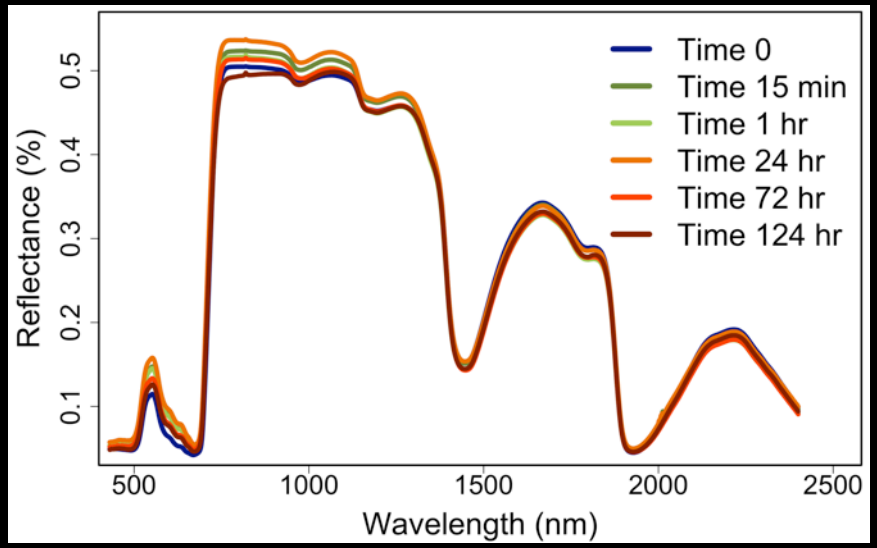
Spectral information can be about differences in reflectance through the canopy of a tree.



Genotypes of aspen.
Different reflectance.
Different chemistry.

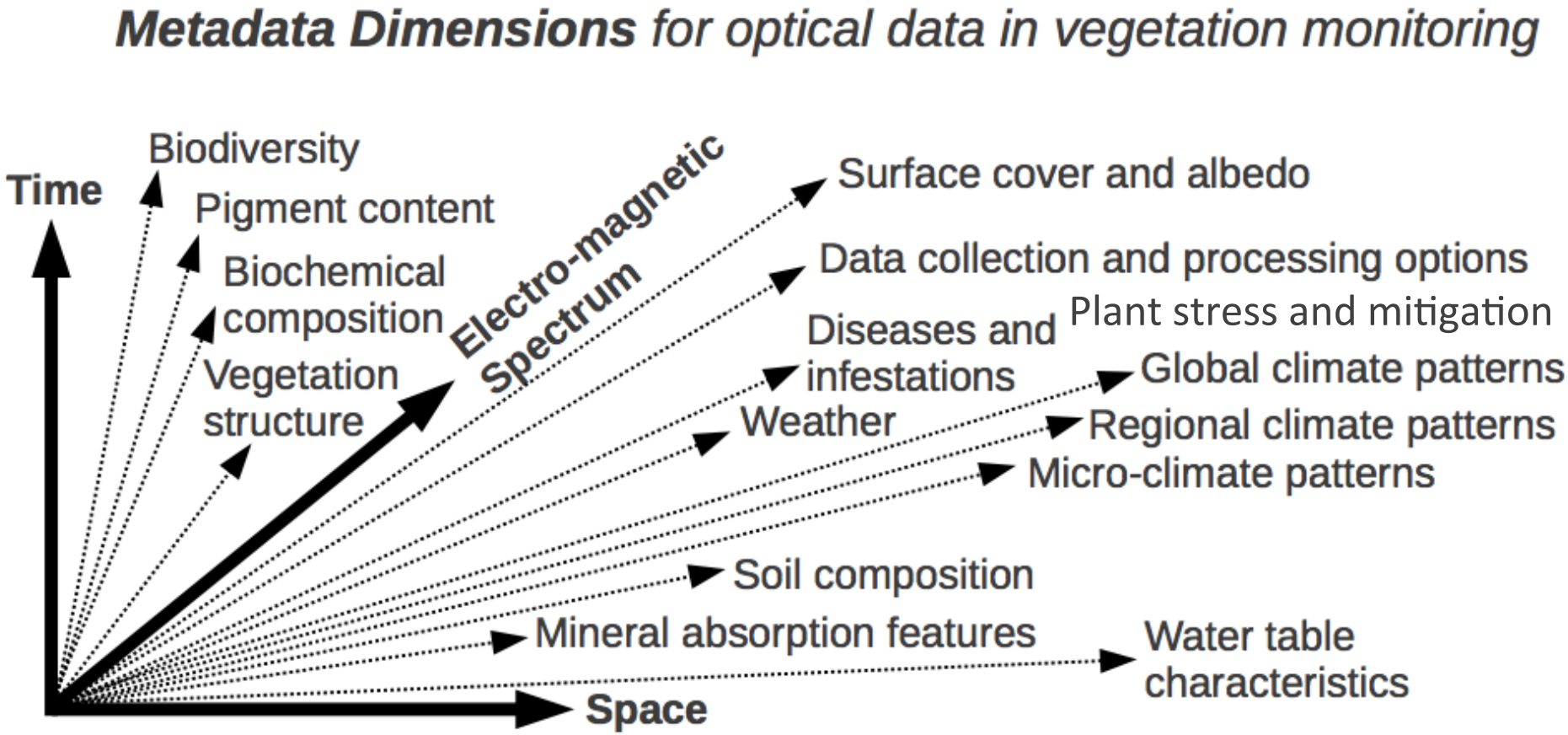
Soybeans: same variety, different levels of pest pressure.





Milkweed.
Rapidly induced chemical defenses to perturbations.

Spectral data serve as “proxy” measurements for all ranges of underlying properties and functions in ecosystems that are costly, impractical, inconvenient or impossible to otherwise characterize at broad spatial and temporal scales.



G. Pastorello and J. Gamon

EcoSIS

EcoSIS Activities
(lead institutions)

- Develop Database Back-End (UC-Davis, JPL)
- Develop EcoSIS User Interface (UC-Davis, JPL, UW)
- Metadata Standards (UW, NEON, Alberta, UNL)
- Best Practices (UCSB, NEON, Alberta, UNL)
- Populate EcoSIS (all members, coordinated by UW)
- QAQC, Error Assessment (UW, JPL)
- EcoSIS Tools (UW, Alberta, community)

Deliverable

EcoSIS Public Database

JPL

- Spectral Library (0.35-13.0 µm)
- Metadata
- Associated measurements (species, chemistry, etc.)

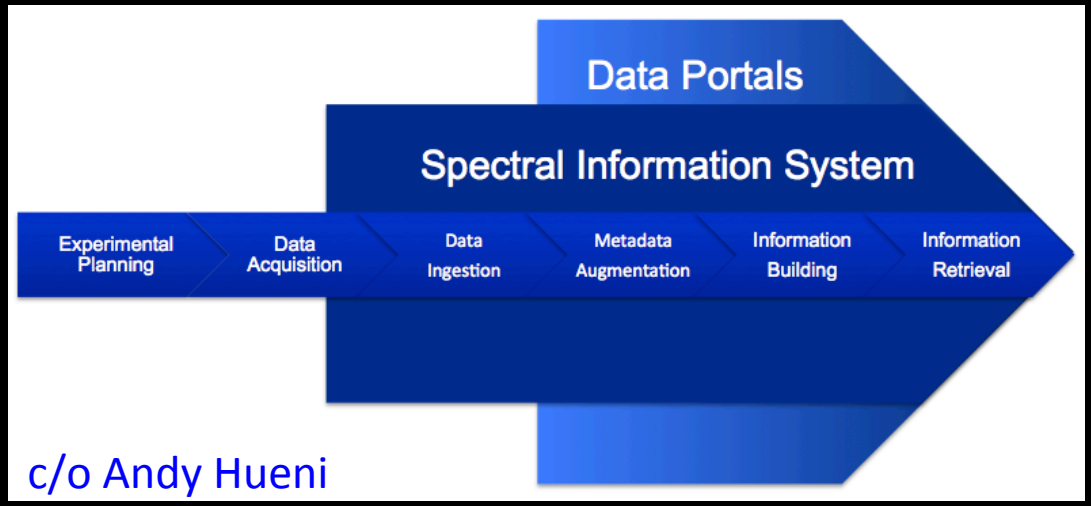
EcoSIS Tools (Open Source)

- Visualization, Query, Discovery

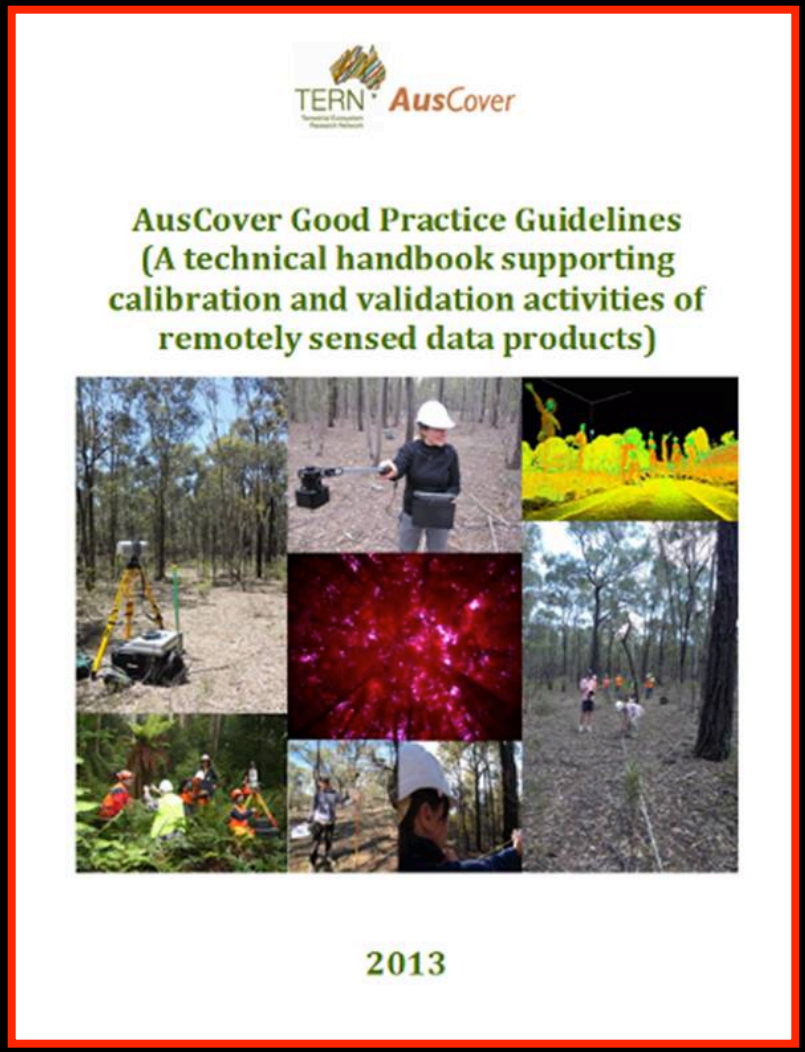
EcoSIS Outcomes
(via community engagement)

- Accommodation of Legacy and New Data Sets
- Evolution of Open-source Tools for Discovery & Analysis
- Synthesis Studies & Meta-Analyses
- Development of a Broader EcoSIS User Community
- Growth of EcoSIS to Reflect Evolving Science Needs

International linkages are important:



c/o Andy Hueni



Moving Forward:

Community participation is essential:

- Decision-making open process
- Review/oversight committee
- Your data contributions to EcoSIS
- Open source data and tools

Virtual meetings, side meetings at AGU, etc.

join-ecosis-community@lists.wisc.edu

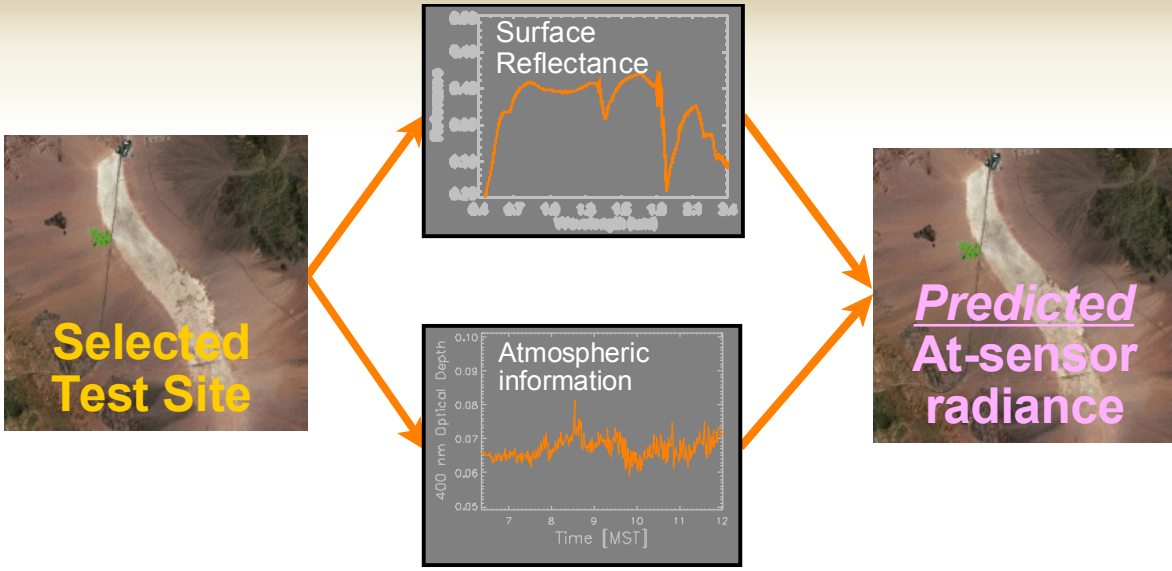
Role of imaging spectrometer data for model-based cross-calibration of imaging sensors

K. Thome

NASA/GSFC

Talk overview

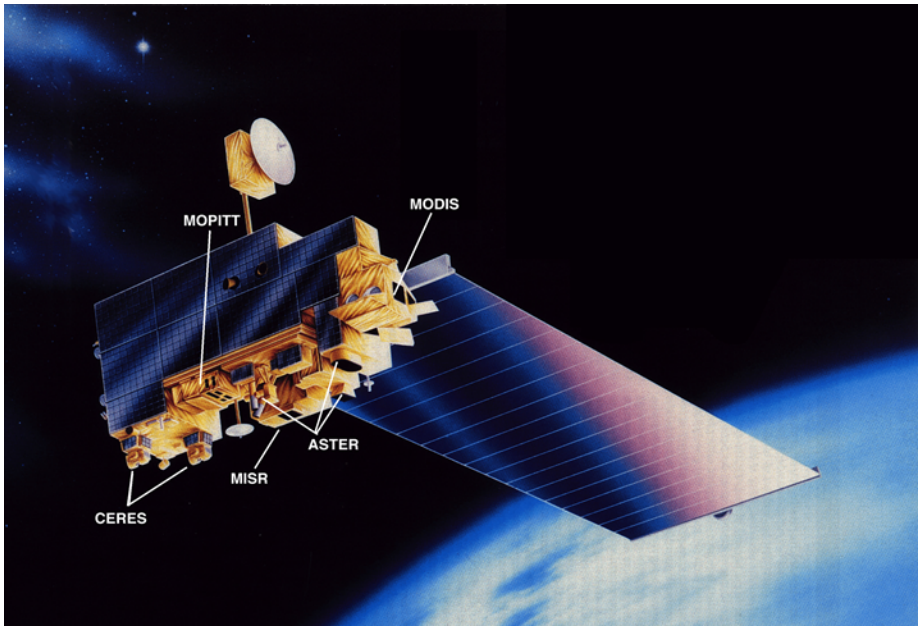
Discuss SI-traceable cross-calibration approach relying on test site characterization



- Site characterization benefits from imaging spectrometry to determine spectral bi-directional reflectance of a well-understood surface
- Outline
  - Cross calibration approaches
  - Uncertainties
  - Role of imaging spectrometry
  - Model-based site characterization

Need for cross-calibration

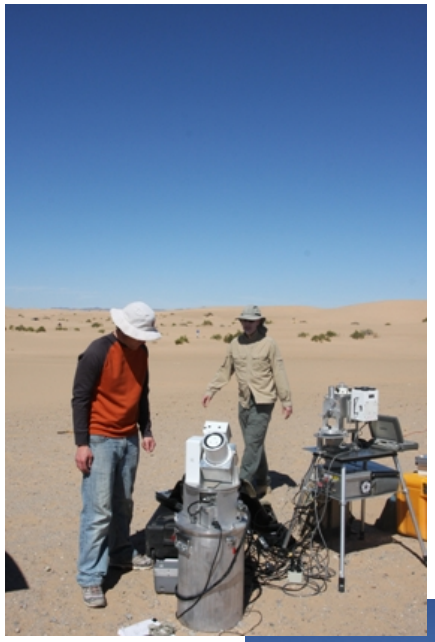
Assume that a single sensor does not give all of the data needed for a science question



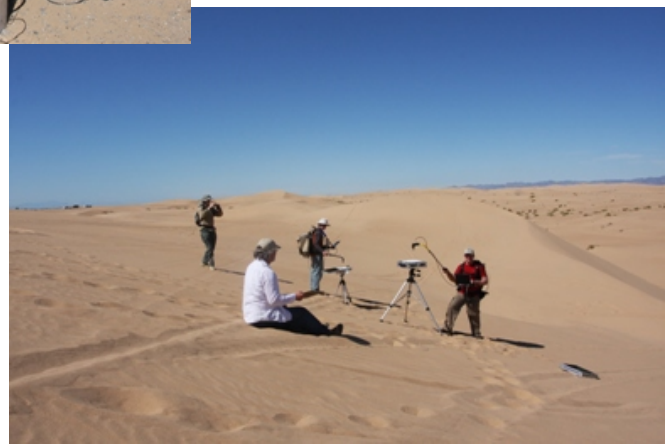
- Multi-sensor applications benefit from having all sensors on the same radiometric scale
- Consider Terra platform for which the synergy of multiple sensors is a key to the mission's success

Best of both worlds

Combine philosophy of in-situ measurements with invariant site approaches



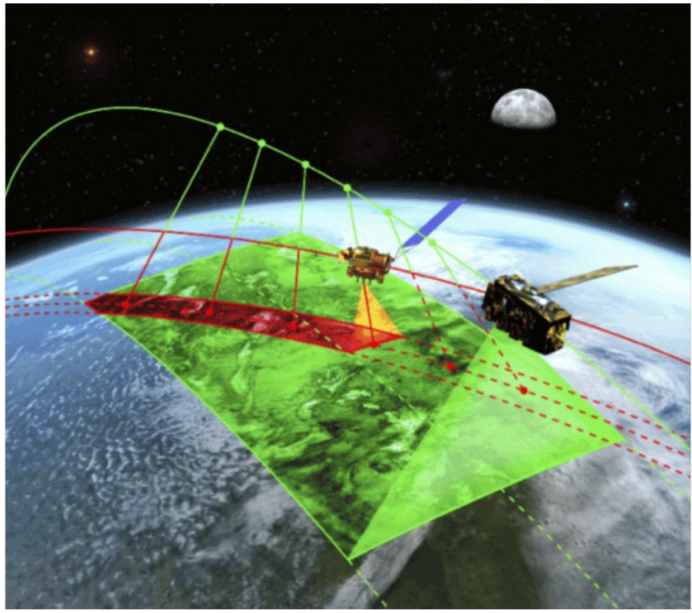
- Site measurements become basis for a physically-based model
  - Atmospheric
  - Surface
- Allows for an SI-traceable result
- **Requires innovative measurement approaches**



On-orbit cross calibration

Recent years have seen great advancements in approaches for cross-calibration

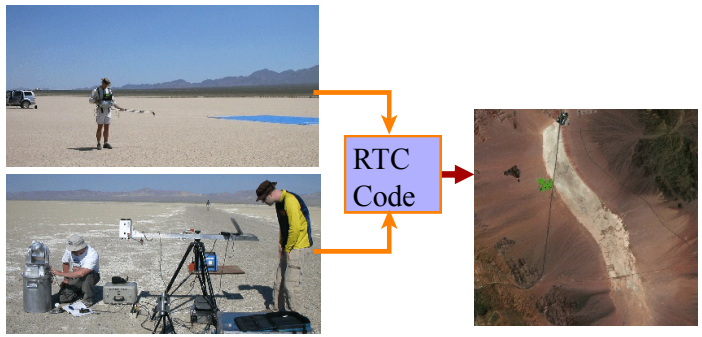
- Typically near-coincident views
  - Simultaneous Nadir Overpasses at Arctic sites
  - Chance coincidence at mid-latitude sites
- More recent work has emphasized methods that do not require simultaneous data collections
  - Invariant scene approaches
  - In-situ ground measurement methods
- Methods with SI traceability do not require sensor data to overlap in time

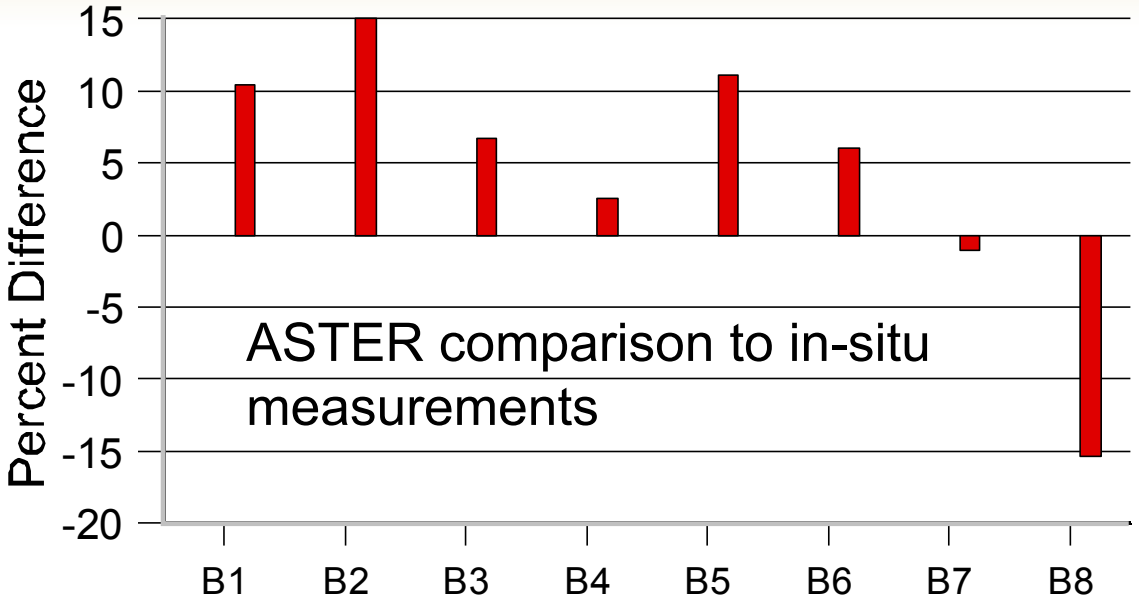


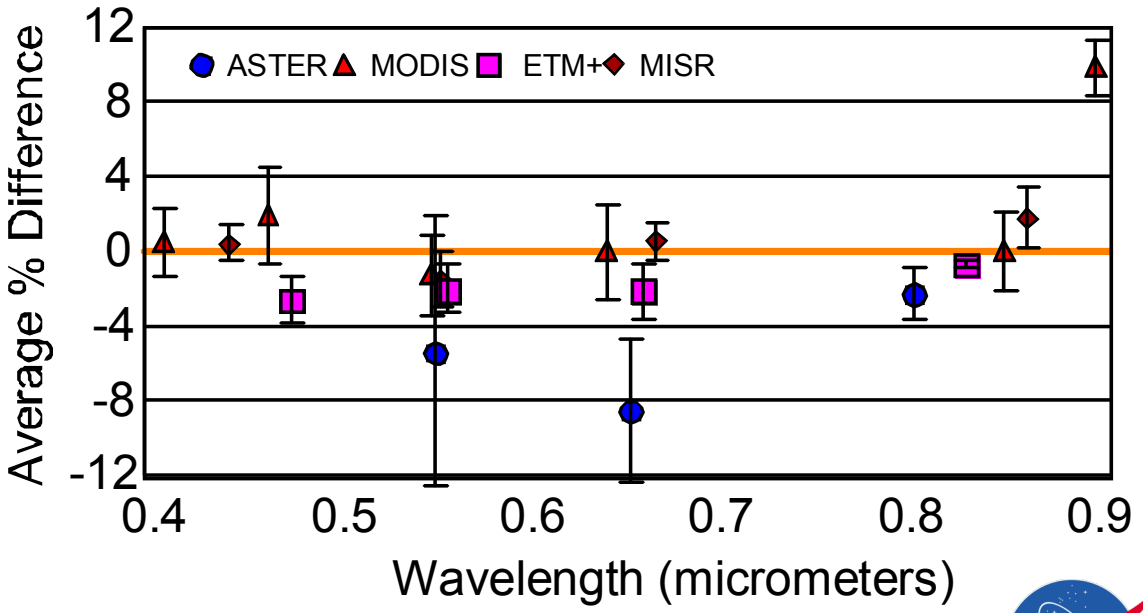
Calibration relative to in-situ

Calibration to SI-traceable, ground-based measurements

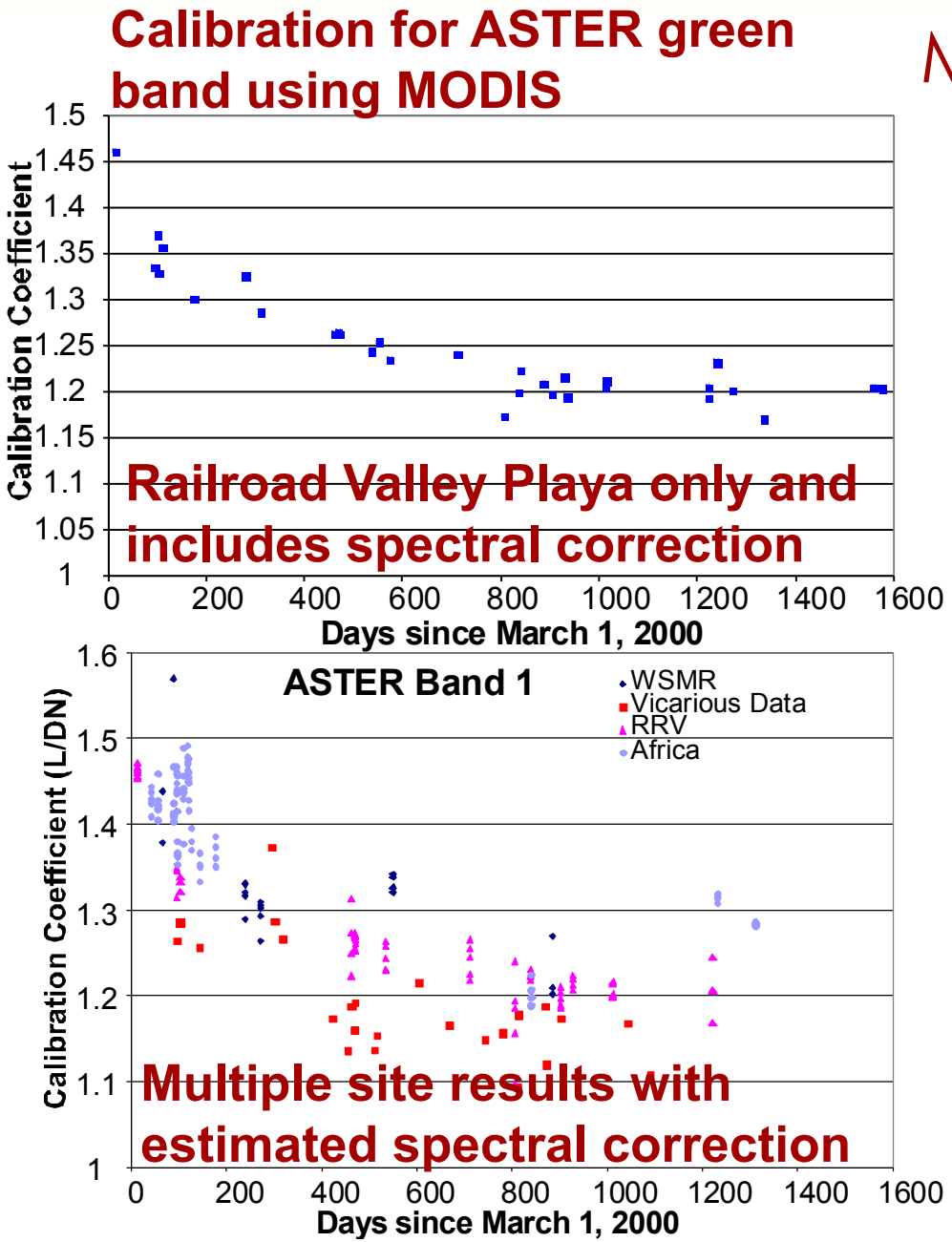
- Cross-calibration relative to in-situ data
- Requires sensors at ground site at overpass time







Coincident view cross-calibration



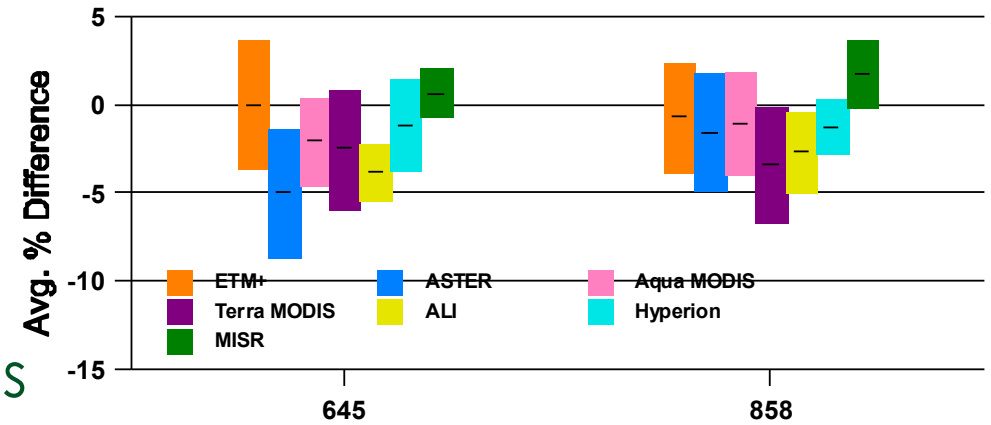
MODIS and ASTER offer same platform, coincident views, similar bands

- ASTER Band 1 (green band) results using MODIS
- Scatter caused by
  - Spectral band differences
  - Registration effects
- Lower graph includes in-situ results

Cause of scatter

Multidimensionality of the at-sensor radiance and non-identical sensors cause scatter

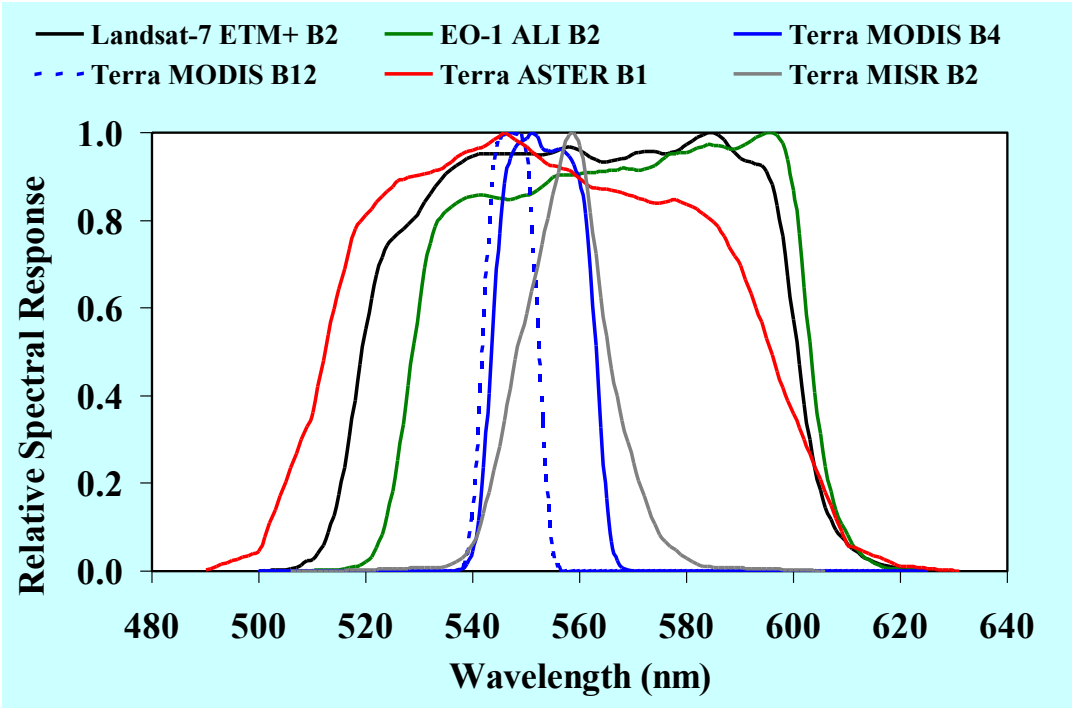
- View/solar geometry differences
  - Surface reflectance changes (BRDF)
  - Atmospheric effects
- Temporal differences
  - Solar angle
  - Surface reflectance
  - Atmospheric changes



- Spatial differences and registration effects
- Spectral differences
- Sensor effects
- All successful methods attempt to account for these effects or minimize the sensitivity

Spectral band differences

ETM+ Band 2 Analogs	A	B	C	D	E	F
A: Landsat-7 ETM+ B2	1	0.996	1.005	0.990	0.988	0.989
B: EO-1 ALI B2		1	1.009	0.994	0.992	0.993
C: Terra ASTER B1			1	0.985	0.983	0.984
D: Terra MODIS B4				1	0.998	0.999
E: Terra MODIS B12					1	1.001
F: Terra MISR B2						1

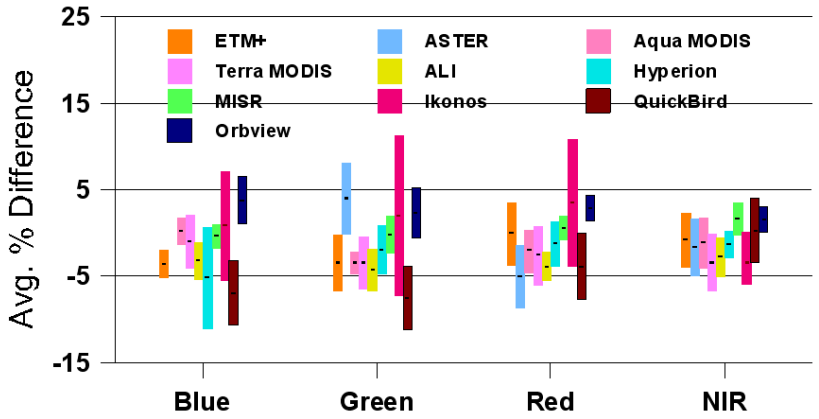


Uncertainty due to spectral differences decrease as **hyperspectral** data of sites are accumulated

Ground data, Hyperion, SCIAMACHY

Site characterization

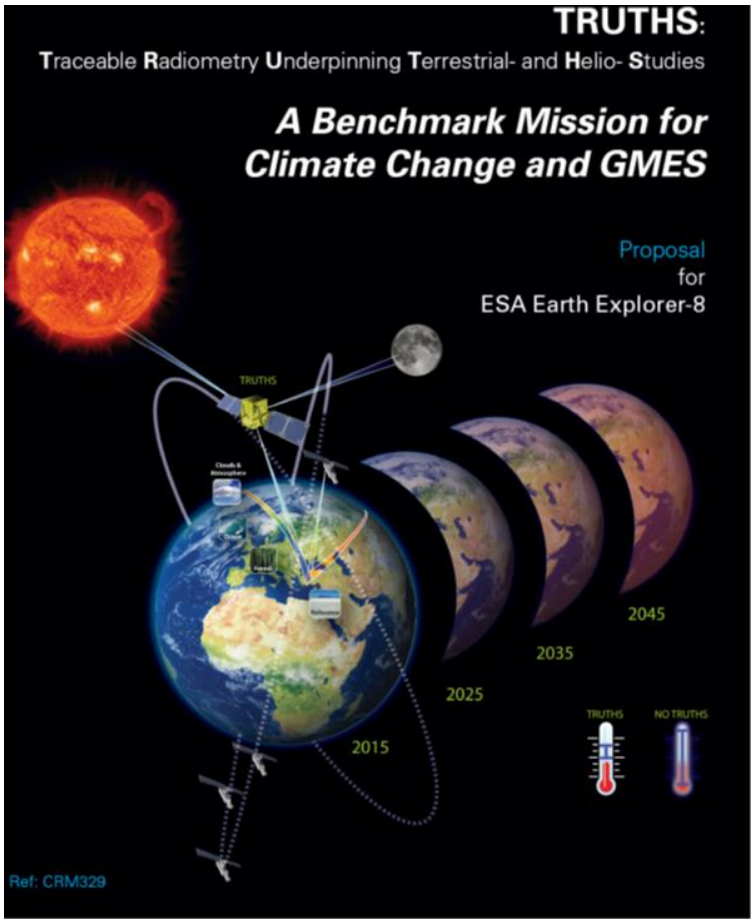
Imaging spectrometry can provide key measurements to understand test sites

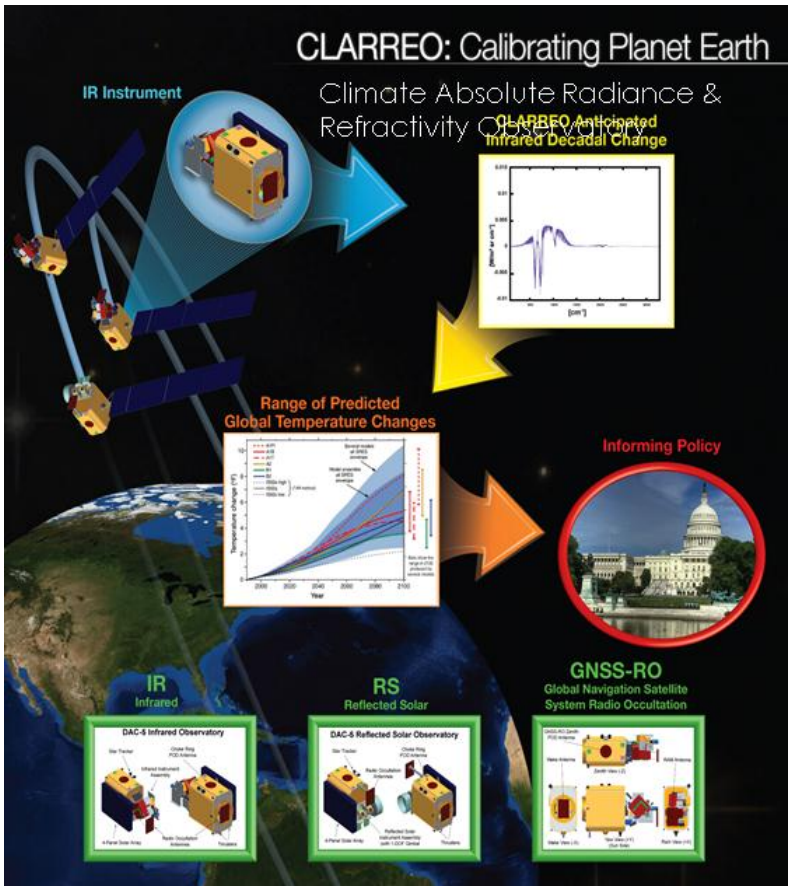


- Cannot decouple
  - On-orbit sensor effects
  - Atmospheric variability
  - Surface variability
- Past results indicate that all three play a role
  - Note that the comparison of sensors improves in the NIR
  - Bands with highest SNR for on-orbit and ground-based sensors
  - Atmospheric effects are not as dominant
- Sensors to do this need to be improved

Site characterization

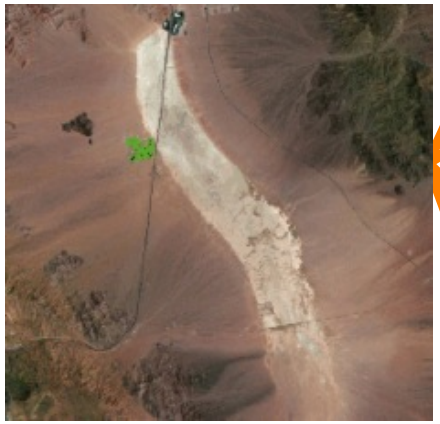
Well-characterized imaging spectrometers such as CLARREO or TRUTHS or HyspIRI can provide site characterizations for SI-traceable cross calibrations





Basic approach

Selected Test Site



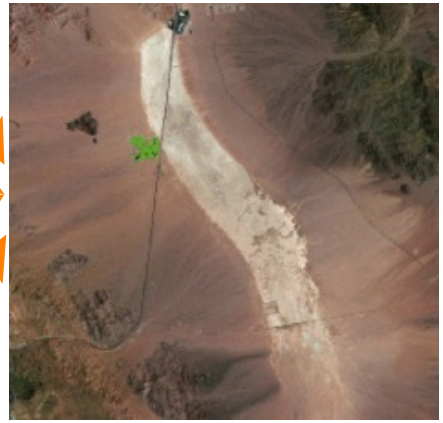
Ground-based Measurements

Satellite-based Measurements

Airborne-based Measurements

Model-based "Measurements"

Predicted At-sensor radiance



Radiance is for arbitrary
1) Time
2) View angle
3) Sun angle

SI-Traceable with documented error budget and uncertainty

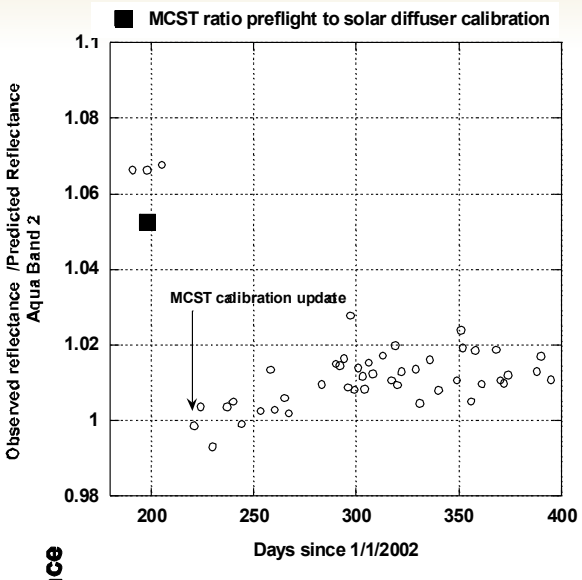
Emphasizes the source radiance

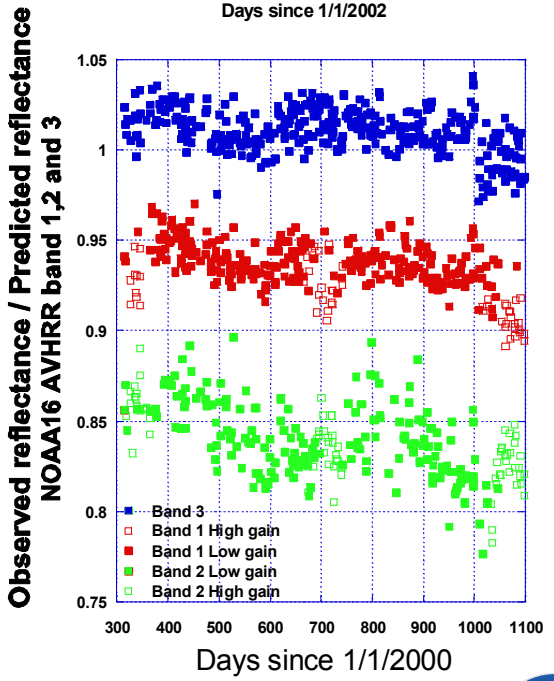
Moves away from one-to-one cross calibrations and empirical only

Model-based measurements

Others have used a similar pathway

- Dome C empirical corrections for BRDF and atmospheric effects
- Inclusion of BRDF models in desert site work for MODIS, AVHRR, MSG
  - Surface BRDF model corrected by Terra MODIS or POLDER
  - Includes atmospheric corrections based on climatological values
- Coupling automated data with surface models
- Deep convective cloud calculations in radiance

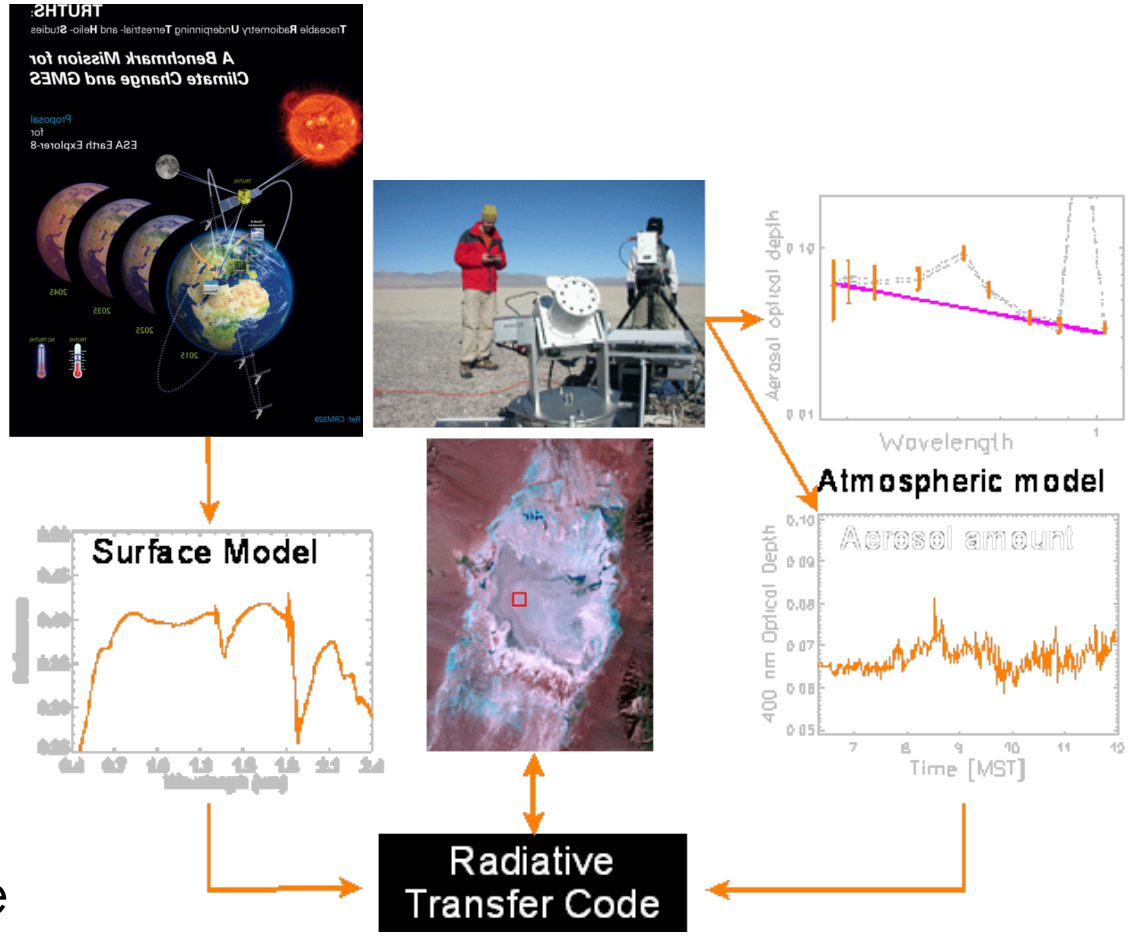




Key measurements

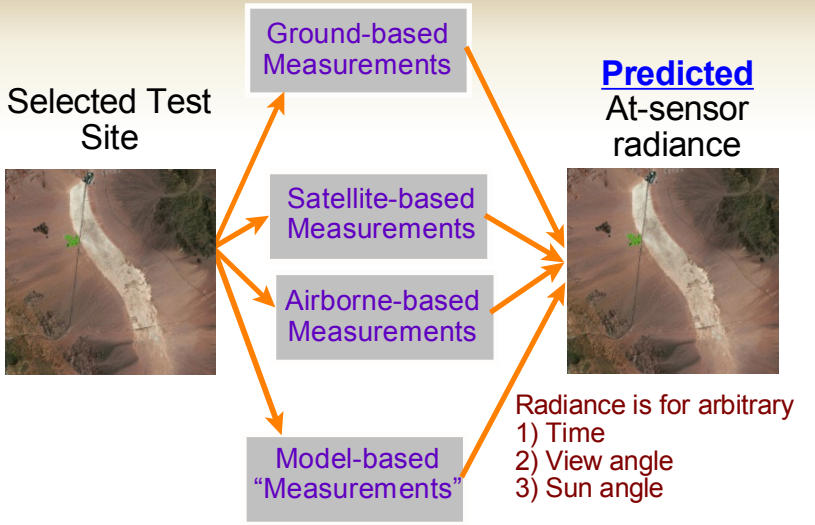
Spectral and directional reflectance of surfaces are highest priority

- Temporal sampling
  - directional reflectance (or at least validation)
  - Site stability
- Imaging provides spatial information
- Spectral samples aggregated to simulate bands
- Imaging spectrometry can lead to knowledge of surface morphology



Summary

Switch from sensor-centric to SI-traceable source-centric mentality is key



- One-by-one empirical comparisons between sensors have been successful but have limits
- Combination of physically-based modeling and empirical data is not be trivial
- Inclusion of highly-accurate, imaging sensors is necessary to develop the physical models
- **Imaging spectrometry provides the best opportunity to determine the spectral reflectance factor**
- Method will provide improved relative calibration precision and absolute calibration that has the capability of matching current methods

Goddard SPACE FLIGHT CENTER

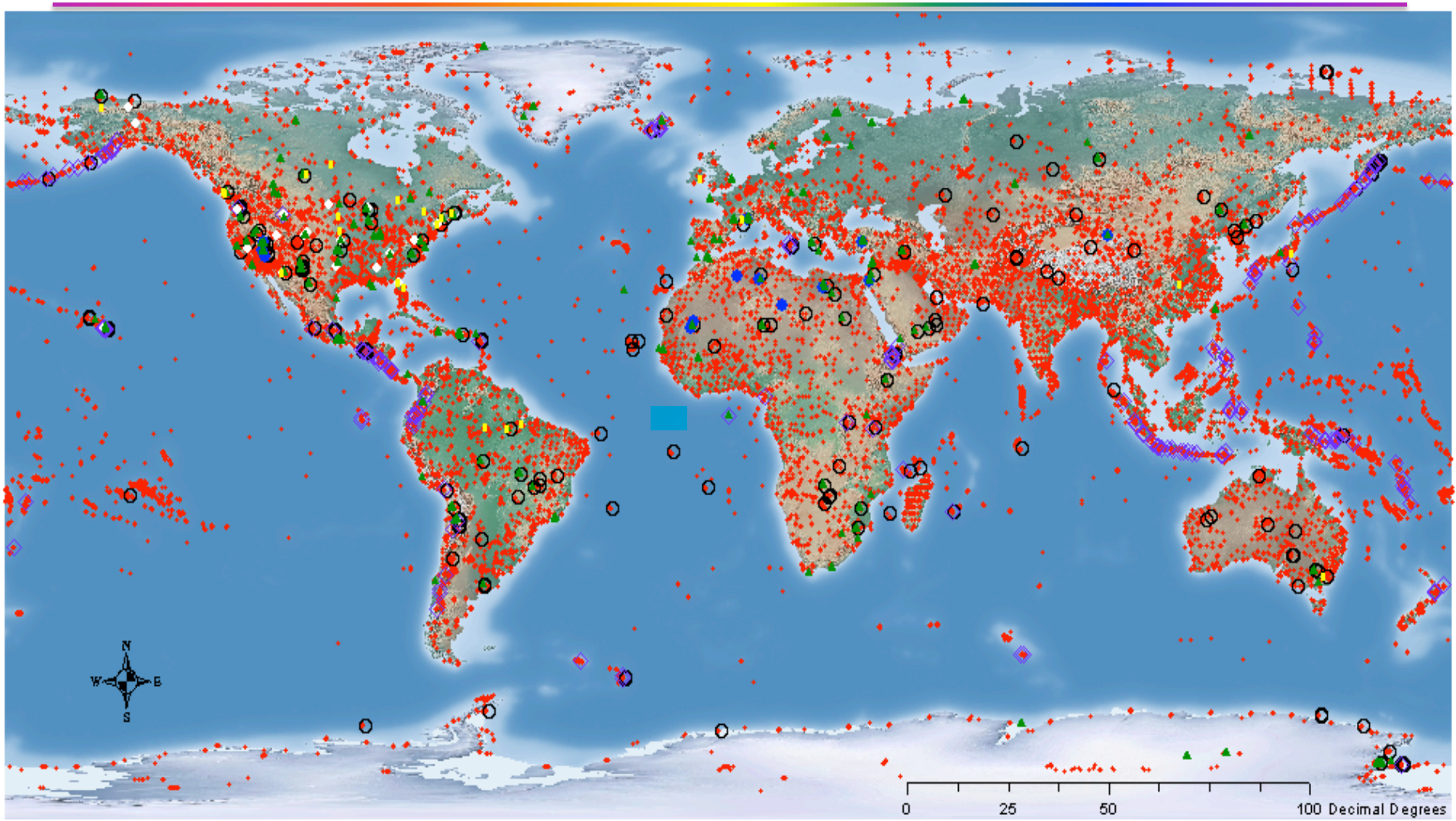
Spectral time series for the study of ecosystem function, using EO-1 Hyperion

Petya Campbell & K. Fred Huemmrich (UMBC) and Elizabeth Middleton (NASA/GSFC)

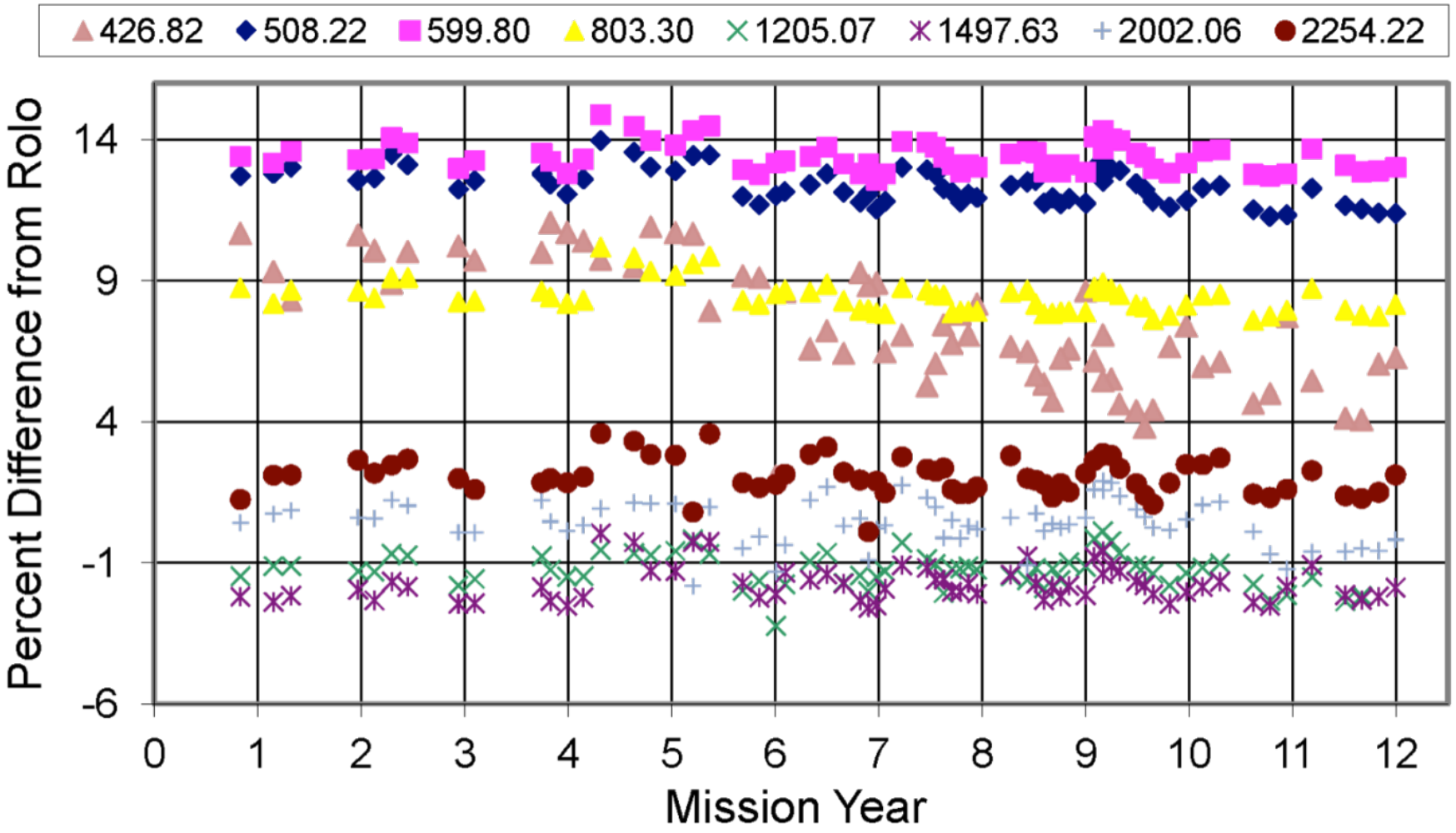
Hydrospheric and Biospheric Sciences

EO-1 Acquisitions, Dec 2000 – Current

> 70,000 Hyperion scenes have been collected



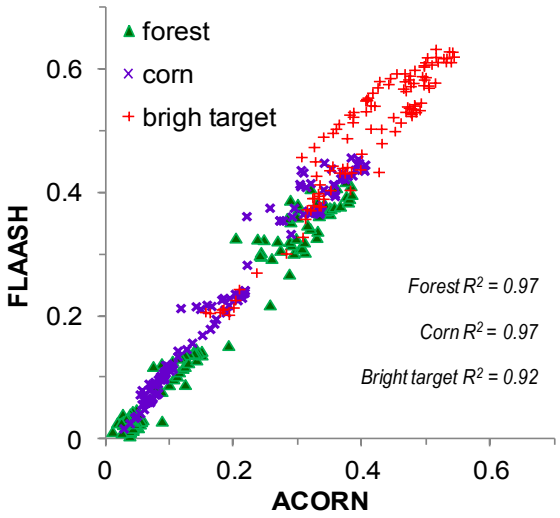
Hyperion Lunar Calibration Trends

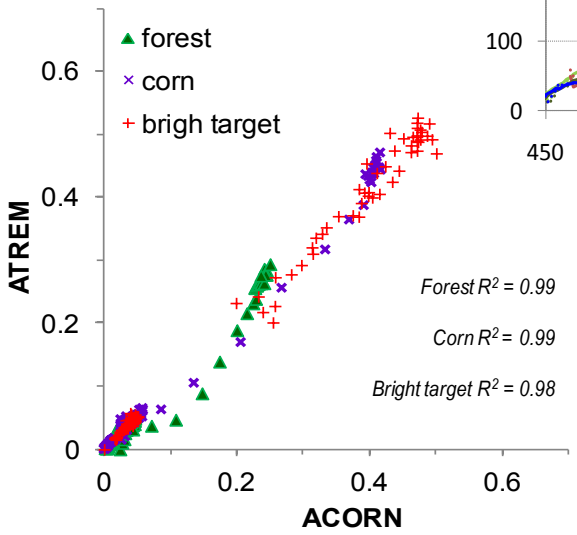


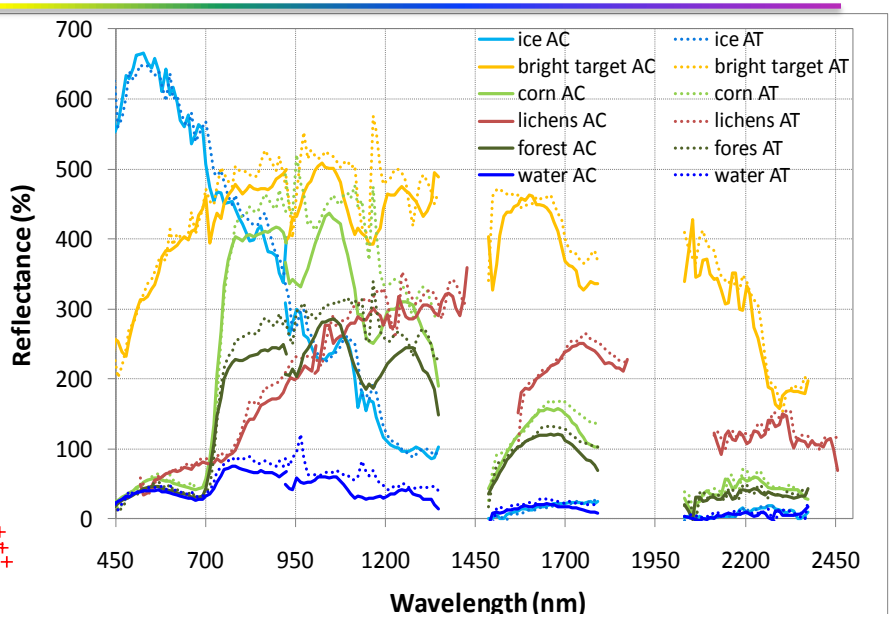
Differences *between Rolo model and Hyperion measurements remain stable (within 5%) over time*

Lawrence Ong 2013

EO-1 Hyperion Image Processing

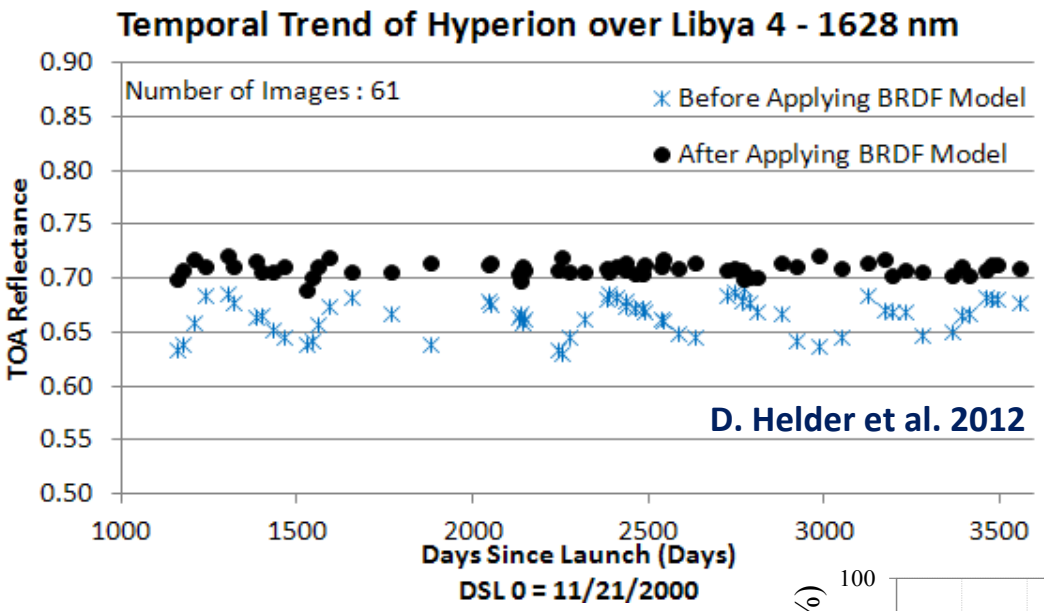






- Level 1R Hyperion data were atmospherically corrected using the Atmosphere CORrection Now (ACORN) model.
- Reflectance spectra were extracted in the vicinity of the existing flux towers, from 30-50 pixels depending on the site size.

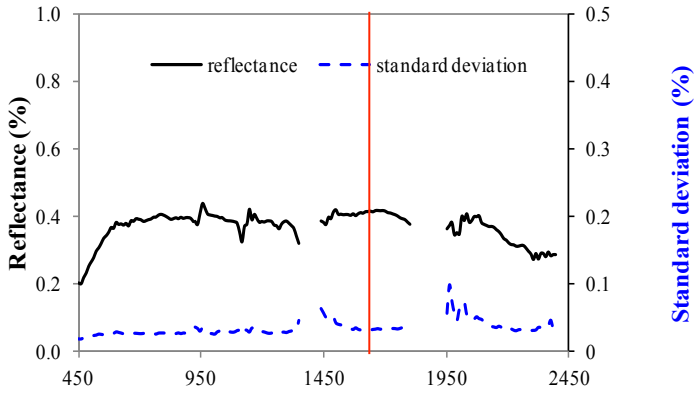
Spectral Time Series at CEOS Cal/Val Sites

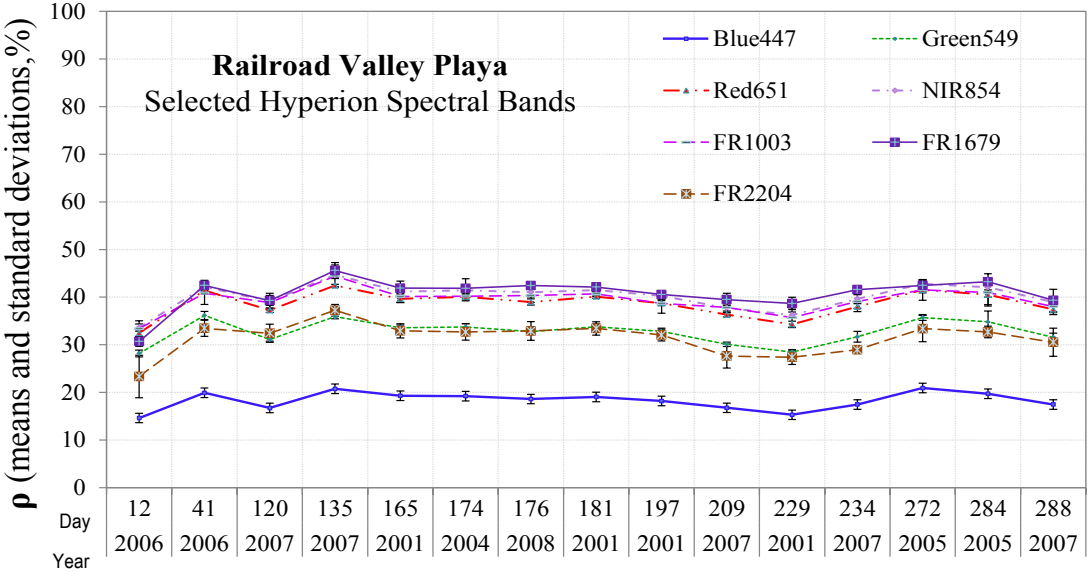


Temporal Profile of Selected Hyperion Bands

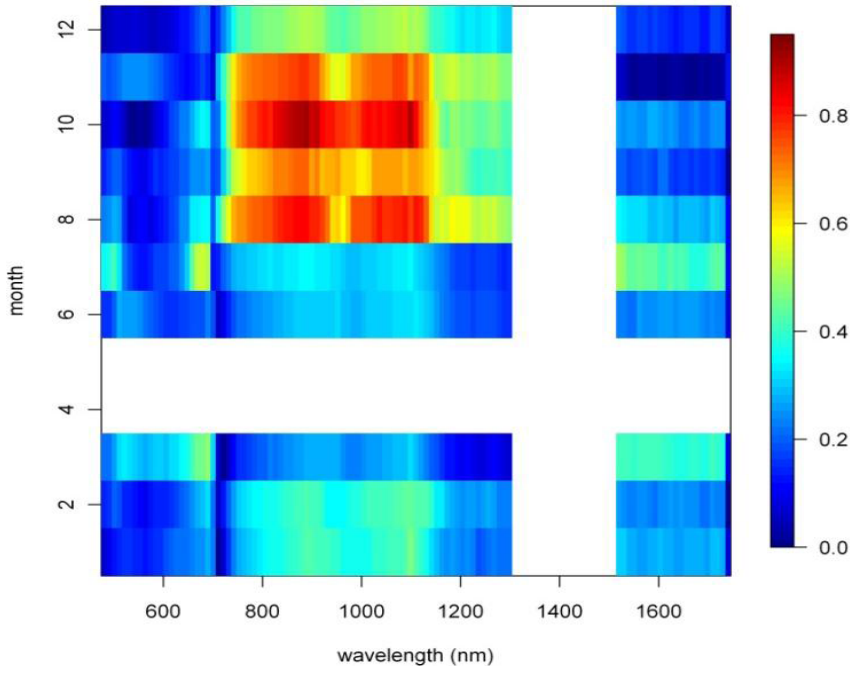
Calibration converts those images from pretty pictures to accurate data sets that can be used for a variety of scientific purposes such as …

D. Helder





Acquisition (Julian day/Year)

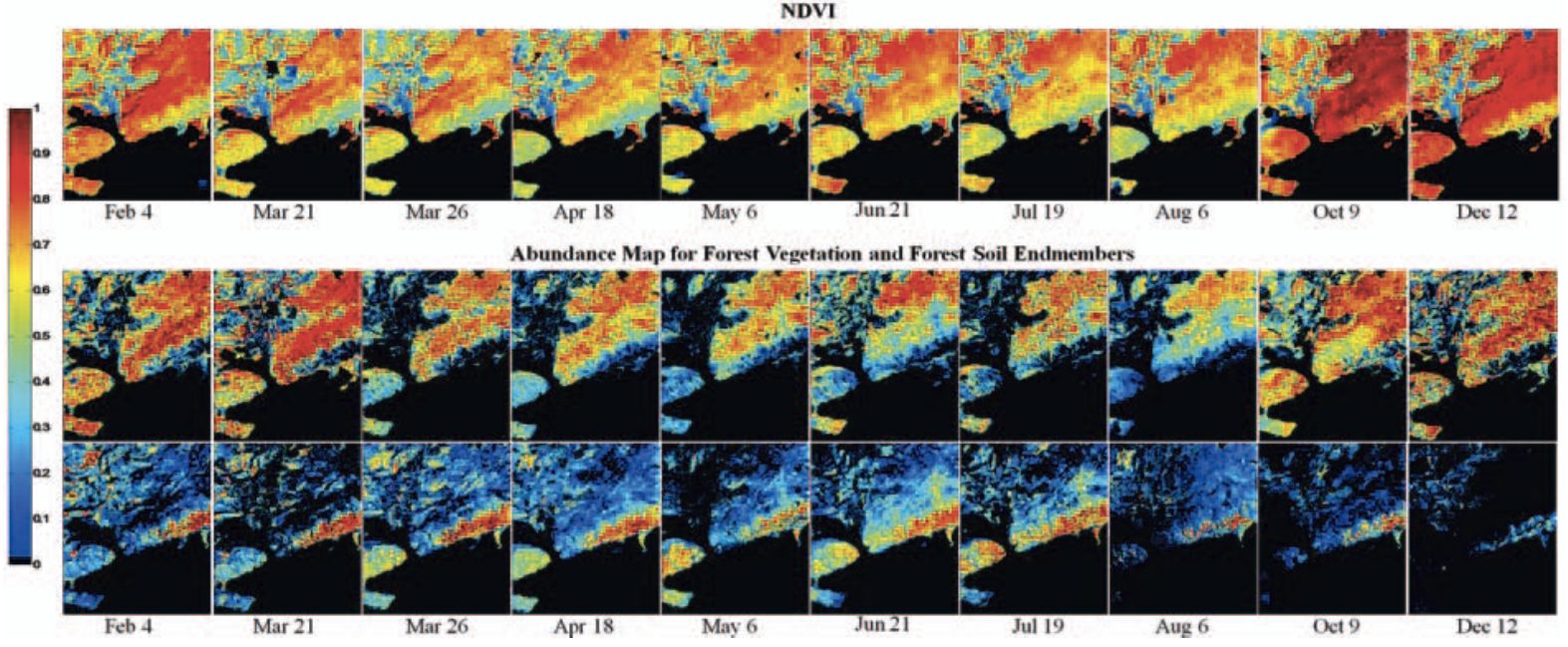


Reflectance spectro-temporal Separability Index comparing native *vs*. invasive tree species in Hawaii, demonstrating that phenology is a key to spectral separability analysis.

Somers & Asner, 2013

NDVI and Endmember abundance maps for vegetation and soil

Torres-Madronero et al. 2012



Science Questions

- **Is there a common (global) spectral approach to trace vegetation function, and it's CO_2 sequestration ability?**

- **How do species and biodiversity composition within ecosystems respond spectrally to the seasonal environmental changes?**

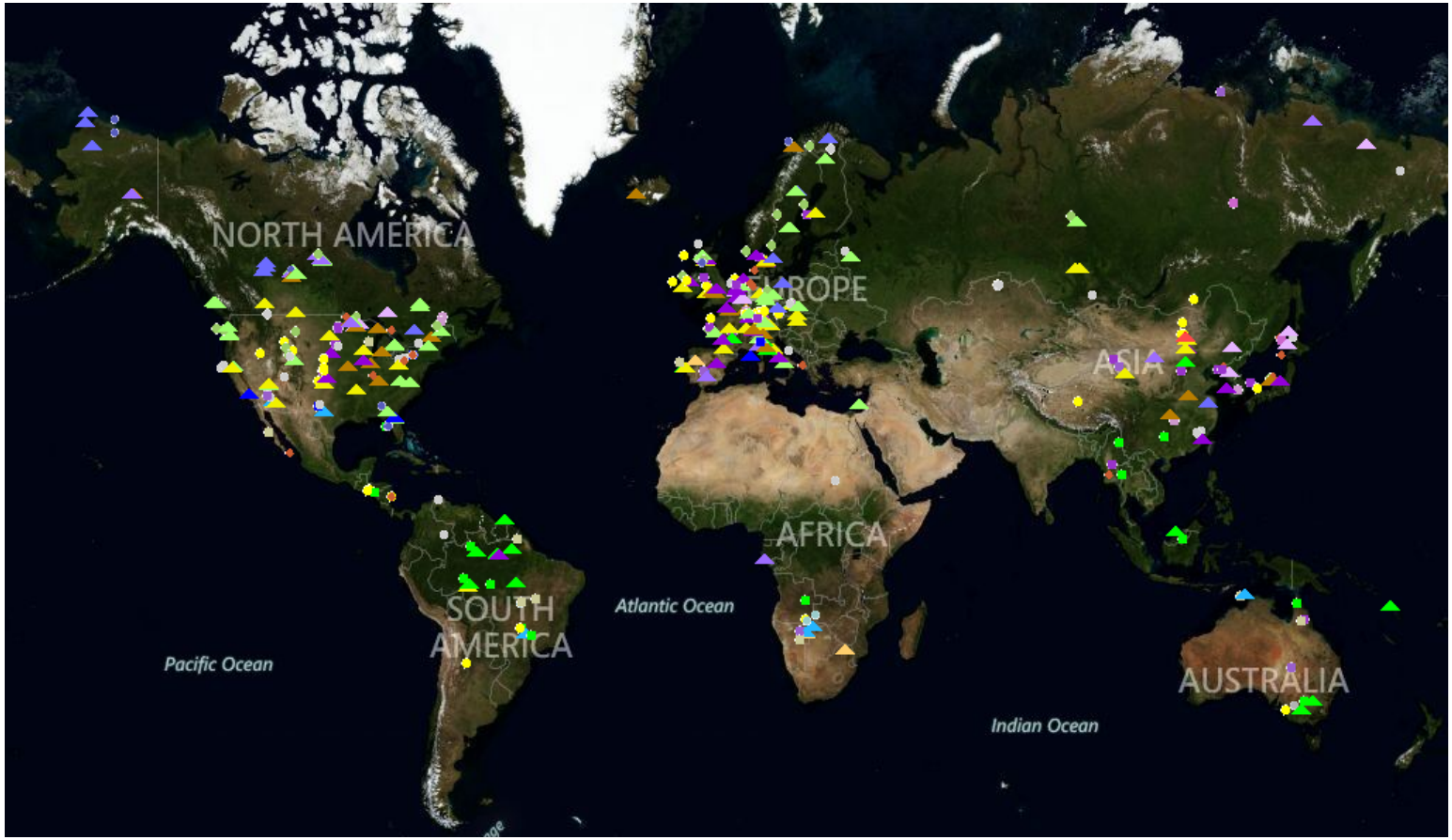
- **How do spectral properties and temporal dynamics of vastly different ecosystems compare?**

Flux Tower Data

Integrating Worldwide CO_2, Water and Energy Flux Measurements

FLUXNET is a "network of regional networks" for regional and global analysis of observations from micrometeorological tower sites. The flux tower sites about 545 (~410 active) use eddy covariance methods to measure the exchanges of carbon dioxide (CO_2), water vapor, and energy between terrestrial ecosystems and the atmosphere.

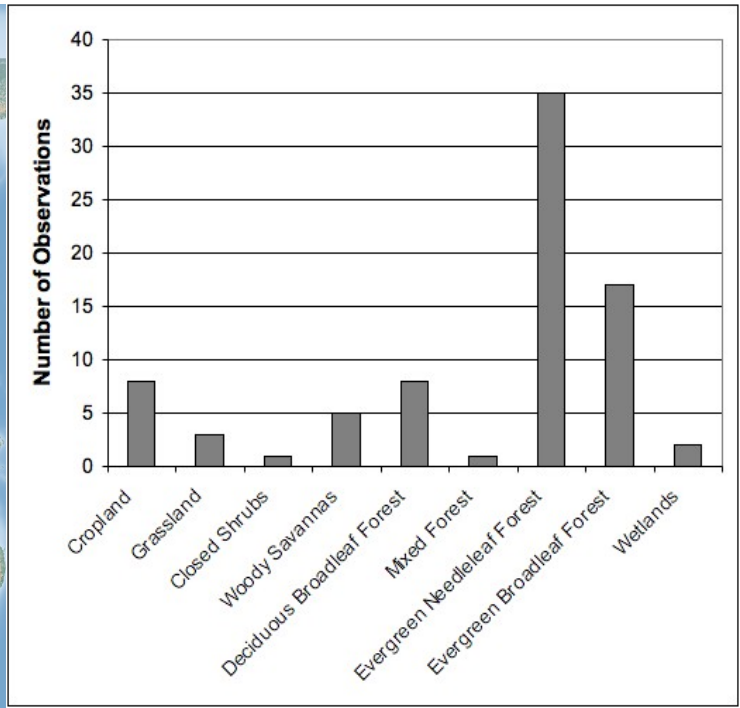
LaThuile Fluxnet Synthesis: A global network of about 250 flux sites with standardized flux calculations and gap filling for all sites (data 1982-2008)



Hyperion & Fluxnet

The time series include more than 90 sites globally, with >40 sites providing observations over flux tower sites

- PLS: 79 images of 33 different LaThuile flux tower sites, data from 2001 to 2007, matched flux data with available Hyperion imagery
- Spectral time series and VIs, 450+ images, 15 flux tower sites



CO_2 Flux Data Processing

- Net Ecosystem Production (NEP, µmol m^{-2} s^{-1}) is the CO_2 absorbed by the vegetation, measured by the flux tower.
- Ecosystem Respiration (Re) was calculated from relationships developed between nighttime Net Ecosystem Exchange (NEE) and air temperature.
  - When available, soil moisture was also used to determine Re
- Gross Ecosystem Production (GEP) is calculated from the observed NEE and Re.

Carbon Flux Variables

We looked at Light Use Efficiency (LUE, ε) derived from the tower data

$$\varepsilon = GEP/(f_{APAR}\ PAR_{in})$$

Where:

GEP is the gross ecosystem production (calculated from tower data)

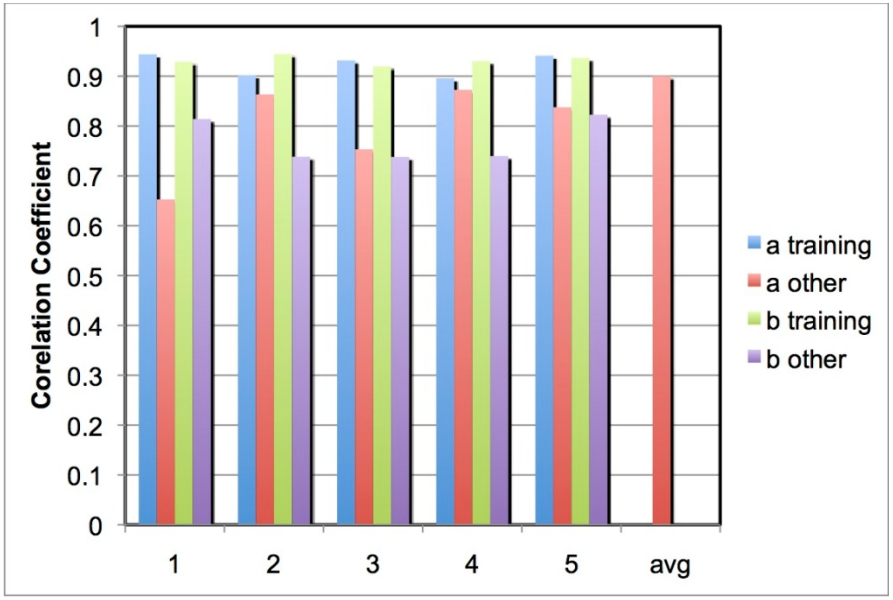
PAR_{in} is the incident Photosynthetically Active Radiation (measured at tower)

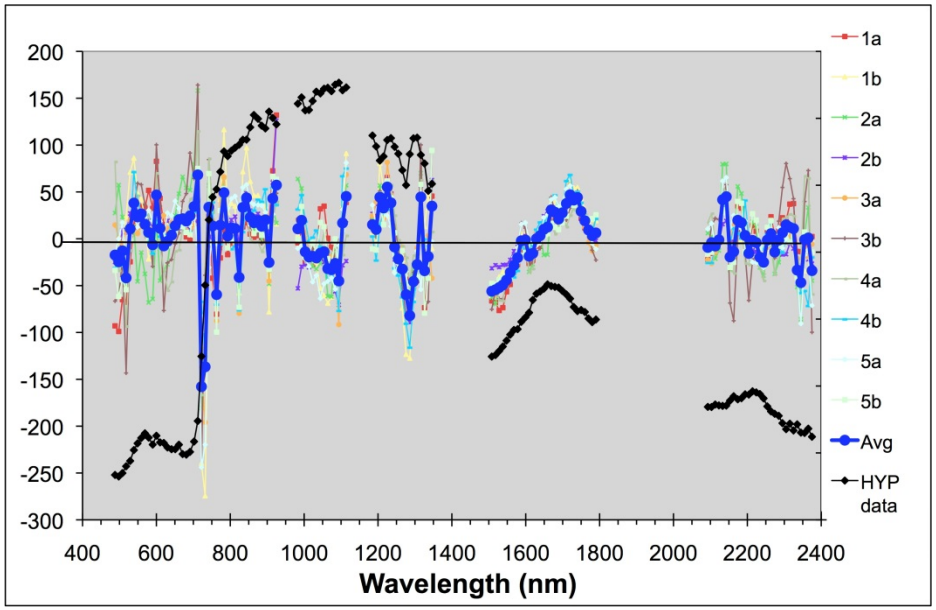
f_{APAR} is the fraction of PAR absorbed by vegetation (used MODIS f_{APAR} values)

Partial Least Squares –LUE

Partial Least Squares is an approach that utilizes all of the spectral information

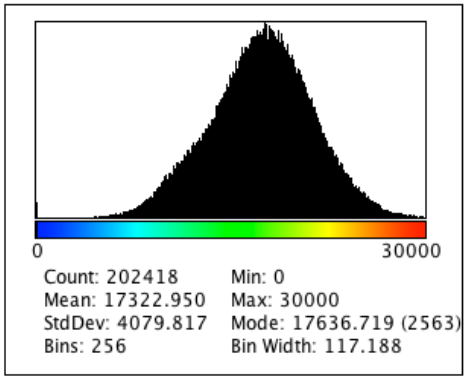
PLS regressions against daily LUE were calculated for all spectral bands for random subsets of half of the data (n=39) – resulted in similar weighting factors for the spectral bands



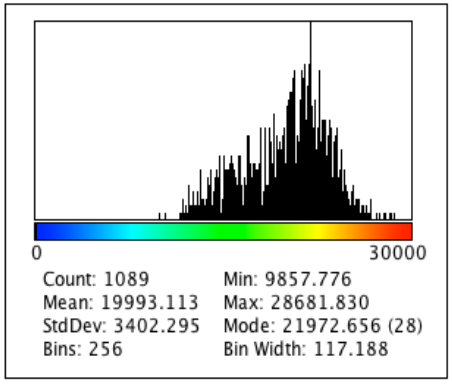


Remote Sensing of Fluxes: Hyperion and Fluxnet

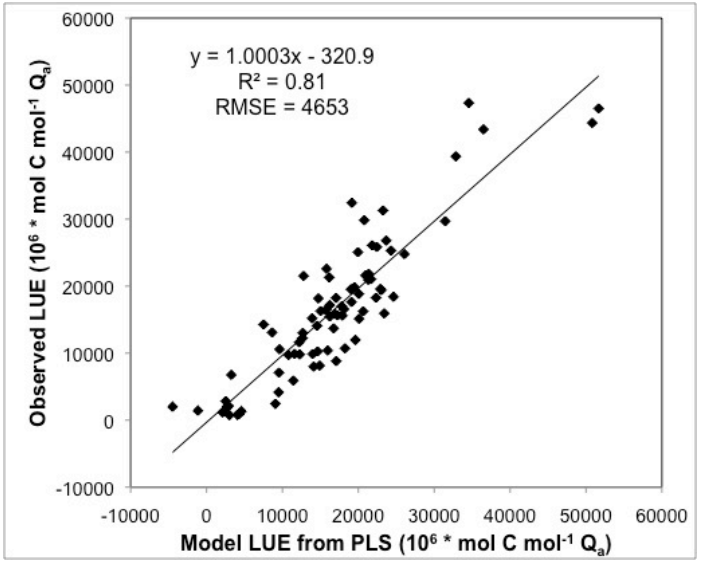
Using matched flux data from LaThuile Fluxnet Synthesis with Hyperion imagery for 33 globally distributed flux tower sites



LUE Histogram for full scene

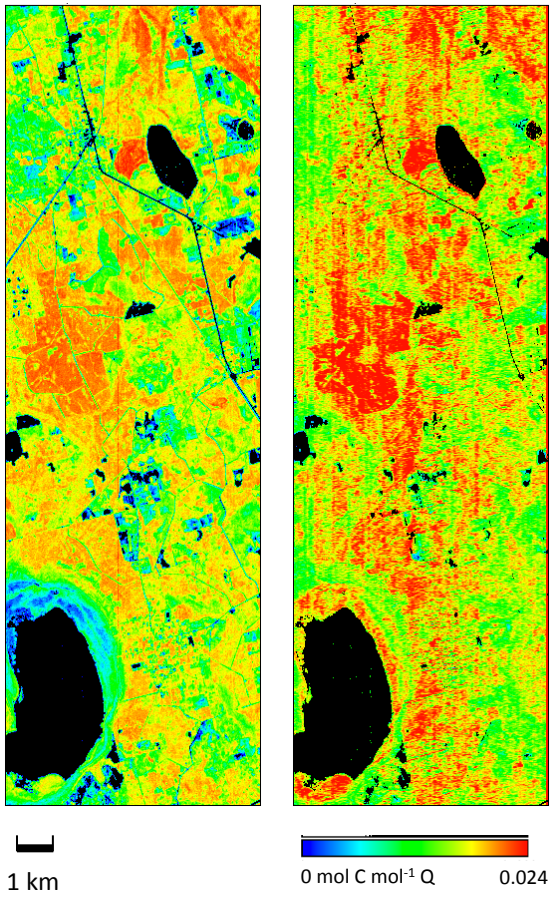


LUE Histogram for km^2 around tower



Light Use Efficiency (LUE) estimated from reflectance using PLS regression of spectra to observed LUE from flux towers

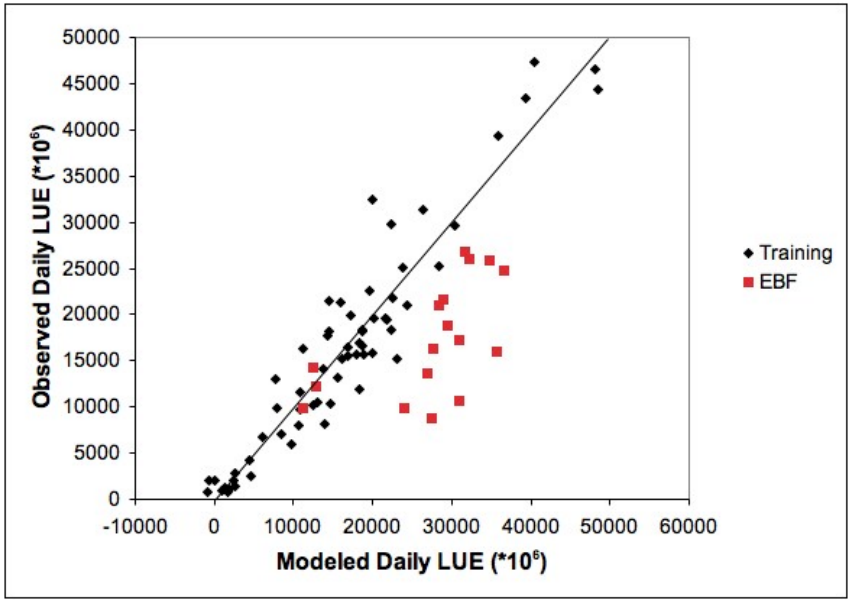
Florida Slashpine



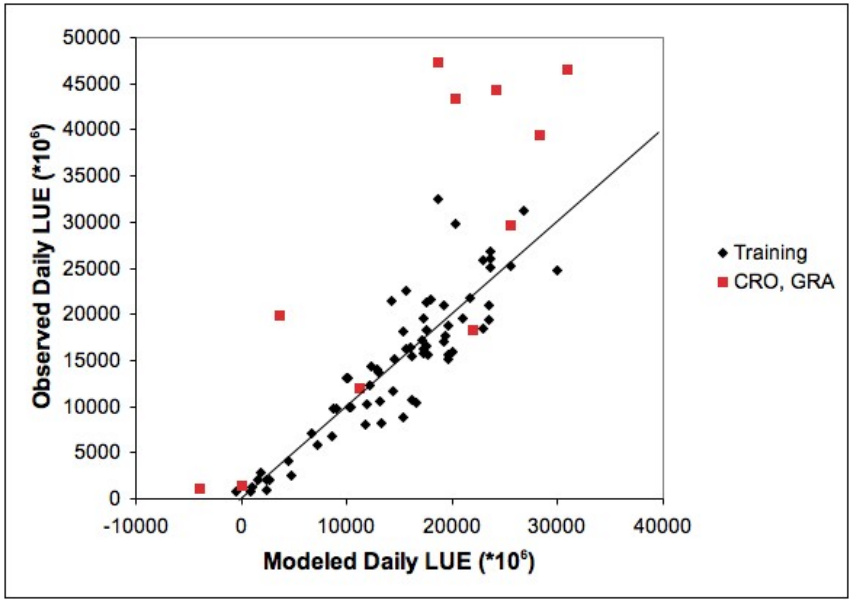
Huemmrich, Campbell & Middleton

Partial Least Squares – LUE

Tests where specific vegetation types were removed from training datasets often performed poorly when applied to the test data



Black points – training data
Red points – Evergreen Broadleaf Forests



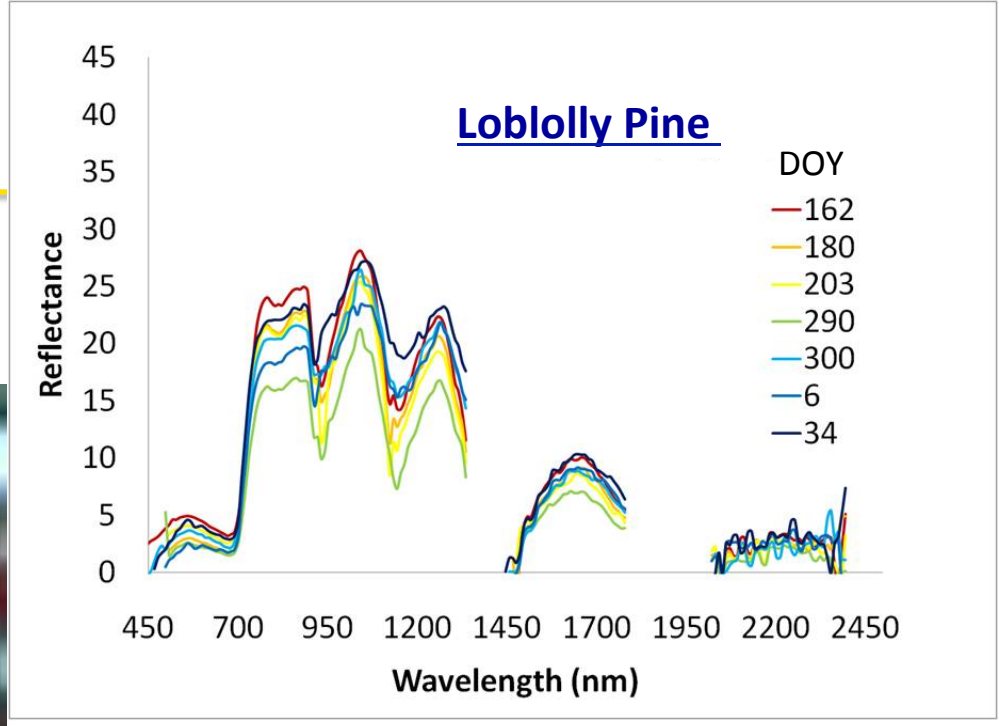
Black points – training data
Red points – Crops and Grasslands

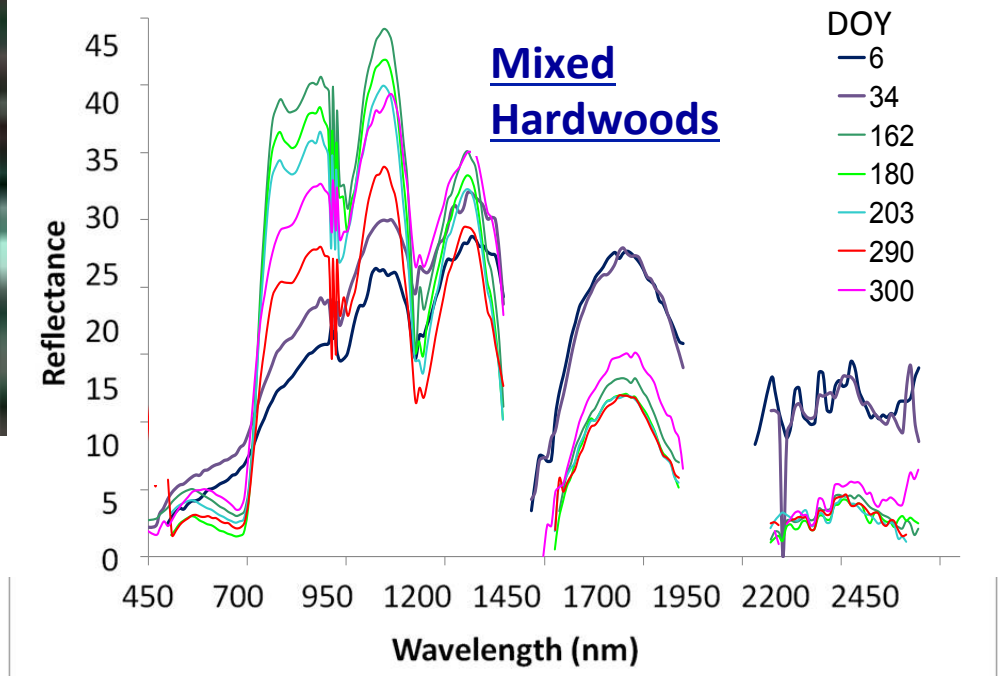
Spectral Time series -- Regression Coefficients for the Top Performing Spectral Bio-indicators (R^2 values)

Spectral indicator	Formula	NEP	GEP	LUE
Dmax	Max D in the 650-750 nm	**0.72 L+**	**0.77** L+	0.76 L+
DP22	Dmax/D(max + 12)	0.64 L+	0.73 NL+	0.70 L+
NDWI	R(870-1240)/R(870-1240)	**0.75** NL +	0.66 NL+	0.62L+
MCARIa	Chlorophyll, R bands at 700, 670, and 550	0.42 L+	0.75 L+	**0.77** L+
PRI4	(R531-R670)/(R531-R670)	0.66 NL+	0.62 NL+	0.49 NL+
NDVI	(NIR-R)/(NIR+R) NIR= Av. 760..900, R=Av. 620..690	0.56 NL+	0.59 NL+	0.44 NL+

Duke, NC

Pine site
Hardwood site


Loblolly Pine
DOY
162
180
203
290
300
6
34
Reflectance
0
5
10
15
20
25
30
35
40
45
450
700
950
1200
1450
1700
1950
2200
2450
Wavelength (nm)


Mixed Hardwoods
DOY
6
34
162
180
203
290
300
Reflectance
0
5
10
15
20
25
30
35
40
45
450
700
950
1200
1450
1700
1950
2200
2450
Wavelength (nm)

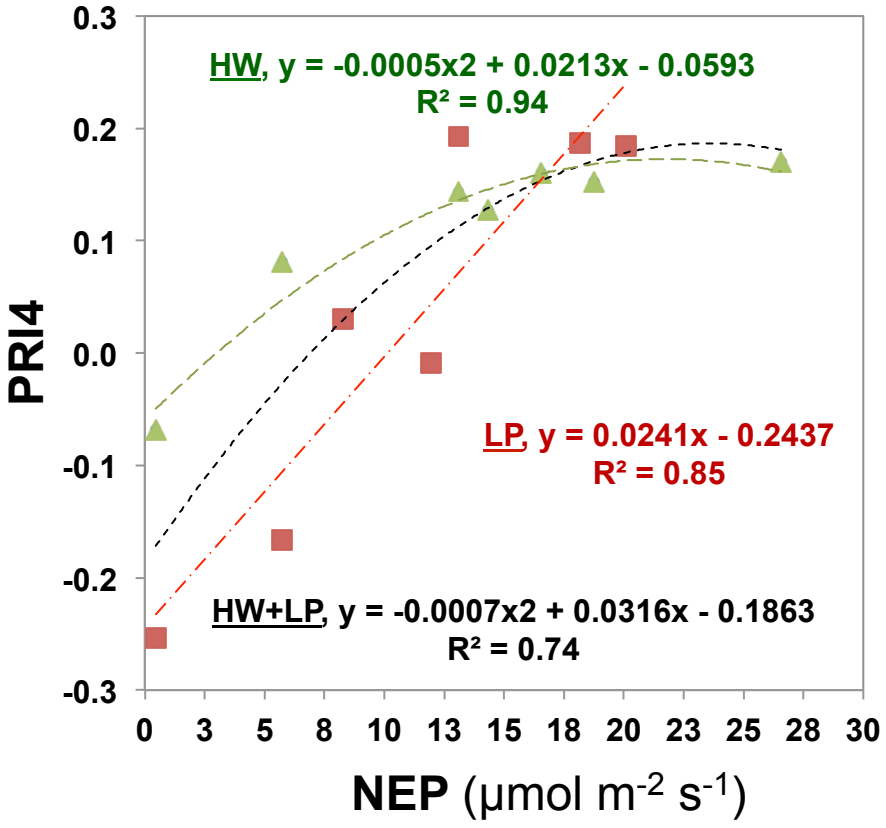
Bio- indicators of *Photosynthetic Function*

Loblolly Pine (LP)

Index	Bands (nm)	R^2 [NEP (GEP) *LUE*]
PRI1	531, 570	0.84 (0.73) L
PRI4	531, 670	0.75 (0.63) *0.73* L
DPI	D 680, 710, 690	0.91 (0.44) NL
NDWI	870, 1240	0.76 (0.60) L
NDVI	NIR, Red	0.19 (0.48) L

Hardwoods (HW)

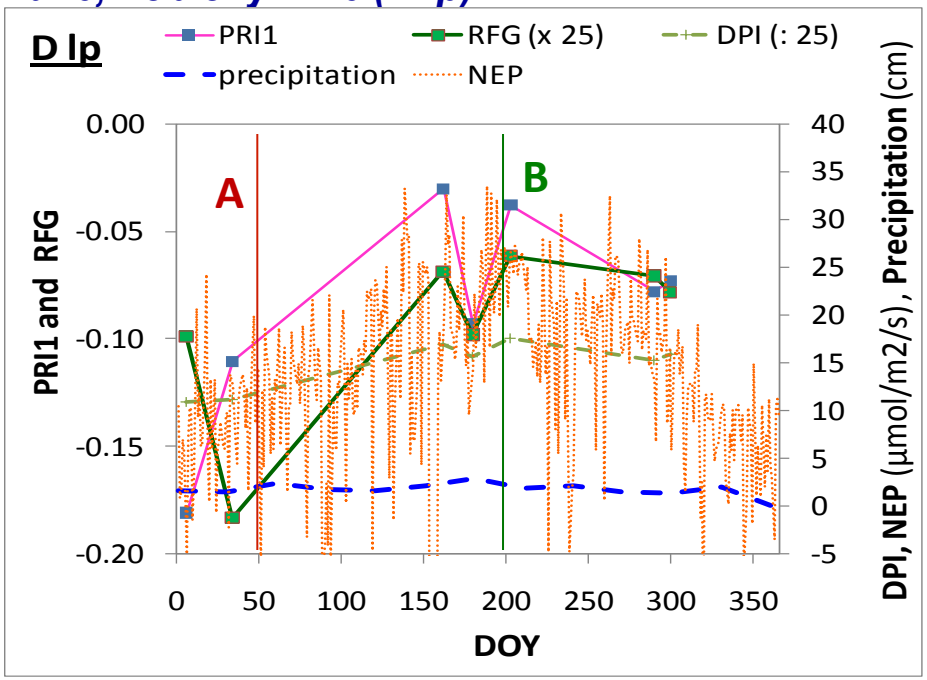
Index	Bands (nm)	R^2 [NEP (GEP) *LUE*]
PRI4	531, 670	0.84 (0.48) NL
Dmax	D max (650…750 nm)	0.83 (0.40) NL
NDII	820, 1650	0.79 (0.34) L
EVI	NIR, Red, Blue	0.84 (0.41) L
NDVI	NIR, Red	0.63 (0.19) L



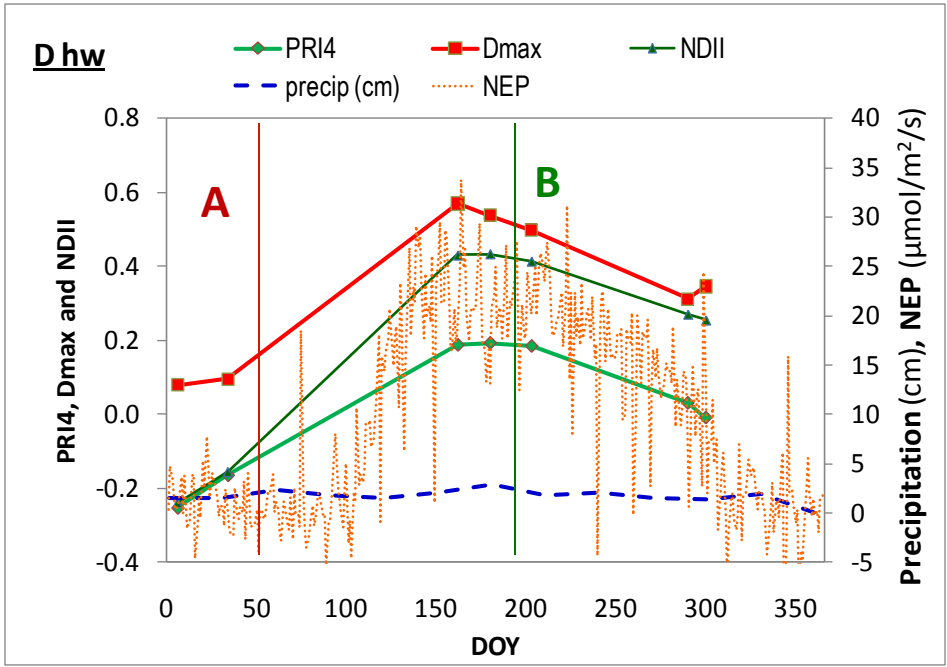
Campbell et al. 2012

Seasonal dynamics in PRI

Duke, Loblolly Pine (D lp)

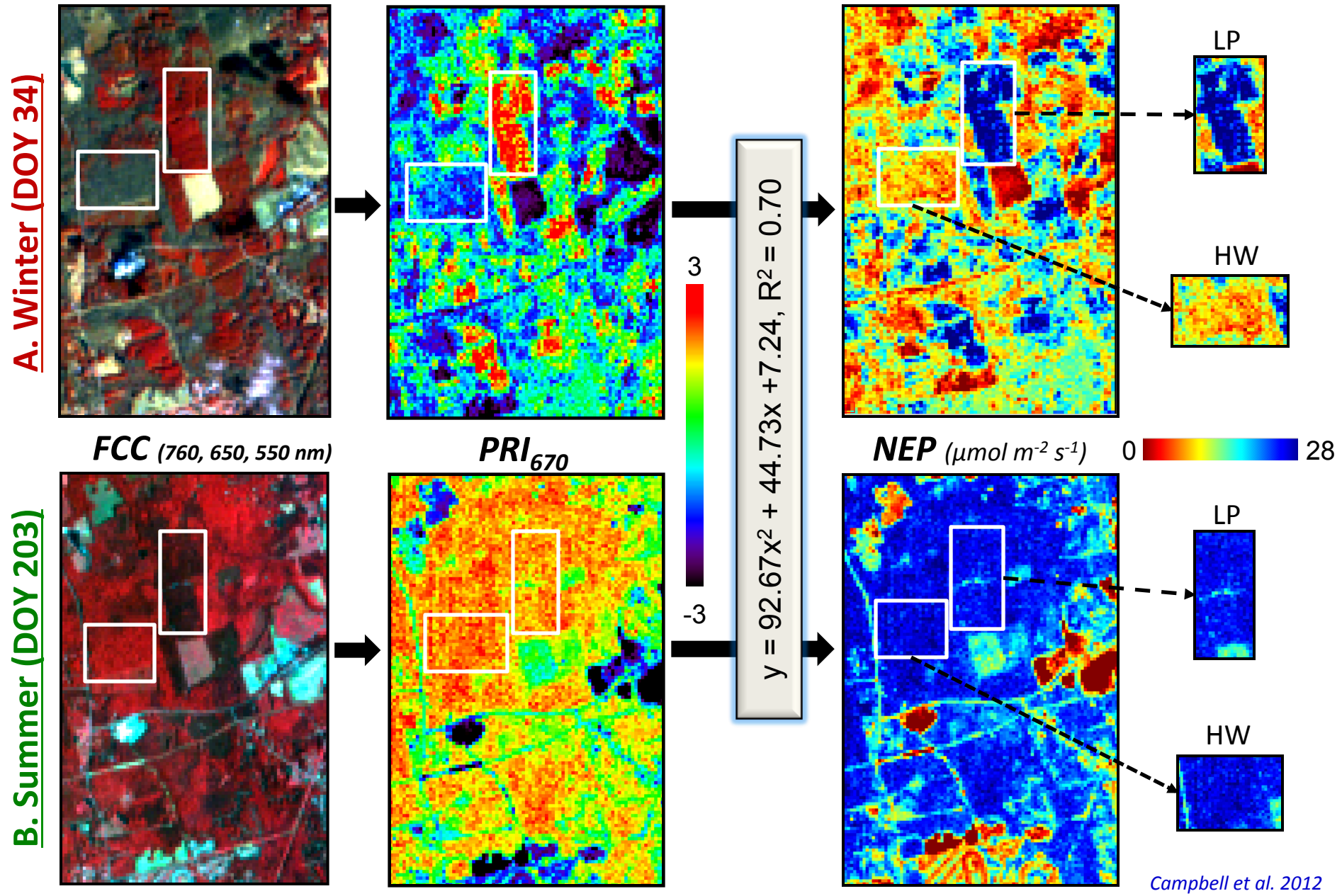


Duke, Hardwoods (D hw)



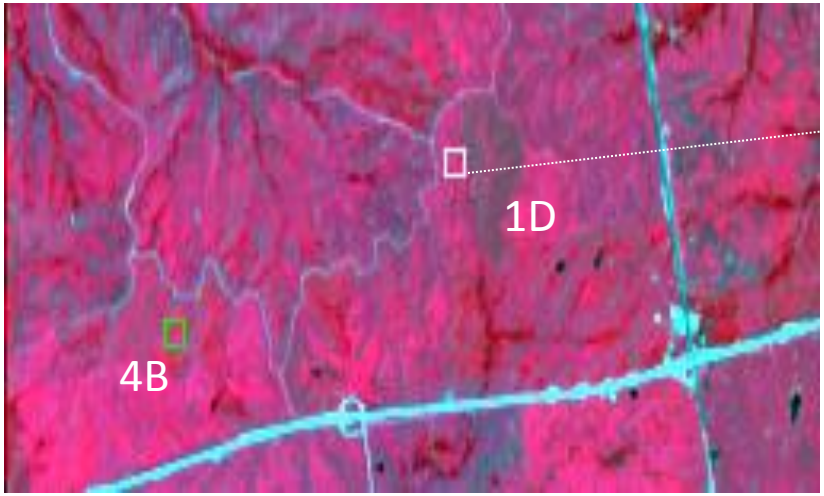
Campbell et al. 2012

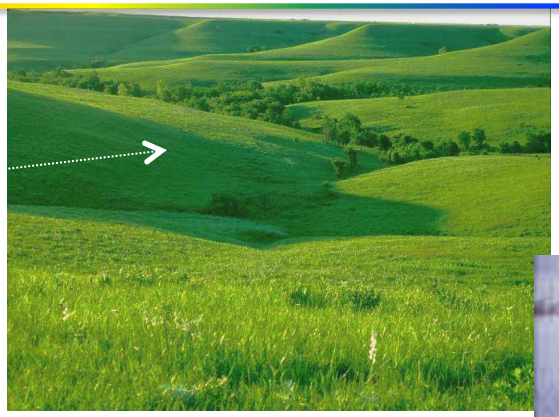
Duke Forest : PRI_{670} & NEP

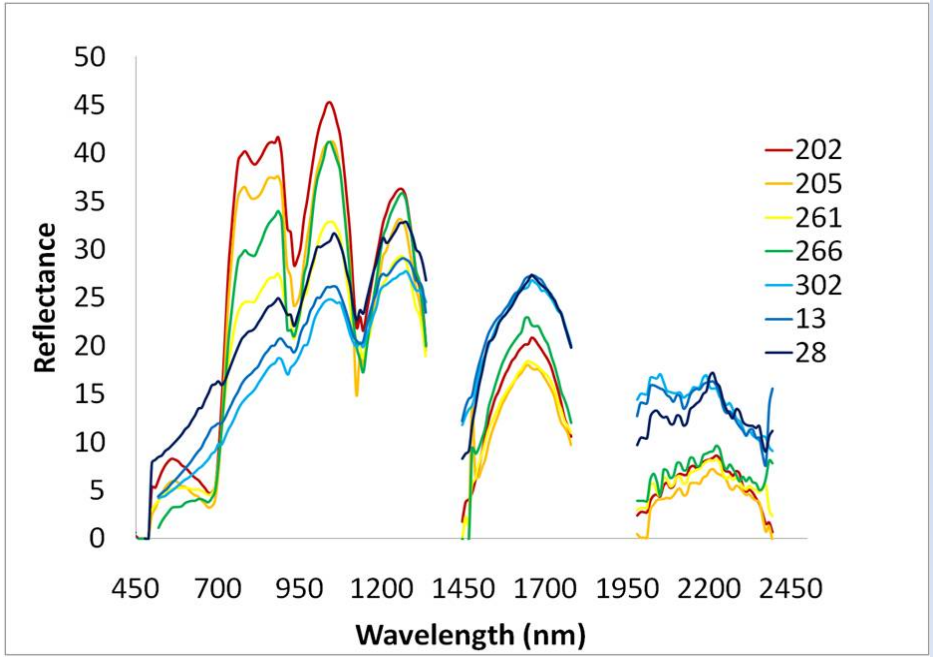


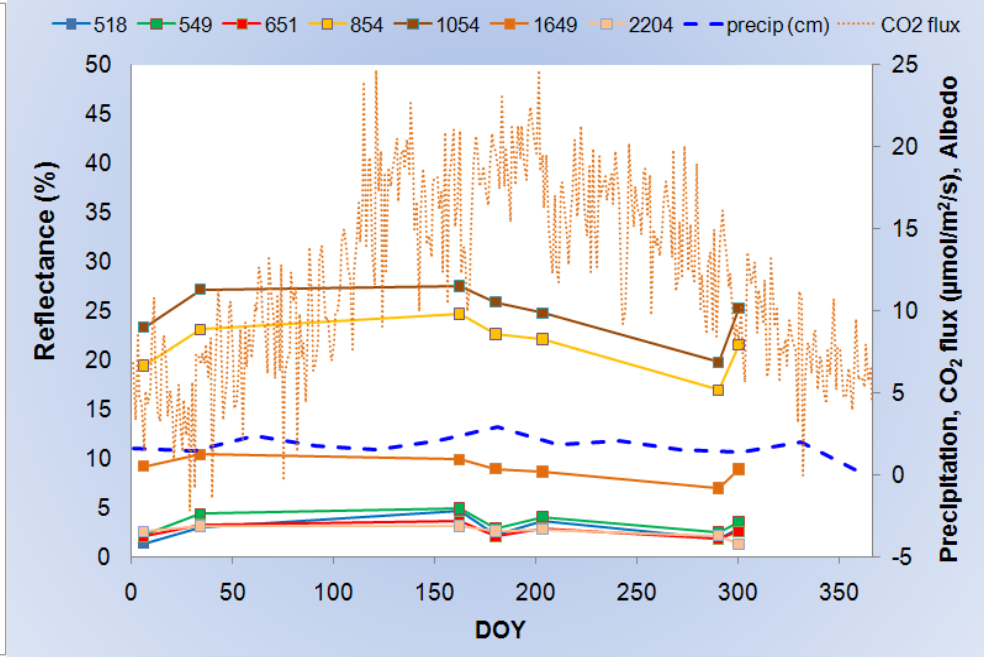
Campbell et al. 2012

Seasonal Spectral Dynamics at Konza

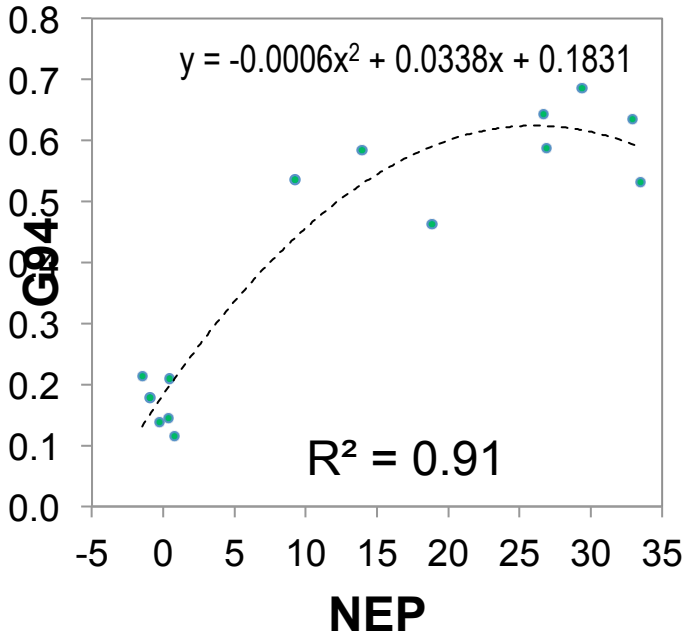


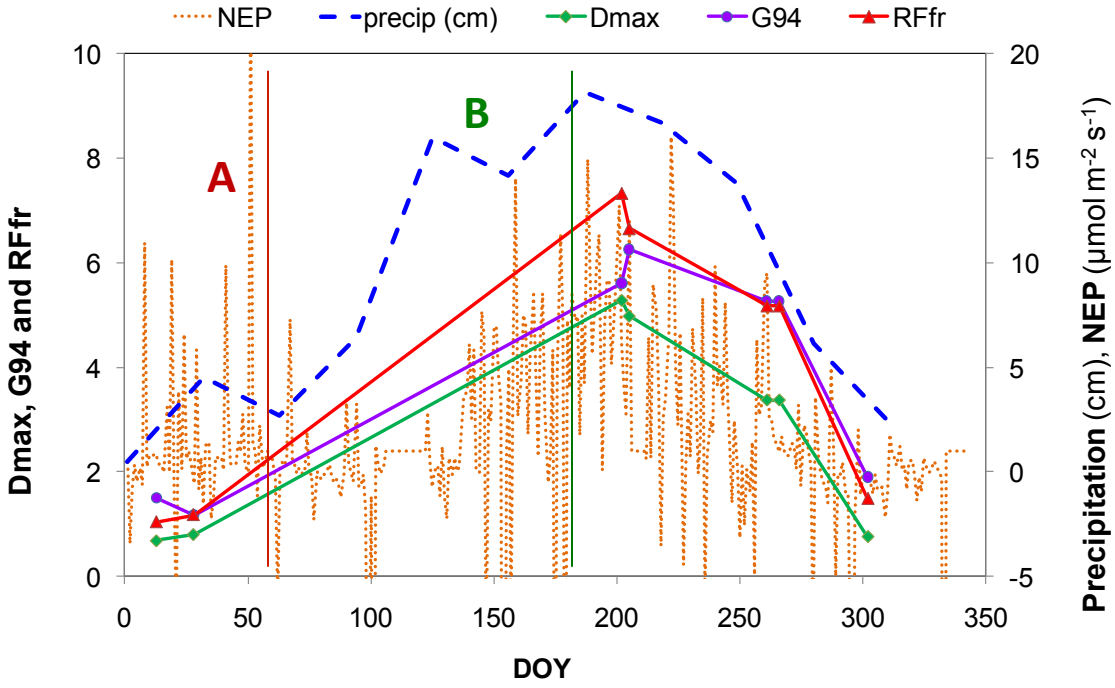




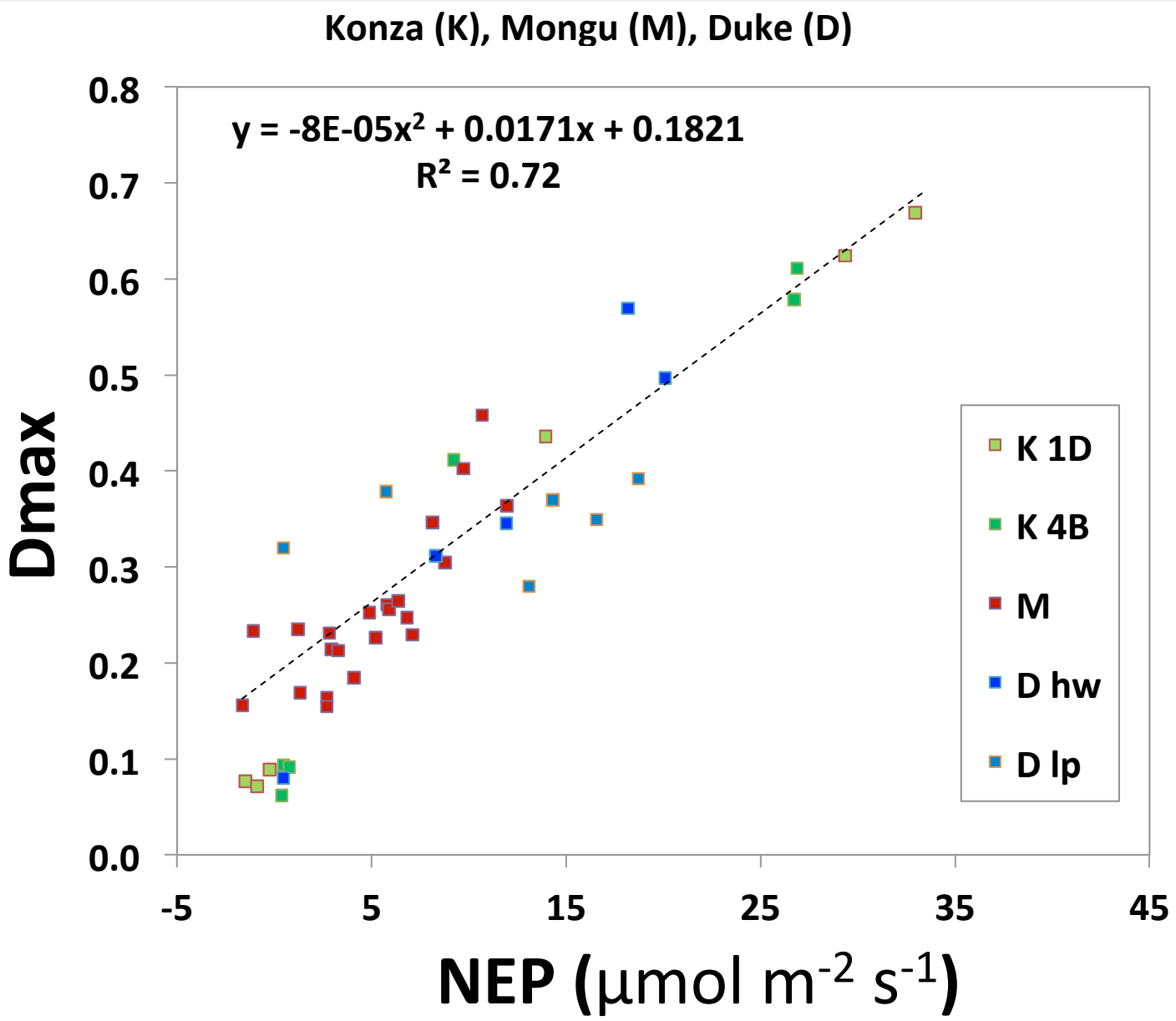


Index	Bands (nm)	R^2 [NEP (GEP) *LUE*]
G94	R 800, 700	0.95 (0.90) *0.75* NL
Dmax	D max	0.93 (0.95) *0.94* L
EVI	NIR, Red, Blue	0.83 (0.92) *0.88* NL
NDWI	R 870, 1240	0.86 (0.91) *0.85* NL
NDVI	Av. R760-900, Av. R620-690	0.63 (0.67) *0.68* L





Derivative Maximum



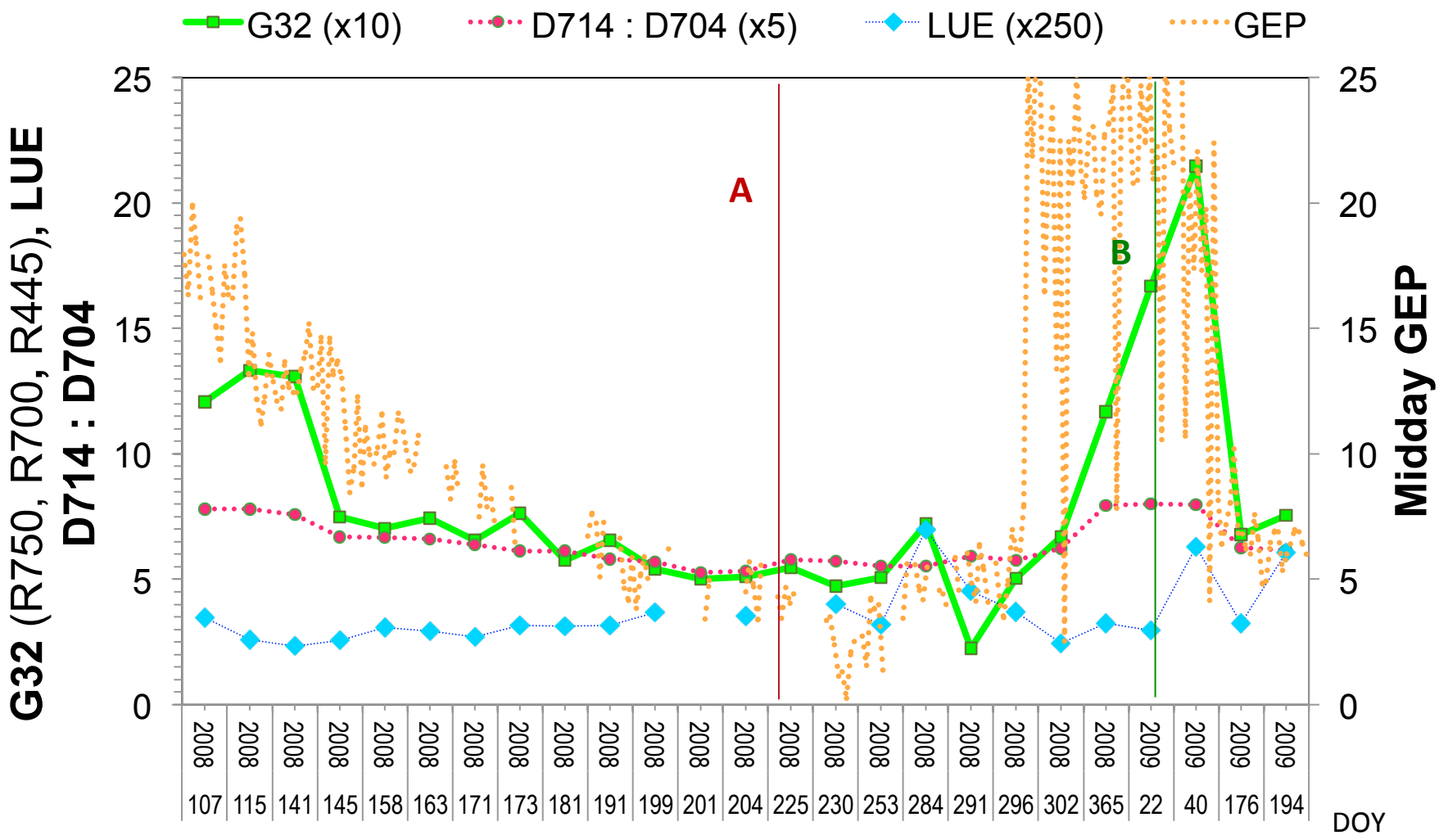
Conclusions

- In different ecosystems, continuous reflectance data and a variety of spectral bio-indicators had strong correlation to CO_2 flux parameters (e.g. NEP, GEE, etc.).
- The PLS regression provides a consistent global approach for estimating CO2 fluxes
- The bio-indicators with strongest relationships were calculated using continuous spectra, using numerous wavelengths associated with chlorophyll content and/or derivative parameters.
- Common (global) spectral approach to trace vegetation function and estimate it's CO_2 sequestration ability is feasible. It requires:
  - a diverse spectral coverage, representative of the major ecosystem types,
  - spectral time series, to cover the dynamics within a cover type.

Future Work

- Expand the tests over additional ecosystem types, including rain forest, temperate and sub-arctic vegetation types.
- Test the importance of specific phenologic periods (or times of year) for systematic estimation of ecosystem functional potential and productivity.
- Test the ability of additional spectral approaches to trace the dynamics in vegetation condition.
- Strategy to assess/confirm the accuracy of the produced maps.

Hyperion Spectral Indices and GEP at Mongu

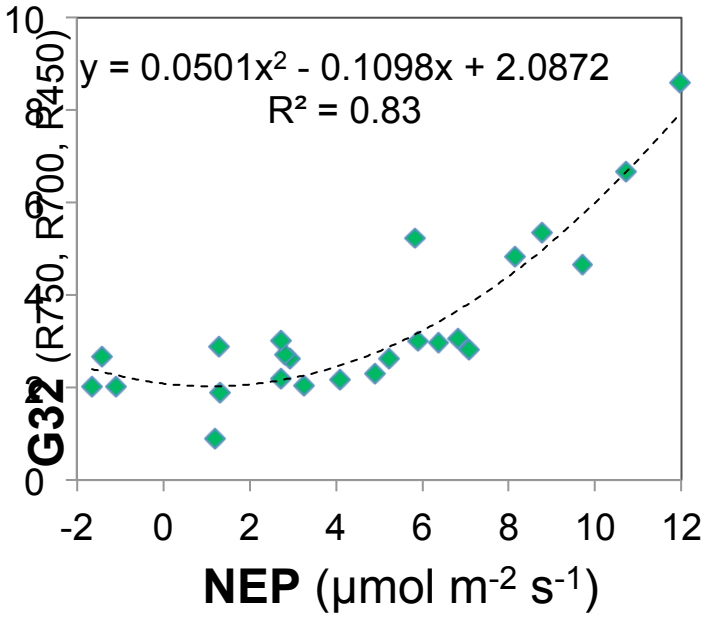


The spectral bio-indicator associated with chlorophyll content (G32, green line) best captured the CO_2 dynamics related to vegetation phenology.

Bio-indicator	Bands (nm)	R^2 [NEP (GEP)]
G32	R750, 700, 450	0.83 (0.81) NL
Dmax	D max (650…750 nm)	0.77 (0.87) NL
Dmax / D704	D(690-730)	0.79 (0.80) NL
mND705	R750, 704, 450	0.75 (0.79) NL
RE1	Av. R 675…705	0.71 (0.56) NL
EVI	R (NIR, Red, Blue)	0.73 (0.88) L
NDVI	Av. R760-900, R620-690	0.52 (0.60) NL

G32, Associated with *Chlorophyll*

(Gitelson et al. 2003)



Ecological forecasting

There were 16 participants, including researchers from different fields: modelers, plant physiologists, forest ecologists, data and cloud computing experts (Petya has a list of the names).

1. Plant functional types:

Natural ecosystems – community compositional changes and dynamics in functional groups

Are plant functional types, developed for use from AVHRR and MODIS time series, relevant for HyspIRI? They were developed as a step beyond biomes. Is there value in using these PFTs with HyspIRI and should they be the same PFTs (given higher spatial/spectral resolutions)?

If growth form and leaf longevity don't define "functional similarity" what groupings can be used? Can we use spectral similarity (leaf optical types) as a surrogate for functional similarity? Quickly gets to issues of varieties, vertical distributions, phenological changes). Needs more work.

Perhaps promote Hierarchy of PFT classes? Do away with PFTclasses or retrieve parameters directly (not all CLM parameters are accessible (e.g. rooting depth), which is accessed from LUT).

We discussed need to discriminate invasive species, especially where the invasive species forms dominance and/or changes ecosystem functionality. Important indicator of ecosystem changes so we need a strategy for providing this as a capacity (probably "on demand" tools).

This led to a discussion of identifying community successional stages. Community composition and functional groups are important for understanding ecosystem succession. However, they are not necessarily the same MODIS PFTs. Need to consider how to identify these stages in ecosystem evolution. Disturbance brings systems back to earlier stages of succession.

- More study can examine variability with PFT spectral properties and break up class if it is high

In the course of ecological succession there dynamic species function and composition changes (gradual or step changes following disturbance). It is necessary to address these changes to enable forecasting.

2. Agriculture and managed (altered) ecosystems:

To consider global ecological dynamics and the effects of climate change agricultural lands, including managed forests, should be included as managed ecosystems?

- Emerging issue of **food security** makes crop monitoring imperative

Desire to monitor for crop health and yield prediction:

- crop species and functional states (identify new genotypes and varieties (GMOs) that have new traits)
- small field sizes in developing world will make this difficult; also 19 d repeat isn't often enough
-

3. HyspIRI data system ("big data" model)

- Support an open data system with user driven products, vs. predetermined set
- Few basic uniform products (e.g., level 2 products: georectified reflectance) delivered to users.
    - Challenge in validating specific functional products and describing their accuracy will be quite serious and needs to be addressed.
    - Open source algorithms can be shared or supported by community development.
      Use prior probabilities
- Considering no computational limitations in the time frame of HyspIRI, produce something like a "data product wiki"?
- Expected ease of data storage and handling will allow delivery of large volumes of diverse data sets to the users to develop custom products as needed (streaming data concept; could be cloud based).
- Modeling and spectral inputs from HyspIRI: The CLM model currently ingests few variables directly (uses PFTs and look up tables). HyspIRI can provide PFT or species, canopy LAI, canopy chemistry: (pigments, water, dry matter (cellulose/lignin), N? …), others ??? The current PFTs in the model can be directly replaced with RS inputs for data parameters.

4. Ecological Forecasting

Seasonal and longer (multiyear, decadal) time steps. Fuse with daily VIIRS/bimonthly Landsat and Sentinel x/. "adaptive reflectance fusion (blending) modeling"(from Arnold Dekker)

- **Phenological stages**
    - **NPP, NEP forecasting**

- **Diurnal time steps** are feasible to be monitored with **data fusion**: Combine HyspIRI data with diurnal GOES data (GOES-R w/1km pixels) combined with targeted, high spatial and spectral resolution ground measurements (using towers, USVs, balloons, buoys).
    - **ET forecasting**

- **Pan Sharpening** capacity for subpixel composition
    - Species composition, biodiversity, change detection
- **Lidar** for canopy structure (3-d canopies),
    - improve chemistry retrieval; new data for CLM models
- **Fluorescence (**photosynthesis, light use efficiency)
    - NPP/NEP forecasting

Disease forecasting is an emerging area of research
Anomaly detection
Facilitate "surprise" changes

5. Need for further research. There is a need for basic functional studies to provide better understanding of the relationship to spectral information.

- The relationship between taxonomic and spectral diversity requires further study.

- Especially, needed is time series data combining spectral and functional information by species and PFTs. Analytical approaches should include data mining and facilitate "surprise". Facilitate detection of temporal anomalies.

- HyspIRI night time observations: The value of HyspIRI observations during night was discussed with applications for study of urban expansion and development. Also carbon emissions (via fires).

- There is interest in using HyspIRI data for assessing **urban energy uses**, however the resolution needed subpixel for HyspIRI.