HyspIRI Science Symposium on Ecosystem Data Products

NASA/GSFC, May 4 and 5, 2010

Building 33, Room H114

GSFC EO-1/HyspIRI Team

Betsy Middleton, NASA
Bob Knox, NASA
Steve Ungar, UMBC

Petya Campbell, UMBC
Qingyuan Zhang, UMBC
Fred Huemmrich, UMBC
Ben Cheng, ERT
Larry Corp, Sigma Space

Other Assistants for Symposium:

Hank Margolis, Laval University [TIMEKEEPER]

Sandi Bussard, Jacob Gude, Sheila Humke & Carla Evans
Sigma Space

look for flags on their name tags

HyspIRI Science Symposium on Ecosystem Data Products

Sponsor: NASA/Goddard Space Flight Center

May 4 & 5, 2010

Building 33, Conference Room H114 (and H118, H120)

Focus: Identifying Potential Higher Level Products for Climate/Carbon End Users

Objectives:

Identify science/application data products to be derived from HyspIRI measurements *by users*;

Discover/Discuss issues underlying data product processing/integration/fusion;

Prioritize the development of product prototypes.

Science Discipline Areas to be addressed: Terrestrial Ecosystems, Agriculture

Participants: 67 Active; 25 part-time

Science Questions for the HyspIRI Mission (http://hyspIRI.jpl.nasa.gov)

HyspIRI has three top-level science questions [identified in the NRC Decadal Survey] related to:

1) Ecosystem function and composition,

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

2) Volcanoes and natural hazards,

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

3) Surface composition and the sustainable management of natural resources.

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

6 over-arching VSWIR questions. *VQ1-6 (with 35 sub-questions)*
5 over-arching TIR questions, *TQ1-5 (with 23 sub-questions)*
6 over-arching Combined VSWIR&TIR questions, *CQ1-6 (with 32 sub-questions)*

Terrestrial Ecosystems: *HyspIRI Science Questions for Symposium*

VQ1: Ecosystem Pattern, Spatial Distribution and Components

What is the global spatial pattern of ecosystem 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: Disturbance Regimes

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

TQ2 and CQ2: Wildfires

TQ2: What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time? CQ2: How are fires and vegetation composition coupled?

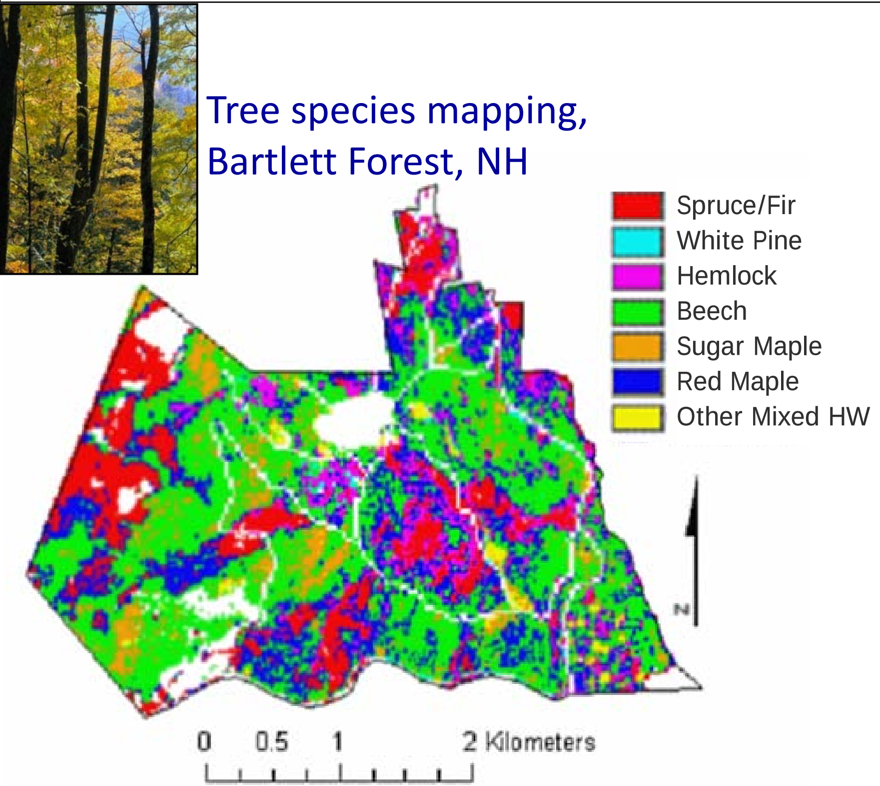
TQ3. Water Use and Availability:

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

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?

Determine the global distribution, composition, and condition of ecosystems, including agricultural lands


Tree species mapping, Bartlett Forest, NH

Societal Issue:

- Forests, farmlands and a variety of other ecosystems are critical to life on the Earth. Many ecosystems are changing in ways that are poorly understood.

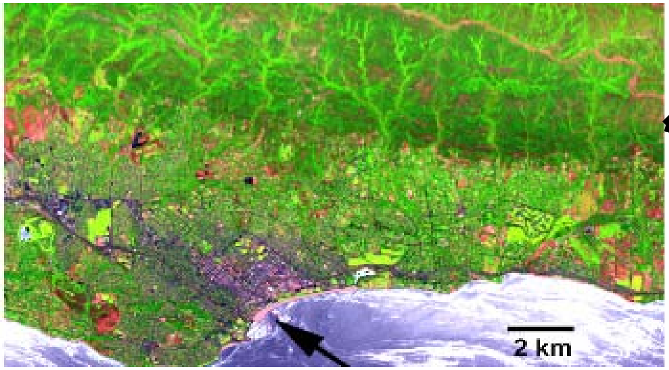
Scientific Issue:

- Understanding the distribution, diversity and status of ecosystems is necessary for understanding how they function and for predicting future changes.

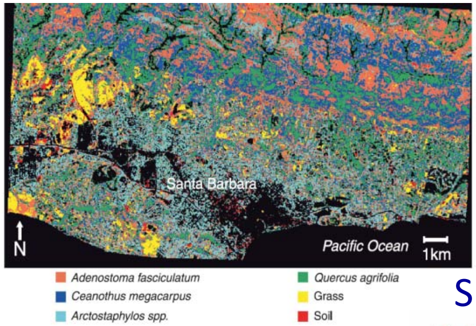
Approach (Why we need HyspIRI):

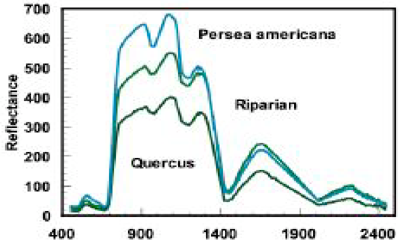
- HyspIRI will provide an important new capability to detect & monitor ecosystem composition and condition globally, with spectroscopic and thermal measurements.

HyspIRI Airborne Simulator Data Set

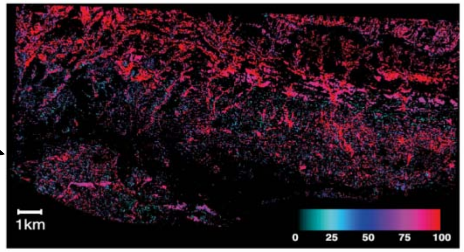


Species Type Determination





Species Fractional Cover



VSWIR Spectrometer (212 contiguous channels)

Level 0: Digital Numbers

Level 1: 1A - Level 0 reconstructed, time-referenced and annotated with ancillary information,
L1B : surface radiance spectra & water leaving radiance spectra at TOA. Cloud screened images.

Level 2: *Description* - Swath data. ***Products*** - TOA and Surface Reflectance (%) Spectra
.
==

User-Derived Products

Level 3: *Description* - Swath *and* Gridded data, Terrain corrected products.
Products: Albedo, Land cover classifications, Composites (seasonal, regional and global composites), Spectral indices for vegetation function/health, Spectral indicators for canopy contents (pigments, nitrogen, water, Maps of end-member abundance.

VSWIR Spectrometer (212 contiguous channels)

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User-Derived Products-- Continued

Level 3: *Description* - Swath *and* Gridded data, Terrain corrected products.

Products: Albedo, Land cover classifications, Composites (seasonal, regional and global composites), Spectral indices for vegetation function/health, Spectral indicators for canopy contents (pigments, nitrogen, water, Maps of end-member abundance.

Level 4: *Description* – Time series, Model outputs, Multi-sensor data fusion, Assimilation with other data types (e.g., ET, Fire fuel & fuel moisture).

Products – Regional Scale (60m-1km): *For specific sites, watersheds, geographical units or global samples of ecosystems, but potentially for global maps:* Gross Primary or Ecosystem Production (GPP, GEP); Net Primary or Ecosystem Production (NPP, NEP); Fractional land cover; Fractional vegetation cover (FVC), based on: photosynthetic vegetation (PV) and non-photosynthetic vegetation (NPV), Soil, Water, Snow, Ice; Fractional PAR absorption (*f*APAR); Leaf area index (LAI); Water Content; Plant functional types (PFT); Fractional vegetation cover by PFT(FVC); Light-use efficiency (LUE); Canopy stress and Physiology (combining PFT, LAI, canopy water, nutrients, pigments); Ecological disturbance (>10% change); Susceptibility to fires (fire fuels & fuel moisture, FVC, canopy water); Susceptibility to hazards (e.g., landslides).

Products -Global Scale (gridded, ¼-1 deg+): *For modeling ecosystems/general cover categories:* GPP, GEP; NPP, NEP; Fractional land cover (Veg., Soil, Water, Snow, Ice); *f*APAR; LAI; Water Content; Disturbance (>10% change).

TIR Multiband Sensor (8 discrete bands)

Level 0: Digital Numbers

Level 1: 1A - Level 0, reconstructed, time-referenced and annotated with ancillary information; 1B – surface band radiances at TOA, Cloud screened images. ***Products*** – Brightness temperature.

Level 2: *Description* - Swath data. ***Products*** – Land Surface Temperature, LST (day or night); Surface Spectral Emissivity (day or night); Detection of fire events.

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Level 3: *Description* – Day or night swath and gridded data, Terrain corrected, Day or Night Composites (seasonal, regional and global).

Products – Distribution and variation in land surface temperature, surface spectral emissivity maps, Water stress indicators; Fire severity, directions and associated risks.

Level 4: *Description* - Time series, Model outputs, Multi-sensor data fusion, Assimilation with other data types.

Products - Regional (60m-1km): *For specific sites, watersheds, geographical units, agricultural fields, or global samples of ecosystems, but potentially for global maps:* LST (from temperature/emissivity separation) by functional groups and ecosystem types, LST urban/sub-urban, Evapotranspiration (ET).

Products - Global (gridded, ¼-1 deg+): *For modeling ecosystems/general cover categories:* LST and emissions by Fractional land cover (Vegetation, Soil, Water, Snow, Ice), ET, Increase in sensible heat due to Urban Heat Islands (anthropogenic heat).

Synergy between TIR Day & Night and VSWIR & TIR

Level 4 Products: Time series, Model outputs, Multi-sensor data fusion, Assimilation with other data types.

TIR, day and night - *Products - Regional (60m-1km) & Global (1-5 deg. grids)*:

Bi-weekly, monthly and/or seasonal averages for day-night temperature & emissivity differences per geographic study unit (watershed, etc.).

VSWIR and TIR – *Products - Regional (60m-1km) & Global (1-5 deg. grids)*:

- Day-night temperature & emissivity differences according to vegetation/ecosystem type,
- LST (from day/night pairs) by functional groups and ecosystem types,
- Water/land boundaries defined,
- Ecosystem & Agricultural Crop Classifications, using both VSWIR & TIR,
- ET per ecosystem or agricultural type, using both VSWIR & TIR,
- Assess fire severity and available fuel by vegetation type,
- Develop spectral Reflectance & Emission libraries by land cover types and/or vegetation functional groups (at regional and global scales),
- Develop *high spectral resolution indicators of ecosystem/crop health,* by combining VSWIR indices and TIR indices; Construct spectral indicators of ecosystem function, disturbance, diversity, maturity to improve modeled predictions.
- Compare high spectral resolution indicators to currently used broadband indicators of ecosystem/crop function.

Expected Outcomes of Symposium

Goal: To Identify and Evaluate Potential Higher Level Products for Climate/Carbon End Users, in Terrestrial Ecosystem & Agriculture Science/Applications.

Objectives/Outcomes:

1] Identify science/application data products that could be derived from HyspIRI measurements ***by users***;

2] Prioritize the development of product prototypes.

3] Discover issues underlying data product processing and related to data integration/fusion.

4] Address the case for relevance of HyspIRI to climate change studies.

5] Develop a report on the community consensus for **1-4** above.

DAY 1 (May 4): Morning Agenda

I. Establish Background

8:30 am: Welcome-- HQ on the HyspIRI mission concept and Decadal Survey status [**Woody Turner**]

8:45 am: Objectives and Outline of the Symposium & Expected Results [**Betsy Middleton**]

8:55 am: Overview of the Mission: Description of the VSWIR and TIR instruments [**Rob Green & Simon Hook**]

9:15 am: Relevance of HyspIRI to Carbon and Climate [**Susan Ustin**]

9:30 am: Orbit & Platform Information, update from Team X [**Bogdan Oaida**]

9:45 am: Description and Examples of Typical VSWIR and TIR Image Collections [**Bob Knox**]

10:00 am: **Questions/Answers** (10 minutes)

10:10 -10:30 am: Coffee Break & Posters

II. Science & Application Products from the User Community: VSWIR & TIR

10:30 am –noon: Proposed VSWIR and TIR High Level Products [7 speakers, 10 min each]

[**Phil Townsend, John Gamon, Anatoly Gitelson, Mary Martin, Ben Cheng, Simon Hook, Martha Anderson, Susan Ustin**]

Noon - 1:00 pm: Lunch and Poster Session (Sandwiches/Drinks in conference serving area)

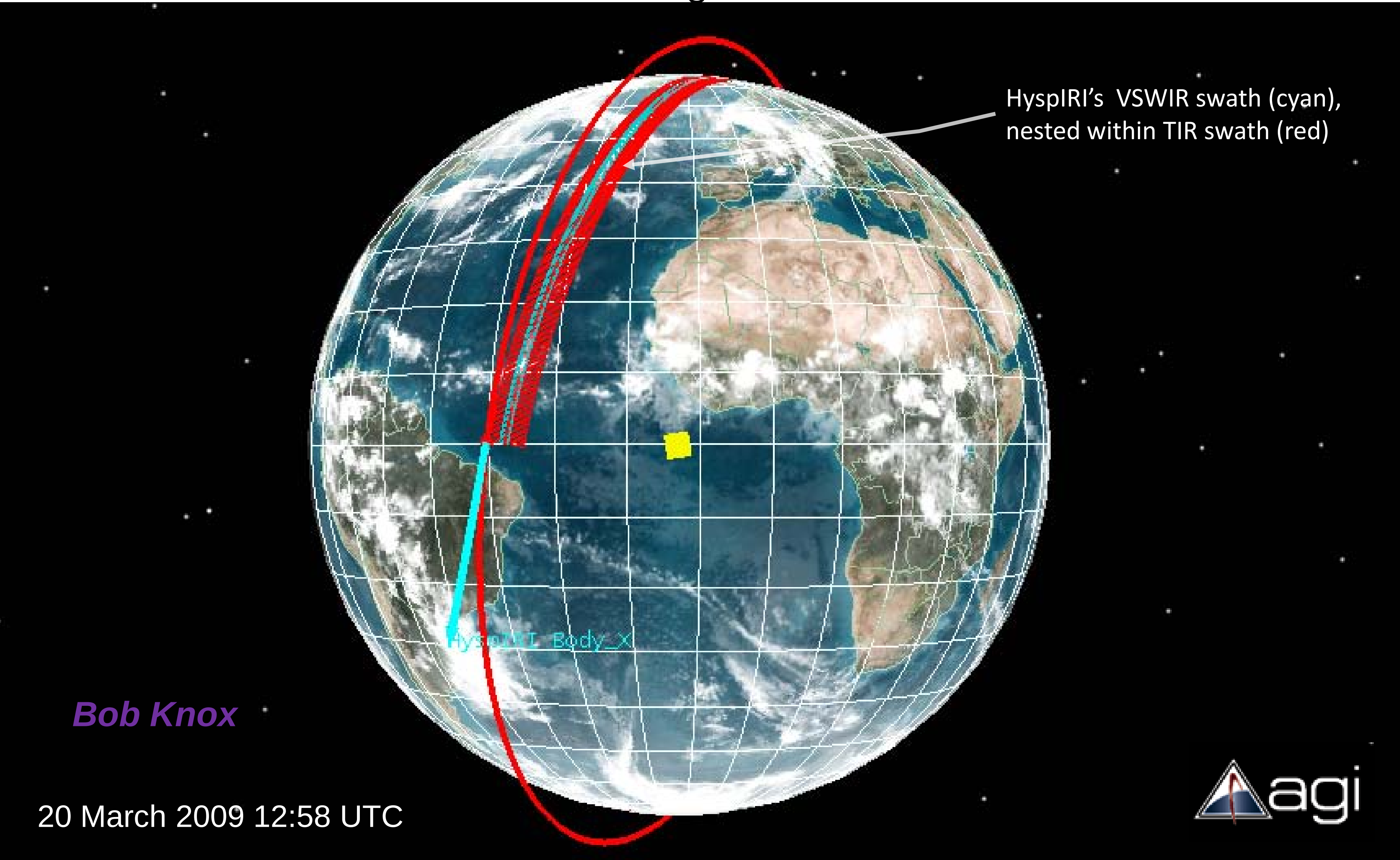
Plans for HyspIRI

Woody Turner

- Stay the course
- Continue to mature our technology and operations
- Strengthen the scientific case for the program
- Focus on the climate-relevance of our mission science
- Explore the potential to build the scientific basis for HyspIRI through utilization of products from airborne systems and upcoming spacecraft missions carrying spectrometers and TIR sensors

  (doing so will require additional funding)
- Look at results of HyspIRI preparatory activities solicitations
- Be ready!

Daylight side of a sun-synchronous reference orbit, with 10:30 AM equatorial crossing (mean local time) at a descending orbit node. The sub-solar point (yellow) shows the location on Earth where the Sun is directly overhead, east of the ground track.

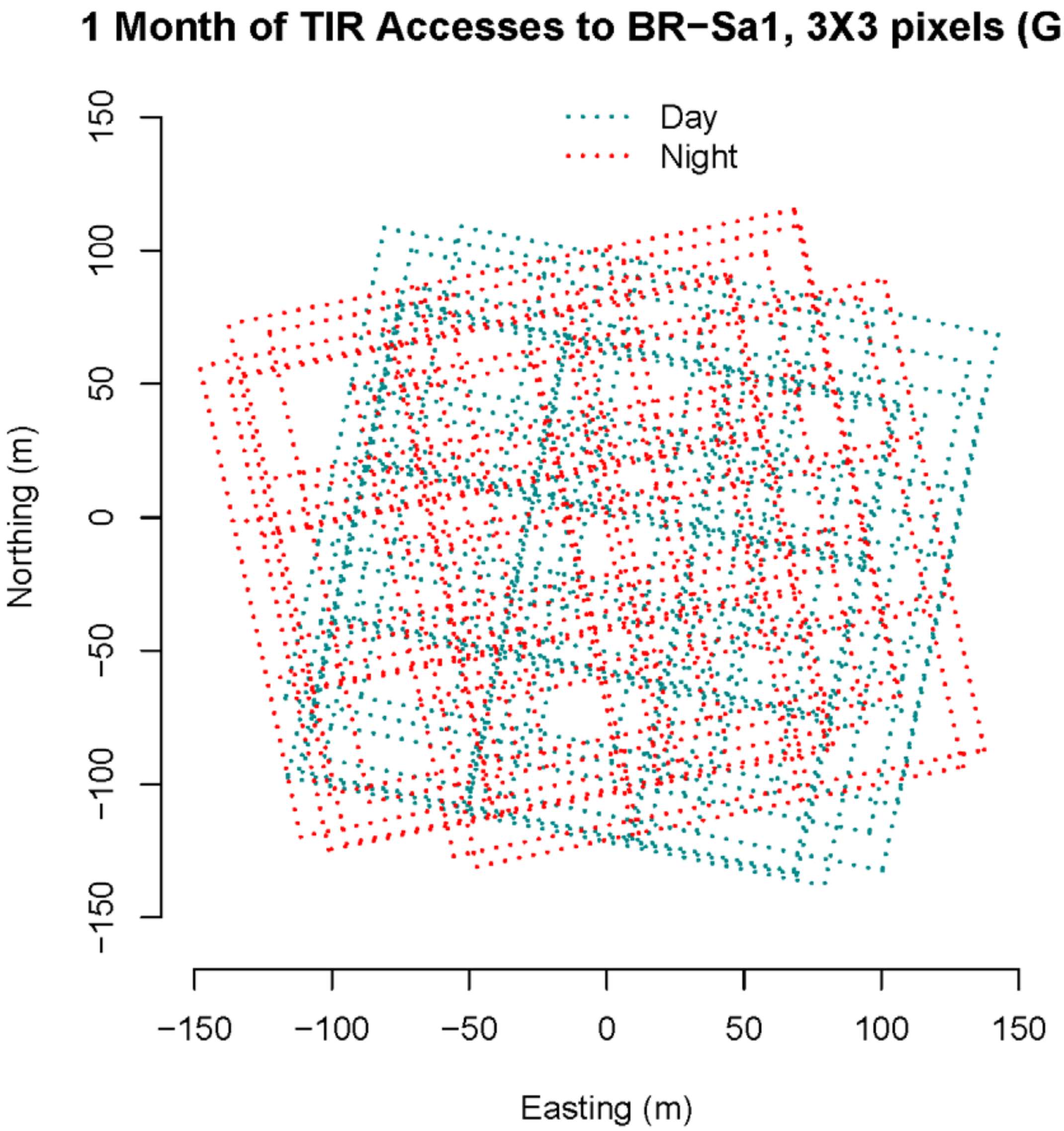


HyspIRI’s VSWIR swath (cyan), nested within TIR swath (red)

Bob Knox

20 March 2009 12:58 UTC

14 potential image collects for 1 simulated month (equatorial site)



Bob Knox

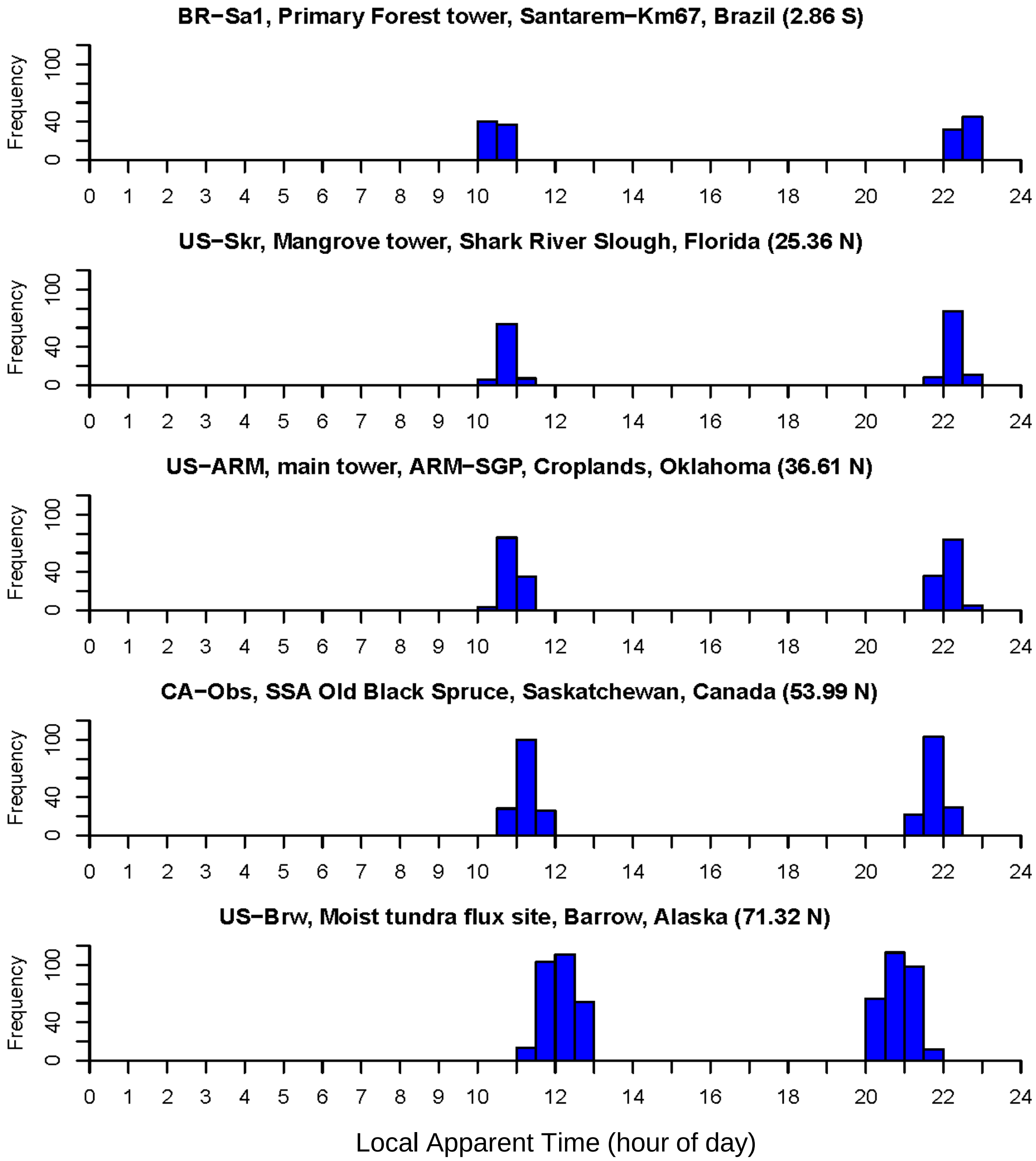
Local time of TIR overpasses of 5 FLUXNET sites, simulated for 1 year

Near the equator, overpass times are separated by 12 hours, on average.

As the N latitude of the site increases, potential TIR collects are more frequent and less tightly clustered in local time.

When moving toward the North orbit pole (82.1 N), daytime collects are later and night collects earlier.

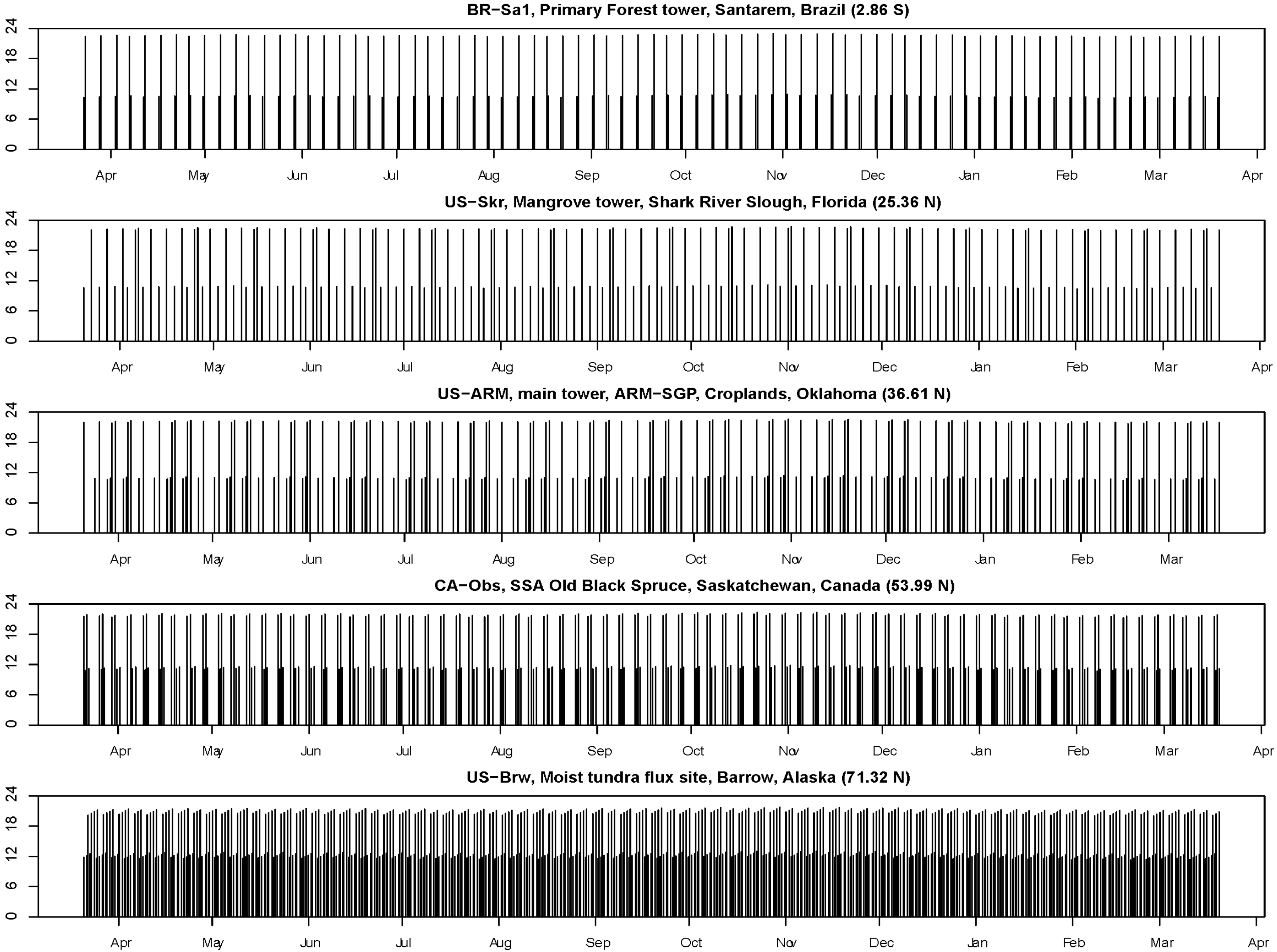
The reverse is true (not shown) when moving South.



Bob Knox

TIR accesses for 1 simulated year

Bob Knox



BR−Sa1, Primary Forest tower, Santarem, Brazil (2.86 S)

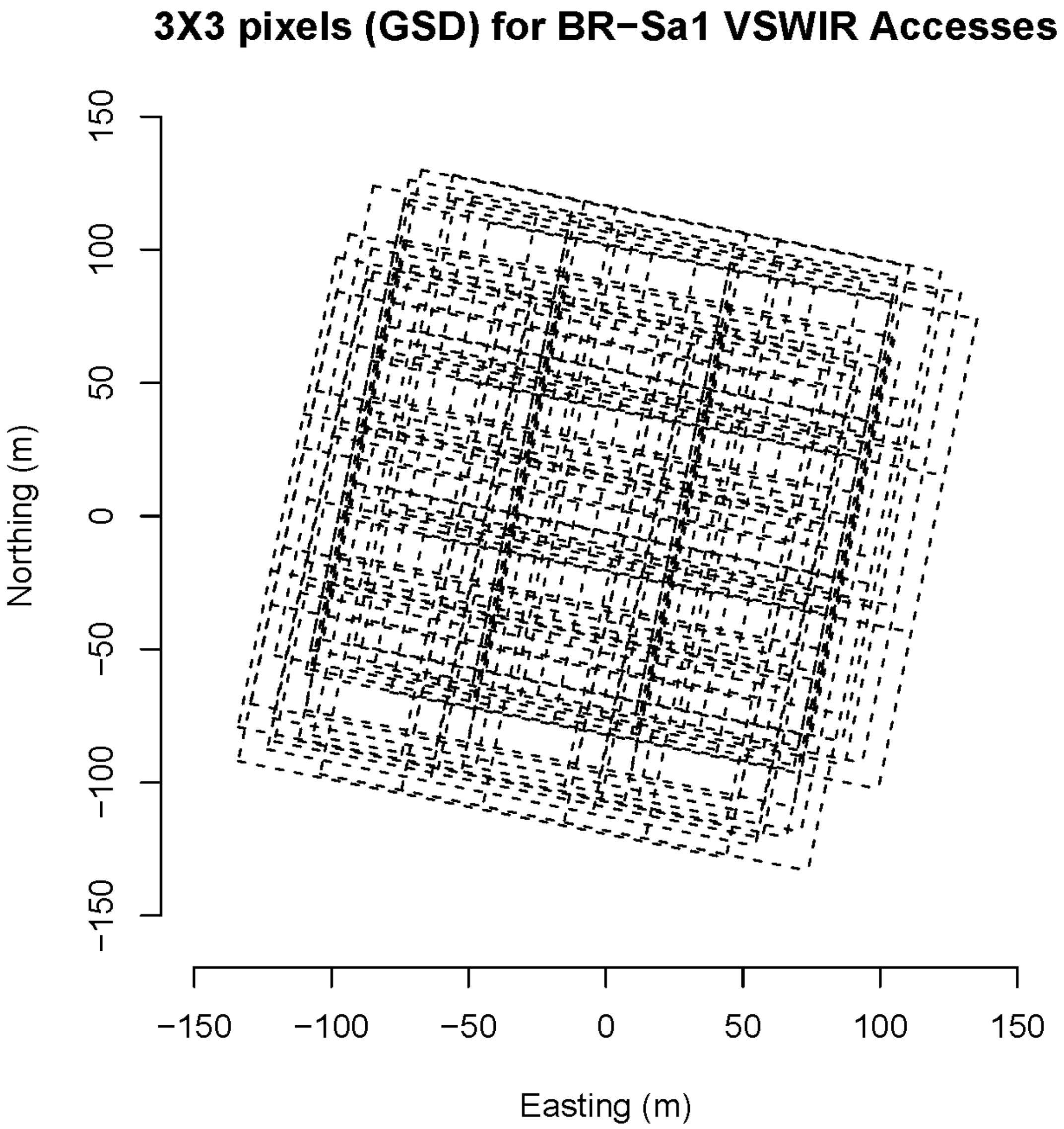
US−Skr, Mangrove tower, Shark River Slough, Florida (25.36 N)

US−ARM, main tower, ARM−SGP, Croplands, Oklahoma (36.61 N)

CA−Obs, SSA Old Black Spruce, Saskatchewan, Canada (53.99 N)

US−Brw, Moist tundra flux site, Barrow, Alaska (71.32 N)

19 potential image collects for 1 simulated year (equatorial site)



Bob Knox

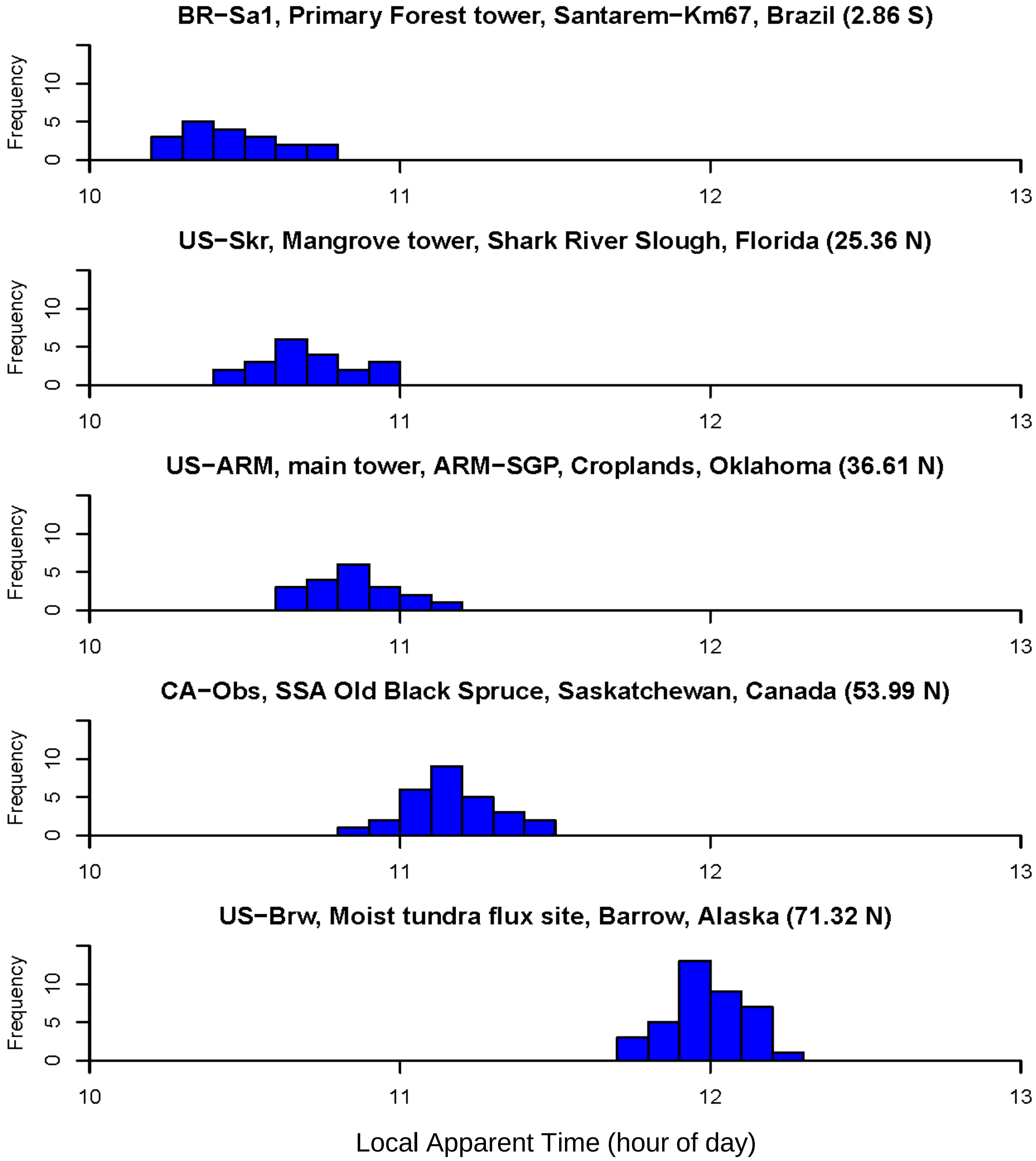
Local time of VSWIR overpasses of 5 FLUXNET sites, simulated for 1 year

Local apparent time, for a fixed mean local time, varies with the Earth’s orbit.

As the N latitude of the site increases, the local apparent time of potential VSWIR accesses also increase.

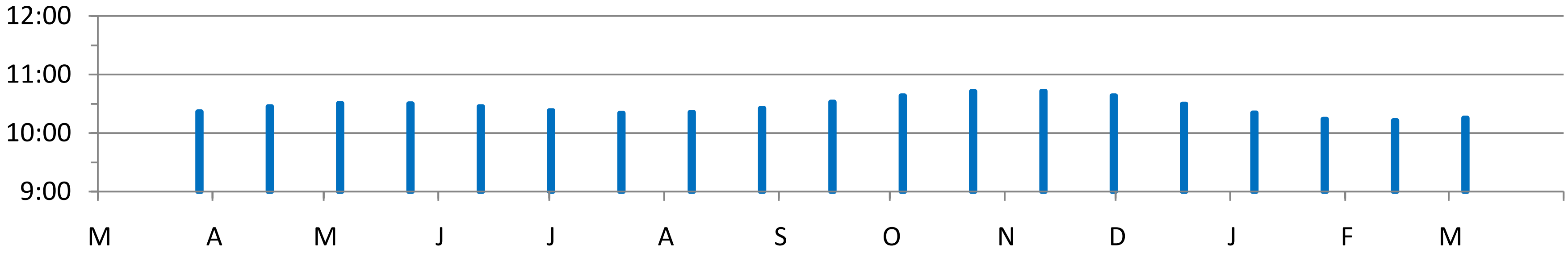
Near the North orbit pole (82.1 N) the local time may be nearly 6 hours later than when crossing the equator (not shown).

Moving toward the South orbit pole, local times are progressively earlier in the morning (not shown).

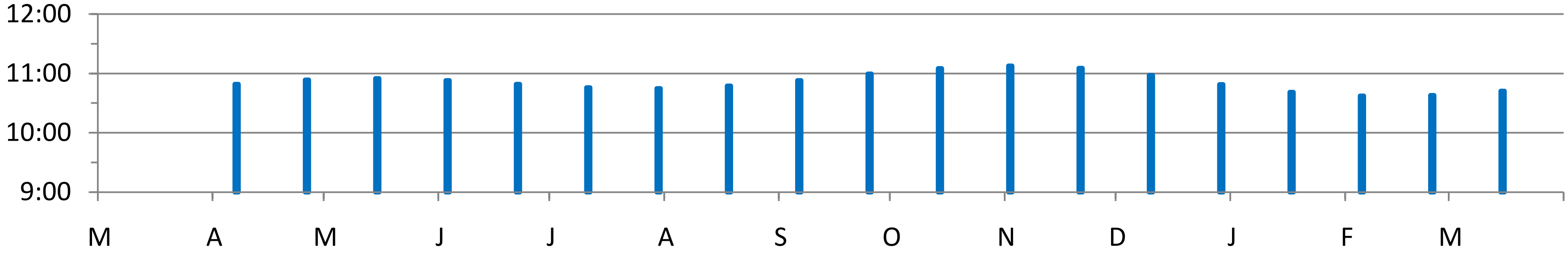


Bob Knox

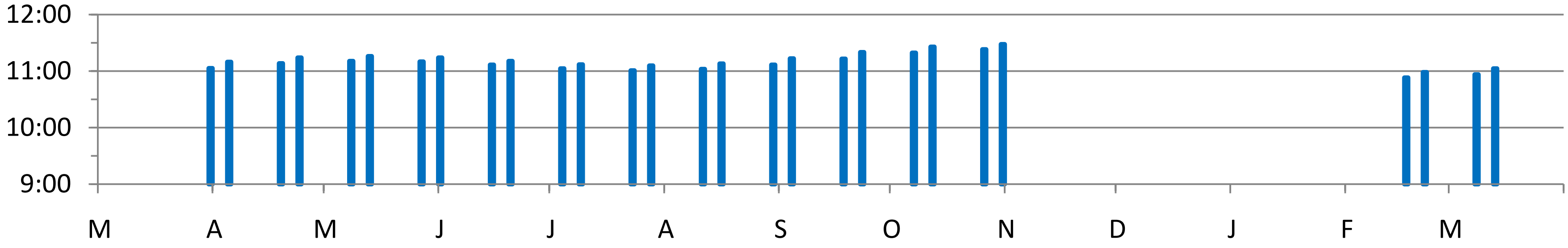
VSWIR spectrometer accesses to three selected FLUXNET sites
1 simulated mission year: date & local apparent time



BR-Sa1: Brazil - Santarem km 67, Primary Forest (2.86 S)



US-ARM: Southern Great Plains, Oklahoma, Main Tower, Croplands (36.6 N)



CA-Obs: Canada, Saskatchewan, BOREAS SSA - Old Black Spruce (53.99 N)

R.G. Knox, NASA GSFC, Biospheric Sciences Branch, Code 614.4. Simulated with STK v8.1.3, March 8, 2010.

DAY 1 (May 4): Afternoon Agenda

III. Factors Affecting Product Integrity and Availability **1:00 – 2:30 pm (10 min each)**

* Atmospheric Correction [**Rob Green**]

* Data volume/compression, SpaceCube [**Tom Flatley**]

* Intelligent Payload Module (IPM) & algorithms for upload [**Vuong Ly/Dan Mandl**]

* Low-latency Applications, Science, and Operations for HyspIRI [**Steve Chien**]

* On-line tools to facilitate HyspIRI products and analysis [**Petya Campbell**]

* Hyperspectral Input to models [**Fred Huemmrich**]

* Calibration/Validation & CEOS/GEO [**Joanne Nightingale**]

* Impact of Spectral-Spatial Misalignment on Measurement Accuracy [**Steve Ungar**]

IV. Science & Application Products from the User Community: Combined VSWIR & TIR

2:30 -2:50 pm: Combined VSWIR/TIR Products Overview: Issues & Examples
[**Bob Knox/Betsy Middleton**]

2:50-3:00 pm: **Questions/Answers** (10 minutes)

3:00-3:20 pm – Coffee Break & Posters

3:20- 4:30 pm: Proposed Combined Products (7 speakers, 10 min each)

[**Rasmus Houborg, Louis Giglio, Dar Roberts, Dale Quattrochi, Ben Cheng, Ray Kokaly, Craig Daughtry**]

DAY 1 (May 4): Afternoon Agenda Con’t

V. Special & Potential Observation Capabilities

4:30-4:40 pm: Special Opportunities for Highly Sampled Areas
(orbit overlaps, high latitudes etc.) [**Bob Knox**]

4:40-4:50 pm: Synergy of VSWIR and Lidar for Ecosystem Biodiversity
[**Bruce Cook/Greg Asner**]

VI. Break-Out Discussions (Guidelines, **Betsy)**

4:55 -6:15 pm: Three Simultaneous Break-Out Discussions
(H114, H118, H120)
VSWIR Products [**Phil Townsend/John Gamon**]
TIR Products [**Simon Hook/Kurt Thome**]
Combined Products [**Dar Roberts/Susan Ustin**]

6:20 pm – Adjourn, Dinner at Chevy’s Restaurant, Carpools Organized

The Break-Out Group Discussions

[Topics for consideration]

How important is HyspIRI to the User Community, for TE and climate?

What are the most important Products for Terrestrial Ecology?

What are the Tools needed to produce these Products?

What are the road-blocks to having Products that users want?

AGENDA – DAY 2 (May 5) Con’t

VIII. Building a Team Consensus

10:30 – 11:00 am: Plenary Discussion, Aligning HyspIRI with Climate Observations
[**Susan Ustin/Dar Roberts**]

11:00 – 11:30 am: Plenary Discussion on Priority Products, [**led by Betsy, Rob & Simon**]

11:30 am – Noon: Consensus on Draft Products for HyspIRI, Outline of Symposium Report
[**Betsy, Rob, Simon**]

Noon – 12:30 pm: Preparation Activities for 3rd Science Workshop
[**Rob, Simon, Woody Turner**]
12:30 pm: Close General Meeting

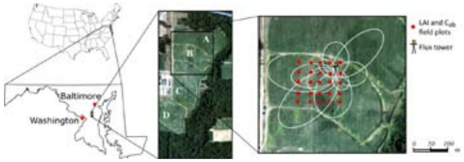
Adjourn, or Lunch at Cafeteria

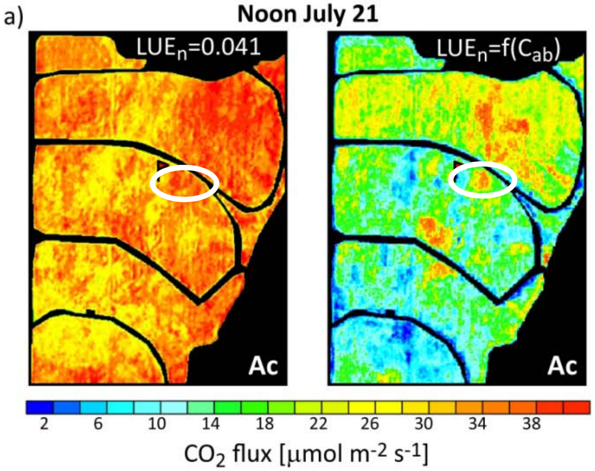
*1:30-3:00 pm: **Optional** Opportunity to show PI presentations in small conference rooms [H118]*

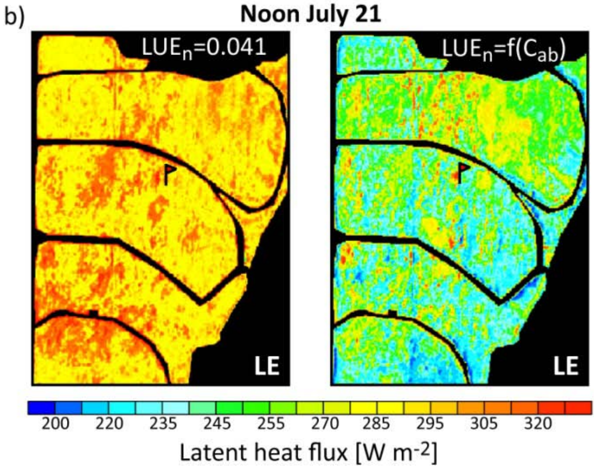
and

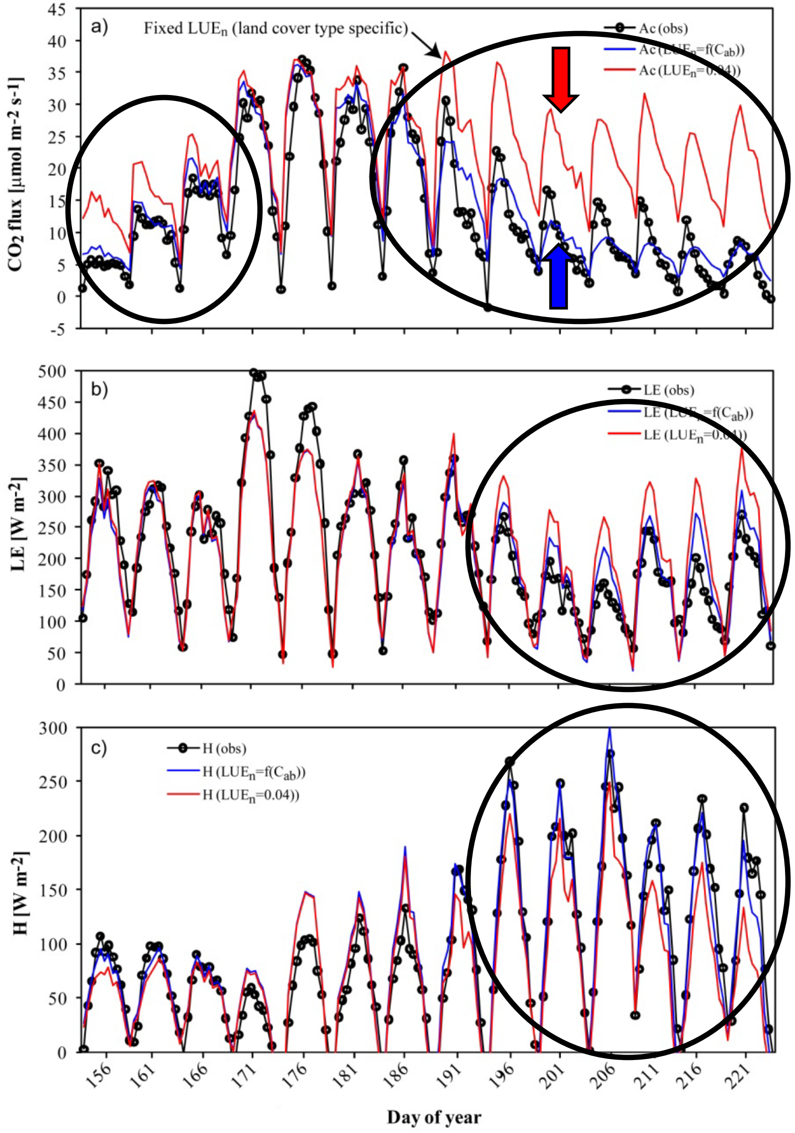
Steering Committee Meeting [H120]

LUE – Leaf chlorophyll inter-correlation
Thermal-based flux mapping



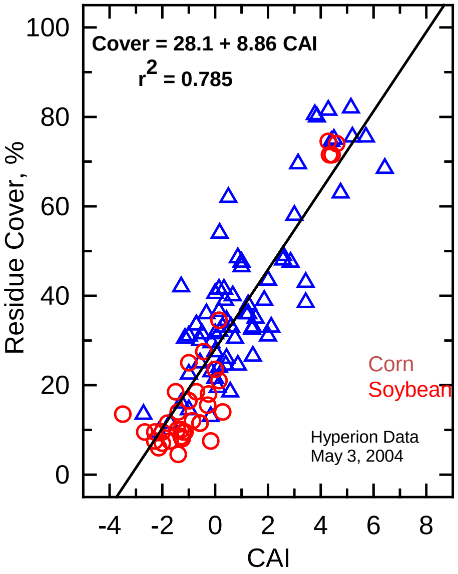






Rasmus Houborg

Iowa 2004

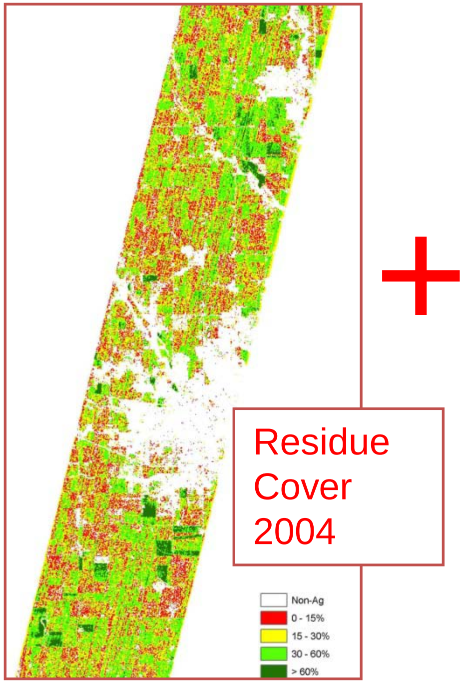


Slope of line is similar to ground-based (ASD) and aircraft (AVIRIS & AISA) data in MD, IN, and IA.

Residue cover was measured: May 10-12

Planting progress for May 9
(Iowa Crop & Weather, 2004)
Corn:
93% planted;39% emerged
Soybeans:
54% planted; 4% emerged

Hyperion Imagery was acquired: May 3



Residue Cover 2004

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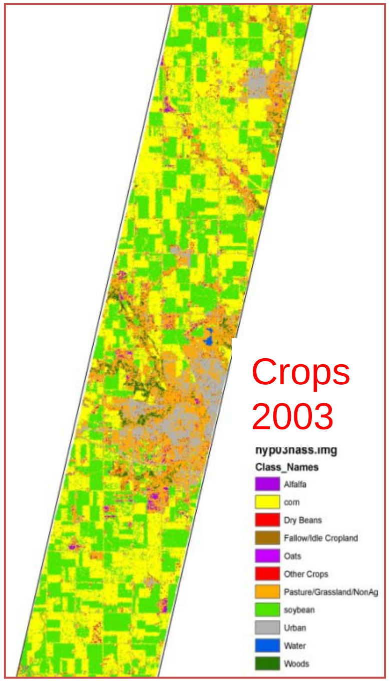
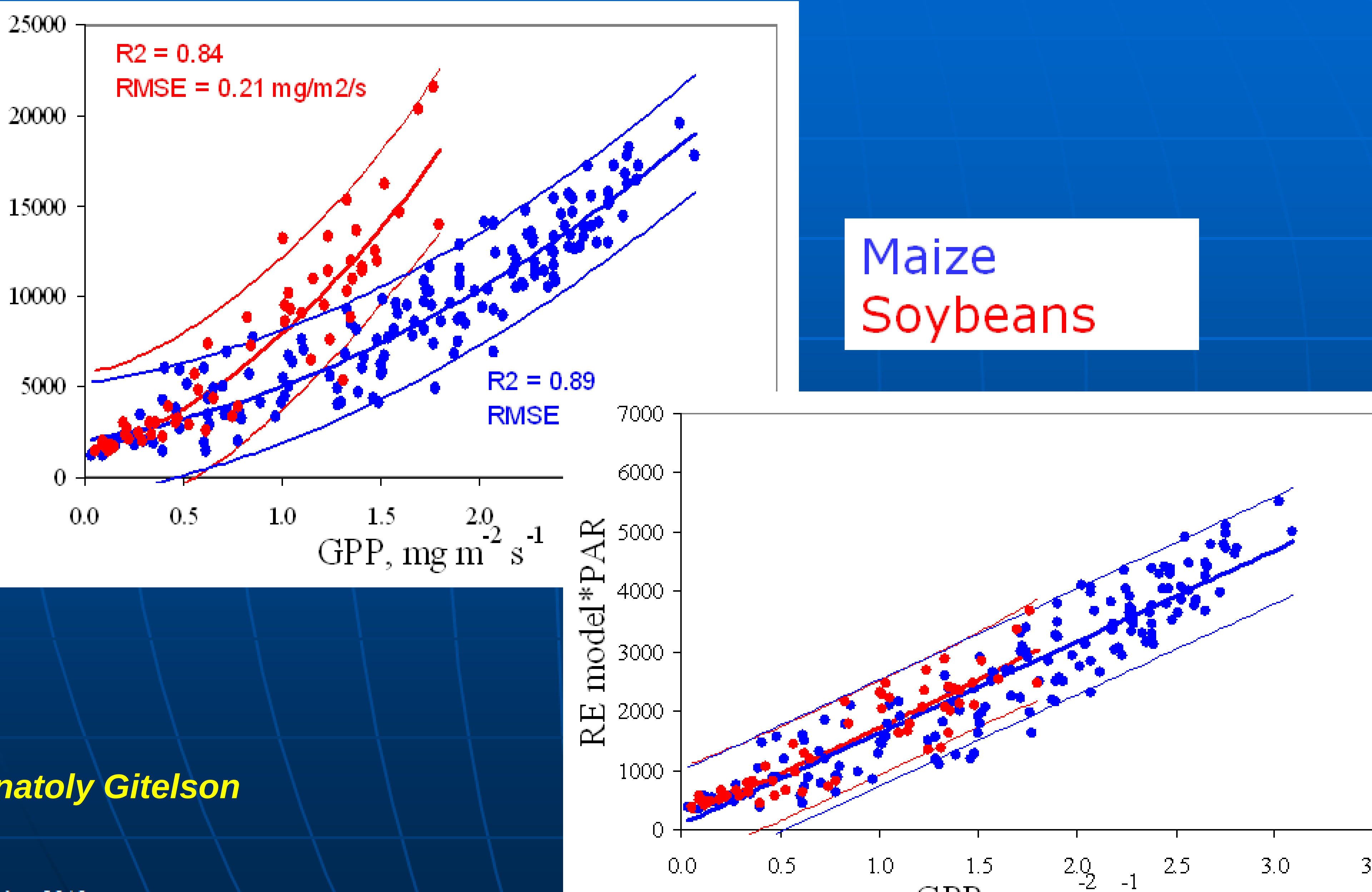


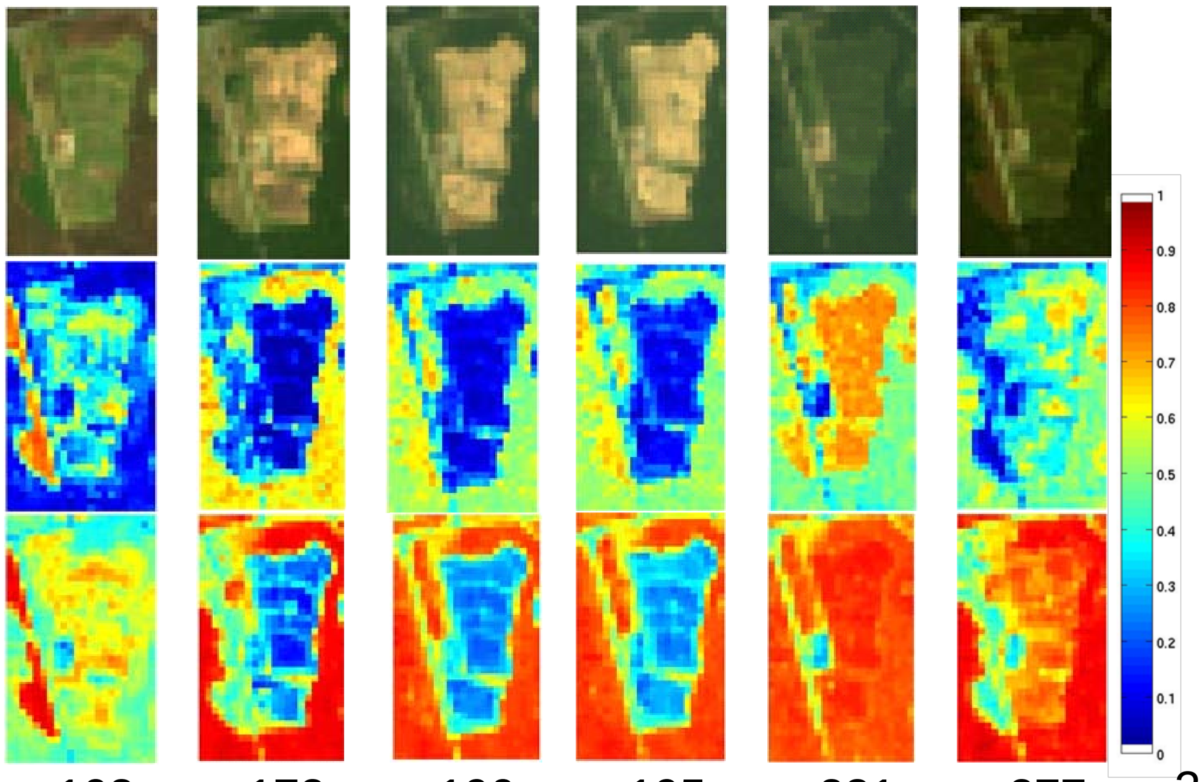
Crops 2003

Daughtry

GPP estimation via Chl



natoly Gitelson



EO-1 Hyperion True color

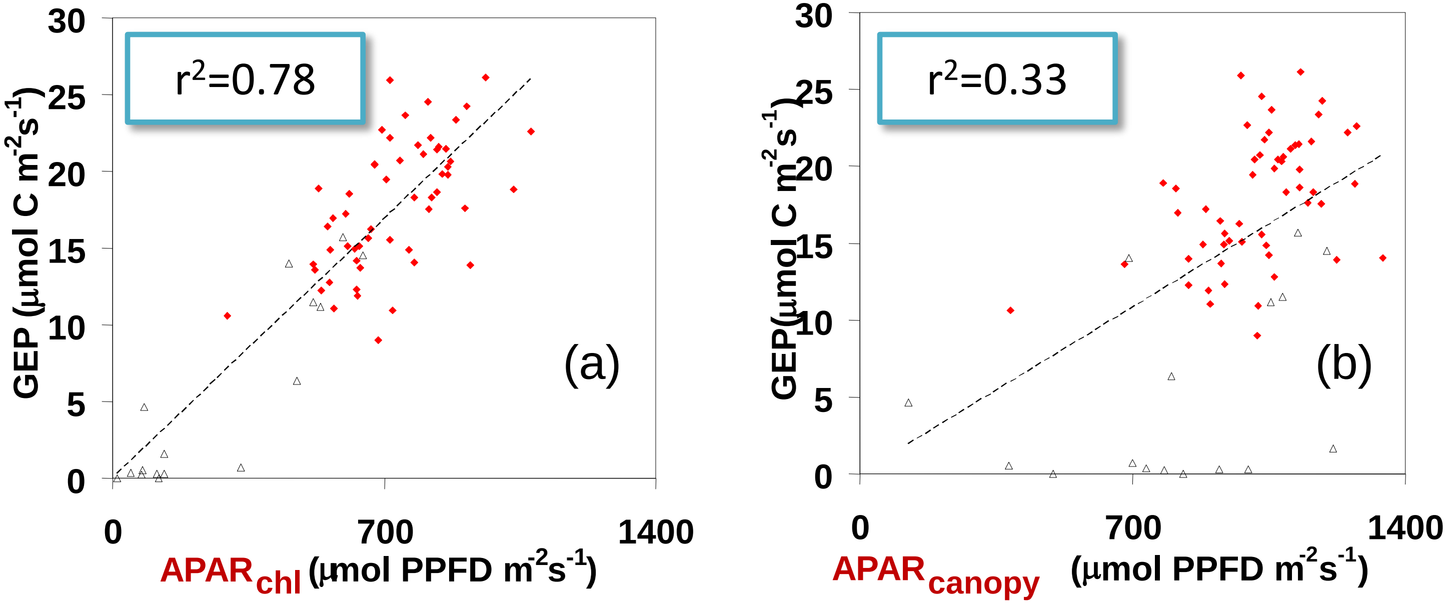
fAPAR_{chl}

fAPAR_{canopy}

DOY 108 172 190 195 231 277 2008

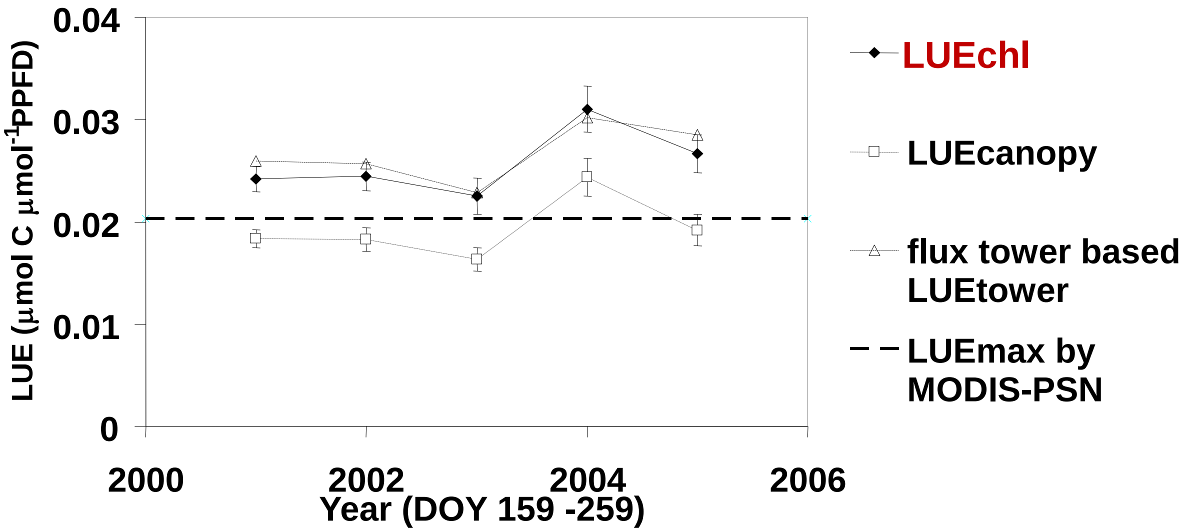
Spring **Summer** **Fall**

Qingyuan Zhang



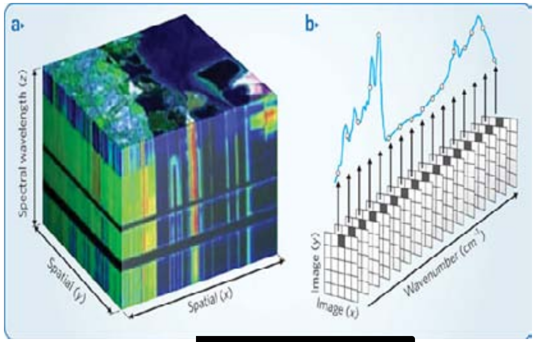
APARchl
LUEchl
Products

Qingyuan Zhang

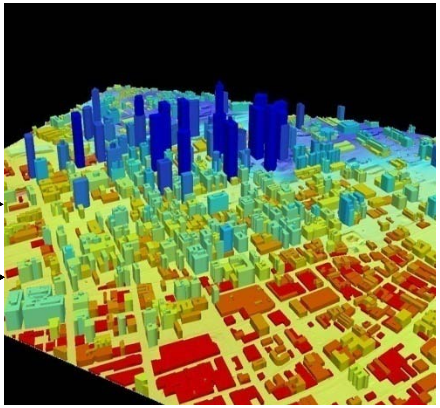


Zhang, Q., Middleton, E.M., Margolis, H.A., Drolet, G.G., Barrd, A.A., & Black, T.A. (2009). Can a satellite-derived estimate of the fraction of PAR absorbed by chlorophyll (FAPARchl) improve predictions of light-use efficiency and ecosystem photosynthesis for a boreal aspen forest? *Remote Sensing of Environment, 113, 880-888*

HyspIRI Combined “Integrated” Advanced Product for Urban Ecosystems Analysis



HyspIRI Hyperspectral VSWIR Level II Product
(NDVI, fPAR, surface reflectance characteristics)



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Lidar Data

HyspIRI VSWIR/TIR and Lidar composite data set
(X, y, z surface reflectance/thermal interactions of urban ecosystem processes)

HyspIRI TIR multispectral Level II product (8 TIR Bands)
(surface temperature, radiance, [day/night], emissivity)

Dale Quattrochi

JJJoanne Nightingale

HyspIRI Products

🟩 Existing Val Methods

🟥 Research Required

LPV Focus Group / Product	**VSWIR L 2/ 3**	**VSWIR L4**	**VSWIR Global**	**TIR L4**	**SWIR / TIR**
LAND COVER					
Fractional land cover / veg cover		🟩	🟩		
Disturbance, PFT, hazard susceptibility		🟥			
SURFACE RADIATION					
Surface Reflectance	🟩				
Albedo	🟩				
BIOPHYSICAL					
Gross / Net Primary Production		🟩	🟩		
fPAR		🟩	🟩		
LAI		🟩	🟩		
Water content, LUE, Pigments		🟥			
FIRE					
Detection of Fire events				🟩	🟩
Fire fuel loads		🟥			
LAND SURFACE TEMPERATURE					
LST				🟩	🟩
Emissivity				🟩	🟩
Evapotranspiration				🟥	

Mature & Ready: *Proposed HyspIRI Terrestrial Ecology Products*

(* = Climate Variable; ** = Essential Climate Variables defined by CEOS/GEO)

(Green text items show significant enhancement over existing multi-spectral observations)

VSWIR Imaging Spectrometer ALONE

Level 4 Biophysical & Physiological Products

1. **Directional Canopy Albedo [**]**
2. Fractional Cover: Snow, Water and Ice [**]
3. Leaf Area Index, LAI [**]
4. Canopy fAPAR (PAR absorbed by vegetation) [**]
5. Canopy fAPARchl (PAR absorbed by chlorophyll-containing canopy only) [*]
6. **Total Canopy Chlorophyll Content [*]**
7. **Fractional Cover: Green Vegetation, Non-Photosynthetic Vegetation, impervious surfaces, soil [*]**
8. **Fractional Cover for Vegetation Classes: Coniferous, Deciduous, and Mixed Forests; Grasslands; Wetlands; Crops [*]**

Multi-Spectral TIR Imagery ALONE

Level 2 & 3 Products [Day or Night swath & gridded data] (Terrain corrected; Day/Night Seasonal Composites)

1. Soil Moisture [**]
2. Fire Severity & Direction & Fire Radiative Power [**]
3. Distribution and variation in land surface temperature [*]
4. Water Stress Indicators [*]
5. Emissivity-Based Land Surface Classification (e.g., pervious vs. impervious) [*]
6. Cloud Mask [*]

VSWIR + TIR Combined

Level 4 Combined Products

1. **Biomass for Grasslands [**]**
2. **Diversity, Coastal Habitats [**]**
3. **Evapotransporation (ET) by Land Cover Type [*]**
4. **Functional Types/Species Composition [*]**
5. **Ecological Disturbance Area (logging, natural disasters, etc.) [*]**
6. **Drought Index (PET/AET) by Land Cover Type [*]**

Proposed Terrestrial Ecology Products from HyspIRI

Potential Products Needing Further Validation (* = Climate Variable; ** = ECV defined by CEOS)

(Green text items show significant enhancement over existing multi-spectral observations)

VSWIR Imaging Spectrometer ALONE

Level 4 Biophysical & Physiological Products

1. **Photosynthetic Parameters (LUE, Jmax, Vcmax) [*]**
2. **Environmental Stress Measurements (response variables) [*]**
3. **Canopy N content (mass/area) [*]**
4. **Canopy Water Content [*]**
5. **Vegetation Pigment Content (Chl a, Chl b, Carotenoids, Anthocyanins)**
6. **Canopy Lignin and Cellulose**

Multi-Spectral TIR Imagery ALONE

L3 Products [Day or Night swath & gridded data]

1. Burn Area (experimental as TIR only)
2. Burn Severity (experimental as TIR only)

VSWIR + TIR Combined

L4 Products – Regional

1. **Surface Energy Flux [**]**
2. **Combusted Biomass [**]**
3. **Sensible Heat due to Urban Heat Islands (Anthropogenic Heat) [*]**
4. **LST: Day/Night Differences for Ecosystems & Urban Areas [*]**
5. **LST Urban/Suburban [*]**
6. **LST by Functional Groups and Ecosystem Types [*]**
7. **Surface Topographic Temperature Mapping [*]**

L4 Products – Global

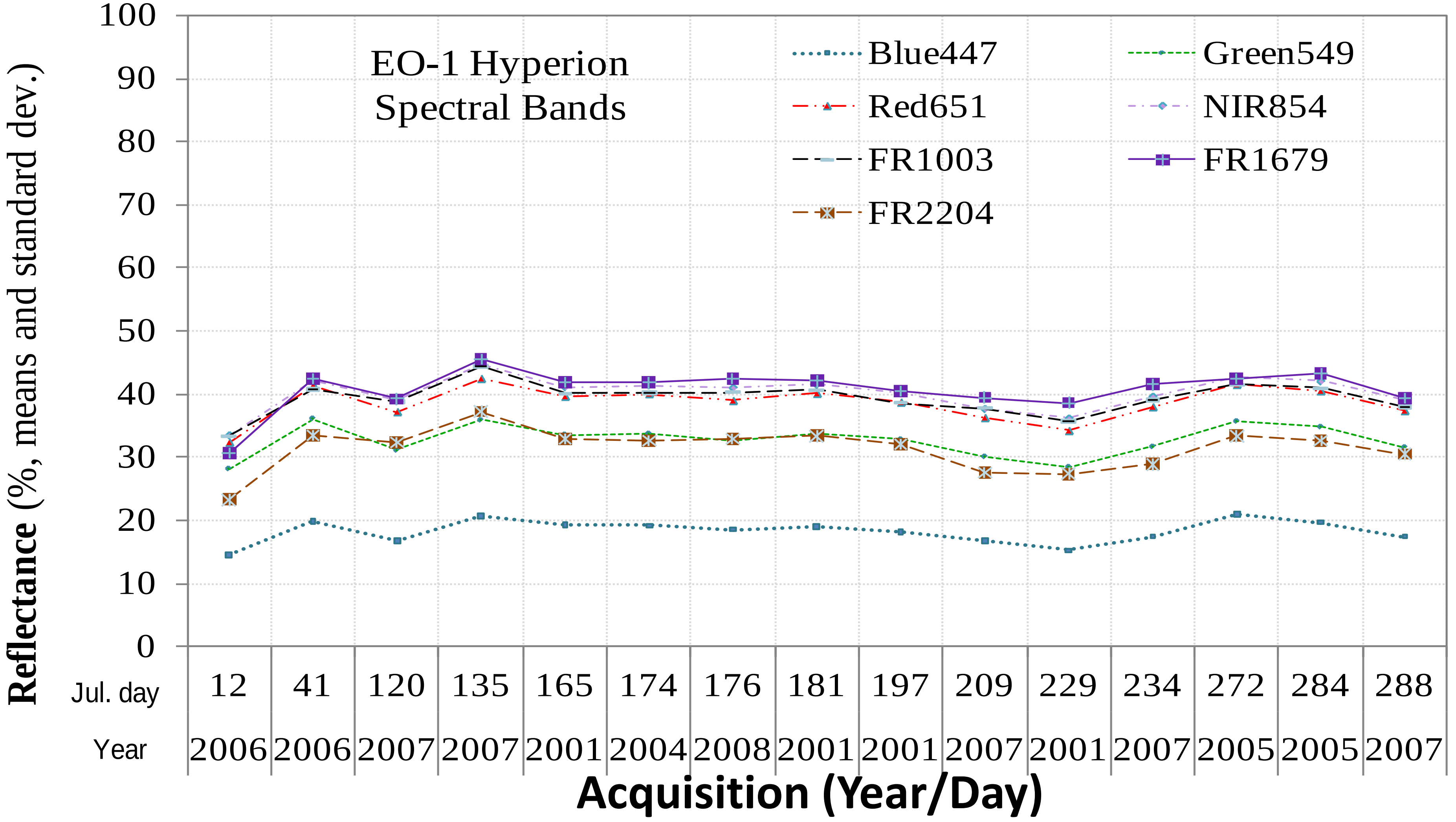
1. **LST & Emissions by Fractional Land Cover (Vegetation, Soil, Water, Snow, Ice, etc.) [**]**
2. **Ecosystem/Crop Phenology with Fusion Approaches [*]**

The EO-1 Project is supporting HyspIRI:

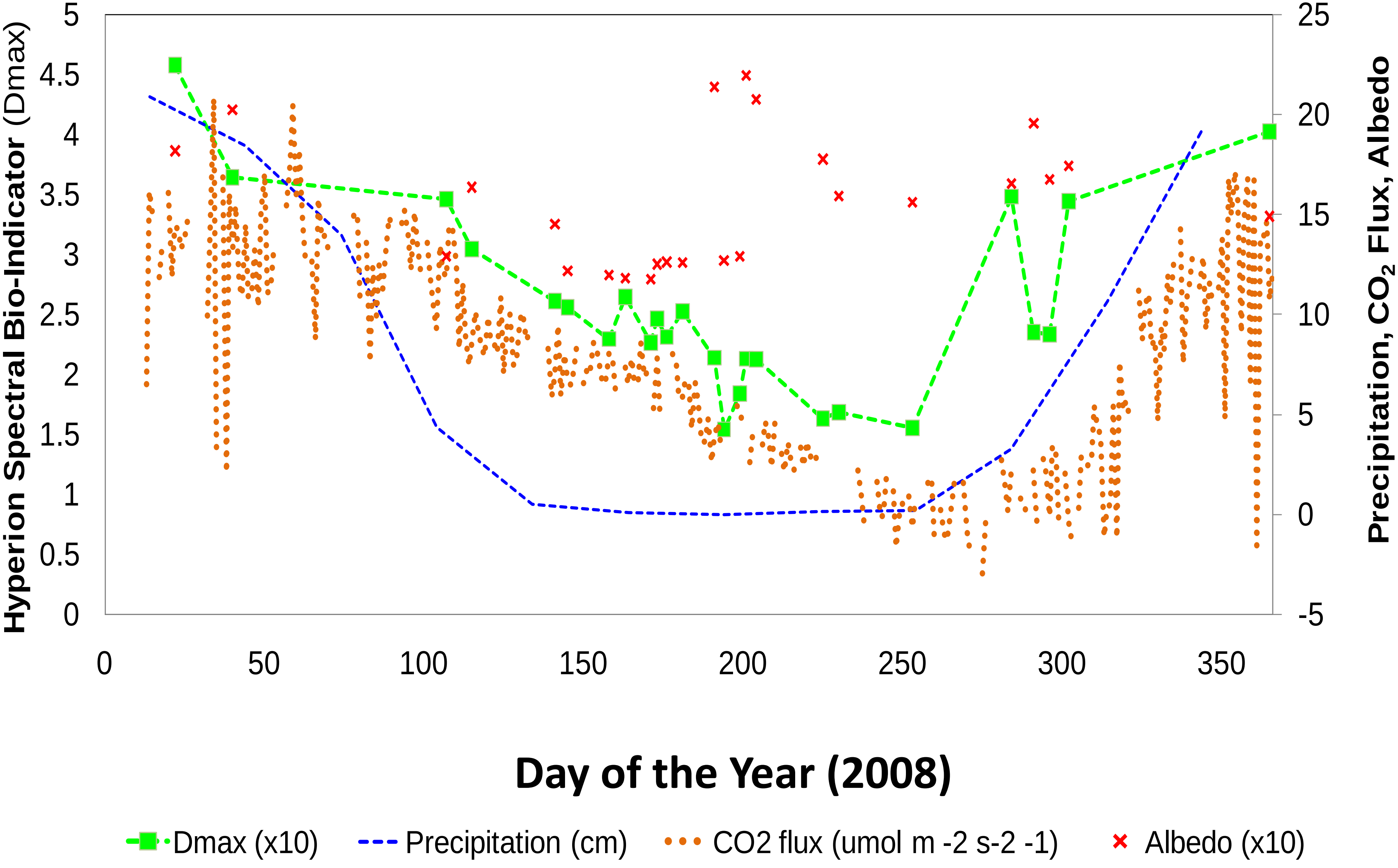
1] with Hyperion Prototype Products;

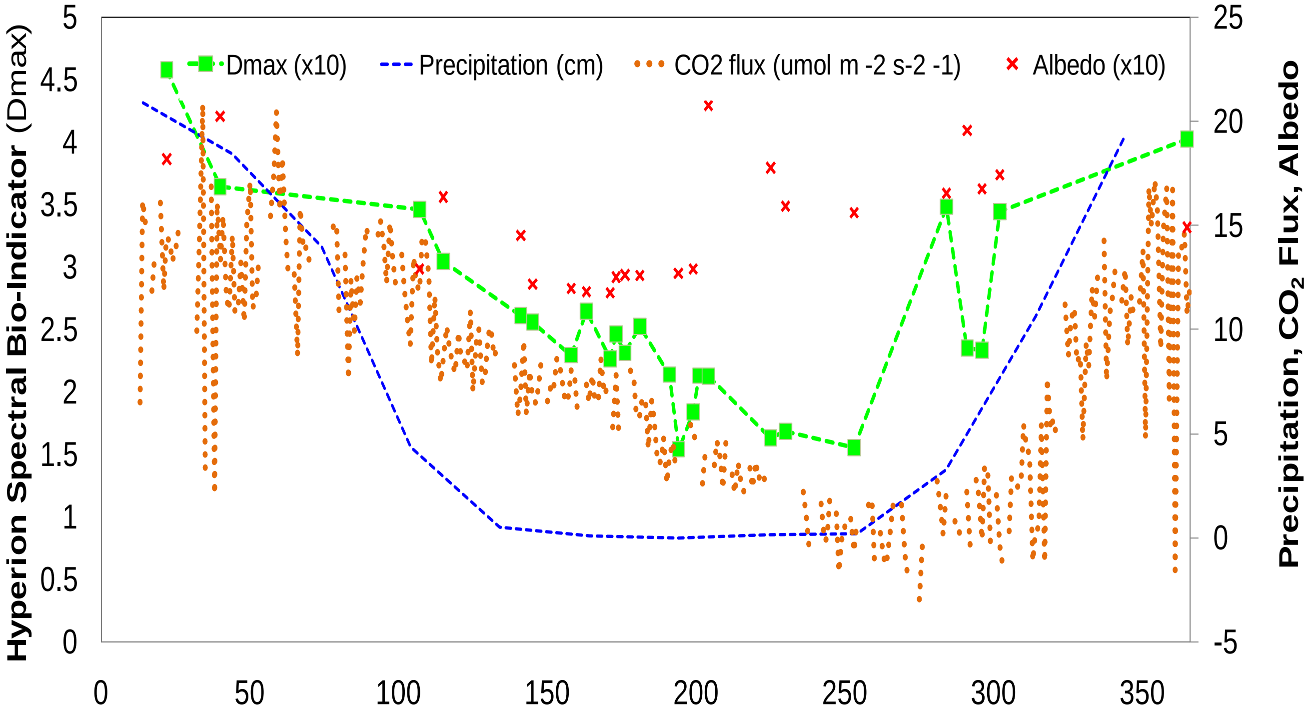
2] with Technology development & Advances

Railroad Valley Playa, Nevada, USA



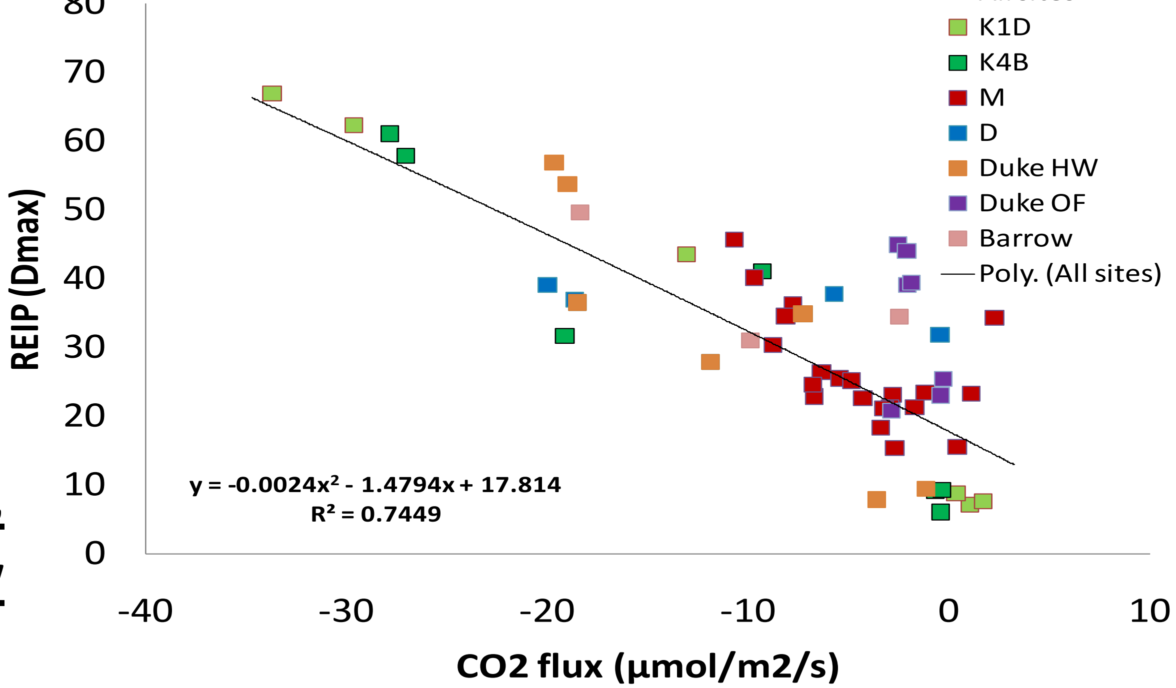
Mongu, Zambia, South Africa





Mongu, Zambia South Africa

Mongu, Konza, Duke, Barrow



Earth Observing-1

10th anniversary

EO-1 Science Validation Meeting and an Evening of Celebration

The events will take place at NASA/GSFC, Greenbelt, MD November 30 to December 2, 2010

Next GSFC Hosted Symosium
May 2011

Topics??

New Technology Developments– IPM, Low Latency?

More on Ecosystem Products– for Regional & Global?

Other Products? Urban, Agriculture, Thermal Features & Events?

IPCC Climate Change 2007: Working

The Physical Science Basis

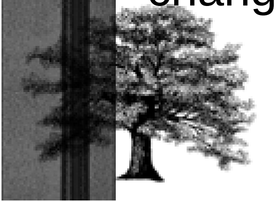
Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

The Land Surface and Climate

- Changes in the land surface (vegetation, soils, water) resulting from human activities can affect regional climate through shifts in radiation, cloudiness and surface temperature.
  - ➢Changes in vegetation cover affect surface energy and water balances at the regional scale, from boreal to tropical forests.

  - ➢The impact of land use change on the energy and water balance may be very significant for climate at regional scales over time periods of decades or longer.

Land Carbon. Understanding land carbon storage is a critical factor in predicting the growth of atmospheric CO_2 and subsequent global climate change. P. 273 , DS.



Susan Ustin

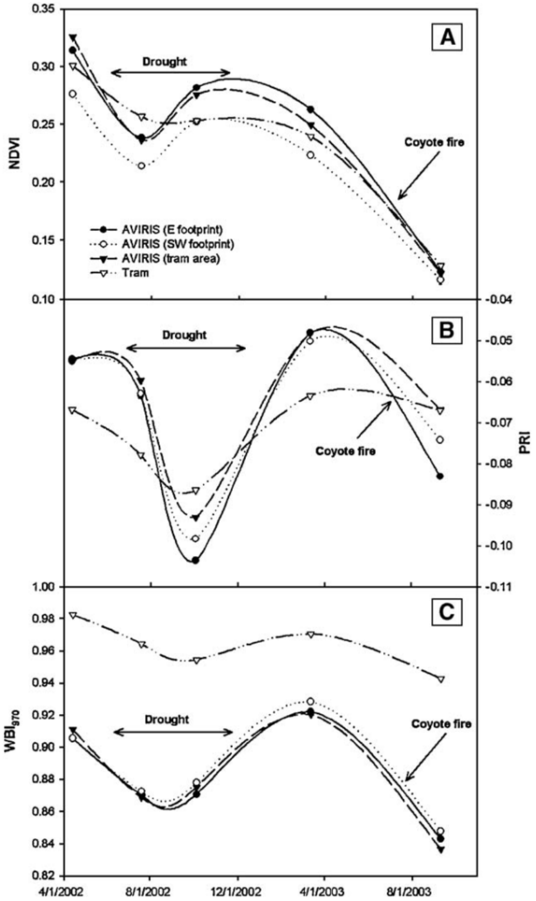
IPCC Climate Change 2007: Working
The Physical Science Basis

2.5.8 Effects of Carbon Dioxide Changes on Climate via Plant Physiology: ‘Physiological Forcing’

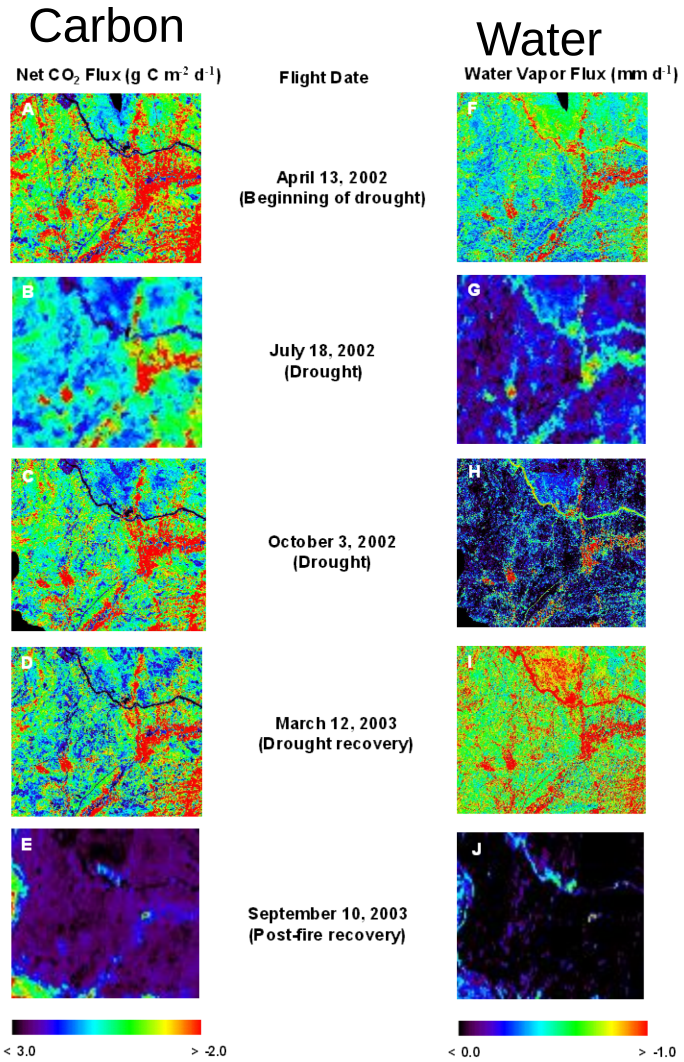
Radiative Forcing and Physiological Forcing

Interactions bertween water and carbon

Spatial and temporal patterns of carbon and water vapor fluxes, Sky Oaks, CA



Fuentes et al. 2006



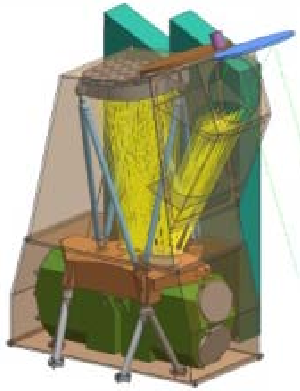
Susan Ustin

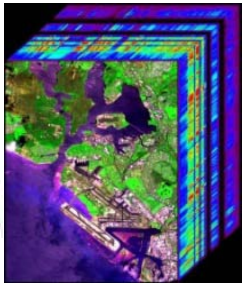
HyspIRI: Instruments, Platform, Observations

Rob Green (JPL)
Simon Hook (JPL)
Bogdan Oaida (JPL)
Bob Knox (GSFC)

HyspIRI - Imaging Spectroscopy (VSWIR) Science Measurements

Rob Green





Mature Instrument concept: All components have flown in space.

Imaging spectrometer: 55kg / 41W

Schedule: 4 year phase A-D, 3 years operations (5 years consumables)

Full terrestrial coverage downlinked every 19 days

VQ1. Pattern and Spatial Distribution of Ecosystems and their Components

– What is the pattern of ecosystem distribution 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 disturbances?

VQ3. Biogeochemical Cycles

– How are biogeochemical cycles for carbon, water and nutrients being altered by natural and human-induced environmental changes?

VQ4. Changes in Disturbance Activity

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

VQ5. Ecosystem and Human Health

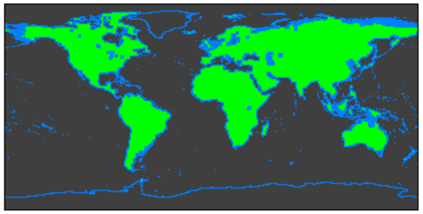
– How do changes in ecosystem composition and function affect human health, resource use, and resource management?

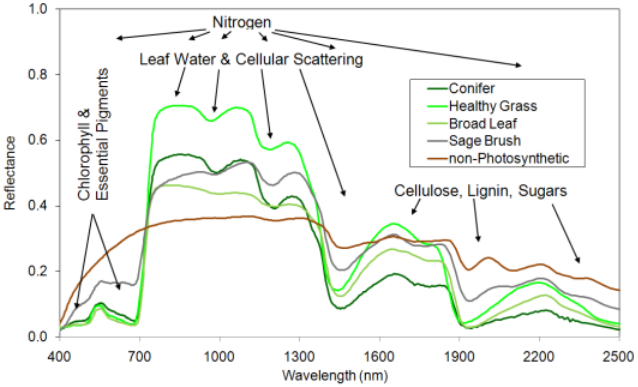
VQ6. Land Surface and Shallow Water Substrate Composition

– What is the land surface soil/rock and shallow water substrate composition?

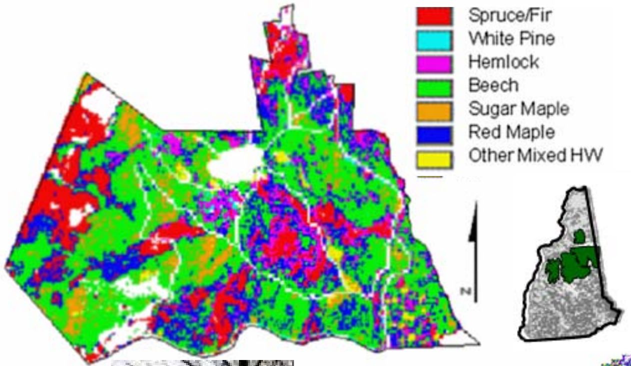
Measurement:

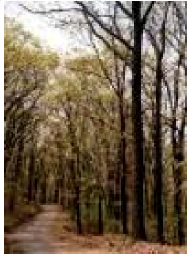
- 380 to 2500 nm at 10 nm
- Accurate 60 m resolution
- 19 days equatorial revisit
- Global land and shallow water





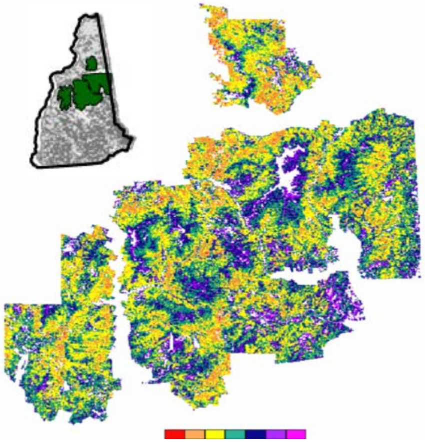
Map of dominant tree species, Bartlett Forest, NH





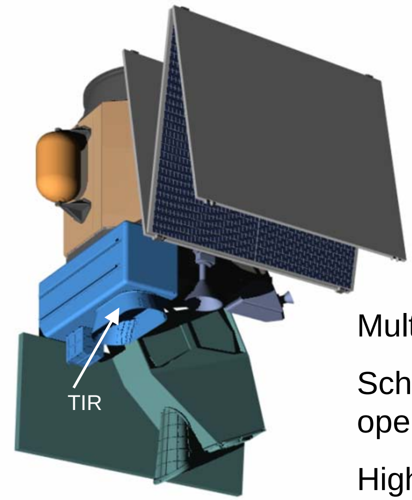
Soil C:N Ratio

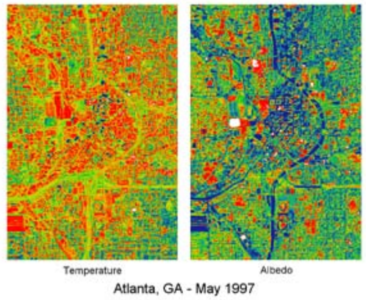
White Mountain National Forest, NH



HyspIRI Thermal Infrared Multispectral (TIR) Science Measurements

Simon Hook





Multispectral Scanner

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

High Heritage

Science Questions:

TQ1. Volcanoes/Earthquakes (MA,FF)

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

- *TQ2. Wildfires (LG,DR)*

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

- *TQ3. Water Use and Availability, (MA,RA)*

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

- *TQ4. Urbanization/Human Health, (DQ,GG)*

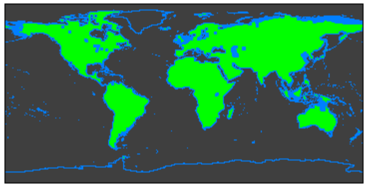
– How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

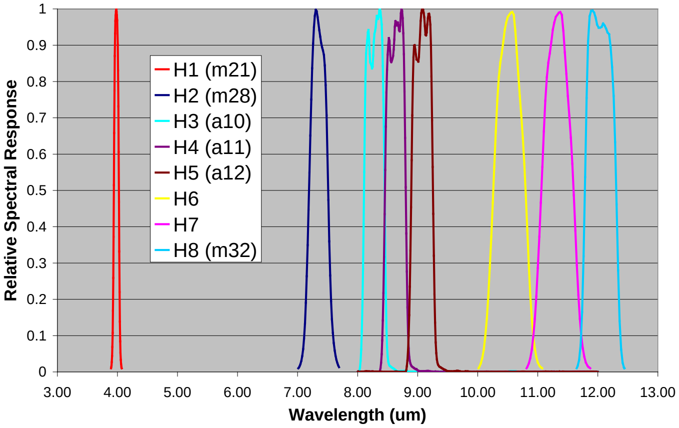
- *TQ5. Earth surface composition and change, (AP,JC)*

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

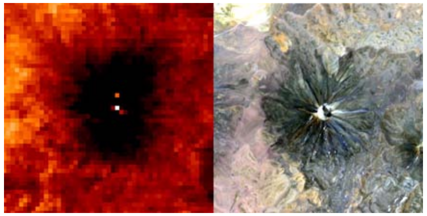
Measurement:

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

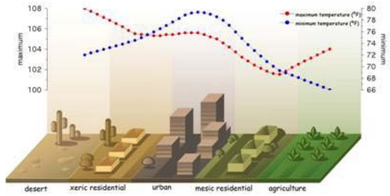




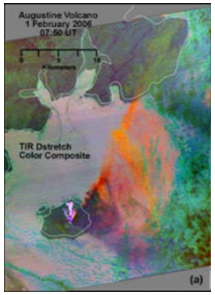
Andean volcano heats up



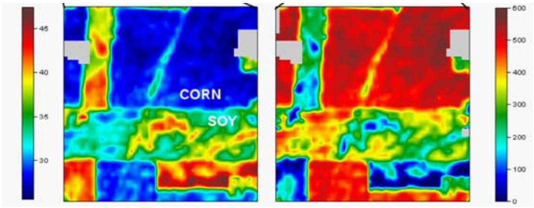
Urbanization



Volcanoes



Water Use and Availability



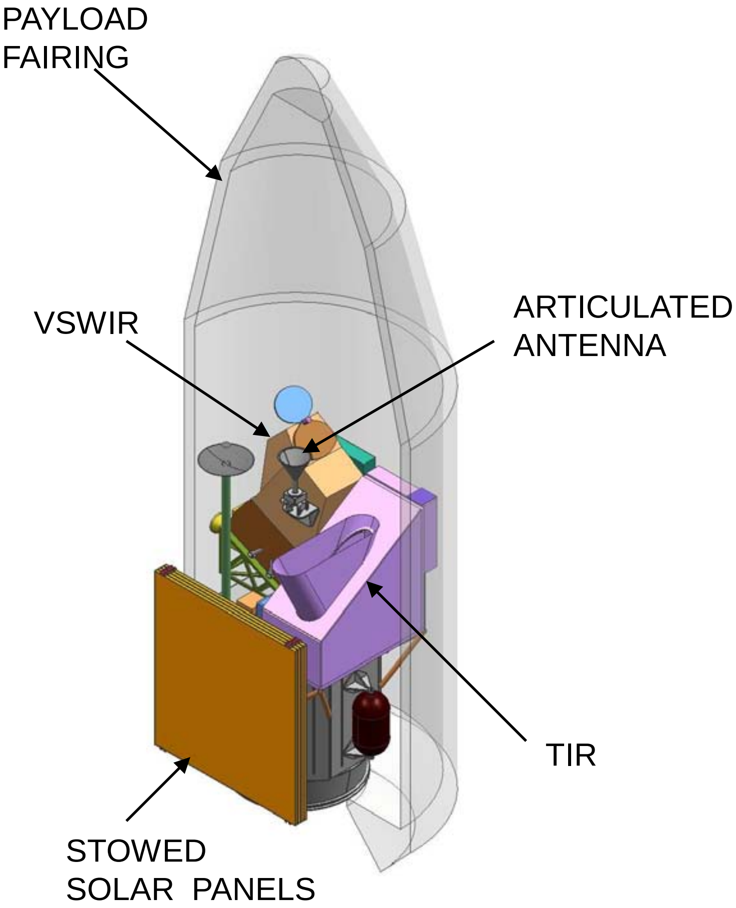
Surface Temperature

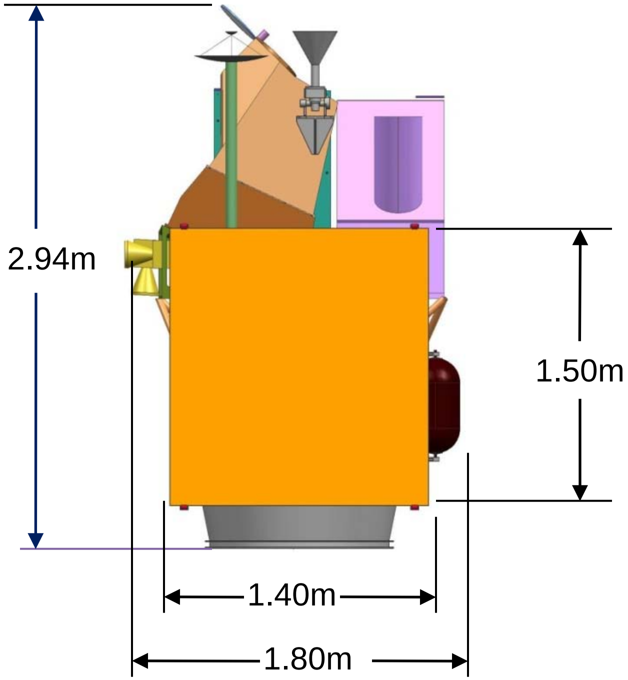
Evapotranspiration

Bogdan Oaida

Launch Vehicle Concept

- Taurus 3210 can meet the mission needs
  - Closest fit among currently NASA approved launchers
  - 30% margin (dry-mass CBE) with a Taurus-class launch vehicle
  - Fits dynamic volume envelope
  - 790 Kg launch capacity for HyspIRI Orbit
- Launch window
  - Mapping orbit reachable once per day



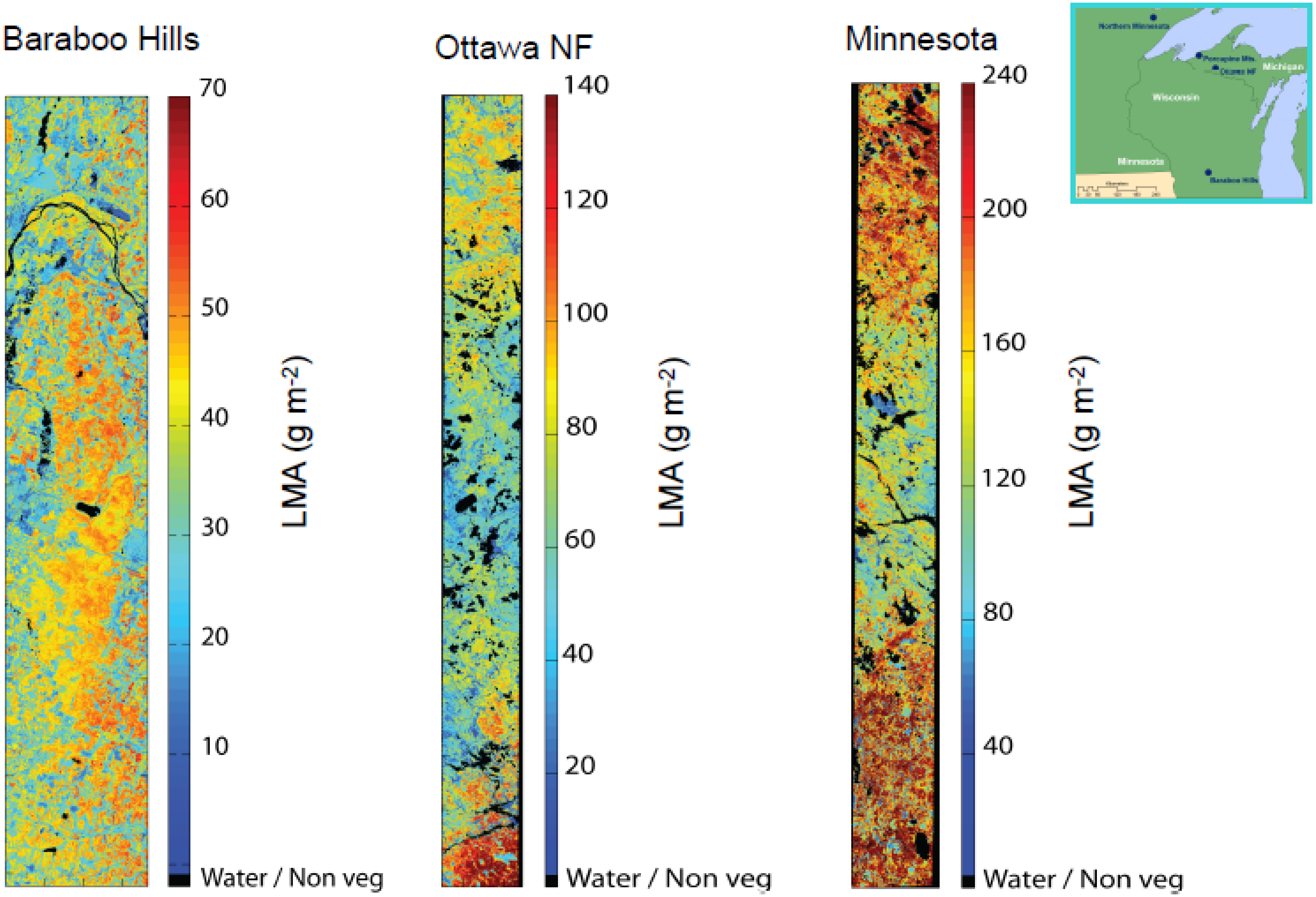


Proposed VSWIR and TIR Products

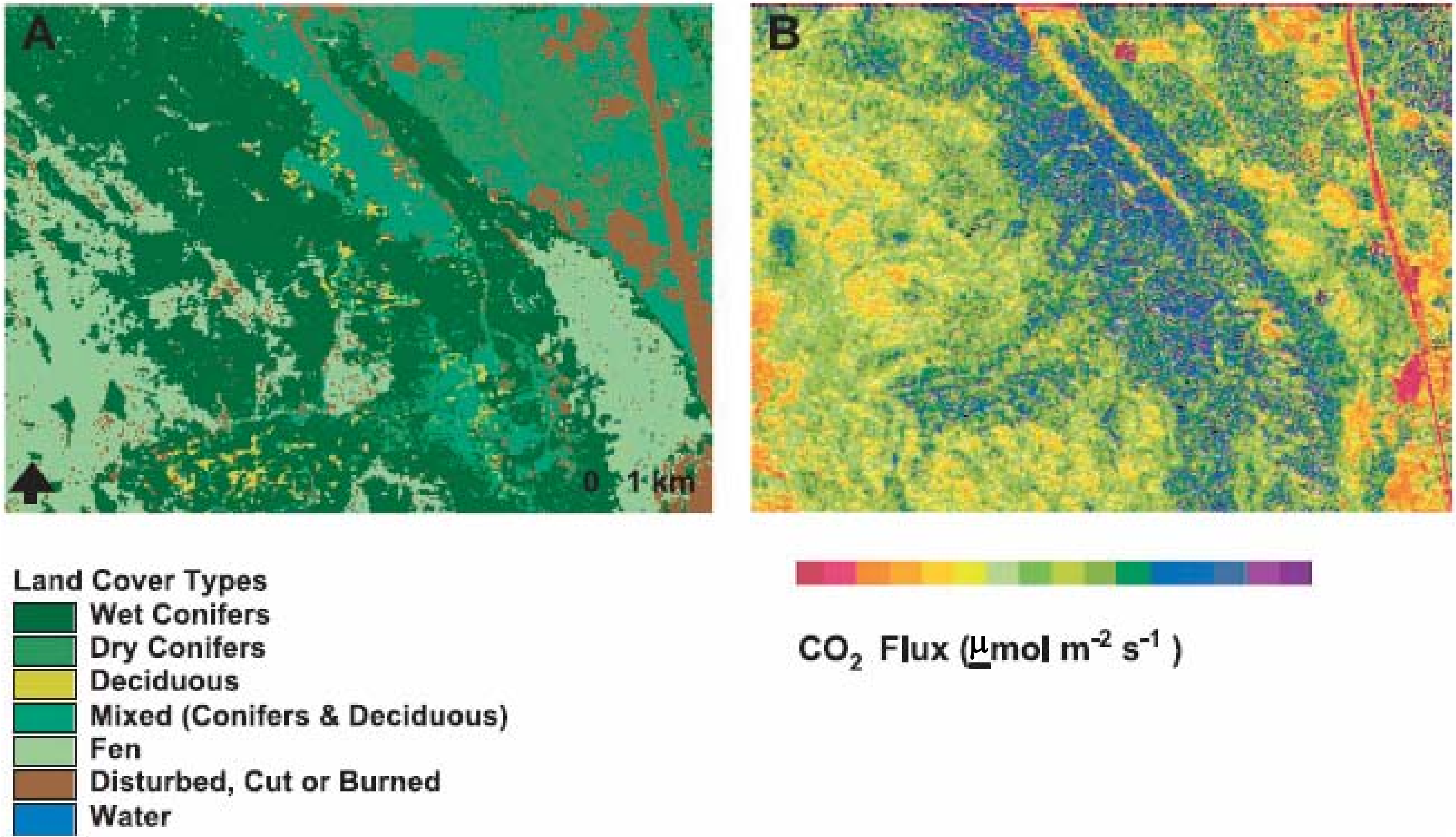
Phil Townsend (U WI)
John Gamon (U Alberta)
Anatoly Gitelson (U NE)
Mary Martin (U NH)
Qingyuan Zhang (GSFC)/Ben Cheng (GSFC)
Simon Hook (JPL)
Martha Anderson (USDA-Beltsville)
Susan Ustin (U California-Davis)

Phil Townsend

Examples: LMA – based on hypothesized relationships



An operational PRI product could improve ecosystem carbon flux estimates, capturing physiological change under disturbance, stress, and changing vegetation composition



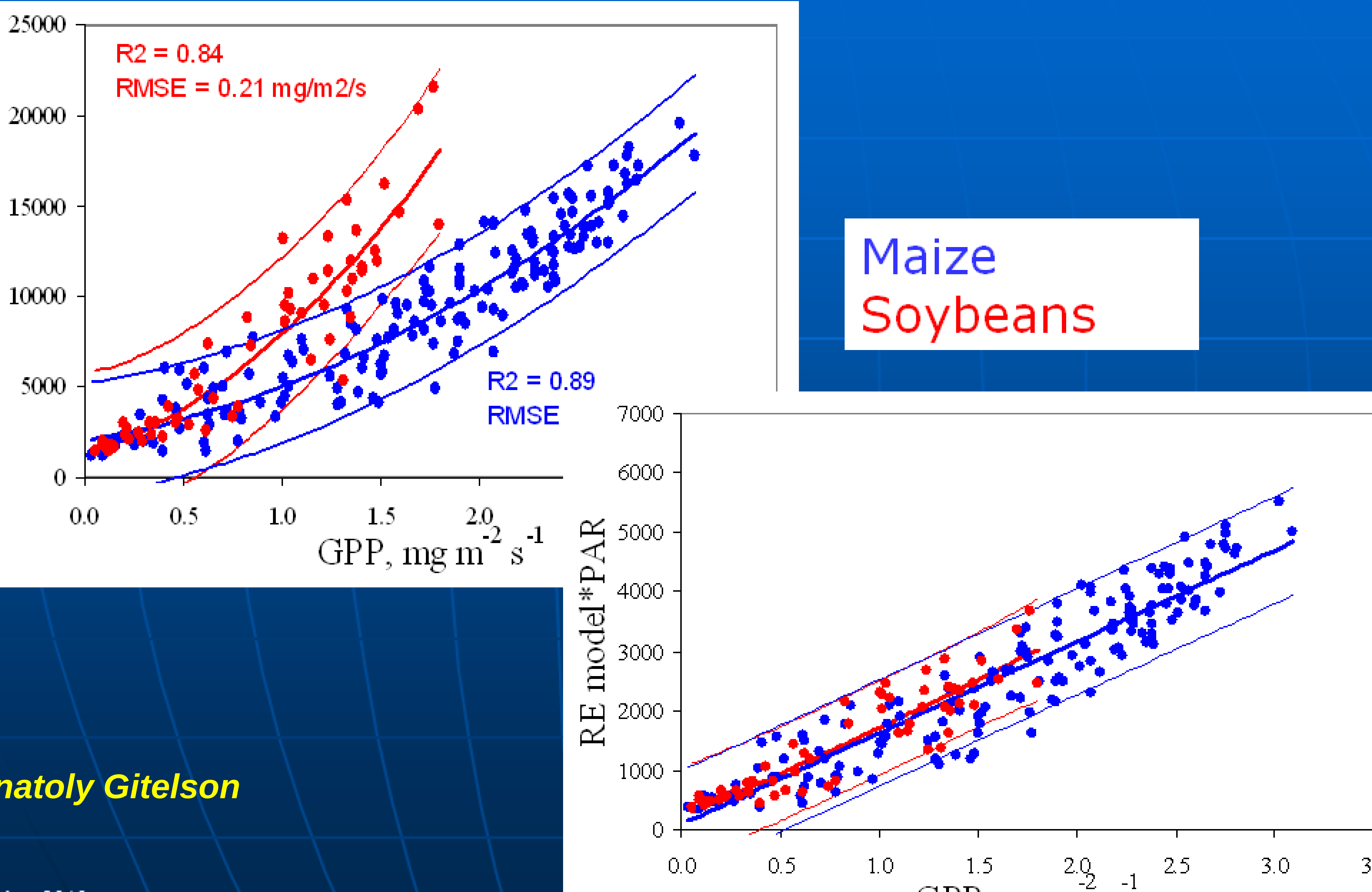
Fuentes et al. 2001

Rahman et al. 2001

John Gamon

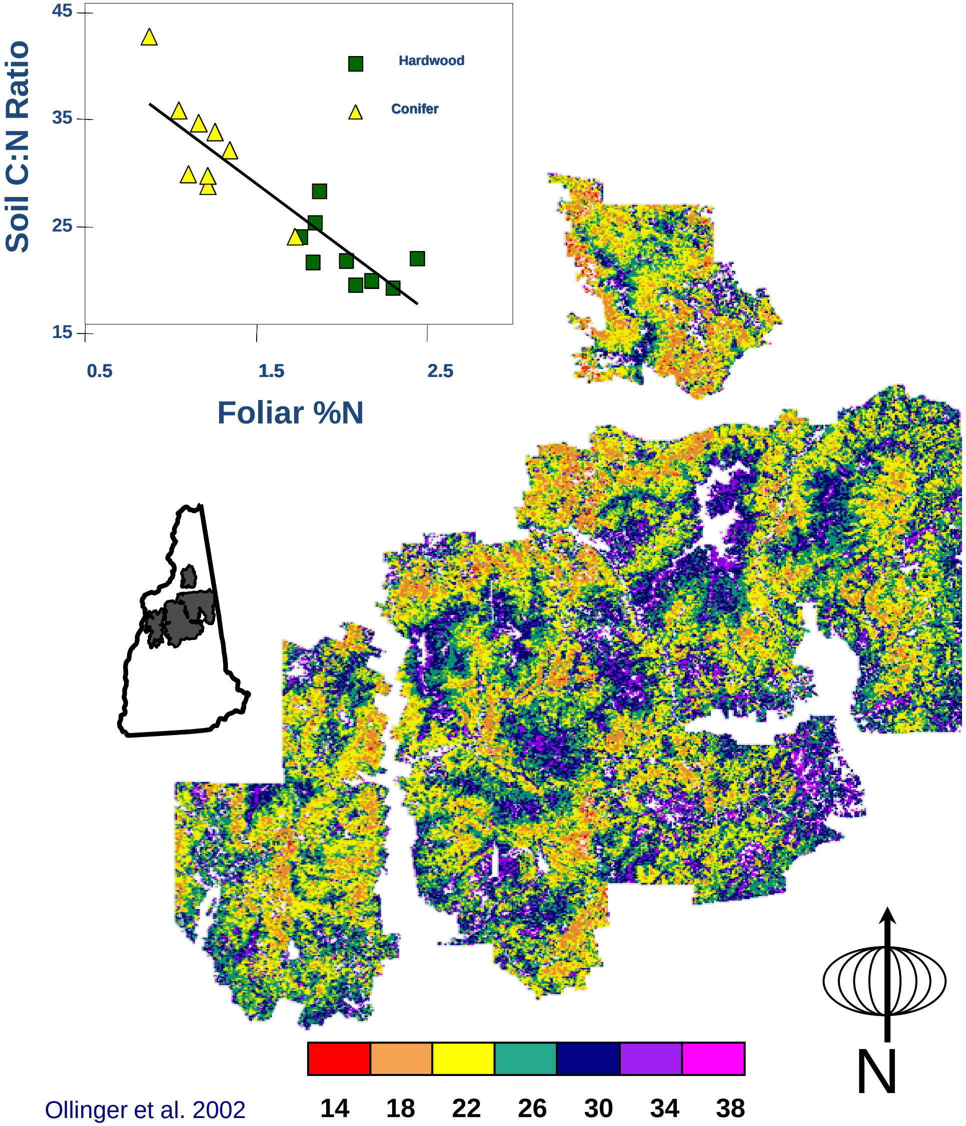
Relevance to climat

GPP estimation via Chl



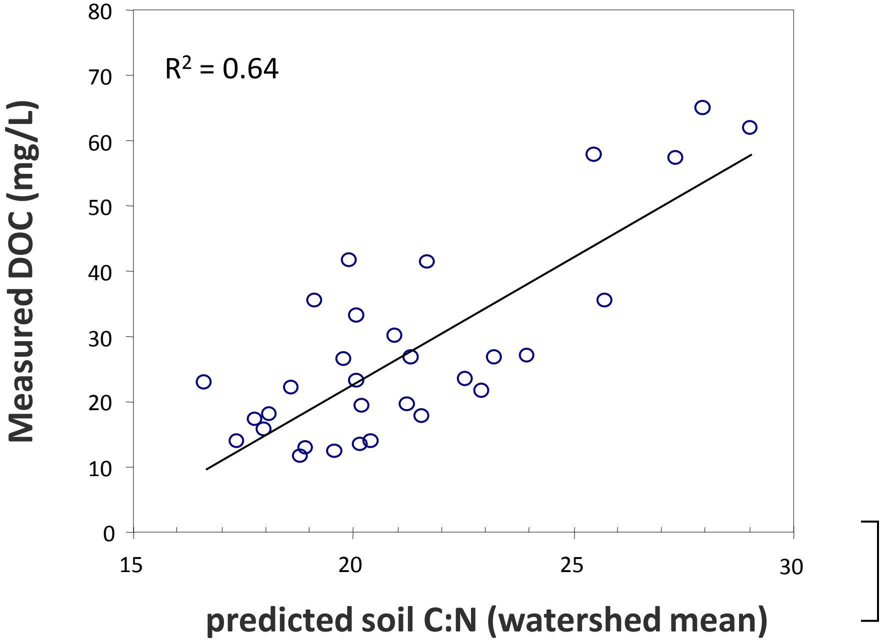
natoly Gitelson

AVIRIS-Predicted Foliar Chemistry Used to Estimate Soil Nitrogen Cycling



Ollinger et al. 2002

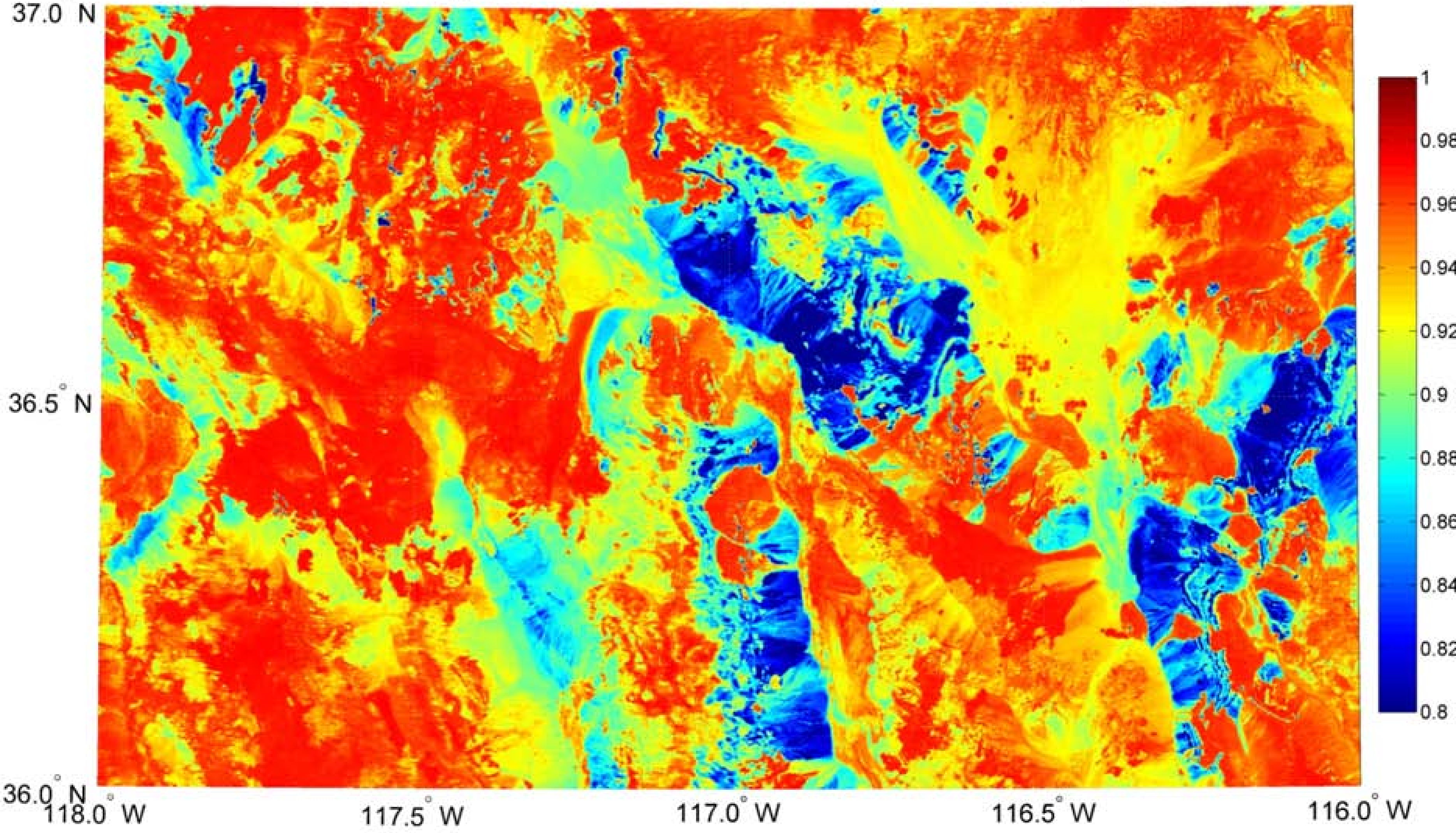
Predicted C:N versus Stream DOC



Mary Martin

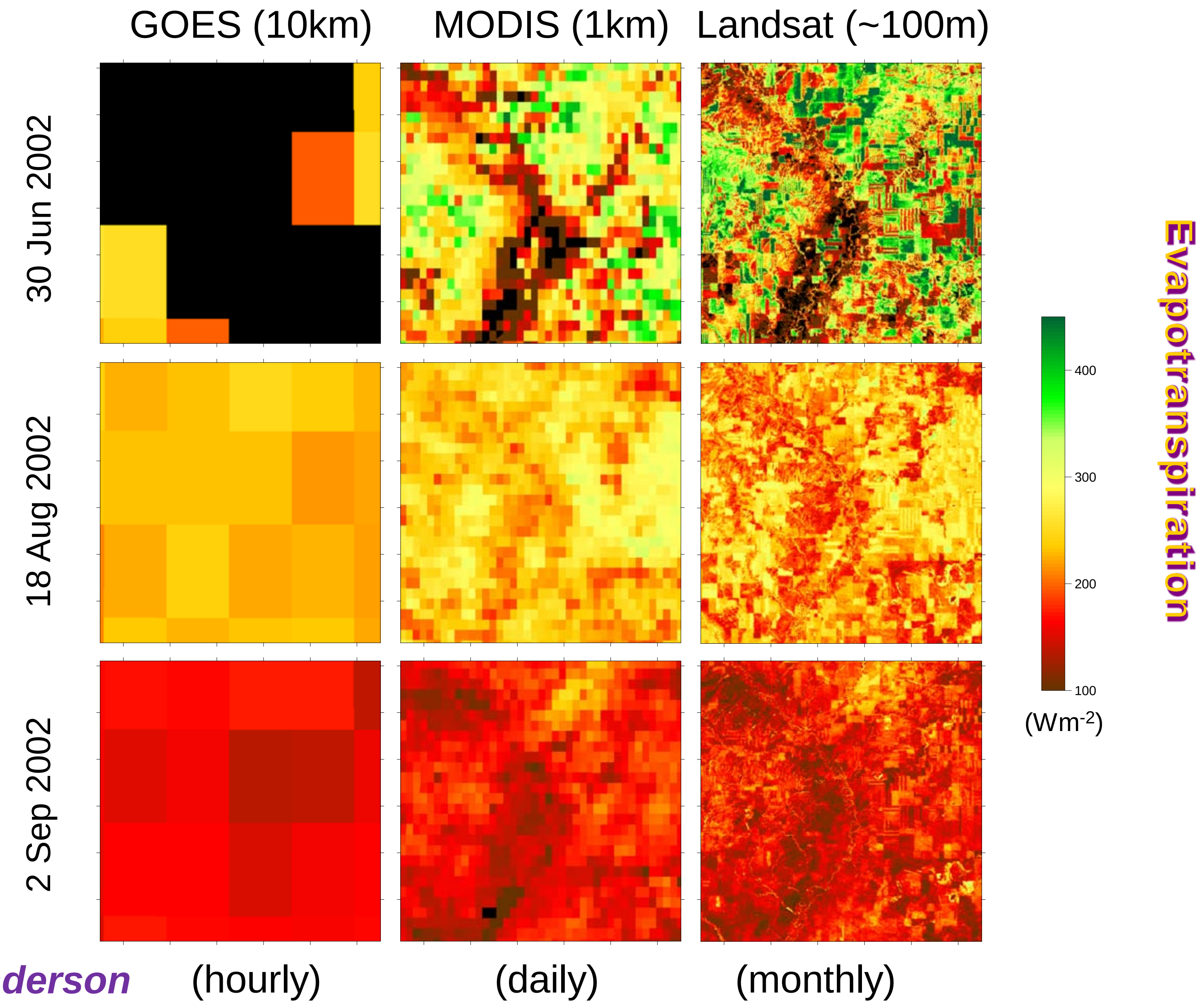
Mary– her slide #5 Canopy N, Amax, and albedo…..

Death Valley - Mean Summer Emissivity - Band 10 (8.3μm)



Simon Hook

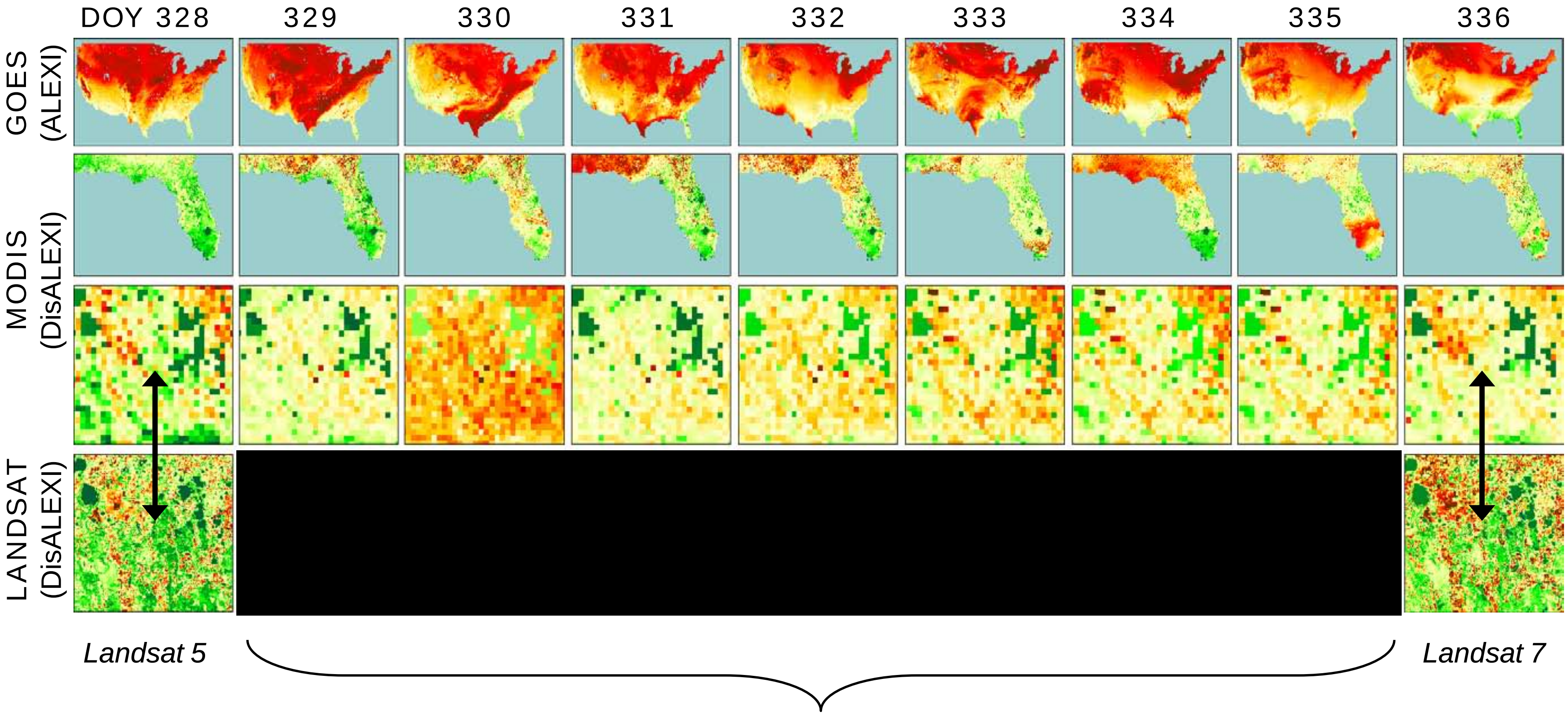
Evapotranspiration: FORT PECK, MONTANA



Martha Anderson

GOES/MODIS/Landsat FUSION

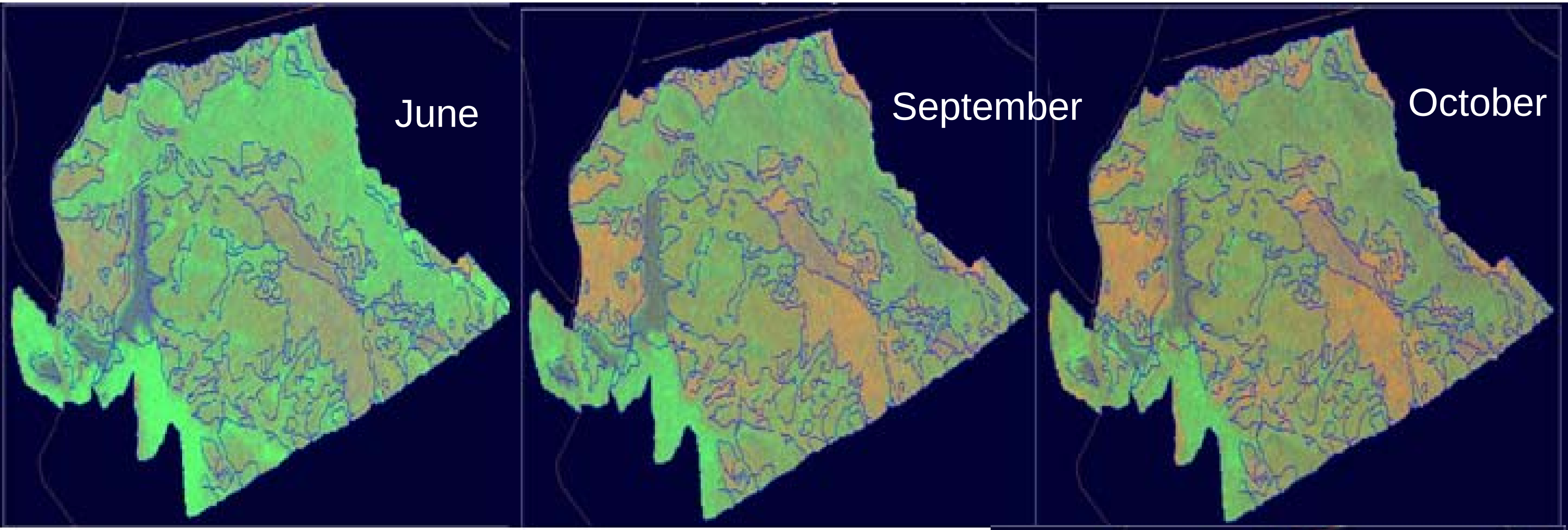
Martha Anderson



Daily Evapotranspiration – Reedy Lake, FL, 2002

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

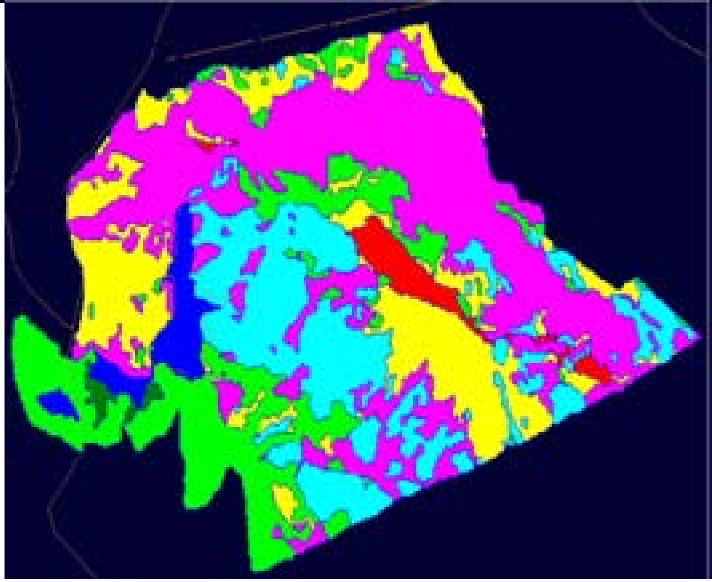
SMA Endmember Fraction Map Tracks Phenological Changes



Endmembers:
Green vegetation
Dry vegetation
Soil

Independent Vegetation Map

Deciduous Forest
Mixed Evergreen Forest
Chaparral
Greenstone Grassland
Serpentine Grassland
Wetland
Lake



Susan Ustin

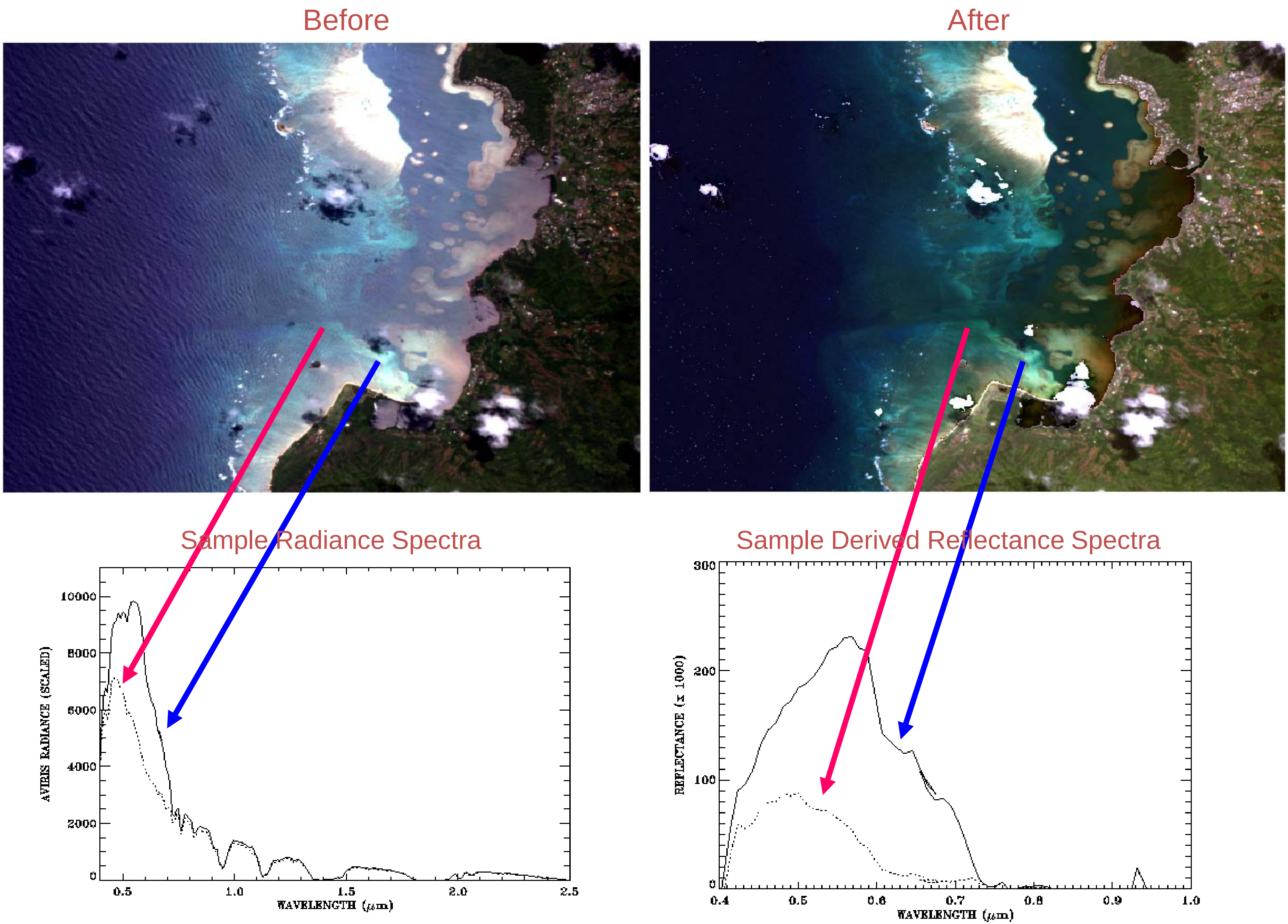
Ustin et al., 1999

Factors Affecting Product Integrity & Availability

Bo-Cai Gao (NRL)/Rob Green (JPL)
Tom Flately (GSFC)
Dan Mandl (GSFC)
Steve Chien (JPL)
Petya Campbell (GSFC)
Fred Huemmrich (GSFC)
Joanne Nightingale (GSFC)
Steve Ungar (GSFC)

Glint Removal Using AVIRIS Data Over Kaneohe Bay, HI

Bo-Cai Gao



Before

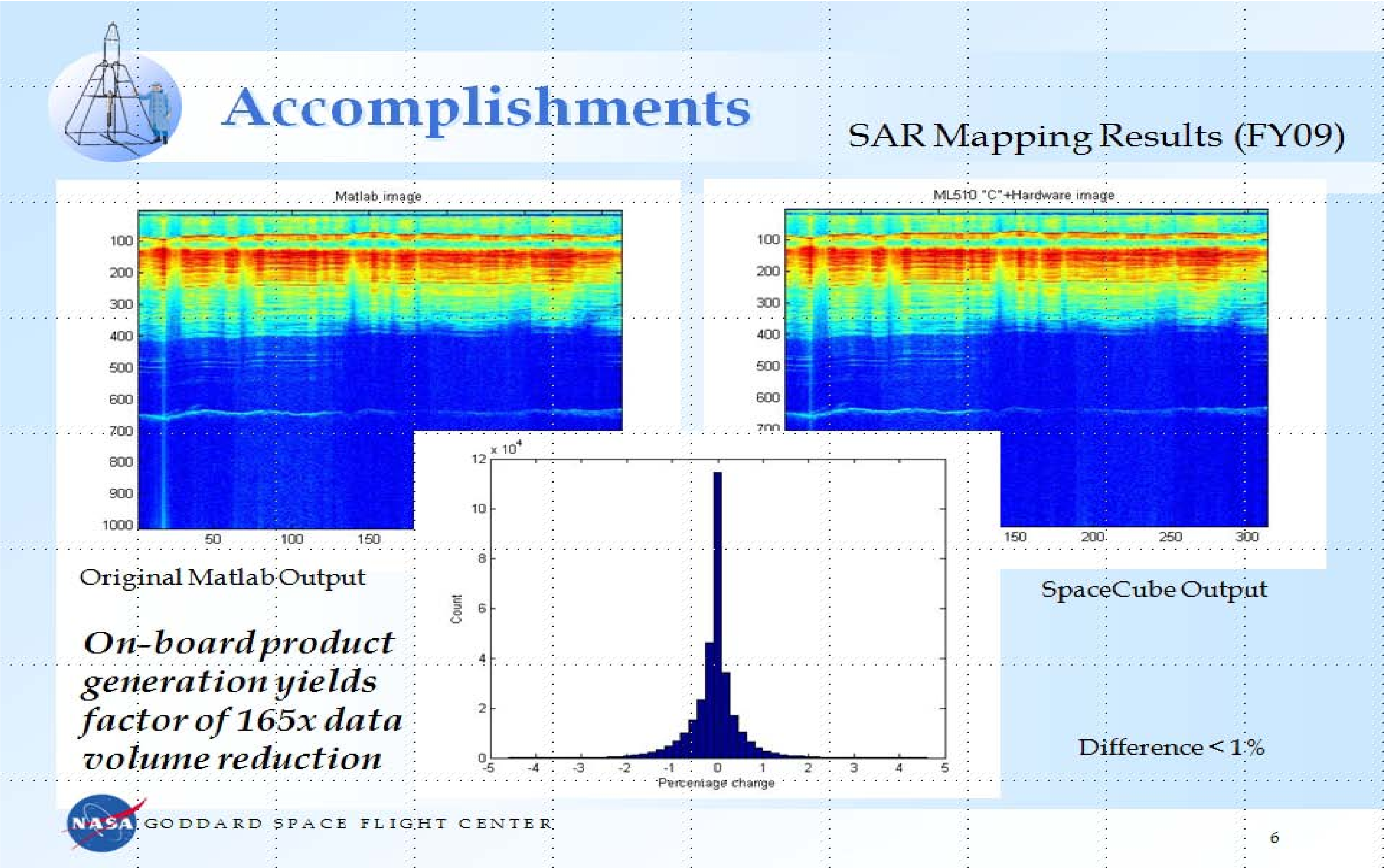
After

Sample Radiance Spectra

Sample Derived Reflectance Spectra

Tom Flately

Space Cube: On-Board Data Reduction



Accomplishments

SAR Mapping Results (FY09)

Original Matlab Output

SpaceCube Output

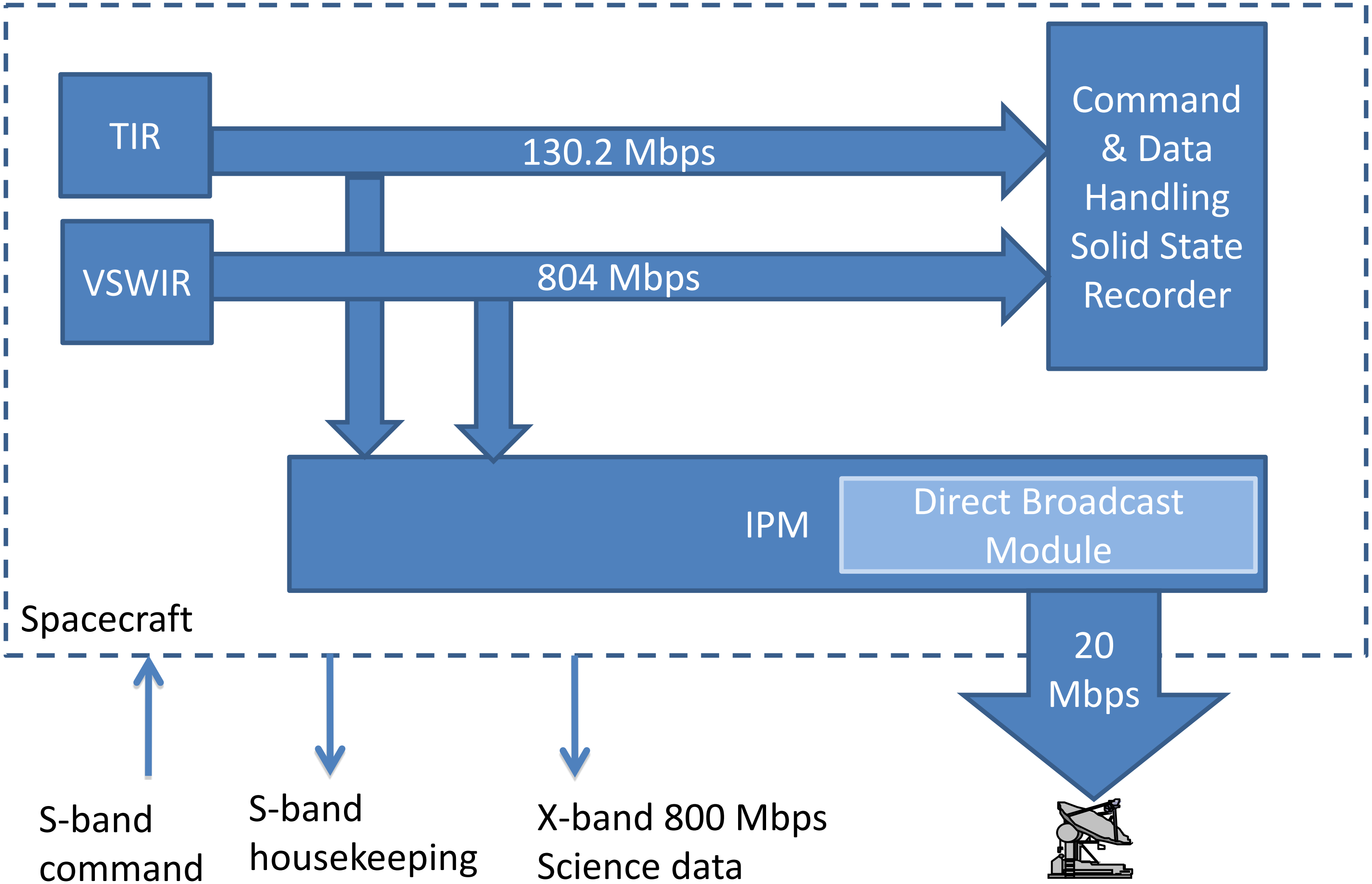
On-board product generation yields factor of 165x data volume reduction

Difference < 1%

GODDARD SPACE FLIGHT CENTER

HyspIRI Data Flow

Dan Mandl



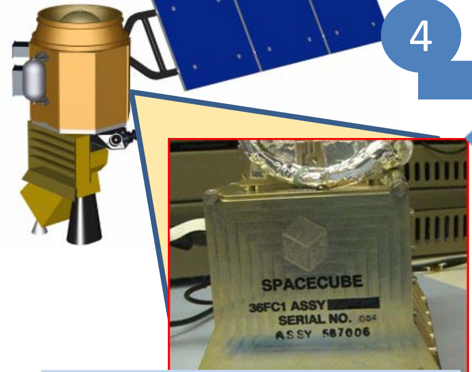
S-band command

S-band housekeeping data

X-band 800 Mbps Science data

Direct Broadcast Antennas

To/From Alaska and Norway Ground Stations

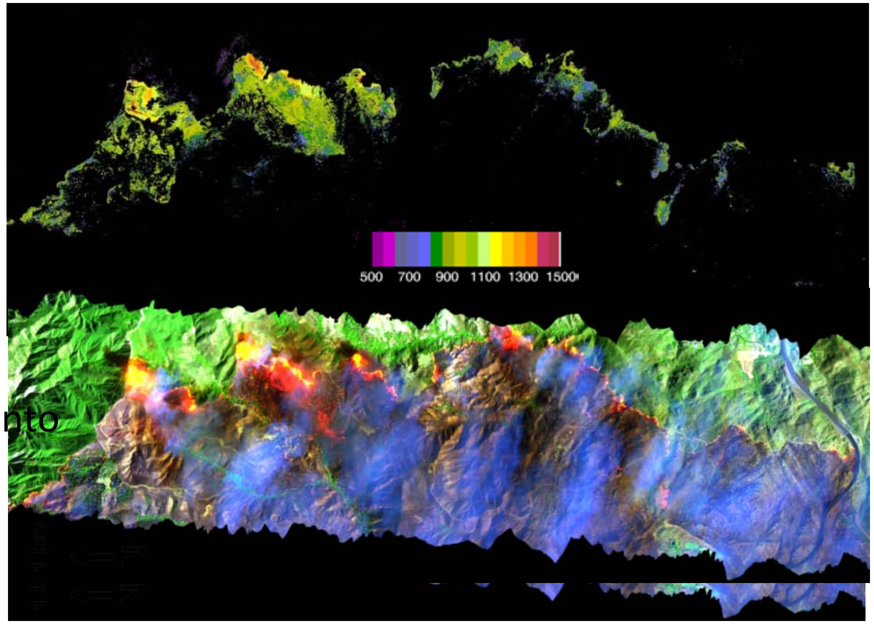


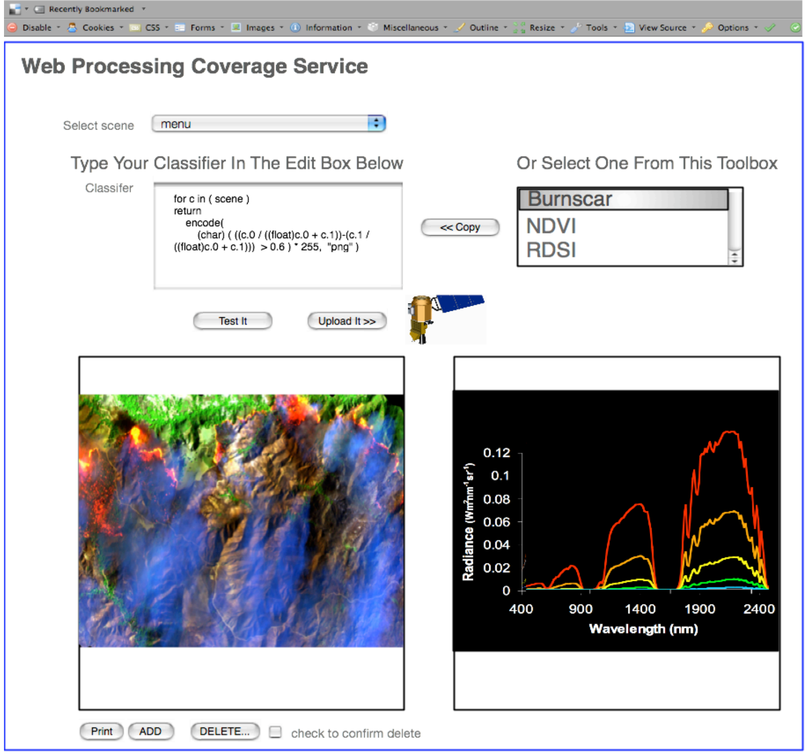
HyspIRI Intelligent Payload Module (IPM)

4 run onboard automatically

3 upload mobile agent

2 transform algorithm into mobile agent





Web Processing Coverage Service

Select scene: menu

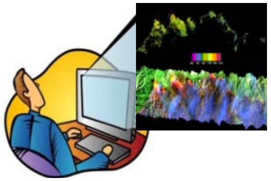
Type Your Classifier In The Edit Box Below

Classifer

```
for c in ( scene )
return
   encode(
      (char) ( ((c.0 / ((float)c.0 + c.1))-(c.1 /
((float)c.0 + c.1)))  > 0.6 ) * 255,  "png" )
```

Or Select One From This Toolbox

5 download customized low-latency onboard generated data products



1 create, edit, test algorithms/classifiers for use onboard space-based sensors

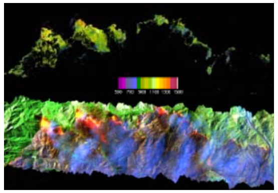


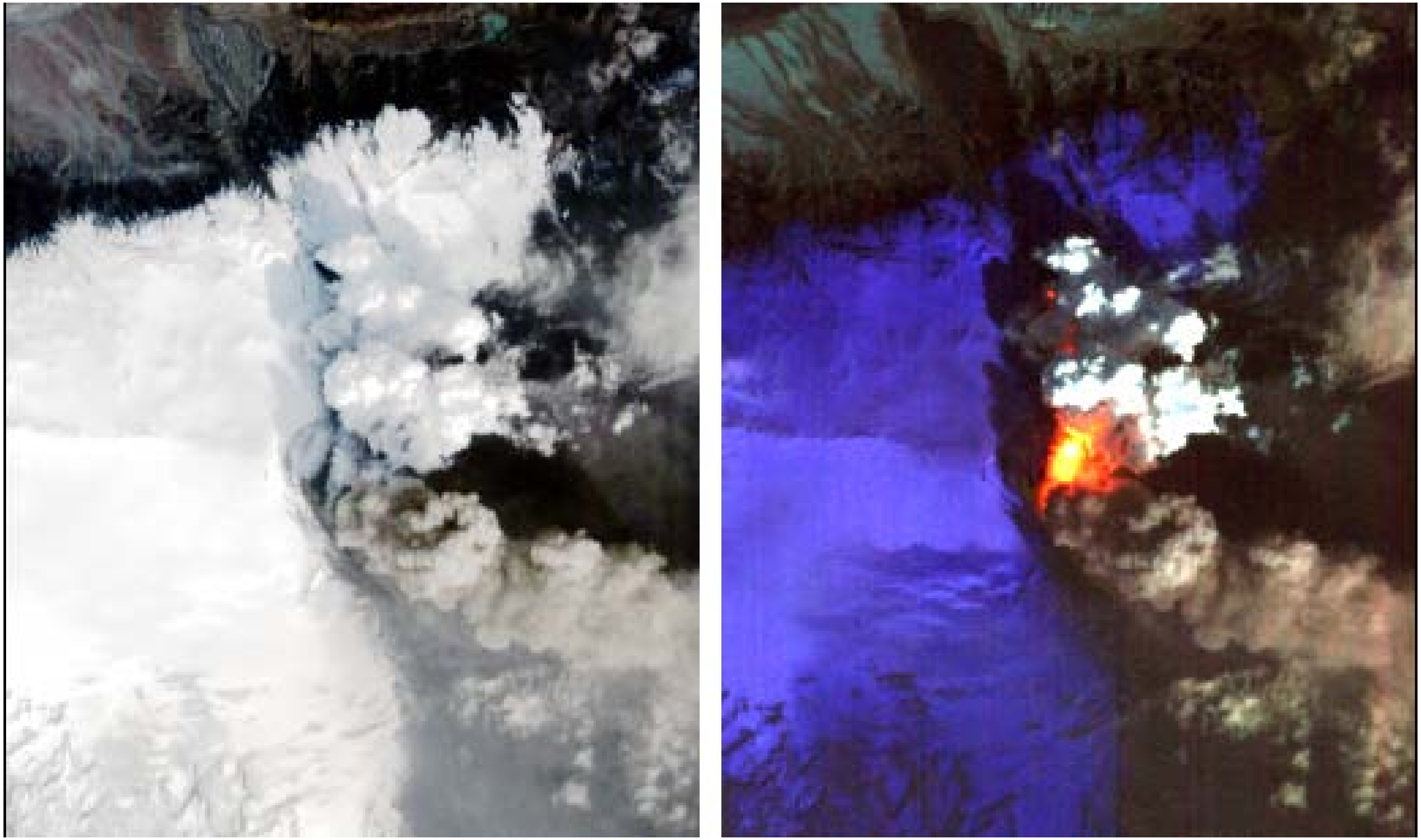
Image data products-
Phil Dennison 2008

One Possible HyspIRI IPM Ops Concept

Dan Mandl

Rapid Data delivery:

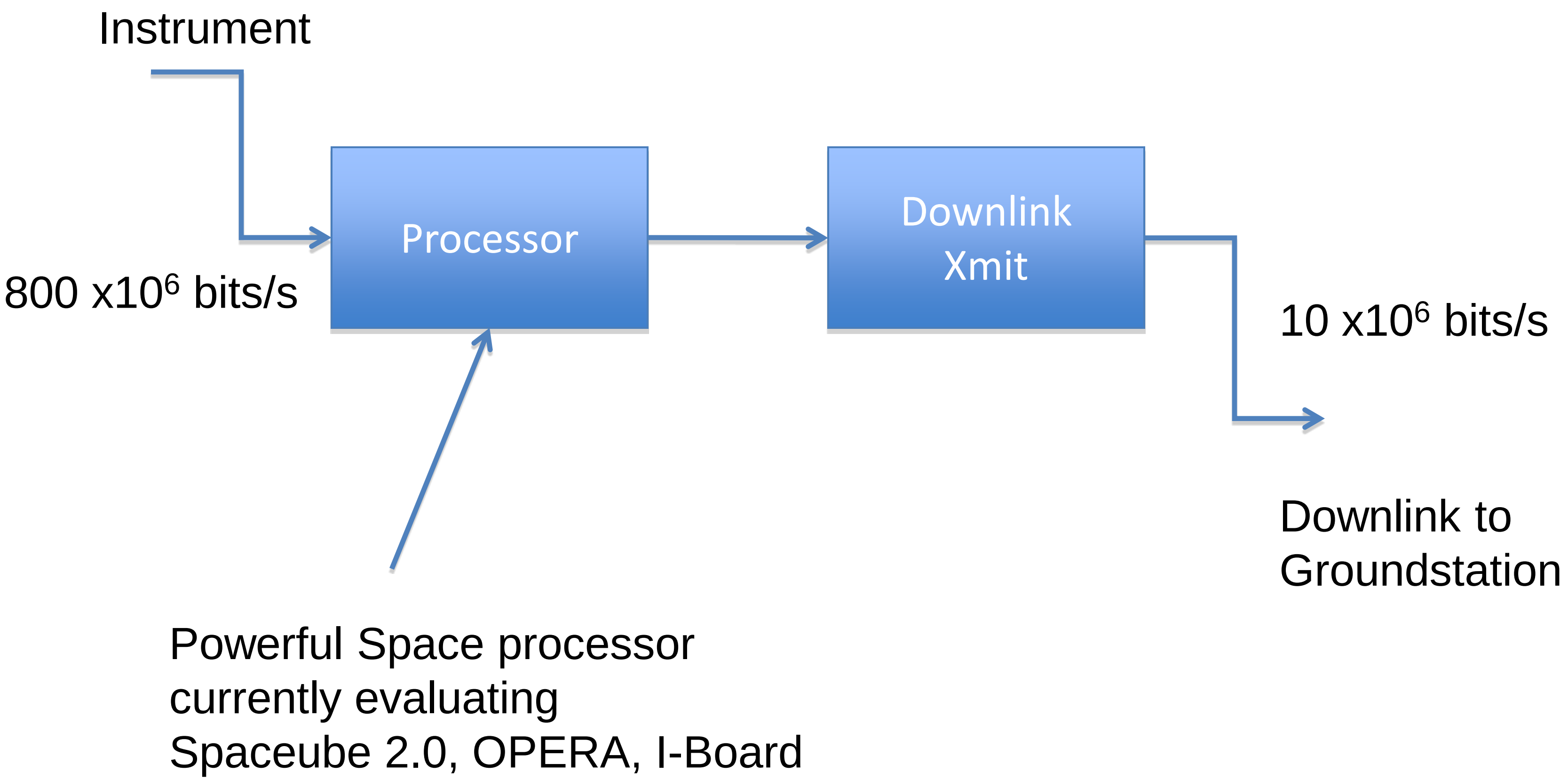
02 May 2010 Hyperion Imagery



Left – True color   Right - thermal false color

Image courtesy EO-1 Mission/GSFC, Volcano Sensorweb/JPL A. Davies

HyspIRI DB Concept



Instrument

800 x10^6 bits/s

Processor

Downlink Xmit

10 x10^6 bits/s

Downlink to
Groundstation

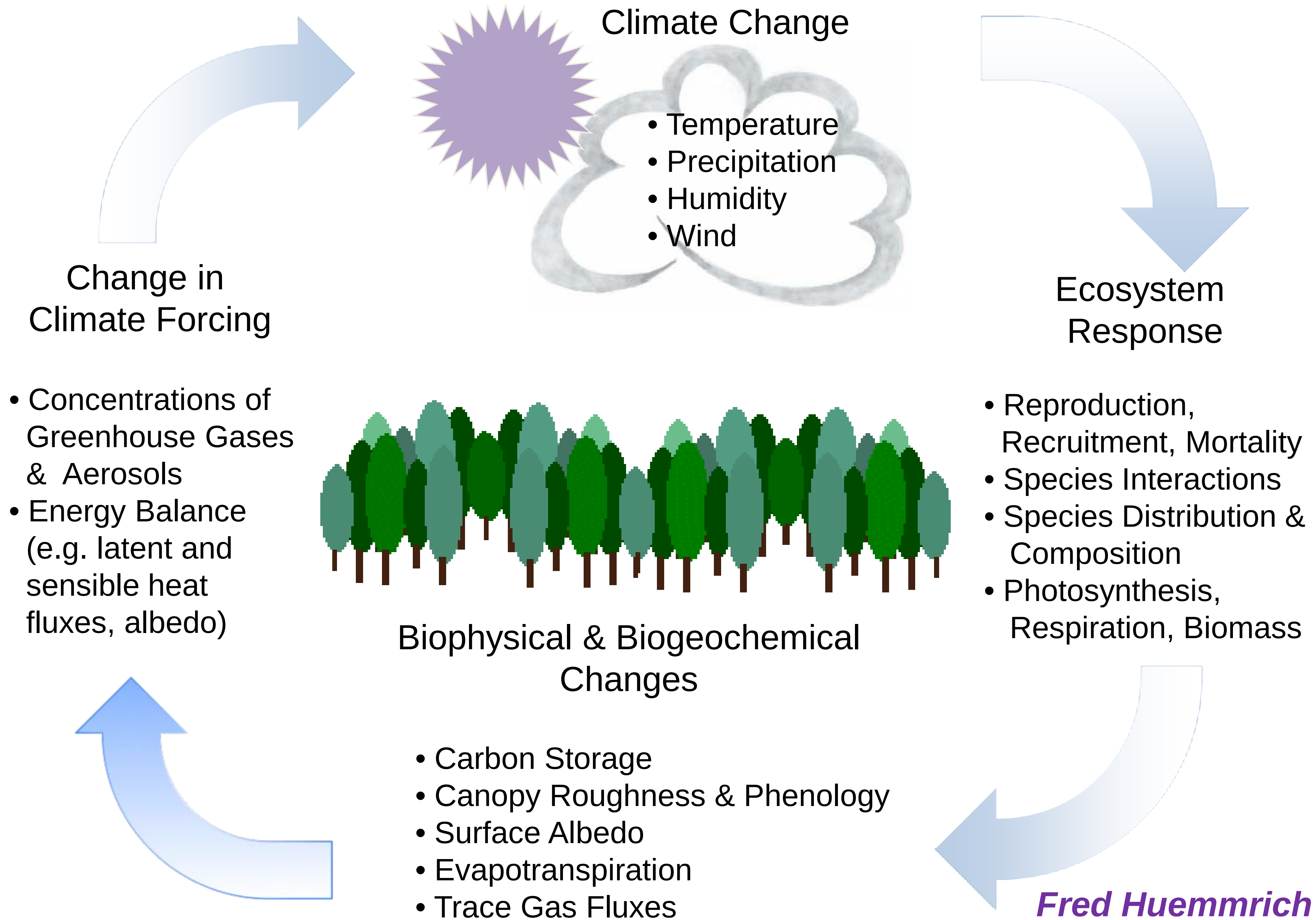
Powerful Space processor
currently evaluating
Spaceube 2.0, OPERA, I-Board

Steve Chien

Operations for HyspIRI DB

- Users specify “areas of interest” which are
  - geographical regions (polygon on surface of Earth)
  - product, (e.g. normalized burn index)
  - priority, (e.g. 50 on 1-100 scale)
  - Constraint (sun must be at least 20 degrees above horizon)
- In generic tool (e.g. Google Earth)
- DB can also be used to rapidly downlink “scenes”

Climate – Ecosystem Feedbacks



Climate Change

- Temperature
- Precipitation
- Humidity
- Wind

Ecosystem Response

- Reproduction, Recruitment, Mortality
- Species Interactions
- Species Distribution & Composition
- Photosynthesis, Respiration, Biomass

Biophysical & Biogeochemical Changes

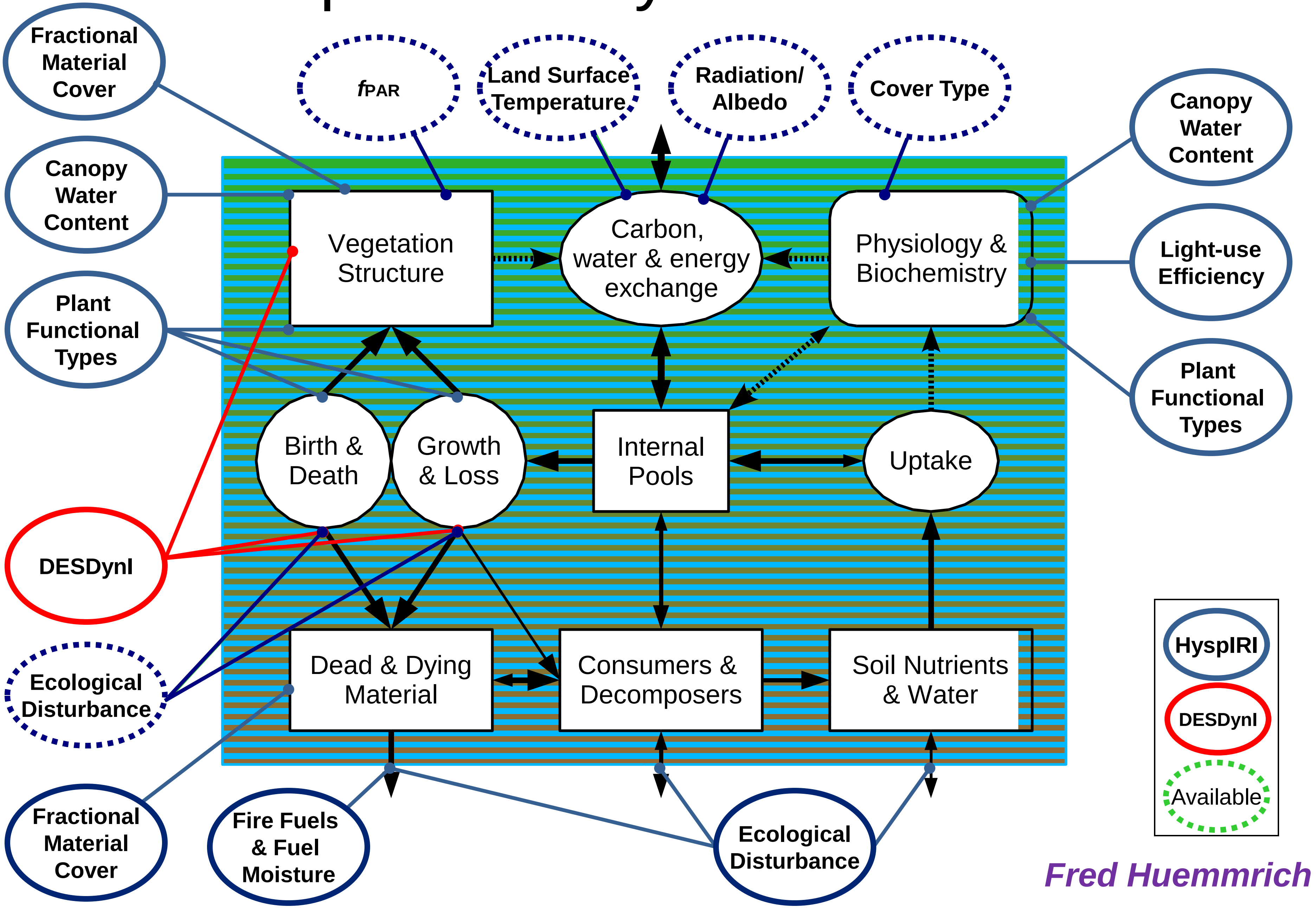
- Carbon Storage
- Canopy Roughness & Phenology
- Surface Albedo
- Evapotranspiration
- Trace Gas Fluxes

Change in Climate Forcing

- Concentrations of Greenhouse Gases & Aerosols
- Energy Balance (e.g. latent and sensible heat fluxes, albedo)

Fred Huemmrich

Conceptual Ecosystem Flux Model



Fred Huemmrich

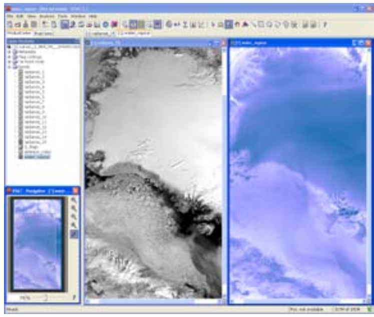
Petya Campbell

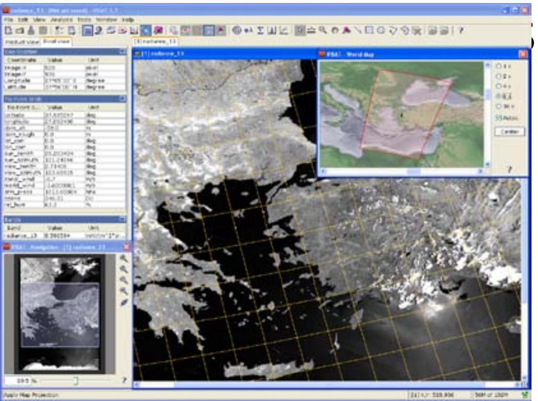
Current Tools - *Examples*

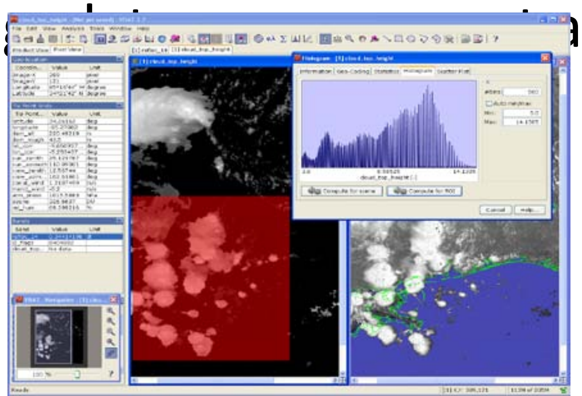
- Visualization and Image Processing of Environmental Resources (VIPER) - Advanced Spectral Mixture Analysis (UCSB, Roberts et al.)
- WINVICAR (JPL, Hook et al.) – work with thermal emissivity data from ASTER, MASTER, other EOS data as well
- Processing Routines in IDL for Spectroscopic Measurements (PRISM, USGS, Kokaly et al.)
- BEAM (C. Brockman/ESA) – data management, viewing and pre-processing for Envisat, PRISM, CHRIS/Proba, AVNIR, MO

  etc.
- Open Source Software Image Map (OSSIM, OSGeo)
- ENVI, ERDAS Imagine, PCI Geomatica, other …

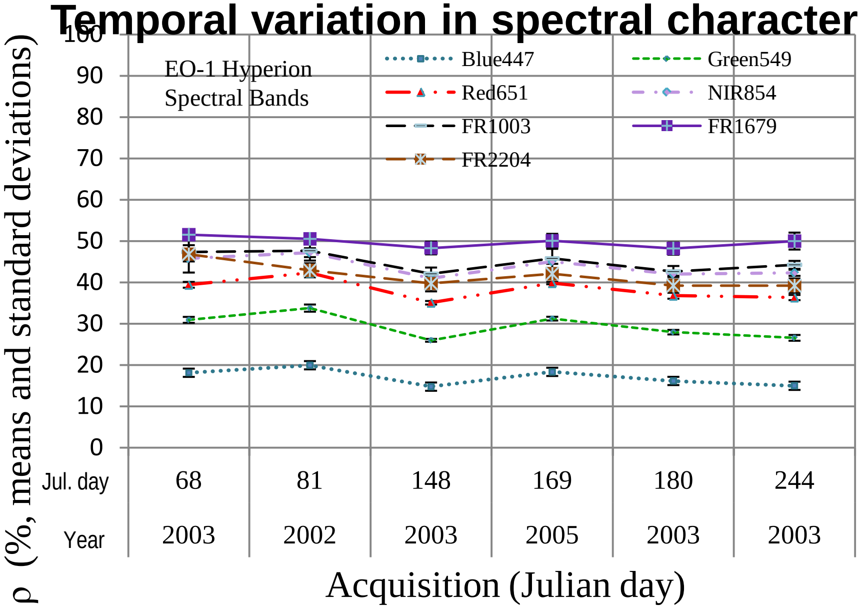
king and

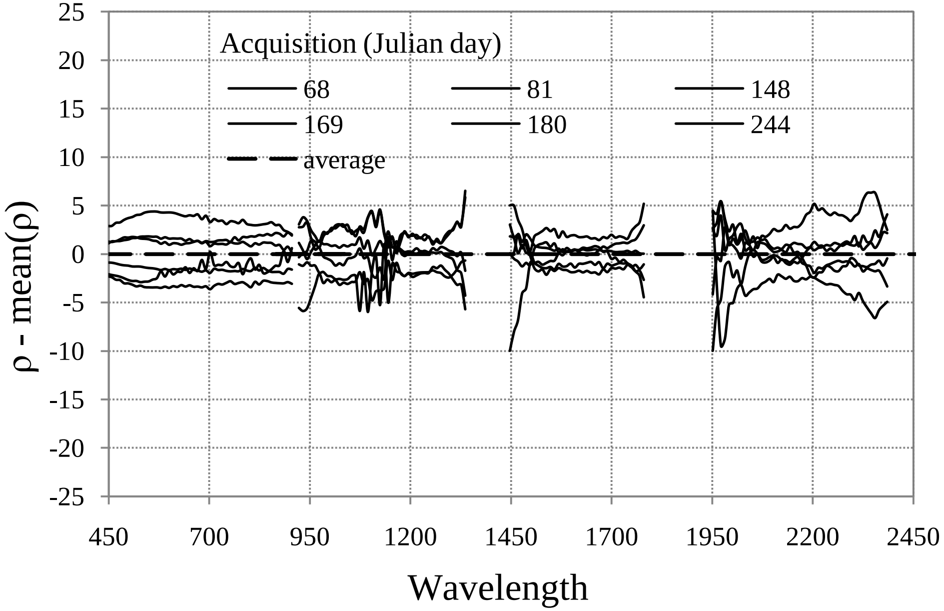


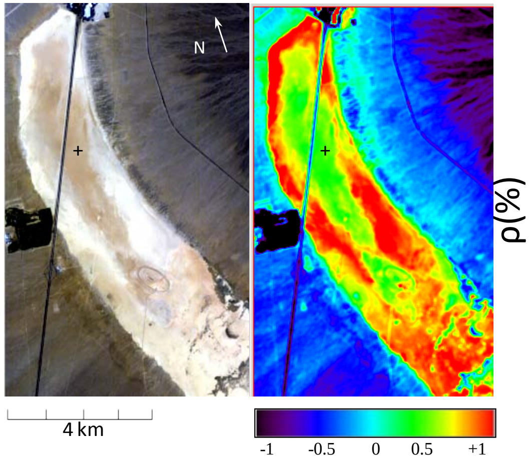


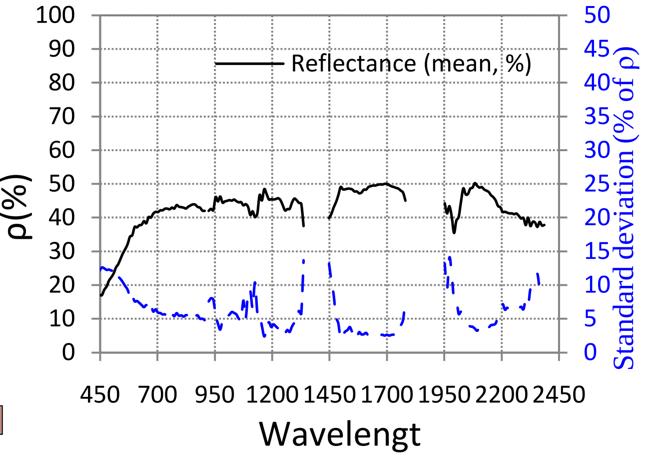


Time Series for CEOS Cal/Val Sites


Temporal variation in spectral characteristics


Reflectance differences



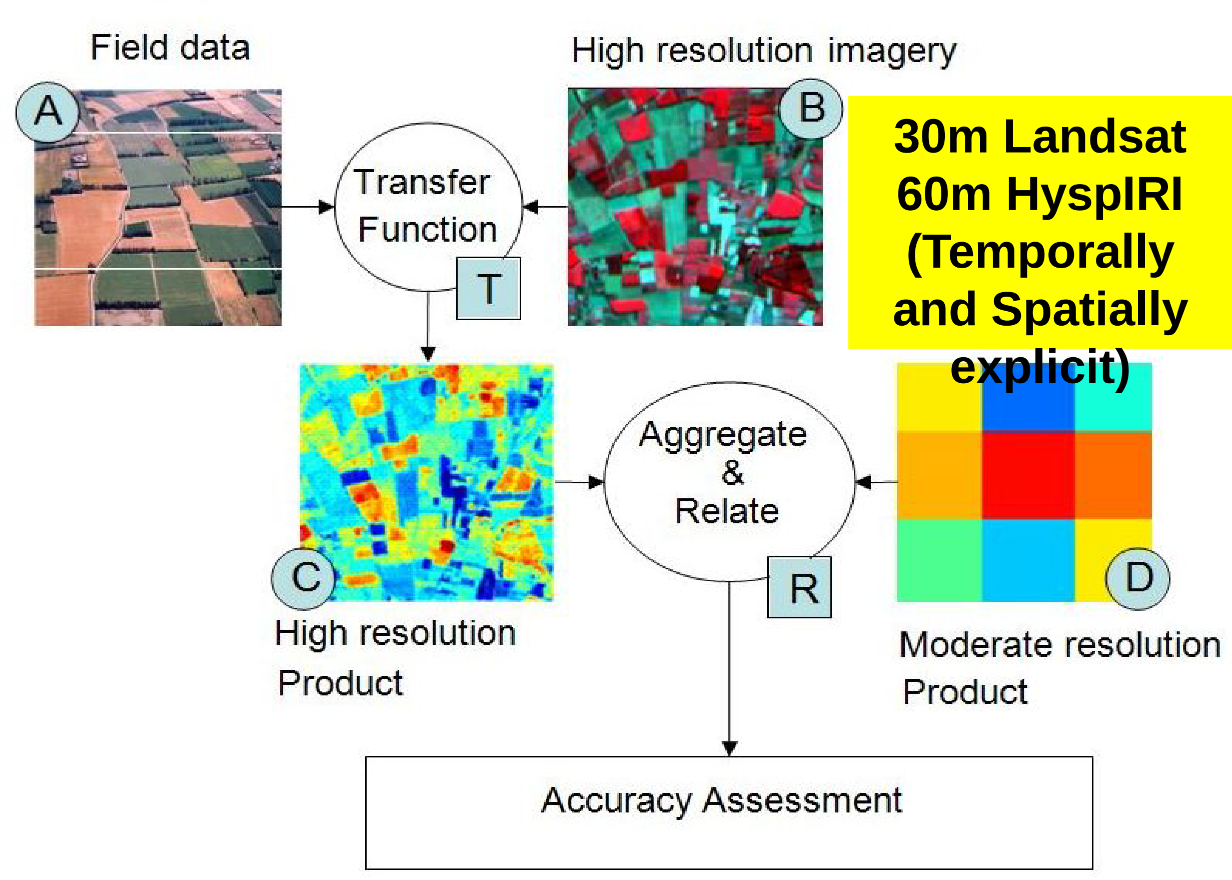


Example from Ivanpah playa: Natural color composite (RGB: 651, 549, 447), Getis Gi* statistics (band 549), Reflectance Mean and Standard Deviation

Petya Campbell

Scaling of Biophysical Products

- LAI, fPAR, GPP, NPP, Albedo
- Protocol for ground sampling, scaling and validation of LAI, fPAR and albedo products in preparation



30m Landsat
60m HyspIRI
(Temporally and Spatially explicit)

- HyspIRI will provide enhanced spatial / temporal capabilities for scaling activities (bridge 30m – 250m/1km+ gap)

Band-to-Band Registration
The Bottom Line

$$\left\langle \frac{R_{NIR}}{R_{VIS}} \right\rangle \neq \frac{\left\langle R_{NIR} \right\rangle}{\left\langle R_{VIS} \right\rangle}$$

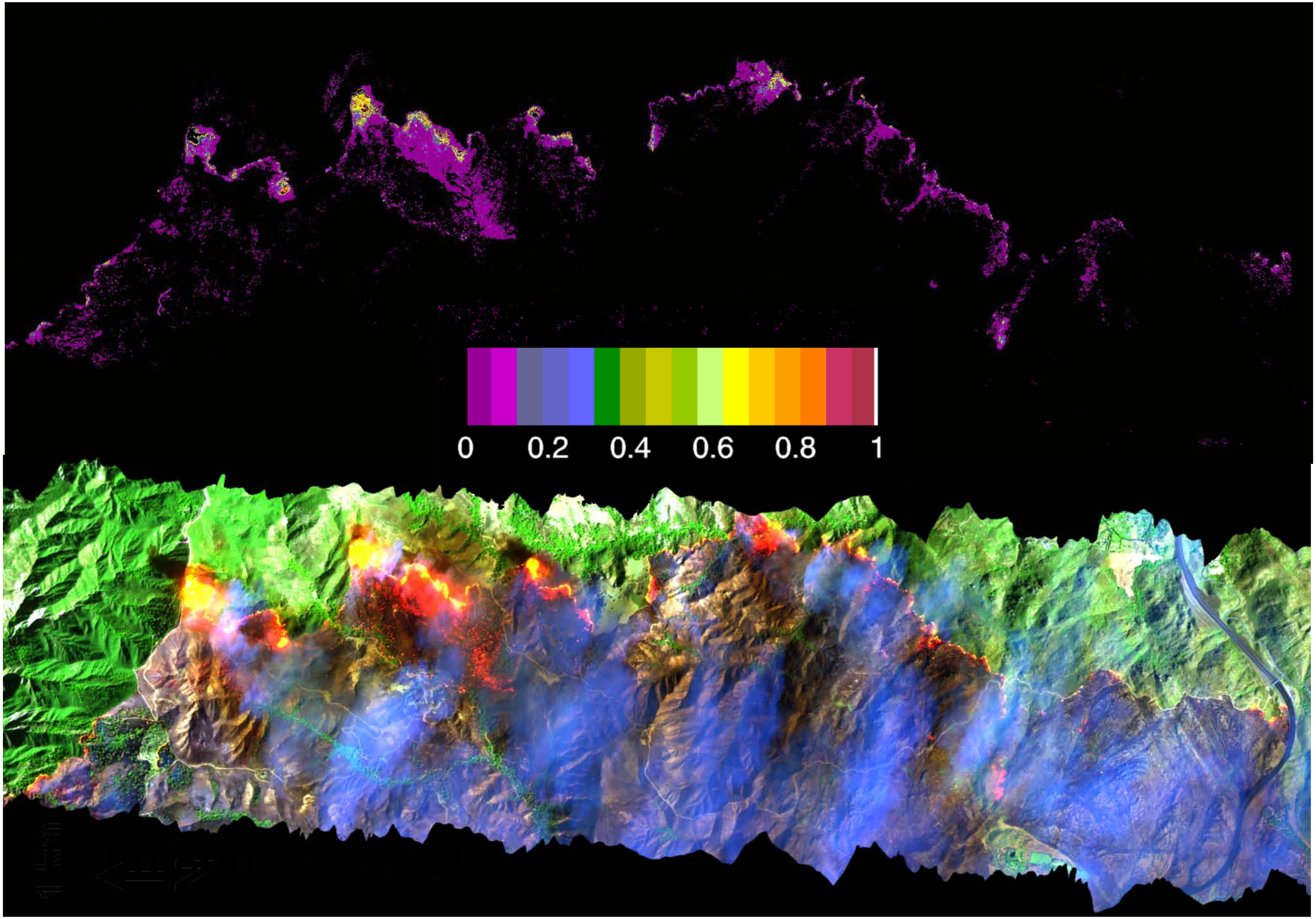
Steve Ungar

Proposed Combined VSWIR /TIR Products

Rasmus Houborg (GSFC)
Louis Giglio (UMD)/ Ivan Csiszar (NOAA)
Dar Roberts (U California-Santa Barbara)
Dale Quattrochi (MSFC)
Ben Cheng (GSFC)
Ray Kokaly (USGS)
Craig Daughtry (USDA-Beltsville)
Bruce Cook (GSFC)/ Greg Asner (Carnegie Institute)

Sub-Pixel Fire Fraction

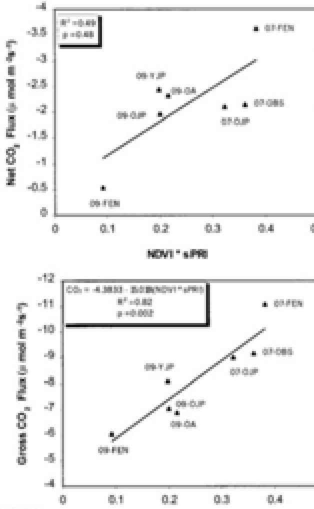
Louis Giglio



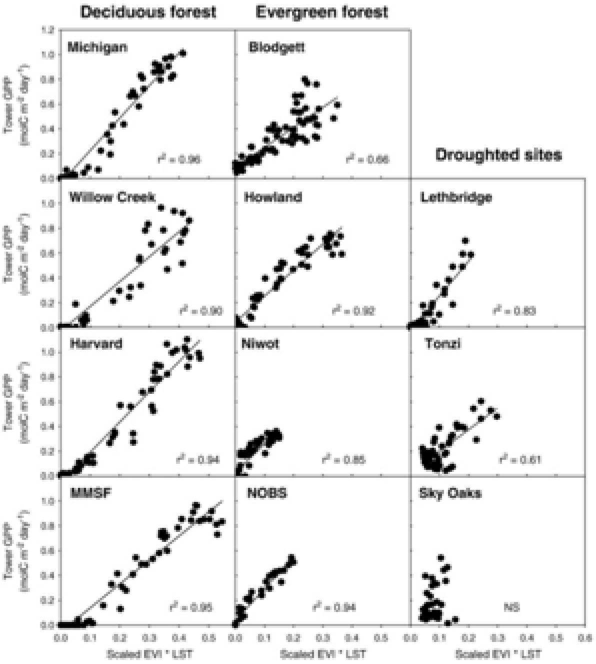
Dar Roberts

Combined VNIR-SWIR Physiological/Thermal Stress Measures

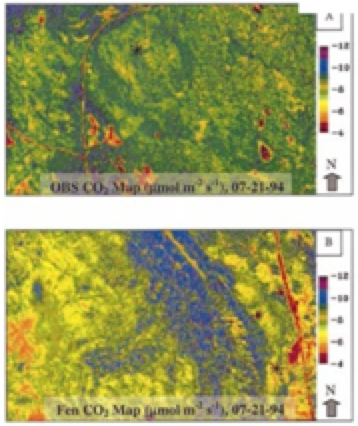
- **The ability to improve estimates of carbon uptake using PRI has been established using flux data and AVIRIS**
- **MODIS estimates of carbon uptake can be improved using LST and a vegetation index. What is the potential at 60 m with better indices?**



Plots of net and gross carbon dioxide flux measured at 7 Boreas flux tower sites compared to estimates of FPAR (NDVI) and quantum efficiency (PRI) from AVIRIS. From Rahman et al., 2001



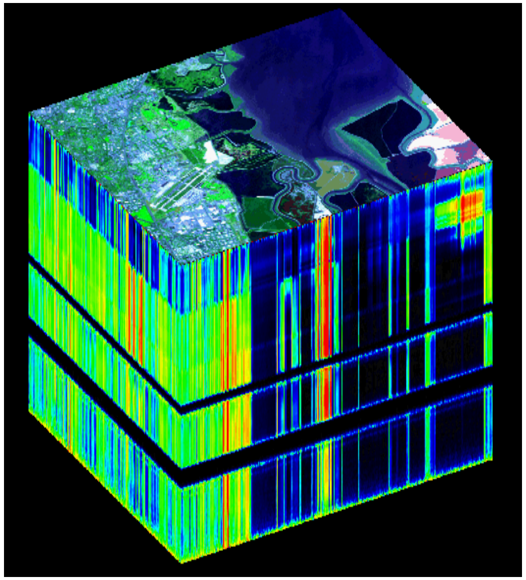
Plot of scaled EVI*LST compared to carbon uptake from flux towers.
Example derived from MODIS
From Sims et al., 2008



Maps of carbon dioxi uptake estimated from scaled PRI and NDVI calibrated to eddy flu data. From Rahman e al., 2001.

Production: Improved ASTER TES algorithm and suites of standard hyperspectr

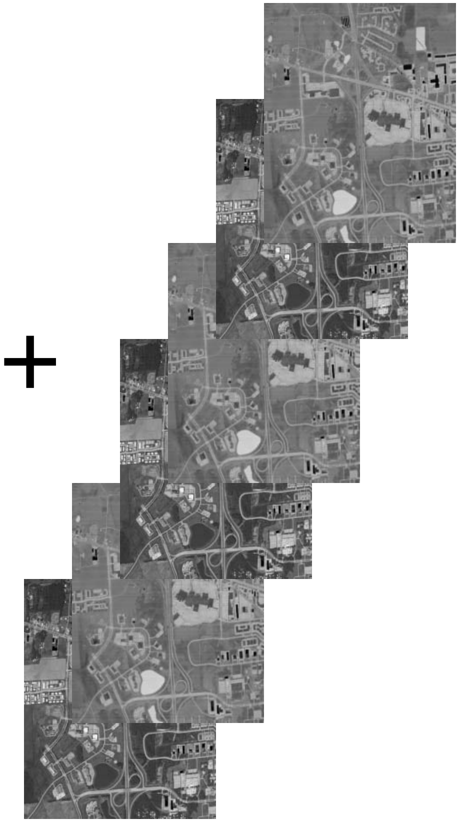
HyspIRI Combined Composite Data Set Advanced Product for Urban Ecosystems Analysis



HyspIRI Hyperspectral VSWIR Level II Product

(NDVI, fPAR, surface reflectance characteristics)

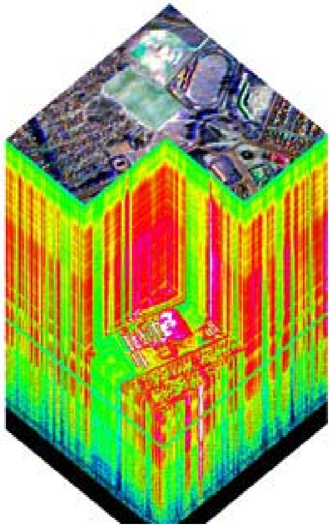
+



HyspIRI TIR multispectral Level II product (8 TIR Bands)

(surface temperature, radiance, [day/night], emissivity)

=

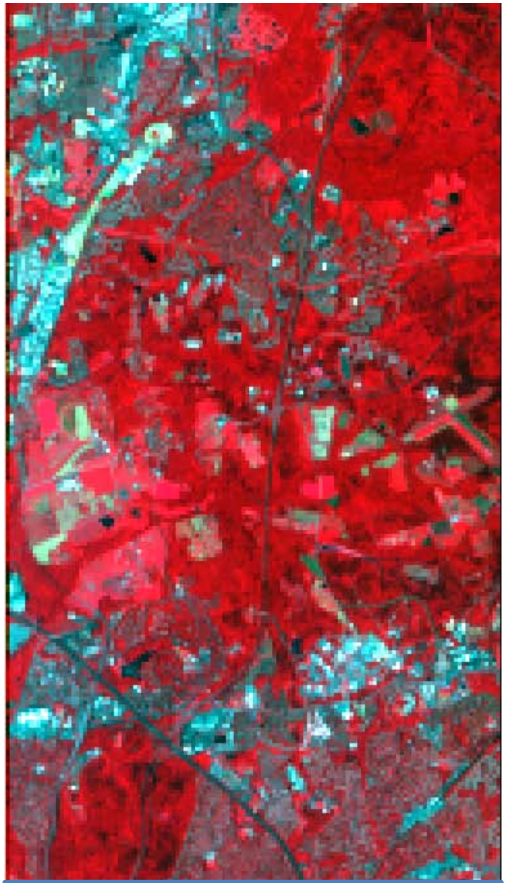


HyspIRI VSWIR/TIR composite data set

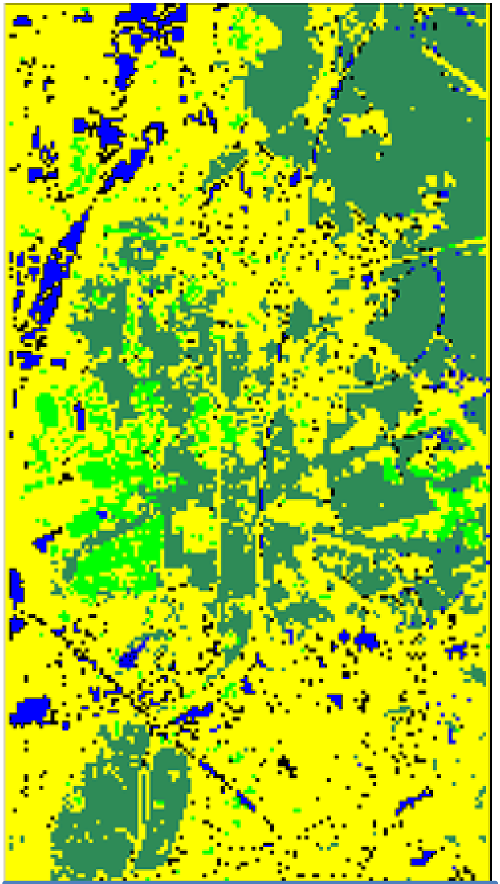
(quantitative integrative measurement of urban surface reflectances, temperatures, and emissivity across the urban ecosystem)

Dale Quattrochi

Ben Cheng

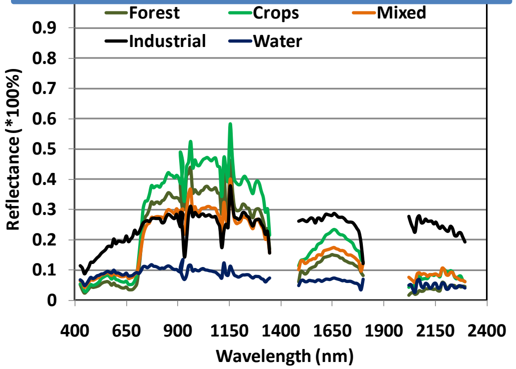


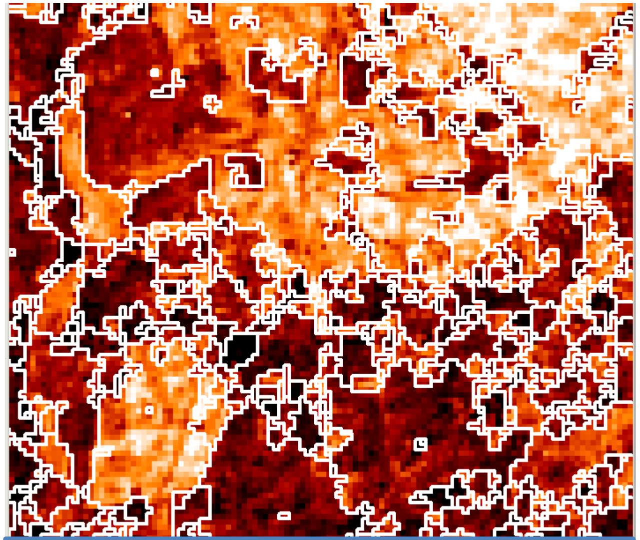
EO-1 Hyperion VSWIR



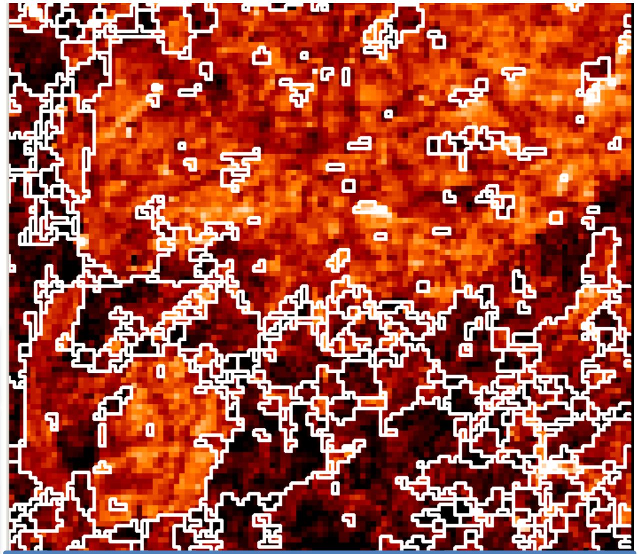
Greenbelt, MD

- 🟩 Mixed Forest
- 🟩 Crops
- 🟨 Residential / Grassland
- 🟦 Business / Industrial





ASTER TIR 04/18/2009



ASTER TIR 11/28/2009

Spectroscopic Remote Sensing

- VSWIR: Detect patterns of pigment, water and cellulose/lignin content consistent with invasive plant and divergent from native plants
- TIR: Calculate land surface temperature, model evapotranspiration, compare to air temperature to reveal temporal patterns divergent from native plants

Spectroscopy and Invasive Plants

- Land management (treatment and evaluation)
- Shifts in plant composition (to non-woody)
- Soil composition (formation of caliche)
- Fire promotion (post-fire soil impact)
- Predictive modeling of expansion
- Climate change
- Identification of areas at risk for invasion

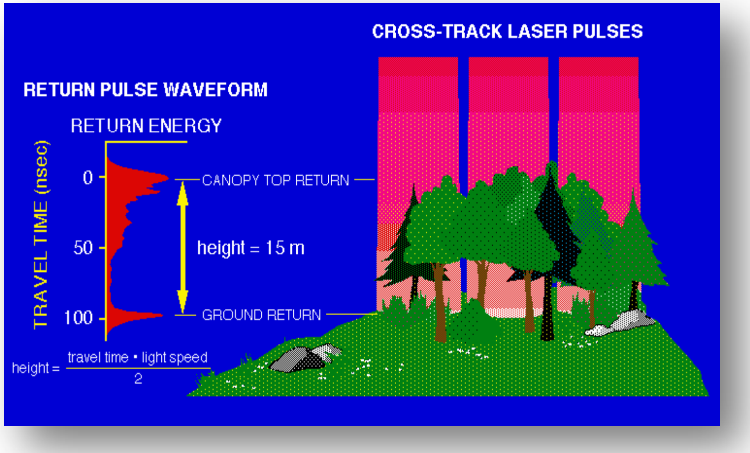
National-level detection, monitoring and early warning system for invasive plant species

Kokaly et al.

Carnegie Airborne Observatory (CAO)

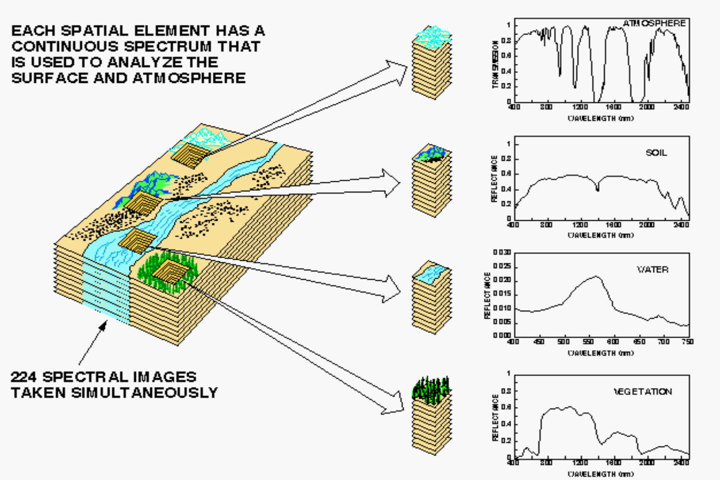
3-D functional imaging of ecosystems

LiDAR for topography, canopy structure, LAI, etc.



+

Hyperspectral for species, chemistry, etc.



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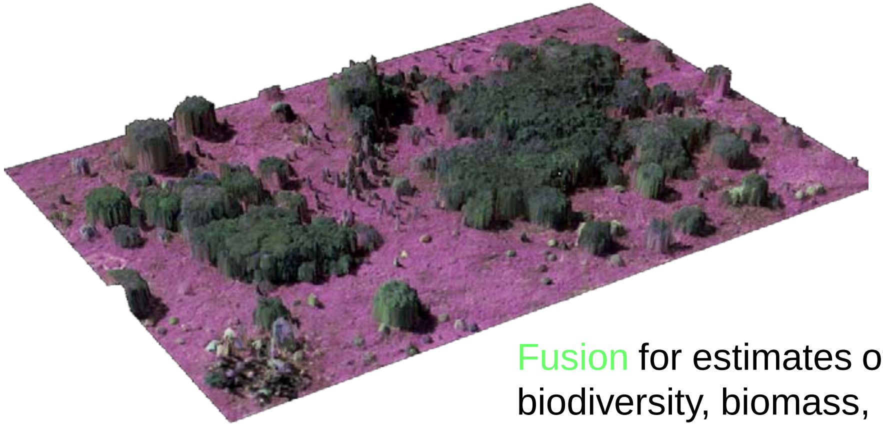
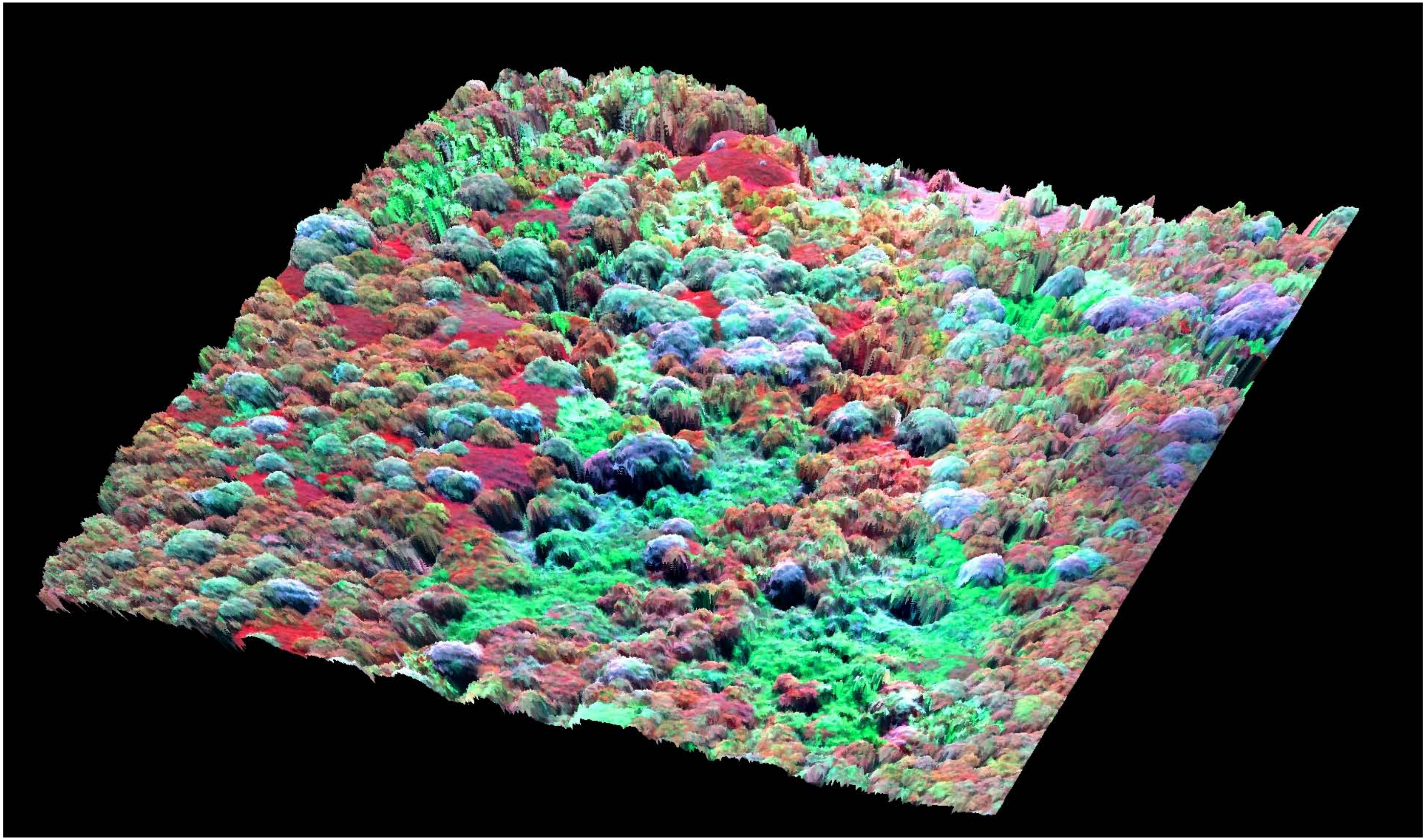


Fusion for estimates of biodiversity, biomass, sun/shade fraction, habitat suitability, etc.

Cook

Canopy chemistry and biodiversity in tropical forest canopies

Cook and
Asner



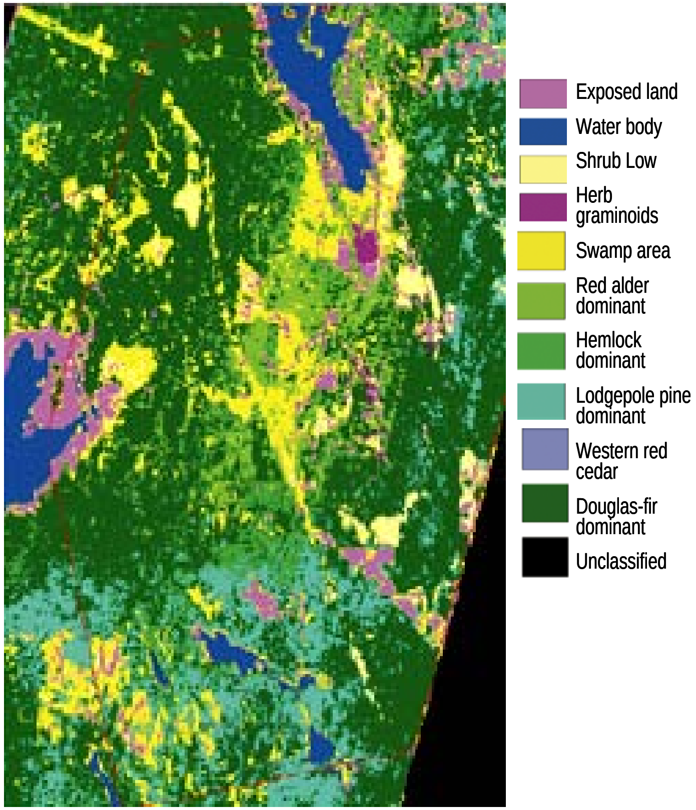
Cook

Study Sites

The study includes two independent locations with different regional climate and ecosystem types. Data aggregated to higher and lower spatial scales will be compared for the same locations.

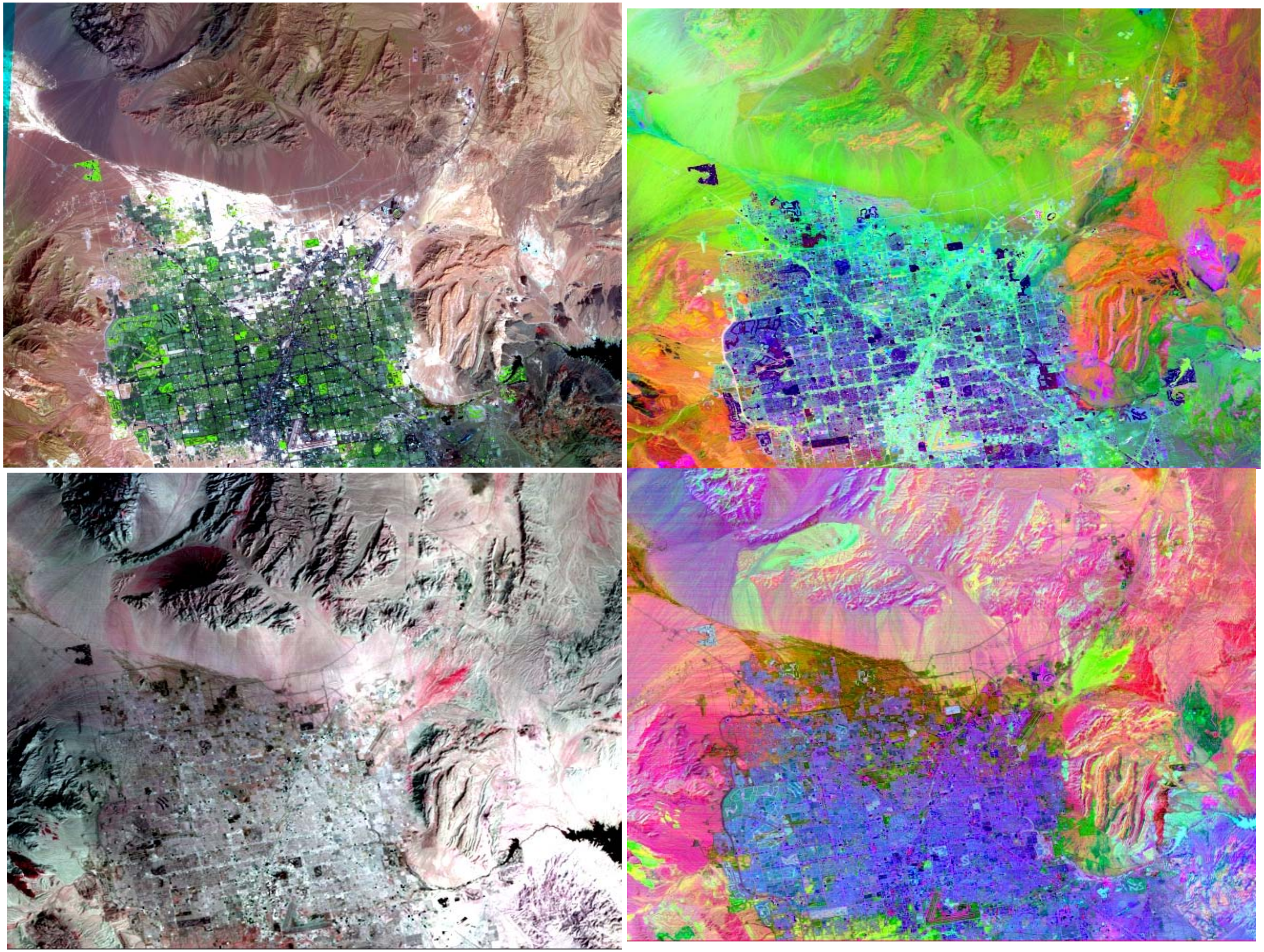
Vancouver Island, Canada/Hoquiam, WA: includes portions of unique natural ecosystems such as the Olympic National Park, WA and the Great Victoria Watershed (GVWD) test site on Vancouver Island, BC and rural, sub-urban and urban environment associated with the city of Victoria, BC.

Jasper Ridge Biological Preserve (JRBP), CA: provides Mediterranean-type climate, with five major vegetation types: evergreen forest, deciduous forest, chaparral shrublands, herbaceous perennial wetlands, and annual grasslands



Hyperion land cover classification of the Greater Victoria Watershed (GVWD) test site on Vancouver Island (September 10 2001, Goodenough et al. 2003).

Campbell



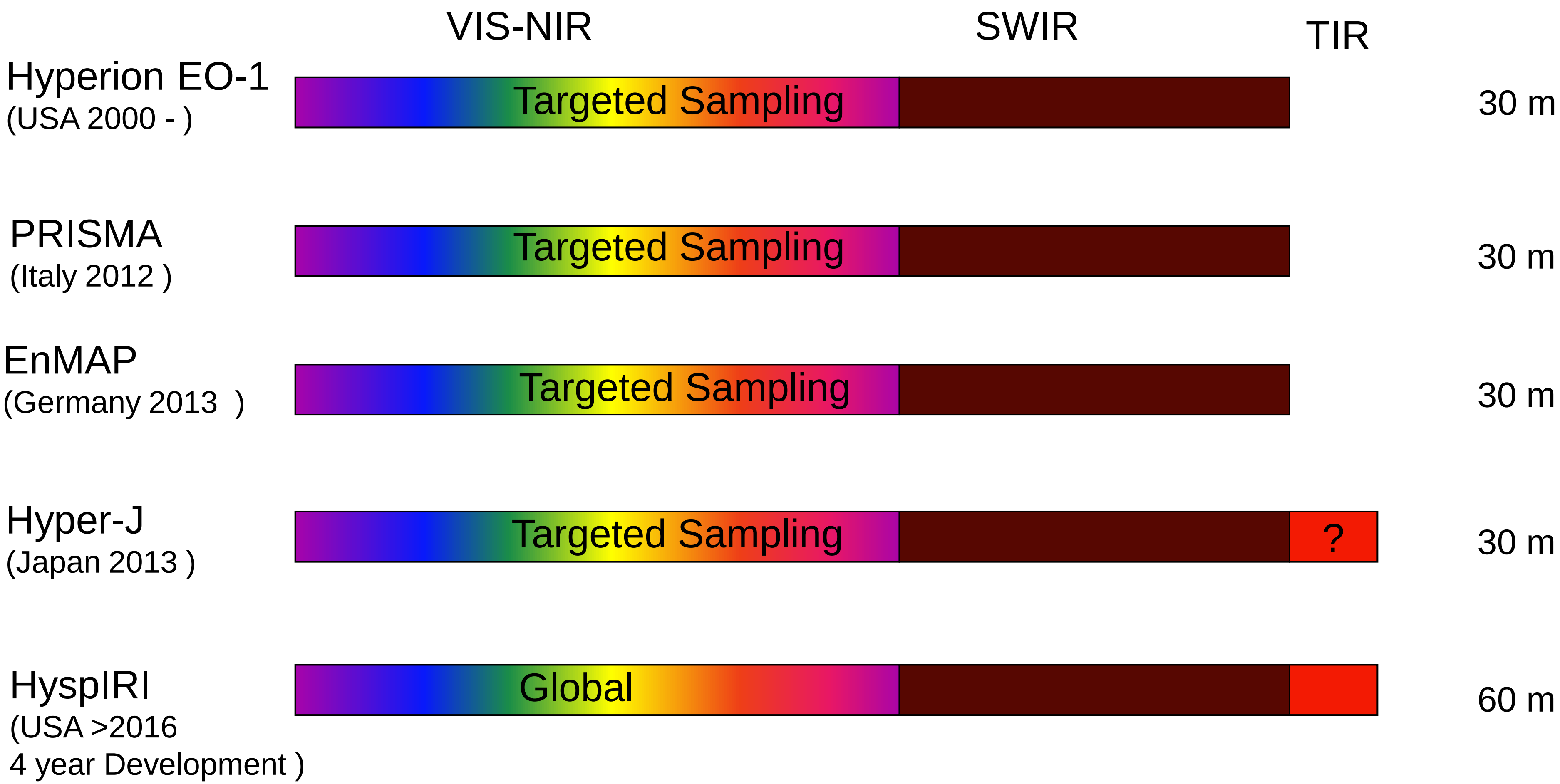
ASTER imagery, Las Vegas area: VSWIR aggregated to 90 m (upper left, vegetation in green) and TIR bands (lower left), principle components of reflective bands (upper right) and all VSWIR and TIR (lower right).

Campbell

Phil Townsend, slides 6, 12, 13

Green

Planned Civilian Satellite Missions



Hyperion EO-1
(USA 2000 -)
30 m

PRISMA
(Italy 2012)
30 m

EnMAP
(Germany 2013)
30 m

Hyper-J
(Japan 2013)
30 m

HyspIRI
(USA >2016
4 year Development)
60 m

HyspIRI compared with possible International Imaging Spectroscopy Missions

Green

Only HyspIRI provides the full spectrum of data required to address climate-carbon cycle feedbacks articulated in the NRC Decadal Survey

HyspIRI Provides Seasonal and Annual Global Coverage that Uniquely Addresses Critical Gaps in Climate Research and Ecosystem Understanding.

>100 years for international mission to equal 1 year of HyspIRI

Country	Instrument	Swath km	Pixel Size, m	Terrestrial Coverage in 19 days	Repeat interval, days	TIR capability
USA	**HyspIRI**	**150**	**60**	**100%**	**19**	**8 TIR bands**
Germany	EnMAP	30	30	<1%	--	NO
Italy	PRISMA	30-60	20-30	<1%	--	NO
Japan?	ALOS3	30	30	<1%	--	NO
India?	IMS Resource Sat-3	25	25	<1%	--	1 TIR band

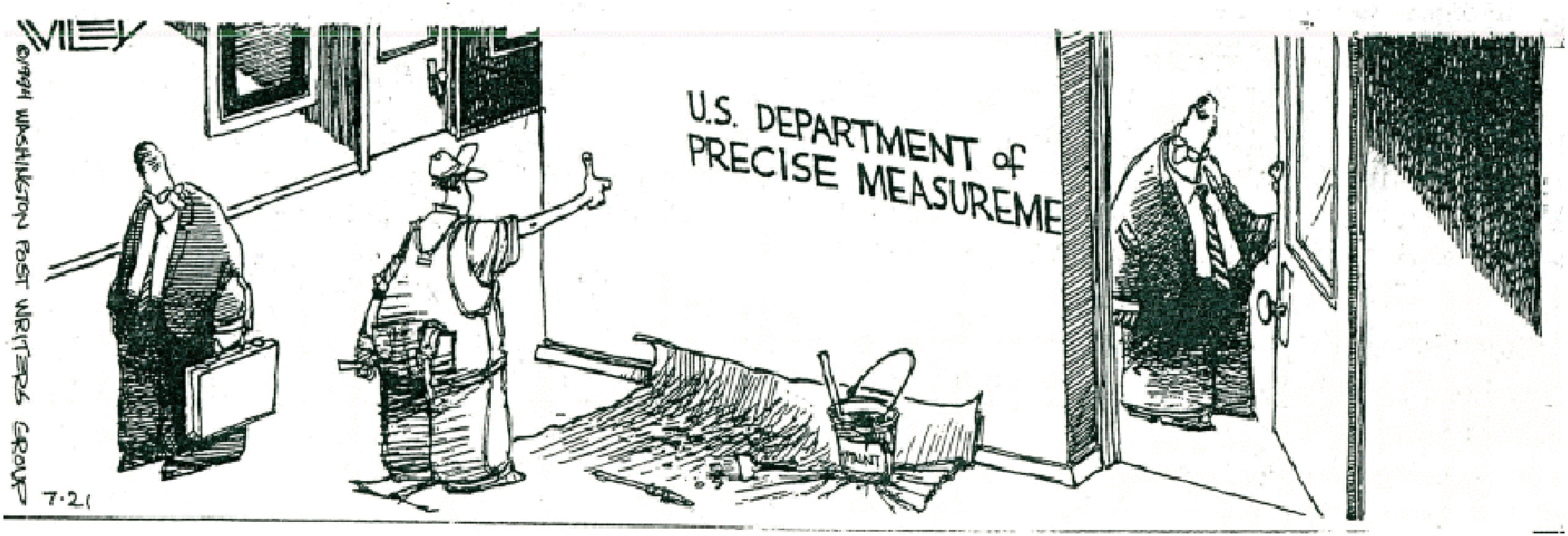
US, HyspIRI: a full spectral range (380 to 2500 at 10 nm), high SNR, uniform, 60m spatial with 150 km swath imaging spectrometer and multiband thermal imager (8 band thermal imager from 3-12 µm).

Other countries are occasionally mentioned (China, South Africa, South Korea, etc.). All are proposing first generation visible-only, small sample process/application missions with scattered terrestrial coverage and no TIR imager

Accuracy

Terms accuracy and precision can be sources of contention in discussions

- Accuracy is essentially how well the results agree to the actual value
- Precision is how well individual measurements agree with each other
- Repeatability is used interchangeably with precision



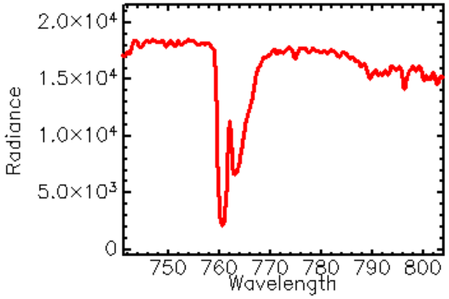
Thome

Spectral and Geometric calibration

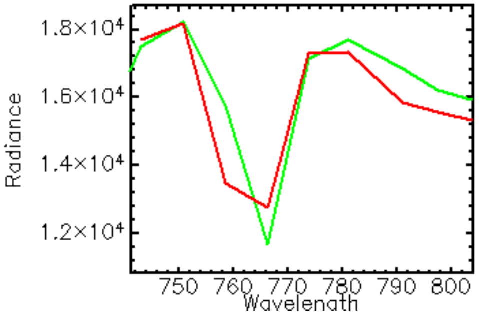
Spectral and geometric calibration takes place prelaunch and on orbit as well

- Alignment between emissive and reflective bands
- Center wavelength and band shapes

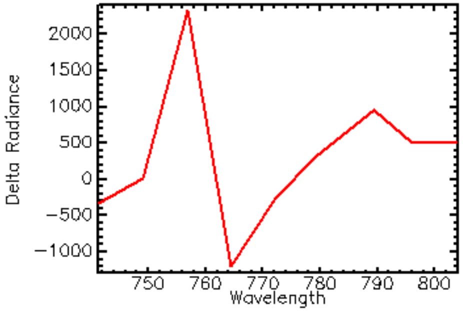
1. **Convolve SRF with High Resolution MODTRAN™ Model**



2. **Normalize Data (Green) to Model (Red)**



3. **Subtract Data from Model**
Fit Straight Line
Compute Statistics



4. **Shift Band Centers**
Repeat Steps 1-4

Thome

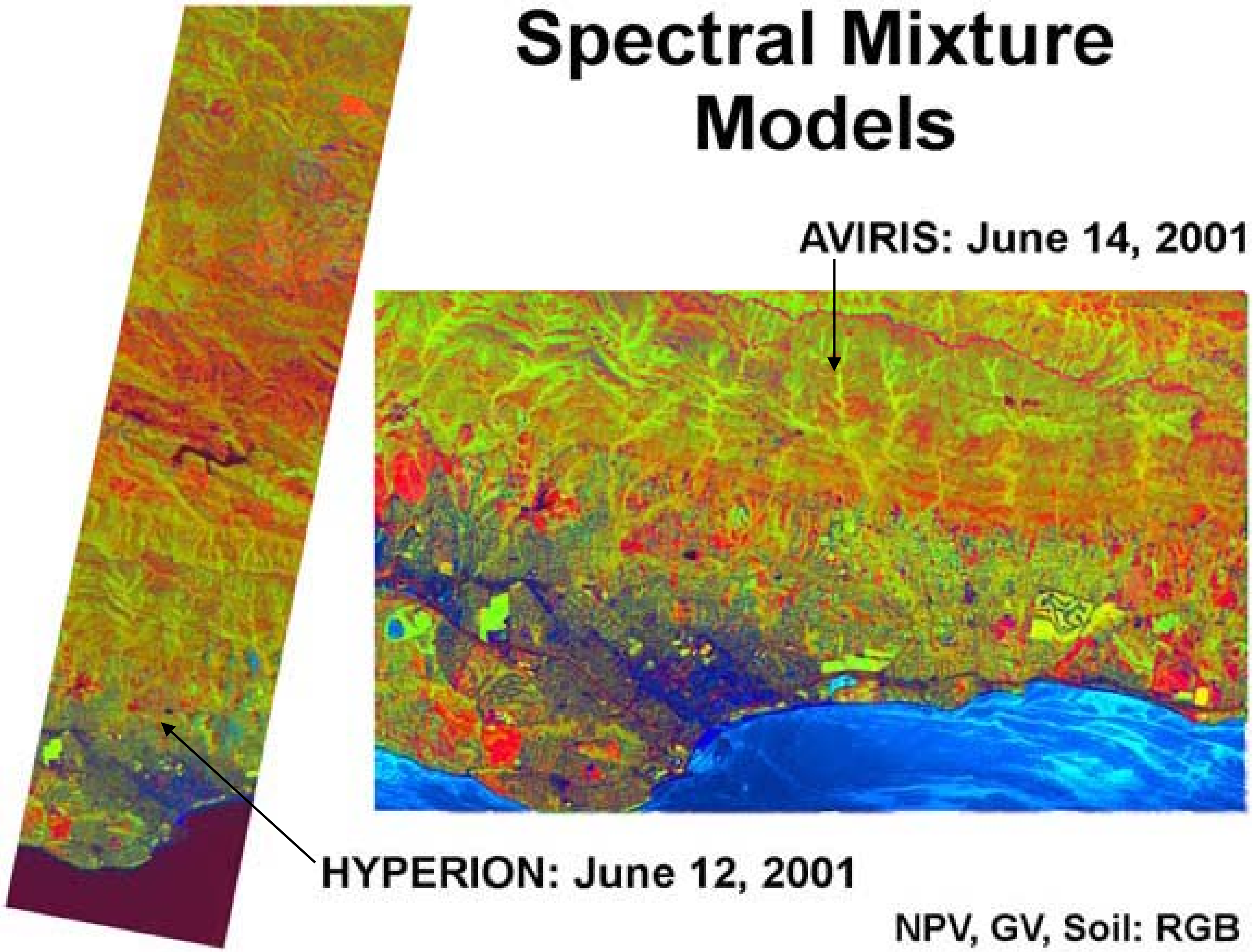
Back-Up Slides

Hyperion Imagery of Barrow, Alaska (July 2009)

July 20, 2009
False-Color and True-Color Images from Hyperion
Barrow, Alaska

Images are from NASA's Earth Observatory web site (http://earthobservatory.nasa.gov/)

Mapping Fuel Condition: Hyperion provides comparable measures to AVIRIS over a larger geographic region



Roberts et al. (2003)

Science Measurements
Summary Measurement Characteristics

Spectral	
Bands (8) µm	3.98 µm, 7.35 µm, 8.28 µm, 8.63 µm, 9.07 µm, 10.53 µm, 11.33 µm, 12.05
Bandwidth	0.084 µm, 0.32 µm, 0.34 µm, 0.35 µm, 0.36 µm, 0.54 µm, 0.54 µm, 0.52 µm
Accuracy	<0.01 µm
Radiometric	
Range	Bands 2-8= 200K – 500K; Band 1= 1400K
Resolution	< 0.05 K, Linear Quantization to 14 bits
Accuracy	< 0.5 K 3-sigma at 250K
Precision (NEdT)	< 0.2K
Linearity	>99% characterized to 0.1 %
Spatial	
IFOV	60 m
MTF	>0.65 at FNy
Scan Type	Push-Whisk
Swath Width	600 km (±25.5° at 623 km altitude)
Cross-Track Samples	10,000
Swath Length	15.4 km (+/- 0.7-degrees at 623km altitude)
Down-Track Samples	256
Band-to-Band Co-registraion	0.2 pixels (12 m)
Pointing Knowledge	10 arcsec (50 microrad, 05 pixels, 30m on ground)

Status of Decadal Survey Missions

Woody Turner

- February 1, 2010: President's Budget released with a 5-year, $2.5 Billion total augmentation for NASA Earth Science
- March 18, 2010: NASA ESD sends Climate Augmentation Plan to OMB
- Plan calls for launch of all Tier 1 Missions by 2017 (also the launch of OCO reflight, GRACE follow-on, and SAGE III missions)
- Also, current plans are for Tier 2 missions to launch at the rate of 1 per year starting in 2019
- President's Budget direction requires NASA to obtain USGCRP Review of the Climate Augmentation Plan
- Review is taking place this month
- In the near-term, Tier 2 mission funding to continue; levels still TBD

IPCC Climate Change 2007: Working

The Physical Science Basis

Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

7.3.3 Terrestrial Carbon Cycle Processes and Feedbacks to Climate

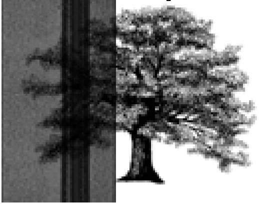
To understand the reasons for CO_2 uptake and its likely future course, it is necessary to understand the underlying processes and their dependence on the key drivers of climate, atmospheric composition and human land management.

Drivers that affect the carbon cycle in terrestrial ecosystems can be classified as:

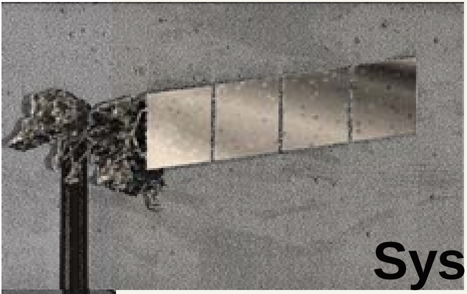
(1) direct climate effects (changes in precipitation, temperature and radiation regime);

(**2) atmospheric composition effects** (CO_2 fertilization, nutrient deposition, damage by pollution); and

(3) land use change effects (deforestation, afforestation, agricultural practices, and their legacies over time).



Susan Ustin

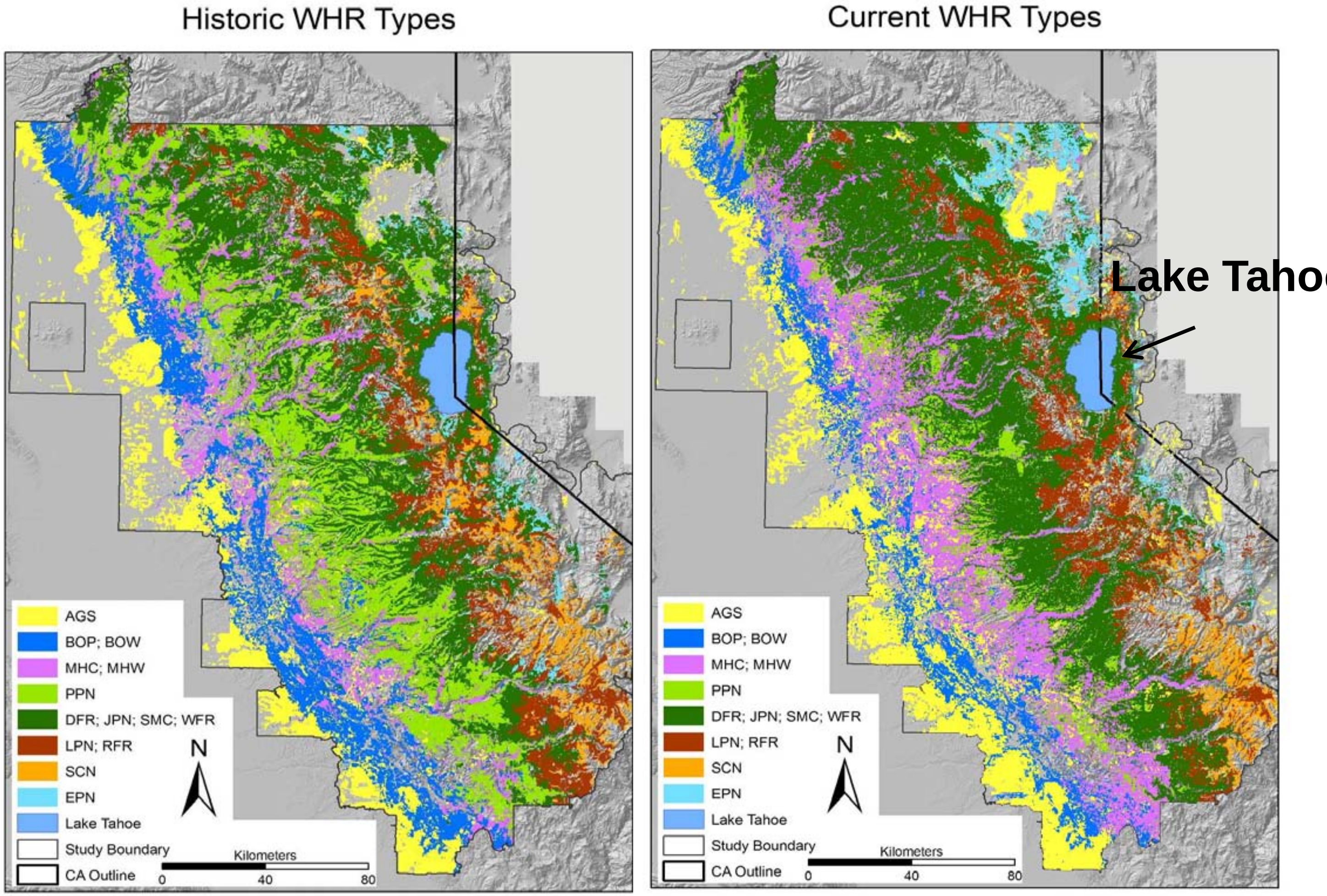


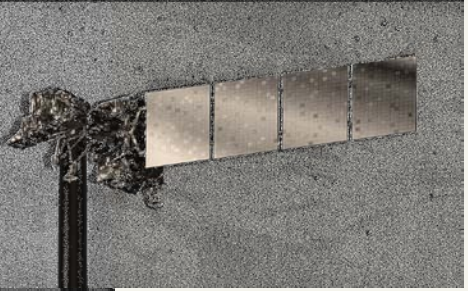
IPCC Climate Change 2007: Working Group
The Physical Science Basis
Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary
7.1.1 Terrestrial Ecosystems and Climate: Carbon Cycle Drivers

Changing Plant Functional Types in California from 1934 to 1996

Analyzed by James Thorne, UC Davis based on the Wieslander VTM Project, 1934

- Grasslands
- Mixed oak-pine savanna
- Ponderosa pine forest
- Mixed Montane Hardwod & Conifer
- Mixed conifer
- Lodgepole pine, red fir
- Subalpine conifers





Susan Ustin

Relevance of HyspIRI to Carbon and Climate Science

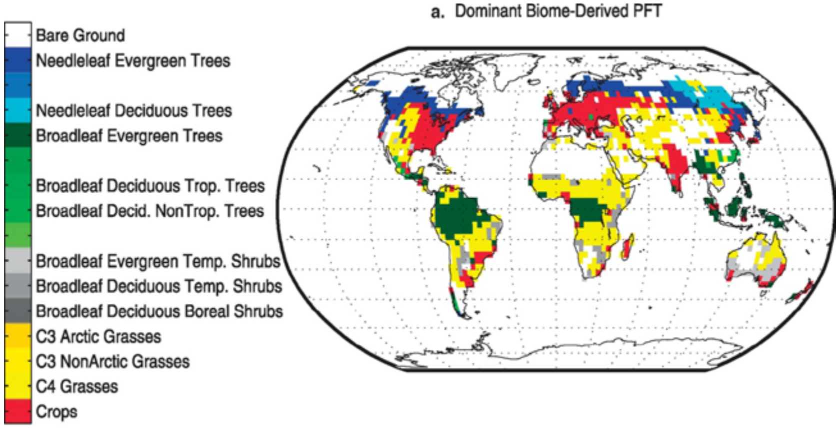
Monitoring Vegetation Type and Functions

Global Land Cover Maps based on climate potential have biased Distributions

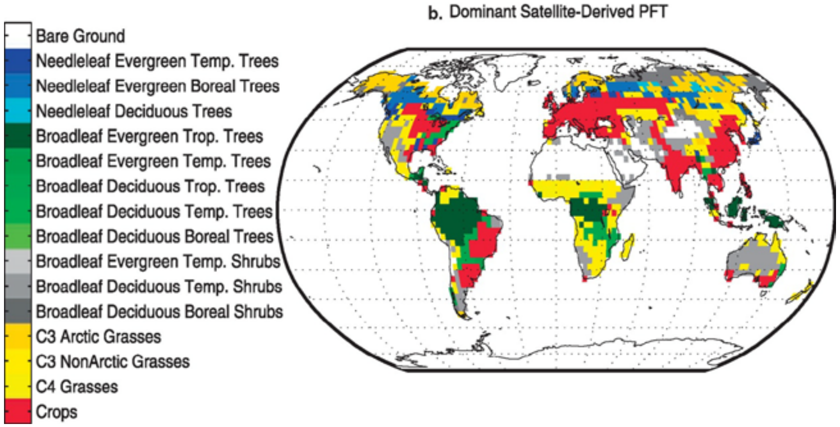
- ➢ Coarse Spatial Resolution data do not agree with actual land cover types

Satellite Based plant functional type maps have higher spatial resolution and are derived from actual measurements

- ➢ Maps remain too spatially coarse to monitor ecosystem changes
- ➢ Limited number of cover types; no subgrid elements



a. Dominant Biome-Derived PFT

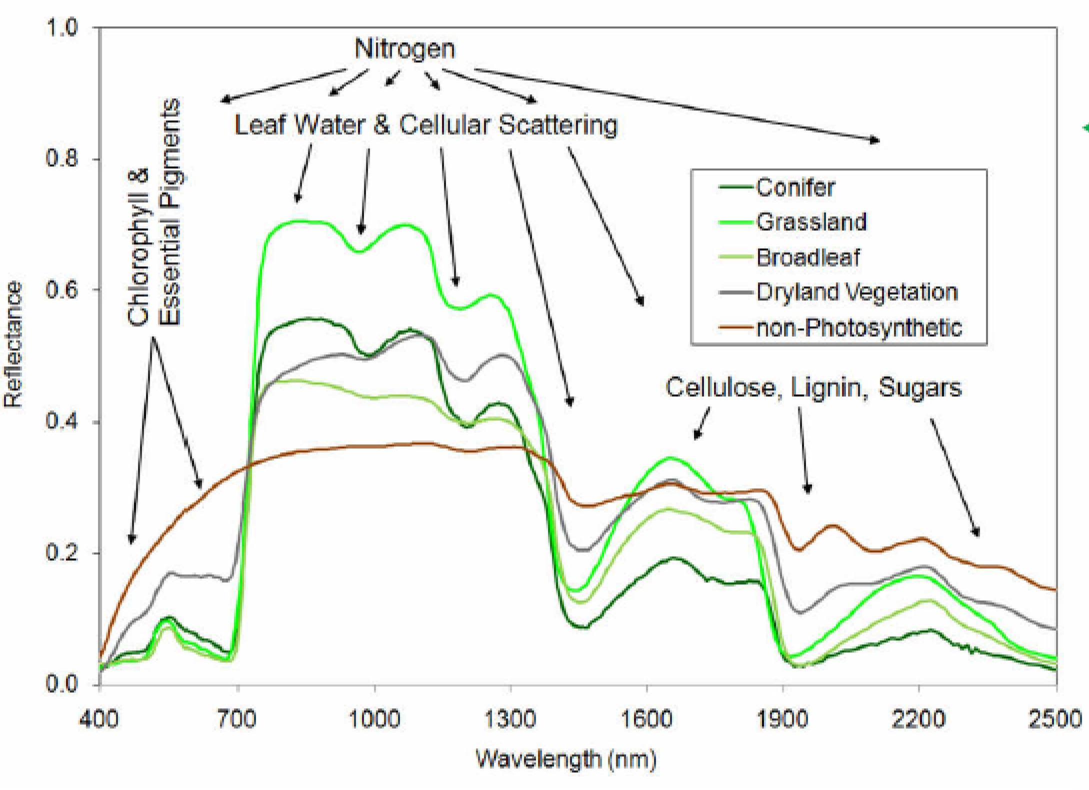


b. Dominant Satellite-Derived PFT

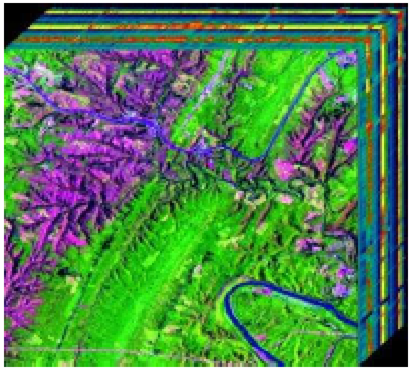
From: Bonan, GB, Levis S, Sitch S, Vertenstein M, Olson KW (2003). Global Change Biology 9: 1543-1556,
Figure b from: Ramankutty N. and Foley JA. (1999). Global Biogeochemical Cycles 13: 997-1027.

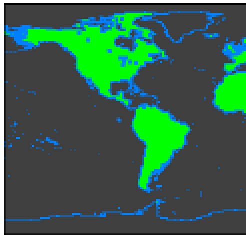
Ro

Measuring the Terrestrial Biosphere

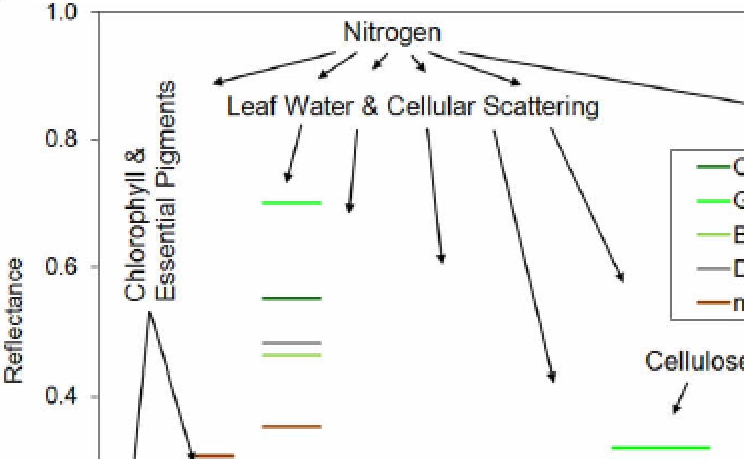


Imaging Spectroscopy is r
to measure critical variabl
terrestrial biosphere.





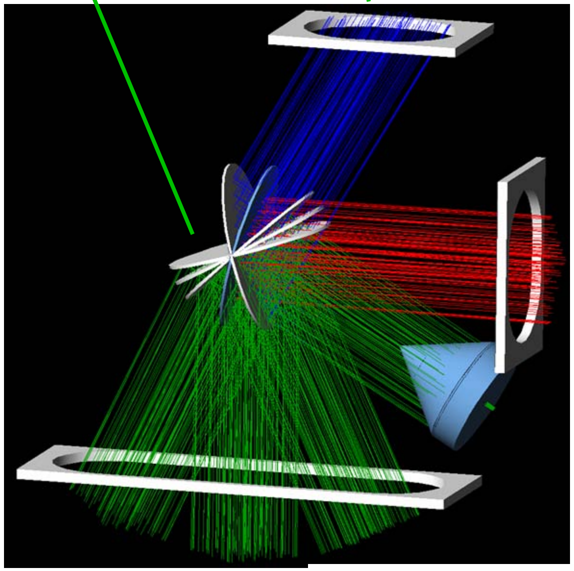
Multi-spectral imaging is insufficient

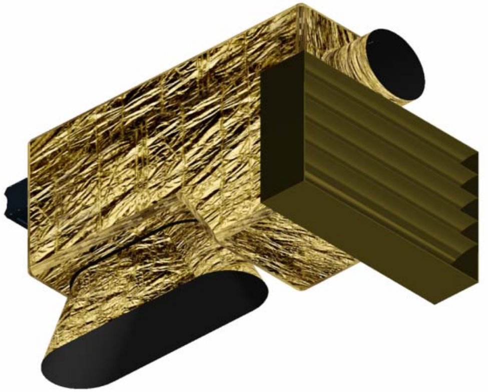


Mission Concept

TIR Overview

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





Simon Hook

Wildfires:

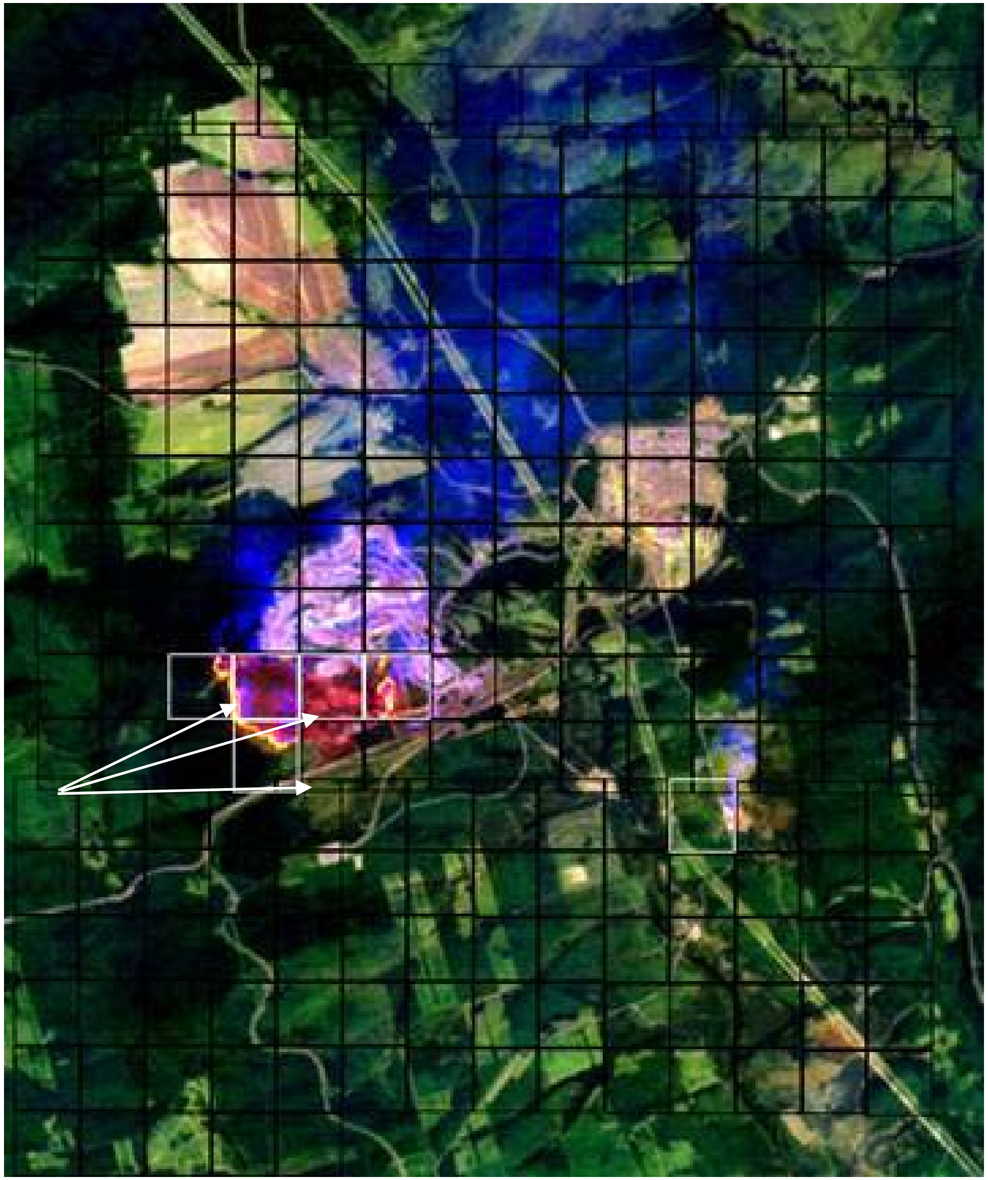
How are global fire regimes changing?

Simon Hook

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

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

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



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

Central Siberia

30 May 2001

HyspIRI will provide high spatial resolution mid to thermal infrared data for determining the fire regime and allowing flux estimation on a weekly basis

Bogdan Oaida

HyspIRI Mission Concept

Orbit Selection

- Key Orbit Design Considerations
  - – Local time of observations
    - Sun-synchronous
    - 10:30 AM LTDN
  - – Altitude
    - Low Earth Orbit
    - Repeating Ground track
  - – Global coverage in a minimum number of days given the swath-width of each instrument.
    - VSWIR: 19 days revisit at the equator
    - TIR: 5 day revisit at the equator (1 day + 1 night)
- 626 km altitude at equator suits the needs of both instruments

Orbit selection and operations concept meet science requirements with very infrequent ground commanding or maintenance.

Operations Concept

- Systematic mapping vs. pointing capability
- Target map driven - No need for uploading acquisition sequences
- High resolution mode and Low resolution mode
- Direct Broadcast capability
  - – Uses Intelligent Payload Module
  - – Applications-driven

Operational Requirement	VSWIR	TIR
10:30 am sun-sync orbit	✓	✓
626 km altitude at equator	✓	✓
19 days revisit at the equator	✓	
5 day revisit at the equator		✓
Day Observation	✓	✓
Night Observation		✓
Pointing strategy to reduce sun glint	✓	
Surface reflectance in the solar reflected spectrum for elevation angles >20	✓	
Avoid terrestrial hot spot	✓	
Monthly Lunar View calibration	✓	✓
Weekly Solar View Calibration	✓	
Blackbody View Calibration		✓
Deep Space View Calibration		✓

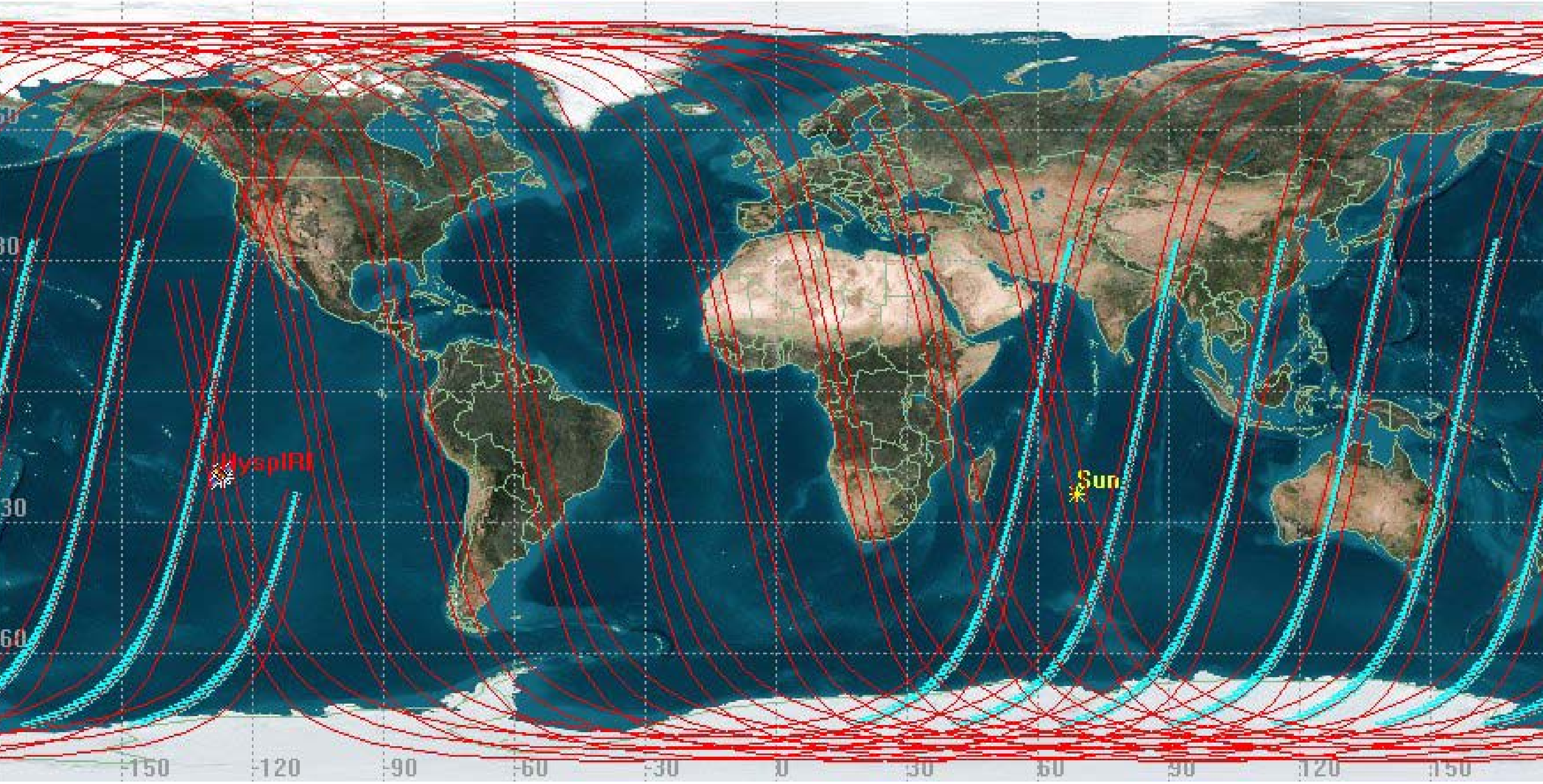
Payload Accommodation and System Margins

Bogdan Oaida

Accommodations	VSWIR	TIR
Mass (CBE)	60 kg	64 kg
Volume	1.1 x 0.5 x 0.8 m	1.2 x 1.1 x 0.6 m
Power	41 W	103 W
FOV (crosstrack)	13.62 deg	50.7 deg
FOV (alongtrack)	95.9 microrad	95.9 microrad
Orientation	4 deg to starboard	nadir
Pointing		
Accuracy	165 arcsec (3σ/axis)	
Knowledge	2 arcsec (Pitch/Yaw axis 3σ); 8 arcsec (Roll axis 3σ)	
Stability	5 arcsec/sec (3σ)	

	Required	Design	Margin (D-R)/D
Swath width VSWIR	141km	151 km	6%
Swath width TIR	536km	600 km	11%
Recorder capacity	2.0 Tb	3.1 Tb	37%
Power	620 W (CBE)	965 W	36%
LV mass capability	530 (CBE, dry)	790 kg	32%

VSWIR's Local solar illumination constraint (SZA < 70 deg.) Northern Hemisphere Winter Solstice



Bob Knox

Justification for PRI-type product

Amount of “Green stuff”

Physiological state (stress)

Photosynthetic rate = f(*APAR*) x ε

PRI – carotenoids
Canopy water
Temperature

NDVI

Note synergy

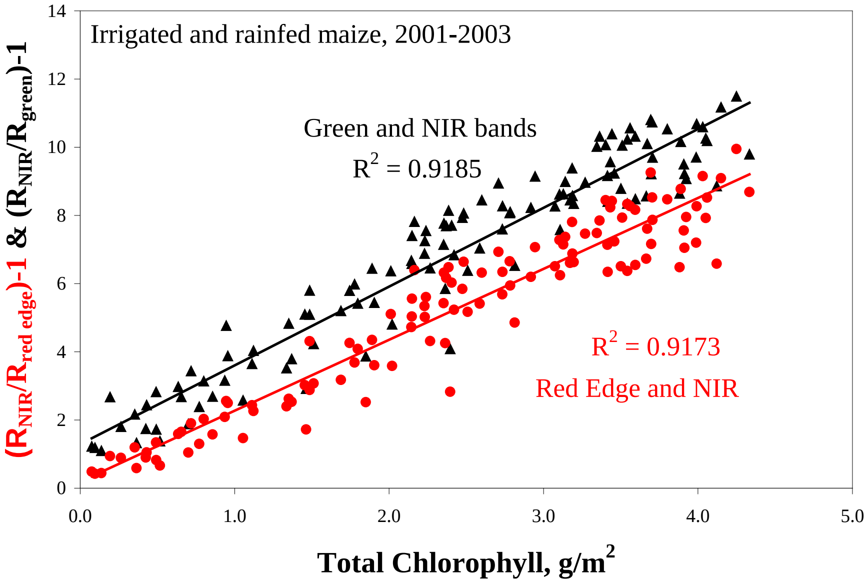
Where:
APAR = Absorbed photosynthetically active radiation
ε = *Efficiency* with which absorbed radiation is converted to fixed carbon

Determination of ε remains a primary challenge **(Field et al. 1998, Running et al. 2009)**

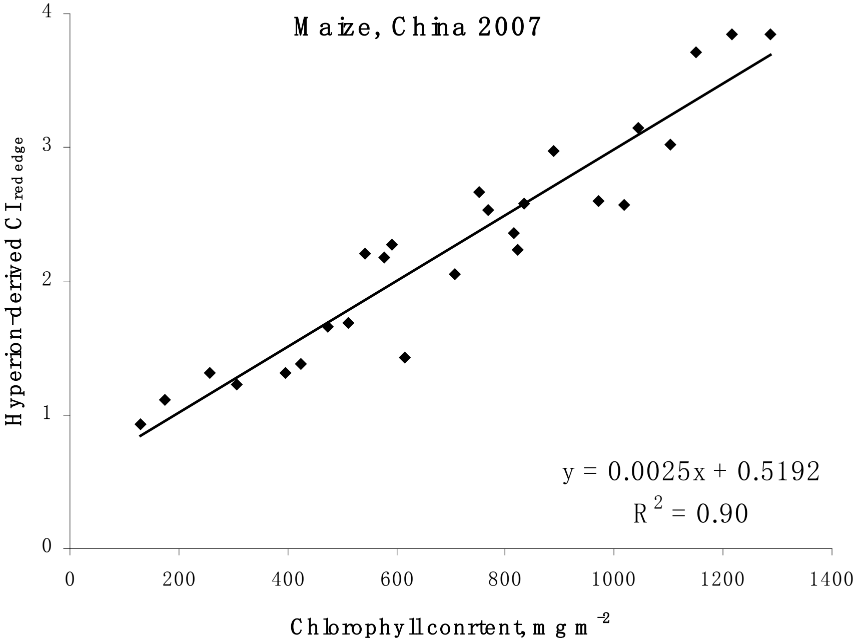
John Gamon

How does it work?

$$CI_{red\ edge} \propto [(\rho_{red\ edge})^{-1} - (\rho_{NIR})^{-1}]\ \rho_{NIR}$$



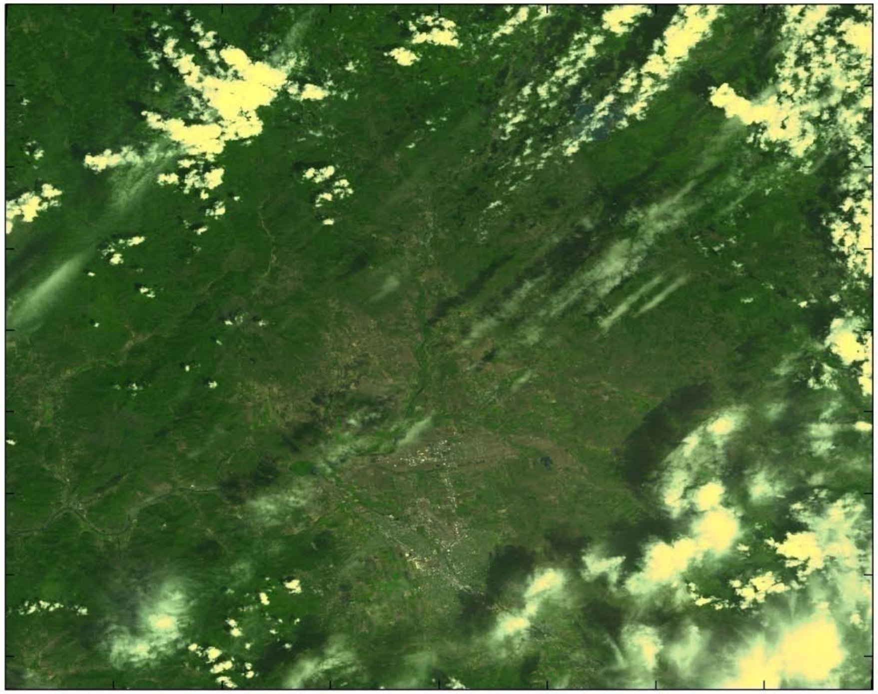
Gitelson et al., GRL, 2005



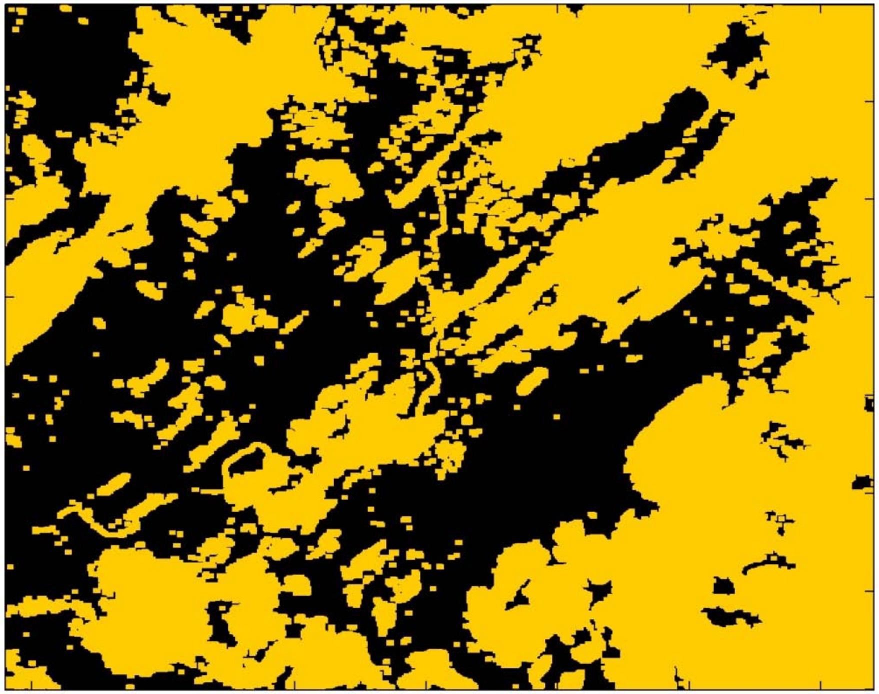
Wu et al., IJRS, 2010

Cloud Mask:
Cumulus + thin cirrus example

ASTER visible image



ASTER Cloud Mask + Fill



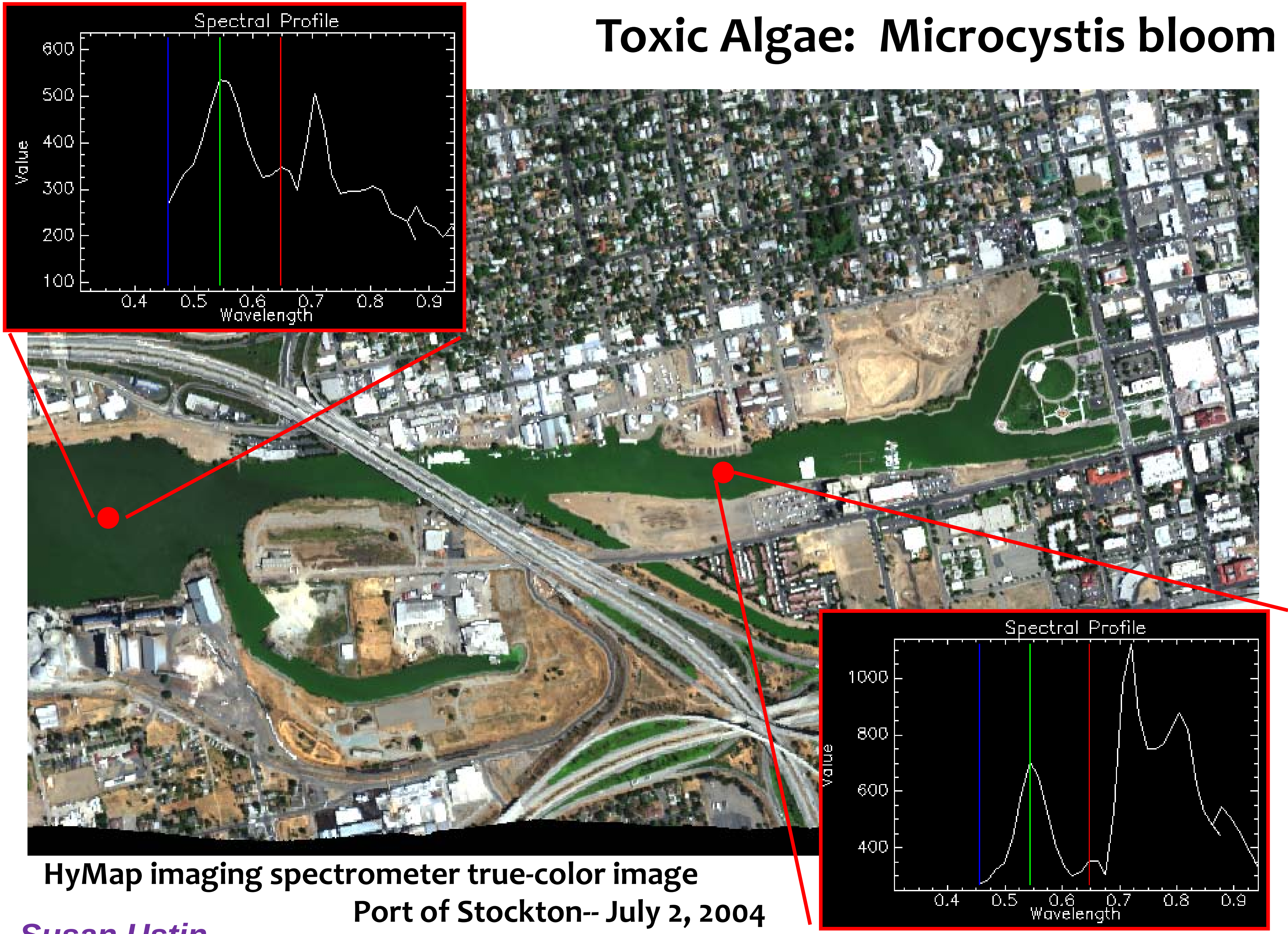
Shadow – Cyan

Cloud – Gold

Clear – **Black**

Simon Hook

Toxic Algae: Microcystis bloom



HyMap imaging spectrometer true-color image

Port of Stockton-- July 2, 2004

Susan Ustin

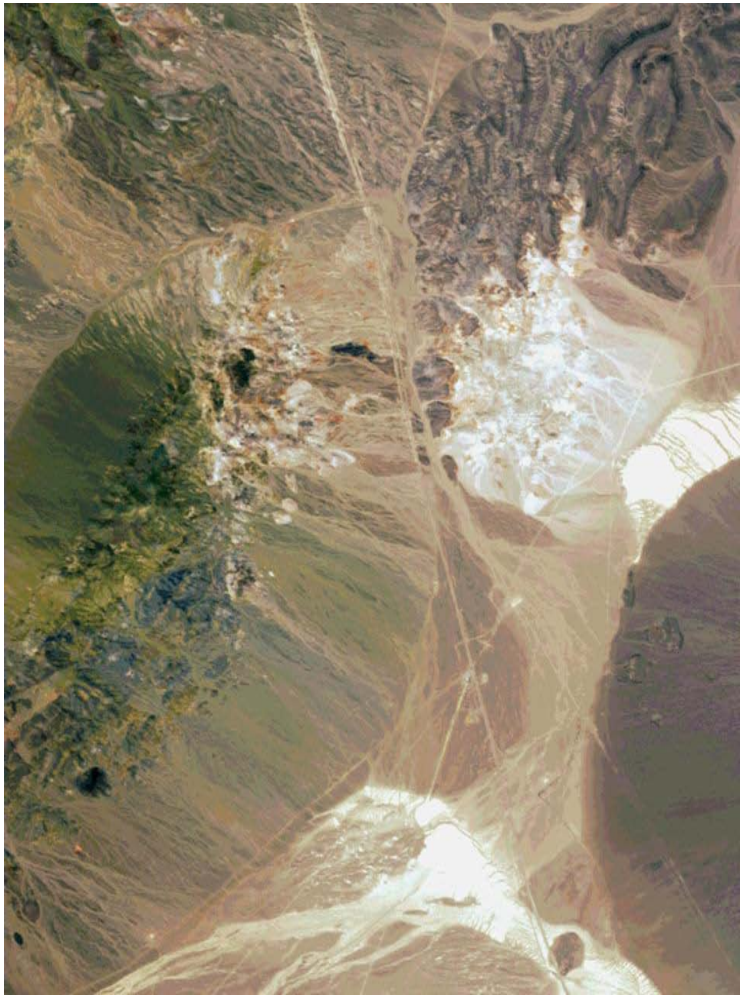
Atmospheric Correction

Bo-Cai Gao

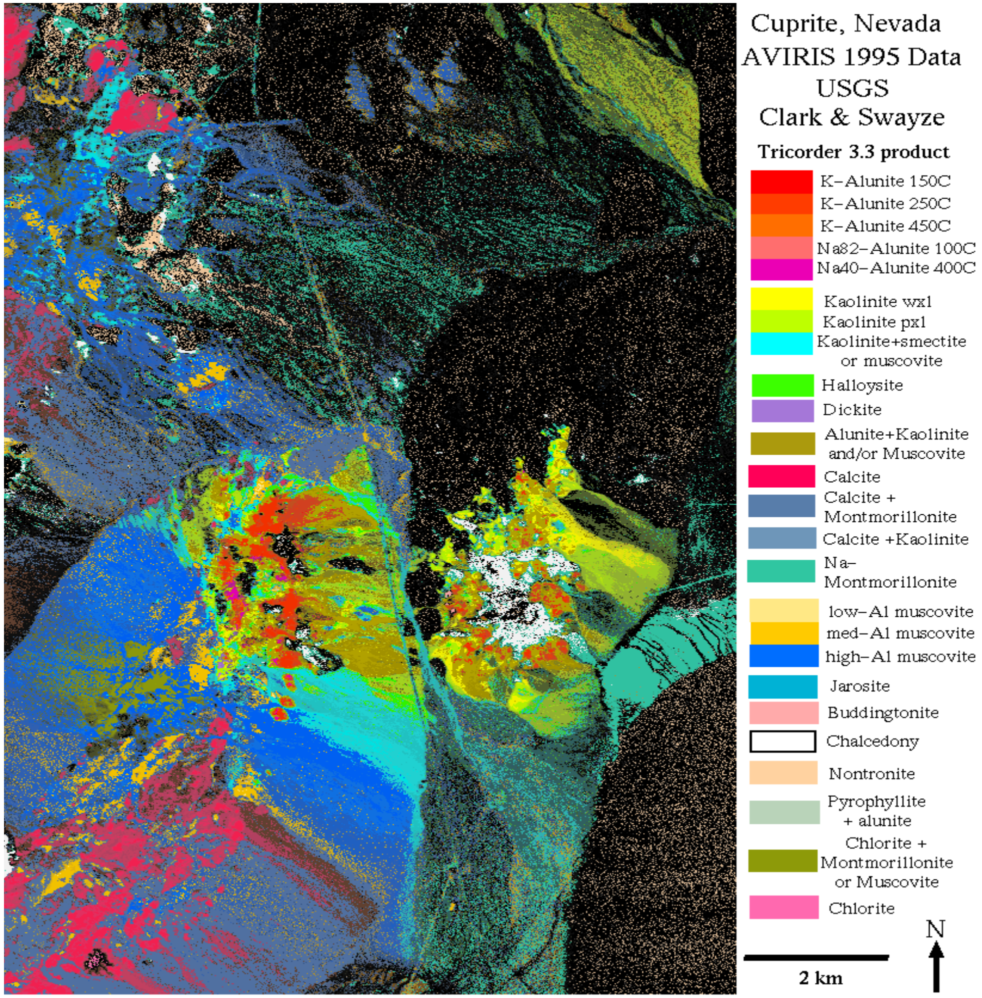
MINERAL MAPPING USING ATREM OUTPUT

by Scientists at USGS in Denver, Colorado

RGB Image (Cuprite, NV)



USGS Mineral Map, ~11x18 km



Processor Comparison

Tom Flately

	MIPS	Power	MIPS/ W
MIL-STD-1750A	3	15W	0.2
RAD6000	35	10-20W	2.33[1]
RAD750	300	10-20W	20[2]
SPARC V8	86	1W[3]	86[3]
LEON 3FT	60	3-5W[3]	15[3]
SpaceCube 1.0	3000	5-15W	400[4]
SpaceCube 2.0	5000	10-20W	500[5]

Notes:

1 – typical, 35 MIPS at 15 watts

2 – typical, 300 MIPS at 15 watts

3 – processor device only ... total board power TBD

4 – 3000 MIPS at 7.5 watts (measured)

5 – 5000 MIPS at 10 watts (calculated)

Results of half pixel misalignment and *"correction"* through linear re-sampling

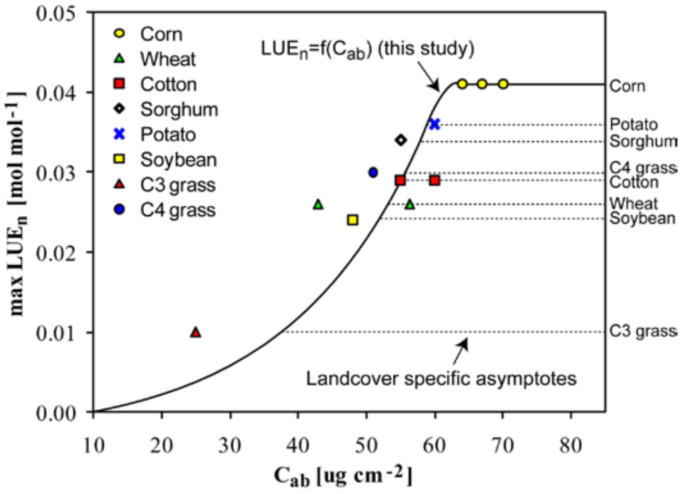
Pixel Shift Scenario	Category 1 Ratio Value	Category 1 Discrepancy	Category 2 Ratio Value	Category 2 Discrepancy
VIS and NIR ½ pixel shift	*1.33*	*+33%*	*4.00*	*-20%*
VIS and NIR resampled	1.27	+27%	3.67	-26%
VIS and NIR unmixed	1.00	0%	5.00	0%

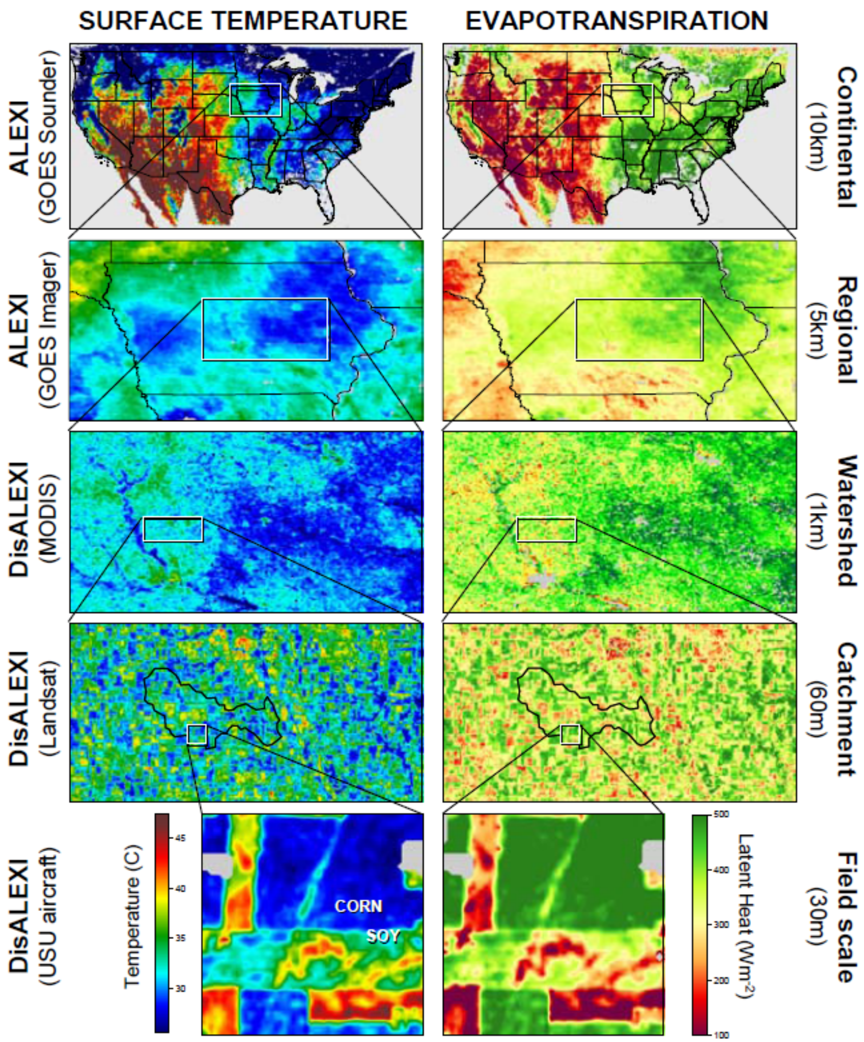
Inherent spectral/spatial integrity, required for HyspIRI, allows for substantially more accurate parameter determination than is possible with *currently planned* sequentially sampled pushbroom multispectral systems.

Unlike these multispectral systems, the rich spectral content offered by HyspIRI has the potential to mitigate the impact of temporal sampling offsets as well as to address mixed pixels.

Thermal-based flux mapping

Application to other regions





Rasmus Houborg

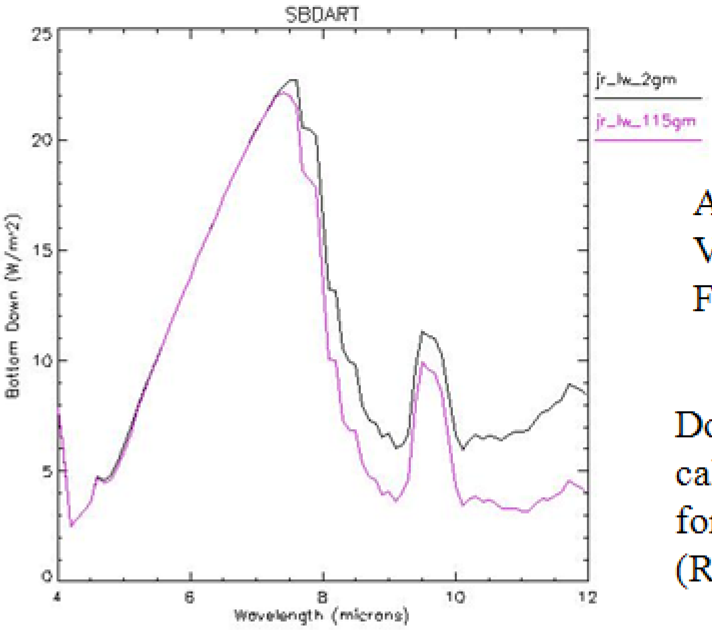
Fire Products: Benefits of HyspIRI

- Unprecedented sensitivity to flaming and smoldering fires
  - Can easily detect small agricultural fires (difficult with coarser resolution sensors)
- Fewer false alarms
- Straightforward retrieval of fire radiative power
  - Single band vs. three or more bands with existing sensors
- Greatly expanded spatial and temporal coverage
- Will provide large samples of detailed fire characteristics useful for statistically modeling fires and their behavior
- Calibrate and validate active fire observations derived from coarser resolution satellite data

Dar Roberts

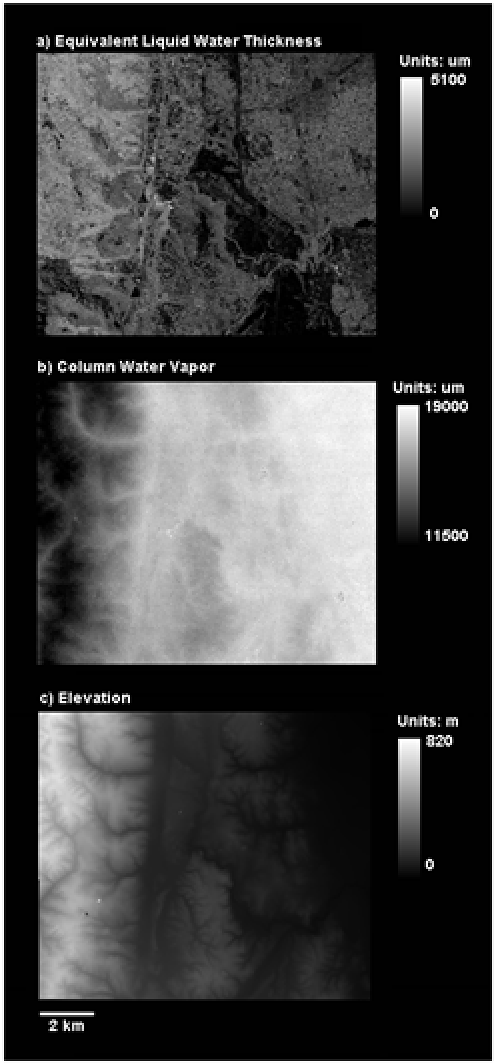
Improved Temperature Emissivity Separation

- **Column water vapor is estimated using forward inversion as it varies spatially and with elevation**
- **Column water vapor is used to calculated downwelling radiance as a first step for emissivity estimation**



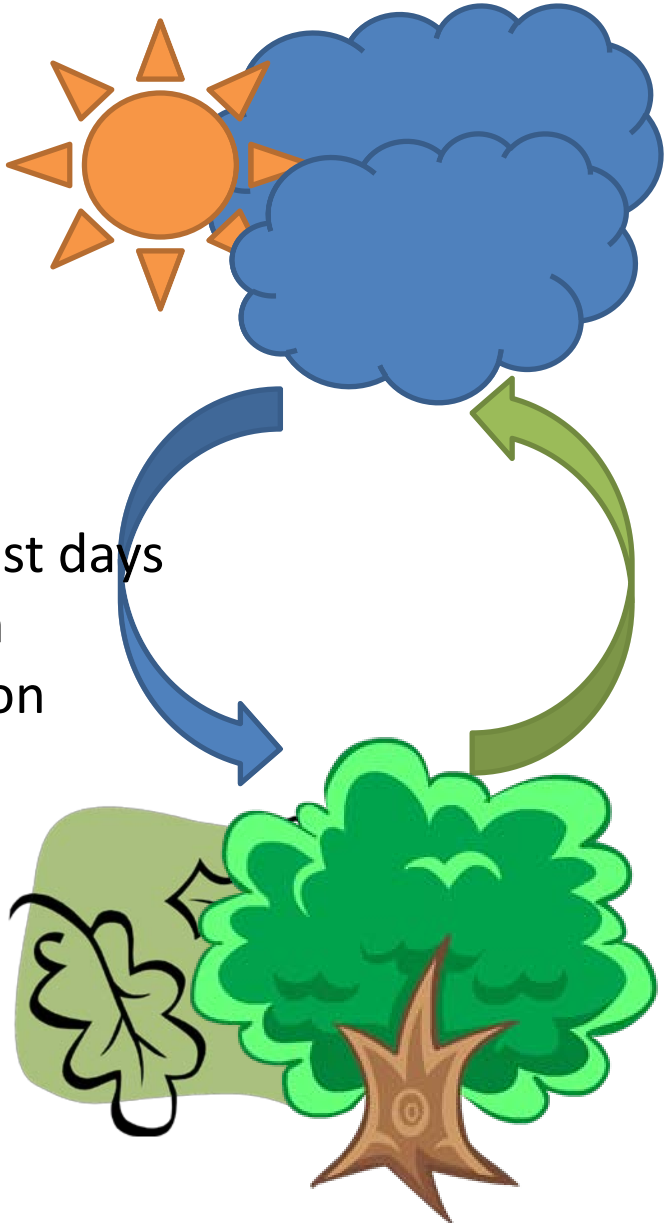
AVIRIS EWT, Column Water Vapor, and a DEM
From Roberts et al., 1997

Downwelling longwave calculated using SBDART for 1.15 and 2 g/m^2 water vapor (Richiazzi et al.)



Production: Standard ASTER TES Algorithm modified to include 60 m

Plant Functional Types



Changes in :

- Air temperature
- Precipitation
- # sunny vs. overcast days
- CO_2 concentration
- Nitrogen deposition

Changes in:

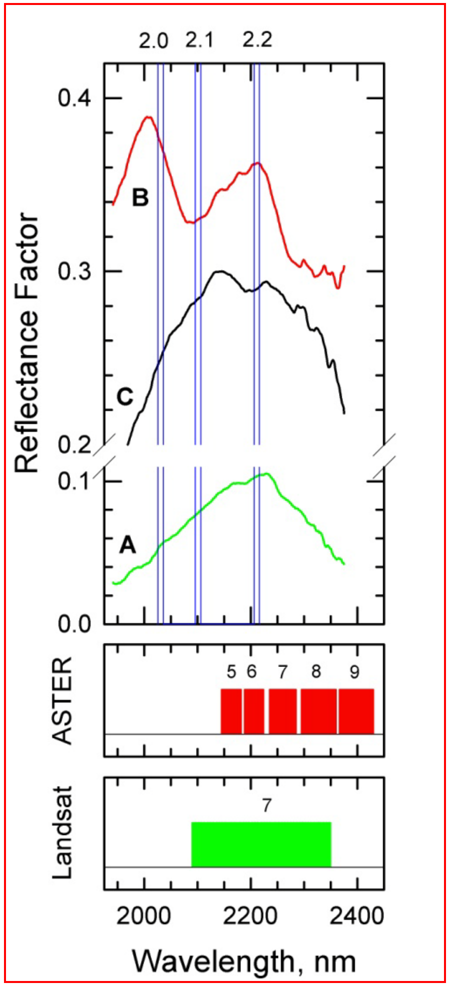
- Albedo
- Evapotranspiration
- Soil moisture
- Surface temperature

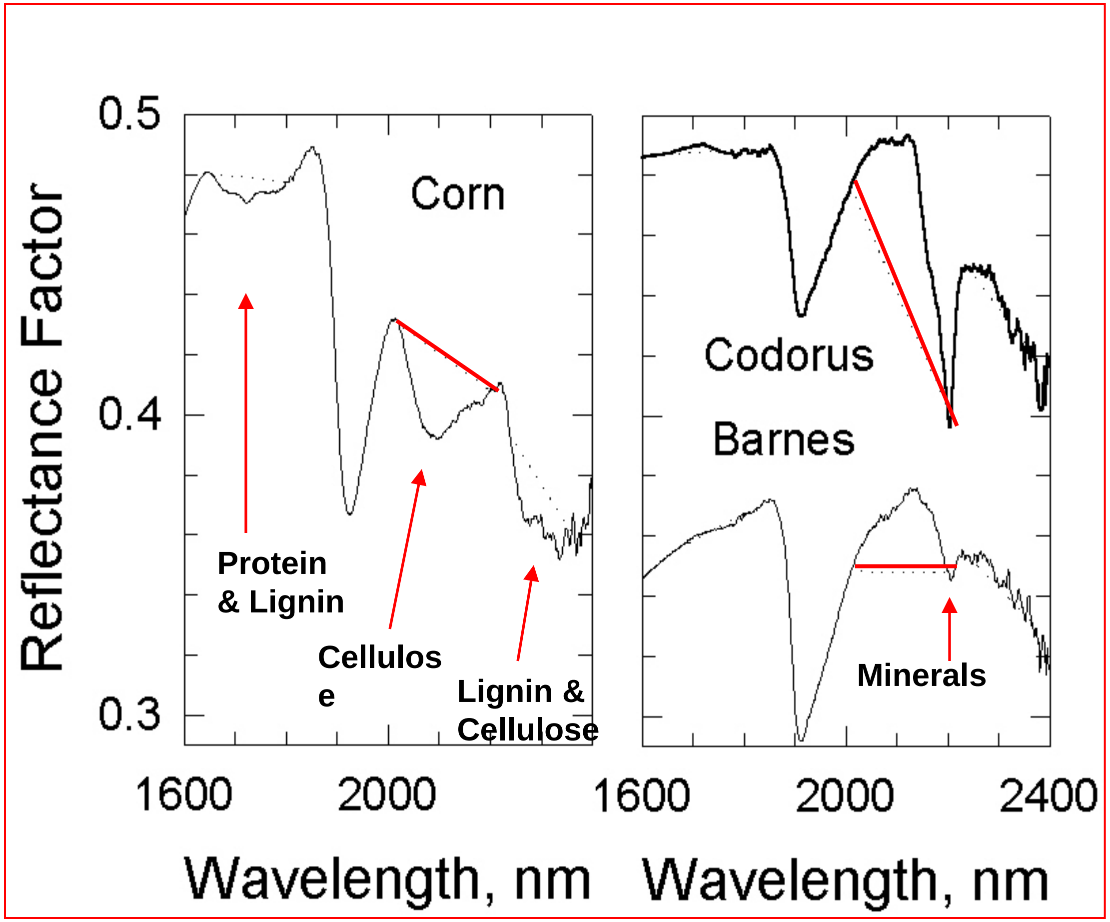
Changes in:

- Timing of greening
- Length of growing season
- Stomatal closure
- Balance among species
- PFTs, spatial & temporal

- Estimates of surface energy balance can be improved by better characterization of the surface.

- Cellulose Absorption Index (CAI) is a measure of the relative depth of the absorption feature near 2100 nm.
- Other features are associated with protein, lignin, and minerals.





Daughtry

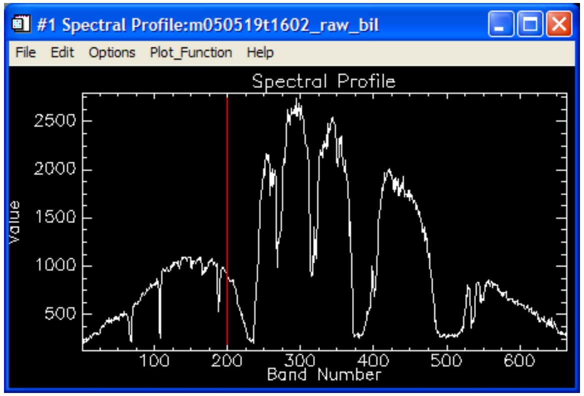
HyspIRI Example from Airborne-IS 2005

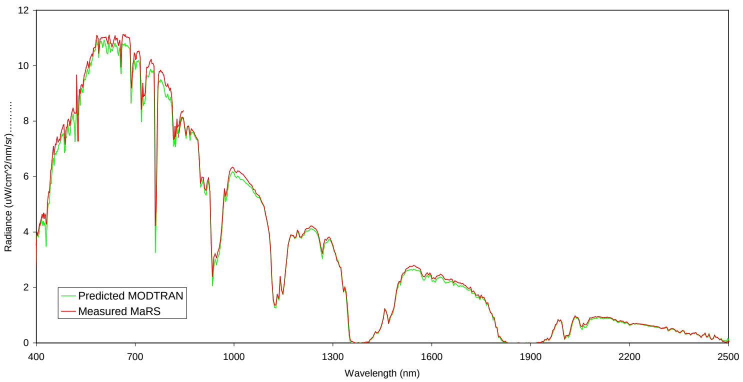
Green

- Airborne-IS example from Ivanpah Playa
- Solar reflected spectrum
- Offner spectrometer
- TCM6604a detector array
- HyspIRI calibration standards and approach

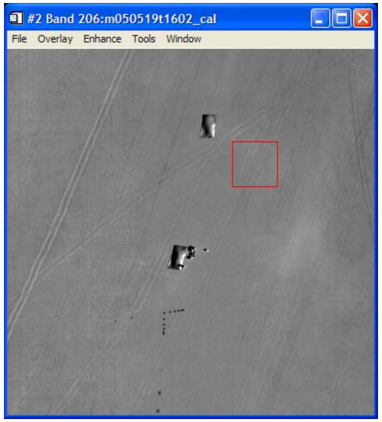
Level O

DN versus Band

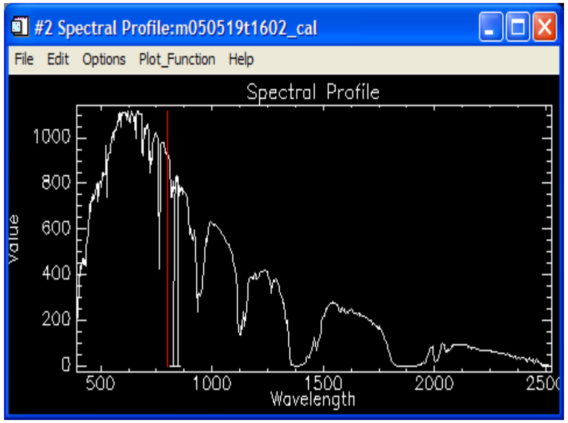




Level 1

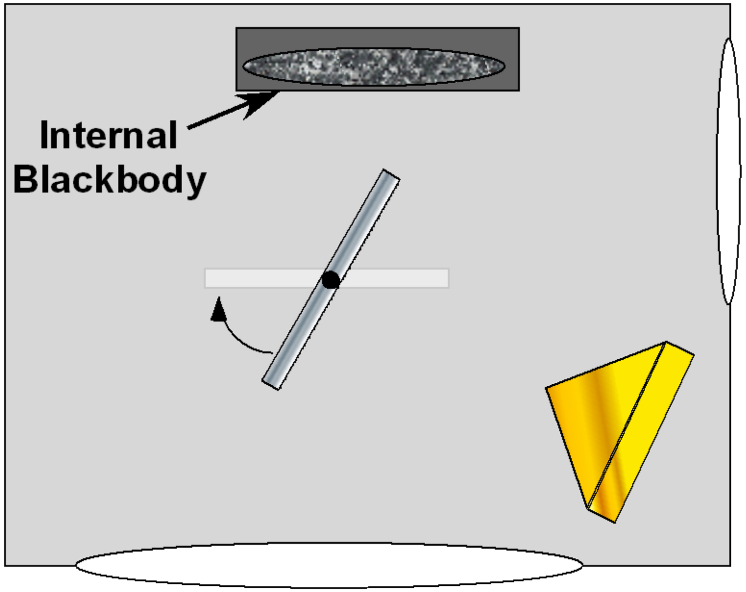


Radiance versus Wavelength



Hook

Radiometric Calibration



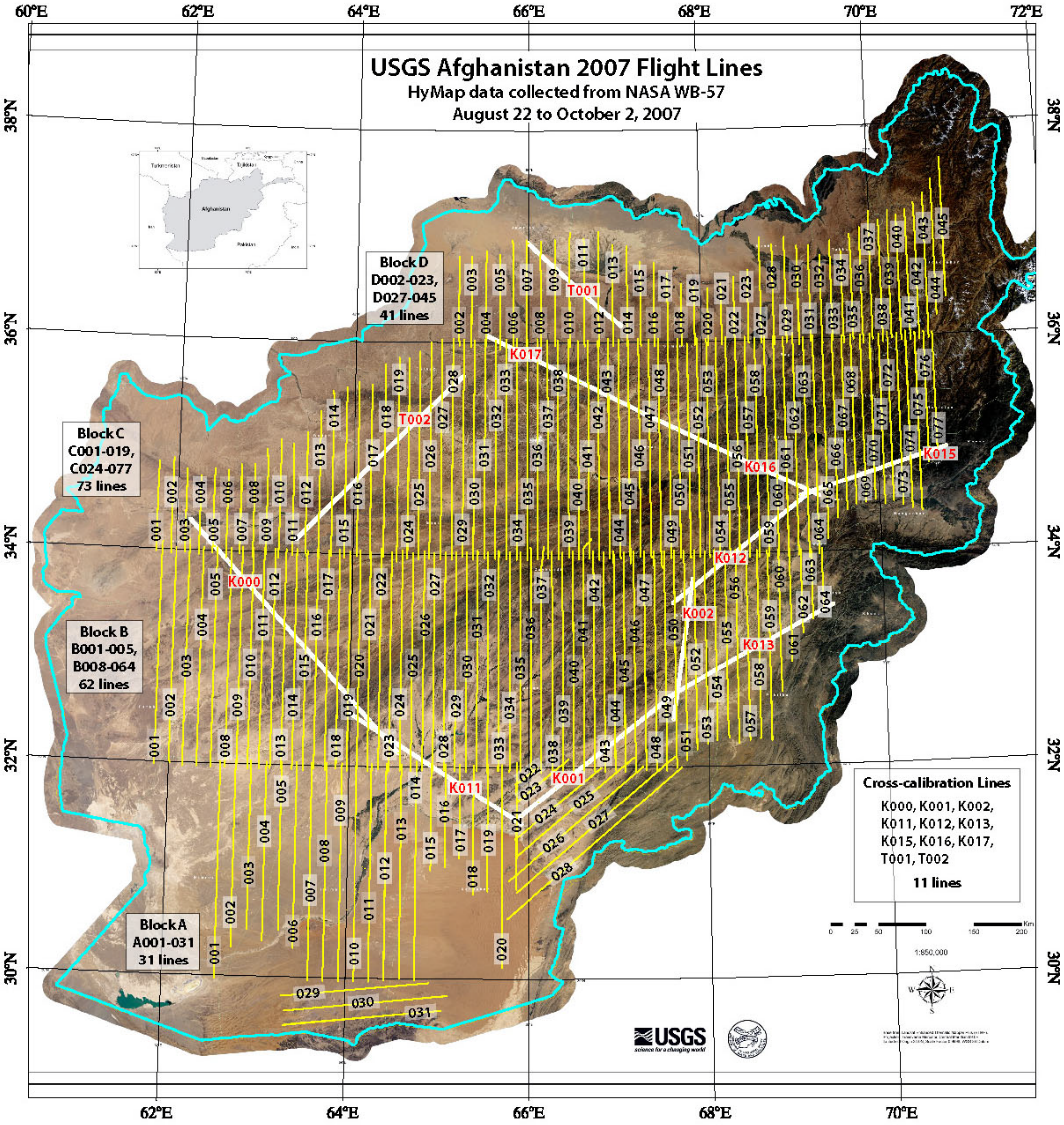
Cold Blackbody Source (LN2)

Variable Temperature Blackbody Source

- Performed in vacuum to prevent condensation on cold blackbody surfaces.
- Scan mirror rotates to scan between internal blackbody, cold blackbody, and variable temperature blackbody.
- Variable temperature blackbody is stepped over entire scene temperature range.
- System nonlinearities can be determined using measured spectral response and blackbody response.
- NETD determined by temperature response and noise level.

Hook

Large Area Coverage



AGENDA – DAY 2 (May 5)

8:00 - 8:20 am: Coffee and donuts, Posters

8:30 -8:40 am: Review of Day 1 [**Betsy**]

VII. Related Activities to HyspIRI Mission

8:40 – 9:00 am: 2 Presentations on 2009 Funded HyspIRI Preparatory Studies
[**Petya Campbell, Phil Townsend**]

9:00 – 9:15 am: International collaborations, ISIS & WGCV [**Rob Green**]

9:15 – 9:35 am: A Mission Calibration Plan to support Products
[**Kurt Thome/Rob Green/Simon Hook**]

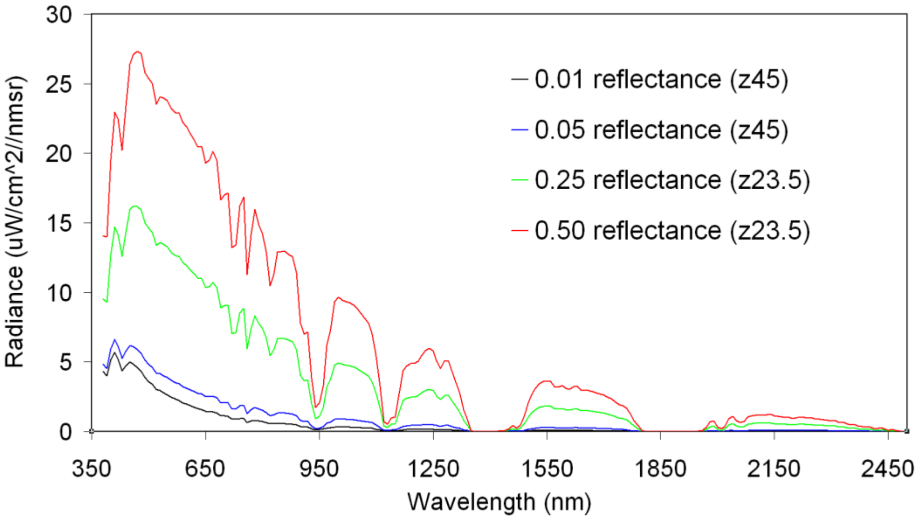
9:35 – 10:10 am: Synthesis of the Three Break-out Group Inputs (10 min each)
[**Phil/John, Simon/Kurt, Dar/Susan**]

10:10 -10:30 am: Coffee Break & Posters

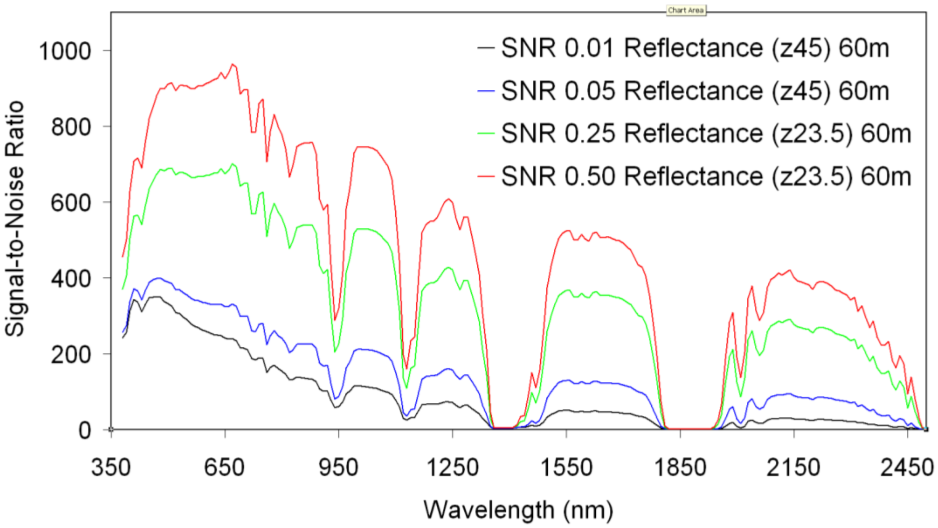
HyspIRI VSWIR Science Measurements
Key SNR and Uniformity Requirements

Green

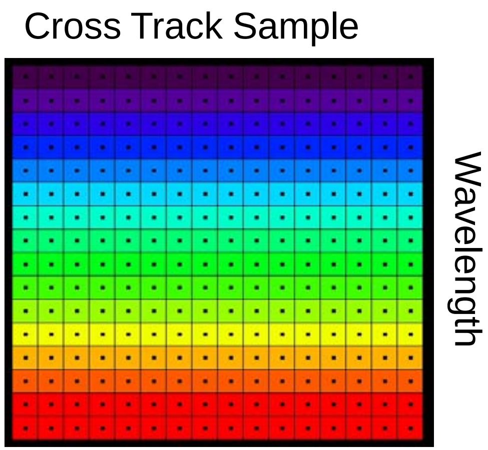
Benchmark Radiances



Required SNR



Uniformity Requirement



Depiction

-Grids are the detectors

-dots are the IFOV centers

-Colors are the wavelengths

Requirement

Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

MODIS Terra Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe CY2000-2008, v4-5.x