HyspIRI: Enabling the Evolution of Land Imaging with New Approaches and Products

How Can HyspIRI Help Address Sustainable Land Imaging Requirements?

NASA/GSFC, June 4 and 5, 2014
Building 34, Conference Room W150

Elizabeth Middleton
and the HyspIRI Teams at GSFC and JPL

HyspIRI Symposium Focus

The 4th Annual HyspIRI Product Symposium at NASA/GSFC, on June 4 and 5, 2014 covered:

- The evolving HyspIRI mission and products;
- Science & application studies: ecosystems, agriculture, coastal/aquatic, health, and disasters/natural hazards;
- HyspIRI's contribution for Sustainable Land Imaging (SLI);
- The HyspIRI Airborne Campaign;
- Data Calibration Issues and Approaches;
- Data Management Approaches and Tools; and
- The Intelligent Payload Module (IPM), and Data Processing and Communication Tools.

An additional one day (June 6) was devoted to a workshop on spectral processing using PRISM, and half a day session for Coastal / Aquatic Studies Forum

HyspIRI Symposium Attendees

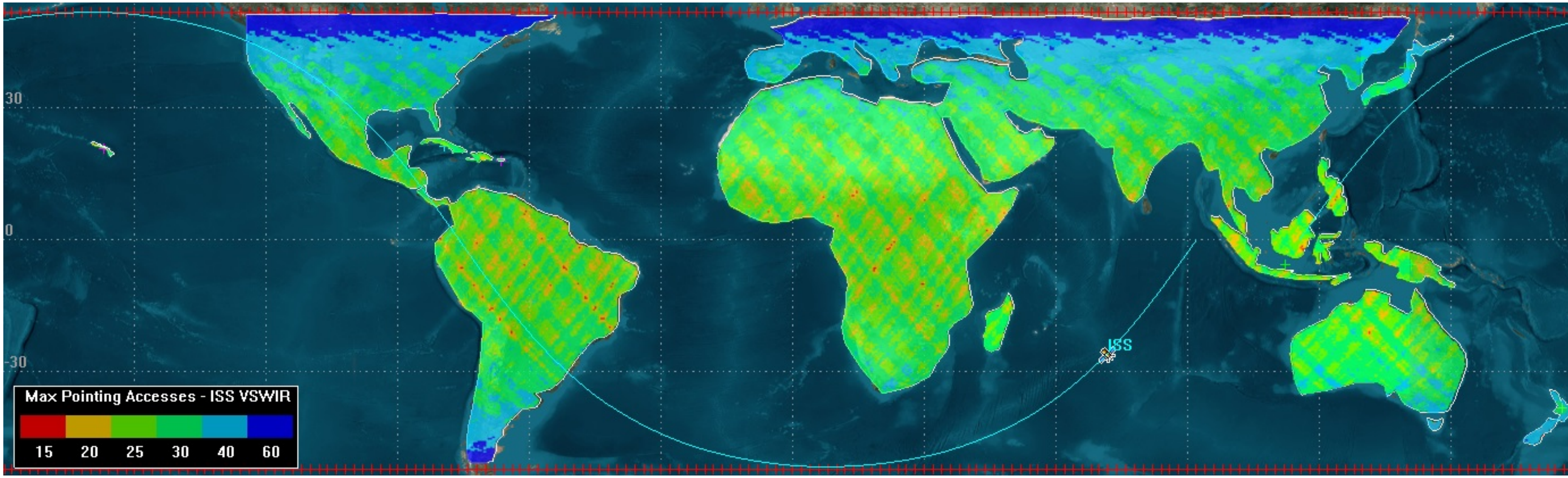
NASA/GSFC, June 4 and 5, 2014

Evolving the HyspIRI Mission and Products

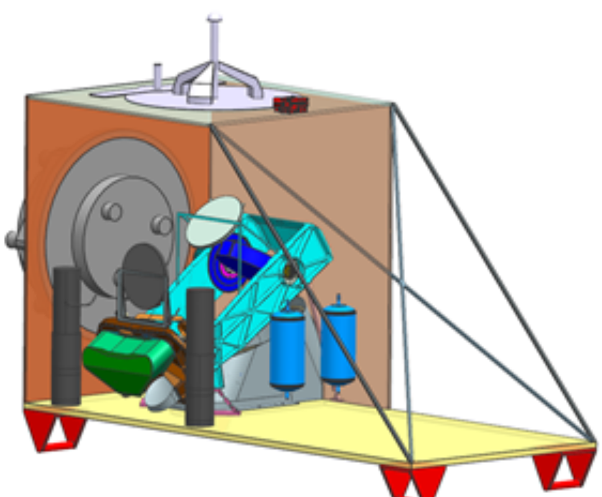
[Chair, Elizabeth Middleton, NASA/GSFC]

- Status of HyspIRI (***Woody Turner, NASA HQ***)
- NASA's Evolving Vision for Space (***Steve Volz, NASA HQ***)
- Summary: Comprehensive Mission Report, 2008-2013 (***Rob Green, JPL***)
- Systems architecture for distributed spacecraft missions (***Jacqueline Le Moigne, GSFC***)
- White Paper Summary: Science Impact, Deploying VSWIR & TIR Instruments on Separate Platforms (***Simon Hook, JPL***)

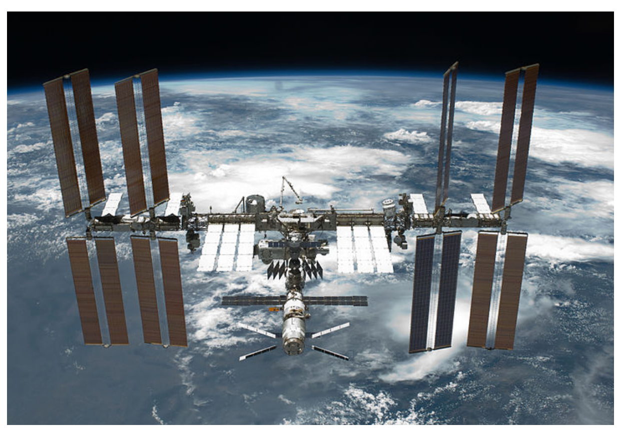
HyspIRI ISS Options



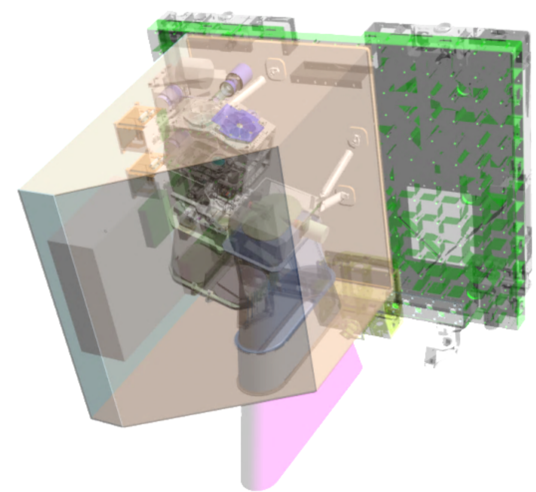
TIR



+IPM

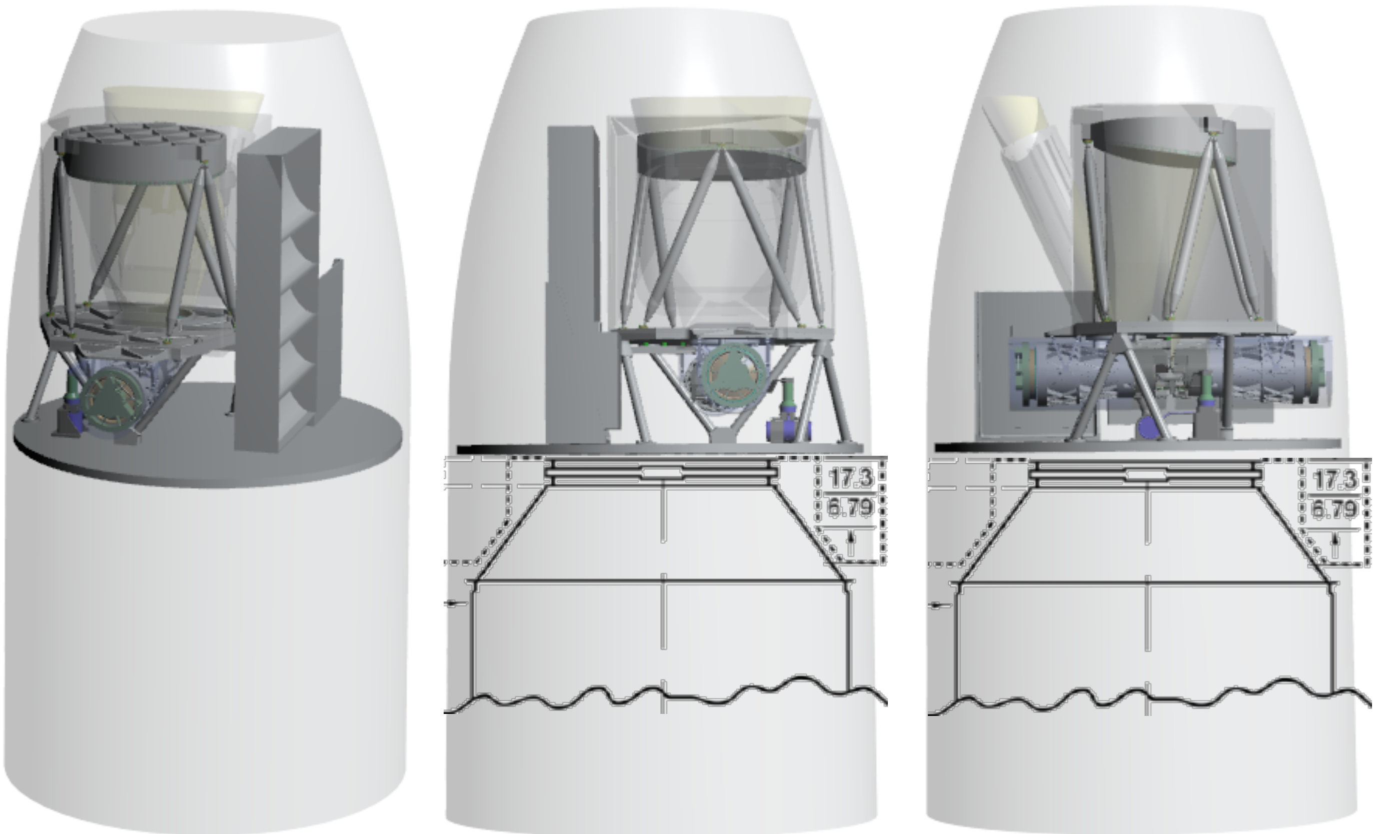


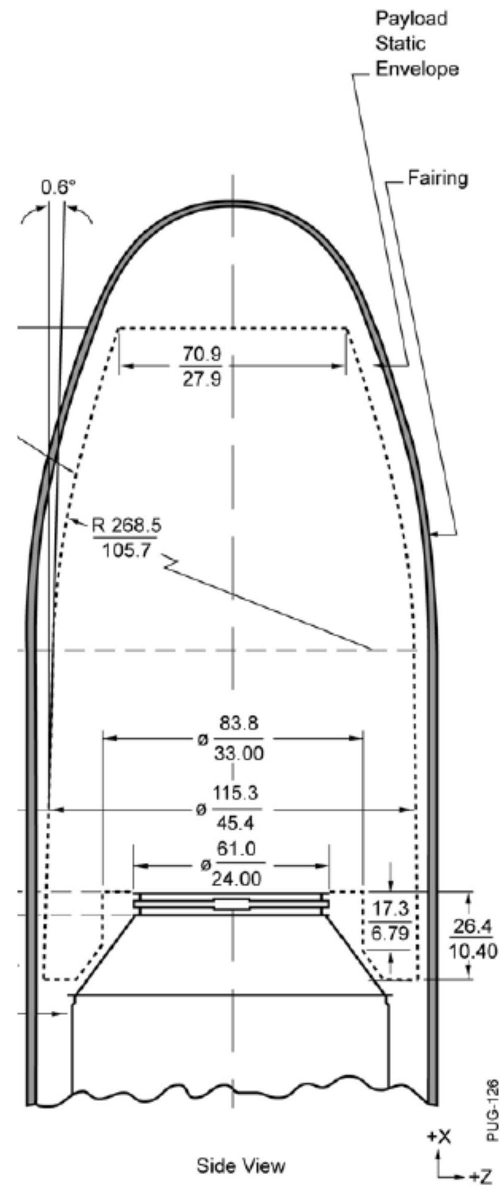
VSWIR



Green, 2014

Example HyspIRI SmallSat on Pegasus





TIR Concept for Pegasus

Separate Small Sats in Polar Orbit

Green, 2014

HyspIRI's Compatibility With Other US Missions and Sustainable Land Imaging (SLI)

[Chair, Petya Campbell, UMBC]

- Architecture Study Scope & Methods / Hyperspectral Imaging & SLI (***Del Jenstrom / Jeff Masek, GSFC***)
- SLI for USGS (***Ray Byrnes, USGS***)
- CEOS/Essential Climate Variables and SLI (***Miguel Roman, GSFC***)
- Landsat 8 (***Jim Irons, GSFC***)
- VIIRS and MODIS (***Robert Wolfe, GSFC***)
- ORCA/PACE and HICO (***Carlos Del Castillo, GSFC***)
- *Open Discussion (**Everyone**)*

The Context for Sustainability

On July 18, 2014 the White House Office of Science & Technology Policy (OSTP) released the first-ever **National Plan for Civil Earth Observations FY2015**, which makes formal recommendations to support a broad spectrum of EO efforts, including NASA and USGS responsibilities to continue joint efforts to sustain moderate-resolution, multispectral, satellite-based Earth observations

NATIONAL PLAN FOR
CIVIL EARTH OBSERVATIONS

PRODUCT OF THE

Office of Science and Technology Policy
Executive Office of the President

July 2014

6.1.2. Land-Imaging

The NASA Administrator, together with the Secretary of the Interior through the Director of USGS, will implement a 25-year program of sustained land-imaging for routine monitoring of land-cover characteristics, naturally occurring and human-induced land-cover change, and water resources, among other uses.[31]

They will also ensure that future land-imaging data will be fully compatible with the 42-year record of Landsat observations. The NASA Administrator will be responsible for satellite development, launch, and commissioning, and the Secretary of the Interior, through the USGS Director, will be responsible for representing users' requirements; development and operation of the ground system; operational control of satellites once on orbit; and processing, archiving, and distributing land-imaging data and routine information products. The NASA Administrator and the Secretary of the Interior, through the USGS Director, will continue to collaborate to address common needs for data continuity and new technology deployment.

6.1.3. Ocean-Color Observations

The Secretary of Commerce, through the NOAA Administrator and in collaboration with the NASA Administrator, will conduct sustained ocean-color observations for marine ecosystem monitoring. The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the S-NPP satellite accomplishes this monitoring, which will be continued with the launches of the JPSS satellite series.[32]

AST Three Basic Study Tenets for the Program

- Sustainability
  - The LI program should provide the *data products* for the long haul, without extraordinary infusions of funds, within the budget guidance provided.
- Continuity
  - The LI program should continue the long term Landsat data record. This does not necessarily mean the imagery per se, but the *usable products* that define the utility of the data record.
- Reliability
  - The LI program should be robust and *not susceptible to single point failures*. The loss of a single satellite or instrument on orbit should not cripple the program or significantly impact users.

AST Findings: User Needs

- The SLI Program should be designed to support the broad range of national and global land monitoring capabilities, and provide continuity with the historic Landsat archive

- The current Landsat user community places the highest priority on increasing revisit frequency
  - Improved ability to defeat cloud cover and use "every clear pixel"
    - Critical for mapping of land cover and vegetation change in cloudy areas, including tropics
  - Intra-annual spectral changes (e.g. phenology) seen as key for mapping vegetation type and condition
  - More frequent revisit advances hydrological and cryospheric applications, where conditions change daily to weekly

- Hyperspectral data are critical for specific applications
  - Detailed mapping of vegetation composition (e.g. species/community level)
  - Biogeochemistry & Photosynthetic rate controls
  - In general, hyperspectral data offer a potential for physically-based modeling of ecosystem function, and ecosystem responses to disturbance, management, and climate change

Del Jenstrom & Jeff Masek, GSFC

Imaging Spectroscopy Technology

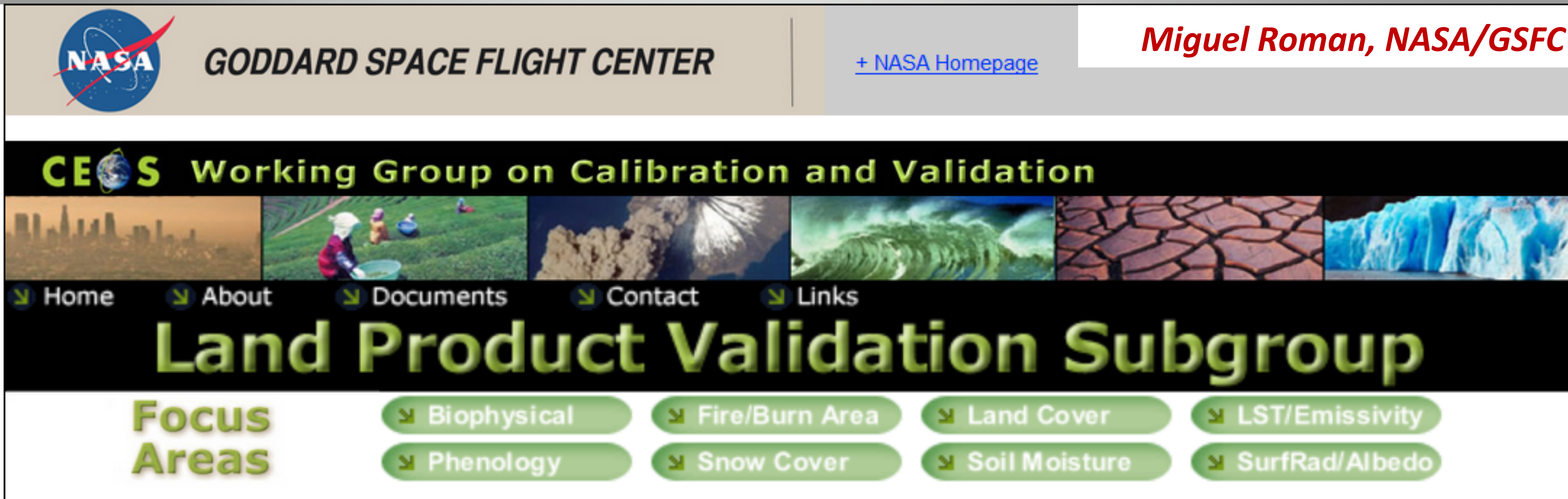
- **Imaging spectroscopy could provide core multispectral data for SLI**
  - In theory, aggregating 10 nm bands from current imaging spectrometer designs should meet OLI SNR requirements
    - A larger aperture may be required to compensate for grating efficiency losses
    - Spectrometers that only meet aggregated L8 SNR requirements may not provide adequate SNR at 10nm for useful hyperspectral applications

- **AST has concerns about *near-term* ability to implement a wide FOV spectrometer that meets all Landsat-8 performance requirements**
  - Stray light due to diffraction grating limitations
    - Spatial
    - Spectral out-of-band
  - Spectral band edge locations and extent for narrow SLI bands
  - Potential for increased polarization sensitivities with a grating

- **These risks are not seen as permanent – mitigation options include:**
  - Additional design & testing using laboratory and airborne systems
  - Tech demo missions, perhaps in cooperation with SLI
  - HyspIRI mission implementation

Del Jenstrom & Jeff Masek, GSFC S

CEOS/Essential Climate Variables and SLI



1. **Good practice protocols**
   - Product definitions
   - Intercomparison guides (eg. spatial, temporal resolution of different products, metrices, reporting)
   - Validation guide (eg. spatial sampling of in situ data, heterogeneity tests)
2. **Identification of (in situ) reference data sets**
3. **Online platform(s) with standardized output for intercomparison and validation (OLIVE)**
4. **Evaluate and develop *new* validation methods**

HyspIRI / SLI Products

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

Existing Val Methods | Research Required

Landsat 8 Launch – Feb. 11, 2013

Landsat Data Continuity Mission (LDCM) developed through an interagency partnership between NASA and the U.S. Geological Survey (USGS)/Dept. of the Interior

LDCM launched Feb. 11, 2013 from Vandenberg Air Force Base (VAFB), California – ATLAS V 401 launch vehicle

On-orbit commissioning completed May 30, 2013

- **USGS assumed lead responsibility for mission operations**
- **Satellite renamed Landsat 8**

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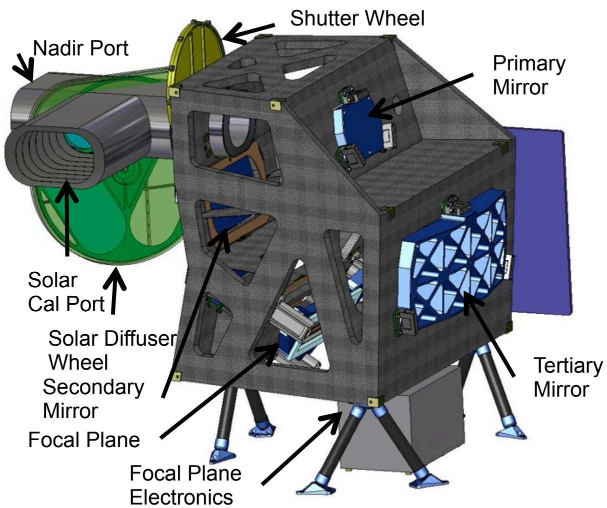
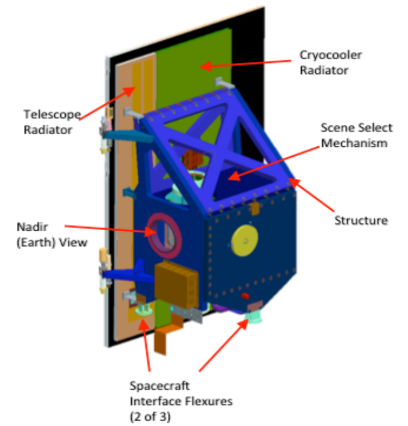
Instruments on Landsat 8

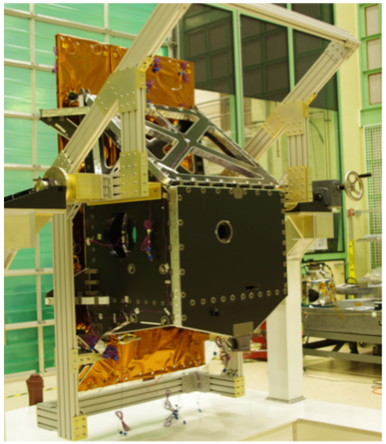
OLI Instrument



- Pushbroom 15° FOV; 6916 detectors per spectral band row; 14 Sensor Chip Assemblies of 494 detectors each
- 9 bands Visible to SWIR (30 meter IFOV spectral with 15 meter IFOV pan)
- 4 mirror anastigmatic telescope
- Solar diffusers (2); Lamps (3) and shutter for calibration
- Designed and built by Ball Aerospace & Technologies, Boulder, CO (photo credit)

TIRS Instrument





- Pushbroom 15° FOV; 1920 detectors/ band row; 3 Sensor Chip Assemblies of 640 detectors each; Quantum Well Infrared Photodetectors (QWIPs)
- Two 100 m IFOV thermal bands plus dark band:
  - 10.9 µm (0.6 µm bandwidth) – "band 10"
  - 12.0 µm (1.0 µm bandwidth) – "band 11"
- Refractive optics
- On board blackbody and deep space view for calibration
- Designed and built by NASA/GSFC, Greenbelt, MD

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Landsat 8 Performance Summary

- **The performance of the Landsat 8 sensors, OLI & TIRS, spacecraft, and ground system exceeds specifications in almost all respects**
  - **Landsat 8 collects, and USGS EROS archives, over 500 scenes per day compared to a 400 scene per day requirement**
  - **By the first anniversary of the launch, USGS EROS distributed 1,332,969 Landsat 8 scenes (Level 1 digital data products)**
  - **Scenes are typically available within 5 hours of data collection compared to a 24 hour latency requirement**
  - **Image geometry and cartographic registration exceed specifications**
  - **The radiometric performance of OLI and TIRS exceeds specifications with one exception**
    - **The absolute radiometric uncertainty of TIRS data currently exceeds a 2% requirement due to a stray light issue under investigation**

Early analyses are demonstrating backward compatibility with the Landsat archive and more accurate land cover mapping results

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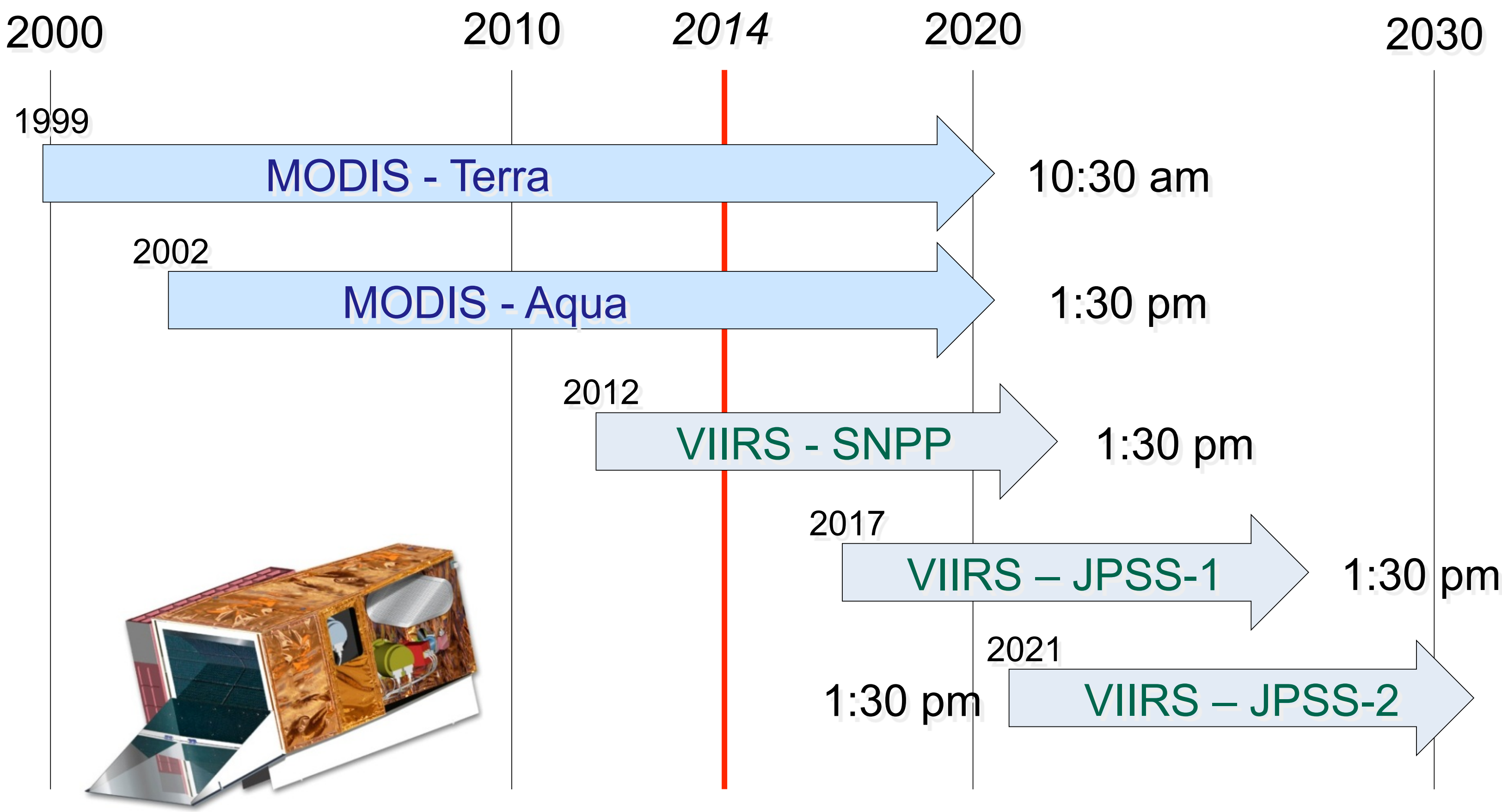
MODIS and VIIRS Missions



Note: Typical on-orbit mission life-time spec. is 5-6 years

MODIS Land Products

Energy Balance Product Suite

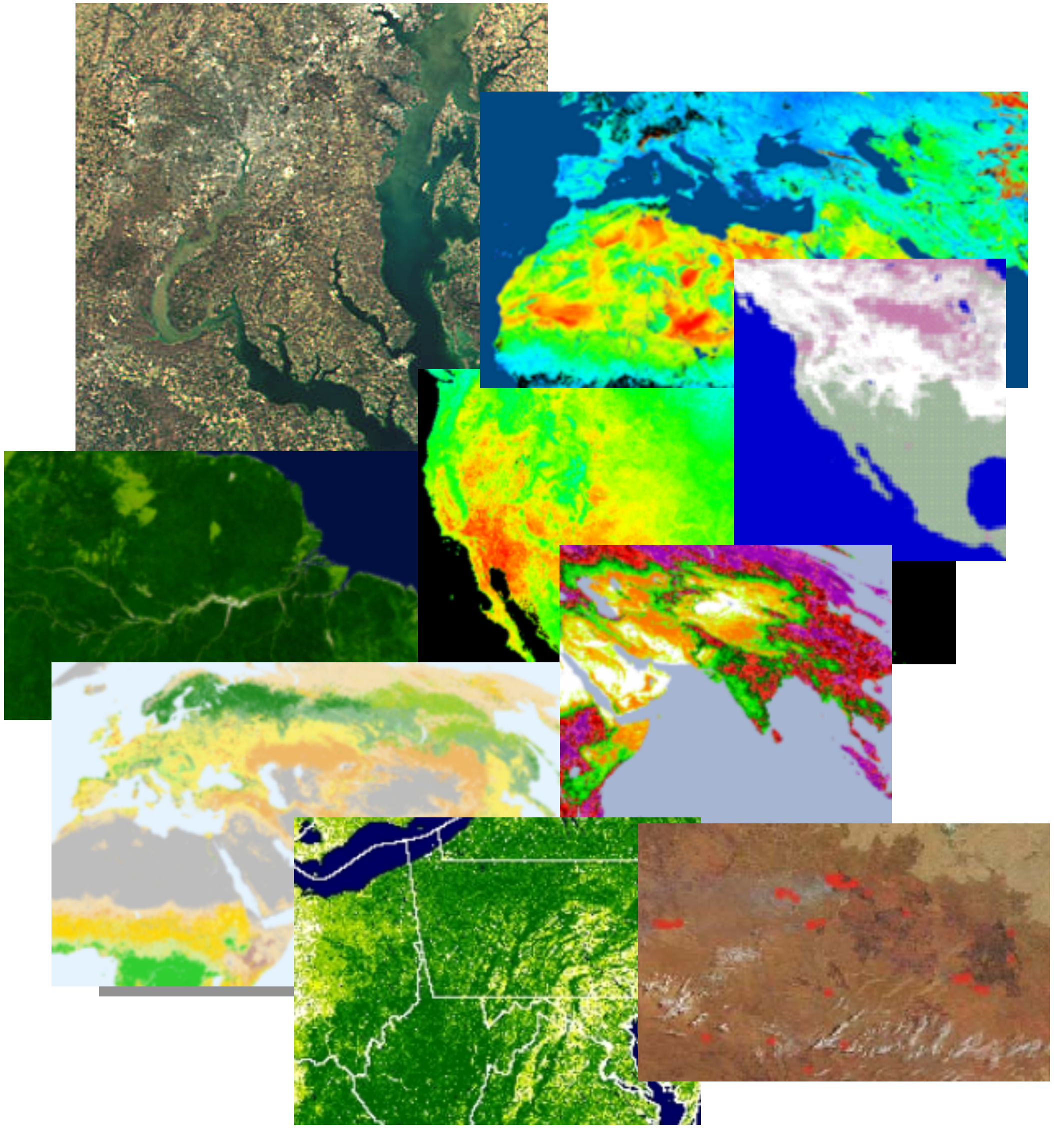
- Surface Reflectance
- Land Surface Temperature, Emissivity
- BRDF/Albedo
- Snow/Sea-ice Cover

Vegetation Parameters Suite

- Vegetation Indices
- LAI/FPAR
- GPP/NPP

Land Cover/Land Use Suite

- Land Cover/Vegetation Dynamics
- Vegetation Continuous Fields
- Fire and Burned Area

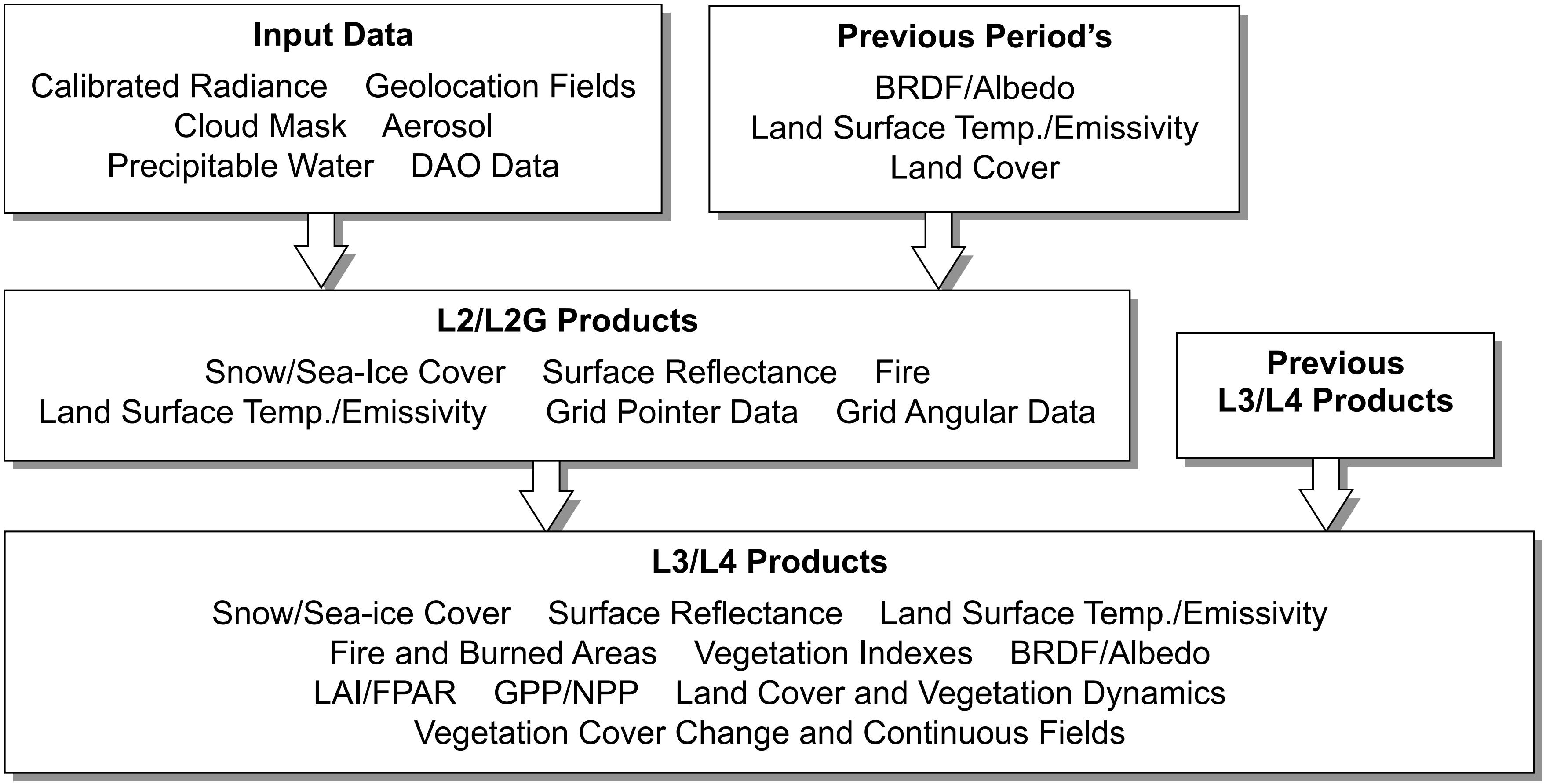


Wolfe/NASA

VIIRS Land Products

- Most NOAA standard VIIRS Land products do not meet NASA science community needs for long-term climate analysis
  - Products are improving but no reprocessing is available
- NASA VIIRS Science Team is being selected to produce MODIS-like standard products
  - Expect to use current “mature” MODIS algorithms
  - *New VIIRS specific products* (e.g. DNB)
- NASA PEATEs (product evaluation systems) are being reconfigured into SIPS (science investigator-led production systems) through a competitive process
  - Land SIPS will produce MODIS-like Land products that will be archived and distributed from a selected NASA DAAC (data archive)

Land Algorithm Dependency



Wolfe/NASA

PACE Pre-Aerosol, Cloud, and ocean Ecosystem Mission

PACE will improve our understanding of ocean ecosystems and carbon cycling through its…

- <u>Spectral Resolution</u> – 5 nm resolution to separate constituents, characterize phytoplankton communities & nutrient stressors
- <u>Spectral Range</u> – Ultraviolet to Near Infrared covers key ocean spectral features
- <u>Atmospheric Corrections</u> – UV bands allow 'spectral anchoring', SWIR for turbid coastal systems. A *<u>polarimeter</u> option for advanced aerosol characterization is TBD.*
- <u>Strict Data Quality Requirements</u> – Reliable detection of temporal trends and assessments of ecological rates
- PACE mission and operations concept will be **<u>similar to the successful SeaWiFS mission.</u>**

Del Castillo 2014

How can HyspIRI (and PACE) Strategy meet Sustainable Land Imaging Requirements?

Operational, standardized set of measurements (thinking like the weather service). Reduce or eliminate the drama, reduce cost.

↔

Research measurements
HyspIRI, PACE, GEOCAPE, etc…
Augment current operational measurements, platform for developing and testing new measurement technologies that will improve next generation standardized measurements.

↓

A rational, no-drama, sustainable land imaging system

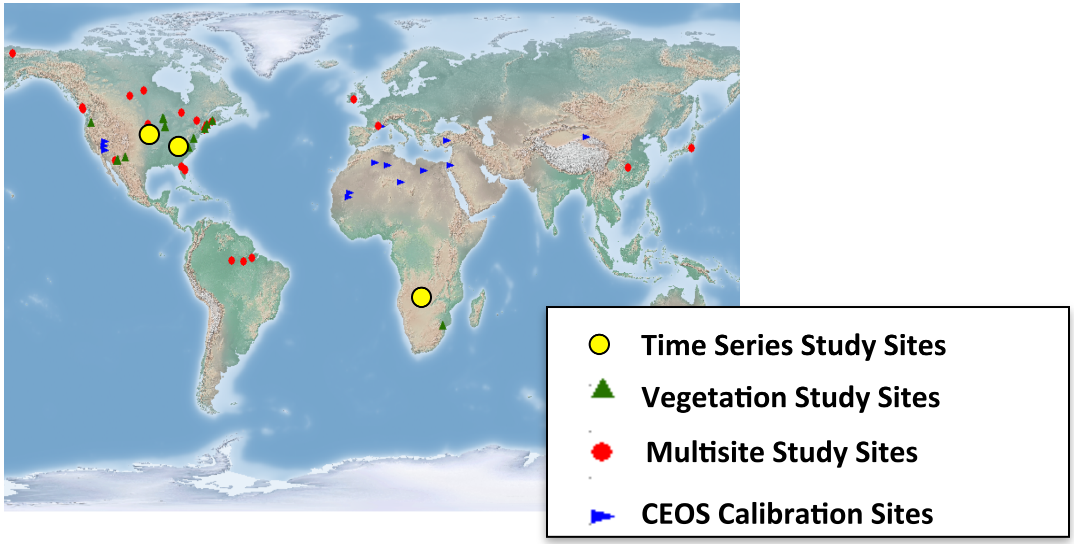
HyspIRI Ecosystem Studies

[Chair, Susan Ustin, UC Davis]

- Retrieving LUE with Hyperion Globally (***Fred Huemmrich, GSFC***)
- Retrieving the new fAPARchl Product from Space (***Qingyuan Zhang, GSFC***)
- Retrieving GPP in Forests and Agriculture (***Ben Cheng, GSFC***)
- Vegetation feature analysis and spectral comparison using the USGS PRISM software **(*Ray Kokaly, USGS*)**
- EcoSIS: The Ecosystem Spectral Information System (**Philip Townsend, UW**)
- Mapping Fire Scars Using Hyperspectral Imagery and Kernel Based Image Analysis (***Saurabh Prasad, UH*)**
- Coastal remote sensing using HICO: results, challenges and potential applications for HyspIRI ***(Wesley Moses, NRL)***

Remote Sensing of Fluxes: Hyperion and Fluxnet

- Can statistical approaches use spectral information to adjust for site differences but capture seasonal changes in flux variables?
- To address this question we examined a number of different sites with different vegetation types throughout the year.
  - Hyperion on EO-1 can provide consistent repeated observations of widely distributed sites
  - Spectra are averages of uniform regions around flux tower
- We combined satellite imagery with carbon flux data from the AmeriFlux and CarboAfrica networks



Huemmrich 2014

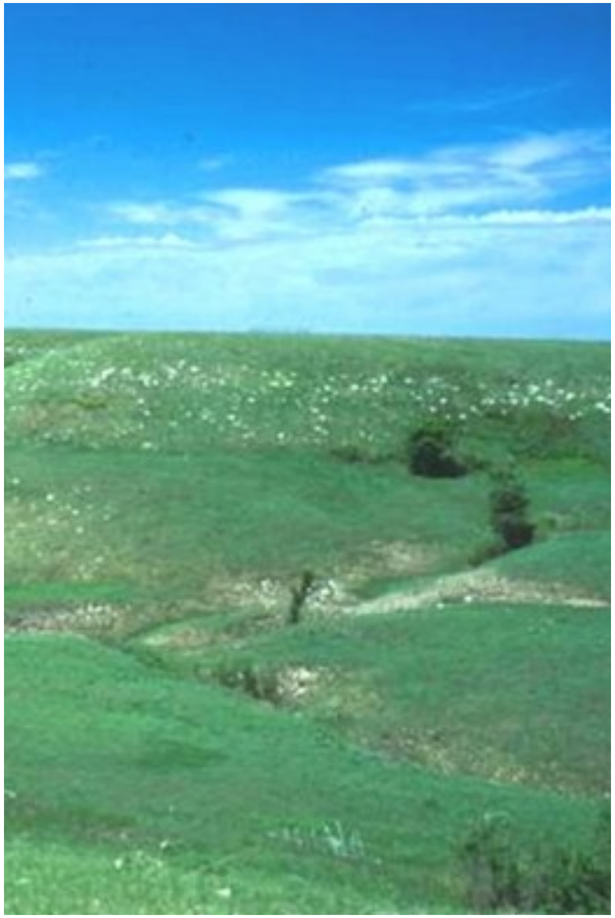
Multitemporal Data for 5 Towers

Data collected in 2008-2009 (n = 47 total)

Duke Forest, NC, USA
- **Hardwood – n=5**
- **Loblolly pine – n=5**

Mongu, Zambia
- **Miombo woodland – n=23**

Konza Prairie, KS, USA
- **Tallgrass Prairie**
- **Two towers, each n=7**



Huemmrich 2014

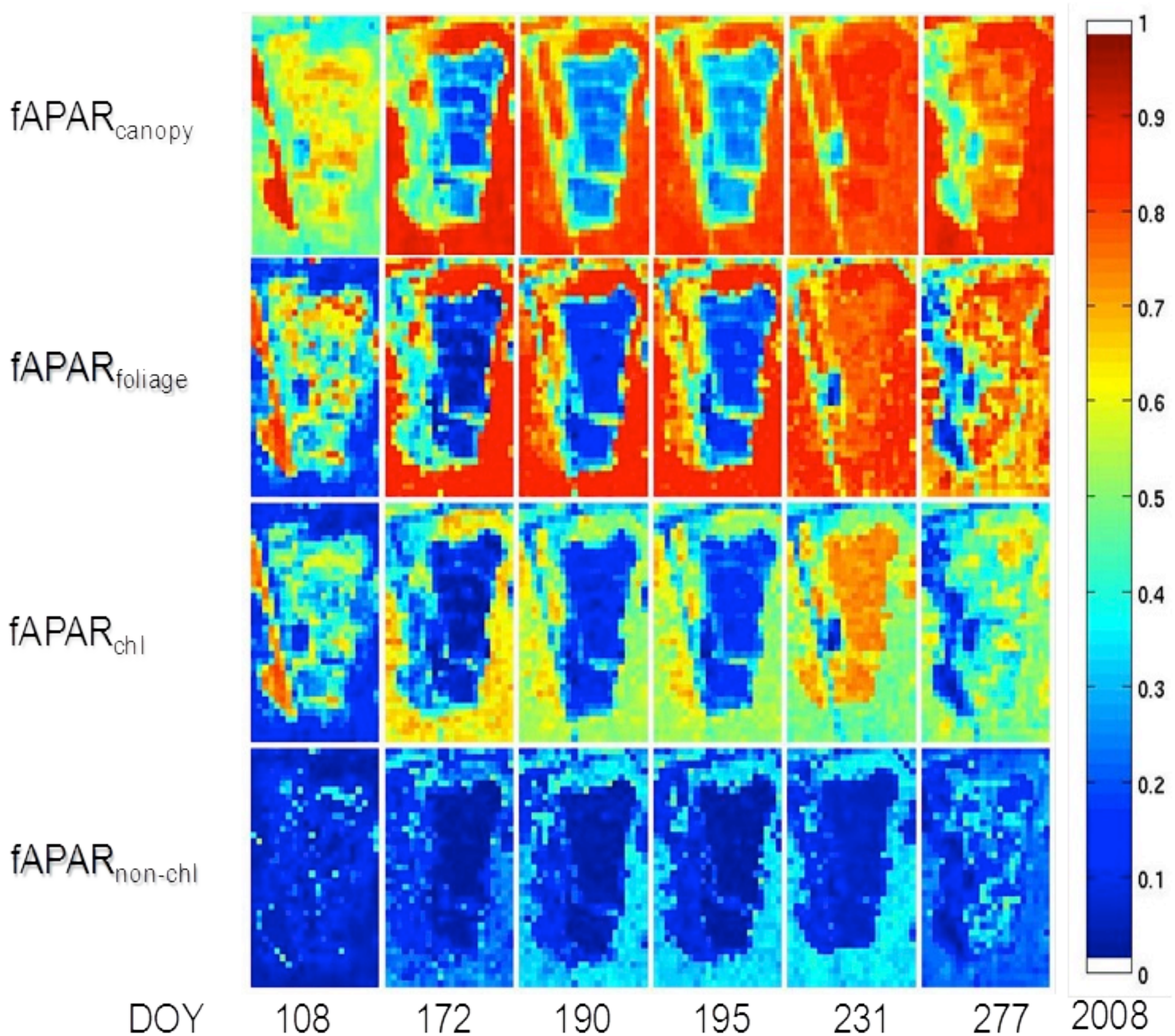
Conclusions

- A general approach for retrieval of biophysical variables without classification may yet be possible
  - Information from multiple spectral bands is required
- Statistical approaches like Partial Least Squares Regression (PLSR) can be powerful tools for data analysis and product generation
  - Critically important to have good training data that represents the full range of cases
  - Differences in processing approaches may result in significant errors
- Hyperion's ability to provide multitemporal and multisite observations makes it an important tool for pre-HyspIRI algorithm development and testing

Huemmrich 2014

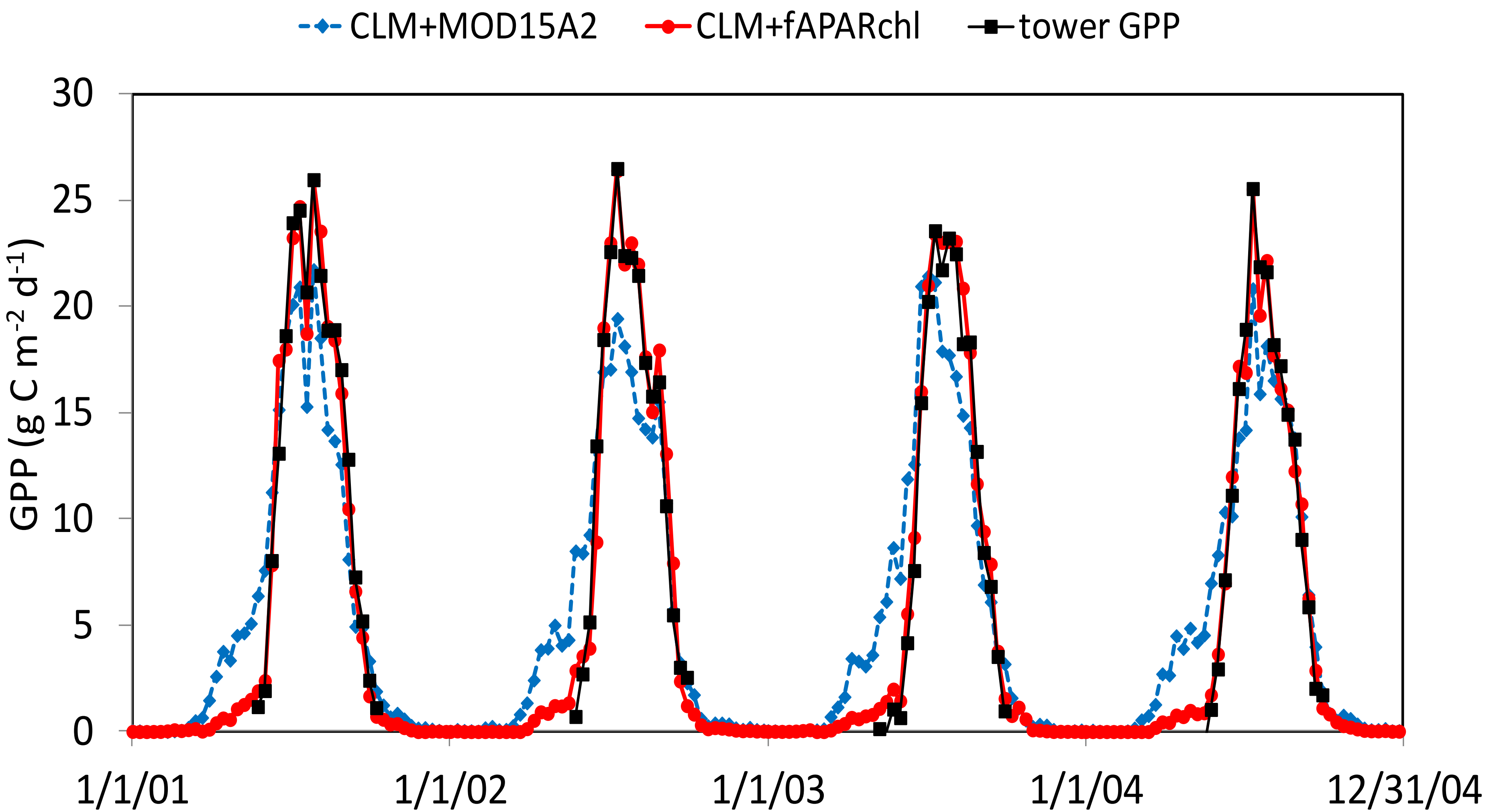
$fAPAR_{chl}$ Demonstration and Validation with Hyperion Images

BARC cornfield, MD



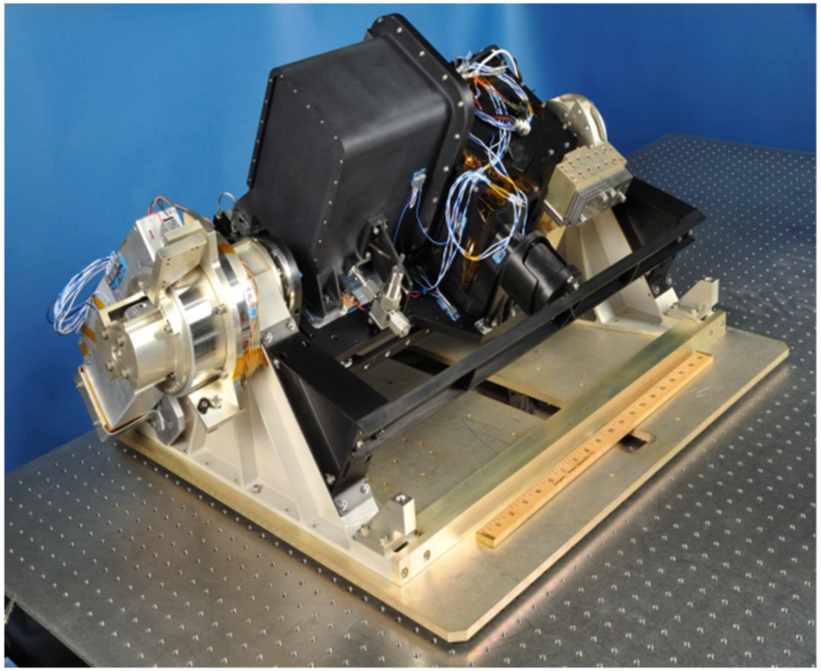
Zhang 2014

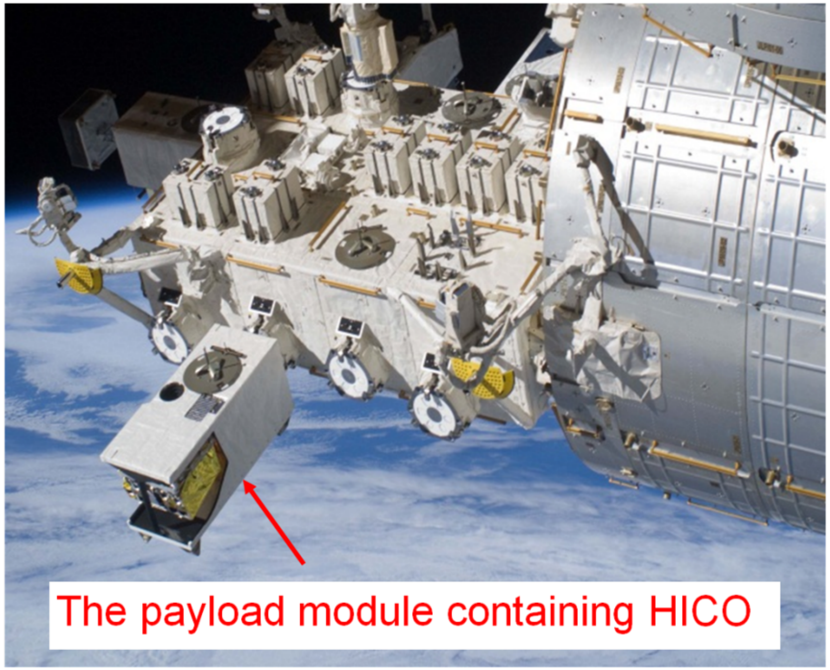
$fAPAR_{chl}$ Demonstration and Validation with MODIS Images



Zhang 2014

Hyperspectral Imager for the Coastal Ocean (HICO)

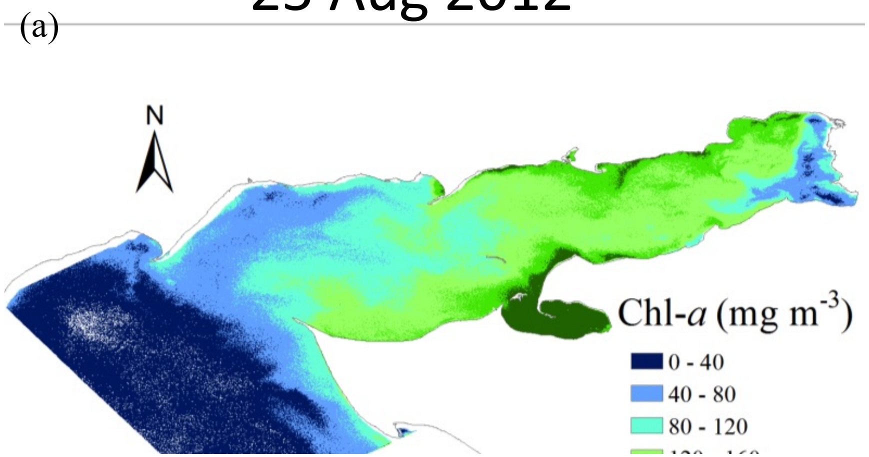




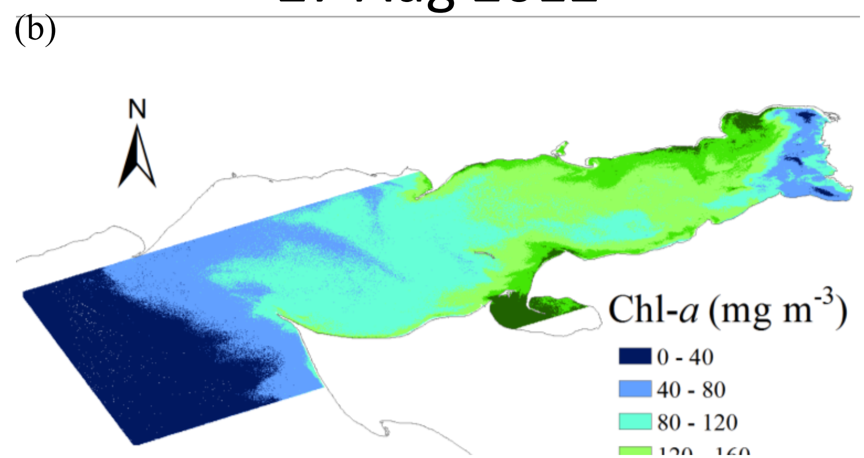
- Demonstration project
- Built mostly using COTS components; conception to launch in **16** months
- 14-bit data; 350 – 1080 nm range; 5.73 nm resolution
- 42 km x 192 km coverage; ~96 m GSD at nadir
- 1 image per orbit; ~16 orbits per day ⟹ 16 images maximum per day
- Off-nadir viewing +35/-45°
- Operational since Sep 2009

Moses 2014

25 Aug 2012



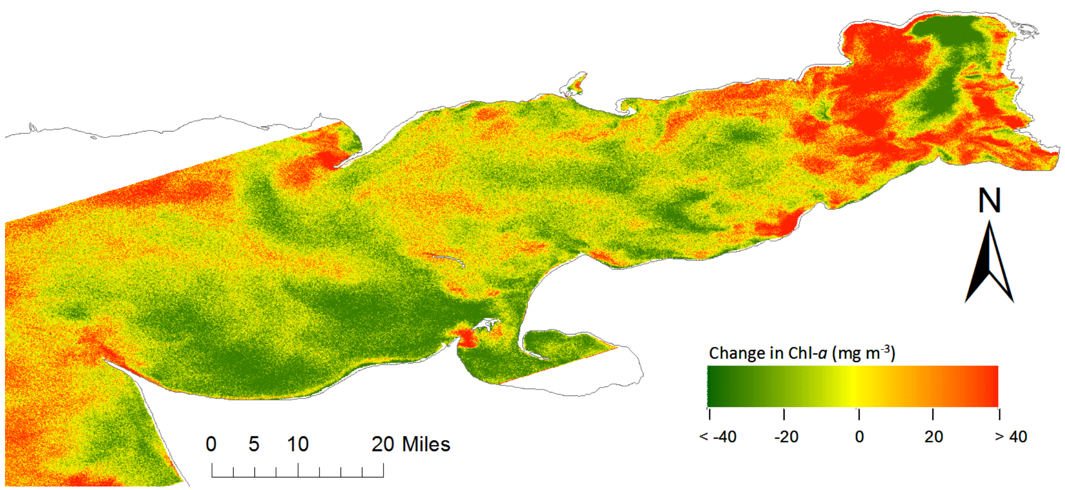
27 Aug 2012



The chl-*a* estimates were quite accurate in spite of the high spatial and temporal variations of chl-*a* concentration in the bay

(Moses et al. 2013)

Changes in the chl-*a* concentration in the Taganrog Bay between 25 Aug and 27 Aug 2012.



Moses 2014

HyspIRI Aquatic Studies Group (HASG)

- **The HASG is chartered to compile community input regarding data products, science and applications for coastal and inland aquatic environment and ecosystems.**

- **Woody Turner** and **Jack Kaye** kindly supported a special studies group to faciliate coastal and inland water studies for the HyspIRI mission.

- Established **Sept 2012** with ~20 members, now over 60, is being sponsored by **Goddard Space Flight Center**.

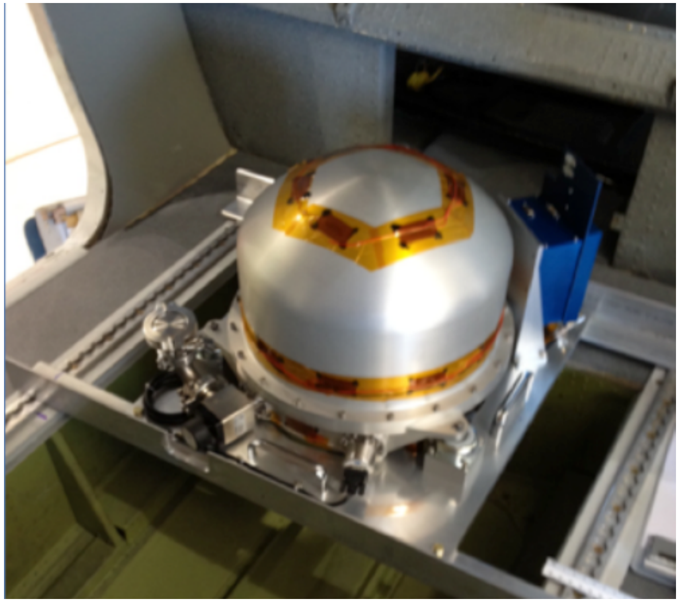
- Affiliations with **international** and **domestic** institutions, including government, university, research or application organizations.

Landsat 8 OLI RGB of wetlands and coastal and inland waters of the eastern Chesapeake Bay, Maryland USA

HyspIRI Aquatic Studies Group (HASG)

The forum began with four talks:

- An overview of HASG, recent white paper and publications, and topics for discussion at the forum**. (Kevin Turpie, UMBC GSFC)**
- Phytoplankton functional type algorithm and lessons learned from the HyspIRI Preparatory Airborne Campaign. **(Liane Guild and Sherry Palacios, AMES)**
- Submerged Aquatic Vegetation (SAV) and data products from the airborne PRISM instrument. **(Heidi Dierssen, U Conn)**
- Atmospheric correction over water. **(Bo-Cai Gao, NRL)**



PRISM Sensor

Aquatic Ecology & Public Health

Aquatic Ecology [Jeff Luvall, MSFC]

- HyspIRI Aquatic Studies Group (HASG) activities (***Wesley Moses, NRL***)
- Decomposition of Hyperspectral data for use in Case 2 environments (***Joseph D. Ortiz, Kent State University***)
- Role of Space Borne Imaging Spectrometry in Global Water Quality Monitoring (***Arnold Dekker, CSIRO***)

Public Health and Disasters [Jeff Luvall, MSFC]

- Health and Air (***John Haynes***, ***NASA/HQ***)
- CEOS Disaster Risk Management for Societal Benefit (***Stu Frye, NASA/GSFC***)
- Volcanoes (***Rick Wessels, USGS***)
- Sustainable land imaging requirements to monitor surface soil moisture with HyspIRI-like data ***(Mike Ramsey)***

NASA Remote Sensing and Applications for Health and Air Quality: *Applications Areas*

Emphasis in 4 Applications Areas

Health & Air Quality

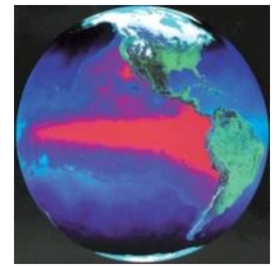
Water Resources

Disasters

Ecological Forecasting

Support opportunities in 5 additional areas

Agriculture



Climate

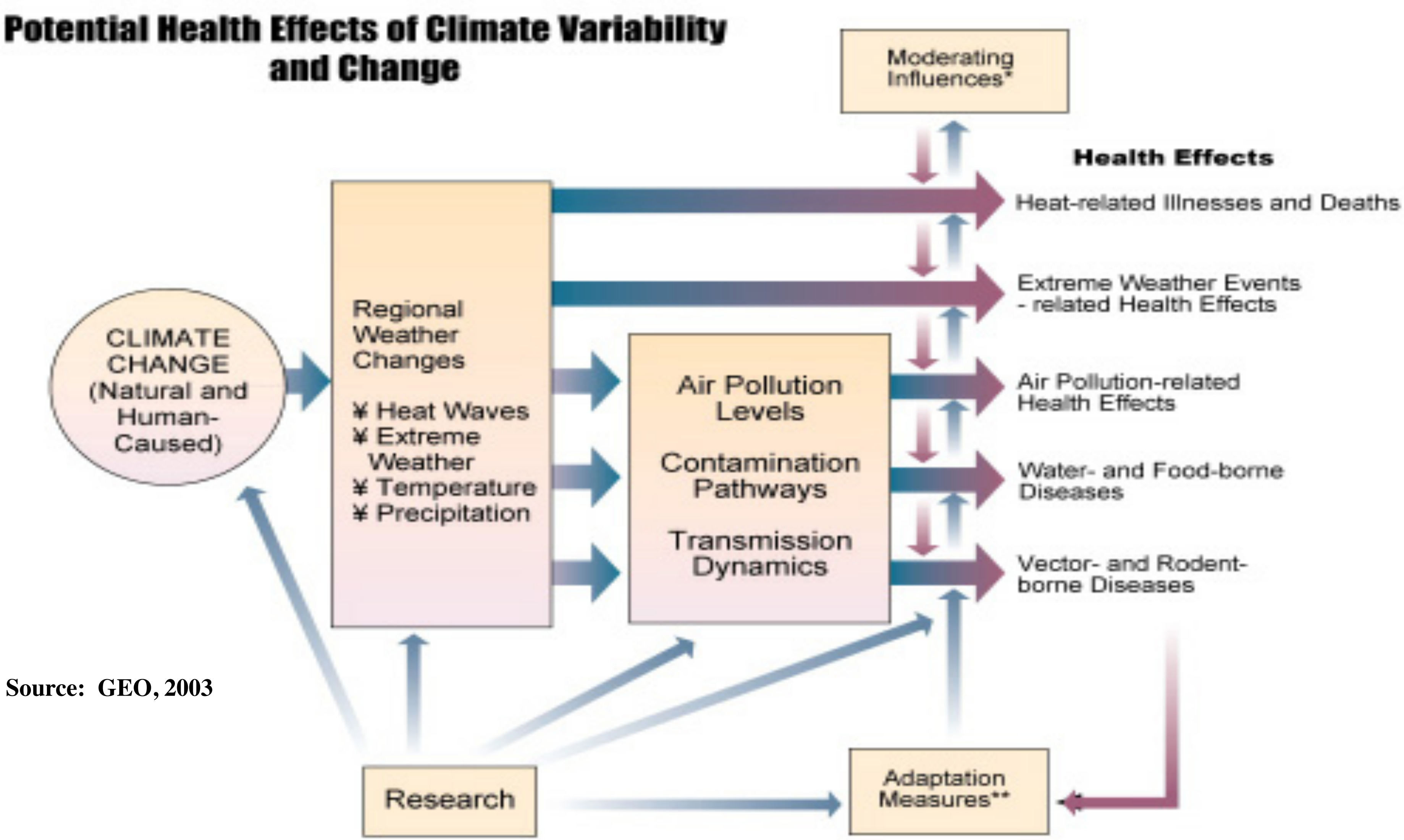
Weather

Energy

Oceans

Haynes 2014

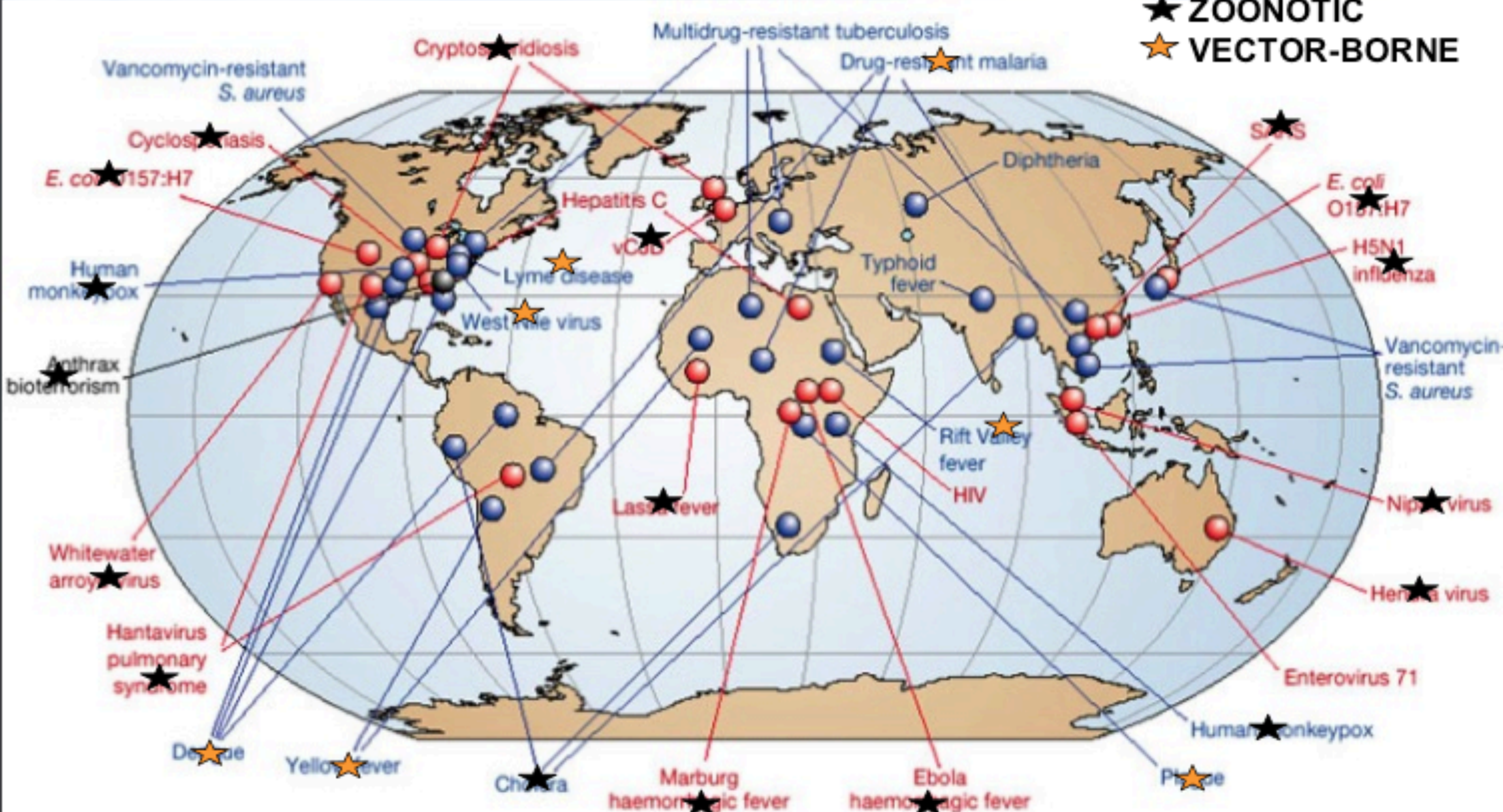
Why Health & Air Quality?



Source: GEO, 2003

Haynes 2014

Global Emerging Diseases*



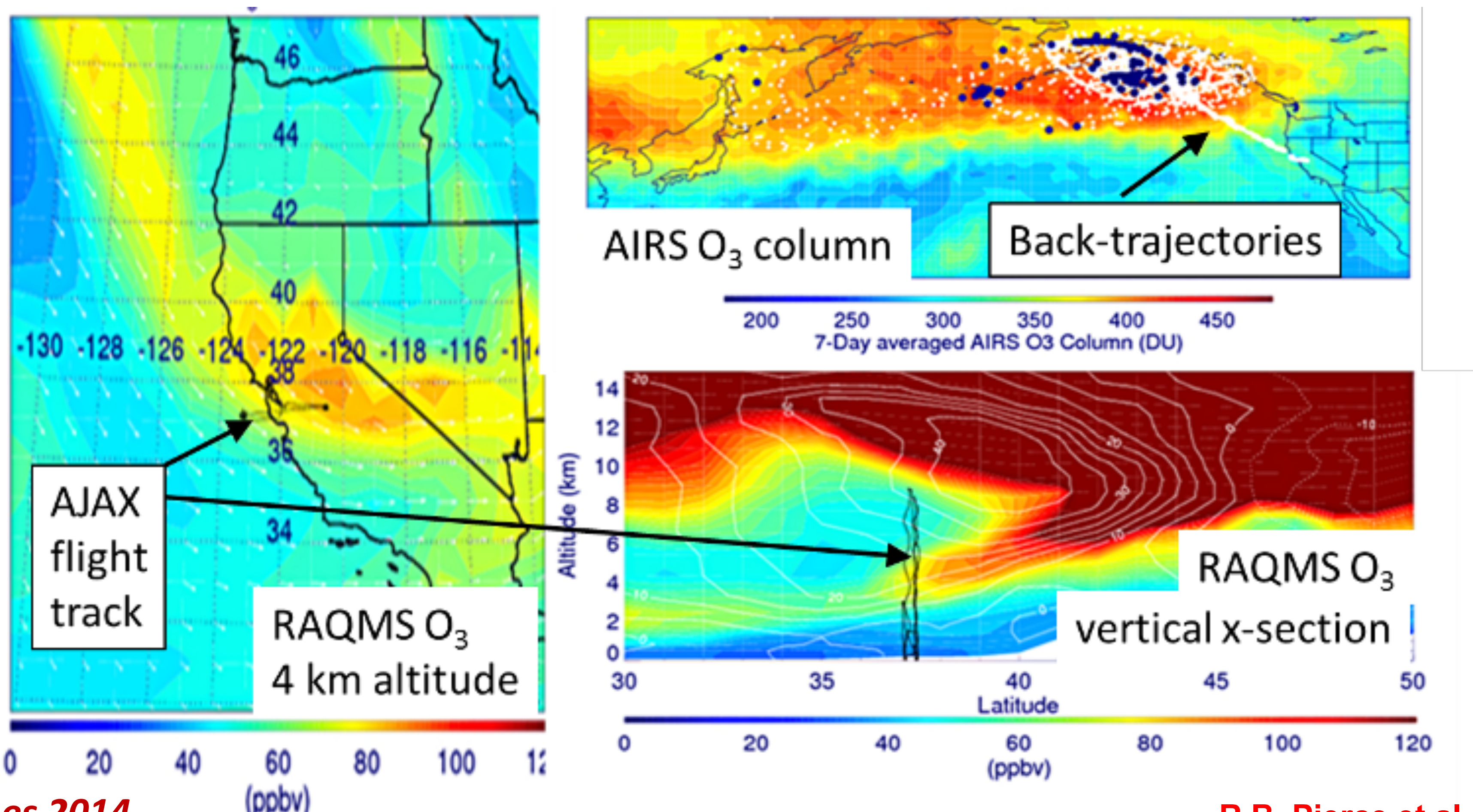
EMERGING
RE-EMERGING

Haynes 2014

* Modified from Morens et al. 2004 *Nature* 430:242

AQAST: Wyoming Exceptional Event Demonstration

Wyoming DEQ/AQD used RAQMS ozone analyses utilizing Aqua/AIRS data to issue an exceptional event demonstration package to the EPA for an ozone exceedance at Thunder Basin, June 6, 2012. This ozone stratospheric intrusion event was documented by the NASA AJAX flight campaign.



Haynes 2014

CEOS Disaster Risk Management for Societal Benefit

- **Purpose** – to improve delivery of satellite data and products for societal benefit in local/regional setting, but on a global scale
- **Method** - develop and infuse Earth Observation (EO) monitoring and modeling technology for data acquisition, processing, and product distribution for disaster applications
  – Sensor Webs and applied science research
- **Experience** - based on Committee on Earth Observation Satellites (CEOS) and Group on Earth Observations (GEO) activities
  – CEOS Disaster Risk Management (DRM) Pilots address ground validation, crowd sourcing, and hand-held clients to validate disaster products and services
  – Capacity building to infuse standardized web servers and clients that provide open access to critical disaster management information, data, and maps via the internet using common, open desktop tools
- **Link** to presentation for GeoSocial API
  – https://www.dropbox.com/s/t15lvyriw3c20nl/AIP7%20Plenary%20Presentation%20May%2027%202014.pptx
- Link to presentation for OJO GeoApp
  – https://cappelaere.wistia.com/medias/faz1hi8bpu

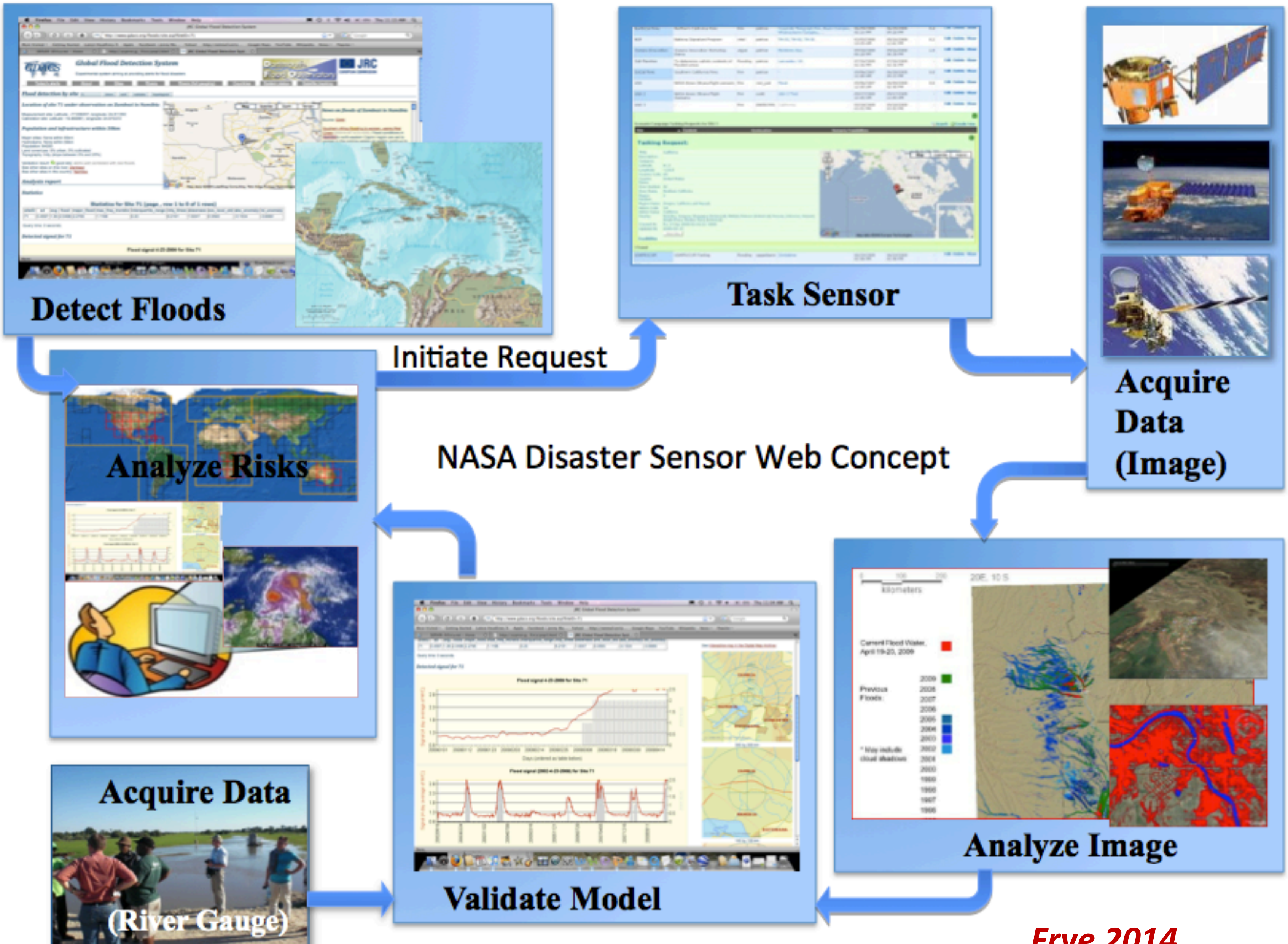
Frye 2014

CEOS DRM Pilots Overview

Pilot	Team Co-Leads	Deliverables
Floods	**NASA**, S. Frye **NOAA**, B. Kuligowski	• **Global Flood Dashboard (single access for multiple existing systems)** • **Three regional pilots showcasing end user benefit of frequent high spatial resolution observations (Caribbean, Southern Africa, Mekong/Java)**
Seismic Risks	**ESA**, P. Bally **DLR**, J. Hoffmann	• **Demonstrator for EO-based global strain map** (main focus on Turkey, Himalayas and Andes) • **Exploitation platform for large data set analysis (strain map, supersites)** • **Rapid scientific products for 4 to 6 earthquakes per year (>M5.8)**
Volcanoes	**USGS**, M. Poland **ASI**, S. Zoffoli	• **Demonstrate feasibility of systematic global monitoring in regional arc (Latin America)** • **Develop new EO-based monitoring products at supersites** • **Real-time in-depth monitoring of one '100-year' category major eruption**

Frye 2014

NASA Disaster Web Concept



Frye 2014

Upgraded Satellite RS Data Availability

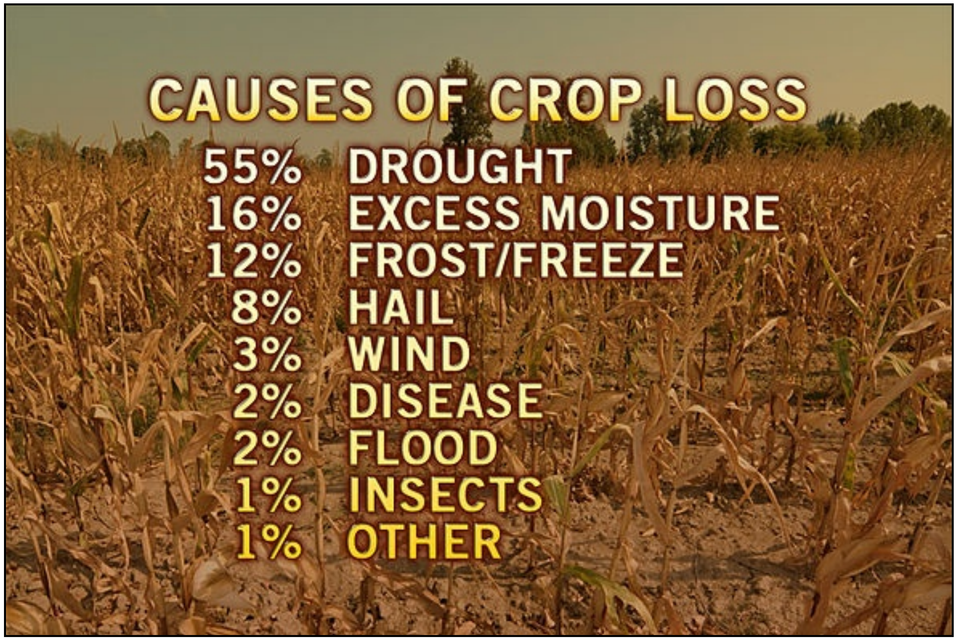
- Landsat 8
  - Daytime and nighttime views over volcanoes currently free via USGS Earth Explorer & glovis.usgs.gov
  - VHP list of 50+ volcanoes for night time acquisition (180x180 km scenes typically contain 2 or more volcanoes of interest

- USGS tasking much more Digital Globe (~50cm)
  - New DG/NGA website featuring current ortho images
  - Anticipate frequent use of WorldView 3 SWIR
  - Data available via USGS Earth Explorer for federally funded

- Commercial SAR
  - Several recent USGS, NOAA, NGA, etc. meetings with Italian Space Agency forging CosmoSkyMed agreement
  - US Gov discussions regarding TerraSar-X
  - New RadarSat still difficult to acquire

Wessels 2014

Sustainable Land Imaging Requirements to Monitor Surface Soil Moisture with HyspIRI-Like Data



- **Background**
  - importance of soil moisture
  - relevant HyspIRI science questions
  - what is TI/ATI and how is it measured?
- **Sustainable Measurements?**
  - HyspIRI-specific possibilities
  - limitations/synergies with other sensors (e.g., SMAP, Landsat, …) and modeling approaches (e.g., ET/PET)

Scheidt et al., 2010

Soil Moisture Content: *Integrative Approach*

- Optical Sensors
  - existing ASTER and new Landsat data
  - use of higher temporal resolution VSWIR data combined with HyspIRI TIR

- ISS Configurations
  - precludes climate and solid earth science (especially at higher latitudes)
  - significant potential for soil moisture studies at mid-latitudes
    - overpass times would vary over the course of the day
    - allow temperature sampling at times excellent for ATI/TI based SMC studies

Scheidt et al., 2010

New HyspIRI-Like Data Sets and Calibration

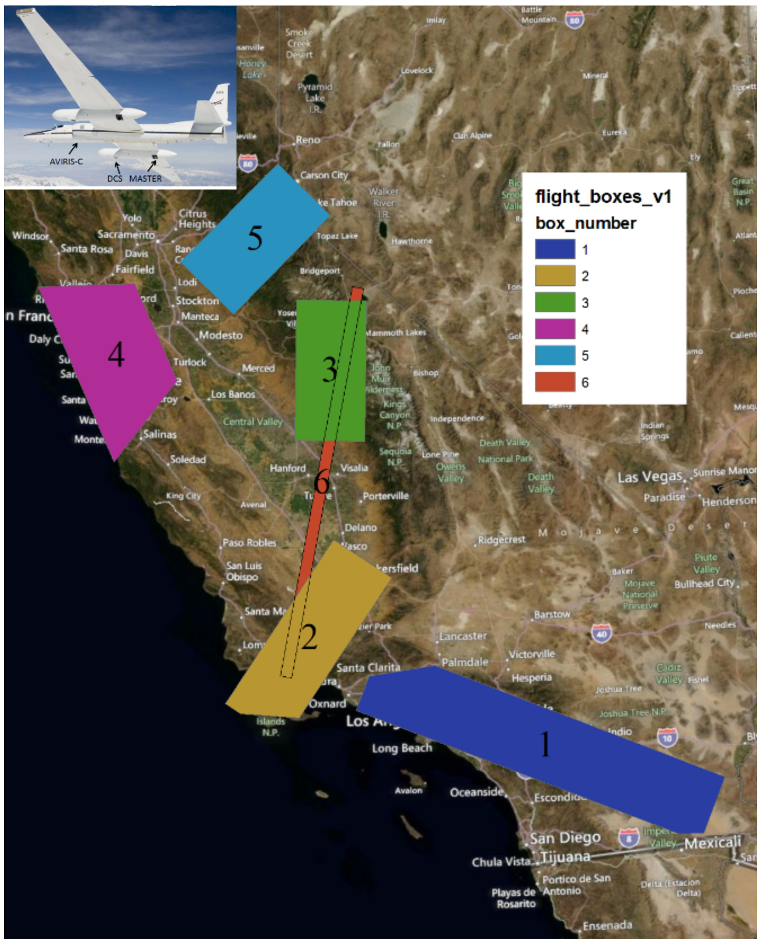
[Chair, Rob Green, JPL]

- HyspIRI Airborne Campaign Overview (**Ian McCubbin, NASA/ GSFC**)
- Level 2 processing of AVIRIS HyspIRI preparatory campaign measurements (***Rob Green, JPL)***
- HyspIRI Flight Campaigns for Summer Sea-Land Thermal Gradients & Sea-Breezes in LA (***Jorge Gonzalez, NOAA***)
- Atmospheric corrections (***Bo-Cai Gao, Naval Research Lab***)

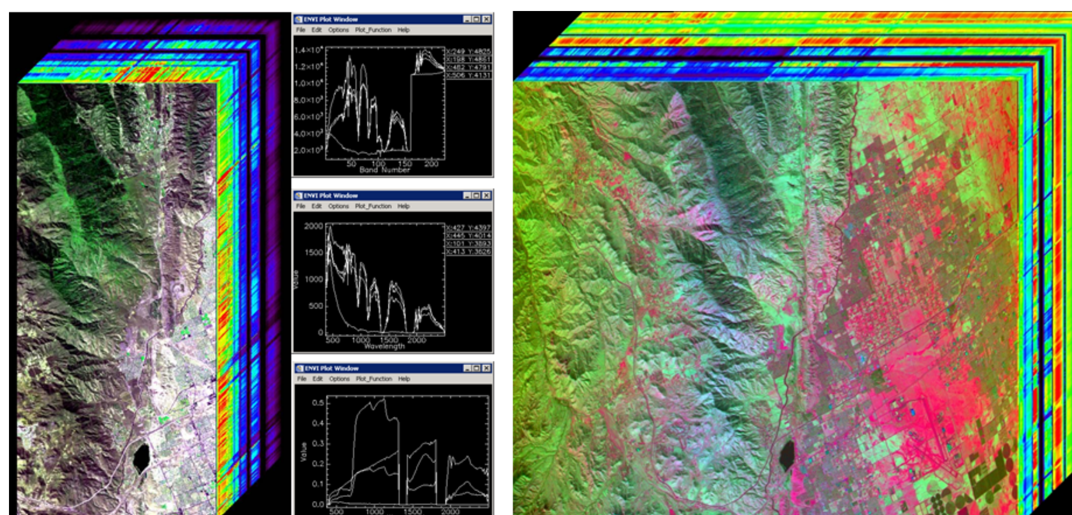
HyspIRI Preparatory Airborne Campaign Third Year Added

- Support R&A HyspIRI Preparatory Science Campaign
  - science team with 14 PIs
  - Delivered Level 1 and Level 2 data products
- Ecosystems, Seasonal, Climate, Coastal, Urban, Resources
- 6 zones, 3 seasons, 2 years

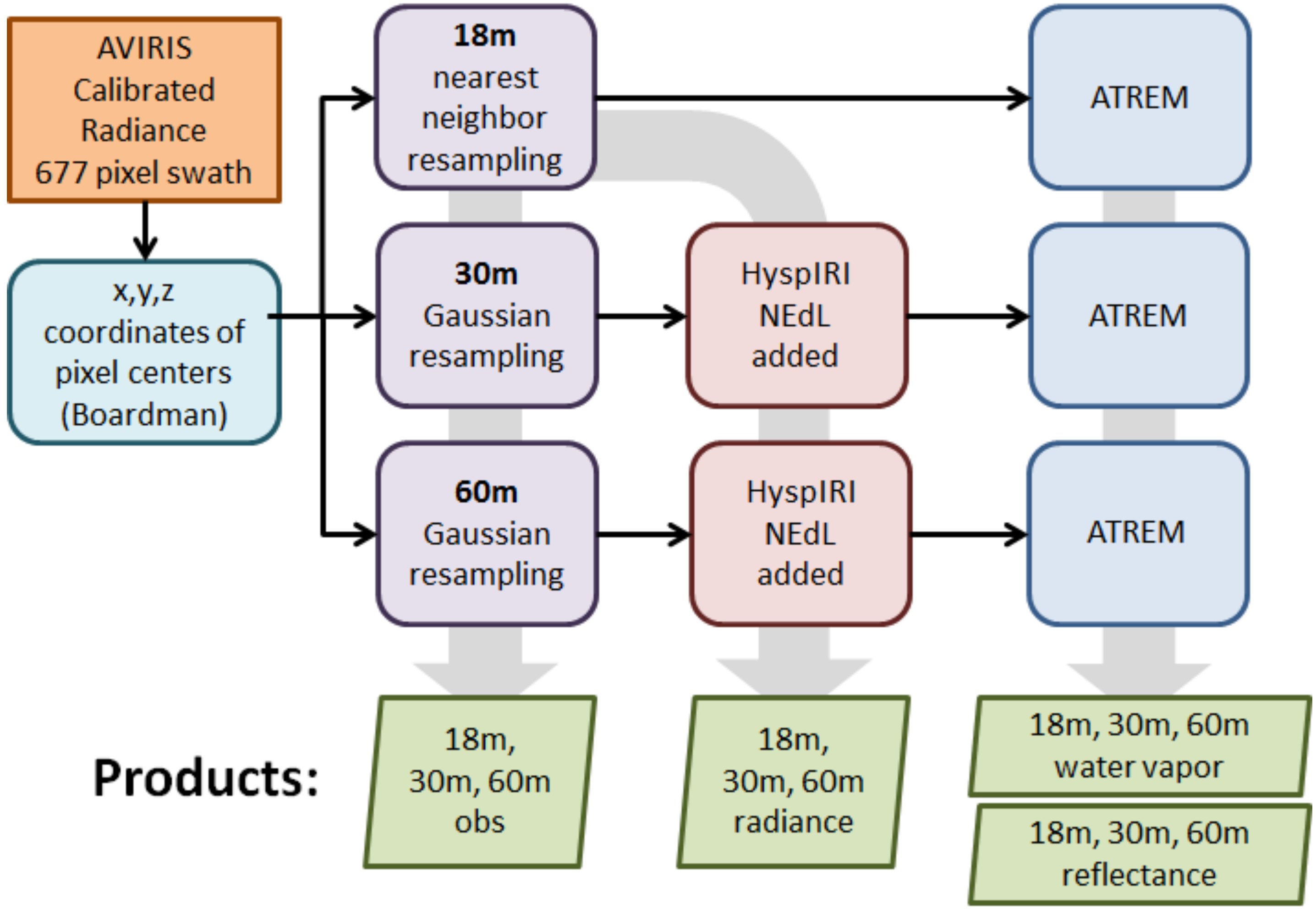
Green, 2014



- **Objective: Advance HyspIRI Mission Science, Algorithm and Processing 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*



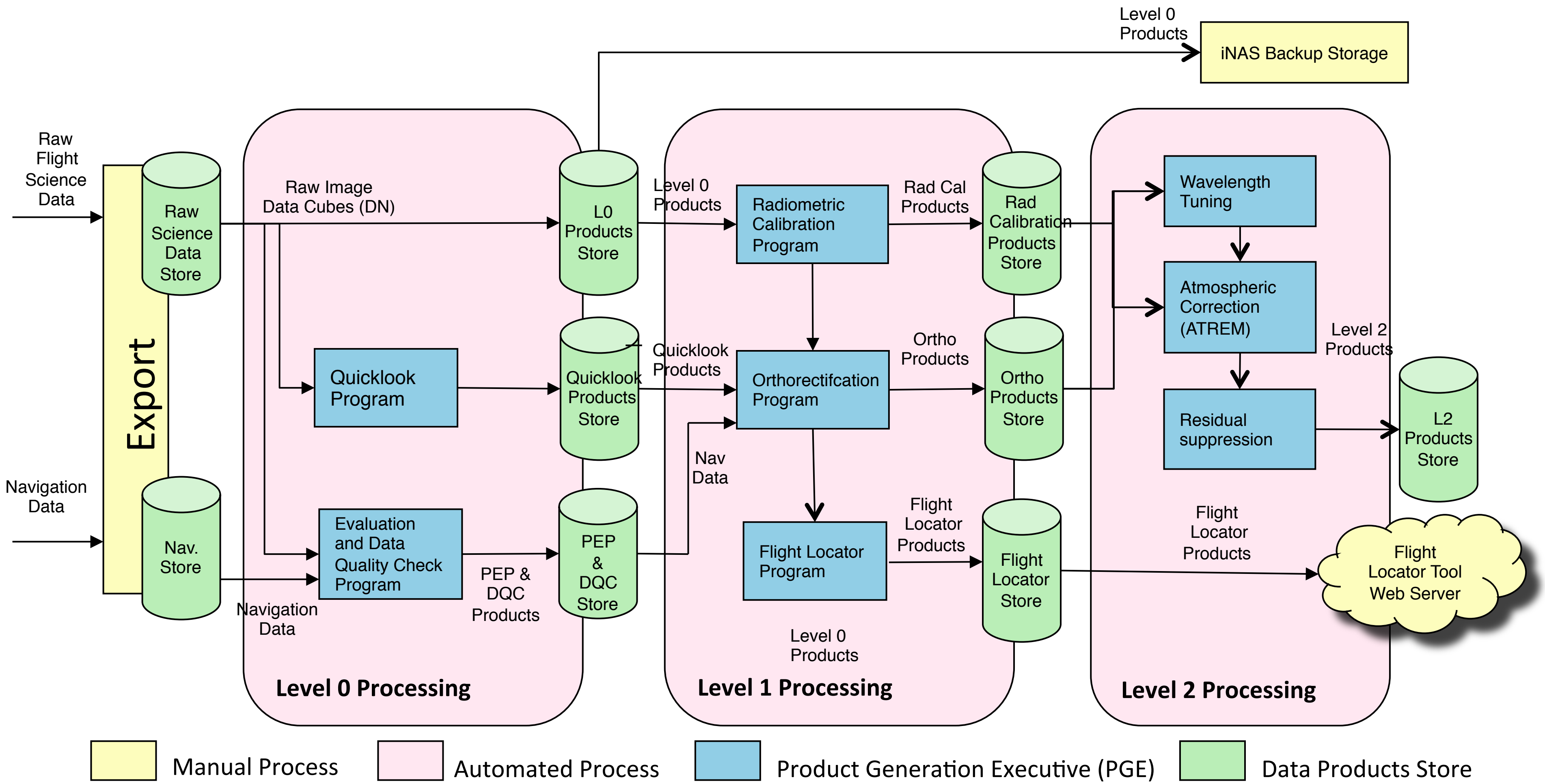
HyspIRI Simulated Data Products



http://aviris.jpl.nasa.gov/data/AV_HyspIRI_Prep_Data.html

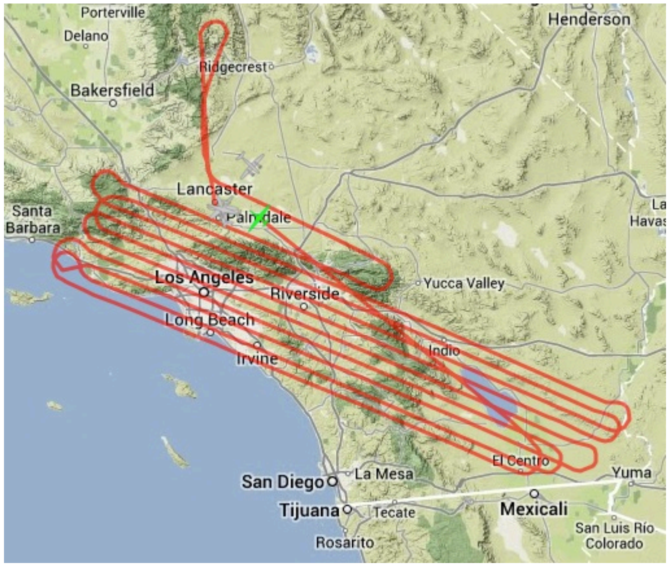
Green, 2014

HyspIRI VSWIR Pipeline

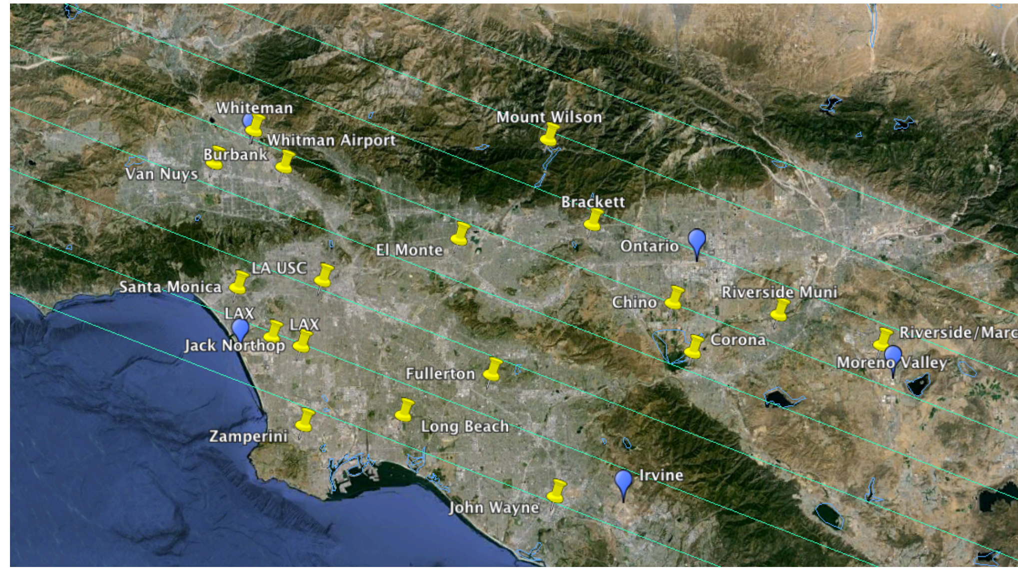


Green, 2014

Flight Campaign, September 24th, 2013



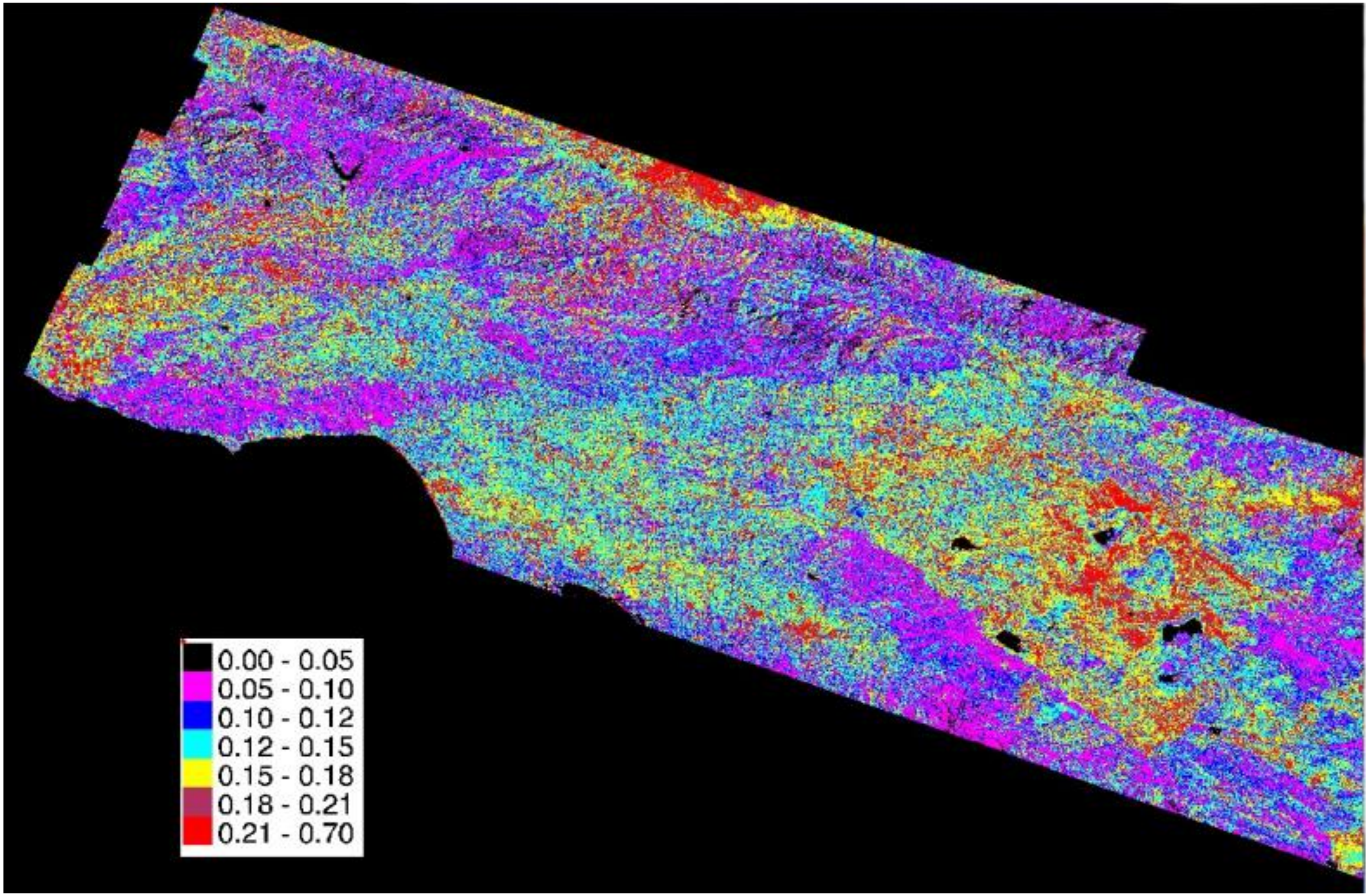
Flight Transect



- **18 surface meteorological stations (in yellow), which provide hourly: temperature, wind speed, wind direction and sea-level pressure.**
- **5 wind profilers (in blue), which provide hourly vertical structure of wind**

Sequera, Gonzalez 2014

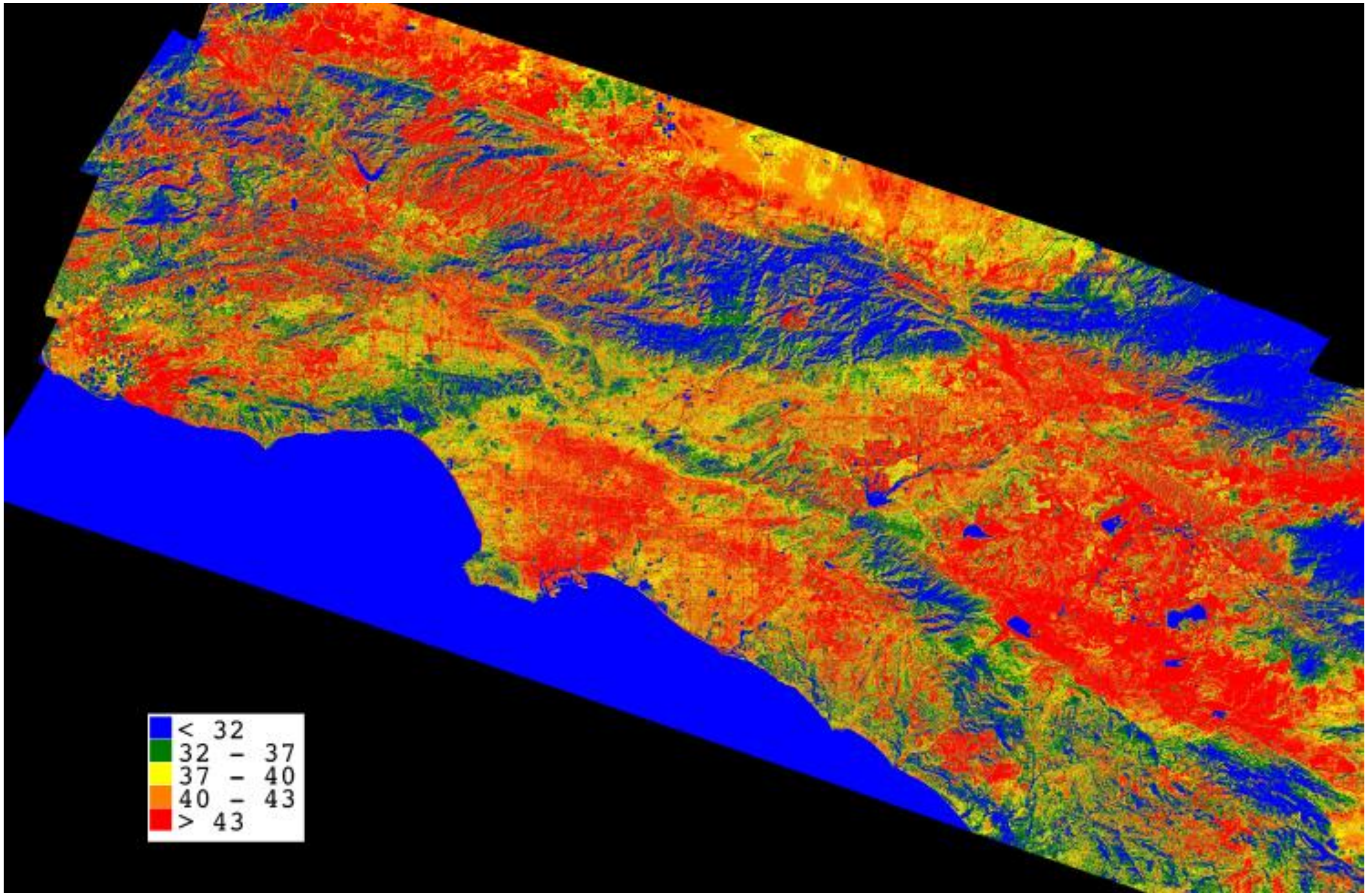
Mosaicking, Masking, Subsetting and Resampling (Albedo)



Broadband albedo map (35 m resolution) from AVIRIS after mosaicking, masking and subsetting (removal of the Salton Sea).

Sequera, Gonzalez 2014

Mosaicking, Masking, Subsetting and Resampling (LST)

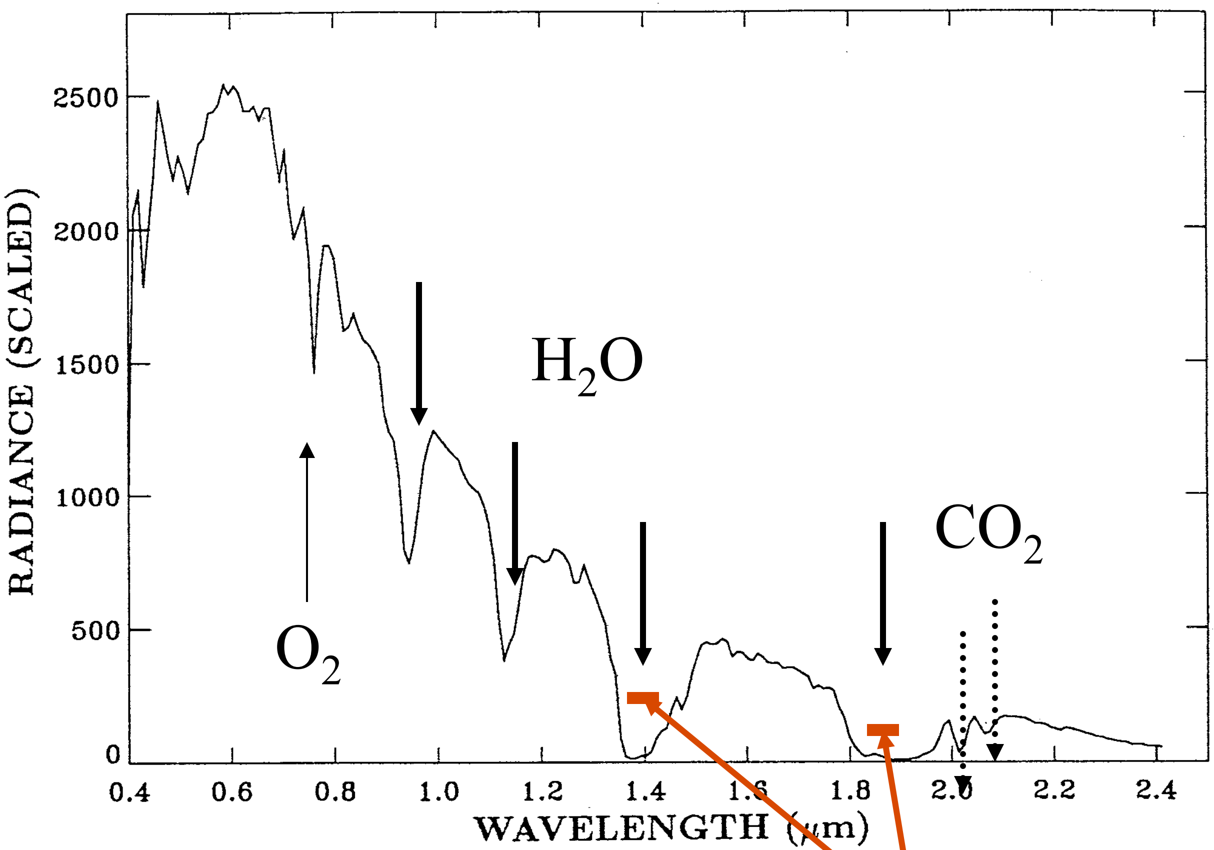


LST map after mosaicking, masking and subsetting (resolution 35 m). Temperature in ˚C. Emissivity was taken from MASTER band 2 (9.03 µm)

Sequera, Gonzalez 2014

Atmospheric Correction Over Land

An AVIRIS Spectrum



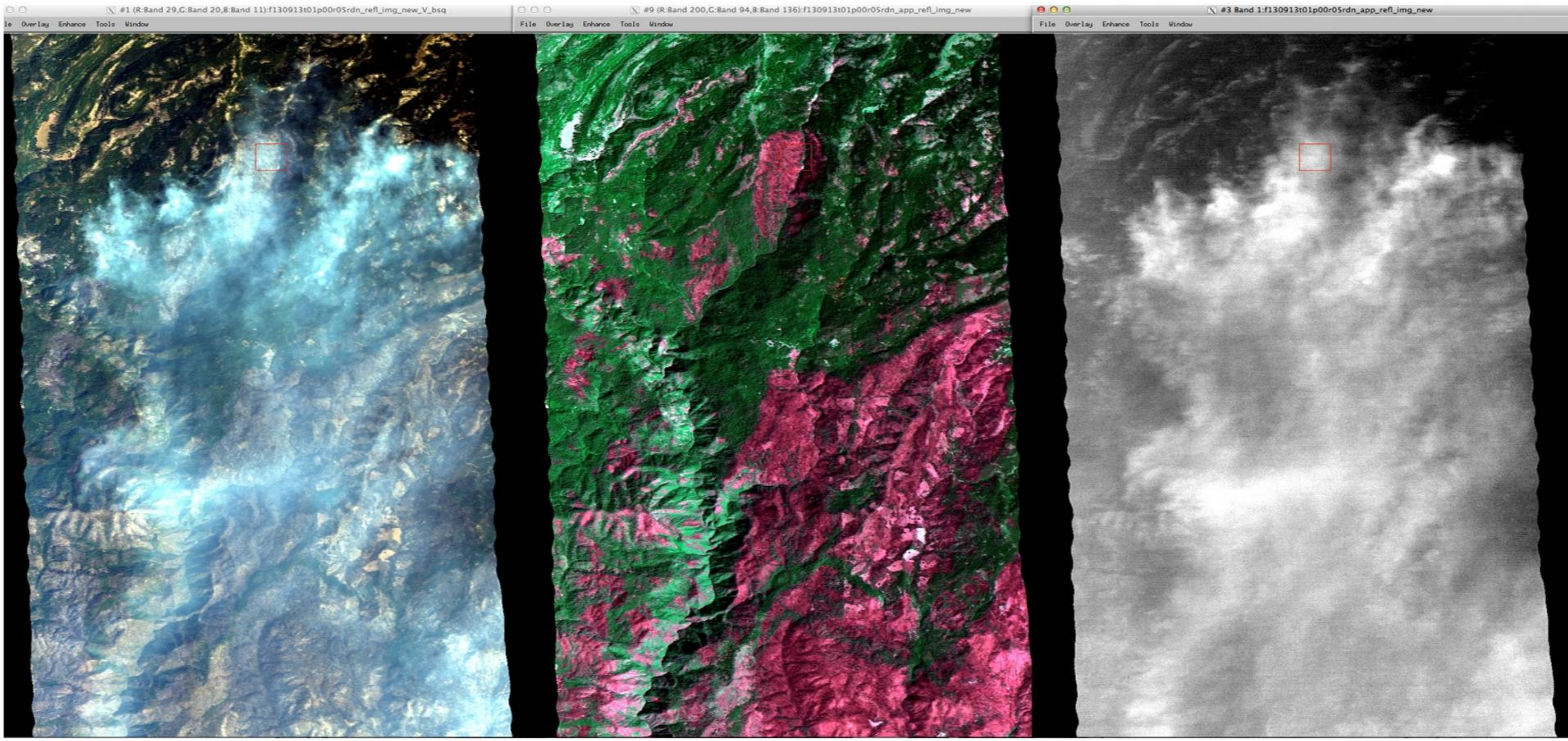
The AVIRIS spectrum is affected by atmospheric absorption and scattering effects. In order to obtain the surface reflectance spectrum, the atmospheric effects need to be removed.

Strong water vapor bands are located near 1.38 and 1.88 micron. No signals are detected under clear sky conditions.

Gao 2014

Aerosol Scattering Effects
(Illustrated with AVIRIS RIM Fire Data)

True Color Image (R: 0.64, G: 0.55, B: 0.46 mm) | **False Color Image (R: 2.13, G:1.24, B:1.64 mm)** | **B/W Single Channel Image (0.37 mm)**



Smoke is seen in visible channel images, but disappears in the SWIR channel images. Smoke particle size is typically 0.1 – 0.2 mm. The UV channel at 0.37 mm is especially sensitive for smoke detection.

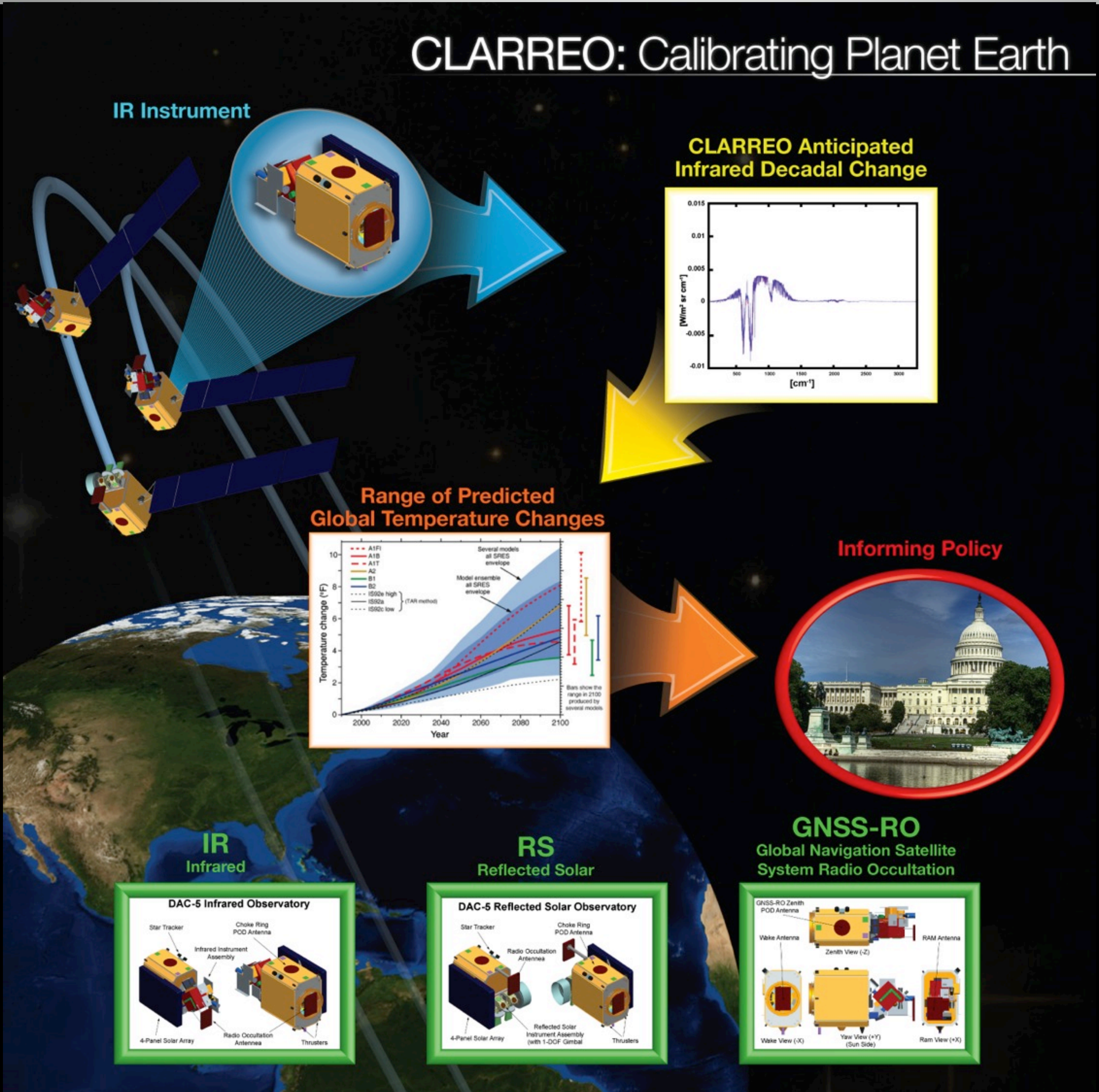
Gao 2014

New HyspIRI-Like Data Sets and Calibration

[Chair, Steve Ungar, NASA/GSFC]

- Calibration and Validation of AVIRIS-C and AVIRIS-NG in Relation to HyspIRI ***(Robert Green and the AVIRIS Team)***
- Landsat-7&8/Hyperion/G-LiHT/CLARREO (***Joel McCorkel, NASA/GSFC***)
- Hyperion stability and sub-pixel heterogeneity in a pseudo-invariant desert site (***Chris Neigh, NASA/GSFC***)
- EO-1 Calibrations (***Lawrence Ong, NASA/GSFC***)
- Geo-correction or Geo-corruption (***Steve Ungar, NASA/GSFC***)

CLARREO

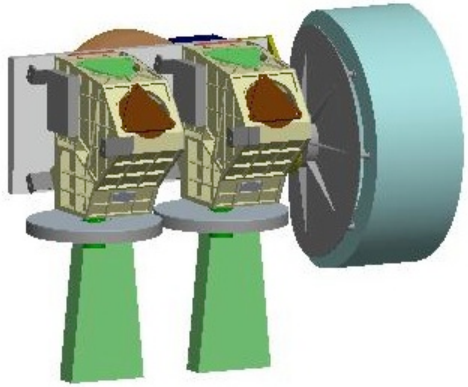


CLimate
Absolute
Radiance &
REfractivity
Observatory

CLARREO Reflected Solar Instrument

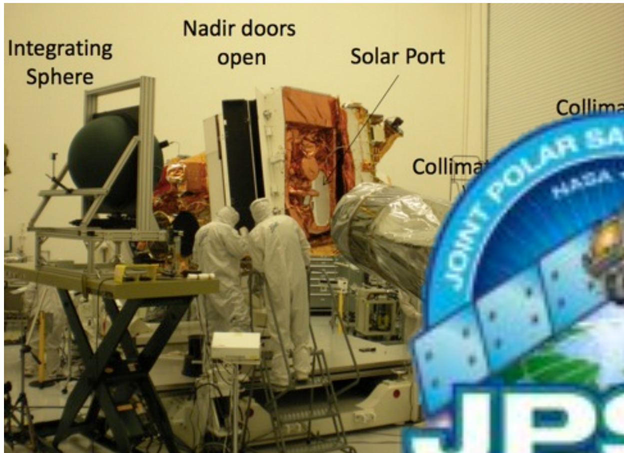
Solar/**L**unar for **A**bsolute **R**eflectance **I**maging **S**pectrometer (SOLARIS)

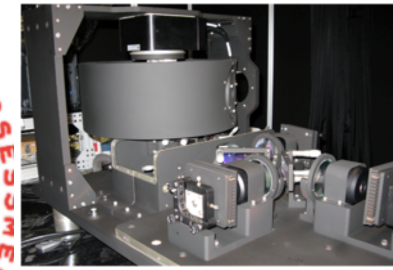
- Spectral range: **320 – 2300 nm**
- Spectral sampling: **≤4 nm**
- Spectral resolution: **8 nm**
- Swath width at nadir from 600 km orbit: **>100 km**
- GIFOV < **0.5 × 0.5 km**
- Spatial resolution per sample:
  - 70% of energy from within a 0.5 km x 0.5 km area
  - ≥ 95% within a 1.0 km x 1.0 km area
- SNR > 33 for λ < 900 nm
- SNR > 25 for λ > 900 nm
- Polarization sensitivity for 100% polarized input:
  - <0.50% (TBD) below 1000 nm and
  - <0.75% (TBD) at other wavelengths
- **Radiometric calibration accuracy: 0.3%** of albedo (integration of reflectance across all wavelengths) and within individual bands

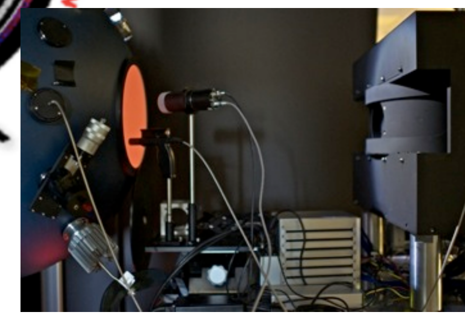


McCorkel 2014

Current SIRCUS Calibration Activities

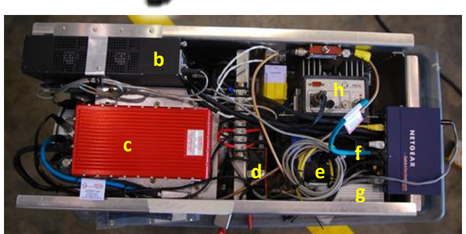




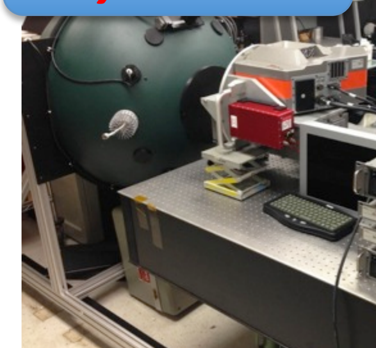


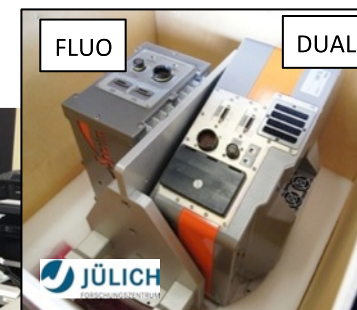
G-LiHT

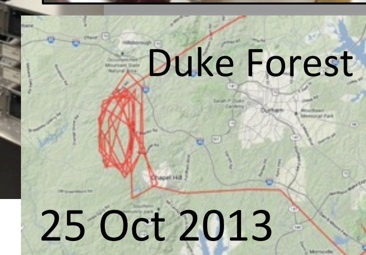
Goddard's Lidar, Hyperspectral, and Thermal airborne platform



HyPlant







McCorkel 2014

CLARREO Summary

- Detector-based calibration with tunable laser source for high accuracy required by CLARREO
  - Full-field, full-aperture spectral and radiometric sensor characterization
  - SI-traceable (primary optical Watt) with 0.09% k=2 uncertainty
  - Calibration methodology applied to other sensors (ORCA, G-LiHT, NPP & JPSS VIIRS, etc.)
- Imaging spectrometer would advance inter-calibration beyond sensor-to-sensor comparisons to a model-based inter-calibration by providing spectral reflectance factor
- CLARREO and HyspIRI are complementary
  - HypsIRI provides measurements for science questions detailed in other sessions of this symposium
  - CLARREO provides benchmark measurement to better understand climate forcings, responses, and feedbacks
  - CLARREO would increase value of HyspIRI by improving its calibration knowledge

McCorkel 2014

Monitoring Hyperion Stability and Sub-pixel Heterogeneity in a Pseudo-invariant Desert Site

Objectives/Questions

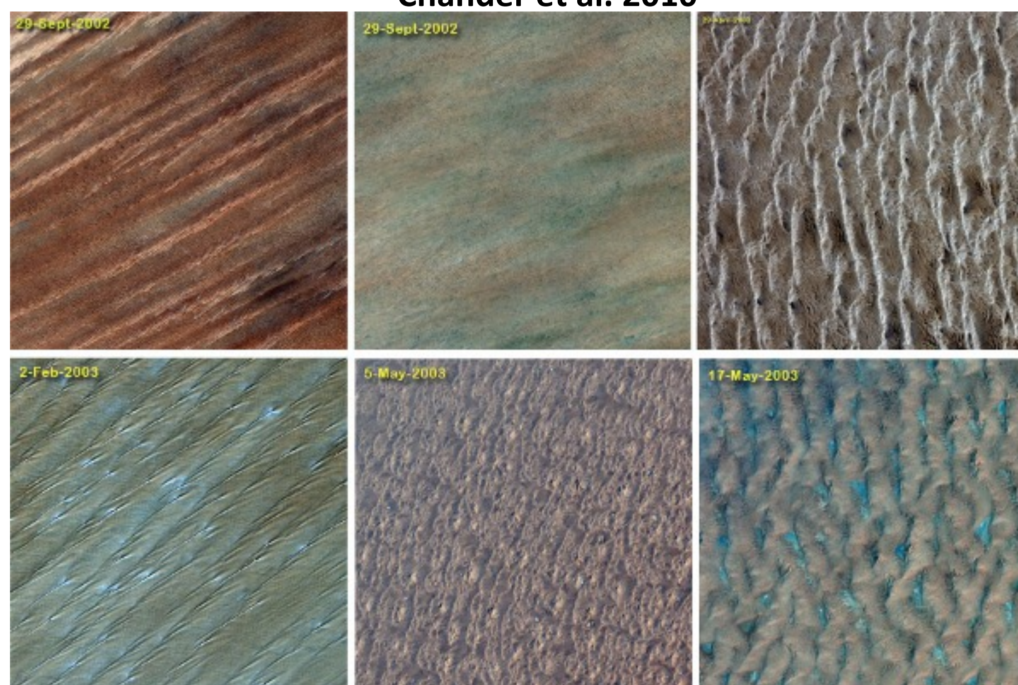
- **How stable is Hyperion through time with atmospherically corrected land surface reflectance from multiple correction approaches?**
- **Can Hyperion be used to cross calibrate a virtual constellation for land surface imaging?**
- **Can high-resolution commercial data be used to understand sub 30m pixel variability in Hyperion data?**

Neigh 2014

Study Area

- **CEOS – core validation sites**
  - **Hyperion data has been routinely collected in the Libyan desert (Libya-4)**
  - **Other studies have used this site to monitor sensor degradation and cross-calibrate measurements**
  - Landsat ETM+, MSS, SRTM, MODIS, EO-1

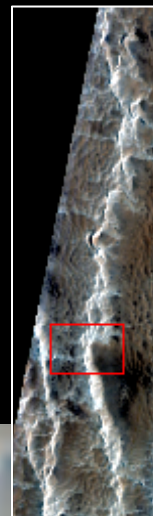
Chander et al. 2010



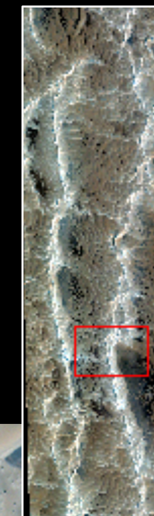
Subset example of Hyperion vs. WorldView-2

Linear stretch applied to enhance image visualization , Hyperion co-registered to WV-2

Hyperion True Color Convolved
FLAASH
8/9/2012
Red 630-690 nm
Green 510-580 nm
Blue 450-510 nm
Cubic Convolution 2m



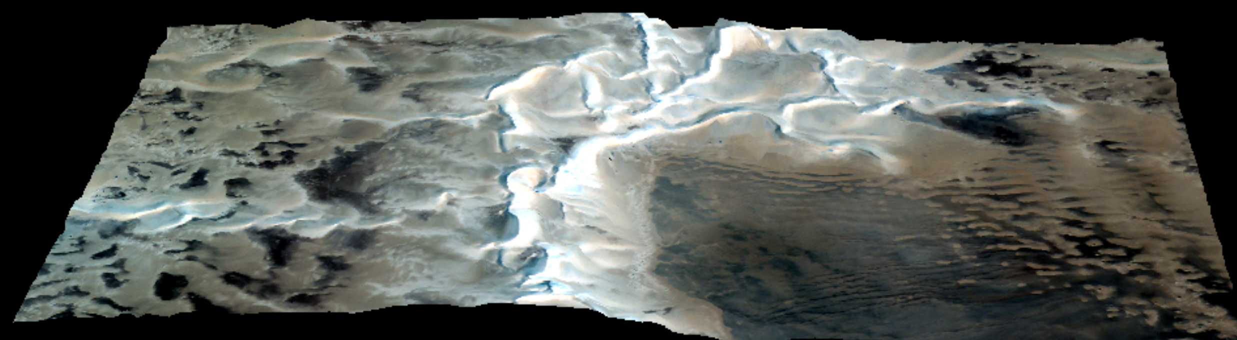
WorldView-2 True Color
FLAASH
8/12/2012
Red Band 5 630-690 nm
Green Band 3 510-580 nm
Blue Band 2 450-510 nm
2m



3D Surface View of Subset Area

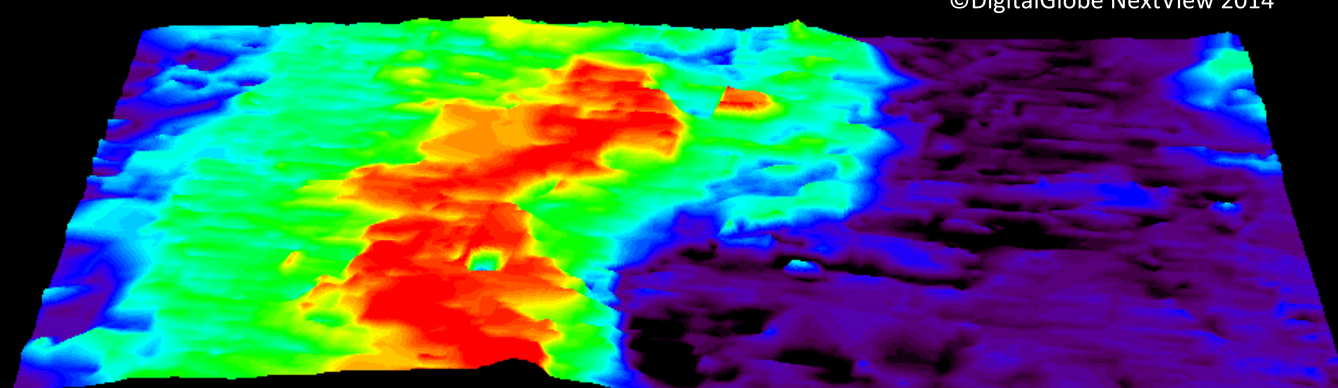
Hyperion True Color Convolved
8/09/12
Red 630-690 nm
Green 510-580 nm
Blue 450-510 nm
Cubic Convolution 2m

WorldView-2 True Color 8/12/12
Red Band 5 630-690nm
Green Band 3 510-580nm
Blue Band 2 450-510 nm
2m



©DigitalGlobe NextView 2014

WorldView-2 – WorldView-1
Digital Terrain Model
2m



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Summary

- **Hyperion is very stable through time.**
  - **CV< 2% locations, FLAASH most Vis bands < 0.18% yr^{-1} most other bands <0.4% yr^{-1}**
  - **CV 5-7% locations, FLAASH most Vis bands < 0.24% yr^{-1}, most other bands <0.4% yr^{-1} compared to other TOA reflectance studies >0.675% yr^{-1}**

- **FLAASH vs. ATREM**
  - **Consistent in Vis and variable in NIR and SWIR**

- **Libya-4 CEOS site exhibits variability from 30m to 2m that can be quantified with a high resolution digital terrain model**
  - **Variation in dune topography impacts BRDF and observed reflectance**
  - **Future work: ACORN and ATCOR can be used with the WV DTM to improve viewing geometry**

- **Is a virtual constellation possible with hyperspectral measurements?**
  - **We provide enhanced estimates of instrument stability useful for cross calibration studies from 30m to 2m resolution. FLAASH reflectance between convolved Hyperion and WorldView-2 are reasonably good in homogenous areas (CV <2%).**
    (R2 > 0.64-0.77, p-val < 0.001)
    Low correlation heterogeneous areas (CV 5-7%).
    (R2 <0.19-0.24, p-val < 0.001)
  - **Libya-4 heterogeneity should be considered when convolving and or cross-calibrating data.**

Neigh 2014

Intelligent Payload Module (IPM)

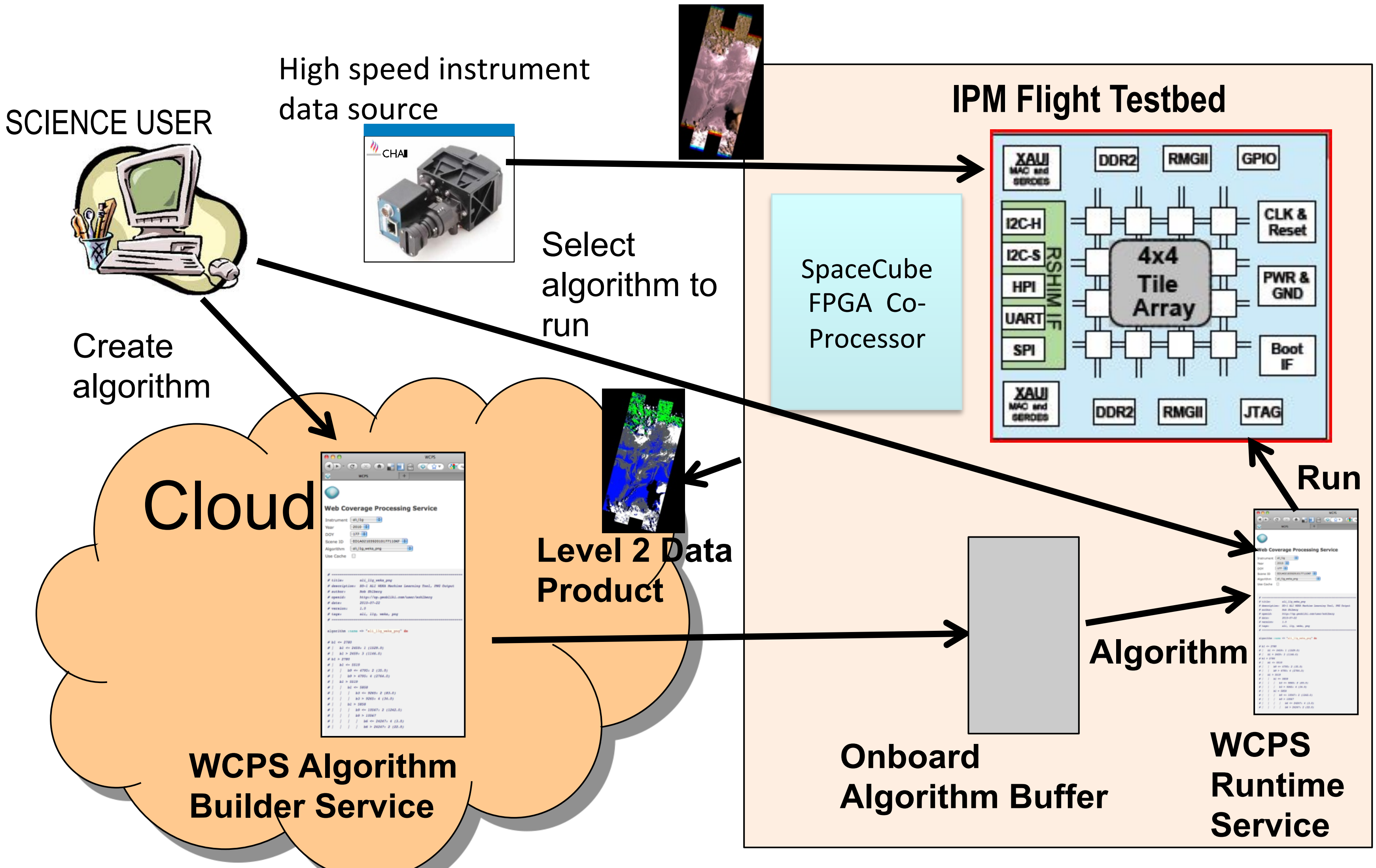
[Chair, Dan Mandl, NASA/GSFC]

- Intelligent Payload Module (IPM) Concept Evolution (***Dan Mandl, NASA/GSFC***)
- Prototype and Metrics for Data Processing Chain Components of IPM (***Vuong Ly, NASA/GSFC***)

- Generation of OLI data products Onboard Earth Observing One: A Preliminary Report ***(Steve Chien, JPL)***
- CubeSat Onboard Processing (***Charles Norton, JPL***)
- Flight Validating the Proposed HypIRI Intelligent Payload Module: Results from Intelligent Payload EXperiment (IPEX) Cubesat Operations ***(Steve Chien, JPL)***

- CSP: A Multifaceted Hybrid System for Space Computing (***Gary Crum, NASA/GSFC***)

Intelligent Payload Module: Low Latency Concept



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

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Intelligent Payload Module: Low Latency Concept

Typical Science Algorithms

Low latency users access data products via onboard Web Coverage Processing Service (WCPS) which allows specifying algorithms in real time and rapid access of resultant products

- Spectral Angle Mapper image classification;
- Regression Tree image classification;
- Vegetation dynamics;
- Water quality;
- Burned area;
- Flooded area;
- Habitat fragmentation; and
- Stretch goals like plume detection.

Exercising the Technology

- Use sub-orbital platforms to demonstrate the IPM architecture in real world situations;
- Employ computationally demanding algorithms in real time;
- Evaluate new processors and compilers;
- Pass data products to users via com links of reduced bandwidth;
- Coordinate collects among multiple assets;
- Engage with next generation design efforts for missions such as an ISS spectrometer, HyspIRI and Landsat 9 mission formulation.

Key Methods to Accelerate Onboard Computing for a Space Environment

- Intelligent onboard data reduction
- Parallel processing, multicore processors
- Use of FPGA as co-processor to accelerate portion of algorithms

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Generation of OLI Data Products Onboard EO-1: A Preliminary Report

Goal: Demonstrate that Hyperion Hyperspectral data can be used to synthesize OLI multispectral data onboard.

Approach: Utilize existing capabilities

- Autonomous Sciencecraft (ASE) Flight Software [Chien et al. 2005] in use to operate EO-1 2004 – present.
- ASE includes
  - Onboard Hyperion Data Analysis
  - Onboard mission re-planning
  - Onboard execution

ASE Usage:

- ASE onboard instrument processing used to demonstrate onboard:
  - Surface water extent mapping (Flood detection)
  - Cryosphere tracking (Snow, Water, Ice, Cloud, Land)
  - Thermal Analysis (Volcano, Wildfire)
- Over 5000 onboard products generated 2004-present [Chien et al. 2013 JSTARS]

ASE Instrument Data Processing

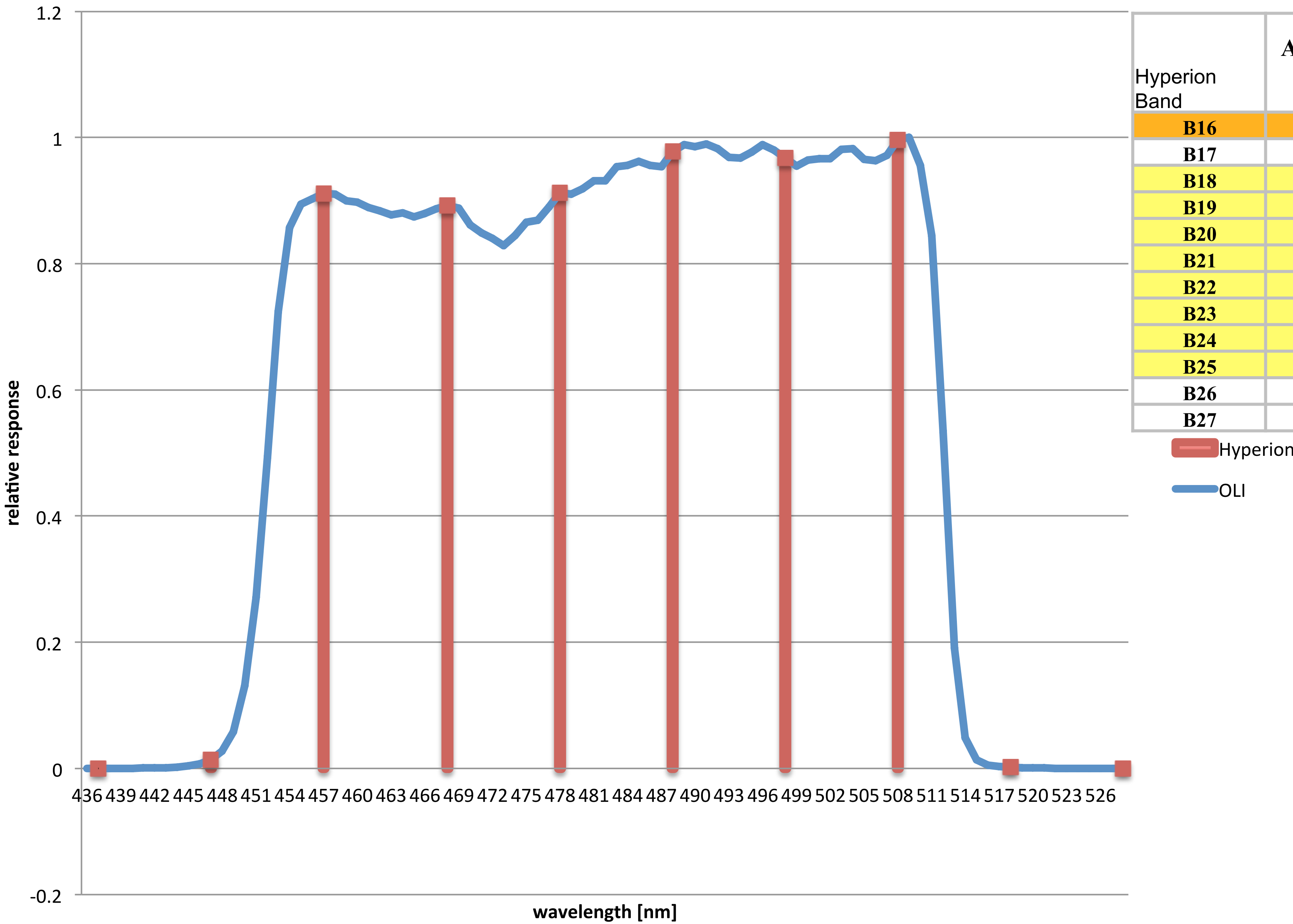
- Band stripping capability
  - Implemented by Microtel
  - Enables band stripping of 12 Hyperion Bands
  - Must include at least 1 SWIR and 1 VNIR band
  - Strips out 1024 x 256 pixel image
  - Requires ~ 20 minutes to strip
- ASE provides
  - Standard interface for accessing the stripped data
  - Standard interface to output data product
  - Data is then downlinked via s-band

Implementing Steps

- Identify selected Hyperion Bands
- Compile out as much computation as possible
- Validate convolution algorithms on ground
  - Convolve ALI data to assist in validation
- Implement to ASE interface spec
- Validate in ground testbeds
- Upload and flight validate
- Operations within current ASE operations framework – no significant disruption to EO-1 operations

Chien 2014

Hyperion/OLI Blue Band Comparison: In-Band Band-Average RSR



Hyperion Band	Average λ (nm)
B16	508.2200
B17	518.3900
B18	528.5700
B19	538.7400
B20	548.9200
B21	559.0900
B22	569.2700
B23	579.4500
B24	589.6200
B25	599.8000
B26	609.9700
B27	620.1500

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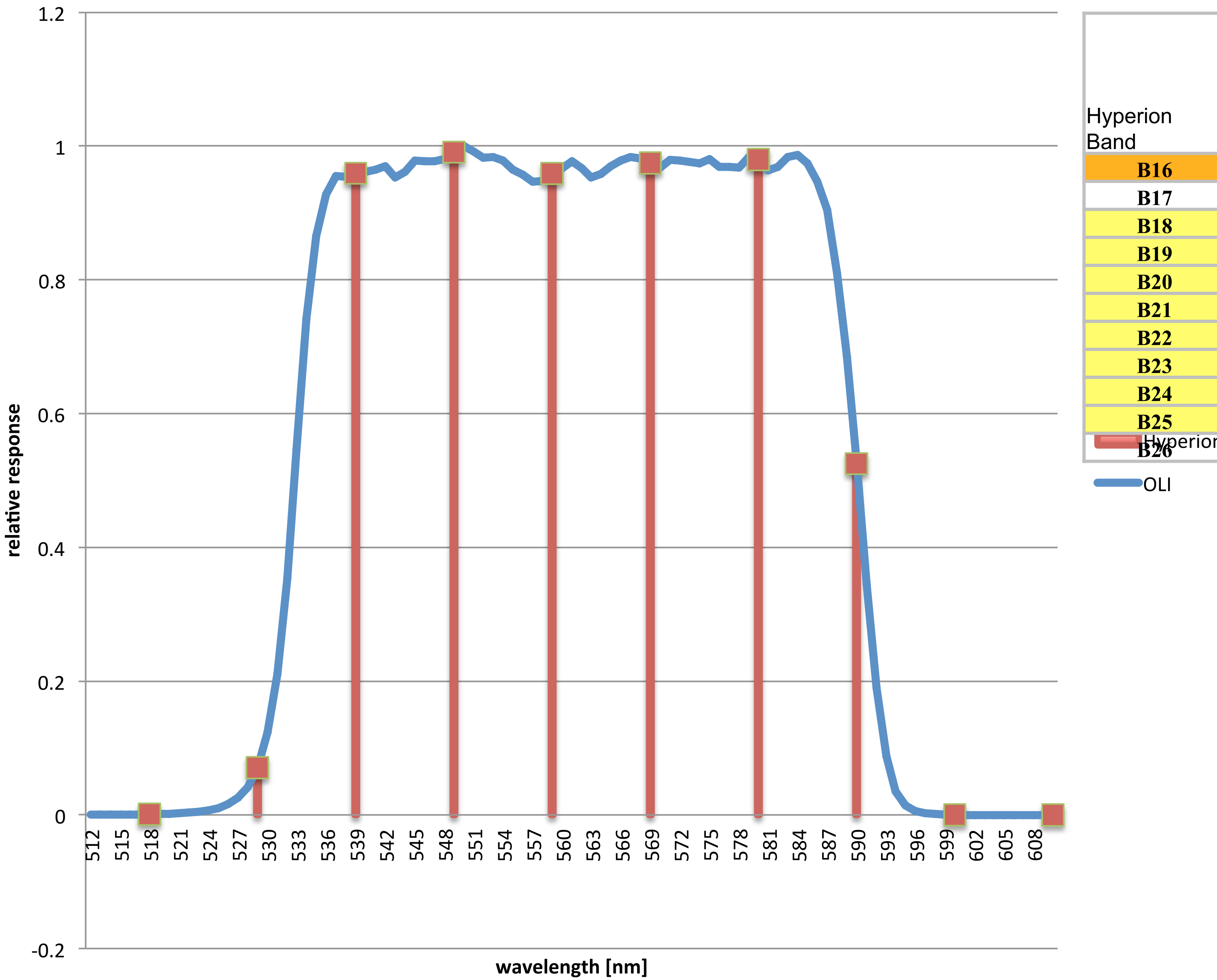
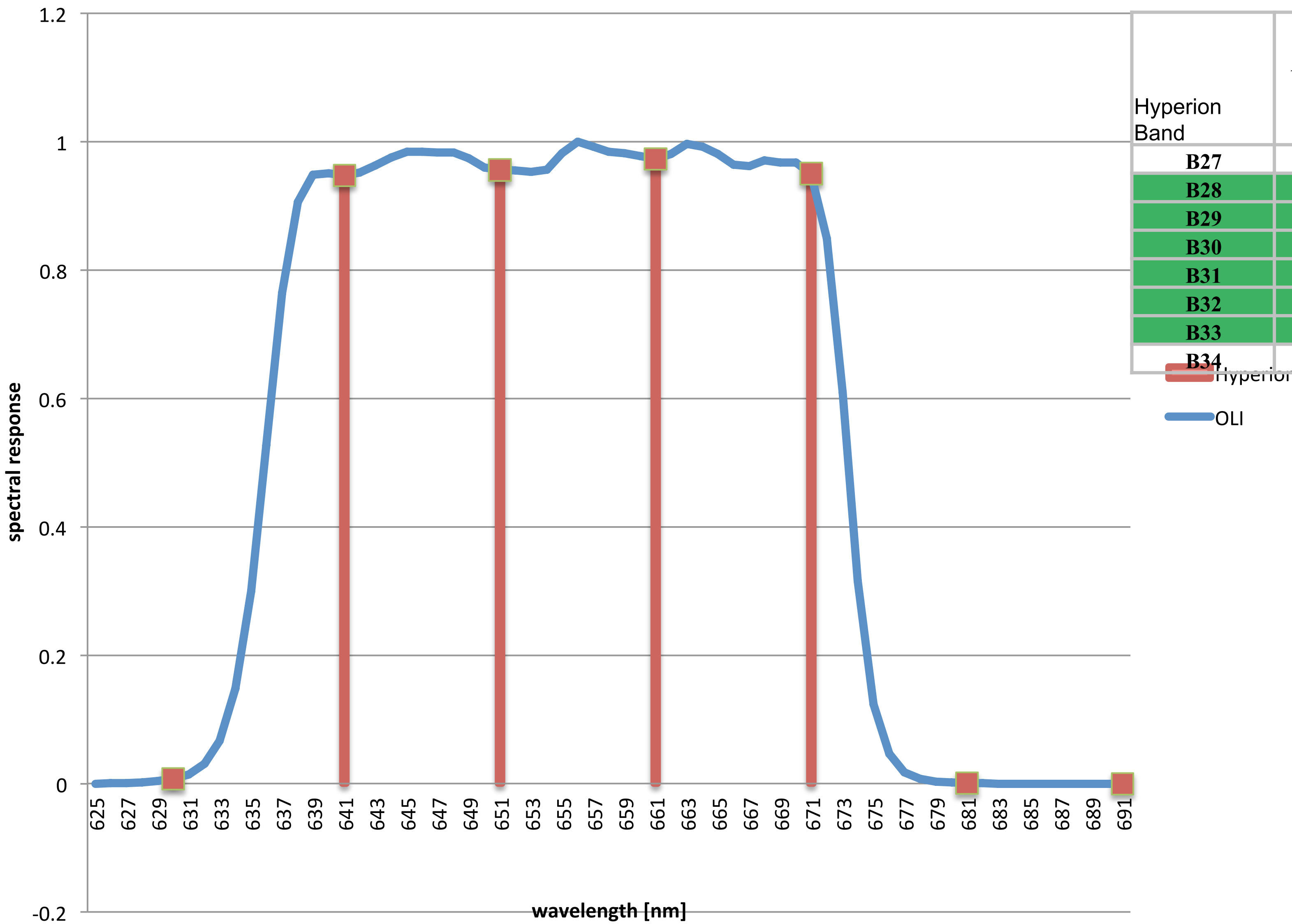
Hyperion/OLI Green Band Comparison: In-Band Band-Average RSR



Hyperion Band	Average Wavelength (nm)
B16	508.2200
B17	518.3900
B18	528.5700
B19	538.7400
B20	548.9200
B21	559.0900
B22	569.2700
B23	579.4500
B24	589.6200
B25	599.8000
B26	609.9700

Chien 2014

Hyperion/OLI Red Band Comparison: In-Band Band-Average RSR



Hyperion Band	Average λ (nm)
B27	620.1500
B28	630.3200
B29	640.5000
B30	650.6700
B31	660.8500
B32	671.0200
B33	681.2000
B34	691.3700

Chien 2014

Conclusions

- EO-1 mission has excellent supporting infrastructure to flight validate OLI product generation onboard
  - Hyperion has sufficient spectral resolution to synthesize OLI data
  - ASE FSW on EO-1 supports band stripping access to Hyperion data (with 12 band limitation)
  - Preliminary work to implement convolution, identify candidate relevant bands, overall design is complete
  - Flight validation can be executed with modest effort
- Future enhancement to band stripping could enable even further capability
  - Generation of more OLI bands within single pass
  - Downlink via WARP and X-band

Chien 2014

CubeSat Technology Flight Validation: IPEX Mission

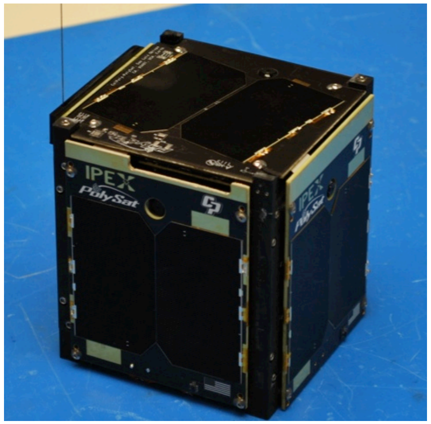
ESTO Activities Directly Supporting HyspIRI Development

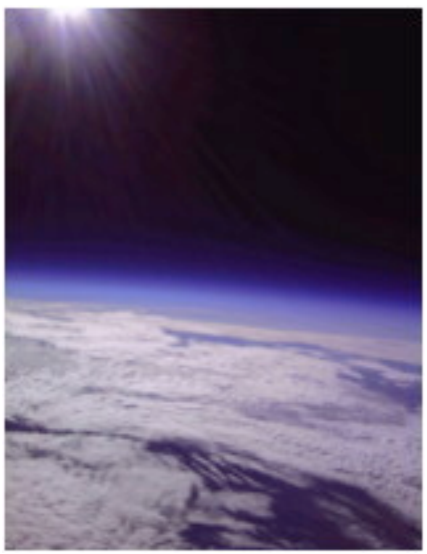
- **PHyTIR raised the TRL of TIR focal plane assembly to 6**
- **ESTO-supported AVIRIS-NG is providing risk reduction and will support cal/val and precursor science, flying since 2012**
- **ESTO-supported HyTES is providing risk reduction and supporting cal/val and Precursor science, makes 1st gas detection in 2013, flying since 2012**
- **IPEX CubeSat, designed for flight validation of IPM autonomous planning, scheduling, and low-latency product generation, delivered to VAFB and integrated onto Atlas-V for NROL-39 GEMSat launch on 12/5/13.**
- **"Plume Tracer: Mapping 3D composition of atmospheric plumes from remotely measured TIR radiance spectra"**
- **"A High Performance Onboard Multicore Intelligent Payload Module for Orbital and Suborbital Remote Sensing Missions"**

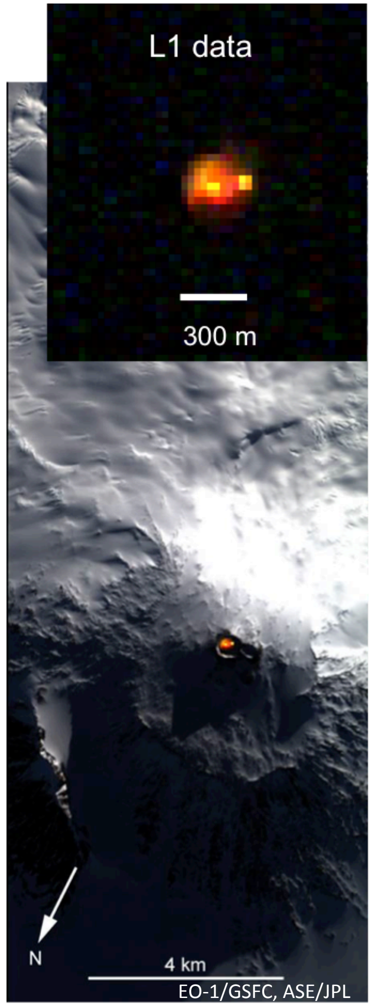
Norton 2014

Intelligent Payload Experiment (IPEX)

Low Latency & Autonomous Science Product Generation







Sponsored by NASA's Earth Science Technology Office (ESTO)

Mission Description

- NASA JPL, GSFC, and Cal Poly SLO Project
  - JPL provides processing payload
  - Cal Poly SLO provides spacecraft
- Advances technology for autonomous and near real-time product generation from high data rate Earth observing instruments
- Will enable 20x data reduction for thermal, visible, and near infrared spectroscopy science
- Orbit: High inclination polar
- Launched: Dec. 2013 from VAFB on NROL-39 GEMSat Atlas V (NASA CSLI)

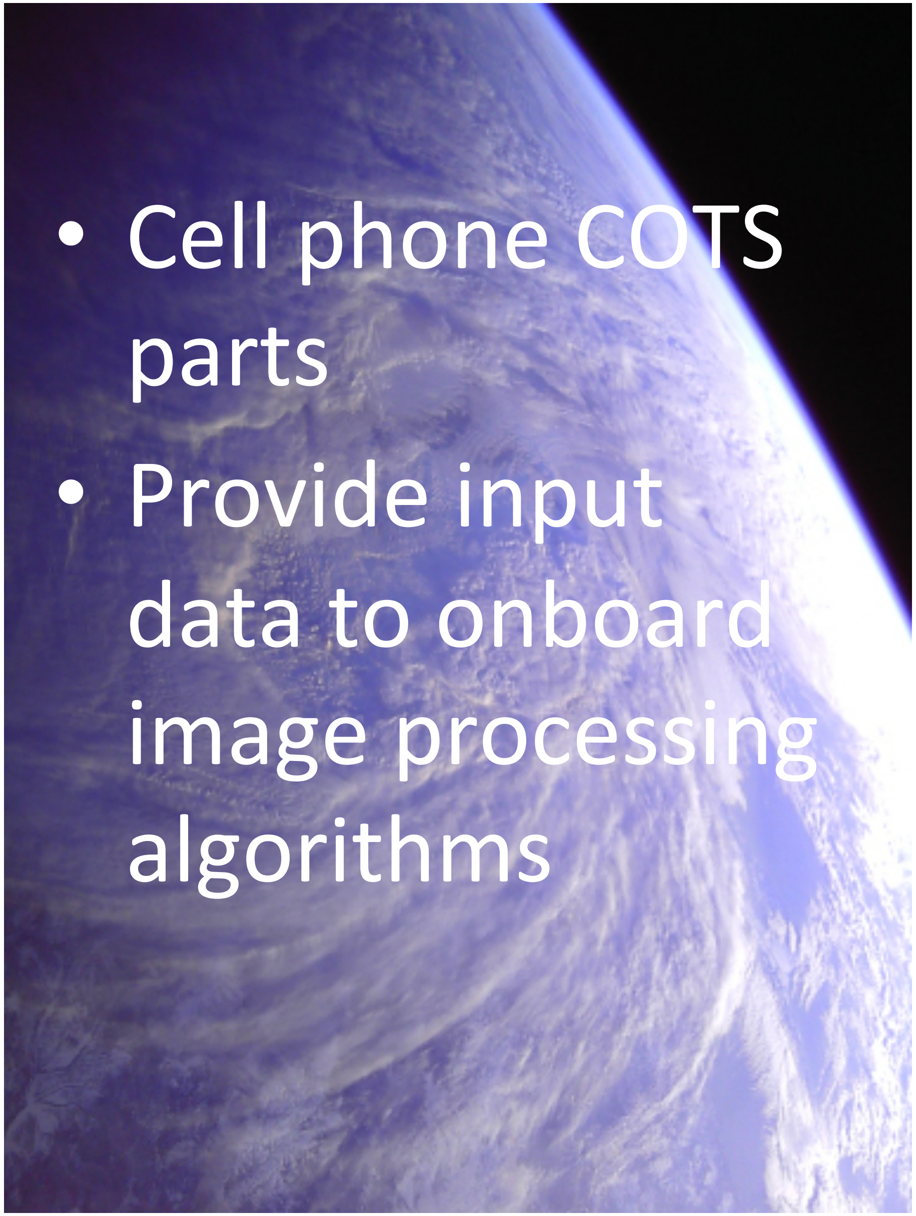
Norton 2014

ESTO Program Philosophy

- Open, competitive program
- Frequent solicitations ensure current approaches and create regular, multiple opportunities for PIs
- Focused, science-driven approach
- Peer-reviewed process
- Technology options rather than point solutions
- Technologies selected for infusion by principal investigators and mission managers, not ESTO
- Currently funded technologies are providing state-of-the-art instruments, components, and information systems capabilities for a wide range of Earth science measurements.

Norton 2014

5 x 3-MegaPixel Cameras



- Cell phone COTS parts
- Provide input data to onboard image processing algorithms

Chien 2014

Conclusions

- IPEX has successfully validated several key technologies for HysPIRI* IPM and other future missions
  - Onboard product generation
    - Evolutionary (band ratio, normalized difference) and
    - Revolutionary (machine learning, e.g. TextureCam)
  - Autonomous Payload Operations
    - Autonomous workflow management
    - Autonomous Response imaging and processing
    - Automatic operations constraint enforcement
    - Priority and geographic-based requests
- Future missions (INSPIRE, NEA Scout*) would further use these technologies

Chien 2014

Ground Processing and Distribution

[Chair, Pat Cappelaere, Vightel]

- Data Products on Cloud - Update (***Vuong Ly, NASA/GSFC***)
- A Cloud-based Scanning Framework for Analyzing Large Volumes of Hyperspectral Data (***Maria T. Patterson, Uchicago***)
- NASA Earth Science Products for Farmer Management and Cell Phone Systems (***Molly Brown, NASA/GSFC***)
- Data Fusion and Compression (***Wojciech Czaja, UMD***)
- OpenGeoSocial API: Product Discovery/Distribution via Social Networks (***Pat Cappelaere, Vightel)***
- Distributed Disaster Architecture (***John Evans, GST***)

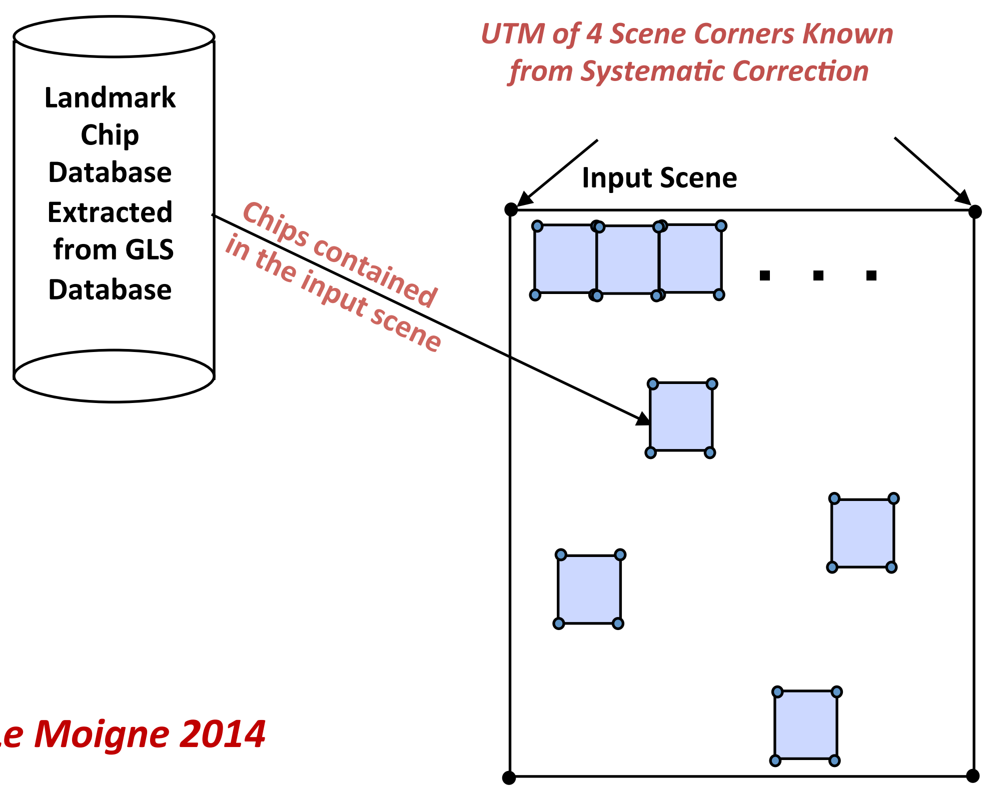
EO-1 Cloud Computing

- EO-1 data are available publicly and instantaneously at ftp://matsu.opencloudconsortium.org
- Namibia Flood Dashboard http://matsu.opencloudconsortium.org/namibiaflood
- Web Coverage Processing Service http://matsu.opencloudconsortium.org/wcps
- EO-1 Geo Business Process Management Service http://geobpms.geobliki.com
- EO-1 Geo Blogging Service http://eo1.geobliki.com

Ly, Le Moigne 2014

Automatic Registration of EO-1 Scenes Using Global Land Survey (GLS) Database

- **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



1. ***Find Chips that correspond*** **to the Incoming Scene**
2. ***For Each Chip, Extract Window*** **from input scene using UTM coordinates**
3. ***Eliminate Windows*** **with insufficient information**
4. ***Smooth and Normalize*** **gray values of both Chip and Window using a Median Filter**
5. ***Register each (Chip,Window) Pair*** **using a wavelet-based automatic registration: get a local rigid transformation for each pair**
6. ***Eliminate Outliers***
7. ***Compute Global Rigid Transformation*** **as the median transformation of all local ones**
8. ***Compute Correct UTM*** **of 4 Scene Corners of input scene**
9. ***If desired, Resample*** **the input scene according to the global transformation**

Ly, Le Moigne 2014

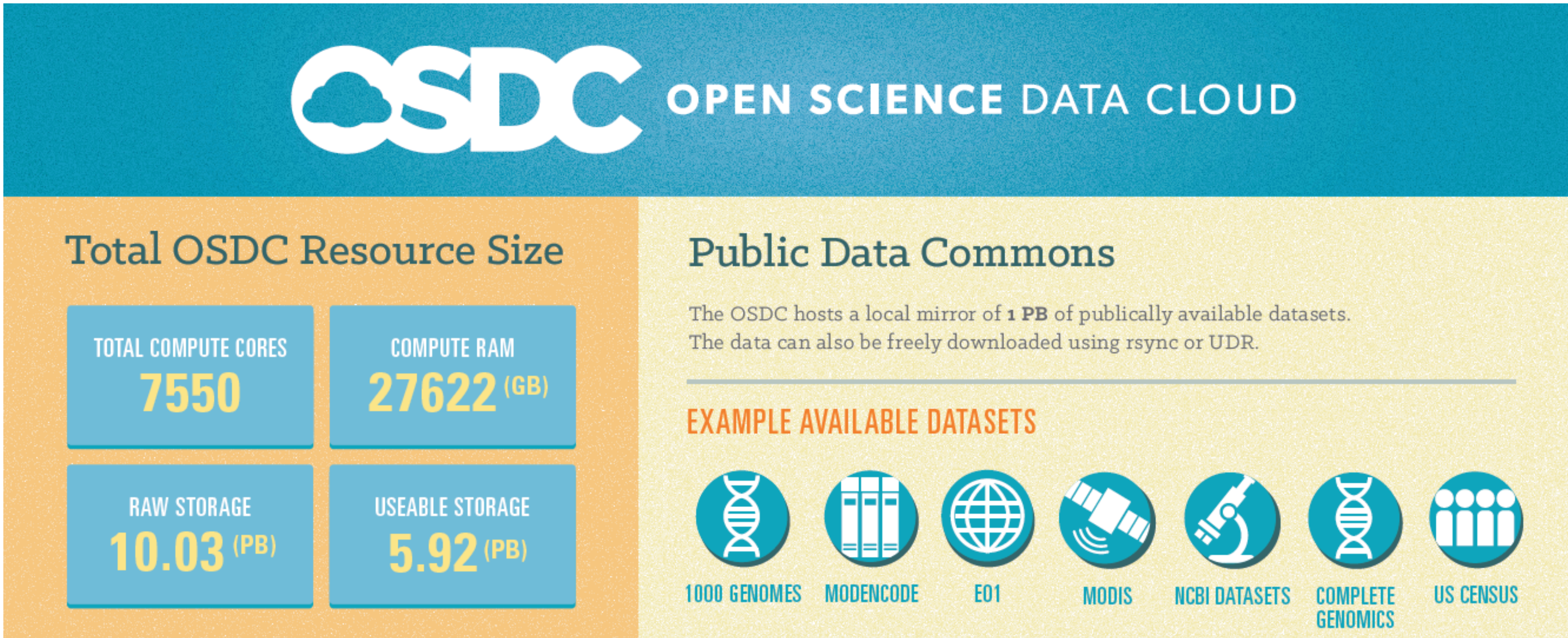
Conclusions and Future Work

- **Results visually acceptable**
- **Computations very fast and real-time**
- **RMS still too high (Translation errors between 0.4 and 2.5 pixels) because:**
  1. **Chips and windows need to be pre-selected based on the information content (e.g., using an entropy measure)**
     - **Registration would be more accurate because transformation would only be computed on pairs that have a significant amount of features**
     - **Registration would be faster because less local registrations**
     - **Chip database would be smaller to be stored onboard**
  2. **Global transformation should be computed by taking the list of original corners coordinates of each window and their corresponding corrected coordinates, and treat them as a list of ground control points and their corresponding points => after outlier elimination, global transformation can be computed using a rigid, an affine or a polynomial transformation.**
  3. **Masks for clouds and water should be included, so registration would not use cloud or water features that are often unreliable**
- **Onboard, computations can be performed on the IPM, SpaceCube, or hybrid processor**

Ly, Le Moigne 2014

The Open Science Data Cloud (OSDC)

The Open Science Data Cloud (OSDC) is an **open-source, cloud-based** infrastructure that allows scientists to manage, share, and analyze medium to large size scientific datasets.



Application for resources available to anyone doing scientific research:

www.opensciencedatacloud.org

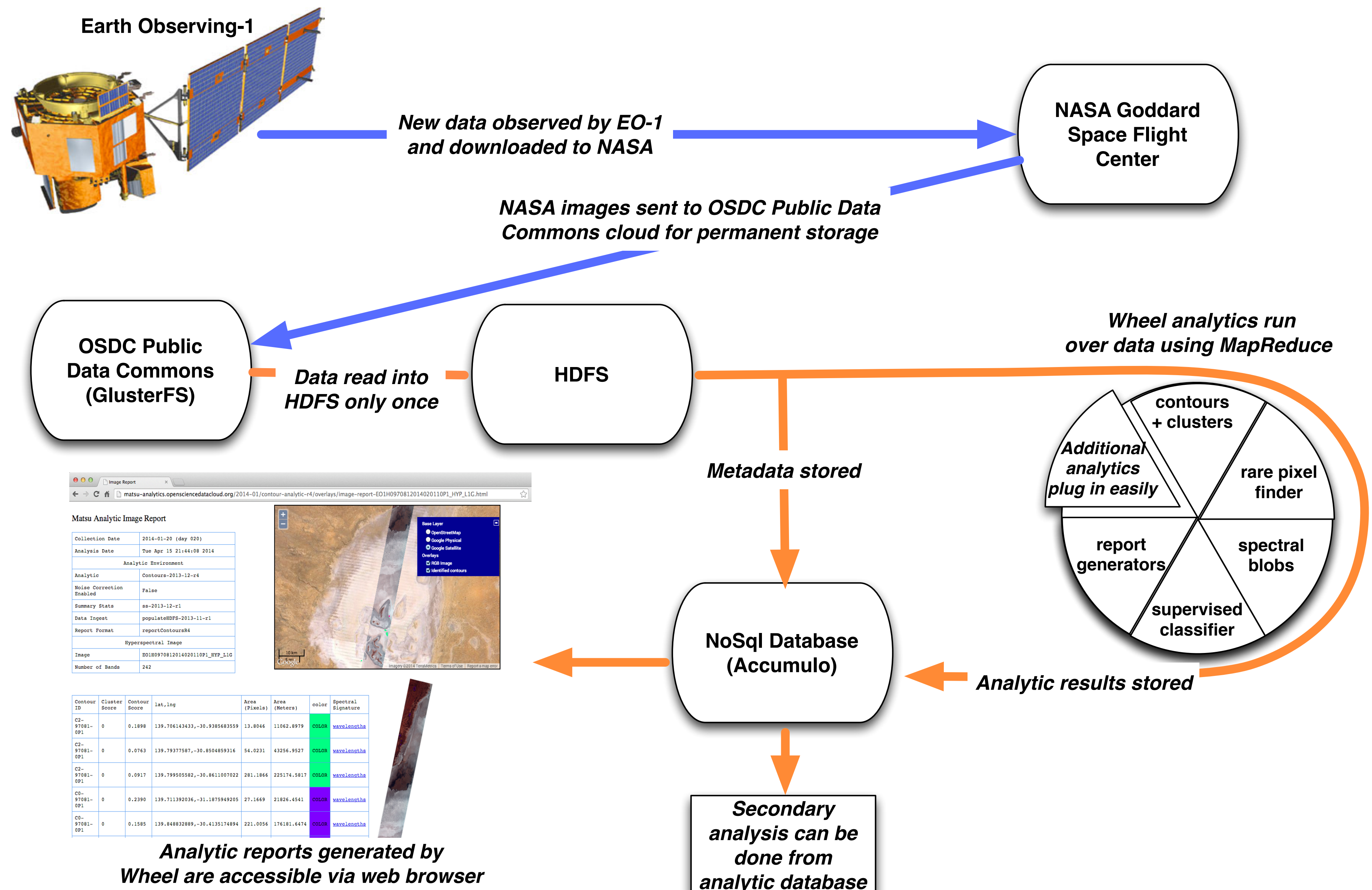
Patterson 2014

Project Matsu

- Joint effort between the Open Cloud Consortium (lead, Robert Grossman) and NASA (lead, Dan Mandl) to develop open source technology for cloud-based processing of satellite imagery to support earth sciences.
- The OSDC is used to process Earth Observing 1 (EO-1) *satellite imagery* from the Advanced Land Imager and the Hyperion instruments and to make this data available to interested users.
  - Namibia flood dashboard, WCPS
  - Hadoop-based 'Matsu Wheel' scanning data algorithm

Patterson 2014

Matsu Analytic Wheel



Patterson 2014

NASA Earth Science Data Products for Farmer Management and Cell Phone Systems

Brown 2014

Africa's food security challenges

Challenges such as climate change, population growth, the need to meet rapidly growing demands for water and energy as well as underlying political, social and economic realities make it difficult to adequately invest in raising agricultural productivity and ensuring food security for all.

ACCESS Project Objectives

- The objective is to allow African farmers, businesses and traders to access NASA Earth Science data relevant to their lives and businesses
- Text SMS message of data and image provision will be provided through a cell phone application
- Mobile website will also be built with the same functionality
- Data are high quality, well established variables – NDVI, rainfall and soil moisture data
- Application and mobile website will be developed through NASA civil servants to remove problems with proprietary ownership

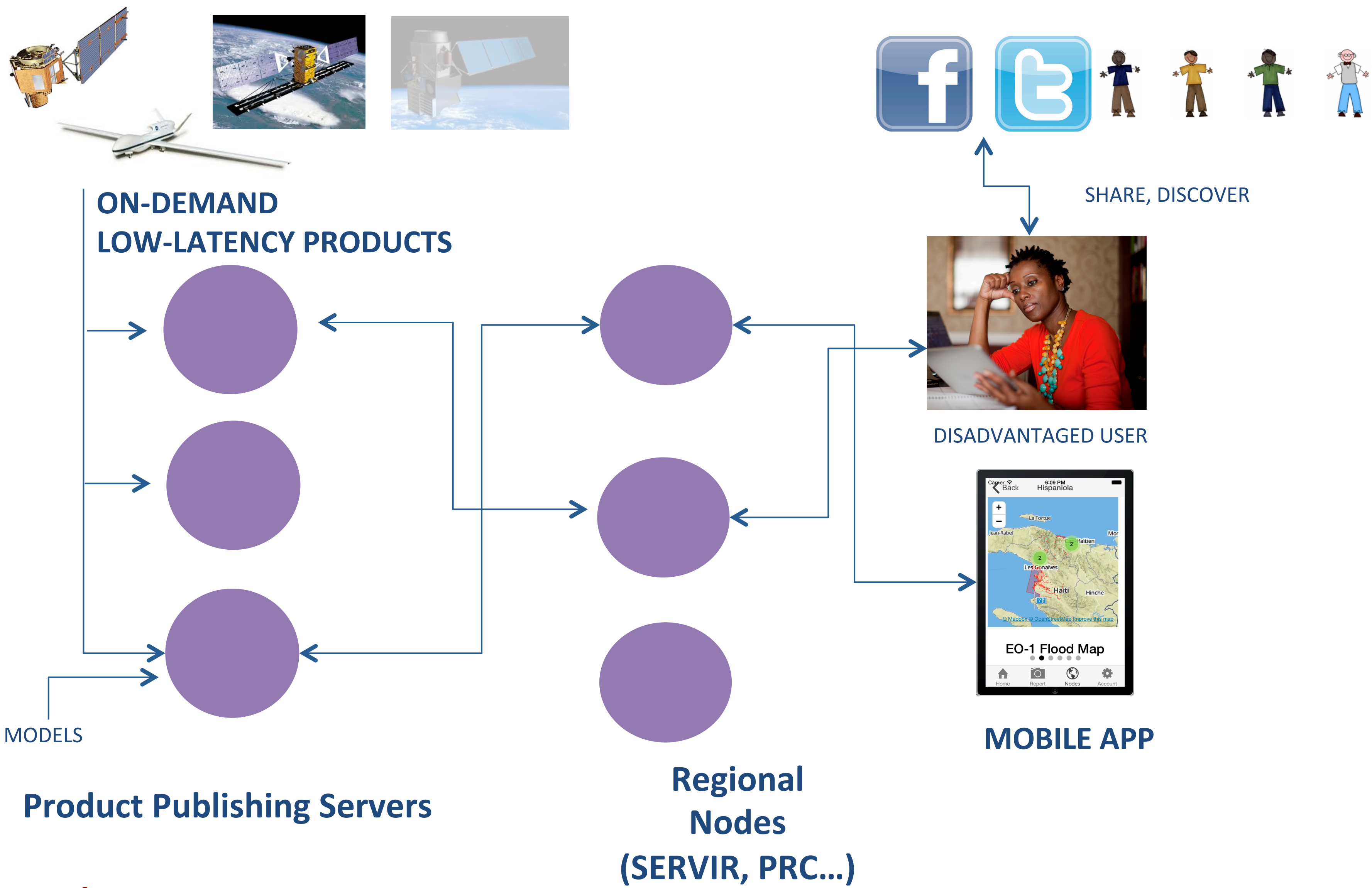
Brown 2014

Open Geo-Social API

- Generate User Products That Can Be Used As Actionable Information
- Tag your Products To Make Stories and Push Stories to Social Networks To Enable Discovery
- Use An Ubiquitous Product Distribution Format for the Net. Think Mobile Platforms
- Provide A Higher Level Hypermedia API To Shield Users From Infrastructure Details. You Want To Make It Easy to Generate, Access, Download Products

Cappelaere 2014

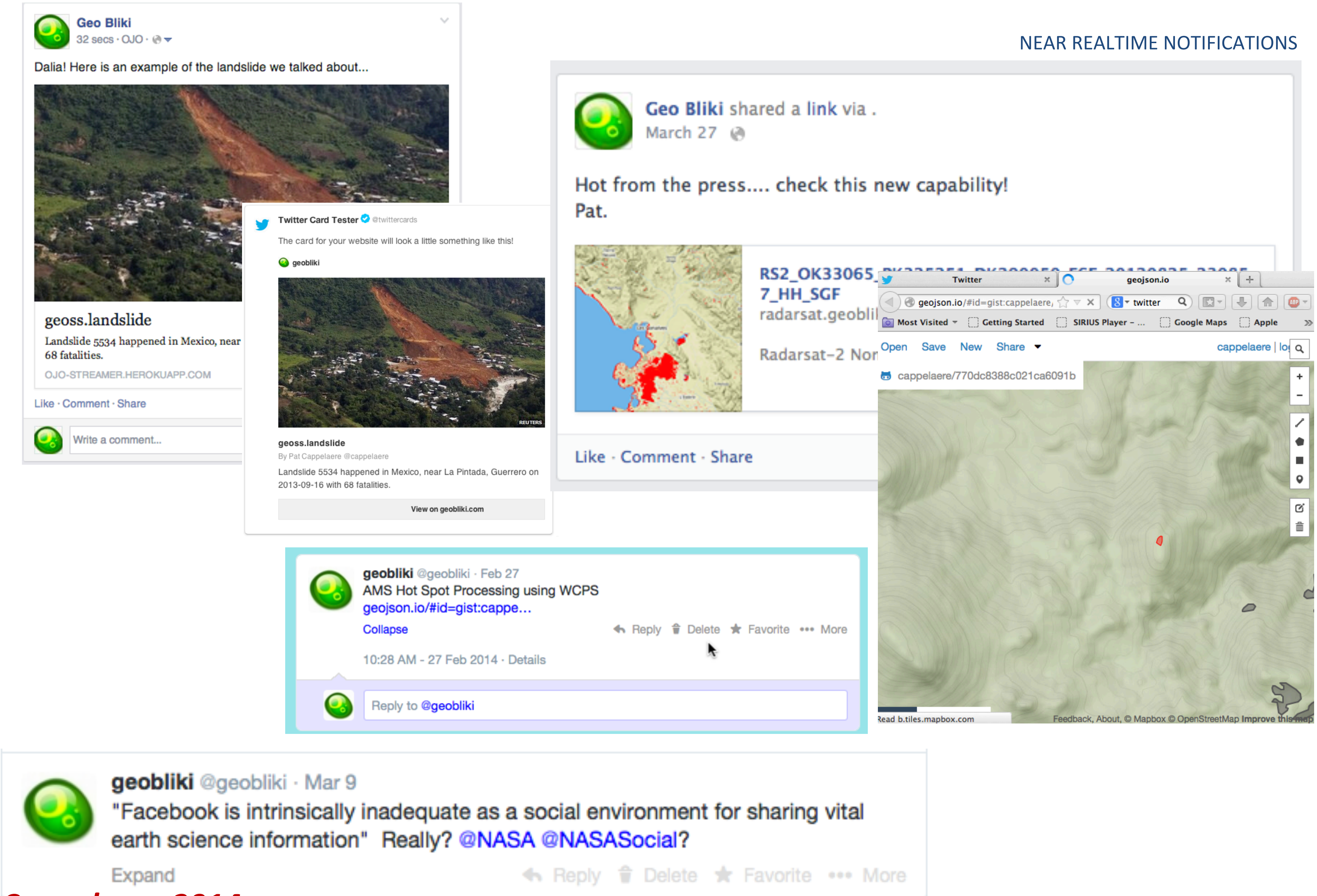
GEOSS Architecture For Disasters



Cappelaere 2014

Science Data on Social Networks

NEAR REALTIME NOTIFICATIONS



Cappelaere 2014

New technologies and architecture viewpoints

Information viewpoint

Data collection:

- Small Satellites
- Drones (UAVs)
- Direct Broadcast / Direct Readout
- Mobile devices
- "Internet of Things"
- Crowdsourcing

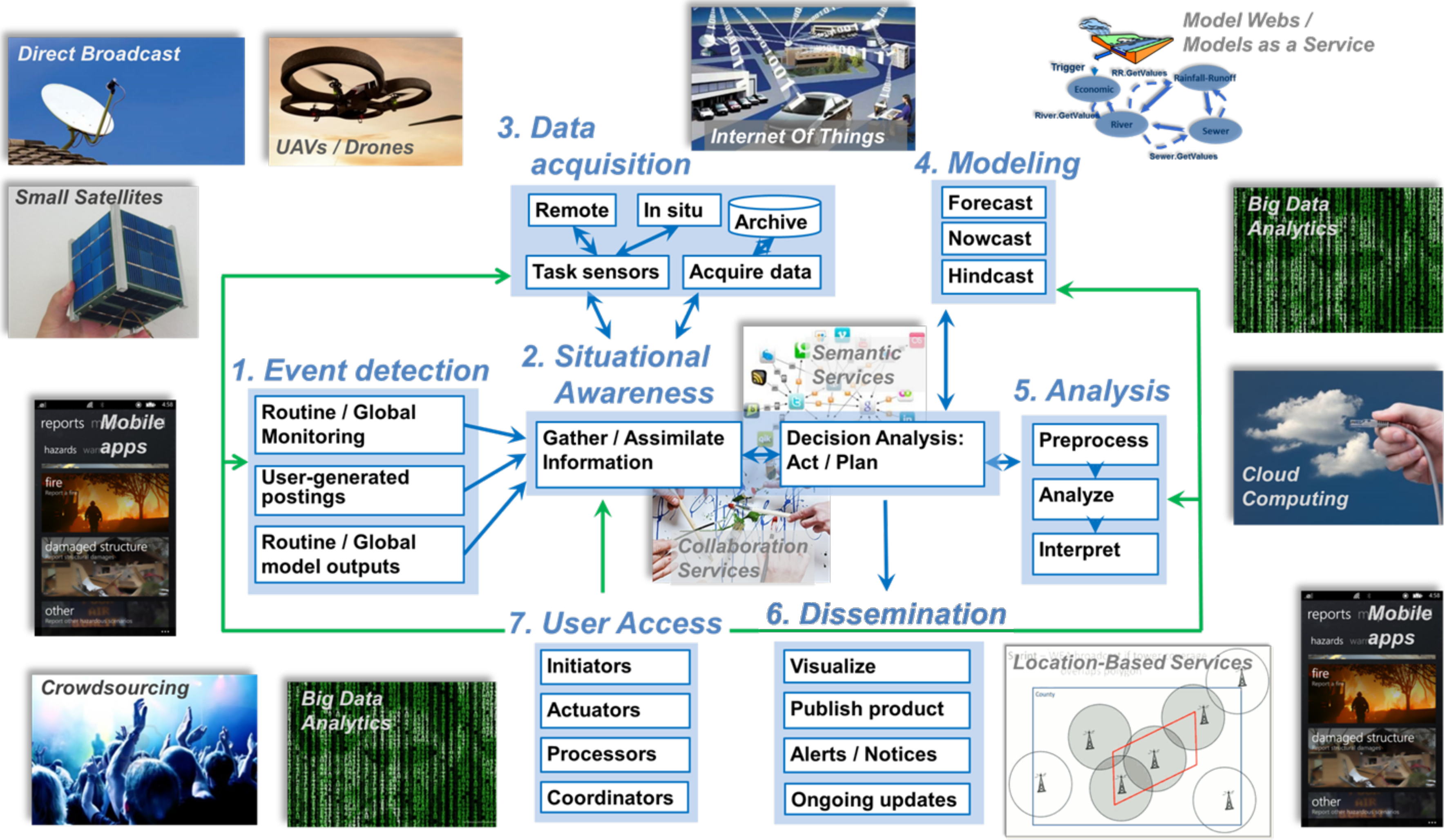
Computation viewpoint

Data processing:

- Model Webs
- Cloud Computing
- Big Data analytics
- Semantic services
- Mobile devices
- Location-based services
- Collaborative services

Evans 2014

Disaster Risk Management Activities and emerging Earth Science Technologies



Preparing for the Next Decadal Survey

[Chair, Woody Turner, NASA HQ]

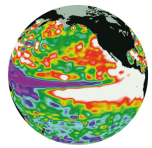
- The New NRC 2015 Decadal Survey (***Woody Turner, HQ***)
- Discussion: *How HyspIRI can contribute?*

Preparing for the Next Decadal Survey

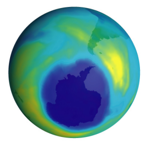
Why We Launch the Missions

Earth Science Focus Areas:

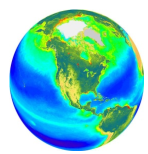
Climate Variability & Change



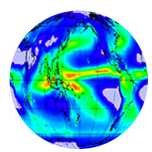
Atmospheric Composition



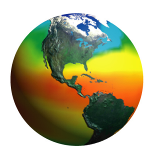
Carbon Cycle & Ecosystems



Water & Energy Cycle



Weather



Earth Surface & Interior

Earth Science Applications Areas:

Health & Air Quality

Water Resources

Disasters

Ecological Forecasting

Turner 2014

Next Year?