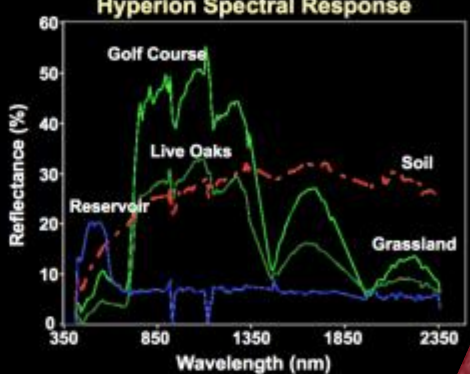
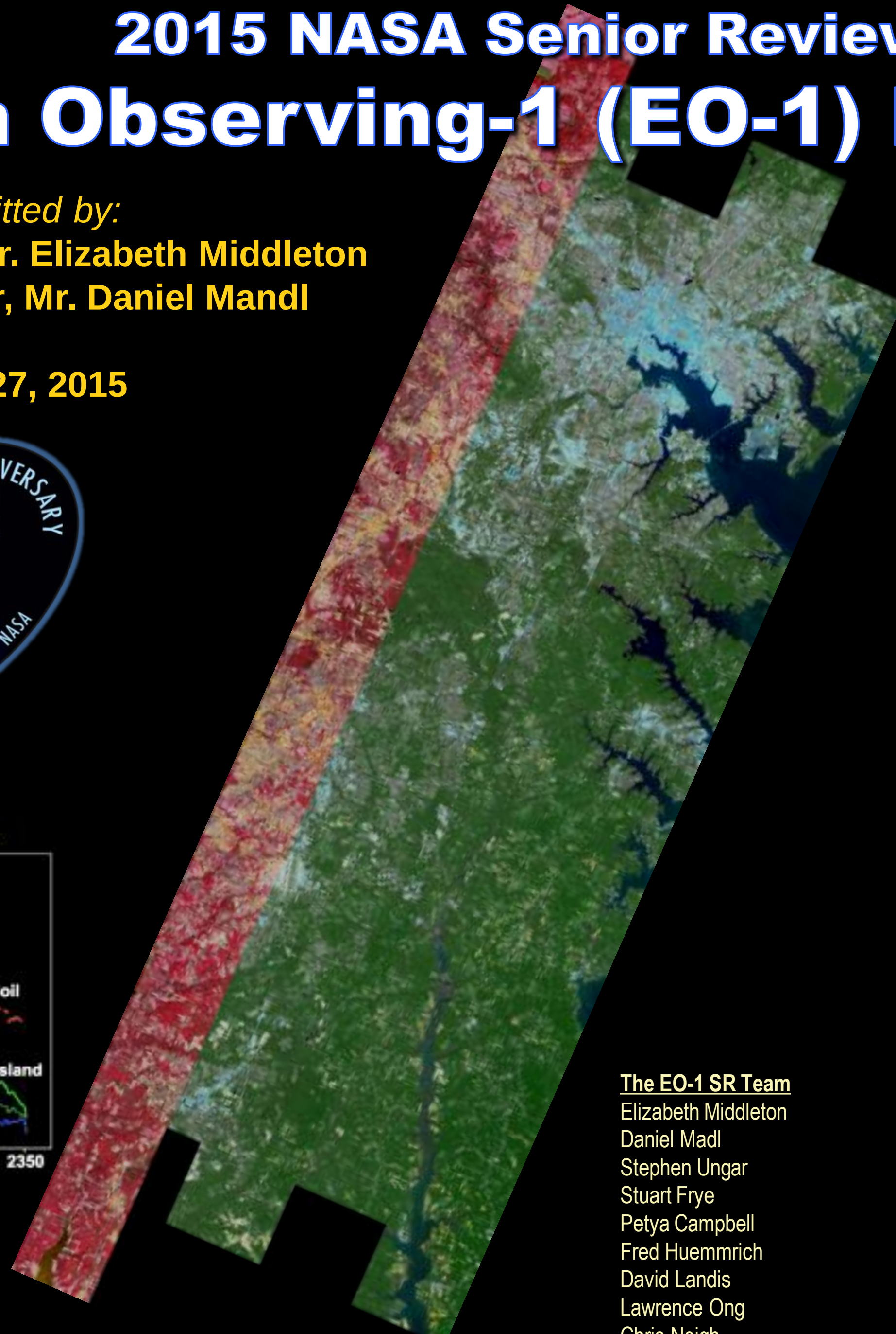
# 2015 NASA Senior Review
# Earth Observing-1 (EO-1) Proposal


*Submitted by:*
**Mission Scientist, Dr. Elizabeth Middleton**
**Mission Manager, Mr. Daniel Mandl**


**April 27, 2015**

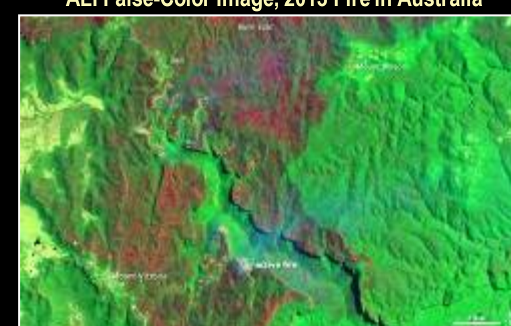



Hyperion (red) overlay on ALI Image (green), Oct 2012 Baltimore, MD

ALI False-Color Image, 2014 San Miguel Volcano

ALI True-Color Image, 2013 Bird Sanctuary in India

ALI False-Color Image, 2013 Fire in Australia




**The EO-1 SR Team**
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Lawrence Ong
Chris Neigh

# Overview: What EO-1 Offers that no other NASA Mission Provides

**EO-1 is a fundamentally unique NASA asset, providing capabilities not available with any existing or currently planned space platform.**

- EO-1 is a highly maneuverable ***testbed*** asset which can be (and has been) assigned a variety of high priority tasks of critical interest to the NASA Earth Science Division.
- Hyperion is the only spaceborne satellite imaging spectrometer (IS), uniquely providing a 14+ year archive of spectroradiometric observations. Data from Hyperion continue to be used as a source for understanding how spectroradiometric properties relate to the physical state (and disturbances) of the Earth's surface.
- Hyperion paves the way for future IS missions, providing unprecedented quantitative assessments of terrestrial and aquatic ecosystems.
- Pathfinder for future technologies, such as:
  - Onboard autonomy software (Autonomous Sciencecraft Experiment – JPL)
  - Onboard intelligent diagnostic software (Livingstone – Ames)
  - IP for space (Delay Tolerant Network – GSFC)
  - Onboard cloud detection (Lincoln Lab – GSFC & JPL)
  - SensorWeb/GeoSocial API for ease of tasking satellites, discovery/delivery of satellite data products (GSFC, JPL, International Disaster community)
  - Intelligent Payload Module (IPM) for low latency HyspIRI products (GSFC)

# EO-1 Mission Extension

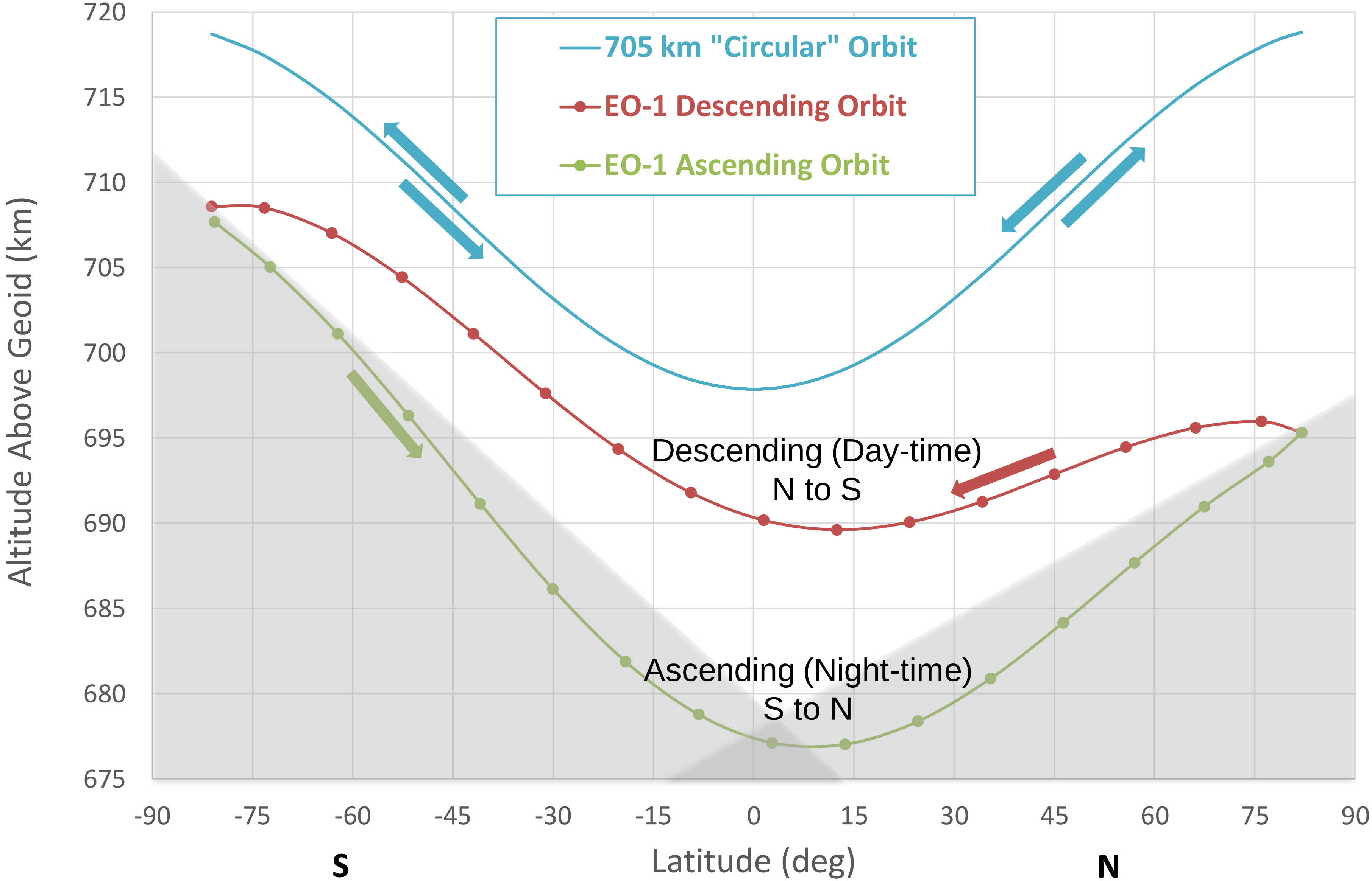
We request an extension of EO-1 because:

- In spite of orbital changes, EO-1 provides unique and valuable data to the science & applications communities and supports SLI, HyspIRI & future mission development.
    - Rapid response
    - Hyperspectral imagery
- The risks are low
- The costs are low

# Topics to be Addressed

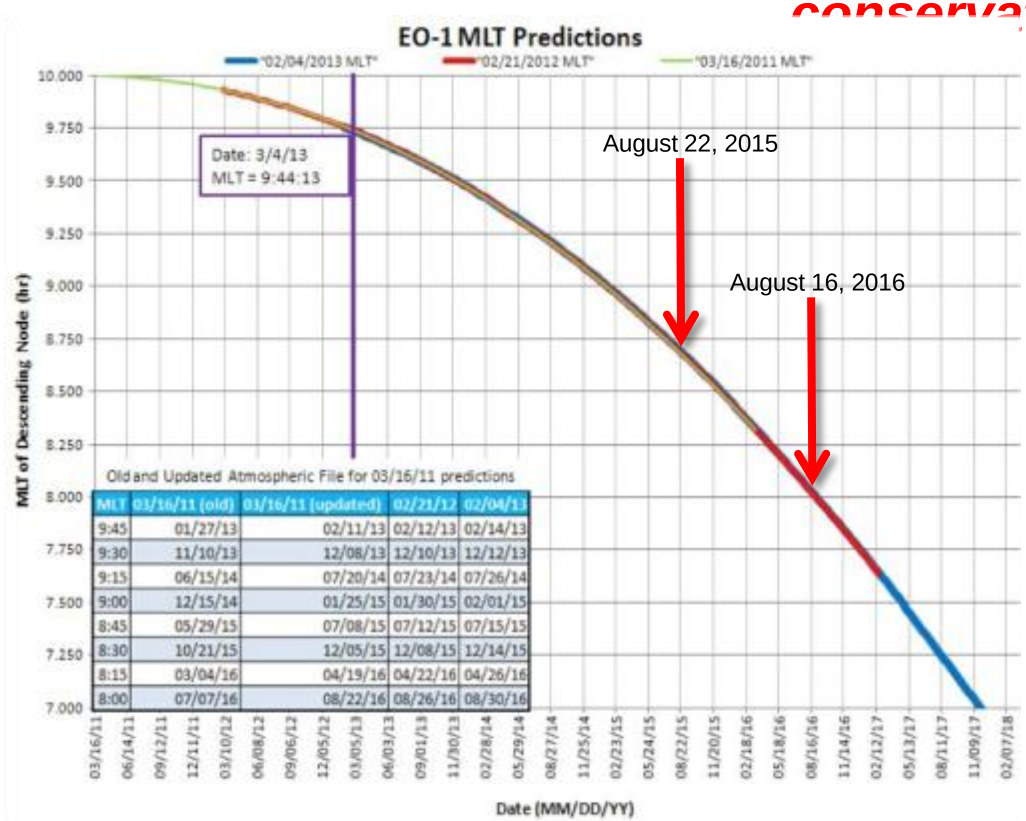
- EO-1 is Still a Valuable Asset:
  - Change in MLT and Illumination
  - Change in Orbit
  - Data Quality
- Reasons to Continue Collections
  - Importance/Usage of Data and Products
  - HyspIRI and SLI Support
- Lunar Lab Concept
- Options for Going Forward

# EO-1 Altitude as a Function of Latitude
(for the first orbit on January 4, 2015)



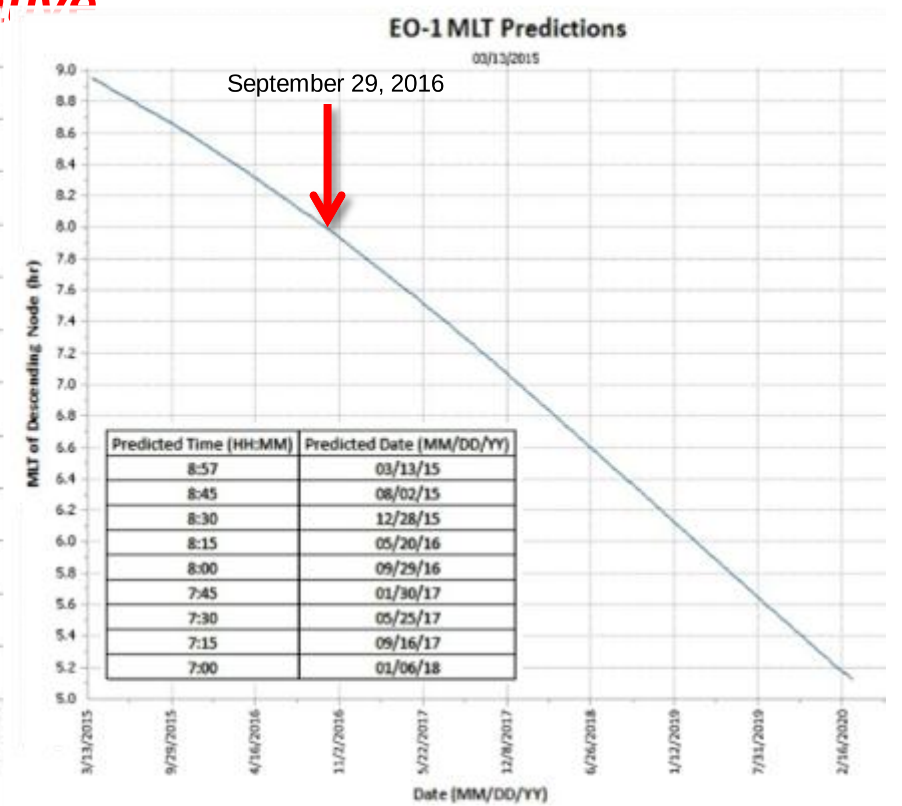
# Comparison of March 2013 Senior Review MLT Projections with March 2015

***Shows orbital projections have been consistent and that earlier predictions were too conservative***




| MLT | 03/16/11 (old) | 03/16/11 (updated) | 02/21/12 | 02/04/13 |
|---|---|---|---|---|
| 9:45 | 01/27/13 | 02/11/13 | 02/12/13 | 02/14/13 |
| 9:30 | 11/10/13 | 12/08/13 | 12/10/13 | 12/12/13 |
| 9:15 | 06/15/14 | 07/20/14 | 07/23/14 | 07/26/14 |
| 9:00 | 12/15/14 | 01/25/15 | 01/30/15 | 02/01/15 |
| 8:45 | 05/29/15 | 07/08/15 | 07/12/15 | 07/15/15 |
| 8:30 | 10/21/15 | 12/05/15 | 12/08/15 | 12/14/15 |
| 8:15 | 03/04/16 | 04/19/16 | 04/22/16 | 04/26/16 |
| 8:00 | 07/07/16 | 08/22/16 | 08/26/16 | 08/30/16 |

***Orbital Projection from March 2013 Senior Review Proposal***




| Predicted Time (HH:MM) | Predicted Date (MM/DD/YY) |
|---|---|
| 8:57 | 03/13/15 |
| 8:45 | 08/02/15 |
| 8:30 | 12/28/15 |
| 8:15 | 05/20/16 |
| 8:00 | 09/29/16 |
| 7:45 | 01/30/17 |
| 7:30 | 05/25/17 |
| 7:15 | 09/16/17 |
| 7:00 | 01/06/18 |

*Orbital Projection from March 2015 Latest Calculations*

**This EO-1 MLT and SMA analysis was independently verified by the Terra, Aqua, Aura Flight Dynamics team.**

# ALI data taken at an 8 AM equatorial crossing time are valuable in spite of the decline in SNR

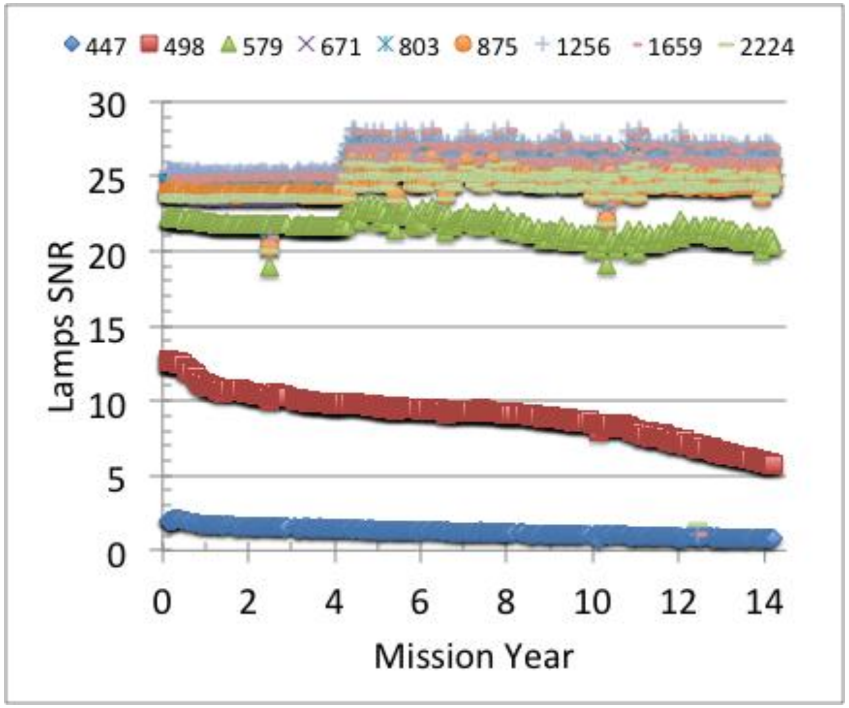
- The ALI SNR is inherently 6 to 10X (~800%) that of ETM+.
- The ALI signal at 8 AM always exceeds 50% of the 10 AM.
- ALI SNR at 8 AM will be 3 to 5X better than that of ETM+ at 10 AM.
- EO-1 will not reach ~8 AM equator crossing time until October 2

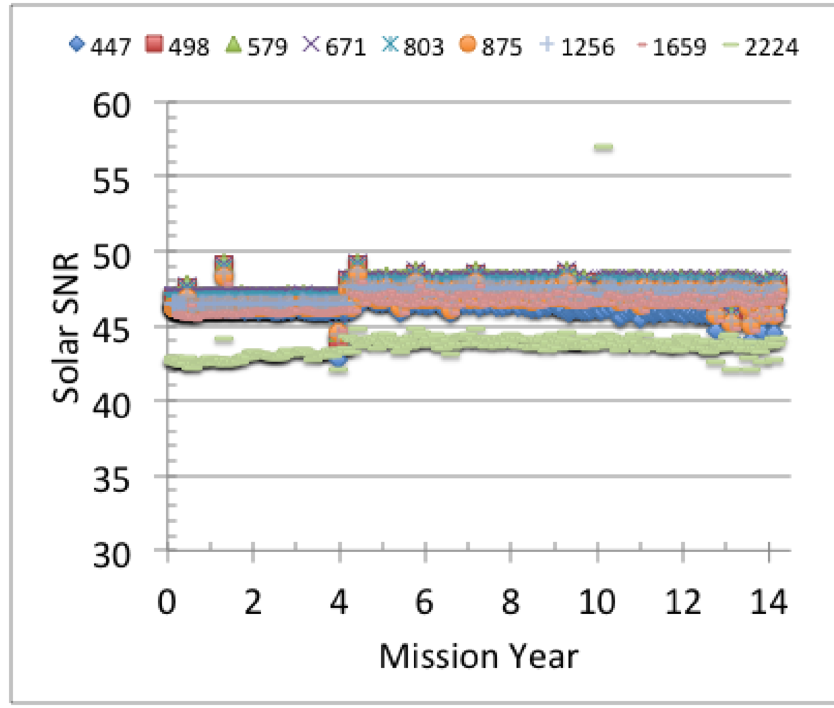
| **Crossing Time at Equator** | **March 22** | | **June 22** | | **September 22** | | **December 22** | |
|---|---|---|---|---|---|---|---|---|
| | Elevation (degrees) | cos(SZA) | Elevation (degrees) | cos(SZA) | Elevation (degrees) | cos(SZA) | Elevation (degrees) | cos(SZA) |
| 8:00 AM | 28.3 | 0.47 | 26.9 | 0.45 | 31.8 | 0.53 | 27.7 | 0.46 |
| 8:30 AM | 35.8 | 0.58 | 33.5 | 0.55 | 39.3 | 0.63 | 34.3 | 0.56 |
| 9:00 AM | 43.8 | 0.69 | 40.1 | 0.64 | 54.3 | 0.81 | 40.8 | 0.65 |
| 9:30 AM | 50.8 | 0.77 | 46.3 | 0.72 | 46.8 | 0.73 | 47.0 | 0.73 |
| 10:00 AM | 58.3 | 0.85 | 52.3 | 0.79 | 61.8 | 0.88 | 52.9 | 0.80 |
| 12:00 PM | 88.14 | 1.00 | 66.57 | 0.92 | 88.17 | 1.00 | 66.57 | 0.92 |
| $\frac{\textbf{Signal@8 AM}}{\textbf{Signal@10 AM}}$ | | **0.56** | | **0.57** | | **0.60** | | **0.58** |

*Signal (i.e. solar irradiance) is a function of the cosine of the solar zenith angle, cos(SZA).*

**Q10.** The presentation slides provided for this SR do not provide much information about current Hyperion performance. I realize Hyperion has degraded, but what is its utility? What does the SNR look like for the hyperspectral bands?

# Hyperion Signal to Noise Ratio (SNR)




**Signal to Noise (SNR) derived from Solar Calibrations. Except in the shortest wavelength where the lamp output is lowest the SNR of the Hyperion has not changed significantly over the mission. The reduced lamp output in the shortest wavelengths is reflected in the apparent downward trend of the lamp SNR below the 579 nm bands show in the plot. The causes for increase in variability after Year 4 is currently unknown.**

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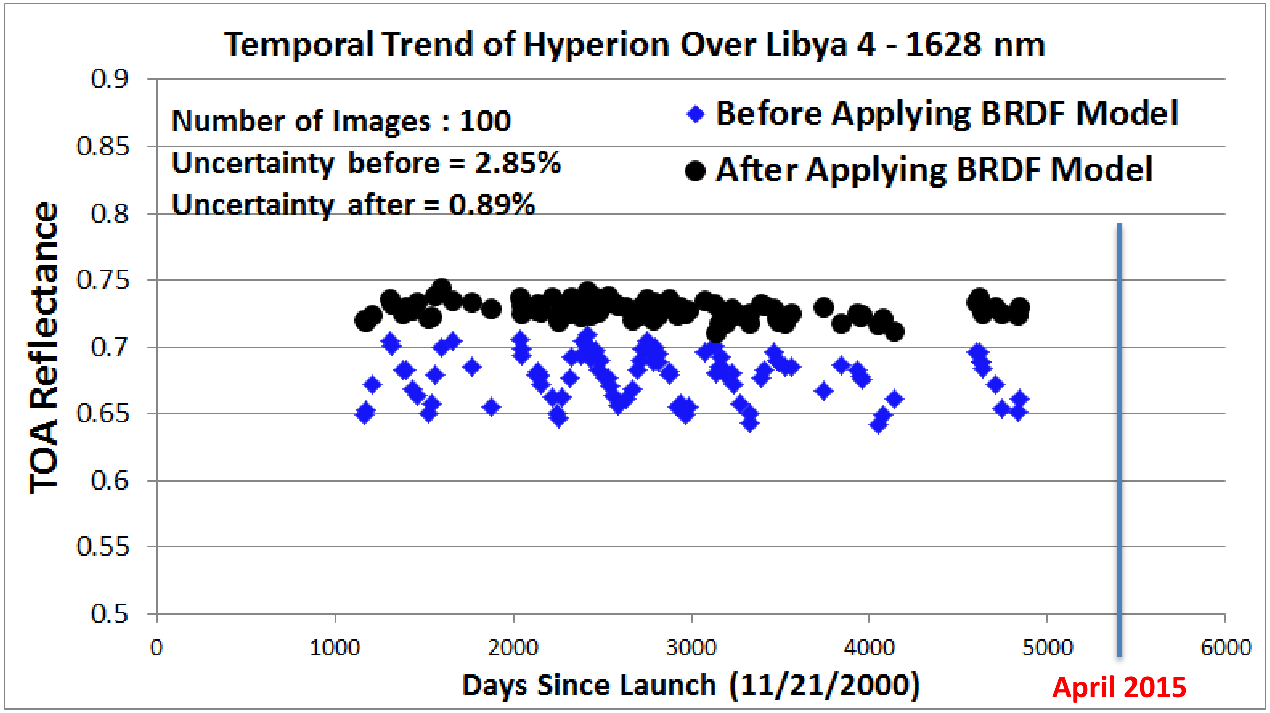
# The Long Term Stability of Hyperion




- In order to do a SBAF correction hyperspectral data is needed for calibration site. Only instrument currently collecting is Hyperion. Therefore the stability of the sensor is crucial to the study.
- Its long term stability is monitored by trending it regularly over PICS.
- Acquires images regularly over Libya 4 PICS and had off nadir capabilities too
- Trends spectral regions with high transmittance SWIR channel indicate the sensor to be stable than sub 1% when nadir scenes are used.

*Helder, et al. 2015*

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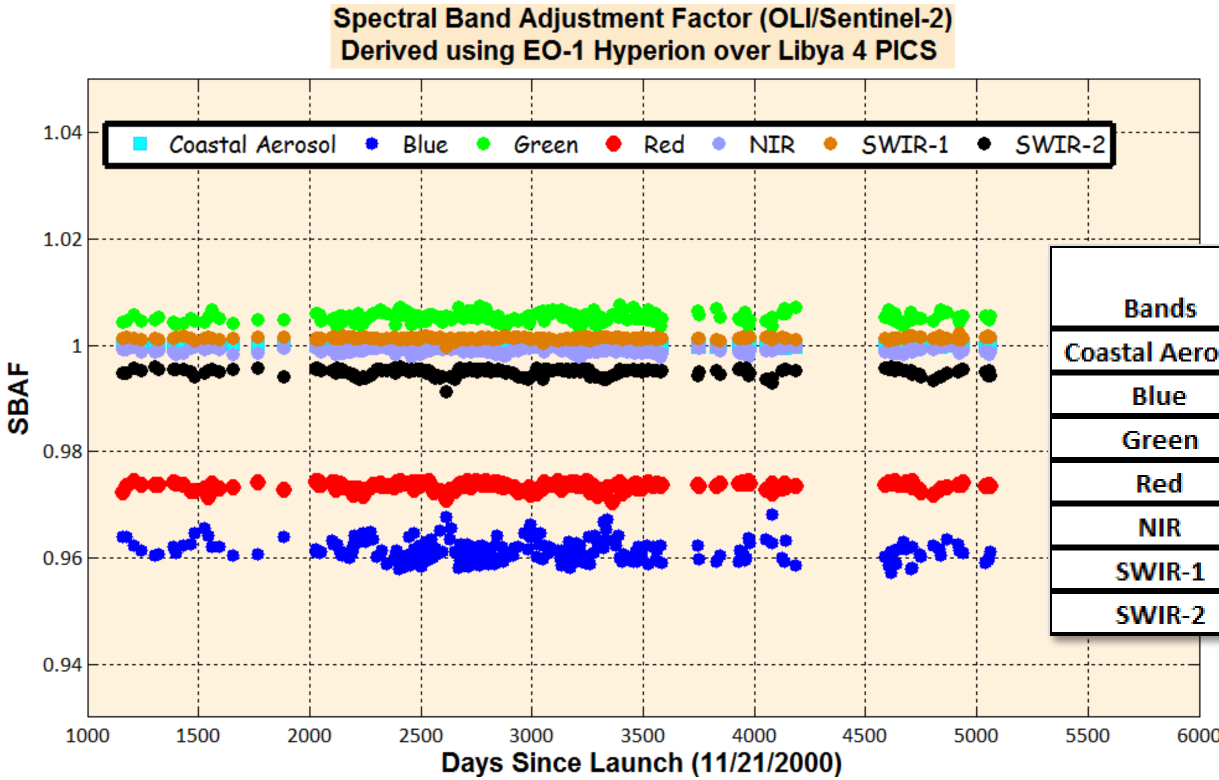
# The Long Term Stability of Hyperion




| Bands | Avg. SBAF | Uncertainty (Stdev/ Mean)% |
|---|---|---|
| Coastal Aerosol | 1.000 | 0.02% |
| Blue | 0.961 | 0.21% |
| Green | 1.005 | 0.08% |
| Red | 0.974 | 0.07% |
| NIR | 0.999 | 0.05% |
| SWIR-1 | 1.001 | 0.02% |
| SWIR-2 | 0.995 | 0.07% |

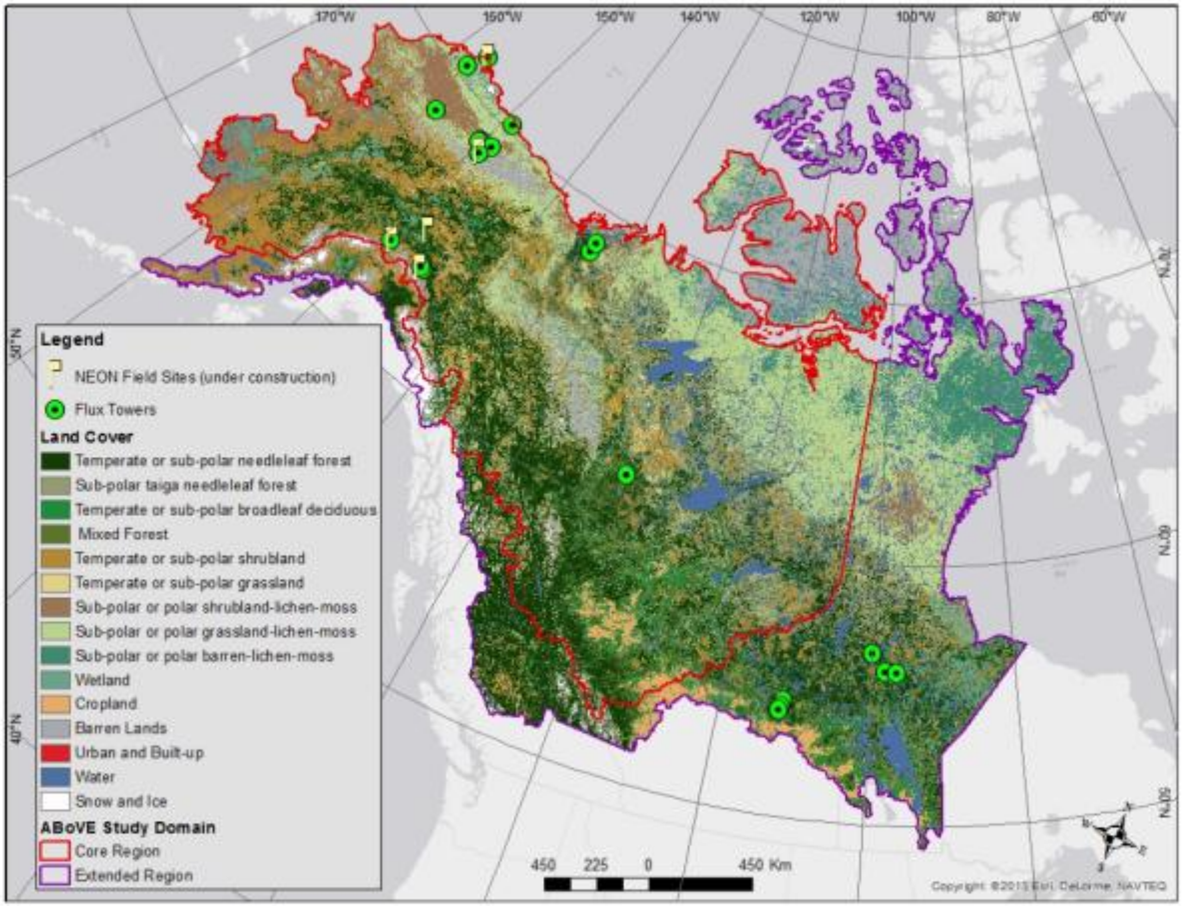
- The alternative way to understand the assess the stability of Hyperion is to perform a SBAF time series study.
  - Figure shows the SBAF (OLI/S2) stability is better than 0.1% for last 12 years (except for blue band).
  - This would also mean that constraint on simultaneous image pair based cross calibration can be relaxed to take advantage of the long term stability of the site,
  - Stability also reduces the impact of an eventual loss of Hyperion.

*Helder, et al. 2015*

# EO-1 and Arctic-Boreal Vulnerability Experiment (ABoVE)

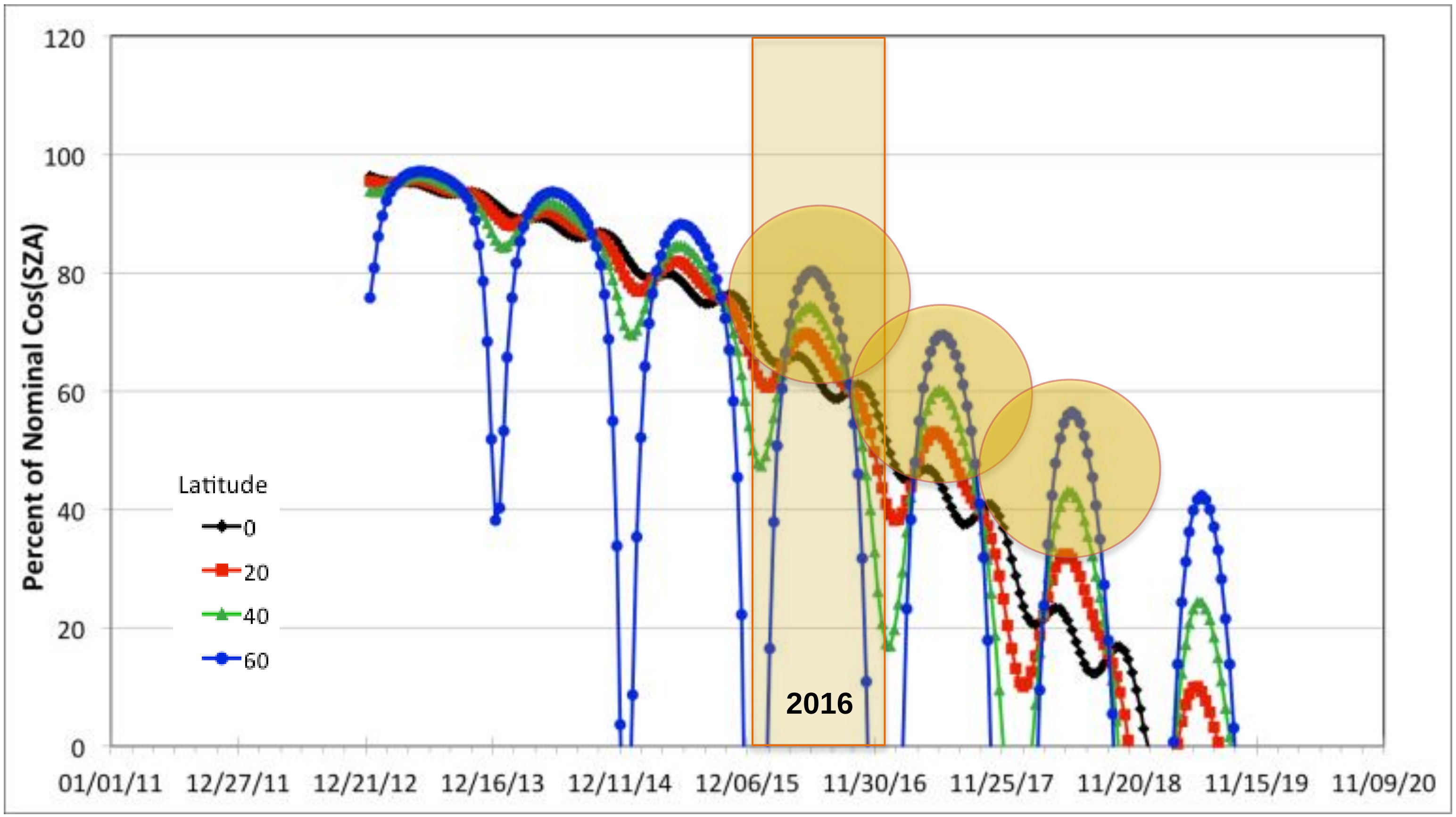
ABoVE is a NASA Terrestrial Ecology field experiment to study the vulnerability and resilience of ecosystems and society to environmental change in the Arctic and boreal region of western North America.

- The first full year of field activities is planned for 2016.
- Aircraft operations will not start until 2018.
- Changes in solar elevation angles at EO-1 overpass times are less affected at high latitudes, making EO-1 still useful for ABoVE.



**Q12.** Please provide specific details of when and how the EO-1 team will provide support for the ABoVE project. Are there data quality issues (e.g., SNR) at high latitudes? What is the impact on this effort if EO-1 is extended but must decommission in 2017?

# ABoVE: Arctic-Boreal Vulnerability Experiment




*At high latitudes in 2016, there is 80% of the incident radiance compared to the nominal 10:00 AM overpass case.*

# EO-1 Hyperion Simulating Multispectral Sensors Example: Landsat 7 ETM+

*From: Thonfeld et al. 2014*

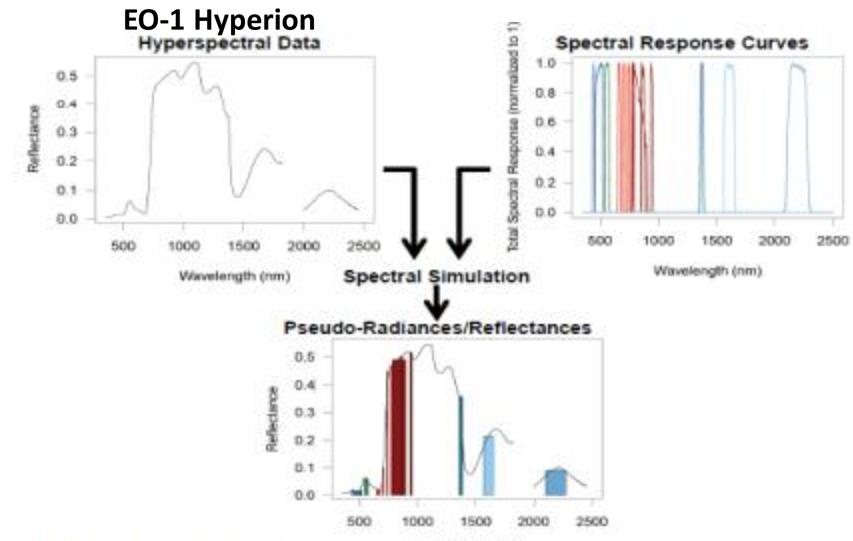
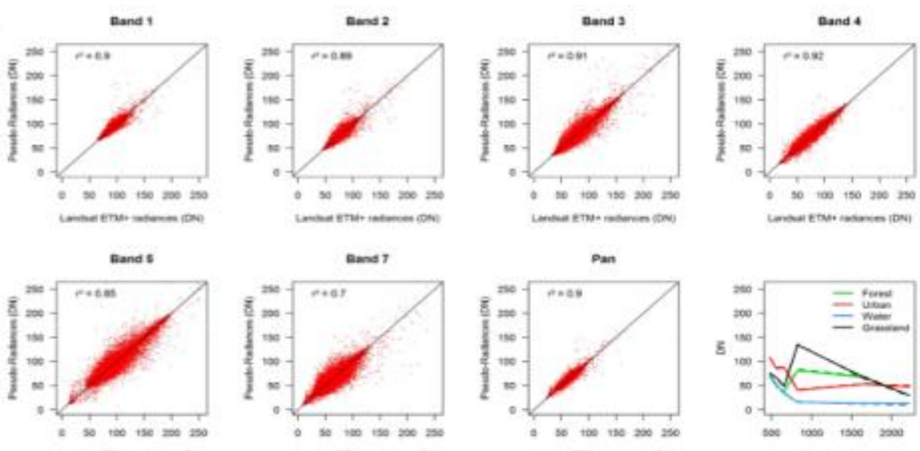



**Fig. 1**: Workflow of data simulation.

## Evaluation example no. 2 - Paris

Landsat 7 ETM+ data are simulated from Hyperion spaceborne hyperspectral data and compared with real ETM+ data from the same day (2002-07-29). There is good agreement between the images (Fig. 3). However, variations occur in heterogeneous settings due to geometric divergences, which is indicated by low correlations values along object borders.



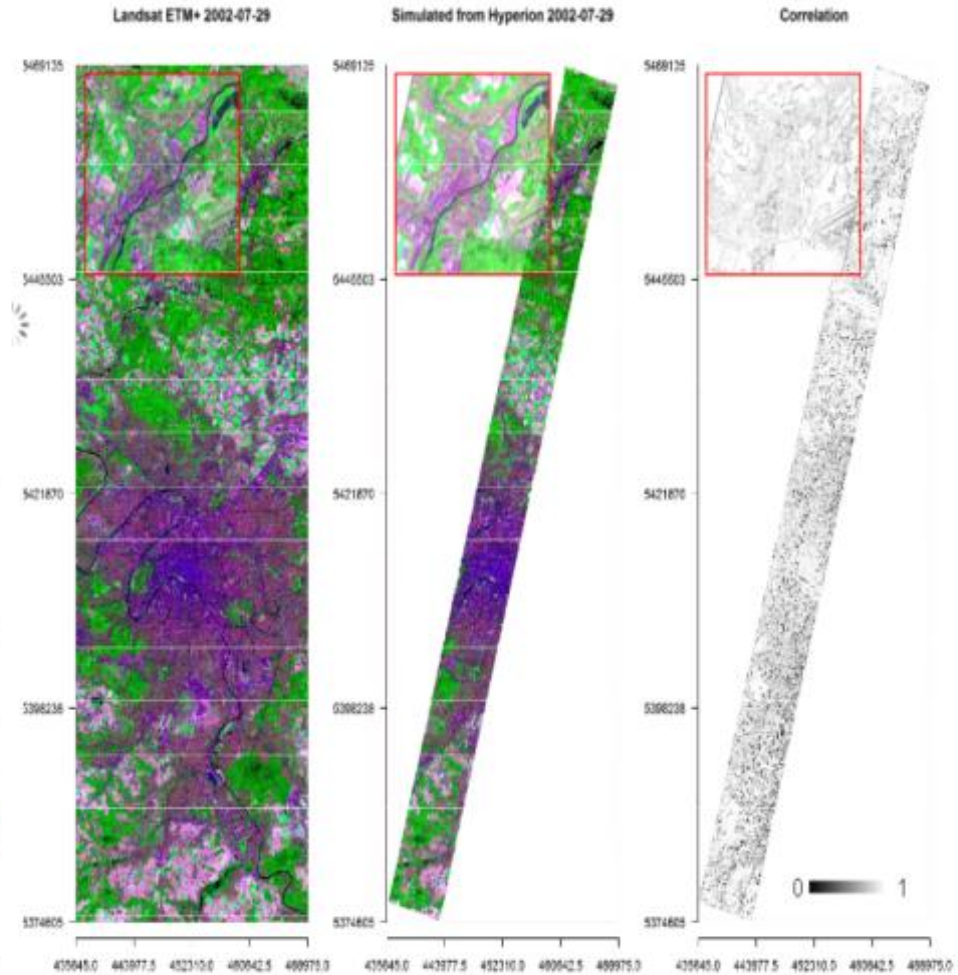




**Fig. 3**: Subset of Landsat ETM+ Paris, 2002-07-29, RGB = bands 7, 4, 2 (left), same scene simulated from Hyperion (mid), and correlation of both images (right). Low correlation values along the borders of land cover objects indicate poor geometric agreement between the images. The scatter plots show good agreement. Divergences can be related to geometric inaccuracies. The spectra of simulated data (dotted lines) correspond well to Landsat ETM+ (solid lines).

# Improved Cross Calibration Approach for Solar Reflective Bands

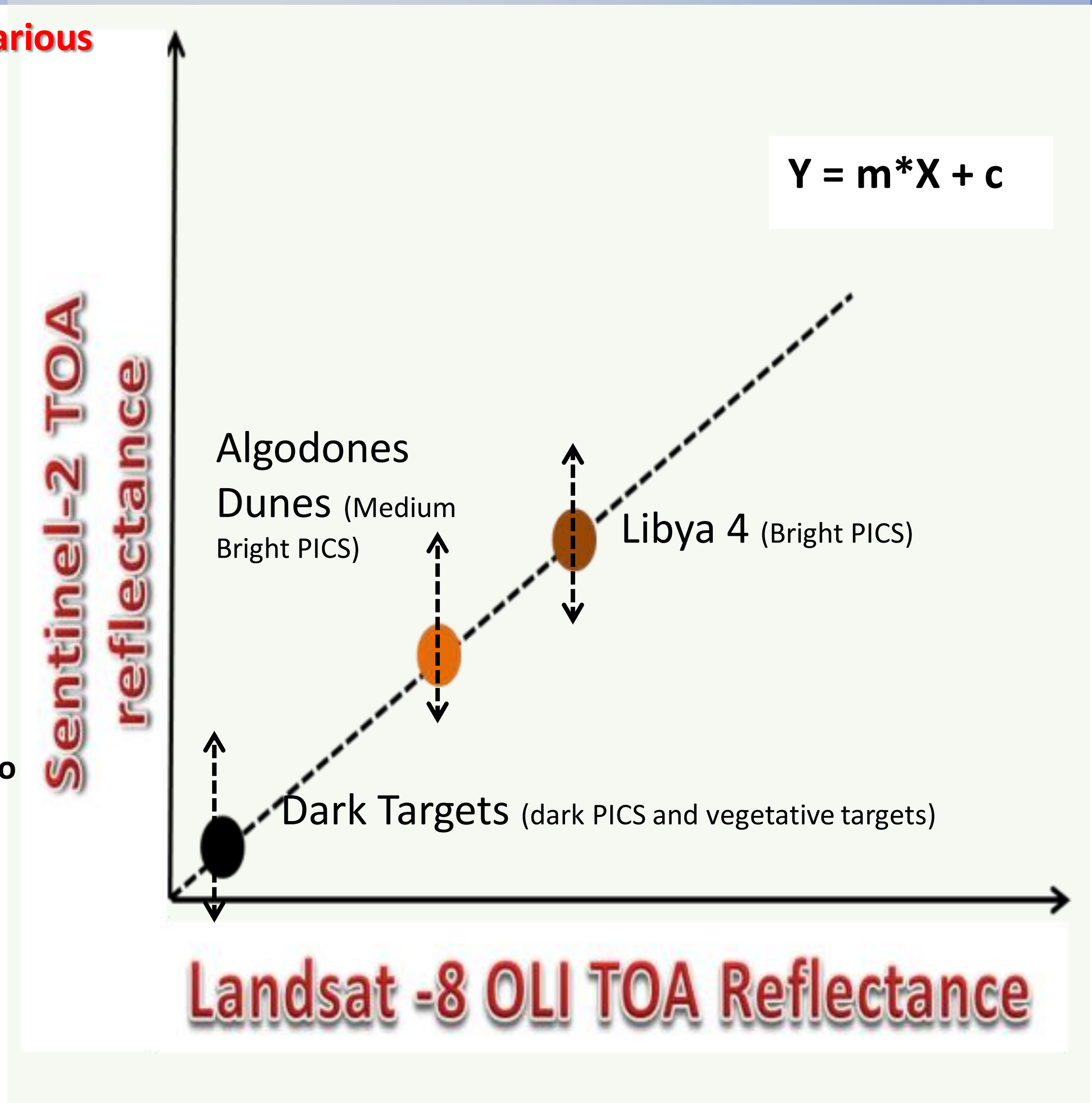
**On-orbit calibration: Use of PICS sites, vicarious campaigns, and global averaging**

- **<u>For ground reflected solar bands</u>:**
  **Provide a two point cross calibration that include bright and dark PICS along with characterized vegetated targets**

- **Use a linear regression but weigh the regression line with the uncertainties.**

- **For bands withatmospheric scatter or absorption: SDSU & LaRC developed a Deep Convective Cloud (DCC) based inter-band calibration**
  **Using hyperspectral data to do a inter-band cross calibration, using VNIR bands to calibrate CA and Cirrus Bands.**

- **Sentinel-2 does not have a thermal band.**




D. Helder, N. Mishra, L. Leigh and D. Aaron. Update on Pre-Cursor Calibration Analysis of Sentinel 2. April 23, 2015 - LCLUC

**Q3.** There were recurring comment and recommendations from the 2009, 2011, and 2013 SRs such as: 1) L2 products not well developed, 2) web-based distribution immature or incomplete, and 3) unknown user-base and process to acquire data. Because the 2011 and 2013 proposals are similar, it remains unclear as to the response/status of these issues. Please clarify with specific examples of what has been accomplished and when and the current status.

# EO-1 Data Products

Standard **EO-1 Level 1** data products are currently distributed **by USGS** as 16-bit scaled radiance values:

- Level 1R , Hyperion and ALI: *Radiometrically* corrected.
- Level 1G, AI: *Geometrically* corrected to Earth spheroid.
- Level 1Gst, Hyperion and ALI: *Geometrically and terrain* corrected through use of a Digital Elevation Model (DEM).
- (New) Level 1T, Hyperion and ALI: Co-registered with Landsat Global Land Survey

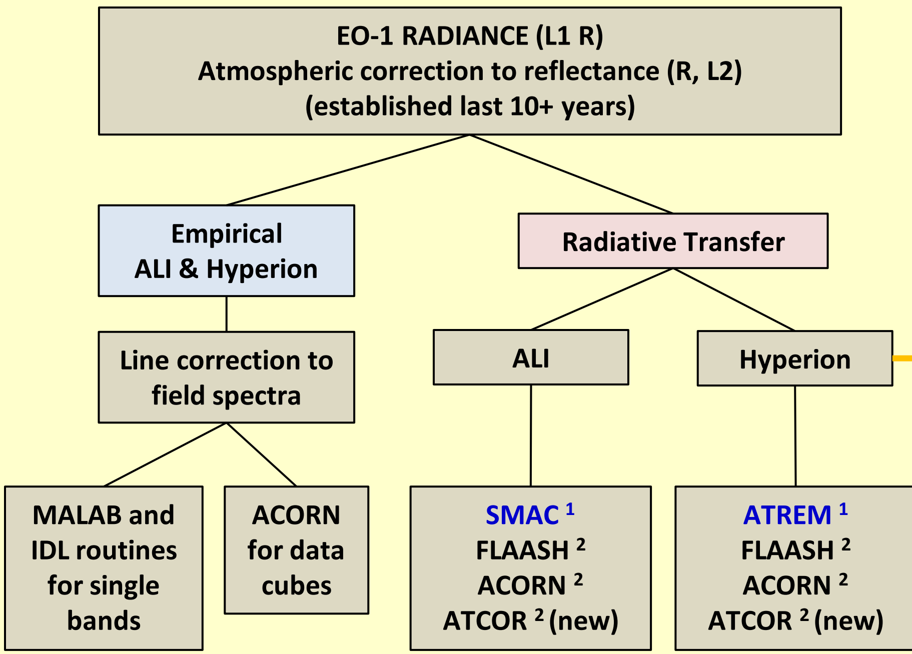
New **EO-1 Level 2** data products:

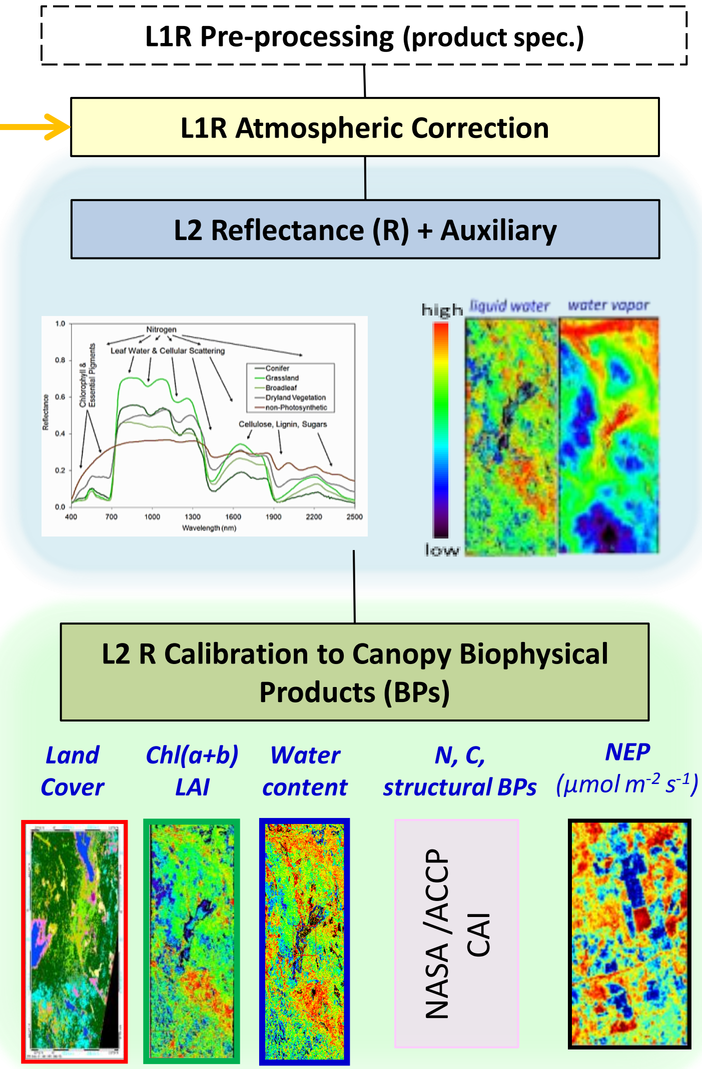
- All Hyperion Level 1R images are atmospherically corrected automatically using FLAASH. Products for 2014-2015 are available at ftp://matsu.opensciencedatacloud.org/. Previous years of data (Level 1 & 2 products) will be added as the Matsu Cloud adds additional storage hardware.
- Fire (detection, severity and temperature); Flood (extent, water quality) for first responders.

**Q3.** There were recurring comment and recommendations from the 2009, 2011, and 2013 SRs such as: **1) L2 products not well developed…**

**Q9.** Are there any consensus processing protocols established for ALI or Hyperion? Are they published?

## Reflectance Processing Protocols Established for ALI and Hyperion Level 2 Products





1. **6S: Second Simulation of a Satellite Signal in the Solar Spectrum**. Vermote, E.F., D. Tanre, J.L. Deuze, M. Herman, and J.J. Morcrette (1997b). Second simulation of the satellite signal in the solar spectrum, 6S: An overview, *IEEE Transactions on Geoscience and Remote Sensing,* 35:675–68.

2. **MODTRAN**. Berk, A., G.P. Anderson, L.S. Bernstein, P.K. Acharya, H. Dothe, M.W. Matthew, S.M. Adler-Golden, J.H. Chetwynd, Jr., S.C. Richtsmeier, B. Pukall, C.L. Allred, L.S. Jeong, and M.L. Hoke (1999). MODTRAN4 Radiative Transfer Modeling for Atmospheric Correction, *SPIE Proceeding, Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research III*, Volume 3756.

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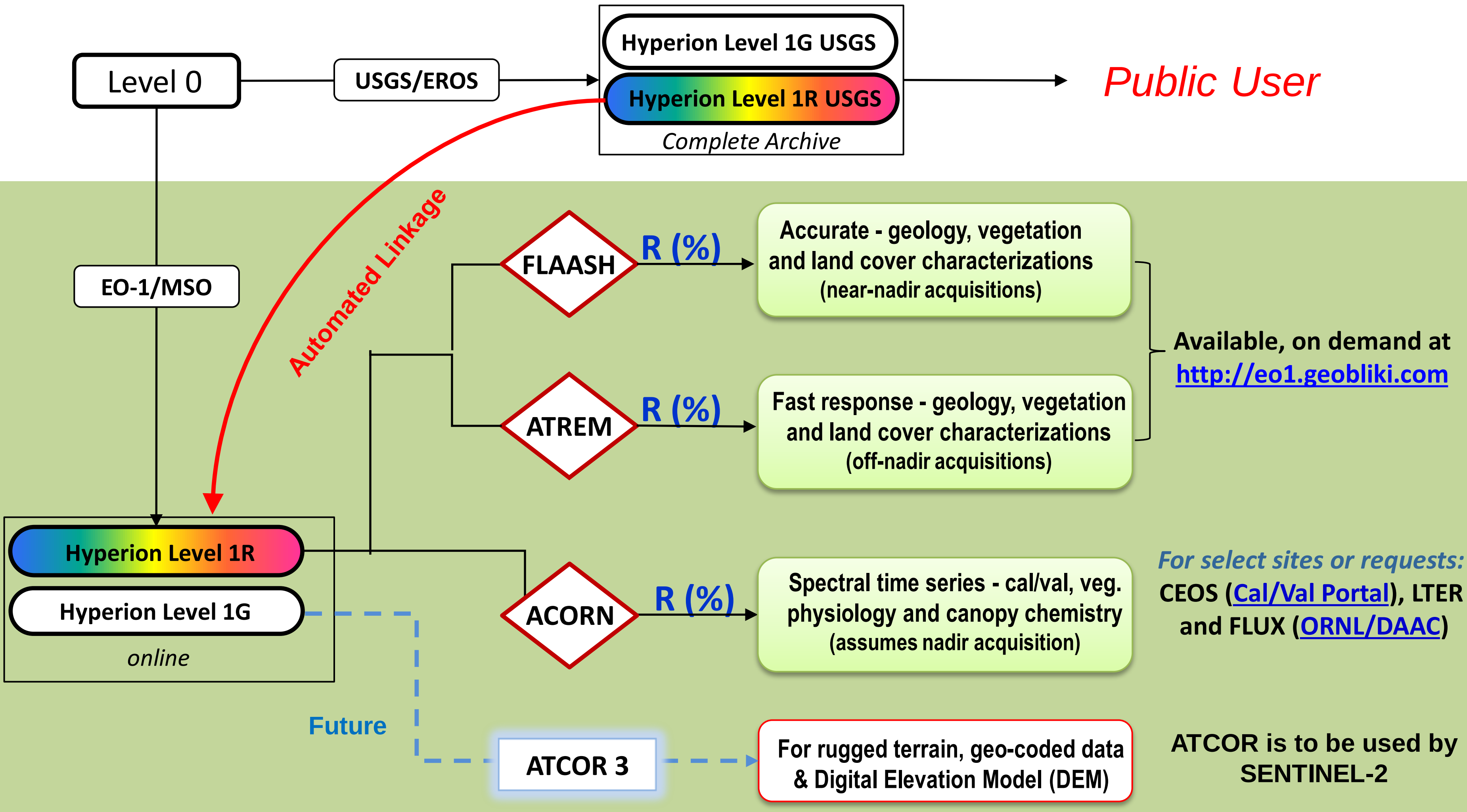
# *Current* Hyperion Level-2 Surface Reflectance Products




*Atmospheric CORrection (ATCOR 3)*

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**Q16.** Expand on current project data distribution activities and how data distribution has evolved or changed since the 2013 SR. Please clearly address progress made with examples and plan forward.

## 2) Web-Based Distribution:

There are currently **five ways** for users to get EO-1 data products (all at no cost):

1. **USGS EarthExplorer Website** (http://earthexplorer.usgs.gov/)
   The site contains the entire archive of Level 1 data from 2001-2015. USGS will continue to process incoming EO-1 data to Level 1 and make it available to all users.

2. **Matsu Cloud Storage, University of Chicago** (ftp://matsu.opensciencedatacloud.org/)
   Level 2 atmospheric correction is being run routinely on all Hyperion Level 1R data using the FLAASH software package. These products are available under the hyperion_l1r_ac folders for 2014-2015.
   - There were some cloud hardware problems in the last 2 years. The old hardware held all of the EO-1 data (14 years' worth). With the new storage upgrades, the problems have been resolved, but there is now limited storage, meaning only recent EO-1 data is currently available. In the future, more storage hardware will be added and the rest of the EO-1 catalog will be online.

3. **GSFC GeoBPMS/Matsu Website** (http://matsu-wcps.opensciencedatacloud.org/wcps/)
   Numerous algorithms for both ALI and Hyperion Level 1G data have been implemented in WCPS (Web Coverage Processing Service) and are available for on-demand execution at the GeoBPMS Web site. Using this interface, approved users can edit existing algorithms or create new ones to run on any EO-1 data stored in the Open Science Data Cloud (Matsu, item 2 above). In the future, this will be expanded even more, adding additional algorithms, more images in the Matsu Cloud, and easier access for more approved users.

4. **JPL Website** (https://ai.jpl.nasa.gov/public/planning/eo1/operations/findobservations.cgi)
   All EO-1 data are processed by JPL, but access to the Website is password protected and only authorized users can obtain a login. To become an authorized user, contact Steve Chien or Danny Tran. Volcano SensorWeb and JPL science users typically have access to this site to check on data delivery status and product availability. The site also contains experimental products that are not ready to share with the general public.

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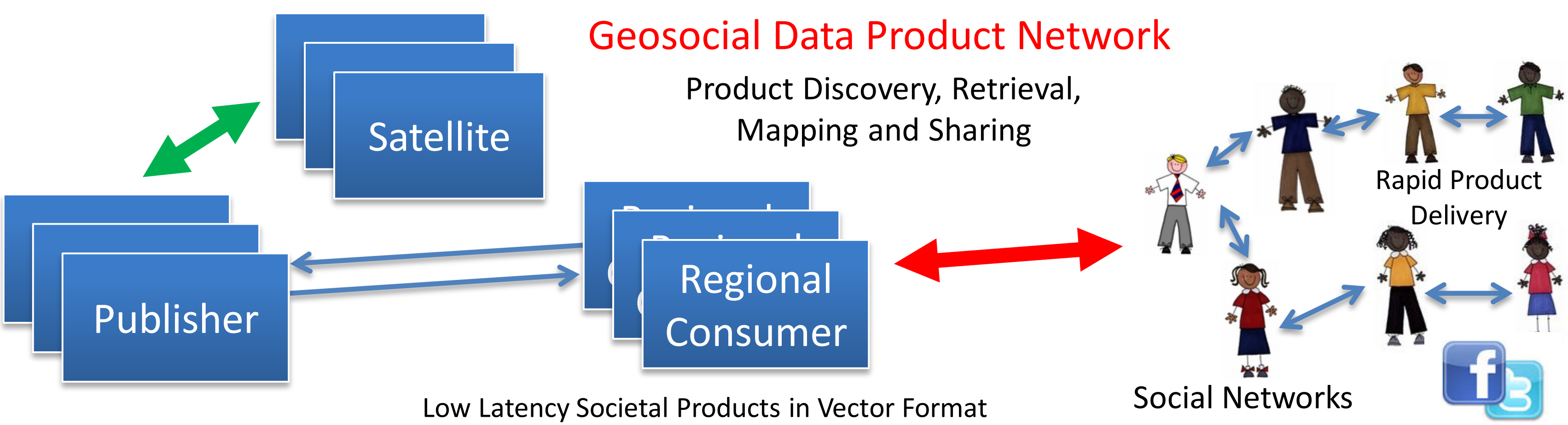
There are currently **five ways** for users to get EO-1 data products (all at no cost):

5. **Regional GeoSocial API Publisher/Consumer Network**
   This is a *NEW* method to distribute EO-1 and other satellite data products in a compact vectorized format (small data size). The vision is to have a network of regional publishers (e.g. Namibia) automatically pre-generate specific satellite data products for a region and then make them available to all consumers. The user obtains the data product by doing a Web browser query based on latitude-longitude. The publisher then provides the user a list of the available products in the region. The user clicks on the ones he/she wants to map and the vectorized data is downloaded to their computer, tablet, or smartphone for display. In the future, it will be possible to share the products via Facebook or other social media.



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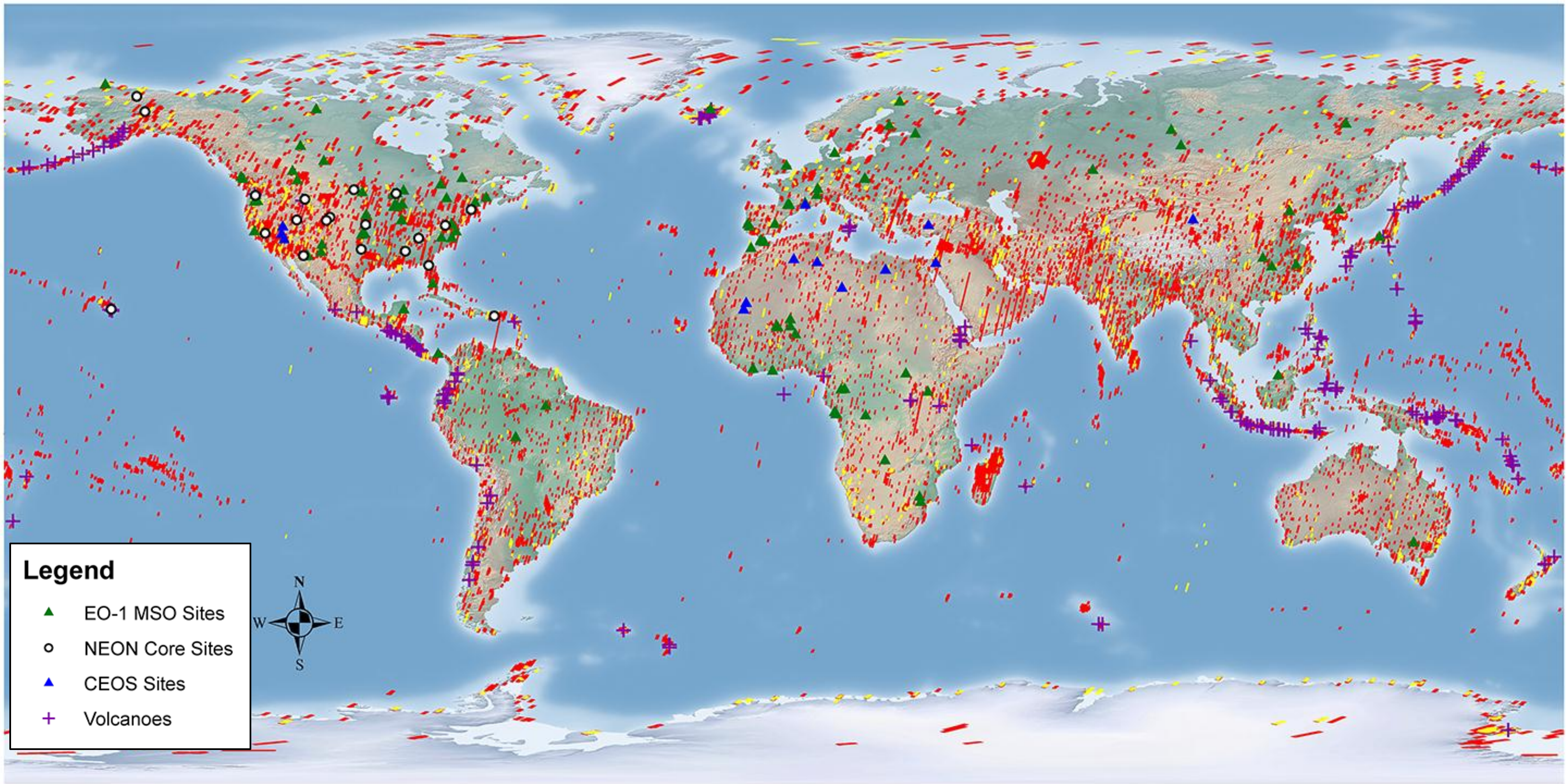
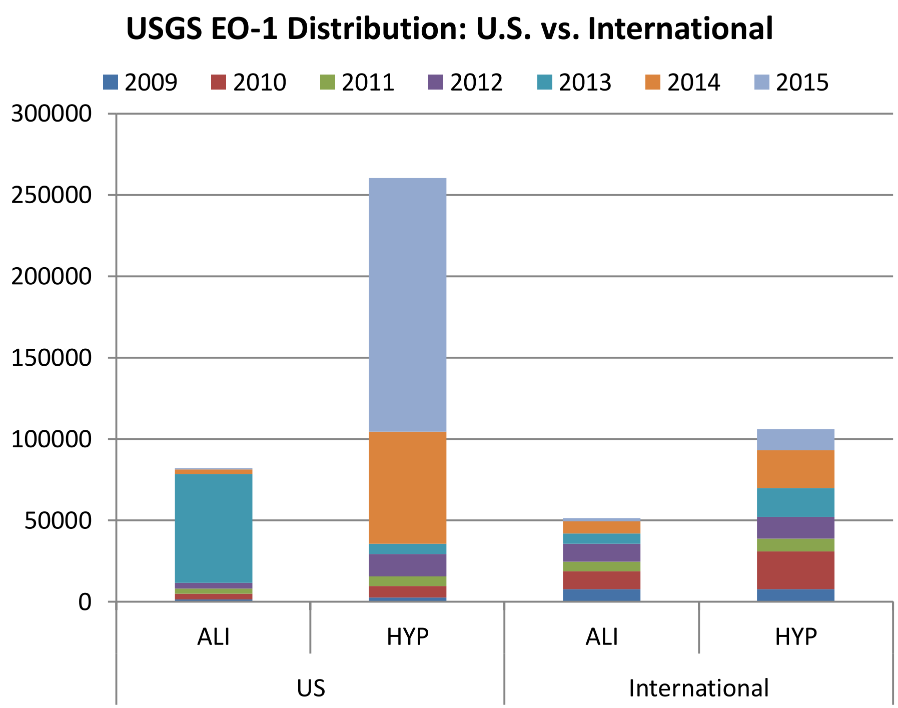
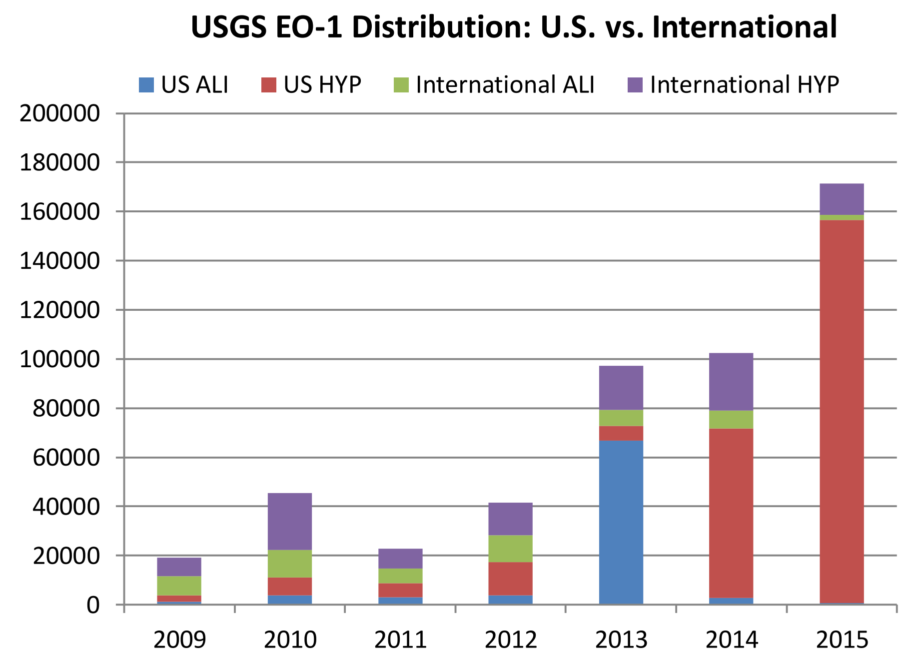



EO-1 has collected nearly 80,000 ALI and nearly 80,000 Hyperion images (as of April 2015). The user community includes science users, disaster, technology development, volcanoes, etc.

## **Q5.** What is the proportion of active US vs. International users?

| | | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| US | ALI | 1276 | 3818 | 2980 | 3737 | 66704 | 2854 | 723 |
| | HYP | 2503 | 7363 | 5901 | 13679 | 6165 | 69003 | 155765 |
| International | ALI | 7748 | 11055 | 5895 | 10844 | 6543 | 7196 | 2150 |
| | HYP | 7572 | 23156 | 7984 | 13339 | 17792 | 23276 | 12807 |

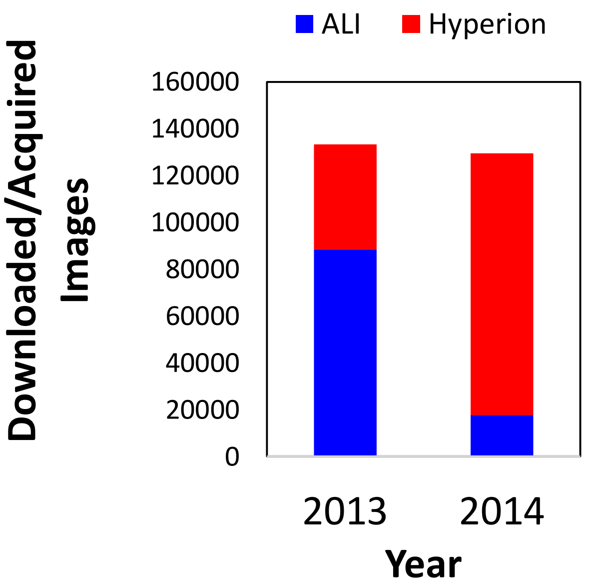



**USGS Accomplishments for EO-1:**

- In the 2012 time frame, USGS released the new L1T product along with the "GIS Bundle" allowing for users to download 3-band, GIS-ready JPEG bundles of the imagery.
- In 2013, USGS introduced the Bulk Download Application (BDA) tool which allowed users to download data through a GUI with little to no interaction.
- In 2014, USGS created a Machine-to-Machine (M2M) interface that allowed authorized users the ability to script downloads while still allowing metrics to be captured. In addition to M2M, USGS also saw a larger increase in the demand of bulk media copies, where users sent in hard drives and the entire USGS EO-1 collection was copied and sent back to them.

**Q6.** Now that Landsat OLI is operational and performing well, what are the current activities that ALI currently supports – please provide statistics to show recent support for individual users? What is the level of effort to support ALI compared to Hyperion?




- There was a large drop in ALI downloads from 2013-2014 after L-8 became available, but there was an equally large increase in Hyperion downloads in 2014.
- For the GLS2010 EO-1 collected a large number of islands and shallow water bodies, which are currently of interest for aquatic studies.

**Level of effort to support ALI vs. Hyperion** – 50/50, the level of acquisition support effort is equal because both instruments are ON during every collect, and different for post-processing, depending on the output product produced.

**Larger EO-1 users include**: The disaster support, "cloud prediction support" study for GeoCape (Decadal Survey Mission), EnMAP pre-launch support (Hyperion), Landsat 8 support, science requests for time series and/or large scale mapping for: mineralogy, tropical spectral diversity, terrestrial ecology, signal processing and Sentinel-2 and EnMAP simulations.

**Q8.** Hyperion has served as a test bed for future hyperspectral imagers and the 2013 proposal states that a primary reason to continue Hyperion is to support HyspIRI. Also in the 2013 proposal, it was stated that "During the 2013 and 2014 intensive HyspIRI Airborne Campaign, the EO-1 project is planning to collect Hyperion and ALI scenes contemporaneously with the airborne acquisitions, to facilitate the simulations of space-borne HyspIRI data and to test large scale spectroscopic methods (e.g., spectral feature analysis, canopy chemistry and mineral identification). Spectral libraries will be compiled and the developed calibration approach will be used in pre-launch simulations and to generate prototype products for HyspIRI and other future missions (esp. EnMAP, EU/DLR for launch in 2017)." Was this accomplished? If so, please highlight your findings and provide references to publications.

Hyperion augmented AVIRIS in the 2013-2014 HyspIRI Airborne Campaign in California.

Recent Hyperion Images over AVIRIS Flightlines:

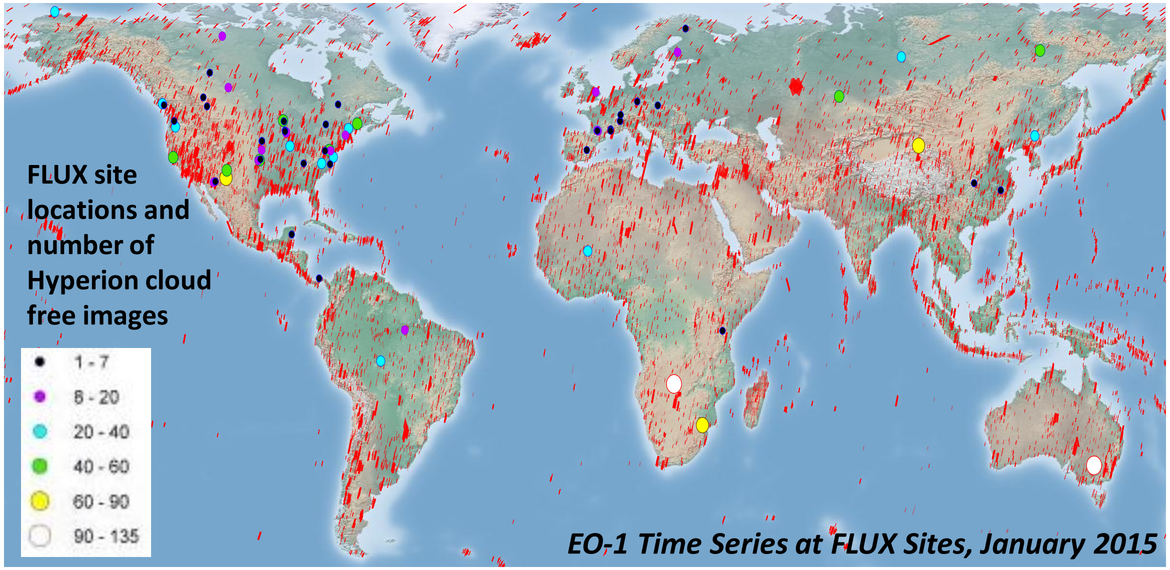
- 2014-04-05 T17:12Z
- 2014-04-06 T17:49Z
- 2014-04-16 T17:24Z
- 2014-05-08 T17:47Z
- 2014-10-07 T17:26Z
- 2014-10-13 T17:50Z
- 2014-10-28 T17:09Z
- 2014-11-02 T16:56Z
- 2014-11-03 T17:31Z
- 2014-11-05 T17:09Z
- 2014-11-17 T17:52Z
- 2014-11-25 T17:49Z

## The HyspIRI Airborne Campaign

***AVIRIS and Hyperion Overflights, April 2013, CA***

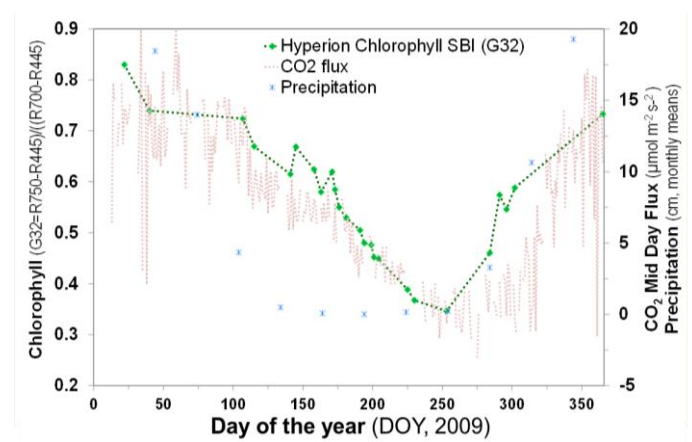

Hyperion (colored vertical bars) was used along with AVIRIS (red lines are AVIRIS flightlines) in support of the HyspIRI Airborne Campaign.

# EO-1 Hyperion Tracing Spectral Dynamics of Ecosystem Function

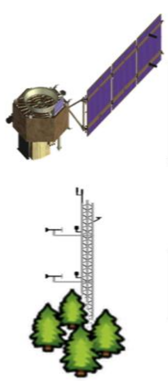



*EO-1 Time Series at FLUX Sites, January 2015*

***EO-1 Hyperion: Spectral Time Series for Vegetation Function, Mongu, Zambia***

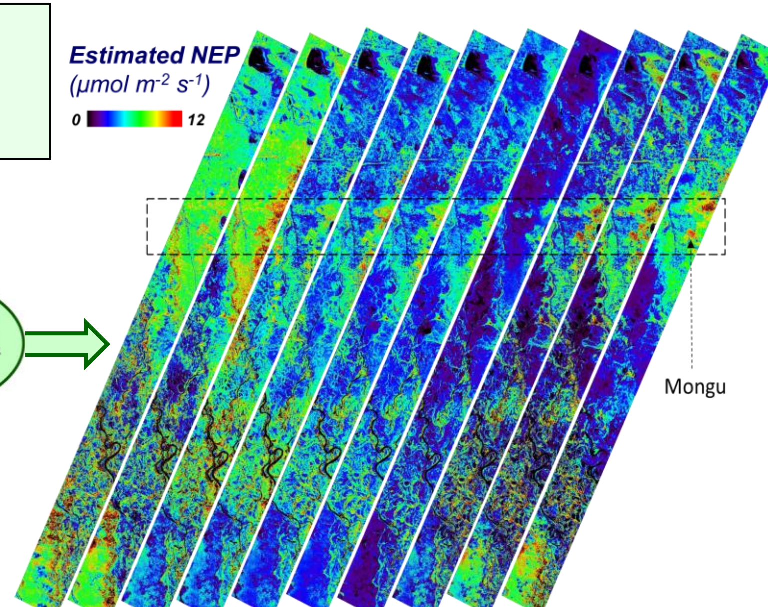



**Unique spectral measurements capturing the seasonal dynamics of ecosystem function are possible because of EO-1 Hyperion's spectral stability and ability to collect repeated coverage**



EO-1 Hyperion seasonal time series (TOA rad) → Atmospheric correction, Pre-processing (TOC reflectance) → Hyperion Spectral Bio-Indicators (SBIs) → Relationship between $CO_2$ FLUX parameters & Hyperion SBIs

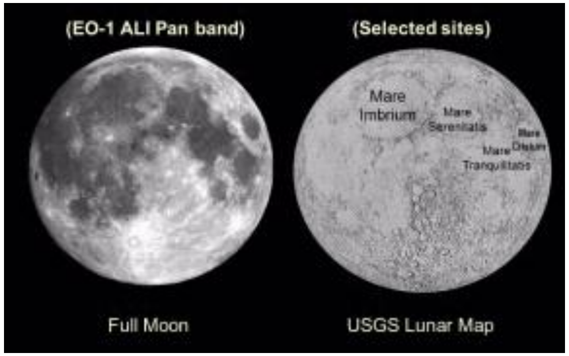
FLUX tower measurements ($CO_2$ flux, $\mu mol\ m^{-2}\ s^{-1}$) → $CO_2$ FLUX parameters (**NEP**, GEE, etc.) → Relationship between $CO_2$ FLUX parameters & Hyperion SBIs



# Current Lunar Acquisitions

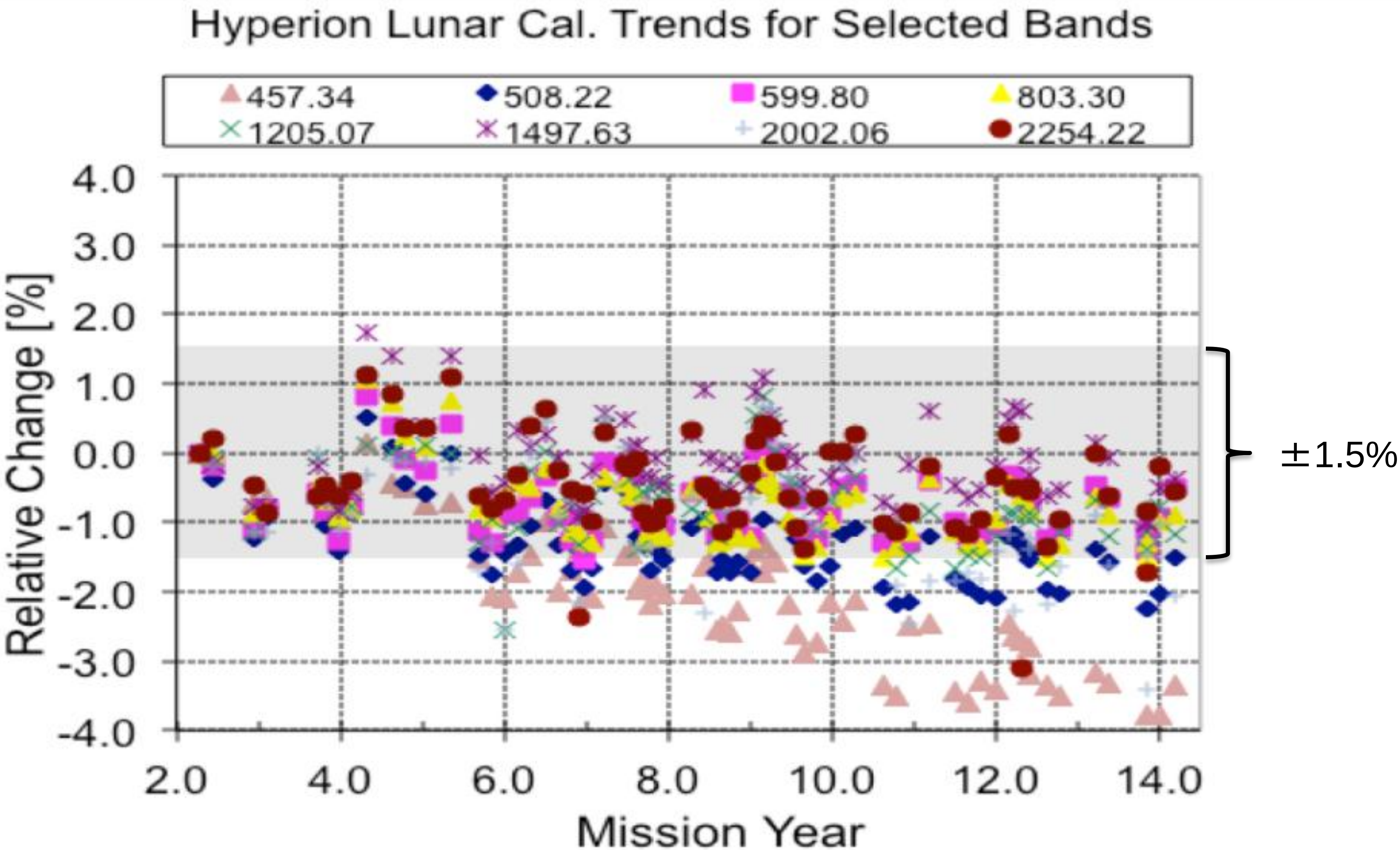
## Current Lunar Collections

- Early in the EO-1 mission, Hyperion lunar observations were collected at 7 different phase angles. These collects clearly indicated a spectral and radiometric dependence on phase angle. This result has been included in several EO-1 calibration presentations over the years. However, a monthly lunar observing scheme was adopted for consistency with other lunar observing missions.
- **Once per month since 2001, EO-1 Hyperion and ALI have each collected nominal 8X oversampled lunar images at *fixed phase angle of ~7.5 degrees* (<1 day after full moon).**
  - **The monthly integrated ALI and Hyperion lunar responses are compared with the USGS RObotic Lunar Observatory (ROLO) lunar model to monitor the EO-1 lifetime trends.**
  - **This will continue to the end of the mission.**




- **A comprehensive analysis of the existing 14 year EO-1 collection of monthly (plus some additional) lunar acquisitions will be evaluated.**
- In light of future mission needs, the relationship between moon phase angle and spectral changes for selected channels requires further investigation.
  - A new lunar acquisition strategy was initiated in late 2013 which enables Hyperion observations of radiometrically stable lunar features at a slower pitch rate – at fixed phase angle of ~7.5 degrees.
  - The resulting lunar images are 32X oversampled to provide higher effective spatial resolution in the along-track direction.

**Q10.** The presentation slides provided for this SR do not provide much information about current Hyperion performance. I realize Hyperion has degraded, but what is its utility? What does the SNR look like for the hyperspectral bands?




This figure shows the results from trending of the lunar calibration data over the mission duration. The current figure normalizes the data to the first data point which are expressed as percent change. The plot shows that, except for the shortest wavelength in the VNIR focal plane, the Hyperion is stable to within ±1.5%.

# Hyperion Lunar Calibration Activities

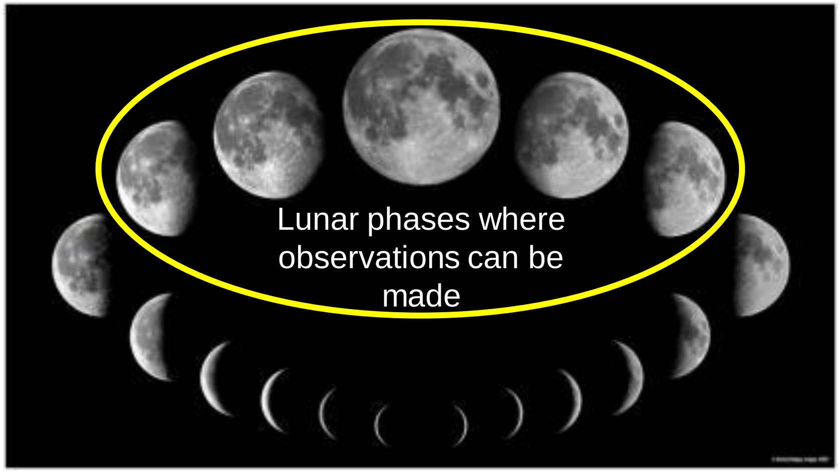
Hyperion is **now being** used to slowly scan the lunar surface at a rate which results in a **32X** oversampling to **effectively increase the SNR**. Several strategies, including comparison against the USGS RObotic Lunar Observatory (ROLO) model, will be employed to **estimate the absolute and relative accuracy** of the measurement set.

*There is an existing need to **resolve discrepancies as high as 10% between ROLO and** solar based calibration of **current NASA EOS assets**. Analysis of this dataset will lead to the development of strategies to ensure more accurate cross calibrations when employing the more capable, future imaging spectrometers*.

# Proposed Lunar Lab (Phase 1)

## Plan for Lunar Lab (Phase 1)

- Dedicate EO-1 to lunar measurements to maximize lunar samples.
  - EO-1 will capture the irradiance signal across *a range of phase angles (±70°)* of the fully illuminated moon. This means from just about half (-70°), through full (0°), and back to just about half (+70°).
  - With Hyperion, an exo-atmospheric lunar spectral radiometric database will be compiled. This data set will reduce uncertainty of the current lunar spectrum and help with improvement/development of lunar models.
  - The continuous spectral coverage of EO-1 Hyperion is another key aspect of this approach: the spectral channels of multispectral broad band sensors operating in the solar reflective spectrum can be emulated from Hyperion channels, as a reference to enhance the quality of the existing 14-year Earth collection.




**Proposed date for Lunar Lab start 10/2016**

- Further studies will exploit the 32X oversampling for select **specific lunar surface areas** (such as lunar maria) and characterize their stability in the presence of lunar nutation and libration. This would use a newly developed observing strategy to expand the EO-1 lunar dataset to include more phase angles during the next 2 years.

- *This Lunar Lab will also provide a bridge to put Earth science sensors that image the moon at different phase angles on the same radiometric scale.*
  - If the EO-1 Lunar Lab is in operation long enough to overlap CLARREO Pathfinder (2019), coincident lunar measurements will allow the entire EO-1 ALI and Hyperion data set to be put on the CLARREO radiometric scale along with the other sensors imaging the moon in the past, present and future.

# THANK YOU!

# EO-1: Request for Mission Extension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**March 23, 2015**



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