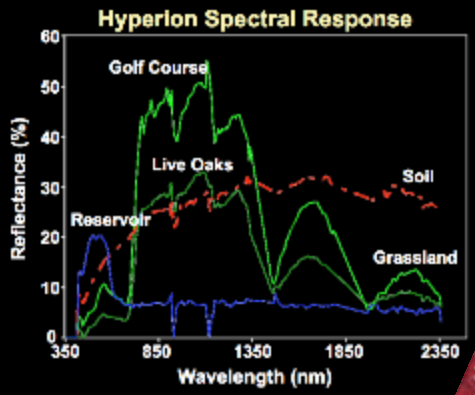
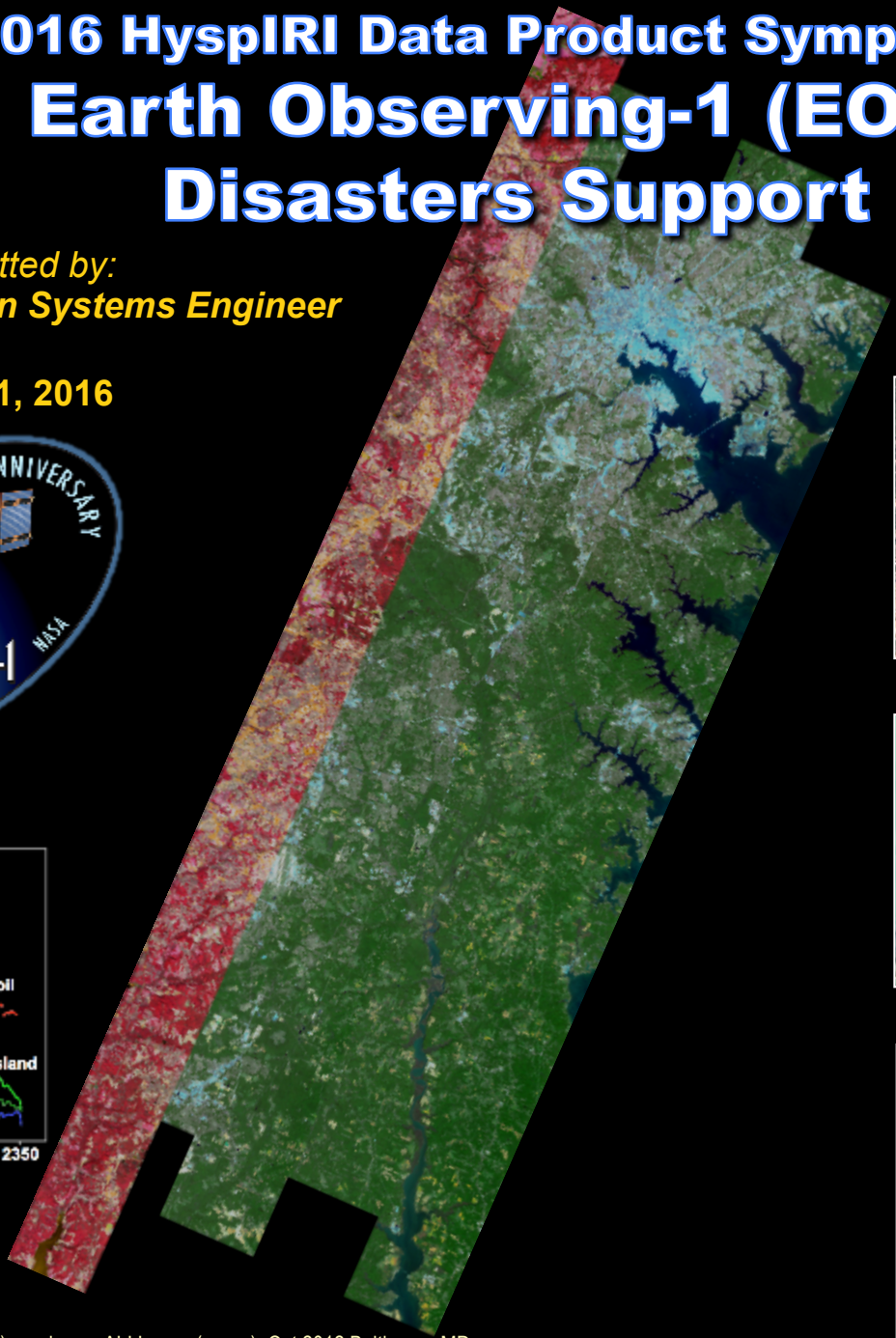
# 2016 HyspIRI Data Product Symposium

# Earth Observing-1 (EO-1) Disasters Support

*Submitted by:*
***Stuart Frye, Mission Systems Engineer***

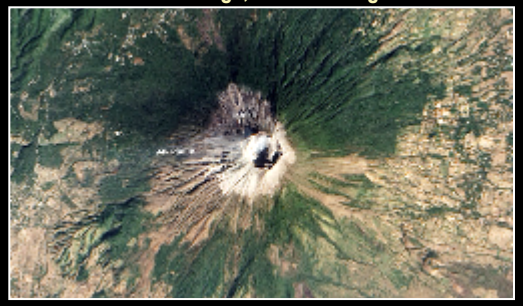
**June 1, 2016**

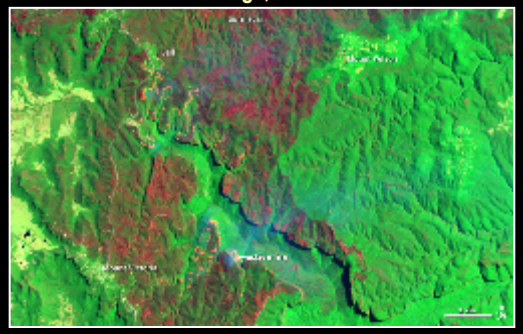
Hyperion (red) overlay on ALI Image (green), Oct 2012 Baltimore, MD

ALI False-Color Image, 2014 San Miguel Volcano



ALI True-Color Image, 2013 Bird Sanctuary in India

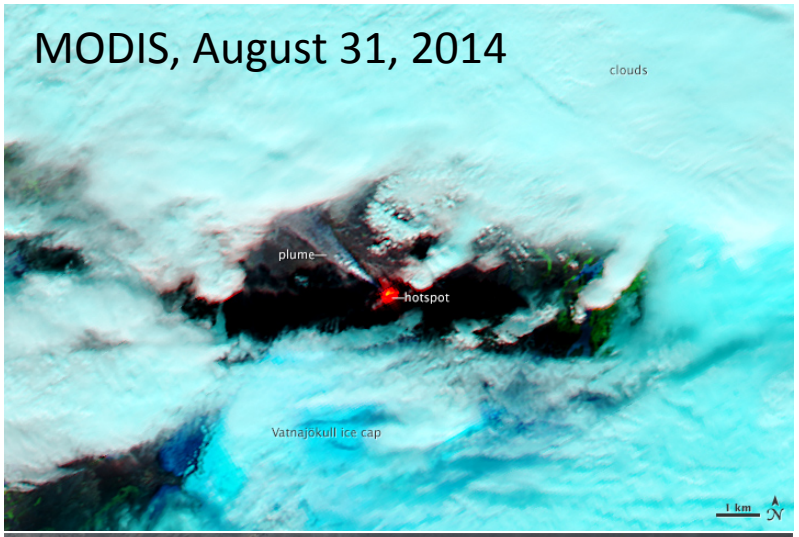
ALI False-Color Image, 2013 Fire in Australia

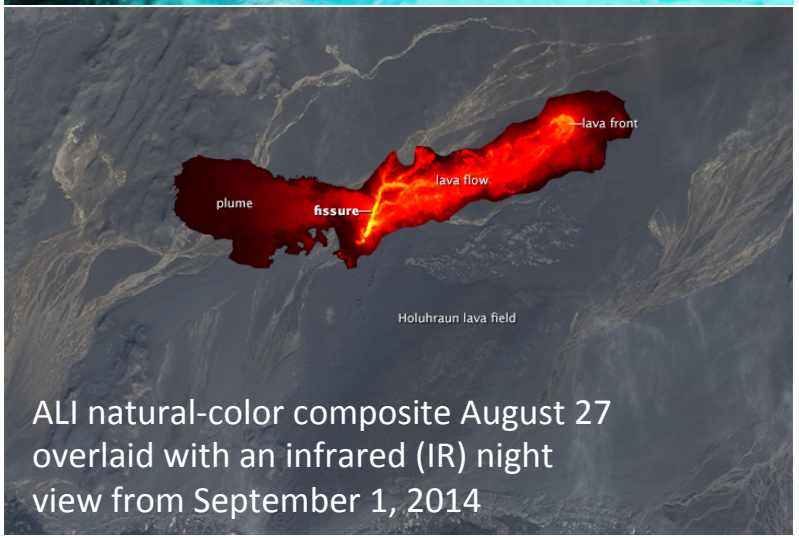


# EO-1 Complimenting Landsat 8 and MODIS



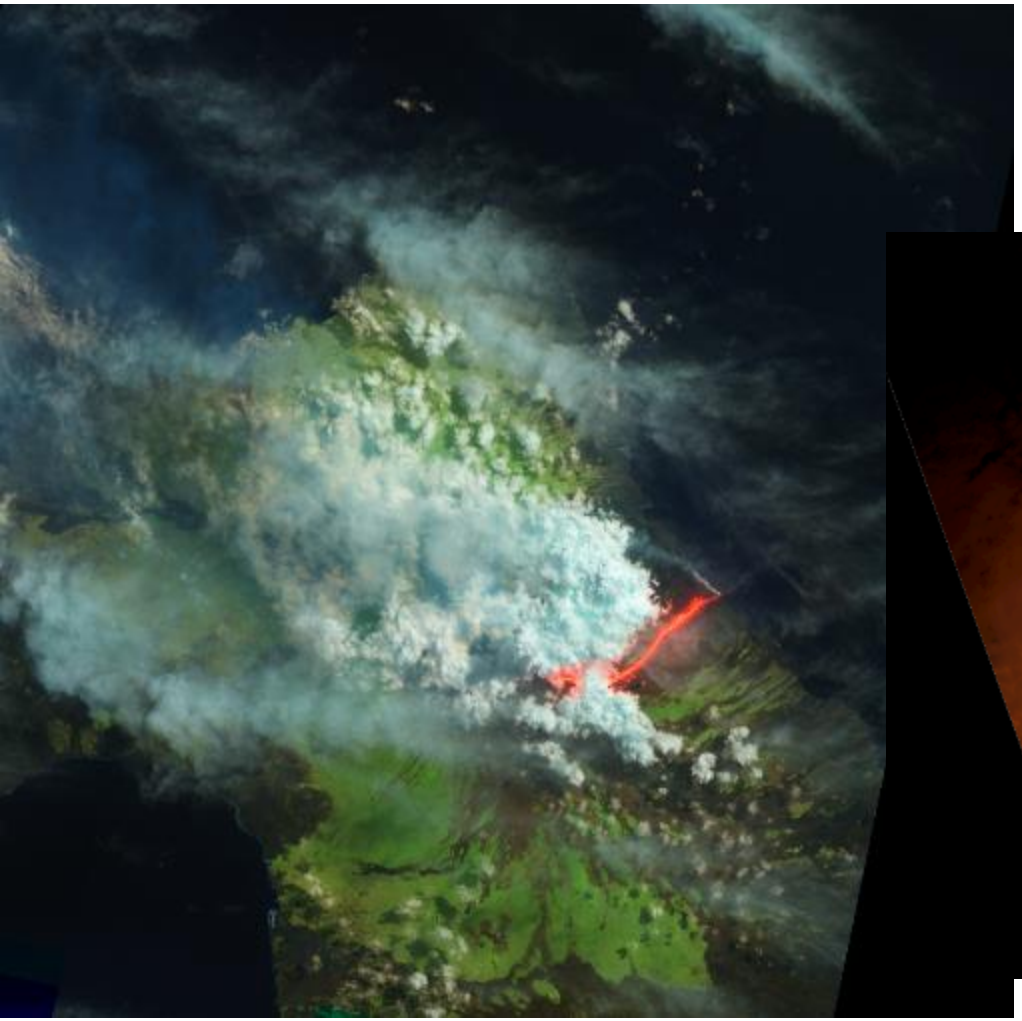
EO-1 ALI complementing OLI. When the Villarrica Volcano erupted, EO-1 was able to acquire an image on March 5, 2015 – **five days before** the next Landsat 8 overpass.

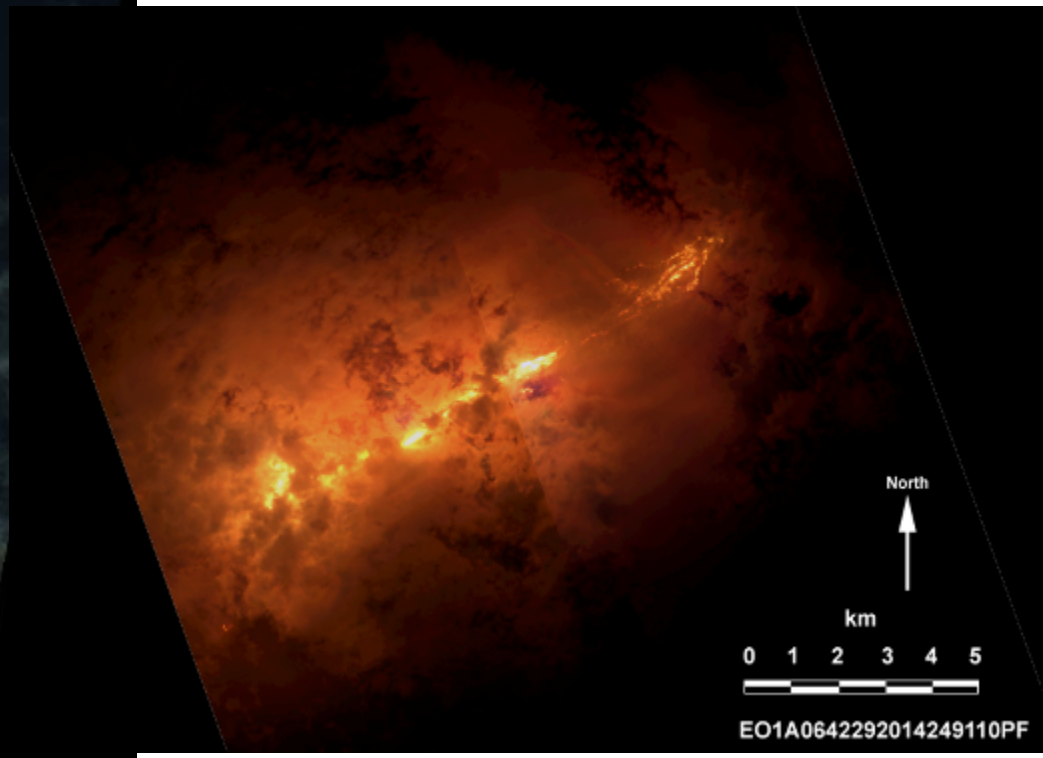



EO-1 ALI night-time image of the Vatnajokull volcano complementing MODIS (top).

# EO-1 Image Gallery

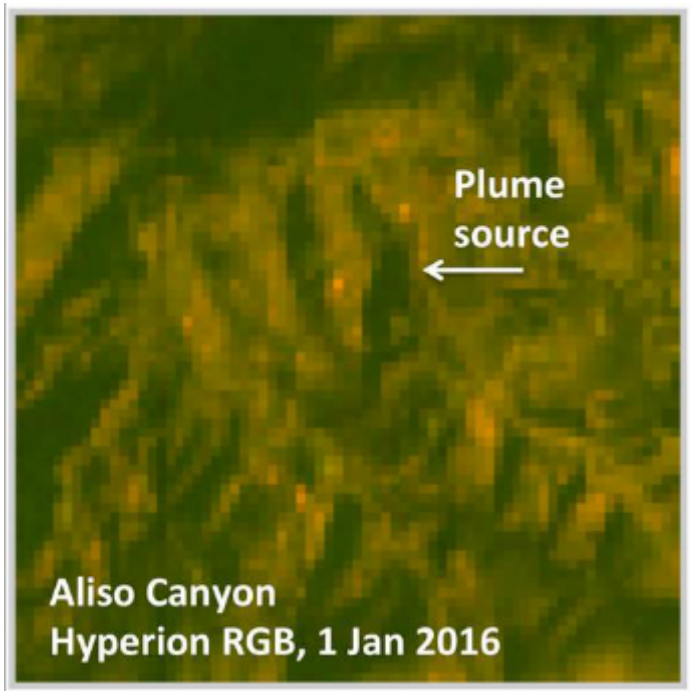


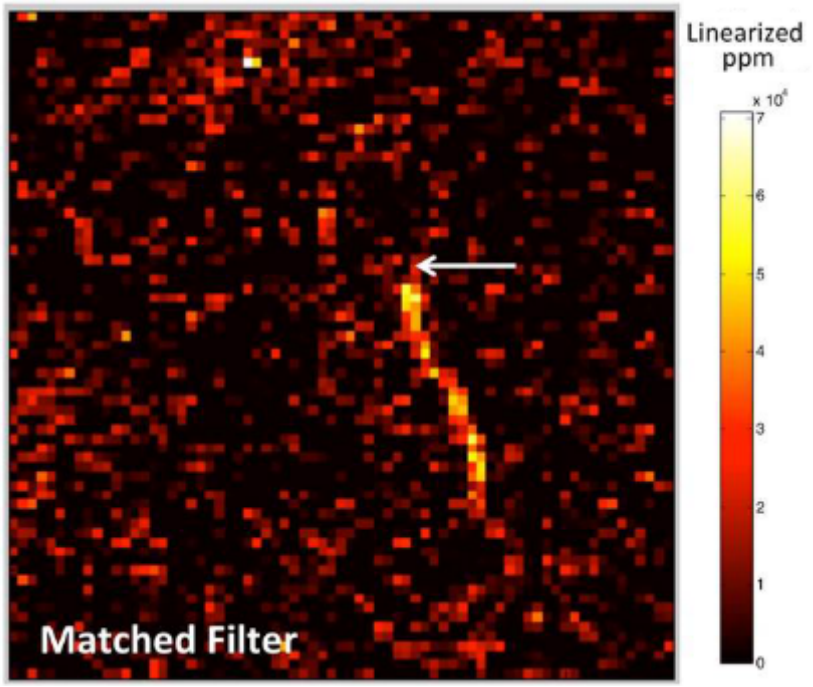


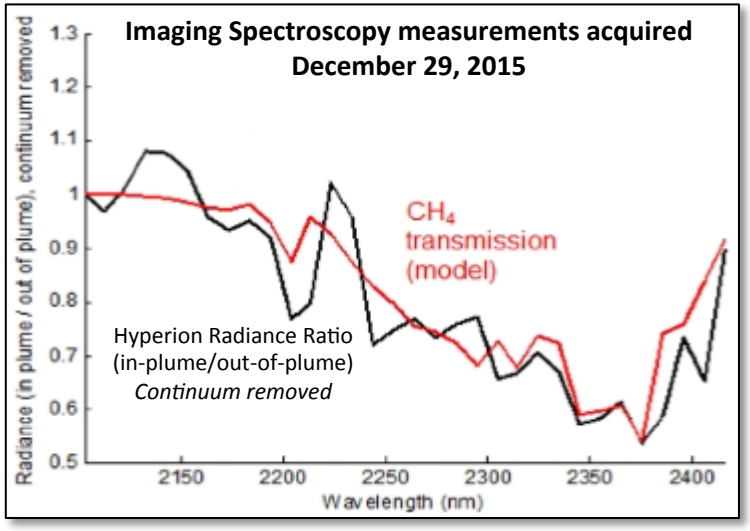

EO-1 image of Wolf Volcano in Galapagos
Eruption on May 25th, image acquired on May 28th

EO-1 ALI night-time image of Holuhraun Iceland volcano

# Hyperion Detects the California Methane Leak



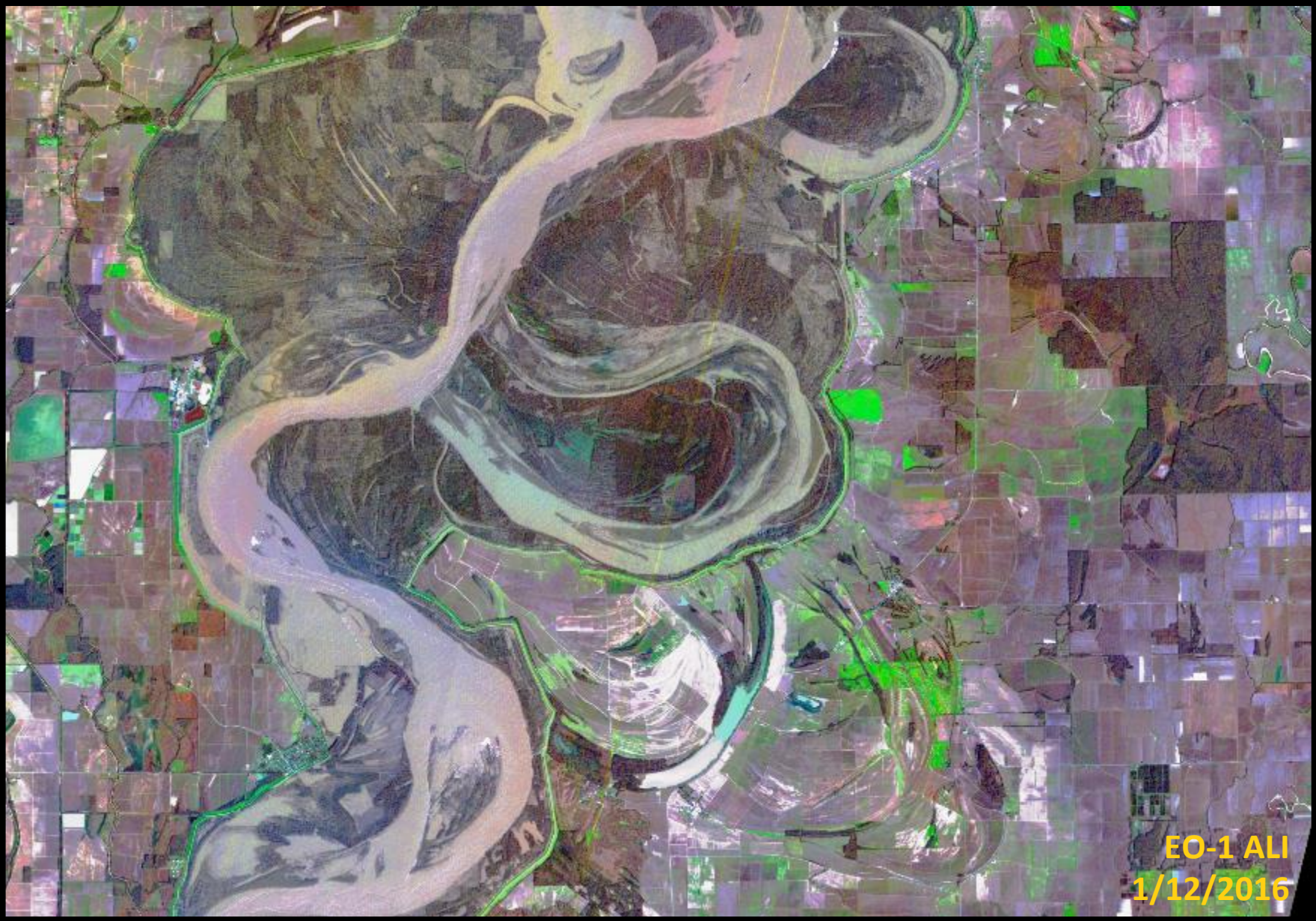




On January 1, 2016, Hyperion imaged the massive methane leak in the Aliso Canyon region of California. David Thompson's (JPL) algorithm detected the methane leak within the Hyperion data and showed a pronounced plume trending to the south. Since then, six additional acquisitions have been made, thanks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

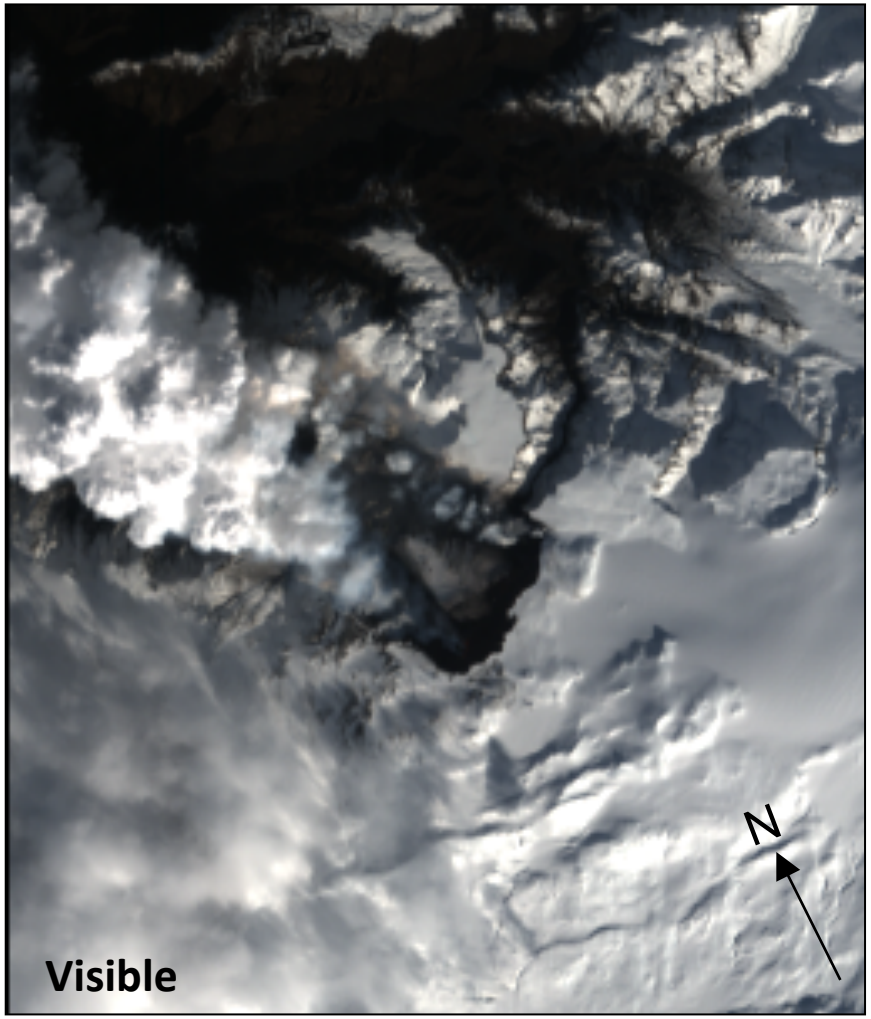
***Hyperion Matched Filter Detection Technique Provided by***
*D. Thompson, A. Thorpe, R.O. Green and The Imaging Spectroscopy Team, JPL, CalTech*

# 2016 Flooding on the Mississippi River

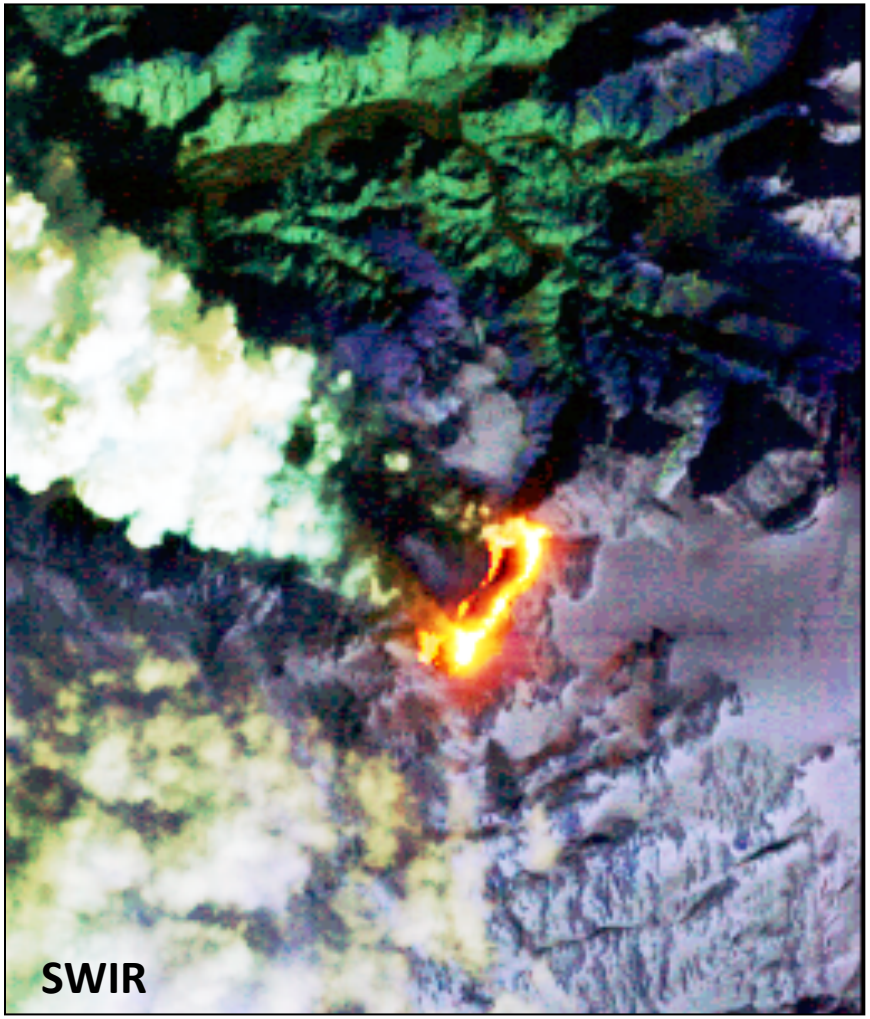


# Eyjafjallajökull Volcano, Iceland

## 24 March. 2010




7.7 km




EO1H2180152010083110KF - Hyperion

Davies *et al.* (2013) JGR

# Recent EO-1 Disaster Images Pre 23 March Anomaly

List of the EO-1 volcano scenes taken since December 2015

| Volcano Site | Path/Row | SZA | Date/Time | Notes |
|---|---|---|---|---|
| Tacora | Path 2 Row 72 | 48.6 | 2015-346/12:35:25 | 12 Dec 2015 – Saturday - Clear, no cloud. No ASE thermal detection |
| Putana | Path 231 Row 76 | 51.47 | 2015-348/12:40:54 | 14 Dec 2015 – Monday - Perfect cloud-free shot |
| Lascar | Path 0 Row 76 | 49.24 | 015-351/12:50:53 | 17 Dec 2015 – Thursday - Perfect cloud-free shot (ASE thermal detection) |
| Lascar Night | Path 117 Row 168 | 116.8 | 2015-353/01:32:34 | 19 Dec 2015 – Saturday - (ASE thermal detection) |
| Guallatiri | Path 3 Row 73 | 48.1 | 2015-357/13:09:41 | 23 Dec 2015 – Wednesday - Heavily impacted by cloud |
| Lastaria | Path 2 Row 77 | 50.48 | 2016-008/12:58:43 | 8 Jan 2016 - Friday - Perfect viewing (no ASE thermal detection) |
| Copahue | | | | 13 Jan 2016 - Wednesday |
| Chaiten | | | | 21 Jan 2016 – Thursday |

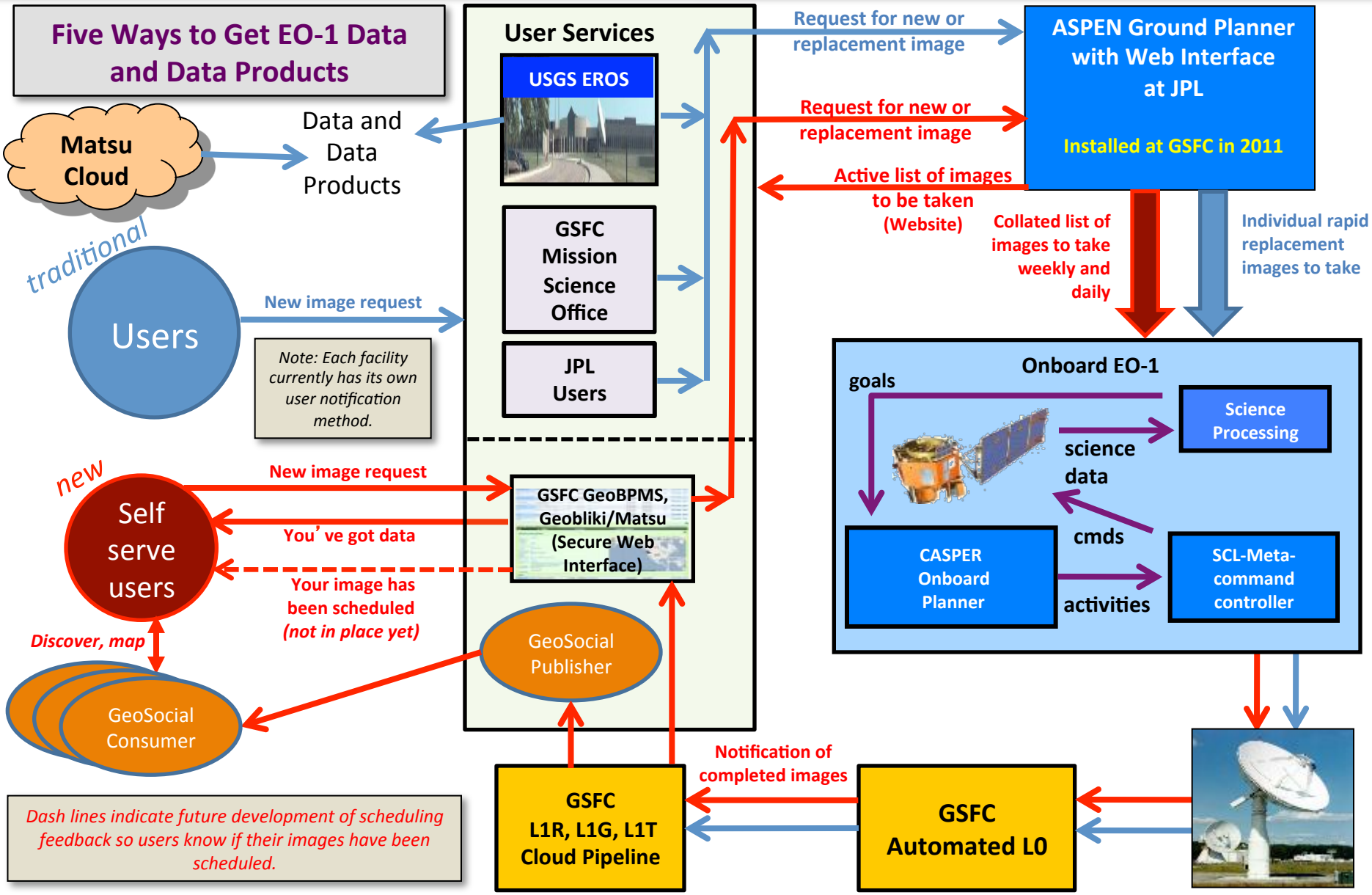
List of the EO-1 flood and tornado scenes taken in January 2016

| Date & Time | Scene ID | Latitude | Longitude | Scene Description |
|---|---|---|---|---|
| 2016-01-01 T15:02Z | EO10230342016001110KF | 37.33 | -89.74 | Cape Girardeau MO flooding |
| 2016-01-03 T14:37Z | EO10220362016003110KF | 34.82 | -89.492 | Holly Springs/Ashland MS tornado scar |
| 2016-01-06 T14:46Z | EO10230352016006110KF | 35.711 | -90.158 | Osceola Ark flooding |
| 2016-01-09 T11:56Z | EO12260782016009110KF | -26.158 | -58.265 | Formosa Argentina flooding |
| 2016-01-17 T11:50Z | EO12260772016017110KF | -25.3 | -57.78 | Asuncion Argentina flooding |
| 2016-01-17 T14:51Z | EO10230372016017110PF | 32.365 | -91.105 | Vicksburg MS flooding |
| 2016-01-28 T06:56Z | EO11750722016028110KF | -17.63 | 23.16 | Kwando River Blockage Angola-Namibia border |

# Overview of Autonomous System Features

- Closed loop satellite autonomy closes the gap between the users and the assets enabling rapid replacement of scheduled targets (less than 4 hours from acquisition) and responsive processing, distribution analysis, and discovery
- Base layer is distributed architecture of services…each sensing asset still under independent control, but allowing requests from many sources
- Situational awareness provided by middleware layer through common application programmer interface distributed components developed at GSFC, but deployed throughout the world
- Users setup their own tasking requests, receive views into immediate past acquisitions in their area of interest, and into future feasibilities for acquisition across all remote sensing assets
- Automated notifications via pub/sub feeds returned to users containing published links to image footprints, algorithm results, and full data sets
- Theme-based algorithms available for on-demand processing and re-distribution

# Example Ground System Architecture (NASA EO-1) for Autonomous Closed-loop Tasking, Acquisition, Processing, and Evaluation for Situational Awareness Feedback



# Distributed Architecture Description

- Middleware services provide rest-ful API (not SOAP-WSDL) user interface
- Nothing is centralized so no single point of failure
- Based on free-ware or open-source tools under the hood so minimal license fees
- Client workflows orchestrated in javascript, Python, or Shell scripts using browser on user platform and single-sign-on protocol with OpenID and Oauth for delegation of user authority across services
- Servers run on Linux, Windows, or MacOS
- Cloud-based container management service from Docker, Software-as-a-Service (SAAS) provided by multiple publishers (open source NASA/GSFC code available on GitHUB), Platform-as-a-Service (PAAS) developed under Convox for easy redeployment, Infrastructure-as-a-Service (IAAS) on cloud provides scalable storage support, simple mail, queue management, registry, caching and content delivery network services
- Products are vectorized TopoJSON overlays that are compact and map-ready running on a cloud platform with metadata links to source data

# Single Sign-On to All Middleware Services

- Security for access to services should be single sign-on handled by a distributed network of security servers that allow users to sign on once, then as they access other services in the network, those services verify with the security servers that the user is allowed to access and perform certain functions.
- This should apply not only to human interactions with the system, but with delegated authority to have machine-to-machine automated interactions on the users behalf.

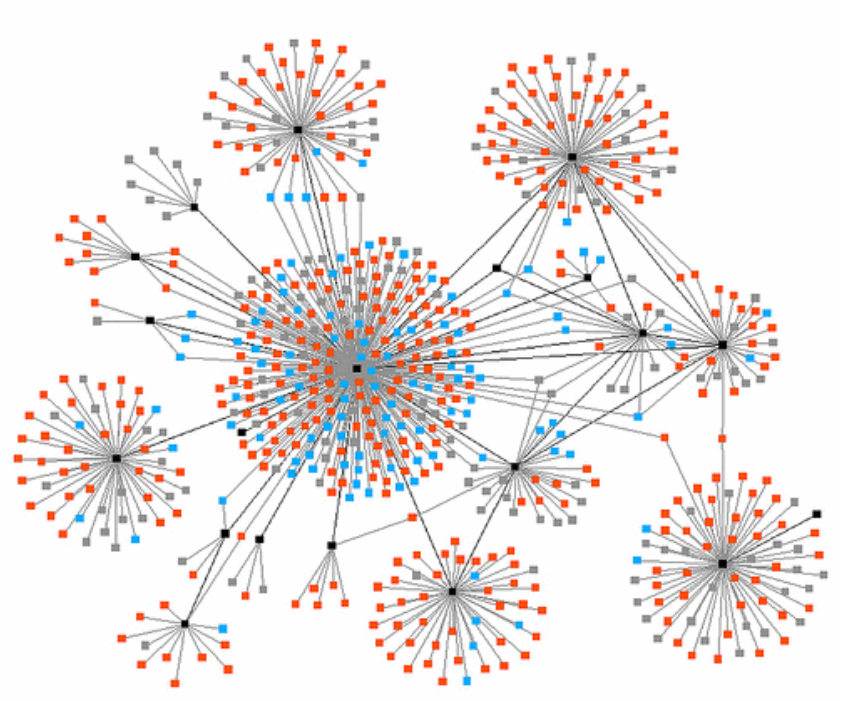
Welcome To the NASA GSFC SensorWeb OpenID Server (BETA 1)

Now supporting Verisign Identity Protection (VIP) Services for two-factor authentication

Please get your own credentials ASAP for a more secure access to the system

*Building Securely The GEOSS Federation One Node At a Time...*

Please Login or New Account



# Target Identification and Submittal

- Users setup their own target requests using either coordinate entry, map box, or geonames (similar to an archive search tool)
- Users view their target requests as footprint locations on a map tool
- In-view dates and acquisition times for the target requests are automatically generated as feasibilities for all satellite assets going out at least 5 days
- Total column cloud predictions for each target in-view time and footprint location automatically supplied and updated every 3 hours going forward about 3 days
- Users are made aware of asset engineering activities that could block their request submittal from being executed
- Users view competing requests from other users to be able to judge likelihood of acquisition in support of task submittal decision making
- Near-term target requests are submitted to the scheduling system of each asset and the status of each request is maintained and visible to the users (status = submitted, scheduled, uplinked, acquired, downlinked, posted)
- Setup of a user target request automatically generates a subscription to receive notifications of data receipt for all images acquired in that target request area
- (See next page for example display)

# Sample User Target Setup

logout | help | main | users | scenarios | requests | tasking | schedule | pending | criteria

## Scenario/Campaign Entries

Search Create New

| Name | Content | Theme | User | Scenario Requests | Created At | Updated At | Weight | |
|---|---|---|---|---|---|---|---|---|
| South America Science 2016 | South America Science 2016 | air | sfrye | King Sejong Station site , La Ciguena Santa Fe, Sinop-Mato Grosso, ... | 01/26/2016 02:48 PM | 01/26/2016 02:48 PM | 0.0 | Edit Delete Show |
| Kwando River Blockage | Kwando River Blockage Namibia/Angola border | flooding | sfrye | Kwando River Blockage | 01/19/2016 01:52 PM | 01/19/2016 01:52 PM | 0.0 | Edit Delete Show |
| Argentina Floods 20160105 | Charter Activation for Argentina Floods 20160105 | flooding | sfrye | Formosa Argentina 20160105 Charter, Asuncion Argentina 20160105 Charter | 01/06/2016 07:07 PM | 01/06/2016 07:07 PM | 0.0 | Edit Delete Show |

**Scenario/Campaign Tasking Requests for Argentina Floods 20160105**

Search Create New

| Id | Name | Content | Geolocation | Daynight Time | Center | Duration | Scenario Feasibilities | Scenario Requests Tasks | |
|---|---|---|---|---|---|---|---|---|---|
| 5307 | Asuncion Argentina 20160105 Charter | Asuncion Argentina 20160105 Charter | -25.3, -57.78 | day time | Hyperion | 12s | , , | - | Edit Delete Show |
| 5306 | Formosa Argentina 20160105 Charter | Formosa Argentina 20160105 Charter | -26.158, -58.265 | day time | Hyperion | 12s | , , | - | Edit Delete Show |

2 Found

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mississippi River 20151229 | Mississippi River 20151229 | flooding | sfrye | Cape Girardeau MO 20151229, Vicksburg MS 20151229, St. Louis 20151229, ... | 12/30/2015 01:09 AM | 12/30/2015 02:15 PM | 0.0 | Edit Delete Show |
| Garland Texas 20151227 | Garland Texas 20151227 | flooding | sfrye | Garland Texas 20151227 | 12/28/2015 03:19 PM | 12/28/2015 03:19 PM | 0.0 | Edit Delete Show |
| Holly Springs MS 20151223 | Holly Springs MS 20151223 | flooding | sfrye | Holly Springs/Ashland MS 20151223, Booneville MS 201512/23 | 12/24/2015 07:28 PM | 12/24/2015 07:28 PM | 0.0 | Edit Delete Show |
| Shenzen China Landslide | Shenzen China Landslide 20151221 | landslide | sfrye | Shenzen China Landslide20151221 | 12/21/2015 09:26 PM | 12/21/2015 09:26 PM | 0.0 | Edit Delete Show |
| Phillippines Typhoon Melor | Phillippines Typhoon Melor 20151214 | flooding | sfrye | Phillippines Typhoon Melor 20151214, Phillippines Typhoon Melor Naga, Phillippines Typhoon Melor Manila | 12/14/2015 02:07 PM | 12/14/2015 02:07 PM | 0.0 | Edit Delete Show |
| Nevado del Ruiz, Colombia | Volcan Nevado del Ruiz activity | volcano | eanderson | Nevado del Ruis activity | 12/10/2015 08:13 PM | 12/11/2015 06:04 PM | 0.0 | Edit Delete Show |

# Awareness for Timing of Delivery

- Users know in advance on a constantly updated basis exactly when to expect data from the next day's acquisitions from all satellites
- Image delivery availability and quality assessment used as input to the planning/ scheduling for the following day's collections
  - For example, Landsat-8 data is acquired and assessed in time to affect decision about tasking for next EO-1 in-view target-by-target



## Scenario/Campaign Tasking Opportunities

Search Update Forecast

| Scenario Name | Theme | Id | Request | User | Org | Asset | Instrument Center | Date | Weather | Score | Tasks | Veto | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belm Germany | technology | 79218 | Osnabrück Germany | bsiegmann | IGF Osnabrueck | EO-1 | hyperion | 2016-02-03T08:35:00Z | 21 | 0 | EO11960242013112110KF(NOT FOUND), EO11960242013125110KF(rejected), EO11960242013159110KF(NOT FOUND) | - | Veto Task Edit Delete Show |
| West Africa - Rangeland | tropical | 79599 | Nazinga | Sumisu | UNKNOWN | EO-1 | hyperion | 2016-02-03T08:46:00Z | 0 | 16 | | - | Veto Task Edit Delete Show |
| West Africa - Rangeland | tropical | 79276 | Aniabiisi | Sumisu | UNKNOWN | EO-1 | hyperion | 2016-02-03T08:47:00Z | 0 | 16 | | - | Veto Task Edit Delete Show |
| South America Science 2016 | air | 79397 | Santarem-Km67-Primary Forest | sfrye | SGT | EO-1 | hyperion | 2016-02-03T12:07:00Z | 90 | 15 | | - | Veto Task Edit Delete Show |
| South America Science 2016 | air | 79370 | Sinop-Mato Grosso | sfrye | SGT | EO-1 | hyperion | 2016-02-03T12:09:00Z | 32 | 15 | | - | Veto Task Edit Delete Show |
| Argentina Floods 20160105 | flooding | 79083 | Asuncion Argentina 20160105 Charter | sfrye | SGT | EO-1 | hyperion | 2016-02-03T12:13:00Z | 98 | 15 | | - | Veto Task Edit Delete Show |
| Argentina Floods 20160105 | flooding | 79072 | Formosa Argentina 20160105 Charter | sfrye | SGT | EO-1 | hyperion | 2016-02-03T12:13:00Z | 100 | 15 | | - | Veto Task Edit Delete Show |
| South America Science 2016 | air | 79361 | La Ciguena Santa Fe | sfrye | SGT | EO-1 | hyperion | 2016-02-03T12:14:00Z | 13 | 15 | | - | Veto Task Edit Delete Show |
| Hong Kong, Shing Mun | tropical | 79229 | Fluorescence mapping | syedirteza | UNKNOWN | EO-1 | hyperion | 2016-02-04T01:07:00Z | 42 | 0 | | - | Veto Task Edit Delete Show |
| South America Science 2016 | air | 79415 | Panderos | sfrye | SGT | EO-1 | hyperion | 2016-02-04T11:08:00Z | 70 | 15 | | - | Veto Task Edit Delete Show |
| South America Science 2016 | air | 79434 | Eucaliptus Sao Paulo | sfrye | SGT | EO-1 | hyperion | 2016-02-04T11:10:00Z | 99 | 15 | | - | Veto Task Edit Delete Show |
| South America Science 2016 | air | 79476 | Atlantic Forest Sao Paulo | sfrye | SGT | EO-1 | hyperion | 2016-02-04T11:10:00Z | 79 | 15 | | - | Veto Task Edit Delete Show |

# Rapid Assessment of Recent Images

- User is provided rapid assessment immediately after new images have been taken to visualize the image quality/cloud cover
  - Geolocated scene overlays of recently acquired data are published and notifications automatically fed to users in a compact file format that is appropriately named (asset ID, date, time, center-point coordinates, relevant geonames)
- Users are sent the image overlays and combine them with planned future footprints without having to search for them
  - Each asset posts image data in a centralized system, but users have particular information delivered to their consumer client on a distributed basis from regional product publishers
- The users can track which targets have been acquired vs. which ones aren't yet including not only the user's own target requests, but all images in the users' area of interest regardless of who submitted them
  - If an image was just taken of an area that fulfills the needs of some other user that was about to submit it for scheduling, then that user doesn't have to submit their request

# Recent Acquisition Notification Process

Acquisition notifications are sorted with links to products

Upcoming collections are displayable on a map and on a timeline

## EO1 Task Requests

Things you can do

All Tasks  All Tasks for past three months  All Tasks for past year

Stuart,

**EO1 Task Requests are:**

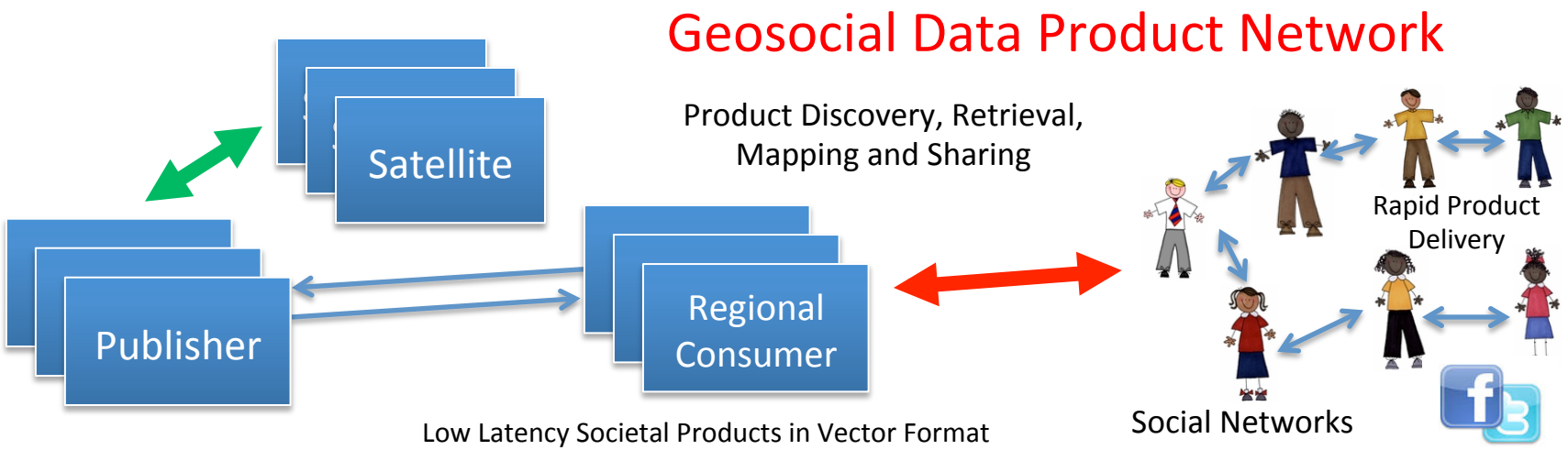
| Taskid | Login | Acquisition Time | DOY | Scene ID | Lat | Long | Comments | Status |
|---|---|---|---|---|---|---|---|---|
| 5137 | sfrye | 2016-02-04T01:07Z | 035 | EO1121045201603511OKF | 22.384306 | 114.142194 | Fluorescence mapping Hong Kong country park Shing Mun | submitted |
| 5138 | sfrye | 2016-02-03T12:09Z | 034 | EO1226068201603411OKF | -11.4122916 | -55.3247 | Sinop-Mato Grosso Sinop-Mato Grosso | submitted |
| 5136 | sfrye | 2016-02-02T14:41Z | 033 | EO1020046201603311OKF | 20.0929 | -89.5639 | Kaxil Kiuic Kaxil Kiuic | submitted |
| 5135 | sfrye | 2016-02-02T11:34Z | 033 | EO1221071201603311OKF | -15.95 | -47.8666 | Brasilia - Campo Sujo Quadrienal and Bienal Tardia Brasilia - Campo Sujo Quadrienal and Bienal Tardia | submitted |
| 5134 | sfrye | 2016-02-01T14:08Z | 032 | EO1016052201603211OKF | 11.0166 | -85.5 | Los Inocentes Los Inocentes | finished |
| 5132 | sfrye | 2016-01-31T12:04Z | 031 | EO1227080201603111OKF | -29.264 | -61.028 | La Ciguena Santa Fe La Ciguena Santa Fe | finished |
| 5133 | sfrye | 2016-01-31T08:36Z | 031 | EO1195052201603111OKF | 11.186017 | -1.568458 | Nazinga Model important forage characteristics | finished |
| 5131 | sfrye | 2016-01-30T12:59Z | 030 | EO1002060201603011OKF | 0.212333 | -66.76473 | Sao Gabriel da Cachoeira Sao Gabriel da Cachoeira | finished |
| 5130 | sfrye | 2016-01-30T11:24Z | 030 | EO1219070201603011OKF | -14.848277 | -43.9879 | Panderos Panderos | finished |
| 5129 | sfrye | 2016-01-28T08:27Z | 028 | EO1194052201602811OKF | 10.84603 | -0.911855 | Aniabiisi Model important forage characteristics | finished |
| 5128 | sfrye | 2016-01-28T06:56Z | 028 | EO1175072201602811OKF | -17.63 | 23.16 | Kwando River Blockage Kwando River Blockage Namibia border | finished |

KML file available here

# Autonomous Delivery of Recent Acquisitions to Regional Publishers for Browse Imagery and Classification/Detection Product Processing

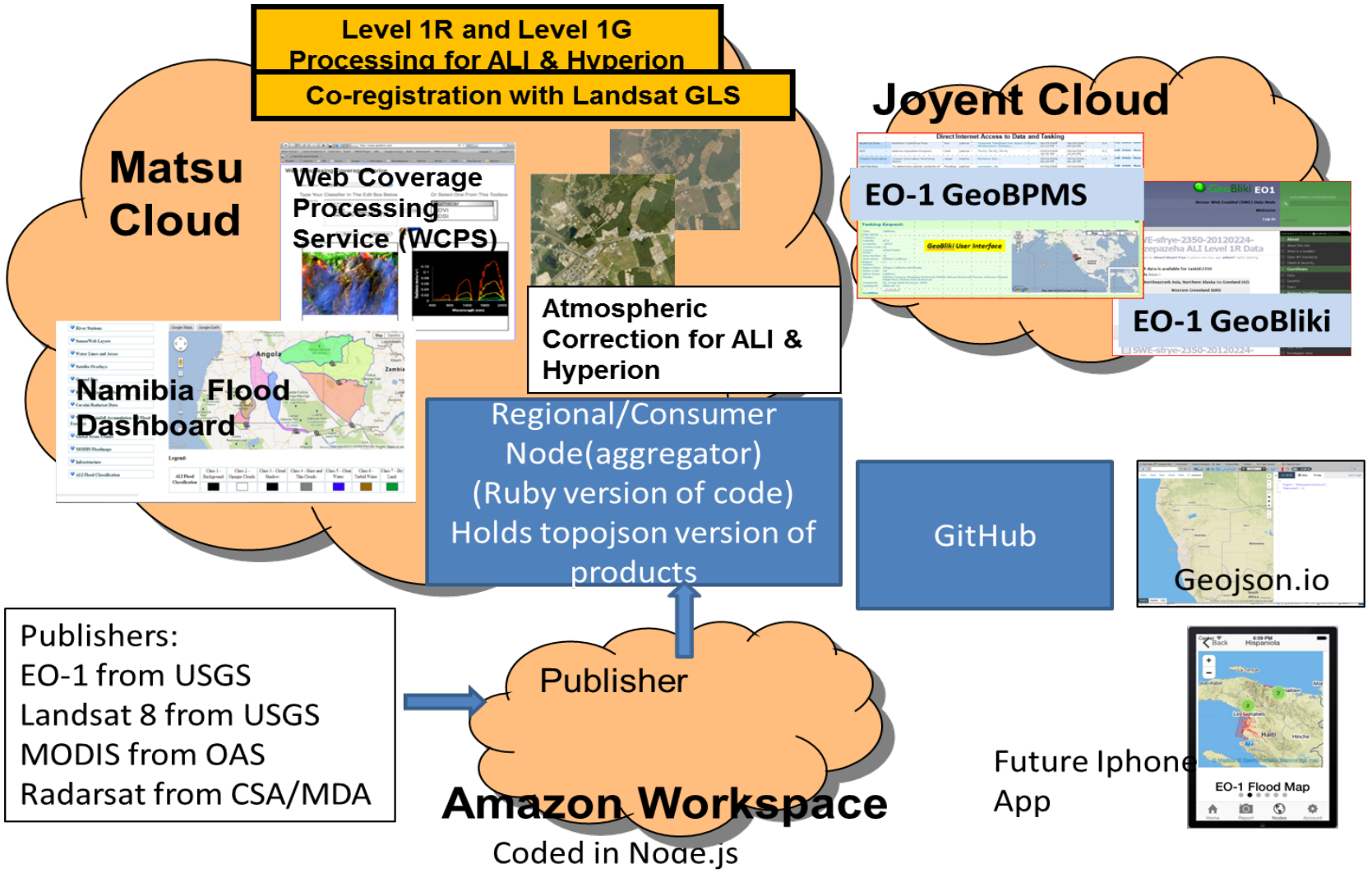
**Regional GeoSocial API Publisher/Consumer Network (HTML/HTTPS)**

This is a *NEW* method to distribute EO-1 and other satellite data products in a compact vectorized format (small data size TopoJSON). The vision is to have a network of regional publishers automatically pre-generate specific satellite data products for a region and then make them available to all consumers in that region. 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. It is built in to share the products via Facebook/Twitter or other social media with a single click.



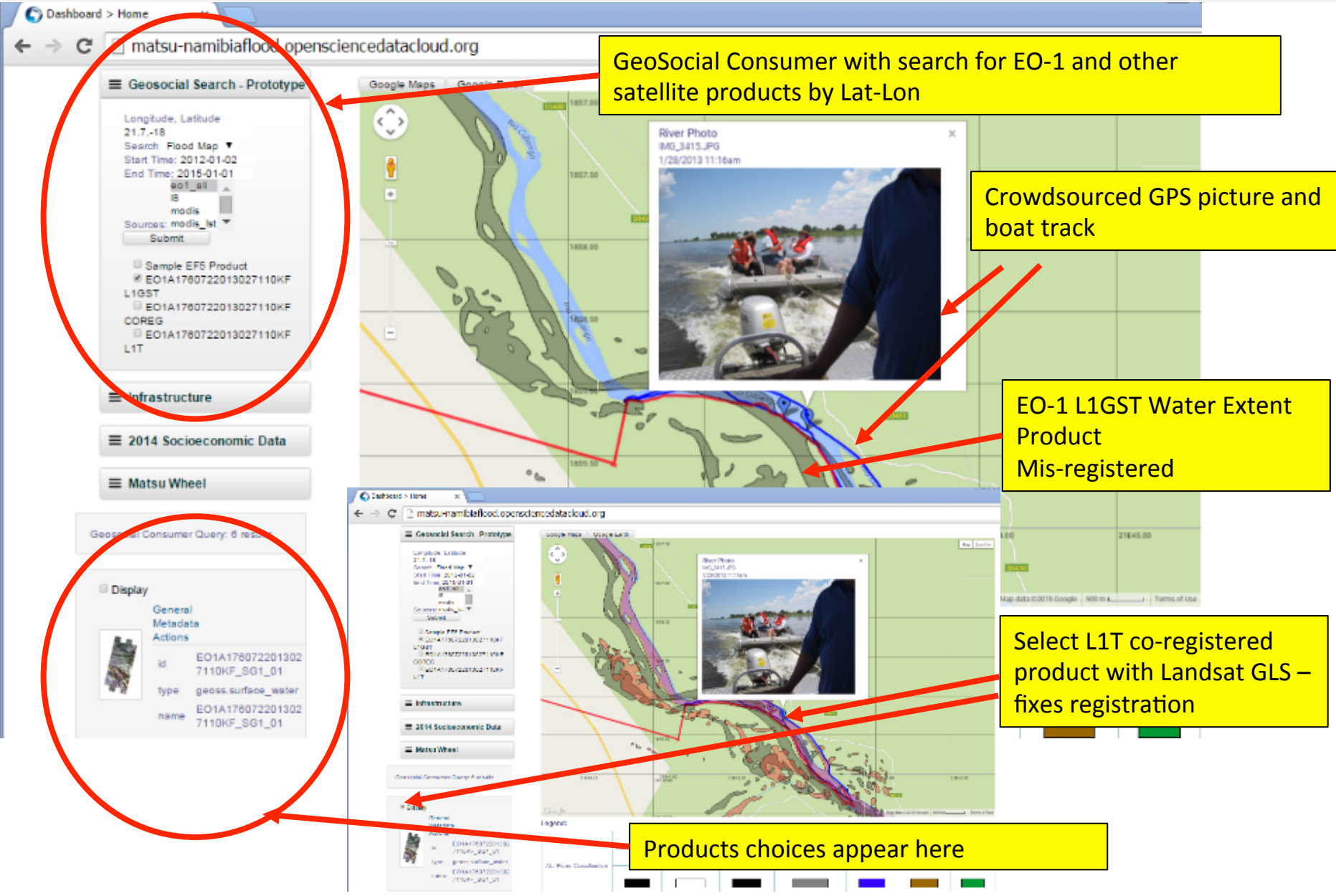
# Cloud-based Processing and Delivery Overview

**Distributed Cloud Architecture for EO-1 Data Product Distribution and Tasking Requests**

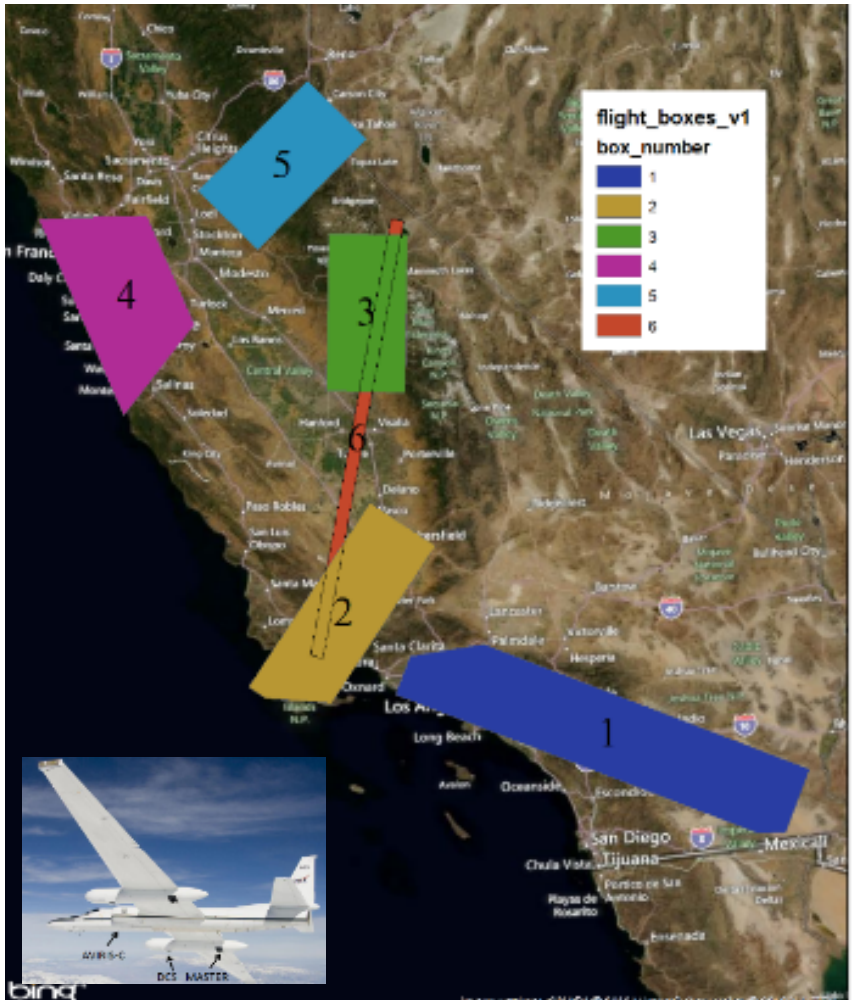


# Distribution Channel for Recently Acquired Products

## GeoSocial API (architecture for discovery, retrieval, mapping, evaluation, and sharing)



# Coordination of Satellite Acquisitions with Flight Campaigns
# Example: HyspIRI Preparatory Airborne Campaign




**Objectives:**

- Acquire contemporaneous satellite images over flight boxes

**Tactics:**

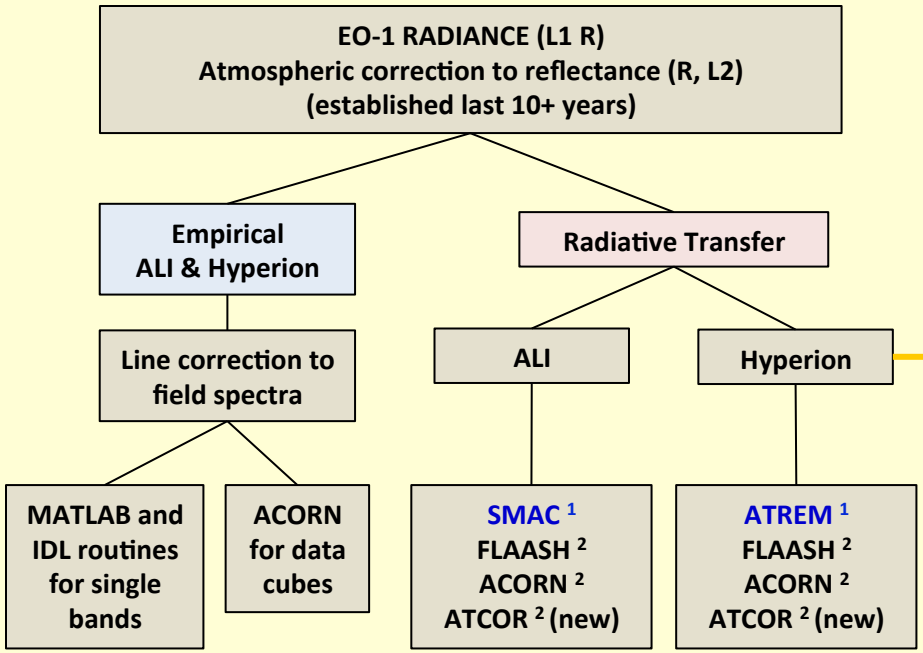
- Satellite in-views by date and time for each box are visible to the flight team along with cloud predictions and other constraints during morning flight meeting
- Which flight area is to be flown today is identified in that meeting 4-5 hours prior to aerial lift-off based on cloudiness, satellite in-views, and engineering considerations
- Once flight box is identified, satellite target request for the selected box needs to be submitted, scheduled, uplinked, and executed within 4-5 hours to acquire data coincidentally with flight

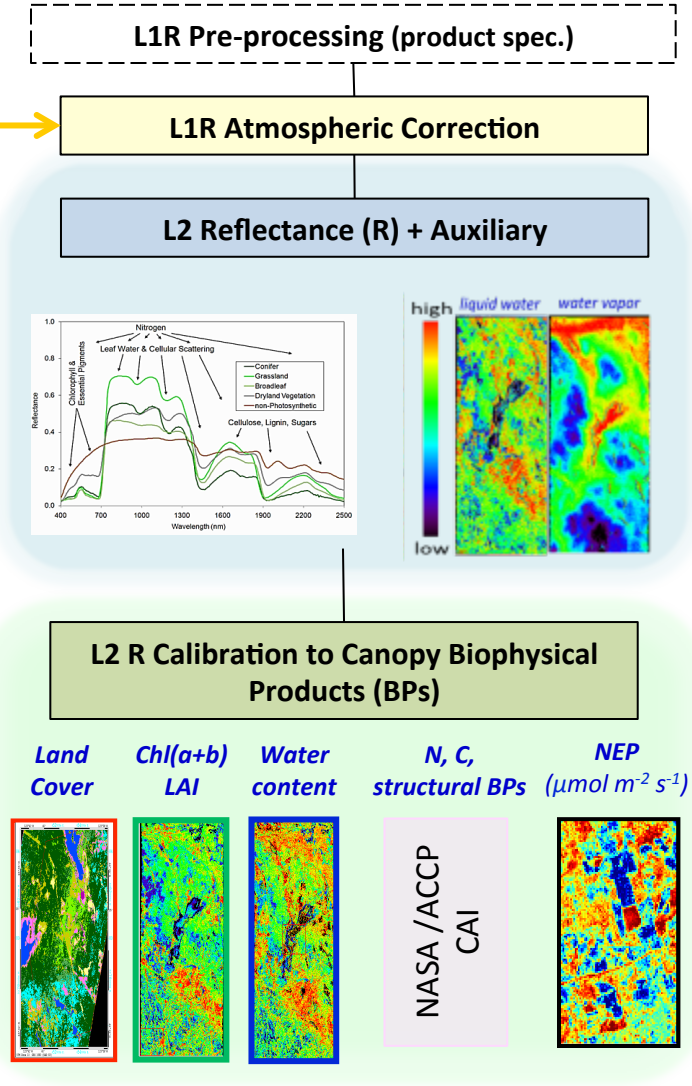
**Results:**

- Maximum number of contemporaneous satellite and aerial images have been acquired

# User Controlled On-Demand Post Processing for Detailed Evaluation

**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.

# EO-1 Anomaly 23 March 2016

- A charge rate differential voltage red limit caused EO-1 load shedding and safehold
- Upon recovery, the on-board GPS exhibited anomalous readings (wrong week since epoch) like GlobalStar, CALIPSO, and JASON-2/3
- Before the anomaly, the GPS unit provided orbit and time for on-board systems
  - Had to command spacecraft computer to ignore GPS input
- Flight operations team began uplinking orbit ephemeris every 8 hours and EO-1 clock was provided by the oscillator, which ran fast by 3-4 seconds every 2-3 weeks causing shift in target locations and geolocation accuracy of 7.5km per second.
- Abandoned search for on-board patch, decided to continue ground management of clock and ephemeris
- Reset S/C clock to ground system GMT time and resumed imaging to assess targeting and geolocation issues 20 April 2016 and again on 9 May
- Fixed on-board autonomy and ground system Level 0 processing to ignore GPS flag and began Level 1R and Level 1Gst processing by 27 April
- Computed oscillator bias and performed correction 18 May 2016
  - Oscillator fluctuates due to thermal and other differences…still gathering data to characterize causes in order to better predict oscillator variation
- Performed most recent clock reset 23 May 2016
- All images since adjustment remain within 1.7km (~1/4$^{th}$ second) target centering and geolocation accuracy

# Calculations of Image Targeting and Geolocation Offsets

| Date | Location | SceneID | Target Coordinates | Time of Image | Clock Reading | Offset Distance | Look Angle | Map Offset Direction | ALI Browse Image URL |
|---|---|---|---|---|---|---|---|---|---|
| 29-May | Cerrado site PNCV | EO122107020161501 10KF | -14.113, -47.713 | 11:22 | | 1.0km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/221/70/2016/EO122107020161501 10KF_WG1_01.jpeg |
| 28-May | Pinnacles_Desert_We | EO111308120161491 10K9 | -30.59, 115.155 | 23:58 | | 1.1km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/113/81/2016/EO111308120161491 10K9_AK3_01.jpeg |
| 28-May | Kilimanjaro [MSO/N] | EO116806220161491 10K2 | -3.0559, 37.3488 | 5:47 | | 0km | | Perfectly aligned | http://earthexplorer.usgs.gov/browse/eo-1/ali/168/62/2016/EO116806220161491 10K2_AK3_01.jpeg |
| 27-May | Sinop_Mato_Grosso [I | EO122606820161481 10K2 | -11.4123, -55.3247 | 11:47 | | 0.9km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/226/68/2016/EO122606820161481 10K2_SG1_01.jpeg |
| 26-May | Italy Olive Groves | EO118703220161471 10KF | 40.47, 18.11 | 7:40 | | 1.3km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/187/32/2016/EO118703220161471 10KF_SG1_01.jpeg |
| 26-May | Afg2010 1 [MSO/E] | EO115803720161471 10K3 | 33.49, 60.96 | 4:25 | | 0.9km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/158/37/2016/EO115803720161471 10K3_AK3_01.jpeg |
| 25-May | Karachi [EDC/W] | EO115204320161461 10KG | 24.8, 66.97 | 3:52 | | 1.7km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/152/43/2016/EO115204320161461 10KG_AK3_011.jpeg |
| 25-May | Dunhuang China HYP | EO113703220161461 10T9 | 40.13, 94.34 | 2:09 | | 1.7km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/137/32/2016/EO113703220161461 10T9_AK3_01.jpeg |
| 24-May | Brazil fire [Brakke/W] | EO122406920161451 10KF | -12.904, -52.3708 | 11:38 | | 0.3km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/224/69/2016/EO122406920161451 10KF_SG1_01.jpeg |
| 24-May | Dripsey [MSO/W2] | EO120702420161451 10T1 | 51.99, -8.75 | 9:42 | | 0.3km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/207/24/2016/EO120702420161451 10T1_SG1_01.jpeg |
| 24-May | Oman_Archaeology_2 | EO115904320161451 10K0 | 23.79, 56.43 | 4:54 | | 0.6km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/159/43/2016/EO115904320161451 10K0_AK3_01.jpeg |
| 23-May | 3rd clock adjustment to UTCF | | | | | | | | |
| 22-May | | | | | | | | | |
| 21-May | | | | | | | | | |
| 20-May | | | | | | | | | |
| 19-May | | | | | | | | | |
| 18-May | Made oscillator drift rate adjustment | | | | | | | | |
| 17-May | | | | | | | | | |
| 16-May | | | | | | | | | |
| 15-May | Colorado | EO103504020161361 10K2 | 28.7, -110.54 | 15:53Z | | 5.2km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/35/40/2016/EO103504020161361 10K2_AK3_01.jpeg |
| 14-May | Nassau Bahamas | EO101304220161351 10PF | 25.16, -77.56 | 13:39Z | | 8.7km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/13/42/2016/EO101304220161351 10PF_SG1_01.jpeg |
| 13-May | Isreal Oil Spill | EO117403920161341 10K8 | 29.6541, 35.0124 | 06:28Z | | 11.4km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/174/39/2016/EO117403920161341 10K8_SG1_01.jpeg |
| 12-May | Voyagers Natl Park | EO114002620161331 10K2 | 48.5022, 92.8846 | 02:30Z | | | | Haven't run yet | http://earthexplorer.usgs.gov/browse/eo-1/ali/140/26/2016/EO114002620161331 10K2_AK3_01.jpeg |
| 11-May | Fort McMurray CA | EO104202020161321 10KF | 56.6289, -111.5946 | 16:37Z | | 12.7km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/42/20/2016/EO104202020161321 10KF_SG1_01.jpeg |
| 11-May | Nassau Bahamas | EO101304220161321 10KF | 25.16, -77.56 | 13:30Z | | 15.8km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/13/42/2016/EO101304220161321 10KF_SG1_01.jpeg |
| 10-May | Isreal Oil Spill | EO117403920161311 10K5 | 29.6541, 35.0124 | 06:19Z | | 13km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/174/39/2016/EO117403920161311 10K5_TR2_01.jpeg |
| 9-May | 2nd clock jam on DOY 130 | | | | | | | | |
| 8-May | Doi Inthanon Thailand | EO113104720161291 10T2 | 18.5248, 98.4965 | 01:53Z | | 6km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/131/47/2016/EO113104720161291 10T2_AK3_01.jpeg |
| 7-May | Po di Pila river mouth | EO119102920161281 10KF | 44.9865, 12.55 | 07:43Z | | | | Waiting on feedback from Liz Atwood | http://earthexplorer.usgs.gov/browse/eo-1/ali/191/29/2016/EO119102920161281 10KF_SG1_01.jpeg |
| 7-May | Isreal Oil Spill | EO117403920161281 10K7 | 29.6541, 35.0124 | 06:09Z | | 5km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/174/39/2016/EO117403920161281 10K7_SG1_01.jpeg |
| 6-May | Nassau Bahamas | EO101304220161271 10KF | 25.16, -77.56 | 13:46Z | | 4.7km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/13/42/2016/EO101304220161271 10KF_AK3_01.jpeg |
| 6-May | Bucharest, Romania | EO118202920161271 10KF | 44.43, 26.11 | 07:07Z | | 4.4km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/182/29/2016/EO118202920161271 10KF_SG1_01.jpeg |
| 5-May | Po di Tolle Secondary | EO119102920161261 10KF | 44.8962, 12.4947 | 08:09Z | | | | Waiting on feedback from Liz Atwood | http://earthexplorer.usgs.gov/browse/eo-1/ali/191/29/2016/EO119102920161261 10KF_SG1_01.jpeg |
| 5-May | Haymana Turkey | EO117703220161261 10PF | 39.6113, 32.6988 | 06:33Z | | | | Waiting on feedback from Feray Oztopra | http://earthexplorer.usgs.gov/browse/eo-1/ali/177/32/2016/EO117703220161261 10PF_SG1_01.jpeg |
| 4-May | La Paz | EO103404320161251 10K2 | 24.1293, -110.438 | 15:51Z | | 1.5km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/19/26/2016/EO101902620161251 10K4_SG1_01.jpeg |
| 4-May | Xilinhot grassland | EO112403020161251 10TA | 43.55, 116,67 | 01:00Z | | 0.6km | | Image is shifted South of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/124/30/2016/EO112403020161251 10TA_AK3_01.jpeg |
| 3-May | Fixing telemetry playback issue on-board DOY 124 | | | | | | | | |
| 2-May | USGS-Alaska-2 | EO107101720161231 10K4 | 61.641, -152.732 | 19:24Z | | 0.9km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/71/17/2016/EO107101720161231 10K4_TR2_01.jpeg |
| 2-May | Isreal Oil Spill | EO117403920161231 10K8 | 29.6541, 35.0124 | 06:25Z | | 3km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/174/39/2016/EO117403920161231 10K8_TR2_01.jpeg |
| 2-May | Sarcheshmeh Copper | EO116103920161231 10KF | 29.987, 55.6316 | 04:47Z | | 2km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/161/39/2016/EO116103920161231 10KF_TR2_01.jpeg |
| 1-May | Lake Frome | EO109708120161221 10K1 | -30.784, 139.784 | 22:30Z | | | | Haven't run yet | http://earthexplorer.usgs.gov/browse/eo-1/ali/97/81/2016/EO109708120161221 10K1_TR2_01.jpeg |
| 30-Apr | Doi Inthanon Thailand | EO113104720161211 10T1 | 18.5248, 98.4965 | 02:00Z | | | | Haven't run yet | http://earthexplorer.usgs.gov/browse/eo-1/ali/131/47/2016/EO113104720161211 10T1_AK3_01.jpeg |
| 29-Apr | Phoenix | EO103703720161201 10KF | 33.32, -112.28 | 16:05Z | | | | Waiting for scene to post on matsu | http://earthexplorer.usgs.gov/browse/eo-1/ali/37/37/2016/EO103703720161201 10KF_AK3_01.jpeg |
| 29-Apr | Isreal Oil Spill | EO117403920161201 10K6 | 29.6541, 35.0124 | 06:16Z | | 4.7km | | Image is shifted North of map underlay | http://earthexplorer.usgs.gov/browse/eo-1/ali/174/39/2016/EO117403920161201 10K6_SG1_01.jpeg |
| 28-Apr | Honolulu | EO106404520161191 10KF | 21.38, -158.04 | 18:49Z | | | | Waiting for scene to post on matsu | http://earthexplorer.usgs.gov/browse/eo-1/ali/64/45/2016/EO106404520161191 10KF_AK3_01.jpeg |
| 20-Apr | 1st clock jam on DOY 111 | | | | | | | | |

No more calculation necessary to establish correlation with clock drift, so analysis halted until drift rate and clock reset had been performed

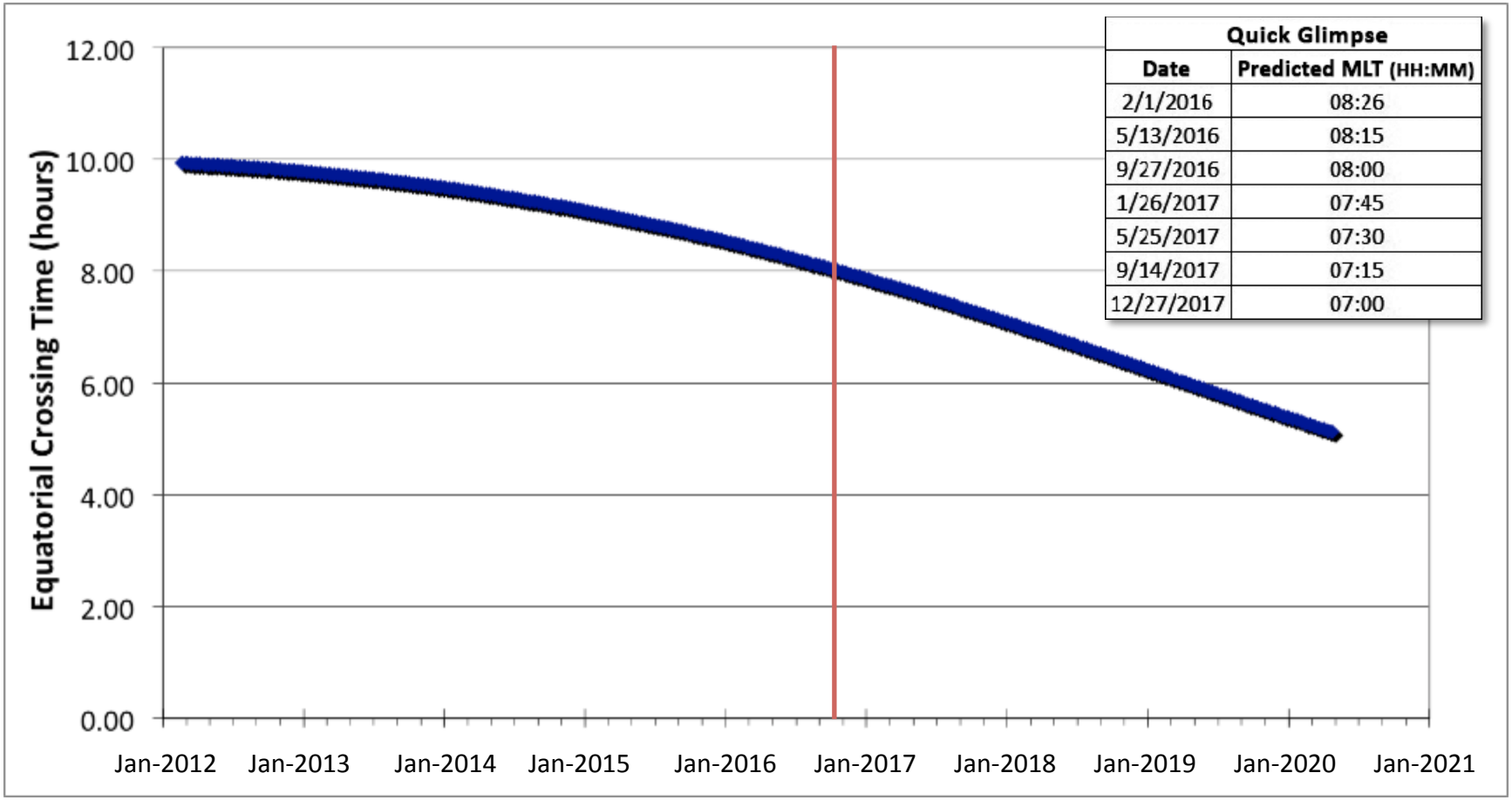
**Note: Targets appeared about 7km further south in footprints even before the anomaly and continue to be about the same amount south of where they should appear compared to the time shift geolocation accuracy problem**

**Note2: When the footprint is shifted toward the North, it implies that the instruments are turning on early compared to true GMT, when they are shifted toward the South, the instruments are turning on late**

**Note3: Differences between Offset for sequential images is probably induced by pointing angle differences**

# Change in EO-1 Equatorial Crossing Time

EO-1 ran out of orbital maintenance fuel in February 2011, when the Mean Local Time (MLT) was 10:00 AM. Since then it has been drifting lower in orbit and earlier in overpass time. EO-1 will reach 8:00 AM MLT by October 2016.




| Quick Glimpse | |
|---|---|
| Date | Predicted MLT (HH:MM) |
| 2/1/2016 | 08:26 |
| 5/13/2016 | 08:15 |
| 9/27/2016 | 08:00 |
| 1/26/2017 | 07:45 |
| 5/25/2017 | 07:30 |
| 9/14/2017 | 07:15 |
| 12/27/2017 | 07:00 |

# ALI data taken at an 8 AM equatorial crossing time is 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 an 8 AM crossing time until October 2016.

| 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 |
| **Signal@8 AM / 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 (SZA).*

# EO-1 Phase F Decommissioning Timeline

| Mission Operations, Science and Decommissioning Timeline | Beginning Date of Activity | Duration | Comments |
|---|---|---|---|
| **Science Activities** | | | **Selected Key Activities** |
| Generate Level 2 Reflectance | 10/1/16 | 1 year | Provided on demand, improvements for water and diverse terrain |
| Prototype Land Cover Products | | | For HyspIRI, NASA TE, C Cycle and Climate Change, Bio-physical variables (Veg. fraction, pigments, LAI, moisture, Albedo) |
| Support NASA Sustainable Land Imaging (SLI) and new satellite mission formulations | | | Data fusion and prototype products (ALI, Hyperion, Landsat, SENTINEL 2 MSI) |
| Spectral time series for VEGETATION targets | | | FLUX sites, instrumented sites (e.g. SpecNet, LED), LTER, etc. |
| Spectral time series for CAL/VAL targets | | | CEOS PICS, VIS/NIR sensor intercomparison |
| **Disaster Response and Mitigation** | 10/1/16 | 2-3 months | Relief efforts- floods, hurricanes, fires, volcanoes |

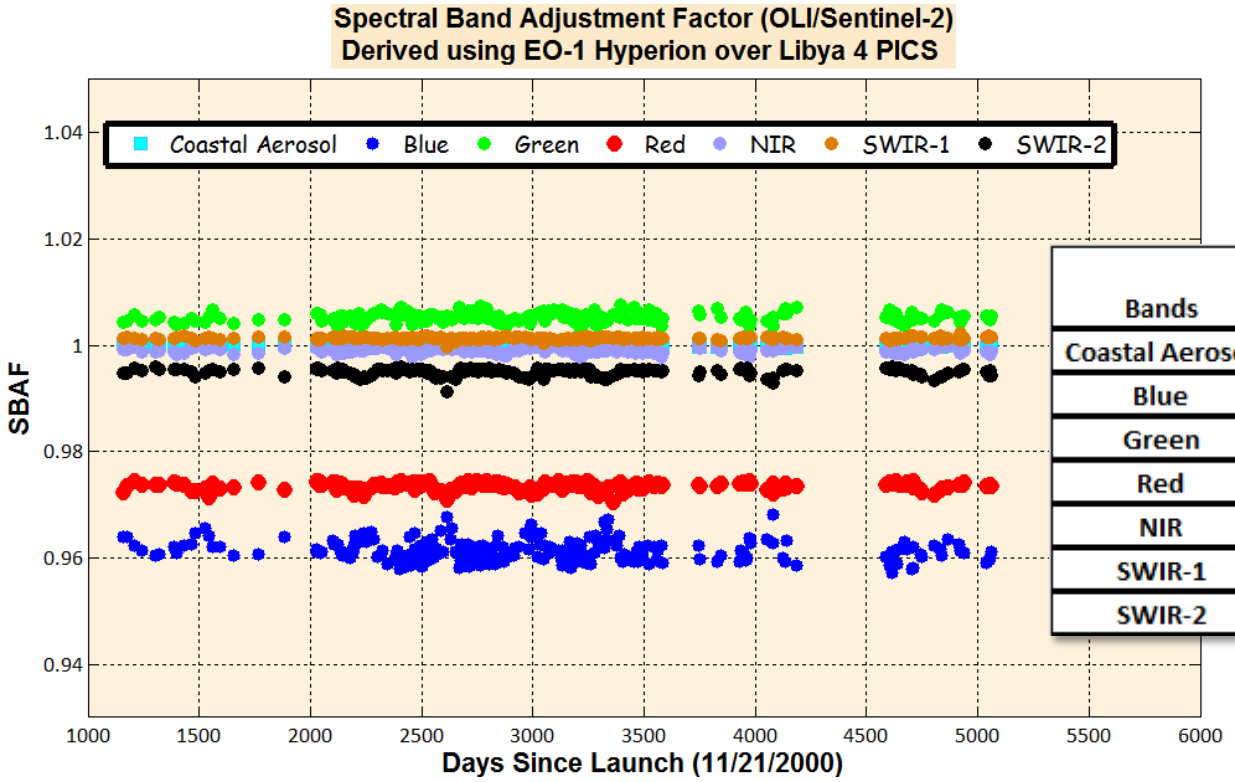
# EO-1 Phase F Decommissioning Timeline

| Decommissioning Timeline | Beginning Date of Activity | Duration | Comments |
|---|---|---|---|
| Receive direction for NASA HQ to begin termination process flow | 8/31/16 | 1 day | Initial trigger to begin proposed steps below |
| Update End of Mission Plan (EOMP) & develop Decommissioning Plan | 9/1/16 | 30 days | Final EOMP will require only 30 days to complete. Decommissioning Plan may take slightly longer to be completed. |
| Notification of Intent to Terminate is sent to Administrator with updated EOMP | 10/1/16 | 1 day | Per NASA Policy Directive NPD8010.3B Notification of Intent to Decommission or Terminate Operating Space Systems and terminate Missions |
| Prepare for Decommissioning Review | 10/1/16 | 90 days | Allow 90 days from Intent to Terminate Notification to Decommissioning Review |
| Final flight build Content Review | 11/1/16 | 1 day | Review content of flight passivation build procedures and patches |
| Final flight build ORR and delivery to MOC | 12/1/16 | 1 day | Approve flight passivation procedures/patches and prepare uplink command packages |
| Passivation Simulation and Rehearsals | 12/1/16 | 25 days | FOT preparatory activities |

# EO-1 Phase F Decommissioning Timeline

| Decommissioning Timeline | Beginning Date of Activity | Duration | Comments |
|---|---|---|---|
| Decommissioning Review | 1/5/17 | 1 day | EO-1 Key Decision Point (KDP) #1 |
| Perform Pulse Plasma Thruster Test and other engineering tests requested by the Satellite Asset Protection Program Office | 1/12/17 | 17 days | Could consider performing some engineering tests prior to HQ authorization to decommission |
| Disposal Readiness Review | 2/1/17 | 1 day | This is KDP-F #2 |
| Execute passivation activities<br>- Instrument Turn-off<br>- S/C Passivation<br>- Verification of RF Silence | 2/15/17 | 15 days | See EOMP for final satellite configuration details |
| Archive flight and ground system data and software | 3/15/17 | 15 days | See Phase F report for archive plan |
| Archive all documentation<br>Code 500 (TWIKI)<br>Facilities/Equipment Disposal | 3/31/17 | 60 days | Operations documentation and data archive delivered through project CM, Flight Projects Sharepoint, Center Archivist, and National Archive packaging reviews |
| Contract/Agreement Modification and/or Closeout | 4/1/17 | 30 days | Contracting Officer and COTR involvement |
| EO-1 Operations and Science Documentation Closeout and shipment to National Archive | 4/1/17 | 180 days | Upload electronic versions to center-level repository. Inventory, box, label, and ship hard copy to National Archive |
| EO-1 Mission Final Report | 4/30/17 | 75 days | |

# The Long Term Stability of Hyperion

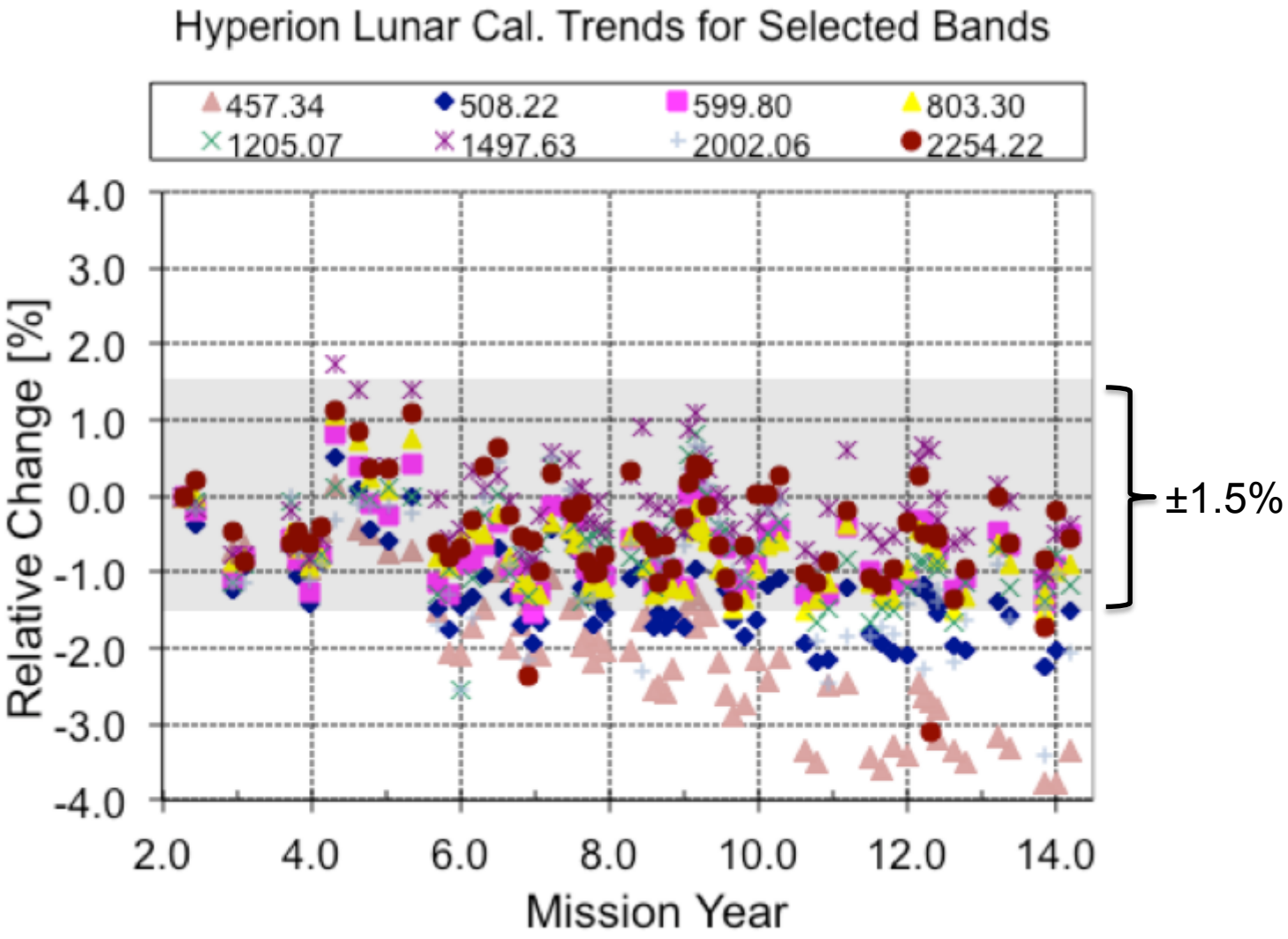



| Bands | Avg. SBAF | Uncertainty (Stdev/ Mean)% |
|---|---|---|
| Coastal Aerosol | 1.000 | 0.02% |
| Blue | 0.961 | 0.21% |
| Green | 1.005 | 0.08% |
| Red | 0.974 | 0.07% |
| NIR | 0.999 | 0.05% |
| SWIR-1 | 1.001 | 0.02% |
| SWIR-2 | 0.995 | 0.07% |

- The alternative way to understand and 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,
  - The stability of Landsat 8 and Sentinel-2 reduces the impact of an eventual loss of Hyperion.

*Helder, et al. 2015*

# Hyperion Lunar Trends




This figure shows the trending of the lunar calibration data over the mission duration. The plot shows that, except for the shortest wavelength in the VNIR focal plane (▲:457.34), the Hyperion data are stable to within ± 1.5%. The data have been normalized to the first acquisition point, and are expressed as percent change from the beginning.

Thank You!

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