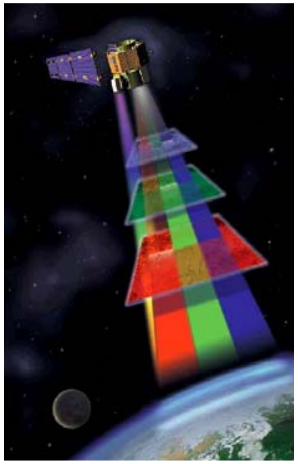
NASA

SensorWeb

Linking Sensors, Products & People

For Science, Humanitarian Assistance and Disaster Relief Applications

NASA SensorWeb



Final Review:

An Interoperable Sensor Architecture to Enable Sensor Webs in Pursuit of Global Earth Observing System of Systems (GEOSS)

September 17, 2009

ESTO Earth Science Technology Office

Goddard Space Flight Center

JPL

UNIVERSITY OF MARYLAND

Ames Research Center

Objective

- Assist future Earth science needs for integrating multiple observations without requiring the end-user to have intimate knowledge of the sensors being used.

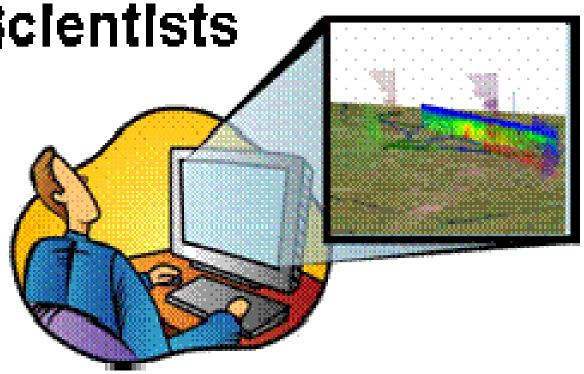
- Demonstrate and validate a path for rapid, low cost sensor integration, which is not tied to a particular system.

- Facilitate the United States contribution to the Global Earth Observation System of Systems by defining a common sensor interface protocol based upon emerging community standards.

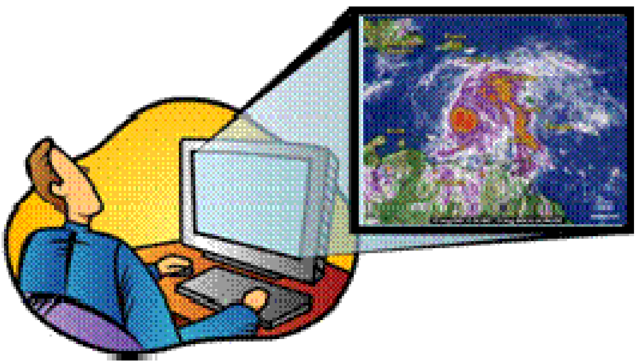
An Interoperable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS

PI: Dan Mandl, GSFC

Scientists



Land Remote Sensing Observation Data

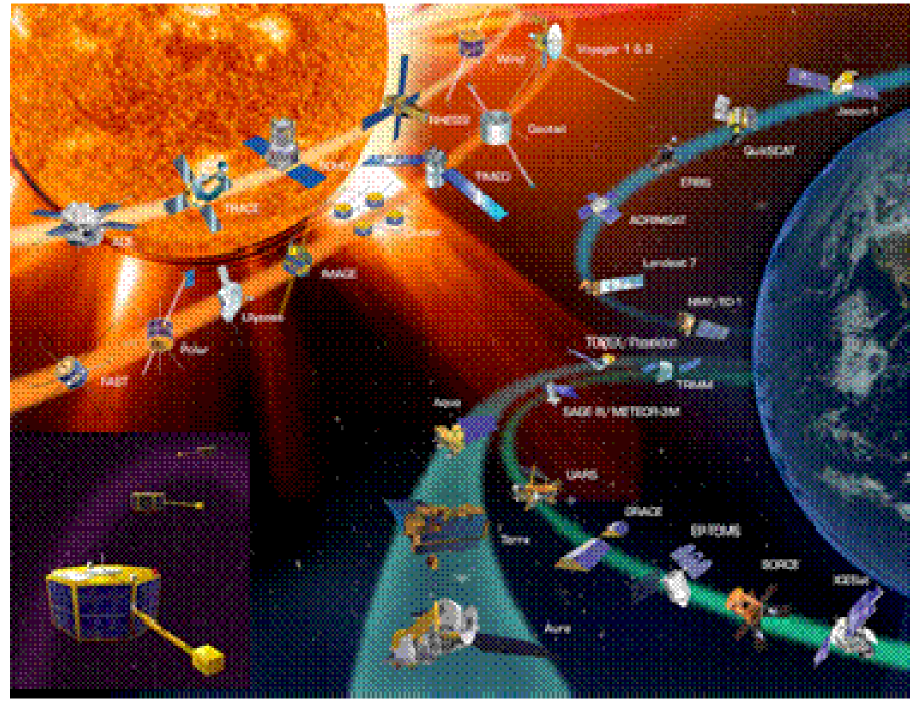


Earth Weather Data

Space Weather Data

Sensor Planning Services (SPS)

Sensor Alert Services (SAS)



Sensor Registry Services (SRS)

Sensor Observation Services (SOS)

Service Chaining Services (SCS)

Vision for Space Sensor and Subsequent Science Data Access Via Generic Web Services to Form Sensor Web

An Interoperable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS

PI: Dan Mandl, GSFC

Approach

- Experiment with interoperability standards
- Demonstrate and specify the discovery process for available sensor resources
- Demonstrate and specify the ability to direct other sensors
- Demonstrate and specify the ability to specify how the available data should be delivered and combined

Co-I's/Partners

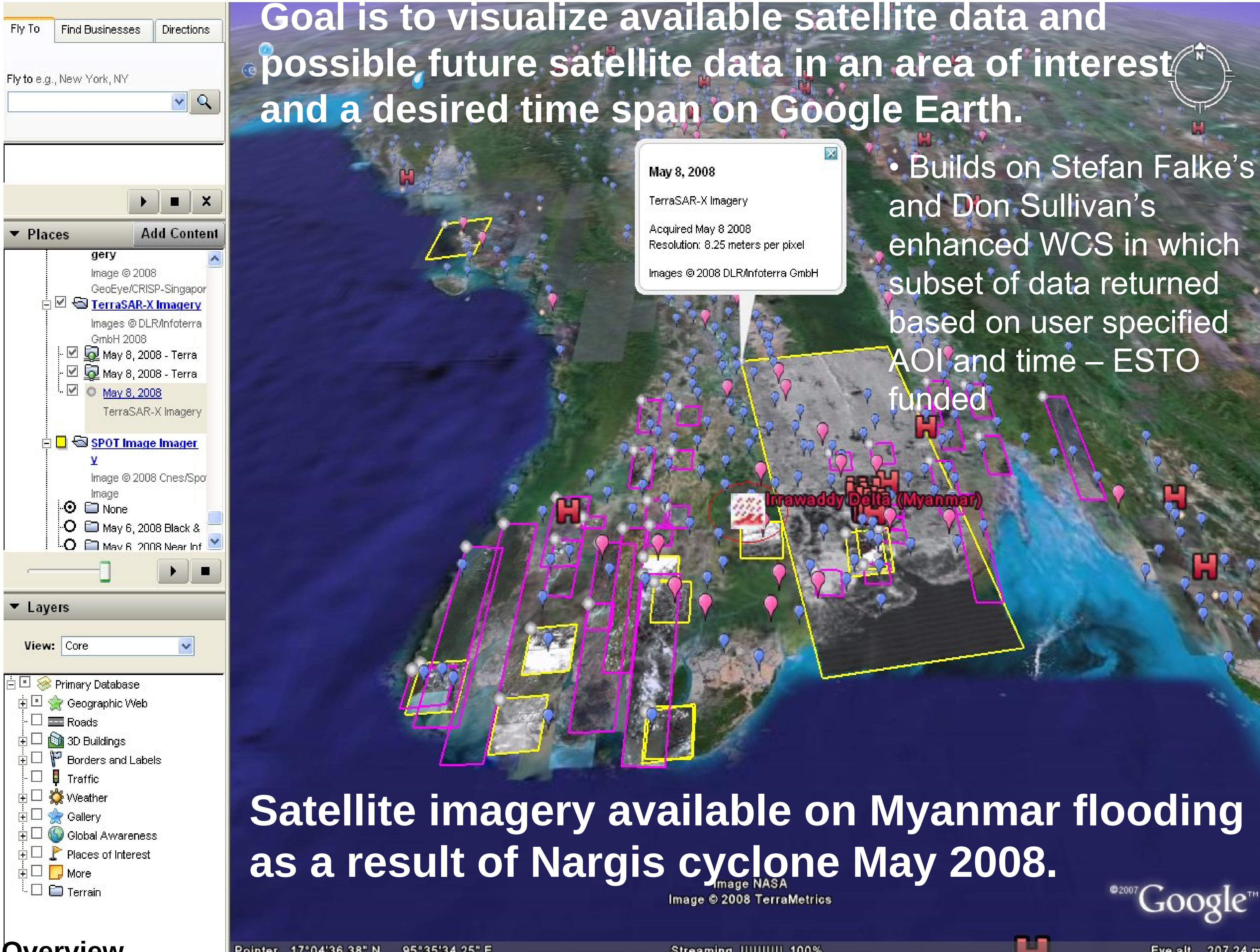
- Rob Sohlberg, Dr. C. Justice, Dr. J. Townshend /UMCP
- Dr. Jeffrey Masek, Stuart Frye / GSFC
- Dr. Stephen Ungar, Troy Ames / GSFC
- Dr. Steve Chien, Daniel Tran/ JPL
- Pat Cappelaere/Vightel, L. Derezinski/Innovative Sol
- D. Smithbauer/WVHTF

Accomplishments

- Developed and tested architecture and that makes use of Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) suite of standards to interoperate space-based, airborne and ground sensors
- Helped to drive OGC SWE standards in first official release
- Proposed additional standards and enhancements (WfCS, Geotorrent, Geoactivities)
- Completed participation in two OGC Webservices (OWS) testbed activities with international partners (OWS-5, OWS-6)
- Completed Fire SensorWeb pilot with variety of partners summer 2007 and summer 2008
- Completed participation in the Empire Challenge summer 2008
- Won R&D 100 Magazine "Top 100 Innovation of 2008" award
- Completed two SensorWeb data simulations in Australia in (floods and fires) Spring 2009
- Completed 1st phase of Namibian Flood SensorWeb Pilot project under auspices of CEOS and UN-SPIDER , Spring 2009

Goal is to visualize available satellite data and possible future satellite data in an area of interest and a desired time span on Google Earth.

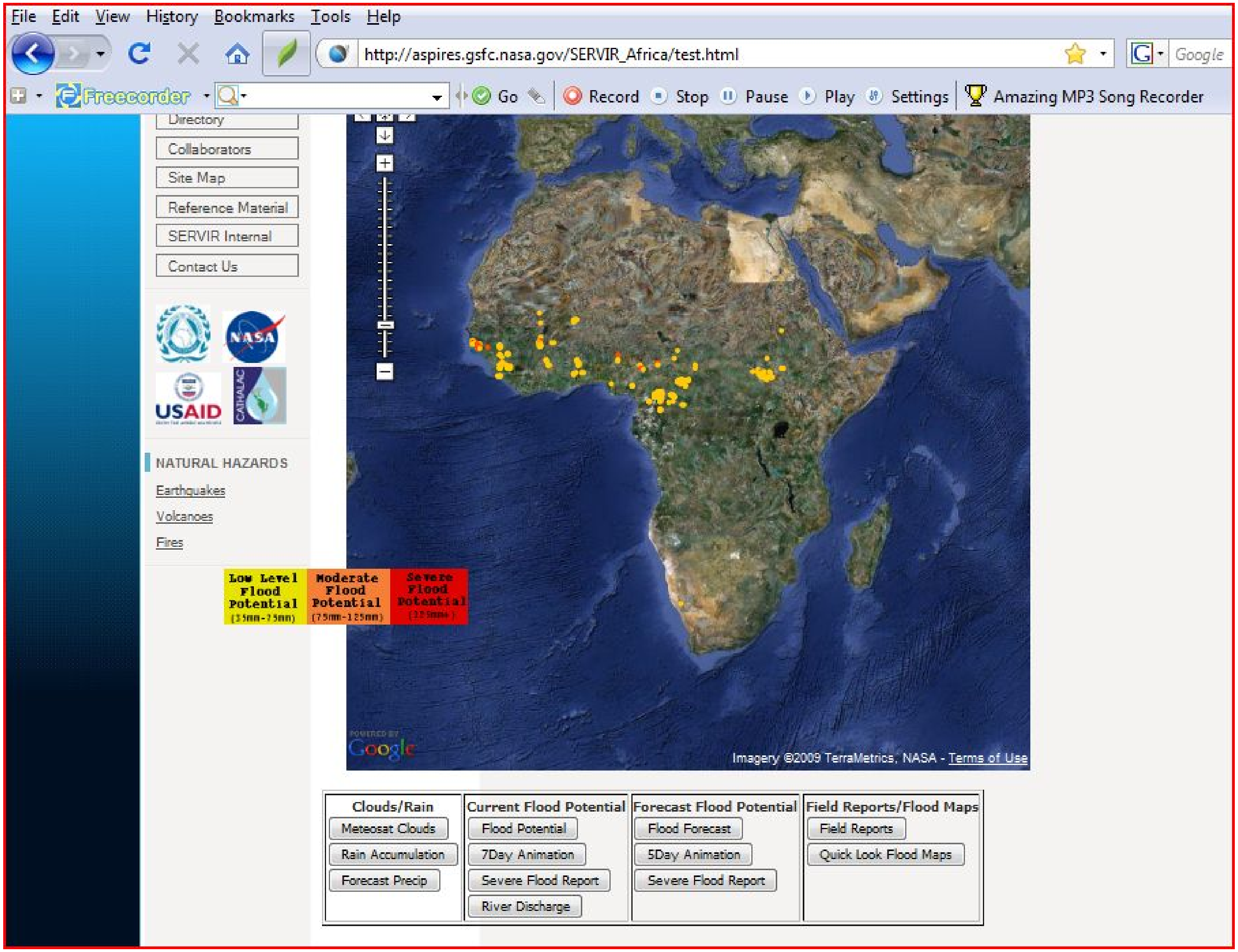
- Builds on Stefan Falke's and Don Sullivan's enhanced WCS in which subset of data returned based on user specified AOI and time – ESTO funded



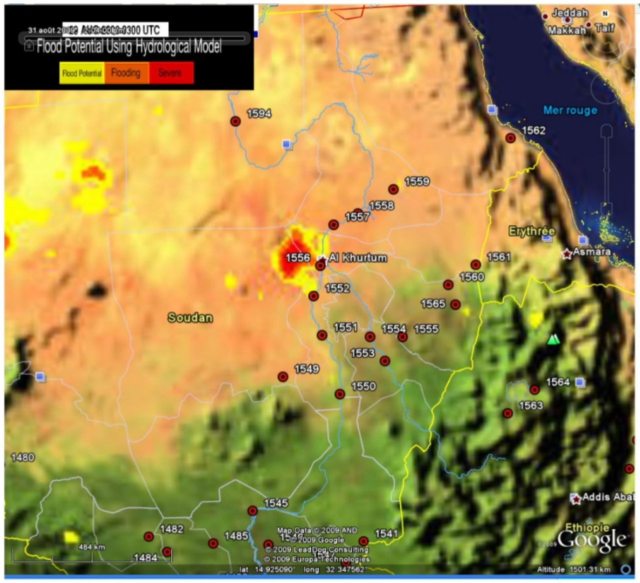
Satellite imagery available on Myanmar flooding as a result of Nargis cyclone May 2008.

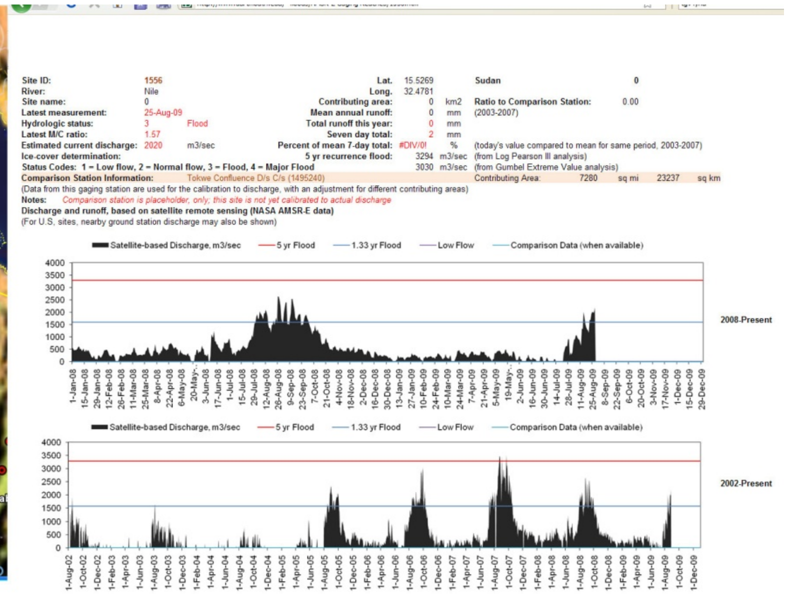
Overview

SERVIR Experimental/Standard Flood Products Page – Policelli/GSFC



Red Cross Used Flood Potential Model and Relavant Info to Launch Appeal





From: Frederic Zanetta [mailto:Frederic.Zanetta@ifrc.org]
Sent: Monday, August 31, 2009 11:05 AM
To: Policelli, Frederick S. (GSFC-6104)
Subject: Use of NASA product

Hi Fritz,

How are you ?
I just want to let you know that we have been using today the TRMM product (see attached) to confirm information from the field about floods near Kartoum and we will probably be launching an Emergency Appeal.

Have a nice day

Frederic

Frédéric Zanetta
Operations Support Department
Disaster information senior officer
Chemin des Crêts 17 | Petit-Saconnex | P.O. Box 372 | 1211 Geneva 19 | Switzerland
Phone: +41 22 730 4291 | Fax: +41 22 730 4480
E-mail: frederic.zanetta@ifrc.org | Skype: fzanetta

Normanton, Queensland, Australian Floods February 2009 Data Simulation

- **Prediction:** TRMM-based Predictive Flood Potential Model
  - Robert Adler/University of Maryland –NASA/GSFC
- **Survey:** MODIS Flood Map
  -Robert Brakenridge/ Dartmouth Flood Observatory
- **Details:**
  - Earth Observing 1 Advanced Land Imager and Hyperion
    -NASA/GSFC – Image acquisition, flood map, automation
      -- Mandl, Frye, Cappelaere
  - Radarsat Flood Image
    -MDA/Canadian Space Agency – Image acquisition
    -Space Research Institute NASU-NSAU, Ukraine – Flood Map Production
      - Serhiy Skakun and Natalia Kussul
  - Landsat Water Mask
    -Space Research Institute NASU-NSAU, Ukraine – Water Mask
      - Serhiy Skakun and Natalia Kussul
  - Formosat Flood Image
    -Taiwan National Program Science Office – Image acquisition
    - National Cheng-Kung University – Data processing
      - Cheng-Chien Liu

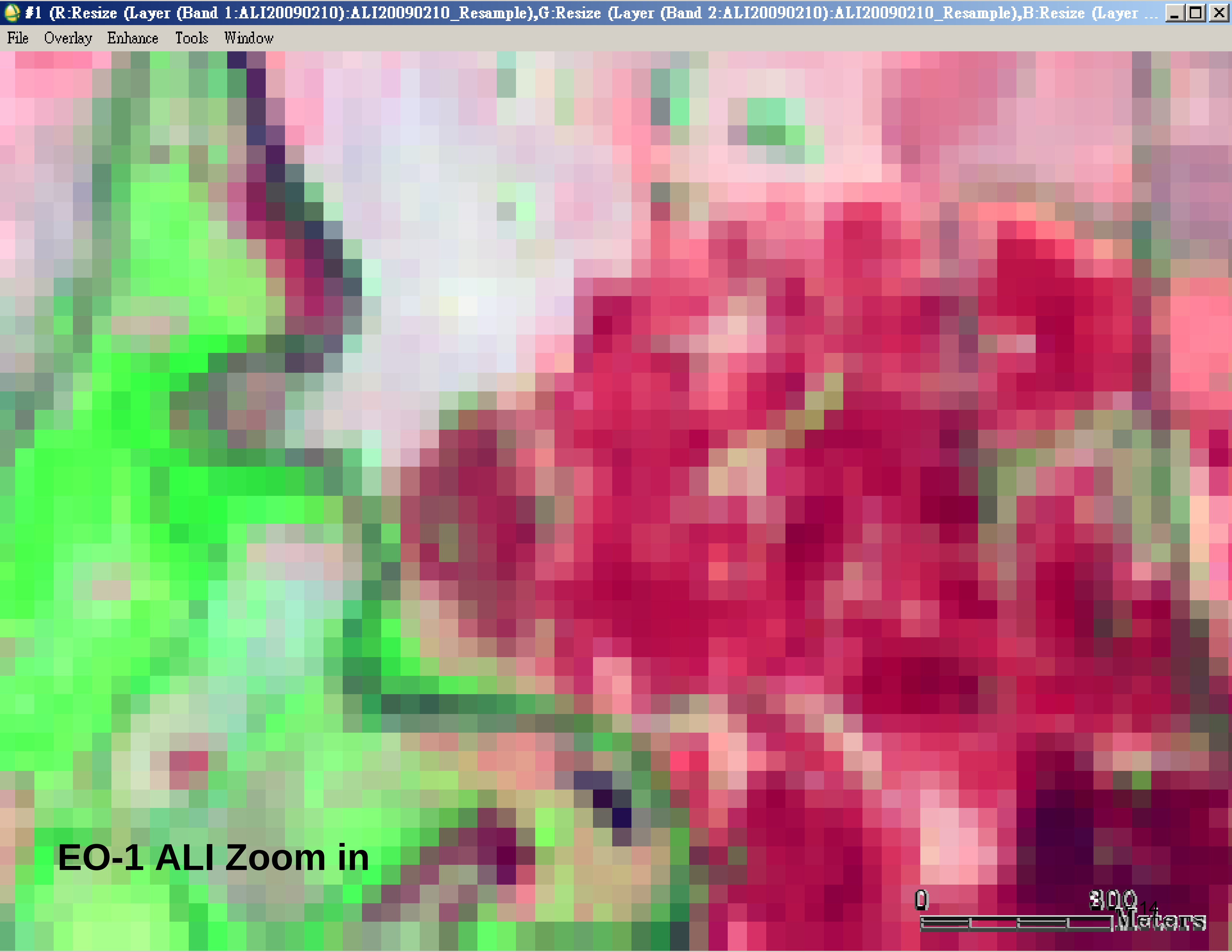
EO-1 Image March 11, 2009 of Normanton Australia as a Result of SensorWeb Simulation Effort

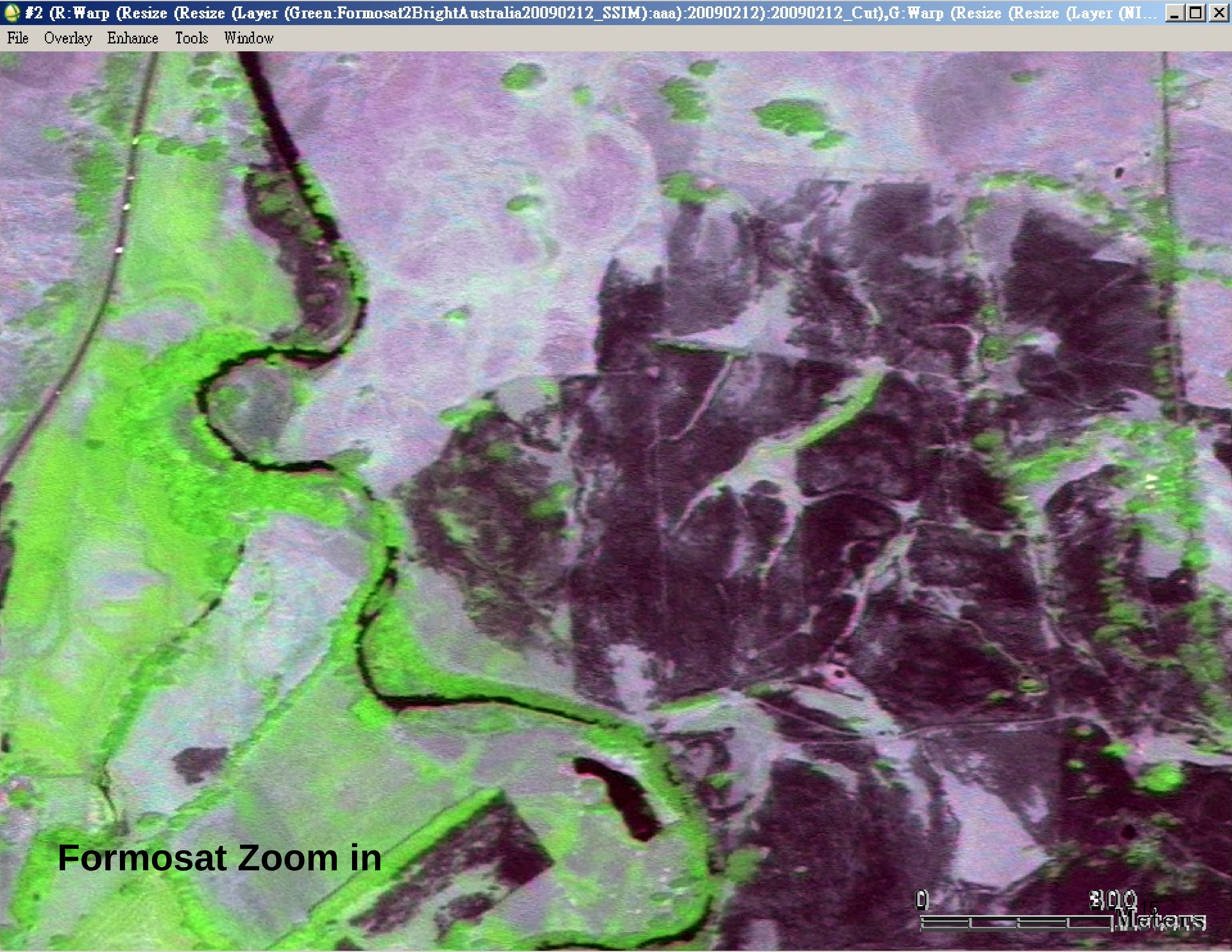
Formosat Flood Image

Triggered by SensorWeb of Normanton Australia

Australian Bright Fire SensorWeb February 2009 Data Simulation

- **Survey:** MODIS Rapdfire
  - -Robert Sohlberg/ University of Maryland
- **Details:**
  - Earth Observing 1 Advanced Land Imager and Hyperion
    - -NASA/GSFC – Image acquisition, flood map, automation
      - -- Mandl, Frye, Cappelaere
  - •Formosat Flood Image
    - -Taiwan National Program Science Office – Image acquisition
    - - National Cheng-Kung University – Data processing
      - - Cheng-Chien Liu


#1 (R:Resize (Layer (Band 1:ALI20090210):ALI20090210_Resample),G:Resize (Layer (Band 2:ALI20090210):ALI20090210_Resample),B:Resize (Layer ...
File Overlay Enhance Tools Window
EO-1 ALI Zoom in
0
300
Meters



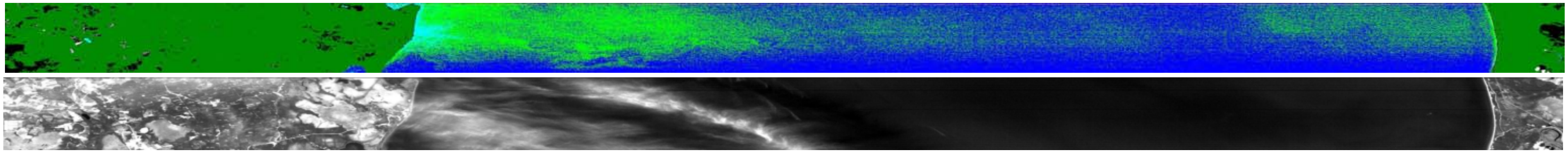
Formosat Zoom in

Ocean SensorWeb: Monterey Bay 2008 Deployment

- In October 2008, numerous assets were deployed to Monterey Bay
  - MBARI – hosts, buoys, gliders, AUV, ships, drifters
  - Rutgers/Cal Poly – gliders
  - NASA/JPL/GSFC – EO-1 ALI Hyperion, ASTER, MODIS
  - JPL/UCLA/Jifresse – ocean simulations
  - UC Santa Cruz – in-situ assets, aerial imaging
- Monterey Bay was selected for
  - Proximity to collaborating institutions
  - Algal bay incubator
- In September and October 2008
  - 10 EO-1 scenes acquired
  - 5 overlapping with the in-situ deployment
  - Automatic delivery of derivative science products
    - Fluorescence Line Height (FLH)
    - Maximum Chlorophyll Index (MCI)

Algal Bloom Identification

- Early prototype classifier (Estonian Lake data)

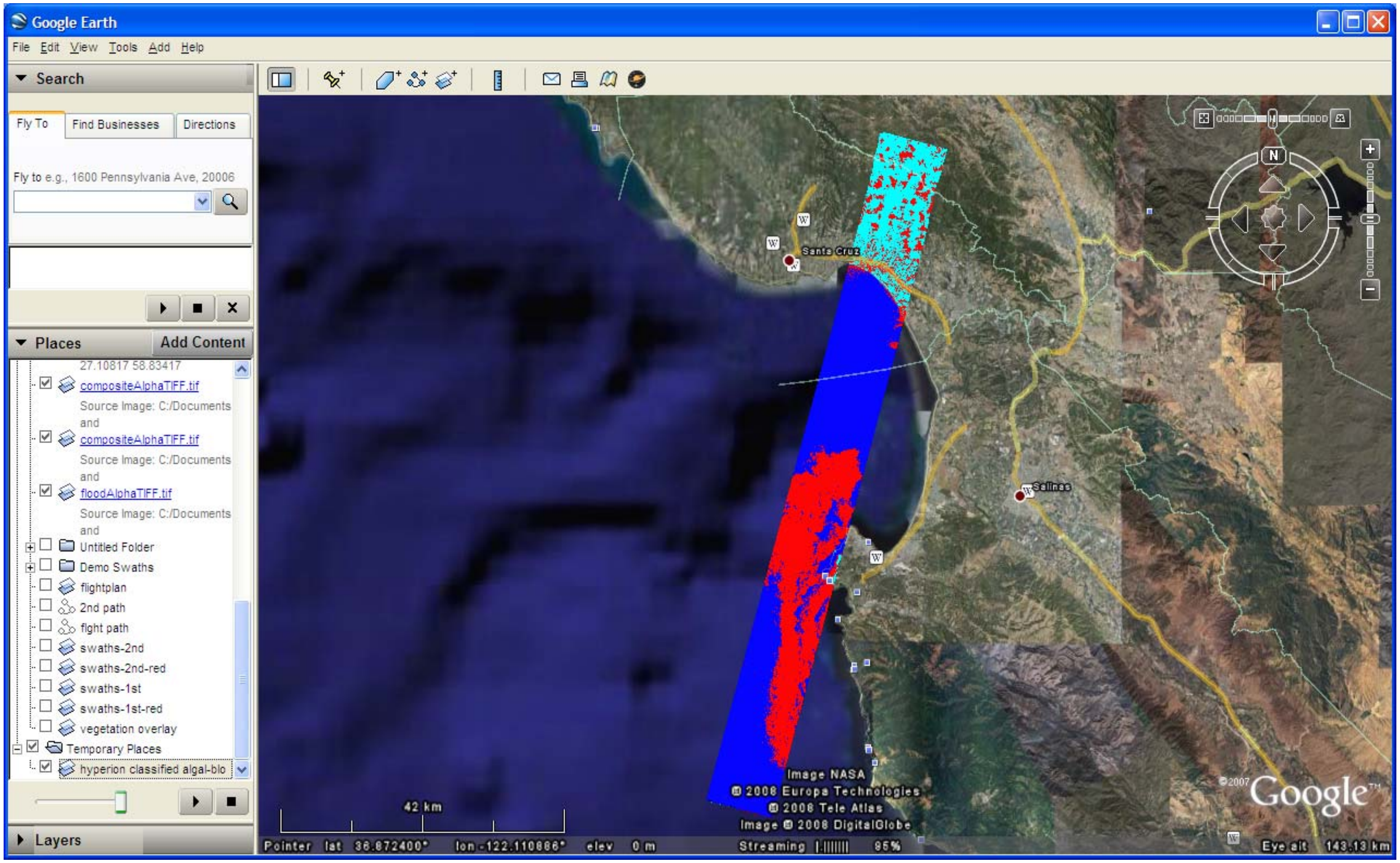


Above: true image and decision tree classification for 2008 Lake Peipsi scene

Decision tree legend:
dark green = land,
black = shadow,
white = cloud,
dark blue = water,
red = dense/surface algae, bright blue = visible algae, bright green = mostly indiscernible algae

Hyperion Data and products

Hyperion image footprint



Caribbean Flood Pilot Project

- GEOSS AIP purpose was to provide a demonstration for multi-hazard management in the Caribbean region with an emphasis on floods produced by tropical storms, using assets that have global reach provided through CEOS members and other participating organizations
- The CEOS Disaster Societal Benefit Area (SBA) team was formed after the November 2007 CEOS plenary session
  - DI-06-09_3 - promote the demonstration of the management of the all phases of a disaster.
  - Caribbean region was chosen to initiate a pilot project to promote demonstration of the four phases of Flood Management.
  - Stuart Frye – NASA/GSFC identified as the POC for the Caribbean Flood Management Pilot Project.
- CEOS Disaster SBA Team presented its proposal at the United Nations Platform for Space-based Information for Disaster Management and Disaster Response (UN-SPIDER) workshop in Barbados
  - UN-SPIDER program run by United Nations Office on Outer Space Affairs (UNOOSA)

Caribbean Flood Pilot Project

- Hosted by the Caribbean Disaster and Emergency Response Agency (CDERA), a 16-nation coalition and one of the potential end user groups for this scenario
- Stu Frye has been conducting and organizing teleconferences weekly for the collaborators
- Pilot expected to start in September and continue for 2 years
- Main source of data will be the International Disaster Charter agreement during disaster events with additional contribution from some CEOS members including JAXA, ESA, NASA and CSA to cover mitigation, warning and recovery phases of flood management.
    - International Disaster Charter is a multination agreement to provide free satellite data when disasters are declared

Namibian Flood-Disease SensorWeb Emergency Response Pilot Project

- Sponsored under the auspices of the Committee on Earth Observing Satellites (CEOS) Working Group on Information Systems and Services (WGISS) and the United Nations Office of Outer Space Affairs (UNOOSA) , specifically the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UNSPIDER) office.
- Effort consists of identifying and prototyping technology which enables the rapid gathering and dissemination of both space-based and ground sensor data and data products for the purpose of flood disaster management and waterborne disease management.
- CEOS input to a subtask under the Group on Earth Observation (GEO) Societal Benefit Area (SBA) task DI-06-09 entitled Use of “Satellite Data for Risk Management” and headed by Guy Seguin of the Canadian Space Agency(CSA)
  - Subtask 1: Disaster Management System Capabilities task with a task number TBS and headed by Lorant Czaran of the UN-SPIDER
  - Subtask 2: “Flood SensorWeb Emergency Response Prototype” with a task number AR-09-02c_2 and headed by Terrance Van Zyl of the South African
  - Subtask 3: “Regional Disaster Management Pilots” with a task number of DI-09-02b_1 and headed by Stuart Frye of SGT Inc./Goddard Space Flight Center

Namibian Floods 2009

Namibian Flood-Disease SensorWeb Emergency Response Pilot Project

- Extensive flooding in Namibia in 2009
- Worked with Guido Van Langhove, head of Hydrological Services in Namibia, to identify flood sensorweb pilot scenario
- Collected satellite imagery for months in the Lake Lambezi area
- Collected the following:
  - Ground measurements (Guido Langenhove)
  - Rainfall estimates, and predictions for first three months of 2009 (Policelli)
  - Flood predictions for 1st three months of year (TRMM – Policelli)
  - Assets:
    - EO-1 30 meter/10 meter 1 -2 times per week(Frye)
    - Formosat 2 meter once per week for 4-6 weeks (requested from Cheng-Chien Liu
    - MODIS flood map 1 per week 4-6- weeks (Requested from Bob Brakenridge)
    - Radarsat about once per week

Namibian Flood-Disease SensorWeb Emergency Response Pilot Project

- Namibian Dept of Hydrology installing flood gauges and rain gauges
- Will correlate ground measurements with satellite imagery to calibrate imagery and thus improve flood forecast models
- NASA will improve our flood forecast model and assist in improving Riverwatch system (Dartmouth Flood Observatory)

Campaign Manager (GeoBPMS 1.0) Triggering EO-1 Flood Image and Possible Other Satellites to Use

Tasking Request:

Title:	Lake Liambezi test1
Description:	Namibia flood campaign requested by Guido Van Langenhove
Category:	
Latitude:	-17.9108028411865
Longitude:	24.21120262146
Day/Night:	day time
Country Code:	
Country Name:	
Zone Number:	576
Zone Name:	Zambia
Region Number:	37
Region Name:	Africa
Admin Code:	
Admin Name:	
Nearby:	
Created At:	Thu, 23 Apr 2009 02:37:14 -0000
Updated At:	2009-04-23

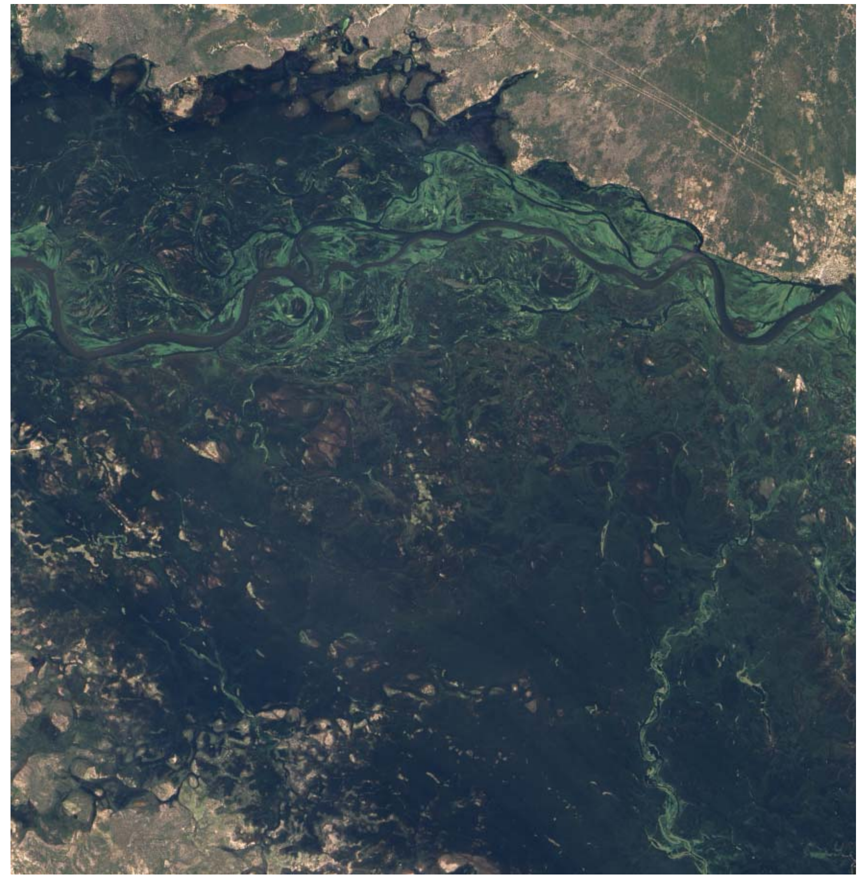
Show Map

Feasibilities

Potential Feasibility	Asset: EO-1, Date: 2009-04-24T08:09:00Z
Potential Feasibility	Asset: ALOS, Date: 2009-04-24T23:24:50Z
Potential Feasibility	Asset: FORMOSAT-2, Date: 2009-04-25T00:45:28Z
Potential Feasibility	Asset: QB-2, Date: 2009-04-25T08:00:21Z
Potential Feasibility	Asset: SPOT-5, Date: 2009-04-25T21:15:14Z
Potential Feasibility	Asset: EO-1, Date: 2009-04-27T08:25:00Z
Potential Feasibility	Asset: FORMOSAT-2, Date: 2009-04-27T12:24:02Z
Potential Feasibility	Asset: SPOT-5, Date: 2009-04-28T06:24:02Z
Potential Feasibility	Asset: QB-2, Date: 2009-04-28T19:10:07Z
Potential Feasibility	Asset: ALOS, Date: 2009-04-29T00:35:33Z
Potential Feasibility	Asset: EO-1, Date: 2009-04-29T08:04:00Z
Potential Feasibility	Asset: ALOS, Date: 2009-04-29T20:38:33Z
Potential Feasibility	Asset: FORMOSAT-2, Date: 2009-04-29T23:19:50Z
Potential Feasibility	Asset: QB-2, Date: 2009-04-30T02:52:57Z
Potential Feasibility	Asset: SPOT-5, Date: 2009-04-30T11:02:33Z
Potential Feasibility	Asset: EO-1, Date: 2009-05-02T08:21:00Z
Potential Feasibility	Asset: ALOS, Date: 2009-05-02T14:09:28Z
Potential Feasibility	Asset: QB-2, Date: 2009-05-02T14:38:16Z
Potential Feasibility	Asset: SPOT-5, Date: 2009-05-03T01:43:33Z
Potential Feasibility	Asset: FORMOSAT-2, Date: 2009-05-03T09:47:24Z

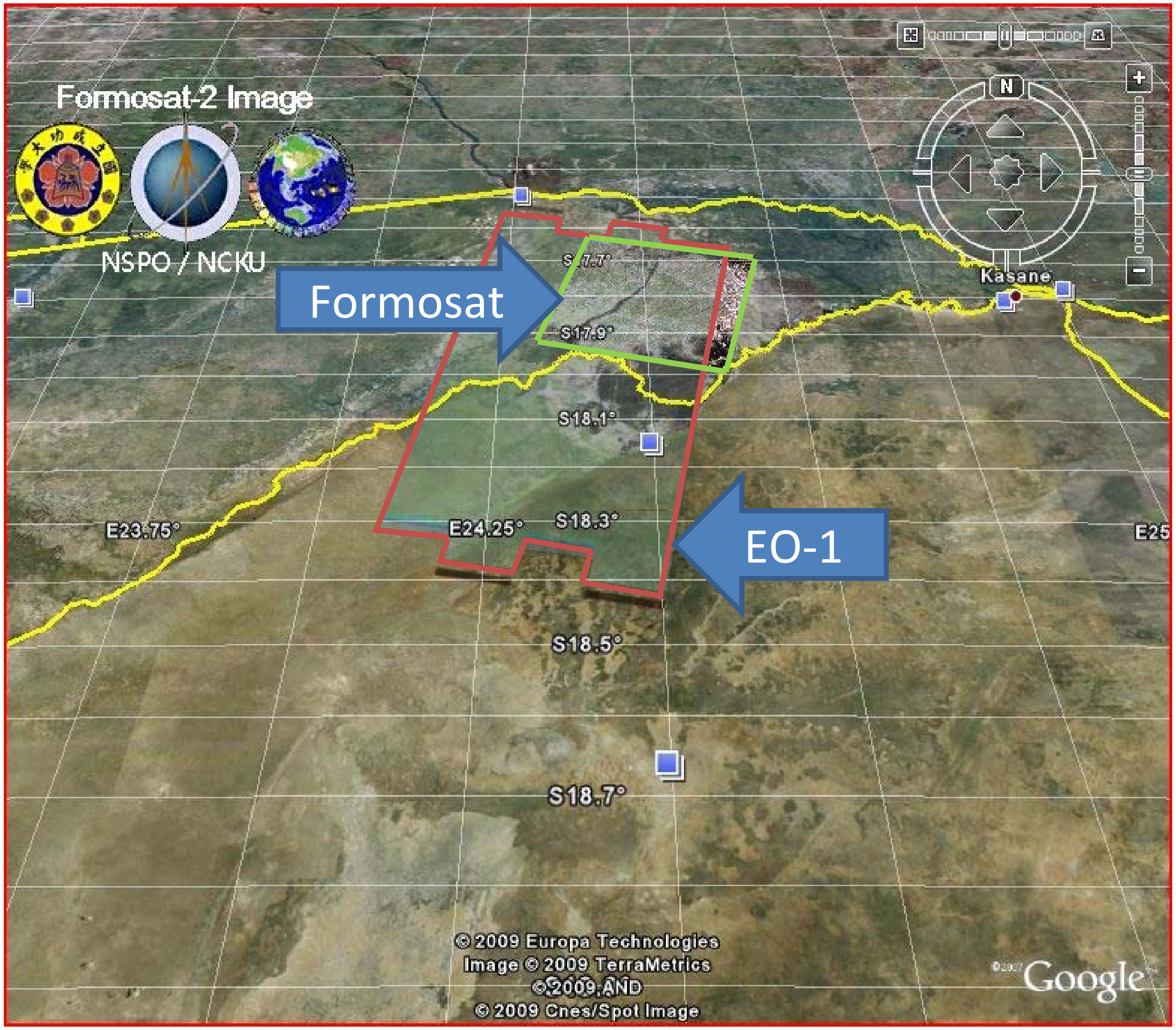
Lake Liambezi Flood in Namibia

Landsat Image Oct 18, 2002



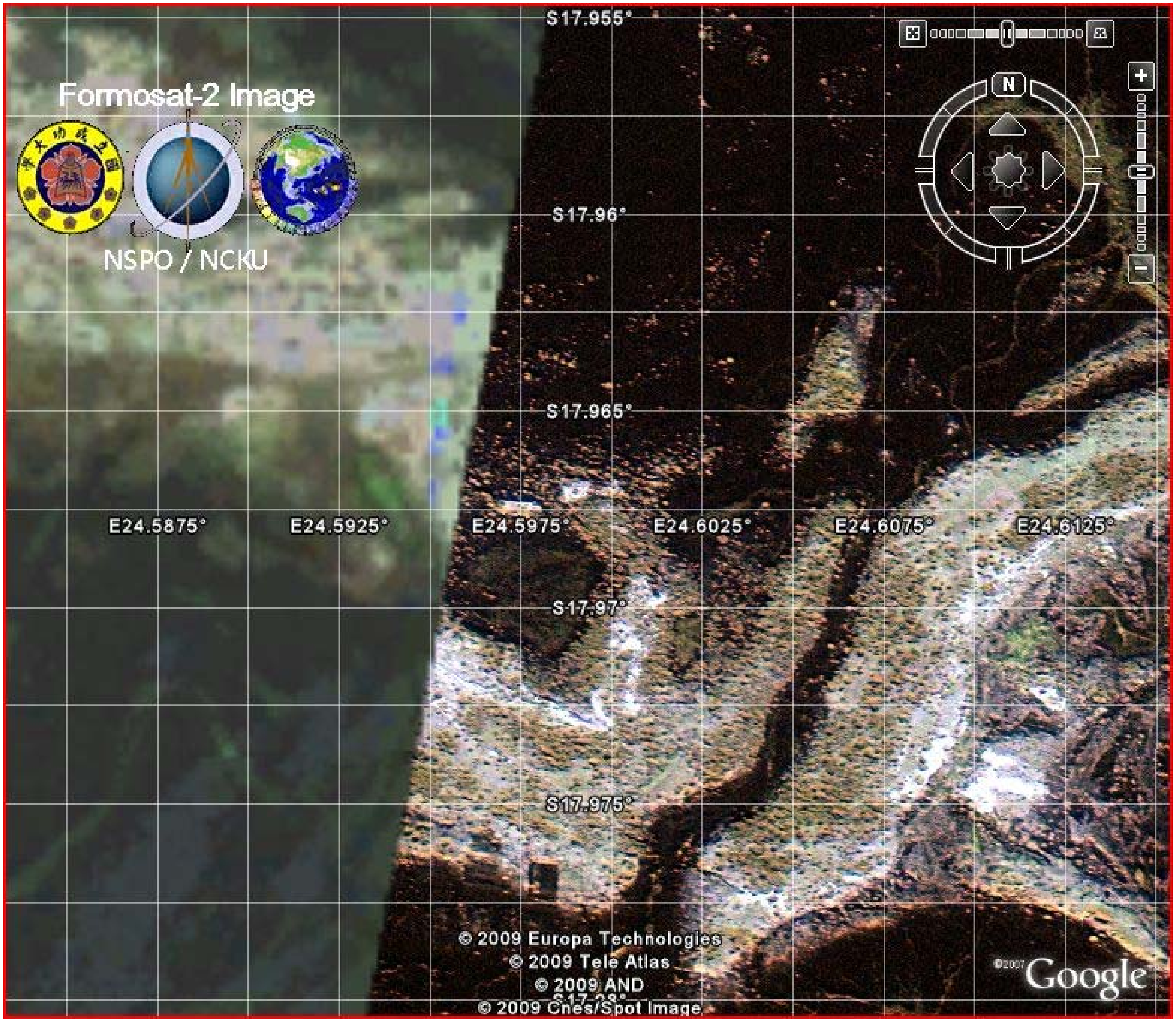
EO-1 Image March 27, 2009

Lake Liambezi: EO-1 ALI Image 4-9-09 Overlaid on Formosat Image 4-5-09 on Google Earth Both images Geo-tiled

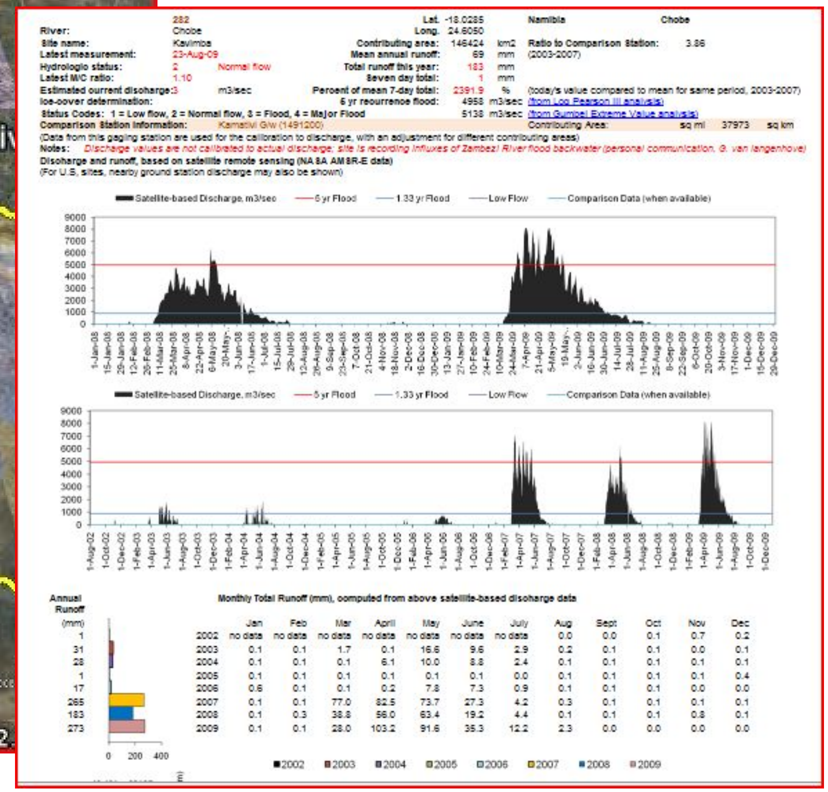


Year 3 Accomplishments

Zoom 2 – Note increased detail of Formosat

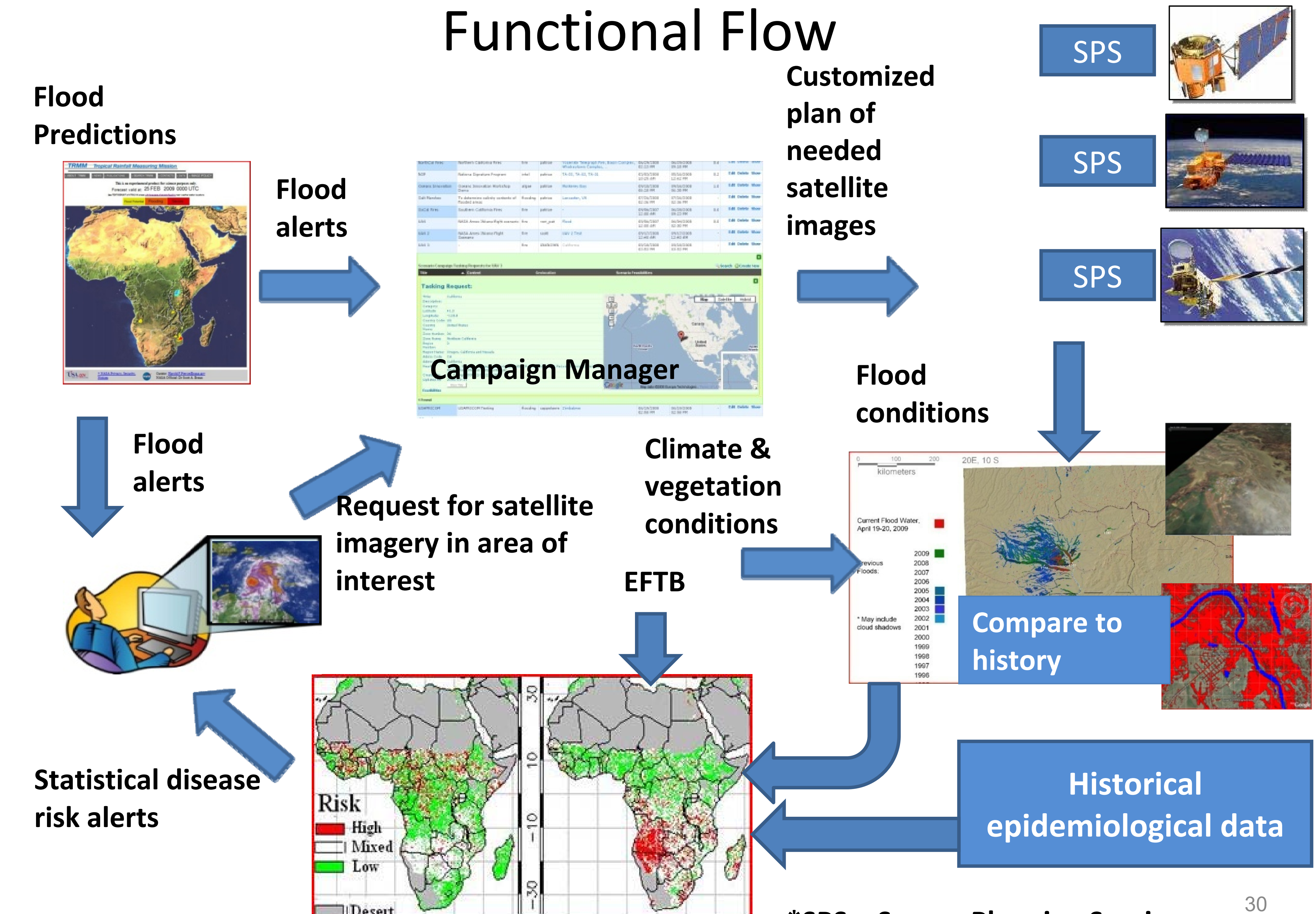


EO-1, Radarsat, River Watch Example



Goal is to calibrate River Watch measurements which use AMSR-E to calculate river flows and thus provide early warning for flooding downstream

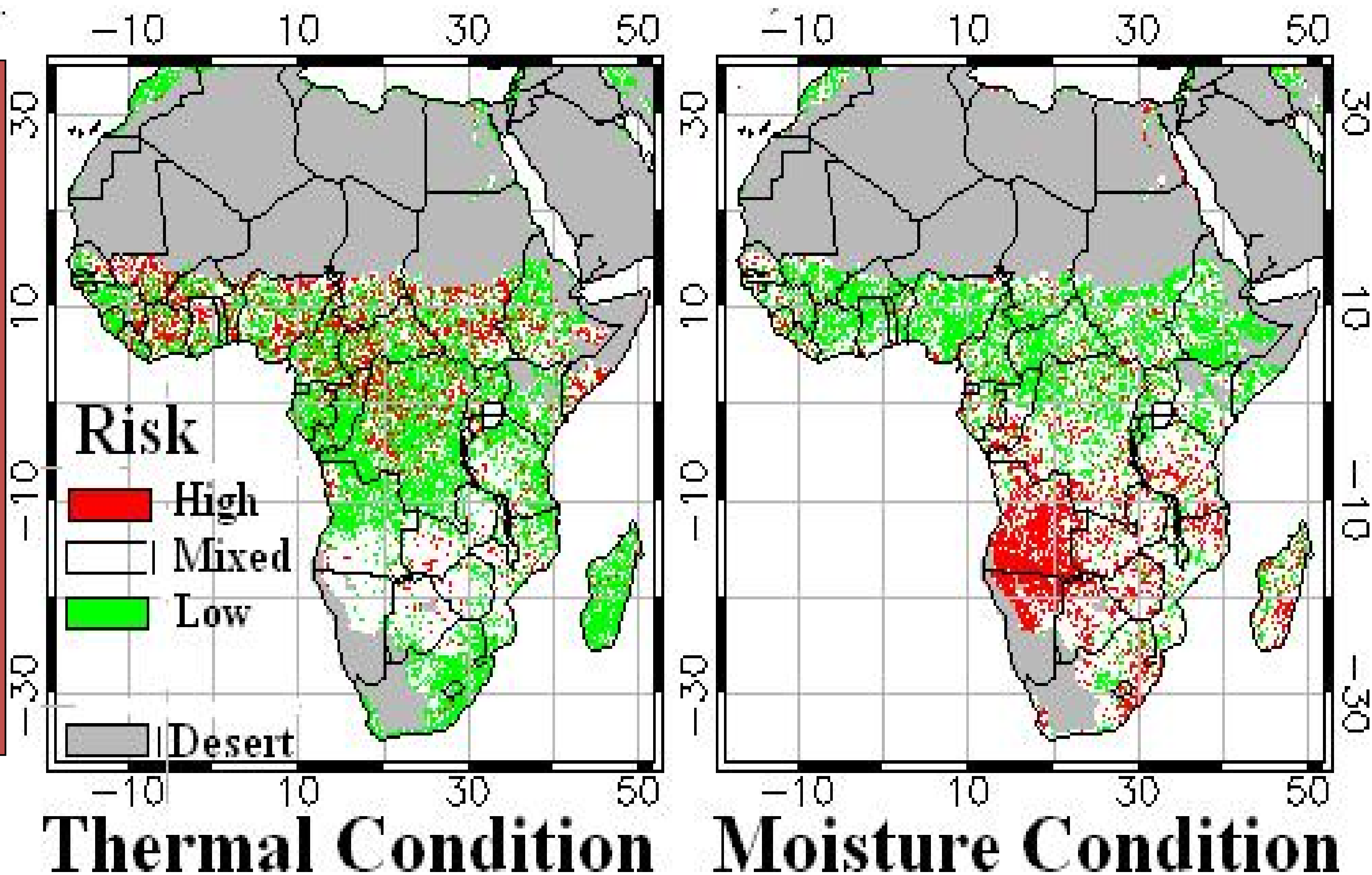
Top Level Malaria Early Warning SensorWeb Functional Flow



Strategy: WEATHER PROXY

AUGUST 26, 2008

Malaria risk map identifies priority areas and additional resources needed to fight epidemics effectively



INTENSIVE MALARIA

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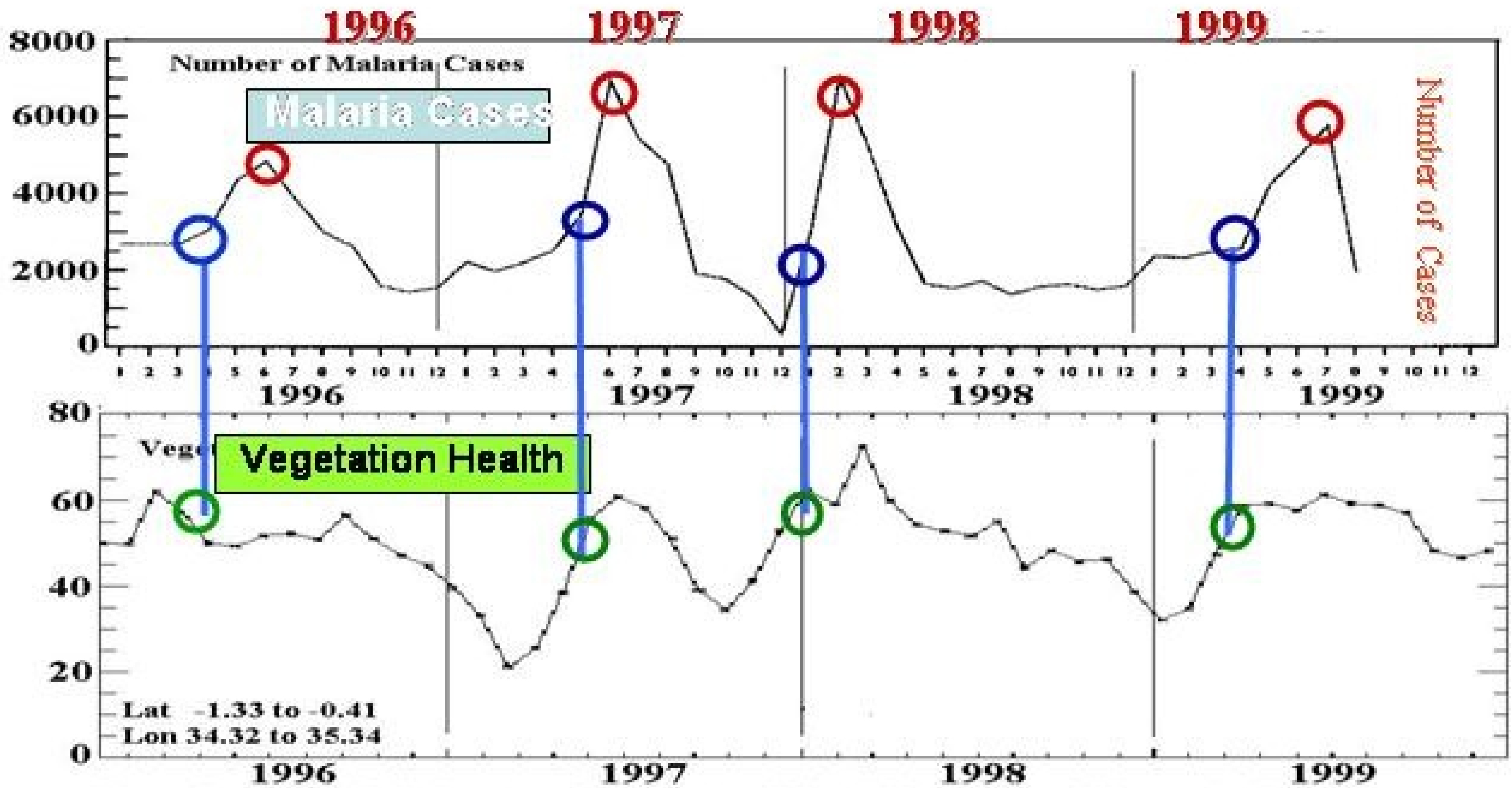
Predicting Malaria in KENYA

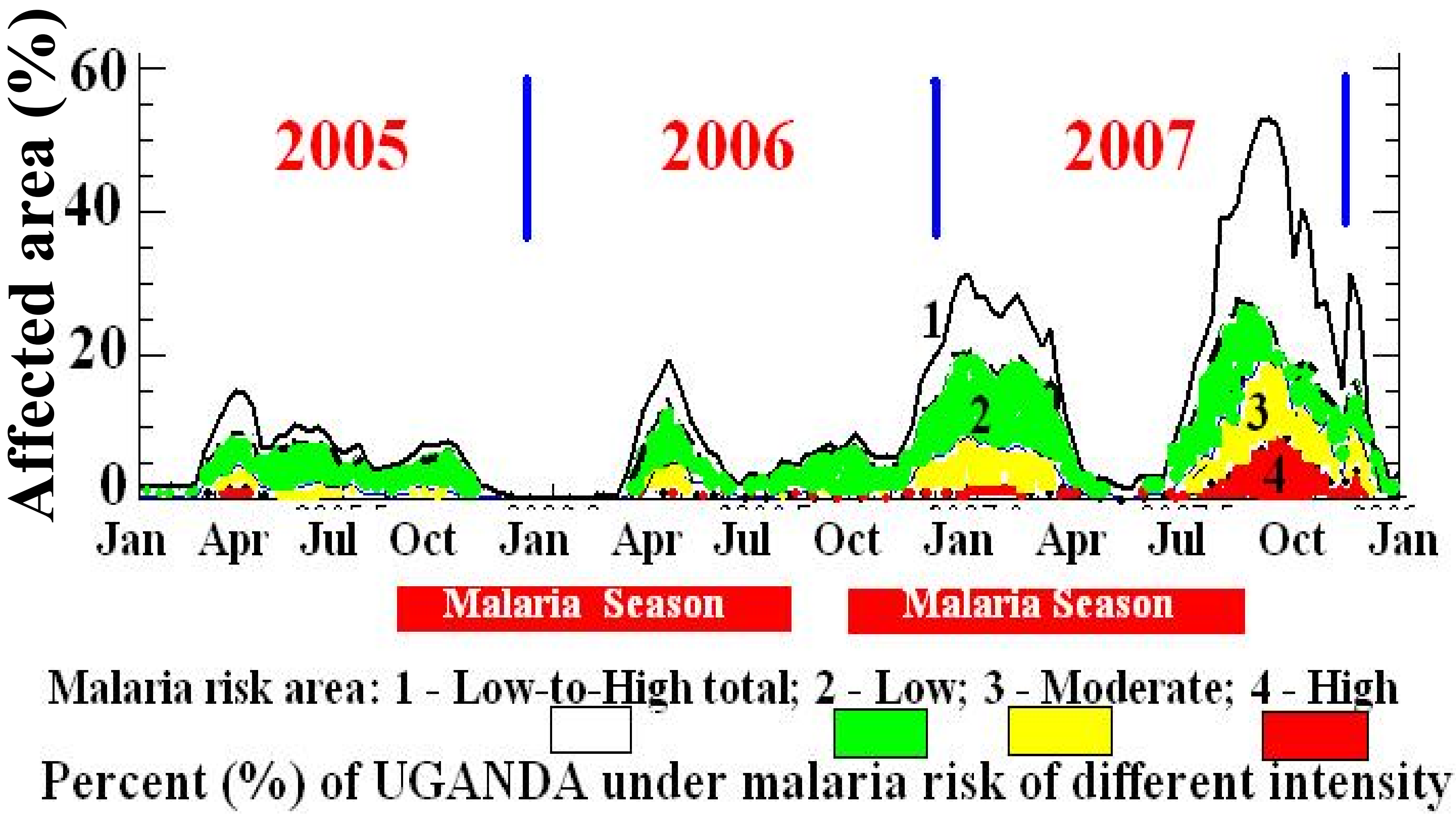


Number of Malaria Cases in Kisii District Hospital, Western Kenya and AVHRR-based Vegetation Health Index (VHI)

VH provides up to 4 months advance malaria warning

Felix Kogan/NOAA/NESDIS

VH Malaria Risk Area (%) by Intensity
UGANDA



VH (a) provides risk area & epidemic intensity
(b) validates effectiveness of mitigation measures

Using HyspIRI to Estimate Edible Fraction of the Total Biomass Feedstock (EFTB) to Predict Malaria and Monitor/Manage Endangered Species

- EFTB possible patentable by CUNY/NOAA/NASA collaboration: Roytman/NOAA-CREST/CUNY, Goldberg/NOAA-NESDIS, Mandl/GSFC
- Malaria kills over 1 million people per year
  - Namibia has 2 million people and 500,000 people contract Malaria each year
- Some factors for plant preferences for mosquitoes
  - Sugar content
  - Sugar composition
  - Color of flower
  - Flower odor
- Builds on architecture for flood early warning system and Vegetative Health Index (VHI) (Felix Kogan- NOAA/NESDIS)
- Epidemiological data is used to correlate space-based observations to risk

Using HyspIRI to Estimate Edible Fraction of the Total Biomass Feedstock (EFTB) to Predict Malaria and Monitor/Manage Endangered Species

- Use HyspIRI to differentiate plants
  - Spatial resolution is not of great importance since only relative breakdown of plants in the entire study area is important for estimation of EFTB
  - It is well known that malaria risk differs greatly even for some areas close in proximity where everything important for mosquito development seems to be same (weather, vegetation health etc). EFTB seems to be key for explanation.
- Estimate the fraction of the volume of major plant varieties to the volume of total Biomass in the area of study (pf_1 ,pf_2 ..)
- Differentiate plants in order of preferences by mosquito
- Quantify plants preferences (q_1 ,q_2 ,…) by mosquitoes on the scale of (0-100)
- Derive mathematical model for malaria Risk Factor (RF) for different regions
- Compare RF for Different Ecosystems
- Extensible to monitor the Endangered Species Habitats
  - Human encroachment on habitats and planting of crops (trees) that suit humans can be counterproductive to elephant feed stock. Biomass can look healthy from space, but with EFTB one can derive that the elephants may be starving
  - With imaging spectrometer capabilities it's possible to overlay a regular NOAA VCI map with the EFTB mask (say for elephants or any other endangered species) and thereby provide an inexpensive Remote Sensing tool to monitor endangered species habitats from space.
- EFTB is species' specific (it's different for say mosquitoes or elephants or lions etc) but all these species have very strong food preferences and it will be easy to compute EFTB for important species on the endangered species list.

EFTB Algorithm

Partial biomass fraction (0 -1)

$pf_1, pf_2, pf_3 ..$

pf_i=Partial volume of plant with q_i;

q_i= quantitative value of preference of a particular species of plant

Quantization Plant preference (0-100)

$q_1, q_2, \ldots$

$$pf_1 \times q_1, pf_2 \times q_2, \ldots$$

$$\sum_{i=1}^{n} pf_i = 1$$

$$RiskFactor \ (RF) = pf_1 \times q_1 + pf_2 \times q_2, \ldots$$

Examples

- Malaria parasites
  - Plasmodium falciparum (predominant in Bangladesh)
  - Plasmodium vivax
  - Plasmodium malariae
  - Plasmodium ovale
- MALARIA Vectors
  - Aedes
  - Anopheles (predominant in Bangladesh)
  - Culex
  - Psorophora

Examples

Tecoma stans L.

Ricinus communis L.

Parthenium hysterophorus L.

Hamelia patens Jacq

Senna didymobotrya Fresen

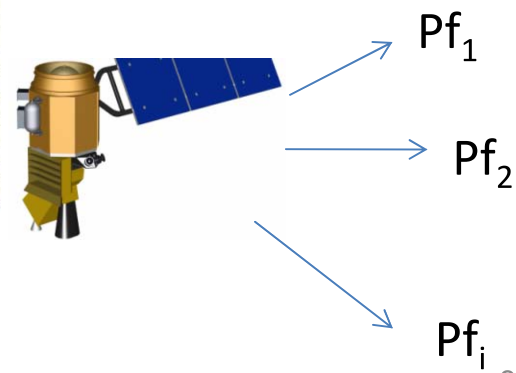
Lantana camara L.

Preferred plants for Anopheles (in order of preference

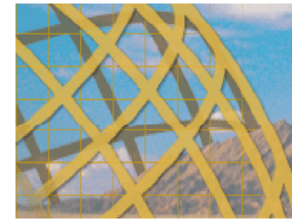
- *T.stans ,S.didymobotrya*
- *R.communis*
- *H.patens*
- *Taraxacum officinale*
- *Hieracium pratense*

Least preferred plants

- *L. camara*
- *Viola sororia*

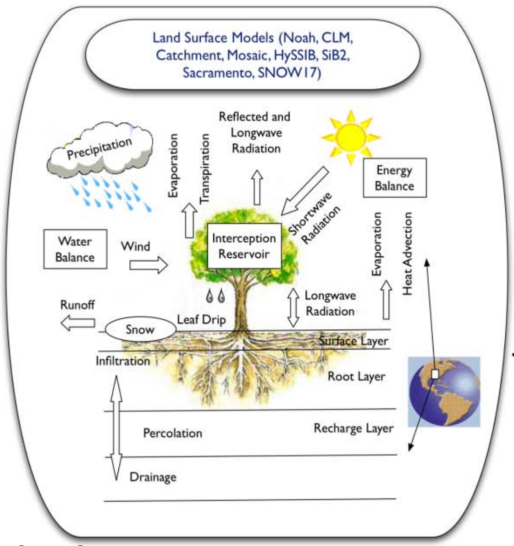


Adaptive Targeting with EO-1 using the Land Information System (LIS)

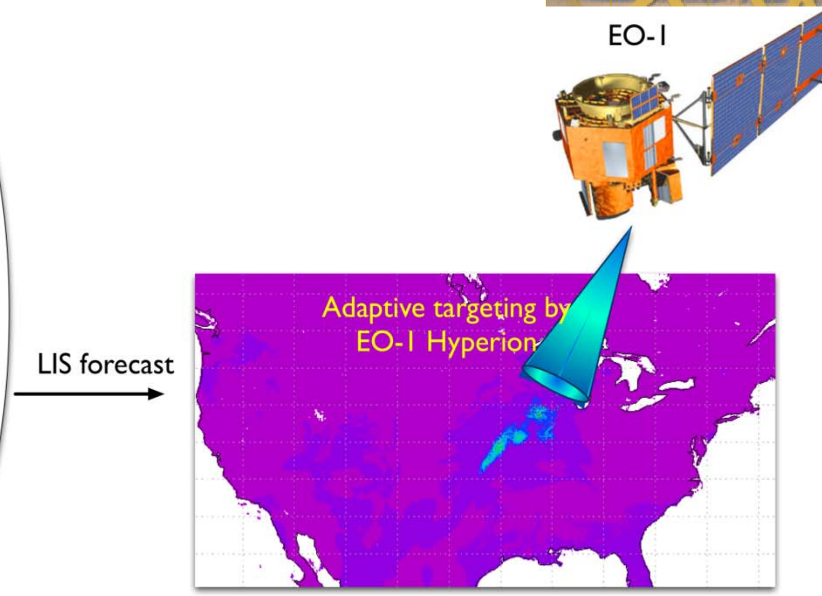


Objectives

- Demonstrate NASA's "sensor web" concept of dynamic targeting of observations assisted by physical modeling tools.
- Assess the value of performing targeted observations for model verification.



LIS



Experiment

- Use predictions from LIS to schedule data collection from the Hyperion high-resolution hyperspectral imager, which is part of the EO-1 mission.
- LIS will be used to issue 48 –hr forecasts of surface runoff, soil moisture, and snow melt at 1km spatial resolution over the continental US.
- Potential target areas for data collection with EO-1 will be identified from the LIS simulations.
- Dynamically targeted observations will be compared against model predictions for evaluation.

Expected Benefit

The "live" test with the operational satellite is expected to help in the optimal design, evaluation, and deployment of future observing systems, and to assist in the AIST-funded Sensor Web Simulator.

Acknowledgement

The effort is made possible by funding from the Earth Science Technology Office and computing resources from NASA High End Computing portfolio.

Year 3 Accomplishments

Earthquake in Honduras May 28, 2009
EO-1 Image Triggered By SERVIR

Imágenes Formosat-2 del Satélite Taiwanés facilitan la evaluación del impacto de terremoto de 28 de mayo de 2009 en Honduras

Mapa generado por CATHALAC / SERVIR el 30 de mayo de 2009

Imagen Ikonos de GeoEye

Imagen Formosat-2 proporcionada por Dr. Cheng-Chien Liu de la Universidad Nacional Cheng-Kung y Dr. An-Ming Wu de la Organización Nacional del Espacio de Taiwan

EFECTOS: En Honduras, se reportaron muertes y daños materiales significativos en la Colonia de Pineda de la Lima, Morazán y Tela, y colapsó parte del puente La Democracia cerca de San Pedro Sula y El Progreso. En Belice, el terremoto causó daños a edificios y carreteras en Monkey River y Placencia, y la muerte de una mujer en Dangriga. En

DAÑOS: El terremoto dañó tres puentes en Honduras, incluyendo la destrucción del segmento central del puente La Democracia en la imagen arriba.

Station Fire near JPL Sept 3, 2009

Station Fire near JPL Sept 3, 2009

The Station Fire, which raged in the hills north of the city of Los Angeles, left behind a changed landscape. The Advanced Land Imager (ALI) on NASA's Earth Observing-1 (EO-1) satellite acquired the true- and false-color images on September 3, 2009.

Last image from the cam at the Mt. Wilson observatory before the web server went down.

The EO-1 images, shown on the next slide, are centered with Hyperion pointed at 34.224N, 118.058W. ALI images extend to the east of Hyperion's coverage.

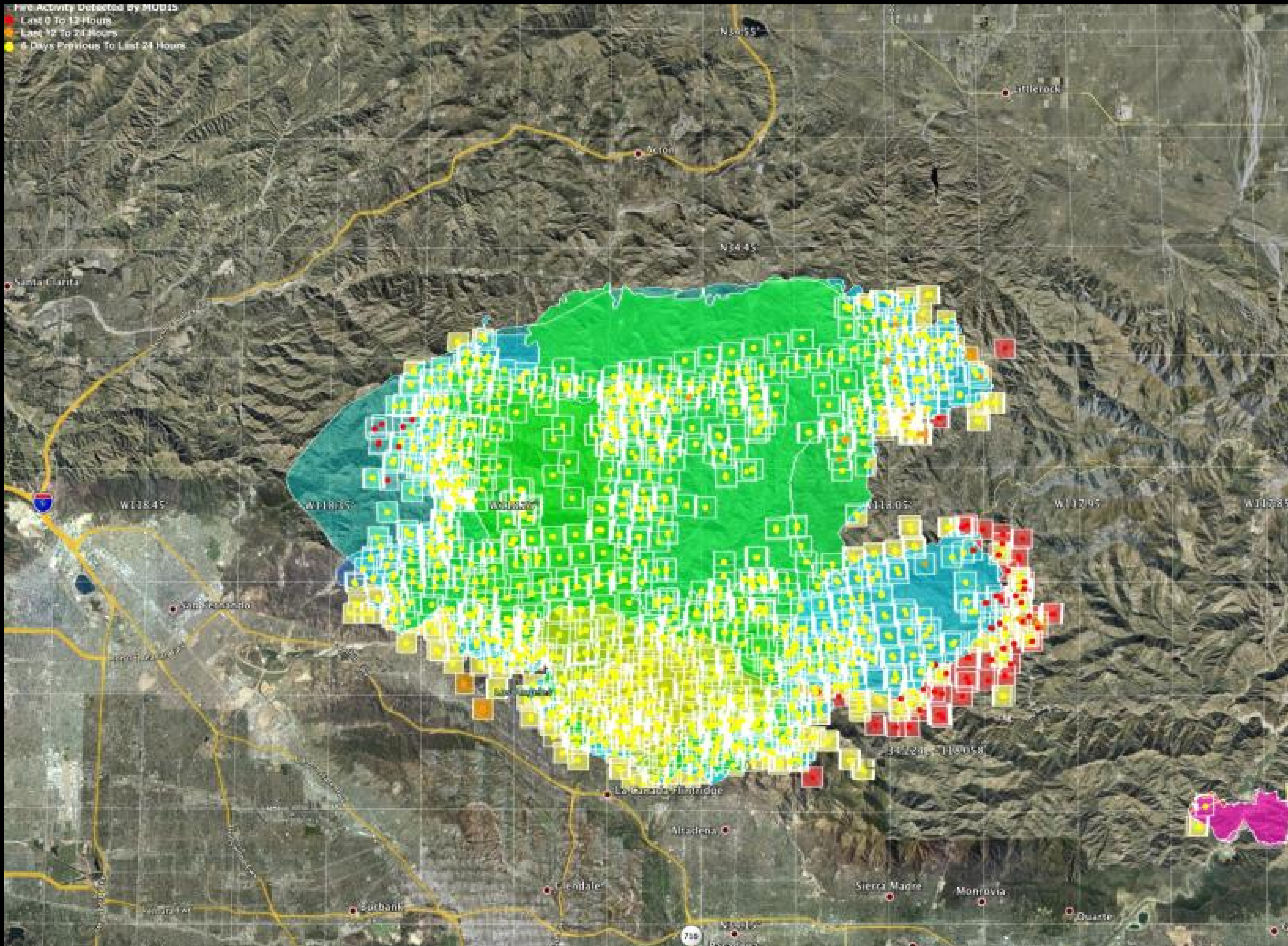
Station Fire near JPL Sept 3, 2009

The true-color image (top right) shows skies choked with thick smoke north of the city. The white outline in the true-color image indicates the area covered by the false color image below on left.

The false color image combines shortwave-infrared light, near-infrared light, and green light. A purple-red burn scar fills most of this image, outlined by deep pink hotspots showing the fire's actively burning front. Land not yet burned appears bright green.

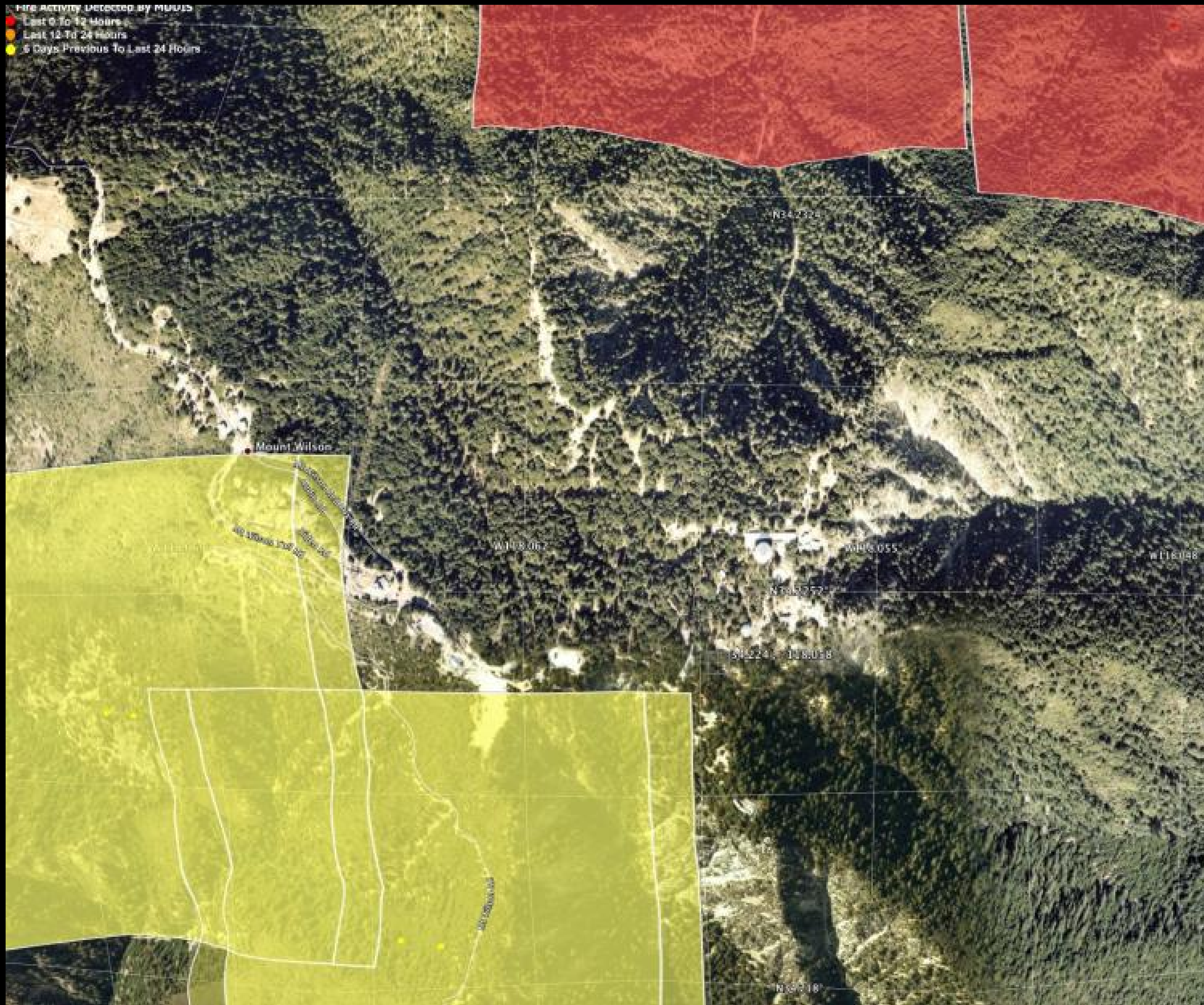
NASA images created by Jesse Allen, using EO-1 ALI data provided courtesy of the NASA EO-1 Team. Captions by Michon Scott (modified by Steve Ungar).

Station Fire near JPL Sept 3, 2009



The MODIS observations show the most activity directly north and east of Mt. Wilson (http://www.inciweb.org/incident/1856/).

Station Fire near JPL Sept 3, 2009



Zoom in to Mt. Wilson area with each square a MODIS hot pixel

A new request has been created called: American Samoa Tsunami task 7
has been created by un-spider-test1

eo-1-svt@googlegroups.com [eo-1-svt@googlegroups.com] on behalf of geobpms@geobliki.com [geobpms@geobliki.com]

Sent: Wednesday, September 30, 2009 1:55 AM
To: eo-1-svt@googlegroups.com; chrisgnicholas@att.net

A new user-defined request has been created. For more information, click **here**

Thank you.
GeoBPMS

Tasking Request:

Title:	American Samoa Tsunami task 7
Description:	American Samoa Tsunami task 7
Category:	
Latitude:	-14.04866632
Longitude:	-171.5789794
Day/Night:	day time
Country Code:	
Country Name:	
Zone Number:	170
Zone Name:	Samoa Islands
Region Number:	12
Region Name:	Kermadec - Tonga - Samoa Basin Area
Admin Code:	
Admin Name:	
Nearby:	
Created At:	Wed, 30 Sep 2009 06:55:39 -0000
Updated At:	2009-09-30

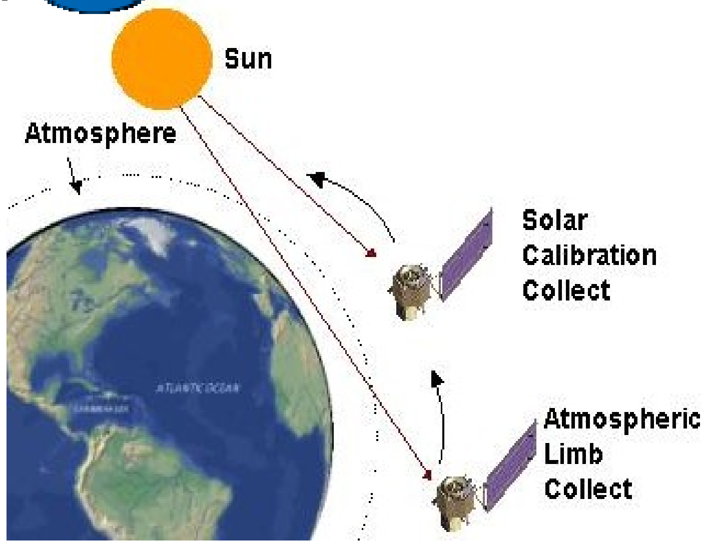
Feasibilities

Potential Feasibility	Asset: FORMOSAT-2/RSI, Date: 2009-10-01T20:45:40Z
Potential Feasibility	Asset: FORMOSAT-2/RSI, Date: 2009-10-01T20:45:44Z
Potential Feasibility	Asset: FORMOSAT-2/RSI, Date: 2009-10-02T20:45:41Z
Potential Feasibility	Asset: FORMOSAT-2/RSI, Date: 2009-10-02T20:45:45Z
Potential Feasibility	Asset: FORMOSAT-2/RSI, Date: 2009-10-03T20:45:42Z
Potential Feasibility	Asset: FORMOSAT-2/RSI, Date: 2009-10-03T20:45:45Z
Potential Feasibility	Asset: EO-1, Date: 2009-10-03T21:12:00Z
Potential Feasibility	Asset: ASTER/VNIR Only, Date: 2009-10-05T21:52:06Z
Potential Feasibility	Asset: EO-1, Date: 2009-10-06T21:28:00Z
Potential Feasibility	Asset: ASTER/VNIR Only, Date: 2009-10-07T21:40:00Z
Potential Feasibility	Asset: EO-1, Date: 2009-10-08T21:06:00Z

NASA Calibration Strategy

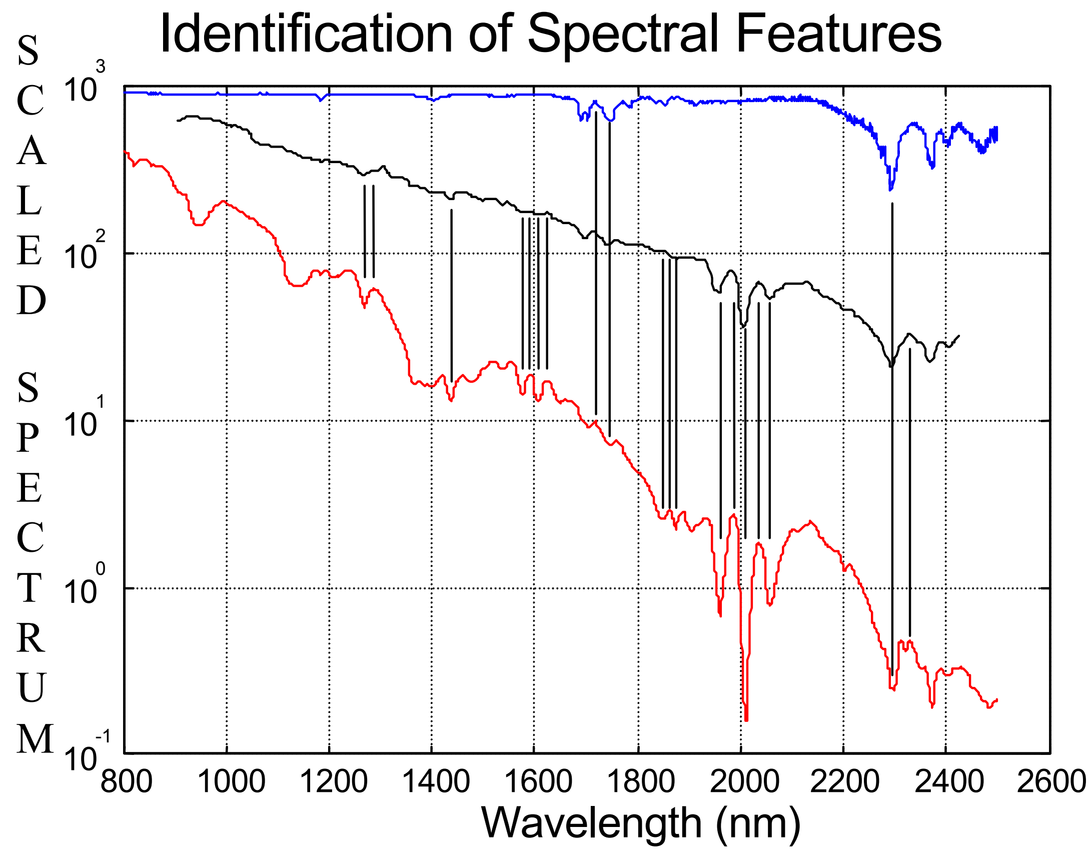
- Prelaunch
  - Calibrate and characterize (component and system level)
  - Characterize the calibration and characterization
  - Ensure conformity with, and comparison against, NMI laboratory standards
- Post-launch
  - Lamps
  - **Solar**
  - Lunar (astronomical)
  - Vicarious
  - "Special Targets" (limb scanning, active illumination)
  - Statistical (trending, 90° yaw)
  - Direct comparison against other satellites

Spectral Calibration –



Process:

- Create Pseudo-Hyperion Spectra from reference: Modtran-3 for atmosphere, and Cary 5 & FTS measurements for diffuse reflectance of the cover
- Correlate Spectral Features: band number units of Hyperion max/min correlated with reference wavelength of max/min
- Calculate Band to Wavelength map: apply low order polynomial to fit the data over the entire SWIR regime



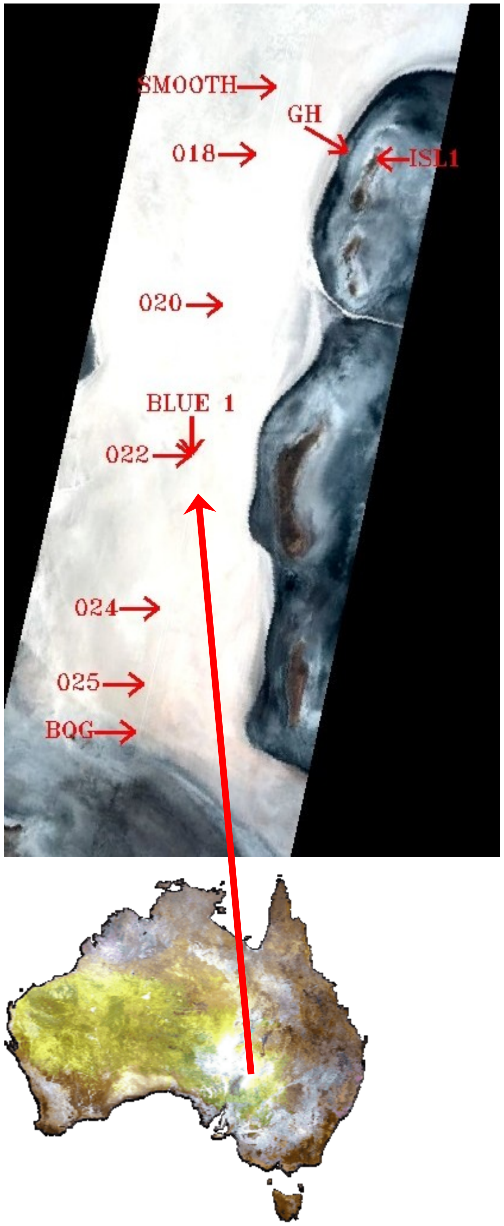
Hyperion Spectra – red

Atmospheric Reference – black

Diffuse Reflectance of cover – blue

Desert Sites used for Vicarious Calibration

Lake Frome

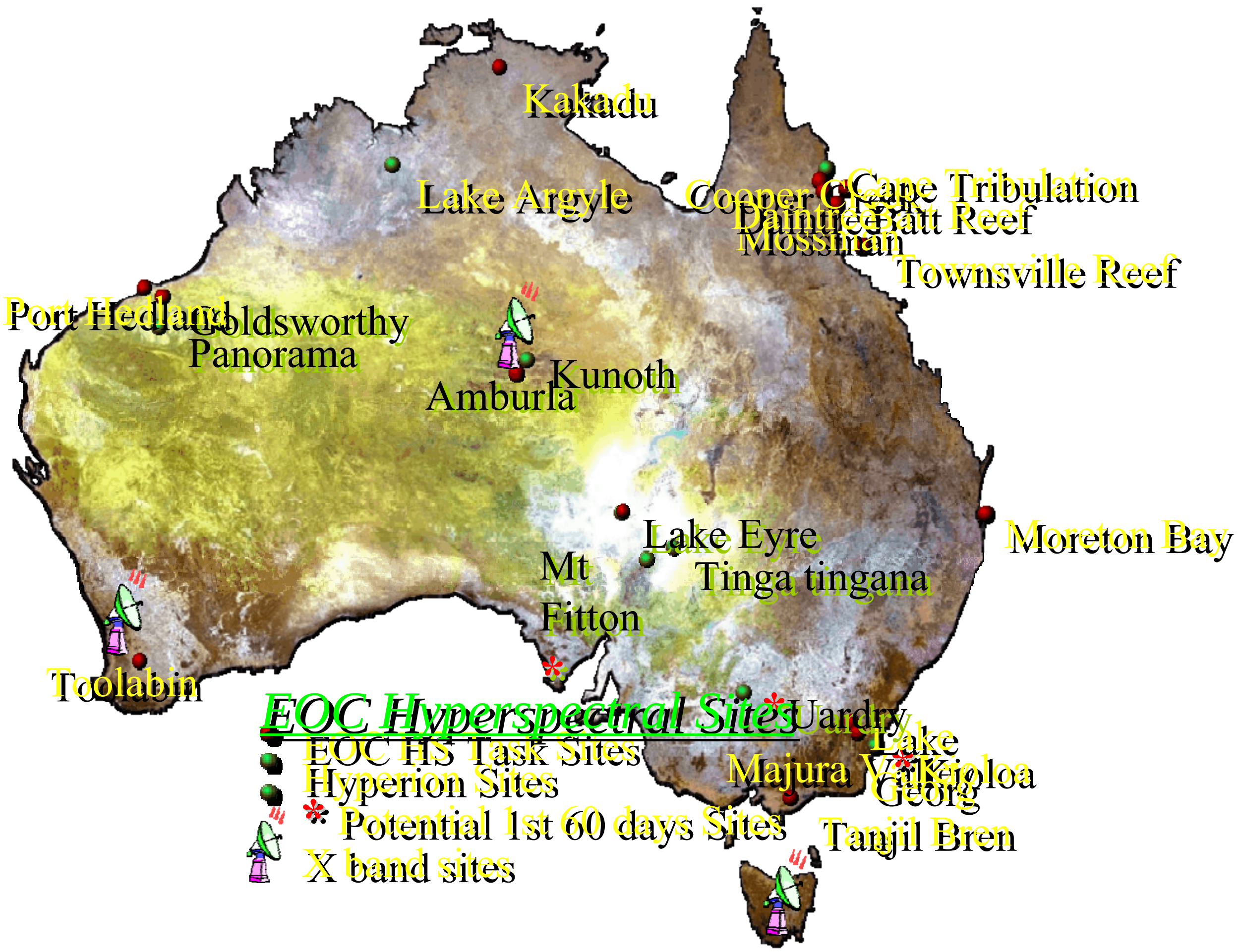


RR Valley

Arizaro/Barreal Blanco

EO-1 Accelerated Mission Southern Hemisphere Field Campaigns

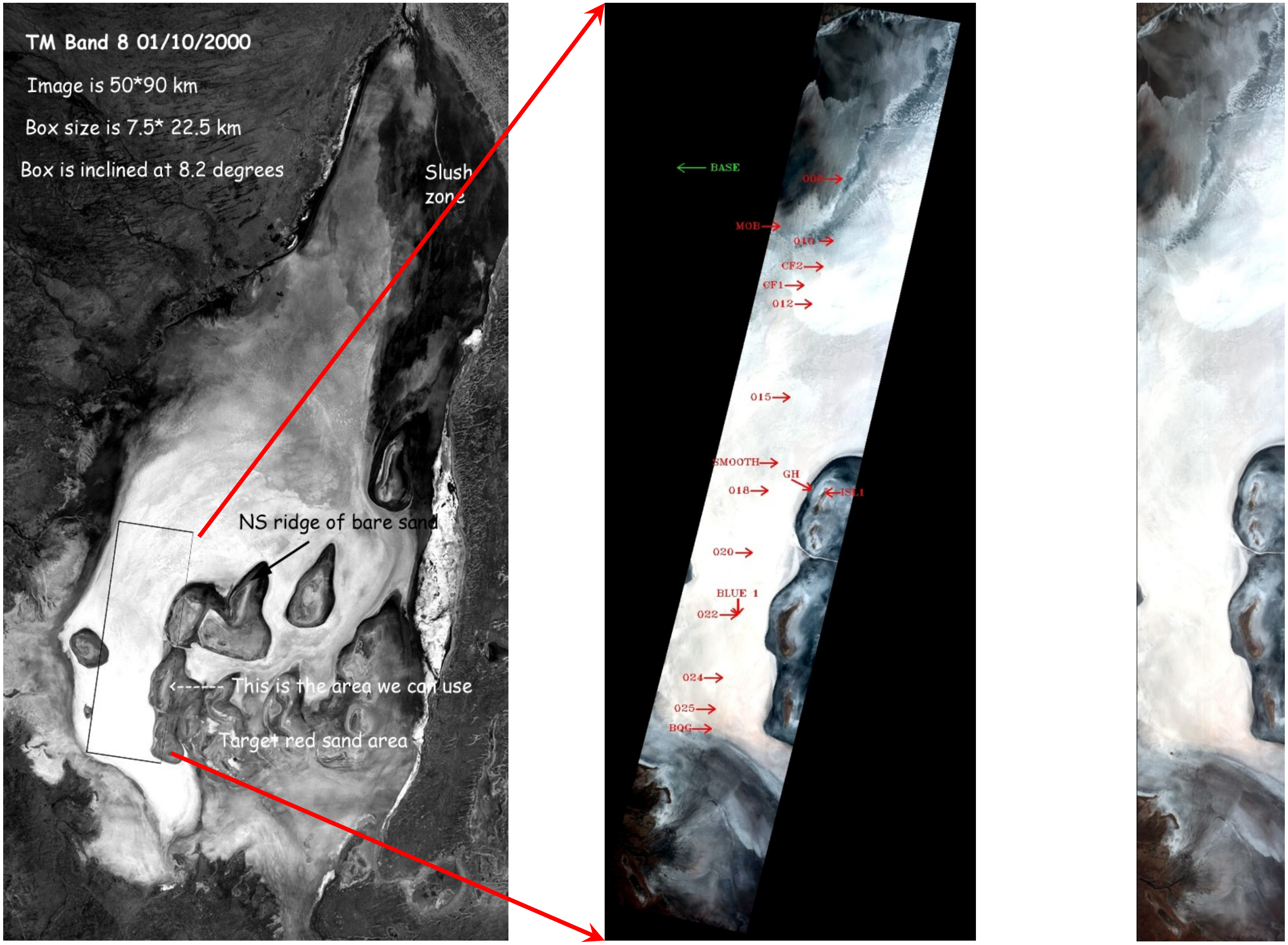
January – February 2001



Australian Test Sites

Argentine/AVIRIS Sites

Lake Frome Calibration Site



Barreal Blanco, Argentina


AVIRIS
Twin Otter

Maricopa, AZ

Deployment coincident with EO-1 and L7 ETM+ overpasses

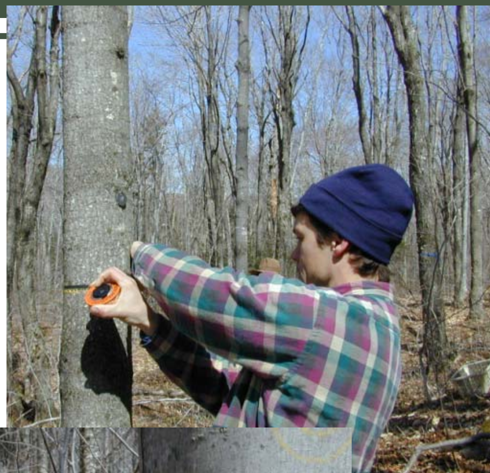
Venice field site

Radiometric Calibration

- **Ground Truth Referencing**
  - Lake Frome, Au ground truth collected by CSIRO.
  - Barreal Blanco and Arizario Argentina ground truth collected by U. of Arizona and U. of Colorado
  - Ivanpah Playa ground truth collected by U. of Arizona
  - AVIRIS underflights

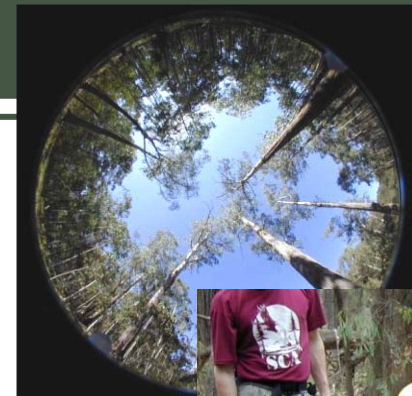
EVEOSD Vegetation Sampling

Field Data Collection

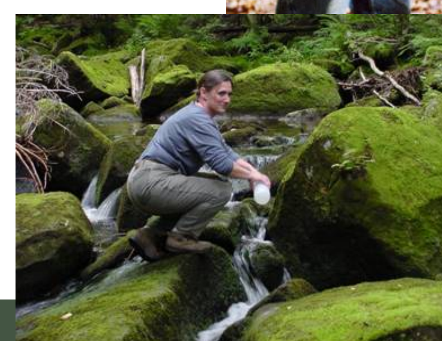


Forest Growth

Leaf & Canopy Chemistry



Canopy Structure



Soil & Water Chemistry


The EO-1 2001 Field Campaign
AVIRIS Overflights
RESTRICTED
NO SMOKING
CLOSED
CLOSED
OPEN

The EO-1 2001 Field Campaign

Barreal Blanco

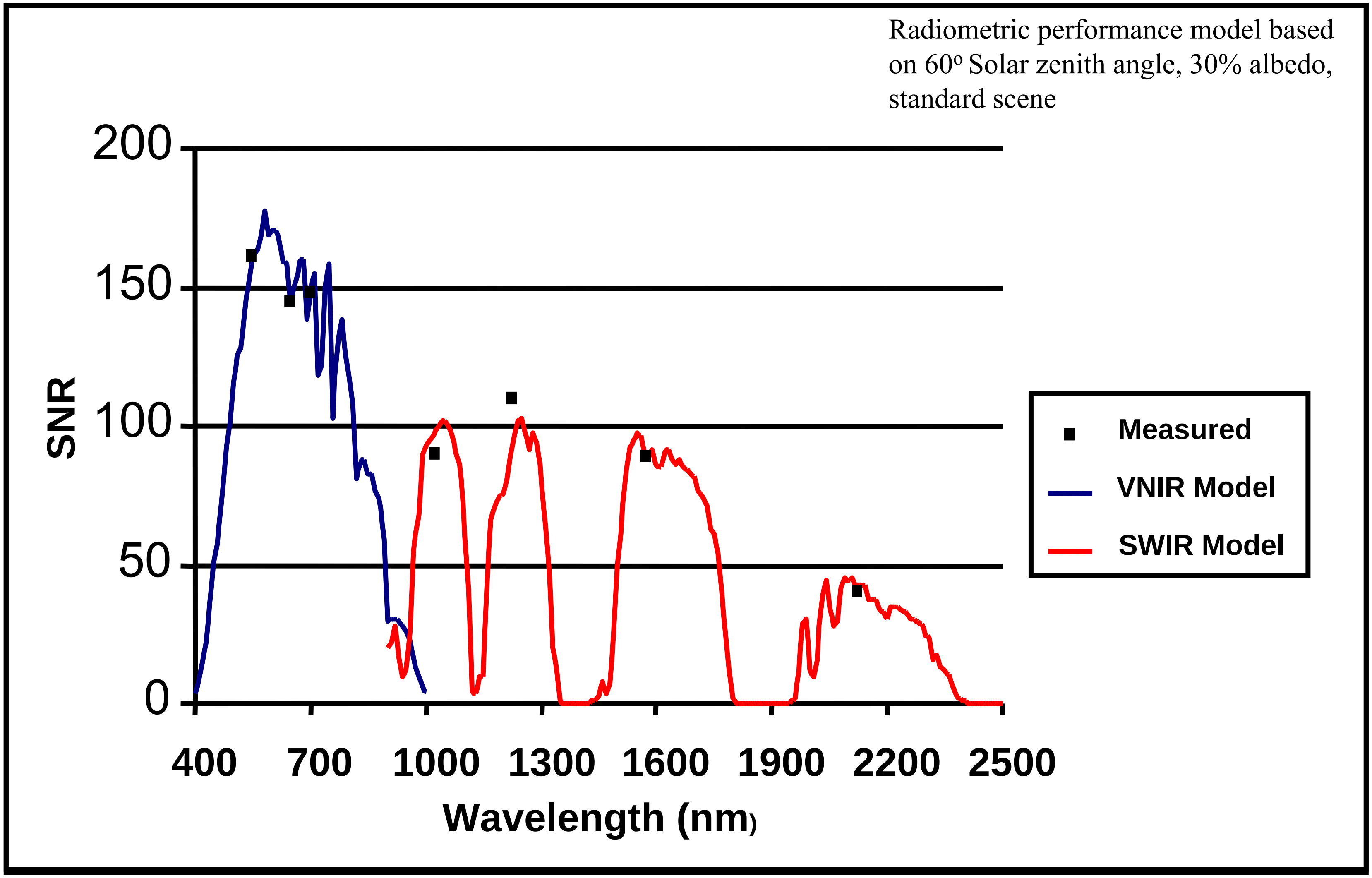
The EO-1 2001 Field Campaign

Central Australia

The EO-1 2002 Field Campaign

Salar de Arizaro - 11 Dec. 2002

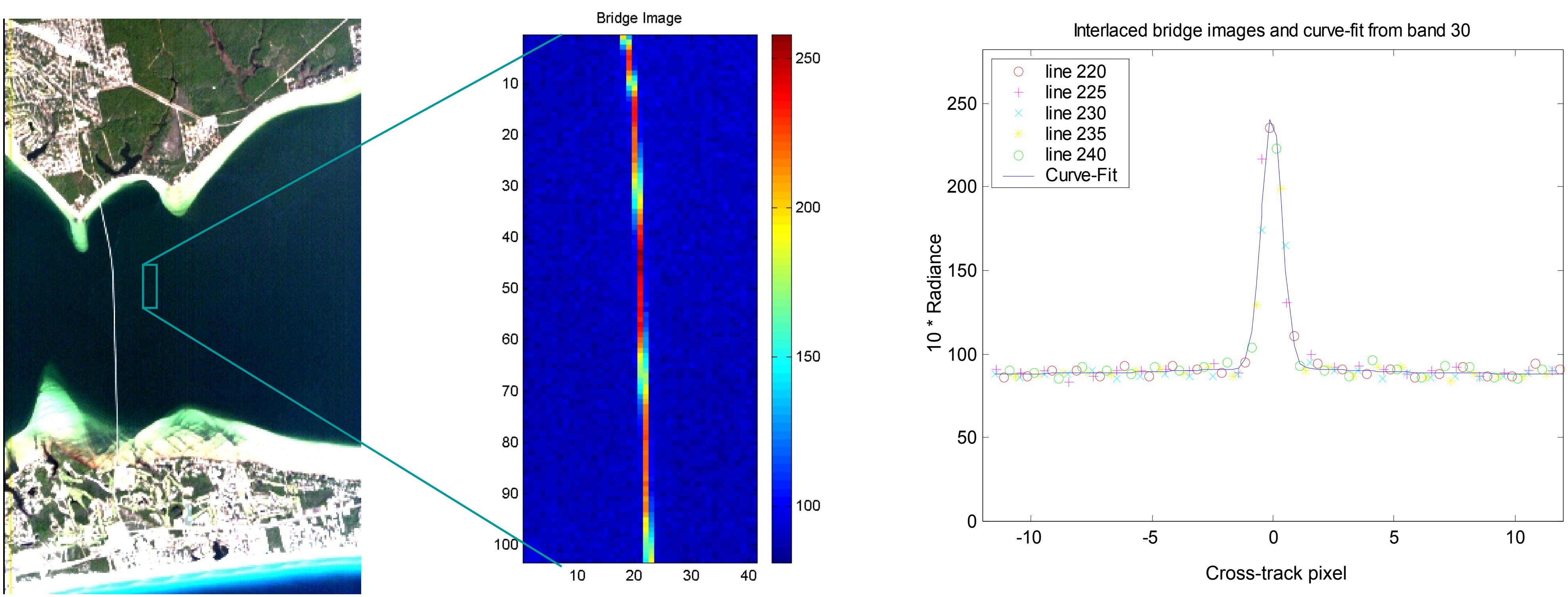
Hyperion SNR



Hyperion Measured SNR						
550 nm	650 nm	700 nm	1025 nm	1225 nm	1575 nm	2125 nm
161	144	147	90	110	89	40

Example: Cross-track MTF

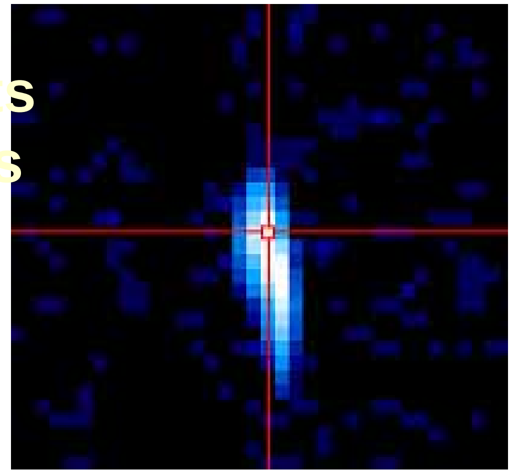
- Scene is Port Eglin from Dec 24, 2000. Bridge is the Mid-bay bridge . Bridge width is 13.02 meters.
- Bridge angle to the S/C direction is small so every 5th line is used to develop the high resolution bridge image.
- MTF result at Nyquist is between 0.39 to 0.42 while the pre-flight measurement was 0.42.



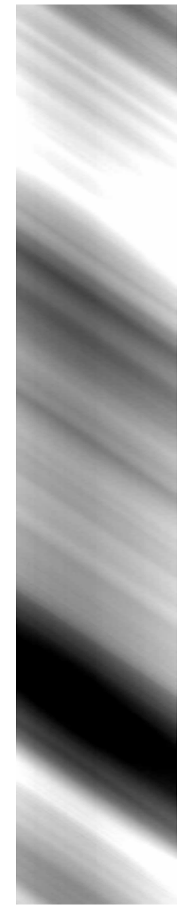
Special targets for characterization

Searchlights
-California

Planets
-Venus

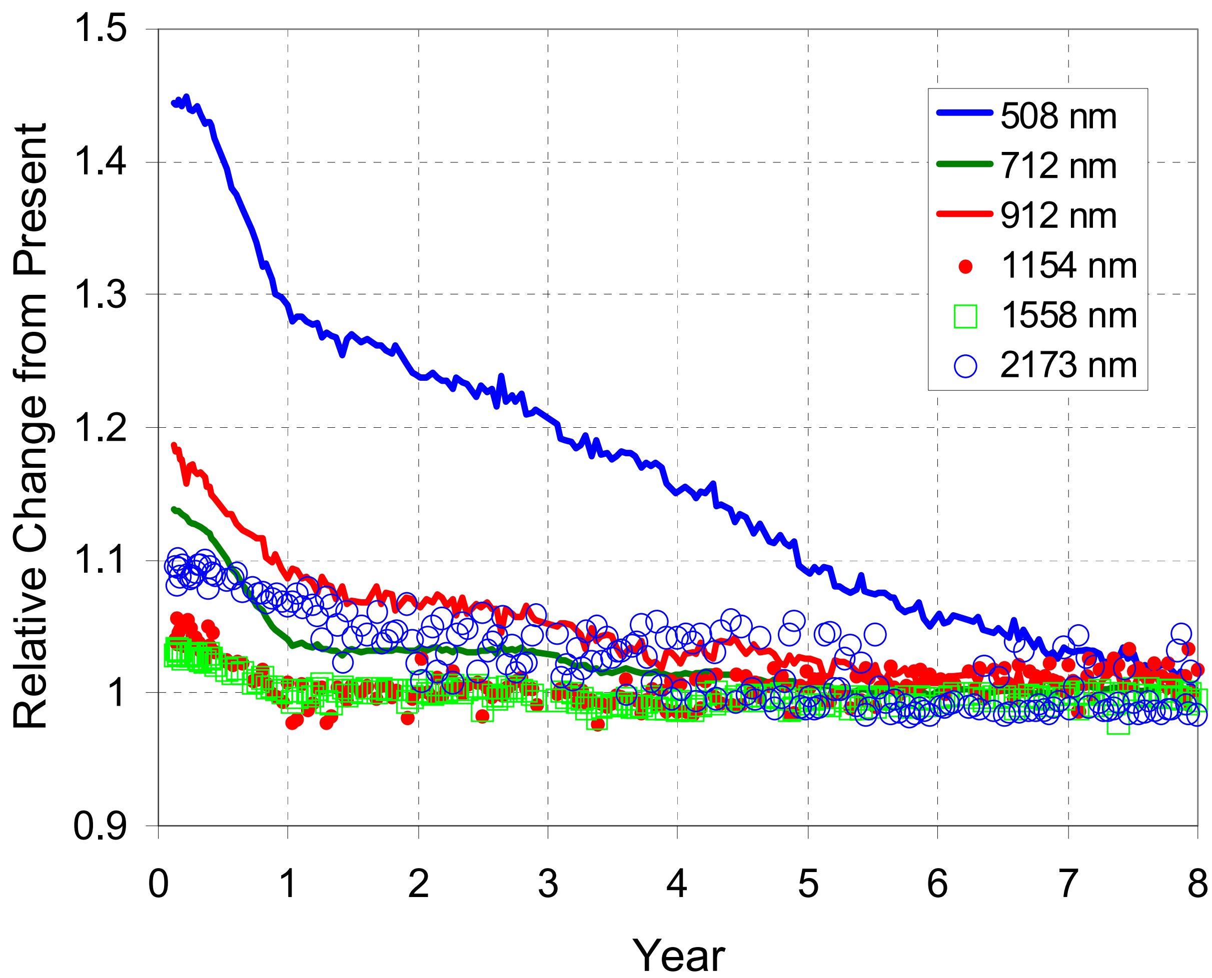


Gas Flares
-Moomba



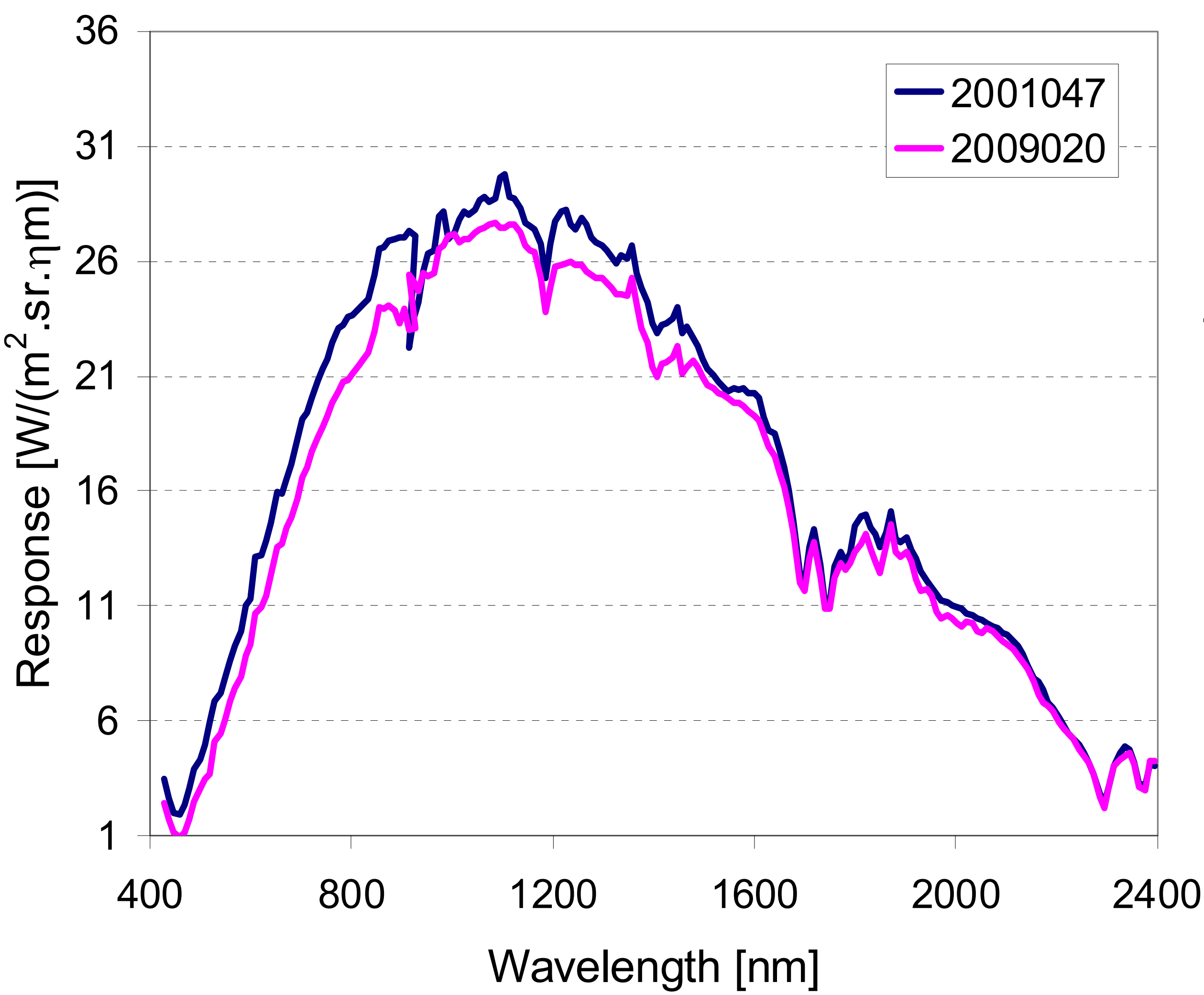
90 deg
Yaw

Hyperion Lamp Trends



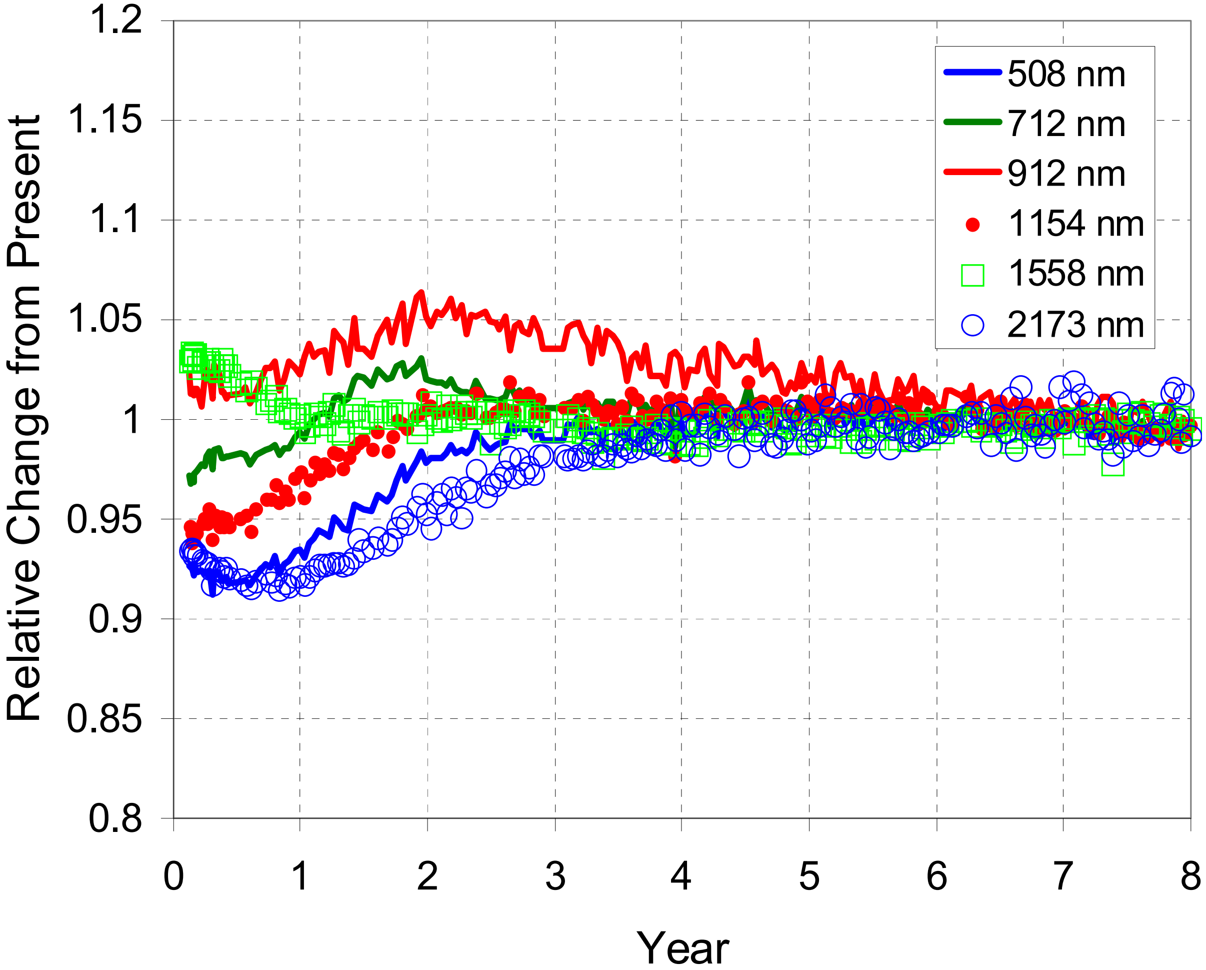
- There is a significant initial decrease in lamp output during the first year of operation.
- The lower wavelength channels (< 500 nm) exhibits the largest change.
- Changes in the SWIR channesl are less than 10%.
- For most bands the lamps appears to achieve some stability after year 4.

Hyperion Lamp Spectra



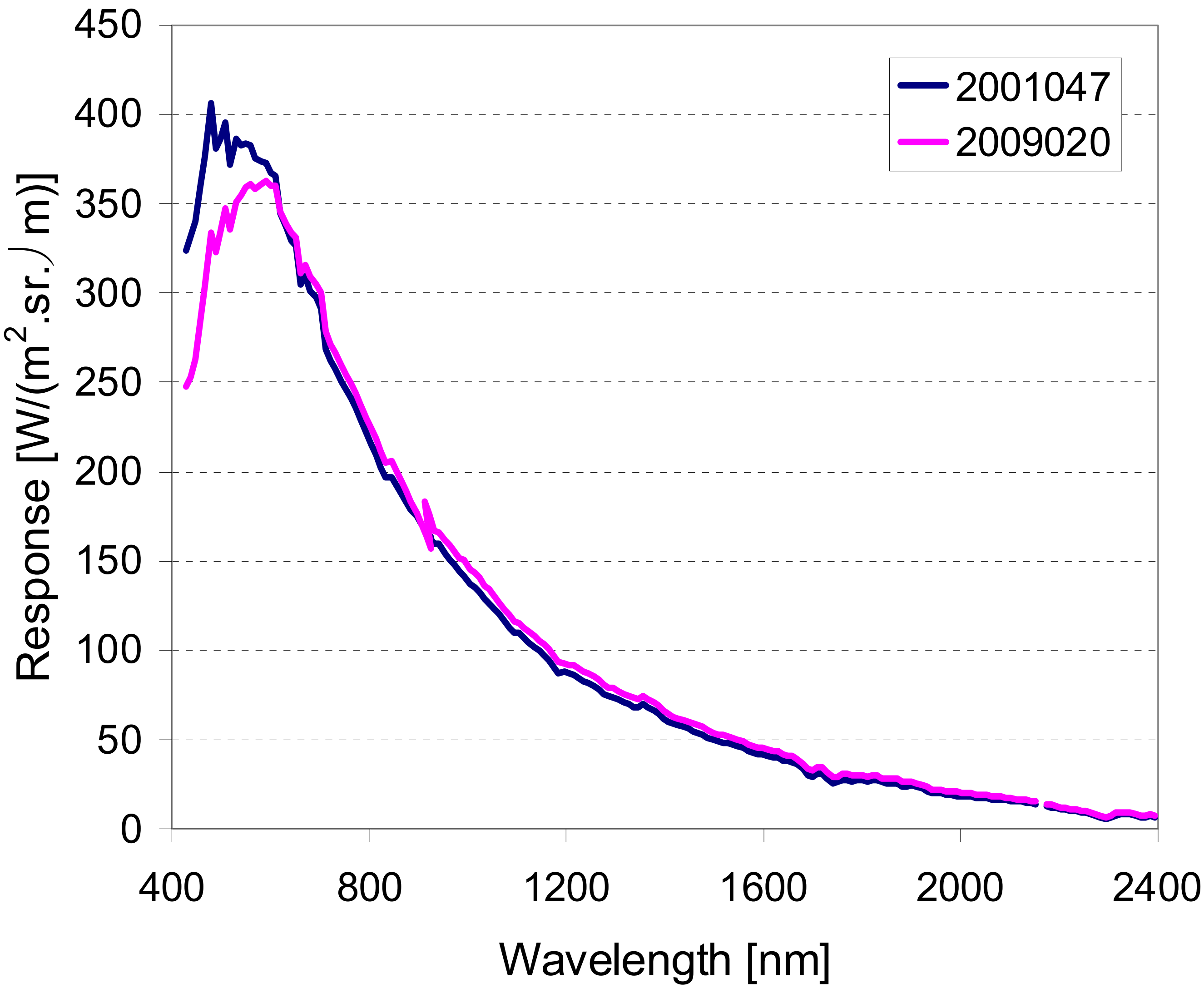
Lamps intensity shows some degradation over the entire spectral range over the 8 years of operation

Hyperion Solar Trends



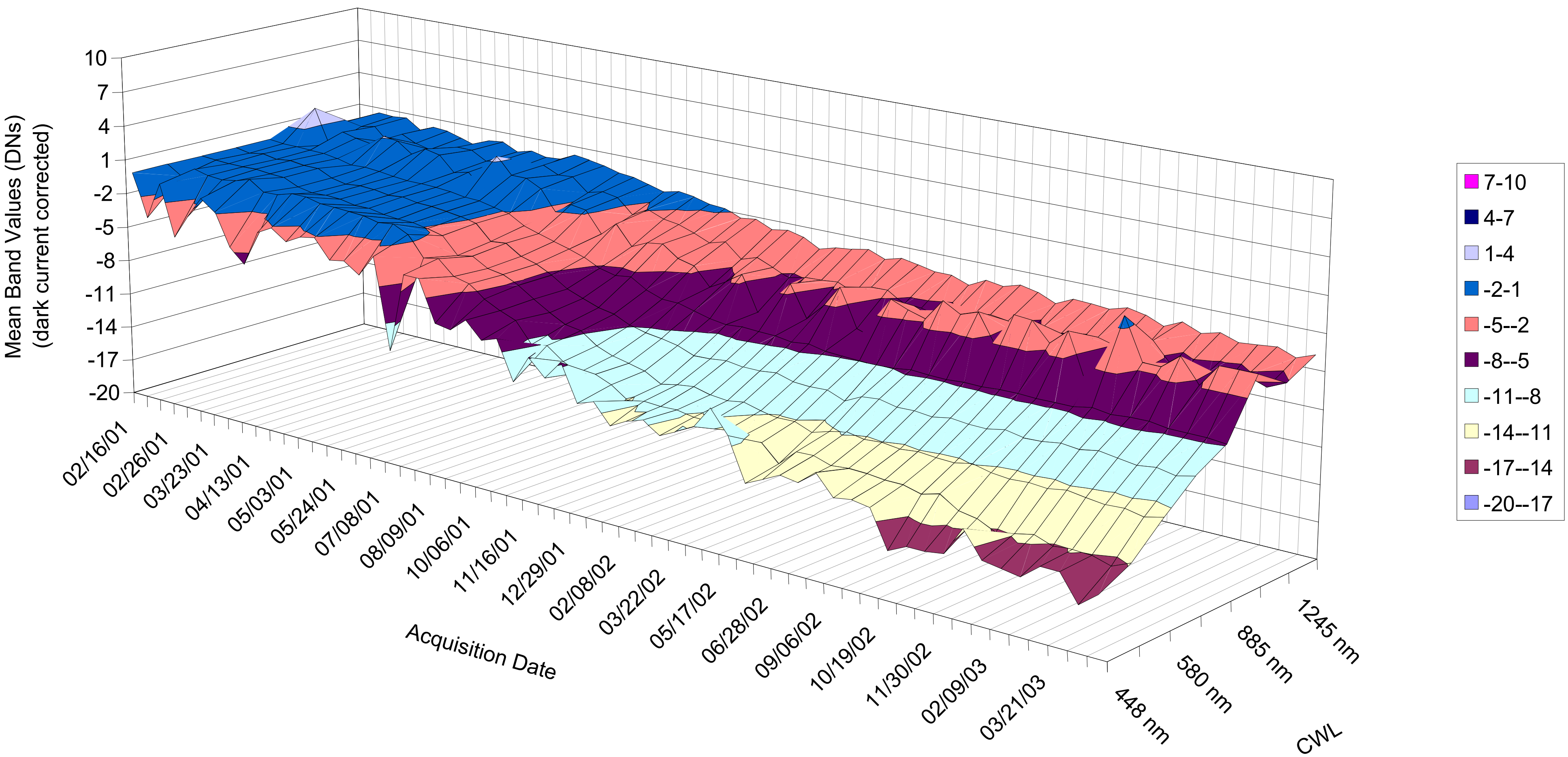
- Changes in the solar panel on orbit are most pronounced during the first 3 years
- Most of the variations are within +/1 5% except for the longer wavelengths.
- For most bands the lamps appears to achieve some stability after year 4.

Solar Panel Spectra

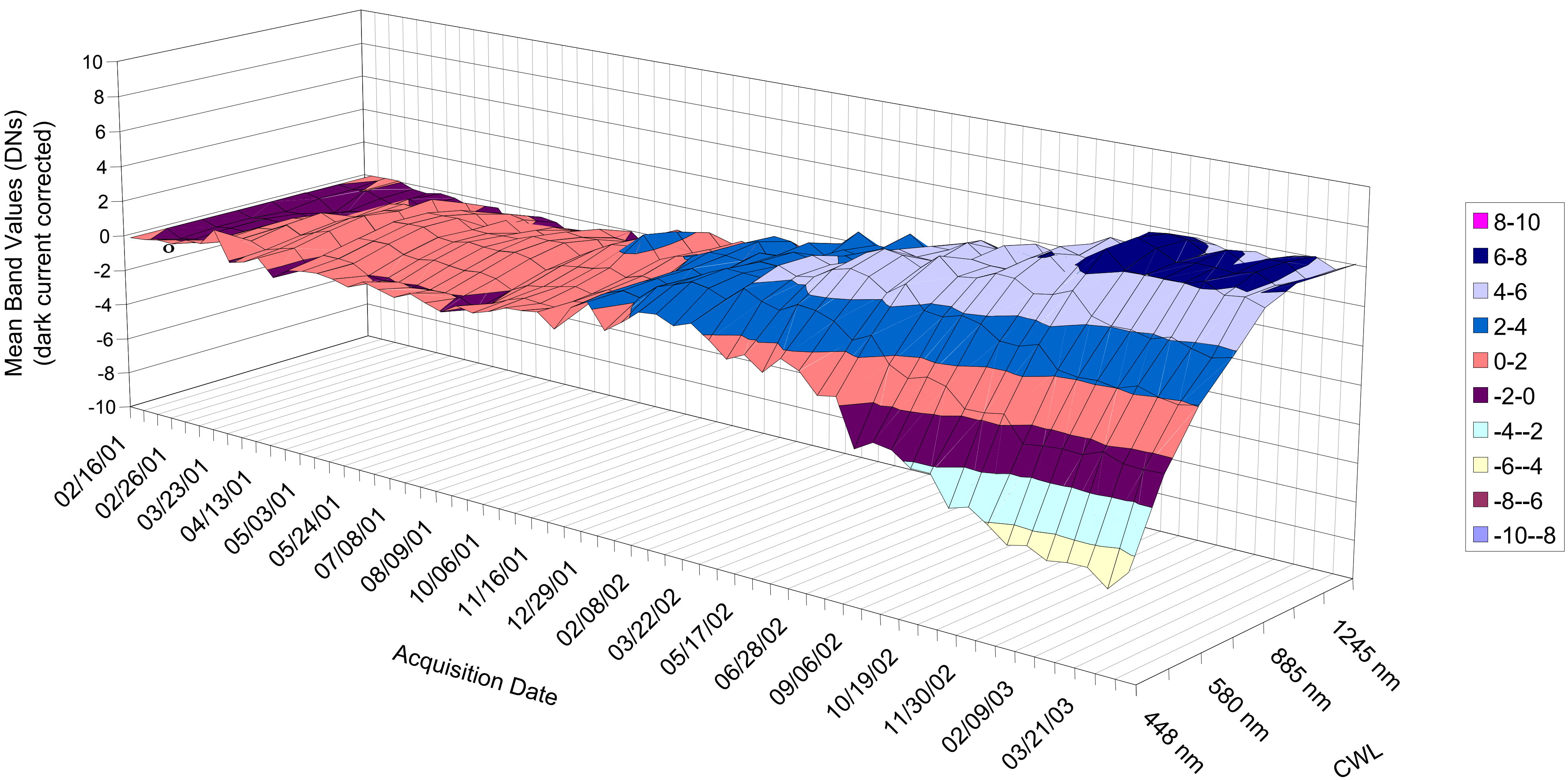


Spectra of the solar panel show large degradation in the shorter wavelengths

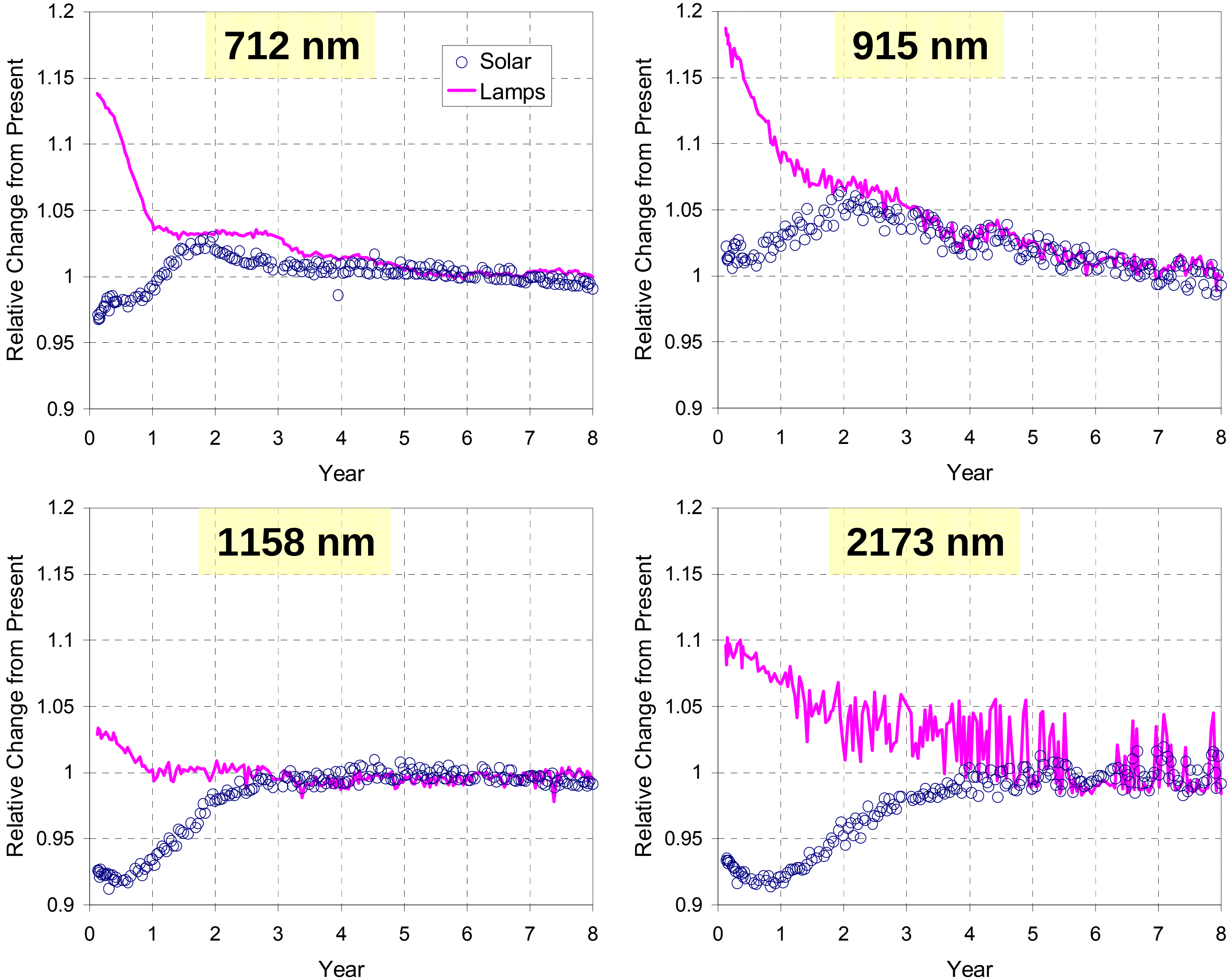
% Change EO-1 Hyperion Lamp Cal. Response



% Change EO-1 Hyperion Solar Cal. Response (normalized for solar distance)



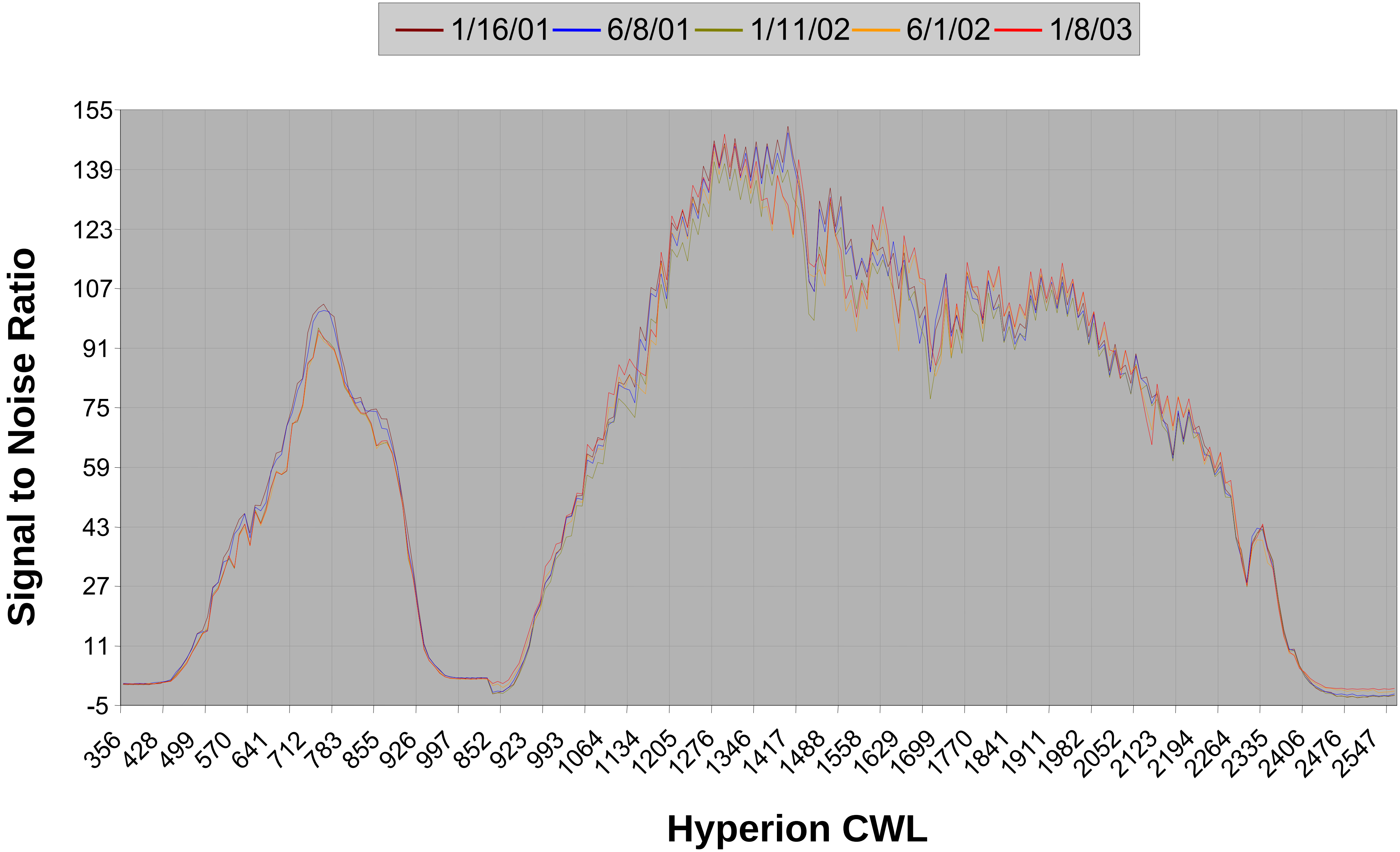
Comparing Lamp & Solar Trends



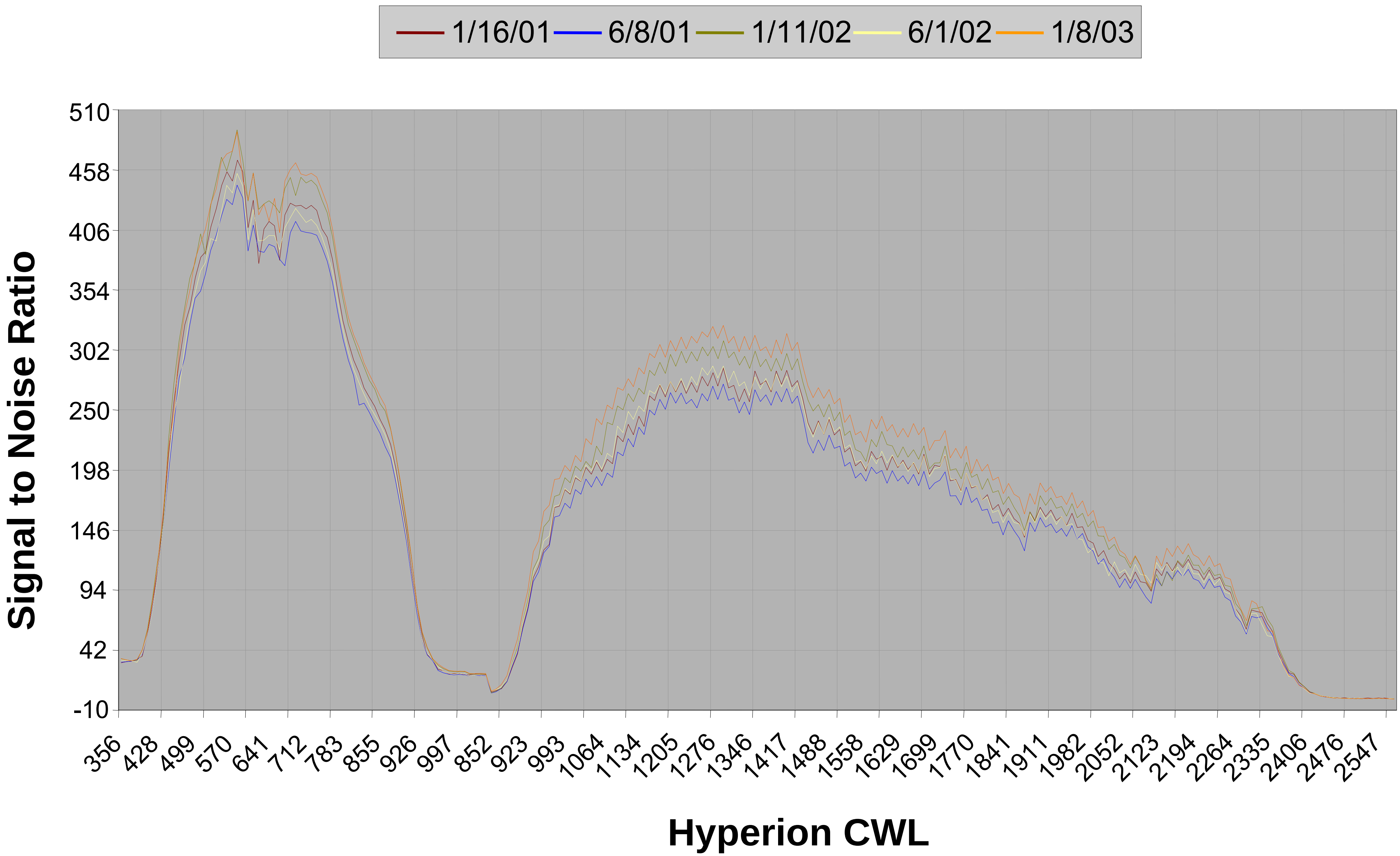
Although inconsistent during early mission life, the solar and Lamp trends agree well after 4 years in orbit

Hyperion Lamp Cal. Signal to Noise Ratio

(normalized lamp mean / standard deviation)



Hyperion Solar Cal. Signal to Noise Ratio
(normalized solar mean / standard deviation)



Radiometric Calibration

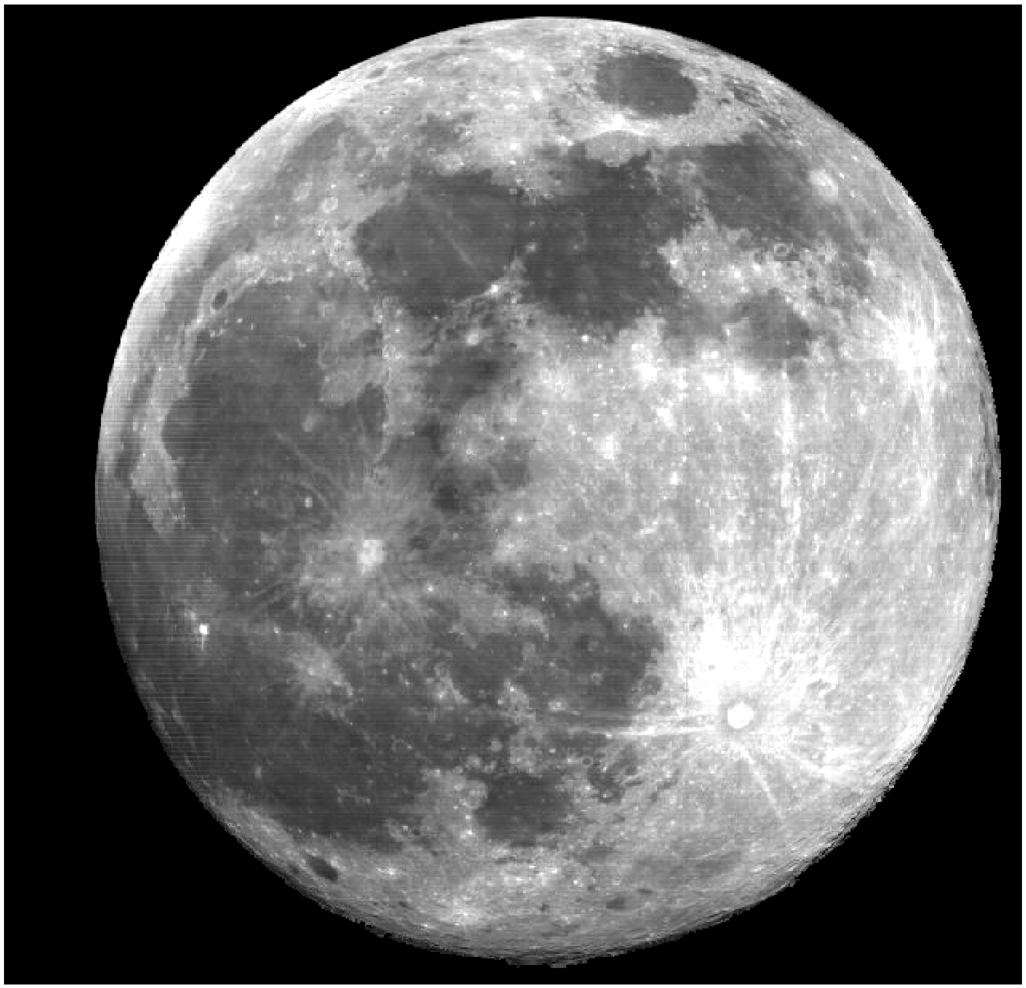
- Lunar Calibration
  - Calculate Lunar spectral irradiance ($E_M(\lambda)$)
  - Compare to the USGS Robotic Lunar Observatory lunar irradiance model

- Intersatellite Comparison
  - Landsat 7
  - Sites Compared
    - CA Super Site Jan 2001
    - Railroad Valley Jan 2001
    - Lake Frome Jan 2001
  - Compared Bands 1, 2, 3, 5, 7 due to similarity of spectral responses
  - Terra comparisons forthcoming

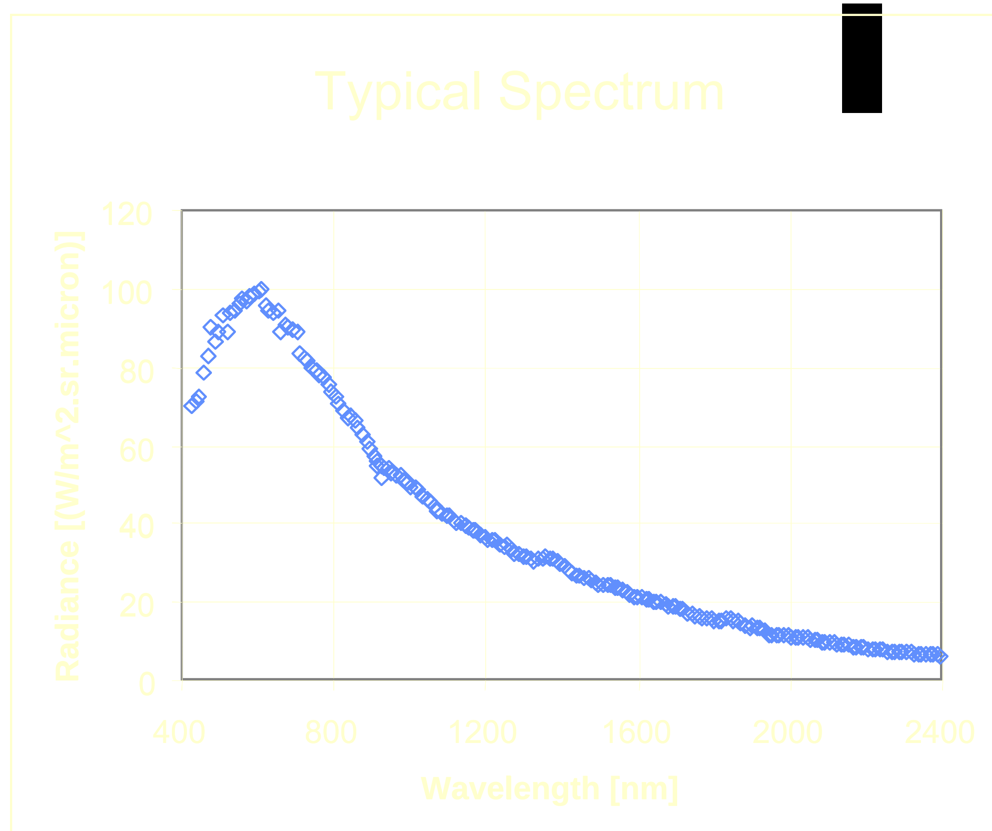
EO-1 views the moon monthly

(EO-1 ALI Pan band)

(EO-1 Hyperion)



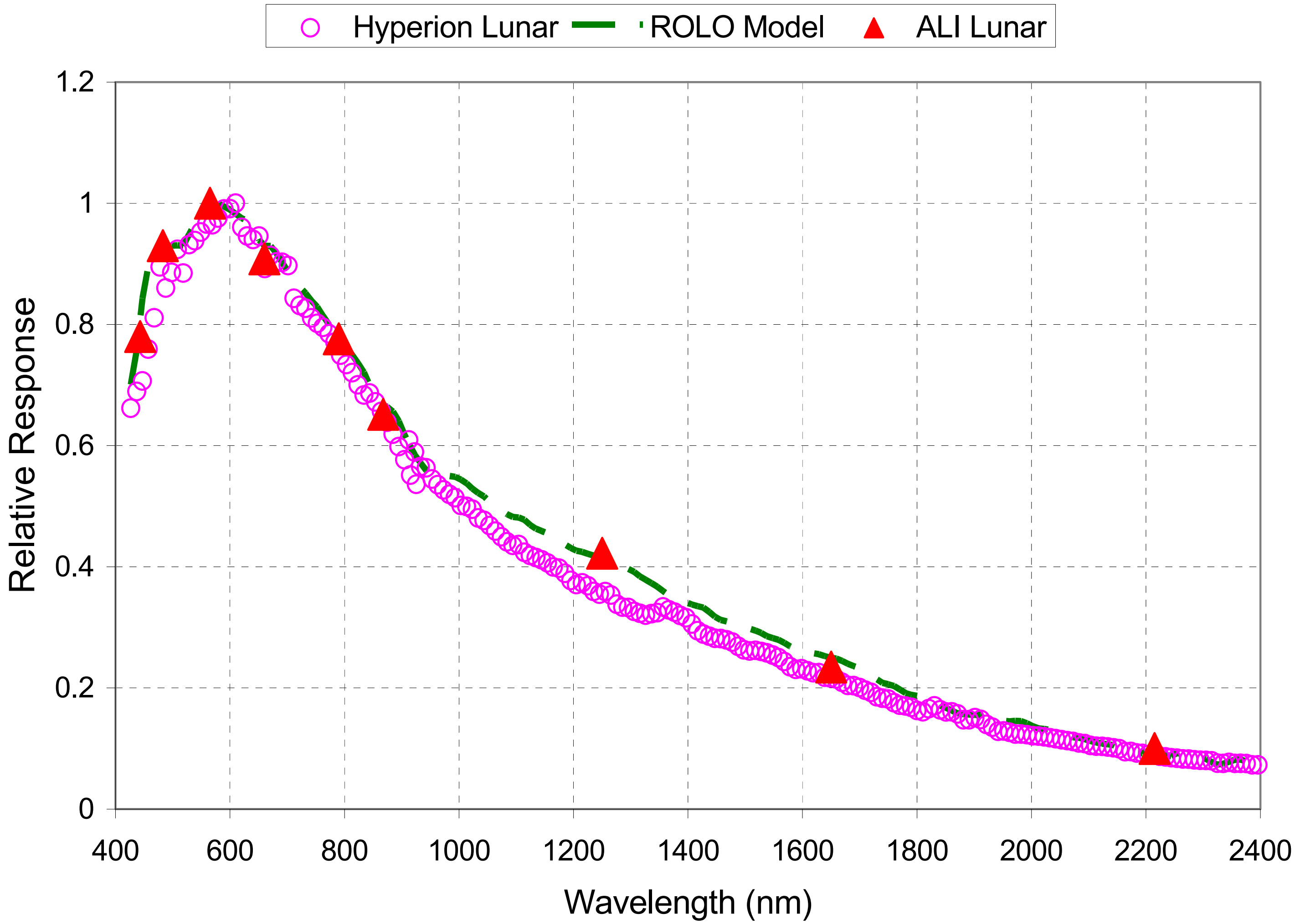
Full Moon



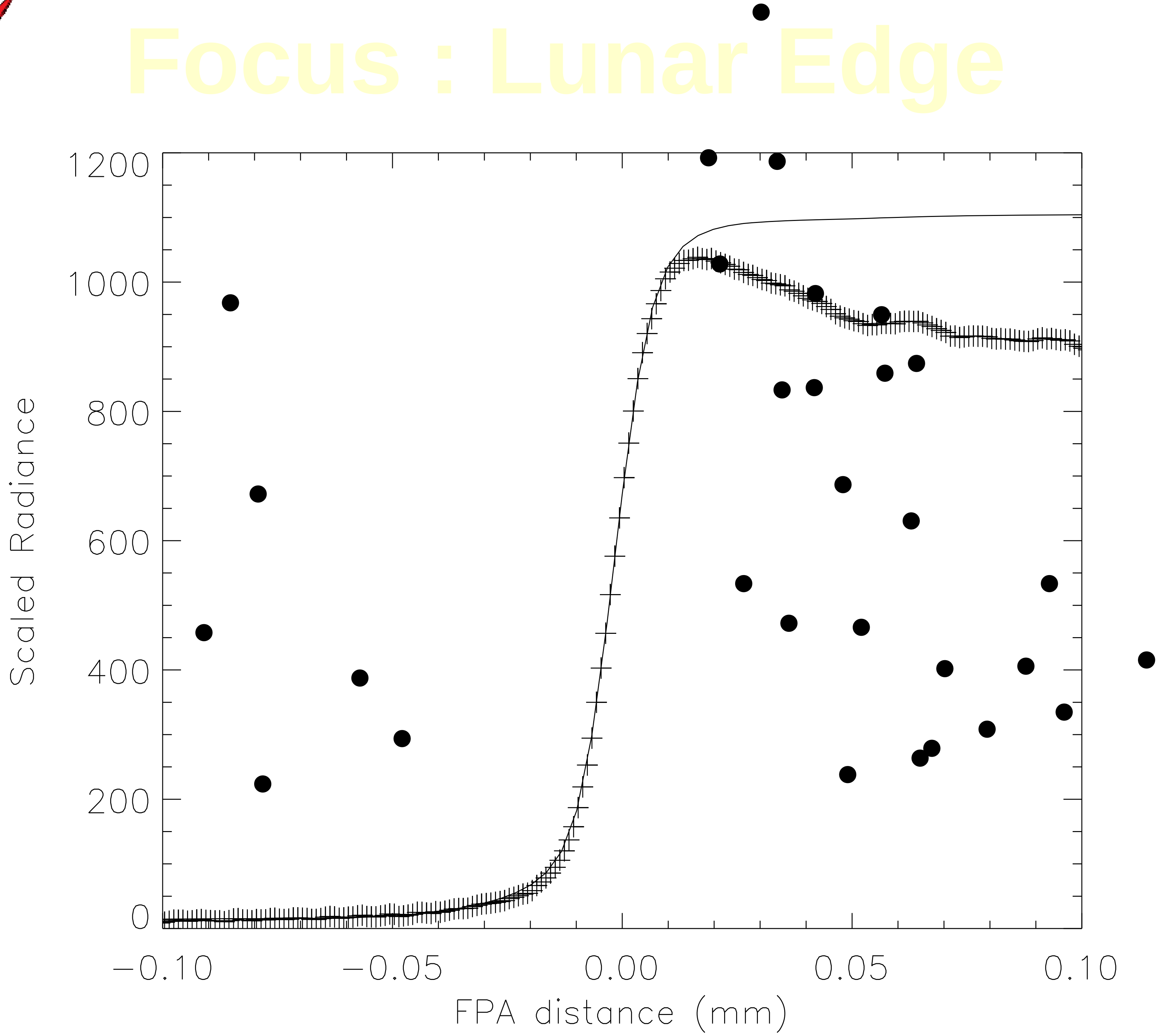
Cumulative Spectral Radiance

Hyperion Lunar Spectra

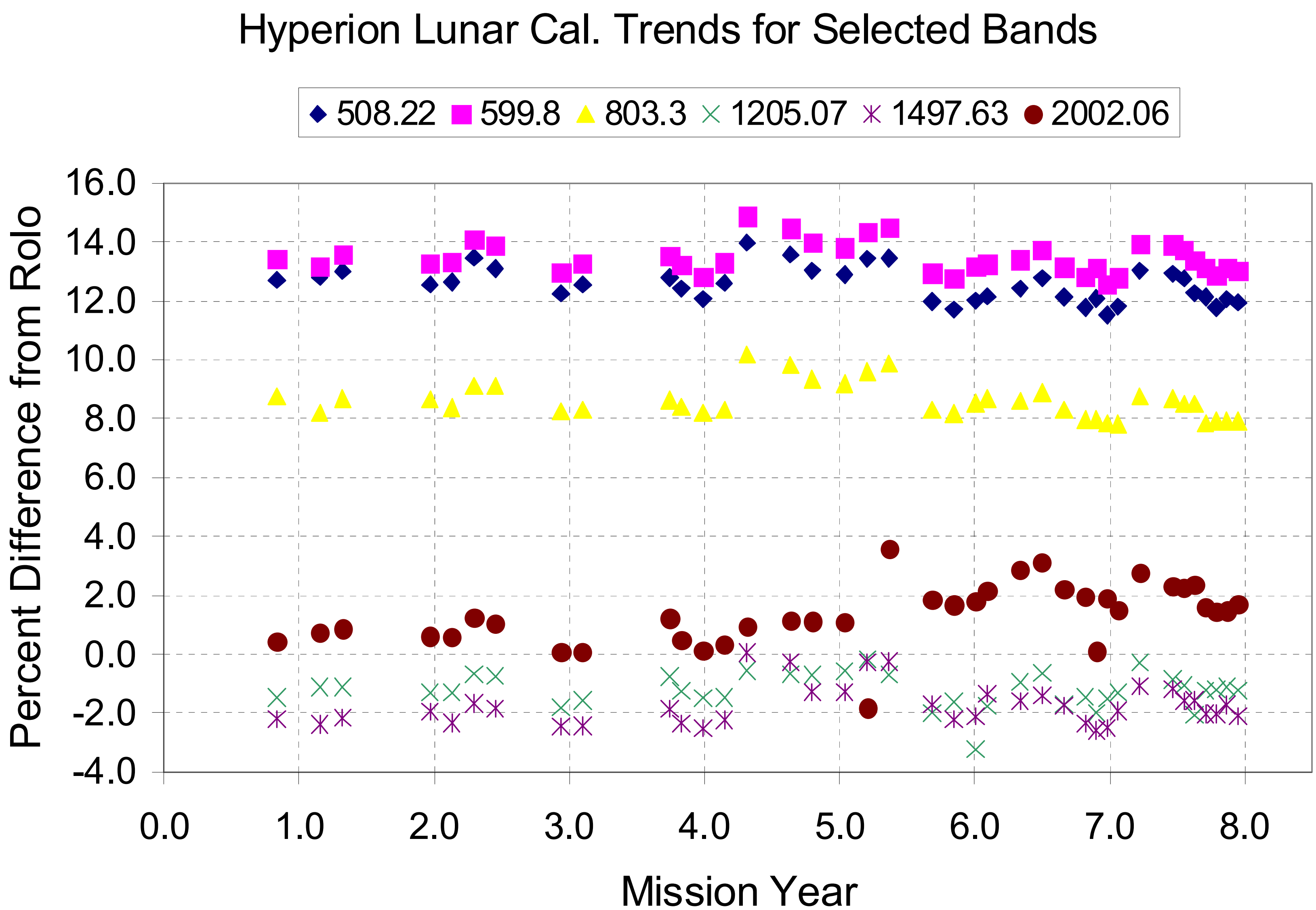
The pitch rate across the moon is the same as that used for earth imaging. This results in a 8X oversampling of the moon.



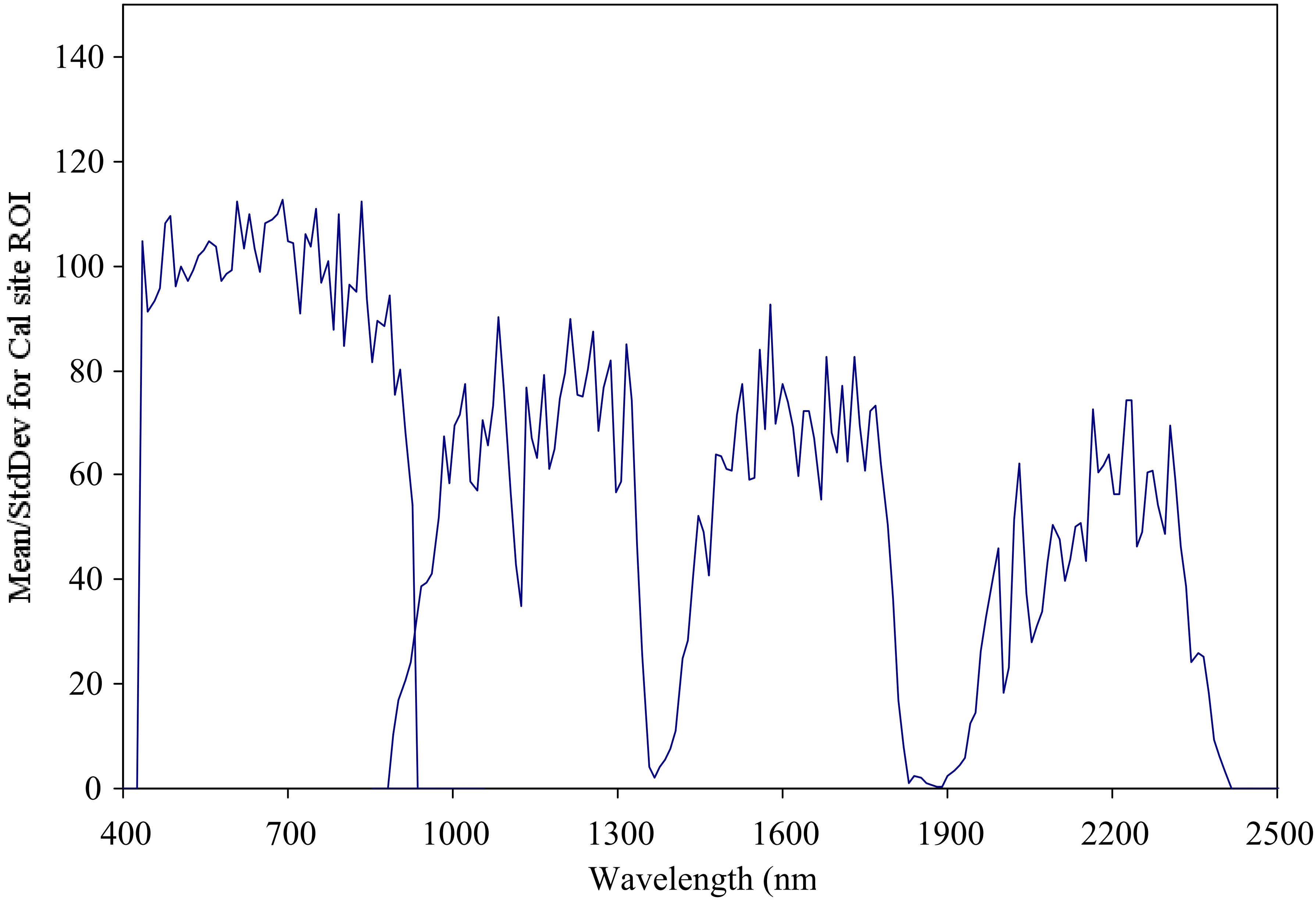
Focus : Lunar Edge



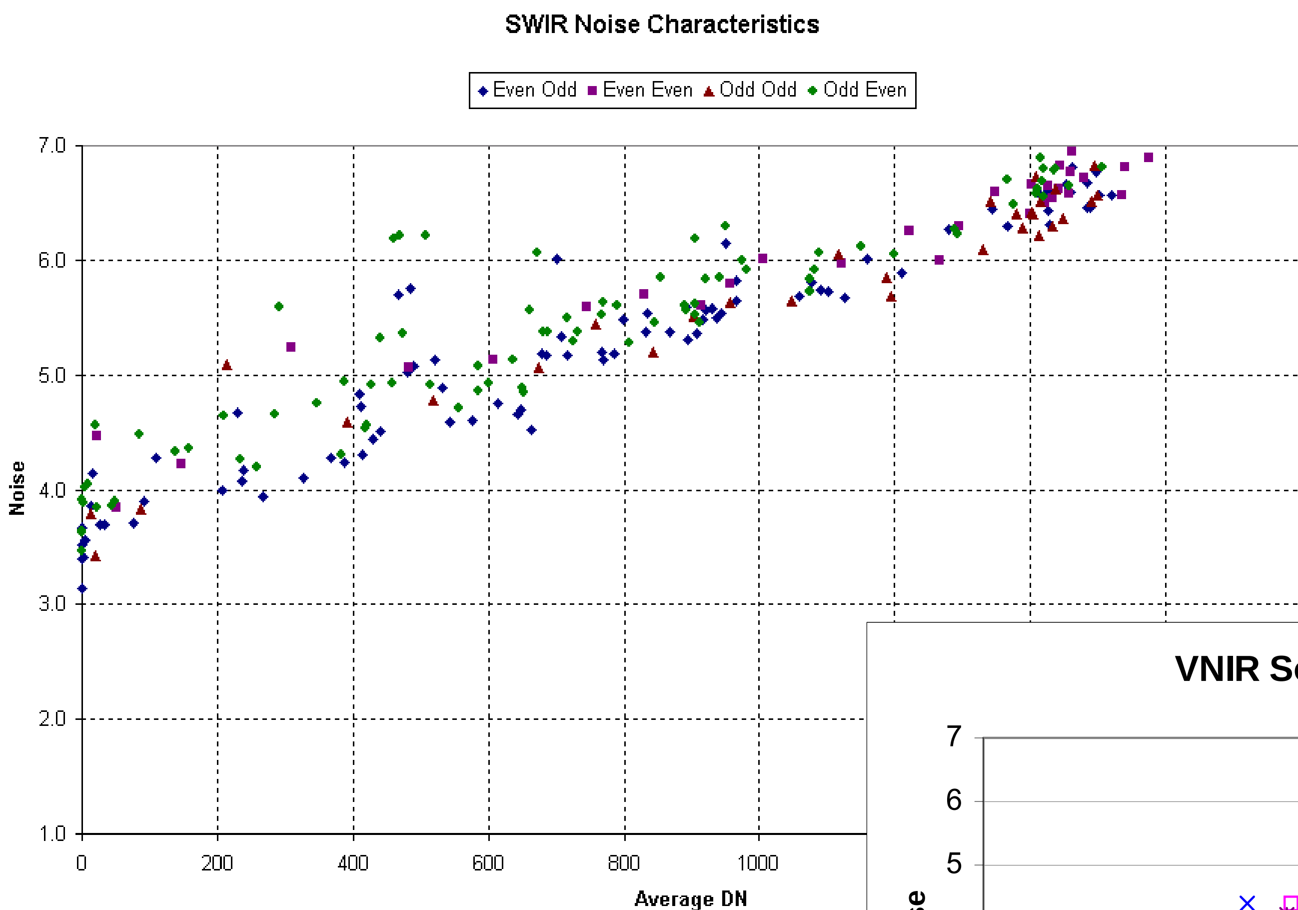
Lunar Calibration Results

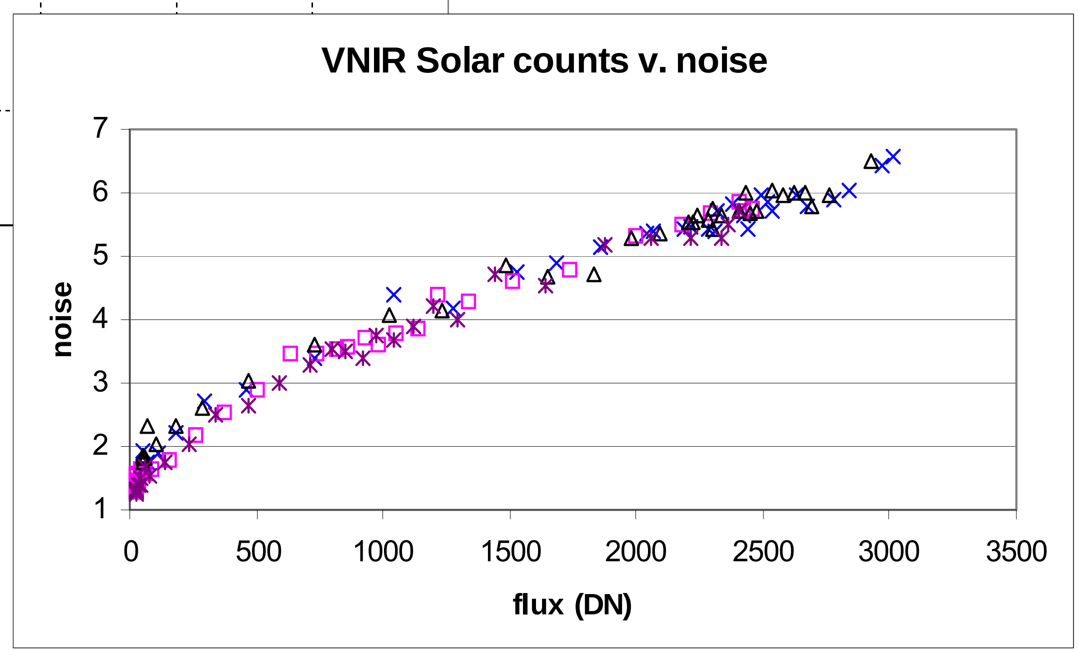


Scene Based Estimate of Hyperion SNR
(Source JPL AVIRIS LAB)

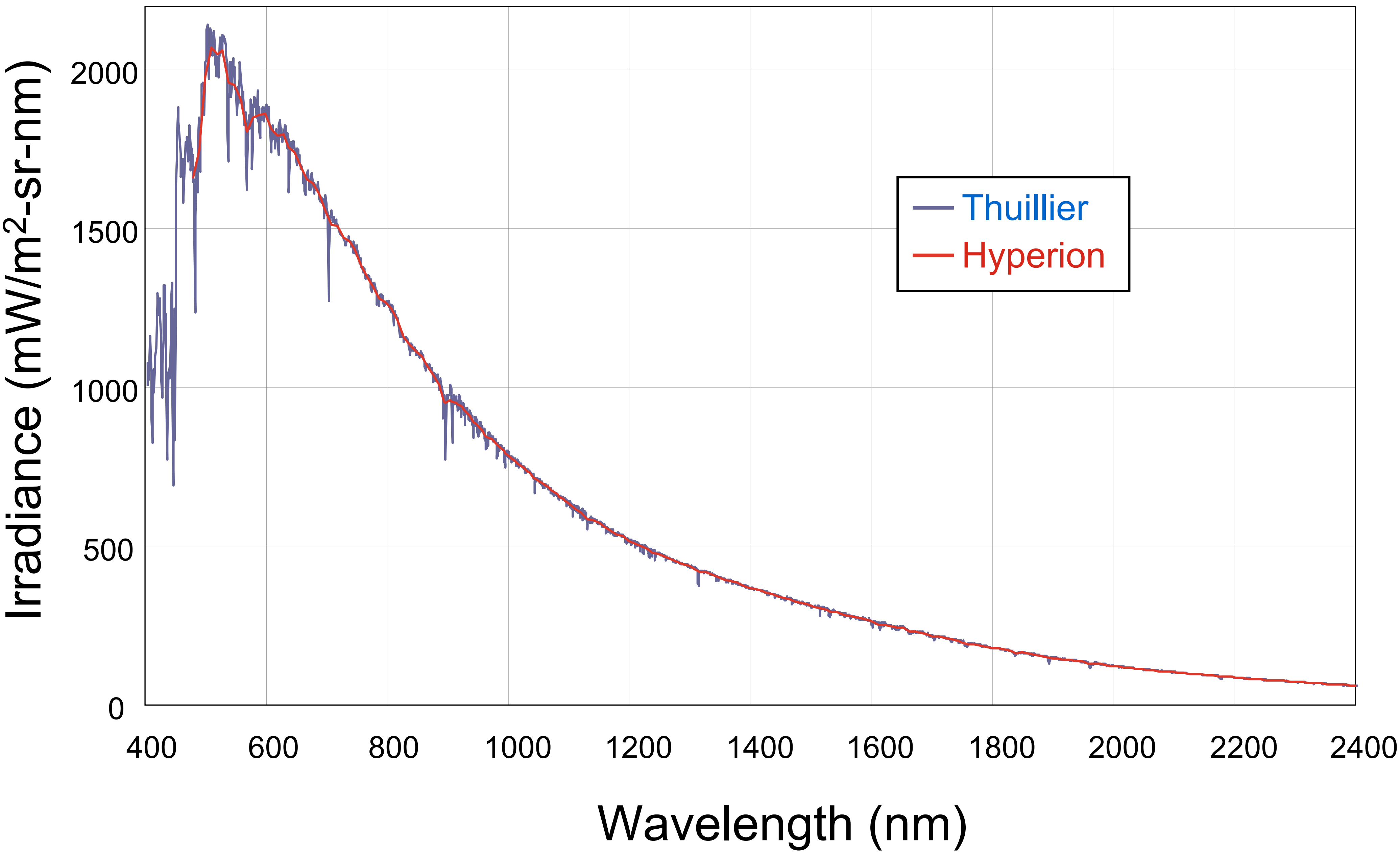


SNR Calculated From Solar Calibration Data





TOA Solar Irradiance



Top of Atmosphere Reflectance for EO-1 Hyperion

Use the Thuillier Solar Spectral Irradiance [E_k] model. Calculate a Solar Spectral Irradiance [E_n] for Hyperion band n by calculating a weighted average of the Thuillier E_k values within each Hyperion band pass. This is achieved by convoluting the Thuillier values with the Hyperion Gaussian spectral response [$f_n(\lambda)$] for the band under consideration.

$$E_n = \frac{\sum_{\lambda_n - \Delta\lambda_n}^{\lambda_n + \Delta\lambda_n} E_k \, f_n(\lambda_k)}{\sum_{\lambda_n - \Delta\lambda_n}^{\lambda_n + \Delta\lambda_n} f_n(\lambda_k)}$$

The conversion to exoatmospheric reflectance [ρ^*] is calculated as follows:

$$\rho_n^* = \frac{\pi L_n d^2}{E_n \sin(\theta)}$$

Where: $\mathbf{L_n}$ is the radiance for the Hyperion band centered at wavelength λ_n, $\boldsymbol{\theta}$ is the sun elevation as given in each scene's metadata, $\mathbf{E_n}$ is the mean Thuillier solar spectral irradiance value for band n as calculated from the description above, and **d** is the earth-sun distance in astronomical units which varies according to the Julian day.

Top of Atmosphere Reflectance for EO-1 Hyperion

Calculate values for Hyperion Gaussian spectral response functions for a band centered at λ_n, with a full-width half-max of $(FWHM)_n$, as follows:

$$f_n(\lambda) = \frac{1}{\sigma_n \sqrt{2\pi}} e^{-(\lambda - \lambda_n)^2/(2\sigma_n^2)}$$

$$\text{use}: \sigma_n = \frac{(FWHM)_n}{2.3548}$$

$$\text{and consider interval}:$$

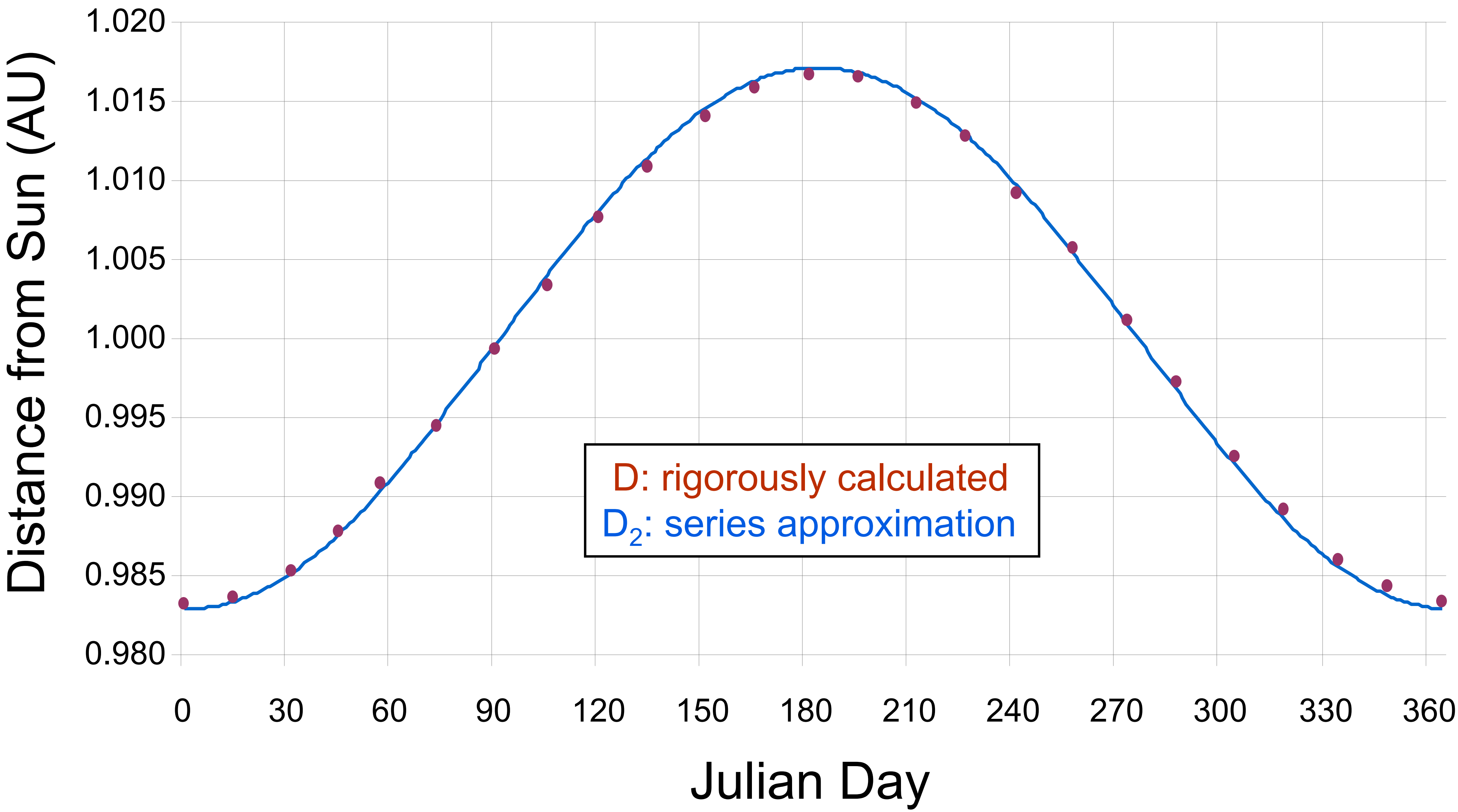
$$\lambda_n - \Delta\lambda_n \le \lambda \le \lambda_n + \Delta\lambda_n$$

$$\text{Where}: \Delta\lambda_n = 3\sigma_n$$

To use with the Thuillier Solar Spectral Irradiance $[E_k]$ model, calculate $f_n(\lambda)$ at $\lambda = \lambda_k$ for each value of

$$\lambda_n - \Delta\lambda_n \le \lambda_k \le \lambda_n + \Delta\lambda_n$$

Earth-Sun Distance (D, D_2)



Earth-Sun Distance (D_2)

$$D_2(\theta) = \frac{1}{\sqrt{A_0 + A_1 \cos(\theta) + A_2 \sin(\theta) + A_3 \cos(2\theta) + A_4 \sin(2\theta)}}$$

$$\text{Where}: \theta = 2\pi \cdot \left(\frac{JulianDay}{\mathbf{365}} \right)$$

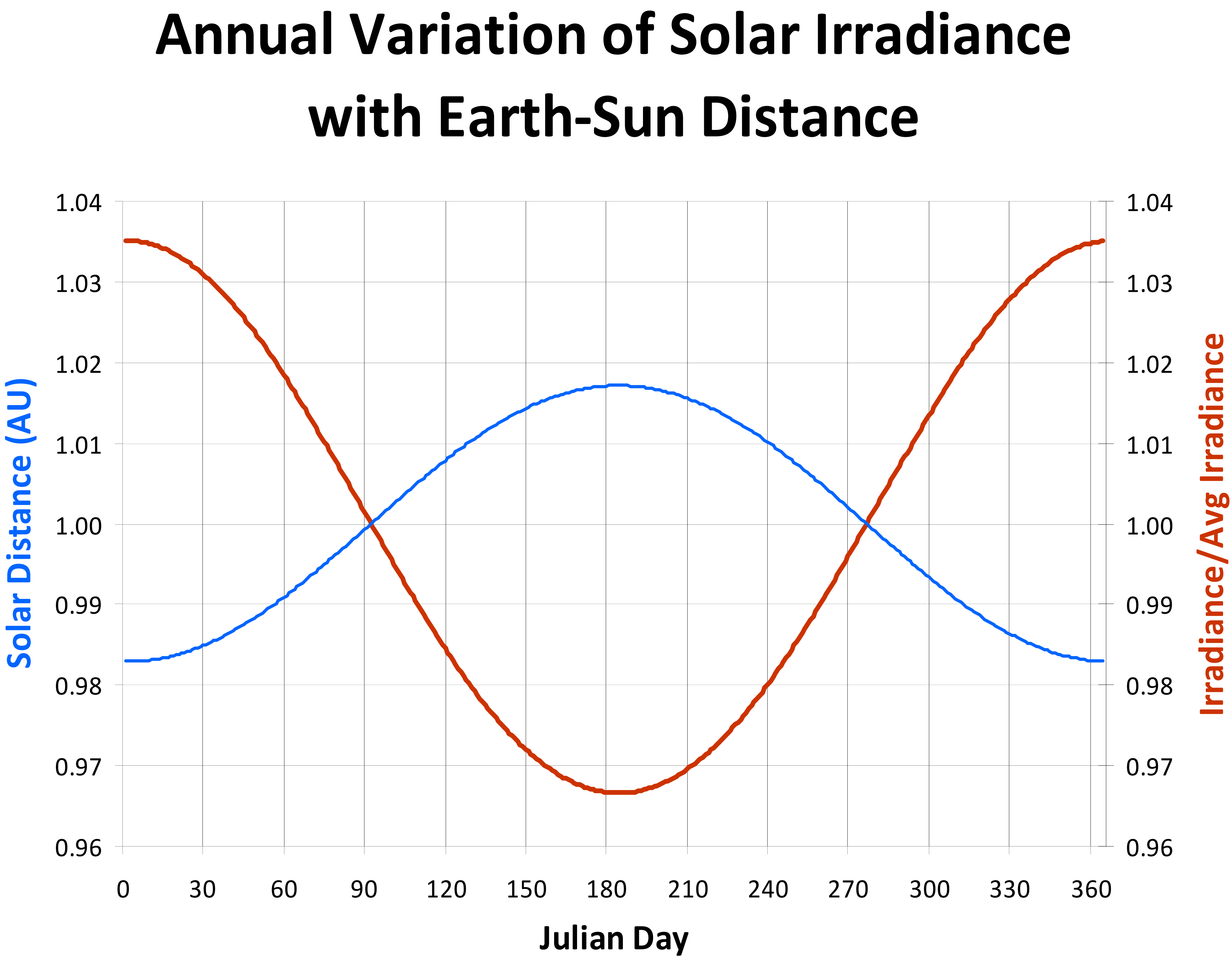
$$A_0 = 1.000110$$

$$A_1 = 0.034421$$

$$A_2 = 0.001280$$

$$A_3 = 0.000719$$

$$A_4 = 0.000077$$


Annual Variation of Solar Irradiance
with Earth-Sun Distance
Solar Distance (AU)
Irradiance/Avg Irradiance
Julian Day
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
0
30
60
90
120
150
180
210
240
270
300
330
360