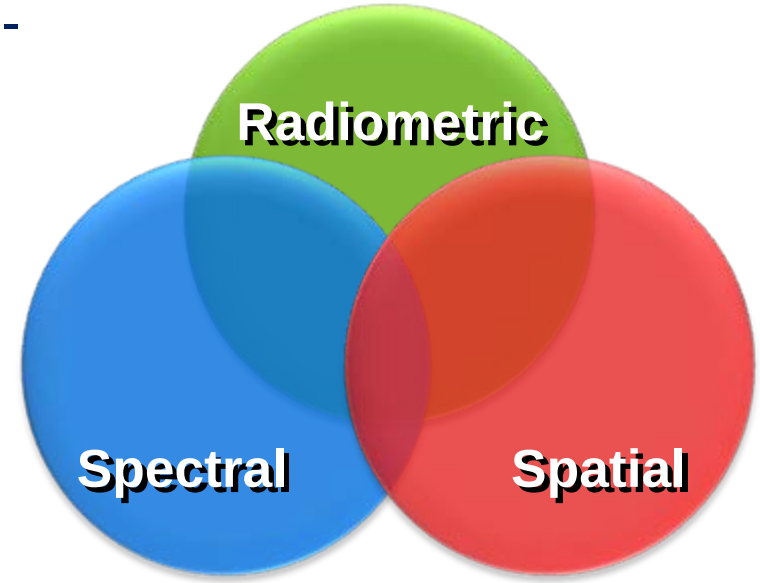
GOES-R Calibration Working Group Report to the AWG

Changyong Cao
NOAA/NESDIS/STAR

June 7, 2010

The GOES-R Calibration Working Group

- Verify and ensure well-calibrated, & well-navigated GOES-R L1b data for the life time of the instruments (ABI, GLM, and SWx)



- Ensure Level 1B data quality. Provide technical oversight and IV&V for:
  - » Radiometric calibration
  - » Spectral calibration
  - » Spatial calibration/navigation check
  - » Independent verification of L1B data
  - » Evaluate and mitigate instrument performance risks (e.g., possible striping, noise, cross-talk, RVS, spectral response uncertainty, etc)

- Provide technical support to the Flight and Ground through PSE

The GOES-R Calibration Working Group

CWG STAR Members

- Changyong Cao (Chair)
- Fred Wu (ABI & current GOES)
- Frank Padula (ABI & CWG Liaison)
- Robert Iacovazzi (ABI, GLM, GSP)
- Aaron Pearlman (T/V data analysis)
- Mike Grotenhuis (ABI geospatial cal.)
- Gordana Rancic (vicarious &knowledge base)
- William Rowland (Space Weather)
- Jonathan Darnel (Space Weather)

- **Technical Advisor/Mentor**
  - Michael Weinreb (ABI & NIST coordination)
  - Tim Schmit (Imagery/L1b)
  - Jack Xiong (Optics & MODIS/VIIRS lessons learned)
  - Jared Clarke (PSE coordinator & INR)

NIST

- Eric Shirley, Raju Datla, Joe Rice, Carol Johnson, Simon Kaplan, David Allen,Allan Smith

NASA Flight

- Jeff Kronenwetter ,Chris Rollins, Dennis Chester, Marv Maxwell, Peter Silverglate, Jim Haney, and Others

MIT/LL

- Monica Coakley & co.

Collaboration:

AWG

- Laurie Rokke, Walter Wolfe, Jamie Daniels, AWG team chairs, and others

MSFC & SWPC

CWG Scope

The CWG provides extensive scientific and technical calibration support through its strong multi-agency partnerships to ensure data quality and mission success

- Provide independent analysis and review of instrument design, characterization and calibration test data provided by the vendor
- **GOES-R Flight Segment** – Independent data analysis and technical oversight
- **GOES-R Ground Segment** – Supporting calibration database preparation, data definition and calibration algorithm evaluation
- **GOES-R Algorithm Working Group (AWG)** – Technical support on calibration related issues, supporting instrument performance impact studies, and definition of calibration parameters
- Coordinate L1b cal/val field campaign and postlaunch scientific validation
- **NIST** – Coordination and oversight of independent verification of SI traceability

Four Phases of Calibration/Validation

1. Pre-Launch (development and I&T)

- CDRL peer review, PDR/CDR
- Algorithm & calibration database development & verification
- Data format/content/quality flags
- Bench/TVAC tests and analysis
- Trade studies and waivers
- Validation capability development and preparation
- Prelaunch SI traceability

2. Operational check-out (Post-Launch Tests)

- Engineering tests to ensure specification compliance
- Calibration processing
- Anomaly analysis

3. On-orbit verification (Environmental cal. initialization)

- Instrument characterization
- Sensor artifact study and correction
- Algorithm adjustment
- Inter-comparison between satellites, and with NWP models
- Both SDR and EDR Validation

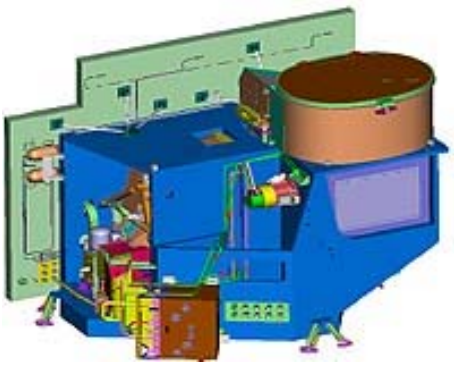
4. Long-Term Monitoring (Mission operational life)

-Routine monitoring of instrument performance
-Inter-satellite comparison and NWP models

GOES-R Flight Calibration Support

Pre-launch Calibration & Testing

- **ABI Irradiance Calibration Methodology Change Study**



» Meeting the solar band calibration spec. was challenging with the original methodology
  – Alternative approach proposed by vendor

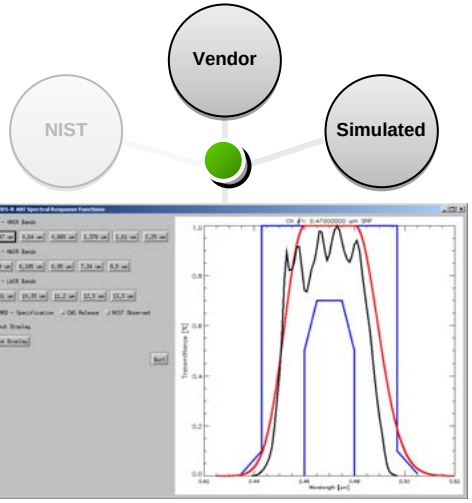
» CWG promptly coordinated a review & comprehensive case study, working closely with calibration experts from NASA, NIST, and MIT/LL

» Evaluated the vendor proposed alternative approach, as well as its potential impacts on post-launch calibration and product quality

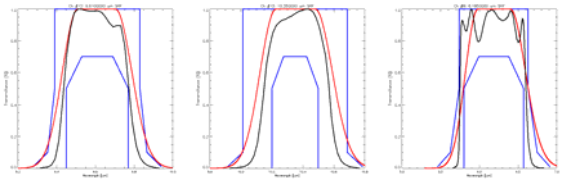
» Assessment and recommendations were provided to the instrument vendor
  – Highlighted areas of further investigation
  – Developing risk mitigation strategies postlaunch

Spectral Response Function Analysis

- CWG pre-launch spectral calibration capabilities and analysis



PTM SRF Investigation:



Identify Concerns/Issues:

1. **PTM data are mostly in good agreement with "simulated" ABI data**
2. **Bands 6, 8 & 12 are out of specification**

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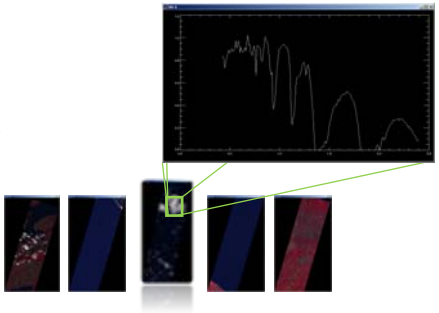
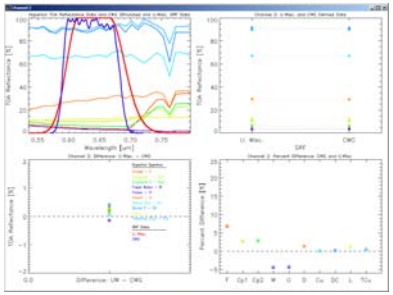
Identify Hyperspectral Targets

Target Spectra



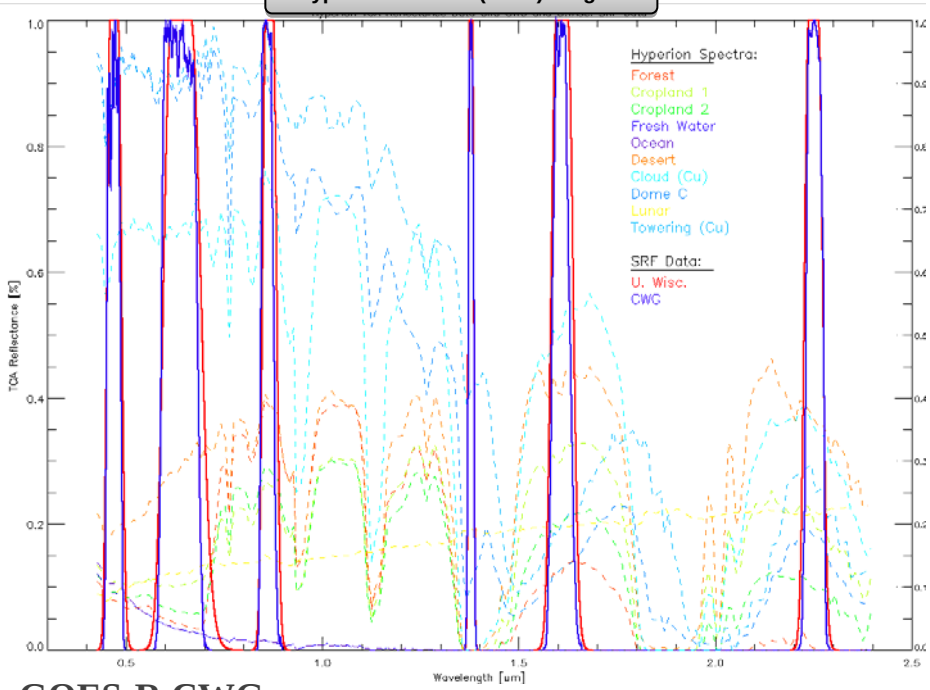
Characterize Spectral Sensitivity



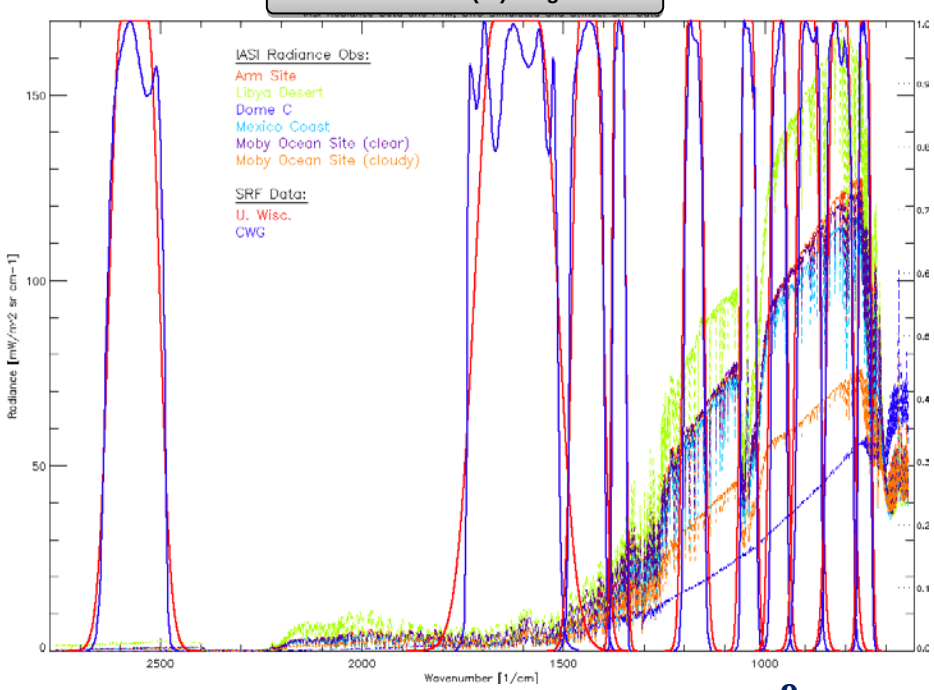
Spectral Response Function Analysis

- Two sets of pre-launch spectral response functions (SRFs) for ABI
  - » The CIMSS version and the CWG version
  - » Quantified the differences between them and their impacts through spectral analysis using Hyperion and IASI spectra
  - » Working with AWG to assess impact (Walter Wolfe & Jamie Daniels)

Hyperion Derived (VNIR) Targets



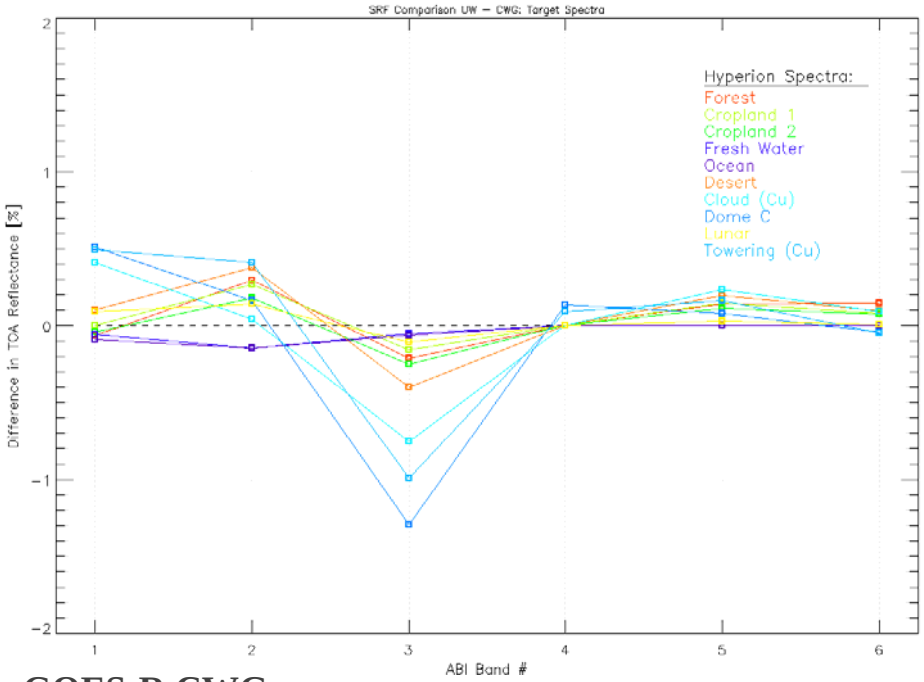
IASI Derived (IR) Targets



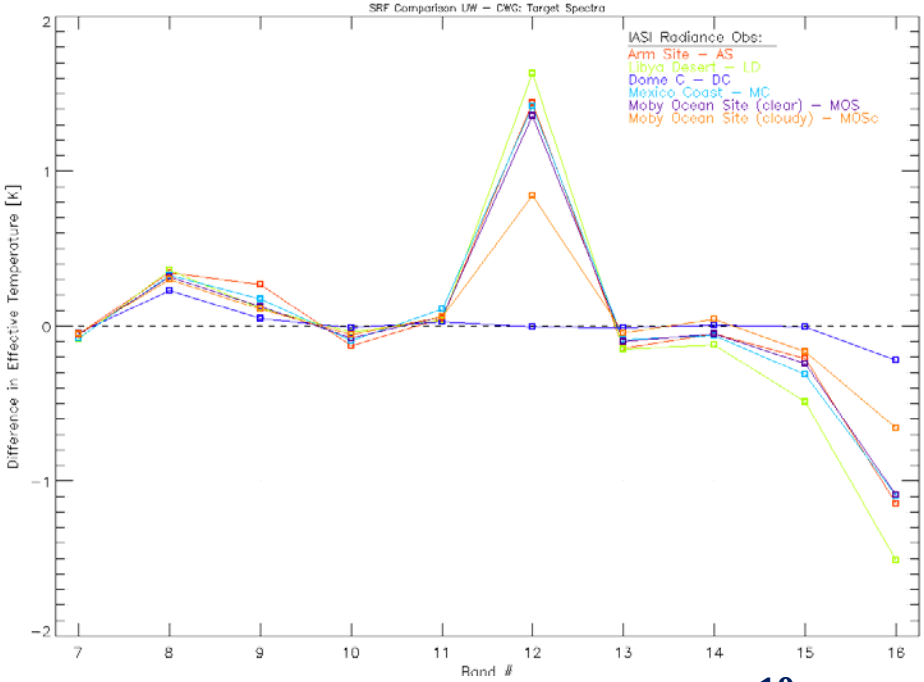
Spectral Response Function Analysis

- Differences found between the two sets of SRFs
  - » **Solar Bands:** differences ranged from near 0 to approaching 2% TOA reflectance
  - » **IR Bands:** differences from near 0 to >1K in brightness temperature
  - » **Recommendation:** users should use a consistent set of SRF, until the flight model SRF becomes available

VNIR Results

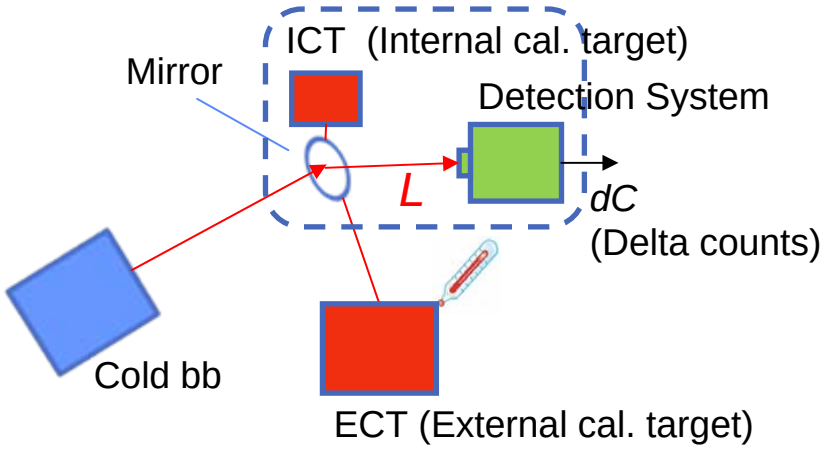


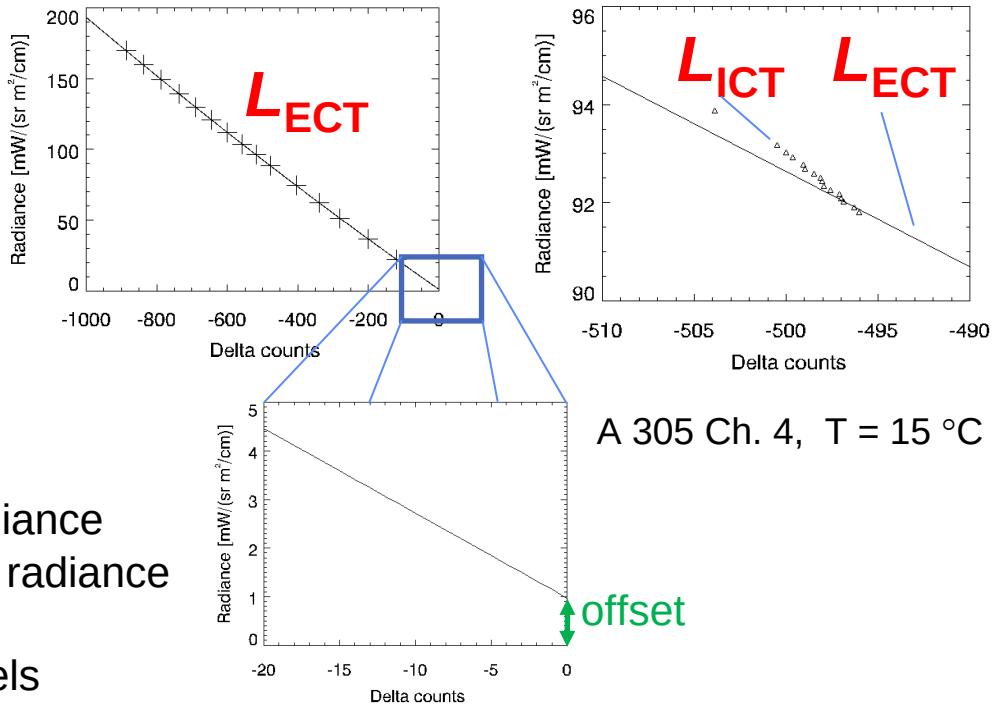
IR Results



Preparation for IR channel thermal vacuum data analysis

Using prelaunch data from other IR instruments (AVHRR, HIRS, GOES) as proxy to develop techniques for resolving T/V test inconsistencies and nonlinearity for GOES-R ABI.





A 305 Ch. 4, T = 15 °C

- Account for instrument response to zero radiance
- Resolve discrepancy between ECT and ICT radiance
- Account for drift in ICT radiance
- Characterize nonlinearity of some IR channels

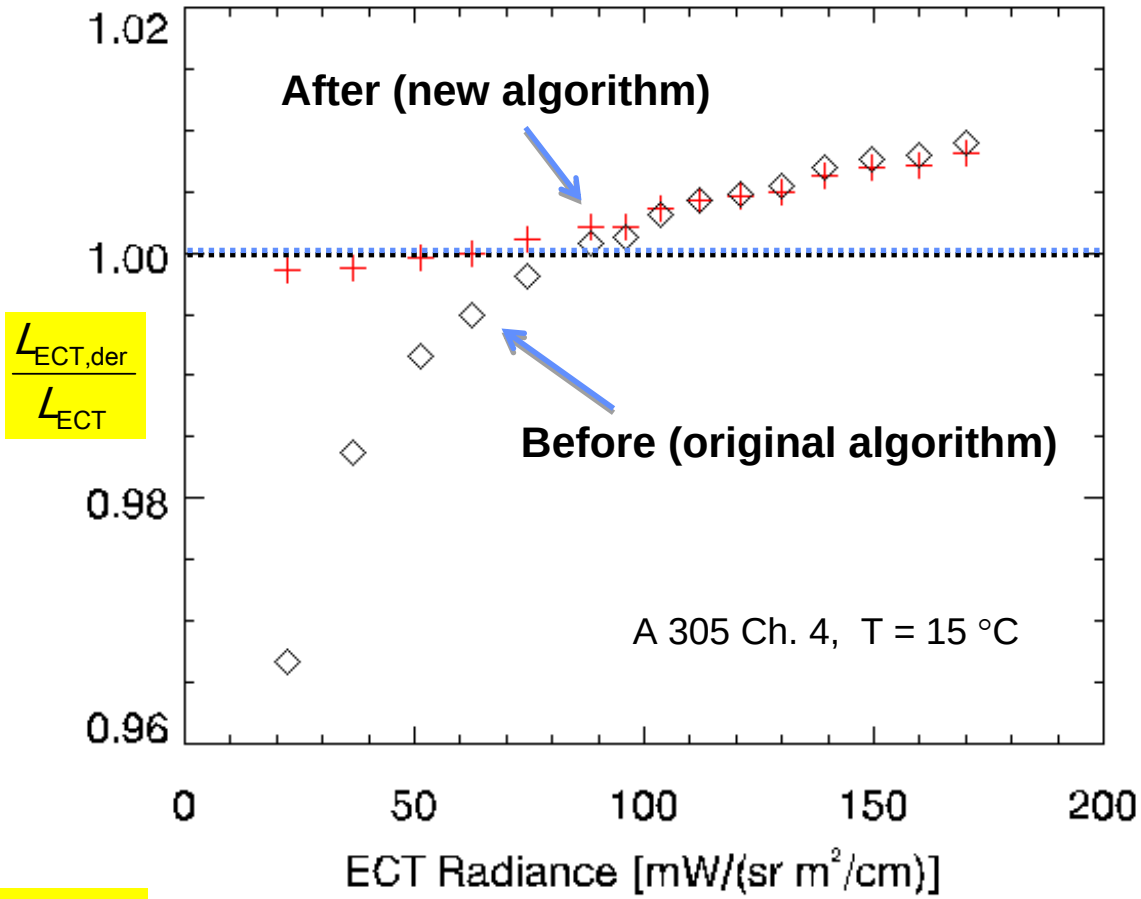
Developing calibration model to account for test artifacts using instrument parameters

Preparation for thermal vacuum IR data analysis

Preliminary results show calibration accuracy can be improved with better understanding of T/V test artifacts and improved calibration algorithms

Remaining inconsistencies yet to be resolved

Getting ready to analyze GOES and then ABI T/V data

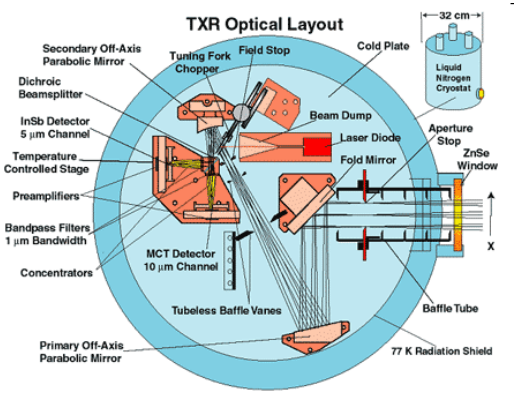


$L_{ECT,der}$ – Modeled radiance of ECT using ECT prelaunch data and ICT data

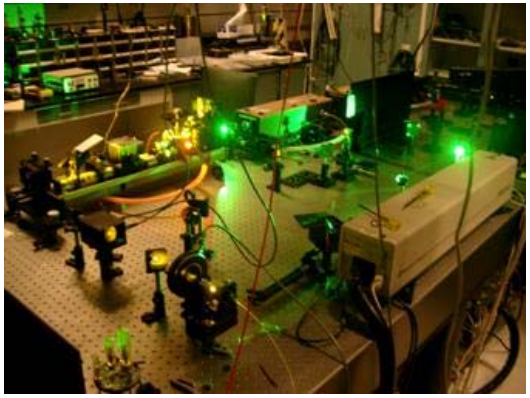
L_{ECT} – Measured radiance of ECT using prelaunch data only

NIST Activities

- Working with NIST and ITT on the deployment of NIST instruments
  - » VXR: ~ Early Fall 2010
  - » TXR: ~ Late Fall 2010
  - » SIRCUS: discussion initiated with ITT



- Thermal Transfer Radiometer (TXR), Visible Transfer Radiometer (VXR), and ASD Spectrometer
  - » Ensure prelaunch SI traceability



- Spectral Irradiance and Radiance Responsivity Calibrations using Uniform Sources (SIRCUS)
  - » Significantly improves solar band spectral response function characterization/validation
  - » Straylight characterization
  - » Capabilities for IR channels are being developed

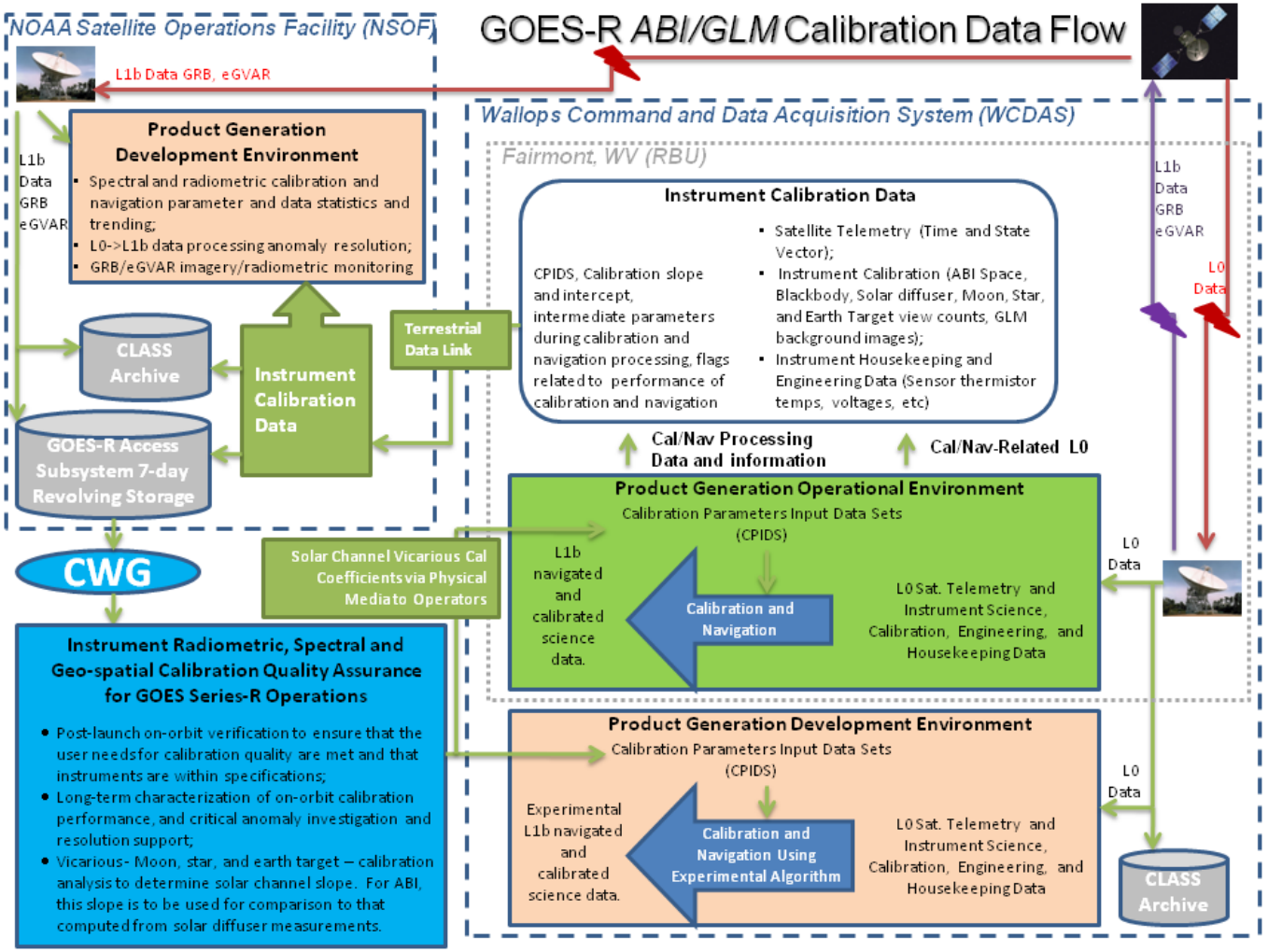
GOES-R Ground System Calibration Support

L1b, GRB, and MM IPT Participation

- Defining instrument calibration data sets
  - » Calibration data files proposed
    - » **Once every two hours; one for each instrument**
    - » **Example items:**
    - Instrument temperatures
    - Calibration event data (e.g., internal target and space view counts)
    - Calibration data statistics (e.g., instrument noise)
    - Level 1b landmark data
  - » Calibration data will go into GAS (GOES-R Access Subsystem, 7day storage), and CLASS (for long-term)
- Collaborating with NSOF calibration specialists to ensure operational monitoring of:
  - Calibration-related instrument engineering and science data
  - L0-to-L1b data processing parameters
- Work in process, not all instruments have passed CDR

Instrument Calibration Data Flow

- Defined the "Instrument Calibration Data" and its flow through the Ground Segment.", in response to request at the Ground Segment Contactor SRR



As of Feb., 2010

Supporting Studies

- **Solar and View Geometry Calculations for ABI**
  - » This information will not be provided in GRB, but needed to derive TOA reflectance
  - » Developed a method to compute these angles, presented to AWG and Ground, and documented in a Whitepaper
    - – Worked with the Level-1b IPT to define the parameters and time interval that the ABI ephemeris and time data to be reported in GRB

  Future work:
  - » AWG will implement the method developed
  - » Code needs to be made available to all users through the ground segment
  - » An “Earth Location User’s Guide” or similar document needs to be created

- ABI GOES Re-Broadcast (GRB) max/min radiance value determination
  - » Including documentation on radiance units and conversion methodology

- ABI GOES GRB Bit Depth analysis (working with Laurie Rokke & Tim Schmit)

Space Weather Instrument Calibration Support

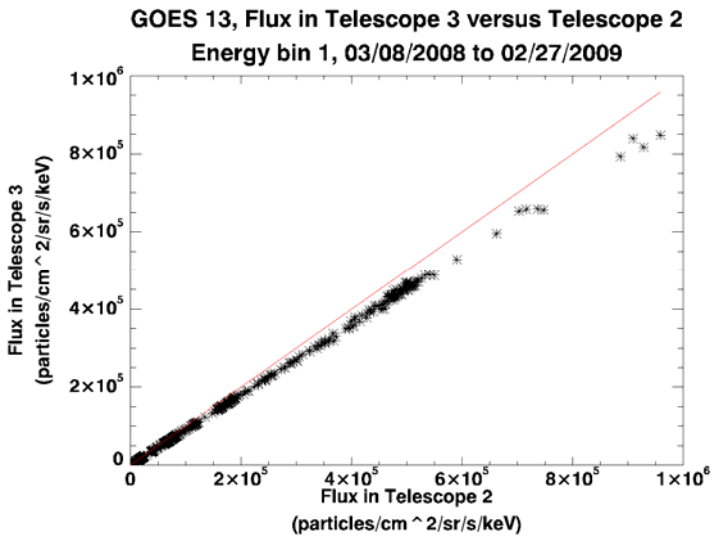
Developing Space Weather Instrument Calibration Support

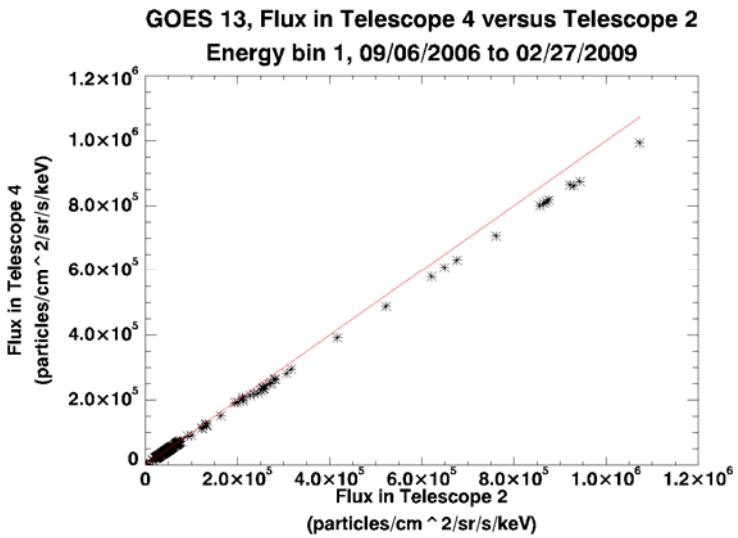
- Provided expertise on technical issues (e.g., subsampling of SEISS L1b data during Storage Mode operations, and instrument performance)
- Contributed to the space weather sections of the Cal/Val Plan
- Supported defining data needed for L1b calibration
- Supported GOES-P PLT (Postlaunch test)
  - » Ran IFC algorithm for data provided by GOES-P personnel to independently confirm their results
  - » Created software which trends the IFC results, for independent confirmation
  - » Obtained TIMED-SEE data for use in comparison to GOES-P EUVS results
    - – Created code which converts it into formats compatible with the GOES-P personnel's analysis tools

Space Weather Pre-launch Calibration Support

- Coordinated the creation of the SEISS and SUVI lists of L1b metadata necessary for the L2+ SWx algorithms
  - » Achieved sufficient maturity for delivery to Harris on 03/09/10
  - » Future revisions fall under Ground Segment's L1b IPT/DEWG
- Identified the lack of SEISS IFC algorithm to the Program
  - » Tasked to develop the necessary code for GOES-R
  - » Evaluated GOES-NOP algorithm. Created list of necessary additional information for GOES-R. Delivered this to the Program on 05/28/10
- Investigated possible difficulties in validating SEISS Product Accuracy requirements with current information
  - » Drafted a document explaining the issue and suggesting possible resolution strategies
- Quantitatively modeled the wavelength dependence for transmission of through contamination for GOES-R's EUVS channels
  - » Identified this as a gap in current GOES-R calibration plan
  - » LASP was already writing a paper which addressed the issue, and plans to add it to GOES-R documentation after publication

Intra-calibration for Magnetospheric Particle Detectors

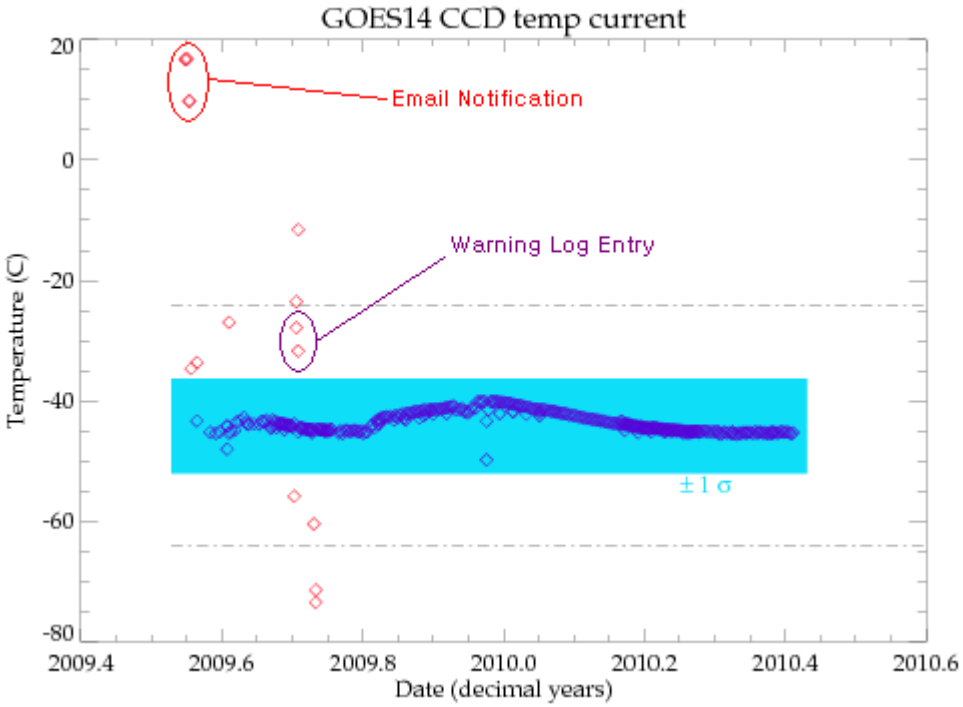




- Functional prototype algorithm and code developed by the CWG.
- Tested using GOES-13 MAGED and Magnetometer data provided by SWPC.
- Locates data for which particle pitch angles permit valid flux comparisons.
- These analyses will be automated.
  - » STAR and the community will be able to easily view all valid comparisons over the full instrument lifetime.
- This capability is essential for maintaining calibration of GOES-R SEISS MPS-Lo and MPS-Hi instruments.
- Currently working to make the program compatible with data directly from the NGDC.
  - » This is a time consuming process for GOES-NOP SEM data.
  - » The GOES-R SEISS data will provide all necessary inputs by default.

Space Weather Instrument Performance Monitoring - SUVI

The SUVI Toolkit in development will monitor the calibration of the SUVI instrument and related operational instrument parameters. Currently testing the approach using the GOES-14 SXI.



✓ The toolkits will generate plots with online tracking tools available to the public.

✓ Email notifications in the event of drastic changes in the instrument behavior.

- Measurements outside of 1σ results in a warning-log entry
- Measurements outside of safe levels (dashed lines) will trigger an email alert.

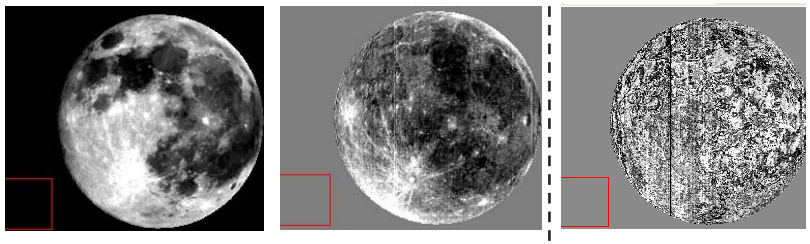
Working with MIT/LL and NIST to encourage the calibration of SUVI at suitable NIST traceable facilities. (SURF-III, MSFC/XRCF)

GOES-R Vicarious Calibration

Hyperspectral Analysis of the Moon

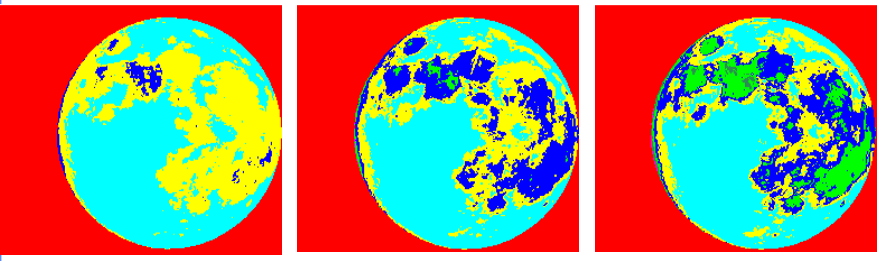
Characterization of spectral and spatial stability of the Lunar surface reflectance using an EO-1 Hyperion Full Moon collect

PCA 1 PCA 2 PCA 3

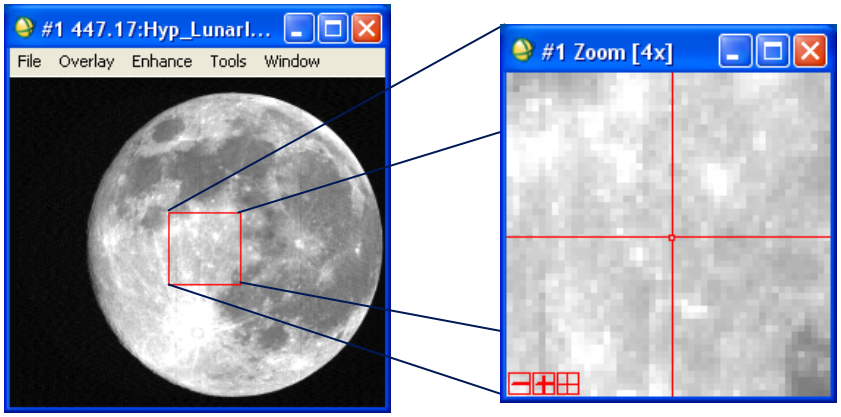


Spatial/Spectral stability identified by classifying the "bulk" Lunar surface material types into **5-7 large lunar classes**

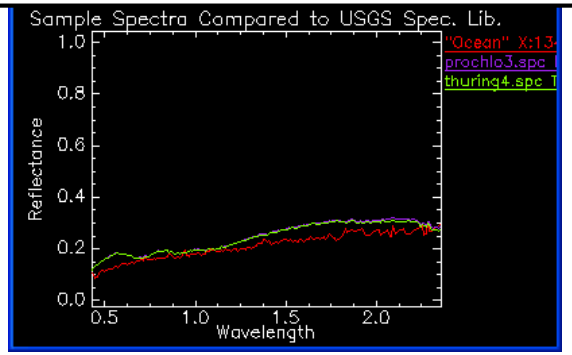
4 classes 6 classes 8 classes



Lunar "Ocean" – Large Stable Target



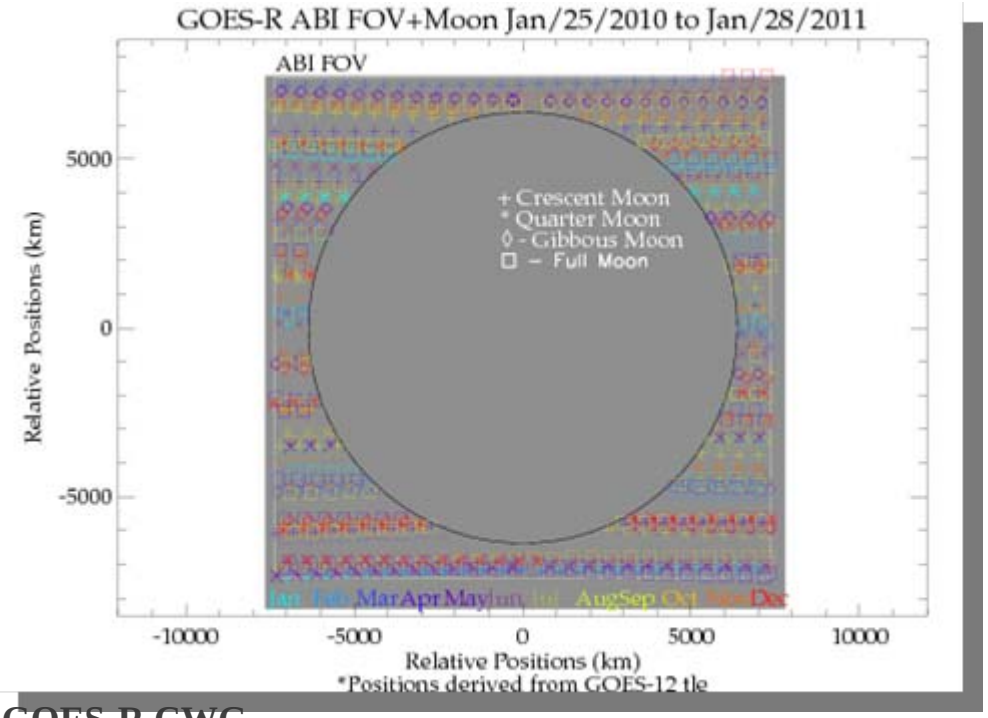
Material Identification: Prochlorite/Thuring



Advanced calibration methodologies being developed for ABI

GOES-R ABI Lunar Study

- An algorithm has been developed to determine when the Moon will be “near” the ABI field of view and the respective phase angle.
- The prediction model will be used to plan lunar observations in conjunction with lunar irradiance models from USGS-ROLO



•Uses SGP4/SDP4 code to predict when the Moon is in the ABI FOV

•Determines the phase angle of the Moon, which greatly affects the amount of irradiance from the Moon

•Tested with GOES-12 orbital data

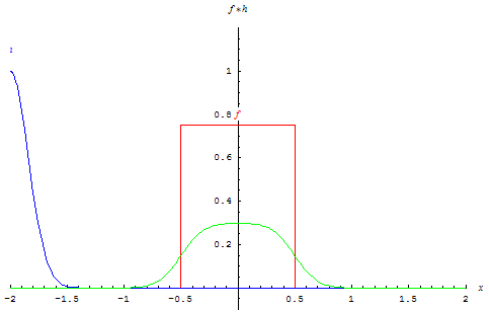
Vicarious Calibration Site Characterization

- AVIRIS/MASTER ER-2 characterization of White Sands Missile Range, NM and Sonoran Desert, Mexico BRDF was slated for Spring 2010.
- For each site, three intersecting flight lines to be flown over the course of four hours to simulate the solar noon zenith angle seasonal cycle.
- Airborne measurements will be coordinated with MODIS and/or AVHRR measurements.
- WSMR flight support – NASA's AErosol RObotic NETwork sunphotometer data from White Sands- HELSTF and Forecast and weather data support from El Paso, Texas NWS Line Office.
- Flights have been preempted since AVIRIS was diverted to take measurements of the Gulf of Mexico oil spill.

GOES-R Geo-Spatial Calibration

Geo-Spatial Calibration is under initial development with 3 primary elements:

1) **Image Navigation & Registration**
   - » Use high resolution images & digital elevation models



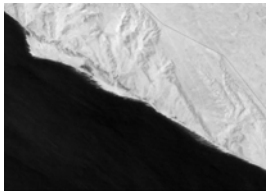
2) **Band-to-band co-registration**

3) **On-orbit PSF Determination**
   - » A very successful collaboration meeting with the MODIS Characterization Support Team (MCST) led to several possible avenues for on-orbit PSF determination

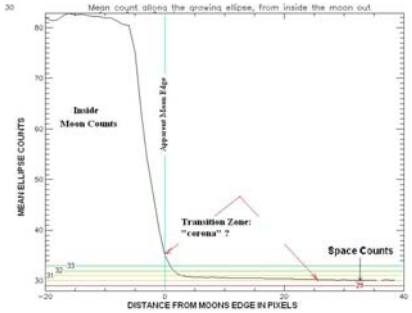
$$y(x) = f(x) \otimes h(x) = \int_{-\infty}^{\infty} f(X)h(x-X)dX$$

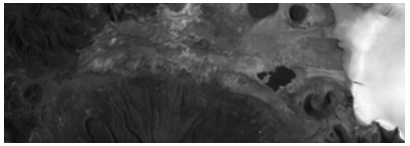
"TRUTH" ⊗ PSF = MEASURED IMAGE

Shoreline images

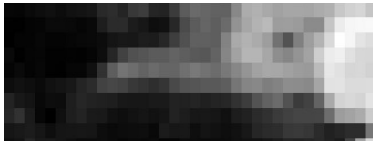


The Lunar Edge





High Resolution



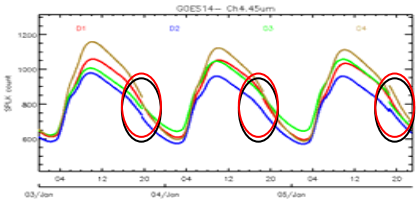
GOES 12/GOES-R

GLM Verification & Validation Trade Study

- GLM INR has to performed during mission operations to assure lightning detection locations are correlated to the correct earth locations at all times.
  - » GLM nighttime INR is not possible using coastline or ground control points
- On-orbit GLM INR monitoring needs to be done for the purpose of verification
- GLM has no on-board calibrator to determine instrument degradation
- Identify and explore methods of on-orbit GLM INR measurement and calibration monitoring for the purpose of post-launch mission-life verification and mission ops

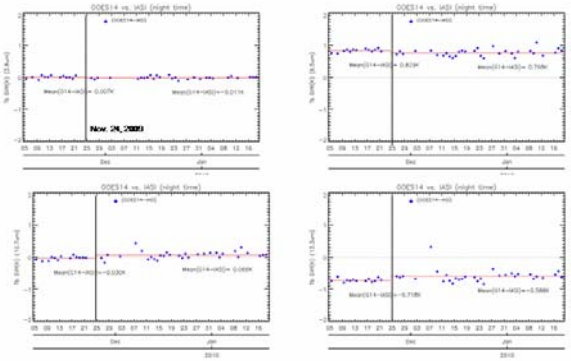
GOES-14 Post-Launch and Science Tests

- Collaborated with Tim Schmit and Don Hillger
- GOES IPM system to evaluate the GOES-14 Imager/Sounder instrument performance
  - » Imager/Sounder NEdT/NEdN are well below the specifications
  - » GOES-14 sounder optical-loose-lens problem



Sudden disrupt of Sounder space look data

- GSICS GEO-LEO inter-calibration to evaluate and monitor GOES-14 Imager/Sounder radiance calibration
  - » Relatively large Tb biases for Imager ch3 (6.5µm) and 6 (13.3µm) reference to both AIRS/IASI
  - » Improved cal. accuracy at Sounder Ch15
  - » Impact of Imager SRF update

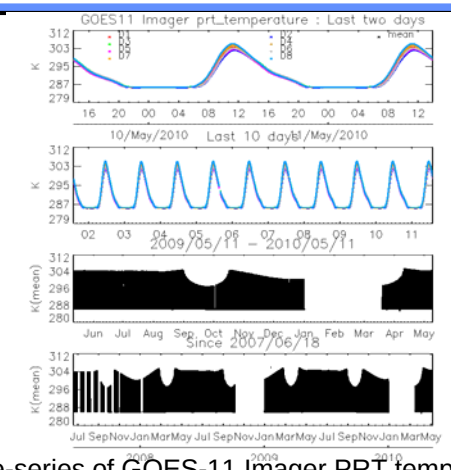


GOES-14 Imager IR channels bias between collocated IASI night-time pixels before and after the SRF update, showing small bias for Ch2 and 4 and relatively large bias for Ch3 and 6. Impacts of SRF update are very small for all the four channels.

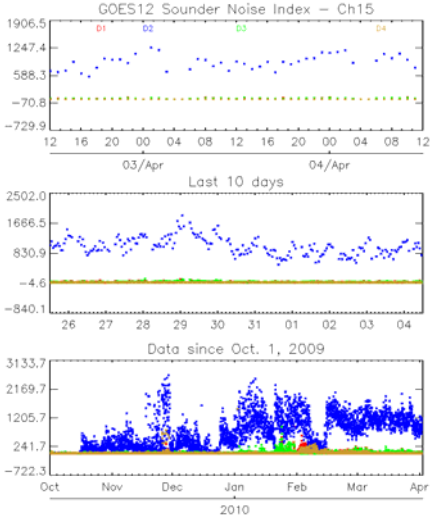
- Initial post-launch calibration for GOES-14 Imager visible channel

GOES Instrument Performance Monitoring (IPM) System

- New version of GOES IPM to routinely track the stability and noise of the sensor parameters that may affect the instrument calibration accuracy.
  - » Expanded from Imager to Sounder
  - » New plot design and efficient data archiving format
  - » Played an important role in GOES-14 post-launch science test
  - » Available at
    - – http://www.star.nesdis.noaa.gov/smcd/spb/fwu/homepage/GOES_Imager_IPM.php
    - – http://www.star.nesdis.noaa.gov/smcd/spb/fwu/homepage/GOES_Sounder_IPM.php



Time-series of GOES-11 Imager PRT temperature



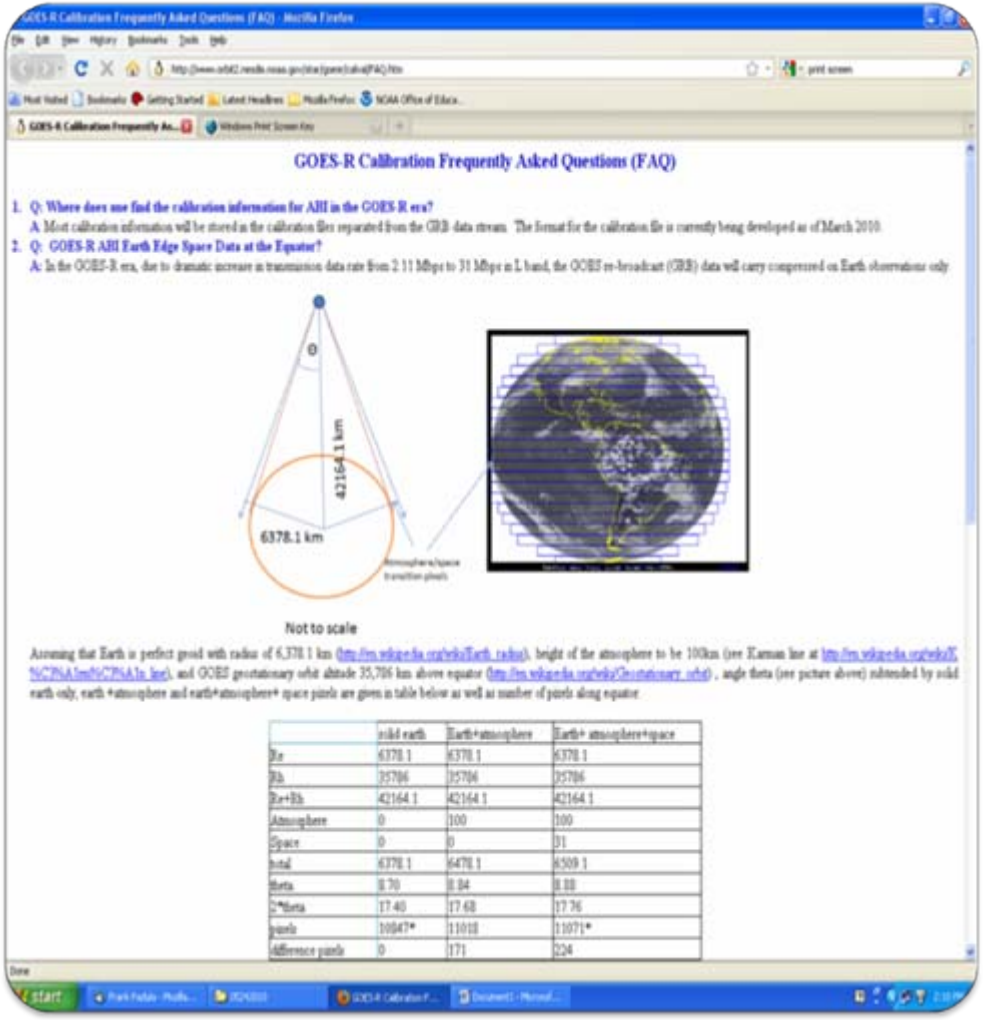
The abnormal noise level associated with the Det#4 at GOES-12 Sounder Ch15

GOES-R Calibration Knowledge Base Development

- Building the Calibration Knowledge Base both on line and offline
- GOES-R Calibration Frequently Asked Questions web page has been started
- Wiki-based online pages will also include monthly reports, meetings and announcements
- ITAR restricted materials will be kept safely off line

http://www.orbit2.nesdis.noaa.gov/star/goesr/calval/FAQ.htm

- Working with AWG to standardize software and data management practices (Walter Wolfe)



Performance Metrics

- **Capability Maturity Model (CMM)**
  - » Level 1: Ad hoc/chaotic
  - » Level 2: Repeatable
  - » Level 3: Standardized/documented
  - » Level 4: Quantitatively managed
  - » Level 5: Optimized

- Started using CMM to qunatitatively evaluate calibration capabilities for GOES-R instruments

Participating in Flight/Ground Segment Reviews

- Prepared for and supported:
  - » ABI, GLM, EXIS, SEISS and SUVI Instrument Meetings, Design Reviews, and Technical Interchange Meetings
  - » Ground Segment System Requirements and System Design Reviews
- Meeting summaries and reports are made available
- Issues are worked in the form of Requests for Action to vendor, or worked as risks within the program
- CWG identified risk items are mitigated through the official PSE channels

CWG Risks and Issues

Risks:

- Identified risk items to PSE
  - » ABI on-board solar diffuser calibration
  - » SUVI calibration (being addressed)
  - » Pre-launch SRF uncertainty

Issues:

- Better communication with ITT
  - » CWG collaboration with ITT
  - » Telecon and meeting participations
- Flight schedule
- ITAR materials (spectral response functions, min/max radiance values, etc)

Summary

The GOES-R CWG:

- » Fully engaged in all segments of the GOES-R program to provide calibration support
- » Strengthening pre-launch calibration support
- » Made good progress in postlaunch capability developments
- » Initiated the use of CMM, and improving the reporting to better monitor progress
- » Close collaboration with all parties involved, with several FY10 projects