U. S. Geological Survey Report on Cal/Val Activities

Ron Morfitt

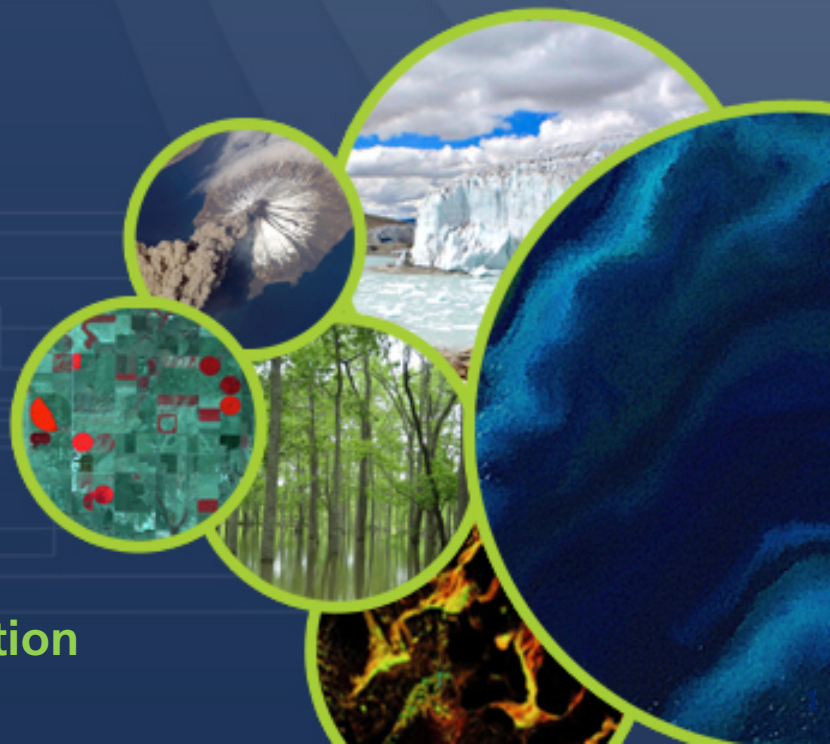
USGS

Agenda Item # XII

WGCV Plenary # 39

Berlin

May 6 – 8, 2015



Working Group on Calibration and Validation

Overview

- Landsat Mission Status
  - Observatory statuses
  - Instrument performance and anomalies
- Additional Activities Relating to Cal/Val
  - GCP improvement
  - Non-Landsat imagery assessments
  - National Earth Observation Assessment (EOA)
  - Land Product Characterization System (LPCS)
  - Land Surface Imaging – Virtual Constellation (LSI-VC)

Landsat 7 Spacecraft Status

≈ 16 years of on-orbit operations

Power Subsystem

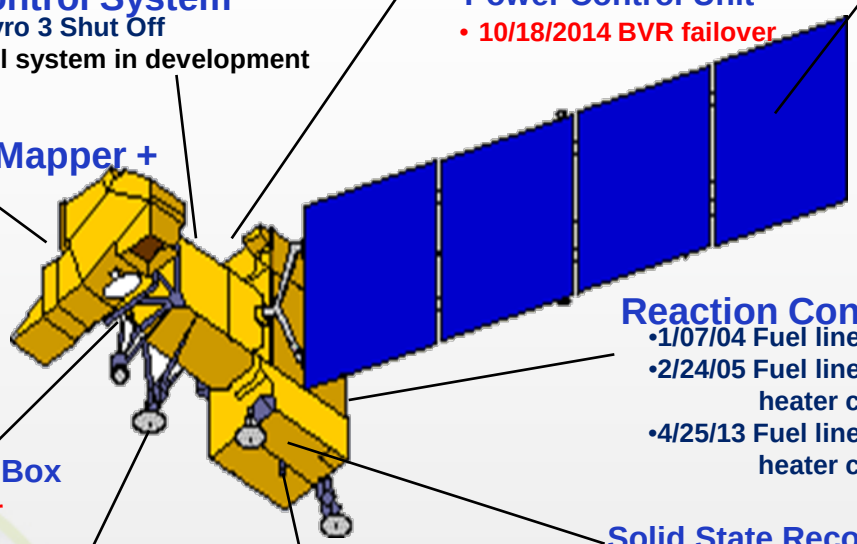
Batteries
Performance nominal

Solar Array
- 5/14/2002 Circuit #14 Failure
- 5/16/2005 Circuit # 6 Failure
- 8/13/2008 Circuit #14 partial recovery
- 14 circuits remain operating
- no impact to ops

Attitude Control System
- 05/05/2004 Gyro 3 Shut Off
- 1-gyro control system in development

Power Control Unit
- 10/18/2014 BVR failover

Enhanced Thematic Mapper +
- 5/31/2003 SLC Failure
- 4/01/2007 Bumper mode



Reaction Control System
- 1/07/04 Fuel line #4 thermostat #1a failure
- 2/24/05 Fuel line #4 thermostat failure; Primary heater circuit disabled
- 4/25/13 Fuel line #2 thermostat failure; Redundant heater circuit disabled

Remote Tlm Cmd (RTC) Box
- 09/27/2014 RTC A Failover

Solid State Recorder
- 11/15/1999 SSR PWA #23 Loss
- 02/11/2001 SSR PWA #12 Loss
- 12/07/2005 SSR PWA #02 Loss
- 08/02/2006 SSR PWA #13 Loss
- 03/28/2008 SSR PWA #22 Loss
- 09/03/2008 SSR PWA #23 Recovered
- 10/12/2013 SSR PWA #11 Loss
- Each PWA is 4% loss of launch capacity
- Boards are likely recoverable

X-band System
Performance nominal

S-band System
Performance nominal

Landsat 8 Spacecraft Status

≈ 2 years of on-orbit operations

Operational Land Imager

RF Communications

S-band System

Thermal Control System

Propulsion Subsystem

Attitude Control System

Electrical Power System

Batteries

Solar array

Thermal Infrared Sensor

- 10/1/2014 - Side-A SSM Encoder

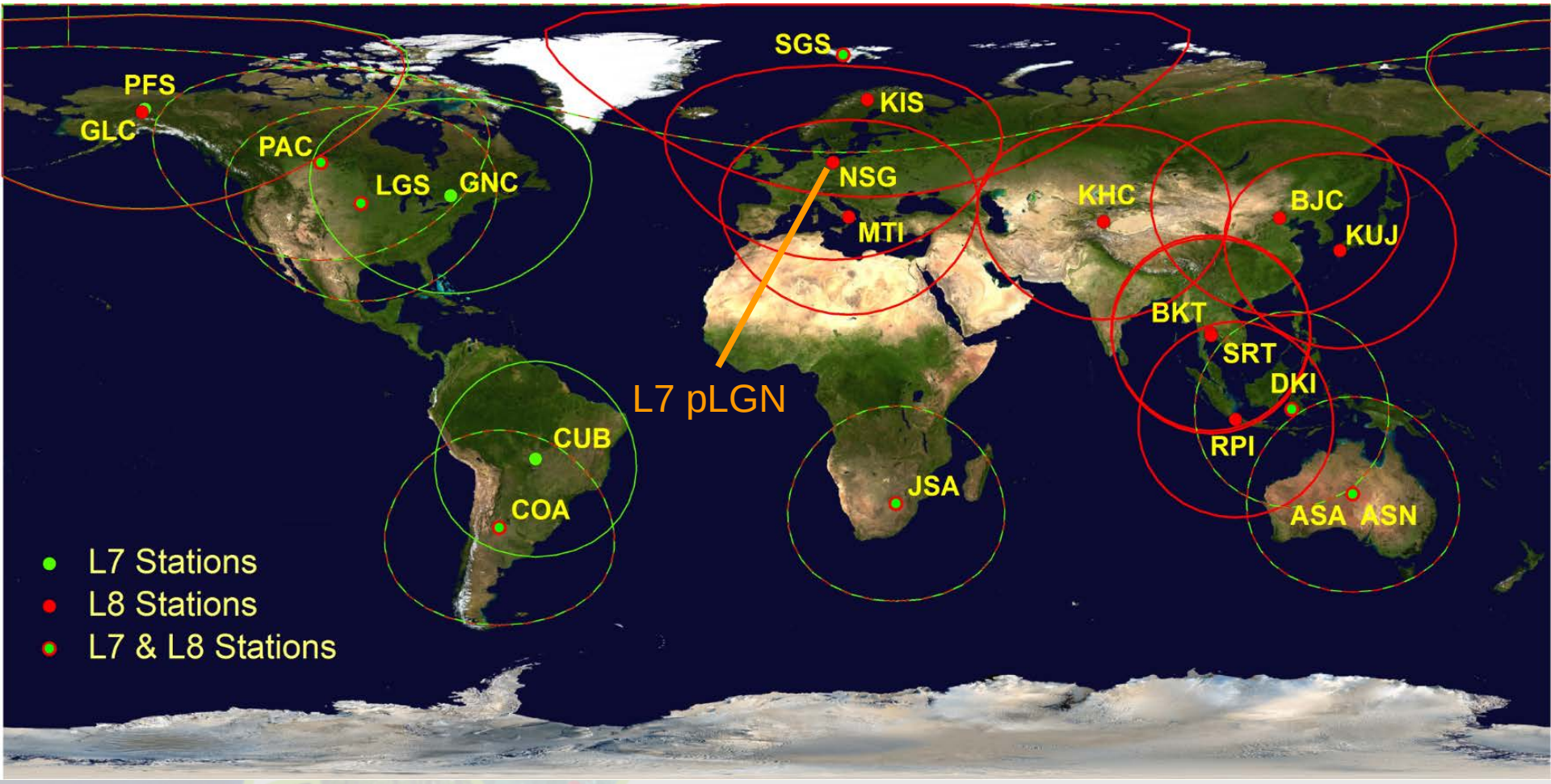
X-band System

Command & Data Handling System

Solid State Recorder

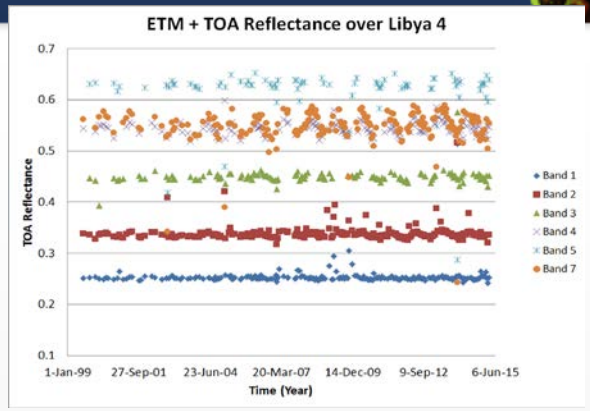
Active Landsat International Ground Stations

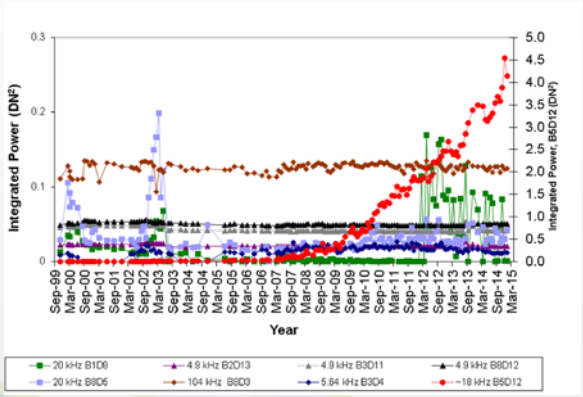
10 Active L7 Stations **17 Active L8 Stations**



Landsat-7 Radiometric Performance

Lifetime TOA reflectance based on PICS stable with seasonal variations



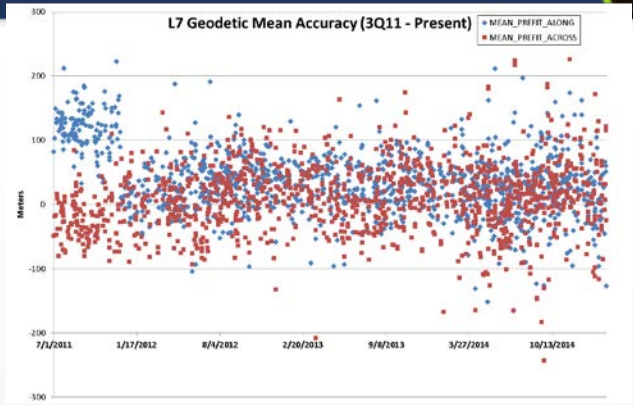


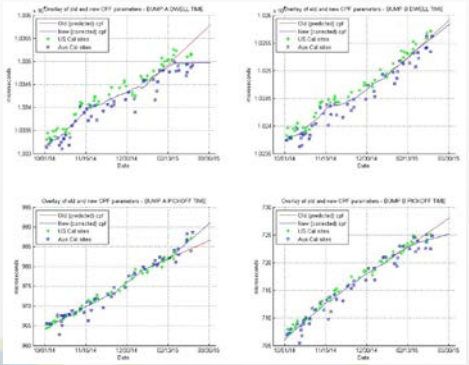
Coherent noise component continues to increase

- **Continuing quarterly ETM+ absolute gain updates**
- **Planning to propagate L8 OLI reflectance based calibration to L1-7**

Landsat-7 Geometric Performance

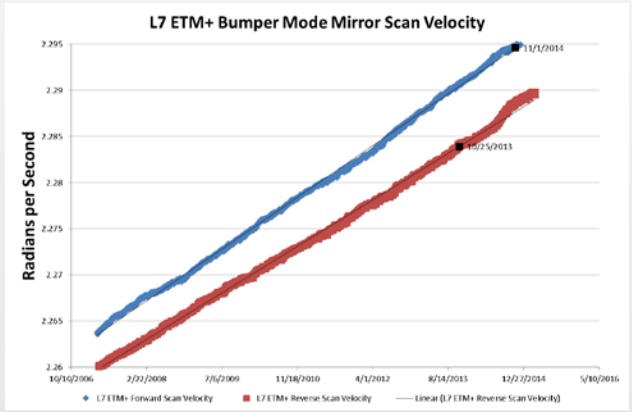
Geodetic accuracy improved since 2012



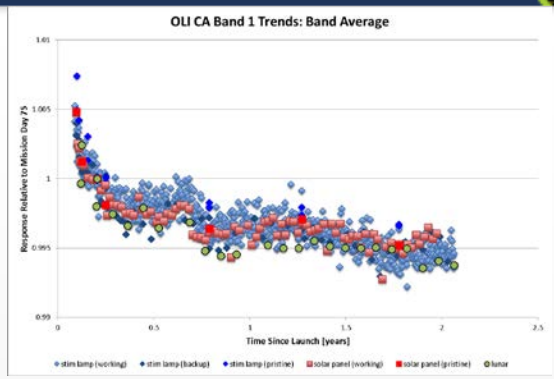


Bumper mode parameters continue to be updated ~2 weeks

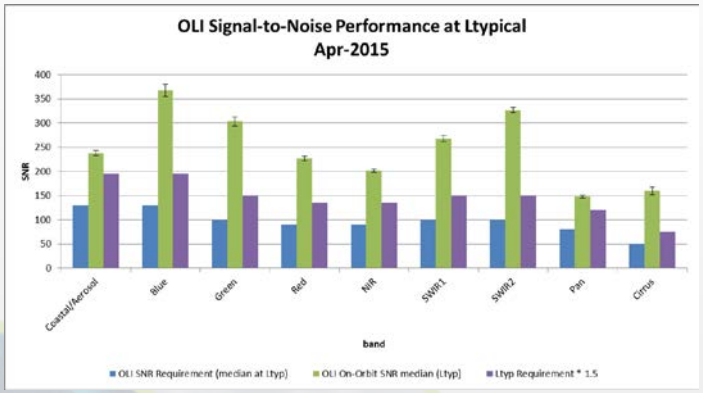
Mirror velocity surpassed Landsat-5 TM velocity



Landsat-8 Radiometric Performance



OLI radiometric stability, worst case band, about 1% over 2 years; most bands ~0.3%

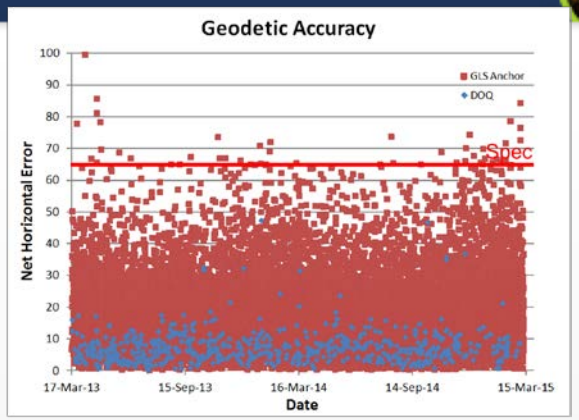


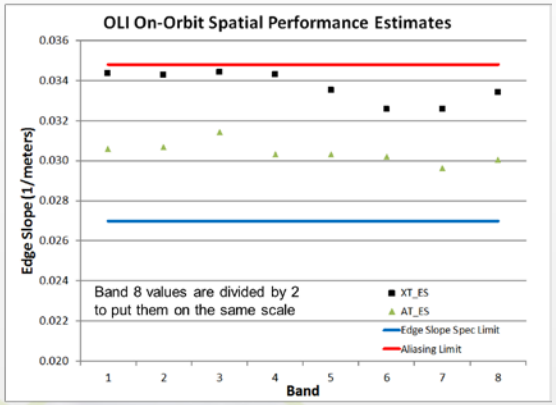
SNR continues to exceed requirements

- **Continuing quarterly relative gain updates**

Landsat-8 Geometric Performance

Geodetic performance well below spec

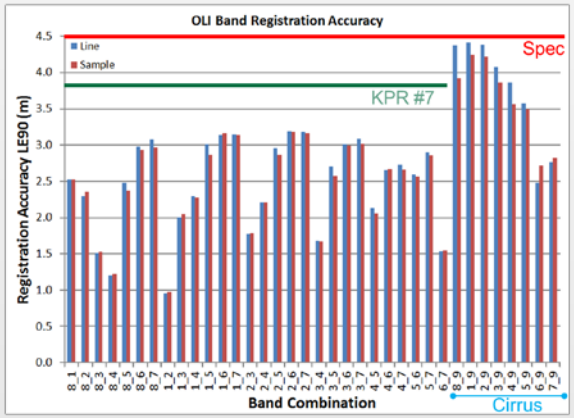




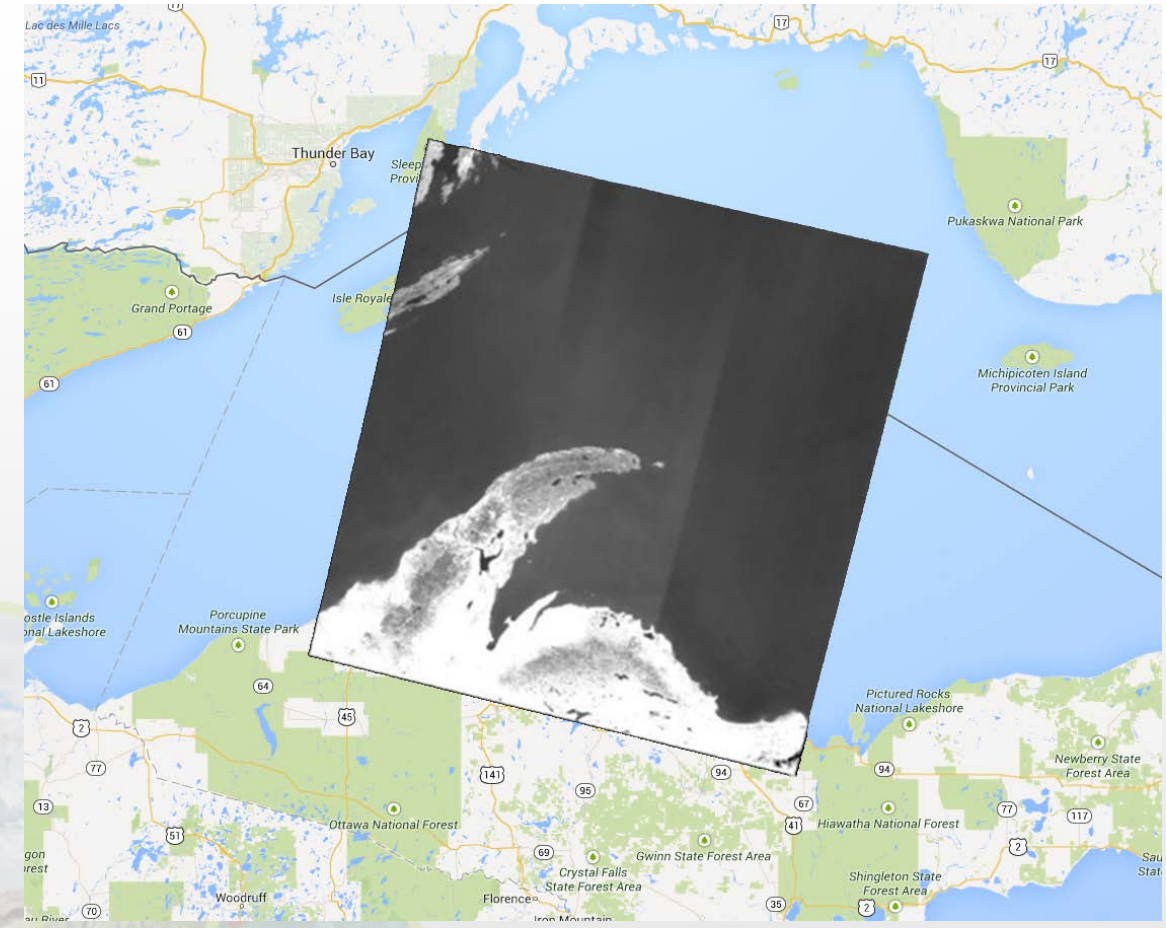
Spatial performance closer to aliasing limit than blur

Band-to-Band registration typically less than 3m

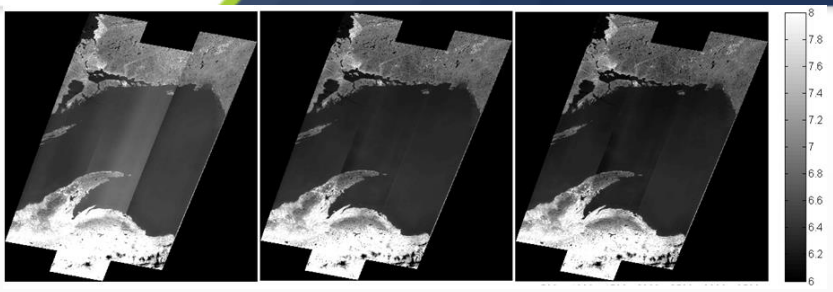
Less than 17m OLI-to-TIRS



TIRS Out-of-field Stray Light



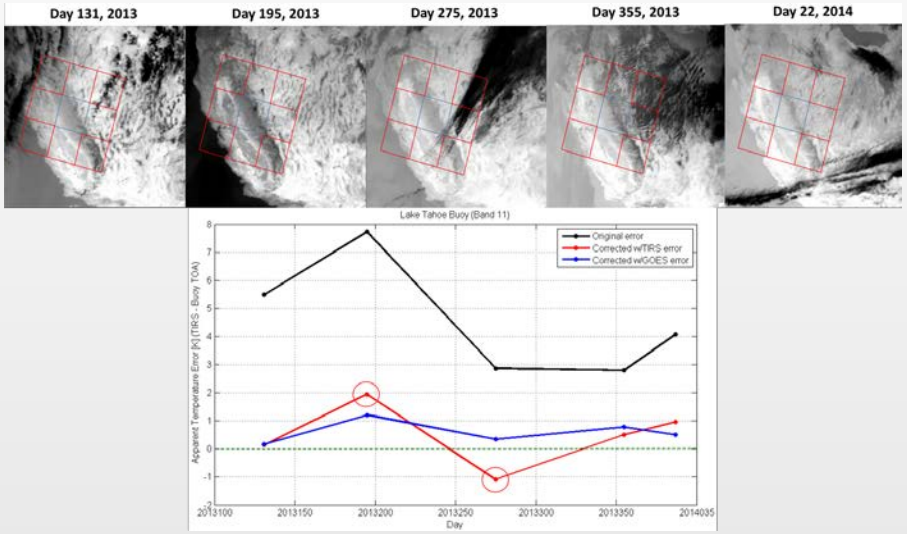
TIRS Stray Light Correction Results



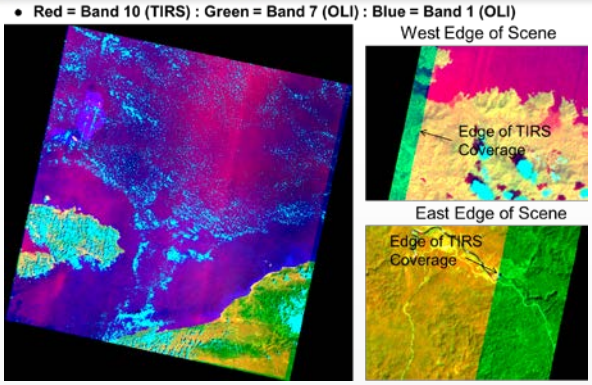
Original GOES Correction TIRS Correction

- **Model of stray light determined by optical model**
  - Effectively a point spread function for each detector
  - Verified by comparing PSF to special lunar scans

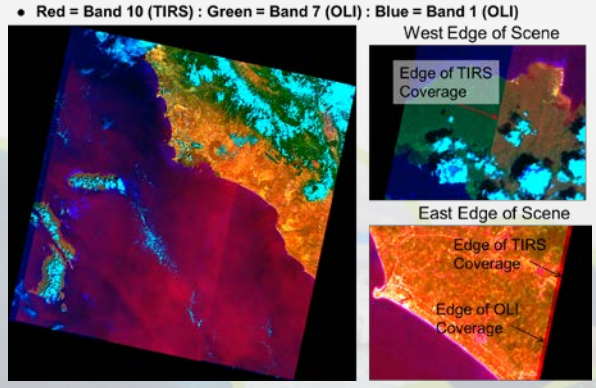
- **Method 1:**
  - Convolves PSF with GOES imagery to estimate stray light per pixel in TIRS image
  - Subtract stray light estimate from TIRS image
- **Method 2:**
  - Convolves PSF with TIRS imagery, scene before and after
  - Where no TIRS imagery, use nearest TIRS pixels
  - Subtract stray light estimate from TIRS image



TIRS Scene Select Mirror Anomaly



Typical OLI-TIRS alignment



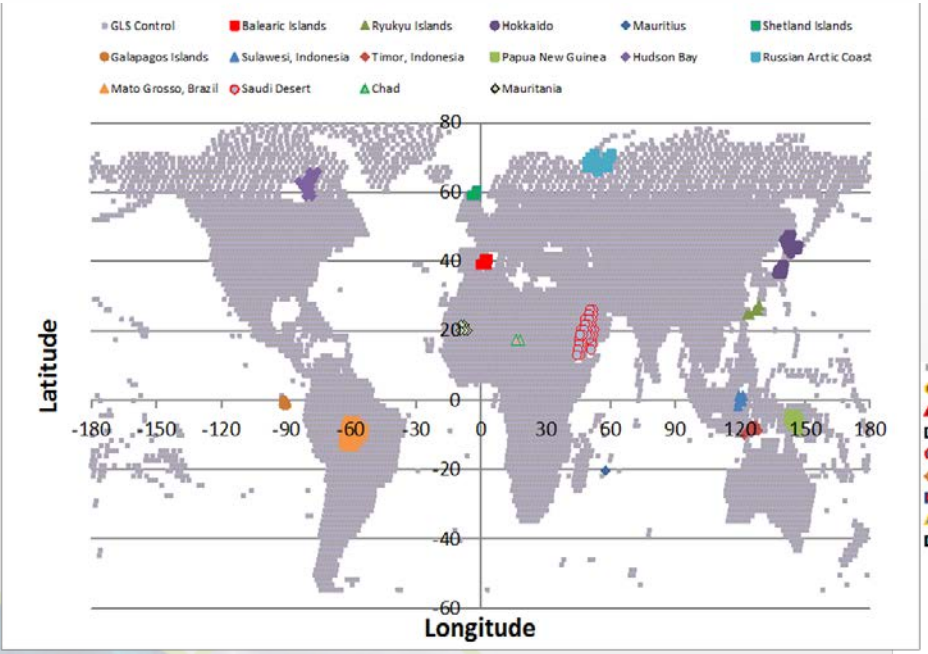
OLI-TIRS alignment without encoder

- **SSM encoder current began increasing last Summer/Fall**
- **Reached yellow limit December 19, 2014**
  - Encoder powered down
  - Product generation system couldn't handle no encoder
  - TIRS imagery zeroed through early March
    - Software updated April 23, 2015
- **TIRS electronics switched to side-B March 4, 2015**
  - Radiometric and Geometric quality attained once more

Landsat GCP Improvement

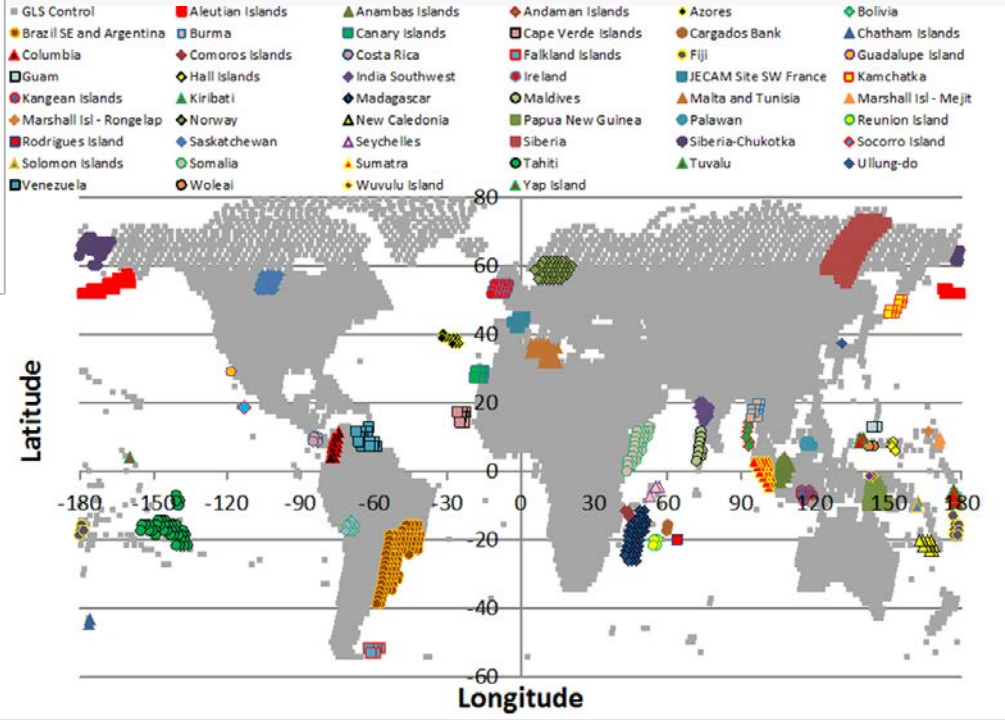
- L8 geolocation accuracy has identified areas where the GLS-derived global GCP library is deficient
- Triangulation updates are proceeding in three phases
  - Phase 1: high priority areas completed September 3, 2014
  - Phase 2: low latitude areas near completion (54/61 blocks complete)
    - GeoScience Australia requested that we rework several areas that were not on our original problem list to better harmonize the GLS framework with their national imagery database
  - Phase 3: high latitude areas not started
- The existing control library image chips are all Landsat 7 ETM+ (8-bit) circa 2000
  - Once the triangulation updates are complete, new 16-bit OLI image chips will be extracted
  - The original ETM+ chips will also continue to be used

GCP Improvement Phase 1 and Phase 2



Phase 1

Phase 2



USGS Imagery Assessments 2013-2015

- Assessments:
  - ResourceSat-2 AWiFS-2, VNREDSat-1, KOMPSAT-3, WorldDEM™, PROBA-V, Planet Labs (Doves-3 & 4, Flock-1a, Flock 1-c), SkyBox-1 & 2, SPOT-7
- Future assessments:
  - More Planet Labs satellites, CBERS-4, KompSat-3A, DMC-3 co
  - Higher-Level Product Quality Monitoring
- Snapshot of results:
  - Spatial resolution is not just GSD
    - More Pixels do not always mean More Resolution
  - Aperture makes all the difference!
    - Small aperture systems: more noise, resolution issues
  - Compression Artifacts – varying degrees
    - More and more systems using compression
    - Minor impact to detection, more impact to science
  - Pictures vs. Measurements
  - Follow-on satellites, or pairs, are very similar
    - AWiFS-1/AWiFS-2, Pleiades-1a/-1b, SPOT-6 & 7, etc.

Planet Labs Image over NYC
07 Sep 2014

Additional Activities

- JACIE collocated with ASPRS
- Evaluation of Lidar Data Quality
  - Developing new methods & tools for monitoring internal quality
- Extensive support to the RCA-EO Project
  - Building “Capabilities” database
  - Developing Analysis methods and processes
- Sentinel-2a
  - Ready to participate in commissioning phase activities
  - Archive Level 1c products when available
- Land Change Monitoring, Assessments and Projections (LCMAP)
- Preparing for Landsat-9 with NASA GSFC

Requirements Capabilities and Analysis for Earth Observations (RCA-EO) Project

- Strong partnership between USGS and NOAA TPIO for developing system for obtaining, characterizing, managing, maintaining, and assessing civil Earth Observation user requirements and capabilities
- Supporting U.S. National EO Strategy/Plan
  - Every 3 years (2012 and 2016) perform National requirements assessment

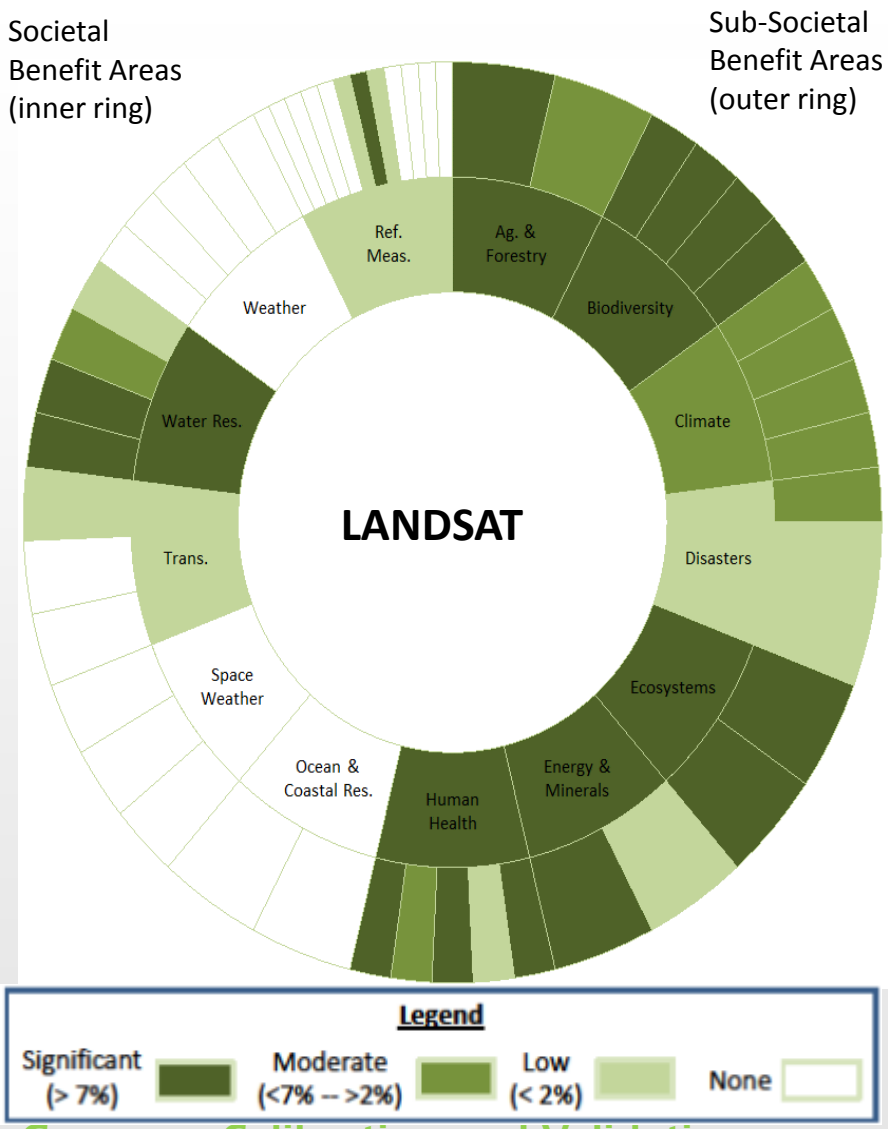
http://remotesensing.usgs.gov/rca-eo/

National Earth Observation Assessment 2012

- First National Earth Observation Assessment (EOA 2012)
  - http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/national_plan_for_civil_earth_observations_-_july_2014.pdf
  - Conducted to inform the National Plan for Civil Earth Observations
  - Identified a portfolio of observing systems relied upon by the Federal agencies
  - Provided a cross-cutting and integrated look at observing capabilities (satellite and non-satellite systems)
  - **Quantified the impact of those observing systems** in delivering societal benefit
- The organizing framework for the assessment was 12 Societal Benefit Areas (SBAs) plus **Reference Measurements**
    - Reference Measurements include geodesy, bathymetry, topography, geolocation, etc.
    - Agriculture & Forestry, Biodiversity, Climate, Disasters, Ecosystems (Terrestrial & Freshwater), Energy & Mineral Resources, Human Health, Ocean & Coastal Resources & Ecosystems, Space Weather, Transportation, Water Resources, Weather
  - SBA Teams each produced an assessment for their SBA

Landsat – EOA 2012 Results

- Assessment of 362 US Earth Obs. Systems (EOS) (space, air, land, and sea platforms) contributions to 13 Societal Benefit Areas (SBAs)
- Landsat was 3rd out of total, and Landsat 2nd "most critical SBA impact" of 132 satellite systems (GPS=1)
- 10 of 13 (77%) SBAs use Landsat data
- Landsat has a Significant Impact on 6 SBAs;
  - Ranked #1 for contributions in Biodiversity, Ecosystems, and Energy
  - Ranked #2 for contributions in Agriculture/Forestry, Climate, Human Health, and Water
- 31 of 52 (60%) Sub-SBA Areas utilize Landsat
  - Landsat had a Significant Impact on 15 Sub-SBAs and a Moderate Impact on 6 Sub-SBAs

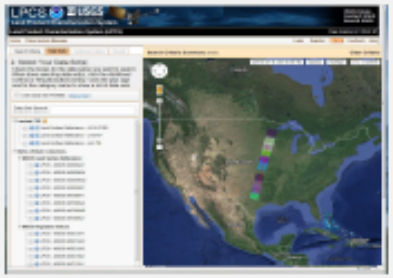


Land Product Characterization System (LPCS)

http://landsat.usgs.gov/lpcs.php

http://lpcsexplorer.cr.usgs.gov/

Order Data Products

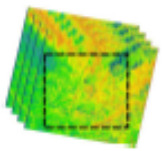


https://espa.cr.usgs.gov

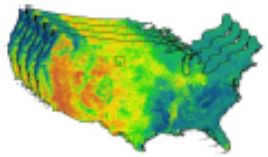
Define output products

Data Transformation

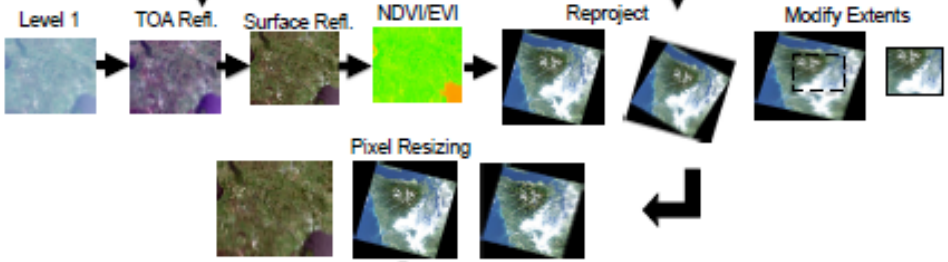
Statistical Characterization & Uncertainty Analysis

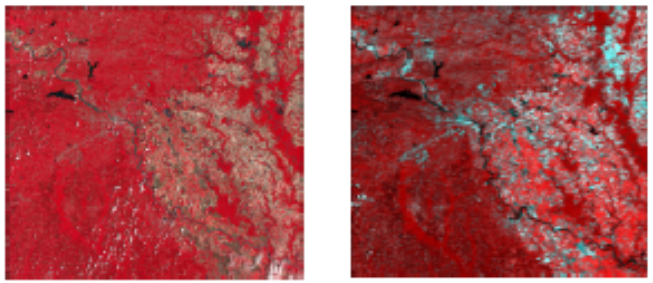


Landsat TM (4-5), Landsat ETM+ (7), Landsat OLI/TIRS (8)



MODIS MOD/MYD09 (Surface Reflectance)
MODIS MOD/MYD13 (NDVI & EVI)





Final data sets

Example: Landsat color infrared (left) and MODIS color infrared (right). Sampled to 30 meter spatial resolution, subset to same extent, and projected to Albers Equal Area.

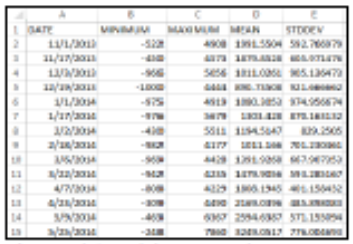
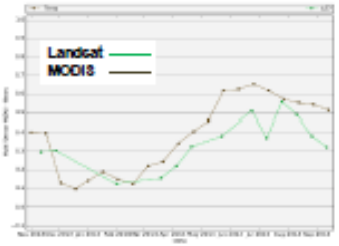


Image date, minimum, maximum, mean and standard deviation



NDVI time series inter-comparisons

Product Information

Example: Sensor or product information includes tables and charts of individual bands or indices.

Future Data Products

Joint Polar Satellite System (JPSS) Visible Infrared Imaging Radiometer Suite (VIIRS)

Geostationary Operational Environmental Satellites - R Series (GOES-R)

European Space Agency (ESA) Sentinel 2

Committee on Earth Observing Satellites (CEOS) validation sites (and other network sites)

April 2015

Current LSI-VC

- USGS is supporting the LSI-VC Team along with CSA, CNES, ESA, JAXA, Australia/GS, and NASA
- An Update on the Land Surface Imaging Virtual Constellation (LSI-VC)
  - Thomas Cecere, USGS; SIT-30 Agenda Item # 9; CEOS Action 28-04 / VC-20; 30th CEOS SIT Meeting; CNES Headquarters, Paris, France; 31st March – 1st April 2015
  - Presentation to SIT-30 and Discussion Paper: A Future LSI-VC Implementation Plan – should be reviewed by WGCV and subgroups – input provided back to LSI VC Team and SIT ASAP before June 1, 2015