Landsat Science Team

Landsat Product Updates

Review and Discussion

02 Feb 2015

Brian Sauer
USGS, Landsat Sustaining Engineering Project Manager
bsauer@usgs.gov, (605) 594-2587

U.S. Department of the Interior
U.S. Geological Survey

Product Improvements Agenda

- **Level-1 Product Updates Status**
- **Product Update Technical Briefing**
  - **Quality Band**
  - **Level-1 Data Format Study**
  - **Metadata Updates**
  - **Bumper Mode Reprocessing**
  - **Ground Control Chip Updates Results/Status (Storey)**
  - **TOA Reflectance Angle Coefficients (Storey)**
  - **ETM+ Systematic Terrain fallback study results (Storey)**
- **Level-2 Product Discussion (Dwyer)**

USGS

Product Updates and Status

- Quality Band and Land-based Cloud Cover Score
- Ground Control Point (GCP) Library Improvements
- ETM+ Automatic Processing and Other Improvements
- Top of Atmosphere Metadata and Coefficients
- Top of Atmosphere Reflectance Product Plans
- Level-1 Product Studies

USGS

Quality Band and Land Base Cloud Cover Score Metadata Update

Improvement	Instrument Data Affected	Description	Reported at Summer '14 Science Team Meeting	Anticipated Release	Current Satus / Notional Date
Quality Band	OLI/TIRS	Updates to include fmask Output	Started – Science Feedback	LPGS 2.5	Apr-2015
	TM/ETM+	Quality band similar to Landsat 8; utilize fmask for cloud detection		LPGS 12.6	Apr-2015
	MSS	Quality band similar to Landsat 8; utilize cubist (existing) algorithm for cloud detection		LPGS 12.6	Apr-2015
Land-based cloud cover score	OLI/TIRS	Calculate CCA on land-only using output from fmask - provide in metadata / user search	Spring 2015	LPGS 2.5	Apr-15
	TM/ETM+	Calculate CCA on land-only using output from fmask - provide in metadata / user search		LPGS 12.6	Apr-15
	MSS	Calculate CCA on land-only using output from cubist - provide in metadata / user search		LPGS 12.6	Apr-15

Note: Don't plan to flush the cache with this release. Products that are on-line will have old QA band. Land-based cloud cover score will be a searchable parameter and in metadata (mtl) file.

Image Attributes Group; CLOUD_COVER_LAND = XX.XX

USGS

Ground Control Points Library Improvement Plan

Improvement	Instrument Data Affected	Description	Reported at Summer '14 Science Team Meeting	Anticipated Release	Current Satus / Notional Date
Ground Control Library Updates	TM/ETM+	Phase I - 177 Path/Row combinations improved; GCP water mask	Fall 2014 (Markham)	LPGS 12.5	Completed - Fall 2014
	OLI/TIRS	Phase I - 177 Path/Row combinations improved; GCP water mask		LPGS 2.4	Completed - Fall 2014
	TM/ETM+, OLI/TIRS	Phase II - Low-latitude areas	Winter 2014/2015	Release Independent	Spring 2015
	TM/ETM+, OLI/TIRS	Phase III - High-latitude areas	Follows Phase II	Release Independent	Starts Spring 2015

- **Parameter set in the metadata (MTL) file**

```
GROUP = IMAGE_ATTRIBUTES
  GROUND_CONTROL_POINTS_VERSION = 1
```

USGS

ETM+ Product Automatic Reprocessing & Other Improvements

Improvement	Instrument Data Affected	Description	Reported at Summer '14 Science Team Meeting	Anticipated Release	Current Satus / Notional Date
Level-1 Systematic Terrain Fallback	ETM+	Fall back to terrain corrected systematic when precision ground control can't be applied; Already do this for Antarctic.	Analysis in work; system capability exists.	LPGS 12.7	Fall 2015
Automatically reprocessing to utilize definitive ephemeris	ETM+	Reprocess utilizing definitive ephermeris may create L1T products for about 7% of the L1G's created.		LPGS 12.6	Apr-15
Automatically reprocessing to apply best bumper mode calibrations	ETM+	New acquisitions utilize predicted bumper mode parameters. Reprocess rececent acquisitions once bumper mode calibrations are released (~21 days)		LPGS 12.7	Fall 2015
Increase product distribution space	MSS,TM, ETM+	Increase distribution space by 2x!	Fall 2014	N/A	Completed 12/2015
	OLI/TIRS	Increase distribution space by 2x!		N/A	Spring 2015
Landsat DEM Improvement	All	Augment or replace existing GLS2000 DEM	Study in queue, USGS Topo project	Not assigned	2017ish

- Reprocessing using definitive ephemeris will take place for data downlinked and processed within 24 hours – LGS EROS and those that use electronic ingest (SGS) / bent pipe
- By summer, Landsat will have about 1.3 PB of space to distribute Level-1 products!
  - Long-term sustainment and refresh plans are being analyzed
- NASA JPL may be releasing 30m DEM in Summer 2016

USGS

TOA Reflectance – Metadata and Coefficients File

Improvement	Instrument Data Affected	Description	Reported at Summer '14 Science Team Meeting	Anticipated Release	Current Satus / Notional Date
TOA Reflectance / Brightness Tempurature Metadata	TM, ETM+	L1-7 consistency w/L8 - Reflectance scaling factors (multiplicative and additive) which are scene based coefficients in mtl file for L1-7 (no sun angle correction); Brightness temperature is also included	Winter 2014/2015	LPGS 12.6	Apr-15
TOA Reflectance Angle Coefficients File (Enhanced Metadata)	OLI/TIRS	Scene-specific per-pixel solar azimuth and sensor viewing angle coefficients (enhanced metadata) to allow users to calculate solar and satellite viewing angles to convert to reflectance	Winter 2014/2015	LPGS 2.5	Apr-15
	TM/ETM+		TM/ETM+ follows OLI/TIRS	LPGS 12.7	Fall 2015

- Supply metadata and coefficients to enable 1) scale to TOA reflectance without solar zenith angle correction (like OLI) 2) generation of solar illumination and viewing angles for per-pixel TOA reflectance and downstream processing (SR)
- Changes only to metadata and ancillary files, per pixel corrections not applied to output product

USGS

TOA Reflectance – Product

Improvement	Instrument Data Affected	Description	Reported at Summer '14 Science Team Meeting	Anticipated Release	Current Satus / Notional Date
TOA per-pixel product	TM/ETM+	Produce TM and ETM+ as per-pixel product using angle coeficients. Utilizes JPEG 2000 format and includes a "versioning" updates. Projection parameters same as existing L1T.		Target Release LPGS 12.8	Spring 2016
	OLI/TIRS	Update L8 to perpixel product using angle coeficients. Utilizes JPEG 2000 format and includes a "versioning" updates. Projection parameters same as existing L1T.		Target Release LPGS 2.7	Spring 2016

- Phase in the generation of the new per-pixel TOA Reflectance product that overlaps the existing L1T for a minimum of six months
  - Need to develop data / resource management plan

USGS

Level-1 Product Studies

Improvement	Instrument Data Affected	Description	Reported at Summer '14 Science Team Meeting	Anticipated Release	Current Satus / Notional Date
Level 1 data format study	All	More flexible alternatives to gzip'd L1T, more condusive to data delivery services such as opendap and OGC WCS	Study wrapping up, requires feedback, no implementation planned at this time	Phase I - TOA	Spring 2016
				Phase II - L1T	6 months after TOA product
Product 'versioning' updates	All	Improve data so users can more readily determine changes in the product	Need a plan - science feedback	Phase I - TOA	Spring 2016

- Level-1 data format study recommends JPEG2000 format; roll-out with new TOA reflectance product
- Need to perform analysis to develop a product versioning plan; update at future science team meetings

USGS

L1 Product Roadmap Summary Discussion

Product Update Steps

1. **QA Bands using CFMask (April)**
2. **Supply metadata and coefficients file**
   - Enable scaling to TOA reflectance without solar zenith angle correction (like OLI) (April)
   - Enable generation of solar illumination and viewing angles for per-pixel TOA reflectance and downstream processing (SR) (Fall 2015)
3. **Allow 6 months from release of last coefficients file (MSS, TM, ETM+) to gather feedback**
4. **New per-pixel TOA reflectance product (Spring 2016) that overlaps the existing L1T for a minimum of six months**
   - JPEG2000 format
   - Version Identification Applied
   - Projection parameters same as current Level-1 product
5. **Re-evaluate**

USGS

Quality Assessment (QA) Band

- **New for MSS, TM, and ETM+**
  - **Like OLI/TIRS**
  - **CFMask for TM and ETM+**
  - **Cubist model for MSS**
- **Change to CFMask for OLI/TIRS**

USGS

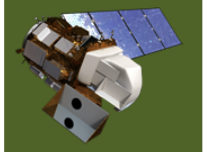
Documentation under "About Landsat"->"Project Documentation"

USGS science for a changing world

Landsat Missions

Home

About Landsat
Gallery
Science
Product Information
Frequently Asked
Tools & Services
Education & Outreach
Contact Us



Project Documentation

This page lists documents directly related to the Landsat and LDCM Projects.

Policy Documents

- National Space Policy (June 28, 2010) - .pdf (350 KB)
- Landsat Data Policy Released (January 2, 2008) - .pdf (769 KB)
- Landsat Data Continuity Strategy Adjustment Memo (December 23, 2005) - .pdf (40.6 KB)
- Landsat Data Continuity Strategy (August 13, 2004) - .pdf (349 KB)
- Presidential Decision Directive NSTC-3, Landsat Remote Sensing Strategy (October 16, 2000) - .pdf (360 KB)
- Public Law on the Commercial Space Act (October 28, 1998) - .pdf (142 KB)
- Commercial Space Act of 1997 (May 22, 1997) - .pdf (69.0 KB)
- Land Remote Sensing Policy Act of 1992 (October 28, 1992) - .pdf (97.4 KB)

Mission Management Office

- Management Plan for the Landsat Program (December 1, 1999) - .pdf (12 KB)
- Landsat 7 FY 2002 Annual Report - .pdf (2.47 MB)
- Landsat 7 FY 2000 Annual Report - .pdf (1.48 MB)
- Landsat Updates

Technical Documentation (LDCM-Landsat 8)

- Landsat Data Continuity Mission (LDCM) Mission Data Data Format Control Book (DFCB) (October 2012) - .pdf (1.13 MB)
- Landsat Data Continuity Mission (LDCM) Level 1 Data Format Control Book (DFCB) (August 2012) - .pdf (410 KB)
- Landsat Data Continuity Mission (LDCM) Level 0 Reformatted Data Format Control Book (DFCB) (October 2012) - .pdf (1.63 MB)
- LDCM CAL/VAL ALGORITHM DESCRIPTION DOCUMENT (February 25, 2013) - .pdf (10.2 MB)

QABand Format is Documented in the Level-1 Data Format Control Book (DFCB)

USGS

Quality Assessment (QA) Band – MSS, TM, ETM+, OLI/TIRS

16-bit Level 1 QA Band

Bit	Description	Bit	Description
0	Designated Fill	8	Reserved (Vegetation)
1	Dropped Frame	9	
2	Terrain Occlusion	10	Snow/Ice
3	Reserved (Saturated)	11	
4	Water	12	Cirrus
5		13	
6	Cloud Shadow	14	Cloud
7		15	

LandsatLook QA Band Legend

Bit	Description
0	Designated Fill
1	Dropped Frame
2	Terrain Occlusion
3	Water
4	Vegetation
5	Snow/Ice
6	Cirrus
7	Cloud

2-bit fields
00 = unset
01 = set, but not found
10 = unused
11 = set and found

OLI/TIRS

TM, ETM+, OLI/TIRS

MSS, TM, ETM+, OLI/TIRS

USGS

Level-1 Data Format

- **Current L8 / L1-7 L1 products are GeoTIFF format compressed into single file using UNIX tar and zip functions**
  - **Users required to decompress and untar download before using data**
  - **No allowance for user to band select data**
- **Landsat users would like ability to access band data directly (without extra steps) and request band-specific data per their application**

USGS

Level-1 Data Format Study Investigation Approach

- **Evaluation Criteria**
  - **Compatibility with user tools**
  - **Simple product distribution**
  - **Compression performance**
  - **Computational creation performance**
  - **Computational decode performance**
  - **Band subsetting capabilities**
  - **Enable future products**

USGS

Level-1 Data Format Study Investigation Approach

- **Format Alternatives**
  - GeoTIFF, uncompressed (current format)
  - GeoTIFF, LZW compression
  - GeoTIFF, Deflate compression
  - HDF5, uncompressed
  - HDF5, Zip compression
  - JPEG2000 (lossless, using Jasper libraries)
  - JPEG2000 (lossless, using openJPEG libraries)
  - JPEG2000 (lossless, using Kakadu libraries)
- **Developed Test Scripts (perl, GDAL, HDF, kakadu)**
- **Executed Conversions**
- **Recorded Data**

USGS

Level-1 Data Format Study Investigation Approach

- **Scenes used for testing**
  - **Consist of calibration sites and varying terrain**
  - **L7 ETM and L5 TM, MSS were included for comparison**

Mission	Scene ID	Description
Landsat 5	LM50180301995275PAC00	Lake Erie urban/water
	LT50180302011239GNC01	Lake Erie urban/water
Landsat 7	LE70180302013236EDC00	Lake Erie urban/water
	LE70180302002222EDC00	Lake Erie urban/water
Landsat 8	LC80180302013324LGN00	Lake Erie urban/water
	LC80180302014055LGN00	Lake Erie urban/water and cloudy
	LC80190392014046LGN00	Panama City (urban/water)
	LC80260462014063LGN00	Mexico City (urban)
	LC80390312014074LGN00	Bonneville Salt Flats
	LC80400332014017LGN00	Railroad Valley (dry/supersite)
	LC80430332014070LGN00	Lake Tahoe
	LC80891132014072LGN00	Antarctica Dome C
	LC82260652014056LGN01	Brazilian Amazon

USGS

Level-1 Data Format Study Findings

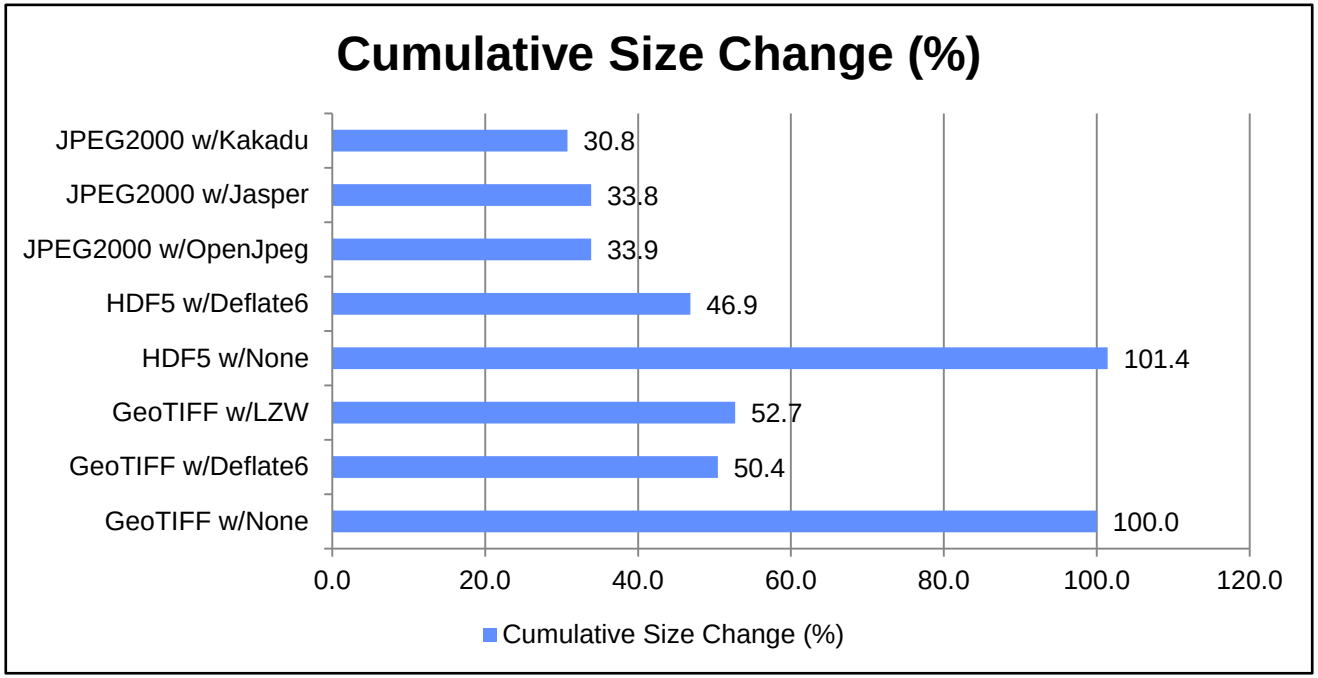
- **Application Compatibility**
  - **Examined popular commercial and open source software applications (Y - yes, N - No, P- partial)**

Software Package	GeoTIFF	GeoTIFF (Deflate)	GeoTIFF (LZW)	HDF5	HDF5 (Zip)	JPEG2000
ENVI 5.1	Y	N	Y	Y	Y	Y
ENVI 5.1 (Classic Mode)	Y	N	Y	N	N	Y
ENVI 4.x	Y	N	Y	N	N	Y
ARCMap 10.2	Y	Y	Y	Y	Y	Y
PCI Geomatica 2013	Y	N	Y	Y	Y	Y
ERDAS Imagine	Y	N	Y	N	N	Y
QGIS 2.2	Y	Y	Y	P	P	Y
Udig 1.4.0	Y	Y	N	N	N	Y
SAGA 2.1.1	Y	Y	Y	Y	Y	Y
GRASS 6.4.3	Y	Y	Y	P	P	Y
UMN Mapserver 6.4.1	Y	Y	Y	Y	Y	Y
GeoServer 2.5.0	Y	P	P	P	P	Y

USGS

Level-1 Data Format Study Findings

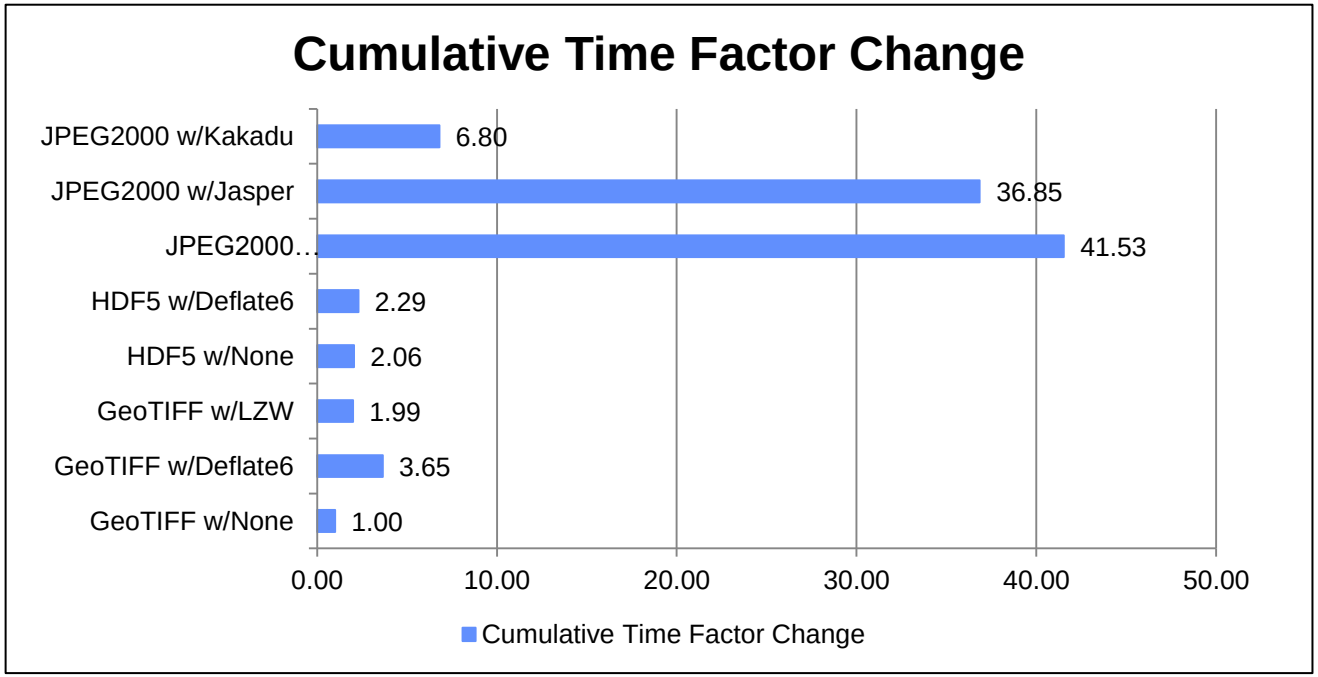
- **Best compression – JPEG2000 w/Kakadu libraries**
  - **Average size change versus GeoTIFF with no compression across all test scenes**



USGS

Level-1 Data Format Study Findings

- **Best conversion time – GeoTIFF w/LZW compression**
  - **Average conversion for GeoTIFF w/no compression across all test scenes was 25-30 seconds – all charted values are shown as a multiple of that number**
  - **All conversions used single-threaded computation; Kakadu libraries will support multi-threaded**



USGS

Conclusion

- **JPEG 2000 for format and compression**
  - **Best compression with small additional computational cost**
  - **Growing use on other missions such as Sentinel 2**
  - **Multi-resolution and area based tiling internal to format**
  - **Capable of storing georeferencing information and metadata within image files**
- **Additional work to be completed**
  - **Define specifications, access methods**
  - **Assess impact to existing systems for implementation**

USGS

Bumper Mode Reprocessing

- **Landsat Bumper Mode**
  - **On April 1, 2007 the Landsat mission switched from the original Scan Angle Monitor mode of operations to what is known as Bumper Mode**
  - **Description of the differences between these two modes and the characterization and calibration processes involved in Bumper Mode operations are described within:**

    "Thematic Mapper/Enhanced Thematic Mapper Plus Bumper Mode Scan Mirror Correction Algorithm Theoretical Basis" document.
  - **Due to the need to produce near real-time imagery, predicted bumper mode parameters are used in the creation of Level-1 products.**
  - **Using imagery over specific calibration sites, changes in the mirror behavior are modelled and the bumper mode parameters are updated.**
  - **Level 1 product scan alignment can be improved by reprocessing using the updated bumper parameters**

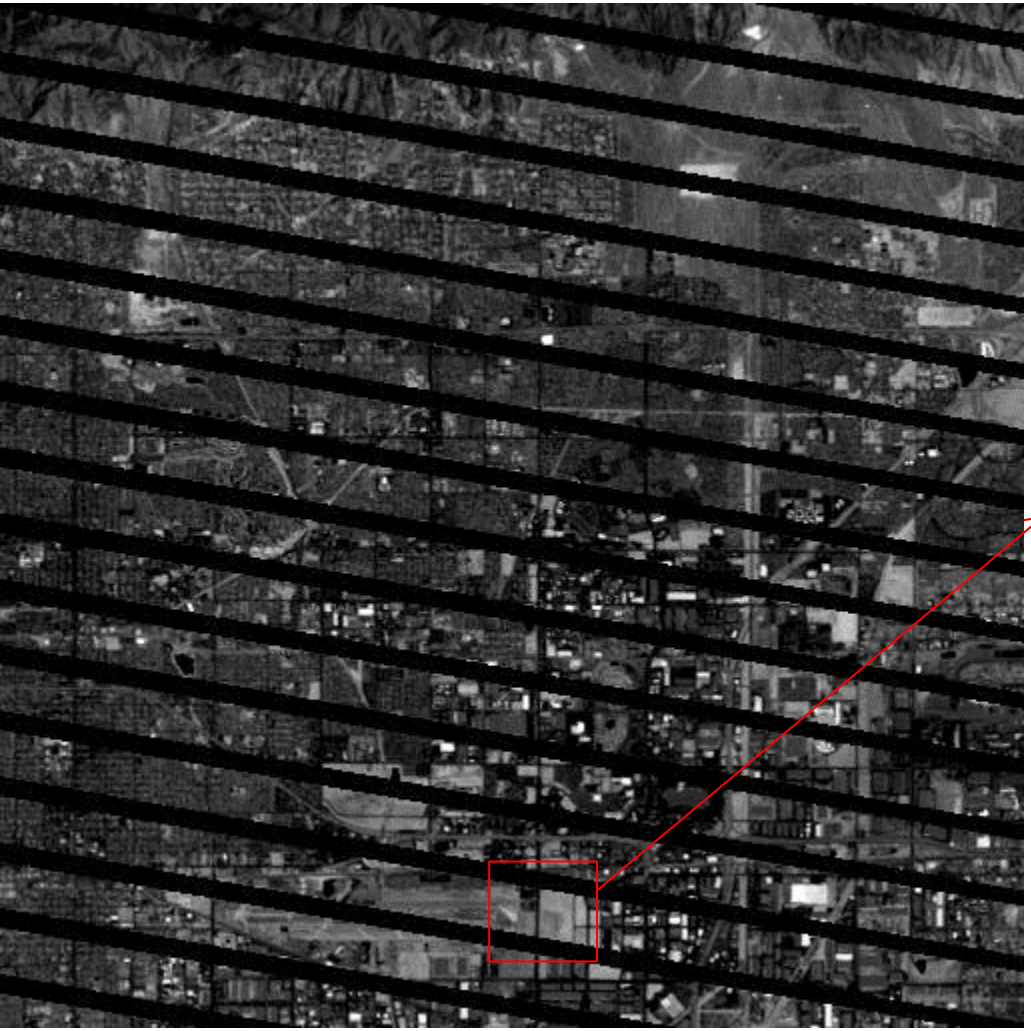
USGS

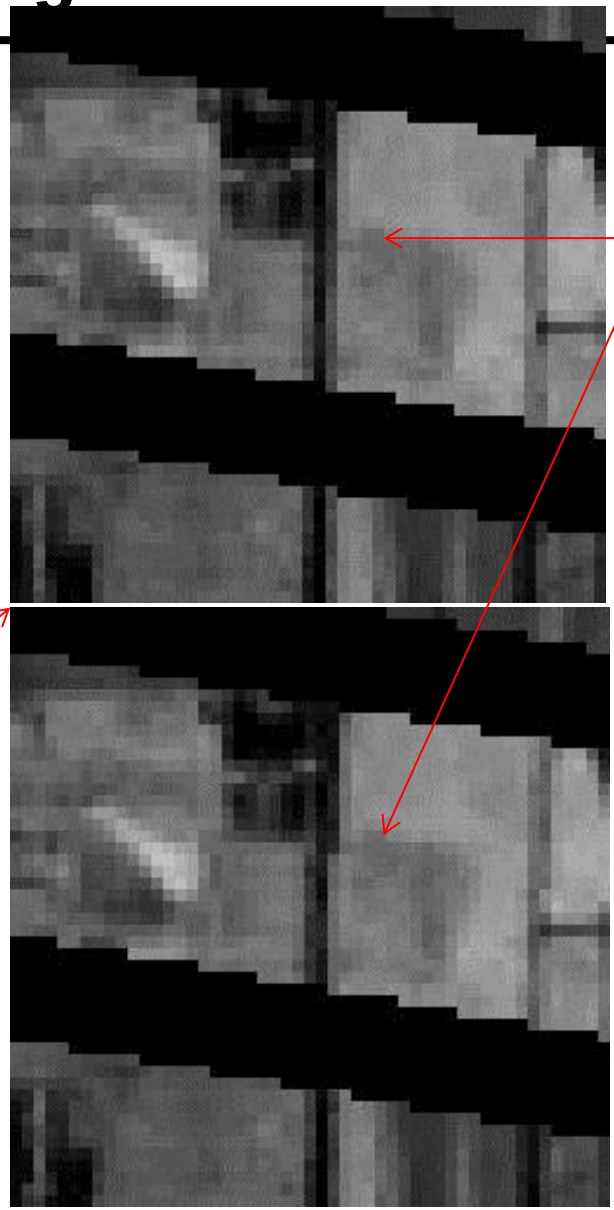
Bumper Mode Reprocessing

- **Landsat Bumper mode**
  - **Using the predicted parameters causes small geometric errors that most often show up as scan-to-scan misalignment within the imagery that cannot be corrected with the ground control reference imagery used to generate L1Ts.**
  - **Two metrics that can be used to show these geometric effects are visual inspection of the imagery and a measure of the change in the start-to-end and end-to-start angles when new bumper mode parameters are generated. Since the ETM+ scans in what is termed forward and reverse scans (scanning is bidirectional) a comparison of the two sets of changes between these angles can be viewed.**

USGS

Bumper Mode Reprocessing





Updated

Scan Misalignment

Predicted

USGS

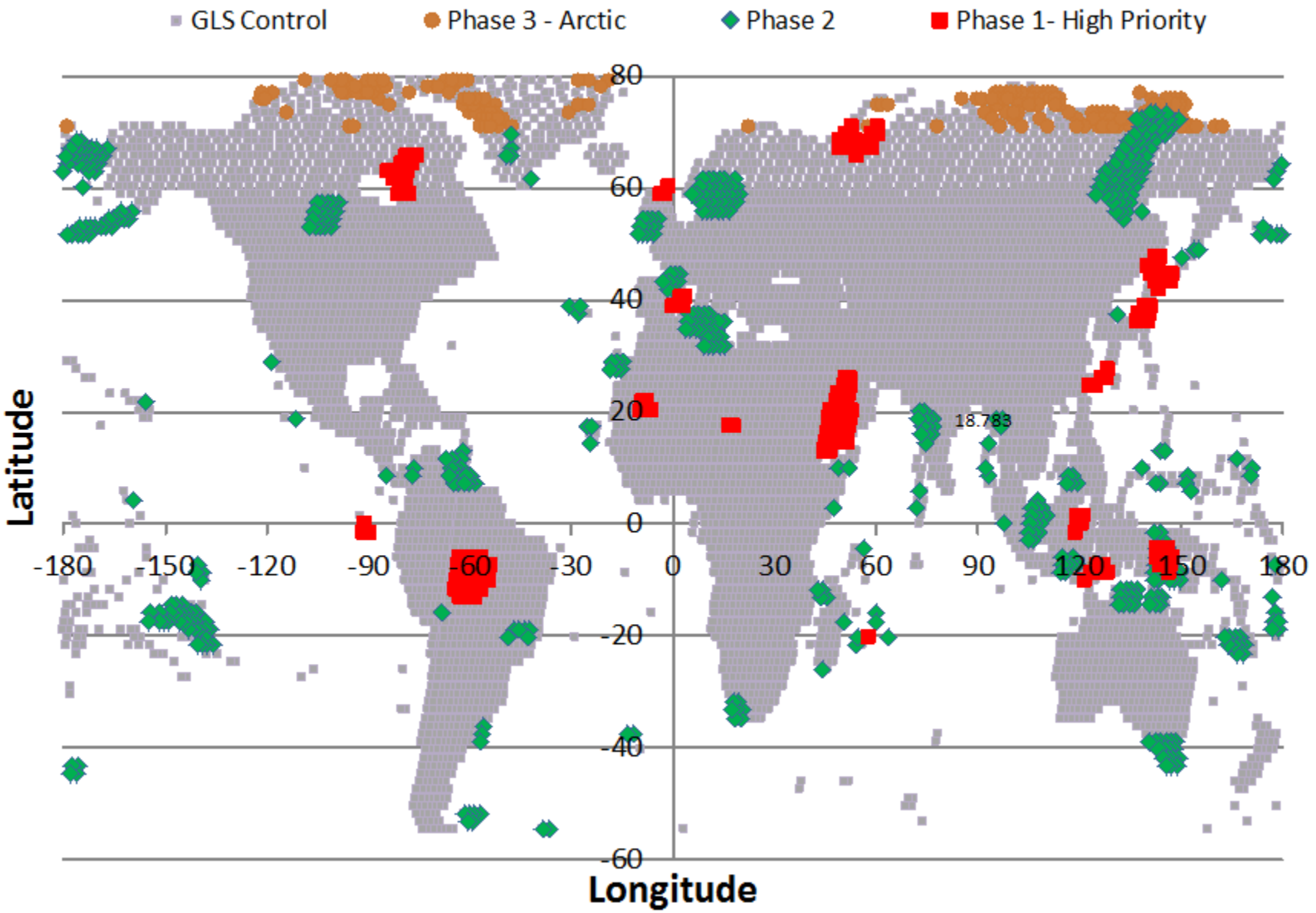
Jim Storey Updates

Landsat GCP Improvement Goals

- **L8 geolocation accuracy has identified areas where the GLS-derived GCP library is deficient**
  - **Regions of poor accuracy are re-triangulated, using Landsat 8 data, while holding the surrounding area fixed to ensure scene-to-scene consistency**
- **Triangulation updates are proceeding in 3 phases**
  - **The phase 1 high priority areas are complete**
  - **The updated GCP positions will be released upon the completion of each phase**
- **The existing control library image chips are all Landsat 7 ETM+ (8-bit) circa 2000**
  - **New 16-bit OLI image chips will be extracted**
  - **The original ETM+ chips will also continue to be used**

USGS

GCP Problem Area Locations

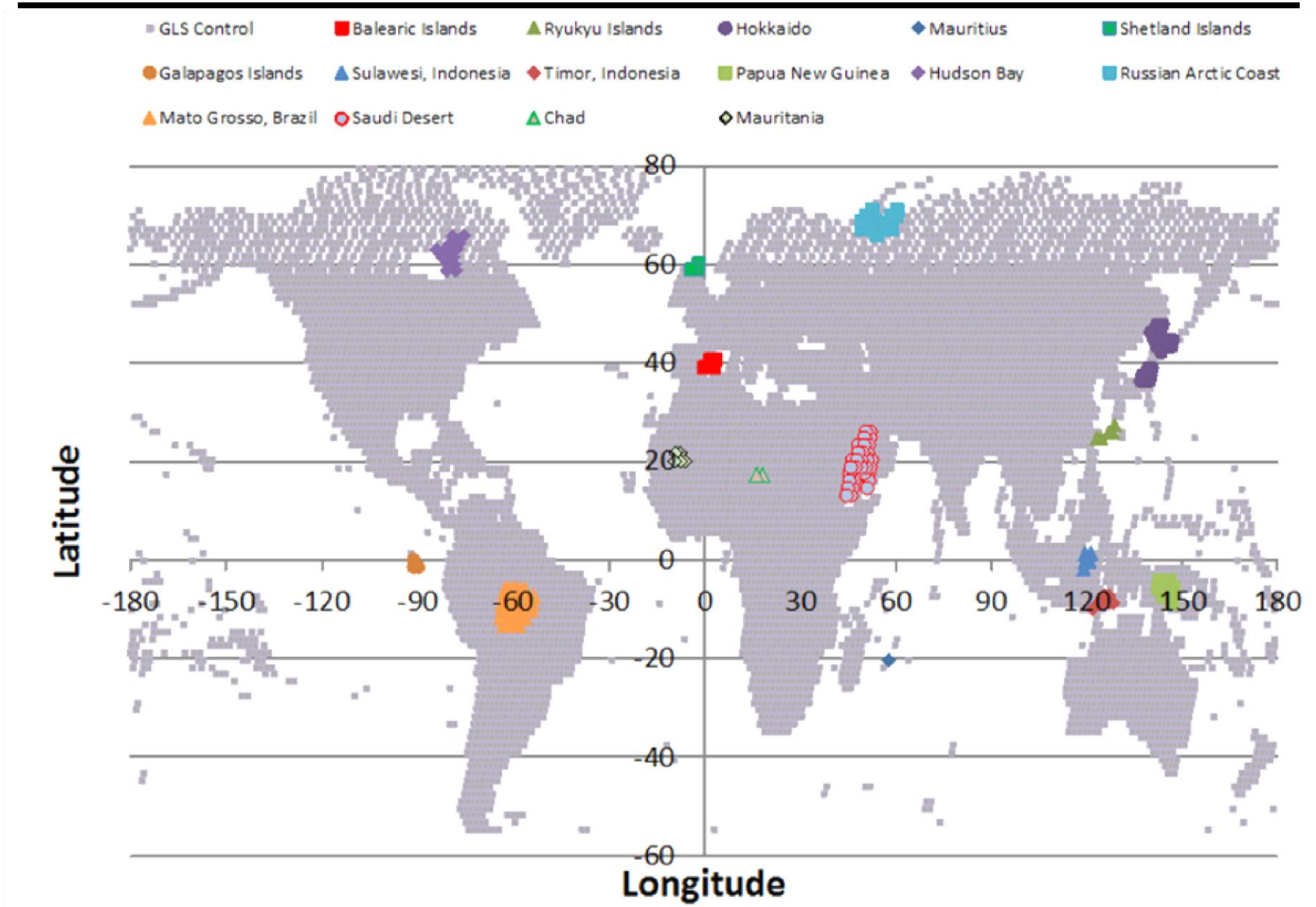


Phase 1 Triangulation Results

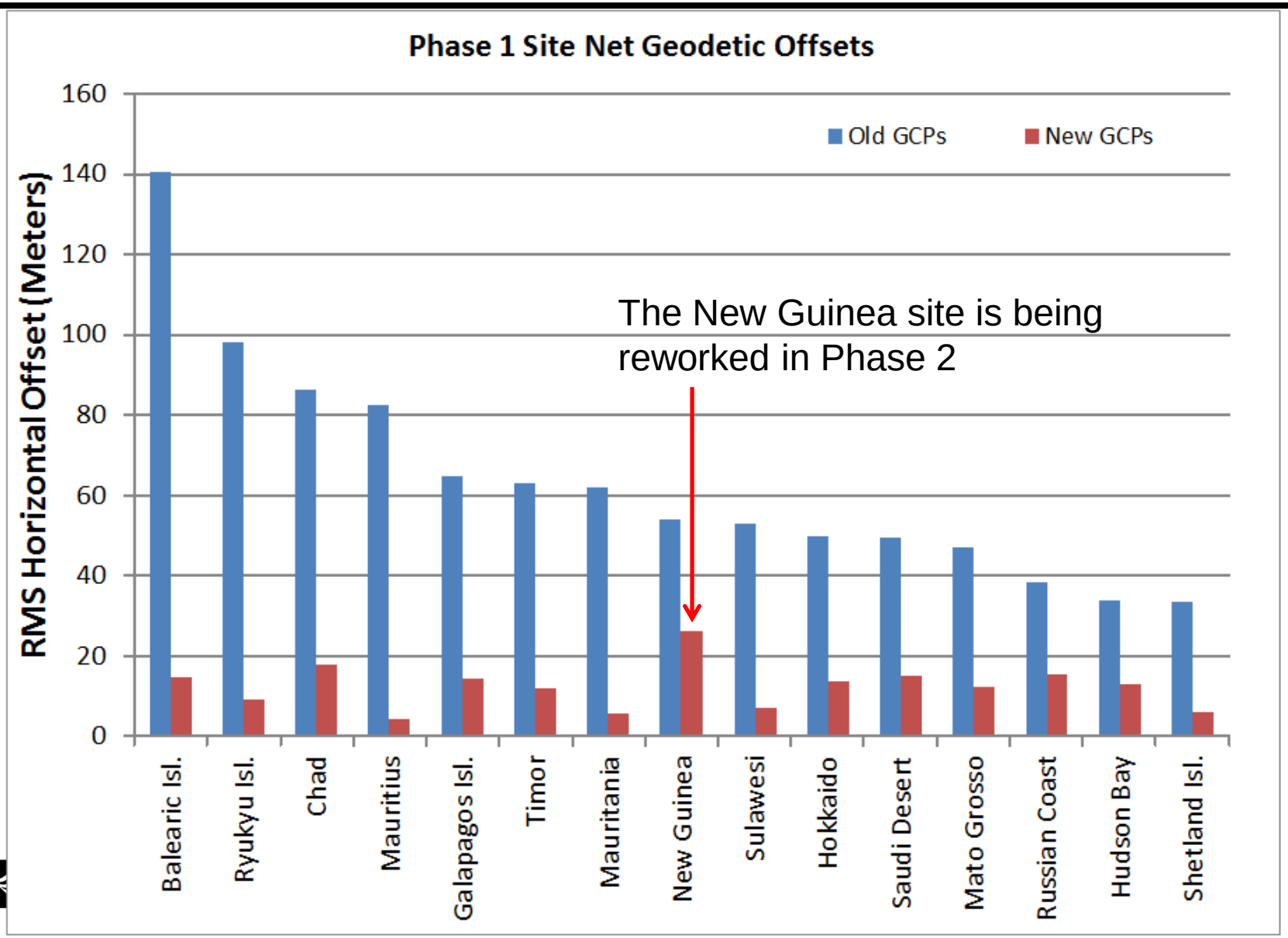
- **The first 15 triangulation blocks are complete**
  - **Updated GCPs were installed into production in conjunction with the 03 September 2014 release of the IAS/LPGS**
  - **Some upgrades to the GCP database design (e.g., GCP version tracking) were required to implement the new points**
- **A triangulation report was created for each block**
  - **Shows the area affected and the pre- and post-adjustment geodetic accuracy as measured by Landsat 8**
  - **Shows independent (e.g., WorldView) accuracy testing results**
- **A summary of the triangulation results is available on the Landsat web site at:**
  http://landsat.usgs.gov/documents/about_LU_Vol_8_Issue_2b.pdf

USGS

Phase 1 Block Locations



Accuracy at GCP Improvement Sites

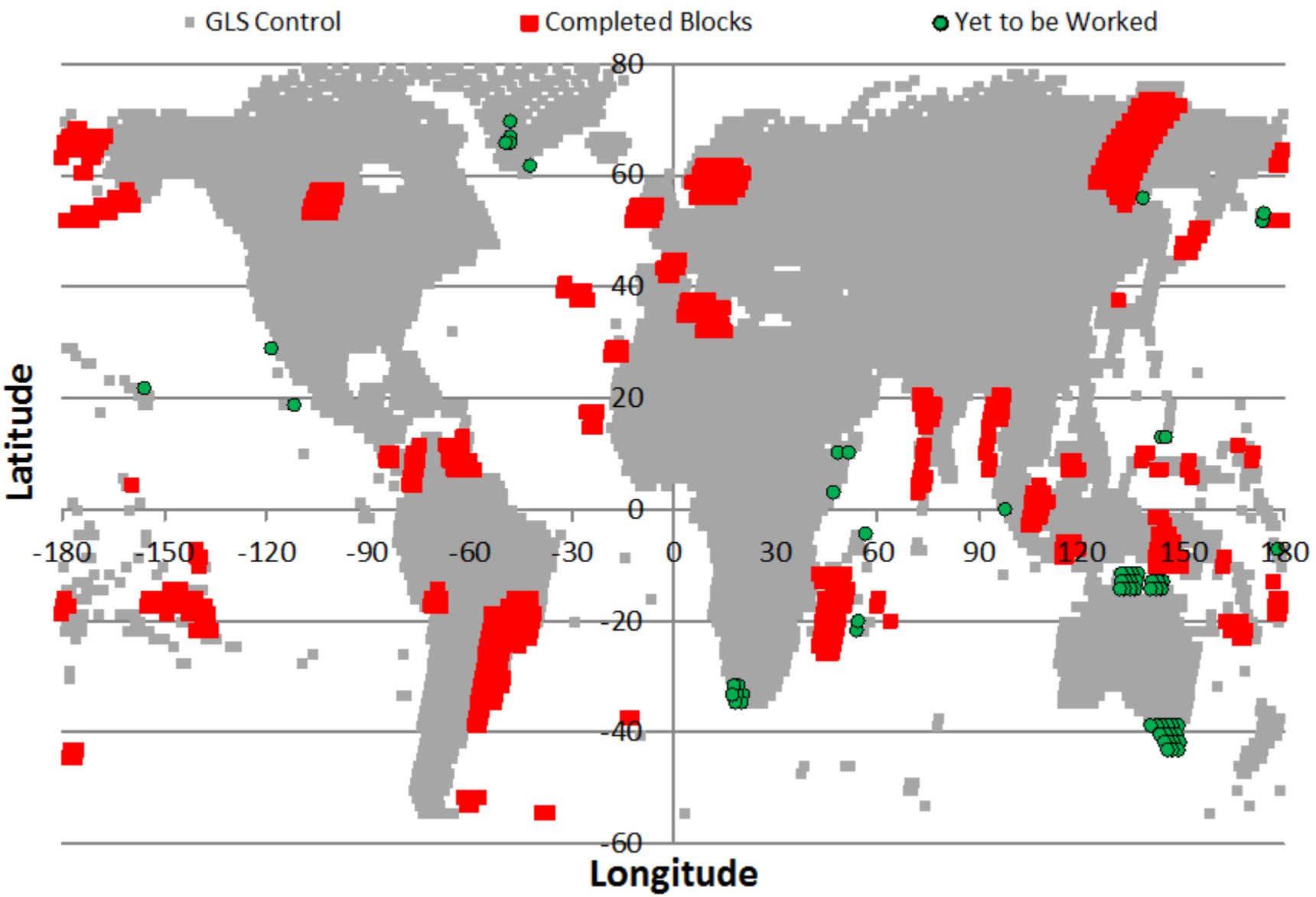


Phase 2 Status

- **Phase 2 contains 61 blocks of which 45 are complete**
  - **The completed blocks contain 659 WRS path/row locations**
- **Of the 16 remaining:**
  - **9 are islands - Many of the island blocks have proven to be troublesome due to persistent cloud cover**
  - **3 are in Australia – 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**

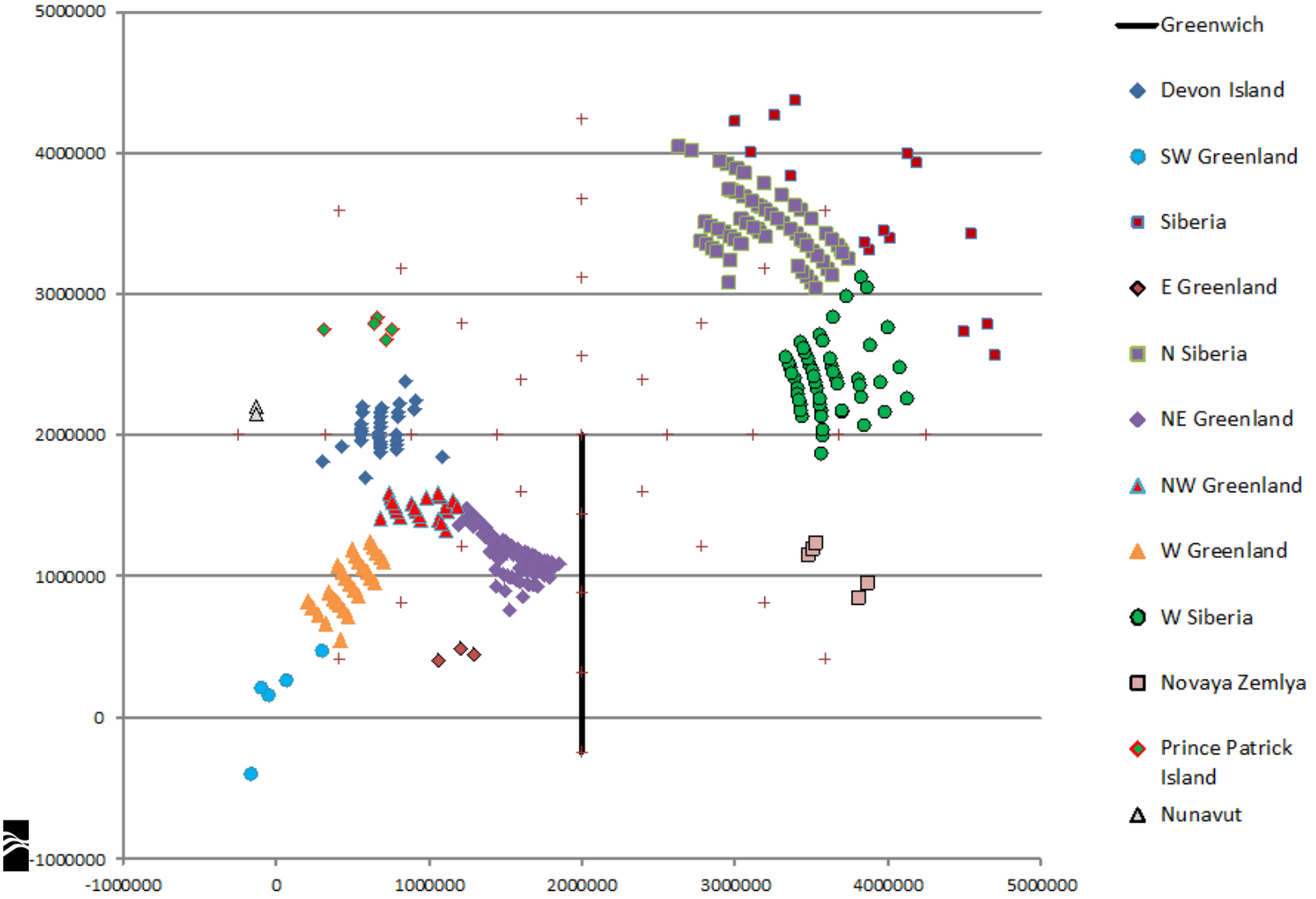
USGS

Phase 2 Block Distribution



Phase 3 – Arctic Areas

- **Arctic problem areas plotted in a polar projection**



Extracting New GCPs

- **Once the GCP position adjustment process is complete, we will densify the control network**
  - **In space – many sites have few/sparse GCPs as a result of limitations of the original GCP selection logic**
    - **Points were selected and the subsequently filtered out if they fell entirely in a water body**
    - **The original cloud avoidance logic did not always work well**
    - **New 16-bit OLI chips will be extracted using cloud and water masks, taking advantage of the greater radiometric sensitivity of the OLI data to identify "interesting" features**
  - **In time – sites that are temporally dynamic (e.g., dune fields) may need additional GCP layers from dates between GLS2000 and OLI to track land cover change**
    - **GCPs from pre-2000 L4/5 data may also benefit some areas**

USGS

GCP Improvement Summary

- **Landsat GCP improvement efforts are underway**
  - **Completed first phase with the 15 worst areas**
  - **GCPs updated in phase 1 are in production for all Landsat missions**
  - **Second phase is about 75% complete – finish 2Q2015**
  - **Third phase (arctic) is next – 3Q2015**
  - **Updated GCPs are released at the completion of each phase and affected data from all missions are reprocessed**
- **New circa 2013-2014 OLI image chips will be extracted for the Landsat GCP library – 4Q2015**
  - **Examine temporally and seasonally variable areas as candidates for extracting GCP chips with multiple dates**

USGS

View Angle / Sun Angle Generation

- **The Science Team asked the CalVal Team to develop a method to either:**
  1. **Provide sensor viewing angles with L1T products; or**
  2. **Provide users a way to calculate sensor viewing angles**
- **Providing explicit per-pixel angles is problematic due to the impact on product size**
- **A method was proposed that provides an "angle coefficient file" with each L1T product**
  - **Also provides a software tool that allows users to compute viewing angles on demand from the new file.**
- **This capability will be included in the next L8 software release due Spring 2015**

USGS

Angle Generation Tool

- **Software to generate per-pixel sun and satellite angles will be available from the Landsat web site**
  - **Standalone GNU/C tool to generate angle "band" files**
- **Callable angle calculation routines that can be invoked by science data processing systems will also be provided**

Usage: l8_angles

<MetadataFilename>: (Required) Angle coefficient filename

<AngleType>: (Required) The type of angles to generate

VALID: (BOTH, SATELLITE, SOLAR)

<SubsampleFactor>: (Required) Sub-sample factor used when calculating the angles (integer)

-f <FillPixelValue>: (Optional) Fill pixel value to use (short int)

units used is degrees scaled by 100

Default: 0

Range: (-32768:32767)

-b <BandList>: (Optional) Band list used to calculate angles for, this defaults to all bands 1 - 11. Must be comma separated with no spaces in between.

Example: 1,2,3,4,5,6,7,8,9

USGS

ETM+/TM Angle Generation

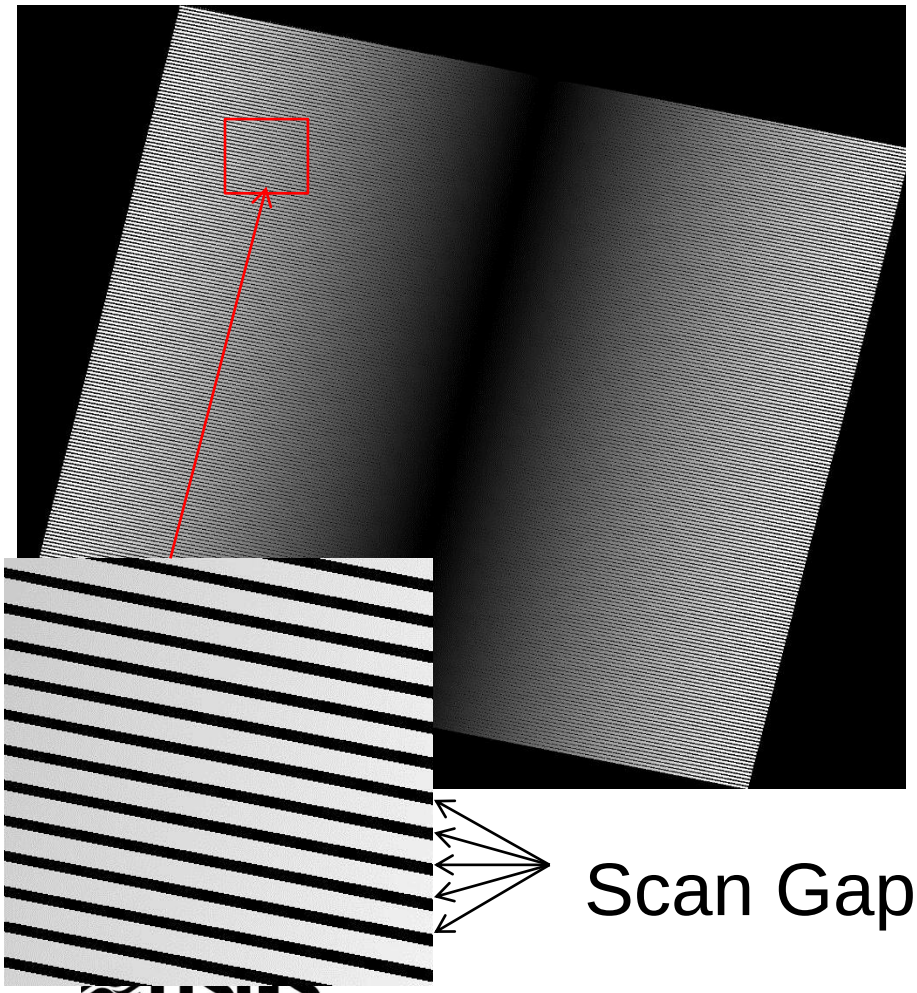
- A similar algorithm has been developed and prototyped for ETM+
  - Handles both SLC-on and SLC-off data (scan gaps)
- Extension to TM should be straightforward
  - No panchromatic band
  - 120m thermal band
- Expected implementation Fall 2015
- Algorithm does not support TM-A data which lacks supporting ephemeris and attitude data
- MSS and TM-A algorithm remains to be developed
  - Will likely be simpler more approximate method based upon scene corners and nominal viewing geometry

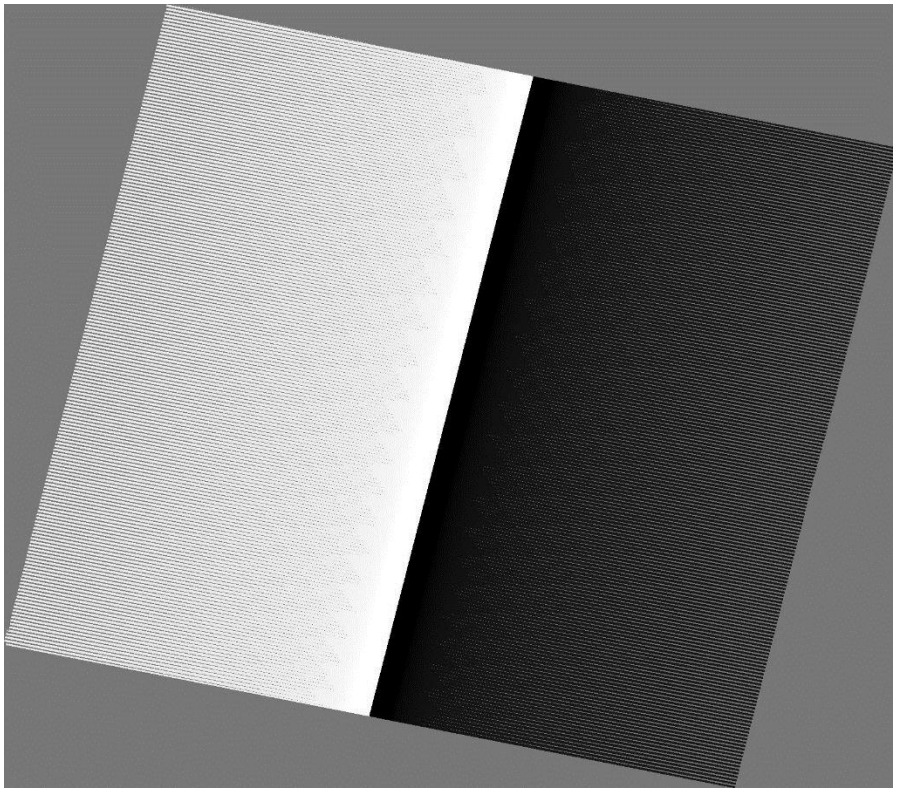
USGS

Landsat 7 ETM+ Prototype – Band 7

Zenith

Azimuth

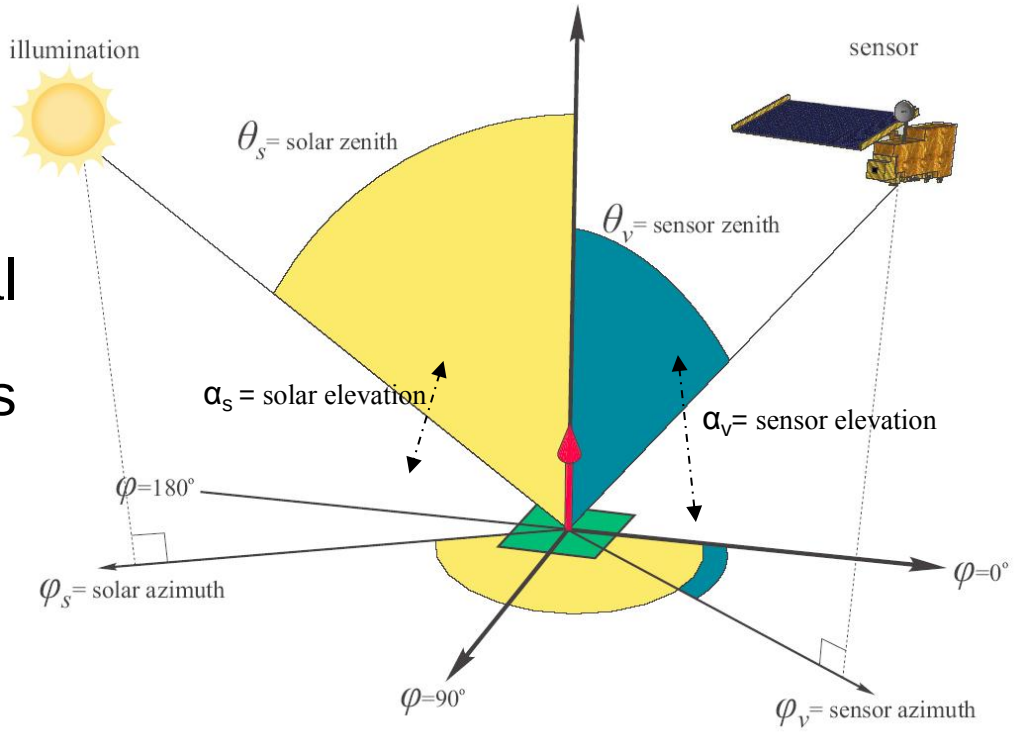




Scan Gaps

Angle Coefficient File

- **Landsat 8 angle coefficient file (Spring 2015)**
- **Landsat 4, 5 & 7 angle coefficient file (Fall 2015)**
- **Level 1 Data Format Control Book describes Angle Coefficient File**
  - Solar angle band – needed for per-pixel TOA reflectance
  - Sensor angle band – needed for Bi-Directional Reflectance Distribution Function (BRDF) models
  - Tool to create solar and sensor elevation bands from Angle Coefficient File



USGS

Terrain Correction Without GCPs (L1GT)

- **L8 products for which GCP matching fails (e.g., due to clouds) are terrain corrected, unlike L1-7**
  - **This is necessary to achieve L8 band registration**
  - **L8 absolute geolocation accuracy is so good there is little image/DEM misregistration**
- **L7 products that are not GCP corrected may also benefit from terrain correction**
  - **Typically, much of the terrain displacement effect is a cross-track scale error**
  - **In areas of moderate topographic complexity the terrain decorrelates relatively slowly (e.g., over 100s of meters)**
  - **So, even a somewhat misregistered DEM data creates a more accurate product than no DEM**

USGS

L1GT Products for Landsat 7

- **Terrain study assessed the impact on product accuracy using U.S. DEM data**
  - **75% of L1Gs scenes contain terrain offsets > 50 meters**
  - **Correcting using a DEM that is misregistered by 100 meters leads to RMS horizontal errors < 5 meters**
    - **Maximum errors were < 30 meters in 80% of the scenes**
    - **L7 geolocation accuracy has varied over the mission but is typically better than 100 meters**
  - **The residual error in the L1GT product would be mostly a bias that could be more easily corrected by users**
- **We are planning to move from L1Gs (no GCPs, no DEM) to L1GT processing for L7 also**
  - **Should improve accuracy of cloud-contaminated data where control point matching fails**

USGS