



# Landsat Update

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*Note: any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.*

## Landsat Products & Processing: 2016 Objectives and Plans

In 2015, the USGS began to implement a series of major changes to Landsat data products and processing systems that support long-term plans for the generation of higher-level science data products and improve traceability in subsequent analyses. Changes to Level 1 products will provide users with more detailed, robust metadata and quality information at the scene and pixel levels. Another major change will involve the implementation of a new Level-1 product naming convention, in support of a new collection management scheme planned for Landsat Level-1 products.

### Landsat 1-8 Collection Management Strategy

The primary focus of 2016 will be to implement a collection management scheme for Landsat Level-1 products that will provide a quality controlled selection of radiometrically calibrated and consistently geolocated data with sufficiently geographically aligned pixels to support time series analysis through the full Landsat record. Many factors were considered when establishing this collection management scheme, particularly those that would facilitate automated scene identification and processing of time-stacked Landsat products.

For all Landsat scenes that meet the highest quality standards to support time-series analysis, the inventory designation will be as follows:

- **Tier 1:** The intent is to create a clearly identified 'Tier 1' collection of the Landsat archive in which the radiometry is well characterized and inter-calibrated across the different Landsat sensors; the georegistration of every Landsat scene is consistent and within prescribed tolerances (<11.9m radial root mean square error); and the product format is stable. All data within the Tier 1 collection will be highest available quality and processing level, and will be suitable for time-series processing analysis. These data will be designated "T1".

For Landsat scenes that do not meet the radiometric and geometric quality criteria of Tier 1, there will be two other collections:

- **Tier 2:** The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and the Landsat 8 Operational Land Imager (OLI) /Thermal Infrared Sensor (TIRS) archives contain scenes that are significantly cloud covered. As a result, sufficient ground control cannot be applied to generate precision and terrain corrected products. These data can, however, be processed to systematic and terrain corrected (Level-1GT) products. Landsat 7 Level-1GT (L1GT) data products do not meet the geodetic accuracy specifications for the Tier 1 collection. Even though Landsat 8's onboard global positioning sensor (GPS) makes the payload correction data (PCD) used for systematic geometric correction highly accurate, no ground control is available to verify that these scenes satisfy the geodetic accuracy criteria for the Tier 1 collection.

The Landsat 4-5 Thematic Mapper (TM) archive contains data that cannot be precision and terrain corrected to a Level-1T (L1T) product, either because of incomplete payload correction (PCD) data or missing parameters in the original archive data. These data will be processed to systematically corrected Level-1G (L1G) products and therefore will not meet the criteria for the Tier 1 collection. These data will be designated "T2."

- **Real Time:** After acquisition, Landsat 7 ETM+ data require a short period of instrument trending/characterization (about 1 week) which results in calibration parameter adjustments to finalize the geometric correction model. When Landsat 7 data are initially downlinked, they are processed in 'near-real time' using predicted ephemeris and initial bumper mode parameters and then made available for download. These data will be designated "RT" until all geometric processing parameters (e.g. bumper mode parameters, definitive ephemeris) are finalized and the data are reprocessed and moved to the Tier 1 or Tier 2 collection based on the radial root mean square error (RMSEr) determined from the post-fit verification of the geometric model.

At this time, processing of Landsat 1-5 Multispectral Scanner (MSS) data remains unchanged until investigation and characterization of the radiometric and geometric quality of these data are completed.

More information about the Landsat Level-1 product collections, such as a Collection Definition Document, Collection Management Plan, and the chronological order in which the data will be reprocessed, will be posted to the Landsat Missions Web site once details are finalized.

## Landsat Data Product Changes

A number of changes and enhancements are being made to the Landsat Level-1 Product Generation System (LPGS) in order to support the generation and management of the Landsat Level-1 product collections. Many of these changes will be implemented in May 2016, although the schedule and sequence for reprocessing of all TM, ETM+, and OLI/TIRS are still under development.

### New Landsat Product Identifier

To better identify in which collection a scene is contained, a new Landsat product ID will be created, and used to download Level-1 products. It will also be added to the metadata (MTL.txt) file. The currently used scene ID will remain in the metadata file as a source for metadata searching. The proposed Product ID will be as follows:

#### **LXSS\_LLL\_PPPRRR\_YYYYMMDD\_yyyymmdd\_CC\_TX**

**L** = Landsat (constant)

**X** = Sensor (C = OLI/TIRS Combined, O=OLI-only, E = ETM, T = TM, M= MSS)

**SS** = Satellite (e.g., 09 for Landsat 9, 10 for Landsat 10)

**LLL** = Processing Correction level (e.g., L1T: precision and terrain, L1G: systematic terrain, L1S: systematic)

**PPP** = WRS path

**RRR** = WRS row

**YYYYMMDD** = Acquisition Year (YYYY) / Month (MM) / Day (DD)

**yyymmdd** = Processing Year (yyyy) / Month (mm) / Day (dd)

**CC** = Collection number (e.g., 01, 02)

**TX** = Collection Category: "RT" for real-time, "T1" for Tier 1 , or "T2" for Tier 2

### New Landsat 8 Metadata File Parameter: Scene Select Mirror (SSM) Model

In April 2016, a new parameter (TIRS\_SSM\_MODEL) will be added to the Landsat 8 data metadata (MTL.txt) file, to help users identify the effects of the SSM encoder current anomaly. Details about the SSM anomaly are provided in an article in the last section of this Update.

The new parameter will have one of three values:

- "Actual": indicates the TIRS data was processed using actual measured SSM position determined from the SSM encoder telemetry. This is the best TIRS quality available, and the TIRS bands should align properly with the OLI bands.
- "Preliminary": indicates initial estimated SSM position information was used to process the data. This is a lower quality TIRS band alignment with the OLI bands and will likely result in TIRS to OLI band misregistration. The data will be reprocessed to improve the quality once SSM encoder telemetry data are available to improve the TIRS line of sight (LOS) model parameters.
- "Final": indicates the TIRS LOS model parameters were updated with SSM encoder telemetry information. The TIRS data quality will closely approximate the "Actual" encoder values, and the TIRS bands should align properly with the OLI bands.

When the TIRS\_SSM\_MODEL parameter is "Preliminary", the IMAGE\_QUALITY\_TIRS parameter in the MTL file will be set to a lower value to provide an additional indication that the TIRS quality is not normal. The new mode of operations will result in the scenes being processed through LPGS twice. The first run will use "Preliminary" estimated SSM encoder position information and will be reprocessed after the "Final" version of the information is available.

## Additional Level 1 Product Changes

### 1. Sun Angle Coefficient Files Added to Landsat TM, ETM+, and OLI/TIRS Level-1 Data Product Package

A file containing parameters needed to calculate the per-pixel solar illumination and sensor view angle bands will be added to Landsat TM, ETM+ and OLI/TIRS scenes. A Linux tool to generate angle bands will also be made available on the Landsat Missions Web site.

The solar zenith angle band can be used in combination with rescaling factors contained in the metadata (.MTL.txt) file to calculate per-pixel top of atmosphere (TOA) reflectance for the solar reflective bands, and brightness temperature for the thermal bands. (Note that thermal constants, located in the metadata, are needed to calculate brightness temperature.)

### 2. Modification to the Landsat 8 Quality Assessment (QA) Band and Addition of QA Bands to Landsat 1-7 Level-1 Data Products

Initially proposed in 2015, information will be provided in the QA band for flagging dropped pixels, radiometric saturation, clouds, cloud shadows, and snow/ice in Landsat 4-5 TM and Landsat 7 ETM+ data products, and will be compatible with the updated Landsat 8 OLI/TIRS QA band. The QA band for Landsat MSS will include values for only fill, non-cloudy, and cloudy pixels.

The table below shows the proposed QA bits and values for Landsat 1-7, and updated bits for Landsat 8, which include saturation bits.

Bit	Value	Cumulative Sum	Description - OLI	Description – TM/ETM+	Description - MSS	8-Bit Browse
0	1	1	Designated Fill	Designated Fill	Designated Fill	Designated Fill
1	2	3	Terrain Occlusion	Dropped Pixel	Dropped Pixel	Occluded/Dropped
2	4	7	Radiometric Saturation	Radiometric Saturation	Radiometric Saturation	
3	8	15	Cloud	Cloud	Cloud	Saturation
4	16	31	Cloud Confidence	Cloud Confidence	Cloud Confidence	Cloud
5	32	63	Cloud Shadow	Cloud Shadow		Shadow
6	64	127	Snow/Ice	Snow/Ice		Snow/Ice
7	128	255	Cirrus			Cirrus
8	256	511				
9	512	1023				
10	1024	2047				
11	2048	4095				
12	4096	8191				
13	8192	16383				
14	16384	32767				
15	32786	65553				

### 3. Saturation Bits Added to Quality Band and Metadata File

Quality Assessments bits will be populated to indicate whether radiometric saturation occurs in any band. The saturation bit values are:

00 = No saturation

01 = 1 to 2 bands saturated

10 = 3 to 4 bands saturated

11 = 4 or more bands saturated

The bands that have saturation will be noted in the metadata (MTL.txt) file in a new yet-to-be-named parameter.

### 4. Implementation of Land-Based Cloud Cover Score to Landsat 1-7 Level-1 Products and Addition to Metadata File

A land-based cloud cover assessment (CCA) will provide an estimate of land in a continental coastal scene that is cloud covered. The percentage of land pixels affected by clouds will be calculated, and written to the metadata file (MTL.txt) as a scene-based score in a new parameter (**CLOUD\_COVER\_LAND**). This parameter will become a searchable metadata attribute in the collections.

The land mask, used to determine land pixels included in the CCA score, is derived from the NOAA World Vector Shoreline dataset (<http://shoreline.noaa.gov/data/datasheets/wvs.html>).

## Landsat 8 Thermal Infrared Sensor (TIRS) Updates

### Thermal Infrared Sensor (TIRS) Scene Select Mirror (SSM) Encoder Current Anomaly

On November 1, 2015, the Thermal Infrared Sensor experienced an anomalous condition related to the instrument's ability to accurately measure the location of the Scene Select Mirror (SSM). While all TIRS data continue to be collected since this date, they are processed and made available as "zero-fill" (black/no data), until processing parameters and algorithm changes are made to allow reprocessing of nominal Level-1 products containing valid TIRS data.

An alternative operations concept for determining the exact position of the SSM through analysis of instrument telemetry data provides information to regularly update the line of sight (LOS) model that is used for geometric correction and alignment of TIRS and OLI data. All collected TIRS data will become available in Level-1 products once the LOS model parameters are finalized, and the geometric processing algorithms and code in the Landsat Level-1 Product Generation System (LPGS) have been updated, tested, and verified.

As of February 12, 2016, many\* of the Landsat 8 scenes acquired from October to December 2015 have been reprocessed into nominal Level-1 products containing valid TIRS data and are available for download, and can also be submitted for higher-level Surface Reflectance data processing via the ESPA On-demand interface (<http://espa.cr.usgs.gov>).

\*A number of scenes acquired from approximately 10 pm CT on November 1, 2015 to approximately 5 pm CT on November 2, 2015 will still contain zero-fill TIRS data. (See this file: [http://landsat.usgs.gov/documents/L8\\_NoTIRS\\_Nov1-2\\_2015.xlsx](http://landsat.usgs.gov/documents/L8_NoTIRS_Nov1-2_2015.xlsx)) These scenes will not be reprocessed until April 2016.

Landsat 8 scenes acquired from January to March 2016 will be reprocessed and made available starting in April 2016.

Additional Information about TIRS SSM can be found on the following Landsat Missions Web site pages:

January 13, 2016 Headline: [http://landsat.usgs.gov/mission\\_headlines2016.php](http://landsat.usgs.gov/mission_headlines2016.php)  
November 3, 2015 Headline: [http://landsat.usgs.gov/mission\\_headlines2015.php](http://landsat.usgs.gov/mission_headlines2015.php)  
Landsat Update Volume 9 Issue 5, July 2015: [http://landsat.usgs.gov/about\\_LU\\_Vol\\_9\\_Issue\\_5.php#2a](http://landsat.usgs.gov/about_LU_Vol_9_Issue_5.php#2a)  
May 8, 2015 Calibration Notice: [http://landsat.usgs.gov/calibration\\_notices.php](http://landsat.usgs.gov/calibration_notices.php)  
December 19, 2014 Headline: [http://landsat.usgs.gov/mission\\_headlines2014.php](http://landsat.usgs.gov/mission_headlines2014.php)

## **Thermal Infrared Sensor (TIRS) Stray Light Investigation**

Shortly after the launch of Landsat 8, the Landsat calibration team noticed that thermal energy from outside the normal field of view (stray light) was affecting the data collected by the satellite's Thermal Infrared Sensor (TIRS). Ground-based measurements indicate a significant error in the radiance measured by the sensor, and investigations showed that stray light increases the reported temperature by up to 4 Kelvin (K) in band 10 and up to 8 K in band 11. The errors vary throughout the scene and depend upon radiance outside the instrument field of view, which is not inherently correctable in the Landsat Level 1 processing.

An algorithm to correct the stray light is showing promise to reduce the errors. The amount of stray light in the scenes is estimated using scenes acquired before and after the target scene, as well as the edge pixels of the target scene. The stray light estimate is then subtracted from the target scene.

Even after this correction, the results **will not** be considered precise enough to use a split-window algorithm for surface temperature retrieval. More information will be provided as results from further analyses become available.

Additional Information about TIRS Stray Light can be found on the following Landsat Missions Web site pages:

January 13, 2016 Headline: [http://landsat.usgs.gov/mission\\_headlines2016.php](http://landsat.usgs.gov/mission_headlines2016.php)  
Landsat Update Volume 9 Issue 5, July 2015: [http://landsat.usgs.gov/about\\_LU\\_Vol\\_9\\_Issue\\_5.php#2c1](http://landsat.usgs.gov/about_LU_Vol_9_Issue_5.php#2c1)  
Landsat Update Volume 8 Issue 2, June 2014: [http://landsat.usgs.gov/about\\_LU\\_Vol\\_8\\_Issue\\_2.php#2a](http://landsat.usgs.gov/about_LU_Vol_8_Issue_2.php#2a)  
November 4, 2014 Headline: [http://landsat.usgs.gov/mission\\_headlines2014.php](http://landsat.usgs.gov/mission_headlines2014.php)

More information about the plans described here will be provided in future Landsat Updates ([http://landsat.usgs.gov/about\\_Landsat\\_Updates.php](http://landsat.usgs.gov/about_Landsat_Updates.php)) and the Landsat Missions Web Site Headlines: <http://landsat.usgs.gov>. Any questions can be directed to USGS Customer Services: [custserv@usgs.gov](mailto:custserv@usgs.gov).