



# Landsat Update

AGU Edition December 2016

## Landsat Collection 1 Reprocessing Status & Data Characteristics

*In 2016, the USGS identified a need to improve the capability of the Landsat data archive to support time series analysis through the full Landsat record. This required the reprocessing of all archived Landsat Level-1 data to achieve radiometric and geometric consistency through time and across all Landsat sensors.*

**Collection 1** consists of Landsat 4-5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper Plus, and Landsat 8 Operational Land Imager and Thermal Infrared Sensor data. Landsat 1-5 Multispectral Scanner data may be incorporated in the future.

New Landsat Product Identifiers, "Collection" and "Tier" designations, metadata changes, modified processing level designations, additional supporting files, and new cloud-cover algorithms are all included in Collection 1 Level-1 data products. (Collection 1 Higher-Level science data products will inherit characteristics of the Level-1 data.)

This Landsat Update AGU Edition provides a status of the Collection 1 reprocessing effort and describes the characteristics of the Landsat Collection 1 Level-1 data products.

**The Landsat Collections webpage provides complete information on Collection 1:**  
<https://landsat.usgs.gov/landsat-collections>.

### Landsat 7 Enhanced Thematic Mapper Plus and Landsat 4-5 Thematic Mapper

Since starting in August 2016, over 667,000 Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) and 672,000 Landsat 4-5 (L4-5) Thematic Mapper (TM) scenes have been reprocessed into Collection 1 Level-1 data products, and are available to download from EarthExplorer (EE): <http://earthexplorer.usgs.gov>.

**Figure 1** shows the location of both the Collection 1 Level-1 and the Pre-Collection data sets on the EE Dataset tab.

L7 ETM+ and L4-5 TM Collection 1 reprocessing will complete during the spring of 2017. A status of the reprocessing efforts (updated weekly) is visible on the Landsat Missions Website: <https://landsat.usgs.gov>.

### Landsat 8 Operational Land Imager/Thermal Infrared Sensor

Collection 1 Level-1 reprocessing for Landsat 8 (L8) Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) scenes is scheduled to begin in January 2017, and data will start becoming available in February 2017.

Samples of Landsat 8 Collection 1 Level-1 data are available to download from <https://landsat.usgs.gov/landsat-collections#sample>.

**NOTE: Users are encouraged to begin using Landsat Collection 1 Level-1 data products, as Pre-Collection data sets will remain available for only a limited time after the completion of Collection 1 reprocessing.**

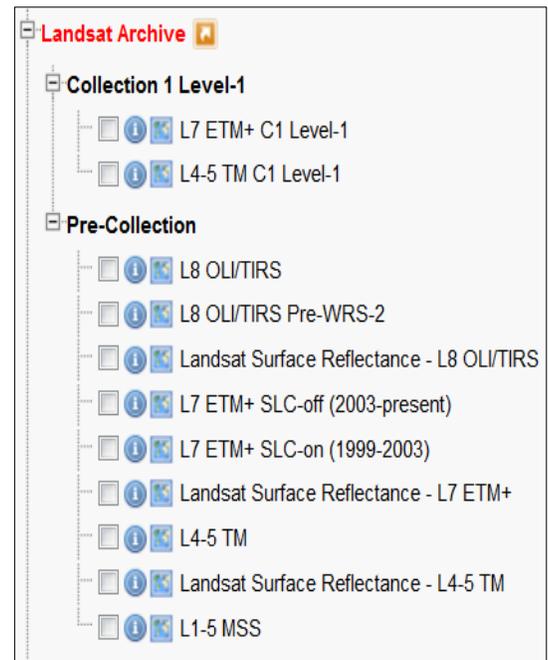


Figure 1. Collection 1 Level-1 datasets on the EarthExplorer "Data Sets" tab.

## Landsat Collection 1 Surface Reflectance Data Status

The ability to request Surface Reflectance and Higher-Level science data products for Landsat 4-5 TM and Landsat 7 ETM+ Collection 1 scenes will become available in January 2017, using the USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) on-demand interface: <https://espa.cr.usgs.gov> or EarthExplorer: <http://earthexplorer.usgs.gov> (Surface Reflectance only). See Page 5 for more details about Landsat Higher-Level science data products.

## Landsat Collection 1 Level-1 Inventory & Data Characteristics

Changes and enhancements have been made to the Landsat data processing system to support the generation and management of the Landsat Collection 1 Level-1 data products.

**Processing Level Designations** have been modified in support of Collection 1 reprocessing. **Table 1** compares the processing level designations of Landsat Pre-Collection Level-1 data products (left column) to Collection 1 Level-1 data products (right column).

Landsat Level-1 Processing Levels		
Pre-Collection	Collection 1	Description
L1T	L1TP	Radiometrically calibrated and orthorectified using ground control points and digital elevation model (DEM) data to correct for relief displacement. These are the highest quality Level-1 products suitable for pixel-level time series analysis.
L1GT	L1GT	Radiometrically calibrated and with systematic geometric corrections applied using the spacecraft ephemeris data and DEM data to correct for relief displacement.
L1G	L1GS	Radiometrically calibrated and with only systematic geometric corrections applied using the spacecraft ephemeris data.

Table 1. Landsat Pre-Collection (left column) and Landsat Collection 1 (right column) processing level designations.

**Landsat Tiers** are the inventory structure for Landsat Collection 1 Level-1 data products and are based on data quality and level of processing.

Landsat scenes with the highest data quality are placed into Tier 1, and scenes not meeting Tier 1 criteria are assigned to Tier 2. The Real-Time Tier is a temporary assignment for newly acquired Landsat 7 and Landsat 8 scenes, as described in **Table 2** below.

Tier 1	Tier 2
L1TP – Precision Terrain Correction	L1GT - Systematic terrain L1GS - Systematic
≤12m radial root mean square error (RMSE)	>12m RMSE
Considered suitable for time-series processing analysis.	Users should analyze RMSE and other properties to determine the suitability for use in individual applications.
<b>Real-Time (Temporary)</b>	
Newly acquired L7 and L8 data require a period of evaluation and calibration adjustment after acquisition, but are processed immediately based on preliminary calibration coefficients, assigned to the temporary "Real-Time" (RT) Tier, and made available for download. When definitive calibration information becomes available, RT scenes are reprocessed and assigned to the appropriate Tier 1 or Tier 2 category.	

Table 2. Landsat Collection 1 Tier designations.

**Table 3** below compares the Landsat Pre-Collection Level-1 Scene ID (left box) to the Landsat Collection 1 Level-1 Product Identifier (right box). The Landsat Product Identifier contains information inherited from the Pre-Collection Scene ID, along with updated processing levels, processing date, collection number, and collection category (red colored text).

Scene ID	Landsat Product Identifier
<b>LXSPPPRRRRYYYYDDGSIVV</b>	<b>LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX</b>
L = Landsat X = Sensor S = Satellite PPP = WRS path RRR = WRS row YYYY = Year DDD = Julian day of year GSI = Ground station identifier VV = Archive version number	L = Landsat X = Sensor ("C" = OLI/TIRS Combined, "O" = OLI-only, "T" = TIRS-only, "E" = ETM+, "T" = TM, "M" = MSS) SS = Satellite ("07" = Landsat 7, "08" = Landsat 8) <b>LLLL = Processing correction level ("L1TP": Precision Terrain, "L1GT": Systematic Terrain, "L1GS": Systematic)</b> PPP = WRS path RRR = WRS row YYYYMMDD = Acquisition year (YYYY) / Month (MM) / Day (DD) <b>yyymmdd = Processing year (yyyy) / Month (mm) / Day (dd)</b> <b>CC = Collection number ("01", "02")</b> <b>TX = Collection category: ("RT" for Real-Time, "T1" for Tier 1, or "T2" for Tier 2)</b>
<b>Examples:</b> LC80290302015343LGN00 LE70160392004262EDC02 LT40170361982320XX08 LM10170391976031AAA01	<b>Examples:</b> LC08_L1GT_029030_20151209_20160131_01_RT LE07_L1TP_016039_20040918_20160211_01_T1 LT04_L1GS_017036_19821115_20160315_01_T2 LM01_L1GS_017039_19760131_20160225_01_T2

Table 3. Comparison of Landsat Pre-Collection Level-1 Scene ID (left box) and Landsat Collection 1 Landsat Level-1 Product Identifier (right box).

## Landsat Collection 1 Level-1 Data Product Files

Landsat Collection 1 Level-1 data products for each scene contain the image data bands; metadata (MTL.txt) file; a new Quality Assessment (QA) band for Landsat 4-5 and Landsat 7 data products (a revised QA band will be used for Landsat 8 Collection 1); and a new Angle Coefficient File. The QA bands and Angle Coefficient File are described below.

### Landsat Collection 1 Level-1 Quality Assessment Band

The Landsat Collection 1 Quality Assessment (QA) band allows users to apply per pixel filters to Landsat Level-1 data products. Each pixel in the QA band contains unsigned integers that represent bit-packed combinations of surface, atmospheric, and sensor conditions that can affect the overall usefulness of a given pixel. **Table 4** illustrates the designated bits for Landsat Collection 1 Level-1 QA bands.

Landsat 4-5 and Landsat 7 Quality Assessment (QA) Band Attributes				Landsat 8 Quality Assessment (QA) Band Attributes			
Bit	Value	Cumulative Sum	Description	Bit	Value	Cumulative Sum	Description
0	1	1	Designated Fill	0	1	1	Designated Fill
1	2	3	Dropped Pixel	1	2	3	Terrain Occlusion
2	4	7	Radiometric Saturation	2	4	7	Radiometric Saturation
3	8	15		3	8	15	
4	16	31	Cloud	4	16	31	Cloud
5	32	63	Cloud Confidence	5	32	63	Cloud Confidence
6	64	127		6	64	127	
7	128	255	Cloud Shadow Confidence	7	128	255	Cloud Shadow Confidence
8	256	511	Snow / Ice Confidence	8	256	511	Snow / Ice Confidence
9	512	1023		9	512	1023	
10	1024	2047	Cirrus Confidence	10	1024	2047	Cirrus Confidence
11	2048	4095		11	2048	4095	
12	4096	8191		12	4096	8191	
13	8192	16383		13	8192	16383	
14	16384	32767		14	16384	32767	
15	32786	65553		15	32786	65553	

Table 4. Landsat Collection 1 Level-1 Quality Assessment Band Attributes for Landsat 4-5 and 7 (left table) and Landsat 8 (right table).

Note: Although the cloud detection algorithm has undergone some degree of validation, the snow cover detection algorithm has not. Additional information about the Landsat Collection 1 QA band can be found at <https://landsat.usgs.gov/collectionqualityband>.

## Landsat Collection 1 Level-1 Angle Coefficient File

The Landsat Collection 1 Level-1 Angle Coefficient File provides sensor viewing angle model coefficients that can be used to compute the solar illumination and sensor viewing angles for every Landsat pixel in a scene.

**Figure 2** shows the contents of the Angle Coefficient File.

Angle bands allow users to better understand how the sensor viewing geometry and solar illumination geometry affect the object being sensed by the imaging instrument, and can be used in science algorithms to produce more accurate results over the current practice of using the single scene-center solar illumination and sensor viewing angles.

NOTE: For most applications, users can continue to use the standard Level-1 data, but the information in this file provides opportunities to investigate refinements to the solar zenith angle corrections in higher-level science data products. Future plans include implementing an end-user web-based tool; however, currently users are responsible for creating usable angle bands.

Tools that allow users to create angle bands in a LINUX environment are available to download from <http://on.doi.gov/2gIX1fk>.

```
LC08_L1TP_140041_20130503_20161018_01_T1_ANG.txt
GROUP = FILE_HEADER
LANDSAT_SCENE_ID = "LC81400412013123LGN01"
SPACECRAFT_ID = "LANDSAT_8"
NUMBER_OF_BANDS = 11
BAND_LIST = (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
END_GROUP = FILE_HEADER
GROUP = PROJECTION
ELLIPSOID_AXES = (6378137.000000, 6356752.314200)
MAP_PROJECTION = "UTM"
PROJECTION_UNITS = "METERS"
DATUM = "WGS84"
ELLIPSOID = "WGS84"
UTM_ZONE = 45
PROJECTION_PARAMETERS = (0.000000, 0.000000, 0.000000,
0.000000, 0.000000, 0.000000,
0.000000, 0.000000, 0.000000, 0.000000,
0.000000, 0.000000)
UL_CORNER = ( 370800.000, 3144000.000)
UR_CORNER = ( 597300.000, 3144000.000)
LL_CORNER = ( 370800.000, 2923500.000)
LR_CORNER = ( 597300.000, 2923500.000)
END_GROUP = PROJECTION
GROUP = EPHEMERIS
EPHEMERIS_EPOCH_YEAR = 2013
EPHEMERIS_EPOCH_DAY = 123
EPHEMERIS_EPOCH_SECONDS = 17011.716060
NUMBER_OF_POINTS = 53
EPHEMERIS_TIME = ( 0.000000, 1.000000, 2.000000,
3.000000, 4.000000,
5.000000, 6.000000, 7.000000,
8.000000, 9.000000,
10.000000, 11.000000, 12.000000,
13.000000, 14.000000,
```

Figure 2. Example of a Landsat Collection 1 Angle Coefficient File.

## Landsat Collection 1 Cloud Cover Identification

A number of different cloud cover algorithms were used in Landsat Pre-Collection Level-1 data. In order to consistently calculate cloud cover in Collection 1 Level-1 data, the C Function of Mask (CFMask) algorithm has been implemented.

CFMask identifies cloud, cloud confidence, cloud shadow, and snow/ice pixels in the processing of Landsat Level-1 data products, with the results represented as bit-mapped values within the Landsat Collection 1 Level-1 Quality Assessment (QA) Band. The multi-pass algorithm uses decision trees to progressively label pixels in a scene; it then validates or discards those labels according to scene-wide statistics. It also creates a cloud shadow mask by iteratively estimating cloud heights and projecting them onto the ground.

CFMask provides full-image "Scene Cloud Cover" estimation, as well as a new "Land Cloud Cover" score, which is calculated over only land pixels in a scene. Both cloud cover scores are listed in the metadata file that is delivered with the Collection 1 Level-1 data product.

*(Users should be aware that, like other cloud algorithms, CFMask may have difficulties over bright targets such as building tops, beaches, snow/ice, sand dunes, and desert playas. Optically thin clouds will always be challenging to identify and have a higher probability of being omitted by the algorithm. In addition, the algorithm performance has only been validated for cloud detection, and to a lesser extent for cloud shadows. No rigorous evaluation of the snow/ice detection has been performed. For further information on the CFMask algorithm, visit <https://landsat.usgs.gov/what-cfmask>.)*

## Landsat Collection 1 Higher-Level Science Data Products

Higher-level science data products (such as Climate Data Records (CDRs) and Essential Climate Variables (ECVs)) can be used to document changes to Earth's terrestrial environment and provide an authoritative basis for regional to continental scale identification of historical change, monitoring current conditions, and helping to predict future scenarios.

### Atmospherically-corrected Surface Reflectance (SR) data for Collection 1 Landsat 7 ETM+ and Landsat 4-5 TM scenes will become available to order from EarthExplorer in January 2017.

Landsat 8 Higher-Level science data products will become available a short time after the release of Landsat 8 Collection 1 Level-1 products (See Page 1).

### The Earth Resources Observation and Science (EROS) Center Science Processing

**Architecture (ESPA)** On-demand interface accepts orders for not only Surface Reflectance data, but also Top-of-Atmosphere Reflectance, Brightness Temperature, and CFMask outputs, as well as multiple spectral indices derived from surface reflectance data, and allows users to customize output formats, map reprojection, and pixel resizing. **Figure 3** shows the ESPA on-demand interface.

Surface reflectance and other higher-level science data products are processed and delivered directly from the ESPA on-demand Interface.

The ESPA User Guide provides further information on how to place an order through ESPA: <http://on.doi.gov/2gZ82XV>.

*Further questions about Landsat Collection 1 Level-1 or Landsat Higher-Level science data products can be directed to Landsat User Services: [custserv@usgs.gov](mailto:custserv@usgs.gov).*

The screenshot displays the ESPA on-demand interface with the following sections and options:

- Add Input Products (Show Available Products)**
  - Scene List: Browse... No file selected.
- Select Product Contents**
  - Source Products:
    - Input Products
    - Input Product Metadata
- Additional Processing (Landsat Only)**
  - Climate Data Records:
    - Surface Reflectance
  - Other Landsat Level-2 Products:
    - Top of Atmosphere Reflectance
    - Brightness Temperature
    - CFMask
    - Spectral Indices
- Customize Outputs**
  - Customization Options:
    - Output Format:  GeoTiff,  ENVI,  HDF-EOS2,  NetCDF
    - Reproject Products
    - Modify Image Extents
    - Pixel Resizing
  - Intercomparison & Statistics:
    - Plot Output Product Statistics
- Add Order Description**
  - Order Description (optional): [Text area]
  - Submit

Figure 3. Example screen shot of Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) on-demand interface (<https://espa.cr.usgs.gov>).

# Landsat Communication Outlets

Landsat Missions Website: <https://landsat.usgs.gov>

Get Landsat Updates: <https://landsat.usgs.gov/landsat-updates>

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## Contact us!

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