Department of the Interior
U.S. Geological Survey

PRODUCT GUIDE

LANDSAT 8 SURFACE REFLECTANCE CODE (LASRC) PRODUCT

Version 4.2

December 2017

USGS
science for a changing world

Executive Summary

This document describes relevant characteristics of the Landsat 8 Surface Reflectance Code (LaSRC) Climate Data Record to facilitate its use in the land remote sensing community.

This document describes Top of Atmosphere (TOA) Reflectance and TOA Brightness Temperature derived from Landsat 8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS), respectively. Surface Reflectance can be derived if both OLI and TIRS data are available. Other processing options, such as spectral indices, format conversion, spatial subset, and/or coordinate system reprojection are described in other product guides.

Document History

Document Version	Publication Date	Change Description
Version 1.0	12/18/2014	Initial Draft
Version 1.1	01/09/2015	Addition of “Known Issues” section.
Version 1.2	03/04/2015	Update to “Known Issues” section with additional information concerning improvements to aerosol retrieval. Update to aerosol bit value descriptions in Table 7-C. Corrected error in Bands 10-11 Brightness Temperature table.
Version 1.3	05/13/2015	Update to “Known Issues” section with additional information concerning improvements to land/water masking. Addition of provisional CFmask cloud confidence band.
Version 1.4	06/08/2015	Clarification of Bands 10-11 Brightness Temperature output.
Version 1.5	07/16/2015	Fixed broken reference.
Version 1.6	09/02/2015	Removed incorrect “_bt” file naming convention from Brightness Temperature description.
Version 1.7	9/21/2015	Added details to caveat describing high latitudes.
Version 1.8	12/01/2015	Added details about TIRS zero-fill data. Added changes to location of SR products on EE. Corrected minor typos and revised the formatting of citations.
Version 1.9	02/10/2016	Edited instances where “shadow” should be “cloud shadow” (in reference to CFmask).
Version 2.0	03/01/2016	Fixed broken L8 QA Band hyperlink. Updated source code links to Github pages.
Version 2.1	05/10/2016	Updates to “Known Issues” and “Caveats and Constraints” sections. Added citation for manuscript describing L8SR’s algorithm creation and initial analysis.
Version 3.0	07/01/2016	Changed name from “L8SR” to “LaSRC”. Fixed nearly all “blockiness” by interpolating missing aerosol data points. A new aerosol interpolation QA band (sr_ipflag) is now provided to show where aerosols have been interpolated versus actual observations. Reflectance is now retrieved over all pixels except those contaminated with cirrus. Added date restriction caveat for when MODIS Terra was in safe mode.
Version 3.1	08/23/2016	Added missing auxiliary data gaps dates.
Version 3.2	09/08/2016	Changed cloud confidence bits to actual representation – “low”, “medium” and “high”.

Version 3.3	10/11/2016	Added specifics on Known Issues, added NetCDF file format.
Version 3.4	12/07/2016	Replaced links to Landsat Missions Website
Version 3.5	03/10/2017	Some level of aerosol retrieval is now attempted for all pixels, and a special routine is used for water pixels (“Known Issues”; “Caveats & Constraints".) Addition of Collection 1 products. Addition of ancillary data chart. “sr_ipflag” and “sr_cloud” have now been replaced with “sr_aerosol” for Pre-Collection and C1. For C1: addition of radiometric saturation (radsat_qa) and pixel quality (pixel_qa) band; removal of cfmask and cfmask_conf bands, unless ordered manually in ESPA. Added caveat stating that TIRS-only (LT8 or LT08) data cannot be processed to Brightness Temperature.
Version 3.6	03/31/2017	Removal of “Provisional” status for all C1 datasets. Updated angle band zenith valid range to 0-9000; angle band azimuth valid range -18000 – 18000; all angle band nodata to -32768. Removed ‘L8SR’ from Appendix (name no longer used.) Added speckling noise caveat.
Version 3.7	04/06/2017	Removal of Pre-Collection Landsat information.
Version 3.8	05/09/2017	Updated pixel_qa description, added “terrain occlusion” bit, added detailed tables with pixel_qa values. Fixed typo – “sr_aerosol” was listed incorrected as “sr_aerosol_qa”. Added CFMask bands’ discontinuation date (02 June 2017).
Version 3.9	06/02/2017	Added interpretation tables for sr_aerosol band. Changed table and figure designation from number-letter (e.g., 8-A) to number-number (e.g., 8-1). Updated radsat_qa description. Updated TOA Reflectance description, stating TOA is created using per-pixel angles from band 4 (formerly scene center angle.) Updated table names.
Version 4.0	06/07/2017	Corrected typographical errors.
Version 4.1	10/05/2017	Aerosol retrieval is now performed for a 3x3 pixel window versus each pixel. Clouds, water, and cloud shadows are assigned the median aerosol value for clear land pixels. Updated sr_aerosol table with new bit descriptions. Pixels in the pixel_qa band which are high confidence cirrus or terrain occluded no longer unset the clear bit. Given that these pixels are now clear, they could be flagged as water or snow. Updated pixel_qa table. Replaced the terms

		high level and higher level products with science data products.
Version 4.2	12/04/2017	Added “top of atmosphere” before “brightness temperature” to clarify that BT products are not atmospherically corrected.

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Section 1 Introduction

Landsat satellite data have been produced, archived, and distributed by the U.S. Geological Survey (USGS) since 1972. Users rely upon these data for historical study of land surface change but shoulder the burden of post-production processing to create applications-ready data sets. To alleviate this burden, USGS has embarked on production of Landsat Science Products to support land surface change studies. Terrestrial variables such as surface reflectance and land surface temperature, 30-meter land cover, burned area extent, snow covered area, and surface water extent will be offered as science data products. These products will offer a framework for producing long-term Landsat science data collections suited for monitoring, assessing, and predicting land surface change over time.

The product described here, the Landsat 8 Surface Reflectance Code (LaSRC) is distinctly different from the algorithm used by USGS to process Landsat 4–5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Level-1 products to Surface Reflectance, known as the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS). Details of these differences are described below in **Table 1-1**.

LaSRC's original development and preliminary characterization is documented in the peer-reviewed manuscript published by Vermote et al., 2016. Please see **Section 12 References** for more details.

Table 1-1 Differences between Landsat 4–7 and Landsat 8 Surface Reflectance algorithms

6S Second Simulation of a Satellite Signal in the Solar Spectrum, AOT Aerosol Optical Thickness, CFMask C Version of Function Of Mask, CMA Climate Modeling Grid - Aerosol, CMG Climate Modeling Grid, DDV Dark Dense Vegetation, DEM Digital Elevation Model, ETM+ Enhanced Thematic Mapper Plus, GSFC Goddard Space Flight Center, INT Integer, LaSRC Landsat Surface Reflectance Code, LEDAPS Landsat Ecosystem Disturbance Adaptive Processing System, MEaSUREs Making Earth Science Data Records for Use in Research Environments, MODIS Moderate Resolution Imaging Spectroradiometer, N/A Not Applicable, NASA National Aeronautics and Space Administration, NCEP National Centers for Environmental Prediction, OLI Operational Land Imager, OMI Ozone Monitoring Instrument, QA Quality Assurance, SR Surface Reflectance, TIRS Thermal Infrared Sensor, TM Thematic Mapper, TOA Top of Atmosphere Reflectance, TOMS Total Ozone Mapping Spectrometer, XML Extensible Markup Language

Parameter	Landsat 4–5, 7 (LEDAPS)	Landsat 8 OLI (LaSRC)
(Original) research grant	NASA GSFC, MEaSUREs (Masek)	NASA GSFC
Global coverage	Yes	Yes
TOA	Visible (1–5,7) + Brightness temp (6) bands	Visible (1–7, 9) +Thermal (10–11) bands
SR	Visible (1–5, 7) bands	Visible (1–7) bands (OLI/TIRS only)
Radiative transfer model	6S	Internal algorithm
Thermal correction level	TOA only	TOA only
Thermal band units	Kelvin	Kelvin
Pressure	NCEP Grid	Surface pressure is calculated internally based on the elevation
Water vapor	NCEP Grid	MODIS CMA

Air temperature	NCEP Grid	MODIS CMA
DEM	Global Climate Model DEM	Global Climate Model DEM
Ozone	OMI/TOMS	MODIS CMG Coarse resolution ozone
AOT	Correlation between chlorophyll absorption and bound water absorption of scene	MODIS CMA
Sun angle	Scene center from input metadata	Scene center from input metadata
View zenith angle	From input metadata	Hard-coded to 0
Undesirable zenith angle correction	SR not processed when solar zenith angle > 76 degrees	SR not processed when solar zenith angle > 76 degrees
Pan band processed?	No	No
XML metadata?	Yes	Yes
Brightness temperature calculated	Yes (Band 6 TM/ETM+)	Yes (Bands 10 & 11 TIRS)
Cloud mask	Internal algorithm; CFmask	Internal algorithm; CFmask
Data format	INT16	INT16
Fill values	-9999	-9999
QA bands	Cloud Adjacent cloud Cloud shadow DDV Fill Land water Snow Atmospheric opacity	Cloud Adjacent cloud Cloud shadow Aerosols Cirrus Aerosol Interpolation Flag

Section 2 Known Issues

2.1 Surface Reflectance Artifacts

The artifacts present in Surface Reflectance data products obtained before July 1, 2016 product have been largely eliminated. The artifacts, or “blockiness” was largely caused by the Global Climate Modeling (GCM) grid’s aerosol values not being correctly interpolated to the Landsat grid, causing grid-shaped artifacts. To prevent this, LaSRC now interpolates missing aerosol grid values to fit continuously within the Landsat grid cells. While making the resulting data product appear more consistent, interpolated values are not direct measurements, therefore a QA band (sr_aerosol) is now provided with the Surface Reflectance data product (**Section 7.1.2**).

Previous interpolation issues along coastal water bodies led us to implement a land/water mask to better identify coastal waters, since aerosols were not being retrieved over coastal waters and this resulted in significant blockiness along the coastal areas. Given the change in the new version of LaSRC to use a separate algorithm for pixels identified as water, the coastal water mask has been removed from the processing stream.

However, some low-radiance speckling still appears over water in some Surface Reflectance bands. Shown in **Figure 2-1**, the speckling exists over water in the shortwave infrared 2 band.

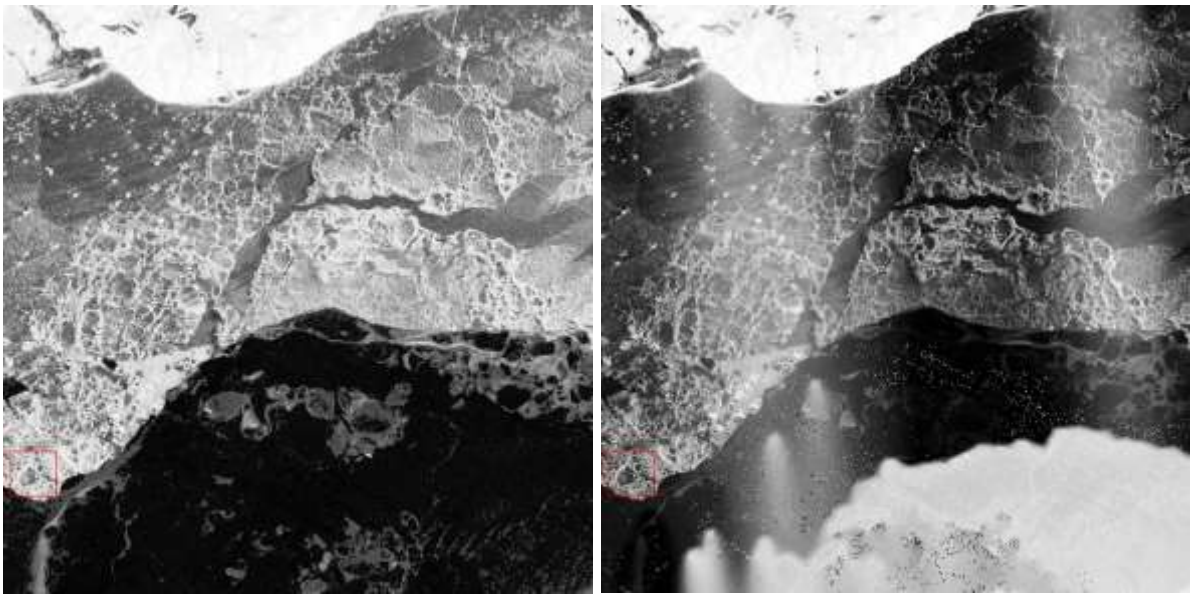

Figure 2-1 Example of speckling in Surface Reflectance bands (right), with Top of Atmosphere (TOA) Reflectance (left) shown for reference. Images are from band 7 (shortwave infrared 2) acquired by Landsat 8 at WRS-2 Path 13, Row 10 on 30 March 2013.

Please see https://landsat.usgs.gov/sites/default/files/documents/lasrc_release_notes.pdf for more information pertaining to the algorithm updates.

Section 3 Caveats and Constraints

1. Corrections from OLI Bands 1 and 2 (coastal aerosol and blue bands, respectively) should not be used for analysis, as they are already used within the algorithm to perform aerosol inversion tests, making them potentially unreliable.
2. Landsat 8 data cannot be processed to Surface Reflectance between specific dates. More information pertaining to the ancillary data characteristics and availability is shown in **Section 8 Ancillary Data**. The most up-to-date information regarding data gaps is in the "Caveats and Constraints" section of https://landsat.usgs.gov/landsat-surface-reflectance-data-products.
3. Aerosol retrieval is attempted over all pixels, though a separate routine is used for pixels flagged by LaSRC as water. These conditions are detailed in the Aerosol QA band (**Section 7.1.2 Aerosol QA Band**).
4. Surface Reflectance cannot be run on Landsat 8 Pre-Worldwide Reference System (WRS)-2 scenes. More information about Pre-WRS-2 scenes can be found at https://landsat.usgs.gov/what-landsat-8-olitirs-pre-wrs-2-data.
5. Top of Atmosphere (TOA) Reflectance data are derived using per-pixel solar illumination angles generated from the angle coefficient file. Previously, the scene center solar illumination angle from the MTL file was used. This will impact the Surface Reflectance (SR) data products, as they are derived from TOA Reflectance.
    - This should ideally improve the accuracy of the TOA Reflectance and subsequent SR corrections.
    - Scene center solar illumination and sensor view angles (i.e., not per-pixel) are still used in the SR processing, as the Lookup Table routines are called on a grid that is spatially coarser than the resolution of the Landsat data, therefore not necessitating per-pixel angle information.
6. Real-Time (RT) Collection 1 data can be processed to Surface Reflectance once the ancillary data become available. Note that RT data will not have finalized geometric or radiometric processing, so the follow-on processing to place the data in Tier 1 (T1) or Tier 2 (T2) categories (approx. 2 weeks after acquisition) will likely be different than the Real Time data. See https://landsat.usgs.gov/landsat-collections for more information on the differences between RT and T1/T2 data sets.
7. Although Surface Reflectance can be processed only from the Operational Land Imager (OLI) bands, SR requires combined OLI/Thermal Infrared Sensor (TIRS) product (LC8) input in order to generate the accompanying cloud mask. Therefore, OLI only (LO8), and TIRS only (LT8) data products cannot be calculated to SR.
8. TIRS-only data (LT08 for Collection 1) cannot currently be processed to TOA Brightness Temperature.
9. SR is not run on scenes with a solar zenith angle of greater than 76º. The primary physical issues with retrieving SR from high solar zenith angles (low sun angle) include:

- Solar elevation varies more near the poles [1], especially when relying upon sun-synchronous observations.
- Lower solar elevations at high latitudes results in longer atmospheric paths (i.e. more scattering) [1].
- The degree of uncertainty in SR retrieval greatly increases, from being negligible to highly inaccurate, at or above a solar zenith angle > 76 degrees.

References: [1] Campbell, J. W., & Aarup, T. (1989). Photosynthetically available radiation at high latitudes. Limnology and Oceanography, 34(8), 1490-1499. http://dx.doi.org/10.4319/lo.1989.34.8.1490.

10. For reasons mentioned above, users are cautioned against processing data acquired over high latitudes (> 65º) to Surface Reflectance.
11. Users are cautioned against using pixels flagged as high aerosol content. See **Section 7.1.4** for details.
12. There are additional adverse conditions that can affect the efficacy of L8SR retrievals, such as:
    - Hyper-arid or snow-covered regions
    - Low sun angle conditions
    - Coastal regions where land area is small relative to adjacent water
    - Areas with extensive cloud contamination.
13. OLI Band 8 (panchromatic band) is not processed to Top of Atmosphere or Surface Reflectance.

Section 4 Product Options

This product guide is specific only to the products listed below. Options for processing other Landsat data are covered in separate product guides.

1. Original Input Products
2. Original Input Metadata
3. Top of Atmosphere (TOA) Reflectance (all bands except Panchromatic Band 8).
4. TOA Brightness Temperature (Calculated from at-sensor radiances. These are separate products generated for Bands 10 and 11).
5. Surface Reflectance (all bands except Panchromatic Band 8, Cirrus Band 9, and Thermal Bands 10 and 11).

These products are available for any Landsat 8 data product available in the USGS archive, with the exceptions noted in **Section 3 Caveats and Constraints.**

4.1 Original Input Products

Selection of this option delivers the original unaltered Landsat 8 Level-1 data product.

Landsat 8 OLI/TIRS Original Input Products output will contain:

- Level-1 data files (Bands 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11)
- Quality Assessment (QA) Band file https://landsat.usgs.gov/collectionqualityband
- Angle Band Coefficients file
- Metadata text file (MTL.txt)

Filenames utilize the product identifier (productID), for example, “LC08_L1TP_220071_20170207_20170216_01_T1”. Product details are found at https://landsat.usgs.gov/landsat-collections

4.2 Original Input Metadata

The Landsat 8 Level-1 metadata (MTL.txt) and angle band coefficients file (ANG.txt) will be distributed when this option is requested.

4.3 Top of Atmosphere Reflectance

This option calculates TOA Reflectance from the Original Input Landsat scene. Further details are given in **Section 7 Product Characteristics**.

Top of Atmosphere Reflectance output from Landsat 8 contains:

- LC8 data: TOA Reflectance data files (Bands 1–7, 9)
- LO8 data: TOA Reflectance data files (Bands 1–7, 9)
- TOA Reflectance header files
- Radiometric Saturation Quality Assurance file (radsat_qa)
- Level-1 metadata files
- Level-2 Pixel Quality Assurance band (pixel_qa)

- Per-pixel solar zenith, solar azimuth, sensor zenith and sensor azimuth bands (band 4 only)
- TOA Reflectance metadata file (.xml)

Filenames utilize the productID followed by "_toa_," for example, "LC08_L1TP_018060_20140904_20160101_01_T1_toa_*."

4.4 Top of Atmosphere Brightness Temperature

This option delivers the Top of Atmosphere (TOA) Brightness Temperature product (Bands 10 and 11), which are converted to Kelvin.

4.4.1 Collection 1

TOA Brightness Temperature output from Landsat 8 contains:

- LC8 data: TOA Brightness Temperature data files (Bands 10–11)
- TOA Brightness Temperature header files
- Radiometric Saturation Quality Assurance file (radsat_qa)
- Level-1 metadata files
- Level-2 Pixel Quality Assurance band (pixel_qa)
- Per-pixel solar zenith, solar azimuth, sensor zenith and sensor azimuth bands (band 4 only)
- TOA Brightness Temperature metadata file (.xml)

Filenames utilize the productID followed by "_bt_," for example, "LC08_L1TP_171061_20140702_2016010_01_T1_bt_*."

4.5 Surface Reflectance

This option delivers the Surface Reflectance product, without the TOA Reflectance or the original input files. **Section 7 Product Characteristics** describes the product in full detail. General contents are listed below.

Landsat Surface Reflectance output from Landsat 8 contains:

- Surface Reflectance data files (Bands 1–7)
- Radiometric Saturation QA band (radsat_qa; see **Section 7.1.1** for more details)
- Surface Reflectance Aerosol QA band (see **Section 7.1.2** for more details)
- Level-1 metadata files
- Level-2 Pixel Quality Assurance band (pixel_qa; see **Section 7.2**, **Table 7-2** for more details)
- Per-pixel solar zenith, solar azimuth, sensor zenith and sensor azimuth bands (band 4 only)
- Surface Reflectance metadata file (.xml)

Filenames utilize the productID followed by "_sr_," for example, "LC08_L1TP_233013_2014265LGN00_sr_*."

4.6 Spectral Indices

Landsat 8 Surface Reflectance can be used to derive several spectral index products, as listed below. Their characteristics are described in a separate product guide for Landsat 4–8 (see Landsat Spectral Indices Product Guide) and currently include:

- Normalized Difference Vegetation Index (NDVI)
- Enhanced Vegetation Index (EVI)
- Soil Adjusted Vegetation Index (SAVI)
- Modified Soil Adjusted Vegetation Index (MSAVI)
- Normalized Difference Moisture Index (NDMI)
- Normalized Burn Ratio (NBR)
- Normalized Burn Ratio 2 (NBR2)

Section 5 Product Access

Landsat 8 Surface Reflectance data products are available through EarthExplorer, under the “Data Sets” > “Landsat” > “Landsat Collection 1 Level-2 (On Demand)” tabs, then “Landsat 8 OLI/TIRS C1 Level-2”.

An on-demand interface called ESPA (U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA)) offers Landsat 8 Surface Reflectance in addition to Original Input Products and Metadata, TOA Reflectance, NDVI, NDMI, NBR, NBR2, SAVI, MSAVI, and EVI data products. Services such as reprojection, spatial subsetting, and pixel resizing are also available through ESPA. ESPA is accessible at https://espa.cr.usgs.gov/. Additional information about ESPA’s spectral indices and service processing options for Landsat 4–8 can be found in the Spectral Indices Product Guide and ESPA On-Demand Interface User Guide, respectively.

Section 6 Product Packaging

Surface Reflectance products are supplied in a gzip file (.tar.gz). Unzipping this file produces a tarball (.tar), which will “untar” to a Georeferenced Tagged Image File Format (GeoTIFF; .tif) file. The filenames are structured as the original scene ID appended with the suffix “_sr_” followed by a band designation to denote the Surface Reflectance transformation.

Following are the components of a typical Collection 1 file:

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CX_TX_prod_band.ext
(e.g., LC08_L1TP_039037_20150728_20160918_01_T1_sr_band1.tif)

L	Landsat
X	Sensor (“O” = OLI; “T” = TIRS; “C” = OLI/TIRS)
SS	Satellite (“08” = Landsat 8)
LLLL	Processing correction level (“L1TP” = Precision Terrain; “L1GT” = Systematic Terrain; “L1GS” = Systematic)
PPP	Path
RRR	Row
YYYY	Year of acquisition
MM	Month of acquisition
DD	Day of acquisition
yyyy	Year of processing
mm	Month of processing
dd	Day of processing
CX	Collection number (“01”, “02”, etc.)
TX	Collection category (“RT” = Real-Time; “T1” = Tier 1; “T2” = Tier 2)
prod	Product, such as “toa” or “sr”
band	Band, such as “band<1-11>,” “qa,” or spectral index.
ext	File format extension, such as “tif,” “tfw,” “xml,” “hdf,” “hdr,” “nc,” or “img”

Section 7 Product Characteristics

Original Input Products and Original Input Metadata are described on https://landsat.usgs.gov/landsat-processing-details. The characteristics of Surface Reflectance, TOA Reflectance, and TOA Brightness Temperature are detailed in the following sections.

7.1 Surface Reflectance Specifications

The Landsat 8 Surface Reflectance product is generated at 30-meter spatial resolution on a Universal Transverse Mercator (UTM) or Polar Stereographic (PS) mapping grid. The default file format is GeoTIFF, but options for delivery in Hierarchical Data Format – Earth Observing System – 2 (HDF-EOS-2; .hdf), NetCDF (.nc) or ENVI binary (.img) are available through the ESPA Ordering Interface. More information on output formats currently used for Landsat 4–8 can be found in the ESPA On Demand Interface User Guide.

Landsat 8 Surface Reflectance will be delivered in files named with the new product ID and appended with "_sr_" followed by a band designation. All packages include Extensible Markup Language (xml)-based metadata.

The Surface Reflectance bands are delivered in separate, condition-specific files, with the exception of the Aerosol QA Band, which is delivered in a single bit-packed layer. **Table 7-1** lists the specifications for the bands included in a Surface Reflectance data file. **Table 7-2** describes the bit assignments for the pixel_qa band. The pixel_qa bit values are given in **Table 7-3**, and shown in greater detail in **Table 7-4**.

Table 7-1 Surface Reflectance Specifications

INT16 16-bit signed integer, UINT8 8-bit unsigned integer, QA quality assurance, CFMask C version of Function of Mask, NA not applicable

Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
sr_band1	Band 1	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band2	Band 2	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band3	Band 3	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band4	Band 4	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band5	Band 5	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band6	Band 6	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band7	Band 7	INT16	Reflectance	-2000 – 16000	0 - 10000	-9999	20000	0.0001
pixel_qa	Level-2 Pixel Quality Band	UINT16	Bit Index	0-32768	0-32768	1 (bit 0)	NA	NA
sr_aerosol	Aerosol QA	UINT8	Bit Index	0 - 255	0 - 255	NA	NA	NA
radsat_qa	Radiometric Saturation QA	UINT16	Bit Index	0-32768	0-3839	1 (bit 0)	NA	NA

solar_azimuth_band4	Solar Azimuth Angles Band 4	INT16	Degrees	-32768 - 32767	-18000 - 18000	-32768	NA	0.0100
solar_zenith_band4	Solar Zenith Angles Band 4	INT16	Degrees	-32768 - 32767	0 - 9000	-32768	NA	0.0100
sensor_zenith_band4	Sensor Azimuth Angles Band 4	INT16	Degrees	-32768 - 32767	0 - 9000	-32768	NA	0.0100
sensor_azimuth_band4	Sensor Zenith Angles Band 4	INT16	Degrees	-32768 - 32767	-18000 - 18000	-32768	NA	0.0100

Table 7-2 Landsat 8 Pixel Quality Attributes (pixel_qa) Bit Index

Bit	Bit Value	Cumulative Sum	Attribute
0	1	1	Fill
1	2	3	Clear
2	4	7	Water
3	8	15	Cloud Shadow
4	16	31	Snow
5	32	63	Cloud
6	64	127	Cloud Confidence 00 = None 01 = Low 10 = Medium 11 = High
7	128	255	
8	256	511	Cirrus Confidence 00 = Not set 01 = low from OLI band 9 reflectance 10 = medium from OLI band 9 reflectance 11 = high from OLI band 9 reflectance
9	512	1023	
10	1024	2047	Terrain Occlusion
11	2048	4095	Unused
12	4096	8191	Unused
13	8192	16383	Unused
14	16384	32767	Unused
15	32786	65553	Unused

Table 7-3 Landsat 8 Pixel Quality Attributes (pixel_qa) Values

Attribute	Pixel Value
Fill	1
Clear	322, 386, 834, 898, 1346
Water	324, 388, 836, 900, 1348
Cloud shadow	328, 392, 840, 904, 1350
Snow/ice	336, 368, 400, 432, 848, 880, 912, 944, 1352
Cloud	352, 368, 416, 432, 480, 864, 880, 928, 944, 992
Low confidence cloud	322, 324, 328, 336, 352, 368, 834, 836, 840, 848, 864, 880
Medium confidence cloud	386, 388, 392, 400, 416, 432, 898, 900, 904, 928, 944
High confidence cloud	480, 992
Low confidence cirrus	322, 324, 328, 336, 352, 368, 386, 388, 392, 400, 416, 432, 480
High confidence cirrus	834, 836, 840, 848, 864, 880, 898, 900, 904, 912, 928, 944, 992
Terrain occlusion	1346, 1348, 1350, 1352

Table 7-4 Landsat 8 Pixel Quality Attributes (pixel_qa) Value Interpretations

Pixel Value	Fill	Clear	Water	Cloud Shadow	Snow	Cloud	Cloud Confidence	Cirrus Confidence	Terrain Occlusion	Pixel Description
1	Yes	No	No	No	No	No	None	None	No	Fill value
322	No	Yes	No	No	No	No	Low	Low	No	Clear terrain, low-confidence cloud, low-confidence cirrus
324	No	No	Yes	No	No	No	Low	Low	No	Water, low-confidence cloud, low-confidence cirrus
328	No	No	No	Yes	No	No	Low	Low	No	Cloud shadow, low-confidence cloud, low-confidence cirrus
336	No	No	No	No	Yes	No	Low	Low	No	Snow/ice, low-confidence cloud, low-confidence cirrus
352	No	No	No	No	No	Yes	Low	Low	No	Cloud, low-confidence cloud, low-confidence cirrus
368	No	No	No	No	Yes	Yes	Low	Low	No	Snow/ice, cloud, low-confidence cloud, low confidence cirrus
386	No	Yes	No	No	No	No	Medium	Low	No	Clear terrain, medium-confidence cloud, low-confidence cirrus
388	No	No	Yes	No	No	No	Medium	Low	No	Water, medium-confidence cloud, low-confidence cirrus
392	No	No	No	Yes	No	No	Medium	Low	No	Cloud shadow, medium-confidence cloud, low-confidence cirrus

400	No	No	No	No	Yes	No	Medium	Low	No	Snow/ice, medium-confidence cloud, low-confidence cirrus
416	No	No	No	No	No	Yes	Medium	Low	No	Cloud, medium-confidence cloud, low-confidence cirrus
432	No	No	No	No	Yes	Yes	Medium	Low	No	Snow/ice, cloud, medium-confidence cloud, low-confidence cirrus
480	No	No	No	No	No	Yes	High	Low	No	Cloud, high-confidence cloud, low-confidence cirrus
834	No	Yes	No	No	No	No	Low	High	No	Clear terrain, low-confidence cloud, high-confidence cirrus
836	No	No	Yes	No	No	No	Low	High	No	Water, low-confidence cloud, high-confidence cirrus
840	No	No	No	Yes	No	No	Low	High	No	Cloud shadow, low-confidence cloud, high-confidence cirrus
848	No	No	No	No	Yes	No	Low	High	No	Snow/ice, low-confidence cloud, high-confidence cirrus
864	No	No	No	No	No	Yes	Low	High	No	Cloud, low-confidence cloud, high-confidence cirrus
880	No	No	No	No	Yes	Yes	Low	High	No	Cloud, snow/ice, low conf. cloud, high conf. cirrus
898	No	Yes	No	No	No	No	Medium	High	No	Clear terrain, medium-confidence cloud, high-

										confidence cirrus
900	No	No	Yes	No	No	No	Medium	High	No	Water, medium-confidence cloud, high-confidence cirrus
904	No	No	No	Yes	No	No	Medium	High	No	Cloud shadow, medium-confidence cloud, high-confidence cirrus
912	No	No	No	No	Yes	No	Medium	High	No	Snow/ice, medium-confidence cloud, high-confidence cirrus
928	No	No	No	No	No	Yes	Medium	High	No	Cloud, medium-confidence cloud, high-confidence cirrus
944	No	No	No	No	Yes	Yes	Medium	High	No	Cloud, snow/ice, medium conf. cloud, high conf. cirrus
992	No	No	No	No	No	Yes	High	High	No	Cloud, high-confidence cloud, high-confidence cirrus
1346	No	Yes	No	No	No	No	Low	Low	Yes	Clear terrain, terrain occluded
1348	No	No	Yes	No	No	No	Low	Low	Yes	Water, terrain occluded
1350	No	No	No	Yes	No	No	Low	Low	Yes	Cloud shadow, terrain occluded
1352	No	No	No	No	Yes	No	Low	Low	Yes	Snow/ice, terrain occluded

7.1.1 Radiometric Saturation Band

The Radiometric Saturation Quality (radsat_qa) band is a bit packed representation of which sensor bands were saturated during data capture, yielding unusable data. The table below displays the interpretation of possible pixel values expected in the radsat_qa band after its bits are unpacked. For example, a pixel value of 1024 indicates that TIRS Band 10 is saturated.

Saturation in Landsat 8 is not common. When saturation does occur, it happens over impervious surfaces in the optical bands, or volcanoes and wildland fires in the SWIR and thermal bands. Saturation can be found in two forms: one, saturated pixels can show as the maximum unsigned 16-bit value of 65535; or two, pixel values can "roll over" to the low end of the valid range (not necessarily just a value of 0), which is called oversaturation. Oversaturation will not occur with the TIRS thermal bands. The L8 radsat_qa band will flag only the saturation cases. **Table 7-5** describes the bit assignments for the radsat_qa band.

Table 7-5 Landsat 8 Radiometric Saturation Quality Attributes (radsat_qa) Bit Index

Bit	Bit Value	Cumulative Sum	Description
Bits are numbered from right to left (bit 1 = LSB, bit 11 = MSB)			
0	1	1	Data Fill Flag (0 valid data, 1 invalid data)
1	2	3	Band 1 Data Saturation Flag (0 valid data, 1 saturated data)
2	4	7	Band 2 Data Saturation Flag (0 valid data, 1 saturated data)
3	8	15	Band 3 Data Saturation Flag (0 valid data, 1 saturated data)
4	16	31	Band 4 Data Saturation Flag (0 valid data, 1 saturated data)
5	32	63	Band 5 Data Saturation Flag (0 valid data, 1 saturated data)
6	64	127	Band 6 Data Saturation Flag (0 valid data, 1 saturated data)
7	128	255	Band 7 Data Saturation Flag (0 valid data, 1 saturated data)
8	N/A	N/A	Not used
9	512	1023	Band 9 Data Saturation Flag (0 valid data, 1 saturated data)
10	1024	2047	Band 10 Data Saturation Flag (0 valid data, 1 saturated data)
11	2048	4095	Band 11 Data Saturation Flag (0 valid data, 1 saturated data)

7.1.2 Aerosol QA Band

Aerosol retrieval is a critical component in the atmospheric correction calculations used in generating Surface Reflectance for Landsat 8. The Internal Surface Reflectance Aerosol Quality (sr_aerosol) band output with the Surface Reflectance product describes that parameter to provide low-level detail about the factors that may have influenced the final product result (**Table 7-6**). The sr_aerosol bit values are given in **Table 7-7**, and shown in greater detail in **Table 7-8**.

Table 7-6 Landsat 8 Internal Surface Reflectance Aerosol Quality (sr_aerosol) Bit Index

Bit	Bit Value	Cumulative Sum	Attribute
0	1	1	Fill
1	2	3	Valid Aerosol Retrieval (center pixel of 3x3 pixel window)
2	4	7	Water Pixel (or water pixel was used in the fill-the-window interpolation)
3	8	15	Cloud or Cirrus
4	16	31	Cloud Shadow
5	32	63	Non-center window pixel for which aerosol was interpolated from surrounding 3x3 window center pixels
6	64	127	Aerosol Level 00 = Climatology 01 = Low 10 = Medium 11 = High
7	128	255	

Note that pixels classified as high aerosol content are not recommended for use.

Table 7-7 Landsat 8 sr_aerosol Values

Attribute	Pixel Value
Fill	1
Valid Aerosol Retrieval (center pixel of 3x3 window)	2, 66, 130, 194
Water Pixel (or water pixel was used in the fill-the-window interpolation)	4, 68, 100, 132, 164, 196, 228
Cloud or Cirrus	8, 72, 136, 200
Cloud Shadow	16, 80, 144, 208
Non-center window pixel for which aerosol was interpolated from surrounding 3x3 center pixels	32, 96, 100, 160, 164, 224, 228
Low-level aerosol	66, 68, 72, 80, 96, 100
Medium-level aerosol	130, 132, 136, 144, 160, 164
High-level aerosol	194, 196, 200, 208, 224, 228

Table 7-8 Landsat 8 sr_aerosol Bit Values

Pixel Value	Fill	Aerosol Retrieval – Valid (center of 3x3 window)	Water	Cloud/ Cirrus	Cloud Shadow	Aerosol Retrieval – Interpolated (non-center of 3x3 window)	Aerosol	Pixel Description
1	Yes	No	No	No	No	No	N/A	Fill
2	No	Yes	No	No	No	No	Climatology	Valid aerosol retrieval
4	No	No	Yes	No	No	No	Climatology	Water
8	No	No	No	Yes	No	No	Climatology	Cloud/cirrus
16	No	No	No	No	Yes	No	Climatology	Cloud shadow
32	No	No	No	No	No	Yes	Climatology	Aerosol interpolated
66	No	Yes	No	No	No	No	Low	Valid aerosol ret., low aerosol
68	No	No	Yes	No	No	No	Low	Water, low aerosol
72	No	No	No	Yes	No	No	Low	Cloud/cirrus, low aerosol
80	No	No	No	No	Yes	No	Low	Cloud shadow, low aerosol
96	No	No	No	No	No	Yes	Low	Aerosol interpolated, low aerosol
100	No	No	Yes	No	No	Yes	Low	Water pixel used in interpolation, aerosol interpolated, low aerosol
130	No	Yes	No	No	No	No	Medium	Valid aerosol retrieval, medium aerosol
132	No	No	Yes	No	No	No	Medium	Water, medium aerosol
136	No	No	No	Yes	No	No	Medium	Cloud/cirrus, medium aerosol
144	No	No	No	No	Yes	No	Medium	Cloud shadow, medium aerosol
160	No	No	No	No	No	Yes	Medium	Aerosol interpolated, medium aerosol

164	No	No	Yes	No	No	Yes	Medium	Water pixel used in interpolation, aerosol interpolated, medium aerosol
194	No	Yes	No	No	No	No	High	Valid aerosol retrieval, high aerosol
196	No	No	Yes	No	No	No	High	Water, high aerosol
200	No	No	No	Yes	No	No	High	Cloud/cirrus, high aerosol
208	No	No	No	No	Yes	No	High	Cloud shadow, high aerosol
224	No	No	No	No	No	Yes	High	Aerosol interpolated, high aerosol
228	No	No	Yes	No	No	Yes	High	Water pixel used in interpolation, aerosol interpolated, high aerosol

7.1.3 Surface Reflectance Metadata

Each Landsat 8 Surface Reflectance order will be accompanied by an xml-based metadata file. The metadata fields included in the xml are listed in **Appendix B Metadata Field**.

7.1.4 Surface Reflectance Special Notes

Metadata are included to help define the orientation of Polar Stereographic scenes acquired in ascending orbit over Antarctica. Whether on a descending or ascending orbit path, the first pixels acquired in a Landsat scene comprise the upper portion of an image. As Landsat crosses the southern polar region, it views the southern latitudes first and progresses north. This places pixels in southern latitudes in the upper part of the image so that it appears to the user that south is up and north is down. The <corner> field in the metadata xml clarifies the upper left and lower right corners of the scene.

7.2 Cloud and Cloud Shadow Specifications

The Level-2 Pixel Quality Assurance band (pixel_qa; **Table 7-2**) is populated using information from the Level-1 Quality Assurance band, specifically Cloud Confidence, Cloud Shadow and Snow/Ice flags derived from the CFMask algorithm. In order to support science data products using Level-2 as input, water values are re-calculated, and high-confidence cloud pixels are dilated, making pixel_qa comparable to the legacy CFMask bands.

Note: the legacy CFMask and CFMask confidence bands are still orderable through the ESPA interface as a separate option (discontinued **02 June 2017**), though the same information is available in the default pixel_qa band.

The algorithm underlying bqa and pixel_qa bands, CFMask, was originally developed at Boston University in a Matrix Laboratory (MATLAB) environment to automate cloud, cloud shadow, and snow masking for Landsat TM and ETM+ images. The MATLAB Function of Mask (Fmask) was subsequently translated into open source C code at the USGS EROS Center, where it is implemented as the C version of Fmask, or CFMask (https://github.com/USGS-EROS/espa-cloud-masking).

7.2.1 CFMask Algorithm Known Issues

1. The cloud indicators in the sr_cloud_qa and CFMask algorithms are known to report erroneous cloud conditions when temperature differentials are either too large or too small. For example, a warm cloud over extremely cold ground may not calculate enough difference in temperature to identify the cloud. Conversely, residual ice surrounded by unusually warm ground can potentially be identified as cloud.
2. CFMask may have issues over-including bright targets such as building tops, beaches, snow/ice, sand dunes and/or salt lakes.
3. Optically thin clouds will always be challenging to identify, and have a chance of being omitted by CFMask.

7.3 Top of Atmosphere Reflectance & Top of Atmosphere Brightness Temperature Specifications

7.3.1 Top of Atmosphere Reflectance - Bands 1–7, 9 Specifications

Calibration coefficients are applied to Landsat digital numbers to derive the TOA Reflectance component, using per-pixel solar angles derived from band 4 (closest to center of focal plane.) All files appended with "_toa_" are related to TOA Reflectance. The "_toa_" packages contain TOA Reflectance and bit-packed quality information for Landsat Bands 1, 2, 3, 4, 5, 6, 7, and 9. The associated header and metadata files present the same kind of information as described for Surface Reflectance, but these are specific to TOA Reflectance processing. Valid data ranges for TOA Reflectance bands are similar to those for Surface Reflectance, but with a higher minimum value. Note: TOA Reflectance is not processed for thermal Bands 10 and 11, but can be ordered separately as TOA Brightness Temperature (**Section 7.3.2**).

The pixel_qa and radsat_qa bands are delivered with all TOA Reflectance products.

Table 7-9 lists the data type, units, value range, fill value, saturation value, and scale factor for the TOA Reflectance product bands.

Table 7-9 Top of Atmosphere Reflectance – Bands 1-7, 9 Specifications

INT16 16-bit signed integer, UINT8 8-bit unsigned integer, TOA top of atmosphere, QA quality assurance, NA not applicable

Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
toa_band1	Band 1 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band2	Band 2 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band3	Band 3 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band4	Band 4 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band5	Band 5 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band6	Band 6 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band7	Band 7 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band9	Band 9 Reflectance	INT16	Reflectance	-100 – 16000	0 – 10000	-9999	20000	0.0001
pixel_qa	Level-2 Pixel Quality Band	UINT16	Bit Index	0-32768	0-32768	1 (bit 0)	NA	NA
radsat_qa	Radiometric Saturation Band	UINT16	Bit Index	0-32768	0-3839	1 (bit 0)	NA	NA
solar_azimuth_band4	Solar Azimuth Angles Band 4	INT16	Degrees	-32768 - 32767	-18000 - 18000	-32768	NA	0.0100
solar_zenith_band4	Solar Zenith Angles Band 4	INT16	Degrees	-32768 - 32767	0 – 9000	-32768	NA	0.0100
sensor_zenith_band4	Sensor Azimuth Angles Band 4	INT16	Degrees	-32768 - 32767	0 - 9000	-32768	NA	0.0100
sensor_azimuth_band4	Sensor Zenith Angles Band 4	INT16	Degrees	-32768 - 32767	-18000 - 18000	-32768	NA	0.0100

7.3.2 Top of Atmosphere Brightness Temperature - Bands 10–11 Specifications

Bands 10–11 TOA Brightness Temperature is derived from TOA radiance and two thermal constants, as described at https://landsat.usgs.gov/using-usgs-landsat-8-product. The associated header and metadata files present the same kind of information as described for Surface Reflectance, but they are specific to TOA Brightness Temperature processing. Specifications for TOA Brightness Temperature bands are similar to those for Surface Reflectance, but with a higher minimum value. **Table 7-10** lists the data type, units, value range, fill value, saturation value, and scale factor for the TOA Brightness Temperature product bands.

Table 7-10 Top of Atmosphere Brightness Temperature – Bands 10–11 Specifications

INT16 16-bit signed integer, UINT8 8-bit unsigned integer, TOA top of atmosphere, QA quality assurance, NA not applicable

Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
bt_band10	Band 10 TOA Brightness Temperature	INT16	Brightness Temperature (Kelvin)	-100 - 16000	0-10000	-9999	20000	0.1
bt_band11	Band 11 TOA Brightness Temperature	INT16	Brightness Temperature (Kelvin)	-100 - 16000	0-10000	-9999	20000	0.1
pixel_qa	Level-2 Pixel Quality Band	UINT16	Bit Index	0-32768	0-32768	1 (bit 0)	NA	NA
radsat_qa	Radiometric Saturation Band	UINT16	Bit Index	0-32768	0-3839	1 (bit 0)	NA	NA
solar_azimuth_band4	Solar Azimuth Angles Band 4	INT16	Degrees	-32768 - 32767	-18000 - 18000	-32768	NA	0.0100
solar_zenith_band4	Solar Zenith Angles Band 4	INT16	Degrees	-32768 - 32767	0 – 9000	-32768	NA	0.0100
sensor_zenith_band4	Sensor Azimuth Angles Band 4	INT16	Degrees	-32768 - 32767	0 - 9000	-32768	NA	0.0100
sensor_azimuth_band4	Sensor Zenith Angles Band 4	INT16	Degrees	-32768 - 32767	-18000 - 18000	-32768	NA	0.0100

7.3.3 TOA Reflectance Special Notes

Metadata are included to help define the orientation of Polar Stereographic scenes acquired in ascending orbit over Antarctica. Whether on a descending or ascending orbit path, the first pixels acquired in a Landsat scene comprise the upper portion of an image. As Landsat crosses the southern polar region, it views the southern latitudes first and progresses north. This places pixels in southern latitudes in the upper part of the image so that it appears to the user that south is up and north is down. The <corner> field in the metadata xml clarifies the upper left and lower right corners of the scene.

Section 8 Ancillary Data

The atmosphere between the satellite and the Earth's surface is composed of different gases that potentially absorb and/or scatter both incoming and reflected sunlight. These gases are primarily aerosols, water vapor and ozone, all of which are partially modulated by the local air temperature. The Landsat instruments do not contain on-board sensors to measure these conditions, so this information is obtained through other observations, known as ancillary data. For LaSRC, ancillary data are assimilated from satellite observations from the MODIS instruments aboard the Terra and Aqua satellites. Both spatial and temporal interpolations are performed to fit this ancillary data within the ground area imaged and time of the Landsat image acquisition. This information is derived from multiple data sources, which have their own unique properties, as described in **Table 8-1**.

Missing data range(s) are periodically updated in this guide; the most up-to-date information regarding data gaps is in the "Caveats and Constraints" section of https://landsat.usgs.gov/landsat-surface-reflectance-data-products.

Table 8-1 Ancillary Data for LaSRC

AOT Aerosol Optical Thickness, MODIS Moderate Resolution Imaging Spectroradiometer, MOD MODIS Terra, MYD Modis Aqua

Data	Product	Source	Version	Instrument	Grid Resolution	Date Begin	Date End	Backup	Backup Begin	Backup End	Missing Range(s)	Additional Missing Data & Date(s)
Ozone	MOD/ MYD09 CMG	ftp://ladssci.nascom.nasa.gov/	v006	Terra & Aqua	0.05° x 0.05°	5/4/2002	Present	N/A	N/A	N/A	2/19/2016 – 2/27/2016; 8/11/2016 – 8/13/2016	N/A
Air Temperature	MOD/ MYD09 CMA											
Water Vapor	MOD/ MYD09 CMA											
AOT (550 nm)	MOD/ MYD09 CMA											

Section 9 Citation Information

There are no restrictions on the use of Landsat Science Products. It is not a requirement of data use, but the following citation may be used in publication or presentation materials to acknowledge the USGS as a data source and to credit the original research.

Landsat Surface Reflectance products courtesy of the U.S. Geological Survey.

Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment. http://dx.doi.org/10.1016/j.rse.2016.04.008.

Reprints or citations of papers or oral presentations based on USGS data are welcome to help the USGS stay informed of how data are being used. These can be sent to the User Services address included in this guide.

Section 10 Acknowledgments

The original Landsat 8 Surface Reflectance Code (LaSRC) algorithm was developed by Dr. Eric Vermote, NASA Goddard Space Flight Center (GSFC).

Section 11 User Services

Landsat Science Products and associated interfaces are supported by User Services staff at USGS EROS. Any questions or comments regarding data products or interfaces are welcomed through the Landsat “Contact Us” online correspondence form: https://landsat.usgs.gov/contact. E-mail can also be sent to the customer service address included below, with the same indication of topic.

USGS User Services
https://landsat.usgs.gov/contact
custserv@usgs.gov

User support is available Monday through Friday from 8:00 a.m. – 4:00 p.m. Central Time. Inquiries received outside of these hours will be addressed during the next business day.

Section 12 References

Campbell, J. W., and Aarup, T. (1989). Photosynthetically available radiation at high latitudes. *Limnology and Oceanography* 34(8):1490- 1499. http://dx.doi.org/10.4319/lo.1989.34.8.1490.

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Zhu, Z., and Woodcock, C. E. (2012). Object-based cloud and cloud shadow detection in Landsat imagery, *Remote Sensing of Environment* 118:83-94. http://dx.doi.org/10.1016/j.rse.2011.10.028.

Zhu, Z., Wang, S., and Woodcock, C. E. (2015). Improvement and expansion of the Fmask algorithm: cloud, cloud shadow, and snow detection for Landsats 4–7, 8, and Sentinel 2 images. *Remote Sensing of Environment* 159:269-277. http://dx.doi.org/10.1016/j.rse.2014.12.014.

Appendix A Default File Characteristics

Table 0-1 Collection 1 Default File Characteristics

Description	Example File Size (bytes)	Example File Name
Source Bands (11)	126,491,737	LC08_L1TP_043031_20130628_20170101_01_T1_B*.tif
Source Band QA	126,491,737	LC08_L1TP_043031_20130628_20170101_01_T1_BQA.tif
Source Metadata	7,791	LC08_L1TP_043031_20130628_20170101_01_T1_MTL.txt
TOA Reflectance Bands (8)	126,491,785	LC08_L1TP_043031_20130628_20170101_01_T1_toa_band*.tif
TOA Brightness Temperature Bands (2)	126,491,785	LC08_L1TP_043031_20130628_20170101_01_T1_toa_band*.tif
Surface Reflectance Bands (7)	126,491,751	LC08_L1TP_043031_20130628_20170101_01_T1_sr_band*.tif
Surface Reflectance Aerosol QA Band (1)	63,278,592	LC08_L1TP_043031_20130628_20170101_01_T1_sr_aerosol.tif
Level-2 Pixel QA (1)	63,278,592	LC08_L1TP_043031_20130628_20170101_01_T1_pixel_qa.tif
Radiometric Saturation Band (1)	63,278,592	LC08_L1TP_043031_20130628_20170101_01_T1_radsat_qa.tif
Metadata	23,532	LC08_L1TP_043031_20130628_20170101_01_T1.xml

Appendix B Metadata Field

Example of global XML metadata:

<global_metadata>
<data_provider>USGS/EROS</data_provider>
<satellite>LANDSAT_8</satellite>
<instrument>OLI_TIRS</instrument>
<acquisition_date>2013-06-28</acquisition_date>
<scene_center_time>18:40:39.8204854Z</scene_center_time>
<level1_production_date>2017-01-01T15:01:34Z</level1_production_date>
<solar_angles zenith="24.733788" azimuth="131.660614" units="degrees"/>
<wrs system="2" path="43" row="31"/>
<lpgs_metadata_file> LC08_L1TP_043031_20130628_20170101_01_T1_MTL.txt</lpgs_metadata_file>
<corner location="UL" latitude="42.801350" longitude="-120.700400"/>
<corner location="LR" latitude="40.691440" longitude="-117.783500"/>
<bounding_coordinates>
<west>-120.700594</west>
<east>-117.783319</east>
<north>42.858456</north>
<south>40.638480</south>
</bounding_coordinates>
<projection_information projection="UTM" datum="WGS84" units="meters">
<corner_point location="UL" x="197400.000000" y="4745400.000000"/>
<corner_point location="LR" x="433800.000000" y="4504800.000000"/>
<grid_origin>CENTER</grid_origin>
<utm_proj_params>
<zone_code>11</zone_code>
</utm_proj_params>
</projection_information>
<orientation_angle>0.000000</orientation_angle>
</global_metadata>

Example of per-band XML metadata:

<band product="sr_refl" name="sr_band1" category="image" data_type="INT16" nlines="8021"
nsamps="7881" fill_value="-9999" scale_factor="0.000100">
<short_name>LC8SR</short_name>
<long_name>band 1 surface reflectance</long_name>
<file_name> LC08_L1TP_043031_20130628_20170101_01_T1_sr_band1.tif</file_name>
<pixel_size x="30" y="30" units="meters"/>
<data_units>reflectance</data_units>
<valid_range min="-2000" max="16000"/>
<app_version>l8_surface_reflectance_0.1.0</app_version>
<production_date>2017-02-22T15:42:29Z</production_date>
</band>

Appendix C Acronyms

Acronym	Description
6S	Second Simulation of a Satellite Signal in the Solar Spectrum
CFMask	C version of Function of Mask (USGS EROS)
CMA	Climate Modeling Grid - Aerosols
CMG	Climate Modeling Grid - Ozone
CSV	Comma Separated Values
DDV	Dark Dense Vegetation
DIR	Directory
ENVI	Exelis Visual Information Solutions
EROS	Earth Resources Observation and Science
ESPA	EROS Science Processing Architecture
ETM+	Enhanced Thematic Mapper Plus
EVI	Enhanced Vegetation Index
Fmask	Function of Mask (Boston University)
GeoTIFF	Geographic Tagged Image File Format
GSFC	Goddard Space Flight Center
HDF-EOS2	Hierarchical Data Format – Earth Observing System (version 2)
HDR	Header
INT	Signed Integer
LaSRC	Landsat Surface Reflectance Code
LDOPE	Land Data Operational Product Evaluation
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LPGS	Landsat Product Generation System
LSB	Least Significant Bit
MATLAB	Matrix Laboratory
M	meter
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MOD	MODIS Terra
MODIS	Moderate Resolution Imaging Spectroradiometer
MSAVI	Modified Soil Adjusted Vegetation Index
MSB	Most Significant Bit
MYD	MODIS Aqua
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NBR	Normalized Burn Ratio
NBR2	Normalized Burn Ratio 2
NC	NetCDF File Format
NCEP	National Centers for Environmental Prediction
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index

OLI	Operational Land Imager
OMI	Ozone Monitoring Instrument
PS	Polar Stereographic
QA	Quality Assurance
SAVI	Soil Adjusted Vegetation Index
SLC	Scan Line Corrector
SR	Surface Reflectance
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TOA	Top of Atmosphere
TOMS	Total Ozone Mapping Spectrometer
UINT	Unsigned Integer
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WRS	Worldwide Reference System
xml	Extensible Markup Language