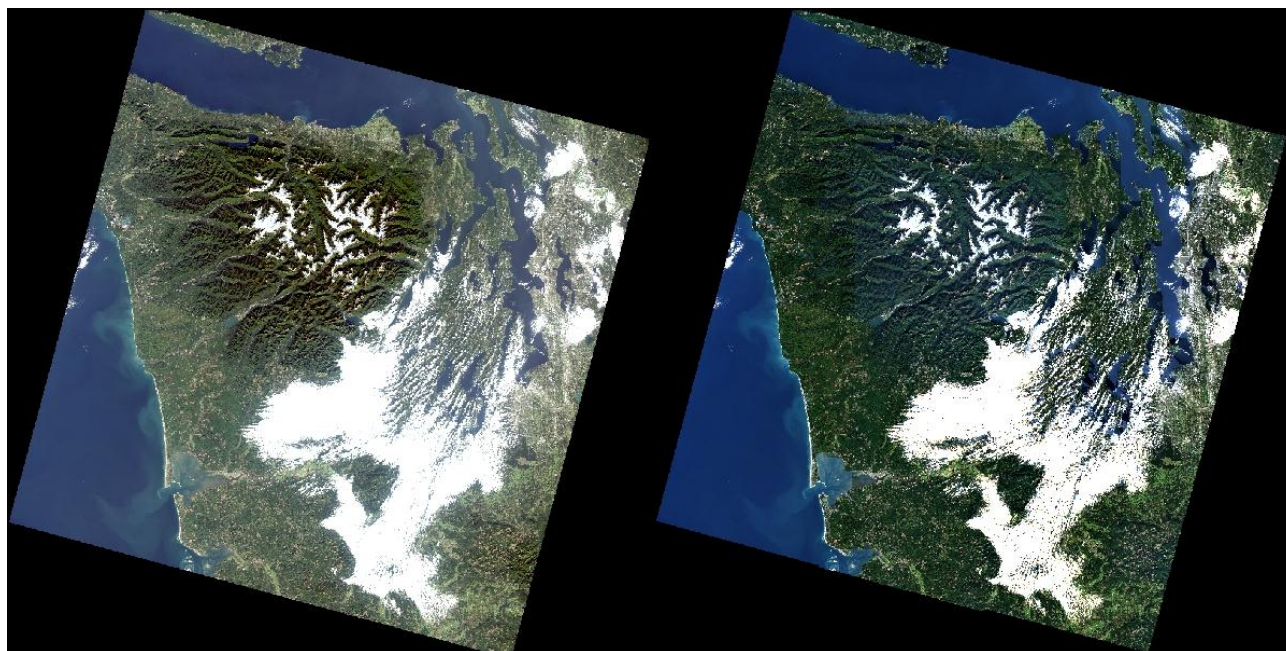


Department of the Interior
U.S. Geological Survey

PRODUCT GUIDE

PROVISIONAL LANDSAT 8 SURFACE REFLECTANCE PRODUCT



Version 1.7

September 2015



Executive Summary

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

This document describes Top of Atmosphere Reflectance and Brightness Temperature derived from Landsat 8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Surface Reflectance can be derived only for OLI data. 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.

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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 higher level Landsat data 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 high-level 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 Provisional Landsat 8 Surface Reflectance product is generated from specialized software called L8SR. This algorithm 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 are described below in **Table 1-A**. Please remember that L8SR is provisional software, and the values are subject to change.

Table 1-A 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, 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 (L8SR)
(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	MODIS CMA

	absorption and bound water absorption of scene	
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	N/A	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	CFmask	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

Section 2 Known Issues

2.1 Surface Reflectance Artifacts

There are persistent artifacts within the Surface Reflectance product, particularly near feature transitions such as cloud (**Figure 2-1**), and high topography variation (**Figure 2-2**). The artifacts are visible as squares in such boundary areas. Aerosol retrieval is not performed over water, but there were issues masking land from water within the algorithm, resulting in artifacts. This has largely been corrected along coastal boundaries in the May 2015 release of L8SR in ESPA, as shown in **Figure 2-3**. Please note that inland water bodies are currently not identified or flagged by the algorithm. Please see http://landsat.usgs.gov/documents/l8sr_release_notes.pdf for more information pertaining to the algorithm updates. Other unknown issues regarding the aerosol retrieval methods for atmospheric correction are under investigation.

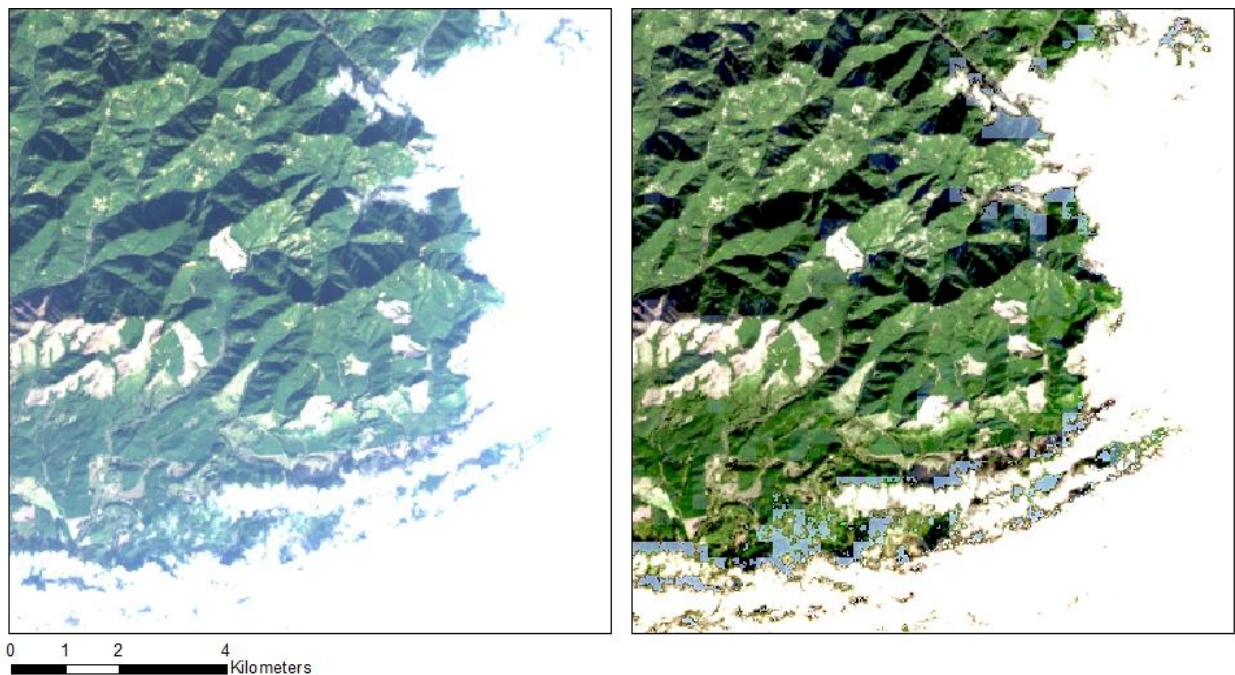


Figure 2-1 Landsat 8 Level 1 product (left) and Landsat 8 Provisional Surface Reflectance product (right) illustrating Surface Reflectance artifacts occurring along cloud edges.

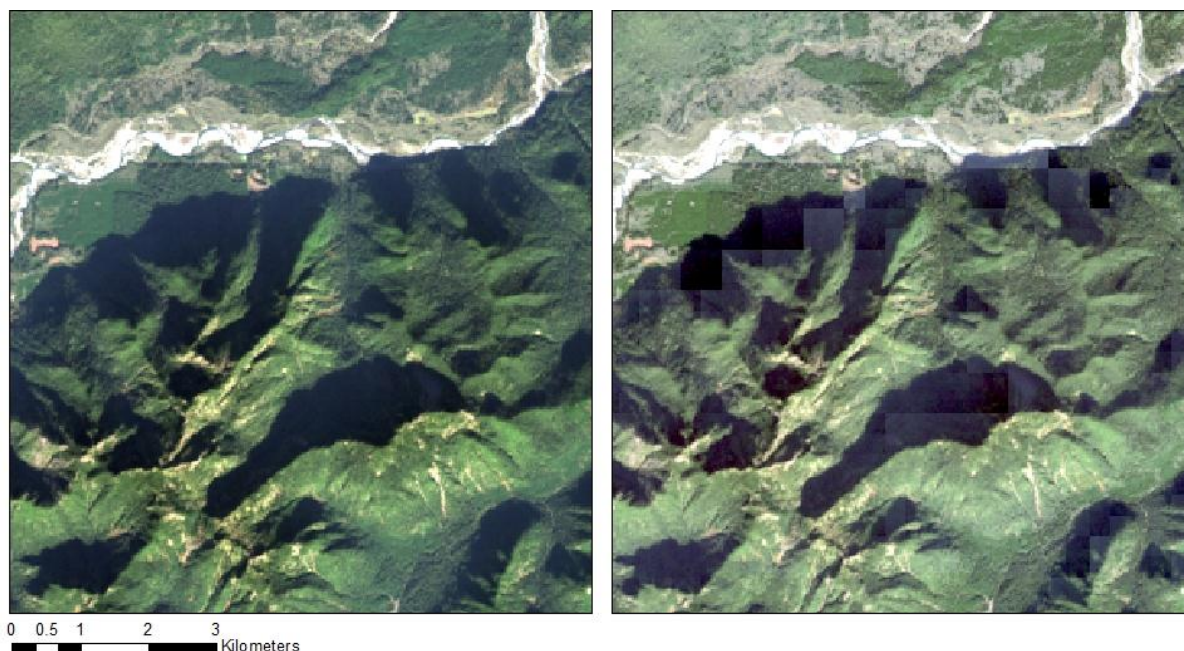


Figure 2-2 Landsat 8 Level 1 product (left) and Landsat 8 Provisional Surface Reflectance product (right) illustrating Surface Reflectance artifacts occurring along areas of high topography variation.



Figure 2-3 Landsat 8 Provisional Surface Reflectance version 0.2.0 (left) and Landsat 8 Provisional Surface Reflectance product version 0.3.0 (right) illustrating the reduction of Surface Reflectance artifacts along coastal land-water boundaries.

Section 3 Caveats and Constraints

1. The Landsat 8 Surface Reflectance product has not been completely validated; the algorithm and subsequent output products are provisional.
2. 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 http://landsat.usgs.gov/L8_Pre_WRS2.php.
3. 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) or TIRS only (LT8) data products cannot be calculated to SR.
4. SR is not run on scenes with a solar zenith angle of greater than 76 degrees. 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>.
5. Users are cautioned against processing data acquired over high latitudes (> 65°) to Surface Reflectance.
6. Users are cautioned against using pixels flagged as high aerosol content. See **Table 7-C** for details.
7. Efficacy of L8SR correction will be likely reduced in areas where atmospheric correction is affected by adverse conditions:
 - 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.

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. Brightness Temperature (calculated from at-sensor radiances to calculate the corresponding TOA Brightness Temperature, or simply referred to as “Brightness Temperature”. 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, which contains:

- Level-1 data files (Bands 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11)
- Quality Assessment (QA) Band file
<http://landsat.usgs.gov/L8QualityAssessmentBand.php>
- Metadata text file

Filenames utilize the original scene identifier (sceneID), for example, “LC80270332014310LGN00_*.” Product details are found at <http://landsat.usgs.gov/landsat8.php>.

4.2 Original Input Metadata

The Original Input Landsat 8 metadata 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 quality files
- TOA Reflectance metadata files
- Readme file

Filenames utilize the original sceneID followed by “_toa_,” for example, “LC80180602014247LGN00_toa_*. ”

4.4 Brightness Temperature

This option delivers the Top of Atmosphere Brightness Temperature product (Bands 10 and 11), which are converted to Kelvin. Brightness Temperature output from Landsat 8 contains:

- Brightness Temperature data files (Bands 10–11)
- Brightness Temperature quality file
- Brightness Temperature header file

Filenames utilize the original sceneID followed by “_toa_,” for example, “LC81710612014183LGN00_toa_*.”

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)
- Cloud QA band (see **Section 7.1.1** for more details)
- Cloud mask (CFmask) band (see **Section 7.1.2** for more details)
- CFmask cloud confidence band (see **Section 7.1.3** for more details)
- Surface Reflectance algorithm quality files
- Surface Reflectance metadata files
- Readme file

Filenames utilize the original sceneID followed by “_sr_,” for example, “LC82330132014265LGN00_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

Provisional Landsat 8 Surface Reflectance data products are available through [EarthExplorer](#), under the “Data Sets” tab as “Landsat CDR/ECV.”

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. ESPA is accessible at <http://espa.cr.usgs.gov/>. Services such as reprojection, spatial subsetting, and pixel resizing are also available through ESPA. 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 file:

LXXPPPRRRYYYYDDDSTNVR_prod_band.ext

(e.g., LC80120542014301LGN00_sr_band1.tif)

LXX LC8 for Landsat 8 OLI and TIRS

PPP Path

RRR Row

YYYY Year of Acquisition

DDD Julian Date of Acquisition

STN Receiving Station

VR Version Number

prod Product, such as “toa” or “sr”

band Band, such as “band<1-8, 10-11>,” “qa,” or spectral index.

ext File format extension, such as “tif,” “tfw,” “xml,” “hdf,” “hdr,” or “img”

Section 7 Product Characteristics

Original Input Products and Original Input Metadata are described on http://landsat.usgs.gov/Landsat_Processing_Details.php. The characteristics of Surface Reflectance, TOA Reflectance, and 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) and 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 original sceneID 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 Cloud QA Band, which is delivered in a single bit-packed layer.

Table 7-A lists the specifications for the bands included in a Surface Reflectance data file.

Table 7-A 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
sr_cloud	Cloud QA	UINT8	Flag	0-7	0-7	NA	NA	NA
sr_cfmask	CFmask	UNIT8	Flag	0-255	0-4	255	NA	NA
sr_cfmask_conf	CFmask Cloud Confidence	UINT8	Flag	0-255	0-4	255	NA	NA

7.1.1 Cloud QA Specifications

The Landsat 8 Surface Reflectance product includes the “sr_cloud” band. This product details the presence of clouds and levels of aerosols and is used to determine the level of surface reflectance correction to apply to each pixel. The interpretation of each bit as shown in the XML metadata file is described in **Table 7-B**.

Three interpreted bit values within this band indicate the level of aerosols and subsequent surface reflectance correction applied to each pixel. **Table 7-C** shows the values and levels found within the “sr_cloud” band.

Table 7-B Cloud QA Bit Values

Bit	Interpretation
0	Cirrus cloud
1	Cloud
2	Adjacent to cloud
3	Cloud shadow
4	Aerosol
5	Aerosol
6	Unused
7	Internal test

Table 7-C Cloud QA Interpreted for Aerosol QA Bits 4-5

Value	Interpretation
00	Climatology-level aerosol content
01	Low aerosol content
10	Average aerosol content
11	High aerosol content

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

7.1.2 CFmask Specifications

The Landsat 8 Surface Reflectance product includes an alternative to cloud, cloud shadow, snow, and water identification, and is likely to present more accurate results than its companion bands (cloud_qa). The “cfmask” band 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://code.google.com/p/cfmask/>).

CFmask designates whether clouds, cloud shadows, snow, or water were identified in each pixel in the Surface Reflectance product, as described by Error! Reference source not found..

Table 7-D CFmask Pixel Values

CFmask C version of Function of Mask

Pixel Value	Interpretation
255	Fill
0	Clear
1	Water
2	Shadow
3	Snow
4	Cloud

7.1.3 CFmask Cloud Confidence Band

A confidence band for the cloud detection portion of CFmask is provided with the Landsat 8 Surface Reflectance product. The output of this band are considered provisional, as the confidence thresholds are subject to change. **Table 7-E** describes each value within the CFmask Confidence Band.

Table 7-E CFmask Cloud Confidence Band Values

Pixel Value	Interpretation
255	Fill
0	None
1	<= 12.5% cloud confidence
2	> 12.5% and <= 22.5% cloud confidence
3	> 22.5% cloud confidence

7.1.4 Surface Reflectance Metadata

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

7.1.5 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 Top of Atmosphere Reflectance Specifications

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

Calibration coefficients are applied to Landsat digital numbers to derive the TOA Reflectance component, using scene center solar angles in the computation. 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 Brightness Temperature (**Section 7.2.2**).

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

Table 7-F 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

7.2.2 Brightness Temperature - Bands 10–11 Specifications

Bands 10–11 Brightness Temperature is derived from TOA radiance and two thermal constants, as described at http://landsat.usgs.gov/Landsat8_Using_Product.php. The associated header and metadata files present the same kind of information as described for Surface Reflectance, but they are specific to Brightness Temperature processing. Specifications for Brightness Temperature bands are similar to those for Surface Reflectance, but with a higher minimum value. **Table 7-G** lists the data type, units, value range, fill value, saturation value, and scale factor for the Brightness Temperature product bands.

Table 7-G 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
toa_band10	Band 10 Brightness Temperature	INT16	Brightness Temperature (Kelvin)	-100 - 16000	0- 10000	-9999	20000	0.1
toa_band11	Band 11 Brightness Temperature	INT16	Brightness Temperature (Kelvin)	-100 - 16000	0- 10000	-9999	20000	0.1

7.2.3 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 Citation Information

There are no restrictions on the use of these high-level Landsat 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.

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 9 Acknowledgments

The original Landsat 8 Surface Reflectance algorithm was developed at NASA Goddard Space Flight Center (GSFC).

The original CFmask software, Fmask, was developed at the Center for Remote Sensing in the Department of Earth and Environment at Boston University, and is available from <https://code.google.com/p/fmask/>.

Section 10 User Services

Landsat high-level 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: <http://landsat.usgs.gov/contactus.php?topic=SRDR>. E-mail can also be sent to the customer service address included below, with the same indication of topic.

USGS User Services

<http://landsat.usgs.gov/contactus.php>
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 11 References

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

Appendix A Default File Characteristics

Table A-1 Default File Characteristics

Description	Example File Size (bytes)	Example File Name
Source Bands (11)	126,491,737	LC80430312013179LGN00_band*.tif
Source Band QA (1)	126,491,737	LC80430312013179LGN00_qa.tif
Source Metadata	7,791	LC80430312013179LGN00_MTL.txt
TOA Reflectance Bands (8)	126,491,785	LC80430312013179LGN00_toa_band*.tif
TOA Brightness Temperature Bands (2)	126,491,785	LE70390372008210MOR00_toa_band*.tif
Surface Reflectance Bands (7)	126,491,751	LE70390372008210MOR00_sr_band*.tif
Surface Reflectance CFmask Band (1)	63,278,592	LE70390372008210MOR00_cfmask.tif
Metadata	23,532	LE70390372008210MOR00.xml

Appendix B Metadata Fields

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>2014-11-13T15:01:34Z</level1_production_date>
  <solar_angles zenith="24.733788" azimuth="131.660614" units="degrees"/>
  <wrs system="2" path="43" row="31"/>
  <lpgs_metadata_file>LC80430312013179LGN00_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>LC80430312013179LGN00_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>2014-11-13T15:42:29Z</production_date>
</band>
```

Appendix C Acronyms

Acronym	Description
6S	Second Simulation of a Satellite Signal in the Solar Spectrum
CDR	Climate Data Record
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
ECV	Essential Climate Variable
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
L8SR	Provisional Landsat 8 Surface Reflectance Algorithm
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
MODIS	Moderate Resolution Imaging Spectroradiometer
MSAVI	Modified Soil Adjusted Vegetation Index
MSB	Most Significant Bit
NA	Not Applicable
NASA	National Aeronautic and Space Administration
NBR	Normalized Burn Ratio
NBR2	Normalized Burn Ratio 2
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
sceneID	Scene Identifier
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