LSDS-1873
Version 4.0

Department of the Interior
U.S. Geological Survey

U.S. LANDSAT
ANALYSIS READY DATA (ARD)
DATA FORMAT CONTROL BOOK (DFCB)

Version 4.0

January 2018

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Executive Summary

This Data Format Control Book (DFCB) presents detailed data formats for U.S. Landsat Analysis Ready Data (ARD), which are the foundation for the Earth Resources Observation and Science (EROS) Center Land Change Monitoring, Assessment, and Projection (LCMAP) initiative. ARD are consistently processed to the highest scientific standards and level of processing required for direct use in applications.

A key goal for ARD is to significantly reduce the burden of processing on applications scientists, who would need to download and prepare large amounts of data for time series analysis (such as perform additional radiometric and/or geometric corrections and geographic subsetting). In doing so, users create their own archives and unique ARD for their specific applications. A successful ARD implementation significantly simplifies this process so data are ready for applications with a minimal amount of independent preparation.

The Landsat Collection based Level 1 Terrain and Precision-corrected products serve as the input for generating ARD.

The Land Satellites Data System (LSDS) Product Control Board (PCB) maintains and controls this DFCB. Staff may update or revise this document only upon Landsat Operations and Sustaining (O&S) Configuration Control Board (CCB) and PCB approval. Please direct comments and questions regarding this DFCB to the following:

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Document History

Document Number	Document Version	Publication Date	Change Number
LSDS-1873	Version 1.0	May 2017	CR 13641
LSDS-1873	Version 2.0	August 2017	CR 13792
LSDS-1873	Version 3.0	August 2017	CR 13862
LSDS-1873	Version 4.0	January 2018	CR 14034

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Section 1 Introduction

1.1 Purpose

This Data Format Control Book (DCFB) provides details of the U.S. Landsat Analysis Ready Data (ARD) specifications.

1.2 Scope

This DFCB describes the formats and data contents of the U.S. Landsat ARD produced for the Earth Resources Observation and Science (EROS) Center Land Change Monitoring, Assessment, and Projection (LCMAP) Project.

1.3 Intended Users

This document is a guide for U.S. Landsat ARD product recipients. It provides detailed information on file specifications and product packaging.

1.4 Definitions

Level 1 – Level 1 processing refers to the generation of radiometrically calibrated and orthorectified Level 1 Terrain Precision (Corrected) (L1TP) data products as a collection.

Level 2 – Level 2 processing refers to the generation of top of atmosphere (TOA) reflectance, surface reflectance, top of atmosphere brightness temperature, quality assessment, and eventually land surface temperature as inputs to ARD.

Level 3 – Level 3 processing refers to temporal composites and science products (burned area, dynamic surface water extent fractional snow-covered area, spectral indices, and land change products) derived from ARD.

Tier 1 – Landsat Level 1 Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS) data processed to L1TP with a post model fit to the Global Land Survey (GLS) control of ≤12-meter (m) Root Mean Square Error (RMSE) (ideal for “stacking”).

Tier 2 –Landsat Level 1 TM data processed to Level 1 Systematic (Corrected) (L1GS) products, and ETM+ and OLI / TIRS data processed to Level 1 Systematic and Terrain (Corrected) (L1GT) products, and to L1TP for which the post model fit to the GLS control is >=12-m RMSE.

Tile – ARD is packaged in tiles, which are units of uniform dimension bounded by static corner points in a defined grid system (see Figure 1-1, Figure 1-2, Figure 1-3 for conterminous U.S., Alaska, and Hawaii examples). An ARD tile is currently defined as 5,000 x 5,000 30-m pixels.

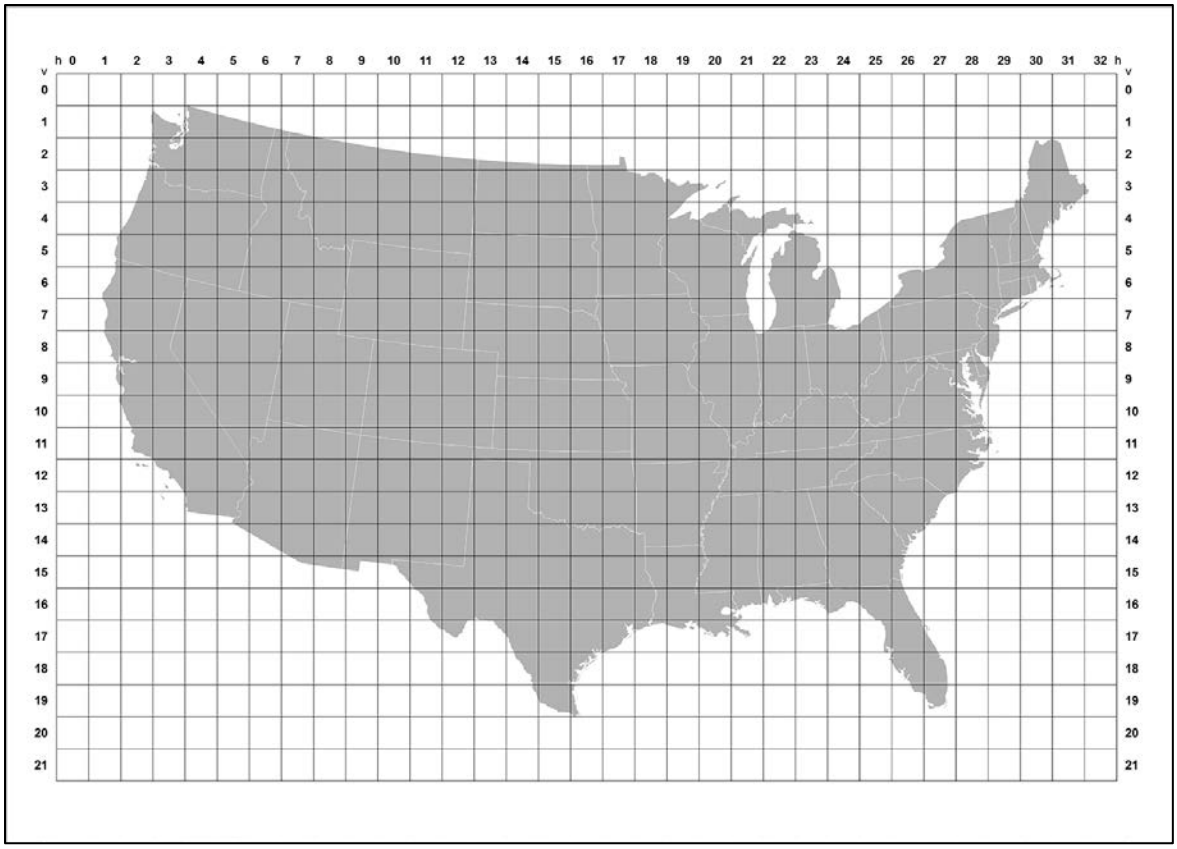

Figure 1-1. Landsat ARD Tile Grid for the Conterminous U.S.

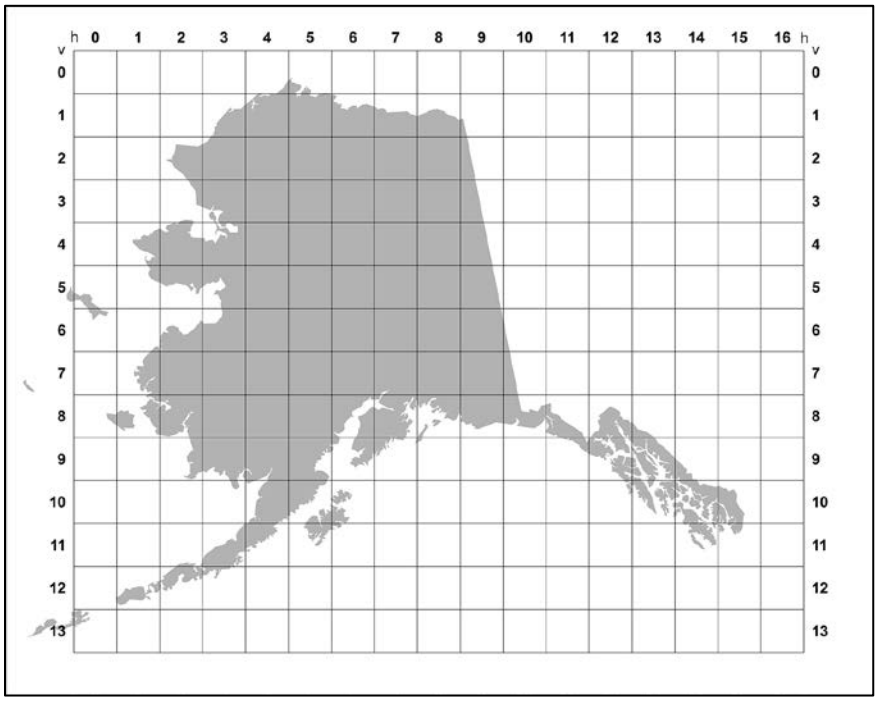

Figure 1-2. Landsat ARD Tile Grid for Alaska

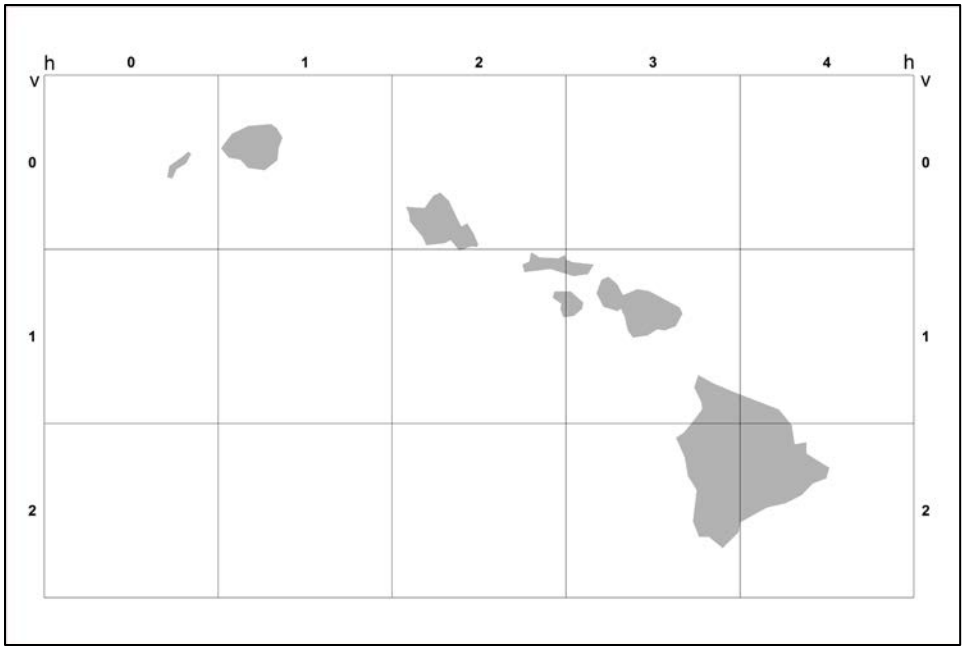

Figure 1-3. Landsat ARD Tile Grid for Hawaii

Section 2 Overview of U.S. Landsat ARD

U.S. Landsat ARD consist of top of atmosphere reflectance, top of atmosphere brightness temperature, surface reflectance, and quality data, gridded to a common cartographic projection, and accompanied by appropriate metadata to enable further processing while retaining traceability of data provenance. Future additions to the ARD may include land surface temperature data and results from change detection algorithms. Subsequently, numerous products are derived from ARD that are used as direct inputs to monitoring and assessment activities, which include, but are not limited to, maps of land cover and land cover change, spectral indices, temporal composites, and Level-3 science data such as burned area, dynamic surface water extent, and fractional snow-covered area.

U.S. Landsat ARD are available for the conterminous United States (CONUS), Alaska and Hawaii, using the following Landsat Collection 1 Level-1 products:

- Landsat 8 Operational Land Imager (OLI)/ Thermal Infrared Sensor (TIRS) Tier 1, Tier 2
- Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Tier 1
- Landsat 4-5 Thematic Mapper (TM) Tier 1

ARD are available for CONUS from 1982-present, and from 1984-present for Alaska. For Hawaii, ARD are available from 1989-1993, and 1999-present.

Eventually, Landsat 1-5 Multispectral Sensor (MSS) data will be added to the U.S. ARD inventory, once these data have been processed into the Landsat Collection 1 archive structure.

The current definition of U.S. Landsat ARD includes the products output by the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) Surface Reflectance Algorithm (Version 3.1.2) and by the Landsat Surface Reflectance Code (LaSRC) (Version 1.2.0), supplemented by Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA)-L2QA-TOOLS (Version 1.2.0) and C version of Function of Mask (CFmask)-based cloud, water, and snow detection code (Version 2.0.2). The latter Level 2 Quality Assessment (QA) code packages replicate the original CFmask dilation functions and water labels needed to provide the input expected by higher-level change detection algorithms and is not available in the Level 1 implementation of CFmask.

2.1 U.S. Landsat ARD Product Band Specifications

2.1.1 U.S. Landsat 4-7 TM / ETM+ ARD Product Specifications

The output products from LEDAPS include top of atmosphere reflectance, top of atmosphere brightness temperature, surface reflectance, and internal pixel quality attributes derived from Landsat 4-5 TM and Landsat 7 ETM+ inputs. Table 2-1 through Table 2-4 list the specifications for all associated bands.

The panchromatic band (ETM+ Band 8) is not processed to top of atmosphere or surface reflectance.

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
toa_band 1	TAB1	Band 1 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 2	TAB2	Band 2 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 3	TAB3	Band 3 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 4	TAB4	Band 4 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 5	TAB5	Band 5 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 7	TAB7	Band 7 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
solar_azimuth_band4	SOA4	Solar Azimuth Angles Band 4	INT16	Degrees	-32767 - 32767	-18000 – 18000	-32768	NA	0.0100
solar_zenith_band4	SOZ4	Solar Zenith Angles Band 4	INT16	Degrees	-32767 - 32767	-9000 - 9000	-32768	NA	0.0100
sensor_azimuth_band4	SEA4	Sensor Azimuth Angles Band 4	INT16	Degrees	-32767 - 32767	-18000 – 18000	-32768	NA	0.0100
sensor_zenith_band4	SEZ4	Sensor Zenith Angles Band 4	INT16	Degrees	-32767 - 32767	-9000 - 9000	-32768	NA	0.0100
toa top of atmosphere reflectance, TAB top of atmosphere reflectance band, INT16 16-bit signed integer, Ref reflectance									

Table 2-1. Landsat 4-7 Top of Atmosphere Reflectance Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
bt_band6	BTB6	Band 6 Brightness Temp	INT16	Top of Atmosphere Brightness Temp (K)	-100 – 16000	0 – 10000	-9999	20000	0.1
bt top of atmosphere brightness temperature, INT16 16-bit signed integer, Temp temperature K Kelvin									

Table 2-2. Landsat 4-7 Top of Atmosphere Brightness Temperature Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturat e Value	Scale Factor
sr_band1	SRB1	Band 1	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band2	SRB2	Band 2	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band3	SRB3	Band 3	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band4	SRB4	Band 4	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band5	SRB5	Band 5	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band7	SRB7	Band 7	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr surface reflectance, INT16 16-bit signed integer, Refl reflectance									

Table 2-3. Landsat 4-7 Surface Reflectance Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Satur ate Value	Scale Factor
pixel_qa	PIXELQA	Pixel Quality Assessment	UINT1 6	Bit Index	1 – 65535	1 – 255	1 (bit 0)	NA	NA
radsat_qa	RADSATQA	Radiometric Saturation QA	UINT8	Bit Index	0 –255	0 –255	1 (bit 0)	NA	NA
NA	LINEAGEQA	Lineage QA	UINT8	NA	0 – 255	0 – 3	0	NA	NA
sr_atmos_op acity	SRATMOSOP ACITYQA	Internal SR Atmospheric Opacity	INT16	NA	-2000 – 16000	0 - 10000	-9999	2000 0	0.0010
sr_cloud_qa	SRCLOUDQA	Internal SR QA	UINT8	Bit Index	0 –255	0 –255	NA	NA	NA
qa quality assessment, UINT16 16-bit unsigned integer, INT16 16-bit signed integer, UINT8 8-bit unsigned integer, NA not applicable, SR surface reflectance									

Table 2-4. Landsat 4-7 U.S. Landsat ARD Quality Assessment Band Specifications

2.1.2 Landsat 4-7 TM/ETM+ U.S. Landsat ARD Quality Assessment Band Specifications

The quality bands delivered with Level 2 products combine information from their Level 1 inputs with additional calculations derived from higher-level processing. A QA band describing the general state of each pixel is accompanied by three other bands that characterize radiometric saturation, as well as parameters specific to atmospheric correction. Table 2-5 through Table 2-11 list all QA bands that are bit-packed and their associated contents.

2.1.2.1 Landsat 4-7 Pixel Quality Assessment Band

The Landsat 4-7 pixel quality assessment (PIXELQA) band is a combination of Level 1 and Level 2 information. Where possible, Level 1 information is carried through unchanged into Level 2 processing (*fill, clear, cloud shadow, cloud confidence*). To support higher-level products that use Level 2 as input, certain QA values are generated or recalculated (*water, cloud, snow*), specifically to include cloud dilation.

Bit	Value	Cumulative Sum	Interpretation
Bits are numbered from right to left (bit 0 = LSB, bit 15 = MSB)			
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	Unused
9	512	1023	Unused
10	1024	2047	Unused
11	2048	4095	Unused
12	4096	8191	Unused
13	8192	16383	Unused
14	16384	32767	Unused
15	32786	65535	Unused
LSB=least significant bit, MSB=most significant bit			

Table 2-5. Landsat 4-7 Pixel Quality Assessment Bit Index

The bit combinations that define certain quality conditions appear as integer values in the pixel quality assessment (PIXELQA) band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions. Table 2-6 displays the interpretation of possible pixel values expected in the PIXELQA band after its bits are unpacked. For example, a pixel value of 16 represents the bit combination indicating snow.

Pixel Value	Fill	Clear	Water	Cloud Shadow	Snow	Cloud	Cloud Confidence	Pixel Description
1	Yes	No	No	No	No	No	None	Fill pixel
66	No	Yes	No	No	No	No	Low	Clear terrain, low-confidence cloud
68	No	No	Yes	No	No	No	Low	Water terrain, low-confidence cloud
72	No	No	No	Yes	No	No	Low	Cloud shadow, low-confidence cloud
80	No	No	No	No	Yes	No	Low	Snow / ice, low-confidence cloud
96	No	No	No	No	No	Yes	Low	Cloud, low-confidence cloud
130	No	Yes	No	No	No	No	Medium	Clear terrain, medium-confidence cloud

132	No	No	Yes	No	No	No	Medium	Water, medium-confidence cloud
136	No	No	No	Yes	No	No	Medium	Cloud shadow, medium-confidence cloud
144	No	No	No	No	Yes	No	Medium	Snow / ice, medium-confidence terrain
160	No	No	No	No	No	Yes	Medium	Cloud, medium-confidence cloud
224	No	No	No	No	No	Yes	High	High confidence cloud

Table 2-6. Landsat 4-7 Pixel Quality Assessment Bit Values

2.1.2.2 Landsat 4-7 Radiometric Saturation Quality Band

The radiometric saturation quality (RADSATQA) band is a bit packed representation of which sensor bands were saturated during data capture, yielding unusable data. Table 2-7 displays the interpretation of possible pixel values expected in the RADSATQA band after its bits are unpacked. For example, a pixel value of 32 indicates that Band 5 is saturated.

Bit	Value	Cumulative Sum	Description
Bits are numbered from right to left (bit 0 = LSB, bit 7 = 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)
LSB=least significant bit, MSB=most significant bit			

Table 2-7. Landsat 4-7 Radiometric Saturation Assessment Bit Index

2.1.2.3 Landsat 4-7 Lineage Index Band

Each U.S. Landsat ARD tile contains only one date of acquisition and may contain information from one, two, or three Level 2 scenes. Each ARD tile package contains a band indicating which Level 2 scene was the source for each pixel. In areas of scene overlap in a single path, the northern-most scene takes precedence. An exception may be noted for Landsat 7 ETM+ scenes, in which it is possible due to scan line pixel gaps that a particular pixel could derive from the southern scene. The pixel values are used in conjunction with the metadata file to retrieve scene-specific information. The lineage index band (LINEAGEQA) is included in all packages related to a particular ARD tile. Figure 2-1 illustrates an example of the lineage index band and tile compositing.

Pixel Value	Fill	Pixel Description
0	Yes	Fill pixel
1, 2, 3	No	Indicates which Level 2 scene was the source for a pixel. Corresponds with an entry in the metadata file.

Table 2-8. Landsat 4-7 Lineage Index Band

Figure 2-1 displays a lineage index band example of color composite tile (left) and tiling logic used to indicate source data (right).

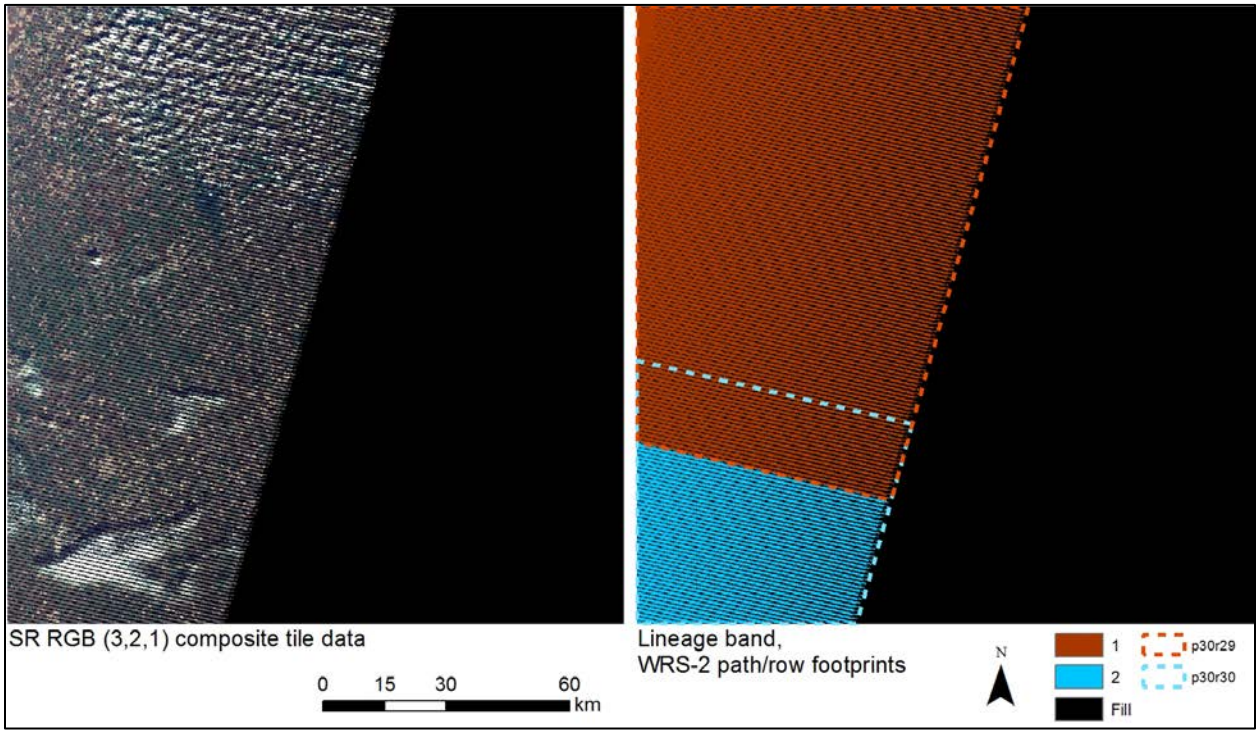

Figure 2-1. Lineage Index Band Example

2.1.2.4 Landsat 4-7 Internal Surface Reflectance Atmospheric Opacity Band

An estimate of atmospheric opacity is derived from the atmospheric correction calculations used in generating Level 2 surface reflectance for Landsat 4-7. The internal surface reflectance atmospheric opacity 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. It may be considered a proxy for aerosol optical thickness (i.e., the greater the atmospheric opacity, the greater the aerosol optical thickness).

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
sr_atmos_opacity	SRATMOS OPACITY QA	Internal SR Atmospheric Opacity	INT16	NA	-2000 – 16000	0 - 10000	-9999	NA	0.0010
SR=surface reflectance, INT=signed integer, NA=not applicable									

Table 2-9. Landsat 4-7 Internal Surface Reflectance Atmospheric Opacity Band Attributes

2.1.2.5 Landsat 4-7 Internal Surface Reflectance Quality Assessment Band

The algorithm used to generate Level 2 surface reflectance for Landsat 4-7 requires specialized data input to perform atmospheric correction. Although some of the needed parameters are included in Level 1 products, the algorithm executes its own calculations to meet the specific requirements of its atmospheric correction routines, and outputs a bit-packed internal surface reflectance quality assessment band (SRCLOUDQA).

Bit	Value	Cumulative Sum	Description
Bits are numbered from right to left (bit 0 = LSB, bit 7 = MSB)			
0	1	1	Dense Dark Vegetation (DDV)
1	2	3	Cloud
2	4	7	Cloud Shadow
3	8	15	Adjacent Cloud
4	16	31	Snow
5	32	63	Land / Water
6	64	127	Unused
7	128	255	Unused
LSB least significant bit, MSB most significant bit			

Table 2-10. Landsat 4-7 Internal Surface Reflectance Quality Assessment Bit Index

The bit combinations that define the quality conditions influencing atmospheric correction appear as integer values in the internal surface reflectance quality assessment (SRCLOUDQA) band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions.

Table 2-11 displays the interpretation of possible pixel values expected in the SRCLOUDQA band after its bits are unpacked. For example, a pixel value of 32 represents the bit combination, indicating the pixel is covered with water.

Pixel Value	DDV	Cloud	Cloud Shadow	Adj. Cloud	Snow	Land / Water	Pixel Description
1	Yes	No	No	No	No	No	Dense / dark vegetation terrain
2	No	Yes	No	No	No	No	Cloudy pixel
4	No	No	Yes	No	No	No	Cloud shadow
8	No	No	No	Yes	No	No	Land terrain adjacent to cloud pixel
16	No	No	No	No	Yes	No	Snow / ice terrain
32	No	No	No	No	No	Yes	Water
40	No	No	No	Yes	No	Yes	Water adjacent to cloud pixel
DDV dense dark vegetation							

Table 2-11. Landsat 4-7 Internal Surface Reflectance Quality Assessment Bit Values

2.1.3 Landsat 8 OLI ARD Product Specifications

The output products from LaSRC include top of atmosphere reflectance, surface reflectance, top of atmosphere brightness temperature, and internal pixel quality attributes derived from Landsat 8 inputs. Table 2-12 lists the specification for all associated bands.

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
toa_band 1	TAB1	Band 1 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 2	TAB2	Band 2 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 3	TAB3	Band 3 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 4	TAB4	Band 4 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 5	TAB5	Band 5 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 6	TAB6	Band 6 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 7	TAB7	Band 7 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band 9	TAB9	Band 9 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
solar_azimuth_band4	SOA4	Solar Azimuth Angles Band 4	INT16	Degrees	-32767 - 32767	-18000 – 18000	-32768	NA	0.0100
solar_zenith_band4	SOZ4	Solar Zenith Angles Band 4	INT16	Degrees	-32767 - 32767	-9000 - 9000	-32768	NA	0.0100
sensor_azimuth_band4	SEA4	Sensor Azimuth Angles Band 4	INT16	Degrees	-32767 - 32767	-18000 – 18000	-32768	NA	0.0100
sensor_zenith_band4	SEZ4	Sensor Zenith Angles Band 4	INT16	Degrees	-32767 - 32767	-9000 - 9000	-32768	NA	0.0100
Toa top of atmosphere reflectance, tab top of atmosphere reflectance band, soa solar azimuth angle, soz solar zenith angle, sea sensor azimuth angle, sez sensor zenith angle, INT16 16-bit signed integer, Refl reflectance, NA not applicable									

Table 2-12. Landsat 8 Top of Atmosphere Reflectance Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
bt_band10	BTB10	Band 10 Brightness Temperature	INT16	top of atmosphere Brightness Temp (K)	-100 – 16000	0 – 10000	-9999	20000	0.1
bt_band11	BTB11	Band 11 Brightness Temperature	INT16	top of atmosphere Brightness Temp (K)	-100 – 16000	0 – 10000	-9999	20000	0.1
bt top of atmosphere brightness temperature, BTB brightness temperature band, INT16 16-bit signed integer, Temp temperature, K Kelvin									

Table 2-13. Landsat 8 Top of Atmosphere Brightness Temperature Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
sr_band1	SRB1	Band 1 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band2	SRB2	Band 2 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band3	SRB3	Band 3 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band4	SRB4	Band 4 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band5	SRB5	Band 5 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band6	SRB6	Band 6 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr_band7	SRB7	Band 7 Surface Reflectance	INT16	Refl	-2000 – 16000	0 - 10000	-9999	20000	0.0001
sr surface reflectance, SRB surface reflectance band, INT16 16-bit signed integer, Refl reflectance									

Table 2-14. Landsat 8 Surface Reflectance Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value
pixel_qa	PIXELQA	Pixel Quality Assessment	UINT16	Bit Index	1 – 65535	1 – 2047	1 (bit 0)
radsat_qa	RADSATQA	Radiometric Saturation QA	UINT16	Bit Index	0 – 65535	0 – 3839	1 (bit 0)
NA	LINEAGEQA	Lineage QA	UINT8	NA	0 – 255	0 – 3	0
sr_aerosol	SRAEROSOL QA	Aerosol QA	UINT8	Bit Index	0 – 255	0 – 255	1
qa quality assessment, NA not applicable, sr surface reflectance, UINT16 unsigned 16-bit signed integer							

Table 2-15. Landsat 8 ARD Quality Assessment Band Specifications

2.1.4 Landsat 8 OLI ARD Quality Assessment Band Specifications

Landsat 8 ARD quality bands are similar to those delivered for Landsat 4-7. These bands combine information from their Level 1 inputs with additional calculations derived from higher-level processing, include a saturation band, and a band describing parameters specific to atmospheric correction. Table 2-16 through Table 2-21 list all QA bands that are bit-packed and their associated contents.

2.1.4.1 Landsat 8 Pixel Quality Assessment Band

The Landsat 8 pixel quality assessment (PIXELQA) band is a combination of Level 1 and Level 2 information. Where possible, Level 1 information is carried through unchanged into Level 2 processing (*fill, clear, cloud shadow, cloud confidence, cirrus confidence, terrain occlusion*). To support higher-level products using Level 2 as input, certain QA values are generated or recalculated (*water, cloud, snow*), specifically to include cloud dilation.

Bit	Value	Cumulative Sum	Interpretation
Bits are numbered from right to left (bit 0 = LSB, bit 15 = MSB)			
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	65535	Unused
LSB least significant bit, MSB most significant bit, OLI operational land imager			

Table 2-16. Landsat 8 Pixel Quality Assessment Bit Index

The bit combinations that define certain quality conditions appear as integer values in the pixel quality assessment (PIXELQA) band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions. Table 2-17 displays the interpretation of possible pixel values expected in the PIXELQA band after its bits are unpacked. For example, a pixel value of 320 represents the bit combination, indicating a moderate chance that the pixel is covered with cloud or cirrus.

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

Table 2-17 Landsat 8 Pixel Quality Assessment Bit Values

2.1.4.2 Landsat 8 Radiometric Saturation Quality Assessment Band

The radiometric saturation quality assessment (RADSATQA) band is a bit packed representation of which sensor bands were saturated during data capture, yielding unusable data. Table 2-18 displays the interpretation of possible pixel values expected in the RADSATQA 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 volcanoes and wildland fires in the Shortwave Infrared (SWIR) and thermal bands. Saturation can be found in two forms:

- Saturated thermal and SWIR pixels show as the maximum unsigned 16-bit value of 65535
- SWIR pixel values “roll over” to the low end of the valid range (not necessarily a value of 0), which is called oversaturation

Oversaturation does not occur with the TIRS thermal bands. The Landsat 8 RADSATQA band flags only the saturation cases.

Bit	Value	Cumulative Sum	Description
Bits are numbered from right to left (bit 0 = LSB, bit 7 = 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)
LSB=least significant bit, MSB=most significant bit			

Table 2-18. Landsat 8 Radiometric Saturation Quality Assessment Bit Index

2.1.4.3 Landsat 8 Lineage Index Band

Each ARD tile contains only one date of acquisition and may contain information from one, two, or three Level 2 scenes. Each ARD tile package contains a lineage index band (LINEAGEQA), which indicates which Level 2 scene was the source for each pixel. In areas of scene overlap in a single path, the northern-most scene takes precedence. The LINEAGEQA band is included in all packages related to a particular ARD tile.

The lineage index pixel values are used in conjunction with the metadata file to retrieve scene-specific information. Figure 2-1 illustrates an example of the lineage index band and tile compositing logic.

Pixel Value	Fill	Pixel Description
0	Yes	Fill pixel
1, 2, 3	No	Indicates which Level 2 scene was the source for a pixel. Corresponds with an entry in the metadata file.

Table 2-19. Landsat 8 Lineage Index Band Values

2.1.4.4 Landsat 8 Internal Surface Reflectance Aerosol Quality Assessment Band

Aerosol retrieval is a critical component in the atmospheric correction calculations used in generating Level 2 surface reflectance for Landsat 8. The internal surface reflectance aerosol quality assessment (SRAEROSOLQA) 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.

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	

Table 2-20. Landsat 8 Internal Surface Reflectance Aerosol Quality Assessment Bit Index

The bit combinations that define the quality conditions influencing atmospheric correction appear as integer values in the internal surface reflectance aerosol quality assessment (SRAEROSOLQA) band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions. Table 2-21 displays the interpretation of possible pixel values expected in the SRAEROSOLQA band after its bits are unpacked. For example, a pixel value of 7 represents the bit combination indicating the pixel value may be unreliable because aerosol retrieval was not possible, and the value had to be interpolated.

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

Table 2-21. Landsat 8 Internal Surface Reflectance Aerosol Quality Assessment Bit Values

2.2 U.S. Landsat ARD Naming Convention

2.2.1 U.S. Landsat ARD Product Identifier Conventions

The U.S. Landsat ARD product identifier (Product ID) follows the naming convention of its Collection-based source data to the extent possible.

Level 1 Product ID
LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX

Table 2-22 decomposes the definition of the Landsat Collection 1 Level 1 Product ID terms.

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX	
Term	**Definition**
L	Landsat
X	Sensor (“C” = OLI / TIRS Combined, “O” = OLI-only, “T” = TIRS-only, “E” = ETM+, “T” = TM)
SS	Satellite (“04” = Landsat 4, “05” = Landsat 5, “07” = Landsat 7, “08” = Landsat 8)
LLLL	Processing correction level (“L1TP” = precision and terrain, “L1GT” = systematic terrain, “L1GS” = systematic)
PPP	World Reference System 2 (WRS-2) path
RRR	WRS-2 row
YYYYMMDD	Acquisition year (YYYY) month (MM) day (DD)
yyyymmdd	Production year (yyyy) month (mm) day (dd)
CC	Collection number (“01,” “02”)
TX	Collection category (“RT” = Real Time, “T1” = Tier 1, “T2” = Tier 2)

Table 2-22. Landsat Collection 1 Level 1 Product Identifier Terms

When Landsat Collection 1 Level 1 data are processed to top of atmosphere reflectance, top of atmosphere brightness temperature, surface reflectance, and quality products, they carry their Product ID into a new Level 2 name, which is appended with the product and band designation. Sample Level 2 package and product file names are defined as follows:

Level 2 Product ID
The Level 2 product files that are input to ARD tiles follow the Level 1 naming convention, but are appended with their Level 2 product band name. The Level 2 Product ID is deconstructed in Table 2-23.

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX_product_band

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX_product_band	
Term	**Definition**
L	Landsat
X	Sensor (“C” = OLI / TIRS Combined, “O” = OLI-only, “T” = TIRS-only, “E” = ETM+, “T” = TM)
SS	Satellite (“04” = Landsat 4, “05” = Landsat 5, “07” = Landsat 7, “08” = Landsat 8)
LLLL	Processing correction level (“L1TP” = precision and terrain, “L1GT” = systematic terrain, “L1GS” = systematic)
PPP	WRS-2 path
RRR	WRS-2 row
YYYYMMDD	Acquisition year (YYYY) month (MM) day (DD)
yyyymmdd	Production year (yyyy) month (mm) day (dd)
CC	Collection number (“01,” “02”)
TX	Collection category (“RT” = Real Time, “T1” = Tier 1, “T2” = Tier 2)
product	Data product (“toa” = top of atmosphere reflectance, “bt” = top of atmosphere brightness temperature, “sr” = surface reflectance, “lst” = land surface temperature, “soa” = solar azimuth angle, “soz” = solar zenith angle, “sea” = sensor azimuth angle, “sez” = sensor zenith angle, “pixel_qa” = pixel quality assessment, “sr_atmos_opacity” = internal Landsat 4-7 surface reflectance atmospheric opacity, “sr_cloud_qa” = internal Landsat 4-7 surface reflectance quality, “sr_aerosol” = internal Landsat 8 surface reflectance aerosol parameters)
band	Band (such as “band1” for reflectance products)

Table 2-23. Landsat Level 2 Product ID Terms

ARD Product ID

An ARD Product ID replaces path/row designations with tile identifiers (HHH horizontal; VVV vertical), as an ARD tile may include data from overlapping rows. Processing level (LLLL) and collection category (TX) are removed from the ARD Product ID as a redundancy; ARD is created only from Landsat 4-7 Tier 1, Landsat 8 Tier 1, or Tier 2 Collection data. The Level 1 production date is also removed from the file name.

The regional grid of the U.S. used in the production of the tile is designated after the sensor term.

The Product ID may need modification when sensor or temporal compositing is enabled.

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PRODUCTBAND

Table 2-24 decomposes the definition of U.S. Landsat ARD Product ID terms.

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PRODUCTBAND	
Term	**Definition**
L	Landsat
X	Sensor (“C” = OLI / TIRS Combined, “O” = OLI-only, “T” = TIRS-only, “E” = ETM+, “T” = TM)
SS	Satellite (“04” = Landsat 4, “05” = Landsat 5, “07” = Landsat 7, “08” = Landsat 8)
US	Regional grid of the U.S. (“CU” = CONUS, “AK” = Alaska, “HI” = Hawaii)
HHH	Horizontal tile number
VVV	Vertical tile number

YYYYMMDD	Acquisition year (YYYY) month (MM) day (DD)
yyyymmdd	Production year (yyyy) month (mm) day (dd)
CCC	Level 1 Collection number (“C01,” “C02”)
VVV	Analysis Ready Data (ARD) Version number (“V01,” “V02”)
PRODUCT	Data product (“TA” = top of atmosphere reflectance, “BT” = top of atmosphere brightness temperature, “SR” = surface reflectance, “LST” = land surface temperature, “SOA” = solar azimuth angle, “SOZ” = solar zenith angle, “SEA” = sensor azimuth angle, “SEZ” = sensor zenith angle, “PIXELQA” = pixel quality assessment, “RADSATQA” = radiometric saturation, “LINEAGEQA” = lineage index, “SRATMOSOPACITYQA” = internal Landsat 4-7 surface reflectance atmospheric opacity, “SRCLOUDQA” = internal Landsat 4-7 surface reflectance quality, “SRAEROSOLQA” = internal Landsat 8 surface reflectance aerosol parameters)
BAND	Band (such as “B1” for reflectance products)

Table 2-24. U.S. Landsat ARD Product Identifier Terms

2.2.2 U.S. Landsat ARD Product Identifier Examples

Example ARD Product IDs follow the convention specified and are listed based on the following sample Level 1 Product ID:

LE07_L1TP_029030_20151209_20160110_01_T1

2.2.2.1 Image Product Identifier

Image files in the Landsat 4-7 TM / ETM+ derived top of atmosphere reflectance product would be output for ARD as:

LE07_CU_016008_20151209_20160118_C01_V01_TAB<1-5, 7>
i.e., LE07_CU_016008_20151209_20160118_C01_V01_TAB4

Image files in the Landsat 4-7 TM / ETM+ derived top of atmosphere brightness temperature product would be output for ARD as:

LE07_CU_016008_20151209_20160118_C01_V01_BTB<6>
i.e., LE07_CU_016008_20151209_20160118_C01_V01_BTB6

Image files in the Landsat 4-7 TM / ETM+ derived surface reflectance product would be output for ARD as:

LE07_CU_016008_20151209_20160118_C01_V01_SRB<1-5, 7 >.
i.e., LE07_CU_016008_20151209_20160118_C01_V01_SRB3

Image files in the Landsat 4-7 TM / ETM+ angle bands product would be output for ARD as:

LE07_CU_016008_20151209_20160118_C01_V01_SOA
LE07_CU_016008_20151209_20160118_C01_V01_SOZ
LE07_CU_016008_20151209_20160118_C01_V01_ SEA
LE07_CU_016008_20151209_20160118_C01_V01_SEZ

2.2.2.2 Quality Product Identifier

The ARD quality products for Landsat 4-7 TM / ETM+ would be output as:

LE07_CU_016008_20151209_20160118_C01_V01_PIXELQA
LE07_CU_016008_20151209_20160118_C01_V01_RADSATQA
LE07_CU_016008_20151209_20160118_C01_V01_LINEAGEQA
LE07_CU_016008_20151209_20160118_C01_V01_SRATMOSOPACITYQA
LE07_CU_016008_20151209_20160118_C01_V01_SRCLOUDQA

For comparison, the ARD quality products for Landsat 8 OLI / TIRS would be output as:

LC08_CU_016008_20151209_20160118_C01_V01_PIXELQA
LC08_CU_016008_20151209_20160118_C01_V01_RADSATQA
LC08_CU_016008_20151209_20160118_C01_V01_LINEAGEQA
LC08_CU_016008_20151209_20160118_C01_V01_ SRAEROSOLQA

2.2.2.3 Metadata Product Identifier

The tile-based ARD metadata file for Landsat 4-7 TM / ETM+ would be output as:

LE07_CU_016008_20151209_20160118_C01_V01.xml

2.3 U.S. Landsat ARD Spatial Attributes

2.3.1 Map Projection

U.S. Landsat ARD are generated in the Albers Equal Area (AEA) Conic map projection and processed directly from Level 1 AEA scenes through Level 2 products using the World Geodetic System 1984 (WGS84) datum. The products cover the Conterminous U.S., Alaska, and Hawaii. Table 2-25 lists the projection parameters for the final product.

USGS Analysis Ready Data (ARD) Projection Parameters			
Projection: Albers Equal Area Conic (AEA)			
Datum: World Geodetic System 1984 (WGS84)			
	Conterminous U.S.	**Alaska**	**Hawaii**
First standard parallel	29.5˚	55.0˚	8.0˚
Second standard parallel	45.5˚	65.0˚	18.0˚
Longitude of central meridian	-96.0˚	-154.0˚	-157.0˚
Latitude of projection origin	23.0˚	50.0˚	3.0˚
False Easting (meters)	0.0	0.0	0.0
False Northing (meters)	0.0	0.0	0.0

Table 2-25. Landsat ARD Map Projection Parameters

2.3.2 Tile Grid System

All AEA-projected ARD products are processed to a common tiling scheme, which is modified from the Web-Enabled Landsat Data (WELD) system developed at South Dakota State University (SDSU) (Roy and others, 2010). The WELD-defined grid is similar to the National Land Cover Dataset (NLCD), except that WELD is based on

WGS84 and NLCD uses North American Datum of 1983 (NAD83), causing an approximately 0.5 pixel offset in the X and Y directions between the two grids.

The U.S. Landsat ARD grid is an adaptation of the WELD grid that aligns with NLCD. The ARD is gridded into tiles of 5,000 x 5,000 30m pixels and is anchored to the coordinates listed in Table 2-26. These grid origins are defined in relation to the WGS84 datum used by WELD, but are adjusted to align with the origin used by NLCD datasets.

	Upper Left Tile (UL Corner)				Lower Right Tile (LR Corner)			
	(h)	**(v)**	**ulX (m)**	**ulY (m)**	**(h)**	**(v)**	**lrX (m)**	**lrY (m)**
CONUS	0	0	-2565585	3314805	32	21	2384415	14805
Alaska	0	0	-851715	2474325	16	13	1698285	374325
Hawaii	0	0	-444345	2168895	4	2	305655	1718895
CONUS conterminous United States, UL upper left, LR lower right, h horizontal tile, v vertical tile, m meters, ulX upper-left X coordinate, ulY upper-left Y coordinate, lrX lower-right X coordinate, lrY lower-right Y coordinate								

Table 2-26. U.S. Landsat ARD Tile Grid Extents

Each U.S. Landsat ARD tile contains all the pixels acquired in a given day within its extent. In the event a tile intersects more than one scene, the data and metadata from the northern row populate the tile. Future changes may implement a more sophisticated compositing scheme to handle the intersect.

Section 3 Data Format Definition

3.1 U.S. Landsat ARD Product Packaging

U.S. Landsat ARD is packaged into product bundles (i.e., top of atmosphere reflectance, surface reflectance, top of atmosphere brightness temperature), and are delivered in separate packages, each with their associated pixel quality attributes. A separate package containing only the quality assessment bands is also provided.

The package identifier (Package ID) of the distributed files is derived from the ARD Product ID (see Section 2), using the production date from the LINEAGEQA index band included with every product.

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PRODUCT.tar

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PRODUCT.tar	
Term	**Definition**
L	Landsat
X	Sensor (“C” = OLI / TIRS Combined, “O” = OLI-only, “T” = TIRS-only, “E” = ETM+, “T” = TM)
SS	Satellite (“04” = Landsat 4, “05” = Landsat 5, “07” = Landsat 7, “08” = Landsat 8)
US	Regional grid of the U.S. (“CU” = CONUS, “AK” = Alaska, “HI” = Hawaii)
HHH	Horizontal tile number
VVV	Vertical tile number
YYYYMMDD	Acquisition year (YYYY) month (MM) day (DD)
yyyymmdd	Production year (yyyy) month (mm) day (dd)
CCC	Level 1 Collection number (“C01,” “C02”)
VVV	Analysis Ready Data (ARD) Version number (“V01,” “V02”)
PRODUCT	Data product (“TA” = top of atmosphere reflectance, “BT” = top of atmosphere brightness temperature, “SR” = surface reflectance, “ST” = land surface temperature, “QA” = quality assessment)

Table 3-1. U. S. Landsat ARD Package ID Terms

3.1.1 Checksum File

A checksum file is created for each delivered ARD package, and contains a listing of Message-Digital Algorithm 5 (MD5) checksums for all files, except for itself. The file is in plain text format and contains the system’s “md5sum” output. For example, a compressed file called

LE07_016008_2015120901_20170106_C01_V01_SR.tar

is accompanied by a checksum file named

LE07_016008_2015120901_20170106_C01_V01_SR.md5.

3.1.2 Metadata Files

The tiling process can include multiple scenes containing pixels acquired on a given day, each of which is associated with specific metadata. To preserve the lineage of the source data used to create a tile, Level 1, Level 2, and tile-based metadata are

appended into a comprehensive Extensible Markup Language (XML) file. Scene-based metadata not applicable to the characteristics of a tile are removed (e.g., scene center times, corner locations), and new tile-based fields are added (e.g., scene count, cloud cover over tile extent).

The general contents of the tile-based XML are listed as follows:

- Global Metadata
- Level 2 Pixel QA Metadata
- Level 2 Radiometric Saturation QA Metadata
- Level 2 Lineage Index Metadata
- Level 2 Angle Band Metadata
- Level 2 Top of Atmosphere Reflectance Metadata
- Level 2 Top of Atmosphere Brightness Temperature Metadata
- Level 2 Surface Reflectance Metadata
- Level 1 Scene Metadata

Excerpts from the sample tile-based metadata XML presented in Appendix A can be viewed as follows:

Example of U.S. Landsat ARD Tile Metadata

```
<ard_metadata>
        <tile_metadata>
                <global_metadata>
                        <data_provider>USGS/EROS</data_provider>
                        <satellite>LANDSAT_7</satellite>
                        <instrument>ETM</satellite>
                        <level1_collection>01</level1_collection>
                        <ard_version>01</ard_version>
                        <region>CU</region>
                        <acquisition_date>2016-10-07</acquisition_date>
                        <tile_id>
                LE07_CU_016006_20161007_20161130_C01_V01</tile_id>
                        <tile_production_date>2016-11-30</tile_production_date>
                        <bounding_coordinates>
                                <west>-98.093857</west>
                                <east>-96.193037</east>
                                <north>44.722110</north>
                                <south>43.360751</south>
                        </bounding_coordinates>
                        <projection_information units="meters" datum="WGS84"
                projection="AEA">
                                <corner_point y="2515800.000000" x="-299100.000000"
                        location="UL"/>
```

```
                <corner_point y="2293500.000000" x="-49800.000000"
            location="LR"/>
                <grid_origin>CORNER</grid_origin>
                <albers_proj_params>
                    <standard_parallel1>29.500000</standard_parallel1>
                    <standard_parallel2>45.500000</standard_parallel2>
                    <central_meridian>-96.000000</central_meridian>
                    <origin_latitude>23.000000</origin_latitude>
                    <false_easting>0.000000</false_easting>
                    <false_northing>0.000000</false_northing>
                </albers_proj_params>
            </projection_information>
            <orientation_angle>0.000000</orientation_angle>
            <tile_grid v="006" h="016"/>
            <scene_count>2</scene_count>
            <cloud_cover>6.4918</cloud_cover>
            <cloud_shadow>5.9551</cloud_shadow>
            <snow_ice>0.0148</snow_ice>
            <fill>64.9755</fill>
        </global_metadata>
```

Example of Level 2 Pixel Quality Assessment Metadata

```
<band product="level2_qa" source="level1" name="PIXELQA" category="qa"
data_type="UINT16" fill_value="1"> nsamps=”5000” nlines=”5000”
    <short_name>LE07PQA</short_name>
    <long_name>level-2 pixel quality band</long_name>
    <file_name>
LE07_CU_016006_20161007_20161130_C01_V01_PIXELQA.tif</file_name>
    <pixel_size x="30" y="30" units="meters"/>
    <resample_method>none</resample_method>
    <data_units>quality/feature classification</data_units>
    <bitmap_description>
      <bit num="0">fill</bit>
      <bit num="1">clear</bit>
      <bit num="2">water</bit>
      <bit num="3">cloud shadow</bit>
      <bit num="4">snow</bit>
      <bit num="5">cloud</bit>
      <bit num="6">cloud confidence</bit>
      <bit num="7">cloud confidence</bit>
      <bit num="8">unused</bit>
      <bit num="9">unused</bit>
      <bit num="10">unused</bit>
      <bit num="11">unused</bit>
      <bit num="12">unused</bit>
```

<bit num="13">unused</bit>
<bit num="14">unused</bit>
<bit num="15">unused</bit>
</bitmap_description>
<app_version>generate_pixel_qa_1.2.0</app_version>
<production_date>2016-11-22T14:43:00Z</production_date>
</band>

Example of Level 2 Radiometric Saturation Metadata

-<band fill_value="1" nsamps="5000" nlines="5000" data_type="UINT8" category="qa" name="RADSATQA" product="toa_refl" source="level1">
<short_name>LE07REF</short_name>
<long_name>radiometric saturation QA band</long_name>
<file_name>
LE07_CU_016006_20161007_20161130_C01_V01_RADSATQA.tif</file_name>
<pixel_size units="meters" y="30" x="30"/>
<resample_method>none</resample_method>
<data_units>bitmap</data_units>
<valid_range max="255.000000" min="0.000000"/>
-<bitmap_description>
<bit num="0">Data Fill Flag (0 = valid data, 1 = invalid data)</bit>
<bit num="1">Band 1 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="2">Band 2 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="3">Band 3 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="4">Band 4 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="5">Band 5 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="6">Band 6 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="7">Band 7 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
</bitmap_description>
<app_version>LEDAPS_3.1.2</app_version>
<production_date>2016-11-22T14:43:28Z</production_date>
</band>

Example of Level 2 Lineage Index Metadata

```
-<band fill_value="0" nsamps="5000" nlines="5000" data_type="UINT8"
category="metadata" name="LINEAGEQA" product="scene_index" source="level2">
        <short_name>TILEIDX</short_name>
        <long_name>index</long_name>
        <file_name>
LE07_CU_016006_20161007_20161130_C01_V01_LINEAGEQA.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>index</data_units>
        <valid_range max="255.000000" min="0.000000"/>
        <production_date>2016-11-22T14:43:43Z</production_date>
</band>
```

Example of Angle Band Metadata

```
</band>
<band nsamps="5000" nlines="5000" data_type="INT16" category="image"
name="SOZ4" product="angle_bands" source="level1" scale_factor="0.0100">
        <short_name>LE07SOLZEN</short_name>
        <long_name>band 4 solar zenith angles</long_name>
        <file_name>
        LE07_CU_016006_20161007_20161130_C01_V01_SOZ4.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>degrees</data_units>
        <app_version>LEDAPS_3.1.2</app_version>
        <production_date>2016-11-22T14:43:43Z</production_date>
</band>
```

Example of Top of Atmosphere Reflectance Band Metadata

```
</band>
<band fill_value="-9999" nsamps="5000" nlines="5000" data_type="INT16"
category="image" name="TAB1" product="toa_refl" source="level1"
add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
        <short_name>LE07REF</short_name>
        <long_name>band 1 TOA reflectance</long_name>
        <file_name>
LE07_CU_016006_20161007_20161130_C01_V01_TAB1.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>reflectance</data_units>
        <valid_range max="16000.000000" min="-100.000000"/>
        <app_version>LEDAPS_3.1.2</app_version>
```

```
        <production_date>2016-11-22T14:43:28Z</production_date>
</band>
```

Example of Top of Atmosphere Brightness Temperature Band Metadata

```
</band>
<band fill_value="-9999" nsamps="5000" nlines="5000" data_type="INT16"
category="image" name="BTB6" product="toa_bt" source="level1"
add_offset="0.000000" scale_factor="0.100000" saturate_value="20000">
        <short_name>LE07BT</short_name>
        <long_name>band 6 brightness temperature</long_name>
        <file_name>
LE07_CU_016006_20161007_20161130_C01_V01_BTB6.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>temperature (kelvin)</data_units>
        <valid_range max="3500.000000" min="1500.000000"/>
        <app_version>LEDAPS_3.1.2</app_version>
        <production_date>2016-11-22T14:43:28Z</production_date>
</band>
```

Example of Surface Reflectance Band Metadata

```
</band>
<band fill_value="-9999" nsamps="5000" nlines="5000" data_type="INT16"
category="image" name="SRB1" product="sr_refl" source="toa_refl"
add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
        <short_name>LE07SR</short_name>
        <long_name>band 1 surface reflectance</long_name>
        <file_name>
        LE07_CU_016006_20161007_20161130_C01_V01_SRB1.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>reflectance</data_units>
        <valid_range max="16000.000000" min="-2000.000000"/>
        <app_version>LEDAPS_3.1.2</app_version>
        <production_date>2016-11-22T14:43:43Z</production_date>
</band>
```

3.1.3 U.S. Landsat ARD Package Contents

Each package of ARD tiles delivered for products from Landsat 4, 5, and 7 include the following bundles and contents. Landsat 8 ARD is similar, differing only in the reflectance band numbers and its specific QA band (SRAEROSOLQA for Landsat 8 instead of SRCLOUDQA and SRATMOSOPACITYQA for Landsat 4-7).

Top of Atmosphere Reflectance Package

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TA.md5
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TA.tar
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV.xml
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TAB1.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TAB2.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TAB3.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TAB4.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TAB5.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TAB7.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SOA4.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SOZ4.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SEA4.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SEZ4.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PIXELQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_RADSATQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_LINEAGEQA.tif

Top of Atmosphere Brightness Temperature Package

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_BT.md5
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_BT.tar
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV.xml
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_BTB6.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PIXELQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_RADSATQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_LINEAGEQA.tif

Surface Reflectance Package

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SR.md5
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SR.tar
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV.xml
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRB1.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRB2.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRB3.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRB4.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRB5.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRB6.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PIXELQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_RADSATQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_LINEAGEQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRCLOUDQA.tif
    LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRATMOSOPACITYQA.tif

Quality Assessment Package

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_QA.md5
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_QA.tar
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV.xml
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PIXELQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_RADSATQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_LINEAGEQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRCLOUDQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRATMOSOPACITYQA.tif

For comparison, the QA package for Landsat 8 ARD would be output as:

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_QA.md5
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_QA.tar
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV.xml
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PIXELQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_RADSATQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_LINEAGEQA.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_SRAEROSOLQA.tif

3.1.4 Product Volumes

Estimations based on the number of Level 1 Collection 1 scenes acquired between 1985 and 2016 in combination with the number of tiles known to cover the extent of the ARD regions yield the compressed volumes for each ARD product as displayed in Table 3-2. Summarizing all products in that time range over all intended ARD regions (CONUS, Alaska, and Hawaii), there are currently at least 631 compressed terabytes (TB) expected in total. Due to the internal compression applied to each product package, uncompressed volumes are not expected to be significantly larger than described in Table 3-2.

ARD Region	Approximate Number of Tiles	Sum of All Products (TB)	Surface Reflectance (TB)	TOA Brightness Temperature (TB)	TOA Reflectance (TB)	Pixel Quality Assessment (TB)
CONUS	15,393,726	223.74	108.41	9.68	102.40	3.25
Alaska	4,977,612	72.35	35.06	3.13	33.11	1.05
Hawaii	276,534	4.02	1.95	0.17	1.84	0.06
Sum of All Regions	20,647,872	300.10	145.41	12.99	137.35	4.35

Table 3-2. Landsat 4-8 ARD Estimated Average Product Volume (terabytes) and Number of Scenes (1985-2016)

The annual growth rate in the number of available input scenes is projected to be 260,000, which equates to approximately 12,318,545 new tiles, increasing the total ARD collection volume by 180 TB per year after 2016.

3.2 GeoTIFF Specifications

3.2.1 GeoTIFF Image Preparation

U.S. Landsat ARD are stored in Georeferenced Tagged Image File Format (GeoTIFF) files using internal tiling to support web application services. Large file sizes are mitigated with internally compressed product and quality bands, meaning that compression is applied to each band rather than compressing all bands together. The lossless Deflate algorithm used to compress the ARD bands was selected due to its superior compression ratio and is expected to respond to most software. When using Geospatial Data Abstraction Library (GDAL) software for the image compression, the following parameters are used:

-co "compress=deflate" -co "zlevel=9" -co "tiled=yes" -co "predictor=2"

3.2.2 GeoTIFF Tags

GeoTIFF tags convey information about the image. The tags describe the image using information a GeoTIFF reader needs to control the appearance of the image on the user's screen. The Tagged Image File Format (TIFF) tags are embedded in the same file as the TIFF image. The GeoTIFF tags provide information on the image projection and corner points, which define the geographic location and extent of the image.

A complete description of the raster data requires the data to be georeferenced, which is accomplished using tags. The Level 2 production system uses the transformation raster, model space tie points, and scaling parameters. ModelTiepointTag and ModelPixelScaleTag are used for this purpose.

3.2.2.1 GeoTIFF ModelTiepointTag

The GeoTIFF ModelTiepointTag stores the raster-to-model tiepoint pairs.

The raster-to-model tiepoint pairs are stored in the following order: ModelTiepointTag = (..., I, J, K, X, Y, Z...), where (I, J, K) is the point at location (I, J) in raster space with pixel-value K, and (X, Y, Z) is a vector in model space. The ModelTiepointTag requires that K and Z are set to zero. See the GeoTIFF Specification document (see References) for more information.

The raster image is geo-referenced by specifying its location, size, and orientation in the model coordinate space. Because the relationship between the raster space and the model space often are exact, the affine transformation relationship can be defined using one set of tiepoints and the ModelPixelScaleTag (see Section 3.2.2.2), which gives the vertical and horizontal raster grid cell size. The ModelTiepointTag parameters are as follows:

Tag = 33922
Type = DOUBLE
N = 6*K, K = number of tiepoints

3.2.2.2 GeoTIFF ModelPixelScaleTag Tag

The GeoTIFF ModelPixelScaleTag tag specifies the size of the raster pixel spacing in the model space units when the raster space is embedded in the model space coordinate system without rotation.

The size of raster pixel spacing in the model space units consists of three values. These values are ModelPixelScaleTag = (ScaleX, ScaleY, ScaleZ), where ScaleX and ScaleY give the horizontal and vertical spacing of raster pixels, and ScaleZ maps the pixel value of a Digital Elevation Model (DEM) into the correct Z-scale.

A single tiepoint in the ModelTiepointTag, together with the ModelPixelScaleTag, determines the relationship between raster and model space. The ModelPixelScaleTag parameters are listed as follows:

Tag = 33550
Type = DOUBLE
N = 3

3.2.3 GeoTIFF Keys

The spatial description of an image in GeoTIFF requires keys stored within the image files and accessible by GeoTIFF readers. Table 3-4 defines the keys necessary to support the AEA map projection used for ARD.

Valid Keys	Possible Values	Meaning
GTModelTypeGeoKey	1	ModelTypeProjected (Projection Coordinate System)
GTRasterTypeGeoKey	1	RasterPixelIsArea (the coordinate is at the upper left corner of the pixel). This matches the Level 2 source scenes.
GTCitationGeoKey	Albers	American Standard Code for Information Interchange (ASCII) reference to public documentation; Albers, Stereographic South Pole, and Universal Transverse Mercator (UTM) are accounted for.
GeographicTypeGeoKey	1	GCS_WGS_84
GeogAngularUnitsGeoKey	9102	Angular_Degree
GeogSemiMajorAxisGeoKey	6378140	
GeogInvFlatteningGeoKey	298.257	
ProjectedCSTypeGeoKey		User-Defined
ProjectionGeoKey		User-Defined
ProjectedCSTypeGeoKey	20000–32760	European Petroleum Survey Group (EPSG) Projection System Codes
ProjectionGeoKey	10000-19999	EPSG / Petrotechnical Open Software Corporation (POSC) Projection Codes (see the EPSG Geodetic Parameter Registry for values)
ProjCoordTransGeoKey	CT_AlbersEqualArea	
ProjLinearUnitsGeoKey	9001	Linear_Meter
ProjStdParallel1GeoKey	45.5	Value in units of GeogAngularUnits
ProjNatOriginLongGeoKey	-96.0	Value in units of GeogAngluarUnits

Valid Keys	Possible Values	Meaning
ProjNatOriginLatGeoKey	23.0	Value in units of GeogAngularUnits
ProjFalseNorthingGeoKey	0.0000000	Value entered in units of ProjLinearUnits
ProjFalseEastingGeoKey	0.0000000	Value entered in units of ProjLinearUnits

Table 3-3. Albers GeoTIFF Key Description

Appendix A U.S. Landsat ARD Tile Metadata Sample

```
<?xml version="1.0" encoding="UTF-8"?>

-<ard_metadata>
        -<tile_metadata>
                -<global_metadata>
                        <data_provider>USGS/EROS</data_provider>
                        <satellite>LANDSAT_7</satellite>
                        <instrument>ETM</instrument>
                        <level1_collection>01</level1_collection>
                        <ard_version>01</ard_version>
                        <region>CU</region>
                        <acquisition_date>2016-10-07</acquisition_date>
                        <tile_id>LE07_CU_016006_20161007_20161130_C01_V01</tile_id>
                        <tile_production_date>2016-11-30</tile_production_date>
                        -<bounding_coordinates>
                                <west>-98.093857</west>
                                <east>-96.193037</east>
                                <north>44.722110</north>
                                <south>43.360751</south>
                        </bounding_coordinates>
                        -<projection_information units="meters" datum="WGS84" projection="AEA">
                                <corner_point y="2515800.000000" x="-299100.000000" location="UL"/>
                                <corner_point y="2293500.000000" x="-49800.000000"location="LR"/>
                                <grid_origin>CORNER</grid_origin>
                                -<albers_proj_params>
                                        <standard_parallel1>29.500000</standard_parallel1>
                                        <standard_parallel2>45.500000</standard_parallel2>
                                        <central_meridian>-96.000000</central_meridian>
                                        <origin_latitude>23.000000</origin_latitude>
                                        <false_easting>0.000000</false_easting>
                                        <false_northing>0.000000</false_northing>
                                </albers_proj_params>
                        </projection_information>
                        <orientation_angle>0.000000</orientation_angle>
                        <tile_grid v="006" h="016"/>
                        <scene_count>2</scene_count>
                        <cloud_cover>6.4918</cloud_cover>
                        <cloud_shadow>5.9551</cloud_shadow>
                        <snow_ice>0.0148</snow_ice>
                        <fill>64.9755</fill>
                </global_metadata>
        -<bands>
                <band product="level2_qa" source="level1" name="PIXELQA" category="qa" data_type="UINT16"
                fill_value="1" nsamps="5000" nlines="5000">
                        <short_name>LE07PQA</short_name>
                        <long_name>level-2 pixel quality band</long_name>
                        <file_name>LE07_CU_016006_20161007_20161130_C01_V01_PIXELQA.tif</file_name>
                        <pixel_size x="30" y="30" units="meters"/>
                        <resample_method>none</resample_method>
                        <data_units>quality/feature classification</data_units>
                        <bitmap_description>
                          <bit num="0">fill</bit>
                          <bit num="1">clear</bit>
                          <bit num="2">water</bit>
                          <bit num="3">cloud shadow</bit>
                          <bit num="4">snow</bit>
                          <bit num="5">cloud</bit>
                          <bit num="6">cloud confidence</bit>
                          <bit num="7">cloud confidence</bit>
```

```
                    <bit num="8">unused</bit>
                    <bit num="9">unused</bit>
                    <bit num="10">unused</bit>
                    <bit num="11">unused</bit>
                    <bit num="12">unused</bit>
                    <bit num="13">unused</bit>
                    <bit num="14">unused</bit>
                    <bit num="15">unused</bit>
                </bitmap_description>
                <app_version>generate_pixel_qa_1.2.0</app_version>
                <production_date>2016-11-22T14:43:00Z</production_date>
</band>
-<band fill_value="1" nsamps="5000" nlines="5000" data_type="UINT8" category="qa" name="RADSATQA"
product="toa_refl" source="level1">
        <short_name>LE07REF</short_name>
        <long_name>radiometric saturation QA band</long_name>
        <file_name> LE07_CU_016006_20161007_20161130_C01_V01_RADSATQA.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>bitmap</data_units>
        <valid_range max="255.000000" min="0.000000"/>
        -<bitmap_description>
                <bit num="0">Data Fill Flag (0 = valid data, 1 = invalid data)</bit>
                <bit num="1">Band 1 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
                <bit num="2">Band 2 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
                <bit num="3">Band 3 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
                <bit num="4">Band 4 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
                <bit num="5">Band 5 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
                <bit num="6">Band 6 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
                <bit num="7">Band 7 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
        </bitmap_description>
        <app_version>LEDAPS_3.1.2</app_version>
        <production_date>2016-11-22T14:43:28Z</production_date>
</band>
-<band fill_value="0" nsamps="5000" nlines="5000" data_type="UINT8" category="metadata"
name="LINEAGEQA" product="scene_index" source="level2">
        <short_name>TILEIDX</short_name>
        <long_name>index</long_name>
        <file_name> LE07_CU_016006_20161007_20161130_C01_V01_LINEAGEQA.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>index</data_units>
        <valid_range max="255.000000" min="0.000000"/>
                <production_date>2016-11-22T14:43:43Z</production_date>
</band>
-<band fill_value="-32768" nsamps="5000" nlines="5000" data_type="INT16" category="image"
name="SOZ4" product="angle_bands" source="level1" scale_factor="0.010000">
        <short_name>LE07SOLZEN</short_name>
        <long_name>band 4 solar zenith angles</long_name>
        <file_name> LE07_CU_016006_20161007_20161130_C01_V01_SOZ4.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>degrees</data_units>
        <app_version>create_angle_bands_1.11.1</app_version>
        <production_date>2016-11-22T14:43:43Z</production_date></band>
</band>
-<band fill_value="-32768" nsamps="5000" nlines="5000" data_type="INT16" category="image"
name="SOA4" product="angle_bands" source="level1" scale_factor="0.010000">
        <short_name>LE07SOLAZ</short_name>
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saturate_value="20000">
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name="TAB7" product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100"
saturate_value="20000">
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        <long_name>band 7 TOA reflectance</long_name>
        <file_name> LE07_CU_016006_20161007_20161130_C01_V01_TAB7.tif</file_name>
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saturate_value="20000">
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        <long_name>band 6 brightness temperature</long_name>
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saturate_value="20000">
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<long_name>band 5 surface reflectance</long_name>
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<production_date>2016-11-22T14:43:43Z</production_date>
</band>
</bands>
</tile_metadata>

-<scene_metadata>
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-<global_metadata>
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                <data_units>quality/feature classification</data_units>
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saturate_value="20000">
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                <long_name>band 2 TOA reflectance</long_name>

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<long_name>band 3 TOA reflectance</long_name>

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<long_name>band 5 TOA reflectance</long_name>

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<long_name>band 7 TOA reflectance</long_name>

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        <long_name>band 6 brightness temperature</long_name>
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        <short_name>LE07SR</short_name>
        <long_name>band 1 surface reflectance</long_name>
        <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_band1.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>reflectance</data_units>
        <valid_range max="16000.000000" min="-2000.000000"/>
        <app_version>LEDAPS_3.1.2</app_version>
        <production_date>2016-11-22T14:43:43Z</production_date>
    </band>
    -<band fill_value="-9999" data_type="INT16" category="image" name="sr_band2" product="sr_refl"
source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
        <short_name>LE07SR</short_name>
        <long_name>band 2 surface reflectance</long_name>
        <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_band2.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>reflectance</data_units>
        <valid_range max="16000.000000" min="-2000.000000"/>
```

```
                <app_version>LEDAPS_3.1.2</app_version>
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="sr_band3" product="sr_refl"
source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
                <short_name>LE07SR</short_name>
                <long_name>band 3 surface reflectance</long_name>
                <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_band3.tif</file_name>
                <pixel_size units="meters" y="30" x="30"/>
                <resample_method>none</resample_method>
                <data_units>reflectance</data_units>
                <valid_range max="16000.000000" min="-2000.000000"/>
                <app_version>LEDAPS_3.1.2</app_version>
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="sr_band4" product="sr_refl"
source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
                <short_name>LE07SR</short_name>
                <long_name>band 4 surface reflectance</long_name>
                <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_band4.tif</file_name>
                <pixel_size units="meters" y="30" x="30"/>
                <resample_method>none</resample_method>
                <data_units>reflectance</data_units>
                <valid_range max="16000.000000" min="-2000.000000"/>
                <app_version>LEDAPS_3.1.2</app_version>
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="sr_band5" product="sr_refl"
source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
                <short_name>LE07SR</short_name>
                <long_name>band 5 surface reflectance</long_name>
                <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_band5.tif</file_name>
                <pixel_size units="meters" y="30" x="30"/>
                <resample_method>none</resample_method>
                <data_units>reflectance</data_units>
                <valid_range max="16000.000000" min="-2000.000000"/>
                <app_version>LEDAPS_3.1.2</app_version>
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="sr_band7" product="sr_refl"
source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
                <short_name>LE07SR</short_name>
                <long_name>band 7 surface reflectance</long_name>
                <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_band7.tif</file_name>
                <pixel_size units="meters" y="30" x="30"/>
                <resample_method>none</resample_method>
                <data_units>reflectance</data_units>
                <valid_range max="16000.000000" min="-2000.000000"/>
                <app_version>LEDAPS_3.1.2</app_version>
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="sr_atmos_opacity"
product="sr_refl" source="toa_refl" scale_factor="0.001000">
                <short_name>LE07SR</short_name>
                <long_name>atmos_opacity</long_name>
                <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_atmos_opacity.tif</file
        _name>
                <pixel_size units="meters" y="30" x="30"/>
                <resample_method>none</resample_method>
                <data_units>reflectance</data_units>
                <valid_range max="16000.000000" min="-2000.000000"/>
                <app_version>LEDAPS_3.1.2</app_version>
```

```
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
        -<band data_type="UINT8" category="qa" name="sr_cloud_qa" product="sr_refl"
source="toa_refl">
                <short_name>LE07SR</short_name>
                <long_name>cloud_qa</long_name>

        <file_name>LE07_L1TP_030029_20161007_20161020_01_A1_sr_cloud_qa.tif</file_name>
                <pixel_size units="meters" y="30" x="30"/>
                <resample_method>none</resample_method>
                <data_units>quality/feature classification</data_units>
                <valid_range max="255.000000" min="0.000000"/>
                -<bitmap_description>
                        <bit num="0">dark dense vegetation</bit>
                        <bit num="1">cloud</bit>
                        <bit num="2">cloud shadow</bit>
                        <bit num="3">adjacent to cloud</bit>
                        <bit num="4">snow</bit>
                        <bit num="5">land/water</bit>
                </bitmap_description>
                <app_version>LEDAPS_3.1.2</app_version>
                <production_date>2016-11-22T14:43:43Z</production_date>
        </band>
</bands>
</scene_metadata>
-<scene_metadata>
        <index>2</index>
        -<global_metadata>
                <data_provider>USGS/EROS</data_provider>
                <satellite>LANDSAT_7</satellite>
                <instrument>ETM</instrument>
                <acquisition_date>2016-10-07</acquisition_date>
                <scene_center_time>17:20:43.1451464Z</scene_center_time>
                <level1_production_date>2016-10-20T20:41:56Z</level1_production_date>
                <wrs row="30" path="30" system="2"/>
                <scene_id>LE70300302016281EDC00</scene_id>
                <product_id>LE07_L1TP_030030_20161007_20161020_01_A1</product_id>
                <lpgs_metadata_file>LE07_L1TP_030030_20161007_20161020_01_A1_MTL.txt</lpgs_
        metadata_file>
                <geometric_rmse_model>5.311</geometric_rmse_model>
                <geometric_rmse_model_x>3.892</geometric_rmse_model_x>
                <geometric_rmse_model_y>3.613</geometric_rmse_model_y>
</global_metadata>
-<bands>
        -<band product="level2_qa" source="level1" name="pixel_qa" category="qa" data_type="UINT16"
        fill_value="1">
                <short_name>LE07PQA</short_name>
                <long_name>level-2 pixel quality band</long_name>
                <file_name>LE07_L1TP_047027_20151231_20161028_01_A1_pixel_qa.tif</file_name>
                <pixel_size x="30" y="30" units="meters"/>
                <resample_method>none</resample_method>
                <data_units>quality/feature classification</data_units>
                <bitmap_description>
                        <bit num="0">fill</bit>
                        <bit num="1">clear</bit>
                        <bit num="2">water</bit>
                        <bit num="3">cloud shadow</bit>
                        <bit num="4">snow</bit>
                        <bit num="5">cloud</bit>
                        <bit num="6">cloud confidence</bit>
                        <bit num="7">cloud confidence</bit>
                        <bit num="8">unused</bit>
```

```
                        <bit num="9">unused</bit>
                        <bit num="10">unused</bit>
                        <bit num="11">unused</bit>
                        <bit num="12">unused</bit>
                        <bit num="13">unused</bit>
                        <bit num="14">unused</bit>
                        <bit num="15">unused</bit>
                    </bitmap_description>
                    <app_version>generate_pixel_qa_1.2.0</app_version>
                    <production_date>2016-11-22T14:43:00Z</production_date>
                    </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="toa_band1"
product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100"
saturate_value="20000">
                    <short_name>LE07REF</short_name>
                    <long_name>band 1 TOA reflectance</long_name>

        <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_toa_band1.tif</file_name>
                    <pixel_size units="meters" y="30" x="30"/>
                    <resample_method>none</resample_method>
                    <data_units>reflectance</data_units>
                    <valid_range max="16000.000000" min="-100.000000"/>
                    <app_version>LEDAPS_3.1.2</app_version>
                    <production_date>2016-11-22T14:43:28Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="toa_band2"
product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100"
saturate_value="20000">
                    <short_name>LE07REF</short_name>
                    <long_name>band 2 TOA reflectance</long_name>

        <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_toa_band2.tif</file_name>
                    <pixel_size units="meters" y="30" x="30"/>
                    <resample_method>none</resample_method>
                    <data_units>reflectance</data_units>
                    <valid_range max="16000.000000" min="-100.000000"/>
                    <app_version>LEDAPS_3.1.2</app_version>
                    <production_date>2016-11-22T14:43:28Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="toa_band3"
product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100"
saturate_value="20000">
                    <short_name>LE07REF</short_name>
                    <long_name>band 3 TOA reflectance</long_name>

        <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_toa_band3.tif</file_name>
                    <pixel_size units="meters" y="30" x="30"/>
                    <resample_method>none</resample_method>
                    <data_units>reflectance</data_units>
                    <valid_range max="16000.000000" min="-100.000000"/>
                    <app_version>LEDAPS_3.1.2</app_version>
                    <production_date>2016-11-22T14:43:28Z</production_date>
        </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="toa_band4"
product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100"
saturate_value="20000">
                    <short_name>LE07REF</short_name>
                    <long_name>band 4 TOA reflectance</long_name>

        <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_toa_band4.tif</file_name>
                    <pixel_size units="meters" y="30" x="30"/>
                    <resample_method>none</resample_method>
```

<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.1.2</app_version>
<production_date>2016-11-22T14:43:28Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="toa_band5" product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
<short_name>LE07REF</short_name>
<long_name>band 5 TOA reflectance</long_name>

<file_name>LE07_L1TP_030030_20161007_20161020_01_A1_toa_band5.tif</file_name>
<pixel_size units="meters" y="30" x="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.1.2</app_version>
<production_date>2016-11-22T14:43:28Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="toa_band7" product="toa_refl" source="level1" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
<short_name>LE07REF</short_name>
<long_name>band 7 TOA reflectance</long_name>

<file_name>LE07_L1TP_030030_20161007_20161020_01_A1_toa_band7.tif</file_name>
<pixel_size units="meters" y="30" x="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.1.2</app_version>
<production_date>2016-11-22T14:43:28Z</production_date>
</band>
-<band fill_value="1" data_type="UINT8" category="qa" name=“RADSATQA”product="toa_refl" source="level1">
<short_name>LE07REF</short_name>
<long_name>radiometric saturation QA band</long_name>
<file_name>LE07_L1TP_030030_20161007_20161020_01_A1_radsat_qa.tif</file_name>
<pixel_size units="meters" y="30" x="30"/>
<resample_method>none</resample_method>
<data_units>bitmap</data_units>
<valid_range max="255.000000" min="0.000000"/>
-<bitmap_description>
<bit num="0">Data Fill Flag (0 = valid data, 1 = invalid data)</bit>
<bit num="1">Band 1 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="2">Band 2 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="3">Band 3 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="4">Band 4 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="5">Band 5 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="6">Band 6 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
<bit num="7">Band 7 Data Saturation Flag (0 = valid data, 1 = saturated data)</bit>
</bitmap_description>
<app_version>LEDAPS_3.1.2</app_version>
<production_date>2016-11-22T14:43:28Z</production_date>
</band>

```
-<band fill_value="-9999" data_type="INT16" category="image" name="bt_band6" product="toa_bt" source="level1" add_offset="0.000000" scale_factor="0.100000" saturate_value="20000">
    <short_name>LE07BT</short_name>
    <long_name>band 6 brightness temperature</long_name>
    <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_bt_band6.tif</file_name>
    <pixel_size units="meters" y="30" x="30"/>
    <resample_method>none</resample_method>
    <data_units>temperature (kelvin)</data_units>
    <valid_range max="3500.000000" min="1500.000000"/>
    <app_version>LEDAPS_3.1.2</app_version>
    <production_date>2016-11-22T14:43:28Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="sr_band1" product="sr_refl" source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
    <short_name>LE07SR</short_name>
    <long_name>band 1 surface reflectance</long_name>
    <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_band1.tif</file_name>
    <pixel_size units="meters" y="30" x="30"/>
    <resample_method>none</resample_method>
    <data_units>reflectance</data_units>
    <valid_range max="16000.000000" min="-2000.000000"/>
    <app_version>LEDAPS_3.1.2</app_version>
    <production_date>2016-11-22T14:43:43Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="sr_band2" product="sr_refl" source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
    <short_name>LE07SR</short_name>
    <long_name>band 2 surface reflectance</long_name>
    <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_band2.tif</file_name>
    <pixel_size units="meters" y="30" x="30"/>
    <resample_method>none</resample_method>
    <data_units>reflectance</data_units>
    <valid_range max="16000.000000" min="-2000.000000"/>
    <app_version>LEDAPS_3.1.2</app_version>
    <production_date>2016-11-22T14:43:43Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="sr_band3" product="sr_refl" source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
    <short_name>LE07SR</short_name>
    <long_name>band 3 surface reflectance</long_name>
    <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_band3.tif</file_name>
    <pixel_size units="meters" y="30" x="30"/>
    <resample_method>none</resample_method>
    <data_units>reflectance</data_units>
    <valid_range max="16000.000000" min="-2000.000000"/>
    <app_version>LEDAPS_3.1.2</app_version>
    <production_date>2016-11-22T14:43:43Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="sr_band4" product="sr_refl" source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
    <short_name>LE07SR</short_name>
    <long_name>band 4 surface reflectance</long_name>
    <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_band4.tif</file_name>
    <pixel_size units="meters" y="30" x="30"/>
    <resample_method>none</resample_method>
    <data_units>reflectance</data_units>
    <valid_range max="16000.000000" min="-2000.000000"/>
    <app_version>LEDAPS_3.1.2</app_version>
    <production_date>2016-11-22T14:43:43Z</production_date>
</band>
-<band fill_value="-9999" data_type="INT16" category="image" name="sr_band5" product="sr_refl" source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
```

```
                        <short_name>LE07SR</short_name>
                        <long_name>band 5 surface reflectance</long_name>
                        <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_band5.tif</file_name>
                        <pixel_size units="meters" y="30" x="30"/>
                        <resample_method>none</resample_method>
                        <data_units>reflectance</data_units>
                        <valid_range max="16000.000000" min="-2000.000000"/>
                        <app_version>LEDAPS_3.1.2</app_version>
                        <production_date>2016-11-22T14:43:43Z</production_date>
                </band>
                -<band fill_value="-9999" data_type="INT16" category="image" name="sr_band7" product="sr_refl"
        source="toa_refl" add_offset="0.000000" scale_factor="0.000100" saturate_value="20000">
                        <short_name>LE07SR</short_name>
                        <long_name>band 7 surface reflectance</long_name>
                        <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_band7.tif</file_name>
                        <pixel_size units="meters" y="30" x="30"/>
                        <resample_method>none</resample_method>
                        <data_units>reflectance</data_units>
                        <valid_range max="16000.000000" min="-2000.000000"/>
                        <app_version>LEDAPS_3.1.2</app_version>
                        <production_date>2016-11-22T14:43:43Z</production_date>
                </band>
        -<band fill_value="-9999" data_type="INT16" category="image" name="sr_atmos_opacity" product="sr_refl"
        source="toa_refl" scale_factor="0.001000">
                        <short_name>LE07SR</short_name>
                        <long_name>atmos_opacity</long_name>

                <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_atmos_opacity.tif</file_name>
                        <pixel_size units="meters" y="30" x="30"/>
                        <resample_method>none</resample_method>
                        <data_units>reflectance</data_units>
                        <valid_range max="16000.000000" min="-2000.000000"/>
                        <app_version>LEDAPS_3.1.2</app_version>
                        <production_date>2016-11-22T14:43:43Z</production_date>
                </band>
                -<band data_type="UINT8" category="qa" name="sr_cloud_qa" product="sr_refl"
        source="toa_refl">
                        <short_name>LE07SR</short_name>
                        <long_name>cloud_qa</long_name>

                <file_name>LE07_L1TP_030030_20161007_20161020_01_A1_sr_cloud_qa.tif</file_name>
                        <pixel_size units="meters" y="30" x="30"/>
                        <resample_method>none</resample_method>
                        <data_units>quality/feature classification</data_units>
                        <valid_range max="255.000000" min="0.000000"/>
                        -<bitmap_description>
                                <bit num="0">dark dense vegetation</bit>
                                <bit num="1">cloud</bit>
                                <bit num="2">cloud shadow</bit>
                                <bit num="3">adjacent to cloud</bit>
                                <bit num="4">snow</bit>
                                <bit num="5">land/water</bit>
                                <bit num=”6”>unused</bit>
                                <bit num=”7”>unused</bit>
                        </bitmap_description>
                        <app_version>LEDAPS_3.1.2</app_version>
                        <production_date>2016-11-22T14:43:43Z</production_date>
                </band>
        </bands>
        </scene_metadata>
</ard_metadata>
```

Appendix B U.S. Landsat ARD Tile Metadata Sample Definitions

Parameter Name	Value, Format and Range	Parameter Description / Remarks
ard_metadata	N/A	Heading for analysis ready data-level metadata
tile_metadata	N/A	Heading for tile-level metadata
global_metadata	N/A	Heading for metadata that applies to entire tile
data_provider	USGS/EROS	Source of the data and subsequent metadata
satellite	LANDSAT_X	Designates acquisition satellite platform
instrument	TM, ETM, OLI/TIRS	Designates acquisition instrument
region	CO, AK, HI	Designates region in the U.S.
level1_collection	CCC	Collection number from Level 1 source
ard_version	VVV	Version number of ARD
acquisition_date	YYYY-MM-DD	Date of data acquisition by satellite
tile_id	LSXX_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_PRODUCT	Tile identifier, or file name, that is defined by sensor, region, tile coordinates, acquisition date, production date, collection number, version number, and product Example: LE07_CO_016006_20161007_20170112_C01_V01_SR
tile_production_date	YYYY-MM-DD	Date of tile creation
bounding_coordinates	west, east (degrees; -180 to 180) north, south (degrees; -90 to 90)	Geographic coordinates (WGS84) of the tile extent, including fill
projection_informmation	N/A	Heading for map projection information
units	meters or degrees	Albers is a meters-based projection
datum	WGS84	The datum used in creating the image
projection	Albers	The projection used in creating the image
corner_point_y,x,location	(Variable)	Corner coordinates for upper-left (“UL”) or lower-right (“LR”) in grid space
grid_origin	corner	Defines origin of pixel (usually ‘corner’ or ‘center’)
albers_proj_params	N/A	Heading for projection-specific parameters
standard_parallel1	29.5	Standard parallel 1
standard_parallel2	45.5	Standard parallel 2
central_meridian	96.0	Central meridian
origin_latitude	23.0	Latitude of origin
false_easting	0.0	False easting
false_northing	0.0	False northing
orientation_angle	0.0	Orientation angle of image
tile grid v,h	VVV, HHH	Vertical (V) and horizontal (H) coordinates of tile grid
scene_count	2	Number of scenes within the tile
cloud_cover	6.4918	Percent of cloud pixel(s) occupying non-fill pixels within the tile
cloud_shadow	5.9551	Percent of cloud shadow pixel(s) occupying non-fill pixels within the tile

Parameter Name	Value, Format and Range	Parameter Description / Remarks
snow_ice	0.0148	Percent of snow / ice pixel(s) occupying non-fill pixels within the tile
fill	64.9755	Percent of fill pixel(s) occupying the entire tile extent
bands	N/A	Heading for individual bands within a tile
product	level2_qa	General product type
source	level1	
name	PIXEL_QA	Name of band
category	qa	Type of data within band
data_type	UINT16	Type of data values within band
fill_value	1	Fill value of band
nsamps	5000	Number of samples in band
nlines	5000	Number of lines in band
short_name	LE07PQA	Short name of the band
long_name	level-2 pixel quality band	Long name of the band
file_name	LE07_CU_016006_20161007_20161130_C01_V01_PIXELQA.tif	Full name of the file
pixel_size units, y, x	meters, 30, 30	Pixel units, size in y and x dimensions
resample_method	none	Resampling method used to transform from Level 0 to current level
data_units	quality/feature classification	Description of data units
valid_range max, min	65535.0, 0.0	Maximum and minimum data units
bitmap_description	N/A	Heading of description for individual bits
bit num	1, 2, etc.	Number of bit and its description
app_version	LPGS_12.8.2	Processing software version used to process data
production_date	2016-10-20T20:35:13Z	Date and Universal Time Code (UTC) time when the data were processed to a tile
scene_metadata	N/A	Heading for scene-level metadata
index	1	Unique index value representing a single Landsat scene, which correlates with tile lineage index band
global_metadata	N/A	Heading for scene-wide metadata
data_provider	USGS/EROS	Provider of the scene-level data
satellite	LANDSAT_7	Satellite from which the data were captured
instrument	ETM	Sensor(s) used to capture this scene
acquisition_date	2016-10-07	Date at which the scene was acquired
scene_center_time	17:20:43.1451464Z	UTC time when the center of the scene's data were captured
level1_production_date	2016-10-20T20:35:13Z	Time at which the scene was processed from Level 0 to Level 1
wrs row, path, system	29, 30, 2	Worldwide Reference System (WRS) row, path index, and WRS system (1 or 2)
scene_id	LE70300292016281EDC00	The unique Landsat scene identifier
product_id	LE07_L1TP_030029_20161007_20161020_01_A1	The unique Landsat product identifier
lpgs_metadata_file	LE07_L1TP_030029_20161007_20161020_01_A1_MTL.txt	Name of Level 1 metadata file
geometric_rmse_model	4.929	Combined RMSE of the geometric residuals (meters) in both across-track and along-track directions measured on the

Parameter Name	Value, Format and Range	Parameter Description / Remarks
		Ground Control Points (GCPs) used in geometric precision correction; this parameter is only present if the DATA_TYPE is Level 1 Terrain (Corrected) (L1T)
geometric_rmse_model_x	3.884	The TM/ E TM+ post-fit RMSE for the along-track direction, or the OLI / TIRS post-fit RMSE for the across-track direction; units are in meters equal to or greater than zero, with no upper limit, and three decimal places; this parameter is only present if the DATA_TYPE is L1T
geometric_rmse_model_y	3.035	The TM / ETM+ post-fit RMSE for the across-track direction or the OLI / TIRS post-fit RMSE for the along-track direction; units are in meters equal to greater than zero, with no upper limit, and three decimal places; this parameter is only present if the DATA_TYPE is L1T

References

Please see https://landsat.usgs.gov/glossary-and-acronyms for a list of acronyms.

LSDS-809. Landsat 8 (L8) Level-1 (L1) Data Format Control Book (DFCB) https://landsat.usgs.gov/sites/default/files/documents/LSDS-809-Landsat8-Level1DFCB.pdf

LSDS-272. Landsat 8 (L7) Level-1 (L1) Data Format Control Book (DFCB) https://landsat.usgs.gov/sites/default/files/documents/LSDS-272-Landsat7-Level1DFCB.pdf

LSDS-284. Landsat Thematic Mapper Level-1 (L1) Level-1 (L1) Data Format Control Book (DFCB) https://landsat.usgs.gov/sites/default/files/documents/LSDS-284.pdf

Landsat 4-7 Surface Reflectance (LEDAPS) Product Guide https://landsat.usgs.gov/sites/default/files/documents/ledaps_product_guide.pdf

Landsat 8 Surface Reflectance Code (LaSRC) Product Guide https://landsat.usgs.gov/sites/default/files/documents/lasrc_product_guide.pdf

Web-Enabled Landsat Data (WELD) ATBD http://globalmonitoring.sdstate.edu/projects/weld/WELD_ATBD.pdf

Roy, D.P., Ju, J., Kline, K., Scaramuzza, P.L., Kovalskyy, V., Hansen, M.C., Loveland, T.R., Vermote, E.F., Zhang, C. (2010). Web-enabled Landsat Data (WELD): Landsat ETM+ Composited Mosaics of the Conterminous United States, Remote Sensing of Environment, 114: 35-49. https://doi.org/10.1016/j.rse.2009.08.011

EPSG Geodetic Parameter Registry. Version 7.4 http://www.epsg-registry.org

GeoTIFF Specification https://trac.osgeo.org/geotiff

Masek, J.G., Vermote, E.F., Saleous N.E., Wolfe, R., Hall, F.G., Huemmrich, K.F., Gao, F., Kutler, J., and Lim, T-K. (2006). A Landsat surface reflectance dataset for North America, 1990–2000. IEEE Geoscience and Remote Sensing Letters 3(1):68-72. http://dx.doi.org/10.1109/LGRS.2005.857030.

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.