LSDS-1873
Version 6.0

Department of the Interior
U.S. Geological Survey

U.S. Landsat
Collection 1 (C1)
Analysis Ready Data (ARD)
Data Format Control Book (DFCB)

Version 6.0

September 2019

USGS
science for a changing world

U.S. Landsat
Collection 1 (C1)
Analysis Ready Data (ARD)
Data Format Control Book (DFCB)

September 2019

Approved By:

CHRISTOPHER ENGEBRETSON

Digitally signed by CHRISTOPHER ENGEBRETSON
Date: 2019.09.27 09:56:25 -05'00'

Chris Engebretson Date
Landsat DPAS CCB Chair
U.S. Geological Survey

EROS
Sioux Falls, South Dakota

Executive Summary

This Data Format Control Book (DFCB) presents detailed data formats for the U.S. Landsat Collection 1 (C1) 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 standard and level of processing required for direct use in remote sensing applications.

A key goal for ARD is to significantly reduce the burden of processing on remote sensing scientists, who would need to download and prepare large amounts of data for time series analysis (such as performing 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 1 (C1) Level 1 Terrain Precision (Corrected) (L1TP) or the Level 1 Systematic Terrain (Corrected) (L1GT) products serve as the input for generating ARD.

This document is under Land Data Processing and Archive System (DPAS) Configuration Control Board (CCB) control. Please submit changes to this document, as well as supportive material justifying the proposed changes, via Change Request (CR) to the Process and Change Management Tool.

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
LSDS-1873	Version 5.0	October 2018	CR 14489
LSDS-1873	Version 6.0	September 2019	CR 15059

Contents

Executive Summary ..... **iii**
Document History ..... **iv**
Contents ..... **v**
List of Figures ..... **v**
List of Tables ..... **vi**
Section 1 Introduction **1**
1.1 Background 1
1.2 Purpose and Scope 1
1.3 Document Organization 1
1.4 Terminology 1
Section 2 Overview of U.S. Landsat ARD **5**
2.1 U.S. Landsat ARD Product Band Specifications 6
2.1.1 U.S. Landsat 4-7 TM/ETM+ ARD Product Specifications 6
2.1.2 Landsat 4-7 TM/ETM+ U.S. Landsat ARD Quality Assessment Band Specifications 8
2.1.3 Landsat 8 OLI-TIRS ARD Product Specifications 13
2.1.4 Landsat 8 OLI-TIRS ARD Quality Assessment Band Specifications 15
2.2 U.S. Landsat ARD Naming Conventions 23
2.2.1 U.S. Landsat ARD Product Identifier Conventions 23
2.2.2 U.S. Landsat ARD Product Identifier Examples 25
2.3 U.S. Landsat ARD Spatial Attributes 27
2.3.1 Map Projection 27
2.3.2 Tile Grid System 27
2.4 U.S. Landsat ARD Known Caveats and Artifacts 28
Section 3 Data Format Definition **29**
3.1 U.S. Landsat ARD Product Packaging 29
3.1.1 Metadata Files 29
3.1.2 U.S. Landsat ARD Package Contents 34
3.1.3 Product Volumes 36
3.2 GeoTIFF Specifications 37
3.2.1 GeoTIFF Image Preparation 37
3.2.2 GeoTIFF Tags 37
3.2.3 GeoTIFF Keys 38
Appendix A U.S. Landsat ARD Tile Metadata Sample **40**
Appendix B U.S. Landsat ARD Tile Metadata Sample Definitions **61**
References **64**

List of Figures

Figure 1-1. Landsat ARD Tile Grid for the Conterminous U.S. 3
Figure 1-2. Landsat ARD Tile Grid for Alaska 3

Figure 1-3. Landsat ARD Tile Grid for Hawaii 4
Figure 2-1. Lineage Index Band Example 11

List of Tables

Table 2-1. Landsat 4-7 Top of Atmosphere Reflectance Band Specifications..... 6
Table 2-2. Landsat 4-7 Top of Atmosphere Brightness Temperature Band Specifications 7
Table 2-3. Landsat 4-7 Surface Reflectance Band Specifications..... 7
Table 2-4. Landsat 4-7 Surface Temperature Band Specification..... 8
Table 2-5. Landsat 4-7 U.S. Landsat ARD Quality Assessment Band Specifications..... 8
Table 2-6. Landsat 4-7 Pixel Quality Assessment Bit Index..... 9
Table 2-7. Landsat 4-7 Pixel Quality Assessment Bit Values..... 10
Table 2-8. Landsat 4-7 Radiometric Saturation Quality Assessment Bit Index 10
Table 2-9. Landsat 4-7 Lineage Index Band 10
Table 2-10. Landsat 4-7 Internal Surface Reflectance Atmospheric Opacity Band Attributes..... 11
Table 2-11. Landsat 4-7 Internal Surface Reflectance Quality Assessment Bit Index... 12
Table 2-12. Landsat 4-7 Internal Surface Reflectance Quality Assessment Bit Values. 12
Table 2-13. Landsat 8 Top of Atmosphere Reflectance Band Specifications..... 14
Table 2-14. Landsat 8 Top of Atmosphere Brightness Temperature Band Specifications 14
Table 2-15. Landsat 8 Surface Reflectance Band Specifications..... 14
Table 2-16. Landsat 8 Surface Temperature Band Specifications 15
Table 2-17. Landsat 8 ARD Quality Assessment Band Specifications..... 15
Table 2-18. Landsat 8 Pixel Quality Assessment Bit Index 16
Table 2-19. Landsat 8 Pixel Quality Assessment Bit Values 19
Table 2-20. Landsat 8 Radiometric Saturation Quality Assessment Bit Index..... 20
Table 2-21. Landsat 8 Lineage Index Band Values..... 20
Table 2-22. Landsat 8 Internal Surface Reflectance Aerosol Quality Assessment Bit Index 21
Table 2-23. Landsat 8 Internal Surface Reflectance Aerosol Quality Assessment Bit Values 22
Table 2-24. Landsat Collection 1 Level 1 Product Identifier Terms 23
Table 2-25. Landsat Level 2 Product Identifier Terms..... 24
Table 2-26. U.S. Landsat ARD Product Identifier Terms..... 25
Table 2-27. Landsat ARD Map Projection Parameters..... 27
Table 2-28. U.S. Landsat ARD Tile Grid Extents 27
Table 3-1. U.S. Landsat ARD Package ID Terms 29
Table 3-2. Landsat 4-8 ARD Estimated Average Product Volume (terabytes) and Number of Scenes (1985-2016)..... 37
Table 3-3. Albers GeoTIFF Key Description..... 39

Section 1 Introduction

1.1 Background

Landsat satellite data have been produced, archived, and distributed by the U.S. Geological Survey (USGS) since 1972. Users rely upon these data for conducting historical studies of land surface change, but have shouldered the burden of post-production processing to create application-ready datasets. To alleviate this burden on the user, the USGS has initiated an effort to produce a collection of Landsat Science Products to support land surface change studies. These products include terrestrial variables such as Surface Reflectance (SR), Provisional Surface Temperature (ST), Burned Area (BA), fractional Snow Covered Area (fSCA), and Dynamic Surface Water Extent (DSWE) that are suitable for monitoring, assessing, and predicting land surface change over time.

This Data Format Control Book (DFCB) provides detailed description of the U.S. Landsat Collection 1 (C1) Analysis Ready Data (ARD) product specifications and product packaging.

1.2 Purpose and Scope

The primary purpose of this document is to provide detailed information on the U.S. Landsat Collection 1 (C1) Analysis Ready Data (ARD) specifications.

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 Document Organization

This document contains the following sections:

- Section 1 provides an introduction
- Section 2 provides an overview of the U.S. Landsat ARD
- Section 3 provides information about data format definition
- Appendix A provides sample metadata
- Appendix B provides definition for metadata
- The Reference section contains a list of reference documents

1.4 Terminology

Level 1 – Level 1 processing refers to the generation of radiometrically calibrated and orthorectified data products as a collection.

Level 2 – Level 2 processing refers to the generation of Top of Atmosphere (TOA) Reflectance, Surface Reflectance (SR), TOA Brightness Temperature (BT), Quality Assessment (QA), and Surface Temperature (ST) scenes as inputs to ARD.

Level 3 – Level 3 processing refers to temporal composites and science products (Burned Area (BA), Dynamic Surface Water Extent (DSWE), fractional Snow Covered Area (fSCA), spectral indices, and land change products) derived from ARD.

Tier 1 – Landsat scenes with the highest available data quality are placed into Tier 1 and are considered suitable for time-series analysis. This includes Landsat Level 1 Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS) data processed to Level 1 Terrain Precision (Corrected) (L1TP) with a post model fit to the Global Land Survey (GLS) control of ≤12- meter (m) Root Mean Square Error (RMSE) (ideal for time series "stacking").

Tier 2 – Landsat scenes not meeting Tier 1 criteria during processing are assigned to Tier 2. This includes Landsat Level 1 TM and ETM+ data processed to Level 1 Geometric Systematic (Corrected) (L1GS) products, and ETM+ and OLI/TIRS data processed to Level 1 Systematic Terrain (Corrected) (L1GT) products and to L1TP, for which the post model fit to the GLS control is >12-m RMSE. Tier 2 scenes adhere to the same radiometric standard as Tier 1 scenes, but do not meet the Tier 1 geometry specification due to less accurate orbital information (specific to older Landsat sensors), significant cloud cover, insufficient ground control, or other factors.

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, and Figure 1-3 for conterminous U.S., Alaska, and Hawaii examples, respectively). An ARD tile is defined as 5,000 x 5,000 30-m pixels.

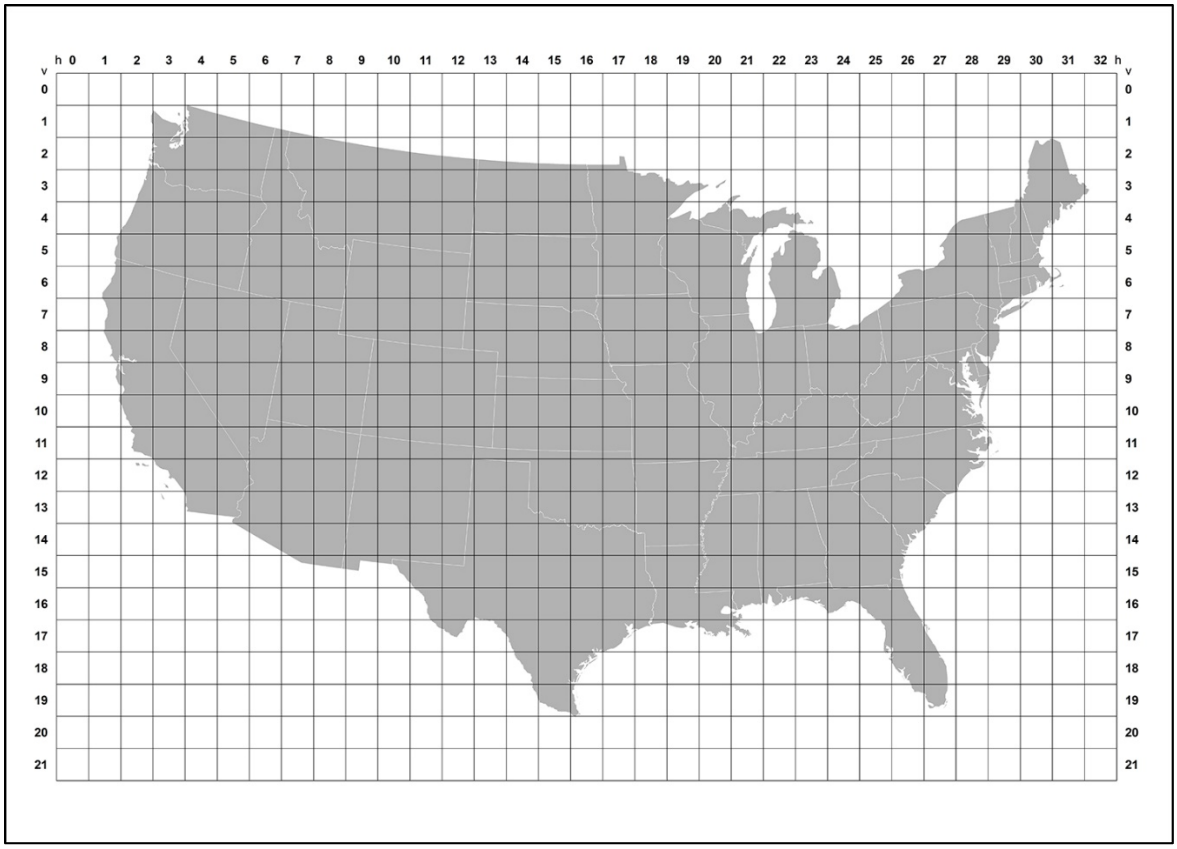

Figure 1-1. Landsat ARD Tile Grid for the Conterminous U.S.

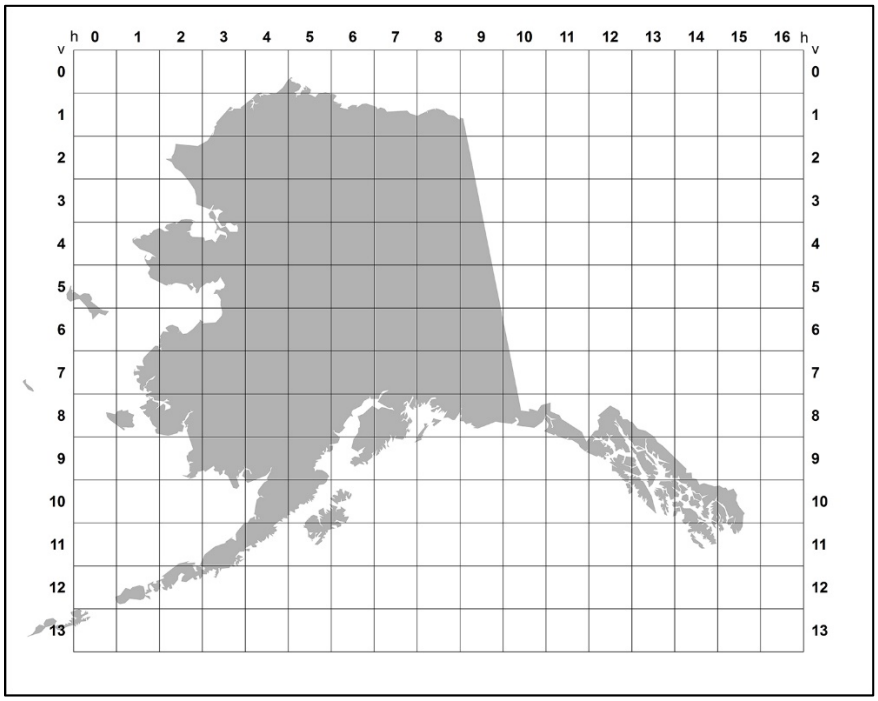

Figure 1-2. Landsat ARD Tile Grid for Alaska

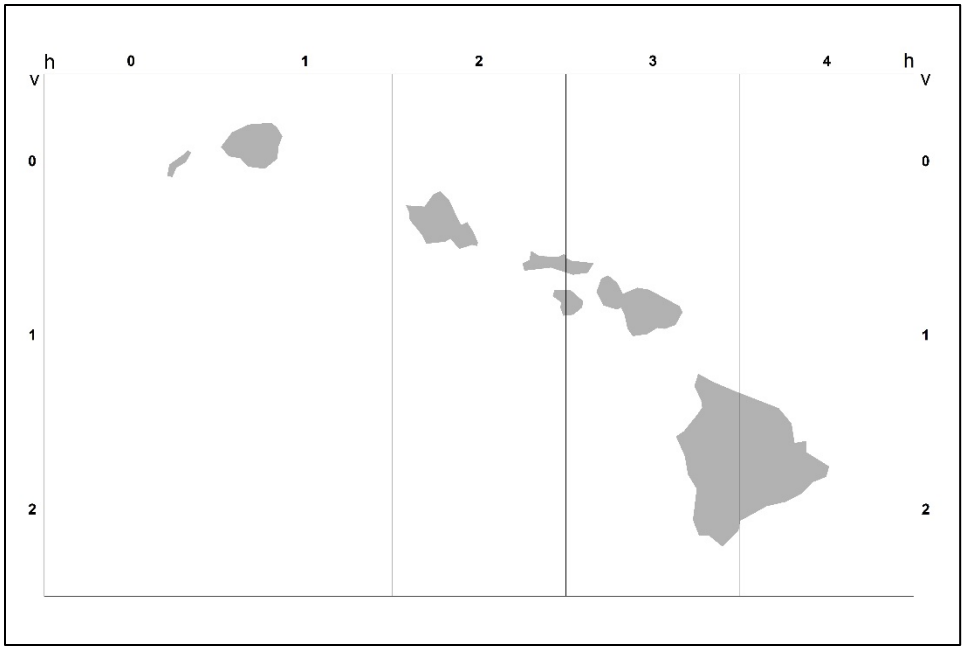

Figure 1-3. Landsat ARD Tile Grid for Hawaii

Section 2 Overview of U.S. Landsat ARD

The Collection 1 U.S. Landsat ARD consist of Top of Atmosphere (TOA) Reflectance, TOA Brightness Temperature (BT), Surface Reflectance (SR), Provisional Surface Temperature (ST), and Quality Assessment (QA) data gridded to a common cartographic projection and accompanied by appropriate metadata to enable further processing while retaining traceability of data provenance. 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 products such as Burned Area (BA), Dynamic Surface Water Extent (DSWE), and fractional Snow Covered Area (fSCA).

The Collection 1 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 OLI/TIRS Tier 1, Tier 2
- Landsat 7 ETM+ Tier 1
- Landsat 4-5 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.

Landsat 1-5 Multispectral Scanner (MSS) data will be considered for processing into the U.S. ARD inventory, once these data have been sufficiently analyzed for their suitability.

The current definition of Collection 1 U.S. Landsat ARD includes the products output by the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) Surface Reflectance algorithm (Version 3.2.1), the Landsat Surface Reflectance Code (LaSRC) (Version 1.3.0), and the Landsat Level 2 Surface Temperature algorithm (Version 1.3.0), supplemented by EROS Science Processing Architecture (ESPA)-L2QA-TOOLS (Version 1.6.0) and C version of Function of Mask (CFMask)-based cloud, water, and snow detection code (Version 2.0.2). The 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 are not available in the Level 1 implementation of CFMask.

The Landsat Level 2 SR science product is generated by applying atmospheric correction routines to Landsat TOA Reflectance data, using auxiliary input data such as water vapor, ozone, and Aerosol Optical Thickness (AOT). The Landsat Level 2 Provisional ST science product is generated from the Level 1 thermal infrared bands and TOA Reflectance, using auxiliary input data such as Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Emissivity Database (GED) data, ASTER Normalized Difference Vegetation Index (NDVI) data, and atmospheric profiles of geopotential height, specific humidity, and air temperature.

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 TOA Reflectance, TOA Brightness Temperature, Surface Reflectance, and internal pixel Quality Assessment derived from Landsat 4-5 TM and Landsat 7 ETM+ inputs. The ARD package also contains the Provisional Surface Temperature science product, which is generated by Single Channel algorithm. Table 2-1 through Table 2-5 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_band1	TAB1	Band 1 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band2	TAB2	Band 2 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band3	TAB3	Band 3 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band4	TAB4	Band 4 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band5	TAB5	Band 5 TOA Reflectance	INT16	Refl	-100 – 16000	0 – 10000	-9999	20000	0.0001
toa_band7	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, Refl=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	1500 – 3500	-9999	20000	0.1
bt=top of atmosphere brightness temperature, BTB= top of atmosphere brightness temperature band, 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	Saturate 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, SRB=surface reflectance band, INT16=16-bit signed integer, Refl=reflectance									

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

Level 2 Band Designation	ARD Band Description	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
surface_temperature	ST	Surface Temperature	INT16	Kelvin	1500 – 3730	1500 – 3730	-9999	NA	0.1
st_atmospheric_transmittance	ATRAN	Atmospheric Transmittance	INT16	Radiance	0 – 10000	0 – 10000	-9999	NA	0.0001
st_downwelled_radiance	DRAD	Downwelled Radiance	INT16	Radiance	0 – 28000	0 – 28000	-9999	NA	0.001
st_upwelled_radiance	URAD	Upwelled Radiance	INT16	Radiance	0 – 28000	0 – 28000	-9999	NA	0.001
st_thermal_radiance	TRAD	Thermal band converted to radiance	INT16	Radiance	0 – 22000	0 – 22000	-9999	NA	0.001
emis	EMIS	Landsat Emissivity estimated from ASTER GED data	INT16	Emissivity coefficient	0 – 10000	0 – 10000	-9999	NA	0.0001
emis_stdev	EMSD	Landsat Emissivity Standard Deviation	INT16	Emissivity coefficient	0 – 32767	0 – 10000	-9999	NA	0.0001

Level 2 Band Designation	ARD Band Description	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
st_cloud_distance	CDIST	Pixel distance to cloud	INT16	Kilometers	0 – 24000	0 – 24000	-9999	NA	0.01
st=surface temperature, INT16=16-bit signed integer									

Table 2-4. Landsat 4-7 Surface Temperature Band Specification

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
pixel_qa	PIXELQA	Pixel Quality Assessment	UINT16	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_opacity	SRATMOSOPACITYQA	Internal SR Atmospheric Opacity	INT16	NA	-2000 – 16000	0 – 10000	-9999	20000	0.0010
sr_cloud_qa	SRCLOUDQA	Internal SR QA	UINT8	Bit Index	0 – 255	0 – 63	NA	NA	NA
st_qa	STQA	ST QA	INT16	Kelvin	0 – 32767	0 – 32767	-9999	NA	0.01
qa=quality assessment, UINT16=16-bit unsigned integer, INT16=16-bit signed integer, UINT8=8-bit unsigned integer, NA=not applicable, SR=surface reflectance, ST=surface temperature									

Table 2-5. 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. Lineage index information and Surface Temperature uncertainty are also included in the U.S. Landsat ARD QA package. Sections 2.1.2.1 through 2.1.2.6 provide additional information on the U.S. Landsat ARD QA bands for Landsat 4-7 TM/ETM+. Table 2-6 through Table 2-12 list all bit-packed QA bands 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

Bit	Value	Cumulative Sum	Interpretation
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	32768	65535	Unused
LSB=least significant bit, MSB=most significant bit			

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

The bit combinations that define certain quality conditions appear as integer values in the PIXELQA band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions. Table 2-7 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

Pixel Value	Fill	Clear	Water	Cloud Shadow	Snow	Cloud	Cloud Confidence	Pixel Description
224	No	No	No	No	No	Yes	High	High-confidence cloud

Table 2-7. 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 2-8 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 2-8. Landsat 4-7 Radiometric Saturation Quality 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. If areas of a scene overlap on 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 (LINEAGEQA) band 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 2-9. 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).

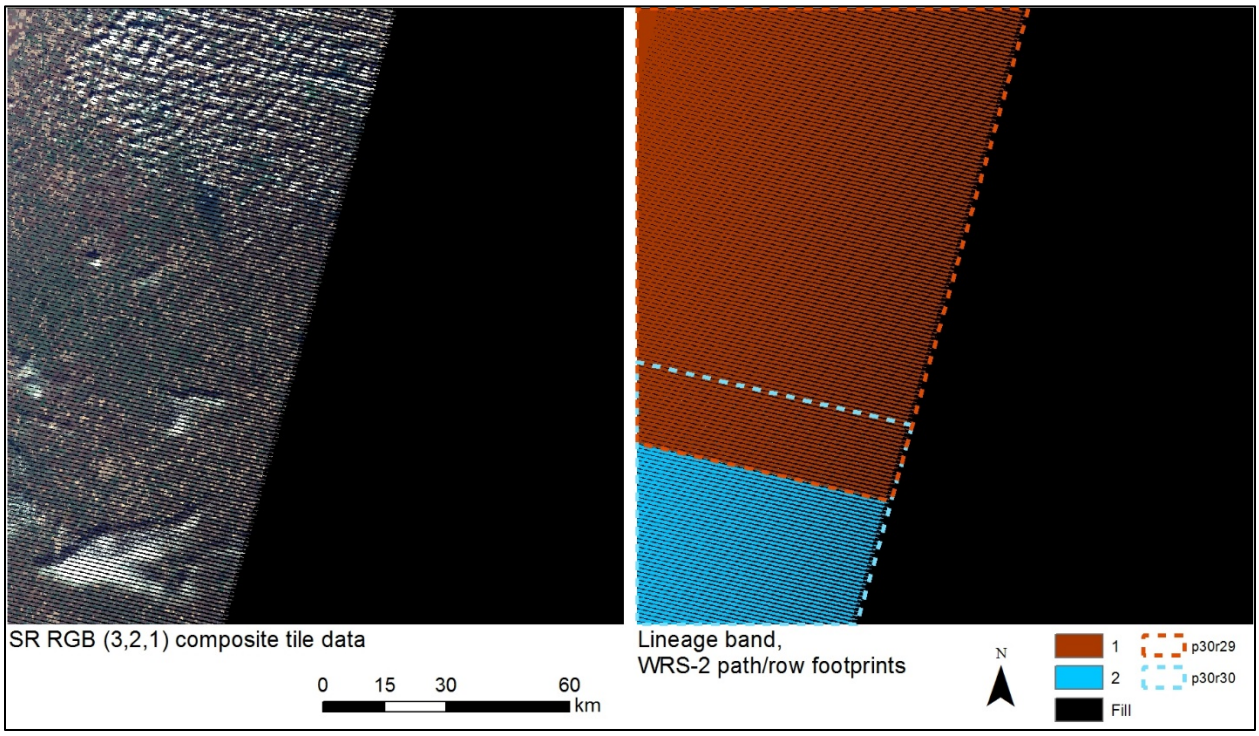

Figure 2-1. Lineage Index Band Example

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. Atmospheric opacity 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	SRATMOSOPACITY 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 2-10. 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 2-11. 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 2-12 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 2-12. Landsat 4-7 Internal Surface Reflectance Quality Assessment Bit Values

2.1.2.6 Landsat 4-7 Surface Temperature Quality Assessment Band

The Landsat 4-7 surface temperature quality assessment (STQA) band provides the surface temperature product uncertainty using a combination of uncertainty values and distance to cloud values.

2.1.3 Landsat 8 OLI-TIRS ARD Product Specifications

The output products from LaSRC include TOA Reflectance, Surface Reflectance, TOA Brightness Temperature, and internal pixel Quality Assessment derived from Landsat 8 inputs. The ARD package also contains the Provisional Surface Temperature (ST) science product, which is generated by Single Channel algorithm. Table 2-13 through Table 2-17 list the specification for all associated bands in the Landsat 8 OLI-TIRS U.S. Landsat ARD product.

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
toa_band1	TAB1	Band 1 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band2	TAB2	Band 2 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band3	TAB3	Band 3 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band4	TAB4	Band 4 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band5	TAB5	Band 5 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band6	TAB6	Band 6 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band7	TAB7	Band 7 TOA Reflectance	INT16	Refl	-2000 – 16000	0 – 10000	-9999	20000	0.0001
toa_band9	TAB9	Band 9 TOA Reflectance	INT16	Refl	-2000 – 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

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
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 2-13. 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)	-2000 – 16000	1500 – 3500	-9999	20000	0.1
bt_band11	BTB11	Band 11 Brightness Temperature	INT16	top of atmosphere Brightness Temp (K)	-2000 – 16000	1500 – 3500	-9999	20000	0.1
bt=top of atmosphere brightness temperature, BTB=brightness temperature band, INT16=16-bit signed integer, Temp= temperature, K=Kelvin									

Table 2-14. 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 2-15. Landsat 8 Surface Reflectance Band Specifications

Level 2 Band Designation	ARD Band Description	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
surface_temperature	ST	Surface Temperature	INT16	Kelvin	1500 – 3730	1500 – 3730	-9999	NA	0.1
st_atmospheric_transmittance	ATRAN	Atmospheric Transmittance	INT16	Radiance	0 – 10000	0 – 10000	-9999	NA	0.0001

Level 2 Band Designation	ARD Band Description	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
st_downwelled_radiance	DRAD	Downwelled Radiance	INT16	Radiance	0 – 28000	0 – 28000	-9999	NA	0.001
st_upwelled_radiance	URAD	Upwelled Radiance	INT16	Radiance	0 – 28000	0 – 28000	-9999	NA	0.001
st_thermal_radiance	TRAD	Thermal band converted to radiance	INT16	Radiance	0 – 22000	0 – 22000	-9999	NA	0.001
emis	EMIS	Landsat Emissivity estimated from ASTER GED data	INT16	Emissivity coefficient	0 – 10000	0 – 10000	-9999	NA	0.0001
emis_stdev	EMSD	Landsat Emissivity Standard Deviation	INT16	Emissivity coefficient	0 – 32767	0 – 10000	-9999	NA	0.0001
st_cloud_distance	CDIST	Pixel distance to cloud	INT16	Kilometers	0 – 24000	0 – 24000	-9999	NA	0.01
st=surface temperature, INT16=16-bit signed integer									

Table 2-16. Landsat 8 Surface Temperature Band Specifications

Level 2 Band Designation	ARD Band Designation	Band Name	Data Type	Units	Range	Valid Range	Fill Value	Scale Factor
pixel_qa	PIXELQA	Pixel Quality Assessment	UINT16	Bit Index	1 – 65535	1 – 2047	1 (bit 0)	NA
radsat_qa	RADSATQA	Radiometric Saturation QA	UINT16	Bit Index	0 – 65535	0 – 3839	1 (bit 0)	NA
NA	LINEAGEQA	Lineage QA	UINT8	NA	0 – 255	0 – 3	0	NA
sr_aerosol	SRAEROSOLQA	Aerosol QA	UINT8	Bit Index	0 – 255	0 – 255	1	NA
st_qa	STQA	ST QA	INT16	Kelvin	0 – 32767	0 – 32767	-9999	0.01
qa=quality assessment, NA=not applicable, sr=surface reflectance, st=surface temperature, UINT16=16-bit unsigned integer, INT16=16-bit signed integer								

Table 2-17. Landsat 8 ARD Quality Assessment Band Specifications

2.1.4 Landsat 8 OLI-TIRS 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, including a saturation band, a band describing parameters specific to atmospheric correction, and a band describing ST uncertainty. Sections 2.1.4.1 through 2.1.4.5 provide detailed information on the Landsat 8 U.S. ARD QA bands. Table 2-18 through Table 2-23 list all bit-packed QA bands and their associated contents.

2.1.4.1 Landsat 8 Pixel Quality Assessment Band

The Landsat 8 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	32768	65535	Unused
LSB=least significant bit, MSB=most significant bit, OLI=operational land imager			

Table 2-18. Landsat 8 Pixel Quality Assessment Bit Index

The bit combinations that define certain quality conditions appear as integer values in the PIXELQA band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions. Table 2-19 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 low 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

Pixel Value	Fill	Clear	Water	Cloud Shadow	Snow	Cloud	Cloud Confidence	Cirrus Confidence	Terrain Occlusion	Pixel Description
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

Pixel Value	Fill	Clear	Water	Cloud Shadow	Snow	Cloud	Cloud Confidence	Cirrus Confidence	Terrain Occlusion	Pixel Description
										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-

Pixel Value	Fill	Clear	Water	Cloud Shadow	Snow	Cloud	Cloud Confidence	Cirrus Confidence	Terrain Occlusion	Pixel Description
										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	Yes	Yes	No	No	No	Low	Low	Yes	Cloud, water, terrain occluded
1352	No	No	No	Yes	No	No	Low	Low	Yes	Cloud shadow, terrain occluded

Table 2-19. Landsat 8 Pixel Quality Assessment Bit Values

2.1.4.2 Landsat 8 Radiometric Saturation Quality Assessment Band

The RADSATQA band is a bit-packed representation of which sensor bands were saturated during data capture, yielding unusable data. Table 2-20 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 2-20. 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 LINEAGEQA band, which indicates which Level 2 scene was the source for each pixel. In areas of scene overlap on 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 2-21. 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 2-22. 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 SRAEROSOLQA band. Unpacking the bits represented by the pixel values deconstructs them into comprehensible condition descriptions. Table 2-23 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

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
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 2-23. Landsat 8 Internal Surface Reflectance Aerosol Quality Assessment Bit Values

2.1.4.5 Landsat 8 Surface Temperature Quality Assessment Band

The Landsat 8 STQA band provides the surface temperature product uncertainty using a combination of uncertainty values and distance to cloud values.

2.2 U.S. Landsat ARD Naming Conventions

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 2-24 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” = terrain precision correction, “L1GT” = systematic terrain correction, “L1GS” = geometric systematic correction)
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	Level 1 collection number (“01,” “02”)
TX	Collection category (“RT” = Real Time, “T1” = Tier 1, “T2” = Tier 2)

Table 2-24. 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, surface temperature, and quality products, they carry their Product ID into a new Level 2 name, which is appended with the projection, product designation, 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 collection category (Tier) label changes from T1 to A1 (or T2 to A2), and the production date might be different from the Level 1 UTM. The Level 2 Product ID is deconstructed in Table 2-25.

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_AX_product_band

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_AX_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” = terrain precision correction, “L1GT” = systematic terrain correction, “L1GS” = geometric systematic correction)
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	Level 1 collection number (“01,” “02”)
AX	Collection category (“A1” = Albers Equal Area Tier 1, “A2” = Albers Equal Area Tier 2)
product	Data product (“toa” = top of atmosphere reflectance, “bt” = top of atmosphere brightness temperature, “sr” = surface reflectance, “surface_temperature” = surface temperature, “solar_azimuth” = solar azimuth angle, “solar_zenith” = solar zenith angle, “sensor_azimuth” = sensor azimuth angle, “sensor_zenith” = sensor zenith angle, “st_atmospheric_transmittance” = atmospheric transmittance, “st_downwelled_radiance” = downwelled radiance, “st_upwelled_radiance” = upwelled radiance, “st_thermal_radiance” = thermal band converted to radiance, “emis” = Landsat emissivity estimated from ASTER GED data, “emis_stdev” = Landsat emissivity standard deviation, “st_cloud_distance” = pixel distance to cloud, “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 assessment, “sr_aerosol” = internal Landsat 8 surface reflectance aerosol parameters, “st_qa” = surface temperature quality assessment)
band	Band (such as “band1” for reflectance products)

Table 2-25. Landsat Level 2 Product Identifier 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 (AX) 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 2-26 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, “ST” = surface temperature, “SOA” = solar azimuth angle, “SOZ” = solar zenith angle, “SEA” = sensor azimuth angle, “SEZ” = sensor zenith angle, “ATRAN” = atmospheric transmittance, “DRAD” = downwelled radiance, “URAD” = upwelled radiance, “TRAD” = thermal band converted to radiance, “EMIS” = Landsat emissivity estimated from ASTER GED data, “EMSD” = Landsat emissivity standard deviation, “CDIST” = pixel distance to cloud, “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 assessment, “SRAEROSOLQA” = internal Landsat 8 surface reflectance aerosol parameters, “STQA” = surface temperature quality assessment)
BAND	Band (such as “B1” for reflectance products)

Table 2-26. 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+ derived surface temperature product would be output for ARD as:

LE07_CU_016008_20151209_20160118_C01_V01_ST
LE07_CU_016008_20151209_20160118_C01_V01_ATRAN
LE07_CU_016008_20151209_20160118_C01_V01_DRAD
LE07_CU_016008_20151209_20160118_C01_V01_URAD
LE07_CU_016008_20151209_20160118_C01_V01_TRAD
LE07_CU_016008_20151209_20160118_C01_V01_EMIS
LE07_CU_016008_20151209_20160118_C01_V01_EMSD
LE07_CU_016008_20151209_20160118_C01_V01_CDIST

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_SOA4
LE07_CU_016008_20151209_20160118_C01_V01_SOZ4
LE07_CU_016008_20151209_20160118_C01_V01_SEA4
LE07_CU_016008_20151209_20160118_C01_V01_SEZ4

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
LE07_CU_016008_20151209_20160118_C01_V01_STQA

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
LC08_CU_016008_20151209_20160118_C01_V01_STQA

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 2-27 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 2-27. 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 2-28. 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 2-28. 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.

2.4 U.S. Landsat ARD Known Caveats and Artifacts

During U.S. Landsat ARD product analysis and user feedback, some caveats and artifacts have been identified. For a list of the current known caveats and artifacts please visit the U.S. Landsat ARD webpage (https://www.usgs.gov/land-resources/nli/landsat/us-landsat-analysis-ready-data-ard-artifacts). Please note that these issues do not significantly impact the scientific integrity of the U.S. Landsat ARD product.

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, surface temperature), and are delivered in separate packages, each with their associated pixel quality assessment. 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 2.2), 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	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” = surface temperature, “QA” = quality assessment)

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

3.1.1 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 provenance 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 Lineage Index Metadata
- Level 2 Pixel QA Metadata

- Level 2 Angle Band Metadata
- Level 2 Top of Atmosphere Reflectance Metadata
- Level 2 Top of Atmosphere Brightness Temperature Metadata
- Level 2 Radiometric Saturation QA Metadata
- Level 2 Surface Reflectance Metadata
- Level 2 Surface Temperature Metadata
- Level 2 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 Global Metadata

```
<ard_metadata version="1.1" xmlns="https://landsat.usgs.gov/ard/v1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="https://landsat.usgs.gov/ard/v1
https://landsat.usgs.gov/ard/ard_metadata_v1_1.xsd">
   <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>2010-08-07</acquisition_date>
         <product_id>LE07_CU_010009_20100807_20180828_C01_V01</product_id>
         <production_date>2018-08-28T16:58:29Z</production_date>
         <bounding_coordinates>
            <west>-108.640181856</west>
            <east>-106.678219138</east>
            <north>40.2264432452</north>
            <south>38.7343536882</south>
         </bounding_coordinates>
         <projection_information datum="WGS84" projection="AEA" units="meters">
            <corner_point location="UL" x="-1065585.000000" y="1964805.000000"/>
            <corner_point location="LR" x="-915585.000000" y="1814805.000000"/>
            <grid_origin>UL</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 h="010" v="009"/>
         <scene_count>2</scene_count>
         <cloud_cover>39.6910</cloud_cover>
         <cloud_shadow>5.3898</cloud_shadow>
         <snow_ice>0.0019</snow_ice>
         <fill>18.9039</fill>
      </global_metadata>
```

Example of Level 2 Lineage Index Metadata

```
<band category="metadata" data_type="UINT8" fill_value="0" name="LINEAGEQA"
nlines="5000" nsamps="5000" product="scene_index" source="level2">
            <short_name>TILEIDX</short_name>
            <long_name>index</long_name>

<file_name>LE07_CU_010009_20100807_20180828_C01_V01_LINEAGEQA.tif</file_
name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>index</data_units>
            <valid_range max="255.000000" min="0.000000"/>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
```

Example of Level 2 Pixel Quality Assessment Metadata

```
<band category="qa" data_type="UINT16" fill_value="1" name="PIXELQA"
nlines="5000" nsamps="5000" product="level2_qa" source="level1">
            <short_name>LE07PQA</short_name>
            <long_name>level-2 pixel quality band</long_name>
            <file_name>PIXELQA</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <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_1.6.0</app_version>
          <production_date>2018-08-28T16:58:29Z</production_date>
        </band>
```

Example of Angle Band Metadata

```
<band category="image" data_type="INT16" fill_value="-32768" name="SOZ4"
nlines="5000" nsamps="5000" product="angle_bands" scale_factor="0.010000"
source="level1">
          <short_name>LE07SOLZEN</short_name>
          <long_name>band 4 solar zenith angles</long_name>
          <file_name>SOZ4</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>degrees</data_units>
          <app_version>create_angle_bands_1.13.2.b</app_version>
          <production_date>2018-08-28T16:58:29Z</production_date>
        </band>
```

Example of Top of Atmosphere Reflectance Band Metadata

```
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999"
name="TAB1" nlines="5000" nsamps="5000" product="toa_refl"
saturate_value="20000" scale_factor="0.000100" source="level1">
          <short_name>LE07REF</short_name>
          <long_name>band 1 TOA reflectance</long_name>
          <file_name>TAB1</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>reflectance</data_units>
          <valid_range max="16000.000000" min="-100.000000"/>
          <app_version>LEDAPS_3.2.1</app_version>
          <production_date>2018-08-28T16:58:29Z</production_date>
        </band>
```

Example of Top of Atmosphere Brightness Temperature Band Metadata

```
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999"
name="BTB6" nlines="5000" nsamps="5000" product="toa_bt" saturate_value="20000"
scale_factor="0.100000" source="level1">
            <short_name>LE07BT</short_name>
            <long_name>band 6 brightness temperature</long_name>
            <file_name>BTB6</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="3500.000000" min="1500.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
```

Example of Level 2 Radiometric Saturation Metadata

```
<band category="qa" data_type="UINT8" fill_value="1" name="RADSATQA"
nlines="5000" nsamps="5000" product="toa_refl" source="level1">
            <short_name>LE07RADSAT</short_name>
            <long_name>saturation mask</long_name>
            <file_name>RADSATQA</file_name>
            <pixel_size units="meters" x="30" y="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_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
```

Example of Surface Reflectance Band Metadata

```
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999"
name="SRB1" nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000"
scale_factor="0.000100" source="toa_refl">
        <short_name>LE07SR</short_name>
        <long_name>band 1 surface reflectance</long_name>
        <file_name>SRB1</file_name>
        <pixel_size units="meters" x="30" y="30"/>
        <resample_method>none</resample_method>
        <data_units>reflectance</data_units>
        <valid_range max="16000.000000" min="-2000.000000"/>
        <app_version>LEDAPS_3.2.1</app_version>
        <production_date>2018-08-28T16:58:29Z</production_date>
    </band>
```

Example of Surface Temperature Band Metadata

```
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999"
name="ST" nlines="5000" nsamps="5000" product="st" scale_factor="0.100000"
source="toa_refl">
        <short_name>LE07ST</short_name>
        <long_name>Surface Temperature</long_name>
        <file_name>ST</file_name>
        <pixel_size units="meters" x="30" y="30"/>
        <resample_method>none</resample_method>
        <data_units>temperature (kelvin)</data_units>
        <valid_range max="3730.000000" min="1500.000000"/>
        <app_version>st_1.1.1</app_version>
        <production_date>2018-08-28T16:58:29Z</production_date>
    </band>
```

3.1.2 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.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.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.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

Surface Temperature Package

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_ST.tar
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV.xml
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_ST.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_ATRAN.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_DRAD.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_URAD.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_TRAD.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_EMIS.tif

LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_EMSD.tif
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_CDIST.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_STQA.tif

Quality Assessment Package

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
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_STQA.tif

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

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
LXSS_US_HHHVVV_YYYYMMDD_yyyymmdd_CCC_VVV_STQA.tif

3.1.3 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 is often 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 3-3 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,

Valid Keys	Possible Values	Meaning
		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
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 version="1.1" xmlns="https://landsat.usgs.gov/ard/v1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="https://landsat.usgs.gov/ard/v1
https://landsat.usgs.gov/ard/ard_metadata_v1_1.xsd">
   <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>2010-08-07</acquisition_date>
         <product_id>LE07_CU_010009_20100807_20180828_C01_V01</product_id>
         <production_date>2018-08-28T16:58:29Z</production_date>
         <bounding_coordinates>
            <west>-108.640181856</west>
            <east>-106.678219138</east>
            <north>40.2264432452</north>
            <south>38.7343536882</south>
         </bounding_coordinates>
         <projection_information datum="WGS84" projection="AEA" units="meters">
            <corner_point location="UL" x="-1065585.000000" y="1964805.000000"/>
            <corner_point location="LR" x="-915585.000000" y="1814805.000000"/>
            <grid_origin>UL</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 h="010" v="009"/>
         <scene_count>2</scene_count>
         <cloud_cover>39.6910</cloud_cover>
         <cloud_shadow>5.3898</cloud_shadow>
         <snow_ice>0.0019</snow_ice>
         <fill>18.9039</fill>
      </global_metadata>
      <bands>
         <band category="metadata" data_type="UINT8" fill_value="0" name="LINEAGEQA" nlines="5000"
nsamps="5000" product="scene_index" source="level2">
            <short_name>TILEIDX</short_name>
            <long_name>index</long_name>
            <file_name>LE07_CU_010009_20100807_20180828_C01_V01_LINEAGEQA.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>index</data_units>
            <valid_range max="255.000000" min="0.000000"/>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="qa" data_type="UINT16" fill_value="1" name="PIXELQA" nlines="5000" nsamps="5000"
product="level2_qa" source="level1">
            <short_name>LE07PQA</short_name>
            <long_name>level-2 pixel quality band</long_name>
            <file_name>PIXELQA</file_name>
```

<pixel_size units="meters" x="30" y="30"/>
<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_1.6.0</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-32768" name="SOZ4" nlines="5000" nsamps="5000" product="angle_bands" scale_factor="0.010000" source="level1">
<short_name>LE07SOLZEN</short_name>
<long_name>band 4 solar zenith angles</long_name>
<file_name>SOZ4</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>degrees</data_units>
<app_version>create_angle_bands_1.13.2.b</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-32768" name="SOA4" nlines="5000" nsamps="5000" product="angle_bands" scale_factor="0.010000" source="level1">
<short_name>LE07SOLAZ</short_name>
<long_name>band 4 solar azimuth angles</long_name>
<file_name>SOA4</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>degrees</data_units>
<app_version>create_angle_bands_1.13.2.b</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-32768" name="SEZ4" nlines="5000" nsamps="5000" product="angle_bands" scale_factor="0.010000" source="level1">
<short_name>LE07SENZEN</short_name>
<long_name>band 4 sensor zenith angles</long_name>
<file_name>SEZ4</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>degrees</data_units>
<app_version>create_angle_bands_1.13.2.b</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-32768" name="SEA4" nlines="5000" nsamps="5000" product="angle_bands" scale_factor="0.010000" source="level1">
<short_name>LE07SENAZ</short_name>
<long_name>band 4 sensor azimuth angles</long_name>
<file_name>SEA4</file_name>

<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>degrees</data_units>
<app_version>create_angle_bands_1.13.2.b</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="TAB1" nlines="5000" nsamps="5000" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 1 TOA reflectance</long_name>
<file_name>TAB1</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="TAB2" nlines="5000" nsamps="5000" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 2 TOA reflectance</long_name>
<file_name>TAB2</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="TAB3" nlines="5000" nsamps="5000" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 3 TOA reflectance</long_name>
<file_name>TAB3</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="TAB4" nlines="5000" nsamps="5000" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 4 TOA reflectance</long_name>
<file_name>TAB4</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="TAB5" nlines="5000" nsamps="5000" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 5 TOA reflectance</long_name>
<file_name>TAB5</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>

```
            <valid_range max="16000.000000" min="-100.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="TAB7"
nlines="5000" nsamps="5000" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
            <short_name>LE07REF</short_name>
            <long_name>band 7 TOA reflectance</long_name>
            <file_name>TAB7</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-100.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="qa" data_type="UINT8" fill_value="1" name="RADSATQA" nlines="5000" nsamps="5000"
product="toa_refl" source="level1">
            <short_name>LE07RADSAT</short_name>
            <long_name>saturation mask</long_name>
            <file_name>RADSATQA</file_name>
            <pixel_size units="meters" x="30" y="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_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="BTB6"
nlines="5000" nsamps="5000" product="toa_bt" saturate_value="20000" scale_factor="0.100000" source="level1">
            <short_name>LE07BT</short_name>
            <long_name>band 6 brightness temperature</long_name>
            <file_name>BTB6</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="3500.000000" min="1500.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="SRB1"
nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 1 surface reflectance</long_name>
            <file_name>SRB1</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
```

<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="SRB2" nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
<short_name>LE07SR</short_name>
<long_name>band 2 surface reflectance</long_name>
<file_name>SRB2</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-2000.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="SRB3" nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
<short_name>LE07SR</short_name>
<long_name>band 3 surface reflectance</long_name>
<file_name>SRB3</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-2000.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="SRB4" nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
<short_name>LE07SR</short_name>
<long_name>band 4 surface reflectance</long_name>
<file_name>SRB4</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-2000.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="SRB5" nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
<short_name>LE07SR</short_name>
<long_name>band 5 surface reflectance</long_name>
<file_name>SRB5</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-2000.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="SRB7" nlines="5000" nsamps="5000" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
<short_name>LE07SR</short_name>
<long_name>band 7 surface reflectance</long_name>
<file_name>SRB7</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-2000.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-28T16:58:29Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="SRATMOSOPACITYQA" nlines="5000" nsamps="5000" product="sr_refl" scale_factor="0.001000" source="toa_refl">

```
            <short_name>LE07SR</short_name>
            <long_name>atmos_opacity</long_name>
            <file_name>SRATMOSOPACITYQA</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="qa" data_type="UINT8" name="SRCLOUDQA" nlines="5000" nsamps="5000"
product="sr_refl" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>cloud_qa</long_name>
            <file_name>SRCLOUDQA</file_name>
            <pixel_size units="meters" x="30" y="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_3.2.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="EMIS" nlines="5000" nsamps="5000"
product="st_intermediate" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07EMIS</short_name>
            <long_name>Landsat emissivity estimated from ASTER GED data</long_name>
            <file_name>EMIS</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>Emissivity Coefficient</data_units>
            <valid_range max="10000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="EMSD" nlines="5000" nsamps="5000"
product="st_intermediate" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07EMIS_STDEV</short_name>
            <long_name>Landsat emissivity standard deviation estimated from ASTER GED data</long_name>
            <file_name>EMSD</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>Emissivity Coefficient</data_units>
            <valid_range max="10000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="TRAD" nlines="5000" nsamps="5000"
product="st_intermediate" scale_factor="0.001000" source="level1">
            <short_name>LE07ST_THERMAL_RADIANCE</short_name>
            <long_name>thermal band converted to radiance</long_name>
            <file_name>TRAD</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
```

```
            <valid_range max="22000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="ATRAN" nlines="5000"
nsamps="5000" product="st_intermediate" scale_factor="0.000100" source="level1">
            <short_name>LE07ST_ATMOSPHERIC_TRANSMITTANCE</short_name>
            <long_name>atmospheric transmittance</long_name>
            <file_name>ATRAN</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
            <valid_range max="10000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="URAD" nlines="5000" nsamps="5000"
product="st_intermediate" scale_factor="0.001000" source="level1">
            <short_name>LE07ST_UPWELLED_RADIANCE</short_name>
            <long_name>upwelled radiance</long_name>
            <file_name>URAD</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
            <valid_range max="28000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="DRAD" nlines="5000" nsamps="5000"
product="st_intermediate" scale_factor="0.001000" source="level1">
            <short_name>LE07ST_DOWNWELLED_RADIANCE</short_name>
            <long_name>downwelled radiance</long_name>
            <file_name>DRAD</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
            <valid_range max="28000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="ST"
nlines="5000" nsamps="5000" product="st" scale_factor="0.100000" source="toa_refl">
            <short_name>LE07ST</short_name>
            <long_name>Surface Temperature</long_name>
            <file_name>ST</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="3730.000000" min="1500.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="CDIST" nlines="5000" nsamps="5000"
product="st_intermediate" scale_factor="0.010000" source="toa_refl">
            <short_name>LE07ST_CLOUD_DIST</short_name>
            <long_name>Surface temperature distance to cloud band</long_name>
            <file_name>CDIST</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>distance (km)</data_units>
            <valid_range max="24000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
```

```
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
         <band category="qa" data_type="INT16" fill_value="-9999" name="STQA" nlines="5000" nsamps="5000"
product="st_qa" scale_factor="0.010000" source="toa_refl">
            <short_name>LE07STQA</short_name>
            <long_name>Surface temperature quality band</long_name>
            <file_name>STQA</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="32767.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-28T16:58:29Z</production_date>
         </band>
      </bands>
   </tile_metadata>
   <scene_metadata>
      <index>1</index>
      <global_metadata>
         <data_provider>USGS/EROS</data_provider>
         <satellite>LANDSAT_7</satellite>
         <instrument>ETM</instrument>
         <acquisition_date>2010-08-07</acquisition_date>
         <scene_center_time>17:41:51.976696Z</scene_center_time>
         <level1_production_date>2018-08-24T14:53:04Z</level1_production_date>
         <wrs path="35" row="32" system="2"/>
         <request_id>0511808240543_00008</request_id>
         <scene_id>LE70350322010219EDC03</scene_id>
         <product_id>LE07_L1TP_035032_20100807_20180824_01_A1</product_id>
         <elevation_source>GLS2000</elevation_source>
         <sensor_mode>BUMPER</sensor_mode>
         <ephemeris_type>DEFINITIVE</ephemeris_type>
         <cpf_name>LE07CPF_20100701_20100930_01.02</cpf_name>
         <lpgs_metadata_file>LE07_L1TP_035032_20100807_20180824_01_A1_MTL.txt</lpgs_metadata_file>
         <geometric_rmse_model>5.416</geometric_rmse_model>
         <geometric_rmse_model_x>3.273</geometric_rmse_model_x>
         <geometric_rmse_model_y>4.315</geometric_rmse_model_y>
      </global_metadata>
      <bands>
         <band category="qa" data_type="UINT16" fill_value="1" name="pixel_qa" nlines="7841" nsamps="8541"
product="level2_qa" source="level1">
            <short_name>LE07PQA</short_name>
            <long_name>level-2 pixel quality band</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_pixel_qa.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <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_1.6.0</app_version>
          <production_date>2018-08-24T23:57:05Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="solar_zenith_band4" nlines="7841"
nsamps="8541" product="angle_bands" scale_factor="0.010000" source="level1">
          <short_name>LE07SOLZEN</short_name>
          <long_name>band 4 solar zenith angles</long_name>
          <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_solar_zenith_band4.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>degrees</data_units>
          <app_version>create_angle_bands_1.13.2.b</app_version>
          <production_date>2018-08-24T23:57:05Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="solar_azimuth_band4" nlines="7841"
nsamps="8541" product="angle_bands" scale_factor="0.010000" source="level1">
          <short_name>LE07SOLAZ</short_name>
          <long_name>band 4 solar azimuth angles</long_name>
          <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_solar_azimuth_band4.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>degrees</data_units>
          <app_version>create_angle_bands_1.13.2.b</app_version>
          <production_date>2018-08-24T23:57:05Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="sensor_zenith_band4" nlines="7841"
nsamps="8541" product="angle_bands" scale_factor="0.010000" source="level1">
          <short_name>LE07SENZEN</short_name>
          <long_name>band 4 sensor zenith angles</long_name>
          <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sensor_zenith_band4.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>degrees</data_units>
          <app_version>create_angle_bands_1.13.2.b</app_version>
          <production_date>2018-08-24T23:57:05Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="sensor_azimuth_band4"
nlines="7841" nsamps="8541" product="angle_bands" scale_factor="0.010000" source="level1">
          <short_name>LE07SENAZ</short_name>
          <long_name>band 4 sensor azimuth angles</long_name>
          <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sensor_azimuth_band4.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>degrees</data_units>
          <app_version>create_angle_bands_1.13.2.b</app_version>
          <production_date>2018-08-24T23:57:05Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band1"
nlines="7841" nsamps="8541" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
          <short_name>LE07REF</short_name>
          <long_name>band 1 TOA reflectance</long_name>
          <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_toa_band1.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>reflectance</data_units>
          <valid_range max="16000.000000" min="-100.000000"/>
          <app_version>LEDAPS_3.2.1</app_version>
          <production_date>2018-08-24T23:57:25Z</production_date>
        </band>
```

<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band2" nlines="7841" nsamps="8541" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 2 TOA reflectance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_toa_band2.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:57:25Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band3" nlines="7841" nsamps="8541" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 3 TOA reflectance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_toa_band3.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:57:25Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band4" nlines="7841" nsamps="8541" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 4 TOA reflectance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_toa_band4.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:57:25Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band5" nlines="7841" nsamps="8541" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 5 TOA reflectance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_toa_band5.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:57:25Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band7" nlines="7841" nsamps="8541" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 7 TOA reflectance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_toa_band7.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:57:25Z</production_date>
</band>
<band category="qa" data_type="UINT8" fill_value="1" name="radsat_qa" nlines="7841" nsamps="8541" product="toa_refl" source="level1">

```
            <short_name>LE07RADSAT</short_name>
            <long_name>saturation mask</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_radsat_qa.tif</file_name>
            <pixel_size units="meters" x="30" y="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_3.2.1</app_version>
            <production_date>2018-08-24T23:57:25Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="bt_band6"
nlines="7841" nsamps="8541" product="toa_bt" saturate_value="20000" scale_factor="0.100000" source="level1">
            <short_name>LE07BT</short_name>
            <long_name>band 6 brightness temperature</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_bt_band6.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="3500.000000" min="1500.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:25Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band1"
nlines="7841" nsamps="8541" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 1 surface reflectance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_band1.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band2"
nlines="7841" nsamps="8541" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 2 surface reflectance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_band2.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band3"
nlines="7841" nsamps="8541" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 3 surface reflectance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_band3.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
```

```
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
          </band>
          <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band4"
nlines="7841" nsamps="8541" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 4 surface reflectance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_band4.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
          </band>
          <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band5"
nlines="7841" nsamps="8541" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 5 surface reflectance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_band5.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
          </band>
          <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band7"
nlines="7841" nsamps="8541" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 7 surface reflectance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_band7.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
          </band>
          <band category="image" data_type="INT16" fill_value="-9999" name="sr_atmos_opacity" nlines="7841"
nsamps="8541" product="sr_refl" scale_factor="0.001000" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>atmos_opacity</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_atmos_opacity.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
          </band>
          <band category="qa" data_type="UINT8" name="sr_cloud_qa" nlines="7841" nsamps="8541"
product="sr_refl" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>cloud_qa</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_sr_cloud_qa.tif</file_name>
            <pixel_size units="meters" x="30" y="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_3.2.1</app_version>
            <production_date>2018-08-24T23:57:32Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="emis" nlines="7841" nsamps="8541"
product="st_intermediate" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07EMIS</short_name>
            <long_name>Landsat emissivity estimated from ASTER GED data</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_emis.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>Emissivity Coefficient</data_units>
            <valid_range max="10000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:01:18Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="emis_stdev" nlines="7841"
nsamps="8541" product="st_intermediate" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07EMIS_STDEV</short_name>
            <long_name>Landsat emissivity standard deviation estimated from ASTER GED data</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_emis_stdev.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>Emissivity Coefficient</data_units>
            <valid_range max="10000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:01:33Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="st_thermal_radiance" nlines="7841"
nsamps="8541" product="st_intermediate" scale_factor="0.001000" source="level1">
            <short_name>LE07ST_THERMAL_RADIANCE</short_name>
            <long_name>thermal band converted to radiance</long_name>
            <file_name>LE07_L1TP_035032_20100807_20180824_01_A1_st_thermal_radiance.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
            <valid_range max="22000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:14:48Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="st_atmospheric_transmittance"
nlines="7841" nsamps="8541" product="st_intermediate" scale_factor="0.000100" source="level1">
            <short_name>LE07ST_ATMOSPHERIC_TRANSMITTANCE</short_name>
            <long_name>atmospheric transmittance</long_name>

<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_st_atmospheric_transmittance.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
            <valid_range max="10000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:14:48Z</production_date>
         </band>
```

<band category="image" data_type="INT16" fill_value="-9999" name="st_upwelled_radiance" nlines="7841" nsamps="8541" product="st_intermediate" scale_factor="0.001000" source="level1">
<short_name>LE07ST_UPWELLED_RADIANCE</short_name>
<long_name>upwelled radiance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_st_upwelled_radiance.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
<valid_range max="28000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:14:48Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="st_downwelled_radiance" nlines="7841" nsamps="8541" product="st_intermediate" scale_factor="0.001000" source="level1">
<short_name>LE07ST_DOWNWELLED_RADIANCE</short_name>
<long_name>downwelled radiance</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_st_downwelled_radiance.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
<valid_range max="28000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:14:48Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="surface_temperature" nlines="7841" nsamps="8541" product="st" scale_factor="0.100000" source="toa_refl">
<short_name>LE07ST</short_name>
<long_name>Surface Temperature</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_surface_temperature.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>temperature (kelvin)</data_units>
<valid_range max="3730.000000" min="1500.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:14:57</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="st_cloud_distance" nlines="7841" nsamps="8541" product="st_intermediate" scale_factor="0.010000" source="toa_refl">
<short_name>LE07ST_CLOUD_DIST</short_name>
<long_name>Surface temperature distance to cloud band</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_st_cloud_distance.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>distance (km)</data_units>
<valid_range max="24000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:15:05Z</production_date>
</band>
<band category="qa" data_type="INT16" fill_value="-9999" name="st_qa" nlines="7841" nsamps="8541" product="st_qa" scale_factor="0.010000" source="toa_refl">
<short_name>LE07STQA</short_name>
<long_name>Surface temperature quality band</long_name>
<file_name>LE07_L1TP_035032_20100807_20180824_01_A1_st_qa.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>temperature (kelvin)</data_units>
<valid_range max="32767.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:15:25Z</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>2010-08-07</acquisition_date>
      <scene_center_time>17:42:15.862272Z</scene_center_time>
      <level1_production_date>2018-08-24T14:52:57Z</level1_production_date>
      <wrs path="35" row="33" system="2"/>
      <request_id>0511808240543_00011</request_id>
      <scene_id>LE70350332010219EDC03</scene_id>
      <product_id>LE07_L1TP_035033_20100807_20180824_01_A1</product_id>
      <elevation_source>GLS2000</elevation_source>
      <sensor_mode>BUMPER</sensor_mode>
      <ephemeris_type>DEFINITIVE</ephemeris_type>
      <cpf_name>LE07CPF_20100701_20100930_01.02</cpf_name>
      <lpgs_metadata_file>LE07_L1TP_035033_20100807_20180824_01_A1_MTL.txt</lpgs_metadata_file>
      <geometric_rmse_model>4.579</geometric_rmse_model>
      <geometric_rmse_model_x>2.838</geometric_rmse_model_x>
      <geometric_rmse_model_y>3.594</geometric_rmse_model_y>
    </global_metadata>
    <bands>
      <band category="qa" data_type="UINT16" fill_value="1" name="pixel_qa" nlines="7821" nsamps="8551"
product="level2_qa" source="level1">
        <short_name>LE07PQA</short_name>
        <long_name>level-2 pixel quality band</long_name>
        <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_pixel_qa.tif</file_name>
        <pixel_size units="meters" x="30" y="30"/>
        <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_1.6.0</app_version>
        <production_date>2018-08-24T23:47:22Z</production_date>
      </band>
      <band category="image" data_type="INT16" fill_value="-32768" name="solar_zenith_band4" nlines="7821"
nsamps="8551" product="angle_bands" scale_factor="0.010000" source="level1">
        <short_name>LE07SOLZEN</short_name>
        <long_name>band 4 solar zenith angles</long_name>
        <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_solar_zenith_band4.tif</file_name>
        <pixel_size units="meters" x="30" y="30"/>
        <resample_method>none</resample_method>
        <data_units>degrees</data_units>
        <app_version>create_angle_bands_1.13.2.b</app_version>
```

```
            <production_date>2018-08-24T23:47:22Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="solar_azimuth_band4" nlines="7821"
nsamps="8551" product="angle_bands" scale_factor="0.010000" source="level1">
            <short_name>LE07SOLAZ</short_name>
            <long_name>band 4 solar azimuth angles</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_solar_azimuth_band4.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>degrees</data_units>
            <app_version>create_angle_bands_1.13.2.b</app_version>
            <production_date>2018-08-24T23:47:22Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="sensor_zenith_band4" nlines="7821"
nsamps="8551" product="angle_bands" scale_factor="0.010000" source="level1">
            <short_name>LE07SENZEN</short_name>
            <long_name>band 4 sensor zenith angles</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sensor_zenith_band4.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>degrees</data_units>
            <app_version>create_angle_bands_1.13.2.b</app_version>
            <production_date>2018-08-24T23:47:22Z</production_date>
        </band>
        <band category="image" data_type="INT16" fill_value="-32768" name="sensor_azimuth_band4"
nlines="7821" nsamps="8551" product="angle_bands" scale_factor="0.010000" source="level1">
            <short_name>LE07SENAZ</short_name>
            <long_name>band 4 sensor azimuth angles</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sensor_azimuth_band4.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>degrees</data_units>
            <app_version>create_angle_bands_1.13.2.b</app_version>
            <production_date>2018-08-24T23:47:22Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band1"
nlines="7821" nsamps="8551" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
            <short_name>LE07REF</short_name>
            <long_name>band 1 TOA reflectance</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_toa_band1.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-100.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:47:43Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band2"
nlines="7821" nsamps="8551" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
            <short_name>LE07REF</short_name>
            <long_name>band 2 TOA reflectance</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_toa_band2.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-100.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:47:43Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band3"
nlines="7821" nsamps="8551" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
            <short_name>LE07REF</short_name>
```

<long_name>band 3 TOA reflectance</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_toa_band3.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:47:43Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band4" nlines="7821" nsamps="8551" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 4 TOA reflectance</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_toa_band4.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:47:43Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band5" nlines="7821" nsamps="8551" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 5 TOA reflectance</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_toa_band5.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:47:43Z</production_date>
</band>
<band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="toa_band7" nlines="7821" nsamps="8551" product="toa_refl" saturate_value="20000" scale_factor="0.000100" source="level1">
<short_name>LE07REF</short_name>
<long_name>band 7 TOA reflectance</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_toa_band7.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>reflectance</data_units>
<valid_range max="16000.000000" min="-100.000000"/>
<app_version>LEDAPS_3.2.1</app_version>
<production_date>2018-08-24T23:47:43Z</production_date>
</band>
<band category="qa" data_type="UINT8" fill_value="1" name="radsat_qa" nlines="7821" nsamps="8551" product="toa_refl" source="level1">
<short_name>LE07RADSAT</short_name>
<long_name>saturation mask</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_radsat_qa.tif</file_name>
<pixel_size units="meters" x="30" y="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_3.2.1</app_version>
          <production_date>2018-08-24T23:47:43Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="bt_band6"
nlines="7821" nsamps="8551" product="toa_bt" saturate_value="20000" scale_factor="0.100000" source="level1">
          <short_name>LE07BT</short_name>
          <long_name>band 6 brightness temperature</long_name>
          <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_bt_band6.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>temperature (kelvin)</data_units>
          <valid_range max="3500.000000" min="1500.000000"/>
          <app_version>LEDAPS_3.2.1</app_version>
          <production_date>2018-08-24T23:47:43Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band1"
nlines="7821" nsamps="8551" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
          <short_name>LE07SR</short_name>
          <long_name>band 1 surface reflectance</long_name>
          <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_band1.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>reflectance</data_units>
          <valid_range max="16000.000000" min="-2000.000000"/>
          <app_version>LEDAPS_3.2.1</app_version>
          <production_date>2018-08-24T23:47:49Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band2"
nlines="7821" nsamps="8551" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
          <short_name>LE07SR</short_name>
          <long_name>band 2 surface reflectance</long_name>
          <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_band2.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>reflectance</data_units>
          <valid_range max="16000.000000" min="-2000.000000"/>
          <app_version>LEDAPS_3.2.1</app_version>
          <production_date>2018-08-24T23:47:49Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band3"
nlines="7821" nsamps="8551" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
          <short_name>LE07SR</short_name>
          <long_name>band 3 surface reflectance</long_name>
          <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_band3.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>reflectance</data_units>
          <valid_range max="16000.000000" min="-2000.000000"/>
          <app_version>LEDAPS_3.2.1</app_version>
          <production_date>2018-08-24T23:47:49Z</production_date>
        </band>
        <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band4"
nlines="7821" nsamps="8551" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
          <short_name>LE07SR</short_name>
          <long_name>band 4 surface reflectance</long_name>
          <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_band4.tif</file_name>
          <pixel_size units="meters" x="30" y="30"/>
          <resample_method>none</resample_method>
          <data_units>reflectance</data_units>
          <valid_range max="16000.000000" min="-2000.000000"/>
```

```
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:47:49Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band5"
nlines="7821" nsamps="8551" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 5 surface reflectance</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_band5.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:47:49Z</production_date>
         </band>
         <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999" name="sr_band7"
nlines="7821" nsamps="8551" product="sr_refl" saturate_value="20000" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>band 7 surface reflectance</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_band7.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:47:49Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="sr_atmos_opacity" nlines="7821"
nsamps="8551" product="sr_refl" scale_factor="0.001000" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>atmos_opacity</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_atmos_opacity.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>reflectance</data_units>
            <valid_range max="16000.000000" min="-2000.000000"/>
            <app_version>LEDAPS_3.2.1</app_version>
            <production_date>2018-08-24T23:47:49Z</production_date>
         </band>
         <band category="qa" data_type="UINT8" name="sr_cloud_qa" nlines="7821" nsamps="8551"
product="sr_refl" source="toa_refl">
            <short_name>LE07SR</short_name>
            <long_name>cloud_qa</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_sr_cloud_qa.tif</file_name>
            <pixel_size units="meters" x="30" y="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_3.2.1</app_version>
            <production_date>2018-08-24T23:47:49Z</production_date>
         </band>
         <band category="image" data_type="INT16" fill_value="-9999" name="emis" nlines="7821" nsamps="8551"
product="st_intermediate" scale_factor="0.000100" source="toa_refl">
            <short_name>LE07EMIS</short_name>
```

<long_name>Landsat emissivity estimated from ASTER GED data</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_emis.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>Emissivity Coefficient</data_units>
<valid_range max="10000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-24T23:51:22Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="emis_stdev" nlines="7821" nsamps="8551" product="st_intermediate" scale_factor="0.000100" source="toa_refl">
<short_name>LE07EMIS_STDEV</short_name>
<long_name>Landsat emissivity standard deviation estimated from ASTER GED data</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_emis_stdev.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>Emissivity Coefficient</data_units>
<valid_range max="10000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-24T23:51:37Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="st_thermal_radiance" nlines="7821" nsamps="8551" product="st_intermediate" scale_factor="0.001000" source="level1">
<short_name>LE07ST_THERMAL_RADIANCE</short_name>
<long_name>thermal band converted to radiance</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_st_thermal_radiance.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
<valid_range max="22000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:03:50Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="st_atmospheric_transmittance" nlines="7821" nsamps="8551" product="st_intermediate" scale_factor="0.000100" source="level1">
<short_name>LE07ST_ATMOSPHERIC_TRANSMITTANCE</short_name>
<long_name>atmospheric transmittance</long_name>

<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_st_atmospheric_transmittance.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
<valid_range max="10000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:03:50Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="st_upwelled_radiance" nlines="7821" nsamps="8551" product="st_intermediate" scale_factor="0.001000" source="level1">
<short_name>LE07ST_UPWELLED_RADIANCE</short_name>
<long_name>upwelled radiance</long_name>
<file_name>LE07_L1TP_035033_20100807_20180824_01_A1_st_upwelled_radiance.tif</file_name>
<pixel_size units="meters" x="30" y="30"/>
<resample_method>none</resample_method>
<data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
<valid_range max="28000.000000" min="0.000000"/>
<app_version>st_1.1.1</app_version>
<production_date>2018-08-25T00:03:50Z</production_date>
</band>
<band category="image" data_type="INT16" fill_value="-9999" name="st_downwelled_radiance" nlines="7821" nsamps="8551" product="st_intermediate" scale_factor="0.001000" source="level1">
<short_name>LE07ST_DOWNWELLED_RADIANCE</short_name>
<long_name>downwelled radiance</long_name>

```
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_st_downwelled_radiance.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
            <valid_range max="28000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:03:50Z</production_date>
          </band>
          <band add_offset="0.000000" category="image" data_type="INT16" fill_value="-9999"
name="surface_temperature" nlines="7821" nsamps="8551" product="st" scale_factor="0.100000"
source="toa_refl">
            <short_name>LE07ST</short_name>
            <long_name>Surface Temperature</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_surface_temperature.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="3730.000000" min="1500.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:03:58</production_date>
          </band>
          <band category="image" data_type="INT16" fill_value="-9999" name="st_cloud_distance" nlines="7821"
nsamps="8551" product="st_intermediate" scale_factor="0.010000" source="toa_refl">
            <short_name>LE07ST_CLOUD_DIST</short_name>
            <long_name>Surface temperature distance to cloud band</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_st_cloud_distance.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>distance (km)</data_units>
            <valid_range max="24000.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:04:07Z</production_date>
          </band>
          <band category="qa" data_type="INT16" fill_value="-9999" name="st_qa" nlines="7821" nsamps="8551"
product="st_qa" scale_factor="0.010000" source="toa_refl">
            <short_name>LE07STQA</short_name>
            <long_name>Surface temperature quality band</long_name>
            <file_name>LE07_L1TP_035033_20100807_20180824_01_A1_st_qa.tif</file_name>
            <pixel_size units="meters" x="30" y="30"/>
            <resample_method>none</resample_method>
            <data_units>temperature (kelvin)</data_units>
            <valid_range max="32767.000000" min="0.000000"/>
            <app_version>st_1.1.1</app_version>
            <production_date>2018-08-25T00:04:26Z</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_information	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/ETM+ 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 or greater than zero, with no upper limit, and three decimal places; this parameter is only present if the DATA_TYPE is L1T

* The current U.S. Landsat ARD tiles contain incomplete *file_name* values in the XML metadata file. The ARD tile ID and file format of the data file name are missing from the *file_name* parameter value. Additional information on the known caveats and constraints of the U.S. Landsat ARD are provided in Section 2.4

References

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

USGS/EROS. LSDS-272. Landsat 7 (L7) Level 1 (L1) Data Format Control Book (DFCB)
https://www.usgs.gov/media/files/landsat-7-level-1-data-format-control-book

USGS/EROS. LSDS-284. Landsat Thematic Mapper (TM) Level 1 (L1) Data Format Control Book (DFCB)
https://www.usgs.gov/media/files/landsat-4-5-thematic-mapper-level-1-data-format-control-book

USGS/EROS. LSDS-809. Landsat 8 (L8) Level 1 (L1) Data Format Control Book (DFCB)
https://www.usgs.gov/media/files/landsat-8-level-1-data-format-control-book

USGS/EROS. LSDS-1330. Landsat Surface Temperature Product Guide,
https://www.usgs.gov/media/files/landsat-provisional-surface-temperature-product-guide.

USGS/EROS. LSDS-1368. Landsat Surface Reflectance Code (LaSRC) Product Guide,
https://www.usgs.gov/media/files/landsat-8-surface-reflectance-code-lasrc-product-guide.

USGS/EROS. LSDS-1370. Landsat 4-7 Surface Reflectance (LEDAPS) Product Guide
https://www.usgs.gov/media/files/landsat-4-7-surface-reflectance-code-ledaps-product-guide

Web-Enabled Landsat Data (WELD) Algorithm Theoretical Basis Document (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.

Cook, Monica J., "Atmospheric Compensation for a Landsat Land Surface Temperature Product" (2014). Thesis. *Rochester Institute of Technology*. Accessed from http://scholarworks.rit.edu/theses/8513.

Cook, M., Schott, J. R., Mandel, J., & Raqueno, N. (2014). Development of an operational calibration methodology for the Landsat thermal data archive and initial testing of the atmospheric compensation component of a Land Surface Temperature (LST) Product from the archive. *Remote Sensing*, *6*(11), 11244-11266. http://dx.doi.org/10.3390/rs61111244.

Hulley, G. C., Hook, S. J., Abbott, E., Malakar, N., Islam, T., & Abrams, M. (2015). The ASTER Global Emissivity Dataset (ASTER GED): Mapping Earth's emissivity at 100 meter spatial scale. Geophysical Research Letters, 42(19), 7966-7976. http://dx.doi.org/10.1002/2015GL065564.