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EROS Science Processing Architecture (ESPA) On-Demand Interface User Guide

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EROS Science Processing Architecture (ESPA)

On-Demand Interface

User Guide

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Executive Summary

This user guide presents a high-level description on the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA), which provides on-demand processing and customization services for the remotely sensed science products.

This document is under Land Satellites Data System (LSDS) 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 Configuration Management Tool.

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Section 1 Introduction

1.1 Background

Landsat data have been produced, archived, and distributed by the U.S. Geological Survey (USGS) since 1972. Scientists and users rely upon Landsat data as well as data obtained by other Earth Observation (EO) missions for historical study of the Earth's surface change but have shouldered the burden of postproduction processing to create application-ready datasets. In compliance with guidelines established through the Global Climate Observing System (GCOS), USGS has initiated an effort to produce remote sensing science products to support land surface change studies.

The USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) is an incubation environment that provides users with an on-demand interface (<https://espa.cr.usgs.gov/>) to process and customize remote sensing science products. These products are provided to build a framework for maturing long-term remote sensing datasets suited for monitoring, characterizing and understanding the Earth's surface change over time. The framework's implementation includes basic customization services and advanced-level science data products processing to provide application-ready datasets for user community evaluation. Currently, ESPA offers science products from Landsat Collection 2 data, Moderate Resolution Imaging Spectroradiometer (MODIS), and Visible Infrared Imaging Radiometer Suite (VIIRS).

The customization services that ESPA offers include:

- Reprojection*
- Spatial subsetting
- Pixel resizing*
- Multiple output formats

*These options do not apply to the Landsat panchromatic band (Band 8 of Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8-9 Operational Land Imager (OLI)).

ESPA is composed of the following two key elements:

- Bulk Ordering
- Bulk Ordering Application Programming Interface (API)*

*The API feature is available for all registered users. The API enables users to write clients to interact with all Bulk Ordering capabilities. More information about the API can be found in Section 4.

1.2 Purpose and Scope

This user guide focuses on the Bulk Ordering component available from <https://espa.cr.usgs.gov/>, which is the primary mechanism for access to ESPA science products.

1.3 Document Organization

This document contains the following sections:

- Section 1 provides an introduction
- Section 2 describes the available products
- Section 3 provides an explanation of the user interface
- Section 4 provides an explanation of application programming interface
- Section 5 provides information about user services
- Appendix A represents Landsat GeoTIFF file characteristics
- Appendix B represents Landsat Hierarchical Data Format (HDF) file characteristics
- Appendix C represents Landsat binary file characteristics
- Appendix D represents MODIS HDF file characteristics
- Appendix E represents MODIS binary file characteristics
- Appendix F represents MODIS GeoTIFF file characteristics
- Appendix G represents VIIRS GeoTIFF file characteristics
- Appendix H represents VIIRS binary file characteristics
- Appendix I represents VIIRS HDF file characteristics
- Appendix J provides a list of acronyms
- Appendix K provides the document change history
- The References section contains a list of reference materials

Section 2 Available Products

This section provides detailed information about the available Landsat, MODIS, and VIIRS products on ESPA. Available products and processing options are also summarized in Table 3-1. A summary of product availability by input data is also available from <https://espa.cr.usgs.gov/static/docs/available-products.html>.

Note: Due to processing system limitations ESPA does not allow ordering Landsat Collection 2 Level 1 or Level 2 data, or MODIS/VIIRS original input data without any customization or without any higher level processing option. In order to retrieve the data in their native format, users are advised to use data distribution services such as USGS EarthExplorer (EE) or NASA Earthdata Search.

Note: ESPA processing and customization services for Landsat Collection 1 data were discontinued in December 2022.

2.1 Landsat Collection 2 Products

ESPA offers Landsat Collection 2 on-demand science products and customization services to facilitate the user community's transition away from Collection 1. The Collection 2 Landsat 4 and 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Level 1 and Level 2 scenes can be submitted for customization. On-demand processing of Collection 2 Provisional Aquatic Reflectance science product is available using Collection 2 Level 1 productIDs. The Collection 2 Level 2 productIDs can be submitted for generation of spectral indices generation and Collection 2 Provisional Actual Evapotranspiration. Available Collection 2 products are described in Sections 2.1.1 through 2.1.3.

The Landsat Level 1 metadata (MTL.txt and MTL.xml) and angle band coefficients file (ANG.txt) are distributed with all Landsat Collection 2 orders. Similarly, the Collection 2 Pixel Quality Assessment (QA_PIXEL) and Radiometric Saturation Quality Assessment (QA_RADSAT) files are distributed with Landsat Collection 2 orders. The Pixel Quality Assessment (QA) contains information about cloud, cloud confidence, cloud shadow, snow/ice, and water. The Radiometric Saturation QA is a bit-packed representation of which spectral bands were saturated during data capture, yielding unusable data. Additional information about the Collection 2 Pixel QA and Radiometric Saturation QA bands are provided in the [Landsat 4-7 Collection 2 Level 2 Science Product Guide](#) and [Landsat 8-9 Collection 2 Level 2 Science Product Guide](#).

2.1.1 Input Products

Selection of this option delivers the Landsat Collection 2 Level 1 or Level 2 scenes. This option is available only if a customization option is requested for the input Level 1 or Level 2 data, or if the Level 2 data is ordered with spectral indices. Additional information about Landsat Level 1 products are available from [Landsat 4-5 TM Collection 2 Level 1 Data Format Control Book](#), [Landsat 7 ETM+ Collection 2 Level 1 Data Format Control Book](#), and [Landsat 8-9 OLI/TIRS Collection 2 Level 1 Data Format](#)

[Control Book](#). The Landsat Level 2 Surface Reflectance and Surface Temperature products are described in [Landsat 4-7 Collection 2 Level 2 Science Product Guide](#) and [Landsat 8-9 Collection 2 Level 2 Science Product Guide](#).

Note: On-demand generation of Collection 2 Level 2 Surface Reflectance or Surface Temperature products is NOT available from ESPA. These products are retrieved from operational Landsat Product Generation System (LPGS) processing stream for customization and/or spectral indices calculation in ESPA.

Landsat 8-9 OLI/TIRS Collection 2 Level 1 Input Products output contains:

- Level 1 data files (Bands 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11)
- Level 1 Pixel QA file (QA_PIXEL).
- Level 1 Radiometric Saturation QA (QA_RADSAT)
- Extensible Markup Language (XML) metadata (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Landsat 8-9 OLI/TIRS Collection 2 Level 2 Input Products output contains:

- Level 2 Surface Reflectance (SR) data files (SR Bands 1, 2, 3, 4, 5, 6, 7, and 9; SR Aerosol QA, Radiometric Saturation QA)
- Level 2 Surface Temperature (ST) data files (ST Band 10, Surface Temperature Uncertainty, Thermal Band Radiance, Upwelled Radiance, Downwelled Radiance, Atmospheric Transmittance, Emissivity estimated from ASTER GED, Emissivity standard deviation, Pixel distance to cloud)
- Level 2 Pixel QA file (QA_PIXEL)
- Level 1 Radiometric Saturation QA (QA_RADSAT)
- XML metadata (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Landsat 7 ETM+ Collection 2 Level 1 Input Products output contains:

- Level 1 data files (Band 1, 2, 3, 4, 5, 6 low gain, 6 high gain, 7, and 8)
- Level 1 Pixel QA band (QA_PIXEL)
- Level 1 Radiometric Saturation QA (QA_RADSAT)
- XML metadata (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Landsat 7 ETM+ Collection 2 Level 2 Input Products output contains:

- Level 2 SR data files (SR Bands 1, 2, 3, 4, 5, and 7; Atmospheric Opacity, Radiometric Saturation QA, Surface Reflectance Cloud QA)

- Level 2 ST data files (ST Band 6 (merged), Surface Temperature Uncertainty, Thermal Band Radiance, Upwelled Radiance, Downwelled Radiance, Atmospheric Transmittance, Emissivity estimated from ASTER GED, Emissivity standard deviation, Pixel distance to cloud)
- Level 2 Pixel QA band (QA_PIXEL)
- Level 1 Radiometric Saturation QA (QA_RADSAT)
- XML metadata (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Landsat 4 and 5 TM Collection 2 Level 1 Input Products output contains:

- Level 1 data files (Band 1, 2, 3, 4, 5, 6, and 7)
- Level 1 Pixel QA band (QA_PIXEL)
- Level 1 Radiometric Saturation QA (QA_RADSAT)
- XML metadata (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Landsat 4 and 5 TM Collection 2 Level 2 Input Products output contains:

- Level 2 SR data files (SR Bands 1, 2, 3, 4, 5, and 7; Atmospheric Opacity, Radiometric Saturation QA, Surface Reflectance Cloud QA)
- Level 2 ST data files (ST Band 6, Surface Temperature Uncertainty, Thermal Band Radiance, Upwelled Radiance, Downwelled Radiance, Atmospheric Transmittance, Emissivity estimated from ASTER GED, Emissivity standard deviation, Pixel distance to cloud)
- Level 2 Pixel QA band (QA_PIXEL)
- Level 1 Radiometric Saturation QA (QA_RADSAT)
- XML metadata (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Filenames utilize the Landsat product identifier (productID), for example

“LC09_L1TP_198024_20220424_20220424_02_T1” for Landsat 9 Level 1,
 “LC09_L2SP_198024_20220424_20220426_02_T1” for Landsat 9 Level 2,
 “LC08_L1TP_220071_20170207_20200905_02_T1” for Landsat 8 Level 1,
 “LC08_L2SP_220071_20170207_20200905_02_T1” for Landsat 8 Level 2,
 “LE07_L1TP_039037_20080728_20200912_02_T1” for Landsat 7 Level 1,
 “LE07_L2SP_039037_20080728_20200912_02_T1” for Landsat 7 Level 2,
 “LT05_L1TP_029030_20100805_20200824_02_T1” for Landsat 5 Level 1, and
 “LT05_L2SP_029030_20100805_20200824_02_T1” for Landsat 5 Level 2.

2.1.2 Provisional Aquatic Reflectance

Collection 2 Level 2 Provisional Aquatic Reflectance (AR) is available for Landsat 8 and Landsat 9. In order to process a Collection 2 AR, a Landsat 8 or Landsat 9 Level 1 Combined (LC08/LC09) or OLI-Only (LO08/LO09) product ID must be submitted. Additional information about the C2 AR science product is available in the [Landsat 8-9 Collection 2 Level 2 Provisional Aquatic Reflectance Product Guide](#).

The Collection 2 Aquatic Reflectance product package for L8-9 contains:

- Aquatic Reflectance for visible bands (AR Bands 1, 2, 3, 4, 5)
- Rayleigh-corrected Reflectance (RHORC Bands 1, 2, 3, 4, 5, 6, 7)
- Processing flags (L2_FLAGS)
- Water mask (WATER_MASK)
- Atmospheric auxiliary bands (Water Vapor, Surface Pressure, Wind Speed, Tropospheric Nitrogen Dioxide, Ozone)
- Digital elevation model (HEIGHT)
- Solar and sensor angles (Solar Zenith Angle, Solar Azimuth Angle, Viewing Zenith Angle, Viewing Azimuth Angle) and scattering angle (SCATTANG)
- Level 1 Pixel QA file (QA_PIXEL). More information about Landsat 8-9 QA_PIXEL band can be found in [Landsat 8-9 Collection 2 Level 2 Science Product Guide](#).
- Level 1 Radiometric Saturation QA (QA_RADSAT). More information about Landsat 8-9 Level 1 QA_RADSAT can be found in [Landsat 8-9 Collection 2 Level 2 Science Product Guide](#).
- Level 2 Aquatic Reflectance metadata file (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

AR filenames utilize the productID followed by “_AR_”, as exemplified by “LC08_L1TP_161042_20171008_20210225_02_T1_AR_BAND*”.

Rayleigh-corrected filenames utilize the Level 1 productID followed by “_RHORC_”, as exemplified by “LC08_L1TP_161042_20171008_20210225_02_T1_RHORC_BAND*”.

2.1.3 Provisional Actual Evapotranspiration

Using an improved parameterization of the surface energy balance model, the Collection 2 Level 3 Provisional Actual Evapotranspiration (ETa) provides a revised estimate of daily water transfer from the Earth's surface to the atmosphere in units of water depth (mm). In order to process Collection 2 ETa a Level 2 Science Product (L2SP) productID must be provided. The required Surface Temperature is read from the Collection 2 L2SP. Additional information about the ETa science product is available in the [Landsat 4-9 Collection 2 Level 3 Provisional Actual Evapotranspiration Product Guide](#).

The C2 ETa product package contains:

- Actual Evapotranspiration (ETA)
- Evapotranspiration fraction (ETF)
- Evapotranspiration Uncertainty (ETUN)
- Level 3 Actual Evapotranspiration metadata file (productID.xml)
- Level 2 Pixel QA file (QA_PIXEL). More information about C2 Pixel QA is provided in the [Landsat 4-7 Collection 2 Level 2 Science Product Guide](#) and [Landsat 8-9 Collection 2 Level 2 Science Product Guide](#).
- Level 1 Radiometric Saturation QA (QA_RADSAT). More information about Level 1 QA_RADSAT can be found in [Landsat 4-7 Collection 2 Level 2 Science Product Guide](#) and [Landsat 8-9 Collection 2 Level 2 Science Product Guide](#).
- Level 3 Evapotranspiration metadata file (productID.xml)
- Level 1 metadata files (MTL.txt and MTL.xml)
- Angle band coefficients file (ANG.txt)

Filenames utilize the L2SP productID followed by product filename, as exemplified by "LC08_L2SP_029029_20130712_20200912_02_T1_ETA.*"

Note: Due to lack of Surface Temperature information, the Collection 2 Level 2 Surface Reflectance (L2SR) products cannot be processed to Actual Evapotranspiration.

2.1.4 Spectral Indices

Landsat Collection 2 Level 2 Surface Reflectance is used to derive several spectral indices products, as listed below. In order to process a Collection 2 spectral indices a Level 2 product ID must be provided. The Level 2 Surface Reflectance is retrieved from Landsat Collection 2 archive for spectral indices processing. The characteristics of spectral indices are described on <https://www.usgs.gov/landsat-missions/landsat-surface-reflectance-derived-spectral-indices>.

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

The Landsat Collection 2 spectral indices do not include a saturation flag. Surface Reflectance of saturated pixels is unreliable and users are advised to use the accompanied Level 1 QA_RADSAT band to mask saturated pixels from their analysis.

As reflected in the metadata file (productID.xml), the NoData value of the Landsat Collection 2 Spectral Indices is -19999 (instead of more common -9999 value) to ensure valid data are not marked as NoData.

Note: Both Level 2 Science Products (L2SP) and Level 2 Surface Reflectance (L2SR) products can be processed to Spectral Indices.

2.2 MODIS Collection 6.1 Products

The following MODIS Collection 6.1 datasets can be submitted for customization.

MOD09 (Terra), MYD09 (Aqua) surface reflectance:

- MOD/MYD09A1
- MOD/MYD09GA
- MOD/MYD09GQ
- MOD/MYD09Q1

MOD/MYD11 Land Surface Temperature and Emissivity (LST/E):

- MOD/MYD11A1

MOD/MYD13 Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI):

- MOD/MYD13Q1
- MOD/MYD13A1
- MOD/MYD13A2
- MOD/MYD13A3

The derivation of the daily Normalized Difference Vegetation Index (NDVI) from the MOD09GA and MYD09GA surface reflectance is also available on ESPA.

Unlike Landsat-based products, the processing options for MODIS granules is limited to customization of the Input Products and generation of Daily NDVI. Available MODIS products are provided in Sections 2.2.1 and 2.2.2.

2.2.1 Input Products

Selection of this option enables customization of the input MODIS surface reflectance (MOD/MYD09), surface temperature and emissivity (MOD/MYD11), or vegetation index (MOD/MYD13) products.

Filenames utilize the MODIS granule identifier, for example
“MOD09GA.A2001335.h08v06.061.2020066212131_” for surface reflectance,
“MYD11A1.A2006282.h22v16.061.2020287183525_” for surface temperature and emissivity, and “MYD13A1.A2012265.h17v08.061.2021216053440_” for vegetation index products.

2.2.2 MODIS Daily NDVI

MODIS daily Surface Reflectance is used to derive daily Normalized Difference Vegetation Index (NDVI) product.

Filenames utilize the MODIS granule identifier followed by “_SR_NDVI”, as exemplified by “MOD09GA.A2001335.h08v06.061.2020066212131_SR_NDVI.*”.

2.3 VIIRS Collection 1 Products

The Suomi National Polar-Orbiting Partnership (S-NPP) VIIRS daily surface reflectance (VNP09GA) Collection 1 product is available for product customization and delivery.

The derivation of the daily NDVI from the VNP09GA surface reflectance is also available. Available VIIRS products are provided in Section 2.3.1 and 2.3.2.

2.3.1 Input Products

Selection of this option enables customization of the input VIIRS surface reflectance (VNP09) products.

Filenames utilize the VIIRS granule identifier, for example
“VNP09GA.A2014187.h10v04.001.2017031030559_*”.

2.3.2 VIIRS Daily NDVI

Selection of this option delivers VIIRS daily NDVI, which is derived from daily VIIRS Surface Reflectance data.

Filenames utilize the VIIRS granule identifier, for example
“VNP09GA.A2014187.h10v04.001.2017031030559_SR_NDVI.*”.

Section 3 User Interface

The ESPA interface is the primary mechanism used to request on-demand processing and services for the available products.

3.1 Submitting Order

To submit an order for science data production, users interact with the “New Order” page on the bulk ordering interface: <https://espa.cr.usgs.gov/>. The page consists of three sections: Notices (when applicable), scene list upload, and product options, as shown in Figure 3-1.

3.1.1 Login Credentials

A USGS Registered Username and password is required to access the bulk ordering interface. This is the same credential used to access EarthExplorer (<https://earthexplorer.usgs.gov>). To register, visit <https://ers.cr.usgs.gov/register>.

3.1.2 Scene List

The first step in submitting an order for science data production is to create a scene list. The scene list is a text file (*.txt), listing one Landsat scene, MODIS granule, or VIIRS granule identifier on each line. Scenes and granules from different sensors can be ordered separately or concurrently. The list can be easily generated by performing a spatial and temporal inventory search through EarthExplorer and exporting search results to a spreadsheet from which filenames can be extracted.

Due to processing system limitations, a user cannot have more than 10,000 open units. There is also a limit of 5,000 units per individual order (i.e., scene and/or granule IDs). Generally, smaller orders can be delivered faster. An example of a scene list is below:

```
espa_request.txt
MYD13Q1.A2002185.h19v05.061.2020072155457
MOD09GA.A2001024.h20v17.061.2020059071304
LC09_L1TP_039037_20220430_20220430_02_T1
LC09_L2SP_038037_20211216_20220121_02_T1
LT05_L1TP_038037_20120505_20200820_02_T1
LC08_L1TP_095066_20210412_20210416_02_T1
LE07_L2SP_005052_20201206_20210103_02_T1
LT04_L2SP_027027_19821208_20200925_02_T2
MYD11A1.A2017069.h16v02.061.2021298190314
VNP09GA.A2014073.h19v10.001.2017018110619
```

Add Input Products ([Show Available Products](#))

Scene List
<input type="button" value="Choose File"/> No file chosen

Select Product Contents

Source Products
<input type="checkbox"/> Input Products

Additional Processing

Landsat Level-2 Products
<input type="checkbox"/> Provisional Aquatic Reflectance - <i>Only Available for Landsat 8 & 9</i>
<input type="checkbox"/> Spectral Indices

Landsat Level-3 Products
<input type="checkbox"/> Provisional Actual Evapotranspiration

Additional MODIS/VIIRS Processing

Spectral Indices (NDVI only)
<input type="checkbox"/> MODIS Daily 500-m NDVI
<input type="checkbox"/> VIIRS Daily 500-m NDVI

Customize Outputs

Customization Options
<input type="radio"/> Output Format <input checked="" type="radio"/> GeoTiff <input type="radio"/> ENVI <input type="radio"/> HDF-EOS2 <input type="radio"/> NetCDF <input type="radio"/> COG
<input type="checkbox"/> Reproject Products
<input type="checkbox"/> Modify Image Extents
<input type="checkbox"/> Pixel Resizing

Add Order Description

Order Description (optional)
<input type="text"/>

Figure 3-1. ESPA On-Demand Order Page

3.1.3 Supported Processing Options by Product

Table 3-1 provides the list of available products and options in ESPA.

Product	Landsat 4-5 TM, Landsat 7 ETM+, Landsat 8-9 OLI/TIRS Collection 2 Level-1	Landsat 4-5 TM, Landsat 7 ETM+, Landsat 8-9 OLI/TIRS Collection 2 Level-2	Select MODIS 09, 11 & 13 Collection 6.1	S-NPP VIIRS Collection 1
Input Product	X ⁽¹⁾	X ⁽¹⁾	X	X
Level 2 Products	X			
Level 3 Products		X ⁽³⁾		
Spectral Indices		X ⁽³⁾	X ⁽⁴⁾	X ⁽⁴⁾
Customize Outputs	X ⁽²⁾	X	X	X

Table Key: TM Thematic Mapper, ETM+ Enhanced Thematic Mapper Plus, OLI Operational Land Imager, TIRS Thermal Infrared Sensor, MODIS Moderate Resolution Imaging Spectroradiometer, VIIRS Visible Infrared Imaging Radiometer Suite

(1) Landsat Collection 2 Input Product can be Level 1 or Level 2.

(2) Reprojection and pixel resizing options do not apply to the Panchromatic Band (Band 8 Landsat 7 ETM+ & Band 8 Landsat 8-9 OLI).

(3) Landsat Collection 2 spectral indices and Collection 2 Level 3 Actual Evapotranspiration are only available with Level 2 Input Products IDs.

(4) The only spectral index available from MODIS and VIIRS is daily NDVI.

Table 3-1. Available ESPA On-Demand Processing Options

3.1.3.1 Real Time Landsat Data Products

Before newly acquired Landsat 8 Level 1 scenes are assigned a tier designation, they are placed into the Real Time (RT) tier until finalized TIRS line-of-sight model parameters (7 to 10 days) have been applied to the data. The Landsat 7 extended science mission data obtained at lower orbit are also placed into RT tier until the updated bumper mode parameters (24 to 26 days) are applied to data.

Users can order Landsat 7 and Landsat 8 RT scenes; however, if an RT scene is replaced by final Tier 1 (T1) or Tier 2 (T2) data before ESPA begins processing the order containing the RT scene, processing will fail, and the user will need to reorder the T1/T2 scene.

3.1.4 Source Products

In the “Source Products” section:

- The Input Products are the Landsat Collection 2 Level 1, or Collection 2 Level 2 scenes, or MODIS MOD/MYD09, MOD/MYD11, MOD/MYD13, or VIIRS VNP09 granules accompanied by metadata obtained from the USGS or Land Processes Distributed Active Archive Center (LP DAAC). Characteristics of the input source products can be found using the links provided in Table 3-2.

Input Product	Characteristics
Landsat Collection 2 Level 1	https://www.usgs.gov/landsat-missions/landsat-collection-2-level-1-data
Landsat Collection 2 Level 2	https://www.usgs.gov/landsat-missions/landsat-collection-2-level-2-science-products
MODIS	https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table
VIIRS surface reflectance	https://lpdaac.usgs.gov/products/vnp09gav001/

Table 3-2. Characteristics of Input Products

3.1.5 Landsat Level 2 Products

Currently, Landsat 8-9 Collection 2 Level 2 Provisional Aquatic Reflectance and Landsat 4-9 Collection 2 spectral indices and associates metadata are available from ESPA.

3.1.6 Landsat Level 3 Products

The Collection 2 Provisional Actual Evapotranspiration science product is available under this section (see Section 2.1.3).

3.1.7 MODIS/VIIRS Spectral Indices

The “MODIS Daily NDVI” option calculates the NDVI for the MOD09GA/MYD09GA surface reflectance input data. Similarly, the “VIIRS Daily NDVI” option calculates the NDVI for the VNP09GA surface reflectance inputs.

3.1.8 Customization Options

Customized Products uses original Input Products and applies any selections from the “Customization Options” section. Clicking any of the boxes along the left side of the “Customization Options” section will expand the options for output format, reprojection, spatial subsetting, and resampling (Figure 3-2). Customized products must be checked for output format, projection, resizing and extent.

Including data from multiple sensors in an order will result in equivalent customization options. For example, if Exelis Visual Information Solutions (ENVI) is selected as an output format, both products will be produced as ENVI binaries. Likewise, if the pixel resizing is set to 100 meters, both datasets will be sampled to 100 meters.

Note: Selection of the customization options may result in outside-of-range values depending on the resampling method provided.

Customization Options

Output Format	<input checked="" type="radio"/> GeoTiff	<input type="radio"/> ENVI	<input type="radio"/> HDF-EOS2	<input type="radio"/> NetCDF	<input type="radio"/> COG
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Reproject Products

Projection:	Albers Equal Area
-90.0 to 90.0	Latitude of Origin
-180.0 to 180.0	Central Meridian
-90.0 to 90.0	1st Standard Parallel
-90.0 to 90.0	2nd Standard Parallel
any float (e.g. 0.0)	False Easting
any float (e.g. 0.0)	False Northing
WGS 84	Datum

Modify Image Extents

<input checked="" type="radio"/> Decimal Degrees	<input type="radio"/> Meters
-180.0 to 180.0	Upper left X coordinate
-90.0 to 90.0	Upper left Y coordinate
-180.0 to 180.0	Lower right X coordinate
-90.0 to 90.0	Lower right Y coordinate

Pixel Resizing

30.0 to 5000.0	Meters
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Resample Method:

Figure 3-2. ESPA On-Demand Customization Services

3.1.8.1 Output Format

Customized Input Products, Level 2 and 3 science products, and/or Spectral Indices can be output in the following formats: Georeferenced Tagged Image File Format (GeoTIFF; ".tif"), Cloud Optimized GeoTIFF (COG; ".TIF"), Exelis Visual Information Solutions (ENVI) binary ("img"), Network Common Data Form (NetCDF; ".nc") or Hierarchical Data Format – Earth Observing System version 2 (HDF-EOS2; ".hdf"). The ESPA default file format is GeoTIFF. The COG file format is an extension of the GeoTIFF file format that enables more flexible access to Geospatial data. Specifications of COG file format offered through ESPA are described in [Landsat Cloud Optimized GeoTIFF Data Format Control Book](#). The HDF-EOS2 is based on HDF-4 file format. The HDF-EOS2 files distributed by ESPA store the actual data as external bands (*.hdf.img) to adhere to the filesize limitations for the HDF-4 files.

3.1.8.2 Reproject Products

Available products can be reprojected from the native Universal Transverse Mercator (UTM) or Polar Stereographic (Landsat Level 1 defaults), or from Sinusoidal (MODIS/VIIRS default) to a different UTM zone, Geographic, Albers Equal Area (AEA), Polar Stereographic, or Sinusoidal. The underlying software performing the reprojections is the Geospatial Data Abstraction Library (GDAL; <http://www.gdal.org/>.)

The Albers Equal Area selection requires user definition of projection parameters and offers choices for datum. Sinusoidal and Polar Stereographic reprojections likewise allow entry of parameters. UTM accepts only a zone parameter and North/South hemisphere specification. Geographic system projects the coordinates into decimal degrees. A full list of parameters is provided in Table 3-3. A graphical example of reprojection is shown in Figure 3-3.

Input Parameters	AEA Projection	UTM Projection	Geographic Projection	Sinusoidal Projection	Polar Stereographic Projection
Units	Meters	Meters	Decimal Degrees	Meters	Meters
Latitude of Origin	-90.0 to 90.0				
Latitude True Scale					-180.0 to 180.0
Longitudinal Pole					-90.0 to -60.0 (South), 60.0 to 90.0 (North)
Central Meridian	-180.0 to 180.0			-180.0 to 180.0	
1 st Standard Parallel	-90.0 to 90.0				
2 nd Standard Parallel	-90.0 to 90.0				
False Easting	Any float			Any float	Any float
False Northing	Any float			Any float	Any float
Datum	WGS84, NAD27, NAD83				
Zone		1-60 North, 1-60 South			

Table key: UTM Universal Transverse Mercator, WGS84 World Geodetic System 1984, NAD27 North American Datum 1927, NAD83 North American Datum 1983

Table 3-3. Possible Input Parameters for Product Reprojection in ESPA

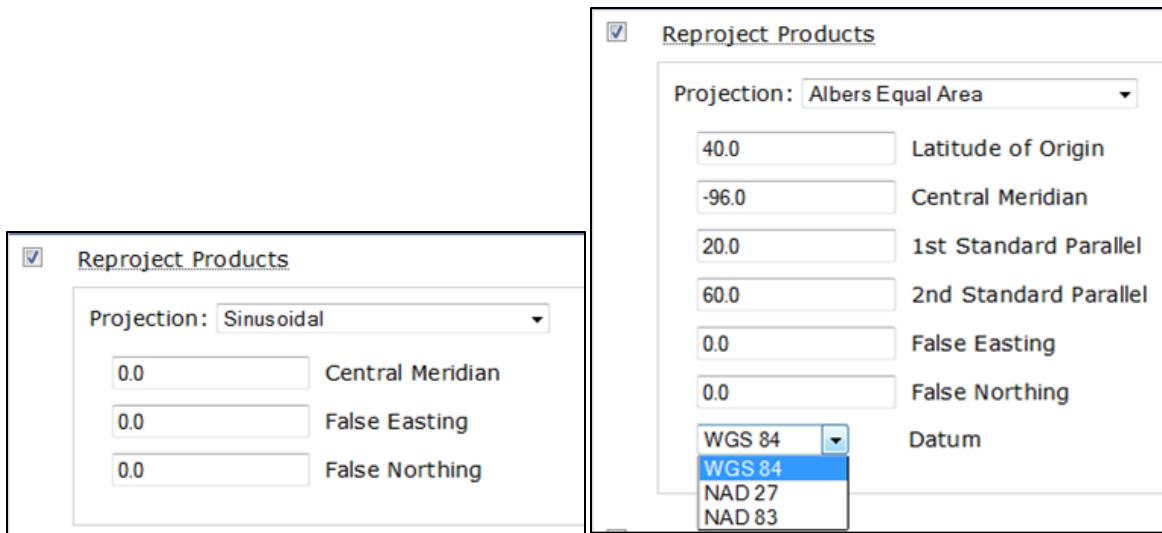


Figure 3-3. Examples of ESPA On-Demand Projection Parameter Entry

3.1.8.3 Modify Image Extents

If the user requires modification of image extents, the output projection must be specified, and entries for the corner points must be in the proper units (decimal degrees for Geographic; meters for Albers Equal Area, Polar Stereographic, Sinusoidal, and UTM).

3.1.8.4 Pixel Resizing and Resampling

The last two customization options are for pixel resizing and resampling. Users can up- or down-sample the available products between 30 and 5,000-meters (m). Pixel size must be in decimal degrees if a Geographic projection is used.

Resampling methods include nearest neighbor, bilinear interpolation, and cubic convolution. As QA bands use discrete, integer-level data, these bands are always resampled with nearest neighbor.

3.1.8.5 Customized Image Limitations

Due to processing system limitations there are some restrictions for the customized outputs.

- a) Maximum number of pixels: This customization limit is applied to all products and sets a maximum of 200 million pixels per image. The total number of pixels is calculated based on Equation 3-1 where the image width and height are derived from maximum and minimum X and Y values in the target projection system.

$$total\ pixels = \frac{Source\ Image\ Width \times Source\ Image\ Height}{Target\ Resolution^2}$$

Equation 3-1. Total Number of Pixels in Customized Image

- b) Pixel resizing: This customization limit is also applied to all products. For customized products, the minimum and maximum pixel size ranges are enforced as listed in Table 3-4.

Pixel resizing unit	Minimum	Maximum
Decimal Degrees (d)	0.0002695	0.0449155
Meters (m)	30	5000

Table 3-4. Pixel Resizing Limits

3.1.9 Order Description

Users may enter an order description if they wish, to help identify the contents of the order for themselves. The “Submit” button at the bottom of the page will send the request to production.

As soon as the order is received, an email acknowledgment is delivered to the user. The email contains a link to tracking information for the order.

3.2 Order Tracking

Product requests are delivered to a hypertext transfer protocol over transport layer security (HTTPS) site. Email notification of location is sent to the user when all files in the order have completed processing. Users can also use the “Show Orders” feature in the ESPA On-Demand Interface (ODI) to monitor the status of production and go directly to the download site as files complete.

Clicking on “Show Orders” presents an entry field requesting the email address associated with the order. The email address will be the same as what is on file in the user’s EarthExplorer account. After entering the address and clicking “Submit,” a listing is shown of all orders for that address (Figure 3-4).

The orders are assigned names, such that the email address, date of submission, and a unique identifier can be used to differentiate requests. For example: “scientist@usgs.gov-12172014-155922” is an order placed by scientist@usgs.gov on December 17, 2014.

The general status of each order is noted next to the order name, and whatever comments the user entered regarding the order are also displayed. Statistics are provided for each order, indicating the total number of products ordered, and the number of orders currently available for download.

Showing all orders for				
Order ID	Products Ordered	Products Complete	Status	Note
04042017-115131-888	= 19	19	complete	XXXXXXXXXXXXXXXXXXXX Compositing tile r04c01 for L7. Order parameters: mask product cloud processing level toa ulx -2362425 uly 2277435 lrx -2062425 lry 1977435. See the order template file for standard tile compositing parameter values.
04042017-115128-244	= 8	8	complete	XXXXXXXXXXXXXXXXXXXX Compositing tile r04c01 for L8. Order parameters: mask product cloud processing level toa ulx -2362425 uly 2277435 lrx -2062425 lry 1977435. See the order template file for standard tile compositing parameter values.
04042017-114717-057	= 20	20	complete	XXXXXXXXXXXXXXXXXXXX Compositing tile r09c07 for L7. Order parameters: mask product cloud processing level toa ulx -562425 uly 777435 lrx -262425 lry 477435. See the order template file for standard tile compositing parameter values.
04042017-114713-226	= 23	23	complete	XXXXXXXXXXXXXXXXXXXX Compositing tile r09c07 for L8. Order parameters: mask product cloud processing level toa ulx -562425 uly 777435 lrx -262425 lry 477435. See the order template file for standard tile compositing parameter values.

Figure 3-4. *ESPA On-Demand ‘Show Orders’ Page*

The order names listed are linked to the distribution site. File-based details can be found there, and users can download any of the files in the order that have reached a complete state (Figure 3-5). An email notice is sent to the user only when all files are complete.

Requested: 1	Completed: 1	Open: 0	Waiting on data: 0	
Order: 012	-05032022-083859-	Date Ordered: 2022-05-03 08:38:59.012310		
Status: complete		Date Completed: 2022-05-03 08:49:30.620399		
Requested Processing: Reproject to geographic, resize pixels to 0.0025 dd, image extents set to ulx:120.0366 uly:38.249 lrx:121.8906 lry:37.3614, Output Format is geotiff				
Products by sensor:	tm5_collection_2_l2: l1, sr_ndvi, sr_evi, sr_savi, sr_msavi, sr_ndmi, sr_nbr, sr_nbr2, stats ,			
The <i>ESPA Bulk Downloader</i> is available HERE		Show JSON		
Product	Status	Product URL	Chksum URL	Note
45823964 - LT05_L2SP_120034_19860206_20200918_02 _T1	complete	Download	Checksum	

Figure 3-5. *ESPA On-Demand Distribution Page*

3.2.1 Cancel Order

Orders containing scenes submitted for processing can be cancelled by the user. Figure 3-6 shows the cancellation option, which is located on the individual orders' status page. Once confirmed, all scenes that have not completed processing will be cancelled and any previously processed scenes from that order will be deleted from disk. Order cancellation is not available for orders that have completed processing.

Note: Once order cancellation is confirmed, the action cannot be undone and the order must be resubmitted if desired.

Requested: 71	Completed: 0	Open: 71	Waiting on data: 0
Order:		Date Ordered: 2017-06-26 11:48:30.090016	
Status: ordered	Date Completed:		
Requested Processing: resize pixels to 35 meters, Output Format is geotiff			
Products by sensor: olitirs8_collection: surface reflectance, l2 pixel qa ,			
The ESPA Bulk Downloader is available on GitHub		Show JSON	CANCEL

Figure 3-6. Cancel Order

To confirm that an order has been successfully cancelled, check that the status of the order displays “cancelled” (Figure 3-7). Verification that the individual scenes within a cancelled order are cancelled can also be done by checking the scene status and notes.

Requested: 1	Completed: 0	Open: 0	Waiting on data: 0			
Order: 934	-12062022-121541-	Date Ordered: 2022-12-06 12:15:41.934447				
Status: cancelled	Date Completed:					
Requested Processing: Output Format is geotiff						
Products by sensor: olitirs9_collection_2_l1: sr ,						
The ESPA Bulk Downloader is available HERE		Show JSON				
Product	Status	Product URL	Chksum URL			
48043339 - LC09_L1TP_042034_20220606_20220606_02 _T1	cancelled		Cancelled			

Figure 3-7. Order Cancellation Verification

3.2.2 Status Message

Each product within an order contains a status, indicating its activity within ESPA. Table 3-5 describes each status message and its meaning.

Status	Interpretation
Submitted	ESPA has received the order request but has not yet determined source product availability.
On Cache	ESPA has found the source product(s) are available for processing.
On Order	The source product(s) are not immediately available, so ESPA has placed an order to the source and is awaiting the source product(s).
Queued	ESPA will attempt to process your orders once they reach the front of the queue.
Processing	ESPA is now processing your order.
Error	ESPA has received an order that could not be processed as requested. Errors will always be described in detail in the "Note" column of the order status. Some possible errors: <ul style="list-style-type: none">• Solar zenith angle is too high (>76 degrees) to accurately retrieve surface reflectance• Auxiliary data are not yet available for the date requested
Retry	An order that could not previously be completed is set to be run again. For products missing auxiliary data for SR retrieval, ESPA retries every 24 hours.
Complete	The order has completed successfully and is ready for download.
Unavailable	ESPA determined the order could not be completed successfully, so it will not be retried.
Cancelled	Processing for this scene/order has been cancelled.

Table 3-5. ESPA Order Status Messages / Meanings

3.3 Download

As files complete processing, they can be downloaded along with their checksums any time directly from the site linked to the user's email address. Notification of delivery is not emailed to the user until all the files in the order are complete.

3.3.1 File Archive Format

The download site contains compressed file archives (.tar.gz), inside of which will be the requested files.

For Landsat Collection 2 data, the archives are formatted as follows:

LXSSPPRYYMMDDCCTX-SCyyyymmddhhmmss.tar.gz

where:

L Landsat
X Sensor ("T" = TM; "E" = ETM+; "O" = OLI; "T" = TIRS; "C" = OLI/TIRS)
SS Satellite ("04" = Landsat 4; "05" = Landsat 5; "07" = Landsat 7; "08" =
Landsat 8; "09" = Landsat 9)
PPP Path
RRR Row
YYYY Year of acquisition
MM Acquisition month
DD Acquisition day
CC Landsat Collection number ("02" for Collection 2)
TX Tier ("01" for Tier 1; "02" for Tier 2; "RT" for Real Time)
SC Science dataset
yyyy Year of ESPA processing
mm Month of ESPA processing
dd Day of ESPA processing
hh Hour of ESPA processing
ss Seconds of ESPA processing.

For MODIS data (applies to all sensors, collections, data products), the archives are formatted as follows:

MXDNNPPhHHvVVYYYYDDDCCC-SCyyyymmddhhmmss.tar.gz

where:

MXD Satellite ("MOD" = Terra; "MYD" = Aqua)
NN Product number ("09", "11", "13")
PP Product designator ("A1", "A2", "A3", "GA", "GQ", or "Q1")
hHH Horizontal tile index
vVV Vertical tile index
YYYY Year of acquisition
DDD Acquisition day of year
CCC MODIS Collection number ("061" for Collection 6.1)
SC Science dataset
yyyy Year of ESPA processing
mm Month of ESPA processing
dd Day of ESPA processing
hh Hour of ESPA processing
ss Seconds of ESPA processing.

For VIIRS data, the archives are formatted as follows:

VNPNNPPhHHvVVYYYYDDDCCC-SCyyyymmddhhmmss.tar.gz

where:

VNP Satellite (“VNP” = VIIRS/NPP)
NN Product number (“09”)
PP Product designator (“GA”)
HHH Horizontal tile index
VVV Vertical tile index
YYYY Year of acquisition
DDD Acquisition day of year
CCC VIIRS Collection number (“001” for Collection 1)
SC Science dataset
yyyy Year of ESPA processing
mm Month of ESPA processing
dd Day of ESPA processing
hh Hour of ESPA processing
ss Seconds of ESPA processing.

Additional information, such as the date ordered, date completed, and requested processing options are listed within the order download page (Figure 3-7).

3.3.2 Distribution Methods

Distribution is currently via direct download from an HTTPS site, which generally requires each file be downloaded individually. Bulk downloads are possible, as noted below.

3.3.3 ESPA Bulk Download Client

A Python-based Bulk Download client is available for downloading either a single ESPA order, or the entire order queue. Python 2.7 or greater is required to run the client.

The tool is available from <https://code.usgs.gov/espa/bulk-downloader/>.

Section 4 Application Programming Interface

4.1 Overview

The ESPA Application Programming Interface (API) is the underlying architecture on which the On-Demand Interface operates. The API's basic functionality allows end users to use a machine-to-machine interface to query order options, place orders, check order status and acquire download URLs. The API is implemented as a Representational State Transfer (REST) service using Hypertext Transfer Protocol (HTTPS) and JavaScript Object Notation (JSON) and therefore is compatible with most programming languages. An overview of the ESPA JSON REST API, object definitions, and operations is at <https://espa.cr.usgs.gov/static/docs/api-readme.html>.

4.2 Documentation

The official ESPA API documentation is at <https://espa.cr.usgs.gov/static/docs/api-readme.html>.

An example Python script for placing and downloading orders through ESPA API is available on <https://espa.cr.usgs.gov/static/docs/api-readme.html>. The example code includes sample JSON data that can be submitted to the ESPA API. The JSON files are constructed using the sensor/dataset objects, input scene/granules, output products, and optional order description, projection information, image extents, pixel resizing, and resampling method of the output products. Table 4-1 lists the sensors/dataset that ESPA supports with the corresponding JSON object names.

Sensor/Dataset	JSON Object
Landsat 4 TM Collection 2 Level 1	"tm4_collection_2_l1"
Landsat 4 TM Collection 2 Level 2	"tm4_collection_2_l2"
Landsat 5 TM Collection 2 Level 1	"tm5_collection_2_l1"
Landsat 5 TM Collection 2 Level 2	"tm5_collection_2_l2"
Landsat 7 ETM+ Collection 2 Level 1	"etm7_collection_2_l1"
Landsat 7 ETM+ Collection 2 Level 2	"etm7_collection_2_l2"
Landsat 8 OLI-TIRS Collection 2 Level 1	"olitirs8_collection_2_l1"
Landsat 8 OLI-TIRS Collection 2 Level 2	"olitirs8_collection_2_l2"
Landsat 8 OLI-only Collection 2 Level 1	"oli8_collection_2_l1"
Landsat 9 OLI-TIRS Collection 2 Level 1	"olitirs9_collection_2_l1"
Landsat 9 OLI-TIRS Collection 2 Level 2	"olitirs9_collection_2_l2"
Landsat 9 OLI-only Collection 2 Level 1	"oli9_collection_2_l1"
MODIS MOD/MYD09A1	"mod09a1" or "myd09a1"
MODIS MOD/MYD09GA	"mod09ga" or "myd09ga"
MODIS MOD/MYD09GQ	"mod09gq" or "myd09gq"
MODIS MOD/MYD09Q1	"mod09q1" or "myd09q1"
MODIS MOD/MYD11A1	"mod11a1" or "myd11a1"
MODIS MOD/MYD13A1	"mod13a1" or "myd13a1"

Sensor/Dataset	JSON Object
MODIS MOD/MYD13A2	"mod13a2" or "myd13a2"
MODIS MOD/MYD13A3	"mod13a3" or "myd13a3"
MODIS MOD/MYD13Q1	"mod13q1" or "myd13q1"
VIIRS VNP09GA	"vnp09ga"

Table 4-1. Available sensors/products

List of the input scenes/granules ("inputs") and product options ("products") are specified within the body of JSON object. Available product options for Landsat, MODIS, and VIIRS are provided in Table 4-2 through Table 4-5.

Product	JSON Keyword
Level 1 and Level 2 Input Product	"l1"
Spectral indices	"sr_ndvi", "sr_evi", "sr_savi", "sr_msavi", "sr_ndmi", "sr_nbr", "sr_nbr2", and "sr_ndsi"
Provisional Aquatic Reflectance*	"aq_refl"
Provisional Actual Evapotranspiration**	"et"
*Provisional Aquatic Reflectance is available for Landsat 8-9 OLI and Landsat 8-9 OLI-TIRS data.	
**Provisional Actual Evapotranspiration is NOT available for Landsat 8-9 SR-only (L2SR) scenes.	

Table 4-2. Available Product Options for Landsat Collection 2

Product	JSON Keyword
Input Product	"l1"
Daily MODIS NDVI	"modis_ndvi"

Table 4-3. Available Product Options for MODIS Collection 6.1 MOD/MYD09GA Dataset

Product	JSON Keyword
Input Product	"l1"

Table 4-4. Available Product Options for MODIS Collection 6.1 Datasets

Product	JSON Keyword
Input Product	"l1"
Daily VIIRS NDVI	"viirs_ndvi"

Table 4-5. Available Product Options for VIIRS Collection 1 Datasets

Table 4-6 lists the “projection” options that are supported for ESPA outputs.

Projection	JSON Keyword
Universal Transverse Mercator (UTM)	"utm"
Polar Stereographic	"ps"
Albers Equal Area	"aea"
Sinusoidal	"sinu"
Geographic	"lonlat"

Table 4-6. Projection Options

Available file “format” options for ESPA outputs are listed in Table 4-7.

File Format	JSON Keyword
Georeferenced Tagged Image File Format (GeoTIFF; .tif)	"gtiff"
Cloud Optimized GeoTIFF (COG; .TIF)	"cog"
Exelis Visual Information Solutions (ENVI) binary (.img)	"envi"
Hierarchical Data Format – Earth Observing System – 2 (HDF-EOS2; .hdf)	"hdf-eos2"
Network Common Data Form (NetCDF; .nc)	"netcdf"

Table 4-7. File Format Options

Section 5 User Services

Landsat Science Products and associated interfaces are supported by User Services staff at USGS EROS. Feedback on the usability of the data products distributed from the ESPA is encouraged and welcome. Any scientific feedback, questions, comments, or interface problems can be directed to USGS EROS Customer Services:

Email: custserv@usgs.gov

Phone: 1-605-594-6151

Phone (toll-free): 1-800-252-4547

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

Appendix A Landsat GeoTIFF File Characteristics

NOTE: A Landsat 8 Collection 2 Level 1 product ID is used only as an example. Landsat 4-5 TM, Landsat 7 ETM+, and Landsat 9 OLI/TIRS files have similar characteristics (with the exception of Aquatic Reflectance product availability).

Description	Example File Size (Kbytes)	Example File Name
Source Level 1 data file (10) (Bands 1-7 and 9-11)	121,520	LC08_L1TP_023030_20191007_20200825_02_T1_B*.tif
Source Level 1 data file (Panchromatic Band 8)	485,891	LC08_L1TP_023030_20191007_20200825_02_T1_B8.tif
Source Product Metadata file (1)	8	LC08_L1TP_023030_20191007_20200825_02_T1_MTL.txt
Source Product Metadata file (1)	12	LC08_L1TP_023030_20191007_20200825_02_T1_MTL.xml
Angle Band Coefficients file (1)	115	LC08_L1TP_023030_20191007_20200825_02_T1_ANG.txt
Radiometric Saturation QA file (1)	121,520	LC08_L1TP_023030_20191007_20200825_02_T1_QA_RADSAT.tif
Per-pixel Band 4 Angle Band Files (4)	121,520	LC08_L1TP_023030_20191007_20200825_02_T1_*.tif
Level 1 Pixel QA file (1)	121,520	LC08_L1TP_023030_20191007_20200825_02_T1_QA_PIXEL.tif
Metadata	38	LC08_L1TP_023030_20191007_20200825_02_T1.xml

Table Key: TM Thematic Mapper, ETM+ Enhanced Thematic Mapper Plus, OLI Operational Land Imager, TIRS Thermal Infrared Sensor, HDF Hierarchical Data Format, SDS Science Data Set, IMG ENVI Binary Image Format, NA Not Applicable, TOA Top of Atmosphere, SR Surface Reflectance, QA Quality Assessment, XML Extensible Markup Language, HDR Header file format, BT Top of Atmosphere Brightness Temperature, CFMask C version Function of Mask, AR Aquatic Reflectance, ET Evapotranspiration

Table A-1. Landsat GeoTIFF File Characteristics for Collection 2

Appendix B Landsat HDF File Characteristics

NOTE: A Landsat 5 Collection 2 Level 1 TM product ID is used only as an example. Landsat 4 TM, Landsat 7 ETM+, and Landsat 8-9 OLI/TIRS files have similar characteristics.

NOTE: An “.img” file is included for each Science Data Set (SDS) within an HDF file because each band is stored as an external SDS.

Description	Example File Size (Kbytes)	Example File Name	Science Data Sets
Source data file	32	LT05_L1TP_018034_19850904_20200918_02_T1.hdf	<p>Grid</p> <ul style="list-style-type: none">• SDS1 band1• SDS2 band2• SDS3 band3• SDS4 band4• SDS5 band5• SDS6 band6• SDS7 band7• SDS8 radsat_qa• SDS9 pixel QA• SDS10 solar zenith angle• SDS11 solar azimuth angle• SDS12 viewing zenith angle• SDS13 viewing azimuth angle
Source Binary file (9)	55,099	LT05_L1TP_018034_19850904_20200918_02_T1_B*_hdf.img	NA
Source Metadata	8	LT05_L1TP_018034_19850904_20200918_02_T1_MTL.txt	NA
Angle Coefficients File	34	LT05_L1TP_018034_19850904_20200918_02_T1_ANG.txt	NA
Radiometric Saturation QA file	55,099	LT05_L1TP_018034_19850904_20200918_02_T1_QA_RADSAT_hdf.img	NA
Level 1 Pixel QA file	110,198	LT05_L1TP_018034_19850904_20200918_02_T1_QA_PIXEL.hdf.img	NA
Metadata	26	LT05_L1TP_018034_19850904_20200918_02_T1.xml	NA
Level 1 Product Metadata file	8	LT05_L1TP_018034_19850904_20200918_02_T1_MTL.txt	NA
Level 1 Product Metadata file	12	LT05_L1TP_018034_19850904_20200918_02_T1_MTL.xml	NA

Description	Example File Size (Kbytes)	Example File Name	Science Data Sets
Angle Band Coefficients file	115	LT05_L1TP_018034_19850904_20200918_02_T1_ANG.txt	NA

Table Key: TM Thematic Mapper, ETM+ Enhanced Thematic Mapper Plus, OLI Operational Land Imager, TIRS Thermal Infrared Sensor, HDF Hierarchical Data Format, SDS Science Data Set, IMG ENVI Binary Image Format, NA Not Applicable, TOA Top of Atmosphere, SR Surface Reflectance, QA Quality Assessment, XML Extensible Markup Language, HDR Header file format, CFMask C version Function of Mask

Table B-1. Landsat HDF File Characteristics for Collection 2

Appendix C Landsat Binary File Characteristics

NOTE: A Landsat 4 Collection 2 Level 2 TM product ID is used only as an example. Landsat 5 TM, Landsat 7 ETM+, and Landsat 8-9 OLI/TIRS files have similar characteristics.

Description	Example File Size (Kbytes)	Example File Name
Surface Reflectance data file (6)	119,277	LT04_L2SP_023028_19821212_20200918_02_T1_SR_B*.img
Surface Reflectance header file (6)	1	LT04_L2SP_023028_19821212_20200918_02_T1_SR_B*.hdr
Surface Reflectance Quality file	59,638	LT04_L2SP_023028_19821212_20200918_02_T1_SR_CLOUD_QA.img
Surface Reflectance Quality header file (7)	1	LT04_L2SP_023028_19821212_20200918_02_T1_SR_CLOUD_QA.hdr
Surface Reflectance Atmospheric Opacity file (1)	119,277	LT04_L2SP_023028_19821212_20200918_02_T1_SR_ATMOS_OPACITY.img
Surface Reflectance Atmospheric Opacity header file (1)	1	LT04_L2SP_023028_19821212_20200918_02_T1_SR_ATMOS_OPACITY.hdr
Radiometric Saturation QA file (1)	59,638	LT04_L2SP_023028_19821212_20200918_02_T1_QA_RADSAT.img
Radiometric Saturation QA header file (1)	1	LT04_L2SP_023028_19821212_20200918_02_T1_QA_RADSAT.hdr
Surface Temperature QA file (1)	118,699	LT04_L2SP_023028_19821212_20200918_02_T1_ST_QA.img
Surface Temperature QA header file (1)	1	LT04_L2SP_023028_19821212_20200918_02_T1_ST_QA.hdf
Surface Temperature Intermediate Bands file (7)	118,745	LT04_L2SP_023028_19821212_20200918_02_T1_ST_*.img

Description	Example File Size (Kbytes)	Example File Name
Surface Temperature Intermediate Bands header (7)	1	LT04_L2SP_023028_19821212_20200918_02_T1_ST_*.hdr
Pixel QA file (1)	59,638	LT04_L2SP_023028_19821212_20200918_02_T1_QA_PIXEL.ing
Pixel QA header file (1)	1	LT04_L2SP_023028_19821212_20200918_02_T1_QA_PIXEL.hdr
Metadata	24	LT04_L2SP_023028_19821212_20200918_02_T1.xml
Source Product MTL Metadata file (1)	8	LT04_L2SP_023028_19821212_20200918_02_T1_MTL.txt
Source Product XML Metadata file (1)	22	LT04_L2SP_023028_19821212_20200918_02_T1_MTL.xml
Angle Band Coefficients file (1)	115	LT04_L2SP_023028_19821212_20200918_02_T1_ANG.txt
<i>Table Key: TM Thematic Mapper, ETM+ Enhanced Thematic Mapper Plus, OLI Operational Land Imager, TIRS Thermal Infrared Sensor, HDF Hierarchical Data Format, SDS Science Data Set, IMG ENVI Binary Image Format, NA Not Applicable, TOA Top of Atmosphere, SR Surface Reflectance, QA Quality Assessment, XML Extensible Markup Language, HDR Header file format, BT Top of Atmosphere Brightness Temperature, CFMask C version Function of Mask</i>		

Table C-1. Landsat Binary File Characteristics for Collection 2

Appendix D MODIS HDF File Characteristics

NOTE: A Collection 6.1 MODIS MYD13 granule ID is used only as an example. MOD13 and MOD/MYD09 files have similar characteristics, though include different output files for each product type.

NOTE: An “.img” file is included for each Science Data Set within an HDF file because each band is stored as an external SDS.

Description	Example File Size (Kbytes)	Example File Name	Science Data Sets
Source data file	28	MYD13A2.A2009057.h17v04.061.2021123160358.hdf	<p>Grid</p> <ul style="list-style-type: none">• SDS1 250m 16 days NDVI• SDS2 250m 16 days EVI• SDS3 250m 16 days VI Quality• SDS4 250m 16 days red reflectance• SDS5 250m 16 days NIR reflectance• SDS6 250m 16 days blue reflectance• SDS7 250m 16 days MIR reflectance• SDS8 250m 16 days view zenith angle• SDS9 250m 16 days sun zenith angle• SDS10 250m 16 days relative azimuth angle• SDS11 250m 16 days composite day of the year• SDS12 250m 16 days pixel reliability
Source Binary file (12)	3,769	MYD13A2.A2009057.h17v04.061.2021123160358.hdf.1_km_16_days_*_.hdf.img	NA
Metadata	13	MYD13A2.A2009057.h17v04.061.2021123160358.hdf.xml	NA

Table Key: MODIS Moderate Resolution Imaging Spectroradiometer, HDF Hierarchical Data Format, SDS Science Data Set, NDVI Normalized Difference Vegetation Index, EVI Enhanced Vegetation Index, VI Vegetation Index, NIR Near Infrared, MIR Middle Infrared, m meter, IMG ENVI Binary Image Format, NA Not Applicable, TOA Top of Atmosphere, QA Quality Assessment, XML Extensible Markup Language, HDR Header file format

Table D-1. MODIS HDF File Characteristics

Appendix E MODIS Binary File Characteristics

NOTE: A Collection 6.1 MOD09 granule ID is used only as an example. MYD09 and MOD/MYD13 files have similar characteristics, though include different output files for each product type.

Description	Example File Size (Kbytes)	Example File Name
Source Band data file (21)	2,813-11,250	MOD09GA.A2001024.h20v17.061.2020059071304.*.img
Source Band header file (21)	1	MOD09GA.A2001024.h20v17.061.2020059071304.*.hdr
Daily NDVI data file	11,250	MOD09GA.A2001024.h20v17.061.2020059071304_SR_NDVI.img
Daily NDVI header file	1	MOD09GA.A2001024.h20v17.061.2020059071304_SR_NDVI.hdr
Metadata	20	MOD09GA.A2001024.h20v17.061.2020059071304.xml

Table Key: MODIS Moderate Resolution Imaging Spectroradiometer, MOD09 MODIS Terra Surface Reflectance Product, MOD/MYD13 MODIS Terra/Aqua Vegetation Index Product, IMG ENVI Binary Image Format, NA Not Applicable, XML Extensible Markup Language, HDR Header file format

Table E-1. MODIS Binary File Characteristics

Appendix F MODIS GeoTIFF File Characteristics

NOTE: A MOD09 granule ID is used as an example. MYD09 and MOD/MYD13 files have similar characteristics, though include different output files for each product type.

Description	Example File Size (Kbytes)	Example File Name
Geolocation Flags	1,409	MOD09GA.A2001024.h20v17.061.2020059071304.gflags_1.tif.tif
Granule Pointer	1,409	MOD09GA.A2001024.h20v17.061.2020059071304.granule_pnt_1.tif
Observation Number in Coarser Grid	5,633	MOD09GA.A2001024.h20v17.061.2020059071304.iobs_res_1.tif
Reflectance Band Quality (500m)	22,520	MOD09GA.A2001024.h20v17.061.2020059071304.QC_500m_1.tif
Range (Pixel to Sensor)	2,817	MOD09GA.A2001024.h20v17.061.2020059071304.Range_1.tif
Sensor Azimuth	2,817	MOD09GA.A2001024.h20v17.061.2020059071304.SensorAzimuth_1.tif
Sensor Zenith	2,817	MOD09GA.A2001024.h20v17.061.2020059071304.SensorZenith_1.tif
Solar Azimuth	2,817	MOD09GA.A2001024.h20v17.061.2020059071304.SolarAzimuth_1.tif
Solar Zenith	2,817	MOD09GA.A2001024.h20v17.061.2020059071304.SolarZenith_1.tif
Daily NDVI	11,270	MOD09GA.A2001024.h20v17.061.2020059071304_SR_NDVI.tif
Reflectance Data State QA (1km)	2,817	MOD09GA.A2001024.h20v17.061.2020059071304.state_1km_1.tif
Surface Reflectance Band 1 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b01_1.tif
Surface Reflectance Band 2 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b02_1.tif
Surface Reflectance Band 3 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b03_1.tif
Surface Reflectance Band 4 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b04_1.tif
Surface Reflectance Band 5 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b05_1.tif
Surface Reflectance Band 6 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b06_1.tif

Description	Example File Size (Kbytes)	Example File Name
Surface Reflectance Band 7 (500m)	11,270	MOD09GA.A2001024.h20v17.061.2020059071304.sur_refl_b07_1.tif
Metadata	21	MOD09GA.A2001024.h20v17.061.2020059071304.xml

Table Key: MODIS Moderate Resolution Imaging Spectroradiometer, MOD09 MODIS Terra Surface Reflectance Product, MOD/MYD13 MODIS Terra/Aqua Vegetation Index Product, tif GeoTIFF File Format, km kilometer, m meter, QC Quality Control, num number, refl reflectance, sur surface, iobs observation number, gflags geolocation flags, IMG ENVI Binary Image Format, NA Not Applicable, XML Extensible Markup Language, HDR Header file format

Table F-1. MODIS GeoTIFF File Characteristics

Appendix G VIIRS GeoTIFF File Characteristics

A Collection 1 VNP09 granule is shown as an example.

Description	Example File Size (Kbytes)	Example File Name
Metadata	6	VNP09GA.A2018305.h17v05.001.2018307065358.xml
Surface Reflectance Band 1 (Red)	11,270	VNP09GA.A2018305.h17v05.001.2018307065358.SurfReflect_I1_1.tif
Surface Reflectance Band 2 (NIR)	11,270	VNP09GA.A2018305.h17v05.001.2018307065358.SurfReflect_I2_1.tif
Surface Reflectance Band 3 (SWIR)	11,270	VNP09GA.A2018305.h17v05.001.2018307065358.SurfReflect_I3_1.tif
Daily NDVI	11,270	VNP09GA.A2018305.h17v05.001.2018307065358_SR_NDVI.tif

Table G-1. VIIRS GeoTIFF File Characteristics

Appendix H VIIRS Binary File Characteristics

A Collection 1 VNP09 granule is shown as an example.

Description	Example File Size (Kbytes)	Example File Name
Metadata	6	VNP09GA.A2018305.h17v05.001.2018307065358.xml
Source Band data file (3)	11,250	VNP09GA.A2018305.h17v05.001.2018307065358.SurfReflect_*.img
Source Band header file (3)	1	VNP09GA.A2018305.h17v05.001.2018307065358.SurfReflect_*.hdr
Daily NDVI data file	11,250	VNP09GA.A2018305.h17v05.001.2018307065358_SR_NDVI.img
Daily NDVI header file	1	VNP09GA.A2018305.h17v05.001.2018307065358_SR_NDVI.hdr

Table H-1. VIIRS Binary File Characteristics

Appendix I VIIRS HDF File Characteristics

A Collection 1 VNP09 granule is shown as an example.

Description	Example File Size (Kbytes)	Example File Name	Science Data Sets
Source data file	14	*.hdf	<ul style="list-style-type: none">• SDS1 Surface Reflectance Band 1 (Red)• SDS2 Surface Reflectance Band 2 (NIR)• SDS3 Surface Reflectance Band 3 (SWIR)• SDS4 NDVI derived from I1 and I2
Source Binary file (3)	11,250	*hdf.img	NA
Daily NDVI	11,250	*_SR_NDVI.hdf.img	NA
Source Metadata	6	*.xml	NA

Table I-1. VIIRS HDF File Characteristics

Appendix J Acronyms

AEA	Albers Equal Area
API	Application Programming Interface
AR	Aquatic Reflectance
ASTER GED	Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Emissivity Dataset
BT	Brightness Temperature
C2	Collection 2
CCB	Configuration Control Board
CFMask	C version of Fmask
COG	Cloud Optimized GeoTIFF
CONUS	Conterminous United States
CR	Change Request
CSV	Comma Separated Values
EE	EarthExplorer
ENVI	Exelis Visual Information Solutions
EO	Earth Observation
EROS	Earth Resources Observation and Science
ESA	European Space Agency
ESPA	EROS Science Processing Architecture
ET	Evapotranspiration
ETa	Actual Evapotranspiration
ETf	Evapotranspiration fraction
ETM+	Enhanced Thematic Mapper Plus
ETUN	Evapotranspiration Uncertainty
EVI	Enhanced Vegetation Index
Fmask	Function of Mask
GCOS	Global Climate Observing System
GDAL	Geospatial Data Abstraction Library
GeoTIFF	Georeferenced Tagged Image File Format
HDF	Hierarchical Data Format
HDF-EOS2	Hierarchical Data Format for Earth Observation Systems (version 2)
HDR	Header File
HTTPS	Hypertext Transfer Protocol Secure
JSON	JavaScript Object Notation
km	Kilometer
L1	Level 1
L2	Level 2
L2SP	Level 2 Science Product
L2SR	Level 2 Surface Reflectance
LaSRC	Land Surface Reflectance Code
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LP DAAC	Land Processes Distributed Active Archive Center
LSDS	Land Satellites Data System

LST/E	Land Surface Temperature and Emissivity
m	Meter
MIR	Middle Infrared
MOD09	MODIS Surface Reflectance – Terra Satellite
MOD11	MODIS Land Surface Temperature and Emissivity – Terra Satellite
MOD13	MODIS Vegetation Indices – Terra Satellite
MODIS	Moderate Resolution Imaging Spectroradiometer
MSAVI	Modified Soil Adjusted Vegetation Index
MSI	Multispectral Instrument
MTL	Metadata Text File Extension
MYD09	MODIS Surface Reflectance – Aqua Satellite
MYD11	MODIS Land Surface Temperature and Emissivity – Aqua Satellite
MYD13	MODIS Vegetation Indices – Aqua Satellite
NA	Not Applicable
NAD27	North American Datum 1927
NAD83	North American Datum 1983
NBR	Normalized Burn Ratio
NBR2	Normalized Burn Ratio 2
NC	NetCDF File Format
NDMI	Normalized Difference Moisture Index
NDSI	Normalized Difference Snow Index
NDVI	Normalized Difference Vegetation Index
NetCDF	Network Common Data Form
NIR	Near Infrared
ODI	On-Demand Interface
OLI	Operational Land Imager
PS	Polar Stereographic
QA	Quality Assessment
QC	Quality Control
RADSAT	Radiometric Saturation
REST	Representational State Transfer
RHORC	Rayleigh-corrected Reflectance
RT	Real Time
S-NPP	Suomi National Polar-Orbiting Partnership
SAVI	Soil Adjusted Vegetation Index
SDS	Science Data Set
SR	Surface Reflectance
ST	Surface Temperature
SWIR	Shortwave Infrared
T1	Tier 1
T2	Tier 2
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TOA	Top of Atmosphere
URL	Uniform Resource Locator

USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VI	Vegetation Index
VIIRS	Visible Infrared Imaging Radiometer Suite
VNP09	VIIRS Surface Reflectance
WGS84	World Geodetic System 1984
XML	Extensible Markup Language

Appendix K Document Change History

Document Version	Publication Date	Change Description
1.0	11/11/2013	Initial Draft
1.1	12/01/2013	Revised after Peer Review
1.2	01/06/2013	Updated with DownThemAll network preference instruction
1.3	06/04/2014	Corrected link to SI Product Guide
1.4	06/26/2014	Modified system login details
2.0	07/29/2014	Added new output format and projection option descriptions
2.1	08/04/2014	Added file format characteristics and appendices.
2.2	08/27/2014	Added MODIS MOD/MYD09 & MOD/MYD13 input options, output files; GeoTIFF output files added; 'fmask' changed to 'cfmask' in file output.
2.3	10/10/2014	Split processing options into more subsections, Land Product Characterization System (LPCS) integration, statistics generation, ability to download only metadata, users must "Define Projection" before modifying image extent.
2.4	10/22/2014	Expanded descriptions of reprojection parameters, updated on-demand order page figure to include statistics generation.
2.5	12/23/2014	Updated "Customization Options" section to show that QA bands are always resampled with Nearest Neighbor. Addition of Landsat 8 products. Updated figures and text to reflect ESPA website updates. Added LPCS processing addition to ESPA.
2.6	03/25/2015	Added ESPA Bulk Download client information to "Download" section.
2.7	9/22/2015	Corrected URLs in document
2.8	10/19/2015	Changed number of days in Section 2.3; adjusted server limits in download plugin documentation and graphic
2.9	12/01/2015	Minor formatting and typo corrections.
3.0	12/16/2015	Added caveat for maximum pixel count per grid. Updated tables to indicate cloud mask (CFmask) ordering option for Landsat products.
3.1	03/01/2016	Added caveat for Intercomparison & Statistics generation – currently not supported for Landsat Level 1 products.
3.2	05/10/2016	Updated link for ESPA bulk download client.
3.3	07/01/2016	Added description of order status messages. Updated links to Land Surface Reflectance Code (LaSRC) Product Guide.
3.4	10/07/2016	Added API information, NetCDF output & corresponding graphics.
3.5	12/07/2016	Updated links to Landsat Missions Website

Document Version	Publication Date	Change Description
3.6	01/13/2017	Added TM/ETM+ Collection 1 information and examples. Updated incorrect graphic of ordering interface. Added note about per-order maximum pixel limit (200 million). Added Table caption to ESPA order status table. Noted that only C5 MODIS products are currently available.
3.7	01/18/2017	Addition of MODIS C6 products.
3.8	03/15/2017	Added OLI/TIRS Collection 1 information and examples. Added caveat stating that TIRS-only (LT8 or LT08) data cannot be run to Brightness Temperature.
3.9	03/31/2017	Addition of MODIS LST/E (MO/YD11A1) to description, appendix, etc. Addition of .tar.gz archive name examples for pre-collection Landsat, Collection 1 Landsat, and MODIS (Section 2.3.) Removed "Provisional" stats from all instances of LaSRC (C1 only.)
4.0	04/06/2017	Removal of Landsat pre-collection data. Added explanation of Real Time (RT) data, and how it may not be available if it is removed from L1 archive and processed to Tier 1 or 2. Moved TOA, BT and CFMask to separate section (they are not CDRs.) Added link to ECV webpage. Updated figures with most recent ESPA interface.
4.1	06/26/2017	Removed CFMask product option information and replaced with pixel_qa product option information. Added order cancellation information.
4.2	10/05/2017	Replaced the terms high-level and higher-level with science data products. Corrected various typos.
4.3	12/04/2017	Added "top of atmosphere" before "brightness temperature" to clarify that BT products are not atmospherically corrected.
4.4	03/13/2018	Removed reference to CDR/ ECV, update graphics. Removed DownThemAll references (Section 2.32, Figure 2.8)
4.5	07/25/2019	Added of MODIS /VIIRS NDVI processing capability.
Version 1.0 LSDS-1417	08/01/2019	Added Water-Leaving Reflectance information
Version 2.0 LSDS-1417	January 2020	Changed Water-Leaving Reflectance to Provisional Aquatic Reflectance.
Version 3.0 LSDS-1417	April 2020	Corrected Spectral Indices information link
Version 4.0 LSDS-1417	June 2020	Added the Provisional Actual Evapotranspiration science product
Version 5.0 LSDS-1417	March 2021	Removed outdated GitHub links, added relevant GOES-R ABI information
Version 6.0 LSDS-1417	May 2021	Added Landsat Collection 2 information
Version 7.0 LSDS-1417	October 2021	Added relevant Collection 2 NDSI information
Version 8.0 LSDS-1417	May 2022	Added relevant Landsat 9 Collection 2 information
Version 9.0 LSDS-1417	June 2022	Added relevant Collection 2 Aquatic Reflectance information
Version 10.0 LSDS-1417	August 2022	Added relevant information about Collection 2 Provisional Actual Evapotranspiration
Version 11.0 LSDS-1417	September 2022	Added MODIS Collection 6.1 information

Document Version	Publication Date	Change Description
Version 12.0 LSDS-1417	October 2022	Removed GOES-R ABI information (LPCS support discontinued)
Version 13.0 LSDS-1417	December 2022	Removed Landsat Collection 1 information
Version 14.0 LSDS-1417	May 2023	Added COG file format availability
Version 15.0 LSDS-1417	January 2024	Removed Intercomparison and Statistics information. Added QA_RADSAT information

References

Please see <https://www.usgs.gov/landsat-missions/landsat-acronyms> for a list of acronyms.

USGS/EROS. LSDS-1618. Landsat 4-7 Collection 2 Level 2 Science Product Guide
<https://www.usgs.gov/media/files/landsat-4-7-collection-2-level-2-science-product-guide>

USGS/EROS. LSDS-1619. Landsat 8-9 Collection 2 Level 2 Science Product Guide
<https://www.usgs.gov/media/files/landsat-8-9-collection-2-level-2-science-product-guide>

USGS/EROS. LSDS-2340. Landsat 8-9 Collection 2 Level 2 Provisional Aquatic Reflectance Product Guide <https://www.usgs.gov/media/files/landsat-8-9-collection-2-level-2-provisional-aquatic-reflectance-product-guide>

USGS/EROS. LSDS-2349 Landsat 4-9 Collection 2 Level 3 Provisional Actual Evapotranspiration Product Guide <https://www.usgs.gov/media/files/landsat-4-9-collection-2-level-3-provisional-actual-evapotranspiration-product-guide>