Department of the Interior
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Earth Resources Observation and Science (EROS) Center
Science Processing Architecture (ESPA)
On-Demand Interface
User Guide

Release 2.35.0

Version 3.0

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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 Process and Change Management Tool.

Document History

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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 producing long-term remote sensing datasets suited for monitoring, characterizing and understanding the Earth's surface change over time. The framework's implementation includes basic processing services for Level 1 data and science data products to provide application-ready datasets to the user community. Currently, ESPA offers science products from Landsat, Moderate Resolution Imaging Spectroradiometer (MODIS), and Visible Infrared Imaging Radiometer Suite (VIIRS). The support for the Sentinel-2 Multispectral Instrument (MSI), Harmonized Landsat and Sentinel-2 (HLS), and Geostationary Operational Environmental Satellite-R Series (GOES-R) products will likely be added in the future.

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 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, which is the primary mechanism for access to USGS 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 Hierarchical Data Format (HDF) file characteristics
- Appendix B represents Landsat binary file characteristics
- Appendix C represents MODIS HDF file characteristics
- Appendix D represents MODIS binary file characteristics
- Appendix E represents MODIS GeoTIFF file characteristics
- Appendix F represents VIIRS GeoTIFF file characteristics
- Appendix G represents VIIRS binary file characteristics
- Appendix H represents VIIRS HDF file characteristics
- Appendix I represents list of acronyms
- Appendix J 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.

Note: Due to processing system limitations ESPA does not allow ordering Landsat Level 1 data or MODIS/VIIRS original input data without any customization. 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.

2.1   Landsat

Except for some periods of unavailability, all Collection 1 Landsat 4 and 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Level 1 scenes can be submitted for science product generation and delivery. Additional information about available Landsat product options are provided in Sections 2.1.1 through 2.1.8.

2.1.1   Input Products

Selection of this option will deliver the Landsat Level 1 scenes. This option is available only if a customization option is requested for the Level 1 data, or if the Level 1 data is ordered with higher level Landsat science products.

Landsat 8 OLI/TIRS Input Products output will contain:

- Level 1 data files (Bands 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11)
- Level 1 Quality Assessment (QA) Band (BQA) file. More information about BQA Band can be found at https://www.usgs.gov/land-resources/nli/landsat/landsat-collection-1-level-1-quality-assessment-band
- Metadata text file (MTL.txt)
- Angle band coefficients file (ANG.txt). More information about angle coefficients file can be found at https://www.usgs.gov/land-resources/nli/landsat/solar-illumination-and-sensor-viewing-angle-coefficient-files
- Extensible Markup Language (XML) metadata

Landsat 7 ETM+ original Input Products output will contain:

- Level 1 data files (Band 1, 2, 3, 4, 5, 6 low gain, 6 high gain, 7, and 8)
- Level 1 Quality Assessment band (BQA)
- Level 1 metadata file (MTL.txt)
- Angle band coefficients file (ANG.txt)
- XML metadata

Landsat 4 and 5 TM original Input Products output will contain:

- Level 1 data files (Band 1, 2, 3, 4, 5, 6, and 7)

- Level 1 Quality Assessment band (BQA)
- Level 1 metadata file (MTL.txt)
- Angle band coefficients file (ANG.txt)
- XML metadata

Filenames utilize the Landsat product identifier (productID), for example "LC08_L1TP_220071_20170207_20170216_01_T1" for Landsat 8, "LE07_L1TP_039037_20080728_20160918_01_T1" for Landsat 7, and "LT05_L1TP_029030_20100805_20160831_01_T1" for Landsat 5.

2.1.2 Input Product Metadata

The Landsat Level 1 metadata (MTL.txt) and angle band coefficients file (ANG.txt) will be distributed when this option is requested. This option is available only if a higher level Landsat product is requested.

2.1.3 Surface Reflectance

This option delivers the Surface Reflectance (SR) product. Detailed description of the Landsat Surface Reflectance product is provided in the Landsat 4-7 Surface Reflectance (LEDAPS) Product Guide, and the Land Surface Reflectance Code (LaSRC) Product Guide, but the general contents are listed below.

Landsat Surface Reflectance output from Landsat 8 contains:

- Surface Reflectance data files (Bands 1–7)
- Radiometric Saturation QA band (radsat_qa)
- Surface Reflectance Aerosol QA band
- Level 2 Pixel Quality Assessment band (pixel_qa)
- Surface Reflectance metadata file (.xml)

Landsat Surface Reflectance output from Landsat 7 ETM+, Landsat 5 TM, and Landsat 4 TM will contain:

- Surface Reflectance data files (Bands 1-5, 7)
- Surface Reflectance quality files (sr_cloud_qa, sr_atmos_opacity)
- Radiometric Saturation Quality Assessment band (radsat_qa)
- Level 2 Pixel Quality Assessment band (pixel_qa)
- Surface Reflectance metadata file (.xml)

Filenames utilize the productID followed by "_sr_," as exemplified by "LT04_L1TP_023028_19821212_20161004_01_T1_sr_*".

2.1.4 Top of Atmosphere (TOA) Reflectance

For users interested in TOA Reflectance calculated from the Level 1 scenes, the "Top of Atmosphere Reflectance" option may be selected. Further details about the product are

provided in the Landsat 4-7 Surface Reflectance (LEDAPS) Product Guide, and the Land Surface Reflectance Code (LaSRC) Product Guide.

Top of Atmosphere Reflectance output from Landsat 8 contains:

- LC8 data: TOA Reflectance data files (Bands 1–7, 9)
- LO8 data: TOA Reflectance data files (Bands 1–7, 9)
- Radiometric Saturation Quality Assessment file (radsat_qa)
- Level 2 Pixel Quality Assessment band (pixel_qa)
- Per-pixel solar zenith, solar azimuth, sensor zenith and sensor azimuth bands (Band 4 only)
- TOA Reflectance metadata file (.xml)

Landsat Top of Atmosphere Reflectance output from Landsat 7 ETM+, Landsat 5 TM, and Landsat 4 TM will contain:

- TOA Reflectance data files (Bands 1-5, 7)
- Radiometric Saturation Quality Assessment band (radsat_qa)
- Per-pixel solar zenith, solar azimuth, sensor zenith, and sensor azimuth bands (Band 4 only)
- Level 2 Pixel Quality Assessment band (pixel_qa)
- TOA Reflectance metadata file (.xml)

Filenames utilize the productID followed by "_toa_", as exemplified by "LT05_L1TP_029030_20100805_20160831_01_T1_toa_*".

2.1.5 Top of Atmosphere Brightness Temperature

This option delivers the TOA Brightness Temperature (BT) for thermal bands (Band 6 of Landsat 4-5 TM and Landsat 7 ETM+ and Bands 10 and 11 of Landsat 8 TIRS), which are converted to Kelvin.

TOA Brightness Temperature output from Landsat 8 contains:

- TOA Brightness Temperature data files (Bands 10–11)
- Radiometric Saturation Quality Assessment file (radsat_qa)
- Level 2 Pixel Quality Assessment band (pixel_qa)
- TOA Brightness Temperature metadata file (.xml)

Note: Landsat 8 TIRS-only ("LT08") cannot be processed to TOA Brightness Temperature.

TOA Brightness Temperature output from Landsat 7 ETM+, Landsat 5 TM, and Landsat 4 TM will contain:

- TOA Brightness Temperature data file (Band 6)

- Radiometric Saturation Quality Assessment band (radsat_qa)
- [Level 2 Pixel Quality Assessment band (pixel_qa)](#)
- TOA Brightness Temperature metadata file (.xml)

Filenames utilize the productID followed by "_bt_", as exemplified by "LC08_L1TP_171061_20140702_20160101_01_T1_bt_*".

Note: For Landsat 7 ETM+ sensor only low-gain thermal band (Band 6-1) is processed to TOA Brightness Temperature.

2.1.6 Pixel Quality Assessment

The Level 2 Pixel Quality Assessment (QA) is created using the C version of Function of Mask (CFMask) algorithm and contains information about cloud, cloud confidence, cloud shadow, snow/ice, and water. Additional information about the Landsat Pixel QA band are provided in the [Landsat 4-7 Surface Reflectance (LEDAPS) Product Guide](#), and the [Landsat 8 Surface Reflectance Code (LaSRC) Product Guide](#).

Filenames utilize the productID followed by "_pixel_qa_", as exemplified by "LC08_L1TP_125030_20150414_20170410_01_T1_pixel_qa_*".

2.1.7 Provisional Aquatic Reflectance

Aquatic Reflectance is an experimental aquatic science product and is currently available only for Landsat 8. Additional information about the Aquatic Reflectance science product is available in the [Landsat Provisional Aquatic Reflectance Product Guide](#). The Aquatic Reflectance product package for Landsat 8 contain:

- Aquatic Reflectance for visible bands (Bands 1-4)
- Quality flags (l2_flags)
- [Level 2 Pixel Quality Assessment band (pixel_qa)](#)
- Aquatic Reflectance metadata file (.xml)

Filenames utilize the productID followed by "_ar_", as exemplified by "LC08_L1TP_014034_20160812_20170222_01_T1_ar_*".

2.1.8 Spectral Indices

Surface Reflectance is used to derive several spectral indices products, as listed below. The characteristics of spectral indices are described on https://www.usgs.gov/land-resources/nli/landsat/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)

2.2   MODIS

The following MODIS Collection 6 datasets can be submitted for customization and comparison with other datasets.

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 will enable 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.h08v06.006.2015146050343_*" for surface reflectance, "MYD11A1.A2006282.h22v16.006.2015299134539_*" for surface temperature and emissivity, and "MYD13A1.A2012265.h17v08.006.2015249154919_*" 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.h08v06.006.2015146050343_sr_ndvi_*".

2.3 VIIRS

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 will enable 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 will deliver 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.h19v05.006.2015149070403
> MOD09GA.A2001024.h20v17.006.2015140115718
> LE07_L1TP_039037_20080728_20170314_01_T1
> LC08_L1TP_039037_20160726_20180201_01_T1
> MYD11A1.A2017069.h16v02.006.2017073045736
> VNP09GA.A2014073.h19v10.001.2017018110619

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 TM, ETM+, OLI/TIRS (Collection 1)	Select MODIS 09, 11 & 13 (Collection 6)	S-NPP VIIRS (Collection 1)
Input Product	X	X	X
Input Product Metadata	X		
Level 2 Products	X		
Spectral Indices	X	X[3]	X[3]
Customize Outputs	X[1]	X	X
Intercomparison & Statistics	X[2]	X	X

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] Reprojection and pixel resizing options do not apply to the Panchromatic Band (Band 8 Landsat 7 ETM+ & Band 8 Landsat 8 OLI only.)
[2] Intercomparison & Statistics apply to all data products except the Landsat Level 1 data products.
[3] 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 and Landsat 7 Collection 1 Level 1 scenes are assigned a tier designation, they are placed into the Real Time (RT) tier until finalized bumper mode and geometric correction parameters (Landsat 7 only – 26 days) or finalized TIRS line-of-sight models (Landsat 8 only – 14 days) have been applied to the data.

Users can order 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 original Level 1 Landsat scenes, or MODIS MOD/MYD09, MOD/MYD11, MOD/MYD13, or VIIRS VNP09 granules accompanied by metadata downloaded directly from the USGS or Land Processes Distributed Active Archive Center (LP DAAC). Landsat Level 1 product characteristics are described on https://www.usgs.gov/land-resources/nli/landsat/landsat-level-1-processing-details. MODIS characteristics are described on https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table and the characteristics of the VIIRS surface reflectance are described on https://lpdaac.usgs.gov/products/vnp09gav001/.
- Input Product Metadata is included when source Input Products are requested but is selectable as a separate option to serve users who want that information to

go along with one of the higher-level science data products without having to download an entire Landsat Level 1 package.

- o Original Input Product Metadata is not available for MODIS or VIIRS products.

3.1.5 Landsat Level 2 Products

As explained in Section 2.1, currently, Landsat Surface Reflectance (SR), Top of Atmosphere (TOA) reflectance, TOA Brightness Temperature (BT), Provisional Aquatic Reflectance, Pixel Quality Assessment (QA), spectral indices and their associated metadata are available on ESPA.

Offerings of Landsat Surface Temperature (ST), Evapotranspiration, and Harmonized Landsat and Sentinel-2 (HLS) will be added to the product selections when each reaches provisional status. Information will be added to https://www.usgs.gov/land-resources/nli/landsat/landsat-science-products when these data become available.

3.1.6 MODIS/VIIRS Spectral Indices

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

3.1.7 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. "Customize Input Products" must be checked for product customization to be applied to MODIS scenes. For example, if Environment for Visualizing Images (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.

Figure 3-2. ESPA On-Demand Customization Services

3.1.7.1   Output Format

Customized Input Products, Level 2 science products, and/or Spectral Indices can be output in the following formats: GeoTIFF (".tif"), ENVI binary (".img"), NetCDF (".nc") or Hierarchical Data Format – Earth Observing System version 2 (HDF-EOS2; ".hdf"). The ESPA default file format is GeoTIFF.

3.1.7.2   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, 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 3-2. A graphical example of reprojection is shown in Figure 3-3.

		Projection				
		Albers Equal Area	UTM	Geographic	Sinusoidal	Polar Stereographic
Input Parameters	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	
	1st Standard Parallel	-90.0 to 90.0				
	2nd 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			
UTM Universal Transverse Mercator, WGS84 World Geodetic System 1984, NAD27 North American Datum 1927, NAD83 North American Datum 1983						

Table 3-2. Possible Input Parameters for Product Reprojection in ESPA

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

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3.1.7.3　　　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).

Note: Due to processing system limitations, image extents cannot be greater than 200 million pixels per image.

3.1.7.4　　　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.

Note: Due to processing system limitations, resized pixels cannot yield more than 200 million pixels per image.

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

3.1.8　Intercomparison & Statistics

Statistics can be generated between geographically intersecting Landsat TM, ETM+, OLI/TIRS, and select MODIS and VIIRS datasets through ESPA by selecting "Plot Output Product Statistics" under the "Intercomparison & Statistics" section. The statistics include plots, text files and CSV files of minimum, maximum, mean, and standard deviation of the image extents. Pixels masked as NoData, areas of the scene outside of the user-specified study area, and pixels with invalid data are not included in statistical calculation.

A list of overlapping scene IDs can be generated from the EarthExplorer, which uses the same credential as ESPA. Statistical results are provided in two different directories: a "Stats" folder and a Statistics archive file.

3.1.8.1　　　"Stats" Folder

Within each scene or granule product identifier's (Product ID) .tar.gz archive, there is a "stats" folder containing text files for each band. The descriptive statistics and their value are separated by an equal sign (=) without spaces. All data in the output text files are represented as their true value and not unscaled. Data are displayed as floating-point values with six digits of precision. For example, the .stats file for band 1 TOA Reflectance of Landsat scene LC08_L1TP_140027_20151016_20170403_01_T1 is formatted as follows:

```
FILENAME=LC08_L1TP_140027_20151016_20170403_01_T1_toa_band1.img
MINIMUM=821.000000
MAXIMUM=10000.000000
MEAN=1602.908792
```

STDDEV=461.408147
VALID=yes

3.1.8.2   Statistics Archive File

On the ESPA order status page, the statistics archive is downloadable under the Product named "Plotting and Statistics". Each .tar.gz archive is named with the order ID appended by "-statistics" suffix. Within the archive, two file types exist:

a. Plots of individual bands and plots of each band across different sensors (if applicable).
b. Comma-Separated Value (.csv) files corresponding to each plot.

Each statistic is separated by band but grouped together by sensor platform type. The groups of sensors are plotted by band and output as a separate statistics CSV file. In cases where a band may not have any values within the valid range, such as pixel saturation, the statistics will be reported as "-9999" and the VALID cell will be flagged with "no". Each CSV file is written by row and contains a header in the first row.

3.1.8.2.1   Plots

Plots are displayed with the date on the X axis (in date format MMM DD YYYY) and individual surface reflectance bands scaled as 0.0 to 1.0 on the Y axis. Plots can represent the following statistics: minimum, maximum, mean, standard deviation, or a combination of minimum-maximum-mean. All data points are represented with a color-coded point, where the color represents a specific sensor platform.

In the minimum-maximum-mean plot, the point represents the mean, the vertical line above the point represents the maximum value, and the vertical line below the point represents the minimum value. An example of the minimum-maximum-mean plot for Landsat 8 NDVI is displayed in Figure 3-4.
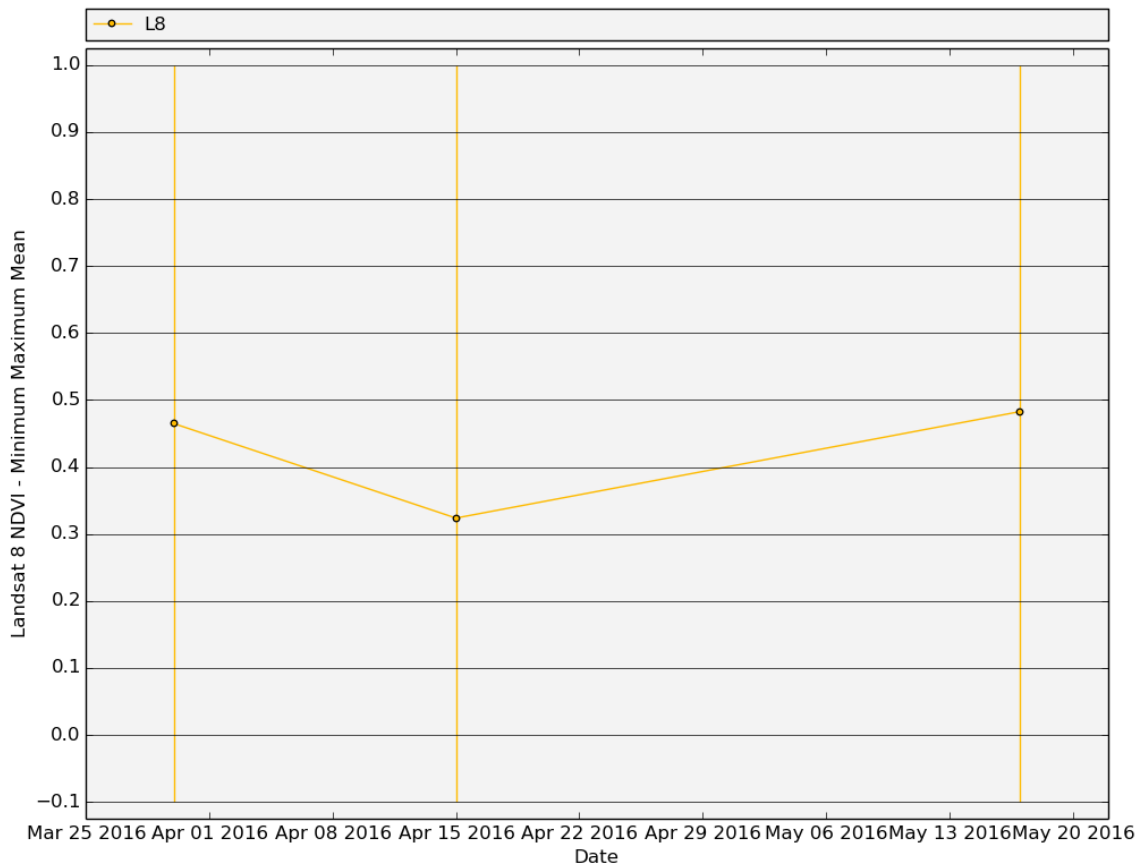
Figure 3-4. Example of Minimum-maximum-mean Plot for Landsat 8 NDVI from Three Scenes

Multiple sensors across similar time scales are represented by different colors of lines and points. All bands are plotted together with the prefix "multi_sensor_" and are plotted against one another. Multi-sensor plots use the same statistics as the individual sensor plots discussed above. Figure 3-5 shows an example of multiple sensor plot for Landsat and MODIS data.
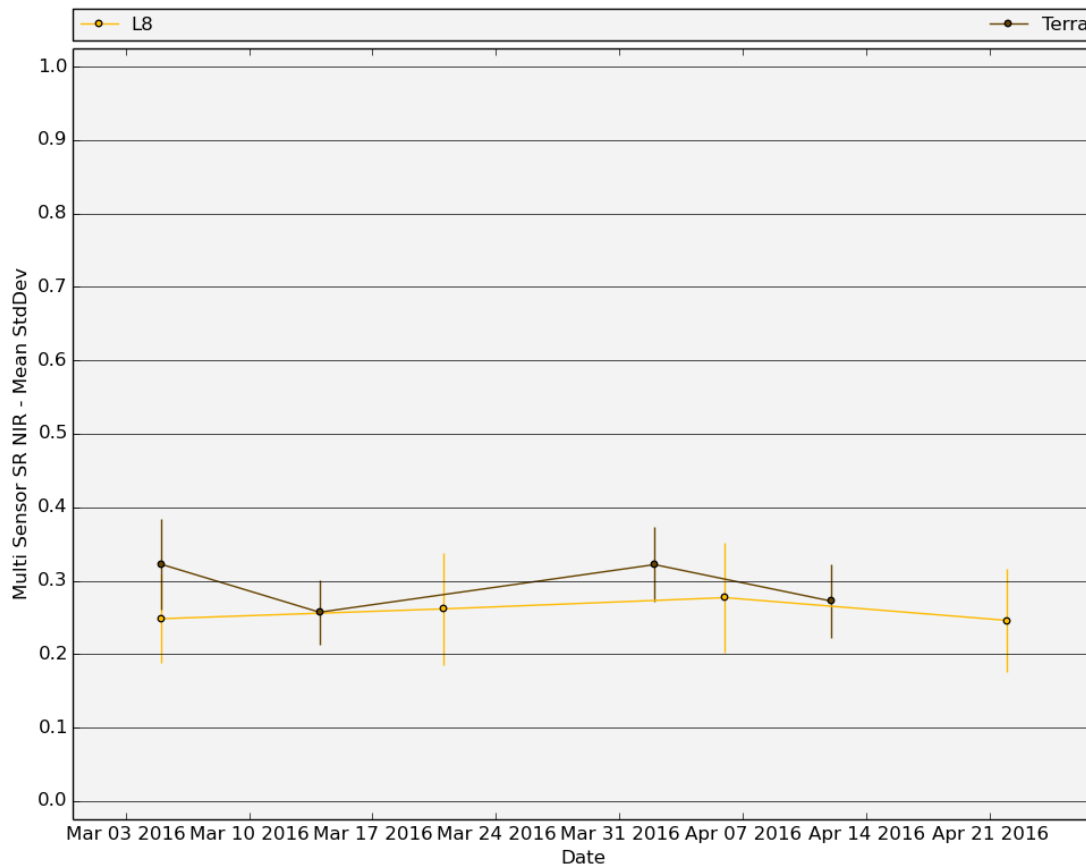
Figure 3-5. Example of Multi-sensor Mean and Standard Deviation Plot for Landsat 8 OLI (Yellow line) and Terra MODIS (Black line) NIR Surface Reflectance

Note that plots are only generated for orders containing two or more scenes/granules for each sensor. For example, an order of two Landsat OLI scenes and one MODIS MYD09 granule would generate plots for "landsat" and "multi_sensor," but not for "modis".

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" will present 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 3-6).

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	XXXXXXXXXXXXXXXXXXXXXXXX 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	XXXXXXXXXXXXXXXXXXXXXXXX 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	XXXXXXXXXXXXXXXXXXXXXXXX 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	XXXXXXXXXXXXXXXXXXXXXXXX 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 3-6. 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 3-7). An email notice is sent to the user only when all files are complete.

Figure 3-7. ESPA On-Demand Distribution Page

3.2.1 Cancel Order

Orders containing scenes submitted for processing can be cancelled by the user. Figure 3-8 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.

Figure 3-8. Cancel Order

To confirm that an order has been successfully cancelled, check that the status of the order displays "cancelled" (Figure 3-9). Verification that the individual scenes within a

cancelled order are cancelled can also be done by checking the scene status and notes.

Figure 3-9. Order Cancellation Verification

3.2.2 Status Message

Each product within an order contains a status, indicating its activity within ESPA. Table 3-3 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:

Status	Interpretation
	• 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 3-3. 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 Collection 1 Landsat data, the archives are formatted as follows:

LXSSPPPRRRYYYYMMDDCCTX-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)
PPP Path
RRR Row
YYYY Year of acquisition
MM   Acquisition month
DD   Acquisition day
CC   Landsat Collection number ("01" for Collection 1)
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 ("006" for Collection 6)
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

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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://github.com/USGS-EROS/espa-bulk-downloader.](https://github.com/USGS-EROS/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://github.com/USGS-EROS/espa-api/blob/master/docs/API-RESOURCES-LIST.md.

4.2   Documentation

The official ESPA API documentation is at https://github.com/USGS-EROS/espa-api.

An example Python code for placing and downloading orders through ESPA API is available on https://github.com/USGS-EROS/espa-api/blob/master/examples/api_demo.ipynb. 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	"tm4_collection"
Landsat 5 TM	"tm5_collection"
Landsat 7 ETM+	"etm7_collection"
Landsat 8 OLI-TIRS	"olitirs8_collection"
Landsat 8 OLI only	"oli8_collection"
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"
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
Input Product	"l1"
Input Product Metadata	"source_metadata"
Surface Reflectance	"sr"
TOA Reflectance	"toa"
TOA Brightness Temperature	"bt"
Pixel Quality Assessment	"pixel_qa"
Provisional Aquatic Reflectance*	"aq_refl"
Spectral indices	"sr_ndvi", "sr_evi", "sr_savi", "sr_msavi", "sr_ndmi", "sr_nbr", and "sr_nbr2"
Statistics	"stats"
Provisional Aquatic Reflectance is available only for Landsat 8 OLI and Landsat 8 OLI-TIRS data.	

Table 4-2. Available Product Options for Landsat Collection 1

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

Table 4-3. Available Product Options for MODIS Collection 6 MOD/MYD09GA Dataset

Product	JSON Keyword
Input Product	"l1"
Statistics	"stats"

Table 4-4. Available Product Options for MODIS Collection 6 Datasets

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

Table 4-5. Available Product Options for VIIRS Datasets

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

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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"
Exelis Visual Information Solutions (ENVI) binary (.img)	"envi"
Hierarchical Data Format – Earth Observing System – 2 (HDF-EOS2; .hdf)	"hdf-eos2"
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. Any 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 HDF File Characteristics

NOTE: A Landsat 5 TM product ID is used only as an example. Landsat 4 TM, Landsat 7 ETM+, and Landsat 8 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 (bytes)	Example File Name	Science Data Sets
Source data file	16,239	LT05_L1TP_018034_19850904_20161004_01_T1.hdf	Grid • SDS1 band1 • SDS2 band2 • SDS3 band3 • SDS4 band4 • SDS5 band5 • SDS6 band61 • SDS7 band62 • SDS8 band7 Grid_15 • SDS1 band8
Source Binary file (9)	56,428,541	LT05_L1TP_018034_19850904_20161004_01_T1_B*_hdf.img	NA
Source Metadata	6,307	LT05_L1TP_018034_19850904_20161004_01_MTL.txt	NA
Angle Coefficients File	6,000	LT05_L1TP_018034_19850904_20161004_01_ANG.txt	NA
Ground Control Points File	10,000	LT05_L1TP_018034_19850904_20161004_01_GCP.txt	NA
TOA Reflectance data file	25,522	LT05_L1TP_018034_19850904_20161004_01_T1_toa.hdf	• SDS1 toa_band1 • SDS2 toa_band2 • SDS3 toa_band3 • SDS4 toa_band4 • SDS5 toa_band5 • SDS6 toa_band7 • SDS7 radsat_qa • SDS8 pixel_qa
TOA Reflectance Binary file (7)	112,857,082	LT05_L1TP_018034_19850904_20161004_01_T1_toa_band*_hdf.img	NA
TOA Reflectance Quality Binary file	56,428,541	LT05_L1TP_018034_19850904_20161004_01_T1_radsat_qa_hdf.img	NA
TOA Reflectance header file	522	LT05_L1TP_018034_19850904_20161004_01_T1_toa.hdf.hdr	NA
Surface Reflectance data file	33,812	LT05_L1TP_018034_19850904_20161004_01_T1_sr.hdf	• SDS1 sr_band1 • SDS2 sr_band2 • SDS3 sr_band3 • SDS4 sr_band4 • SDS5 sr_band5 • SDS6 sr_band7 • SDS7 sr_atmos_opacity • SDS8 sr_cloud_qa

Description	Example File Size (bytes)	Example File Name	Science Data Sets
			• SDS14 radsat_qa • SDS15 pixel_qa
Surface Reflectance Binary file (6)	112,857,082	LT05_L1TP_018034_19850904_20161004 _01_T1_sr_band*_hdf.img	NA
Surface Reflectance Quality Binary file	56,428,541	LT05_L1TP_018034_19850904_20161004 _01_T1_sr_cloud_qa_hdf.img	NA
Surface Reflectance Atmospheric Opacity Binary file	112,857,082	LT05_L1TP_018034_19850904_20161004 _01_T1_sr_atmos_opacity_hdf.img	NA
Surface Reflectance Pixel QA file	56,428,541	LT05_L1TP_018034_19850904_20161004 _01_T1_pixel_qa.hdf.img	NA
Surface Reflectance header file	612	LT05_L1TP_018034_19850904_20161004 _01_T1_sr.hdf.hdr	NA
Metadata	13,365	LT05_L1TP_018034_19850904_20161004 _01_T1.xml	NA
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 A-1. Landsat HDF File Characteristics

Appendix B   Landsat Binary File Characteristics

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

Description	Example File Size (bytes)	Example File Name
Source Band data file (9)	59,638,671	LT04_L1TP_023028_19821212_20161004_01_T1_B*.img
Source Band header file (9)	348	LT04_L1TP_023028_19821212_20161004_01_T1_B*.hdr
TOA Reflectance data file (7)	119,277,342	LT04_L1TP_023028_19821212_20161004_01_T1_toa_band*.img
TOA Reflectance header file (7)	348	LT04_L1TP_023028_19821212_20161004_01_T1_toa_band*.hdr
TOA Reflectance Quality file (1)	59,638,671	LT04_L1TP_023028_19821212_20161004_01_T1_radsat_qa.img
TOA Reflectance Quality header file (1)	333	LT04_L1TP_023028_19821212_20161004_01_T1_radsat_qa.hdr
Surface Reflectance data file (6)	119,277,342	LT04_L1TP_023028_19821212_20161004_01_T1_sr_band*.img
Surface Reflectance header file (6)	352	LT04_L1TP_023028_19821212_20161004_01_T1_sr_band*.hdr
Surface Reflectance Quality file	59,638,671	LT04_L1TP_023028_19821212_20161004_01_T1_sr_cloud_qa.img
Surface Reflectance Quality header file (7)	332	LT04_L1TP_023028_19821212_20161004_01_T1_sr_cloud_qa.hdr
Surface Reflectance Atmospheric Opacity file (1)	119,277,342	LT04_L1TP_023028_19821212_20161004_01_T1_sr_atmos_opacity.img
Surface Reflectance Atmospheric Opacity header file (1)	339	LT04_L1TP_023028_19821212_20161004_01_T1_sr_atmos_opacity.hdr
Surface Reflectance Pixel QA file (1)	59,638,671	LT04_L1TP_023028_19821212_20161004_01_T1_pixel-qa.img
Surface Reflectance Pixel QA header file (1)	336	LT04_L1TP_023028_19821212_20161004_01_T1_pixel_qa.hdr
Metadata	32,139	LT04_L1TP_023028_19821212_20161004_01_T1.xml

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

Table B-1. Landsat Binary File Characteristics

Appendix C   MODIS HDF File Characteristics

NOTE: A MODIS MYD13 granule ID is used only as an example. MOD13 and MOD/MYD09 files (Collections 5 and 6) 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 (bytes)	Example File Name	Science Data Sets
Source data file	28	*.hdf	Grid • 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)	9,748	*hdf.img	NA
Metadata	13	*.xml	NA
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 C-1. MODIS HDF File Characteristics

Appendix D   MODIS Binary File Characteristics

NOTE: A 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.h20v17.006.2015140115718.*.img
Source Band header file (21)	1	MOD09GA.A2001024.h20v17.006.2015140115718.*.hdr
Daily NDVI data file	11,250	MOD09GA.A2001024.h20v17.006.2015140115718_sr_ndvi.img
Daily NDVI header file	1	MOD09GA.A2001024.h20v17.006.2015140115718_sr_ndvi.hdr
Metadata	20	MOD09GA.A2001024.h20v17.006.2015140115718.xml
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 D-1. MODIS Binary File Characteristics

Appendix E 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.h20v17.006.2015140115718_gflags_1.tif.tif
Granule Pointer	1,409	MOD09GA.A2001024.h20v17.006.2015140115718_granule_pnt_1.tif
Observation Number in Coarser Grid	5,633	MOD09GA.A2001024.h20v17.006.2015140115718_iobs_res_1.tif
Number of Observations (1km)	1,409	MOD09GA.A2001024.h20v17.006.2015140115718_num_observations_1km.tif
Number of Observations (500m)	5,632	MOD09GA.A2001024.h20v17.006.2015140115718_num_observations_500m.tif
Observation Coverage (500m)	5,632	MOD09GA.A2001024.h20v17.006.2015140115718_obscov_500m_1.tif
Orbit Pointer	1,409	MOD09GA.A2001024.h20v17.006.2015140115718_orbit_pnt_1.tif
Reflectance Band Quality (500m)	22,520	MOD09GA.A2001024.h20v17.006.2015140115718_QC_500m_1.tif
Range (Pixel to Sensor)	2,817	MOD09GA.A2001024.h20v17.006.2015140115718_Range_1.tif
Sensor Azimuth	2,817	MOD09GA.A2001024.h20v17.006.2015140115718_SensorAzimuth_1.tif
Sensor Zenith	2,817	MOD09GA.A2001024.h20v17.006.2015140115718_SensorZenith_1.tif
Solar Azimuth	2,817	MOD09GA.A2001024.h20v17.006.2015140115718_SolarAzimuth_1.tif
Solar Zenith	2,817	MOD09GA.A2001024.h20v17.006.2015140115718_SolarZenith_1.tif
Daily NDVI	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sr_ndvi.tif
Reflectance Data State QA (1km)	2,817	MOD09GA.A2001024.h20v17.006.2015140115718_state_1km_1.tif
Surface Reflectance Band 1 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b01_1.tif
Surface Reflectance Band 2 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b02_1.tif
Surface Reflectance Band 3 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b03_1.tif
Surface Reflectance Band 4 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b04_1.tif
Surface Reflectance Band 5 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b05_1.tif
Surface Reflectance Band 6 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b06_1.tif
Surface Reflectance Band 7 (500m)	11,270	MOD09GA.A2001024.h20v17.006.2015140115718_sur_refl_b07_1.tif
Metadata	21	MOD09GA.A2001024.h20v17.006.2015140115718.xml
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, obscov observation coverage algorithm, iobs observation number, gflags geolocation flags, IMG ENVI Binary Image Format, NA Not Applicable, XML Extensible Markup Language, HDR Header file format		

Table E-1. MODIS GeoTIFF File Characteristics

Appendix F   VIIRS GeoTIFF File Characteristics

A 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 F-1. VIIRS GeoTIFF File Characteristics

Appendix G   VIIRS Binary File Characteristics

A 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 G-1. VIIRS Binary File Characteristics

Appendix H   VIIRS HDF File Characteristics

A VNP09 granule is shown as an example.

Description	Example File Size (Kbytes)	Example File Name	Science Data Sets
Source data file	14	*.hdf	• 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	*.hdf.hdr	NA
Source Metadata	6	*.xml	NA

Table H-1. VIIRS HDF File Characteristics

Appendix I   Acronyms

AEA	Albers Equal Area
API	Application Programming Interface
BQA	Quality Assessment Band
BT	Brightness Temperature
C1	Collection 1
CCB	Configuration Control Board
CFMask	C version of Fmask
CR	Change Request
CSV	Comma Separated Values
EE	EarthExplorer
ENVI	Environment for Visualizing Images
EO	Earth Observation
EROS	Earth Resources Observation and Science
ESA	European Space Agency
ESPA	EROS Science Processing Architecture
ETM+	Enhanced Thematic Mapper Plus
EVI	Enhanced Vegetation Index
Fmask	Function of Mask
GCOS	Global Climate Observing System
GDAL	Geospatial Data Abstraction Library
GEOS-R	Geostationary Operational Environmental Satellite-R Series
GeoTIFF	Georeferenced Tagged Image File Format
HDF	Hierarchical Data Format
HDF-EOS2	Hierarchical Data Format for Earth Observation Systems (version 2)
HDR	Header File
HLS	Harmonized Landsat and Sentinel-2
HTTPS	Hypertext Transfer Protocol Secure
JSON	JavaScript Object Notation
km	Kilometer
L1	Level 1
L2	Level 2
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
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
ODI	On-Demand Interface
OLI	Operational Land Imager
PIXELQA	Pixel Quality Assessment
PS	Polar Stereographic
QA	Quality Assessment
QC	Quality Control
RADSAT	Radiometric Saturation
REST	Representational State Transfer
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 J 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 L8 Surface Reflectance Code (LaSRC) Product Guide.
3.4	10/07/2016	Added API information, NetCDF output & corresponding graphics.

Document Version	Publication Date	Change Description
3.5	12/07/2016	Updated links to Landsat Missions Website
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	03/31/3017	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

References

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

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

USGS/EROS. LSDS-1368. Landsat 8 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

USGS/EROS. LSDS-1422. Landsat Provisional Aquatic Reflectance Product Guide
https://www.usgs.gov/media/files/landsat-provisional-aquatic-reflectance-product-guide