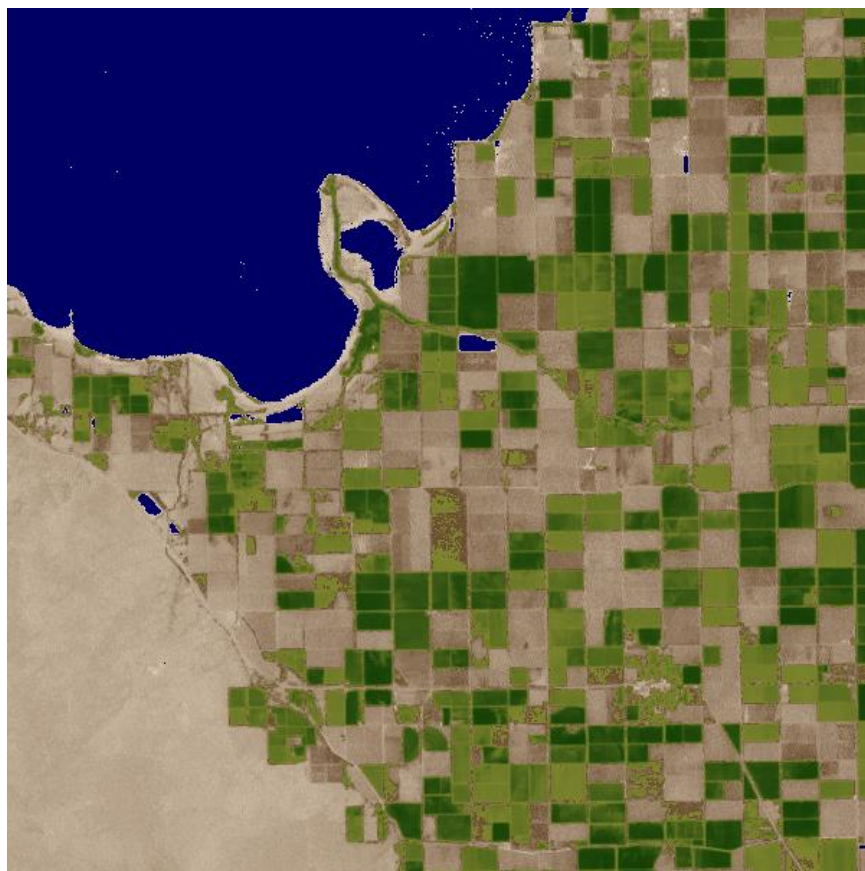Department of the Interior
U.S. Geological Survey

PRODUCT GUIDE

LANDSAT SURFACE REFLECTANCE-DERIVED SPECTRAL INDICES

Version 3.3

December 2016

Executive Summary

This document describes relevant characteristics of the Spectral Indices products derived from Landsat Surface Reflectance to facilitate use in the land remote sensing community.

Document History

Document Version	Publication Date	Change Description
Version 1.0	11/10/2013	Initial Draft
Version 1.1	12/01/2013	Revised after Peer Review
Version 1.2	12/17/2013	Corrected typographical error on page 15
Version 2.0	03/28/2014	Revised to accommodate new file format options
Version 2.1	07/24/2014	Updated ESPA product access and product packaging
Version 2.2	08/05/2014	Revised HDF file characteristics
Version 2.3	09/16/2014	Corrected typographical error in EVI equation.
Version 2.4	12/23/2014	Added Provisional Landsat 8 Surface Reflectance information (product guide references, SI equation updates.)
Version 2.5	03/06/2015	Updated default EarthExplorer file format output information. Replaced Appendix D Metadata Fields with example directly from XML metadata file.
Version 2.6	04/03/2015	Corrected typo in Landsat 8 Enhanced Vegetation Index (EVI) equation.
Version 2.7	6/26/2015	Updated URLS in Source Products and added L8SR comparison images. Revised Data Access.
Version 2.8	12/01/2015	Corrected minor typos and revised the formatting of citations. Added details pertaining to values >+1.0 or <-1.0 being set to 10000 and -10000, respectively. Updated "User Services" section with correct information. Updated "File Characteristics" appendix to be more accurate.
Version 2.9	03/01/2016	Fixed broken hyperlink to L8SR product guide. Updated Default File Characteristics (Appendix A).
Version 3.0	07/01/2016	Updated reference and links to Landsat 8 Surface Reflectance Code (LaSRC) algorithm product and product guide. Added unavailability notice of LaSRC products between 2016-050 and 2016-058 due to MODIS Terra safe mode.
Version 3.1	10/07/2016	Added NetCDF file format. Added unavailable data range for L4-7 SR products.
Version 3.2	12/07/2016	Replaced links to Landsat Missions Website
Version 3.3	12/13/2016	Corrected typographical error in EVI formula

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Section 1   Introduction

Landsat satellite data have been produced, archived, and distributed by the U.S. Geological Survey (USGS) since 1972. Users rely on these data for historical study of land surface change, but shoulder the burden of post-production processing to create applications-ready data sets. In compliance with guidelines established through the Global Climate Observing System, USGS has embarked on production of higher-level Landsat data products to support land surface change studies. One such product is Surface Reflectance, from which spectral indices can be derived to further the ease of user application in land remote sensing science.

USGS is currently offering these 30-meter (m) Landsat Surface Reflectance-derived spectral indices products for Landsat 4–5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS):

- 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)

This product guide describes the characteristics of each product, as well as data access and available user services.

Section 2   Caveats and Constraints

The spectral indices products are under the same constraints as the source Landsat Surface Reflectance products.

1. Spectral indices products are considered provisional.

2. The following date ranges apply to the availability of the Landsat archive for spectral indices processing, with the exceptions noted below.

    - Landsat 4 TM: July 1982 to December 1993
    - Landsat 5 TM: March 1984 to May 2012
    - Landsat 7 ETM+: April 1999 to within one week of present
    - Landsat 8 OLI/TIRS (LC8): March 2013 to within one week of present

3. Spectral indices can only be processed on day-lit scenes (descending node).

4. Landsat 4 TM scenes processed through the National Landsat Archive Processing System (NLAPS) cannot be used to generate spectral indices products. NLAPS scenes are formatted and calibrated differently than those processed through the standard Landsat Product Generation System (LPGS).

    - A list of known NLAPS scenes can be found online (https://landsat.usgs.gov/sites/default/files/documents/L4-5TM_NLAPS.xlsx).

    NLAPS-based scenes will be automatically removed from user orders. The order status will be updated with this action and the remaining scenes will continue processing.

5. Landsat 7 ETM+ scenes acquired on the day of the Scan Line Corrector (SLC) failure (May 31, 2003) cannot be used to generate spectral indices products. See https://landsat.usgs.gov/using-landsat-7-data for information on Landsat 7 SLC-off data products.

6. Landsat 7 ETM+ SLC-off inputs acquired after May 31, 2003 are not gap-filled in spectral indices production.

7. Landsat 4-7 Surface Reflectance (LEDAPS)-derived products cannot be generated for acquisitions between May 30, 2016 and June 12, 2016 due to missing ozone data.

8. Landsat 8 Surface Reflectance (LaSRC)-derived products cannot be generated for acquisitions between February 19, 2016 and February 27, 2016 due to MODIS Terra going into safe mode.

9. The Landsat 8 Surface Reflectance Code (LaSRC) products are considered provisional, therefore the Landsat Spectral Indices are also considered provisional.

10. Spectral indices cannot be processed for products not on the WRS-2 system.

11. Spectral indices products may have increased uncertainties, inherited from the Surface Reflectance source data, in areas where atmospheric correction is affected by adverse conditions, including:

- Hyper-arid or snow-covered regions

- Low sun angle conditions

- Coastal regions where land area is small relative to adjacent water

- Areas with extensive cloud contamination

12. SR is not run on scenes with a solar zenith angle greater than or equal to 76 degrees.

13. Users are cautioned against requesting spectral indices products for areas in high latitudes (> 65 degrees North or South).

14. Spectral indices products do not carry any quality information, however, saturated pixels are identified in the outputs. Surface Reflectance data products can be utilized to obtain quality information for the scene.

15. Any pixel values resulting in a spectral index less than/equal to -1 will be set to -10000, and a spectral index greater than/equal to +1 will be set to 10000 in the output product.

Section 3   Source Products

The spectral indices products are derived from Landsat 4-5 Thematic Mapper (TM), Landsat 7, and Landsat 8 Surface Reflectance data.

Landsat 4-7 Surface Reflectance data are generated from specialized software called Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS). LEDAPS was originally developed through a National Aeronautics and Space Administration (NASA) Making Earth System Data Records for Use in Research Environments (MEaSUREs) grant by NASA Goddard Space Flight Center (GSFC) and the University of Maryland (Masek et al., 2006). The software applies Moderate Resolution Imaging Spectroradiometer (MODIS) atmospheric correction routines to Level-1 Landsat TM or ETM+ data. Water vapor, ozone, geopotential height, aerosol optical thickness, and digital elevation are input with Landsat data to Second Simulation of a Satellite Signal in the Solar Spectrum (6S) radiative transfer models to generate Top of Atmosphere (TOA) Reflectance, Surface Reflectance, Brightness Temperature, and masks for clouds, cloud shadows, adjacent clouds, land, and water. The result is delivered as the Landsat 4-7 Surface Reflectance product, the characteristics of which are described in a separate product guide: https://landsat.usgs.gov/sites/default/files/documents/ledaps_product_guide.pdf.

The LEDAPS code is maintained by the USGS Earth Resources Observation and Science (EROS) Center as open source software and is available at https://github.com/USGS-EROS/espa-surface-reflectance/tree/master/ledaps. LEDAPS is implemented in the USGS EROS Science Processing Architecture (ESPA) as fundamental input to the development of higher level data products such as burned area, surface water extent, and snow covered area. Generation of many of these higher level data products requires further processing of Surface Reflectance to spectral indices.

Figure 3-1 *Example of LEDAPS atmospheric correction. Left, Top of Atmosphere (TOA) Reflectance composite (bands 3,2,1) for Landsat-7 ETM+ image of San Francisco Bay (July 7, 1999); Right, Surface Reflectance composite. Both images are linearly scaled from p = 0.0 to 0.15.*

Surface Reflectance for Landsat 8 is generated using the Landsat 8 Surface Reflectance Code (LaSRC) algorithm. LaSRC is distinctly different from the LEDAPS algorithm to process Landsat 4–5 and Landsat 7 Surface Reflectance data.

Details about LaSRC are described in its Product Guide:
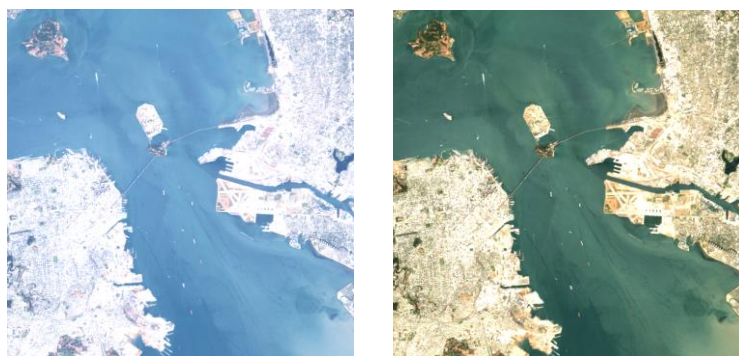https://landsat.usgs.gov/sites/default/files/documents/provisional_lasrc_product_guide.pdf.
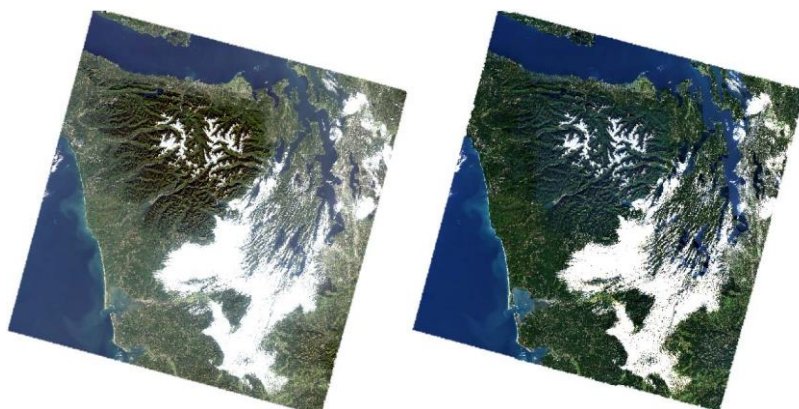
Figure 3-2: *Example of L8SR atmospheric correction. Left, Top of Atmosphere (TOA) Reflectance composite (bands 4,3,2) for Landsat 8 image of Northwest Washington State (October 14,2013); Right, Surface Reflectance composite.*

Section 4   Product Access

Landsat Spectral Indices can be requested on the USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface: https://espa.cr.usgs.gov.

Details about the ESPA On Demand Interface can be found in the ESPA On-Demand Interface User Guide:
https://landsat.usgs.gov/sites/default/files/documents/espa_odi_userguide.pdf.

Section 5   Product Packaging

Surface Reflectance data acquired from EarthExplorer will are supplied in a gzip file (".tar.gz"). Unzipping this file produces a tarball (".tar"), and then will untar to a GeoTIFF (".tif") file. Each GeoTIFF filename has the suffix "_sr_" after the sceneID to denote the Surface Reflectance transformation.

Files acquired from ESPA will are supplied in a gzip file (".tar.gz"). Unzipping this file produces a tarball (".tar"), and then will untar to GeoTIFF (".tif") (default), HDF-EOS2 (".hdf"), NetCDF (".nc") or ENVI binary (".img") files. The naming convention used in these products builds on the filenames of the Landsat original input scenes. An example breaking down the components of a typical file is:

> **LXXPPPRRRYYYYDDDSTNVR_prod_band.ext**
> (e.g., LE70390372008210MOR00_sr_band1.tif)
>
> LCX   LC8 for Landsat 8 Operational Land Imager/Thermal Infrared Sensor
> LEX   LE7 for Landsat 7 Enhanced Thematic Mapper Plus
> LTX   LT4 for Landsat 4 Thematic Mapper; LT5 for Landsat 5 Thematic Mapper
> PPP   Path
> RRR   Row
> YYYY Year of Acquisition
> DDD   Julian Date of Acquisition
> STN   Receiving Station
> VR   Version Number
> prod   Product, such as "level1," "toa," or "sr"
> band   Band, such as "band<1-7>," "qa," or spectral index.
> ext   File format extension, such as "tif," "tfw," "xml," "hdf," "hdr," "nc," or "img"

Section 6　Product Characteristics

6.1　Vegetation Indices (VI)

The vegetation indices options include NDVI, EVI, SAVI, and MSAVI. Products are generated at 30-m spatial resolution on a Universal Transverse Mercator (UTM) or Polar Stereographic (PS) mapping grid. The default file format is GeoTIFF, but options for delivery in Hierarchical Data Format (HDF) and binary are available through the ESPA Ordering Interface. Likewise, processing services can be requested such as reprojection and spatial sub-setting.   Temporal coverage varies depending on the selected sensor, with the exceptions noted in Section 2 Caveats and Constraints.

6.1.1　Normalized Difference Vegetation Index (NDVI)

NDVI is calculated as a ratio between the red (R) and near infrared (NIR) values in traditional fashion.

(NIR - R) / (NIR + R)

In Landsat 4-7,
NDVI = (Band 4 – Band 3) / (Band 4 + Band 3).

In Landsat 8,
NDVI = (Band 5 – Band 4) / (Band 5 + Band 4).

NDVI is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-1 NDVI Specifications

Attribute	Value
Long Name	Normalized Difference Vegetation Index
Short Name	LC8NDVI, LE7NDVI, LT5NDVI, or LT4NDVI
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

6.1.2　Enhanced Vegetation Index (EVI)

EVI incorporates an "L" value to adjust for canopy background, "C" values as coefficients for atmospheric resistance, and values from the blue band (B). These enhancements allow for index calculation as a ratio between the R and NIR values, while reducing the background noise, atmospheric noise, and saturation in most cases.

EVI = G * ((NIR - R) / (NIR + C1 * R – C2 * B + L))

In Landsat 4-7,
EVI = 2.5 * ((Band 4 – Band 3) / (Band 4 + 6 * Band 3 – 7.5 * Band 1 + 1)).

In Landsat 8,
EVI = 2.5 * ((Band 5 – Band 4) / (Band 5 + 6 * Band 4 – 7.5 * Band 2 + 1)).

EVI is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-2 EVI Specifications

Attribute	Value
Long Name	Enhanced Vegetation Index
Short Name	LC8EVI, LE7EVI, LT5EVI, or LT4EVI
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

6.1.3 Soil Adjusted Vegetation Index (SAVI)

SAVI is calculated as a ratio between the R and NIR values with a soil brightness correction factor (L) defined as 0.5 to accommodate most land cover types.

((NIR - R) / (NIR + R + L)) * (1 + L)

In Landsat 4-7,
SAVI = ((Band 4 – Band 3) / (Band 4 + Band 3 + 0.5)) * (1.5).

In Landsat 8,
SAVI = ((Band 5 – Band 4) / (Band 5 + Band 4 + 0.5)) * (1.5).

SAVI is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-3 SAVI Specifications

Attribute	Value
Long Name	Soil Adjusted Vegetation Index
Short Name	LC8SAVI, LE7SAVI, LT5SAVI, or LT4SAVI
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

6.1.4 Modified Soil Adjusted Vegetation Index (MSAVI)

MSAVI is calculated as a ratio between the R and NIR values with an inductive L function applied to maximize reduction of soil effects on the vegetation signal.

$(2 * NIR + 1 - sqrt ((2 * NIR + 1)^2 - 8 * (NIR - R))) / 2$

In Landsat 4-7,
MSAVI = $(2 * Band 4 + 1 - sqrt ((2 * Band 4 + 1)^2 - 8 * (Band 4 - Band 3))) / 2$.

In Landsat 8,
MSAVI = $(2 * Band 5 + 1 - sqrt ((2 * Band 5 + 1)^2 - 8 * (Band 5 - Band 4))) / 2$.

MSAVI is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-4 MSAVI Specifications

Attribute	Value
Long Name	Modified Soil Adjusted Vegetation Index
Short Name	LC8MSAVI, LE7MSAVI, LT5MSAVI, or LT4MSAVI
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

6.2 Normalized Difference Moisture Index (NDMI)

NDMI is calculated as a ratio between the NIR and SWIR values in traditional fashion.

(NIR - SWIR) / (NIR + SWIR)

In Landsat 4-7,
NDMI = (Band 4 – Band 5) / (Band 4 + Band 5).

In Landsat 8,
NDMI = (Band 5 – Band 6) / (Band 5 + Band 6).

NDMI is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-5 NDMI Specifications

Attribute	Value
Long Name	Normalized Difference Moisture Index
Short Name	LC8NDMI, LE7NDMI, LT5NDMI, or LT4NDMI
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

6.3   Normalized Burn Ratio (NBR)

NBR is calculated as a ratio between the NIR and SWIR values in traditional fashion.

(NIR - SWIR) / (NIR + SWIR)

In Landsat 4-7,
NBR = (Band 4 – Band 7) / (Band 4 + Band 7).

In Landsat 8,
NBR = (Band 5 – Band 7) / (Band 5 + Band 7).

NBR is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-6 NBR Specifications

Attribute	Value
Long Name	Normalized Burn Ratio
Short Name	LC8NBR, LE7NBR, LT5NBR, or LT4NBR
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

6.4   Normalized Burn Ratio 2 (NBR2)

NBR2 is calculated as a ratio between the SWIR values, substituting the SWIR1 band for the NIR band used in NBR to highlight sensitivity to water in vegetation.

(SWIR1 – SWIR2) / (SWIR1 + SWIR2)

In Landsat 4-7,
NBR2 = (Band 5 – Band 7) / (Band 5 + Band 7).

In Landsat 8,
NBR2 = (Band 6 – Band 7) / (Band 6 + Band 7).

NBR2 is a single band product specified as shown in the table below. A full listing of all associated metadata fields is found in Appendix D.

Table 6-7 NBR2 Specifications

Attribute	Value
Long Name	Normalized Burn Ratio 2
Short Name	LC8NBR2, LE7NBR2, LT5NBR2, or LT4NBR2
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 – 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

Section 7   Citation Information

There are no restrictions on the use of these high-level Landsat products. It is not a requirement of data use, but please include the following citation in publication or presentation materials based on these products to acknowledge the USGS as a data source, and to credit the original research.

Landsat Spectral Indices products courtesy of the U.S. Geological Survey Earth Resources Observation and Science Center.

Masek, J.G., Vermote, E.F., Saleous, N., Wolfe, R., Hall, F.G., Huemmrich, F., Gao, F., Kutler, J., and Lim, T.K. (2006). A Landsat surface reflectance data set for North America, 1990-100, IEEE Geoscience and Remote Sensing Letters. 3:68-72.

Reprints or citations of papers or oral presentations based on USGS data are welcome at the User Services addresses included in this guide. Such cooperation will help USGS stay informed of how the data are being used.

Section 8   Acknowledgments

Section 9   User Services

Landsat high-level products and associated interfaces are supported by User Services staff at USGS EROS. Any questions or comments regarding data products or interfaces are welcomed through the Landsat "Contact Us" online correspondence form: https://landsat.usgs.gov/contact.   E-mail can also be sent to the customer service address included below, with the same indication of topic.

USGS User Services
https://landsat.usgs.gov/contact
custserv@usgs.gov

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

Section 10 References

Chander, G., Markham, B.L., and Helder, D.L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sensing of Environment 113:893-903.http://dx.doi.org/10.1016/j.rse.2009.01.007.

Claverie, M., Vermote, E. F., Franch, B., and Masek, J. G. (2015). Evaluation of the Landsat-5 TM and Landsat-7 ETM+ surface reflectance products. Remote Sensing of Environment 169:390-403. http://dx.doi.org/10.1016/j.rse.2015.08.030.

Jones, J. W., Starbuck, M. J., and Jenkerson, C. B. (2013). Landsat surface reflectance quality assurance extraction (version 1.7) (No. 11-C7). US Geological Survey. http://pubs.usgs.gov/tm/11/c07/pdf/tm11-c7.pdf.

Ju, J., Roy, D. P., Vermote, E., Masek, J., and Kovalskyy, V. (2012). Continental-scale validation of MODIS-based and LEDAPS Landsat ETM+ atmospheric correction methods. Remote Sensing of Environment 122:175-184. http://dx.doi.org/10.1016/j.rse.2011.12.025.

Maiersperger, T., Scaramuzza, P., Leigh, L., Shrestha, S., Gallo, K., Jenkerson, C., and Dwyer, J. (2013). Characterizing LEDAPS surface reflectance products by comparisons with AERONET, field spectrometer, and MODIS data. Remote Sensing of Environment 136:1-13. http://dx.doi.org/10.1016/j.rse.2013.04.007.

Masek, J.G., Huang, C., Wolfe, R., Cohen, W., Hall, F., Kutler, J., and Nelson, P. (2008). North American forest disturbance mapped from a decadal Landsat record. Remote Sensing of Environment 112:2914-2926. http://dx.doi.org/10.1016/j.rse.2008.02.010.

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

Schmidt, G.L., Jenkerson, C.B., Masek, J., Vermote, E., and Gao, F. (2013). Landsat ecosystem disturbance adaptive processing system (LEDAPS) algorithm description: U.S. Geological Survey Open-File Report 2013–1057, 17 p.

Vermote, E. F., and Kotchenova, S. (2008). Atmospheric correction for the monitoring of land surfaces. Journal of Geophysical Research: Atmospheres (1984–2012) 113(D23). http://dx.doi.org/10.1029/2007JD009662.

Vermote, E.F., El Saleous, N., Justice, C.O., Kaufman, Y.J., Privette, J.L., Remer, L., Roger, J.C., and Tanre, D. (1997). Atmospheric correction of visible to middle-infrared EOS-MODIS data over land surfaces: Background, operational algorithm, and validation. Journal of Geophysical Research 102:17131-17141.

Vermote, E.F., Tanre, D., Deuze, J.L., Herman, M., and Morcrette, J.J. (1997). Second simulation of the satellite signal in the solar spectrum, 6S: An overview. IEEE Transactions on Geoscience and Remote Sensing 35:675-686. http://dx.doi.org/10.1109/36.581987.

Zhu, Z. and Woodcock, C. E. (2012). Object-based cloud and cloud shadow detection in Landsat imagery, Remote Sensing of Environment 118:83-94. http://dx.doi.org/10.1016/j.rse.2011.10.028.

Appendix A Default File Characteristics

Table 11-1 Default File Characteristics

EVI enhanced vegetation index, MSAVI modified soil adjusted vegetation index, NBR normalized burn ratio, NBR2 normalized burn ratio 2, NDMI normalized difference moisture index, NDVI normalized difference vegetation index, SAVI soil adjusted vegetation index

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

Description	Example File Size (bytes)	Example File Name
EVI data file	119,336,079	LE70230282011250EDC00_sr_evi.tif
MSAVI data file	119,336,079	LE70230282011250EDC00_sr_msavi.tif
NBR data file	119,336,079	LE70230282011250EDC00_sr_nbr.tif
NBR2 data file	119,336,079	LE70230282011250EDC00_sr_nbr2.tif
NDMI data file	119,336,079	LE70230282011250EDC00_sr_ndmi.tif
NDVI data file	119,336,079	LE70230282011250EDC00_sr_ndvi.tif
SAVI data file	119,336,079	LE70230282011250EDC00_sr_savi.tif
Metadata	25,556	LE70230282011250EDC00.xml

Appendix B HDF File Characteristics

Table 12-1 Default File Characteristics

EVI enhanced vegetation index, MSAVI modified soil adjusted vegetation index, NA not applicable, NBR normalized burn ratio, NBR2 normalized burn ratio 2, NDMI normalized difference moisture index, NDVI normalized difference vegetation index, SAVI soil adjusted vegetation index

NOTE: A Landsat 5 TM sceneID 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 within an HDF file because each band is stored as an external SDS.

Description	Example File Size (bytes)	Example File Name	Science Data Sets
Spectral Indices data file	20,239	LT50180341985263XXX04.hdf	• SDS1 ndvi • SDS2 evi • SDS3 ndmi • SDS4 savi • SDS5 msavi • SDS6 nbr • SDS7 nbr2
Spectral Indices Bands (7)	112,857,082	LT50180341985263XXX04_sr_*_hdf.img	NA
Spectral Indices Bands header file	555	LT50180341985263XXX04.hdf.hdr	NA
Spectral Indices Metadata file (1)	6,699	LT50180341985263XXX04.xml	NA

Appendix C Binary File Characteristics

Table 13-1 Binary File Characteristics

EVI enhanced vegetation index, MSAVI modified soil adjusted vegetation index, NBR normalized burn ratio, NBR2 normalized burn ratio 2, NDMI normalized difference moisture index, SAVI soil adjusted vegetation index

NOTE: A Landsat 4 TM sceneID 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
EVI Band	112,857,082	LT40230281982346XXX04_sr_evi.img
EVI data header file	350	LT40230281982346XXX04_sr_evi.hdr
MSAVI Band	112,857,082	LT40230281982346XXX04_sr_msavi.img
MSAVI data header file	364	LT40230281982346XXX04_sr_msavi.hdr
NBR Band	112,857,082	LT40230281982346XXX04_sr_nbr.img
NBR data header file	346	LT40230281982346XXX04_sr_nbr.hdr
NBR2 Band	112,857,082	LT40230281982346XXX04_sr_nbr2.img
NBR2 Band header file	348	LT40230281982346XXX04_sr_nbr2.hdr
NDMI Band	112,857,082	LT40230281982346XXX04_sr_ndmi.img
NDMI Band header file	361	LT40230281982346XXX04_sr_ndmi.hdr
NDVI Band	112,857,082	LT40230281982346XXX04_sr_ndvi.img
NDVI Band header file	363	LT40230281982346XXX04_sr_ndvi.hdr
SAVI Band	112,857,082	LT40230281982346XXX04_sr_savi.img
SAVI Band header file	355	LT40230281982346XXX04_sr_savi.hdr
Metadata	30,828	LT40230281982346XXX04.xml

Appendix D Metadata Fields

Example of global XML metadata:

```
<global_metadata>
     <data_provider>USGS/EROS</data_provider>
     <satellite>LANDSAT_8</satellite>
     <instrument>OLI_TIRS</instrument>
     <acquisition_date>2013-06-28</acquisition_date>
     <scene_center_time>18:40:39.8204854Z</scene_center_time>
     <level1_production_date>2014-11-13T15:01:34Z</level1_production_date>
     <solar_angles zenith="24.733788" azimuth="131.660614" units="degrees"/>
     <wrs system="2" path="43" row="31"/>
     <lpgs_metadata_file>LC80430312013179LGN00_MTL.txt</lpgs_metadata_file>
     <corner location="UL" latitude="42.801350" longitude="-120.700400"/>
     <corner location="LR" latitude="40.691440" longitude="-117.783500"/>
     <bounding_coordinates>
        <west>-120.700594</west>
        <east>-117.783319</east>
        <north>42.858456</north>
        <south>40.638480</south>
     </bounding_coordinates>
     <projection_information projection="UTM" datum="WGS84" units="meters">
        <corner_point location="UL" x="197400.000000" y="4745400.000000"/>
        <corner_point location="LR" x="433800.000000" y="4504800.000000"/>
        <grid_origin>CENTER</grid_origin>
        <utm_proj_params>
           <zone_code>11</zone_code>
        </utm_proj_params>
     </projection_information>
     <orientation_angle>0.000000</orientation_angle>
   </global_metadata>
```

Example of per-band XML metadata:
```
<band scale_factor="0.000100" fill_value="-9999" nsamps="7681" nlines="7811" data_type="INT16"
category="index" name="sr_ndvi" product="spectral_indices" source="sr_refl" saturate_value="20000">
<short_name>LC8SR_NDVI</short_name>
        <long_name>normalized difference vegetation index</long_name>
        <file_name> LC80430312013179LGN00_sr_ndvi.tif</file_name>
        <pixel_size units="meters" y="30" x="30"/>
        <resample_method>none</resample_method>
        <data_units>band ratio index value</data_units>
        <valid_range max="10000" min="-10000"/>
        <app_version>spectral_indices_2.0.1</app_version>
        <production_date>2015-02-27T15:52:32Z</production_date>
</band>
```

Appendix E Acronyms

Acronym	Description
6S	Second Simulation of a Satellite Signal in the Solar Spectrum
CDR	Climate Data Record
DDV	Dark Dense Vegetation
DIR	Directory
DOI	Department of the Interior
ECV	Essential Climate Variable
ENVI	Exelis Visual Information Solutions
EROS	Earth Resources Observation and Science
ESPA	EROS Science Processing Architecture
ETM+	Enhanced Thematic Mapper Plus
EVI	Enhanced Vegetation Index
GCOS	Global Climate Observing System
GeoTIFF	Geographic Tagged Image File Format
GSFC	Goddard Space Flight Center
HDF-EOS2	Hierarchical Data Format – Earth Observing System (version 2)
HDR	Header
INT	Signed Integer
LaSRC	Landsat Surface Reflectance Code
LDOPE	Land Data Operational Product Evaluation
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LPGS	Landsat Product Generation System
LSB	Least Significant Bit
MATLAB	Matrix Laboratory
m	meter
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MODIS	Moderate Resolution Imaging Spectroradiometer
MSAVI	Modified Soil Adjusted Vegetation Index
MSB	Most Significant Bit
NA	Not Applicable
NASA	National Aeronautic and Space Administration
NBR	Normalized Burn Ratio
NBR2	Normalized Burn Ratio 2
NC	NetCDF File Format
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index
NLAPS	National Landsat Archive Processing System
OLI	Operational Land Imager
PS	Polar Stereographic
QA	Quality Assurance
SAVI	Soil Adjusted Vegetation Index

sceneID	Scene Identifier
SLC	Scan Line Corrector
SR	Surface Reflectance
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TOA	Top of Atmosphere
UINT	Unsigned Integer
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
xml	Extensible Markup Language