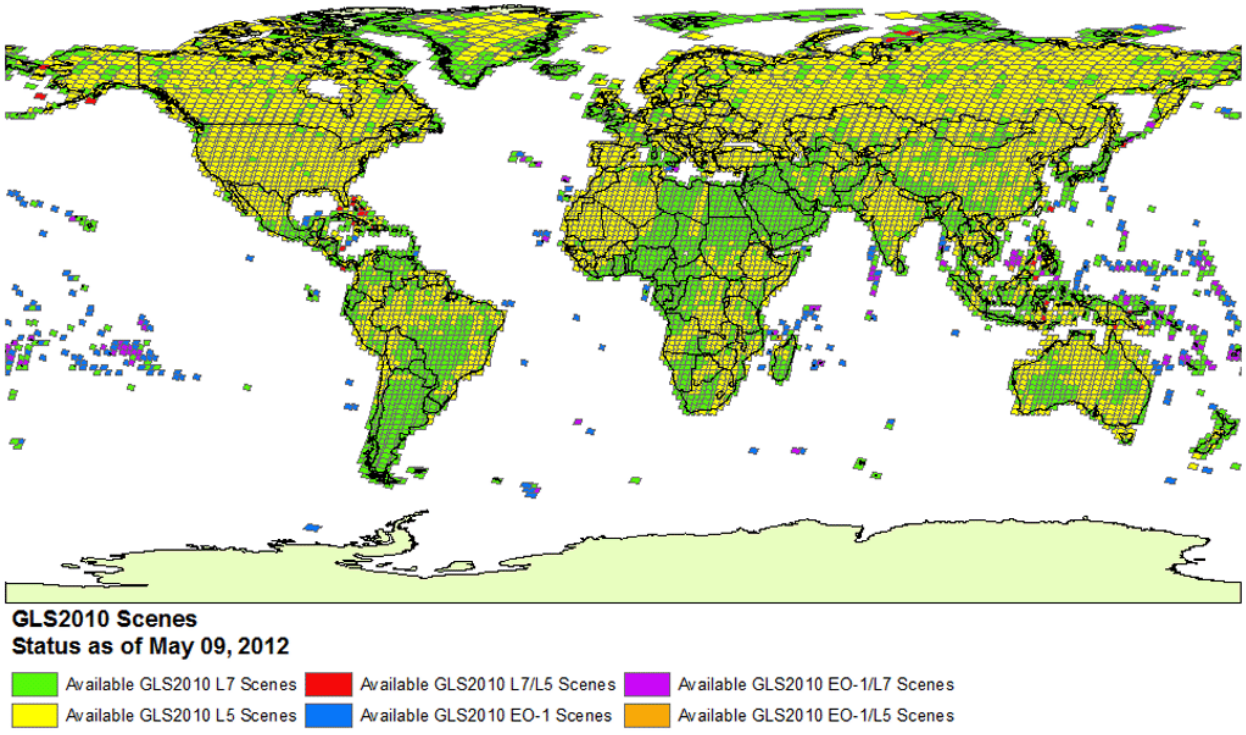
Department of the Interior
U.S. Geological Survey

PRODUCT GUIDE

LANDSAT CLIMATE DATA RECORD (CDR) SURFACE REFLECTANCE AND NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) DERIVED FROM GLOBAL LAND SURVEY (GLS) COLLECTIONS



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Executive Summary

This document describes relevant characteristics of the Landsat Surface Reflectance Climate Data Records and normalized difference vegetation index products derived from the Global Land Survey collections to facilitate use in the land remote sensing community.

Document History

Document Version	Publication Date	Change Description
Version 1.0	01/03/2013	Initial Draft based on Landsat CDR Surface Reflectance Product Guide v. 1.5
Version1.1		Revision after Peer Review
Version1.2		
Version 1.3		
Version 1.4		
Version 1.5		

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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 (GCOS), USGS has embarked on production of higher-level Landsat data products to support land surface change study. Terrestrial variables such as surface reflectance and land surface temperature will be offered as Climate Data Records (CDR). Leaf area index, burned area extent, snow covered area, and surface water extent will represent Essential Climate Variables (ECV). These CDRs and ECVs will offer a framework for producing long-term Landsat data sets suited for monitoring, characterizing and understanding land surface change over time.

The surface reflectance CDR is 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 Thematic Mapper (TM) or Enhanced Thematic Mapper Plus (ETM+) data. Water vapor, ozone, geopotential height, aerosol optical thickness, and digital elevation are input with Landsat data to the 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 surface reflectance CDR.

To demonstrate the utility of this product and to provide a frame of reference, the Global Land Survey (GLS) collections were targeted for surface reflectance processing. The Landsat surface reflectance CDR has been generated for the GLS collections from 2000, 2005 and 2010, and made publicly available as provisional data sets through the USGS EarthExplorer. The delivered data package also includes a normalized difference vegetation difference (NDVI) image calculated from the standard ratio between red and near-infrared bands.

Section 2 Caveats and Constraints

1. The Landsat surface reflectance CDR products are considered provisional.
2. Efficacy of the correction is likely to be reduced in:
   - 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.
3. Users are strongly cautioned against correcting data acquired over high latitudes (> 65 degrees North or South).
4. Refer to the quality assurance (QA) layers for pixel-level condition and validity flags.

Section 3 Product Package

The GLS surface reflectance and NDVI products are distributed in compressed file packages which include several data layers in Hierarchical Data Format for Earth Observing System (HDF-EOS). The characteristics of each file package vary slightly depending on whether the GLS scene was derived from Landsat 7 or Landsat 5 inputs.

3.1 Landsat 7

GLS surface reflectance and NDVI collections include Landsat 7 scenes acquired before and after the Scan Line Corrector (SLC) failure (SLC-On and SLC-Off). File details are given below.

3.1.1 Naming Convention

Landsat 7-based GLS products build on the naming convention of the source scenes. An example breaking down the components of a typical file package is:

LE71450312004238PFS01-sr.tar.gz

LE7	Landsat 7 Enhanced Thematic Mapper Plus
145	Path 145
031	Row 31
2004	Year of Acquisition
238	Julian Date of Acquisition (August 25)
PFS	Received at the Poker Flats, Alaska International Ground Station
01	Version
-sr	Surface Reflectance
tar	Tar-based file compression
gz	g-zip file compression

3.1.2 Contents

The zipped and tarred file package has to be decompressed in two steps to extract the data files. Following the example given above,

unzip to file: LE71450312004238PFS01-sr.tar
untar to file: LE71450312004238PFS01-sr
open directory: LE71450312004238PFS01

The unzipped directory will contain two subdirectories, the HDF data files, the metadata file from the source Landsat scene, and text files used in surface reflectance production. An example of the final directory content for a GLS surface reflectance and NDVI package is shown below.

```
<DIR>             gap_mask
<DIR>             ndvi
933               LE71450312004238PFS01.metadata.txt
639,141           LE71450312004238PFS01_MTL.txt
728,758,018       lndcal.LE71450312004238PFS01.hdf
332               lndcal.LE71450312004238PFS01.hdf.hdr
231               lndcal.LE71450312004238PFS01.txt
1,009,166,745     lndsr.LE71450312004238PFS01.hdf
332               lndsr.LE71450312004238PFS01.hdf.hdr
423               lndsr.LE71450312004238PFS01.txt
```

The files of primary interest have names starting with “lndsr” and deliver surface reflectance data. The “lndsr.*.hdf” includes reflectance data layers for Landsat bands 1, 2, 3, 4, 5, and 7, band 6 temperature, atmospheric optical thickness, and quality assurance. The “lndsr.*.hdr” contains Exelis Visual Information Solutions (ENVI) header information, and the “lndsr.*.txt” is a small file with production input information.

The “ndvi” directory contains an NDVI image derived from the associated surface reflectance data. The NDVI is delivered in georeferenced tagged image file format (GeoTIFF).

All files prepended with “lndcal” are related to TOA reflectance. The “lndcal.*.hdf” contains TOA reflectance and quality information for Landsat bands 1, 2, 3, 4, 5, and 7. The associated “hdr” and “txt” files include the same kind of information as described for surface reflectance, but it is specific to TOA processing.

The “gap_mask” directory holds nine zipped files, each representing SLC gap information for the Landsat 7 bands 1, 2, 3, 4, 5, 6-1, 6-2, 7, and 8. Please note that though gap information is provided for Band 8, neither the surface reflectance nor TOA products include Band 8 values.

The “metadata.txt” file contains select metadata information from the source scene formatted for use in production. Full metadata from the originating Landsat scene is delivered in “MTL.txt.”

3.2 Landsat 5

Landsat 5 TM scenes are also used to generate GLS surface reflectance and NDVI products. File details are similar to those for Landsat 7, as described below.

3.2.1 Naming Convention

Landsat 5-based products build on the naming convention of the source scenes. An example breaking down the components of a typical file package is:

LT51480302007211IKR00-sr.tar.gz

LT5	Landsat 5 Thematic Mapper
148	Path 148
03	Row 30
2007	Year of Acquisition

211 Julian Date of Acquisition (August 30)
IKR Received at the Irkutsk, Russia International Ground Station
00 Version
-sr Surface Reflectance
tar Tar-based file compression
gz g-zip file compression

3.2.2 Contents

The zipped and tarred file package has to be decompressed in two steps to extract the data files. Following the example given above,

unzip to file: LT51480302007211IKR00-sr.tar

untar to file: LT51480302007211IKR00-sr

open directory: LT51480302007211IKR00

The unzipped directory from a Landsat 5-derived scene will contain only one subdirectory, but the HDF data files, the metadata file from the source Landsat scene, and text files produced to support surface reflectance are basically identical to those for Landsat 7. An example of the final directory content for a GLS surface reflectance and NDVI package derived from Landsat 5 is shown below.

```
<DIR>           ndvi
924             LT51480302007211IKR00.metadata.txt
1,252           LT51480302007211IKR00_MTL.txt
810,489,404     lndcal.LT51480302007211IKR00.hdf
332             lndcal.LT51480302007211IKR00.hdf.hdr
380             lndcal.LT51480302007211IKR00.txt
1,122,333,275   lndsr.LT51480302007211IKR00.hdf
332             lndsr.LT51480302007211IKR00.hdf.hdr
419             lndsr.LT51480302007211IKR00.txt
```

Section 4 Product Characteristics

4.1 Basic Characteristics

Basic product characteristics are shared by the surface reflectance (lndsr), TOA reflectance (lndcal), and NDVI (ndvi) components delivered in the GLS packages. File sizes vary according to the scene of interest.

Table 4-1 Basic Product Characteristics

GLS Global Land Survey, HDF-EOS Hierarchical Data Format 4 for Earth Observing Systems, m meter, UTM Universal Transverse Mercator

Characteristic	Definition
Projection	UTM
Format	HDF-EOS
Pixel Size	30-m
Temporal Coverage GLS 2000	June 29, 1999 – December 8, 2002
Temporal Coverage GLS 2005	July 19, 2003 – July 30, 2008
Temporal Coverage GLS 2010	November 23, 2008 – January 30, 2012

Each component has unique specifications pertaining to the geophysical derivation it represents. The following tables detail the Science Data Sets (SDSs) in the surface reflectance, TOA reflectance, and brightness temperature HDF-EOS files, and the characteristics of the NDVI GeoTIFF. An additional table (*Table 4-4*) is included to provide a legend for the bit mapped QA SDS in TOA reflectance temperature files. Surface reflectance QA information is delivered in separate SDSs within “lndsr.”

4.2 Surface Reflectance Specifications

The surface reflectance SDSs are defined very much as MODIS, with the notable exception that the QA is delivered in separate, condition-specific SDSs rather than as a single bit-packed layer as was present in previous versions. Table 2 lists the specifications for the 16 SDSs.

Regarding the the “fill_QA” SDS, a pixel is set to 255 (fill) if any of the reflectance bands holds a fill value for that pixel. There is a separate “fill_QA” layer specific to Band 6.

By default, LEDAPS selects the low gain thermal band (Band 6-1) when processing ETM+ data. The specific thermal band used for processing is specified in the “*metadata.txt” and the source MTL for reference.

Table 4-2 Surface Reflectance Specifications

DDV dark dense vegetation, INT16 16-bit signed integer, NA not applicable, QA quality assurance, SDS Science Data Set, UINT8 8-bit unsigned integer

SDS Order	SDS Name	Data Type	Units	Range	Fill Value	Saturate Value	Scale Factor	Calibrated NT
1	Band 1 Reflectance	INT16	Reflectance	-2000 - 16000	-9999	20000	0.0001	5.5
2	Band 2 Reflectance	INT16	Reflectance	-2000 - 16000	-9999	20000	0.0001	5.5
3	Band 3 Reflectance	INT16	Reflectance	-2000 - 16000	-9999	20000	0.0001	5.5
4	Band 4 Reflectance	INT16	Reflectance	-2000 - 16000	-9999	20000	0.0001	5.5
5	Band 5 Reflectance	INT16	Reflectance	-2000 - 16000	-9999	20000	0.0001	5.5
6	Band 7 Reflectance	INT16	Reflectance	-2000 - 16000	-9999	20000	0.0001	5.5
7	Atmospheric Opacity	INT16	Reflectance	-2000 - 16000	-9999	NA	0.0010	NA
8	Fill QA	UINT8	Flag	0 not fill 255 fill	NA	NA	NA	NA
9	DDV QA	UINT8	Flag	0 clear 255 DDV	NA	NA	NA	NA
10	Cloud QA	UINT8	Flag	0 clear 255 cloud	NA	NA	NA	NA
11	Cloud Shadow QA	UINT8	Flag	0 clear 255 cloud shadow	NA	NA	NA	NA
12	Snow QA	UINT8	Flag	0 clear 255 snow	NA	NA	NA	NA
13	Land Water QA	UINT8	Flag	0 land 255 water	NA	NA	NA	NA
14	Adjacent Cloud QA	UINT8	Flag	0 clear 255 adjacent cloud	NA	NA	NA	NA
15	Band 6 Temperature	INT16	Celsius	-7000 – 7000	-9999	NA	0.0100	NA
16	Band 6 Fill QA	UINT8	Flag	0 not fill 255 fill	NA	NA	NA	NA

4.3 Top of Atmosphere Reflectance Specifications

Calibration is applied to Landsat digital numbers to derive the TOA reflectance component in these products. Specifications for TOA SDSs are similar to those for surface reflectance, but with a higher minimum value. Table 3 lists the data type, units, value range, fill value, saturation value, scale factor, and calibrated NT for the 7 TOA reflectance SDSs.

Table 4-3 Top of Atmosphere Reflectance Specifications

INT16 16-bit signed integer, lndcal Landsat TOA Reflectance, NA not applicable, QA quality assurance, SDS Science Data Set, TOA top of atmosphere, UINT8 8-bit unsigned integer

SDS Order	SDS Name	Data Type	Units	Range	Fill Value	Saturate Value	Scale Factor	Calibrated NT
0	Band 1 Reflectance	INT16	Reflectance	-100 - 16000	-9999	20000	0.0001	5.0
1	Band 2 Reflectance	INT16	Reflectance	-100 - 16000	-9999	20000	0.0001	5.0
2	Band 3 Reflectance	INT16	Reflectance	-100 - 16000	-9999	20000	0.0001	5.0
3	Band 4 Reflectance	INT16	Reflectance	-100 - 16000	-9999	20000	0.0001	5.0
4	Band 5 Reflectance	INT16	Reflectance	-100 - 16000	-9999	20000	0.0001	5.0
5	Band 7 Reflectance	INT16	Reflectance	-100 - 16000	-9999	20000	0.0001	5.0
6	lndcal QA	UINT8	Bit Index	0 - 255	1	NA	NA	NA

TOA reflectance uses a generic 8-bit QA derivation to simply express the saturation state of all input bands.

Table 4-4 Top of Atmosphere Reflectance QA Bit Map Index

LSB least significant bit, MSB most significant bit, QA quality assurance

QA Bit	Description
Bits are numbered from right to left (bit 0 = LSB, bit 7 = MSB)	
0	Data Fill Flag (0 valid data, 1 invalid data)
1	Band 1 Data Saturation Flag (0 valid data, 1 saturated data)
2	Band 2 Data Saturation Flag (0 valid data, 1 saturated data)
3	Band 3 Data Saturation Flag (0 valid data, 1 saturated data)
4	Band 4 Data Saturation Flag (0 valid data, 1 saturated data)
5	Band 5 Data Saturation Flag (0 valid data, 1 saturated data)
6	Band 6 Data Saturation Flag (not set)
7	Band 7 Data Saturation Flag (0 valid data, 1 saturated data)

4.4 NDVI Specifications

The NDVI delivered with reflectance data for GLS collections is calculated using the standard ratio between Landsat Bands 3 and 4 (red and near-infrared). The table below shows the general characteristics of the resulting image.

Table 4-5 NDVI Specifications

NDVI normalized difference vegetation index, UINT unsigned integer

Parameter	Data Type	Units	Range	Fill Value	Scale Factor
NDVI	UINT16	NDVI	0 – 10000	0	0.0001

Section 5 Product Manipulation

The format of the surface reflectance component in the GLS product packages (HDF-EOS) facilitates the derivation and delivery of key parameters in the product. However, it may not facilitate ready application of the products. Tools are available to assist users with visualization and basic processing services such as format conversion, data extraction, and reprojection.

5.1 Visualization

Any software packages capable of reading HDF-EOS will be able to open the GLS surface reflectance products and display them to users. MODIS users will notice familiar discrepancies between the functionality of one or the others, but all HDF-capable software can be expected to nominally display an SDS and its attributes.

The following image processing software suites are known to provide visualization for GLS surface reflectance products. This list does not include all possible solutions. Although these software programs have been used by USGS, no warranty, expressed or implied, is made by the USGS or the U.S. Government as to the accuracy and functioning of the program and related program material nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the USGS in connection therewith.

Table 5-1 Visualization Tools

*Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Any usability questions relating to software packages are to be directed to the software vendor.

Software	Domain	Access
HDFView	Public	http://www.hdfgroup.org/hdf-java-html/hdfview/
ENVI ®	Private	http://www.exelisvis.com/language/en-us/productsservices/envi.aspx
ERDAS Imagine ®	Private	http://geospatial.intergraph.com/products/ERDASIMAGINE/ERDASIMAGINE/Details.aspx

5.2 Basic Processing Services

Data manipulation tools that function with MODIS products are likely to work with GLS surface reflectance as well. The public domain tools listed below are suggested for format conversion, SDS extraction, QA bit extraction (for TOA saturation values only, Jones, J., et al., 2012), and reprojection. The Landsat-Land Data Operational Product Evaluation (L-LDOPE) Toolbelt is, in fact, a subset of the MODIS LDOPE Toolbox, and is available with other surface reflectance tools at http://landsat.usgs.gov/cdrtools.php.

Table 5-2 Manipulation Tools

HDF Hierarchical Data Format, HEG HDF to GeoTIFF, GeoTIFF Geospatial Tagged Image File Format MODIS Moderate Resolution Imaging Spectroradiometer, MRT MODIS Reprojection Tool, LDOPE Land Data Operational Product Evaluation, L-LDOPE Landsat LDOPE

Software	Domain	Access
MRT	Public	https://lpdaac.usgs.gov/tools/modis_reprojection_tool
L-LDOPE Toolbelt	Public	http://landsat.usgs.gov/L-LDOPE_Toolbelt.php
HEG	Public	http://newsroom.gsfc.nasa.gov/sdptoolkit/HEG/HEGHome.html

Section 6 Citation Information

There are no restrictions on the use of the surface reflectance CDR. 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 Surface Reflectance 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.

If possible, 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 7 Acknowledgments

The original LEDAPS software was developed by Eric Vermote, Nazmi Saleous, Jonathan Kutler, and Robert Wolfe with support from the NASA Terrestrial Ecology program (Principal Investigator: Jeff Masek). Subsequent versions were adapted by Dr. Feng Gao (GSFC/ERT Corp.) with support from the NASA Advancing Collaborative Connections for Earth System Science (ACCESS) and the USGS Landsat Programs.

Section 8 User Services

The Landsat CDRs, ECVs, and associated interfaces are supported by User Services staff at USGS EROS. Any questions, comments, or interface problems are welcomed through the Landsat “Contact Us” on-line correspondence form. Please indicate “Surface Reflectance Data/LAI Request” as the topic of regard. Electronic mail can also be sent to the customer service address included below, with the same indication of topic.

USGS User Services
http://landsat.usgs.gov/contactus.php
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 9 References

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Section 10 Acronyms

Acronym	Description
6S	Second Simulation of a Satellite Signal in the Solar Spectrum
ACCESS	Advancing Collaborative Connections for Earth System Science
CDR	Climate Data Record
DDV	Dark Dense Vegetation
DOI	Department of the Interior
ECV	Essential Climate Variable
ENVI	Exelis Visual Information Solutions
EOS	Earth Observing System
EROS	Earth Resources Observation and Science
ETM+	Enhanced Thematic Mapper Plus
GCOS	Global Climate Observing System
GeoTIFF	Geospatial Tagged Image File Format
GLS	Global Land Survey
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HEG	HDF to GeoTIFF
INT	Signed Integer
LDOPE	Land Data Operational Product Evaluation
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LSB	Least Significant Bit
m	meter
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MODIS	Moderate Resolution Imaging Spectroradiometer
MRT	MODIS Reprojection Tool
MSB	Most Significant Bit
NA	Not Applicable
NASA	National Aeronautic and Space Administration
NDVI	Normalized Difference Vegetation Index
QA	Quality Assurance
SDS	Science Data Set
SLC	Scan Line Corrector
SR	Surface Reflectance
TM	Thematic Mapper
TOA	Top of Atmosphere
UINT	Unsigned Integer
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator