LSDS-2321
Version 1.0

Department of the Interior
U.S. Geological Survey

Land Change Monitoring, Assessment, and Projection (LCMAP) Collection 1.2 Data Format Control Book (DFCB)

Version 1.0

November 2021

Land Change Monitoring, Assessment, and Projection (LCMAP) Collection 1.2 Data Format Control Book (DFCB)

November 2021

Approved By:

JESSLYN BROWN Digitally signed by JESSLYN BROWN
Date: 2021.11.16 10:57:21 -06'00'

Jesslyn Brown Date
LCMAP CCB Chair
U.S. Geological Survey

EROS
Sioux Falls, South Dakota

Executive Summary

This Data Format Control Book (DFCB) presents data format specifications for the Land Change Monitoring, Assessment, and Projection (LCMAP) Collection 1.2 Science Products. LCMAP is a U.S. Geological Survey (USGS) science initiative implemented at the Earth Resources Observation and Science (EROS) Center that harnesses the remotely sensed Landsat data record to provide state-of-the-art land surface change information needed by scientists, resource managers, and decision-makers. LCMAP uses a modernized, integrated approach to map, monitor, synthesize, and understand the complexities of land use, cover, and condition change.

Basic foundational elements of the LCMAP project include:

- Landsat Collection 1 U.S. Analysis Ready Data (ARD)
- Land surface change and land cover data
- Independent reference data for validation and area estimation
- Scenario-driven projections of future land use and land cover extents and patterns
- Assessments focused on land change processes, characteristics, and consequences

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

Document History

Document Number	Document Version	Publication Date	Change Number
LSDS-2321	Version 1.0	November 2021	CR 20833

Contents

List of Figures

List of Tables

Section 1 Introduction

1.1 Purpose

This Data Format Control Book (DFCB) provides detailed information on data formats for Land Change Monitoring, Assessment, and Projection (LCMAP) Collection 1.2 Science Products, including information on product and file specifications, product packaging, and metadata file examples.

1.2 Scope

This DFCB describes the formats and data contents of the LCMAP Collection 1.2 Science Products produced at the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center.

1.3 Document Organization

This document contains the following sections:

- Section 1 introduces this DFCB
- Section 2 provides an overview of Continuous Change Detection and Classification (CCDC) land cover and land surface change products
- Section 3 provides data format definitions
- Appendix A provides a list of acronyms
- Appendix B provides excerpts from tile-based metadata Extensible Markup Language (XML)
- The References section contains a list of reference documents

1.4 LCMAP Project Documentation Suite

In accompaniment to the LCMAP Collection 1.2 Science Products, the LCMAP project provides a documentation suite, described in Table 1-1. All LCMAP documentation can be found on the LCMAP Website.

Document	Document Contents
LSDS-2320 LCMAP Collection 1.2 CCDC Algorithm Description Document (ADD)	Describes the Continuous Change Detection and Classification (CCDC) algorithm that is used to produce the associated science products part of the LCMAP project. The ADD gives in-depth descriptions of how various components of the CCDC operate and how the products and product values are derived.
LSDS-2321 LCMAP Collection 1.2 Data Format Control Book (DFCB)	Provides detailed information on data formats for the LCMAP Science Products. This includes information on product and file specifications, product packaging, and metadata file examples.
LSDS-2322 LCMAP Collection 1.2 Science Product Guide	Provides an overview of the current LCMAP approach, descriptions of the science products and their characteristics, and other relevant information to facilitate the use of LCMAP Science Products in the land change and land cover science community.

Table 1-1. LCMAP Collection 1.2 Documentation Suite

1.5 Intended Users

This document is a guide for LCMAP Collection 1.2 Science Product users. It provides detailed information on file specification and product packaging.

1.6 Definitions

Analysis Ready Data – Landsat Collection 1 U.S. Analysis Ready Data (ARD) are used as input in production of LCMAP Science Products. U.S. Landsat ARD consist of the most radiometrically and geometrically accurate Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS) data that are consistently processed to the highest scientific standards and level of processing required for direct use in monitoring and assessing landscape change.

Additional information specific to U.S. Landsat ARD product characteristics can be found on the Landsat Missions Website, in the Collection 1 ARD Data Format Control Book, and in Dwyer et al., 2018.

Continuous Change Detection and Classification (CCDC) – The CCDC algorithm was developed at the Center for Remote Sensing, Department of Geography and Environment, Boston University. A modified version of the CCDC algorithm is implemented as part of the LCMAP project to produce LCMAP Science Products (Zhu and Woodcock, 2014; Brown et al., 2020). For more information about the USGS LCMAP implementation of the CCDC algorithm, see Brown et al., 2020.

CCDC utilizes all available Surface Reflectance (SR), Brightness Temperature (BT), and associated observation quality data to create harmonic regression fits for each input band to characterize the spectral response of every pixel. The harmonic regression fits are then used to categorize the pixel history into temporal segments of stable periods and to estimate the dates at which the spectral time-series data diverge from past responses or patterns. Spectral time-series data divergence from past responses or patterns in a temporal segment indicates a model "break" that is generally the result of an abrupt change (e.g., wildfire, logging, and mining), or can also result from a gradual shift (e.g., forest growth, insect infestation, disease). A formal LCMAP Collection 1.2 CCDC Algorithm Description Document is available on the LCMAP website.

Tile – ARD are packaged in tiles, which are units of uniform dimension bounded by static corner points in a defined grid system (Figure 1-1 provides an example of the conterminous U.S. (CONUS) tile grid system). An ARD tile is currently defined as 5,000 x 5,000 30-meter (m) pixels (a tile can also be expressed as 150 x 150-kilometer (km) in size). The tile boundaries form the basis for the annual LCMAP Science Products.

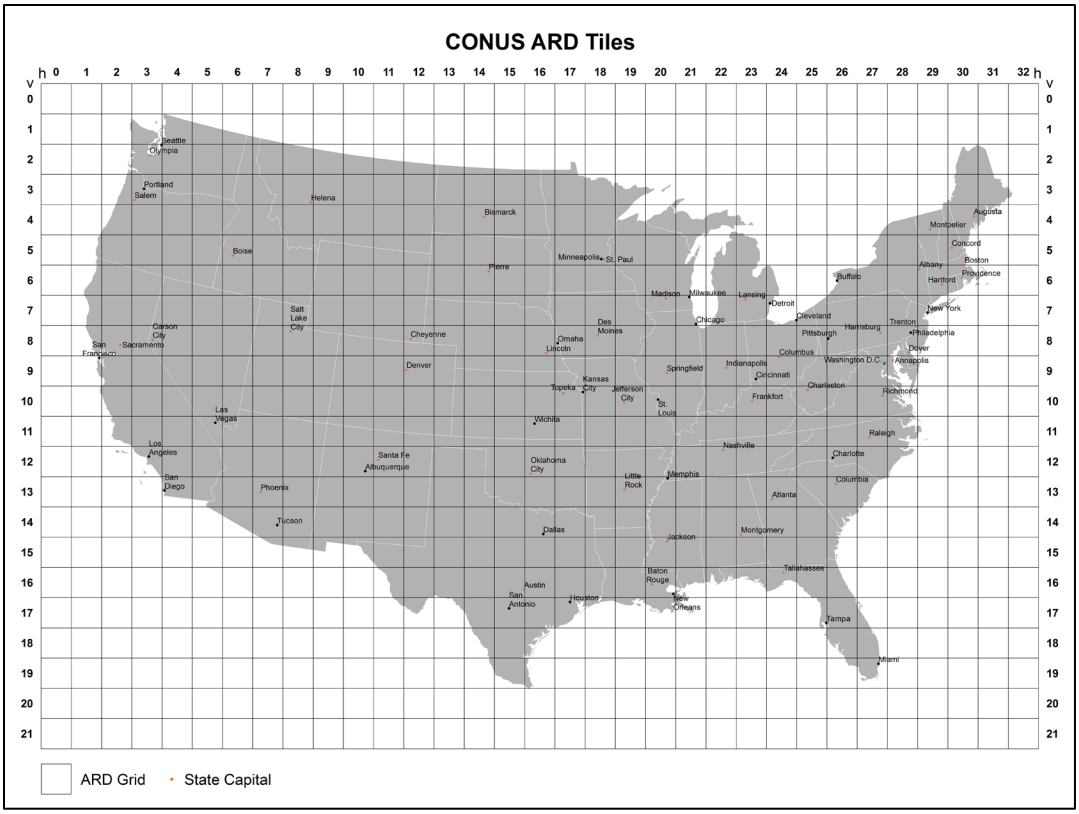

Figure 1-1. Landsat ARD Tile Grid for Conterminous U.S.

Section 2 Overview of CCDC Land Cover and Land Surface Change Products

The CCDC algorithm is implemented as part of the LCMAP project and employs every observation in a time series of Landsat data to model reflectance values such that they can be predicted and mathematically compared to future observations in the time series to determine whether change has occurred at any given time. The algorithm further classifies the time series to indicate what land cover types were observed before and after a detected change. By employing such methods, 10 LCMAP Collection 1.2 Science Products are generated.

The LCMAP Collection 1.2 Science Product suite consists of five annual land cover products, denoted by the "LC" prefix in the short name, and five annual land surface change products, denoted by the "SC" prefix in the short name.

Land cover products:

- Primary Land Cover (LCPRI)
- Primary Land Cover Confidence (LCPCONF)
- Secondary Land Cover (LCSEC)
- Secondary Land Cover Confidence (LCSCONF)
- Annual Land Cover Change (LCACHG)

Land surface change products:

- Time of Spectral Change (SCTIME)
- Change Magnitude (SCMAG)
- Spectral Stability Period (SCSTAB)
- Time Since Last Change (SCLAST)
- Spectral Model Quality (SCMQA)

LCMAP Science Products are available for the conterminous United States (CONUS) from 1985 – 2020.

Product Name	Product Designation	Description
Time of Spectral Change	SCTIME	Attributes of land surface change, and as such associated with a specific Day of Year (DOY). SCTIME is the DOY of a change, SCMAG is a measure of that change.
Change Magnitude	SCMAG	
Spectral Stability Period	SCSTAB	Provides temporal change information by counting, in days, into the past. Beginning with July 1st of current year back to the DOY of the last break (SCLAST) or the DOY of the start date of the current spectral state (SCSTAB).
Time Since Last Change	SCLAST	

Product Name	Product Designation	Description
Spectral Model Quality	SCMQA	Representative of conditions as of July 1st of current year.
Primary Land Cover	LCPRI	
Primary Land Cover Confidence	LCPCONF	
Secondary Land Cover	LCSEC	
Secondary Land Cover Confidence	LCSCONF	
Annual Land Cover Change	LCACHG	Synthesis of current year and previous year LCPRI. Indirectly representative of conditions on July 1st.

Table 2-1. LCMAP Science Products Description

2.1 LCMAP Science Product Specifications

The following sections provide LCMAP Collection 1.2 Science Product specification details and definitions. The 10 science products are created in an integrated fashion, inform each other, and are meant to be used together. For general usage purposes, products are organized into land cover and land surface change product categories. For more in-depth product descriptions and definitions, a formal LCMAP Collection 1.2 Science Product Guide document and a LCMAP Collection 1.2 CCDC Algorithm Description Document (ADD) are available on the LCMAP website.

2.1.1 Land Cover Products

LCMAP land cover products provide information about land cover classification, including land cover classification information for a given area before and after change is detected by CCDC. The five land cover products are built on broad Anderson Level 1 based classes (Anderson et al., 1976) provided in Table 2-3. Table 2-2 provides information on land cover product specifications.

Product Name	Product Designation	Data Type	Range	Valid Range	Fill Value	Description
Primary Land Cover	LCPRI	UINT8	0-255	0-8	0	Land cover classification consisting of eight general land cover types in Table 2-3. The most likely land cover according to the modeling process.
Secondary Land Cover	LCSEC	UINT8	0-255	0-8	0	Land cover classification consisting of eight general land cover types in Table 2-3. The second most likely land cover according to the modeling process.
Annual Land Cover Change	LCACHG	UINT8	0-255	0-87	0	Synthesis of Primary Land Cover of current and previous year identifying changes in land cover class.

Product Name	Product Designation	Data Type	Range	Valid Range	Fill Value	Description
Primary Land Cover Confidence	LCPCONF	UINT8	0-255	0-255	0	Provides provenance tracking and a measure of confidence that the Primary Land Cover label matches the training data.
Secondary Land Cover Confidence	LCSCONF	UINT8	0-255	0-255	0	Provides provenance tracking and a measure of confidence that the Secondary Land Cover label matches the training data.

Table 2-2. General Land Cover Product Specifications

Land Cover Class	Description
Developed	Areas of intensive use with much of the land covered with structures (e.g., high-density residential, commercial, industrial, mining, or transportation), or less intensive uses where the land cover matrix includes vegetation, bare ground, and structures (e.g., low-density residential, recreational facilities, cemeteries, transportation/utility corridors, etc.), including any land functionality related to the developed or built-up activity.
Cropland	Land in either a vegetated or unvegetated state used in production of food, fiber, and fuels. This includes cultivated and uncultivated croplands, hay lands, orchards, vineyards, and confined livestock operations. Forest plantations are considered as forests or woodlands (Tree Cover class) regardless of the use of the wood products.
Grass/Shrub	Land predominantly covered with shrubs and perennial or annual natural and domesticated grasses (e.g., pasture), forbs, or other forms of herbaceous vegetation. The grass and shrub cover must comprise at least 10% of the area and tree cover is less than 10% of the area.
Tree Cover	Tree-covered land where the tree cover density is greater than 10%. Cleared or harvested trees (i.e., clearcuts) will be mapped according to current cover (e.g., Barren, Grass/Shrub).
Water	Areas covered with water, such as streams, canals, lakes, reservoirs, bays, or oceans.
Wetland	Lands where water saturation is the determining factor in soil characteristics, vegetation types, and animal communities. Wetlands are composed of mosaics of water, bare soil, and herbaceous or wooded vegetated cover.
Ice/Snow	Land where accumulated snow and ice does not completely melt during the summer period (i.e., perennial ice/snow).
Barren	Land comprised of natural occurrences of soils, sand, or rocks where less than 10% of the area is vegetated.

Table 2-3. LCMAP Level 1 Land Cover Classes

Table 2-4 contains information on the Primary and Secondary Land Cover class assignments. Annual Land Cover Change assignments are provided as well.

Pixel Value	Land Cover Class	Color Table RGB Value
0	No Data	0,0,0
1	Developed	255,50,50
2	Cropland	190,140,190
3	Grassland/Shrubland	230,240,210
4	Tree Cover	28,99,48
5	Water Bodies	0,112,255
6	Wetlands	179,217,255
7	Snow and Ice	255,255,255
8	Natural Barren	179,174,163
12 - 87 (excluding 33, 44, 55, 66, 77)	Cover Change	171,0,214

Table 2-4. Primary and Secondary Land Cover class assignments and Annual Land Cover Change assignments

The Primary and Secondary Land Cover Confidence products provide a measure of confidence in the Primary and Secondary Land Cover classifications or additional information regarding the provenance of the result if the label was not produced by the initial classification method. Table 2-5 provides a summary of pixel values for LCPCONF and Table 2-6 provides a summary of pixel values for LCSCONF.

Pixel Value	Land Cover Label Source	Description
1-100	Initial classifier	Measure of confidence that the Primary Land Cover label matches the training data.
151	Secondary analysis	Time series model identified as transition from a Grass/Shrub class to a Tree Cover class. Primary Land Cover class assignment based on secondary analysis.
152	Secondary analysis	Time series model identified as transition from a Tree Cover class to a Grass/Shrub class. Primary Land cover class assignment based on secondary analysis.
201	Rule-based	No stable time series models were produced for this location. Primary Land Cover was assigned the land cover class present in NLCD-2001 (cross-walked to LCMAP Level 1 classification schema, see LCMAP Science Product Guide for more information)

Pixel Value	Land Cover Label Source	Description
202	Rule-based	Insufficient data available to extend most recent time series model past July 1st of current year. Land cover assigned the last identified cover class from earlier year.
211	Rule-based	July 1st falls in a gap between two stable time series models of the same land cover class. Primary Land Cover assigned the primary land cover class of those before/after models.
212	Rule-based	July 1st falls in a gap between two stable time series models of differing land cover class. If July 1st is before the "break date" of the earlier model, Primary Land Cover is assigned the primary land cover class of that earlier model. Otherwise, Primary Land Cover is assigned the primary land cover class of the subsequent, later model.
213	Rule-based	Insufficient data available to establish a stable time series model at the beginning of the time series prior to July 1st of the current year. Primary Land Cover assigned the primary land cover class of 1st subsequent model.
214	Rule-based	Insufficient data available to establish a new stable time series model following a break near the end of the time series prior to July 1st of the current year. Primary Land Cover assigned the last identified primary land cover class from earlier year.

Table 2-5. Description of Assignments for Primary Land Cover Confidence

Pixel Value	LC Label Source	Description
1-100	Initial classifier	Measure of confidence that the Secondary Land Cover label matches the training data.
151	Secondary analysis	Time series model identified as transition from a Grass/Shrub class to a Tree Cover class in Primary Land Cover. Primary Land Cover class assignment based on secondary analysis and Secondary Land Cover class assigned logical opposite of Primary.
152	Secondary analysis	Time series model identified as transition from a Tree Cover class to a Grass/Shrub class in Primary Land Cover. Primary Land Cover class assignment based on secondary analysis and Secondary Land Cover class assigned logical opposite of Primary.
201	Rule-based	No stable time series models were produced for this location. Secondary Land Cover assigned the land cover class present in NLCD-2001 (cross-walked to LCMAP classification schema, see LCMAP Science Product Guide for more information).

Pixel Value	LC Label Source	Description
202	Rule-based	Insufficient data available to extend most recent time series model past July 1st of current year. Secondary Land Cover assigned the last identified secondary cover class from earlier year.
211	Rule-based	July 1st falls in a gap between two stable time series models of the same secondary land cover class. Secondary Land Cover assigned the land cover class of those before/after models.
212	Rule-based	July 1st falls in a gap between two stable time series models of differing secondary land cover classes. If July 1st is before the “break date” of the earlier model, Secondary Land Cover is assigned the secondary land cover class of the earlier model. Otherwise, Secondary Land Cover is assigned the secondary land cover class of the subsequent model.
213	Rule-based	Insufficient data available to establish a stable time series model at the beginning of the time series prior to July 1st of the current year. Secondary Land Cover assigned the secondary land cover class of 1st subsequent model.
214	Rule-based	Insufficient data available to establish a new stable time series model following a break near the end of the time series prior to July 1st of the current year. Secondary Land Cover assigned the last identified secondary cover class from earlier year.

Table 2-6. Description of Assignments for Secondary Land Cover Confidence

2.1.2 Land Surface Change Products

The five land surface change products provide spectrally and temporally specific information about land surface change. The land surface change products offer different perspectives and ways to study land surface change taking place through space and time. Table 2-7 provides general land surface change product specifications and Table 2-8 details Spectral Model Quality pixel values and descriptions.

Product Name	Product Designation	Data Type	Range	Valid Range	Fill Value	Description
Time of Spectral Change	SCTIME	UINT16	0-65535	0-366	NA	Represents the timing of a spectral change within the current product year as the day of year the change occurred.
Change Magnitude	SCMAG	FLOAT32	-3.4E+38 to +3.4E+38	0 to +3.4E+38	NA	The spectral strength or intensity of a time series model "break" when spectral observations have diverged from the model predictions.

Product Name	Product Designation	Data Type	Range	Valid Range	Fill Value	Description
Spectral Stability Period	SCSTAB	UINT16	0-65535	0-65535	NA	Measure of the amount of time in days that a pixel has been in its current spectral state as of July 1st. Current spectral state can refer to both during stable time series segments or a period outside of stable time series segments.
Time Since Last Change	SCLAST	UINT16	0-65535	0-65535	NA	Time, in days, since the last identified Spectral Change (SCTIME).
Model Quality	SCMQA	UINT8	0-255	0-4,6,8,14,24,44,54	NA	Information regarding the type of time series model applied to the current product year. Spectral Model Quality pixel values and descriptions are provided in Table 2-8.

Table 2-7. General Land Surface Change Product Specifications

Pixel Value	Model Type	Description
0	No Model	No model established for July 1st of current year.
4	Simple Model	A partial, 4-coefficient harmonic model.
6	Advanced Model	A partial, 6-coefficient harmonic model.
8	Full Model	A full, 8-coefficient harmonic model.
14	Start Fit	A simple model at the beginning of a time series where sparse and/or highly variable spectral measurements prevent establishment of a harmonic model.
24	End Fit	A simple model at the end of a time series where there are insufficient observations and/or time to establish a new harmonic model following a model break.
44	Insufficient Clear	A simple model for the entire time series in cases where fewer than 25% of input observations are labeled as “Clear” or “Water” by the U.S. Landsat ARD per-pixel quality band (PIXELQA).
54	Persistent Snow	A simple model for the entire time series in cases where 75% or more of input observations are labeled as “Snow” by the U.S. Landsat ARD per-pixel quality band (PIXELQA).

Table 2-8. Model Quality Assignments

2.2 Naming Conventions

Table 2-9 contains the filenames associated with LCMAP Collection 1.2 Science Products. Spatial referencing of LCMAP data product filenames use the same H-V indexing system as the CONUS ARD Grid (Figure 1-1). As of Collection 1.1, LCMAP has changed version numbering, where the first digit represents major version increments and the second digit represents minor version increments.

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_PRODUCT	
Term	**Definition**
LCMAP	Land Change Monitoring, Assessment, and Projection
US	Regional grid of the U.S. (“CU” = CONUS)
HHH	Horizontal tile number
VVV	Vertical tile number
YYYY	Representative year
yyyymmdd	Production year (yyyy) month (mm) day (dd)
VER	Continuous Change Detection and Classification (CCDC) Version number (“V11”, “V12”)
PRODUCT	Data product: "LCPRI" = Primary Land Cover "LCSEC" = Secondary Land Cover "LCPCONF" = Primary Land Cover Confidence "LCSCONF" = Secondary Land Cover Confidence "LCACHG" = Annual Land Cover Change "SCTIME" = Time of Spectral Change "SCMAG" = Change Magnitude "SCLAST" = Time Since Last Change "SCSTAB" = Spectral Stability Period "SCMQA" = Spectral Model Quality

Table 2-9. Product Identifier Terms

2.2.1 Example File Names

LCMAP Science Products are packaged into a suite of 10 products delivered in a single .tar file. The .tar packages “untar” (unzip) into 10 individual Georeferenced Tagged Image File Format (GeoTIFF) (.tif) raster files for each Product Year and an Extensible Markup Language (XML) (.xml) metadata file.

See Section 3.1 for more information on product packaging.

Example of Product Bundle (tar file):
LCMAP_CU_003010_2010_20201222_V12_CCDC.tar

Example of GeoTIFF Product File:
LCMAP_CU_003010_2010_20201222_V12_LCPRI.tif

2.3 Spatial Attributes

2.3.1 Map Projection

LCMAP Collection 1.2 Science Products utilize Landsat Collection 1 U.S. ARD that are generated in the Albers Equal Area (AEA) Conic map projection and processed directly from Level 1 AEA scenes through Level 2 products using the World Geodetic System 1984 (WGS84) datum. The products cover the Conterminous U.S. Table 2-10 lists the projection parameters that are carried through from ARD into LCMAP final products.

USGS Analysis Ready Data (ARD) Projection Parameters	
Projection: Albers Equal Area Conic (AEA)	
Datum: World Geodetic System 1984 (WGS84)	
	Conterminous U.S.
First standard parallel	29.5˚
Second standard parallel	45.5˚
Longitude of central meridian	-96.0˚
Latitude of projection origin	23.0˚
False Easting (meters)	0.0
False Northing (meters)	0.0

Table 2-10. CONUS Landsat ARD Projection Parameters

2.3.2 Tile Grid System

All LCMAP Collection 1.2 Science Products generated by CCDC are derived from AEA-projected ARD products processed to a common tiling scheme, which is modified from the Web-Enabled Landsat Data (WELD) system developed at South Dakota State University (SDSU) (Roy and others, 2010). The WELD-defined grid is similar to the National Land Cover Database (NLCD), except that WELD is based on WGS84 and NLCD uses North American Datum of 1983 (NAD83), causing an approximately 0.5 pixel offset in the X and Y directions between the two grids.

The U.S. Landsat ARD grid is an adaptation of the WELD grid that aligns with the NLCD. The ARD is gridded into tiles of 5,000 x 5,000 30m pixels (or expressed 150 x 150-kilometer (km) tile size) and is anchored to the coordinates listed in Table 2-11.

	Upper Left Tile (UL Corner)				**Lower Right Tile (LR Corner)**			
	(h)	**(v)**	**ulX (m)**	**ulY (m)**	**(h)**	**(v)**	**lrX (m)**	**lrY (m)**
CONUS	0	0	-2565585	3314805	32	21	2384415	14805
CONUS=conterminous United States, UL=upper left, LR=lower right, h=horizontal tile, v=vertical tile, m=meters, ulX=upper-left X coordinate, ulY=upper-left Y coordinate, lrX=lower-right X coordinate, lrY=lower-right Y coordinate								

Table 2-11. CONUS Landsat ARD Tile Grid Extents

Section 3 Data Format Definition

3.1 LCMAP Product Packaging

LCMAP Collection 1.2 Science Products generated by CCDC are packaged into a suite of 10 products delivered in a single .tar file. The LCMAP .tar packages “untar” (unzip) into 10 individual GeoTIFF (.tif) raster files for each product year and an XML (.xml) metadata file.

The package identifier (Package ID) of the distributed files is derived from the CCDC science product ID (see Section 2.2).

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_CCDC.tar	
	Definition
LCMAP	Land Change Monitoring, Assessment, and Projection
US	Regional grid of the U.S. (“CU” = CONUS)
HHH	Horizontal tile number
VVV	Vertical tile number
YYYY	Representative year
yyyymmdd	Production year (yyyy) month (mm) day (dd)
VER	Continuous Change Detection and Classification (CCDC) Version number (“V11,” “V12”)
CCDC	Continuous Change Detection and Classification

Table 3-1. LCMAP Collection 1.2 Science Product Package ID Terms

3.1.1 Metadata Files

Example metadata files for LCMAP Collection 1.2 Science Products produced by CCDC can be found in Appendix B.

3.1.2 LCMAP Package Contents

Each LCMAP Collection 1.2 Science Product package includes the following:

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_CCDC.tar

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCPRI.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCPRI.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCSEC.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCSEC.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCPCONF.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCPCONF.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCSCONF.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCSCONF.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCACHG.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_LCACHG.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCTIME.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCTIME.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCMAG.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCMAG.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCLAST.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCLAST.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCSTAB.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCSTAB.xml

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCMQA.tif

LCMAP_US_HHHVVV_YYYY_yyyymmdd_VER_SCMQA.xml

LCMAP_US_HHHVVV_yyyymmdd_VER_ACQS.txt

3.1.3 Product Volumes

Summarizing all products in the 35-year time range (1985-2020) over a single tile, there are currently at least 904.03 compressed gigabytes (GiB) expected in total. Due to the internal compression applied to each product package, uncompressed volumes are not expected to be significantly larger than described in Table 3-2.

Product	Single Tile (GiB)	Estimate for CONUS (GiB)
LCPRI	0.07	27.66
LCSEC	0.15	62.99
LCPCONF	0.31	130.59
LCSCONF	0.27	119.99
LCACHG	0.07	31.09
SCLAST	0.37	157.49
SCMAG	0.21	89.02
SCMQA	0.04	16.31

Product	Single Tile (GiB)	Estimate for CONUS (GiB)
SCSTAB	0.57	239.86
SCTIME	0.08	33.03
Sum of All Products	2.14	904.03

Table 3-2. Single Tile Estimated Average Product Volume (Gigabytes)

3.2 GeoTIFF Specifications

3.2.1 GeoTIFF Image Preparation

LCMAP Collection 1.2 Science Products that are stored in GeoTIFF files use internal tiling to support web application services. Large file sizes are mitigated with internally compressed products, meaning that compression is applied to each raster rather than compressing all rasters together. The lossless Deflate algorithm used to compress the LCMAP Science Product rasters was selected due to its superior compression ratio and is expected to respond to most software. When using Geospatial Data Abstraction Library (GDAL) software for the image compression, the following parameters are used:

-co "compress=deflate" -co "zlevel=9" -co "tiled=yes" -co "predictor=2"

3.2.2 GeoTIFF Tags

GeoTIFF tags convey information about the image. The tags describe the image using information a GeoTIFF reader needs to control the appearance of the image on the user's screen. The Tagged Image File Format (TIFF) tags are embedded in the same file as the TIFF image. The GeoTIFF tags provide information on the image projection and corner points, which define the geographic location and extent of the image.

A complete description of the raster data requires the data to be georeferenced, which is accomplished using tags. The Level 2 production system uses the transformation raster, model space tiepoints, and scaling parameters. ModelTiepointTag and ModelPixelScaleTag are used for this purpose.

3.2.2.1 GeoTIFF ModelTiepointTag

The GeoTIFF ModelTiepointTag stores the raster-to-model tiepoint pairs. The raster-to-model tiepoint pairs are stored in the following order: ModelTiepointTag = (..., I, J, K, X, Y, Z...), where (I, J, K) is the point at location (I, J) in raster space with pixel-value K, and (X, Y, Z) is a vector in model space. The ModelTiepointTag requires that K and Z are set to zero. See the GeoTIFF Specification document (see References) for more information.

The raster image is geo-referenced by specifying its location, size, and orientation in the model coordinate space. Because the relationship between the raster space and the model space is often exact, the affine transformation relationship can be defined using one set of tiepoints and the ModelPixelScaleTag (see Section 3.2.2.2), which gives the vertical and horizontal raster grid cell size. The ModelTiepointTag parameters are as follows:

Tag = 33922
Type = DOUBLE
N = 6*K, K = number of tiepoints

3.2.2.2 GeoTIFF ModelPixelScaleTag Tag

The GeoTIFF ModelPixelScaleTag tag specifies the size of the raster pixel spacing in the model space units when the raster space is embedded in the model space coordinate system without rotation.

The size of raster pixel spacing in the model space units consists of three values. These values are ModelPixelScaleTag = (ScaleX, ScaleY, ScaleZ), where ScaleX and ScaleY give the horizontal and vertical spacing of raster pixels, and ScaleZ maps the pixel value of a Digital Elevation Model (DEM) into the correct Z-scale.

A single tiepoint in the ModelTiepointTag, together with the ModelPixelScaleTag, determines the relationship between raster and model space. The ModelPixelScaleTag parameters are listed as follows:

Tag = 33550
Type = DOUBLE
N = 3

3.2.3 GeoTIFF Keys

The spatial description of an image in GeoTIFF requires keys stored within the image files and accessible by GeoTIFF readers. Table 3-3 defines the keys necessary to support the AEA map projection used for LCMAP Science Products.

Valid Keys	Possible Values	Meaning
GTModelTypeGeoKey	1	ModelTypeProjected (Projection Coordinate System)
GTRasterTypeGeoKey	1	RasterPixelsArea (the coordinate is at the upper left corner of the pixel). This matches the Level 2 source scenes.
GTCitationGeoKey	Albers	American Standard Code for Information Interchange (ASCII) reference to public documentation; Albers, Stereographic South Pole, and Universal Transverse Mercator (UTM) are accounted for.
GeographicTypeGeoKey	1	GCS_WGS_84
GeogAngularUnitsGeoKey	9102	Angular Degree
GeogSemiMajorAxisGeoKey	6378140	
GeogInvFlatteningGeoKey	298.257	
ProjectedCSTypeGeoKey		User-Defined
ProjectionGeoKey		User-Defined
ProjectedCSTypeGeoKey	20000–32760	European Petroleum Survey Group (EPSG) Projection System Codes

Valid Keys	Possible Values	Meaning
ProjectionGeoKey	10000-19999	EPSG / Petrotechnical Open Software Corporation (POSC) Projection Codes (see the EPSG Geodetic Parameter Registry for values)
ProjCoordTransGeoKey	CT AlbersEqualArea	
ProjLinearUnitsGeoKey	9001	Linear Meter
ProjStdParallel1GeoKey	45.5	Value in units of GeogAngularUnits
ProjNatOriginLongGeoKey	-96.0	Value in units of GeogAngularUnits
ProjNatOriginLatGeoKey	23.0	Value in units of GeogAngularUnits
ProjFalseNorthingGeoKey	0.0000000	Value entered in units of ProjLinearUnits
ProjFalseEastingGeoKey	0.0000000	Value entered in units of ProjLinearUnits

Table 3-3. Albers GeoTIFF Key Description

Appendix A Acronyms

ADD	Algorithm Description Document
AEA	Albers Equal Area
ARD	Analysis Ready Data
ASCII	American Standard Code for Information Interchange
BT	Brightness Temperature
CCB	Configuration Control Board
CCDC	Continuous Change Detection and Classification
CONUS	Conterminous United States
CR	Change Request
DEM	Digital Elevation Model
DFCB	Data Format Control Book
DOI	Department of the Interior
DOY	Day of Year
EPSG	European Petroleum Survey Group
EROS	Earth Resources Observation and Science
ETM+	Enhanced Thematic Mapper Plus
GDAL	Geospatial Data Abstraction Library
GeoTIFF	Georeferenced Tagged Image File Format
GiB	Gigabyte
IWDS	Information Warehouse and Data Store
km	Kilometer
LCACHG	Annual Land Cover Change
LCMAP	Land Change Monitoring, Assessment, and Projection
LCPCONF	Primary Land Cover Confidence
LCPRI	Primary Land Cover
LCSCONF	Secondary Land Cover Confidence
LCSEC	Secondary Land Cover
LSDS	Land Satellites Data System
m	Meter
NAD83	North American Datum of 1983
NLCD	National Land Cover Database
OLI	Operational Land Imager
PIXELQA	Pixel Quality Assessment Band
POSC	Petrotechnical Open Software Corporation
QA	Quality Assessment
RGB	Red, Green and Blue Color Value
SCLAST	Time Since Last Change
SCMAG	Change Magnitude
SCMQA	Spectral Model Quality
SCSTAB	Spectral Stability Period
SCTIME	Time of Spectral Change

SDSU	South Dakota State University
SR	Surface Reflectance
.tar	Tape Archive – file extension
.tif	Georeferenced Tagged Image File Format – file extension
TIFF	Tagged Image File Format
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
UINT	Unsigned Integer
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WELD	Web-Enabled Landsat Data
WGS84	World Geodetic System 1984
.xml	Extensible Markup Language – file extension
XML	Extensible Markup Language

Appendix B Example Metadata

The general contents of the LCMAP Science Products tile-based XML are listed as follows:

- Global Metadata
- Primary Land Cover Metadata
- Secondary Land Cover Metadata
- Primary Land Cover Confidence Metadata
- Secondary Land Cover Confidence Metadata
- Annual Land Cover Change Metadata
- Time of Spectral Change Metadata
- Change Magnitude Metadata
- Time Since Last Change Metadata
- Spectral Stability Period Metadata
- Spectral Model Quality Metadata

Excerpts from the tile-based metadata XML can be viewed as follows:

Example of Tile Metadata

```
<?xml version="1.0" encoding="UTF-8"?>
<metadata>
  <idinfo>
    <citation>
      <citeinfo>
        <origin>U.S. Geological Survey</origin>
        <pubdate><%= pubdate %></pubdate>
        <title>LCMAP Land Cover and Land Change</title>
        <geoform>raster digital data</geoform>
        <pubinfo>
          <pubplace>Sioux Falls, SD</pubplace>
          <publish>U.S. Geological Survey</publish>
        </pubinfo>
        <onlink>https://doi.org/10.5066/P9SW95Z0</onlink>
      </citeinfo>
    </citation>
    <descript>
      <abstract>The Land Change Monitoring Assessment and Projection (LCMAP)
raster dataset is a suite of five annual land surface change and five annual land
cover (and land cover derivative) products.  The LCMAP approach is the foundation
for an integrated land change science framework led by the U.S. Geological Survey
(USGS). The data were calculated using the Continuous Change Detection and
Classification (CCDC) algorithm developed by Zhu and Woodcock (2014) and are
derived from a time series of satellite imagery consisting of all available
cloud- and shadow-free pixels in the USGS Landsat Analysis Ready Data (ARD)
archive (Dwyer and others, 2018). The CCDC methodology supports the continuous
tracking and characterization of changes in land cover, and condition enabling
assessments of current, historical, and future processes of change.
```

Landsat ARD, as the source data for LCMAP, are standardized Landsat data pre-processed to ensure the data meet a minimum set of requirements and are organized into a form that allows immediate analysis with a minimum of additional user effort. ARD data are provided as tiled, georegistered, surface reflectance products defined in a common equal area projection and tiled to a common grid. ARD observations must be transformed into time series vectors before further calculations using the CCDC methodology.
The CCDC methodology, initially developed at Boston University (Zhu and Woodcock, 2014), has been adopted and modified by USGS for LCMAP. CCDC involves harmonic modeling that characterizes the seasonality, trends, and breaks from those trends based on the time series spectral reflectance data from multiple Landsat bands (i.e., green, red, near-infrared, short-wave infrared). The CCDC approach involves two major components: change detection and classification. The change detection component utilizes available high-quality surface reflectance data in a pixel-based time series to calculate a mathematical model for the spectral response of each pixel and to estimate the dates at which the spectral time series data diverge from past responses or patterns. The basis of change detection is the comparison of clear satellite observations with model predictions. 'Divergence' (referred to as a model 'break') often is identified as the result of an abrupt change (e.g. wildfire, logging, mining, and urban development) but may also result from a gradual shift (e.g., forest regrowth, insect infestation, disease) in the spectral signal over time. Breaks are detected by CCDC by applying a criterion based on the root mean square error of the harmonic modeling. Time periods for established models are referred to as 'model segments.' After a break is identified in the time series, a new model can be established following the break provided there are enough clear observations going forward in time.
The classification component of CCDC involves using the coefficients of time series models as the inputs for land cover classification. The CCDC method has the capability to generate land cover for any date in the time series; the USGS has selected an annual time step for land cover classification. The suite of land cover and change products are nominally identified at a central point in the year, July 1. Classification is performed using a boosted decision tree method based on training data developed from 2001 NLCD land cover classes (Homer and others, 2007). The land cover legend for the Primary and Secondary Land Cover products is comparable to an Anderson level 1 classifcation scheme.</abstract>
      <purpose>The data set depicts LCMAP CCDC Collection v1.2 raster products consisting of five land surface change and five land cover layers created to support the land change science community.</purpose>
    </descript>
    <timeperd>
      <timeinfo>
        <rngdates>
          <begdate>1985</begdate>
          <enddate>2020</enddate>
        </rngdates>
      </timeinfo>
      <current>ground condition</current>
    </timeperd>
    <status>
      <progress>Complete</progress>
      <update>None planned</update>

```
    </status>
    <spdom>
      <bounding>
        <westbc><%= westbc %></westbc>
        <eastbc><%= eastbc %></eastbc>
        <northbc><%= northbc %></northbc>
        <southbc><%= southbc %></southbc>
      </bounding>
    </spdom>
    <keywords>
      <theme>
        <themekt>NGDA Portfolio Themes</themekt>
        <themekey>Land Use Land Cover Theme</themekey>
        <themekey>National Geospatial Data Asset</themekey>
      </theme>
      <theme>
        <themekt>None</themekt>
        <themekey>time series</themekey>
        <themekey>Landsat</themekey>
        <themekey>Analysis Ready Data</themekey>
        <themekey>Land Cover</themekey>
        <themekey>Change Detection</themekey>
        <themekey>Earth observations</themekey>
      </theme>
      <place>
        <placekt>Common geographic areas</placekt>
        <placekey>United States</placekey>
      </place>
    </keywords>
    <accconst>none</accconst>
    <useconst>none</useconst>
    <ptcontac>
      <cntinfo>
        <cntperp>
          <cntper>Customer Service</cntper>
          <cntorg>U.S. Geological Survey (USGS) Earth Resources Observation and
Science (EROS) Center</cntorg>
        </cntperp>
        <cntaddr>
          <addrtype>mailing and physical</addrtype>
          <address>47914 252Nd Street</address>
          <city>Sioux Falls</city>
          <state>SD</state>
          <postal>57198</postal>
          <country>US</country>
        </cntaddr>
        <cntvoice>800-252-4547</cntvoice>
        <cntemail>custserv@usgs.gov</cntemail>
      </cntinfo>
    </ptcontac>
    <crossref>
      <citeinfo>
```

```
        <origin>Zhe Zhu</origin>
        <origin>Curtis E. Woodcock</origin>
        <pubdate>20140325</pubdate>
        <title>Continuous change detection and classification of land cover using
all available Landsat data</title>
        <pubinfo>
          <pubplace>Amsterdam</pubplace>
          <publish>Remote Sensing of Environment</publish>
        </pubinfo>
        <onlink>https://doi.org/10.1016/j.rse.2014.01.011</onlink>
      </citeinfo>
    </crossref>
    <crossref>
      <citeinfo>
        <origin>John L. Dwyer</origin>
        <origin>David P. Roy</origin>
        <origin>Brian Sauer</origin>
        <origin>Calli B. Jenkerson</origin>
        <origin>Hankui K. Zhang</origin>
        <origin>Leo Lymburner</origin>
        <pubdate>20180828</pubdate>
        <title>Analysis Ready Data: Enabling Analysis of the Landsat
Archive</title>
        <pubinfo>
          <pubplace>Basel, Switzerland</pubplace>
          <publish>Remote Sensing</publish>
        </pubinfo>
        <onlink>https://doi.org/10.3390/rs10091363</onlink>
      </citeinfo>
    </crossref>
    <crossref>
      <citeinfo>
        <origin>Collin G. Homer</origin>
        <origin>Chengquan Huang</origin>
        <origin>Limin Yang</origin>
        <origin>Bruce K. Wyle</origin>
        <origin>Michael J. Coan</origin>
        <pubdate>2004</pubdate>
        <title>Development of a 2001 National Landcover Database for the United
States</title>
        <pubinfo>
          <pubplace>Bethesda, MD. USA</pubplace>
          <publish>Photogrammetric Engineering and Remote Sensing</publish>
        </pubinfo>
        <onlink>https://doi.org/10.14358/PERS.70.7.829</onlink>
      </citeinfo>
    </crossref>
  </idinfo>
  <dataqual>
    <attracc>
      <attraccr>https://doi.org/10.5066/P9M6T45Z</attraccr>
    </attracc>
```

```
    <logic>No formal logical accuracy tests were conducted</logic>
    <complete>Data set is considered complete for the information presented, as
described in the abstract. Users are advised to read the rest of the metadata
record carefully for additional details.</complete>
    <posacc>
      <horizpa>
        <horizpar>No formal positional accuracy tests were conducted</horizpar>
      </horizpa>
      <vertacc>
        <vertaccr>No formal positional accuracy tests were conducted</vertaccr>
      </vertacc>
    </posacc>
    <lineage>
      <procstep>
        <procdesc>An Algorithm Description Document (ADD) for the LCMAP
implementation of CCDC Collection v1.2 can be found at:
https://www.usgs.gov/media/files/lcmap-collection-12-ccdc-add</procdesc>
        <procdate>Unknown</procdate>
      </procstep>
      <procstep>
        <procdesc>Continuous Change Detection. Landsat ARD surface reflectance
(SR), brightness temperature (BT), and PixelQA data are retrieved through LCMAP
data access services for the date range 1982-01-01 through 2021-01-01 (exclusive)
from the LCMAP Information Warehouse and Data Store (IWDS). These data are then
processed by the LCMAP implementation of the Continuous Change Detection
component of the CCDC algorithm, with results stored back in the LCMAP IWDS. The
full list of observation dates from ARD used for processing through Continuous
Change Detection is available in the separate file <%= observations_name
%></procdesc>
        <procdate>Unknown</procdate>
      </procstep>
      <procstep>
        <procdesc>Classification: Prediction. Change detection results, wetlands
agreement (hydric soils, National Wetlands Inventory, NLCD model), digital
elevation model (DEM) data and derivatives (slope, aspect, and position index),
and the trained CCDC v1.0 classifier are retrieved from the LCMAP IWDS. For each
July 1st that a time series model crosses, the intercept values from the time
series model are replaced with a predicted overall reflectance, and then
processed by the classifier. The set of per-class predictions are stored back on
the LCMAP IWDS.</procdesc>
        <procdate>Unknown</procdate>
      </procstep>
      <procstep>
        <procdesc>Product Generation. Change detection and classification
information is retrieved from the LCMAP IWDS for a specific tile. Data are then
interpreted into 10 annual Land Cover/Land Change products. The complete CCDC
time series model for a pixel is made up of one or more individual temporal model
segments, which allows for continuous characterization of that pixel at any point
in time. Time of Spectral Change and Change Magnitude are based on the calendar
year, while the other 8 products are created by intersecting an annual July 1st
date with the CCDC time series models. CCDC time series models are initiated
starting in 1982 when Landsat 4 TM data becomes available in the ARD record. The
```

```
sparseness of early TM data in the period of the record prevents the
establishment of reasonable harmonic time series models. Therefore, no products
were created for the first three years. 1985 was demonstrated to be the year when
ARD data density reached a sufficient level for the derived time series models to
provide consistent patterns and results could be generated. The end of the time
series often lacks adequate information to determine if an existing model segment
is stable or is in the process of changing. Therefore, the final year of the time
series and products is considered provisional.</procdesc>
        <procdate>Unknown</procdate>
      </procstep>
    </lineage>
  </dataqual>
  <spdoinfo>
    <direct>Raster</direct>
  </spdoinfo>
  <spref>
    <horizsys>
      <planar>
        <mapproj>
          <mapprojn>Albers Conical Equal Area</mapprojn>
          <albers>
            <stdparll>29.5</stdparll>
            <stdparll>45.5</stdparll>
            <longcm>-96.0</longcm>
            <latprjo>23.0</latprjo>
            <feast>0.0</feast>
            <fnorth>0.0</fnorth>
          </albers>
        </mapproj>
        <planci>
          <plance>row and column</plance>
          <coordrep>
            <absres>30.0</absres>
            <ordres>30.0</ordres>
          </coordrep>
          <plandu>METERS</plandu>
        </planci>
      </planar>
      <geodetic>
        <horizdn>World Geodetic System 1984 (WGS 84)</horizdn>
        <ellips>WGS_1984</ellips>
        <semiaxis>6378140.0</semiaxis>
        <denflat>298.2569999999957</denflat>
      </geodetic>
    </horizsys>
  </spref>
```

Example of Primary Land Cover Metadata

```
<attr>
        <attrlabl>LCPRI</attrlabl>
        <attrdef>Primary Land Cover. Classification consisting of eight general
land cover classes.</attrdef>
```

```
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <edom>
            <edomv>0</edomv>
            <edomvd>No Data.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>1</edomv>
            <edomvd>Developed. Areas of intensive use with much of the land
covered with structures (e.g., high density residential, commercial, industrial,
mining, or transportation), or less intensive uses where the land cover matrix
includes vegetation, bare ground, and structures (e.g., low density residential,
recreational facilities, cemeteries, transportation and utility corridors, etc.),
including any land functionally related to the developed or built-up
activity.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>2</edomv>
            <edomvd>Cropland. Land in either a vegetated or unvegetated state
used for the production of food, fiber, and fuels.  This includes cultivated and
uncultivated croplands, hay lands, orchards, vineyards, and confined livestock
operations.  Note that forest plantations are considered as forests or woodlands
regardless of the use of the wood products.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>3</edomv>
            <edomvd>Grass/Shrub. Land predominantly covered with shrubs and
perennial or annual natural and domesticated grasses (e.g., pasture), forbs, or
other forms of herbaceous vegetation. The grass and shrub cover must comprise at
least 10% of the area and tree cover is less than 10% of the area.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>4</edomv>
            <edomvd>Tree Cover. Tree-covered land where the tree cover density is
greater than 10%.  Note that cleared trees (i.e., clearcuts) will be mapped
according to current cover (e.g., transitional, bare ground, shrubs, or
grasses).</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
```

```
        <attrdomv>
          <edom>
            <edomv>5</edomv>
            <edomvd>Water. Areas covered with water, such as streams, canals,
lakes, reservoirs, bays, or oceans.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>6</edomv>
            <edomvd>Wetland. Lands where water saturation is the determining
factor in soil characteristics, vegetation types, and animal communities.
Wetlands are composed of mosaics of water, bare soil, and herbaceous or wooded
vegetated cover.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>7</edomv>
            <edomvd>Ice/Snow. Land where the accumulation of snow and ice does
not completely melt during the summer period.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>8</edomv>
            <edomvd>Barren. Land comprised of natural occurrences of soils, sand,
or rocks where less than 10% of the area is vegetated.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
      </attr>
```

Example of Secondary Land Cover Metadata

```
       <attr>
        <attrlabl>LCSEC</attrlabl>
        <attrdef>Secondary Land Cover. Classification consisting of eight general
land cover classes.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <edom>
            <edomv>1</edomv>
            <edomvd>Developed. Areas of intensive use with much of the land
covered with structures (e.g., high density residential, commercial, industrial,
mining, or transportation), or less intensive uses where the land cover matrix
includes vegetation, bare ground, and structures (e.g., low density residential,
recreational facilities, cemeteries, transportation and utility corridors, etc.),
including any land functionally related to the developed or built-up
activity.</edomvd>
```

```
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>2</edomv>
            <edomvd>Cropland. Land in either a vegetated or unvegetated state
used for the production of food, fiber, and fuels.  This includes cultivated and
uncultivated croplands, hay lands, orchards, vineyards, and confined livestock
operations.  Note that forest plantations are considered as forests or woodlands
regardless of the use of the wood products.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>3</edomv>
            <edomvd>Grass/Shrub. Land predominantly covered with shrubs and
perennial or annual natural and domesticated grasses (e.g., pasture), forbs, or
other forms of herbaceous vegetation. The grass and shrub cover must comprise at
least 10% of the area and tree cover is less than 10% of the area.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>4</edomv>
            <edomvd>Tree Cover. Tree-covered land where the tree cover density is
greater than 10%.  Note that cleared trees (i.e., clearcuts) will be mapped
according to current cover (e.g., transitional, bare ground, shrubs, or
grasses).</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>5</edomv>
            <edomvd>Water. Areas covered with water, such as streams, canals,
lakes, reservoirs, bays, or oceans.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>6</edomv>
            <edomvd>Wetland. Lands where water saturation is the determining
factor in soil characteristics, vegetation types, and animal communities.
Wetlands are composed of mosaics of water, bare soil, and herbaceous or wooded
vegetated cover.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
```

```
        <attrdomv>
          <edom>
            <edomv>7</edomv>
            <edomvd>Ice/Snow. Land where the accumulation of snow and ice does
not completely melt during the summer period.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>8</edomv>
            <edomvd>Barren. Land comprised of natural occurrences of soils, sand,
or rocks where less than 10% of the area is vegetated.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
      </attr>
```

Example of Primary Land Cover Confidence Metadata

```
<attr>
  <attrlabl>LCPCONF</attrlabl>
  <attrdef>Primary Land Cover Confidence. A measure of confidence in the primary
land cover class designation. Values greater than 100 identify locations where
additional interpretation procedures were used to assign the Primary Land Cover
label.</attrdef>
  <attrdefs>Producer Defined</attrdefs>
  <attrdomv>
    <rdom>
      <rdommin>1</rdommin>
      <rdommax>100</rdommax>
      <attrunit>Unitless</attrunit>
    </rdom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>151</edomv>
      <edomvd>The model time segment has been identified as a tree cover increase
(grass/shrub to tree cover) and has been modified to reflect this in the primary
class. The secondary class was assigned the logical inverse.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>152</edomv>
```

```
      <edomvd>The model time segment has been identified as a tree cover decrease
(tree cover to grass/shrub) and has been modified to reflect this in the primary
class. The secondary class was assigned the logical inverse because the fields
cannot be empty.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>201</edomv>
      <edomvd>CCDC was unable to establish any model segments for the time
series, pixel was assigned with 2001 NLCD value in both the primary and secondary
land cover class.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>202</edomv>
      <edomvd>The annual date of July 1 occurred after the last model time
segment, and the model ran out of data without a break detected. Pixel was
assigned with the last known cover class.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>211</edomv>
      <edomvd>The annual date of July 1 occurred between two model time segments
where the same land cover was classified before and after the break between
segments. Pixel was assigned the same land cover class.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>212</edomv>
      <edomvd>The annual date of July 1 occurred between two model time segments
that were classified as different land cover classes. If July 1 occurred before
the time of the segment break, the pixel was assigned the previous land cover
class. If July 1 occurred after the time of the segment break, the pixel was
assigned posterior land cover class.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
```

```
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>213</edomv>
      <edomvd>The annual date of July 1 occurred prior to the start date of the
first model segment identified in the time series. Pixel was assigned posterior
land cover class.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>214</edomv>
      <edomvd>The annual date of July 1 occurred after the last model time
segment, and the model ran out of data with a break detected. Pixel was assigned
the last known cover class.</edomvd>
      <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
    </edom>
  </attrdomv>
</attr>
```

Example of Secondary Land Cover Confidence Metadata

```
      <attr>
        <attrlabl>LCPCONF</attrlabl>
        <attrdef>Primary Land Cover Confidence. A measure of confidence in the
primary land cover class designation. Values greater than 100 identify locations
where additional interpretation procedures were used to assign the Primary Land
Cover label.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <rdom>
            <rdommin>1</rdommin>
            <rdommax>100</rdommax>
            <attrunit>Unitless</attrunit>
          </rdom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>151</edomv>
            <edomvd>The model time segment has been identified as a tree cover
increase (grass/shrub to tree cover) and has been modified to reflect this in the
primary class. The secondary class was assigned the logical inverse.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
```

```
          <edom>
            <edomv>152</edomv>
            <edomvd>The model time segment has been identified as a tree cover
decrease (tree cover to grass/shrub) and has been modified to reflect this in the
primary class. The secondary class was assigned the logical inverse because the
fields cannot be empty.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>201</edomv>
            <edomvd>CCDC was unable to establish any model segments for the time
series, pixel was assigned with 2001 NLCD value in both the primary and secondary
land cover class.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>202</edomv>
            <edomvd>The annual date of July 1 occurred after the last model time
segment, and the model ran out of data without a break detected. Pixel was
assigned with the last known cover class.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>211</edomv>
            <edomvd>The annual date of July 1 occurred between two model time
segments where the same land cover was classified before and after the break
between segments. Pixel was assigned the same land cover class.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>212</edomv>
            <edomvd>The annual date of July 1 occurred between two model time
segments that were classified as different land cover classes. If July 1 occurred
before the time of the segment break, the pixel was assigned the previous land
cover class. If July 1 occurred after the time of the segment break, the pixel
was assigned posterior land cover class.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>213</edomv>
```

```
            <edomvd>The annual date of July 1 occurred prior to the start date of
the first model segment identified in the time series. Pixel was assigned
posterior land cover class.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>214</edomv>
            <edomvd>The annual date of July 1 occurred after the last model time
segment, and the model ran out of data with a break detected. Pixel was assigned
the last known cover class.</edomvd>
            <edomvds>LCMAP Legend Land Cover Confidence Descriptions</edomvds>
          </edom>
        </attrdomv>
      </attr>
```

Example of Annual Land Cover Change Metadata

```
      <attr>
        <attrlabl>LCACHG</attrlabl>
        <attrdef>Annual Land Cover Change. Indicator of thematic land cover
change that has occurred from the prior year to the current year.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <edom>
            <edomv>1</edomv>
            <edomvd>Developed. Areas of intensive use with much of the land
covered with structures (e.g., high density residential, commercial, industrial,
mining, or transportation), or less intensive uses where the land cover matrix
includes vegetation, bare ground, and structures (e.g., low density residential,
recreational facilities, cemeteries, transportation and utility corridors, etc.),
including any land functionally related to the developed or built-up
activity.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>2</edomv>
            <edomvd>Cropland. Land in either a vegetated or unvegetated state
used for the production of food, fiber, and fuels.  This includes cultivated and
uncultivated croplands, hay lands, orchards, vineyards, and confined livestock
operations.  Note that forest plantations are considered as forests or woodlands
regardless of the use of the wood products.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>3</edomv>
            <edomvd>Grass/Shrub. Land predominantly covered with shrubs and
perennial or annual natural and domesticated grasses (e.g., pasture), forbs, or
```

other forms of herbaceous vegetation. The grass and shrub cover must comprise at least 10% of the area and tree cover is less than 10% of the area.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>4</edomv>
            <edomvd>Tree Cover. Tree-covered land where the tree cover density is greater than 10%. Note that cleared trees (i.e., clearcuts) will be mapped according to current cover (e.g., transitional, bare ground, shrubs, or grasses).</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>5</edomv>
            <edomvd>Water. Areas covered with water, such as streams, canals, lakes, reservoirs, bays, or oceans.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>6</edomv>
            <edomvd>Wetland. Lands where water saturation is the determining factor in soil characteristics, vegetation types, and animal communities. Wetlands are composed of mosaics of water, bare soil, and herbaceous or wooded vegetated cover.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>7</edomv>
            <edomvd>Ice/Snow. Land where the accumulation of snow and ice does not completely melt during the summer period.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>8</edomv>
            <edomvd>Barren. Land comprised of natural occurrences of soils, sand, or rocks where less than 10% of the area is vegetated.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>Any two digit combination of differing values.</edomv>

```
            <edomvd>Indication that land cover change has occurred between the
current year and the previous year. The prior year land cover class provides the
first value and the current year land cover class provides the second
value.</edomvd>
            <edomvds>LCMAP Legend Land Cover Class Descriptions</edomvds>
          </edom>
        </attrdomv>
      </attr>
```

Example of Time of Spectral Change Metadata

```
      <attr>
        <attrlabl>SCTIME</attrlabl>
        <attrdef>Time of Spectral Change. The day of year that a spectral change
was detected for a given year.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <rdom>
            <rdommin>1</rdommin>
            <rdommax>366</rdommax>
            <attrunit>Days</attrunit>
          </rdom>
        </attrdomv>
      </attr>
```

Example of Change Magnitude Metadata

```
<attr>
        <attrlabl>SCMAG</attrlabl>
        <attrdef>Change Magnitude. A measure of the spectral magnitude (or
spectral shift) of the change found within a given year.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <rdom>
            <rdommin>1</rdommin>
            <rdommax>3.4e38</rdommax>
            <attrunit>Unitless</attrunit>
          </rdom>
        </attrdomv>
      </attr>
```

Example of Time Since Last Change Metadata

```
      <attr>
        <attrlabl>SCLAST</attrlabl>
        <attrdef>Time Since Last Change. A measure of the amount of time in days
that has passed since the last detected spectral break.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <rdom>
            <rdommin>1</rdommin>
            <rdommax>65535</rdommax>
            <attrunit>Days</attrunit>
          </rdom>
```

```
        </attrdomv>
      </attr>
```

Example of Spectral Stability Period Metadata

```
<attr>
        <attrlabl>SCSTAB</attrlabl>
        <attrdef>Spectral Stability Period. A measure of the amount of time in
days that a pixel has been in its current spectral state.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <rdom>
            <rdommin>1</rdommin>
            <rdommax>65535</rdommax>
            <attrunit>Days</attrunit>
          </rdom>
        </attrdomv>
      </attr>
```

Example of Spectral Model Quality Metadata

```
<attr>
        <attrlabl>SCMQA</attrlabl>
        <attrdef>Spectral Model Quality. Characterization of the time series
model quality as it relates to model input data and model fit.</attrdef>
        <attrdefs>Producer Defined</attrdefs>
        <attrdomv>
          <edom>
            <edomv>0</edomv>
            <edomvd>No Model. No model segment established for July 1st of
current year.</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>4</edomv>
            <edomvd>Simple Model. A partial, 4-coefficient harmonic
model.</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>6</edomv>
            <edomvd>Advanced Model. A partial, 6-coefficient harmonic
model.</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>8</edomv>
            <edomvd>Full Model. A full, 8-coefficient harmonic model.</edomvd>
```

```
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>14</edomv>
            <edomvd>Start Fit. A Simple Model was established for the annual July
1st date at the beginning of the time series due to sparse and/or highly variable
spectral measurements.</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>24</edomv>
            <edomvd>End Fit. A Simple Model was established for the annual July
1st date at the end of the time series due to insufficient observations and/or
time to create a standard Simple/Advanced/Full Model following a model
break.</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>44</edomv>
            <edomvd>Insufficient Clear. A simple model for the entire time series
in cases where fewer than 25% of input observations are labeled as “Clear” or
“Water” by the Landsat ARD per-pixel quality band (PIXELQA).</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
        <attrdomv>
          <edom>
            <edomv>54</edomv>
            <edomvd>Persistent Snow. A simple model for the entire time series in
cases where 75% or more of input observations are labeled as “Snow” by the
Landsat ARD per-pixel quality band (PIXELQA).</edomvd>
            <edomvds>LCMAP Legend Model Quality Descriptions</edomvds>
          </edom>
        </attrdomv>
      </attr>
```

References

Please see https://www.usgs.gov/core-science-systems/nli/landsat/landsat-acronyms for a list of acronyms.

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E. (1976). A land use and land cover classification system for use with remote sensor data. Professional Paper 964, U.S. Geological Survey. Washington, DC: U.S. Government Printing Office. https://doi.org/10.3133/pp964

Brown, J.F., Tollerud, H.J., Barber, C.P., Zhou, Q., Dwyer, J.L., Vogelmann, J.E., Loveland, T.R., Woodcock, C.E., Stehman, S.V., Zhu, Z., Pengra, B.W., Smith, K., Horton, J.A., Xian, G., Auch, R.F., Sohl, T.L., Sayler, K.L., Gallant, A.L., Zelenak, D., Reker, R.R., and Rover, J., (2020). Lessons learned implementing an operational continuous United States national land change monitoring capability: The Land Change Monitoring, Assessment, and Projection (LCMAP) approach. Remote Sensing of Environment,. https://doi.org/10.1016/j.rse.2019.111356

Dwyer, J., Roy, D., Sauer, B., Jenkerson, C., Zhang, H., and Lymburner, L. (2018). Analysis Ready Data: Enabling analysis of the Landsat archive. Remote Sensing. https://doi.org/10.3390/rs10091363

EPSG Geodetic Parameter Registry. Version 7.4 http://www.epsg-registry.org

GeoTIFF Specification https://github.com/OSGeo/libgeotiff/issues

Homer, C., Huang, C., Yang, L., Wylie, B., and Coan, M. (2004). Development of a 2001 National Land-Cover Database for the United States. Photogrammetric Engineering & Remote Sensing. https://doi.org/10.14358/PERS.70.7.829

LSDS-1873. Landsat Analysis Ready Data (ARD) Data Format Control Book (DFCB) https://www.usgs.gov/media/files/landsat-analysis-ready-data-ard-data-format-control-book-dfcb

Pengra, B.W., Stehman, S.V., Horton, J.A., Dockter, D.J., Schroeder, T.A., Yang, Z., Cohen, W.B., Healey, S.P., and Loveland, T.R., (2020). Quality control and assessment of interpreter consistency of annual land cover reference data in an operational national monitoring program. Remote Sensing of Environment. https://doi.org/10.1016/j.rse.2019.111261

Roy, D.P., Ju, J., Kline, K., Scaramuzza, P.L., Kovalskyy, V., Hansen, M.C., Loveland, T.R., Vermote, E.F., Zhang, C. (2010). Web-enabled Landsat Data (WELD): Landsat ETM+ Composited Mosaics of the Conterminous United States, Remote Sensing of Environment, 114: 35-49. https://doi.org/10.1016/j.rse.2009.08.011

TimeSync. (2018). TimeSync -- Human Interpretation of Landsat Time Series. Retrieved from http://timesync.forestry.oregonstate.edu/

Web-Enabled Landsat Data (WELD)
ATBD https://lpdaac.usgs.gov/documents/177/WELD_ATBD.pdf

Zhu, Z., Woodcock, C.E. (2014). Continuous change detection and classification of land cover using all available Landsat data: Remote Sensing of Environment 144: 152–171. https://doi.org/10.1016/j.rse.2014.01.011.