
# WELD: WEB-ENABLED LANDSAT DATA

## Version 1.5

## User Guide*

## September 2017

**This User Guide was adapted from information provided on the [Algorithm Theoretical Based Document (ATBD),](#) which should be referred to for the most updated information on WELD data products.*

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# 1. Introduction

The Web-enabled Landsat Data (WELD) project has produced 30 meter Landsat 7 Enhanced Thematic Mapper Plus (ETM+) mosaics of the conterminous United States (CONUS) and Alaska for the time period of 2002 to 2012. WELD data products are developed specifically to provide consistent data that can be used to derive land cover, as well as geophysical and biophysical products, for regional assessment of surface dynamics and to study the functions of Earth systems. The WELD products are processed so that users do not need to apply the equations, spectral calibration coefficients, and solar information to convert the ETM+ digital numbers to reflectance and brightness temperature. Successive products are defined in the same coordinate system and align precisely, making them simple to use for multi-temporal applications. They provide the first instance of continental-scale science-quality Landsat data with a level of pre-processing comparable to the National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS) land products.

The WELD project is funded by NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) program. Version 1.5 products are currently available for ten years from 2002-2012. These products will be reprocessed as improved versions of the algorithms are developed.

The WELD products are available at no charge for educational, research, commercial, or other applications. If you use any WELD products, please cite them following the WELD Citation guidelines on page 19 of this document.

# 2.0 Product Types

## 2.1 WELD Version 1.5

WELD Hierarchical Data Format (HDF) data products are available for the conterminous United States (CONUS) and Alaska as weekly, monthly, seasonal (3 month), and annual composite data products.

The monthly, seasonal, and annual data products are defined in a temporally nested manner following climate modeling conventions. The weekly data products are defined more simply with respect to each calendar year. A complete list of temporal definitions for each product type is provided below.

*Table 1: WELD Version 1.5 Product Types*

| Product Type | Temporal Definition |
|---|---|
| **Annual** | The preceding year's December through the current year's November. |
| **Seasonal:** | |
| *Winter* | December, January, February |
| *Spring* | March, April, May |
| *Summer* | June, July, August |

| | |
|---|---|
| *Autumn* | September, October, November |
| **Monthly** | The days in each calendar month. |
| **Weekly** | Consecutive 7-day products with *Week01*: January 1 to January 7, *Week02*: January 8 to January 14… *Week 52*: December 24 to December 30 (non-leap years) or December 23 to December 29 (leap years), *Week 53*: December 30 to December 31 (leap years) or December 31 (non-leap years). |

### 2.1.2 WELD Version 1.5 Product Digital Object Identifiers

The Digital Object Identifier (DOI) for each dataset is given below to provide users with a persistent link to the product information.

*Table 2: List of WELD Version 1.5 Product DOIs*

| **Product Short Name** | **DOI** |
|---|---|
| WELDUSYR | 10.5067/MEaSUREs/WELD/WELDUSYR.001 |
| WELDUSWK | 10.5067/MEaSUREs/WELD/WELDUSWK.001 |
| WELDUSSE | 10.5067/MEaSUREs/WELD/WELDUSSE.001 |
| WELDUSMO | 10.5067/MEaSUREs/WELD/WELDUSMO.001 |
| WELDUSLL | 10.5067/MEaSUREs/WELD/WELDUSLL.001 |
| WELDAKYR | 10.5067/MEaSUREs/WELD/WELDAKYR.001 |
| WELDAKWK | 10.5067/MEaSUREs/WELD/WELDAKWK.001 |
| WELDAKSE | 10.5067/MEaSUREs/WELD/WELDAKSE.001 |
| WELDAKMO | 10.5067/MEaSUREs/WELD/WELDAKMO.001 |
| WELDAKLL | 10.5067/MEaSUREs/WELD/WELDAKLL.001 |

## 2.2 WELD Version 1.5 5 Year Land Cover Land Use Change Product

A 30 meter Land Cover Land Use Change (LCLUC) WELD tiled HDF product has been developed for CONUS. These data products contain information about tree cover loss and bare ground gain in five-year composites. The LCLUC WELD data product was generated from five years of consecutive growing season WELD weekly composite inputs from April 15, 2006 to November 17, 2010. WELD data are created using terrain corrected Landsat 7 ETM+ data.

### 2.2.1 WELD Version 1.5 5 Year Land Cover Land Use Change Product Digital Object Identifier

The Digital Object Identifier (DOI) for each dataset is given below to provide users with a persistent link to the product information.

*Table 3: List of Weld Version 1.5 LCLUC Product DOIs*

| Product Short Name | DOI |
|---|---|
| WELDLCLUC | 10.5067/MEaSUREs/WELD/WELDLCLUC.001 |

# 3.0 Algorithm Description

## 3.1 WELD Version 1.5 Products Algorithm Description

For complete details of the theoretical description and algorithms used to generate the WELD Version 1.5 Products, see the ATBD.

### 3.1.1 Input Data

The WELD data products are generated from Landsat 7 ETM+ acquisitions. The Landsat data are processed at the USGS Earth Resources Observation and Science (EROS) Center to Level 1 terrain corrected (L1T). The Level 1T processing includes radiometric correction, systematic geometric correction, precision correction using ground control chips, and the use of a digital elevation model to correct parallax error due to local topographic relief. Only the L1T data are used to make the WELD data products. Landsat acquisitions with cloud cover less than 40% are processed by the U.S. Landsat project. The WELD team manually orders all ETM+ acquisitions with cloud cover ranging between 40% and 80%. These ETM+ acquisitions are then copied automatically via dedicated file transfer protocol from the USGS EROS to WELD project computers. Approximately 8,000 to 1,800 ETM+ L1T processed acquisitions were obtained per year for CONUS and Alaska respectively.

### 3.1.2 Top of Atmosphere Reflectance (TOA) and Brightness Temperature Computation

All of the Landsat ETM+ bands, except the 15 meter panchromatic band are processed. The spectral radiance sensed by each ETM+ detector is stored as an 8-bit digital number (Markham et al. 2006). The digital numbers are converted to spectral radiance (units: W-m-2-sr-1-μm-1) using the sensor calibration gain and bias coefficients derived from the ETM+ L1T file metadata. The radiance sensed at the Landsat reflective and thermal wavelengths is then converted to reflectance (unitless) and brightness temperature (Kelvin) respectively. The radiance sensed in the Landsat reflective wavelength bands include the blue (0.45-0.52μm), green (0.53-0.61μm), red (0.63-0.69μm), near-infrared (0.78-0.90μm), and the two mid-infrared (1.55-1.75μm and 2.09-2.35μm) bands. The radiances are converted to top of atmosphere reflectance using a standard formula:

$$\rho_\lambda = \frac{\pi \times L_\lambda \times d^2}{ESUN_\lambda \times \cos\theta_s}$$

Where $\rho_\lambda$ is the top of atmosphere (TOA) reflectance (unitless), $L_\lambda$ is the TOA spectral radiance (W-m-2-sr-1-μm-1), d is the Earth-Sun distance (astronomical units), $ESUN_\lambda$ is the mean TOA solar spectral irradiance (W-m-2 μm-1), and $\theta_s$ is the solar zenith angle (radians). The quantities $ESUN_\lambda$ and d are tabulated by Chander et al. (2009).

The radiance sensed in the Landsat low and high gain thermal bands are converted to TOA brightness temperature (i.e., assuming unit surface emissivity) using a standard formula:

$$T = \frac{K_2}{\log(K_1 \div L_\lambda + 1)}$$

Where $T$ is the 10.40-12.50µm TOA brightness temperature (Kelvin), $K_1$ and $K_2$ are thermal calibration constants set as 666.09 (W-m-2-sr-1-µm-1) and 1282.71 (Kelvin) respectively (Chander et al. 2009), and $L_\lambda$ is the TOA spectral radiance. The Landsat L1T data are produced at USGS EROS with the 60 meter thermal bands resampled to 30 meter since February 26, 2010. Prior to this date, other resampling methods were used and are described under the Known Issues section on page 20.

The 30 meter low and high gain TOA brightness temperature data are stored as signed 16-bit integers with units of degrees Celsius by subtracting 273.15 from the brightness temperature and then scaling by 100.

### 3.1.3 Normalized Difference Vegetation Index Computation

The normalized difference vegetation index (NDVI) is the most commonly used vegetation index to assess vegetation greenness. The 30 meter TOA NDVI is computed from the TOA red and near-infrared Landsat reflectance data and is stored as signed 16-bit integers after being scaled by 10,000.

### 3.1.4 Band Saturation Computation

To account for over-saturated pixels caused by highly reflective surfaces, such as clouds and snow, as well as for under-saturated pixels caused by cold surfaces in some cases, a saturation mask is applied. Over- and under-saturated pixels are designated by digital numbers of 255 and 1, respectively, in the L1T data. As the radiance values of saturated pixels are unreliable, a 30 m 8-bit saturation mask is generated, storing bit packed band saturation (1) or unsaturated (0) values for the eight Landsat bands.

### 3.1.5 Cloud Masking

Both the Landsat automatic cloud cover assessment algorithm (ACCA) and a classification tree based cloud detection approach are implemented for WELD Version 1.5 products. More detailed information on the cloud cover assessments used is described in the ATBD.

### 3.1.6 Angular Geometry Computation

The Landsat viewing vector (Ω = view zenith angle, view azimuth angle) and the solar illumination vector (Ω = solar zenith angle, solar azimuth angle) are defined for each Landsat ETM+ L1T pixel. The solar illumination vector is computed using an astronomical model parameterized for geodetic latitude and longitude and time following the approach developed for MODIS geolocation (Wolfe et al. 2002).

The calculations to derive the solar illumination vector and the viewing vector are described in detail beginning on page 15 of the ATBD.

### 3.1.7 Reprojection, Resampling, and Tiling

After each Landsat ETM+ L1T acquisition is processed as above, the 30 meter TOA reflective bands, TOA NDVI, TOA brightness temperature bands, band saturation mask, the solar and viewing geometry, and the two cloud masks are reprojected from the L1T UTM coordinates to a continental map projection. The Albers Equal Area projection was selected for large areas that are mainly east-west oriented such as CONUS (Snyder, 1993), and was defined with standard parallels and central meridians to provide heritage with the USGS EROS National Land Cover Database (Homer et al. 2004, Chander et al. 2009b). Additional information on the reprojection, resampling, and tiling of WELD products can be found on page 17 of the ATBD.

### 3.1.8 Compositing

The WELD compositing logic is based on the selection of a "best" pixel over the compositing period. The WELD compositing logic is provided below. Each row reflects a comparison of two acquisitions of the same pixel. If the criterion in a row is not met, then the criterion in the row beneath is used, and this process is repeated until the last row. This implementation enables the composites to be updated on a per pixel basis shortly after the input ETM+ data are processed and regardless of the chronological processing order. For example, after 16 days, the same Albers pixel location may be sensed again, and the compositing criteria are used to decide if the more recent ETM+ pixel data should be allocated to overwrite the previous data. For each composited Albers pixel, the day of the year that the selected pixel was acquired on, and the number of different valid acquisitions considered at that pixel over the compositing period, are stored. Additional information on the WELD compositing logic can be found on page 19 of the ATBD.

*Table 4: WELD Compositing Logic*

| Priority | Compositing Criteria |
|---|---|
| 1 | If either fill: Select non-fill |
| 2 | If either saturated: Select unsaturated |
| 3 | If both saturated: Select the one with maximal Brightness Temperature |
| 4 | If one cloudy and one non-cloud: Select non-cloudy |
| 5 | If one cloudy and one uncertain cloud: Select uncertain cloud if it has maximal Brightness Temperature or maximal NDVI, else select cloudy |
| 6 | If one non-cloudy and one uncertain cloud: Select non-cloud if it has maximal Brightness Temperature or maximal NDVI, else select uncertain cloud |
| 7 | If either or both "unvegetated" and both have NDVI < 0.5: Select the one with maximal Brightness Temperature |
| 8 | Select the one with maximal NDVI |

### 3.1.9 Browse Generation

Browse images with reduced spatial resolution are generated from the weekly, monthly, seasonal and annual composited mosaics to enable synoptic product quality assessment with reduced data volume (Roy et al. 2002).

CONUS and Alaska browse images are generated in JPEG format with fixed contrast stretching and color look-up tables to enable consistent temporal comparison. Additional information on browse generation can be found on page 23 of the ATBD.

## 3.2 WELD Version 1.5 5 Year Land Cover Land Use Change Product Algorithm Description

The WELD Version 1.5 year Land Cover Land Use Change Products quantified forest cover loss and bare ground gain from 2006 to 2010 for CONUS at 30 meter spatial resolution using weekly WELD data products (M.C. Hansen et al. 2014). To generate this product, a bagged decision tree methodology based on the Classification and Decision Tree Methodology (CART) was implemented. Annual estimated land cover and land use change from 2006 to 2010 was also calculated. More information about this product can be found on the [WELD Version 1.5 LCLUC Product Page].

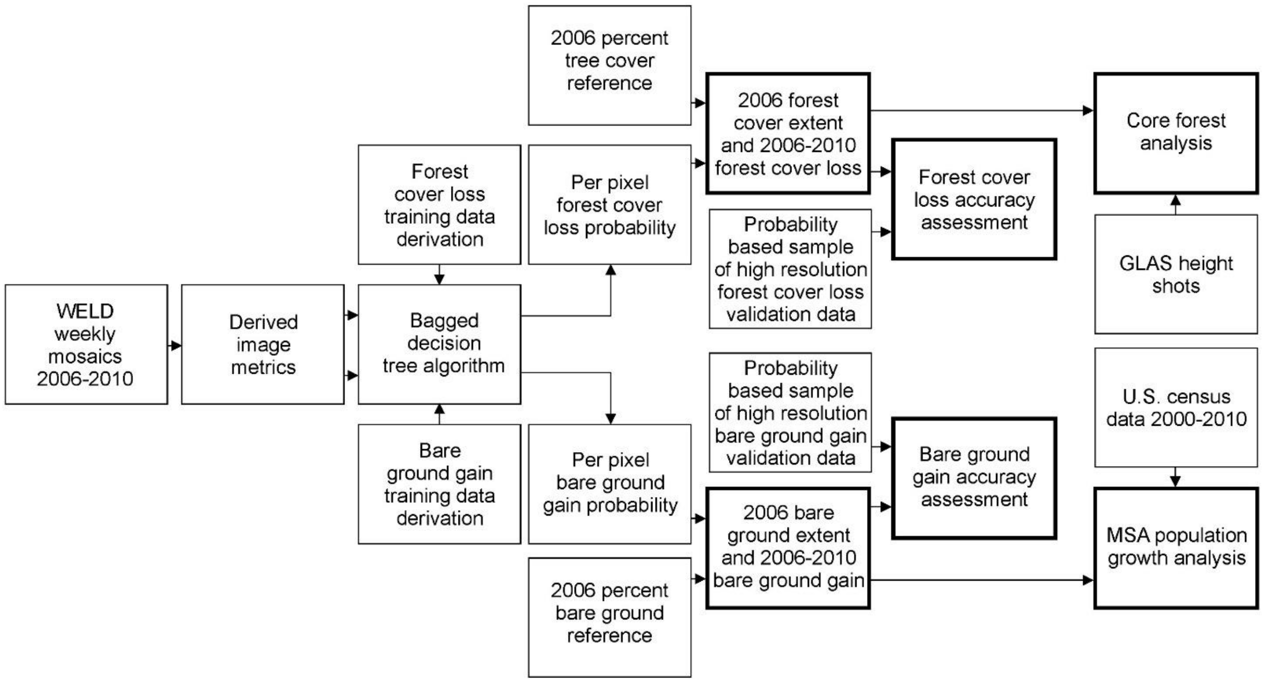


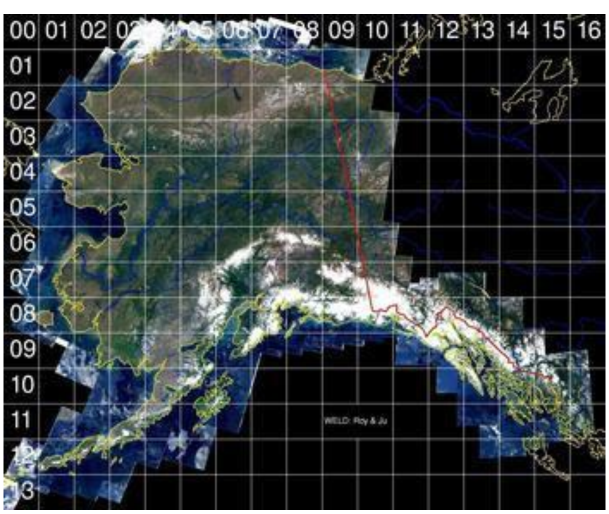

*Figure 1: WELD Version 1.5 5 Year Land Cover Land Use Change Product Analysis Flowchart (M.C. Hansen et al. 2014).*

# 4.0 Product Contents

## 4.1 File Format

The WELD data products are generated in HDF-4 format in separate 5,000 by 5,000 30 meter pixel tiles defined in the Albers Equal Area projection.

There are a total of 501 CONUS and 162 Alaskan tiles referenced using a two-digit horizontal and vertical tile coordinate system that is reflected in the HDF product filename.



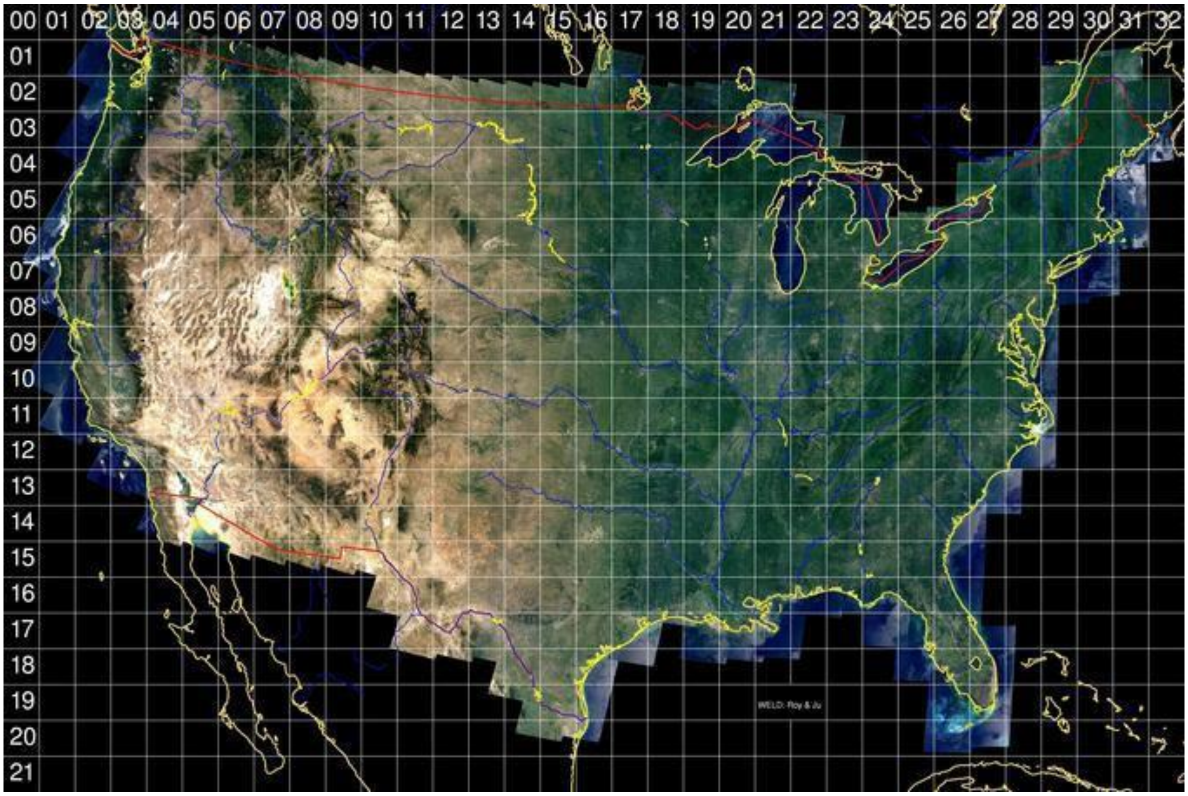



*Figure 2: WELD Product Tile Coordinate System across CONUS and Alaska*

### 4.1.1 WELD Version 1.5 Filename Convention

The file naming convention for WELD Version 1.5 products is provided below.

*Table 5: WELD HDF Product Filename Convention*

| **HDF Product Filename Convention** | | |
|---|---|---|
| **<*Region*>.<*Period*>.<*Year*>.h<*xx*>v<*yy*>.doy<*min DOY*>to<*max DOY*>.v<*Version Number*>.hdf** | | |
| | **Valid Range** | **Notes** |
| <Region> | CONUS / Alaska | |
| <Period> | annual,<br><br>spring/summer/autumn/winter,<br><br>month01/month02/, …,/month12,<br><br>week01/week02/, …, /week52/week53 | Annual products are generated from a year of data sensed from December 1 of the previous year to November 30 of the current year.<br><br>The standard seasonal definition adopted by the climate modeling community is used where winter is defined by the months: December, January, and February.<br><br>Week01 = January 1 to January 7,<br>Week02 = January 8 to January 14<br>Week52 = December 24 to December 30 (non-leap years) or December 23 to December 29 (leap years) |

| | | |
|---|---|---|
| | | Week53 = December 30 to December 31 (leap years) or December 31 (non-leap years). |
| <Year> | 2005, 2006, 2007, ..., 2012 | |
| <xx> | 00, 01, ..., 32 (CONUS) or<br>00, 01, ..., 16 (Alaska) | Horizontal WELD tile coordinate. |
| <yy> | 00, 01, ..., 21 (CONUS) or<br>00, 01, ..., 13 (Alaska) | Vertical WELD tile coordinate. |
| <min DOY> | 001, 002, …, 366 | Minimum non-fill Day_Of_Year pixel value present in the tile. |
| <max DOY> | 001, 002, …, 366 | Maximum non-fill Day_Of_Year pixel value present in the tile. |
| <Version Number> | 1.1, 1.3, …, 2.0, 2.1, 2.2, … | Major and minor algorithm version changes reflected in the first and second digits, respectively. |

In addition, for each WELD tile there is a corresponding static file that contains the geographic latitude and longitude for the center of each 30 meter pixel (decimal degrees, scale factor 1, data type double, datum WGS84):

Alaska.latlon.h<*xx*>v<*yy*>.v<*Version Number*>.hdf

CONUS.latlon.h<*xx*>v<*yy*>.v<*Version Number*>.hdf

### 4.1.2 WELD LCLUC Version 1.5 Products Filename Convention

The filename convention for WELD LCLUC Version 1.5 products is provided below.

*Table 6: WELD LCLUC HDF Product Filename Convention*

| **WELD LCLUC HDF Product Filename Convention** | | |
|---|---|---|
| **<Region>.<Period>.<StartYear>to<EndYear>.h<xx>v<yy>.lcluc.v<WELD Version Number>.hdf**<br>e.g. CONUS.5year.2006to2010.h29v01.lcluc.v1.5.hdf | | |
| | **Valid Range** | **Notes** |
| <Region> | CONUS | Only conterminous United States products are available currently. |
| <Period> | 5 year | Product made from 5 years of consecutive WELD inputs. |
| <Start Year> | 2006 | Start Year generated from growing season 2006 inputs. |
| <End Year> | 2010 | End year generated from growing season 2010 inputs. |
| <xx> | 00, 01, ..., 32 | Horizontal WELD tile coordinate. |
| <yy> | 00, 01, ..., 21 | Vertical WELD tile coordinate. |
| <WELD Version Number> | 1.5, 1.6... 2.0, 2.1... | Product version number. Major and minor algorithm version changes reflected in the first and second digits, respectively. |

## 4.2 Product Map Projections

The CONUS and Alaskan products are in Albers Equal Area projection. The CONUS and Alaskan products are defined with the following map projection parameters.

*Table 7: WELD Product Projection Parameters*

| **WELD Product Projection Parameters** | | |
|---|---|---|
| **Projection:** Albers Equal Area | | |
| **Datum:** World Geodetic System 84 (WGS84) | | |
| | **CONUS** | **Alaska** |
| First standard parallel | 29.5° | 55.0° |
| Second standard parallel | 45.5° | 65.0° |
| Longitude of central meridian | -96.0° | -154.0° |
| Latitude of projection origin | 23.0° | 50.0° |
| False Easting | 0.0 | 0.0 |
| False Northing | 0.0 | 0.0 |

## 4.3 Scientific Data Sets (SDS) Layers

### 4.3.1 WELD Version 1.5 Product SDS Layers

The contents of each HDF product tile have 14 bands storing the information described below.

*Table 8: WELD Version 1.5 Product SDS Layers*

| **WELD Version 1.5 Product Contents** | | | | | | |
|---|---|---|---|---|---|---|
| **Band Name** | **Data Type** | **Valid Range** | **Scale factor** | **Units** | **Fill Value** | **Notes** |
| Band1_TOA_REF | int16 | -32767 – 32767 | 0.0001 | unitless | -32768 | Top of atmosphere (TOA) reflectance and brightness temperature (BT) are computed using standard formulae and calibration coefficients associated with each ETM+ acquisition. Band 6 brightness temperature data are resampled to 30 m. The conventional ETM+ band numbering scheme is used. |
| Band2_TOA_REF | int16 | -32767 – 32767 | 0.0001 | unitless | -32768 | |
| Band3_TOA_REF | int16 | -32767 – 32767 | 0.0001 | unitless | -32768 | |
| Band4_TOA_REF | int16 | -32767 – 32767 | 0.0001 | unitless | -32768 | |
| Band5_TOA_REF | int16 | -32767 – 32767 | 0.0001 | unitless | -32768 | |
| Band61_TOA_BT | int16 | -32767 – 32767 | 0.01 | Degrees Celsius | -32768 | |
| Band62_TOA_BT | int16 | -32767 – 32767 | 0.01 | Degrees Celsius | -32768 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Band7_TOA_REF | int16 | -32767 – 32767 | 0.0001 | unitless | -32768 | |
| NDVI_TOA | int16 | -10000 – 10000 | 0.0001 | unitless | -32768 | Normalized Difference Vegetation Index (NDVI) value generated from Band3_TOA_REF and Band4_TOA_REF. |
| Day_Of_Year | int16 | 1 – 366 | 1 | Day | 0 | Day of year the selected ETM+ pixel was acquired. Note (a) days 1-334 (or 1-335) were sensed in January-November of the non-leap (or leap) current year; (b) days 335-365 (or 336-366) were sensed in December of the non-leap (or leap) previous year; (c) in the annual composite of a leap year, day 335 always means November 30. |
| Saturation_Flag | uint8 | 0 – 255 | 1 | unitless | None | The least significant bit to the most significant bit corresponds to bands 1, 2, 3, 4, 5, 61, 62, 7; with a bit set to 1 signifying saturation in that band and 0 not saturated. |
| DT_Cloud_State | uint8 | 0, 1, 2, 200 | 1 | unitless | 255 | Decision Tree Cloud Classification, 0 = not cloudy, 1 = cloudy, 2 = not cloudy but adjacent to a cloudy pixel, 200 = could not be classified reliably. |
| ACCA_State | uint8 | 0, 1 | 1 | unitless | 255 | ACCA Cloud Classification, 0 = not cloudy, 1 = cloudy. |
| Num_Of_Obs | uint8 | 0 – 255 | 1 | unitless | None | Number of ETM+ observations considered over the compositing period. |

### 4.3.2 WELD Version 1.5 LCLUC Product SDS Layers

The contents of each HDF product tile have 12 bands storing the information described below.

*Table 9: WELD Version 1.5 5 Year Land Cover Land Use Change Product SDS Layers*

| **WELD LCLUC Version 1.5 Product Contents** | | | | | | |
|---|---|---|---|---|---|---|
| **Band Name** | **Data Type** | **Valid Range** | **Scale factor** | **Units** | **Fill Value** | **Notes** |
| LCLUC_TREE_COVER | uint8 | 0 – 100 | 1 | percent | 255 | Peak growing season Tree Canopy cover per 30 m pixel (0-100%) estimated over 5 annual growing seasons. |
| LCLUC_TREE_COVER_DQAPRO | uint8 | 0 – 4 | - | level of confidence | 255 | The Data Quality Assessment layer for tree cover, estimating the level of confidence for tree/no-tree classification where 0 = high confidence trees or no trees, 1 = medium confidence trees, 2 = low confidence trees or no trees, 3 = medium confidence no trees, and 4 = no confidence |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | / no decision. |
| LCLUC_TREE_COVER_DQASTD | uint8 | 0 – 100 | 1 | percent | 255 | The Data Quality Assessment layer for Tree Canopy cover: For 25 regression trees applied per pixel, the mean of the per node standard deviations. |
| LCLUC_BARE_GROUND | uint8 | 0 – 100 | 1 | percent | 255 | Peak growing season Bare Ground cover per 30 m pixel (0-100%) estimated over 5 annual growing seasons. |
| LCLUC_BARE_GROUND_DQASTD | uint8 | 0 – 100 | 1 | percent | 255 | The Data Quality Assessment layer for Bare Ground cover: For 25 regression trees applied per pixel, the mean of the per node |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | standard deviations. |
| LCLUC_WATER_SURFACE | uint8 | 0 – 100 | 1 | percent | 255 | Growing season Water Surface cover per 30 m pixel (0-100%) estimated over 5 annual growing seasons. |
| LCLUC_WATER_SURFACE_DQAPRO | uint8 | 0 – 4 | - | level of confidence | 255 | The Data Quality Assessment layer for water surface, estimating the level of confidence for water/land classification where 0 = high confidence water or land, 1 = medium confidence water 2 = low confidence water or land, 3 = medium confidence land, and 4 = no confidence / no decision. |
| LCLUC_SNOW_AND_ICE | uint8 | 0 – 100 | 1 | percent | 255 | Growing season Snow and Ice cover per 30 m pixel (0- |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | 100%) estimated over 5 annual growing seasons. |
| LCLUC_SNOW_AND_ICE_DQAPRO | uint8 | 0 – 4 | - | level of confidence | 255 | The Data Quality Assessment layer for snow and ice, estimating the level of confidence for snow and ice / no snow and ice classification where 0 = high confidence snow and ice or no snow and ice, 1 = medium confidence snow and ice 2 = low confidence snow and ice and no snow and ice, 3 = medium confidence no snow and ice, and 4 = no confidence / no decision. |
| LCLUC_NUMBER_OF_GOOD_ACQUISITIONS | uint8 | 0 – 254 | 1 | number of acquisitions | 255 | Number of good (not cloudy) acquisitions over 5 annual growing seasons |

| | | | | | | |
|---|---|---|---|---|---|---|
| LCLUC_TREE_COVER_LOSS | int16 | 0,6017 – 10046 | - | coded date | -32768 | Forest loss (yes or no) and bare ground gain (yes or no) over the 5 year period. 0 represents no forest loss and no bare ground gain over the 5 year period. Positive values store the week of the detected forest loss or bare ground gain where the thousands place represents the year of the 2000 decade and tens represents the week within the given year (e.g., 8034 represents year 2008, week 34). |
| LCLUC_BARE_GROUND_GAIN | int16 | 0,6017 – 10046 | - | coded date | -32768 | |

## 5.0 Product Quality

For complete and updated information regarding product quality, see the WELD ATBD.

## 5.1 Known Issues

### 5.1.1 Pixel Alignment

The Albers coordinates of the WELD pixels have a sub-pixel misalignment with the Albers coordinates defining the U.S. National Land Cover Database. The WELD Albers projection origin does not fall perfectly at a WELD product pixel center. For example, the CONUS projection origin is in horizontal tile 17, vertical tile 22 at column 520.000, row 493.333, and the Alaska projection origin is in horizontal tile 5, vertical tile 16 at column 3390.000, row 2478.333 (where column 0.5, row 0.5 refers to the center of the NW pixel of a tile). This issue will be rectified in the next WELD product version.

### 5.1.2 Missing June 2003 Data

The Landsat 7 ETM+ Scan Line Corrector failed May 31, 2003, and reduced the amount of available data in each ETM+ acquisition by about 22%. For operational reasons after this failure, no Landsat 7 ETM+ L1T data were generated for nearly a 5 week period. Consequently, the June 2003 monthly product and the weekly products for Week 23, 24, 25, 26 and 27 in 2003 are all fill values (i.e, no data). More information about the failure can be found at: http://landsat.usgs.gov/products_slcoffbackground.php.

### 5.1.3 2007 and 2010 Product Mixed 30 Meter Thermal Band Resolution Issue

Since February 26, 2010, the Landsat L1T data have been produced at USGS EROS with the 60 meter thermal bands resampled to 30 meters (resampling applied in the L0 to L1T processing at USGS). Prior to February 26, 2010, the WELD product thermal bands were generated at 30 meters as part of the WELD processing using a different nearest neighbor resampling methodology. As a consequence, the 30 meter thermal bands for the 2007 and 2010 annual WELD data products were generated from L1T data processed with both methodologies. The impact of this mixed thermal bandresolution issue is thought to be minimal.

### 5.1.4 2010 Summer and Annual Composite (Central Iowa, SE Minnesota, Wisconsin)

Due to unusually cloudy conditions at the time of Landsat 7 ETM+ overpass for a single Landsat path over central Iowa, southeast Minnesota, and west-central Wisconsin, the 2010 Summer WELD data product is cloudy and the 2010 Annual WELD data product does not include summer observations in this locality.

### 5.1.5 Extent of Alaska

Because of the scarcity of Landsat 7 ETM+ acquisitions over the islands off the Alaskan west coast, many western islands are not included in the Version 1.5 Alaska WELD products. More of these Aleutian Islands are being considered for inclusion in the next WELD product version.

### 5.1.6 New Version GDAL Utilities Are Unable to Read HDF Tile Information for Certain WELD Product Years

GDAL Version 1.8.1 is unable to read certain 2007-2009 CONUS and Alaska products and unable to read all years of the weekly Alaska products. Earlier versions, such as GDAL 1.4.2, do not have this problem.

### 5.1.7 GDAL Utilities in Ubuntu Operating System Are Unable to Read HDF Tile Information for Certain WELD Product Years

This issue is currently under investigation. It occurs for product years 2006-2009 only; we suspect that it is caused by a production system library incompatibility.

### 5.2 Improvements on Previous Versions

- Improved compositing algorithm
- Atmospheric correction of the top of atmosphere reflectance bands
- Radiometric normalization of the reflectance to nadir view and fixed solar zenith angle

### 5.3 Accuracy/Consistency

No formal assessment of the WELD product accuracy/consistency has been undertaken. This is planned for the Version 2.0 products.

## 6.0 Data Ordering

### 6.1 LP DAAC Data Access

The following tools offer options to search the LP DAAC data holdings and provide access to the data:

Bulk download: LP DAAC Data Pool and DAAC2Disk
Search and browse: USGS EarthExplorer and NASA Earthdata Search
Subset and explore: AppEEARS

### 6.2 Software Tools

Please refer to the GWELD User Guide for information on software tools.

### 6.3 Citations

If you wish to cite the WELD products in a report or publication please cite using the product's DOI that is listed in section 2.1.2 for WELD Version 1.5 products and in section 2.2.1 for WELD LCLUC Version 1.5 products.

In addition to citing the dataset with the product DOI, please include these additional citations:

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.

Citation for the LCLUC Version 1.5 product:

Hansen, M.C., Egorov, A., Potapov, P.V., Stehman, S.V., Tyukavina, A., Turubanova, S.A., Roy, D.P., Goetz, S.J., Loveland, T.R., Ju, J., Kommareddy, A., Kovalskyy, V., Forsythe, C., Bents, T., 2014, Monitoring conterminous United States (CONUS) land cover change with Web-Enabled Landsat Data (WELD), Remote sensing of Environment, 140, 466-484

If you use a WELD product generated graphic or browse image, please insert the text "WELD" somewhere that is clearly visible.

## 7.0 References

Chander, G., Huang, C., Yang, L., Homer, C., & Larson, C. (2009a). Developing consistent Landsat data sets for large area applications: The MRLC 2001 protocol. *IEEE Transactions on Geoscience and Remote Sensing*, 6, 777-781.

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