

Department of the Interior
U.S. Geological Survey

Landsat Collection 2 (C2) Level 3 (L3) Dynamic Surface Water Extent (DSWE) Algorithm Description Document (ADD)

Version 1.0

January 2022



Landsat Collection 2 (C2) Level 3 (L3) Dynamic Surface Water Extent (DSWE) Algorithm Description Document (ADD)

January 2022

Document Owner:

CHRISTOPHER
ENGEBRETSON

Digitally signed by
CHRISTOPHER ENGEBRETSON
Date: 2022.01.26 14:38:26
-06'00'

Chris Engebretson
Landsat DPAS CCB Chair
U.S. Geological Survey

Date

EROS
Sioux Falls, South Dakota

Executive Summary

This Algorithm Description Document (ADD) defines the algorithms used for the creation of Landsat Collection 2 (C2) Level 3 (L3) Dynamic Surface Water Extent (DSWE) data products at the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center.

This document is under Data Processing and Archive System (DPAS) 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 LSDS CCB Process and Change Management Tool.

Document History

Document Number	Document Version	Publication Date	Change Number
LSDS-2084	Version 1.0	January 2022	CR 20895

Contents

Executive Summary	iii
Document History	iv
Contents.....	v
List of Figures	vi
List of Tables	vi
Section 1 Introduction.....	1
1.1 Background.....	1
1.2 Purpose and Scope	1
1.3 Document Organization	1
Section 2 Dynamic Surface Water Extent Algorithm Details	2
2.1 Dynamic Surface Water Extent Details	2
2.2 Dynamic Surface Water Extent Inputs	2
2.3 Dynamic Surface Water Extent Outputs	2
2.4 Dynamic Surface Water Extent Flow Diagram	3
Section 3 Dynamic Surface Water Extent Algorithm Procedure	4
3.1 Get Arguments.....	4
3.2 Land Cover Mask Band (LCMASK)	4
3.3 Hillshade (SHADE)	6
3.4 Hillshade Mask (OTSU)	6
3.5 Diagnostic Tests (DIAG)	7
3.6 Recode to Interpreted DSWE (INTR).....	9
3.7 Interpreted with Some Masks Applied (INTSM)	10
3.8 Interpreted with All Masks Applied (INWAM)	11
3.9 Mask (MASK).....	11
Section 4 Citation Information.....	13
Appendix A DSWE Algorithm Static Inputs	14
Appendix B Acronyms.....	15
References	16

List of Figures

Figure 2-1. Dynamic Surface Water Extent Flow Diagram	3
---	---

List of Tables

Table 2-1. Dynamic Surface Water Extent Algorithm Inputs	2
Table 2-2. Dynamic Surface Water Extent Algorithm Outputs.....	3
Table 3-1. DSWE Land Cover Mask Schema	6
Table 3-2. INTSM Masking Actions	11

Section 1 Introduction

1.1 Background

The Dynamic Surface Water Extent (DSWE) algorithm produces raster files that indicate whether surface water is present for each pixel in a Landsat scene. The original algorithm was created by John Jones at the U.S. Geological Survey (USGS) Eastern Geographic Science Center and implemented by USGS Earth Resources Observation and Science (EROS) Center. It was designed to be globally applicable by limiting required inputs to Surface Reflectance (SR) data generated from Landsat satellites and a digital elevation model. And, while it has been implemented by many organizations worldwide through a variety of hardware/software configurations, the USGS operational implementation of DSWE at EROS is restricted to the U.S. because EROS only produces it using Landsat U.S. Analysis Ready Data (ARD) as the surface reflectance input. Given the opportunity presented by Landsat Collection 2 U.S. ARD processing, and the fact that USGS DSWE production is limited to the U.S., the algorithm was revised at the USGS Hydrologic Remote Sensing Branch to use U.S.-specific auxiliary inputs to reduce errors uncovered through extensive DSWE data evaluation and use. This document describes the revised DSWE algorithm, termed C2 DSWE.

1.2 Purpose and Scope

The primary purpose of this document is to provide technical information on the C2 DSWE algorithm's function.

1.3 Document Organization

This document contains the following sections:

- Section 1 introduces C2 DSWE
- Section 2 provides technical details on the inputs and outputs of C2 DSWE
- Section 3 provides details on the C2 DSWE algorithm procedures
- Section 4 provides citation information
- Appendix A provides information specific to the C2 DSWE algorithm auxiliary inputs
- Appendix B contains a list of acronyms
- The References section contains a list of reference documents and supporting webpages

Section 2 Dynamic Surface Water Extent Algorithm Details

2.1 Dynamic Surface Water Extent Details

The DSWE algorithm is designed to detect both open water and water in areas where vegetation or soils are mixed with the water at Landsat pixel resolution.

The algorithm is currently applied to Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) products.

The DSWE algorithm involves the following steps:

1. Pre-process the input elevation data to produce a terrain shadow mask.
2. Apply 5 independent tests to each pixel to detect water.
3. Recode the initial test results to categories that indicate the likelihood of water.
4. Filter the likelihood of water output using land cover/terrain-shadow based masking.
5. Label clouds and cloud shadows in the land cover/terrain shadow masked version depending on cloud/cloud shadow presence indicated in the Level 2 Pixel Quality Assessment (QA) band.
6. Create a band showing what masking was applied to water likelihood pixels.

2.2 Dynamic Surface Water Extent Inputs

Table 2-1 lists the inputs for the DSWE algorithm.

Description	Purpose
Landsat Surface reflectance	Reflectance, band ratios, and spectral indices (MNDWI, MBSRV, MBSRN, AWESH, NDVI) used for independent water detection tests.
Landsat Level 2 pixel QA (QA_PIXEL)	Used for identifying cloudy pixels classified from CFMask
Elevation data	Used to create the terrain shadow
Land cover mask	Used to filter the commission error in likelihood of water
<i>MNDWI = Modified Normalized Difference Wetness Index, MBSRV = Multi-band Spectral Relationship Visible, MBSRN = Multi-band Spectral Relationship Near-Infrared, NDVI = Normalized Difference Vegetation Index</i>	

Table 2-1. Dynamic Surface Water Extent Algorithm Inputs

2.3 Dynamic Surface Water Extent Outputs

Table 2-2 lists the outputs of the DSWE algorithm.

Description	Units	Type
Diagnostic band showing the results of each of the 5 water tests on a per-pixel basis	Flag	16-bit integers
Interpreted band with each pixel assigned to a water category	Flag	unsigned 8-bit integers
Interpreted band with land cover and terrain shadow masking applied	Flag	unsigned 8-bit integers
Interpreted, land cover/terrain shadow masked band with cloud/cloud shadow masks applied	Flag	unsigned 8-bit
Bit-packed mask band indicating why each masked pixel is masked	Flag	unsigned 8-bit integers
Hillshade intermediate results	N/A	unsigned 8-bit integers

Table 2-2. Dynamic Surface Water Extent Algorithm Outputs

2.4 Dynamic Surface Water Extent Flow Diagram

Figure 2-1 shows the overall flow diagram of the C2 DSWE algorithm.

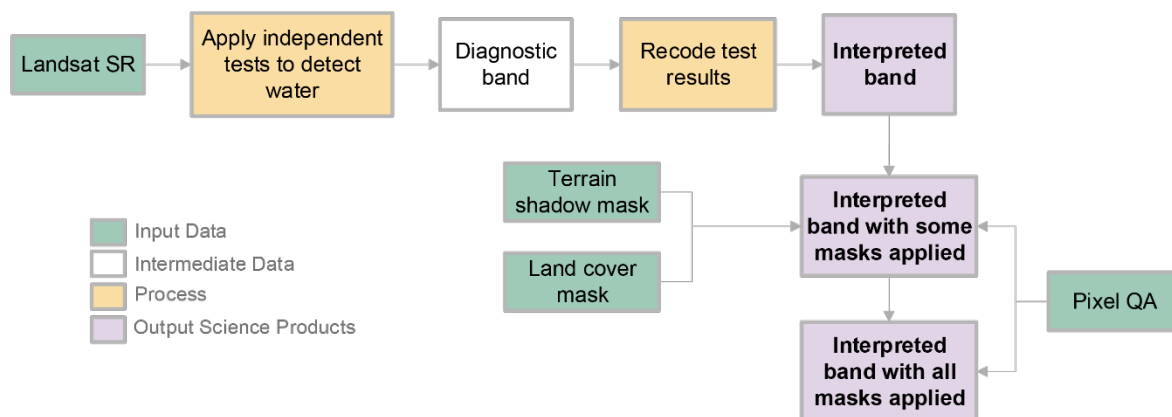


Figure 2-1. Dynamic Surface Water Extent Flow Diagram

Section 3 Dynamic Surface Water Extent Algorithm Procedure

The DSWE algorithm procedure contains several steps that are defined in the following sections.

3.1 Get Arguments

The DSWE algorithm is controlled by several thresholds (tolerance values). Given the calibration of all inputs to at-surface reflectance, the default thresholds are the same for Landsat 4, Landsat 5, Landsat 7, and Landsat 8.

Thresholds

- Wigt: Modified Normalized Difference Wetness Index (MNDWI) Threshold
- Awgt: Automated Water Extent Shadow Threshold
- pswt_1_mndwi: Partial Surface Water Test-1 MNDWI Threshold
- pswt_1_nir: Partial Surface Water Test-1 NIR Threshold
- pswt_1_swir1: Partial Surface Water Test-1 SWIR1 Threshold
- pswt_1_ndvi: Partial Surface Water Test-1 NDVI Threshold
- pswt_2_mndwi: Partial Surface Water Test-2 MNDWI Threshold
- pswt_2_blue: Partial Surface Water Test-2 Blue Threshold
- pswt_2_nir: Partial Surface Water Test-2 NIR Threshold
- pswt_2_swir1: Partial Surface Water Test-2 SWIR1 Threshold
- pswt_2_swir2: Partial Surface Water Test-2 SWIR2 Threshold
- lcmask_nir: Land Cover Mask based test NIR threshold.

3.2 Land Cover Mask Band (LCMASK)

Inputs

1. NLCD
2. LCMAP-LCPRI

Outputs

1. LCMASK band

Description

The land cover mask (LCMASK) is used to reduce errors either through direct masking or control of additional testing and the application of hillshade-based shadow masking. The LCMASK layer was created by combining the USGS National Land Cover Database (NLCD) and Land Change Monitoring, Assessment and Project (LCMAP) Primary Land Cover (LCPRI) data.

The NLCD provides LCMASK land cover categories relevant to masking. Locations in any NLCD epoch that have been labeled as Evergreen Forest (42) or Shrub/Scrub (52) are labeled the same in LCMASK. Locations in any NLCD epoch that have been labeled as open water (11), woody wetlands (90) or emergent herbaceous wetlands (95) are

labeled as class 25000 in LCMASK. The annual LCPRI data determine the LCMASK class values given land development. The result indicates the year of land conversion from any class to Developed, Open Space; Developed, Low Intensity; and Developed, medium intensity. The year of development multiplied by 10 and incremented by 1 indicates the year a pixel was converted from an undeveloped land cover class to Developed, High Intensity. Finally, all other locations, that is those which have not been labeled as any of the preceding values, receive a value of 30000. The entire schema for the period 1982 – present is indicated in Table 3-1. Note that DSWE input data from years preceding 1985 assume the development conditions depicted for 1985.

YEAR	Evergreen Forest	Shrub/Scrub	Developed	Developed High Intensity	Water or Wetland	Other
1985	42	52	1985	19851	25000	30000
1986	42	52	1986	19861	25000	30000
1987	42	52	1987	19871	25000	30000
1988	42	52	1988	19881	25000	30000
1989	42	52	1989	19891	25000	30000
1990	42	52	1990	19901	25000	30000
1991	42	52	1991	19911	25000	30000
1992	42	52	1992	19921	25000	30000
1993	42	52	1993	19931	25000	30000
1994	42	52	1994	19941	25000	30000
1995	42	52	1995	19951	25000	30000
1996	42	52	1996	19961	25000	30000
1997	42	52	1997	19971	25000	30000
1998	42	52	1998	19981	25000	30000
1999	42	52	1999	19991	25000	30000
2000	42	52	2000	20001	25000	30000
2001	42	52	2001	20011	25000	30000
2002	42	52	2002	20021	25000	30000
2003	42	52	2003	20031	25000	30000
2004	42	52	2004	20041	25000	30000
2005	42	52	2005	20051	25000	30000
2006	42	52	2006	20061	25000	30000
2007	42	52	2007	20071	25000	30000
2008	42	52	2008	20081	25000	30000
2009	42	52	2009	20091	25000	30000
2010	42	52	2010	20101	25000	30000
2011	42	52	2011	20111	25000	30000
2012	42	52	2012	20121	25000	30000
2013	42	52	2013	20131	25000	30000
2014	42	52	2014	20141	25000	30000
2015	42	52	2015	20151	25000	30000

YEAR	Evergreen Forest	Shrub/Scrub	Developed	Developed High Intensity	Water or Wetland	Other
2016	42	52	2016	20161	25000	30000
2017	42	52	2017	20171	25000	30000
2018	42	52	2018	20181	25000	30000
2019	42	52	2019	20191	25000	30000

Table 3-1. DSWE Land Cover Mask Schema

Thus, a single band provides time variant information on land cover change for classes that impact DSWE water detection performance. And the coding scheme allows annual update using combinations of yet-to-be developed NLCD and LCMAP data products through the year 2499.

3.3 Hillshade (SHADE)

Inputs

1. Elevation band
2. Solar zenith angle band
3. Solar azimuth angle band

Outputs

1. Hillshade (shaded relief) band

Description

The hillshade algorithm uses Digital Elevation Model (DEM) input to produce an image structure representing the extent of terrain-produced shadow for each pixel. For C2 DSWE, Sun elevation and azimuth for the observation date and location are estimated by averaging the per-pixel values provided in the input Landsat U.S. ARD tile to determine the source location of light casting shadows. These values are applied to DEM data clipped to the entire area of the U.S. ARD tile, regardless of Landsat image coverage within the tile area.

The algorithm uses Horn's algorithm to calculate slope (Horn, 1981). Then aspect and finally shaded relief are calculated. The algorithm takes a 3x3 elevation window as input while shaded relief is calculated across the pixels in the DEM. The algorithm computes relief for the outermost rows and columns of the ARD tile where the 3x3 elevation window isn't complete by extrapolating the existing values in the 3x3 window to fill the missing values. The shade values for each pixel are first calculated in the range 0.0 to 1.0, and are then scaled to a 1 to 255 range and converted to integer.

3.4 Hillshade Mask (OTSU)

Inputs

1. Hillshade

2. Otsu candidate tiles database

Outputs

1. Hillshade (OTSU) mask band

Description

The Otsu method of automatic binary thresholding is used to classify the hillshade layer into two classes: shaded and not shaded (Otsu, 1979). Depending on location, this output is used to reduce false positives caused by darker surface reflectance in terrain shaded areas. Pixels are either in shaded areas (0) or not shaded (1). The Otsu method is statistically based and performs best where distinct bimodal frequency distributions are present in a grayscale image. This is difficult to achieve given hillshade results in flat or undulating, but not rugged terrain. Statistics on a digital elevation model and its derivatives were analyzed to distinguish which tiles in the Conterminous U.S. (CONUS) and Alaska regions should have OTSU thresholding applied. A database was developed for each region and serves as the guide for OTSU threshold processing.

3.5 Diagnostic Tests (DIAG)

Inputs

1. Scaled Surface Reflectance bands
 - Blue band
 - Green band
 - Red band
 - NIR band
 - SWIR1 band
 - SWIR2 band

Outputs

1. Diagnostic test band

Description

The diagnostic tests phase performs several tests on the input bands. The following indices are calculated for each non-fill pixel based on the input bands:

1. Modified Normalized Difference Wetness Index (MNDWI) = $(\text{green} - \text{SWIR1}) / (\text{green} + \text{SWIR1})$
2. Multi-band Spectral Relationship Visible (MBSRV) = $\text{green} + \text{red}$
3. Multi-band Spectral Relationship Near-Infrared (MBSRN) = $\text{NIR} + \text{SWIR1}$
4. Automated Water Extent Shadow (AWESH) = $\text{blue} + (2.5 * \text{green}) - (1.5 * \text{MBSRN}) - (0.25 * \text{SWIR2})$
5. Normalized Difference Vegetation Index (NDVI) = $(\text{NIR} - \text{red}) / (\text{NIR} + \text{red})$

Five diagnostic tests are then performed for each pixel using these indices and several threshold values. The result of each test is assigned to a decimal place (1, 10, 100, etc.).

Test 1: Compare MNDWI to the wigt Wetness Index threshold, where the threshold ranges from 0.0 to 2.0 and is defaulted to a value of 0.124.

```
if (mndwi > wigt) set the ones digit (Example 00001)
```

Test 2: Compare the MBSRV and MBSRN values to each other.

```
if (mbsrv > mbsrn) set the tens digit (Example 00010)
```

Test 3: Compare AWESH to the awgt Automated Water Extent Shadow threshold, where the threshold ranges from -2.0 to 2.0 and is defaulted to a value of 0.0.

```
if (awesh > awgt) set the hundreds digit (Example 00100)
```

Test 4: Compare the MNDWI and NDVI along with the NIR and SWIR1 bands to the following thresholds.

- Partial Surface Water Test-1 MNDWI (pswt_1_mndwi) threshold, where the threshold ranges from -2.0 to 2.0 and is defaulted to a value of -0.44.
- Partial Surface Water Test-1 SWIR1 (pswt_1_swir1) threshold, where the threshold ranges from 0 to data maximum and is defaulted to a value of 0.0900.
- Partial Surface Water Test-1 NIR (pswt_1_nir) threshold, where the threshold ranges from 0 to data maximum and is defaulted to a value of 0.15.
- Partial Surface Water Test-1 NDVI (pswt_1_ndvi) threshold, where the threshold ranges from 0 to 2.0 and is defaulted to a value of 0.7.

```
if (mndwi > pswt_1_mndwi
    && SWIR1 < pswt1_1_swir1
    && NIR < pswt_1_nir
    && NDVI < pswt_1_ndvi)
    set the thousands digit (Example 01000)
```

Test 5: Compare the MNDWI along with the Blue, NIR, SWIR1, and SWIR2 bands to the following thresholds.

- Partial Surface Water Test-2 MNDWI (pswt_2_mndwi) threshold, where the threshold ranges from -2.0 to 2.0 and is defaulted to a value of -0.5.
- Partial Surface Water Test-2 Blue (pswt_2_blue) threshold, where the threshold ranges from 0 to data maximum and is defaulted to a value of 0.1000.
- Partial Surface Water Test-2 NIR (pswt_2_nir) threshold, where the threshold ranges from 0 to data maximum and is defaulted to a value of 0.2500.
- Partial Surface Water Test-2 SWIR1 (pswt_2_swir1) threshold, where the threshold ranges from 0 to data maximum and is defaulted to a value of 0.3000.
- Partial Surface Water Test-2 SWIR2 (pswt_2_swir2) threshold, where the threshold ranges from 0 to data maximum and is defaulted to a value of 0.1000.

```

if (mndwi > pswt_2_mndwi
    && Blue < pswt_2_blue
    && SWIR1 < pswt_2_swir1
    && SWIR2 < pswt_2_swir2
    && NIR < pswt_2_nir)
    set the ten-thousands digit (Example 10000)

```

3.6 Recode to Interpreted DSWE (INTR)

Inputs

1. Diagnostic tests band

Outputs

1. Interpreted DSWE band

Description

The diagnostic tests band gives a five-digit decimal output where each digit is either 0 or 1, representing the results of the five diagnostic tests. The results of the five tests are recoded to an interpreted class DSWE band.

The interpreted class DSWE band has the following possible values:

```

0 -> Not Water
1 -> Water - High Confidence
2 -> Water - Moderate Confidence
3 -> Potential Wetland
4 -> Low Confidence Water or Wetland
255 -> Fill (no data)

```

The following translation is performed to recode from the diagnostic test values to the interpreted class values:

```

00000 : 0 (Not Water)
00001 : 0
00010 : 0
00100 : 0
01000 : 0

01111 : 1 (Water - High Confidence)
10111 : 1
11011 : 1
11101 : 1
11110 : 1
11111 : 1

```

```

00111 : 2 (Water - Moderate Confidence)
01011 : 2
01101 : 2
01110 : 2
10011 : 2
10101 : 2
10110 : 2
11001 : 2
11010 : 2
11100 : 2

11000 : 3 (Partial Surface Water - Conservative)

00011 : 4 (Partial Surface Water - Aggressive)
00101 : 4
00110 : 4
01001 : 4
01010 : 4
01100 : 4
10000 : 4
10001 : 4
10010 : 4
10100 : 4

255 : 255 (Fill)

```

3.7 Interpreted with Some Masks Applied (INTSM)

Inputs

1. Interpreted band
2. Near-Infrared Surface Reflectance band
3. Pixel QA band
4. OTSU band
5. LCMASK band

Outputs

1. INTSM filtered interpreted band

This step starts with the interpreted band (INTR) and applies the terrain shadow and land cover-based masking or an additional reflectance-based test. The OTSU mask band is applied depending on the DSWE tile location and LCMASK value. For pixels in Evergreen Forest or Shrub/scrub prevalent as well as Developed, Open Space through Medium Intensity locations at the time of DSWE input image collection, an additional test is applied depending on the DSWE INTR value. And for LCMASK locations/time periods where Developed, High Intensity, all INTR water values are masked. Also, the algorithm checks the pixel QA band and labels locations noted as 'snow' in the QA band as 'not water'. Table 3-2 shows the actions associated with INTSM band production.

Band	Value	INTR Value	First Action	Second Action	Third Action	Result
OTSU	1	1-4	None	None	None	Water
	0	1-4	Check LCMASK	LCMASK != 25000, mask	None	Not Water
LCMASK	42	3 or 4	Check NIR	If > 0.12	None	Not Water
	52	3 or 4	Check NIR	If > 0.12	None	Not Water
	YYYY	3 or 4	DSWE Year >= YYYY	Check NIR	If > 0.12	Not Water
	$10 * YYYY + 1$	1-4	DSWE Year >= $10 * YYYY + 1$	Mask	None	Not Water
Pixel QA	Snow bit	1-4	Relabel	None	None	Snow

Table 3-2. INTSM Masking Actions

3.8 Interpreted with All Masks Applied (INWAM)

Inputs

1. INTSM filtered interpreted band
2. QA band

Outputs

1. INWAM interpreted with all masks applied band

Description

This step starts with the interpreted band with some masks applied (INTSM) and embeds the cloud and cloud shadow labels provided in the QA band.

If the QA band indicates the pixel is in cloud or cloud shadow, the INWAM value is set to Cloud/Cloud Shadow (9). Otherwise, all INTSM values are retained.

3.9 Mask (MASK)

Inputs

1. Interpreted with some masks band
2. Interpreted with all masks band
3. Pixel QA band
4. OTSU
5. LCMASK

Outputs

1. Mask band

Description

The DSWE mask band identifies where and why pixels are filtered in the INTSM and INWAM Bands.

The mask band is a bit-packed band where the bits have the following values:

- 0 - Cloud shadow mask applied
- 1 - Snow mask applied
- 2 - Cloud mask applied
- 3 - Hillshade mask applied
- 4 - Land cover mask applied

Multiple mask reasons can apply for each pixel in the mask band. For example, a pixel masked for cloud shadow, Hillshade, and Land cover would have a value of 25 ($2^0 + 2^3 + 2^4 = 1 + 8 + 16 = 25$).

The mask band is created with the following steps:

1. The mask is initialized to 0, and the contribution of the pixel QA mask values is added:

```
if (pixel QA cloud shadow bit is set)
    set mask shadow bit (0)
if (pixel QA snow bit is set)
    set mask snow bit (1)
if (pixel QA cloud bit is set)
    set mask cloud bit (2)
```

2. The contribution of the Hillshade mask values is added:

```
if (any hillshade test caused Interpreted DSWE to
be recoded to 0)
    set mask hillshade bit (3)
```

3. The contribution of the land cover mask values is added:

```
if (the land cover test caused Interpreted DSWE
to be recoded to 0)
    set mask land cover bit (4)
```

Section 4 Citation Information

There are no restrictions on the use of Landsat Science Products. It is not a requirement of data use, but the following citation may be used in publication or presentation materials to acknowledge the USGS as a data source and to credit the original research.

Landsat Collection 2 Level 3 Dynamic Surface Water Extent (DSWE) Science Products courtesy of the U.S. Geological Survey.

Jones, J.W. (2019). Improved Automated Detection of Subpixel-Scale Inundation—Revised Dynamic Surface Water Extent (DSWE) Partial Surface Water Tests. Remote Sens. 11, 374. <https://doi.org/10.3390/rs11040374>

Reprints or citations of papers or oral presentations based on USGS data are welcome to help the USGS stay informed of how data are being used. These can be sent to the contact information listed below:

USGS EROS Customer Services
Email: custserv@usgs.gov

Appendix A DSWE Algorithm Static Inputs

DSWE processing is based on the following input to the algorithm, which needs to be processed and made available prior to running the DSWE algorithm:

- Elevation dataset
- Land Cover Mask (LCMASK)
- Hillshade mask candidate tiles

The Landsat Collection 2 DEM is used to generate the elevation dataset based on the extent of the ARD tile.

Appendix B Acronyms

ADD	Algorithm Description Document
ARD	Analysis Ready Data
AWESH	Automated Water Extent Shadow
C2	Collection 2
CCB	Configuration Control Board
CONUS	Conterminous United States
CR	Change Request
DEM	Digital Elevation Model
DSWE	Dynamic Surface Water Extent
EROS	Earth Resources Observation and Science
ETM+	Enhanced Thematic Mapper Plus
INTR	Interpreted Layer
INTSM	Interpreted Layer with Some Masks Applied
INWAM	Interpreted Layer with All Masks Applied
L2	Level 2
L3	Level 3
LCMAP	Land Change Monitoring, Assessment, and Projection
LCMASK	Land Cover Mask Band
LCPRI	LCMAP Primary Land Cover
LSDS	Land Satellites Data System
MBSRN	Multi-band Spectral Relationship Near-Infrared
MBSRV	Multi-band Spectral Relationship Visible
MNDWI	Modified Normalized Difference Wetness Index
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
NLCD	National Land Cover Database
OLI	Operational Land Imager
PSW	Partial Surface Water
QA	Quality Assessment
SR	Surface Reflectance
SWIR	Shortwave Infrared
TM	Thematic Mapper
USGS	U.S. Geological Survey

References

Please see <https://www.usgs.gov/landsat-missions/landsat-acronyms> for a list of acronyms.

Horn, B. K. (1981). Hill shading and the reflectance map. *Proceedings of the IEEE*, 69(1), 14-47.

Jones, J.W. (2015). Efficient wetland surface water detection and monitoring via Landsat: Comparison with in situ data from the Everglades Depth Estimation Network. *Remote Sensing*, 7(9), 12503-12538. <http://dx.doi.org/10.3390/rs70912503>.

Jones, J.W. (2019). Improved Automated Detection of Subpixel-Scale Inundation—Revised Dynamic Surface Water Extent (DSWE) Partial Surface Water Tests. *Remote Sens.* 11, 374. <https://doi.org/10.3390/rs11040374>

Otsu, N. (1979). A threshold selection method from gray-level histograms. *IEEE transactions on systems, man, and cybernetics*, 9(1), 62-66.