National Aeronautics and Space Administration

OPERA

Observational Products for End-Users from Remote Sensing Analysis

Product Specification Document for Dynamic Surface Water Extent from Sentinel-1

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Observational Products for End-Users from Remote Sensing Analysis (OPERA) Project

OPERA Level-3 Dynamic Surface Water Extent from Sentinel-1A/B Product Specification

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1 INTRODUCTION

1.1 Document Purpose

The primary purpose of this document is to convey product specifications of the Observational Products for End-Users from Remote Sensing Analysis (OPERA) Level-3 Dynamic Surface Water Extent (DSWx) product that uses Sentinel-1A/B as the primary image-based inputs. This product, referred to by the short name DSWx-S1, will be generated by the OPERA Data System (SDS). It will be openly distributed by NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC).

1.2 Document Organization

Section 2 provides an overview of the product, including its purpose.

Section 3 provides the structure of the product, including tile definition, file organization, spatial resolution, and temporal and spatial organization of the content, as well as the typical file size and total data volume.

Section 4 provides a detailed description of DSWx-S1 product layers and corresponding metadata.

Appendix A provides a list of the acronyms used in this document.

1.3 Applicable and Reference Documents

The product described in this document responds to requirements imposed by applicable documents indicated below. In case of conflict between the applicable documents and this one, the OPERA Project shall review the conflict to find the most effective resolution.

Applicable Documents

[AD1] NASA SNWG Cycle 2 – OPERA Program Level (Level 1) Requirements Document, Oct. 15, 2021

[AD2] OPERA Level 2 Requirements, JPL D-107391, Rev A, Dec. 16, 2021

[AD3] Level-3 Algorithm Requirements Document, JPL D-107406, Jan 25, 2022

[AD4] OPERA Product Description, JPL D-107389, Rev A, Dec. 14, 2021

Reference Documents

[RD1] OPERA Algorithm Theoretical Basis Document for Dynamic Surface Water Extent from Sentinel-1 A/B data, JPL D-108763, Initial Revision, June 15, 2023

[RD2] Product Specification Document for the OPERA Radiometric Terrain Corrected SAR Backscatter from Sentinel-1, JPL D-108758, Rev Preliminary, December 15, 2022

[RD3] Copernicus DEM – Global and European Digital Elevation Model, https://doi.org/10.5270/ESA-c5d3d65

[RD4] Pekel, J. F., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. Nature, 540(7633), 418-422. https://doi.org/10.1038/nature20584

[RD5] Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., Santoro, M., Fritz, S., Lesiv, M., Herold, M., Tsendbazar, N.E., Xu, P., Ramoino, F., Arino, O., 2022. ESA WorldCover 10 m 2021 v200. https://doi.org/10.5281/zenodo.7254221

[RD6] "Coordinate Systems." National Geospatial-Intelligence Agency (NGA), 1 Mar. 2022, earth-info.nga.mil/index.php?dir=coordsys&action=coordsys#mgrs. Accessed 15 Oct. 2021.

[RD7] *Cloud Optimized GeoTIFF: An imagery format for cloud-native geospatial processing.* www.cogeo.org/. Accessed 14 Oct. 2021.

[RD8] Earth Science Data and Information System (ESDIS) Standards Office (ESO). "GeoTIFF File Format, ESDS-RFC-040v1.1." Earthdata, 16 Sept. 2019. earthdata.nasa.gov/esdis/eso/standards-and-references/geotiff. Accessed 14 Oct. 2021.

[RD9] "TIFF/IT for Image Technology." *The National Digital Information Infrastructure and Preservation Program at the Library of Congress*, 3 Oct. 2006, www.loc.gov/preservation/digital/formats/fdd/fdd000072.shtml. Accessed 21 June 2022.

The latest official versions of OPERA documents should be obtained from https://www.jpl.nasa.gov/go/opera/about-opera.

1.4 Applicable Software

This document is being released for the Final version of the DSWx-S1 products. The Science Application Software (SAS) is available at this GitHub repository: https://github.com/opera-adt/DSWX-SAR/releases/tag/v1.0. The products generated by this version of the SAS are consistent with this document.

2 PRODUCT OVERVIEW

2.1 Product Background

DSWx-S1 product maps the extent of surface water features on a near-global basis, i.e., all land masses excluding Antarctica from Sentinel-1A/B data.

The theoretical basis and processing sequence used to generate DSWx-S1 are described in [RD1]. Figure 2-1 conceptually summarizes the DSWx-S1 product workflow. The input dataset for generating each DSWx-S1 product is the OPERA Level-2 Radiometric Terrain Corrected Product from Sentinel-1A/B (RTC-S1) [RD2]. The OPERA RTC-S1 products provide the radiometric terrain corrected γ0 (gamma naught) backscatter coefficient in geocoded burst domain, approximately every 6 to 12 days. The OPERA RTC-S1 products are produced and distributed in the Universal Transverse Mercator (UTM) coordinate System for each single burst [RD2].

The current DSWx-S1 algorithm requires multiple RTC-S1 products to correctly delineate the boundary between the water and not water as well as to avoid the discontinuity between the neighboring DSWx-S1 products. The number of OPERA RTC-S1 bursts are variable depending on the size of the collections of Military Grid Reference System (MGRS) tiles.

The DSWx-S1 products will be produced over MGRS tiles that each cover an area of 109.8 km × 109.8 km with 3660 x 3660 pixels.

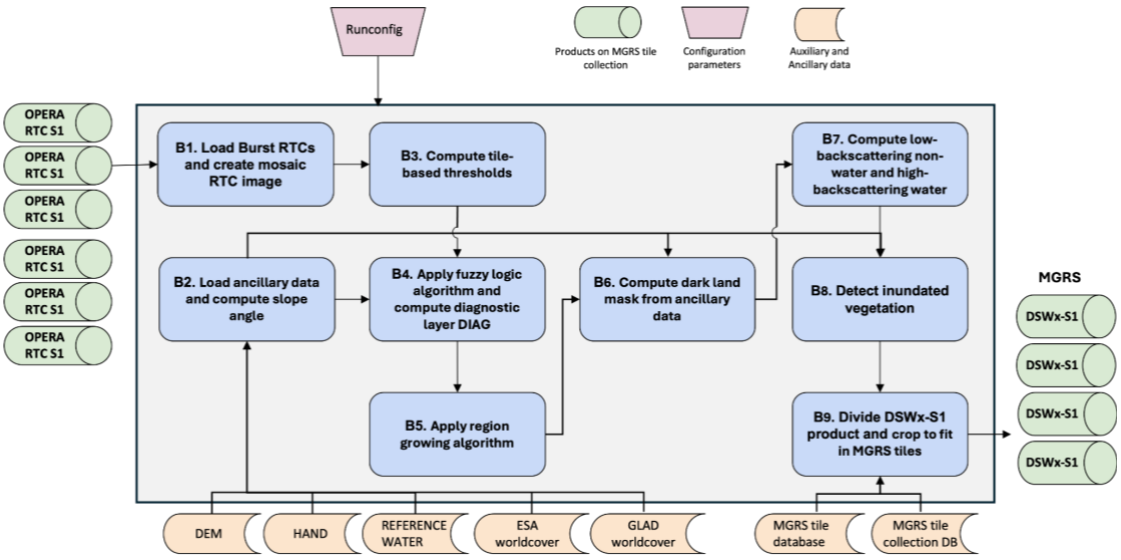

Figure 2-1. OPERA DSWx-S1 workflow diagram.

Table 2-1. Product Dependency Diagram.

Product	Scope	Description	Granule Size
OPERA RTC-S1	Near-Global	The input RTC-S1 [RD2] products from Sentinel-1	Variable
Copernicus DEM	Global	GLO-30 Copernicus Digital Elevation Model (DEM) 30-m spatial resolution [RD3]	Variable from 360 × 3600 to 3600 × 3600 (x, y)
JRC Global Surface Water	Near-Global	Water Seasonality or Occurrence map, 30-m spatial resolution [RD4]	Variable
ESA Worldcover	Near-Global	ESA Land-cover classes with 10-m spatial resolution [RD5]	Variable
ASF HAND	Global	Alaska Satellite Facility (ASF) Height Above Nearest Drainage (HAND), 30-m spatial resolution	Variable
GLAD Land cover and land use	Near-Global	Global Land Analysis & Discovery (GLAD) Annual maps of land cover and land use, 30-m spatial resolution	Variable
MGRS tile database	Global	MGRS tile to define output bounding box [RD6]	SQLite
MGRS tile collection database	Global	MGRS tile collections consisting of MGRS tile	SQLite

2.2 DSWx-S1 Product Overview

Each DSWx-S1 product is distributed as a set of 4 GeoTIFF (Geographic Tagged Image File Format) files corresponding to each DSWx-S1 layer (see Section 4.1) and 1 PNG (Portable Network Graphic) for a browse image. The GeoTIFF files are saved as Cloud-Optimized GeoTIFFs (COGs) [RD7] to make retrieval of GeoTIFF data from web storage, including Distributed Active Archive Centers (DAACs), more efficient.

The pixel spacings of the DSWx-S1 product in east and north directions are consistent with the input OPERA RTC-S1 product (Table 2-2).

Table 2-2. Posting of DSWx-S1 product.

Product	Posting in Northing (m)	Posting in Easting (m)
DSWx-S1	30	30

3 PRODUCT ORGANIZATION

In this section, we describe the DSWx-S1 file format and naming convention, as well as tile definition, labeling scheme, and spatial organization.

3.1 File Format – GeoTIFF

Each OPERA DSWx-S1 product is distributed as a set of 4 Cloud Optimized GeoTIFF [RD7] files containing additional metadata.

The GeoTIFF is a format to store georeferenced raster images and is widely used by remote-sensing communities. The GeoTIFF format is defined in the public domain as Tagged Image File Format (TIFF) [RD8]. It enables the storage of compressed images with associated metadata that can be easily read by Geographic Information System (GIS) software, including the open Geospatial Data Abstraction Library (GDAL) and Quantum GIS (QGIS).

3.2 File-Naming Convention

OPERA DSWx-S1 granule names are designed to ensure unique and descriptive identification for the OPERA DSWx_S1 products. The following file-naming convention is used:

Project_**L**evel_**P**roduct**S**hort**N**ame-
Source_**T**ile**ID**_**D**ate**T**ime_**P**roduct**G**eneration**D**ate**T**ime_**S**ensor_**P**ixel**S**pacing_**P**roduct**V**ersion
**L**ayer**N**umber**L**ayer**N**ame.**E**xt

- **P**roject: “OPERA”
- **L**evel: “L3”
- **P**roduct**S**hort**N**ame: “DSWx”
- **S**ource: The input source of the product (“S1” in this case)
- **T**ile**ID**: Specific MGRS tile ID of the product.
- **D**ate**T**ime: The acquisition date and time (Greenwich Mean Time or GMT) of the input RTC-S1 burst imagery (format: YYYYMMDDTHHMMSSZ). The earliest acquisition time is extracted from the RTC-S1 bursts overlapped with the MGRS tile.
- **P**roduct**G**eneration**D**ate**T**ime: The date and time (GMT) at which the product was generated by OPERA (format: YYYYMMDDTHHMMSSZ)
- **S**ensor: The image input sensor “S1A” (Sentinel-1A) or “S1B” (Sentinel-1B)
- **P**ixel**S**pacing: Pixel spacing in meters
- **P**roduct**V**ersion: OPERA DSWx-S1 product version number with four characters, including the letter “v” and two digits indicating the major and minor versions, which are delimited by a period
- **L**ayer**N**umber: Three characters corresponding to the letter “B,” followed by a two-digit integer indicating the DSWx-S1 layer number, starting with 01 for the WTR layer

- **L**ayer**N**ame: Name of the DSWx-S1 layer (see Table 4-1)
- **E**xt: File extension (“tif” in this case)

Example:
OPERA_L3_DSWx-S1_T15SXR_20210205T163901Z_20220101T140222Z_S1A_30_v1.0_B01_WTR.tif

3.3 Tile Definition

OPERA DSWx-S1 products conform to the tiling scheme of OPERA DSWx-HLS products to optimize the integration of surface water-related OPERA products. Each tile spans a ground area of 109.8 km x 109.8 km, structured into 3,660 rows and 3,660 columns with a pixel spacing of 30 m in both horizontal and vertical directions. To facilitate seamless mosaicking, both DSWx-S1 and DSWx-HLS products feature a 4,900 m overlap in every direction, aligning with the MGRS 100,000-m square tiling system, thus preventing gaps between contiguous DSWx-S1 product tiles. Additionally, DSWx-S1 tiles are aligned with projected map coordinates consistent with MGRS [RD6].

MGRS is a geographic grid reference system defined using the Universal Transverse Mercator (UTM) for most latitudes and the Universal Polar Stereographic (UPS) coordinate systems for polar regions (North of 84°N and South of 80°S). The OPERA DSWx-S1 products are defined over the UTM coordinate system with a 100 km-by-100 km tiling scheme with 9.8 km buffer in vertical and horizontal directions. At this precision level, MGRS tiles are labeled using the grid zone designation followed by the 100,000-m square identification.

The grid zone designation is defined by the UTM zone number followed by the latitude band. Each longitude section has a width of 6^{o}, resulting in 60 UTM zones. Each zone is divided into 20 latitude bands of 8^{o} in the latitude direction and each band (tile) is identified by a letter starting from “C” at 80^{o}S to “X” at 80^{o}N, omitting letters “I” and “O” because of their similarity to numerals 1 and 0. Both latitude bands “C” and “X” are extended 4^{o} towards the Poles, i.e., the latitude band “C” comprises the latitude range from -84^{o} to -72^{o} and the latitude band “X” identifies the latitude range from 72^{o} to 84^{o}. The 100,000-m square identification, or 100_SID, consists of a 100_SID column letter “A” to “Z” followed by a 100_SID row letter from “A” to “V.” Similar to latitude bands, 100_SID column and row letters also omit letters “I” and “O.” The resulting MGRS tiling scheme DSWx-S1 has the following format:

UTM_ZONE_NUMBER**L**ATITUDE_BAND100_SID_**C**OLUMN_LETTER100_SID_**R**OW_LETTER>

For instance, the Louisiana example that is shown in Section 5 is located at the tile identified as “15SXR,” where “15” is the UTM zone number, “S” is the latitude band, “X” is the 100_SID column letter, and “R” is the 100_SID row letter.

3.4 Spatial Organization

Salient features of the output grid for the DSWx-S1 product are as follows:

1. The output grid is common to all layers in each product.
2. The DSWx-S1 data are arranged on a uniformly spaced, north-up and west-left grid – i.e., decreasing north or Y coordinate in the row direction and increasing east or X coordinate in the column direction following the row-major order convention of representing 2D raster arrays.

3.5 Grid Alignment

OPERA DSWx-S1 products will use a “pixel is area” convention. The “pixel is area” convention, uses northing and easting coordinates Y and X, with (0,0) denoting the upper-left corner of the image, and increasing X to the east, increasing Y to the south. The first pixel value fills the grid cell with the top-left position (0,0) and bottom-right position (1,1).

4 PRODUCT SPECIFICATION

In this section, we describe the DSWx-S1 product layers and associated metadata.

4.1 Product Raster Layers

Each DSWx-S1 product contains 4 GeoTIFF files (layers), each with 3,660 rows and 3,660 columns. Layers are provided as Unsigned Integers of 8 bits (UInt8). It also contains a single browse image in Portable Network Graphic format, as noted by its '.png' file name extension. Specifics regarding GeoTIFF layer names and content are shown in Table 4-1.

Table 4-1. DSWx-S1 raster layers.

Product Variables		
Layer: 1	**Water classification (WTR)**	
Format: Geotiff	**Type:** UInt8	**Shape (x, y):** (3660 × 3660)
Description: Masked interpreted water classification layer. This represents pixel-wise classification into one of three water classes (not water, open water and inundated vegetation), masks (HAND mask and layover/shadow mask), or no data classes.		
Layer classes: 0: Not water – an area with valid data that is not open water (class 1), inundated vegetation (class 3), height above nearest drainage masked (class 250), or layover/shadow masked (class 251). Masking can result in "not water" (class 0) where land cover masking is applied. 1: Open water – an area that is entirely water and unobstructed to the sensor, including obstructions by vegetation, terrain, and buildings. 3: Inundated vegetation – an area that is considered inundated, extracted from the high value in dual polarization ratio and the wetland class in land cover map. 250: Height Above Nearest Drainage (HAND) masked - an area where topographic height is higher than the HAND threshold. 251: Layover/shadow masked - an area identified as layover or shadow computed from the geometry of the digital elevation model and sensor. The area is directly copied from input burst RTC-S1 products. 255: Fill value (no data)		
Layer: 1	**Binary water (BWTR)**	
Format: Geotiff	**Type:** UInt8	**Shape (x, y):** (3660 × 3660)
Description: The binary water map is derived from the WTR layer as a union of water classes (open water and inundated vegetation) into a binary map indicating areas with and without water. Invalid data classes (HAND masked, layover/shadow masked and fill value) are also provided to indicate areas in which the binary classification does not provide water/not water classification.		
Layer classes: 0: Not water – an area with valid data that is not water (class 1) and not HAND masked (class 252), layover or shadow (class 253) 1: water – an area classified as "open water" or "inundated vegetation" (see WTR layer). 250: Height Above Nearest Drainage (HAND) masked - an area where topographic height is higher than the HAND threshold. 251: Layover/shadow masked - an area identified as layover or shadow computed from the geometry of the digital elevation model and sensor. The area is directly copied from input burst RTC-S1 products. 255: Fill value (no data)		
Layer: 3	**Confidence (CONF)**	
Format: Geotiff	**Type: UInt8**	**Shape (x, y):** (3660 × 3660)

Description: A representation of the confidence associated with the WTR classification that is based on DIAG results. For example, the Open water class of the WTR layer is split into two classes: High Confidence and Moderate Confidence. Additionally, this layer includes areas characterized by low backscattering that are not water: Low-backscattering not water and land cover masked. Detailed explanations of these classifications are outlined in [RD1]. Similar to the WTR and BWTR layers, the Confidence (CONF) layer also marks pixels where water detection is challenging or unfeasible due to factors like layover/shadow effects, no-data areas, and regions where water presence is hydrologically unrealistic (identified by HAND mask).

Layer classes:

Not-potential wetland:
0: Not water – an area with valid data that is not open water high-confidence (class 1), open water moderate-confidence (class 2), inundated vegetation (class 3), low-backscattering not water estimated from bimodality test(class 5), low-backscattering not water estimated from ancillary mask (class 6), height above nearest drainage masked (class 250), or layover/shadow masked (class 251).
1: Open water high-confidence – an area that is entirely water and unobstructed to the sensor, including obstructions by vegetation, terrain, and buildings and is not overlapping with wetland areas in the Input land cover map.
2: Open water moderate-confidence – an area with higher backscattering than initial thresholds, considered as water due to the unimodal distribution with surrounding water pixels and not overlapping with wetland areas in the Input land cover map.5: Potential inundated vegetation - an area with a high dual polarization ratio that is not overlapping with wetland areas in the input land cover map.
6: Low-backscattering not water (bimodality test)- an area with lower backscattering than thresholds, not considered water based on the bimodality test, and not overlapping with wetland areas in the input land cover map.
7: Low-backscattering not water (ancillary mask) - an area with lower backscattering than the threshold, considered not water based on historical records of water extents, backscattering level, slope angle, and land cover classes, and not overlapping with wetland areas in the input land cover map.

Potential Wetland Areas Based on the Land Cover Map:
30: Not water – an area with valid data that is not open water high-confidence (class 31), open water moderate-confidence (class 32), inundated vegetation (class 35), low-backscattering not water estimated from bimodality test(class 36), low-backscattering not water estimated from ancillary mask (class 37), height above nearest drainage masked (class 250), or layover/shadow masked (class 251) and overlap with wetland areas in the Input land cover map.
31: Open water high-confidence – an area entirely composed of water, unobstructed to the sensor by vegetation, terrain, or buildings, and overlapping with wetland areas in the input land cover map.
32: Open water moderate-confidence – an area with higher backscattering than initial thresholds, considered water due to its unimodal distribution with surrounding water pixels, and overlapping with wetland areas in the input land cover map.
35: Inundated vegetation - an area considered inundated due to a high value in dual polarization ratio and overlapping with wetland areas in the input land cover map.
36: Low-backscattering not water (bimodality test)- an area with lower backscattering than thresholds, not considered water based on the bimodality test, and overlapping with wetland areas in the input land cover map.
37: Low-backscattering not water (ancillary mask) - an area with lower backscattering than the threshold, considered not water based on historical records of water extents, backscattering level, slope angle, and land cover classes, and overlapping with wetland areas in the input land cover map.

250: Height Above Nearest Drainage (HAND) masked - an area where topographic height is higher than the HAND threshold.
251: Layover/shadow masked - an area identified as layover or shadow computed from the geometry of the digital elevation model and sensor. The area is directly copied from input burst RTC products.255: Fill value (no data)

Layer: 4	**Diagnostic (DIAG)**	
Format: Geotiff	**Type:** UInt8	**Shape (x, y):** (3660 × 3660)

Description: A metric of Fuzzy values is computed using ancillary data, including HAND, terrain slope angle, reference water, and RTC-S1 backscattering, applying specific thresholds. These values fall within a range of 0 to 100, where a higher value signifies a greater likelihood of the presence of open water.		
Layer classes: 0-100: Fuzzy value associated with the WTR classification that is computed from backscattering intensity, reference water, slope angle, and HAND values. 120: Fill value (no data). 252: Height Above Nearest Drainage (HAND) masked - an area where topographic height is higher than the HAND threshold. 253: Layover/shadow masked - an area identified as layover or shadow computed from the geometry of the digital elevation model and sensor. The area is directly copied from input burst RTC-S1 products.		
Browse images (PNG)		
Format: PNG	**Type:** UInt8	**Shape (x, y):** (1024 × 1024)
Description: The browse images provide a visual representation of the DSWx-S1 product for browsing. They contain a mix of classes from multiple DSWx-S1 layers providing a quick assessment of the interpreted water classes.		
Color interpretation: **white**: Not water - an area with valid data that is not open water, Inundated vegetation, height above nearest drainage masked, or layover/shadow masked. **Blue**: Open water - an area that is entirely water and unobstructed to the sensor, including obstructions by vegetation, terrain, and buildings. **Green**: Inundated vegetation - an area that is considered inundated due to the high value in dual polarization ratio and the Herbaceous wetland class in land cover map. **Translucent**: mask and no data - areas identified as layover or shadow computed from the geometry of the digital elevation model and sensor or where data does not exist.		

4.2 GeoTIFF Metadata

All DSWx-S1 product layers (GeoTIFF files) are saved with the same metadata. The DSWx-S1 metadata is divided into three sections: 1) Product Identification and Processing Information, 2) input datasets, and 3) Sentinel-1 A/B product metadata.

4.2.1 Product Identification and Processing Information

Table 4-2 lists the product identification fields of the GeoTIFF metadata. The attribute PRODUCT_VERSION informs the version of the DSWx-S1 product (structure and metadata), whereas the attribute SOFTWARE_VERSION describes the version of the software that generated the DSWx-S1 product.

Table 4-2. GeoTIFF metadata: product identification.

Attribute	Description
DSWX_PRODUCT_VERSION	The DSWx-S1 product version

SOFTWARE_VERSION	The software version used to generate the DSWx-S1 product
PROJECT	OPERA
PRODUCT_LEVEL	3
PRODUCT_TYPE	DSWx-S1
PRODUCT_SOURCE	OPERA RTC S1
INSTITUTION	NASA JPL
CONTACT_INFORMATION	operasds@jpl.nasa.gov
PROCESSING_DATETIME	DSWx-S1 product processing date. Format: YYYY-MM-DDTHH:MM:SSZ
SPACECRAFT_NAME	Name of the sensor platform (i.e. Sentinel-1A/B)
SENSOR	Name of the sensor instrument (i.e. IW)

4.2.2 OPERA RTC-S1 product Metadata

Table 4-3 lists the metadata copied or derived from the OPERA RTC product metadata to the DSWx-S1 GeoTIFF metadata.

Table 4-3. GeoTIFF metadata: OPERA RTC-S1 product metadata.

Attribute	Description
RTC_SENSING_START_TIME	Sensing start time. Earliest acquisition time of OPERA burst RTC set. Format: YYYY-MM-DDTHH:MM:SSZ
RTC_SENSING_END_TIME	Sensing start time. Latest acquisition time of OPERA burst RTC set. Format: YYYY-MM-DDTHH:MM:SSZ
RTC_ABSOLUTE_ORBIT_NUMBER	Absolute orbit number. Copied from OPERA RTC-S1 products.
RTC_ORBIT_PASS_DIRECTION	Orbit direction (e.g. Ascending or Descending). Copied from OPERA RTC-S1.
RTC_TRACK_NUMBER	Track number. Copied from OPERA RTC-S1.
RTC_QA_RFI_INFO_AVAILABLE	A flag to indicate whether RFI information is available in the source data.
RTC_QA_RFI_NUMBER_OF_BURSTS	Number of RTC-S1 bursts affected by RFI
RTC_BURST_ID	List of the burst id. format: TrackNumber_BurstID_Swathnumber
RTC_INPUT_L1_SLC_GRANULES	List of input L1 SLC products used
RTC_INPUT_LIST	List of input RTC-S1 files

RTC_PRODUCT_VERSION	The version of OPERA RTC-S1 algorithm used for RTC products. Copied directly from OPERA RTC-S1 metadata.
POLARIZATION	Polarizations (e.g. VV, VH)

4.2.3 Input Ancillary datasets

Table 4-4 lists the input ancillary dataset fields.

Table 4-4. GeoTIFF metadata: input ancillary datasets.

Attribute	Description
INPUT_DEM_SOURCE	Description of the input DEM
INPUT_REFERENCE_WATER_SOURCE	Description of the input reference water file
INPUT_WORLDCOVER_SOURCE	Description of the input ESA WorldCover 10-m file
INPUT_HAND_SOURCE	Description of the input ASF GLO-30 HAND 30-m file
INPUT_GLAD_CLASSIFICATION_SOURCE	Description of the input GLAD Annual maps of land cover and land use 30-m file
INPUT_SHORELINE_SOURCE	Description of the input shoreline vector file

4.2.4 DSWx-S1 Processing and Product Parameters

Table 4-5 lists the algorithm parameters used for DSWx-S1 SAS.

Table 4-5. GeoTIFF metadata: algorithm processing parameters.

Attribute	Description
AREA_OR_POINT	Indicates that pixel values are assumed to represent an area rather than points: “Area”
PROCESSING_INFORMATION_THRESHOLDING	initial thresholding algorithm, either “Kittler-Illingworth” or “OTSU”
PROCESSING_INFORMATION_THRESHOLD_MULTI_THRESHOLD	Indicate a Boolean indicator specifying whether a trimodal distribution is assumed in the processing
PROCESSING_INFORMATION_THRESHOLD_TILE_AVERAGE	indicates whether averaging of thresholds within a tile is enabled or not.
PROCESSING_INFORMATION_THRESHOLD_TILE_SELECTION	Tile selection method (e.g. Tweles, Chini, Bimodality or combined)

PROCESSING_INFORMATION_THRESHOLD_BIMODALITY	Bimodality threshold for identifying bimodality in data tiles. It is used to select tiles that exhibit a bimodal distribution, essential for specific analyses where recognizing two distinct data groups is crucial.
PROCESSING_INFORMATION_THRESHOLD_TWELE	Threshold value for tile selection using the 'twele' method
PROCESSING_INFORMATION_THRESHOLD_BOUNDS	Threshold bounds for polarizations (e.g. co-pol and cross-pol)
PROCESSING_INFORMATION_FILTER	RTC intensity filtering method (bregman, lee, guided_filter, anisotropic_diffusion, etc.)
PROCESSING_INFORMATION_FILTER_ENABLED	Indicate if the filter is applied to the input RTC
PROCESSING_INFORMATION_FILTER_OPTION	Parameters used for despeckle filter
PROCESSING_INFORMATION_INUNDATED_VEGETATION	Indicates whether inundated vegetation is a factor in the processing
PROCESSING_INFORMATION_INUNDATED_VEGETATION_AREA_DATA_TYPE	Indicates what sources are used to define the potential wetland areas (e.g., GLAD, WorldCover)
PROCESSING_INFORMATION_INUNDATED_VEGETATION_CROSS_POL_MIN	The cross-polarization backscattering value [dB] used to filter out areas for inundated vegetation mapping. The areas that have this threshold are automatically considered not inundated vegetation.
PROCESSING_INFORMATION_INUNDATED_VEGETATION_DUAL_POL_RATIO_MAX	The maximum threshold for the ratio of co-polarization to cross-polarization in mapping inundated vegetation. It defines the upper limit for this ratio, beyond which vegetation is not considered inundated.
PROCESSING_INFORMATION_INUNDATED_VEGETATION_DUAL_POL_RATIO_MIN	The minimum threshold for the ratio of co-polarization to cross-polarization required to identify inundated vegetation
PROCESSING_INFORMATION_INUNDATED_VEGETATION_DUAL_POL_RATIO_THRESHOLD	Threshold value for co-pol to cross-pol ratio used to map inundated vegetation areas
PROCESSING_INFORMATION_INUNDATED_VEGETATION_FILTER	Filtering method used for dual polarization ratio
PROCESSING_INFORMATION_INUNDATED_VEGETATION_TARGET_CLASS	Land cover classes used to define potential wetland areas
PROCESSING_INFORMATION_FUZZY_VALUE_AREA	The foot and shoulder values used to construct an S-shaped function for water body areas
PROCESSING_INFORMATION_FUZZY_VALUE_DARK_AREA	List of the intensity values to define dark land
PROCESSING_INFORMATION_FUZZY_VALUE_HAND	Foot and shoulder value to construct a Z-shape function for height above nearest drainage (HAND)
PROCESSING_INFORMATION_FUZZY_VALUE_HIGH_FREQUENT_AREA	The minimum and maximum values representing reference water levels to identify areas with frequent water extent changes

PROCESSING_INFORMATION_FUZZY_VALUE_REFERENCE_WATER	Foot and shoulder value to construct a S-shape function for reference water
PROCESSING_INFORMATION_FUZZY_VALUE_SLOPE	Foot and shoulder value to construct a Z-shape function for slope angle
PROCESSING_INFORMATION_REGION_GROWING_INITIAL_SEED	Seed value for region-growing method
PROCESSING_INFORMATION_REGION_GROWING_RELAXED_THRESHOLD	Tolerance value for region-growing method
PROCESSING_INFORMATION_MASKING_ANCILLARY_CO_POL_THRESHOLD	Threshold level [dB] to be used for dark land identification for co-polarization
PROCESSING_INFORMATION_MASKING_ANCILLARY_CROSS_POL_THRESHOLD	Threshold level [dB] to be used for dark land identification for cross-polarization
PROCESSING_INFORMATION_MASKING_ANCILLARY_WATER_THRESHOLD	Threshold to be used for dry region identification for reference water data. The fuzzy values computed from cross-polarization are replaced with the one from co-polarization.
PROCESSING_INFORMATION_REFINE_BIMODALITY_MINIMUM_PIXEL	Minimum number of pixels to pass to bimodality test
PROCESSING_INFORMATION_REFINE_BIMODALITY_THRESHOLD	List of the thresholds to determine if the distribution is close to bimodal distribution
SPATIAL_COVERAGE	The area percentage of the tile with data
LAYOVER_SHADOW_COVERAGE	The percentage of layover and shadow in the DSWx-S1 product based on OPERA RTC-S1 product
MGRS_COLLECTION_ACTUAL_NUMBER_OF_BURSTS	The number of actual RTC-S1 bursts that are collected within MGRS tile collection ID
MGRS_COLLECTION_EXPECTED_NUMBER_OF_BURSTS	The number of expected RTC-S1 bursts that are supposed to be collected within MGRS tile collection ID
MGRS_COLLECTION_MISSING_NUMBER_OF_BURSTS	The number of missing RTC-S1 bursts
MGRS_POL_MODE	The description for the polarizations of the collected bursts. 'MIX_DUAL_POL': ['HH', 'HV', 'VV', 'VH'], 'MIX_DUAL_H_SINGLE_V_POL': ['HH', 'HV', 'VV'], 'MIX_DUAL_V_SINGLE_H_POL': ['VV', 'VH', 'HH'], 'MIX_SINGLE_POL': ['HH', 'VV'], 'DV_POL': ['VV', 'VH'], 'SV_POL': ['VV'], 'DH_POL': ['HH', 'HV'], 'SH_POL': ['HH'],

5 DSWx-S1 Sample Product

To visually present the product, a randomly selected OPERA RTC-S1 input was used to generate the following graphics, as shown in Figure 5-1 (left). This collection consists of 40 OPERA RTC S1 products acquired over the Eastern Kazakhstan on December 13, 2023, covering 9 MGRS tile IDs: 44UNA, 44UPA, 44UPV, 44UQA, 44UQV, 45UUQ, 45UUR, 45UVQ, and 45UVR. Individual DSWx-S1 products consist of four layers; WTR, BWTR, CONF, and DIAG and one browser image as described in table 4-1.

Figure 5-1 (right) shows one of the DSWx-S1 water (WTR) layers. The WTR layer contains six values: *not water* (0, shown in white); *open water* (1, blue); *inundated vegetation* (3, green); *HAND masked* (250, shown in dark gray); l*ayover/shadow masked* (251, shown in light gray); and *fill or no data value* (255, transparent, although not present in this example).

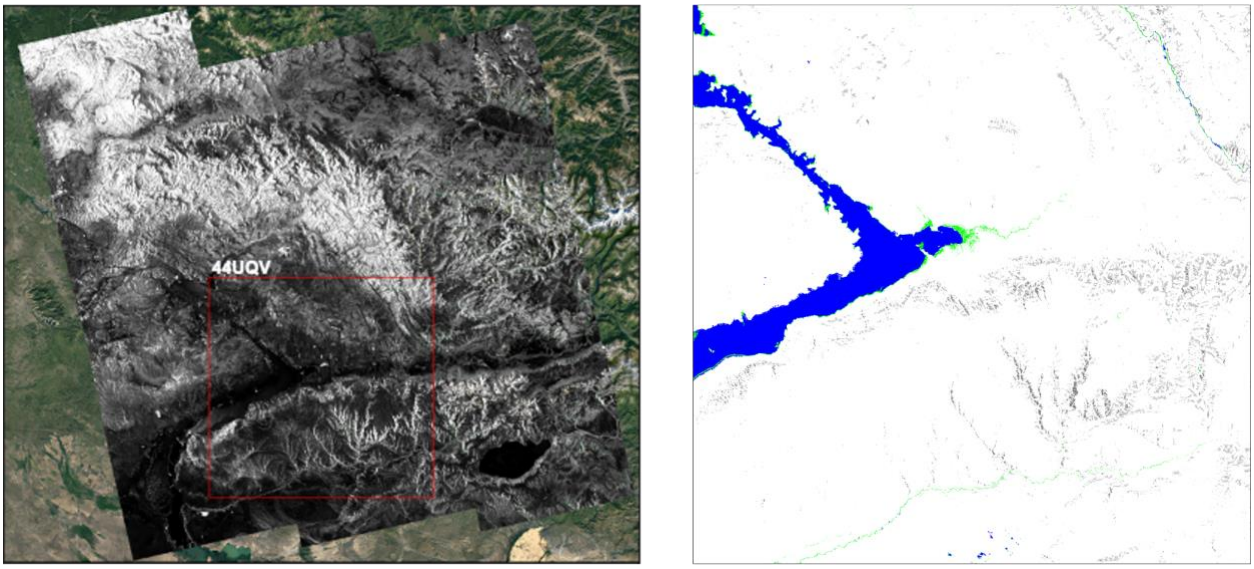

Figure 5-1. Input OPERA RTC-S1 [polarization: VV] layers (left) and water classification layer WTR (right) for MGRS tile 44UQV (red box in left figure).

Figure 5-2 (left) shows the BWTR layer, which is a binary water map distinguishing between *not-water* (0, shown in white) and *water* (1, shown in blue), as well as masked and invalid classes 252-255 following the WTR layer. The single water class represents a union of all water classes (i.e., *open water* and *inundated vegetation*) in the WTR layer.

Figure 5-2 (right) depicts the CONF layer, which indicates the confidence level associated with the WTR classification. The confidence is derived from factors such as backscattering intensity, reference water, slope angle, and HAND values. A complete description of the confidence values is provided in Table 4-1. The *open water* in the WTR layer combines all open water classes;

- *open water – high confidence* (1, show in blue)
- *open water – moderate confidence* (2, shown in light blue)
- *open water – high confidence (31, show in dark blue)*

- *open water – moderate confidence* (32, shown in Slate Gray).

The *inundated vegetation* (class 3 in WTR layer) corresponds to the *inundated vegetation* (class 35) in the CONF layer. The DSWx-S1 defines the inundated vegetation areas based on the intersection of high dual-polarization ratio areas from OPERA RTC-S1, and potential wetland areas from land cover maps. Consequently, the potential wetland areas are represented by a union of classes 30-37. Also, areas with high dual-polarzation ratio can be identified by combining *potential inundated vegetation* (class 5 in the CONF layer) and *inundated vegetation* (35 in the CONF layer).

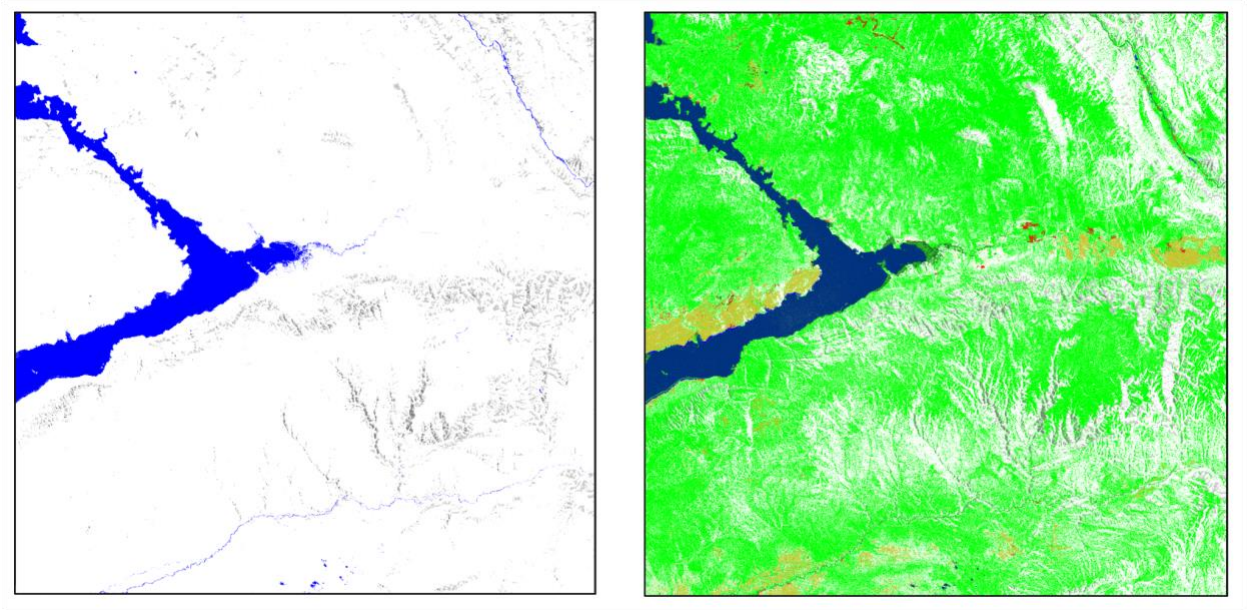

Figure 5-2. BWTR (left) and CONF (right) layers for MGRS tile 44UQV.

Figure 5-3 (left) shows the DIAG layer representing the water existence possibility ranging from 0 to 100 with masked and invalid classes 252-255 following the WTR layer. The value 100 represents the high possibility of the water existence. Figure 5-3 (right) shows the Browse image, which is in a PNG format, containing a mix of classes from multiple DSWx-S1 layers providing a quick assessment of the interpreted water classes.

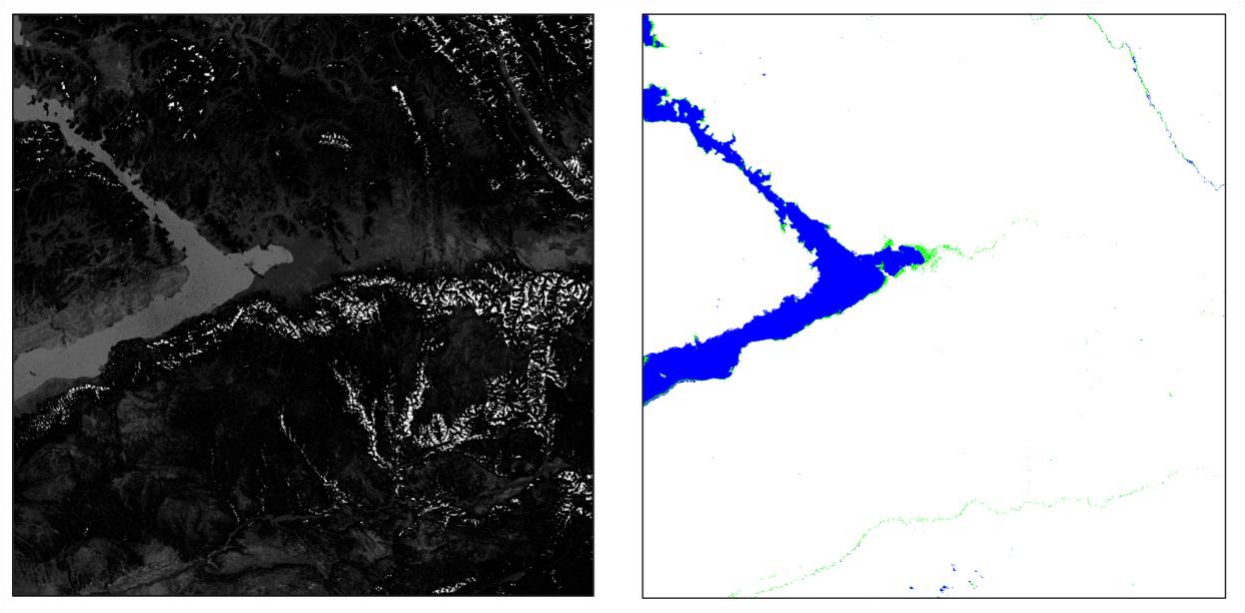

Figure 5-3. DIAG (left) and Browse (right) layers for MGRS tile 44UQV.

APPENDIX A: ACRONYMS

ADT	Algorithm Development Team
ASF	Alaska Satellite Facility
COG	Cloud-Optimized GeoTIFF
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
DOI	Digital Object Identifier
DSWx	Dynamic Surface Water Extent
ESA	European Space Agency
ESDIS	Earth Science Data and Information System
ESO	ESDIS Standards Office
GDAL	Geospatial Data Abstraction Library
GeoTIFF	Georeferenced Tagged Image File Format
GIS	Geographic Information System
GLAD	Global Land Analysis & Discovery
HAND	Height Above Nearest Drainage
HLS	Harmonized Landsat Sentinel-2
MGRS	Military Grid Reference System
NGA	National Geospatial-Intelligence Agency
OPERA	Observational Products for End-Users from Remote-sensing Analysis
PNG	Portable Network Graphic
PO.DAAC	NASA’s Physical Oceanography Distributed Active Archive Center
QA	Quality Assurance
QGIS	Quantum Geographic Information System
S1	Sentinel-1 A/B
SAR	Synthetic Aperture Radar
SAS	Science Application Software
SDS	Science Data System
TIFF	Tagged Image File Format
UInt8	Unsigned Integers of 8 bits
UPS	Universal Polar Stereographic
UTM	Universal Transverse Mercator