

OPERA

Observational Products for End-Users from Remote Sensing Analysis

Product Specification Document for
the OPERA Radiometric Terrain-
Corrected SAR Backscatter from
Sentinel-1 Static Layers

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

Product Specification Document for the OPERA Radiometric Terrain-Corrected SAR Backscatter from Sentinel-1 Static Layers

Version 0.4.2

JPL D-108764, Rev - Preliminary

August 15, 2023

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Key Authors

Shiroma, Gustavo H. X. *Jet Propulsion Laboratory, California Institute of Technology*



This research was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).

SIGNATURE PAGE

Prepared by:

Gustavo H. X. Shiroma
OPERA RTC-S1 Product Lead
Jet Propulsion Laboratory, California Institute of Technology

Date

Approved by:

David Bekaert
OPERA Project Manager
Jet Propulsion Laboratory, California Institute of Technology

Date

Heresh Fattahi
Project Sub-element Manager for OPERA Algorithms
Jet Propulsion Laboratory, California Institute of Technology

Date

Steven K. Chan
OPERA Project Scientist
Jet Propulsion Laboratory, California Institute of Technology

Date

Steven Lewis
OPERA Project System Engineer
Jet Propulsion Laboratory, California Institute of Technology

Date

Concurred by:

Luca Cinquini
OPERA Science Data System Manager
Jet Propulsion Laboratory, California Institute of Technology

Date

DOCUMENT CHANGE LOG

| Revision | Cover Date | Sections Changed | ECR # | Reason, ECR Title, LRS #* |
|--------------------|------------------|------------------|-------|--|
| Preliminary (v0.1) | June 15 30, 2022 | All | N/A | New document |
| v0.4.1 | Aug 3, 2023 | All | N/A | Update for Cal/Val Point Release 4.1 (R4.1) |
| v0.4.2 | Aug 15, 2023 | Sec. 4.3 | N/A | Update metadata field names and descriptions |

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1 INTRODUCTION

1.1 Document Purpose

This document provides a specification of the OPERA (Observational Products for End-users from Remote-sensing Analysis) Level-2 Radiometric Terrain-Corrected SAR backscatter from Sentinel-1 (RTC-S1) static layers (RTC-S1-STATIC) product to be generated by the OPERA Data System and provided to the NASA's Alaska Satellite Facility (ASF) Distributed Active Archive Center (ASF.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 granule definition, file organization, spatial resolution, temporal and spatial organization of the content, the size and data volume.

Section 4 provides qualitative descriptions of the information provided in the product's GeoTIFF layers.

Appendix A provides a description of geolocation grids and projection systems used for the product.

Appendix B provides a listing 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] OPERA Product Description, JPL D-107389, Rev A, Dec. 14, 2021

Reference Documents

- [RD1] Shiroma, Gustavo H. X. and Lavalle, Marco and Buckley, Sean M., “An Area-Based Projection Algorithm for SAR Radiometric Terrain Correction and Geocoding.” *IEEE Transactions on Geoscience and Remote Sensing* 60 (2022): 1–23. [[link](#)]
- [RD2] OPERA Algorithm Theoretical Basis Document for Radiometric Terrain-Corrected SAR Backscatter from Sentinel-1, JPL D-107393, Rev Preliminary, Sep 31, 2022.
- [RD3] Earth Science Data and Information System (ESDIS) Standards Office (ESO). “GeoTIFF File Format, ESIS-RFC-040v1.1.” Earthdata, 16 Sept. 2019. earthdata.nasa.gov/esdis/eso/standards-and-references/geotiff. Accessed 14 Oct. 2021.
- [RD4] Cloud Optimized GeoTIFF: An imagery format for cloud-native geospatial processing. www.cogeo.org/. Accessed 14 Oct. 2021.
- [RD5] “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>. This document is a ‘live’ one with the primary purpose of developing and describing the RTC-S1-STATIC product for the OPERA Algorithm Development Team’s (ADT) Calibration/Validation delivery to the OPERA SDS.

1.4 Applicable Software

This document is being released with the Calibration/Validation delivery of the RTC-S1 Science Application Software (SAS) at this GitHub repository: <https://github.com/opera-adt/RTC> version 0.4.2 (v0.4.2). The products generated by this version of the SAS are consistent with this document.

2 PRODUCT OVERVIEW

2.1 Product Background

Radar-geometry layers such as incidence angle, local incidence angle, mask, number of looks, and radiometric terrain correction (RTC) area normalization factor (ANF) γ_0 to β_0 and RTC ANF γ_0 to σ_0 vary slightly over time for each position on the ground, and therefore are considered static for the project. These static layers are packaged into an RTC-S1-STATIC product for each burst ID, and are provided separately from the OPERA RTC-S1 product, as they are produced only once or a limited number of times, to account for changes in the DEM, in the S1 orbit, or in the static-layers generation algorithm. Static layers will also be provided as single-band COG files, with map grid matching RTC-S1 products with the same burst ID.

The standard OPERA RTC-S1 product is derived from the original Copernicus Sentinel-1 (S1) interferometric wide (IW) single-look complex (SLC) data, provided by the European Space Agency (ESA), with a temporal sampling coincident with the availability of S1 A/B SLC data. The OPERA RTC-S1-STATIC and RTC-S1 products are provided at a near global scope (land masses excluding Antarctica).

Each OPERA RTC-S1-STATIC product corresponds to a single S1 burst ID. The workflow for generating the RTC-S1-STATIC is the same used for generating the standard RTC-S1 product. It requires a run configuration (runconfig) file, three input products (Table 2-1), namely the S-1 SAFE file containing the burst to process, the associated S1 orbit ephemerides, and a reference DEM; an optional input consisting of a burst database provided by the OPERA ADT that is used to make sure that all RTC-S1 products with the same burst identification (burst ID) are projected over the same geographic grid. The DEM used for generating the standard OPERA RTC-S1 product is based on the Copernicus DEM 30m (GLO-30) and Copernicus DEM 90 (GLO-90) models.

The processing for generating OPERA RTC-S1 and RTC-S1-STATIC product follows a similar workflow consisting of six blocks B1-B6 (Figure 2-1). The field “product_type” in the runconfig selects the type of the output product “RTC_S1” (RTC-S1) or “RTC_S1_STATIC” (RTC-S1-STATIC). The steps that are disabled in the processing of RTC-S1-STATIC products are shown in dark blue color in the diagram.

In block B1, the workflow inputs, i.e., S1 SLCs (SAFE file), S1 orbit, and burst DB, are loaded into memory. For the RTC-S1-STATIC product, an artificial SLC filled with dummy values and with extended radar grid is created in B1, and the process continues to B3, skipping the radiometric calibration and thermal noise correction that are normally applied to S1 SLCs in the standard processing. In block B3, the layover/shadow mask is computed over the range-Doppler geometry and geocoded over the output grid. In the standard processing, the shadow pixels are

dilated by pre-defined window size (if not set by the user) and the azimuth and range shifts due to bistatic and static-troposphere delays are computed as look-up tables (LUTs). The processing of static layers bypasses the creation of delay LUTs. The layover/shadow mask, range and azimuth LUTs, along with the reference DEM are passed to ISCE3 for radiometric terrain correction (RTC) and geocoding [RD1][RD2]. Resulting layers are saved as cloud optimized GeoTIFFs (COGs) in block B5, and the full product metadata is saved in the HDF5 format in block B6 in the standard processing (not applicable for static layers).

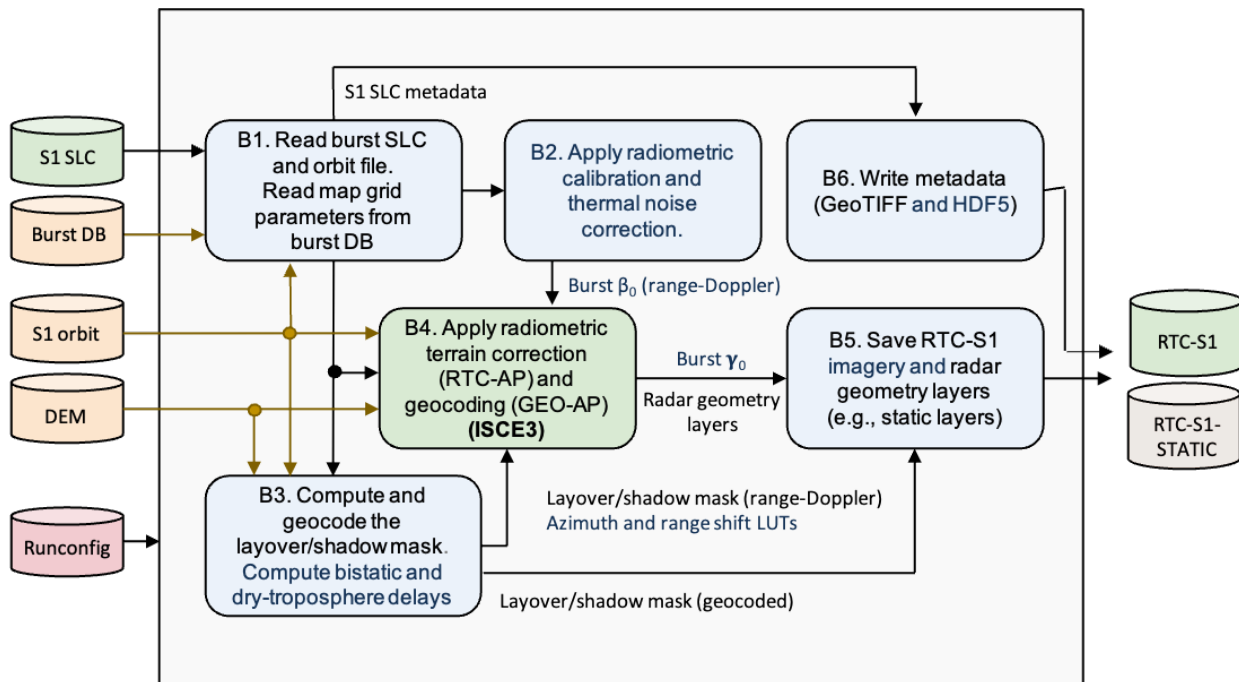


Figure 2-1 Diagram illustrating the OPERA RTC-S1 and RTC-S1-STATIC products’ workflow. The steps shown in dark blue color are only enabled in the production of OPERA RTC-S1 products.

Table 2-1 Input products and files for RTC-S1 product.

| Product | Description | Granule Size |
|----------------------|--------------------------------|--------------|
| S1 SAFE file | The input S1 SAFE file | Variable |
| S1 orbit ephemerides | The input S1 orbit ephemerides | Variable |
| DEM | Reference DEM | Variable |

| | | |
|----------|---------------------------------|-------|
| Burst DB | Burst database in SQLite format | Fixed |
|----------|---------------------------------|-------|

2.2 RTC-S1-STATIC Product Overview

The RTC-S1-STATIC product is a Level 2 product that contains static radar geometry layers associated with the RTC-S1 product. These layers are generated over pre-defined UTM/ Polar stereographic system map grid (Appendix A: Geocoded Product Grids) with a 30-meter spacing (TBC) (Table 2-2).

RTC-S1 images are normalized to the backscatter coefficient γ_0 obtained from the original radar brightness β_0 through radiometric terrain correction. The RTC-S1-STATIC product includes an RTC area normalization factor (ANF) layer, provided with the same dimensions as the RTC-S1 imagery, that can be used to approximate the images to the β_0 convention. The RTC-S1 polarimetric imagery is distributed in a lexicographic polarimetric basis as individual cloud-optimized GeoTIFFs (COGs) [RD3][RD4], i.e., one GeoTIFF file per processed polarization.

Table 2-2 Pixel spacing of the RTC-S1 product.

| Product | Pixel spacing in Northing (m) | Pixel spacing in Easting (m) |
|---------------|-------------------------------|------------------------------|
| RTC-S1 | 30 | 30 |
| RTC-S1-STATIC | 30 | 30 |

3 PRODUCT ORGANIZATION

The RTC-S1-STATIC product is distributed as cloud-optimized GeoTIFF files (COGs) containing the layers such as local incidence angle, incidence angle, mask, number of looks, and RTC ANF gamma0 to beta0 and RTC ANF gamma0 to sigma0.

3.1 File Naming Convention

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

OPERA_L2_RTC-S1-STATIC_
[BurstID]_[ValidityStartDate]_[ProductGenerationDateTime]_[Sensor]_[PixelSpacing]_[ProductVersion]_{_[LayerName]}.tif

- **BurstID:** Unique burst identification string consistent with ESA burst map convention in the form of T[TrackNumber]-[ID]-[SubSwath] (e.g, T069-147170-IW1)
- **ValidityStartDate:** The validity start date of the RTC-S1-STATIC product (format: YYYYMMDD)
- **ProductGenerationDateTime:** The date and time (GMT) at which the product was generated by OPERA (format: YYYYMMDDTHHMMSSZ)
- **Sensor:** The input product sensor, e.g., “S1A” representing Sentinel-1A
- **PixelSpacing:** Pixel spacing in meters
- **ProductVersion:** OPERA RTC-S1-STATIC 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
- **LayerName:** Name of the RTC-S1-STATIC product layer (e.g., “incidence_angle”), if applicable.

Example:

OPERA_L2_RTC-S1-STATIC_T069-147170-IW1_20140403_20230601T140222Z_S1A_30_v0.4_local_incidence_angle.tif
OPERA_L2_RTC-S1-STATIC_T069-147170-IW1_20140403_20230601T140222Z_S1A_30_v0.4_incidence_angle.tif
OPERA_L2_RTC-S1-STATIC_T069-147170-IW1_20140403_20230601T140222Z_S1A_30_v0.4_number_of_looks.tif
OPERA_L2_RTC-S1-STATIC_T069-147170-IW1_20140403_20230601T140222Z_S1A_30_v0.4_mask.tif
OPERA_L2_RTC-S1-STATIC_T069-147170-IW1_20140403_20230601T140222Z_S1A_30_v0.4_rtc_anf_gamma0_to_beta0.tif
OPERA_L2_RTC-S1-STATIC_T069-147170-IW1_20140403_20230601T140222Z_S1A_30_v0.4_rtc_anf_gamma0_to_sigma0.tif

3.2 Temporal Organization

The OPERA RTC-S1-STATIC is expected to be generated only once or a limited number of times for each burst ID. The generation of new versions of static layers will be determined by the OPERA project considering changes in the DEM, in the S1 orbit, or processing algorithm.

3.3 Spatial Organization

The OPERA RTC-S1-STATIC are provided in the same grids as used for standard RTC-S1 products. Layers 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. Pixel-is-area convention (see Appendix A: Geocoded Product Grids) is used to tag the raster layers with coordinate information.

3.4 Spatial Sampling and Resolution

Some salient features of the output grid for the RTC-S1-STATIC product are:

1. All RTC-S1-STATIC will be located over the same geographical grid for each burst ID.
2. The geographical grid coordinates will be a multiple of the pixel spacing for easy comparison with RTC-S1 products.

3.4.1 Mosaicking

The spatial sampling of the output grid has been designed to facilitate the mosaicking of contiguous RTC-S1-STATIC products. See Appendix A: Geocoded Product Grids for details on the common output grid used for all L2 products.

4 THE OPERA RTC-S1-STATIC PRODUCT

OPERA RTC-S1-STATIC layers are generated over UTM/ Polar Stereographic coordinates (see Appendix A: Geocoded Product Grids). The RTC-S1-STATIC product can be directly overlaid on a map or combined with other similar RTC-S1-STATIC products.

In this section, we briefly describe the layout of RTC-S1-STATIC data packaged into GeoTIFF files and associated metadata. The standard RTC-S1 product represents radar backscattering in γ_0 . Conversion to β_0 is accomplished by multiplying RTC-S1 imagery with the RTC area normalization factor (ANF) gamma0 to beta0 layer provided in the RTC-S1-STATIC product. Similarly, conversion to σ_0 is achieved by multiplying RTC-S1 imagery with the RTC area normalization factor (ANF) gamma0 to sigma0 layer provided in the RTC-S1-STATIC.

4.1 File format - GeoTIFF

OPERA RTC-S1-STATIC are distributed as single-band cloud optimized GeoTIFFs (COGs) [RD3] [RD4]. 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) [RD5] 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).

To save storage space, each GeoTIFF file is compressed using the DEFLATE algorithm.

4.2 RTC-S1-STATIC Layers

RTC-S1-STATIC layers are provided in the same map grid as the RTC-S1 product imagery. Static layers include the incidence angle, and local-incidence angle. number of looks, mask layer, RTC ANF gamma0 to beta0, and RTC ANF gamma0 to sigma0.

4.2.1 Local-incidence angle

Local-incidence angle is defined as angle between LOS vector and terrain normal vector at the target provided in the same geographic grid as the geocoded imagery.

4.2.2 Incidence angle

Incidence angle is defined as angle between LOS vector and the ellipsoid normal at the target provided in the same geographic grid as the geocoded imagery.

4.2.3 Mask

The mask layer contains the valid/invalid, layover, and shadow classification computed over the reference RTC-S1-STATIC burst orbit, and it is provided over the same geographic grid as the associated geocoded imagery. The mask layer contains 5 classes represented by an unsigned byte data type:

- Class 0: Valid sample not affected by layover or shadow
- Class 1: Valid sample affected by shadow
- Class 2 - Valid sample affected by layover
- Class 3: Valid sample affected by layover and shadow
- Class 255: Invalid sample (fill value)

4.2.4 Number of Looks

The radar imagery is obtained from the geocoding of S1 SLCs using an adaptive multi-looking algorithm. The algorithm uses an area-based projection approach to multi-look radar samples that intersect completely or partially with each geographical grid pixel according to topography and radar geometry. The number of looks layer indicates the number of radar samples used to compute each RTC-S1 imagery pixel and it is provided in the same geographic grid as the RTC-S1 product imagery.

4.2.5 Radiometric Terrain Correction (RTC) Area Normalization Factor (ANF) Gamma0 to Beta0

The radar backscatter is normalized to gamma0 γ_0 to reduce the dependence of the radar backscatter with the topography. The radiometric terrain correction (RTC) normalizes the original S1 backscatter from beta0 to gamma0. The RTC area normalization factor (ANF) gamma0 to beta0 provides the factors to normalize the gamma0 backscatter to beta0. This layer is provided in the same grid as the corresponding RTC-S1 imagery.

4.2.6 Radiometric Terrain Correction (RTC) Area Normalization Factor (ANF) Gamma0 to Sigma0

The RTC area normalization factor (ANF) gamma0 to sigma0 provides the factors to normalize the gamma0 backscatter to sigma0. This layer is provided in the same grid as the corresponding RTC-S1 imagery.

4.3 GeoTIFF metadata

All RTC-S1-STATIC product layers (GeoTIFF files) are saved with the same metadata, divided into four sections: 1) Product Identification, 2) Input Datasets, 3) Sentinel-1 IW SLC Parameters, and 4) RTC-S1-STATIC Processing Information.

4.3.1 Product Identification

Table 4-1 lists the product identification fields of the GeoTIFF metadata. The attribute `PRODUCT_VERSION` informs the version of the RTC-S1-STATIC product (structure and metadata), whereas the attribute `SOFTWARE_VERSION` describes the version of the software that generated the RTC-S1-STATIC product.

Table 4-1. GeoTIFF metadata: product identification.

| Attribute | Description |
|-----------------------|--|
| LAYER_NAME | Product layer name |
| LAYER_DESCRIPTION | Product layer description |
| ABSOLUTE_ORBIT_NUMBER | Absolute orbit number |
| TRACK_NUMBER | Track number |
| PLATFORM | Name of the sensor platform (e.g., "Sentinel-1A") |
| INSTRUMENT_NAME | Name of the instrument used to collect the remote sensing data provided in this product (e.g., "Sentinel-1A CSAR") |
| PRODUCT_TYPE | The product type: "RTC-S1-STATIC" |
| PROJECT | The project name: "OPERA" |
| INSTITUTION | Institution that created this product: "NASA JPL" |

| | |
|--|---|
| PRODUCT_VERSION | The product version (same as in the product filename and ID). It increments with changes to the structure and/or metadata contained within the product. This document is consistent with PRODUCT_VERSION 0.4 |
| PRODUCT_SPECIFICATION_VERSION | Product specification version which represents the schema of this product. This document is consistent with PRODUCT_SPECIFICATION_VERSION 0.1. |
| ACQUISITION_MODE | Acquisition mode: "IW" |
| CEOS_ANALYSIS_READY_DATA_PRODUCT_TYPE | CEOS Analysis Ready Data (CARD) product type |
| LOOK_DIRECTION | Look direction: "right" |
| ORBIT_PASS_DIRECTION | Orbit direction can be ascending or descending |
| PRODUCT_LEVEL | The product level: "L2". Product levels: <ul style="list-style-type: none"> - L0A: Unprocessed instrument data; - L0B: Reformatted, unprocessed instrument data; - L1: Processed instrument data in radar coordinates system; - L2: Processed instrument data in geocoded coordinates system |
| PROCESSING_TYPE | Processing type: "NOMINAL" or "URGENT" or "CUSTOM" or "UNDEFINED" |
| PROCESSING_DATETIME | RTC-S1 product processing date. Format: YYYY-MM-DDTHH:MM:SSZ. |
| RADAR_BAND | Acquired frequency band: "C" |
| CEOS_ANALYSIS_READY_DATA_DOCUMENT_IDENTIFIER | CEOS Analysis Ready Data (CARD) document identifier |
| PRODUCT_DATA_ACCESS | Location from where this product can be retrieved (URL or DOI) |

| | |
|-------------------------|-----------------------------------|
| BURST_ID | Burst identification (burst ID) |
| SUB_SWATH_ID | Sub-swath identification |
| ZERO_DOPPLER_START_TIME | Azimuth start time of the product |
| ZERO_DOPPLER_END_TIME | Azimuth stop time of the product |

4.3.2 Input Datasets

Table 4-2 describes the metadata fields that list the input datasets used to generate the RTC-S1-STATIC product.

Table 4-2. GeoTIFF metadata: input datasets.

| Attribute | Description |
|------------------------|-------------------------------------|
| INPUT_L1_SLC_GRANULES | List of input L1 SLC products used |
| INPUT_ORBIT_FILES | List of input orbit files used |
| INPUT_DEM_SOURCE | Description of the input DEM |
| INPUT_ANNOTATION_FILES | List of input annotation files used |

4.3.3 Sentinel-1 IW SLC Parameters

Table 4-3 describes the metadata fields describing the input Sentinel-1 SLC parameters.

Table 4-3. GeoTIFF metadata: Sentinel-1 SLC parameters.

| Attribute | Description |
|--------------------|---|
| SOURCE_DATA_ACCESS | Location from where the source data can be retrieved (URL or DOI) |

| | |
|--|--|
| SOURCE_DATA_NUMBER_OF_ACQUISITIONS | Number of source data acquisitions: "1" |
| SOURCE_DATA_INSTITUTION | Institution that created input product: "ESA" |
| SOURCE_DATA_PROCESSING_CENTER | Source data processing center |
| SOURCE_DATA_PROCESSING_DATETIME | Processing date and time of the source data |
| SOURCE_DATA_SOFTWARE_VERSION | Version of the software used to create the source data (IPF version) |
| SOURCE_DATA_PRODUCT_LEVEL | Product level of the source data: "L1". Product levels: <ul style="list-style-type: none"> - L0A: Unprocessed instrument data; - L0B: Reformatted, unprocessed instrument data; - L1: Processed instrument data in radar coordinates system; - L2: Processed instrument data in geocoded coordinates system |
| SOURCE_DATA_SLANT_RANGE_SPACING | Distance in meters between consecutive range samples of the source data |
| SOURCE_DATA_SLANT_RANGE_RESOLUTION_IN_METERS | Slant-range resolution of the source data in meters |
| SOURCE_DATA_ZERO_DOPPLER_TIME_SPACING | Time interval in the along-track direction of the source data |
| SOURCE_DATA_AZIMUTH_RESOLUTION_IN_METERS | Azimuth resolution of the source data in meters |
| SOURCE_DATA_ZERO_DOPPLER_START_TIME | Azimuth start time of the input product in the format YYYY-MM-DDThh:mm:ss.sZ |
| SOURCE_DATA_ZERO_DOPPLER_END_TIME | Azimuth stop time of the input product in the format YYYY-MM-DDThh:mm:ss.sZ |

4.3.4 Processing Information

Table 4-4 lists processing and other product parameters associated with the RTC-S1-STATIC product.

Table 4-4. GeoTIFF metadata: RTC-S1-STATIC processing parameters.

| Attribute | Description |
|---|--|
| SOFTWARE_VERSION | The algorithm software version used to generate the RTC-S1-STATIC product. This document is consistent with SOFTWARE_VERSION 0.4.2 |
| ISCE3_VERSION | Version of the ISCE3 framework used for processing |
| S1_READER_VERSION | Version of the OPERA s1-reader |
| AREA_OR_POINT | Indicates that pixel values are assumed to represent an area rather than points: "Area" |
| PROCESSING_INFORMATION_MULTILOOKING_APPLIED | Flag to indicate if pre-processing multilooking has been applied |
| PROCESSING_INFORMATION_FILTERING_APPLIED | Flag to indicate if post-processing filtering has been applied |
| PROCESSING_INFORMATION_STATIC_TROPOSPHERIC_GEOLOCATION_CORRECTION_APPLIED | Flag to indicate if the static tropospheric correction has been applied |
| PROCESSING_INFORMATION_WET_TROPOSPHERIC_GEOLOCATION_CORRECTION_APPLIED | Flag to indicate if the wet tropospheric correction has been applied |
| PROCESSING_INFORMATION_BISTATIC_DELAY_CORRECTION_APPLIED | Flag to indicate if the bistatic delay correction has been applied |
| PROCESSING_INFORMATION_DEM_INTERPOLATION_ALGORITHM | DEM interpolation method |

| | |
|---|--|
| PROCESSING_INFORMATION_DEM_EGM_MODEL | Earth Gravitational Model associated with the DEM |
| PROCESSING_INFORMATION_GEOCODING_ALGORITHM | Geocoding algorithm |
| PROCESSING_INFORMATION _RADIOMETRIC_TERRAIN_CORRECTION_ALGORITHM | Radiometric terrain correction (RTC) algorithm |
| PROCESSING_INFORMATION _RADIOMETRIC_TERRAIN_CORRECTION_ALGORITHM_REFERENCE | A reference to the radiometric terrain correction (RTC) algorithm applied |
| PROCESSING_INFORMATION _GEOCODING_ALGORITHM_REFERENCE | A reference to the geocoding algorithm applied |
| PROCESSING_INFORMATION _INPUT_BACKSCATTER_NORMALIZATION_CONVENTION | Backscatter normalization convention of the source data |
| PROCESSING_INFORMATION _OUTPUT_BACKSCATTER_NORMALIZATION_CONVENTION | Backscatter normalization convention of the radar imagery associated with this product |
| PROCESSING_INFORMATION _OUTPUT_BACKSCATTER_EXPRESSION_CONVENTION | Backscatter expression convention |
| PROCESSING_INFORMATION _OUTPUT_BACKSCATTER_DECIBEL_CONVERSION_EQUATION | Equation to convert provided backscatter to decibel (dB) |
| PROCESSING_INFORMATION _CEOS_ANALYSIS_READY_DATA_PIXEL_COORDINATE_CONVENTION | CEOS Analysis Ready Data (CARD) pixel coordinate convention |
| PROCESSING_INFORMATION _BURST_GEOGRID_SNAP_X | Burst geogrid snap for Coordinate X (W/E) |
| PROCESSING_INFORMATION _BURST_GEOGRID_SNAP_Y | Burst geogrid snap for Coordinate Y (S/N) |

APPENDIX A: GEOCODED PRODUCT GRIDS

OPERA RTC-S1 and RTC-S1-STATIC products are generated on a pre-defined Track/Burst system. The projection system for a particular burst ID is available to the users as a predefined map and will be held constant through the life of the system. Each product layer includes information indicating the projection used for the product.

Map Projections

OPERA’s SDS is able to ingest any Digital Elevation Model whose vertical datum represents height above the WGS84 Ellipsoid and the horizontal datum can be represented by a European Petroleum Standards Group (EPSG) code for generating geocoded product. Table B-00-1 lists the various projection systems used to output RTC-S1-STATIC products.

Table B-00-1. Projection Systems for L2 RTC-S1 Products

| EPSG code | PROJ.4 string | Common Name | Geographical scope |
|-------------|---|---|---|
| 3413 | +proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs | NSIDC Sea Ice Polar Stereographic North | Greenland and Northern Hemisphere Sea Ice (products with center latitude greater than 75 degrees) |
| 32601-32660 | +proj=utm +zone=X-32600 +datum=WGS84 +units=m +no_defs | UTM Zone North | Northern Hemisphere Land except Greenland |
| 32701-32760 | +proj=utm +zone=X-32700 +south +datum=WGS84 +units=m +no_defs | UTM Zone South | Southern Hemisphere Land |

Grid Alignment

OPERA RTC-S1 products will use a “pixel is area” convention. The “pixel is area” convention, which is the default, 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).

APPENDIX B: ACRONYMS

| | |
|-------------------------|--|
| ADT | Algorithm Development Team |
| ARD | Analysis Ready Data |
| ASF | Alaska Satellite Facility |
| ASF.DAAC | NASA's Alaska Satellite Facility Distributed Active Archive Center |
| CARD | CEOS Analysis Ready Data |
| CEOS | Committee on Earth Observation Satellites |
| COG | Cloud optimized GeoTIFF |
| DAAC | Distributed Active Archive Center |
| DEM | Digital Elevation Model |
| ECEF | Earth Centered Earth Fixed |
| ESA | European Space Agency |
| Float32 | Floating-point number of 32 bits |
| GDAL | Geospatial Data Abstraction Library |
| GeoTIFF | Georeferenced Tagged Image File Format |
| GIS | Geographic Information System |
| InSAR | Interferometric Synthetic Aperture Radar |
| ISCE3 | InSAR Scientific Computing Environment Enhanced Edition |
| OPERA | Observational Products for End-users from Remote-sensing Analysis |
| MHz | Mega-Hertz |
| MOE | Medium-precision Orbit Ephemeris |
| QA | Quality Assurance |
| RTC | Radiometric Terrain Correction |
| RTC-S1 | Radiometric Terrain Corrected SAR backscatter from Sentinel-1 |
| RTC-S1-STATIC Layers | Radiometric Terrain Corrected SAR backscatter from Sentinel-1 Static |
| SAR | Synthetic Aperture Radar |
| SAFE | Standard Archive Format for Europe |
| SAS | Science Application Software |
| SDS | Science Data System |
| SLC | Single Look Complex |
| UInt8 | Unsigned Integers of 8 bits |
| UInt16 | Unsigned Integers of 16 bits |
| UPS | Universal Polar Stereographic |
| URI | Uniform Resource Identifier |
| UTM | Universal Transverse Mercator |

WRS World Reference System
ZSTD Zstandard (compression algorithm)