Surface Water and Ocean Topography (SWOT) Project

SWOT Product Description
Long Name: Level 2 KaRIn high rate raster product
Short Name: L2_HR_Raster

Revision B

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See Sect 1.4 for how to cite this document

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1 Introduction

1.1 Purpose

The purpose of this Product Description Document is to describe the Level 2 Ka-band Radar Interferometer (KaRIn) high-rate (HR) raster data product from the Surface Water Ocean Topography (SWOT) mission. This data product is also referenced by the short name L2_HR_Raster.

This document describes both operationally processed and on-demand versions of the L2_HR_Raster product as described in Section 2.1.

1.2 Document Organization

Section 2 provides a general description of the product, including its purpose and latency.

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.

Section 5 provides a detailed identification of the individual fields within the L2_HR_Raster product, including for example their units, size, coordinates, etc.

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

Appendix B provides a description of bitwise quality flags in the product.

1.3 Document Conventions

Where specific names of data variables and groups of the data product are given in the body text of this document, they are usually represented in italicized text.

1.4 Citing This Document

Please cite this document as follows:

> JPL D-56416, Revision B, "SWOT Product Description Document: Level 2 KaRIn High Rate Raster (L2_HR_Raster) Data Product," Jet Propulsion Laboratory Internal Document, 2023.

2 Product Description

2.1 Purpose

The L2_HR_Raster product contains rasterized water surface elevation and inundation extent data from the HR data stream of the KaRIn instrument, along with appropriate uncertainties and flags, resampled onto a uniform grid. The HR data stream from the KaRIn instrument is controlled by a reloadable HR mask. The L2_HR_PIXC [1] and L2_HR_PIXCVec [2] products serve as the source for generating the L2_HR_Raster product. While the L2_HR_PIXC and L2_HR_PIXCVec products provide adaptively averaged, ellipsoid-relative heights of detected water and water fraction at sampling intervals of ~20 m along-track and varying between 10-60 m cross-track, the L2_HR_Raster product aggregates those measurements into coarser resolution and sampling to reduce measurement noise. A uniform grid is superimposed onto the pixel cloud from the L2_HR_PIXC and L2_HR_PIXCVec products, and all pixel-cloud samples within each grid cell are aggregated to produce a single value per raster cell (for example, average water surface elevation and water surface area, as shown in Figure 1).

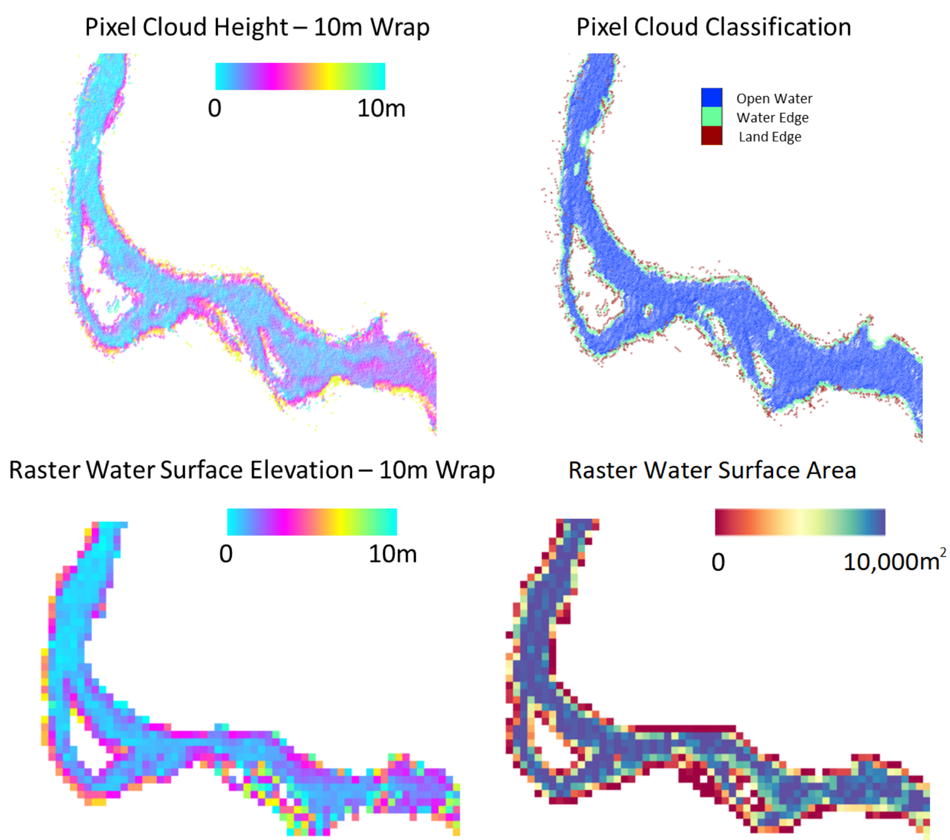

Figure 1. Example pixel cloud height (top left), and classification (top right) from which a raster product is produced, and the resulting raster water surface elevation (bottom left) and water surface area (bottom right). Note that this image shows layers from a 100 m raster in the UTM projection.

The L2_HR_Raster product can be used to study complex flow environments and internal spatial variability in river reaches and lakes not effectively captured by SWOT vector products [3] [4] without having to work with the irregularly sampled and more complicated L2_HR_PIXC product. Note that the SWOT low rate (LR) data stream and its associated data products [5] may be more appropriate for large water features since the LR data allow for finer vertical precision, albeit possibly at coarser horizontal resolution; the geophysical corrections included in the LR data products also differ from those of the L2_HR_Raster product. The L2_HR_Raster product is generated in response to the SWOT project science requirements described in [6].

L2_HR_Raster data are generally produced for inland waters, estuaries, and coastal ocean surfaces, as controlled by the reloadable KaRIn HR mask. The product is produced using algorithms that are detailed in [7]. Because SWOT is focused on water surfaces, these algorithms discard data from areas that are not classified as water or land near water in the L2_HR_PIXC product. The L2_HR_Raster data hence give measurements primarily for water surfaces, which usually comprise a small fraction of the total area covered by the L2_HR_Raster footprint. Therefore, the great majority of pixels in L2_HR_Raster images (i.e., most pixels corresponding to land) are usually void (null filled). It is the responsibility of the user to examine the quality flags in the data in order to determine which pixels are valid.

The L2_HR_Raster Standard Data Products (SDPs) are available for all HR data collected by KaRIn. Note that the L2_HR_Raster resolution is equivalent to the horizontal sampling, and that operational processing produces two SDPs at the two resolutions specified below. The SDPs are generated as follows:

- Universal Transverse Mercator (UTM) projection grid
- 128 km x 128 km non-overlapping granule sizes
- Provided at each of 100 m and 250 m resolutions
- NetCDF file format

Additionally, the NASA and CNES data-distribution centers offer a related on-demand HR raster data product. The On-Demand Product (ODP) is created upon request with user-specified combinations of processing and formatting parameters. On-demand processing allows the user to specify at least the following:

- Universal Transverse Mercator (UTM) projection or geodetic latitude-longitude grids
- 128 km x 128 km non-overlapping or 128 km x 256 km overlapping granule sizes
- A variety of spatial resolutions
- NetCDF or GeoTIFF file formats

The organization of this document is oriented toward the SDPs. This document also describes the possible differences between the SDPs and the ODPs.

2.2 Latency

The L2_HR_Raster SDPs are generated with a latency of at most 45 days from data collection. The latency allows for consolidation of instrument calibration and the required auxiliary or ancillary data that are needed to generate this product. Different versions of the SDPs may be generated at different latencies and/or through reprocessing with refined input data.

3 Product Structure

3.1 Granule Definition

The term “granule” is used within this document to represent an individual data product file with a specific temporal or spatial coverage. The term “tile” is used to indicate a granule that covers a half swath in cross track and approximately 64 km in along track, while “scene” is used to indicate a granule which is constructed from a set of multiple tiles, and covers a full swath in cross track.

The L2_HR_Raster SDPs are organized into swath-aligned scenes, with each granule corresponding to a non-overlapping 2 x 2 set of L2_HR_PIXC reference tiles [7] (see Figure 2). The reference tiles define the set of tiles that are constructed along the ideal repeat ground track that is used as a reference for controlling the spacecraft orbit, assuming ideal spacecraft attitude. The actual SWOT ground track will typically deviate from the reference ground track by +/- 1 km. As the L2_HR_PIXC reference tiles have nominal dimensions of 64 km x 64 km, the L2_HR_Raster SDP scenes nominally contain data over 128 km x 128 km granules. The geographically aligned uniform sampling grid for each scene encompasses a greater area than the data coverage, with null-filled values in areas not covered by the granule. As a granule is constructed from a single pass observation, a given location on the ground may be covered by multiple granules corresponding to different passes.

Also note that boundaries of the L2_HR_Raster granules do not correspond exactly to the actual tile boundaries of the L2_HR_PIXC product, as the L2_HR_Raster scenes are defined to coincide with reference tile boundaries with respect to the nominal reference spacecraft ground track, whereas the actual L2_HR_PIXC tile boundaries approximate the reference tile boundaries but also depend on the particular spacecraft position and velocity and the KaRIn pulse timing when the data were collected. As a result, L2_HR_Raster SDP scenes may contain data from the prior and subsequent L2_HR_PIXC tiles on both swath sides, and L2_HR_PIXC data outside of the reference tile cross-track boundaries will be excluded from the L2_HR_Raster product. See [7] for more detailed information regarding the reference tile boundaries. The L2_HR_Raster SDP scenes do not contain overlap between successive scenes.

The raster ODP supports an alternative, overlapping granule definition that corresponds to a 2 x 4 set of L2_HR_PIXC reference tiles to give a 128 km x 256 km raster granule. The granules of this product have a 128 km along-track overlap with each other to facilitate use of the raster product where the region of interest falls at the edges of the non-overlapping standard product. The 128 km x 256 km raster scenes are always centered on the same 2 x 2 sets of L2_HR_PIXC reference tiles as the corresponding non-overlapping scenes and are represented in Figure 3.

Scenes for both the non-overlapping and overlapping granules are numbered sequentially by pass number in the ideal reference orbit repeat cycle then by along-track scene number within the pass. Along-track scene numbers are numbered sequentially following the spacecraft flight direction, so the scene numbers increase from south to north for ascending passes and from north to south for descending passes.

The first and last scenes of each pass will generally have somewhat different along-track lengths because the pass length is not an exact integer multiple of the scene length.

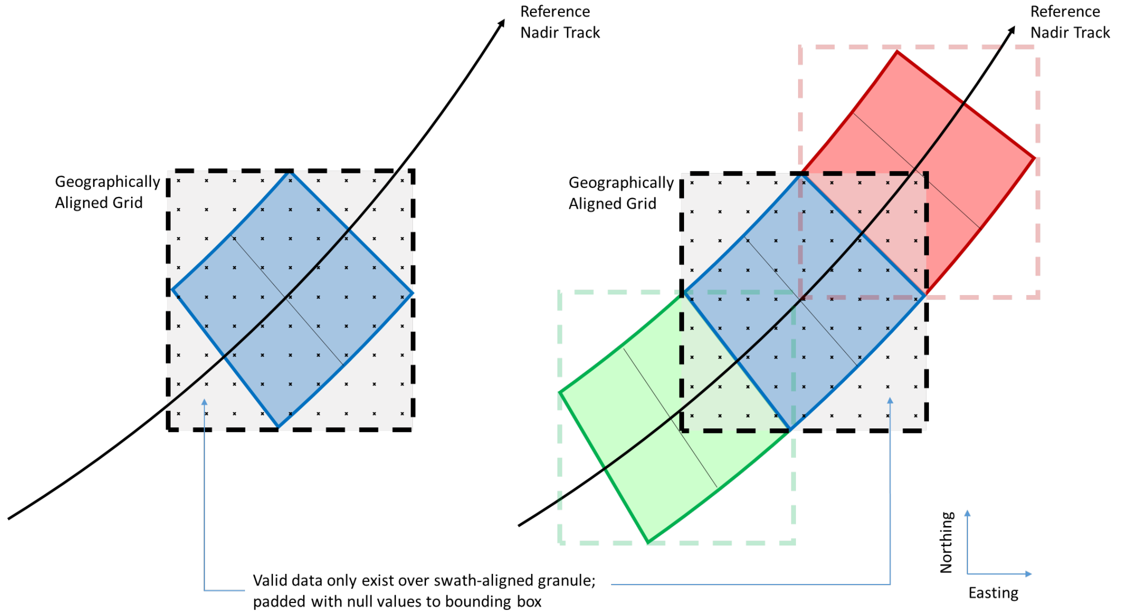

Figure 2. L2_HR_Raster product 128 km x 128 km non-overlapping granule illustration, as is provided in standard and on-demand products. Left: Raster sampling grid (black dashed line) and associated granule extent (shaded blue). Right: The L2_HR_Raster sampling grid and granule extent, along with those of the previous (shaded green) and next (shaded red) granules.

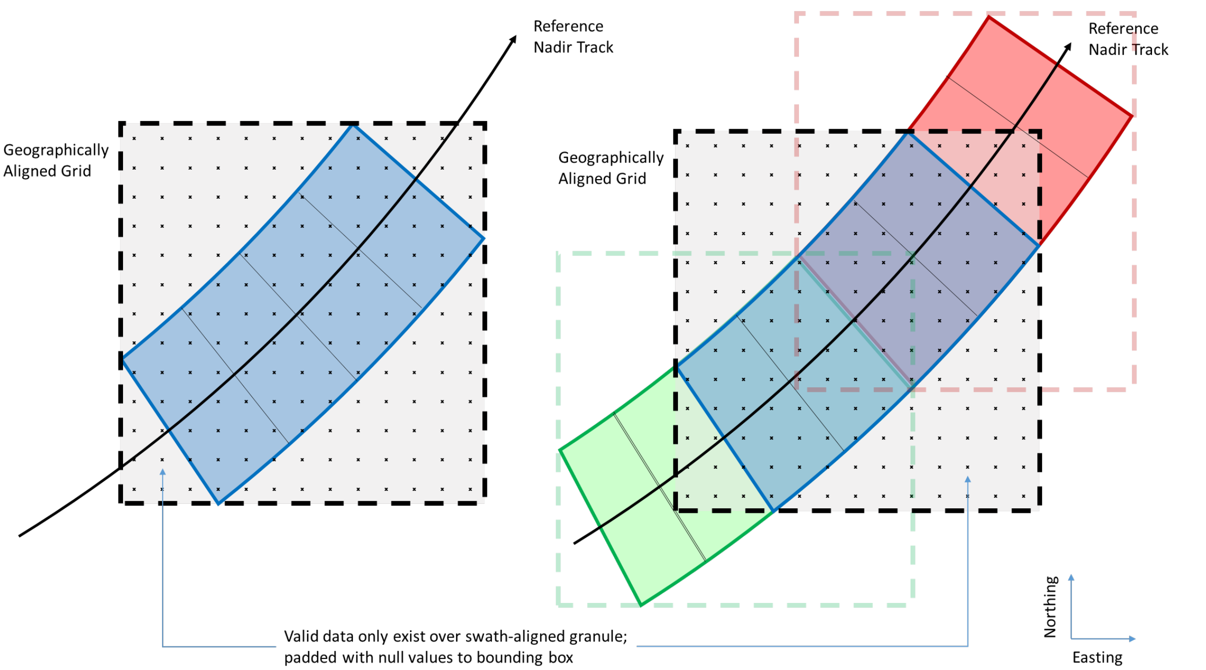

Figure 3. L2_HR_Raster product 128 km x 256 km overlapping granule illustration, as is provided in the on-demand product only. Left: Raster sampling grid (black dashed line) and associated granule extent (shaded blue). Right: Raster sampling grid and granule extent, along with those of the previous (shaded green) and next (shaded red) granules. Note the 128 km overlap between successive granules, indicated by color blending of the green, blue, and red

shaded granules.

3.2 File Organization

The L2_HR_Raster SDP adopts the NetCDF-4 file format. Operationally, L2_HR_Raster SDPs are produced at two resolutions of 100 m and 250 m. As indicated in Table 1, each SDP consists of a single NetCDF file containing rasterized Level 2 measurement information at the specified resolution. Each file contains a section of global attributes and a number of variable layers. Users can also request the ODP in GeoTIFF format, but this document does not discuss specific details of that format. However, much of the information in this document also applies to the GeoTIFF ODP, which is typically provided as a single file with user-specified parameters.

Table 1. Description of the file comprising the L2_HR_Raster product.

File	Name	Description
1	Level 2 KaRIn high-rate raster product	Provides rasterized Level 2 water surface elevation, area, and fraction measurement information. Operational products are generated at two resolutions, 100 m and 250 m, in separate files.

3.3 File Naming Convention

The L2_HR_Raster products adopt the following file naming convention:

SWOT_L2_HR_Raster_<DescriptorString>_<CycleID>_<PassID>_<SceneID>_<RangeBeginningDateTime>_<RangeEndingDateTime>_<CRID>_<ProductCounter>.nc

The *DescriptorString* label encodes information regarding the horizontal resolution, granule overlap, and coordinate grid of the raster data, for both the SDP and ODP. The format of the *DescriptorString* label is as follows:

<GridResolution><GridUnits>_<CoordinateSystem>_<GranuleOverlapFlag>_x_x_x

The *GridResolution* and *GridUnits* labels describe the sampling grid of the raster data, and the *CoordinateSystem* label describes the projected (UTM) or geographic (GEO) coordinate reference system, including the UTM zone and MGRS latitude band for raster products produced in that projection. The *GranuleOverlapFlag* is a single character flag indicating whether the raster data is provided for a non-overlapping 128 km x 128 km granule ("N") or an overlapping 128 km x 256 km granule ("O"). The *DescriptorString* contains three spare fields (currently filled with "x") which are provided to support possible future on-demand raster options. The *SceneID* is a number that increases with acquisition time in each pass, followed by the character "F" to indicate full-swath coverage (both left and right sides) in the granule.

The <CycleID>, <PassID>, and <SceneID> identify the repeat cycle, pass, and scene of the data. The <RangeBeginningDateTime> and <RangeEndingDateTime> provide the time range of data used to derive the data product. The <CRID> above contains the composite release identifier. It contains the version code of the data product, which changes if the processing software is updated. The <ProductCounter> identifies the version of product that may have been generated multiple times with the same version of processing software.

Example filenames for an SDP and an ODP granule are:

```
SWOT_L2_HR_Raster_100m_UTM14S_N_x_x_x_001_037_109F_20210612T072103_20210612T075103_PGA2_03.nc
SWOT_L2_HR_Raster_3arcsec_GEO_O_x_x_x_001_037_109F_20210612T072103_20210612T075103_PGA2_03.nc
```

3.4 Spatial Sampling and Resolution

The term "sampling" is used generically to refer to the manner or locations at which the data are discretized. While image resolution and sampling are not necessarily equivalent in general (images may be oversampled), the L2_HR_Raster product is always produced such that resolution is equivalent to the horizontal sample spacing. In this document, the term "sampling" is usually equivalent to the terms "posting" or "ground sample distance" in other contexts. One individual data value is called a sample. Samples from a 2-D image array are often also called "pixels." When the location of pixel is discussed in this document, the location refers to the center of the pixel (not a corner).

L2_HR_Raster data are stored as 2-D image arrays with geographically fixed sample spacing. Sample locations will not change from cycle to cycle for a given pass number and resolution. The data for each raster variable are aggregated from the L2_HR_PIXC samples into raster pixels using height-constrained geolocations, which are computed from the L2_HR_PIXC geolocations after spatial averaging to reduce noise. Each L2_HR_Raster SDP contains rasterized data produced in the UTM projection at a single resolution. Operational processing produces L2_HR_Raster SDPs at resolutions of 100 m and 250 m. As mentioned above, alternative resolutions are available through the raster ODP.

The UTM projection is a composite projection system which divides the earth into 60 zones and projects from the ellipsoid to a given zone using a local transverse Mercator projection for the respective zone. Each UTM zone has a width of 6 degrees in longitude, with UTM zone 1 spanning longitudes 180 to 174 degrees W, and zone numbering increasing eastward to zone 60. Additionally, Military Grid Reference System (MGRS) latitude bands are commonly used with the UTM projection for more specific location referencing. Each UTM zone is segmented into 24 MGRS latitude bands, which are represented as characters from "A" to "Z" (excluding "I" and "O" for readability). The ellipsoid is defined in the metadata of the product file itself.

All data in a given L2_HR_Raster file generated on a UTM grid are referenced to the UTM zone at the center of the scene. The pixel centers of products generated on a UTM grid are aligned with the central meridian of the UTM zone and the equator. For each UTM zone, the central meridian is assigned a false easting value of 500 km, and the equator is assigned a false northing value of 0 km for northern latitude bands and 10,000 km for southern latitude bands as shown in Figure 4. The raster ODP on a UTM grid can be optionally produced within a range of +/- 1 UTM zone and +/- 1 MGRS latitude band from the zone and band containing the scene center.

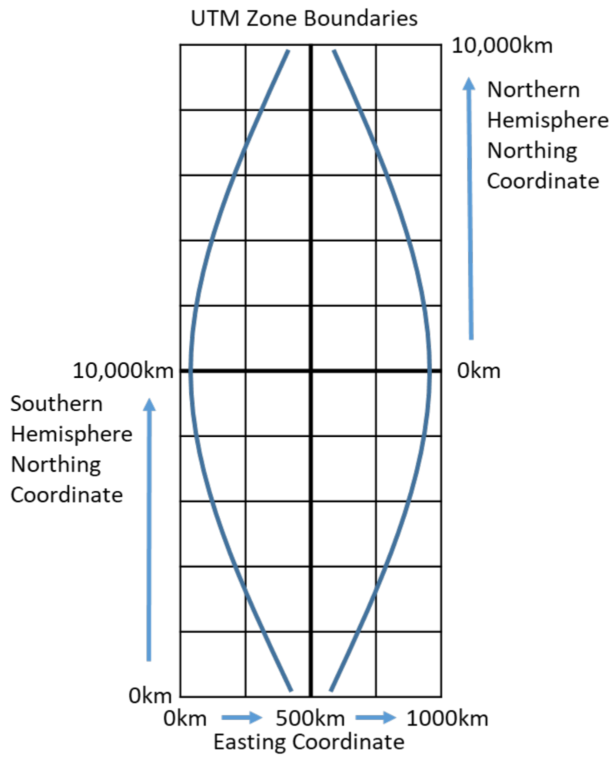

Figure 4. UTM Zone Northing and Easting Coordinate Reference. The blue curves represent the boundaries of this example UTM Zone.

For the L2_HR_Raster data product generated on a geodetic latitude-longitude grid, the pixel centers are aligned with the prime (Greenwich) meridian and the equator. On-demand resolution options for data on geodetic latitude-longitude grids are limited to a specific list of integer arc-second values. The resolution values are constrained such that 1296000 arc-seconds (i.e. 360 degrees) is evenly divisible by the resolution, giving an integer number of uniformly spaced pixels in longitude. For example, 6 arc-seconds is allowed (216000 pixels in longitude), while 7 arc-seconds is not.

3.5 Temporal Organization

Time tags corresponding to the start time of the first tile and the stop time of the last tile in the raster scene are associated with the data product as metadata. In addition, the average Coordinated Universal Time (UTC) and International Atomic Time (Temps Atomique International; TAI) illumination times of the pixel cloud samples aggregated to each raster pixel are provided in the *illumination_time* and *illumination_time_tai* variables in the L2_HR_Raster product respectively. The variables in the L2_HR_Raster product are organized geospatially and not temporally.

3.6 Spatial Organization

As described in sections 3.1 and 3.4, the raster data product is organized as 2-D image arrays with geographically fixed sample spacing. The image array coordinate indices increase from west to east and from south to north.

3.7 Volume

Table 2 provides the expected volume of the L2_HR_Raster SDPs. These data volume estimates assume that no NetCDF compression is applied. The data volume of the raster ODP is dependent upon the chosen resolution and granule size, and is not described in this document.

The L2_HR_Raster SDPs contain data for 128 km x 128 km non-overlapping granules. The raster sampling grid dimensions vary over each pass as the compass orientation of the ground track changes, ranging from 128 km x 128 km to 181 km x 181 km for the standard raster grid. This results in a range of 1,638,400 pixels to 3,276,800 pixels for the 100 m resolution UTM raster product, and 262,144 pixels to 524,288 pixels for the 250 m resolution UTM raster product. Many of these pixels will fall outside of the granule boundaries and will therefore be null filled (represented by the fill value associated with each variable). Because most raster scenes will contain many zero and null-filled values, they will often be highly compressible, which may allow reduction of file size.

The L2_HR_Raster SDPs contain a number of 2-D image arrays, and 2 1-D coordinate vectors. Therefore, for the 100 m UTM raster product, the uncompressed non-overlapping granule data volume ranges from 224.48 MB to 448.95 MB. For the 250 m resolution UTM raster product, the uncompressed non-overlapping granule data volume ranges from 35.92 MB to 71.84 MB.

Table 2. Description of the data volume of the L2_HR_Raster SDPs

Product	Minimum Volume/Scene (MB)	Maximum Volume/Scene (MB)
L2_HR_Raster 100 m Resolution Raster	224.48	448.95
L2_HR_Raster 250 m Resolution Raster	35.92	71.84
Total	**260.40**	**520.79**

4 Qualitative Description

4.1 Level 2 High Rate Raster Data File

Each L2_HR_Raster SDP is produced as a single NetCDF file per granule. Each file contains a number of global attributes and a set of NetCDF variable layers.

For the raster ODP, a number of the attributes and variables will differ depending on the grid type and may depend on user selection of variables. Note that the raster ODP will always provide the uncertainty and quality flags associated with a chosen measurement if only a subset of variables is requested.

When appropriate, the descriptions of global attributes and NetCDF variable layers in this document make a distinction between the UTM and the geodetic latitude-longitude variants of the raster product. Except where otherwise noted, however, the structure, names, and definitions of the global attributes and variables are identical between the file variants. Note that all latitude and longitude coordinates are assumed to be geodetic wherever the datum is not explicitly specified.

4.1.1 Global Attributes

A complete list of global attributes is given in section 5.2.1. In addition to common global attributes, several global attributes give information that describe the data projection and spatial sampling of the raster product. These attributes are therefore dependent on the sampling grid of the product:

Product files on UTM grids:

- *projection*: Projection full name. “Universal Transverse Mercator” for the UTM L2_HR_Raster product.
- *resolution*: Resolution of the data in meters. The horizontal sampling is always equal to the resolution for L2_HR_Raster data. The resolution in easting is always the same as the resolution in northing.
- *utm_zone_num*: UTM zone number.
- *mgrs_latitude_band*: Military Grid Reference System (MGRS) latitude band.
- *x_min, x_max*: Minimum and maximum x (easting) coordinates of the sampling grid in meters.
- *y_min, y_max*: Minimum and maximum y (northing) coordinates of the sampling grid in meters.

Product files on geodetic latitude-longitude grids:

- *projection*: Projection full name. “Geodetic Latitude/Longitude” for the geodetic latitude-longitude L2_HR_Raster product.
- *resolution*: Resolution of the data in degrees. The horizontal sampling is always equal to the resolution for L2_HR_Raster data. The resolution in latitude is always the same as the resolution in longitude, which will usually result in non-square pixels on the ground.
- *longitude_min, longitude_max*: Minimum and maximum (westernmost and easternmost) longitude coordinates of the sampling grid in decimal degrees.
- *latitude_min, longitude_max*: Minimum and maximum latitude coordinates of the

sampling grid in decimal degrees.

4.1.2 Variables

The L2_HR_Raster SDP files consist of one dimensionless coordinate reference system variable, two 1-D coordinate vectors, and a number of 2-D image variables. All 2-D image variables contained within the L2_HR_Raster product files are sampled evenly in the same Coordinate Reference System (CRS). The coordinate reference system and reference datum parameters are provided as a collection of attributes associated with the dimensionless (i.e., empty) *crs* variable. The associated *crs* attributes depend on the sampling grid of the product and are given in Table 11 and Table 12 for product files on UTM grids and on geodetic latitude-longitude grids, respectively.

- *crs*: Coordinate reference system of the product. This is a dimensionless variable containing coordinate reference system parameters as variable attributes.

The L2_HR_Raster product contains two 1-D coordinate vectors to define the gridded sampling locations of the raster pixels. The names of these variables are dependent on the sampling grid of the product variables.

Product files on UTM grids:

- *x, y*: UTM projection x (easting) and y (northing) coordinates giving the horizontal location of the center of the observed pixel.
- *longitude, latitude*: Geodetic longitude and latitude coordinates giving the horizontal location of the center of the observed pixel. These are defined identically to the *longitude* and *latitude* variables described below for product files on latitude-longitude grids, but in product files that are sampled on UTM grids, the longitude and latitude variables are 2-D arrays, not 1-D coordinate vectors.

Product files on geodetic latitude-longitude grids:

- *longitude, latitude*: Geodetic longitude and latitude coordinates giving the horizontal location of the center of the observed pixel. The latitude is a geodetic latitude with respect to the reference ellipsoid, which is defined by the *semi_major_axis* and *inverse_flattening* attributes of the *crs* variable. Positive latitude values increase northward from the equator. Positive longitude values increase eastward from the prime meridian.

The primary raster variable layers are water surface elevation (WSE, in the variable *wse*), water surface area (*water_area*), water_fraction (*water_frac*) and normalized radar cross section (*sig0*). Aggregation of these quantities includes the actual SWOT-detected water areas, including open water and area near land-water boundaries, as well as any dark water (the area of water that was not observed directly by SWOT owing to a low radar echo level, which can occur over very smooth water surfaces, or by significant attenuation of the radar signal due to propagation through rain). Dark water areas are identified through the use of a prior water probability map. The variable layers are as follows. Please see Table 11 for a description of units for these quantities.

- *wse*: Water surface elevation. The WSE is reported relative to the provided model of the geoid (*geoid*) with corrections for media delays (wet and dry troposphere, *model_wet_tropo_cor* and *model_dry_tropo_cor*, and ionosphere, *iono_cor_gim_ka*), the crossover correction (*height_cor_xover)*, and models for tidal effects (*solid_tide*, *load_tide_fes*, and *pole_tide*) applied so that the WSE values can be compared across SWOT observations at different times.
- *wse_qual*: Summary quality indicator for the WSE of a given raster water pixel. Values of 0, 1, 2, and 3 indicate good, suspect, degraded and bad measurements, respectively. Measurements that are marked as suspect may have large errors. Measurements that are marked as degraded very likely do have large errors. Measurements that are marked as bad may be nonsensical and should be ignored.
- *wse_qual_bitwise*: Bit flag that provides details on why the *wse_qual* flag is set as it is. See Appendix B for details.
- *wse_uncert*: 1-sigma uncertainty in the water surface elevation.
- *water_area*: Water surface area estimate. The reported value is the total estimated water surface area within the pixel, including detected water and any dark water that was not detected as water in the SWOT observation but identified through the use of a prior water probability map.
- *water_area_qual*: Summary quality indicator for the water surface area and water fraction of a given raster water pixel. Values of 0, 1, 2, and 3 indicate good, suspect, degraded and bad measurements, respectively. Measurements that are marked as suspect may have large errors. Measurements that are marked as degraded very likely do have large errors. Measurements that are marked as bad may be nonsensical and should be ignored.
- *water_area_qual_bitwise*: Bit flag that provides details on why the *water_area_qual* flag is set as it is. See Appendix B for details.
- *water_area_uncert*: 1-sigma uncertainty in the water surface area.
- *water_frac*: Water fraction estimate. The reported value is the total estimated water fraction within the pixel, including detected water and any dark water that was not detected as water in the SWOT observation but identified through the use of a prior water probability map. The value is calculated as *water_area* divided by the total pixel area. The pixel area may vary over the image, especially if the data are sampled on a latitude-longitude grid at high latitudes.
- *water_frac_uncert*: 1-sigma uncertainty in the water fraction.
- *sig0:* Normalized radar cross section (NRCS) or sigma0. This radar backscatter estimate is given in linear units (not decibels). The value may be slightly negative due to errors in noise estimation and subtraction. While such values are aphysical, they are kept in order to avoid biasing the results.
- *sig0_qual*: Summary quality indicator for the sigma0 of a given raster water pixel. Values of 0, 1, 2, and 3 indicate good, suspect, degraded and bad measurements, respectively. Measurements that are marked as suspect may have large errors. Measurements that are marked as degraded very likely do have large errors. Measurements that are marked as bad may be nonsensical and should be ignored.
- *sig0_qual_bitwise*: Bit flag that provides details on why the *sig0_qual* flag is set as it is. See Appendix B for details.
- *sig0_uncert*: 1-sigma uncertainty in sigma0. The value is provided in linear units. This

value is a one-sigma additive (not multiplicative) uncertainty term, which can be added to or subtracted from sigma0.

- *inc*: Incidence angle, which is the angle of the look vector with respect to the local "up" direction where the look vector intersects with the reference DEM. The incidence angle is between 0 and 90 ˚.
- *cross_track*: Approximate cross-track location of the pixel aggregated from the reported values in the L2_HR_PIXC product. This value is reported as a signed distance to the right of the spacecraft nadir point; negative values indicate that the pixel is on the left side of the nadir track. The distance is computed using a local spherical Earth approximation and corresponds to the pixel reference location based on the reference digital elevation model (DEM), not the computed geolocation.

The illumination time of the pixel is the average measurement time of the contributing L2_HR_PIXC samples. Illumination time tags are provided in the UTC and TAI time scales using the attributes *illumination_time* and *illumination_time_tai*, respectively

- *illumination_time*: Pixel illumination time in UTC time scale (seconds since January 1, 2000 00:00:00 UTC, which is equivalent to January 1, 2000 00:00:32 TAI)
- *illumination_time_tai*: Pixel illumination time in TAI time scale (seconds since January 1, 2000 00:00:00 TAI, which is equivalent to December 31, 1999 23:59:28 UTC)

The variable *illumination_time* has an attribute *tai_utc_difference*, which represents the difference between TAI and UTC (i.e., total number of leap seconds) at the time of the first measurement record in the raster product.

- *illumination_time_tai[0] = illumination_time[0] + tai_utc_difference*

The above relationship holds true for all measurement records unless an additional leap second occurs within the time span of the raster product. To account for this potential difference, the variable *illumination_time* also has an attribute named *leap_second*, which provides the date at which a leap second might have occurred within the time span of the product granule. The variable *illumination_time* will exhibit a jump when a leap second occurs. If no additional leap second occurs within the time span of the product granule *illumination_time:leap_second* is set to "0000-00-00T00:00:00Z".

With this approach, the value of *illumination_time* will have a 1 second regression during a leap second transition, while *illumination_time_tai* will be continuous. That is, when a positive leap second is inserted, two different instances will have the same value for the variable *illumination_time*, making *illumination_time* non-unique by itself; the difference between *illumination_time* and *illumination_time_tai*, or the *tai_utc_difference* and *leap_second* fields, can be used to resolve this. Some examples are provided in Table 3.

Table 3. Example Time Tags

UTC Date	TAI Date	time	time_tai	tai_utc_difference
January 1, 2000 00:00:00	January 1, 2000 00:00:32	0.0	32.0	32
December 31, 2016 23:59:59	January 1, 2017 00:00:35	536543999.0	536544035.0	36
December 31, 2016 23:59:59.5	January 1, 2017 00:00:35.5	536543999.5	536544035.5	36
December 31, 2016 23:59:60	January 1, 2017 00:00:36	536543999.0	536544036.0	37
January 1, 2017 00:00:00	January 1, 2017 00:00:37	536544000.0	536544037.0	37
January 1, 2017 12:00:00	January 1, 2017 12:00:37	536587200.0	536587237.0	37

The following flags and values indicate conditions that affect the quality of the data:

- *n_wse_pix*: Number of samples from the L2_HR_PIXC product which contribute to the WSE of a given raster water pixel. This value includes both detected and dark water samples.
- *n_water_area_pix*: Number of samples from the L2_HR_PIXC product which contribute to the water surface area and water fraction of a given raster water pixel. This value includes both detected and dark water samples.
- *n_sig0_pix*: Number of samples from the L2_HR_PIXC product which contribute to the sigma0 of a given raster water pixel. This value includes both detected and dark water samples.
- *n_other_pix*: Number of samples from the L2_HR_PIXC product which contribute to the aggregated quantities of a given raster water pixel not related to WSE, water surface area, water fraction or sigma0. This value includes both detected and dark water samples.
- *dark_frac*: Fraction of *water_area* covered by dark water. This value is typically between 0 and 1, with 0 indicating no dark water and 1 indicating 100% dark water. However, the value may be outside the range from 0 to 1 due to noise in the underlying area estimates.
- *ice_clim_flag*: Climatological ice cover flag indicating whether the pixel is ice-covered on the day of the observation based on external climatological information [8] (not the SWOT measurement). Values of 0, 1 and 2 indicate that the pixel is likely not ice covered, may or may not be partially or fully ice covered, and likely fully ice covered, respectively.
- *ice_dyn_flag*: Dynamic ice cover flag indicating whether the pixel is ice-covered on the day of the observation based on analysis of external optical satellite data [8] (not the SWOT measurement). Values of 0, 1 and 2 indicate that the pixel is not ice covered, partially ice covered, and fully ice covered, respectively. Due to the latency of computing the dynamic ice flag, this value may be completely null filled in some processing versions of the data product. When available, the *ice_dyn_flag* is likely to be more reliable than *ice_clim_flag* given that it is based on optical observations.
- *layover_impact*: Continuous value indicating an estimate of the systematic WSE error in meters due to layover.

As described in the context of the *wse* variable, several corrections are applied to the measurements during processing to obtain the reported values. These correction values are reported so that expert users can gain insight into the ways that raw instrument measurements were combined with calibration factors and external model information. Corrections are given in the product following the sign convention that the reported correction term is added to an uncorrected value to obtain the corrected value.

- *sig0_cor_atmos_model:* 2-way atmospheric radiometric correction to *sig0* applied as a scale factor in linear units (or equivalently additive in dB). The correction is obtained from a numerical weather prediction model (e.g., ECMWF). The user can remove this correction by a dividing the linear sig0 by *sig0_cor_atmos_model*, or the user can replace the correction by dividing it out and multiplying by a new correction.
- *height_cor_xover*: Height correction to *wse* computed from a combination of sea surface

height crossovers between KaRIn/KaRIn measurements and KaRIn/nadir altimeter measurements on different passes within a temporal window surrounding the height measurement. This correction provides an estimate of residual errors that have not been removed with use of ancillary attitude and calibration data during processing. The correction is applied before geolocation, but it is reported in the product as an equivalent height correction. The correction term should be subtracted from the reported pixel height to obtain the uncorrected pixel height.

Corrections due to propagation delays from the dry troposphere, wet troposphere, and the ionosphere are applied during L2_HR_PIXC data processing. The reported pixel height, latitude and longitude are computed after adding corrections for these propagation delays to the uncorrected range along the slant-range paths. The corrections account for the differential delay between the two KaRIn antennas. These corrections are reported in the L2_HR_Raster product, however, as equivalent vertical path corrections (rather than slant-path corrections) that are computed by applying obliquity factors to the slant-path correction values so that the values in the product can be directly applied to the reported height if desired. The additional path delay relative to free space results in a negative correction value that is added as a correction to the uncorrected range. However, a decrease in the measured range gives an increase in the measured height. Consequently, adding the reported correction terms to the reported height results in the uncorrected pixel height. Model-based corrections are based on SWOT-independent information from the European Centre for Medium-Range Weather Forecasts (ECMWF) and Jet Propulsion Laboratory (JPL Global Ionosphere Maps).

- *model_dry_tropo_cor*: Model-based equivalent vertical dry tropospheric path delay correction. This value is computed using surface pressure from the ECMWF numerical weather model.
- *model_wet_tropo_cor*: Model-based equivalent vertical wet tropospheric path delay correction. This value is computed from the ECMWF numerical weather model.
- *iono_cor_gim_ka*: Equivalent vertical ionospheric path delay correction from the JPL Global Ionosphere Maps (GIM) for the KaRIn Ka-band signal.

Geophysical references from models are applied during L2_HR_Raster processing, and the model values are reported in the L2_HR_Raster SDP. The sign convention of these geophysical references is such that adding the reported value to the reported WSE (*wse*) gives the uncompensated pixel height as observed at the time of the SWOT overpass and reported in the L2_HR_PIXC data. The geoid height is given with respect to the reference ellipsoid whose parameters are defined in the *crs* variable of the product. This information is provided to enable the user to convert the observed WSE to a different representation. Note that while the model solution used to account for the effect of the ocean tide loading on the Earth's crust is provided in the variable *load_tide_fes*, a second model solution (*load_tide_got*) is provided for users who desire to swap these models.

- *geoid*: Model for geoid height above the reference ellipsoid whose parameters are given in the *crs* variable. The geoid model is EGM2008 [9]. The geoid model includes a correction to refer the value to the mean tide system (i.e. it includes the zero-frequency permanent tide).
- *solid_earth_tide*: Model for the solid Earth (body) tide height. The reported value is

calculated using Cartwright/Taylor/Edden [10] [11] tide-generating potential coefficients and consists of the second and third degree constituents. The permanent tide (zero frequency) is not included.

- *load_tide_fes*: Model for geocentric surface height displacement from the load tide. The value is from the FES2014b ocean tide model [12]. The value is used to compute *wse*.
- *load_tide_got*: Model for geocentric surface height displacement from the load tide. The value is from the GOT4.10c ocean tide model [13]. To compute *wse* with this model, add *load_tide_fes* to *wse* and subtract *load_tide_got*.
- *pole_tide*: Model for the surface height displacement from the geocentric pole tide. The value is the sum of the contribution from the solid-Earth (body) pole tide height [14] and a model for the load pole tide height [15]. The value is computed using the reported Earth pole location after correction for a linear drift [16]: in milliarcsec,

$$Xp = 55.0 + 1.677dt$$

$$Yp = 320.5 + 3.46dt$$

where *dt* is the time in years since 2000.

5 Detailed Product Description

5.1 NetCDF Variables

Variables are used to store the various measurements. Each variable is assigned a name and a particular data type. Variables can be scalar values (i.e. 0 dimension), or can have one or more dimensions. Each variable then has attributes that provide additional information about the variable. Table 4 below identifies the data types used in the L2_HR_Raster SDP, and

Table 5 identifies the attributes that may be assigned to each variable.

Table 4. Variable data types in NetCDF products

Data Type	Description
char	characters
byte	8-bit signed integer
unsigned byte	8-bit unsigned integer
short	16-bit signed integer
unsigned short	16-bit unsigned integer
int	32-bit signed integer
unsigned int	32-bit unsigned integer
long	64-bit signed integer
unsigned long	64-bit unsigned integer
float	IEEE single precision floating point (32 bits)
double	IEEE double precision floating point (64 bits)

Table 5. Common variable attributes in NetCDF files.

Attribute	Description
_FillValue	The value used to represent missing or undefined data. (Before applying add_offset and scale_factor).
add_offset	If present this value should be added to each data element after it is read. If both scale_factor and add_offset attributes are present, the data are first scaled before the offset is added.
calendar	Reference time calendar
comment	Miscellaneous information about the data or the methods to generate it.
coordinates	Coordinate variables associated with the variable
flag_meanings	Used in conjunction with flag_values. Describes the meanings of each of the elements of flag_values.
flag_values	Used in conjunction with flag_meanings. Possible values of the flag variable.
flag_masks	Used in conjunction with flag_meanings. Describes a number of independent Boolean conditions using bit field notation by setting unique bits in each flag_masks value. A flagged condition is identified by performing a bitwise AND of the variable value and each flag_masks value; a non-zero result indicates a true condition. Thus, any or all of the flagged conditions may be true, depending on the variable bit settings.
institution	Institution which generates the source data for the variable, if applicable.
leap_second	UTC time at which a leap second occurs within the time span of data within the file.
long_name	A descriptive variable name that indicates its content.
quality_flag	Names of variable quality flag(s) that are associated with this variable to indicate its quality.

scale_factor	If present, the data are to be multiplied by the value after they are read. If both scale_factor and add_offset attributes are present, the data are first scaled before the offset is added.
source	Data source (model, author, or instrument)
standard_name	A standard variable name that indicates its content.
tai_utc_difference	Difference between TAI and UTC reference time.
units	Unit of data after applying offset (add_offset) and scale_factor.
valid_max	Maximum theoretical value of variable before applying scale_factor and add_offset (not necessarily the same as maximum value of actual data)
valid_min	Minimum theoretical value of variable before applying scale_factor and add_offset (not necessarily the same as minimum value of actual data)

5.2 Level 2 High Rate Raster Data File

5.2.1 Global Attributes

Global attributes for the L2_HR_Raster SDP are dependent on the sampling grid of the file. Common global attributes are provided in Table 6. Global attributes exclusive to product files on a UTM grid are provided in Table 7, and global attributes exclusive to product files on a geodetic latitude-longitude grid are provided in Table 8.

Table 6. Common global attributes for L2_HR_Raster product files

Attribute	Format	Description
Conventions	string	NetCDF-4 conventions adopted in this group. This attribute should be set to CF-1.7 to indicate that the group is compliant with the Climate and Forecast NetCDF conventions.
title	string	Level 2 KaRIn High Rate Raster Data Product
institution	string	Name of producing agency.
source	string	The method of production of the original data. If it was model-generated, source should name the model and its version, as specifically as could be useful. If it is observational, source should characterize it (e.g., 'Ka-band radar interferometer').
history	string	UTC time when file generated. Format is: 'YYYY-MM-DDThh:mm:ssZ : Creation'
platform	string	SWOT
references	string	Published or web-based references that describe the data or methods used to produce it. Provides version number of software generating product.
reference_document	string	Name and version of Product Description Document to use as reference for product.
contact	string	Contact information for producer of product. (e.g., 'ops@jpl.nasa.gov').
cycle_number	short	Cycle number of the product granule.
pass_number	short	Pass number of the product granule.
scene_number	short	Scene number of the product granule.
tile_numbers	short	List of pixel cloud tile numbers in the product granule. Tile numbers are listed in order of increasing measurement time for the left side, followed by the right side.
tile_names	string	List of pixel cloud tile names in the product granule using format PPP_TTTS, where PPP is a 3 digit pass number with leading zeros, TTT is a 3 digit tile number within the pass, and S is a character 'L' or 'R' for the left and right swath,

		respectively. The tile order matches that of the *tile_numbers* attribute.
tile_polarizations	string	List of pixel cloud tile polarization flags, indicating whether the tile was observed with a horizontal (H) or vertical (V) radar signal polarization. The tile order matches that of the *tile_numbers* attribute.
coordinate_reference_system	string	Name of the coordinate reference system.
resolution	float	Raster sampling grid resolution. Units depend on the coordinate reference system.
short_name	string	L2_HR_Raster
descriptor_string	string	<GridResolution><GridUnits>_<CoordinateSystem>_ <GranuleOverlapFlag>_x_x_x
crid	string	Composite release identifier (CRID) of the data system used to generate this file
product_version	string	Version identifier of this data file
pge_name	string	Name of the product generation executable (PGE) that created this file
pge_version	string	Version identifier of the product generation executable (PGE) that created this file
time_granule_start	string	Nominal starting UTC time of product granule. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ
time_granule_end	string	Nominal ending UTC time of product granule. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ
time_coverage_start	string	UTC time of first measurement. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ
time_coverage_end	string	UTC time of last measurement. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ
geospatial_lon_min	double	Westernmost longitude (deg) of raster sampling grid.
geospatial_lon_max	double	Easternmost longitude (deg) of raster sampling grid.
geospatial_lat_min	double	Southernmost latitude (deg) of raster sampling grid.
geospatial_lat_max	double	Northernmost latitude (deg) of raster sampling grid.
left_first_longitude	double	Nominal swath corner longitude for the first range line and left edge of the swath (degrees_east).
left_first_latitude	double	Nominal swath corner latitude for the first range line and left edge of the swath (degrees_north).
left_last_longitude	double	Nominal swath corner longitude for the last range line and left edge of the swath (degrees_east).
left_last_latitude	double	Nominal swath corner latitude for the last range line and left edge of the swath (degrees_north).
right_first_longitude	double	Nominal swath corner longitude for the first range line and right edge of the swath (degrees_east).
right_first_latitude	double	Nominal swath corner latitude for the first range line and right edge of the swath (degrees_north).
right_last_longitude	double	Nominal swath corner longitude for the last range line and right edge of the swath (degrees_east).
right_last_latitude	double	Nominal swath corner latitude for the last range line and right edge of the swath (degrees_north).
xref_l2_hr_pixc_files	string	Names of input Level 2 high rate water mask pixel cloud files.
xref_l2_hr_pixcvec_files	string	Names of input Level 2 high rate pixel cloud vector attribute files.
xref_param_l2_hr_raster_file	string	Name of input Level 2 high rate raster processor configuration parameters file.
xref_reforbittrack_files	string	Names of input reference orbit track files.

Table 7. Global attributes exclusive to product files on UTM grids

Attribute	Format	Description
utm_zone_num	short	UTM zone number of the projection.
mgrs_latitude_band	string	Military Grid Reference System (MGRS) latitude band.
x_min	double	Westernmost x coordinate (easting) of raster sampling grid.
x_max	double	Easternmost x coordinate (easting) of raster sampling grid.
y_min	double	Southernmost y coordinate (northing) of raster sampling grid.
y_max	double	Northernmost y coordinate (northing) of raster sampling grid.

Table 8. Global attributes exclusive to product files on geodetic latitude-longitude grids

Attribute	Format	Description
longitude_min	double	Westernmost longitude (deg) of raster sampling grid.
longitude_max	double	Easternmost longitude (deg) of raster sampling grid.
latitude_min	double	Southernmost latitude (deg) of raster sampling grid.
latitude_max	double	Northernmost latitude (deg) of raster sampling grid.

5.2.2 Dimensions

The L2_HR_Raster NetCDF files use the dimensions attributes to identify the physical dimensions of variables within the file. The dimension names are dependent on the data projection of the product, and are shown in Table 9 and Table 10 for L2_HR_Raster product files on UTM grids and on geodetic latitude-longitude grids respectively.

Table 9. Variable dimensions for product files on UTM grids

Name	Description
x	The number of x (easting) coordinate pixels for each 2-D image variable.
y	The number of y (northing) coordinate pixels for each 2-D image variable.

Table 10. Variable dimensions for product files on geodetic latitude-longitude grids

Name	Description
longitude	The number of longitude coordinate pixels for each 2-D image variable.
latitude	The number of latitude coordinate pixels for each 2-D image variable.

5.2.3 Detailed NetCDF Format Description

This section provides a detailed listing of each of the variables within the L2_HR_Raster product files and their attributes. Table 11 and Table 12 show the grid-specific variables for L2_HR_Raster product files on UTM grids and on geodetic latitude-longitude grids, respectively. Table 13 shows the common variables for each product. In each of these tables, the expressions “[ew_dim]” and “[ns_dim]” represent the east-west and north-south dimensions of the relevant grid, respectively (i.e. *x* and *y* for UTM, and *longitude* and *latitude* for geodetic latitude-longitude, respectively). Similarly, “[ew_var]” and “[ns_var]” represent the east-west and north-south coordinate variables.

Table 11. Variables exclusive to L2_HR_Raster product files on UTM grid

Variables		
char crs()		
	_FillValue	*
	long_name	CRS Definition
	grid_mapping_name	transverse_mercator
	projected_crs_name	[OGS projected CRS name]
	geographic_crs_name	[OGS geographic CRS name]
	reference_ellipsoid_name	[Reference ellipsoid name]
	horizontal_datum_name	[Horizontal datum name]
	prime_meridian_name	[Prime meridian name]
	false_easting	[Projection false easting value]
	false_northing	[Projection false northing value]
	longitude_of_central_meridian	[Projection longitude of central meridian]
	longitude_of_prime_meridian	[Longitude of prime meridian]
	latitude_of_projection_origin	[Latitude of projection origin]
	scale_factor_at_central_meridian	[Scale factor at central meridian]
	semi_major_axis	[Ellipsoid semi-major axis]
	inverse_flattening	[Ellipsoid inverse flattening]
	crs_wkt	[OGS Well-Known Text string]
	spatial_ref	[OGS Well-Known Text string]
	comment	UTM zone coordinate reference system.
double x(x)		
	_FillValue	9.969209968386869e+36
	long_name	x coordinate of projection
	standard_name	projection_x_coordinate
	units	m
	valid_min	-10000000
	valid_max	10000000
	comment	UTM easting coordinate of the pixel.
double y(y)		
	_FillValue	9.969209968386869e+36
	long_name	y coordinate of projection
	standard_name	projection_y_coordinate
	units	m
	valid_min	-20000000
	valid_max	20000000
	comment	UTM northing coordinate of the pixel.
double longitude(y, x)		
	_FillValue	9.969209968386869e+36
	long_name	longitude (degrees East)
	standard_name	longitude
	grid_mapping	crs
	units	degrees_east
	valid_min	-180
	valid_max	180
	coordinates	x y
	comment	Geodetic longitude [-180,180) (east of the Greenwich meridian) of the pixel.
double latitude(y, x)		
	_FillValue	9.969209968386869e+36
	long_name	latitude (positive N, negative S)
	standard_name	latitude

	grid_mapping	crs
	units	degrees_north
	valid_min	-80
	valid_max	80
	coordinates	x y
	comment	Geodetic latitude [-80,80] (degrees north of equator) of the pixel.

Table 12. Variables exclusive to L2_HR_Raster product files on geodetic latitude-longitude grid

Variables		
char crs()		
	_FillValue	*
	long_name	CRS Definition
	grid_mapping_name	latitude_longitude
	geographic_crs_name	[OGS geographic CRS name]
	reference_ellipsoid_name	[Reference ellipsoid name]
	horizontal_datum_name	[Horizontal datum name]
	prime_meridian_name	[Prime meridian name]
	longitude_of_prime_meridian	[Longitude of prime meridian]
	semi_major_axis	[Ellipsoid semi-major axis]
	inverse_flattening	[Ellipsoid inverse flattening]
	crs_wkt	[OGS Well-Known Text string]
	spatial_ref	[OGS Well-Known Text string]
	comment	Geodetic latitude/longitude coordinate reference system.
double longitude(longitude)		
	_FillValue	9.969209968386869e+36
	long_name	longitude (degrees East)
	standard_name	longitude
	units	degrees_east
	valid_min	-180
	valid_max	180
	comment	Longitude [-180,180) (east of the Greenwich meridian) of the pixel.
double latitude(latitude)		
	_FillValue	9.969209968386869e+36
	long_name	latitude (positive N, negative S)
	standard_name	latitude
	units	degrees_north
	valid_min	-80
	valid_max	80
	comment	Latitude [-80,80] (degrees north of equator) of the pixel.

Table 13. L2_HR_Raster common variables

Variables		
float wse([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	water surface elevation above geoid
	grid_mapping	crs
	units	m
	quality_flag	wse_qual

	valid_min	-1500
	valid_max	15000
	coordinates	[ew_var] [ns_var]
	comment	Water surface elevation of the pixel above the geoid and after using models to subtract the effects of tides (solid_earth_tide, load_tide_fes, pole_tide).
unsigned byte wse_qual([ns_dim], [ew_dim])		
	_FillValue	255
	long_name	summary quality indicator for the water surface elevation
	standard_name	status_flag
	grid_mapping	crs
	flag_meanings	good suspect degraded bad
	flag_values	0 1 2 3
	valid_min	0
	valid_max	3
	coordinates	[ew_var] [ns_var]
	comment	Summary quality indicator for the water surface elevation quantities. A value of 0 indicates a nominal measurement, 1 indicates a suspect measurement, 2 indicates a degraded measurement, and 3 indicates a bad measurement.
unsigned int wse_qual_bitwise([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	bitwise quality indicator for the water surface elevation
	standard_name	status_flag
	grid_mapping	crs
	flag_meanings	classification_qual_suspect geolocation_qual_suspect large_uncert_suspect bright_land few_pixels far_range_suspect near_range_suspect classification_qual_degraded geolocation_qual_degraded low_coherence_water_degraded value_bad no_pixels outside_scene_bounds inner_swath missing_karin_data
	flag_masks	2 4 32 128 4096 8192 16384 262144 524288 2097152 16777216 268435456 536870912 1073741824 2147483648
	valid_min	0
	valid_max	4046221478
	coordinates	[ew_var] [ns_var]
	comment	Bitwise quality indicator for the water surface elevation quantities. If this word is interpreted as an unsigned integer, a value of 0 indicates good data, positive values less than 32768 represent suspect data, values greater than or equal to 32768 but less than 8388608 represent degraded data, and values greater than or equal to 8388608 represent bad data.
float wse_uncert([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	uncertainty in the water surface elevation
	grid_mapping	crs
	units	m
	valid_min	0
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	1-sigma uncertainty in the water surface elevation.
float water_area([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	water surface area
	grid_mapping	crs
	units	m^2
	quality_flag	water_area_qual

	valid_min	-2000000
	valid_max	2000000000
	coordinates	[ew_var] [ns_var]
	comment	Surface area of the water pixels.
unsigned byte water_area_qual([ns_dim], [ew_dim])		
	_FillValue	255
	long_name	summary quality indicator for the water surface area
	standard_name	status_flag
	grid_mapping	crs
	flag_meanings	good suspect degraded bad
	flag_values	0 1 2 3
	valid_min	0
	valid_max	3
	coordinates	[ew_var] [ns_var]
	comment	Summary quality indicator for the water surface area and water fraction quantities. A value of 0 indicates a nominal measurement, 1 indicates a suspect measurement, 2 indicates a degraded measurement, and 3 indicates a bad measurement.
unsigned int water_area_qual_bitwise([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	bitwise quality indicator for the water surface area
	standard_name	status_flag
	grid_mapping	crs
	flag_meanings	classification_qual_suspect geolocation_qual_suspect water_fraction_suspect large_uncert_suspect bright_land low_coherence_water_suspect few_pixels far_range_suspect near_range_suspect classification_qual_degraded geolocation_qual_degraded value_bad no_pixels outside_scene_bounds inner_swath missing_karin_data
	flag_masks	2 4 8 32 128 256 4096 8192 16384 262144 524288 16777216 268435456 536870912 1073741824 2147483648
	valid_min	0
	valid_max	4044124590
	coordinates	[ew_var] [ns_var]
	comment	Bitwise quality indicator for the water surface area and water fraction quantities. If this word is interpreted as an unsigned integer, a value of 0 indicates good data, positive values less than 32768 represent suspect data, values greater than or equal to 32768 but less than 8388608 represent degraded data, and values greater than or equal to 8388608 represent bad data.
float water_area_uncert([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	uncertainty in the water surface area
	grid_mapping	crs
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	[ew_var] [ns_var]
	comment	1-sigma uncertainty in the water surface area.
float water_frac([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	water fraction
	grid_mapping	crs
	units	1
	quality_flag	water_area_qual
	valid_min	-1000

	valid_max	10000
	coordinates	[ew_var] [ns_var]
	comment	Fraction of the pixel that is water.
float water_frac_uncert([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	uncertainty in the water fraction
	grid_mapping	crs
	units	1
	valid_min	0
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	1-sigma uncertainty in the water fraction.
float sig0([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	sigma0
	grid_mapping	crs
	units	1
	quality_flag	sig0_qual
	valid_min	-1000
	valid_max	10000000
	coordinates	[ew_var] [ns_var]
	comment	Normalized radar cross section (sigma0) in real, linear units (not decibels). The value may be negative due to noise subtraction.
unsigned byte sig0_qual([ns_dim], [ew_dim])		
	_FillValue	255
	long_name	summary quality indicator for the sigma0
	standard_name	status_flag
	grid_mapping	crs
	flag_meanings	good suspect degraded bad
	flag_values	0 1 2 3
	valid_min	0
	valid_max	3
	coordinates	[ew_var] [ns_var]
	comment	Summary quality indicator for the sigma0 quantities. A value of 0 indicates a nominal measurement, 1 indicates a suspect measurement, 2 indicates a degraded measurement, and 3 indicates a bad measurement.
unsigned int sig0_qual_bitwise([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	bitwise quality indicator for the sigma0
	standard_name	status_flag
	grid_mapping	crs
	flag_meanings	sig0_qual_suspect classification_qual_suspect geolocation_qual_suspect large_uncert_suspect bright_land low_coherence_water_suspect few_pixels far_range_suspect near_range_suspect sig0_qual_degraded classification_qual_degraded geolocation_qual_degraded value_bad no_pixels outside_scene_bounds inner_swath missing_karin_data
	flag_masks	1 2 4 32 128 256 4096 8192 16384 131072 262144 524288 16777216 268435456 536870912 1073741824 2147483648
	valid_min	0
	valid_max	4044255655
	coordinates	[ew_var] [ns_var]
	comment	Bitwise quality indicator for the sigma0 quantities. If this word is interpreted as an unsigned integer, a value of 0 indicates good data, positive values less than 32768

		represent suspect data, values greater than or equal to 32768 but less than 8388608 represent degraded data, and values greater than or equal to 8388608 represent bad data.
float sig0_uncert([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	uncertainty in sigma0
	grid_mapping	crs
	units	1
	valid_min	0
	valid_max	1000
	coordinates	[ew_var] [ns_var]
	comment	1-sigma uncertainty in sigma0. The value is provided in linear units. This value is a one-sigma additive (not multiplicative) uncertainty term, which can be added to or subtracted from sigma0.
float inc([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	incidence angle
	grid_mapping	crs
	units	degrees
	valid_min	0
	valid_max	90
	coordinates	[ew_var] [ns_var]
	comment	Incidence angle.
float cross_track([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	approximate cross-track location
	grid_mapping	crs
	units	m
	valid_min	-75000
	valid_max	75000
	coordinates	[ew_var] [ns_var]
	comment	Approximate cross-track location of the pixel.
double illumination_time([ns_dim],[ew_dim])		
	_FillValue	9.969209968386869e+36
	long_name	time of illumination of each pixel (UTC)
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DDThh:mm:ssZ
	units	seconds since 2000-01-01 00:00:00.000
	coordinates	[ew_var] [ns_var]
	comment	Time of measurement in seconds in the UTC time scale since 1 Jan 2000 00:00:00 UTC. [tai_utc_difference] is the difference between TAI and UTC reference time (seconds) for the first measurement of the data set. If a leap second occurs within the data set, the attribute leap_second is set to the UTC time at which the leap second occurs.
double illumination_time_tai([ns_dim],[ew_dim])		
	_FillValue	9.969209968386869e+36
	long_name	time of illumination of each pixel (TAI)
	standard_name	time
	calendar	gregorian
	units	seconds since 2000-01-01 00:00:00.000
	coordinates	[ew_var] [ns_var]

	comment	Time of measurement in seconds in the TAI time scale since 1 Jan 2000 00:00:00 TAI. This time scale contains no leap seconds. The difference (in seconds) with time in UTC is given by the attribute [illumination_time:tai_utc_difference].
unsigned int n_wse_pix ([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	number of water surface elevation pixels
	grid_mapping	crs
	units	1
	valid_min	0
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	Number of pixel cloud samples used in water surface elevation aggregation.
unsigned int n_water_area_pix ([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	number of water surface area pixels
	grid_mapping	crs
	units	1
	valid_min	0
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	Number of pixel cloud samples used in water surface area and water fraction aggregation.
unsigned int n_sig0_pix ([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	number of sigma0 pixels
	grid_mapping	crs
	units	1
	valid_min	0
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	Number of pixel cloud samples used in sigma0 aggregation.
unsigned int n_other_pix ([ns_dim], [ew_dim])		
	_FillValue	4294967295
	long_name	number of other pixels
	grid_mapping	crs
	units	1
	valid_min	0
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	Number of pixel cloud samples used in aggregation of quantities not related to water surface elevation, water surface area, water fraction or sigma0.
float dark_frac([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	fractional area of dark water
	grid_mapping	crs
	units	1
	valid_min	-1000
	valid_max	10000
	coordinates	[ew_var] [ns_var]
	comment	Fraction of pixel water surface area covered by dark water.
unsigned byte ice_clim_flag([ns_dim], [ew_dim])		
	_FillValue	255
	long_name	climatological ice cover flag

	standard_name	status_flag
	source	UNC
	grid_mapping	crs
	flag_meanings	no_ice_cover uncertain_ice_cover full_ice_cover
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	[ew_var] [ns_var]
	comment	Climatological ice cover flag indicating whether the pixel is ice-covered on the day of the observation based on external climatological information (not the SWOT measurement). Values of 0, 1, and 2 indicate that the pixel is likely not ice covered, may or may not be partially or fully ice covered, and likely fully ice covered, respectively.
unsigned byte ice_dyn_flag([ns_dim], [ew_dim])		
	_FillValue	255
	long_name	dynamic ice cover flag
	standard_name	status_flag
	source	UNC
	grid_mapping	crs
	flag_meanings	no_ice_cover partial_ice_cover full_ice_cover
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	[ew_var] [ns_var]
	comment	Dynamic ice cover flag indicating whether the surface is ice-covered on the day of the observation based on analysis of external satellite optical data. Values of 0, 1, and 2 indicate that the pixel is not ice covered, partially ice covered, and fully ice covered, respectively.
float layover_impact([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	layover impact
	grid_mapping	crs
	units	m
	valid_min	-999999
	valid_max	999999
	coordinates	[ew_var] [ns_var]
	comment	Estimate of the water surface elevation error caused by layover.
float sig0_cor_atmos_model([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	two-way atmospheric correction to sigma0 from model
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	grid_mapping	crs
	units	1
	valid_min	1
	valid_max	10
	coordinates	[ew_var] [ns_var]
	comment	Atmospheric correction to sigma0 from weather model data as a linear power multiplier (not decibels). sig0_cor_atmos_model is already applied in computing sig0.
float height_cor_xover([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	height correction from KaRIn crossovers
	grid_mapping	crs

	units	m
	valid_min	-10
	valid_max	10
	coordinates	[ew_var] [ns_var]
	comment	Height correction from KaRIn crossover calibration. The correction is applied before geolocation but reported as an equivalent height correction.
float geoid([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	geoid height
	standard_name	geoid_height_above_reference_ellipsoid
	source	EGM2008 (Pavlis et al., 2012)
	grid_mapping	crs
	units	m
	valid_min	-150
	valid_max	150
	coordinates	[ew_var] [ns_var]
	comment	Geoid height above the reference ellipsoid with a correction to refer the value to the mean tide system, i.e. includes the permanent tide (zero frequency).
float solid_earth_tide([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	solid Earth tide height
	source	Cartwright and Taylor (1971) and Cartwright and Edden (1973)
	grid_mapping	crs
	units	m
	valid_min	-1
	valid_max	1
	coordinates	[ew_var] [ns_var]
	comment	Solid-Earth (body) tide height. The zero-frequency permanent tide component is not included.
float load_tide_fes([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	geocentric load tide height (FES)
	source	FES2014b (Carrere et al., 2016)
	institution	LEGOS/CNES
	grid_mapping	crs
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	[ew_var] [ns_var]
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust.
float load_tide_got([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	geocentric load tide height (GOT)
	source	GOT4.10c (Ray, 2013)
	institution	GSFC
	grid_mapping	crs
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	[ew_var] [ns_var]
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust. This value is reported for reference but is not applied to the reported height.
float pole_tide([ns_dim], [ew_dim])		

	_FillValue	9.96921e+36
	long_name	geocentric pole tide height
	source	Wahr (1985) and Desai et al. (2015)
	grid_mapping	crs
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	[ew_var] [ns_var]
	comment	Geocentric pole tide height. The total of the contribution from the solid-Earth (body) pole tide height and the load pole tide height (i.e., the effect of the ocean pole tide loading of the Earth's crust).
float model_dry_tropo_cor([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	dry troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	grid_mapping	crs
	units	m
	valid_min	-3
	valid_max	-1.5
	coordinates	[ew_var] [ns_var]
	comment	Equivalent vertical correction due to dry troposphere delay. The reported water surface elevation, latitude and longitude are computed after adding negative media corrections to uncorrected range along slant-range paths, accounting for the differential delay between the two KaRIn antennas. The equivalent vertical correction is computed by applying obliquity factors to the slant-path correction. Adding the reported correction to the reported water surface elevation results in the uncorrected pixel height.
float model_wet_tropo_cor([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	wet troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	grid_mapping	crs
	units	m
	valid_min	-1
	valid_max	0
	coordinates	[ew_var] [ns_var]
	comment	Equivalent vertical correction due to wet troposphere delay. The reported water surface elevation, latitude and longitude are computed after adding negative media corrections to uncorrected range along slant-range paths, accounting for the differential delay between the two KaRIn antennas. The equivalent vertical correction is computed by applying obliquity factors to the slant-path correction. Adding the reported correction to the reported water surface elevation results in the uncorrected pixel height.
float iono_cor_gim_ka([ns_dim], [ew_dim])		
	_FillValue	9.96921e+36
	long_name	ionosphere vertical correction
	source	Global Ionosphere Maps
	institution	JPL
	grid_mapping	crs
	units	m
	valid_min	-0.5
	valid_max	0

	coordinates	[ew_var] [ns_var]
	comment	Equivalent vertical correction due to ionosphere delay. The reported water surface elevation, latitude and longitude are computed after adding negative media corrections to uncorrected range along slant-range paths, accounting for the differential delay between the two KaRIn antennas. The equivalent vertical correction is computed by applying obliquity factors to the slant-path correction. Adding the reported correction to the reported water surface elevation results in the uncorrected pixel height.

6 References

[1] JPL D-56411, "SWOT Product Description, Level 2 KaRIn high rate water mask pixel cloud product," Jet Propulsion Laboratory Internal Document, 2023.

[2] C. Pottier, "Product Description Document, Level 2 KaRIn high rate pixel cloud vector attribute product," Centre National d'Études Spatiales, SWOT-TN-CDM-0677-CNES, 2022.

[3] JPL D-56413, "Product Description Document, Level 2 KaRIn high rate river single pass vector product," Jet Propulsion Laboratory Internal Document, 2023.

[4] C. Pottier, "Product Description Document, Level 2 KaRIn high rate lake single pass vector product," Centre National d'Études Spatiales, SWOT-DD-CDM-0565-CNES, 2020.

[5] JPL D-56407, "Product Description Document, Level 2 KaRIn Low Rate Sea Surface Height Product," Jet Propulsion Laboratory Internal Document, 2023.

[6] JPL D-61923, "SWOT Science Requirements Document," Jet Propulsion Laboratory Internal Document, 2018.

[7] JPL D-102104, "SWOT Project Science Data Product Granule Boundary and Sampling Definition," Jet Propulsion Laboratory Internal Document, 2018.

[8] X. Yang, T. Pavelsky and G. H. Allen, "The past and future of global river ice," *Nature,* vol. 577, pp. 69-73, 2020, https://doi.org/10.1038/s41586-019-1848-1.

[9] N. K. Pavlis, S. A. Holmes, S. C. Kenyon and J. K. Factor, "The development and evaluation of the Earth Gravitational Model 2008 (EGM2008)," *J. Geophys. Res.: Solid Earth,* vol. 117, pp. 1978-2012, 2012, https://doi.org/10.1029/2011JB008916.

[10] D. E. Cartwright and R. J. Taylor, "New computations of the tide-generating potential," *Geophys. J. R. Astr. Soc.,* vol. 23, pp. 45-74, 1971.

[11] D. E. Cartwright and A. C. Edden, "Corrected tables of tidal harmonics," *Geophys. J. R. Astr. Soc.,* vol. 33, pp. 253-264, 1973.

[12] L. Carrere, F. Lyard, M. Cancet, A. Guillot and N. Picot, "FES 2014, a new tidal model - Validation results and perpectives for improvements," ESA Living Planet Conference, Prague, 2016.

[13] R. D. Ray, "Precise comparisons of bottom-pressure and altimetric ocean tides," *J. Geophys. Res: Oceans,* vol. 118, pp. 4570-4584, 2013.

[14] J. M. Wahr, "Deformation induced by polar motion," *J. Geophys. Res.,* vol. 90(B11), pp. 9363-9368, 1985, https://doi.org/10.1029/JB090iB11p09363.

[15] S. Desai, J. Wahr and B. Beckley, "Revisiting the pole tide for and from satellite altimetry," *J. Geod.,* vol. 89, pp. 1233-1243, 2015, https://doi.org/10.1007/s00190-015-0848-7.

[16] J. C. Ries and S. D. Desai, "Conventional model update for rotational deformation," in *Fall AGU Meeting*, New Orleans, LA, 2017, http://dx.doi.org/10.26153/tsw/2659.

[17] JPL D-105507, "SWOT Algorithm Theoretical Basis Document: L2_HR_Raster," Jet Propulsion Laboratory Internal Document, 2023.

Appendix A. **Acronyms**

AD	Applicable Document
ATBD	Algorithm Theoretical Basis Document
CNES	Centre National d'Études Spatiales
CRID	Composite Release Identifier
CRS	Coordinate Reference System
ECMWF	European Centre for Medium-Range Weather Forecasts
HR	High Rate
JPL	Jet Propulsion Laboratory
KaRIn	Ka-band Radar Interferometer
LR	Low Rate
MGRS	Military Grid Reference System
NASA	National Aeronautics and Space Administration
ODP	On-Demand Product
SDP	Standard Data Product
SDS	Science Data System
SWOT	Surface Water Ocean Topography
TAI	Temps Atomique International / International Atomic Time
TBC	To Be Confirmed
TBD	To Be Determined
TVP	Time Varying Parameters
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator

Appendix B. **Quality Flag Bit Definitions**

Quality flags in SWOT products are sometimes represented as bit flags such that the information from multiple individual conditions is captured in a single flag variable. This is accomplished by defining the flag variable as an unsigned integer whose bits in a binary (base-2 number system) representation reflect the states (true or false) of the individual conditions captured by the flag.

For example, a bit-flag variable *q* might capture information from three independent binary conditions C_3, C_2, and C_1, each of which might be true or false, in its three least significant bits (LSBs). The value of the variable *q* would then give the states of C_3, C_2, and C_1 per the table below:

Table 14. Bit Flag Example

Value of *q*	State of C_3	State of C_2	State of C_1
0	False	False	False
1	False	False	True
2	False	True	False
3	False	True	True
4	True	False	False
5	True	False	True
6	True	True	False
7	True	True	True

Equivalently, the value of the bit-flag variable *q* is defined mathematically as

$$q = \sum_{k=0}^{n-1} 2^k C_k$$

where *n* is the number of bits and C_k (whose value is either 0 or 1 to represent the false and true states, respectively) is the condition associated with bit *k*.

The bit meanings of the *wse_qual_bitwise*, *water_area_qual_bitwise* and *sig0_qual_bitwise* flags are given in Table 15.

For each row of the table, the decimal and hexadecimal values represent the value of the flag variable if the bit of that row were 1 and all other bits were 0. All of the information in this table is captured by the *flag_masks* and *flag_meanings* attributes of a given bit-flag variable. Where no condition is specified in the table, the bit is unassigned (not used) and should never be 1. It is possible that these bits will become assigned in future versions of the product, however. The color shading of the table gives a rough, qualitative indication of how much a nonzero bit value for each row would be expected to reduce confidence in the measurement, with redder hues indicating greater degradation.

Table 15. Measurement Quality Flag Bit Definitions

Bit (from LSB)	Decimal	Hex	wse_qual_bitwise	water_area_qual_bitwise	sig0_qual_bitwise
0	1	1			sig0_qual_suspect
1	2	2	classification_qual_suspect	classification_qual_suspect	classification_qual_suspect
2	4	4	geolocation_qual_suspect	geolocation_qual_suspect	geolocation_qual_suspect
3	8	8		water_fraction_suspect	
4	16	10			
5	32	20	large_uncert_suspect	large_uncert_suspect	large_uncert_suspect
6	64	40			
7	128	80	bright_land	bright_land	bright_land
8	256	100		low_coherence_water_suspect	low_coherence_water_suspect
9	512	200			
10	1024	400			
11	2048	800			
12	4096	1000	few_pixels	few_pixels	few_pixels
13	8192	2000	far_range_suspect	far_range_suspect	far_range_suspect
14	16384	4000	near_range_suspect	near_range_suspect	near_range_suspect
15	32768	8000			
16	65536	10000			
17	131072	20000			sig0_qual_degraded
18	262144	40000	classification_qual_degraded	classification_qual_degraded	classification_qual_degraded
19	524288	80000	geolocation_qual_degraded	geolocation_qual_degraded	geolocation_qual_degraded
20	1048576	100000			
21	2097152	200000	low_coherence_water_degraded		
22	4194304	400000			
23	8388608	800000			
24	16777216	1000000	value_bad	value_bad	value_bad
25	33554432	2000000			
26	67108864	4000000			
27	134217728	8000000			
28	268435456	10000000	no_pixels	no_pixels	no_pixels
29	536870912	20000000	outside_scene_bounds	outside_scene_bounds	outside_scene_bounds
30	1073741824	40000000	inner_swath	inner_swath	inner_swath
31	2147483648	80000000	missing_karin_data	missing_karin_data	missing_karin_data

The meanings of the different conditions specified by Table 15 are described below:

- *sig0_qual_suspect*: The measurement uses L2_HR_PIXC samples whose sigma0 information is marked suspect in the pixel-cloud inputs to the raster processing.
- *classification_qual_suspect*: The measurement uses L2_HR_PIXC samples whose land/water classification information is marked suspect in the pixel-cloud inputs to the raster processing.
- *geolocation_qual_suspect*: The measurement uses L2_HR_PIXC samples whose geolocation information is marked suspect in the pixel-cloud inputs to the raster processing.
- *water_fraction_suspect*: The measurement uses L2_HR_PIXC samples whose water-fraction information is suspiciously large.
- *large_uncert_suspect*: The measurement uncertainty is greater than a pre-defined threshold.
- *bright_land*: The measurement uses L2_HR_PIXC samples that are flagged as bright land and is therefore suspect.

- *low_coherence_water_suspect*: The measurement uses L2_HR_PIXC samples that are classified as low coherence water and is therefore suspect.
- *few_pixels*: The measured value is based on very few L2_HR_PIXC samples.
- *far_range_suspect*: The L2_HR_Raster pixel is located at a cross track location greater than a pre-defined threshold, indicating that it may be outside of the useful portion of the SWOT swath.
- *near_range_suspect*: The L2_HR_Raster pixel is located at a cross track location less than a pre-defined threshold, indicating that it may be outside of the useful portion of the SWOT swath.
- *sig0_qual_degraded*: The measurement uses L2_HR_PIXC samples whose sigma0 information is marked degraded in the pixel-cloud inputs to the raster processing.
- *classification_qual_degraded*: The measurement uses L2_HR_PIXC samples whose land/water classification information is marked degraded in the pixel-cloud inputs to the raster processing.
- *geolocation_qual_degraded*: The measurement uses L2_HR_PIXC samples whose geolocation information is marked degraded in the pixel-cloud inputs to the raster processing.
- *low_coherence_water_degraded*: The measurement uses L2_HR_PIXC samples that are classified as low coherence water and is therefore degraded.
- *value_bad*: The measured value is outside of pre-defined sanity-check thresholds.
- *no_pixels*: No pixels are assigned.
- *outside_scene_bounds*: The L2_HR_Raster pixel is located outside of the L2_HR_Raster swath-aligned scene boundaries.
- *inner_swath*: The L2_HR_Raster pixel is located at a cross track location less than a pre-defined threshold and no pixels are assigned.
- *missing_karin_data*: The L2_HR_Raster pixel is missing KaRIn data and no pixels are assigned. This includes large KaRIn gaps that are indicated by the L2_HR_PIXC *pixc_line_qual large_karin_gap* flag value, gaps in time varying parameters (TVP) that are greater than a pre-defined time threshold, and gaps that are due to missing L2_HR_PIXC tiles.