Surface Water and Ocean Topography (SWOT) Project

SWOT Product Description
Long Name:
Level 2 KaRIn Low Rate Sea Surface Height Product
Short Name: L2_LR_SSH

Revision A (DRAFT)

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CHANGE LOG

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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) low rate (LR) sea surface height (SSH) data product from the Surface Water and Ocean Topography (SWOT) mission. This data product is also referenced by the short name L2_LR_SSH.

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, 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 product, including for example their units, size, coordinates, etc.

Section 6 provides references for the product.

1.3 Document Conventions

When the 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.

2 Product Description

2.1 Purpose

The L2_LR_SSH product provides data from the low-rate (LR) data stream of the SWOT KaRIn instrument. KaRIn LR data are available continuously and globally, although LR measurements are designed primarily for ocean surfaces and may be of limited use over other surfaces. The L2_LR_SSH product is generated in response to SWOT project science requirements described in [1]. A general description of the algorithms that are used to generate the data product can be found in [2].

The L2_LR_SSH product provides:

- Sea surface height (SSH) and SSH anomaly (SSHA).
- Measured significant wave height (SWH) and normalized radar cross section (NRCS or backscatter cross section or sigma0), wind speed derived from sigma0 and SWH, and wind and wave fields from numerical weather models.
- Uncertainty estimates for all measurements.
- Flags indicating data quality and off-nominal conditions.
- Information on instrument and environmental corrections from both SWOT measurements (including the microwave radiometers) and external models.
- Additional geophysical model data that may be useful in analysis and interpretation of the data.

The L2_LR_SSH product does not provide SSH data from the SWOT nadir altimeter. Nadir altimeter data are available from a separate data product [3].

2.2 Latency

The L2_LR_SSH product is generated with a latency of less than 45 days from data collection. The latency allows for consolidation of instrument calibration and the required auxiliary and ancillary data that are needed to generate this product. Different versions of the product may be generated at different latencies and/or through reprocessing with refined input data.

3 Product Structure

3.1 Granule Definition

The granule size of the data product defines the spatial or temporal extent of the information given in each set of product files. The L2_LR_SSH product is organized into granules that each span a single spacecraft pass. A pass is half of an orbit revolution around the Earth by the satellite from extreme south to extreme north latitudes for ascending passes and north to south latitudes for descending passes.

Details of granule definitions are given in [4]. As described below, each granule of the product comprises four different files (see Sections 3.2) containing KaRIn measurement information. Each of these four files follows one of the two conventions for granule overlap described below.

The three files that are given on a geographically fixed sampling grid (see Section 3.4) overlap in their spatial coverage between granules at the ends of passes. However, successive granules will each be sampled on their own geographically fixed grids, so the samples in the overlap region will not be aligned between the successive granules (see Section 3.4). That is, overlap between successive granules of geographically fixed-grid files is provided in order to facilitate the handling of the discontinuity between the sampling grids of the successive granules.

The file that is given in the KaRIn-native sampling grid (see Section 3.4) does not overlap between pass granules given the continuity of the native sampling grid between granules.

All granules contain KaRIn measurements from both sides of the nadir track.

3.2 File Organization

The L2_LR_SSH product is organized into four files per product granule. The files are organized so that users can access only the measurement types that they desire while still making all data available. Many users may be interested in only a small fraction of the total data volume of the complete data product.

Three of the files in the L2_LR_SSH product are sampled on a geographically fixed, swath-aligned 2 km grid. These files are referred to as:

(1) Basic SSH [‘Basic’],

(2) Wind and Wave [‘WindWave’], and

(3) Expert SSH with Wind and Wave [‘Expert’].

The Basic file is intended for users who are interested in SSH measurements and who will use the KaRIn measurements as provided. The WindWave file is intended for users who are interested in wind and wave information. The Expert file is intended for expert users who are interested in the details of how the KaRIn measurements were derived and who may use detailed information for their own customized processing.

The fourth file in the L2_LR_SSH product contains SSH and NRCS data that have not undergone significant additional smoothing beyond that which is applied in the KaRIn on-board processor (OBP). This Unsmoothed SSH [‘Unsmoothed’] file, which is also intended for expert users, is therefore sampled on a finer spatial grid of approximately 250 m and has a significantly larger data volume than the other files. Because of its large data volume, the Unsmoothed file contains a more limited set of variables than the other files. Note that the measurements in this file have a resolution of approximately 500 m (the data are oversampled by about a factor of 2 in each direction). The sampling grid of this file is tied to the native sampling of the center Doppler beam formed by the KaRIn OBP during processing [5]. Figure 1 gives an illustration of the Doppler beam geometry, where the Doppler beams form cotemporaneous images that are offset spatially from each other. Section 3.4 of [6] provides additional details on the spatial arrangement of the nine beam measurements. The measurements from the eight non-central Doppler beams are resampled to the center-beam grid, then the measurements from all nine beams are combined on this grid [2]. Therefore, the grid for this file is not geographically fixed. While the horizontal resolution of data in this file is finer, the measurement values are also substantially noisier as compared to the first three files.

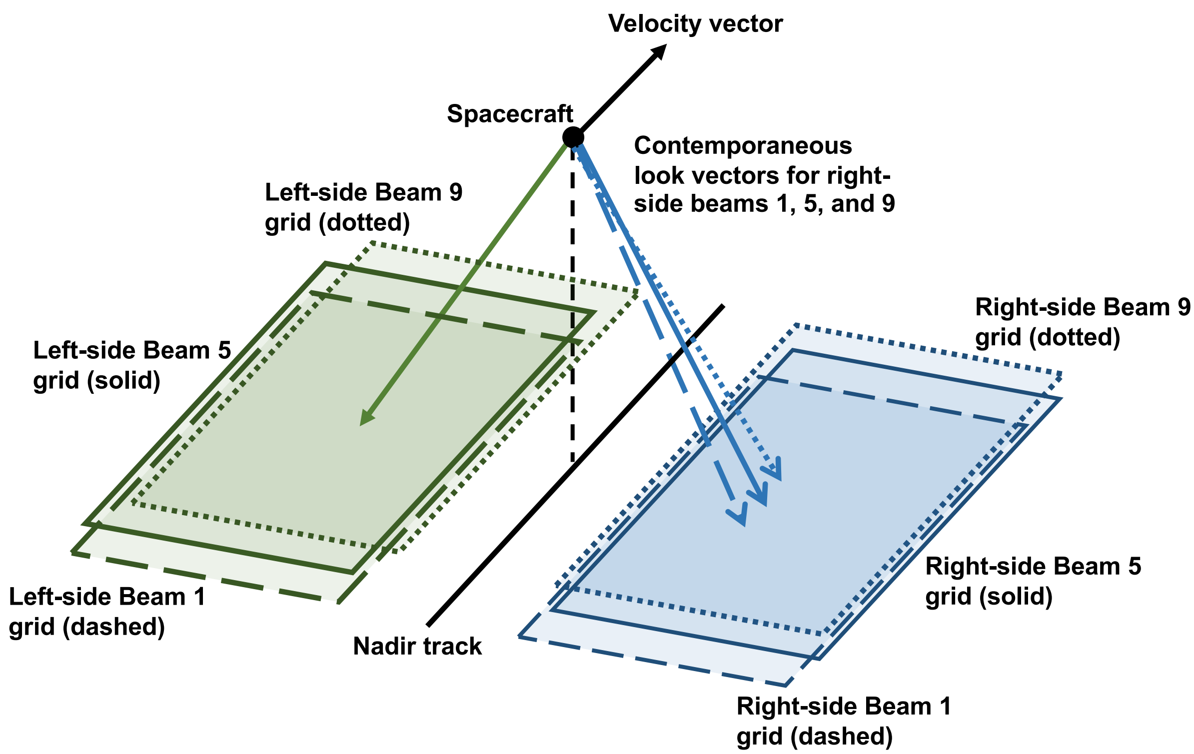

Figure 1. Illustration of the interferogram image geometry for each beam and each side.

All files in the product provide time and location information for the reported measurements. All files are NetCDF files. A brief description of these files is provided in Table 1 below.

Table 1. Description of the files comprising the L2_LR_SSH product.

File	Name	Description
1	Basic SSH ['Basic']	Provides corrected sea surface height (SSH), sea surface height anomaly (SSHA), flags to indicate data quality, geophysical reference fields, and height-correction information on a 2 km geographically fixed grid.

2	Wind and Wave ['WindWave']	Provides measured significant wave height (SWH), normalized radar cross section (NRCS or backscatter cross section or sigma0), wind speed derived from sigma0 and SWH, model information on wind and waves, and quality flags on a 2 km geographically fixed grid.
3	Expert SSH with Wind and Wave ['Expert']	Includes copies of the all variables in the Basic and the Wind and Wave files plus more detailed information on instrument and environmental corrections, radiometer data, and geophysical models on a 2 km geographically fixed grid.
4	Unsmoothed SSH ['Unsmoothed']	Provides sea surface height (SSH) and sigma0 without additional smoothing relative to the native KaRIn downlink resolution on a ~250 m native (center-beam) grid.

The Expert file contains all of the variables in the Basic and WindWave files, and additional variables for detailed analysis and processing of the data. The Unsmoothed file contains two groups, *left* and *right*, each of which contains the data for half (one side from nadir) of the KaRIn swath. The terms "left" and "right" are defined as if standing on the Earth surface at the spacecraft nadir point facing in the direction of the spacecraft velocity vector. The data from the two sides are separated because the sampling grids for the two sides can differ from each other, as they are tied to KaRIn parameters that are not necessarily the same between the two sides [5]. These groups are summarized in Table 2. Where no group name is given in the table, all variables of the corresponding file are at the top level of the NetCDF file.

Table 2. Description of the NetCDF groups in L2_LR_SSH product files

File	Group Name	Description
Basic SSH	-	Basic SSH measurement data and related information for the full swath.
Wind and Wave	-	Wind and wave measurement data and related information for the full swath.
Expert SSH with Wind and Wave	-	All of the measurement data provided in the Basic SSH and Wind and Wave files, and detailed contextual information, for the full swath, on the SWOT measurements; this information is intended to facilitate advanced analyses.
Unsmoothed SSH	*left*	Unsmoothed SSH measurement data and related information for the left half swath.
	right	Unsmoothed SSH measurement data and related information for the right half swath.

3.3 File Naming Convention

The files that comprise the L2_LR_SSH products adopt the following file naming convention:

SWOT_L2_LR_SSH_<FileIdentifier>_<CycleID>_<PassID>_<RangeBeginningDateTime>_<RangeEndingDateTime>_<CRID>_<ProductCounter>.nc where <*FileIdentifier*> is one of the following: “Basic”; “WindWave”; “Expert”; or “Unsmoothed”.

3.4 Spatial Sampling and Resolution

In this document, the term “posting” refers to the spatial sampling of a horizontally gridded data set. The term “sampling” is used generically to refer to the manner in which some continuous spatial or temporal quantity is discretized. One individual data value is called a “sample.” Samples from a 2-D spatial array are sometimes also called “pixels.”

Following historical terminology in the synthetic aperture radar (SAR) community, rows of image samples with a common along-track or time index are called “lines” of pixels. The along-track and cross-track dimensions of a 2-D array can therefore be characterized by the number of lines and the number of pixels per line, respectively. These are specified in the product by the *num_lines* and *num_pixels* dimensions as described in Table 7. Correspondingly, the term “pixel” is sometimes used in SWOT documents to indicate the cross-track sample index within a line. The usage of the term “pixel” should be evident from context.

As described in [5] and [6], the LR interferogram data downlinked from KaRIn comprise nine different Doppler beams on each side of nadir. The nine beams from a given side are sampled cotemporaneously, although the beams from the two sides are slightly offset from one another in time. As each of the nine beams are sensitive to radar echoes from different Doppler frequencies, or equivalently from different azimuth angles, each beam is associated with a different spatial sampling grid on the Earth surface. The sample spacing in each grid varies slightly spatially such that the grids are not perfectly uniform. The beams are numbered from 1-9. Beam 5 is the center beam, which is nominally aligned with the peak of the KaRIn antenna pattern in azimuth.

During ground processing (see [7] and [2]), after a number of other processing steps, the KaRIn measurements from beams other than the center beam are resampled (i.e., interpolated) to the native sampling grid of Beam 5. Once the measurements from the different beams (for each side) are on a common sampling grid, the KaRIn measurements from the different beams are combined (via weighted averaging over the beams) for each sample location. The beam-combined measurements on the native sampling grid of Beam 5 are given in the Unsmoothed file of the product for each of the left and right sides. These beam-combined measurements have a spatial posting of approximately 250 m and a resolution of approximately 500 m in both the cross-track and along-track directions. Note that the term “unsmoothed” in this context refers to the lack of significant additional spatial smoothing during ground processing. Spatial smoothing occurs during KaRIn on-board processing as a necessary step in reducing the data volume to meet mission constraints, however. Additionally, the resampling (i.e., interpolation) of other beams to the center-beam grid shapes the response of the data slightly [2].

In order to reduce noise and to facilitate the interpretation of the data, the unsmoothed data are further resampled and spatially smoothed to a 2 km geographically fixed grid. The data from the left and right sides are both resampled to the same geographically fixed grid. Data on this fixed grid are given in the Basic, WindWave, and Expert files of the product for the full swath.

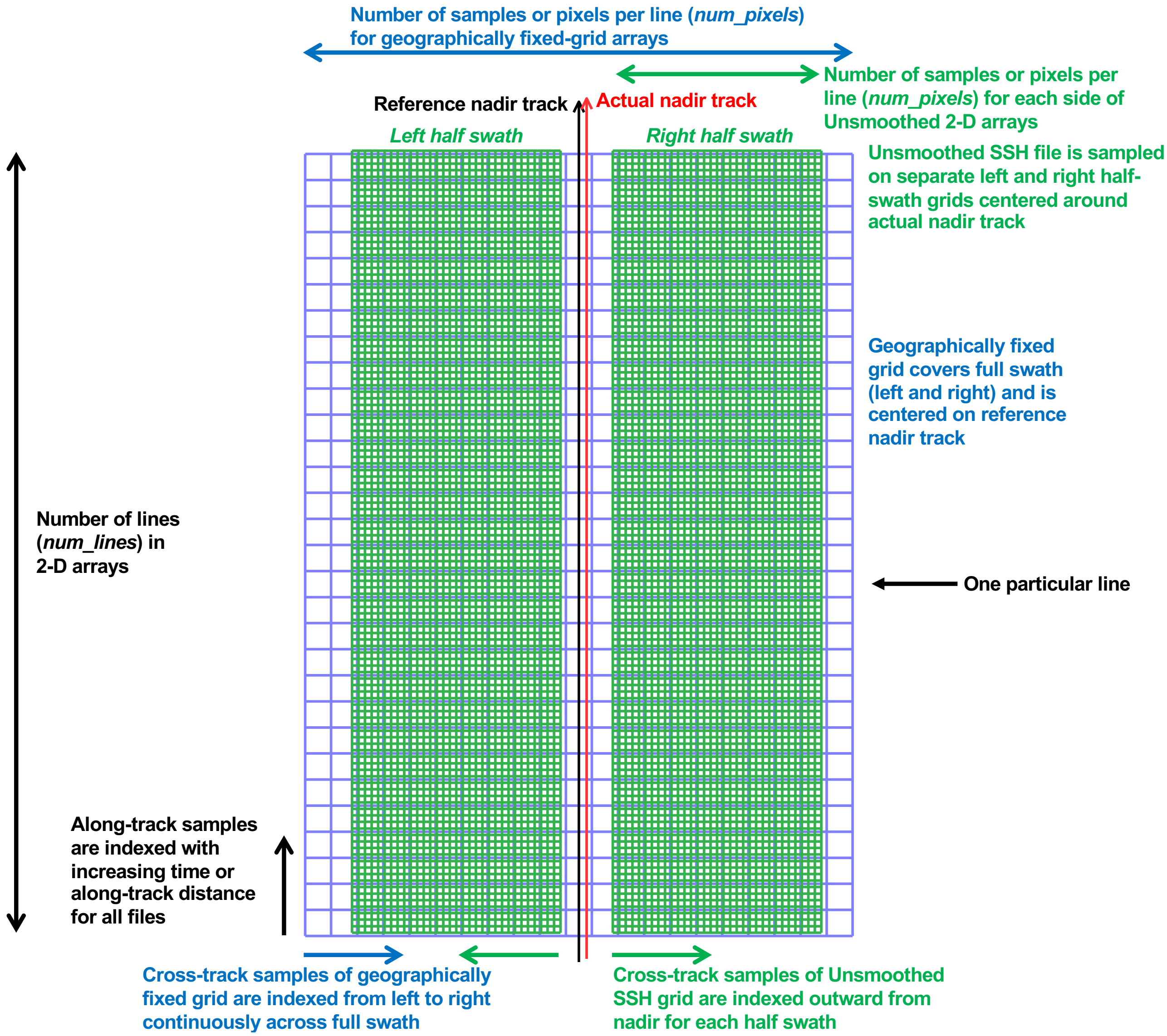

Figure 2. Illustration of sampling grids used in the L2_LR_SSH product.

3.4.1 Spatial Resolution

Measurements in the Basic, WindWave, and Expert files have a spatial resolution of approximately 2 km in both the along-track and cross-track directions. Measurements in the Unsmoothed file have a spatial resolution of approximately 500 m in both directions. The term "spatial resolution" refers here to the width of the spatial response function (two-sided, half-power width of the point-target response function) after ground processing. Radiometer and SWH measurements are posted on the same grid but have much lower resolution than the SSH measurements (e.g., only one independent measurement per side). See [2] for additional details that define the resolution of the data more precisely.

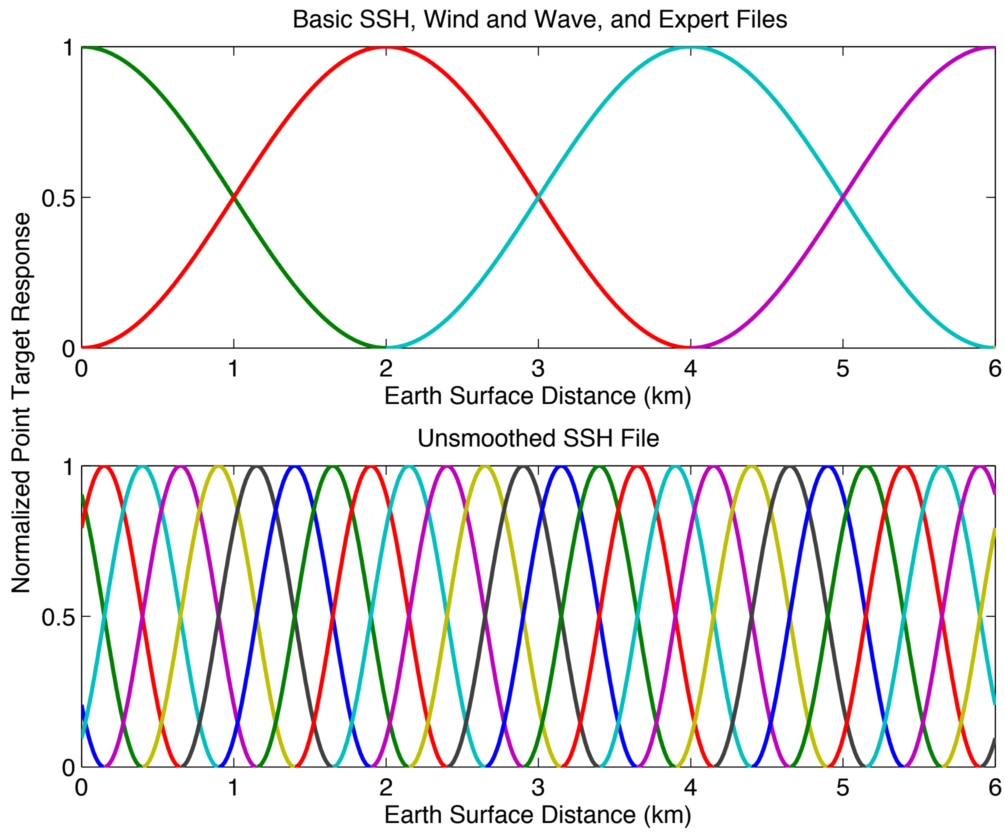

Figure 3. Illustration of the point target responses to show the relationship between resolution and sampling of data in the L2_LR_SSH product. Colors distinguish different (notional) response functions centered at sample locations.

3.4.2 Geographically Fixed Sampling Grid

The Basic, WindWave, and Expert files contain data from both the left and right half swaths, smoothed spatially and resampled onto a geographically fixed, swath-aligned grid. The fixed grid facilitates comparisons of data from corresponding passes from different cycles. The grid is centered in cross track on the ideal ground track that is used as a reference for controlling the spacecraft orbit. The actual SWOT ground track will typically deviate from the reference ground track by +/- 1 km. The fixed grid is aligned to the reference ground track, and not the actual ground track. Therefore, which grid samples contain useful measurements from the KaRIn left and right half swaths will vary slightly from cycle to cycle. Samples are flagged where useful measurement information is not available (usually at the outer edges of the swath and along the actual nadir track).

Samples on the fixed grid have an along-track spacing of exactly 2 km along the reference nadir track over the reference ellipsoid, as illustrated by the upper panel in Figure 3. Samples are spaced exactly 2 km apart in the cross-track direction over a spherical approximation to the reference ellipsoid beginning at the reference nadir track and extending outward 70 km in either direction toward the swath edges. Note that the SWOT requirements are applicable only from 10–60 km from the actual nadir track, but measurement flags in the product are based on computed information regarding the quality of the data irrespective of the requirement limits (measurements outside the 10–60 km span may be flagged as good and vice versa). The fixed grid deviates slightly (less than 1 m) from a perfectly rectangular grid to follow the curvature of the Earth surface and of the reference ground track. The grids for different passes within an orbit cycle that cover the same location on the Earth are not aligned, as the nadir tracks differ between such passes. Being geographically fixed, however, the sampling grid for any given pass will be identical to the grid for a corresponding pass (following the same reference nadir track) of a different orbit cycle.

The fixed grid for each pass is defined so that one sample along the nadir track falls on the equator, and samples are evenly spaced along the nadir track extending to the ends of the pass in either direction (the equator will be near the middle of the array). Because the length of each pass is not a perfect integer multiple of the 2 km sample spacing, the sampling grids of consecutive passes do not align with each other at pass boundaries, which occur at the farthest north and south latitudes. Overlap at pass boundaries between product granules is therefore provided to allow users to resample data as necessary in such regions (see Figure 4).

The mathematical details of the fixed grid are described in [4]. The organization of the data arrays containing the grid samples is described in Section 3.6.

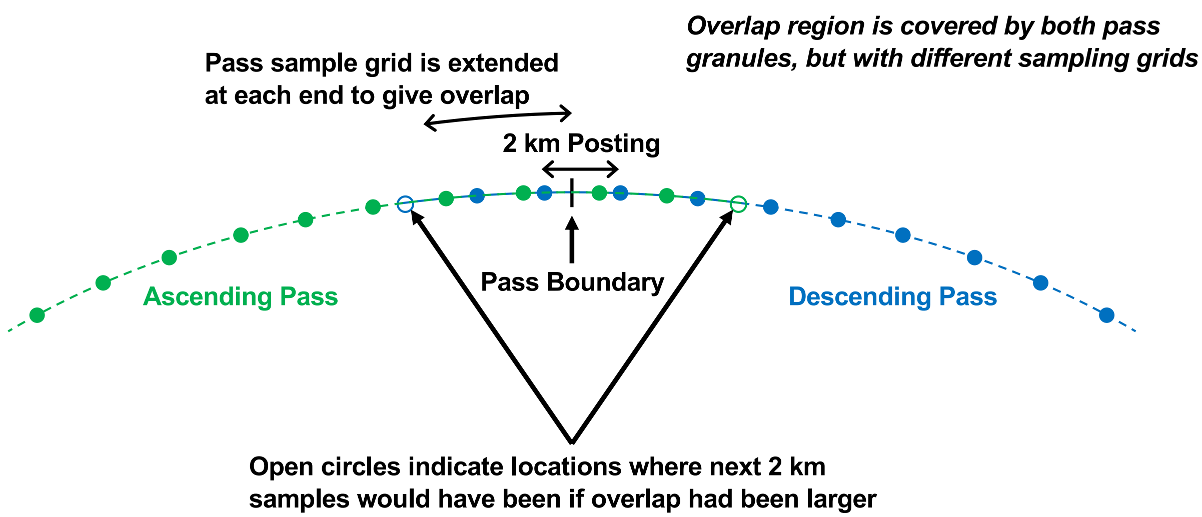

Figure 4. Illustration of granule overlap at pass ends for fixed-grid files.

3.4.3 Center-Beam Sampling Grid

The Unsmoothed file contains data from the KaRIn half swaths to the left and to the right of the actual nadir track prior to the resampling and spatial smoothing to the 2 km geographically fixed grid described in Section 3.4.2. The terms "left" and "right" are defined as if standing on the Earth surface at the spacecraft nadir point facing in the direction of the spacecraft velocity vector. Each half swath is sampled on a grid that is nominally aligned with the along-track and cross-track directions. The grid sampling is tied to the KaRIn timing and OBP parameters as well as the spacecraft ephemeris, which vary from one pass to another. Specifically, the sampling grid is tied to the KaRIn parameters used for the center of the nine beams formed in KaRIn OBP Doppler processing. Each KaRIn half swath spans approximately 4-64 km from nadir. The sampling grids differ slightly between the left and right sides given the temporal offset between the pulses for the two sides.

The center-beam (“native”) sampling grids of the Unsmoothed file are not entirely uniform; they vary in the along-track direction with instrument timing, and they vary slightly in the cross-track direction with surface height. Notably, they contain slight discontinuities in the along-track sample spacing when the KaRIn timing parameters change. The spacecraft ground track is typically controlled to +/-1 km (at all latitudes) from one orbit repeat cycle to another given the expected accuracy of orbit predictions, so the sampling grids will be shifted in the cross-track direction by a commensurate amount when comparing data from corresponding passes of different repeat cycles.

Samples on the grids for the Unsmoothed file are spaced approximately 250 m apart in both the along-track and cross-track dimensions. Given the resolution of approximately 500 m (see Section 3.4.1), neighboring samples are oversampled by about a factor of two in each dimension; neighboring pixels are therefore highly correlated, as illustrated by the lower panel in Figure 3. Note that the response functions for each sample (distinguished by color) in the lower panel cross each other at values around 0.85 on the vertical axis, which is higher than the respective curves for the fixed grid in the upper panel. The shapes of the response functions shown here are for illustration only, however; see [2] for details on the exact shapes of the response functions.

3.5 Temporal Organization

A time tag is given for each index in the along-track dimension of the spatial data arrays containing KaRIn swath measurements in the L2_LR_SSH data product. This time tag gives the observation time for all indices in the cross-track dimension of the spatial data arrays. The data are given in order of increasing time or along-track coordinate (see Figure 2). The time separation between successive cross-track lines of 2 km samples is approximately 300 ms (the temporal sample rate of 2 km cross-track lines is approximately 3.3 Hz).

3.6 Spatial Organization

The organization of the data within the product files differs depending on how the data are sampled spatially (see Figure 2).

3.6.1 Basic, WindWave, and Expert File Spatial Organization

The Basic, WindWave, and Expert files contain arrays that include the full KaRIn swath (both the left and right half swaths together). The index of the along-track dimension increases with time or, equivalently, with distance along the spacecraft nadir track. The index of the cross-track dimension increases from the leftmost edge toward the rightmost edge of the full KaRIn swath such that the nadir track of the reference orbit will run along the middle of the array. As the sampling grid of the array is geographically fixed while the spacecraft ground track deviates from the ideal reference trajectory for any given pass, however, the location of the true nadir track in the array will vary slightly (typically less than the width of a 2 km pixel). The cross-track dimension has the faster varying (i.e., memory contiguous) array index.

3.6.2 Unsmoothed File Spatial Organization

The Unsmoothed file contains separate arrays for the left and right KaRIn half swaths. The left and right half-swath arrays are in separate NetCDF groups. The index of the along-track dimension increases with time or, equivalently, with distance along the spacecraft nadir track. The index of the cross-track dimension increases with distance from nadir. Therefore, with left and right defined with respect to the spacecraft velocity direction, the cross-track index increases from left to right for the right half swath but from right to left for the left half swath. The cross-track dimension has the faster varying array index.

3.7 Volume

Table 3 provides the expected volume of L2_LR_SSH product, broken down by file. These volume estimates assume that no NetCDF compression is applied.

Table 3. Data volume of the L2_LR_SSH product.

File	Name	Volume (MB/granule)
1	Basic SSH	32
2	Wind and Wave	36
3	Expert Sea Surface Height with Wind and Wave	122
4	Unsmoothed SSH	1624
Total		**1814**

4 Qualitative Description

This section provides an overview of the data elements in the L2_LR_SSH product. The description is organized by file, with the Basic, WindWave, Expert, and Unsmoothed files covered in each of the following subsections. Information on how the data values are computed is provided in the L2_LR_SSH Algorithm Theoretical Basis Document (ATBD) [2].

4.1 Basic SSH File

4.1.1 Time

Time tags for each measurement data record are provided in the UTC and TAI time scales using the variables *time* and *time_tai*, respectively. The time tag for each sample corresponds approximately to the mean observation time of the multiple KaRIn measurements that are incorporated into the sample.

- *time*: 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)
- *time_tai*: 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 *time* has an attribute named *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 product granule.

- *time_tai[0] = 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 product granule. To account for this, the variable *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 *time* will exhibit a jump when a leap second occurs. If no additional leap second occurs within the time span of the product granule *time: leap_second* is set to “0000-00-00 00:00:00”.

The table below provides some examples for the values of *time*, *time_tai*, and *tai_utc_difference*. With this approach, the value of *time* will have a 1 second regression during a leap second transition, while *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 *time*, making time non-unique by itself; the difference between *time* and *time_tai*, or the *tai_utc_difference* and *leap_second* fields, can be used to resolve this. Some examples are provided in the table below.

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

4.1.2 Location

The location on the Earth surface is provided for each grid sample. The horizontal location refers nominally to the centroid of the response function of the sample (not a pixel corner).

- *latitude*, *longitude*: Coordinates giving the location of the sample. The latitude is a geodetic latitude with respect to the reference ellipsoid, whose parameters are given in the global attributes of the product. Positive latitude values increase northward from the equator. Positive longitude values increase eastward from the prime meridian.

4.1.3 KaRIn Swath Measurements

The following measurements are provided for each sample in the swath:

- *ssh_karin*: Sea surface height (SSH) above the reference ellipsoid whose parameters are given in the global attributes of the product, as measured by KaRIn. All instrument corrections are applied except for the crossover calibration estimate, which is provided separately in the *height_cor_xover* variable. Corrections for the dry and wet troposphere, ionosphere, and sea state bias have been applied to the data. Measurements of the wet troposphere delay from the on-board microwave radiometer are used to compute this value of SSH. As such, reported values are not available (the value will be null filled) when the radiometer measurements are not available. Reported values are available if the radiometer measurements have degraded quality (e.g., rain, ice, or land contamination). In both of these cases the degraded or unavailable radiometer measurements are indicated by a bit in the quality flag (*ssha_karin_qual*), and should be considered as unreliable. When radiometer measurements are available, the value of *ssh_karin* is computed from *ssh_karin_2* (see below), which uses a meterological model for the effects of the wet troposphere on range delays and sigma0 atmospheric attenuation. The value of *ssh_karin* is computed as shown in the equation below.

$$
\begin{aligned}
ssh\_karin \; &= ssh\_karin\_2 + model\_wet\_tropo\_cor - rad\_wet\_tropo\_cor \\
&+ sea\_state\_bias\_cor\_2 \; - sea\_state\_bias\_cor
\end{aligned}
$$

- *ssh_karin_uncert*: Estimated 1-sigma uncertainty in the *ssh_karin* measurement. The reported uncertainty is an analytical estimate of the KaRIn random error based on the observed interferometric correlation. Because this value includes only random errors, the uncertainty is reduced approximately as sqrt(*N*) if *N* 2-km fixed grid samples are averaged together. Note that because the unsmoothed data described in Section 4.4 are oversampled so that each pixel (250 m by 250 m) is one quarter of the size of the resolution cell (500 m by 500 m), averaging down from the unsmoothed posting reduces the error by approximately sqrt(*N*/4) if *N* 250 m pixels over a 2-D window are averaged.

- *ssha_karin*: Sea surface height anomaly (SSHA). The SSHA is obtained by using models to subtract the contribution of the mean sea surface, tides (solid Earth, ocean, load, coherent internal, and pole tides), and the high frequency response to atmospheric forcing (*dac*) from the SSH measurement (*ssh_karin*). The values removed are reported in the variables *mean_sea_surface_cnescls, solid_earth_tide*, *ocean_tide_fes* (includes sum total of ocean and load tide), *internal_tide_hret*, *pole_tide* (includes the sum of body, ocean, and load pole tide), and *dac*. The applied values of *mean_sea_surface_cnescls* and *internal_tide_hret* are reported in this file, while values for the other models are available in the Expert file. The crossover calibration correction *height_cor_xover* has not been applied. Note that if *ssh_karin* or any model term is not available, the SSHA value will not be available either (the value will be null filled and the *ssha_karin_qual* flag will be set).

$$\begin{aligned} ssha\_karin \ &= ssh\_karin \ - mean\_sea\_surface\_cnescls - solid\_earth\_tide \\ &\quad - ocean\_tide\_fes \ - internal\_tide\_hret - pole\_tide - dac \end{aligned}$$

- *ssh_karin_2:* Same as *ssh_karin* except that model-based corrections for wet tropospheric range delays and sigma0 atmospheric attenuation are used to avoid discontinuities and voids due to degraded or missing radiometer data. Specifically, the wet troposphere range delay is from *model_wet_tropo_cor* instead of *rad_wet_tropo_cor* , and the sea state bias is from *sea_state_bias_cor_2* instead of *sea_state_bias_cor,* all of which are provided in the Expcert SSH file. The respective sea state bias values have a dependency on sigma0 atmospheric attenuation through sigma0 (*sig0_karin_2* and *sig0_karin*) and subsequently wind speed (*wind_speed_karin_2* and *wind_speed_karin*).
- *ssha_karin_2:* Same as *ssha_karin* except that the value is computed from *ssh_karin_2*.

4.1.4 KaRIn Measurement Quality

The following items are provided for each sample in the swath to indicate data quality.

- *ssha_karin_qual*: Flag indicating whether various conditions have affected the quality of the *ssha_karin* measurement. The flag is an integer for which each bit represents a different condition. The value of each bit is 0 if the condition is nominal. Therefore, if the composite value of the integer is zero, all conditions are nominal ("good"). The meanings of the individual bits are TBD. For example, one of the bits will indicate when the radiometer measurement of the the wet troposphere correction is degraded. This bit should be ignored when applying this flag to reported measurements of *ssha_karin_2*.
- *num_pt_avg*: Number of unsmoothed, beam-combined KaRIn samples (at approximately 250 m posting) that were used to compute the smoothed values of *ssh_karin*, *ssh_karin_2*, *sig0_karin*, and *sig0_karin_2* at 2 km resolution. If this number is less than the nominal window size used for spatial averaging, then *ssha_karin_qual*, *swh_karin_qual*, and *sig0_karin_qual* will be nonzero.

4.1.5 Distance and Heading to Coast

The vector from the reported sample location to the nearest coast point is given as a distance along the Earth surface and a heading with respect to true north that indicates the direction to the coast. These values are approximate. The coast is defined with respect to a surface type map used during processing (see *ancillary_surface_classification_flag*). A value exists for each sample.

- *distance_to_coast*: Approximate distance along the Earth surface to the nearest coast point. This value is nonnegative and is zero when the sample is over land.
- *heading_to_coast*: Approximate heading with respect to true north to the nearest coast point. Headings of 0, 90˚, 180˚, and 270˚ indicate that the coast is to the north, east, south, or west of the sample. This value is defined to be zero when *distance_to_coast* is zero.

4.1.6 Geophysical Flags

The following flags are provided for each sample in the swath:

- *ancillary_surface_classification_flag*: Surface type at the location of the KaRIn measurement derived from a surface classification map that has been built from MODIS and GlobCover [8] data. The flag values have meanings as follows: 0 = open ocean, 1= land, 2 = continental water, 3 = aquatic vegetation, 4 = continental ice or snow, 5 = floating ice, and 6 = salted basin.
- *dynamic_ice_flag*: Flag indicating that there is probable ice at the location of the KaRIn measurement. The value is derived from the ice concentation value provided in *ice_conc*. The flag values have meanings as follows: 0 = no ice, 1 = probable ice, and 2 = ice (TBC).
- *rain_flag*: Flag indicating that the KaRIn signal is weaker than expected and/or rain is likely. A nonzero value indicates possible data degradation.

The following flag gives the surface type from an a priori surface type database for each of the left and right radiometer beams. Each radiometer beam has a footprint that is much coarser than the KaRIn measurement sampling (e.g., of *ancillary_surface_classification_flag*), so there is only one value of *rad_surface_type_flag* for each half swath. The first and second values of the fastest-varying array index are for the left and right radiometer beams, respectively.

- *rad_surface_type_flag*: Surface type applied for the generation of the radiometer wet troposphere correction as derived from a static surface type database. The surface type database accounts for the antenna patterns of each radiometer, and is therefore unique to each radiometer. A nominal open ocean retrieval algorithm is used to determine the wet troposphere correction when there is no land contamination of the radiometer footprint, a coastal retrieval algorithm is used when there is partial land contamination of the radiometer footprint, and radiometer wet troposphere measurements are invalid over land. The flags values have meanings as follows: 0 = open ocean retrieval, 1 = coastal ocean retrieval, 2 = land [9]. There is only one value per side.

4.1.7 Geophysical References

The following values are provided for each sample in the swath from models interpolated to the sample location:

- *mean_sea_surface_cnescls*: Model for the mean sea surface (MSS) height above the reference ellipsoid whose parameters are given in the global attributes of the product. This MSS value is from the CNES_CLS15 model [10]. This value is used to compute the values of *ssha_karin* and *ssha_karin_2* from the values of *ssh_karin* and *ssh_karin_2*.
- *mean_sea_surface_cnescls_uncert:* Accuracy or uncertainty of *mean_sea_surface_cnescls* [10]. This represents a 1-sigma confidence level.
- *geoid*: Model for geoid height above the reference ellipsoid whose parameters are given in the global attributes of the product. The geoid model is EGM2008 [11]. The geoid model includes a correction to refer the value to the mean tide system (i.e., it includes the zero-frequency permanent tide).
- *internal_tide_hret*: Model for sea surface displacement from the coherent internal tide. The value comes from [12] and does not include the contribution from the incoherent tide. This value is used to compute the values of *ssha_karin* and *ssha_karin_2* from the values of *ssh_karin* and *ssh_karin_2*.

4.1.8 KaRIn Corrections

The following measurement is provided for each sample in the swath:

- *height_cor_xover*: Height correction to *ssh_karin* and *ssh_karin_2* computed from a combination of crossovers between KaRIn/KaRIn measurements and KaRIn/nadir altimeter measurements on different passes within a temporal window surrounding the SSH measurement. This correction provides an estimate of residual errors that have not been removed with use of ancillary attitude and calibration data during processing. This correction is not applied in forming *ssh_karin*, *ssh_karin_2, ssha_karin*, or *ssha_karin_2*. The value of *height_cor_xover* should be added to the value of *ssh_karin*, *ssh_karin_2*, *ssha_karin*, and/or *ssha_karin_2* by the user if it is to be applied.

4.2 Wind and Wave File

4.2.1 Time and Location

This file includes *time*, *time_tai*, *latitude* and *longitude* as described in Section 4.1 for the Basic SSH file.

4.2.2 KaRIn Polarization

The radar signal polarization generally affects the backscatter at non-nadir incidence angles, thereby affecting wind and wave estimates from the radar data. The KaRIn instrument uses different polarizations (co-polarized linear horizontal and vertical) on either side of the nadir track. However, which of the polarizations is used for each side changes as the spacecraft periodically reorients itself in yaw by 180˚ for thermal management reasons. The polarizations for the left and right sides are H and V, respectively, when the yaw (*sc_yaw* in the Expert file) is close to 0; the opposite is true when the yaw is close to 180˚. The KaRIn polarization for each of the left and right half swaths is given for each along-track index in the *polarization_karin* variable.

- *polarization_karin*: Polarization of the KaRIn radar signal. The values 'H' and 'V' represent horizontal and vertical polarization. The first and second values of the fastest-varying array index are for the left and right sides, respectively.

4.2.3 KaRIn Swath Measurements

The following measurements are provided for each sample in the swath. Note that while quantities associated with SWH are given on the same 2 km grid as the SSH, the resolution of the KaRIn SWH estimates is much coarser [2].

- *swh_karin*: Significant wave height (SWH) estimated from the volumetric coherence of the KaRIn interferograms. Details are given in [2].
- *swh_karin_uncert*: 1-sigma uncertainty in the *swh_karin* measurement.
- *sig0_karin*: Fully corrected normalized radar cross section (NRCS or sigma0) estimated from the KaRIn echo power. The value is given in units, not decibels. A value in decibels may be obtained by computing $10\log_{10}$(*sig0_karin*). The value is computed from data acquired by both the $+y$ and $-y$ KaRIn anternna channels (both of which collect data for each side). Because the estimate includes noise subtraction, it is possible for the linear values of the estimate to be negative. The *sig0_karin* value is computed using the *sig0_cor_atmos_rad* atmospheric correction from the radiometer contained in the Expert file. As such, reported values are not available (the value will be null filled) when the radiometer measurements are not available. Reported values are available if the radiometer measurements have degraded quality (e.g., ice, or land contamination). In both of these cases the degraded or unavailable radiometer measurements are indicated by a bit in the quality flag (*sig0_karin_qual*).When radiometer measurements are available, this value is computed from *sig0_karin_2* as shown below, where the model and radiometer measurements of atmospheric attenuation (*sig0_cor_atmos_model* and *sig0_cor_atmos_rad*) are provided in the Expert file.

$$sig0\_karin = sig0\_karin\_2 * sig0\_cor\_atmos\_rad / sig0\_cor\_atmos\_model$$

- *sig0_karin_uncert*: 1-sigma uncertainty in the *sig0_karin* measurement. The value is given as an additive (not multiplicative) linear term (not a term in decibels).

- *sig0_karin_2*: Same as *sig0_karin* except that the *sig0_karin_2* value is computed using the model value of atmospheric correction (*sig0_cor_atmos_model*) contained in the Expert file. By using a model-based correction, discontinuities and voids due to missing radiometer data are avoided.
- *wind_speed_karin*: Wind Speed 10-m above the surface from a TBD model function that uses the KaRIn measurements of SWH and sigma0. This value is computed using *sig0_karin*.
- *wind_speed_karin_2*: Same as *wind_speed_karin* but computed using *sig0_karin_2*.

4.2.4 KaRIn Measurement Quality

The following items are provided for each sample in the swath to indicate data quality.

- *swh_karin_qual*: Flag indicating whether various conditions have affected the quality of the *swh_karin* measurement. A value of 0 indicates nominal (good) data. The meaning of other bits/values is TBD.
- *sig0_karin_qual*: Flag indicating whether various conditions have affected the quality of the *sig0_karin* measurement. A value of 0 indicates nominal (good) data. The meaning of other bits/values is TBD. For example, one of the bits will indicate when radiometer measurements of the atmospheric attenuation are degraded. This bit should be ignored when applying this flag to reported measurements of *sig0_karin_2*.
- *num_pt_avg*: Number of native KaRIn samples that were used to compute *sig0_karin* as described in Section 4.1.4.

4.2.5 Wave, Wind References

The following items are provided for each sample in the swath. The SWH values are computed from meteorological models from the European Centre for Medium-Range Weather Forecasts (ECMWF) and Metéo France. All parameters from the ECMWF are based upon their operational analysis.

- *swh_model*: ECMWF model for significant wave height (SWH).
- *mean_wave_direction*: Mean sea surface wave direction from the Metéo France Wave Model (MF-WAM). The value is the angle of the wave propagation direction defined to be clockwise from North. Zero degrees means 'coming from the north,' and 90 degrees 'coming from the east.' (TBD Reference).
- *mean_wave_period_t02*: Sea surface wind wave mean period from the second moment of the wave model spectral density from the Metéo France Wave Model (MF-WAM). ' (TBD Reference).
- *wind_speed_model_u*: Easterly (u) component of the ECMWF model wind speed at 10 meters [13].
- *wind_speed_model_v*: Northerly (v) component of the ECMWF model wind speed at 10 meters [14].

The wind speeds derived from the two radiometer beams are given for each along-track index.

- *wind_speed_rad*: Wind speed computed from radiometer brightness temperature measurements [9]. The first and second values of the fastest-varying array index are for the left and right radiometer beams, respectively.

4.2.6 Distance and Heading to Coast

This file includes the same *distance_to_coast* and *heading_to_coast* information as described in Section 4.1.5 for the Basic SSH file.

4.2.7 Geophysical Flags

This file includes the same geophysical flags *ancillary_surface_classification_flag*, *dynamic_ice_flag*, *rain_flag*, and *rad_surface_type_flag* as described in Section 4.1.6 for the Basic SSH file.

4.3 Expert SSH with Wind and Wave File

The Expert SSH with Wind and Wave file is a superset of the Basic SSH and the Wind and Wave files. The Expert file contains all of the information from the Basic and the WindWave files. Additional data elements intended for expert analyses are also provided.

This section contains a description of the additional data elements provided in the Expert file. See Sections 4.1 and 4.2 for descriptions of the variables that are copies of those also provided in the Basic and WindWave files.

4.3.1 Location Information

Several variables are defined relative to a reference frame that is fixed to the KaRIn instrument called the KaRIn Metering Structure Frame (KMSF), illustrated in Figure 5. This frame is defined with the origin near the middle of the interferometric baseline, with the two antennas along the $+y$ and $-y$ axes. The $+z$ axis of this frame is controlled to point approximately toward nadir, so the $+x$ axis is approximately parallel or antiparallel to the Earth-relative spacecraft velocity vector. However, the spacecraft periodically performs 180° yaw flips (for thermal management reasons, several times per year) such that sometimes the $+x$ axis is in the direction of the velocity vector (i.e., satellite flying forward), and sometimes the $-x$ axis is in the direction of the velocity vector (i.e., satellite flying backward). Which of the $+y$ and $-y$ antennas is to the left or right of the spacecraft along-track direction therefore depends on the yaw state of the spacecraft. As elsewhere in this document, "left" and "right" are defined as if standing on the Earth surface and facing the direction of the spacecraft velocity vector.

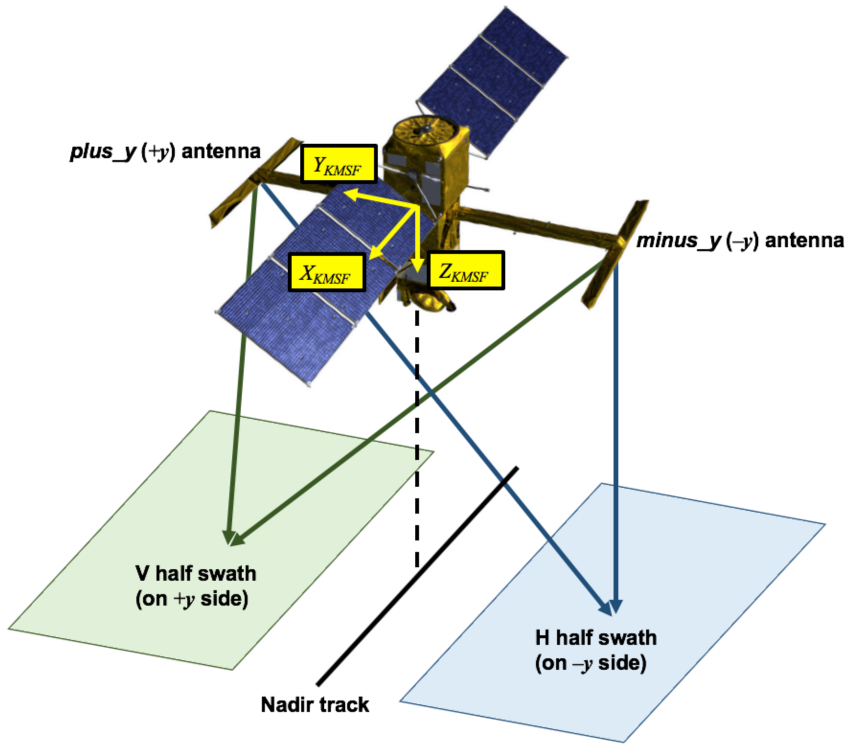

Figure 5. Illustration of the KMSF frame and the polarizations (V and H) of the two KaRIn half swaths. The velocity direction can be along $+X_{KMSF}$ or $-X_{KMSF}$ depending on the yaw state of the spacecraft.

KaRIn uses different polarizations for the two sides. The radar signal is horizontally (H) and vertically (V) polarized for the half swaths on the -*y* and +*y* sides of the KaRIn frame, respectively. Therefore, the polarizations for the left and right swaths are H and V, respectively, when the yaw is close to 0˚; they are swapped when the yaw is close to 180˚.

When the KaRIn prime high-power amplifier (HPA) is used, the +*y* antenna transmits regardless of the yaw state. The –*y* antenna transmits when the cold-spare HPA is used (likely only in the event of a failure of the prime unit). Which of the antennas is transmitting is given by the global attribute *transmit_antenna*. A swap to the spare HPA would necessitate recalibration of the instrument, though in principle the swap should eventually be transparent with respect to the primary measurement quantities of the L2_LR_SSH product.

All variables that give position, velocity, and attitude relative to the Earth frame are defined with respect to the International Terrestrial Reference Frame (ITRF). In this Earth-Centered, Earth-Fixed (ECEF) frame, the +*z* axis of the ECEF frame goes through the north pole, and the +*x* axis goes through both the equator (zero latitude) and the prime meridian (zero longitude).

All variables that are defined with respect to a reference ellipsoid assume the reference ellipsoid parameters that are given in the global attributes (*ellipsoid_semi_major_axis* and *ellipsoid_flattening*) of the product file itself.

The attitude angles are defined as follows. Let v_{KMSF} and v_{ENU} be the same vector represented in KMSF and in the local east-north-up (ENU) frame, respectively, with the rotation matrix *R* giving the transformation between the two vectors representations:

$$v_{KMSF} = Rv_{ENU}.$$

This rotation matrix is given by

$$R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -\cos r & -\sin r \\ 0 & \sin r & -\cos r \end{bmatrix} \begin{bmatrix} \cos p & 0 & \sin p \\ 0 & 1 & 0 \\ -\sin p & 0 & \cos p \end{bmatrix} \begin{bmatrix} \sin h_p & \cos h_p & 0 \\ -\cos h_p & \sin h_p & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where *r* and *p* represent the *sc_roll* and *sc_pitch* variables, and the platform heading h_p is defined as the sum of the *velocity_heading* variable h_v and the *sc_yaw* variable h_y

$$h_p = h_v + h_y$$

with all of these angles defined modulo 360˚.

Each of the variables below is a 1-D array that varies with time only, not cross-track location on the Earth surface.

- *sc_altitude*: Altitude of the KMSF origin above the reference ellipsoid given in the global attributes.
- *latitude_nadir*: Latitude of the satellite nadir point, following the same representation conventions as for the Basic SSH files.
- *longitude_nadir*: Longitude of satellite nadir point, following the same representation conventions as for the Basic SSH files.
- *orbit_alt_rate*: Rate of change of the spacecraft altitude relative to the combination of the mean sea surface over the ocean and geoid over land.
- *cross_track_angle*: Angle with respect to true north of the cross-track direction to the right of the spacecraft velocity vector. The value of *cross_track_angle* is generally 90˚ greater than the value of *velocity_heading* (modulo 360˚).
- *sc_roll*, *sc_pitch*, *sc_yaw*, *velocity_heading*: Attitude of the KMSF frame with respect to the local ENU frame at the location given by *latitude_nadir* and *longitude_nadir*. The velocity heading is the angle with respect to true north of the nadir track direction such that if the spacecraft were flying due east, the velocity heading would be 90˚. The yaw is the angle of right-handed rotation of the nominal KMSF +*x* axis about the nadir direction. If the KMSF +*x* axis is aligned with the horizontal projection of the Earth-relative spacecraft velocity vector, the yaw will be zero. If the KMSF -*x* axis is aligned with the horizontal projection of the Earth-relative spacecraft velocity vector, the yaw will be 180˚. The heading of the KMSF +*x* axis relative to true north is consequently the sum of the velocity heading and the yaw (modulo 360˚). The pitch is defined such that a positive pitch moves the KMSF axis +*x* up. The roll is defined such that a positive roll moves the +*y* antenna down. Note that when the yaw is near 180˚, the sense of pitch and roll may be counterintuitive to users who are accustomed to airborne platforms since the spacecraft would be flying "tail first."
- *orbit_qual*: Flag indicating the quality of the determined orbit, including maneuver perturbations. The meanings of bits and values are TBD.

The following items are provided for each sample in the swath from the processing of the KaRIn data.

- *latitude_avg_ssh, longitude_avg_ssh*: Coordinates giving the weighted horizontal location of the SSH sample (*ssh_karin_2*) with the model-based wet tropospheric delay correction applied. The variables *latitude_avg_ssh* and *longitude_avg_ssh* follow the same representation conventions as *latitude* and *longitude* in the Basic SSH file. Typically, the two sets of coordinates will be identical. However, if any samples at the 250-m posting of the KaRIn data are discarded before smoothing to 2 km resolution (for example, due to off-nominal flag values), the 3-D position of the smoothed result will be horizontally biased toward the locations of the samples that were not discarded. Therefore, the weighted-average location may not fall on a grid sample location. The values of *latitude_avg_ssh* and *longitude_avg_ssh* give the weighted-average horizontal location of the KaRIn data that were actually used to compute the corresponding SSH value, whereas the values of *latitude* and *longitude* represent the grid locations desired for the measurement. The flag *ssha_karin_qual* will be nonzero if *latitude_avg_ssh* and *longitude_avg_ssh* differ from *latitude* and *longitude*.

The cross-track position of each sample in the swath is given by the variable *cross_track_distance*. The value represents the distance from the spacecraft nadir point to the geolocated sample position along a local spherical approximation to the ellipsoid.

- *cross_track_distance*: Distance from nadir to the sample location in the cross-track direction. The value is positive for the right swath and negative for the left swath. The distance is measured from the actual nadir track, not the reference nadir track.

4.3.2 KaRIn Sigma0 Calibration and Corrections

The following calibration and correction terms are given for each sample in the swath. The sigma0 estimate (*sig0_karin* in the Wind and Wave file) already incorporates some of these terms. All of these terms are given as dimensionless linear power-scaling quantities (not values in decibels). The model-based values of atmospheric attenuation are used to compute *sig0_karin_2*, after which *sig0_karin* is computed using the difference (when using units of decibels) between the reported atmospheric attenuations from the model and the radiometer (see Section 4.2.3).

- *x_factor*: Ratio between (noise-subtracted) received power and sigma0 [sigma0 = (uncalibrated_power-noise_power)/x_factor]. The X factor is based on the radar equation and includes instrument geometry, wavelength, antenna gain, and conversion from data numbers to SI units. It does not include atmospheric attenuation. The value here is a composite value for the X factors of the *+y* and *-y* KaRIn antenna channels, both of which collect data for each side.

- *sig0_cor_atmos_model, sig0_cor_atmos_rad*: Two-way atmospheric correction to sigma0 across the swath based on the ECMWF model and radiometer data, respectively. The radiometer-based correction, *sig0_cor_atmos_rad*, is used to compute *sig0_karin* in the Wind and Wave file. The model-based correction, *sig0_cor_atmos_model*, is used to compute *sig0_karin_2* to ensure continuous availability of sigma0 regardless of availability of radiometer measurements. With all quantities in linear units, the uncorrected sigma0 is multiplied by these values to obtain corrected sigma0. (If converted to units of decibels, these corrections are added to uncorrected sigma0 to compute corrected sigma0.)

4.3.3 KaRIn Instrument and Processing Information

The following instrument and processing information is provided to give additional insight into the KaRIn measurement. One value is provided for each grid sample for each of the following quantities:

- *doppler_centroid*: Doppler centroid value (in hertz) used by the OBP [5]. The value reported here is the weighted average of the Doppler centroid values of the native KaRIn samples that contribute to the SSH sample.
- *phase_bias_ref_surface*: Height above the reference ellipsoid at the sample location of the reference plane surface used in the phase bias calculation of interferogram ground processing.
- *obp_ref_surface*: Height above the reference ellipsoid at the sample location of the reference surface used in KaRIn OBP calculations [5].

4.3.4 Radiometer Data

The following items are provided for the two radiometer beams. Brightness temperatures are given in Kelvin, while water content information is given as a mass per unit area. All quantities are given such that the first and second values of the fastest-varying array index are for the left and right radiometer beams, respectively. A description of the algorithms used to compute radiometer parameters is provided in [9]. Additional radiometer data are available in a dedicated radiometer product [15].

- *rad_tmb_187*: Radiometer measured 18.7 GHz main beam brightness temperature.
- *rad_tmb_238*: Radiometer measured 23.8 GHz main beam brightness temperature.
- *rad_tmb_340*: Radiometer measured 34.0 GHz main beam brightness temperature.
- *rad_water_vapor*: Columnar water vapor content from radiometer measurements.
- *rad_cloud_liquid_water*: Columnar cloud liquid water content from radiometer measurements.

4.3.5 Geophysical Information

The following geophysical fields are provided for each sample in the swath from models evaluated at the sample location. All of the reported geophysical variables are computed at the reported fixed-grid locations (*longitude, latitude*). Some of these fields are already incorporated into the calculation of *ssha_karin* and *ssha_karin_2.* Note that the sign of the reported values of the models for these geophysical contributions to SSH is such that they should be subtracted from SSH when they are used to remove these effects from the measured SSH. For example, the reported SSHA is generated by subtracting the model values from reported SSH.

- *mean_sea_surface_dtu*: Model for mean sea surface (MSS) height above the reference ellipsoid from a second solution (as an alternative to *mean_sea_surface_cnescls* as provided in the Basic file and replicated in the Expert file). The model is DTU18 [16]. To use, add *mean_sea_surface_cnescls* to *ssha_karin* and *ssha_karin_2* and subtract *mean_sea_surface_dtu*.
- *mean_sea_surface_dtu_uncert*: Accuracy or uncertainty of *mean_sea_surface_dtu*. This represents a 1-sigma confidence level. Note that the accuracy for the DTU18 model [16] is not available so this field will be set to a Fill Value.
- *mean_dynamic_topography*: Model for mean dynamic topography above the geoid. The model is CNES/CLS2018 (TBD Reference).
- *mean_dynamic_topography_uncert*: Accuracy or uncertainty of *mean_dynamic_topography*. This represents a 1-sigma confidence level.
- *depth_or_elevation*: Ocean depth or land elevation above reference ellipsoid. Ocean depth (bathymetry) is given as negative values, and land elevation positive values. The source is the European Space Agency (ESA) Altimeter Corrected Elevations version 2 (ACE2) data set [17].
- *solid_earth_tide*: Model for the solid Earth (body) tide height. The reported value is calculated using Cartwright/Taylor/Edden [18] [19] tide-generating potential coefficients and consists of the second and third degree constituents. The permanent tide (zero frequency) is not included.
- *ocean_tide_fes*: Model for sea surface height displacement from the ocean tide. The value is from the FES2014b model [20]. This value is subtracted from *ssh_karin* and *ssh_karin_2* when computing *ssha_karin* and *ssha_karin_2*. Note that the reported value includes the sum total of the ocean tide, corresponding load tide (*load_tide_fes*), and equilibrium long-period ocean tide (*ocean_tide_eq*).
- *ocean_tide_got*: Model for sea surface height displacement from the ocean tide. The value is from the GOT4.10c ocean tide model [21]. This is an alternative to *ocean_tide_fes*. Note that the reported value includes the sum total of the ocean tide, corresponding load tide (*load_tide_got*), and equilibrium long-period ocean tide (*ocean_tide_eq*). To use, add *ocean_tide_fes* to *ssha_karin* and subtract *ocean_tide_got*.
- *load_tide_fes*: Model for geocentric surface height displacement from the load tide. The value is from the FES2014b ocean tide model [20]. This value is already included in *ocean_tide_fes*.

- *load_tide_got*: Model for geocentric surface height displacement from the load tide. The value is from the GOT4.10c ocean tide model [21]. This value is already included in *ocean_tide_got*.
- *ocean_tide_eq*: Model for sea surface height displacement from the equilibrium long-period ocean tides. This value is already included in *ocean_tide_fes* and *ocean_tide_got*.
- *ocean_tide_non_eq*: Model for sea surface height from non-equilibrium long-period ocean tides. The reported value is from the FES2014b model [20]. It is reported as a relative height with respect to *ocean_tide_eq*. This value can be added to *ocean_tide_eq*, *ocean_tide_fes*, or *ocean_tide_got,* or subtracted from *ssha_karin* and *ssha_karin_2,* to account for the total long-period ocean tides from equilibrium and non-equilibrium contributions.
- *internal_tide_sol2*: Model for sea surface height displacement from coherent internal tide. This is an alternative to *internal_tide_hret* (as provided in the Basic file and replicated in the Expert file). The source of this model is TBD. To use, add *internal_tide_hret* to *ssha_karin* and *ssha_karin_2* and subtract *internal_tide_sol2*.
- *pole_tide*: Model for the sea surface height displacement from the geocentric pole tide. The value is the sum total of the contribution from the solid-Earth (body) pole tide height [22], and a model for the ocean and load pole tide heights [23]. The value is computed using the reported Earth pole location after correction for a linear drift [24]: in milliarcsec,

  $$Xp = 55.0 + 1.677dt$$

  $$Yp = 320.5 + 3.46dt$$

  where *dt* is the time in years since 2000.0.
- *dac*: Model for the dynamic atmospheric correction to sea surface height. This is a model estimate of the effect on sea surface topography due to high frequency air pressure and wind effects and the low-frequency height from the inverted barometer effect (*inv_bar_cor*). The reported value is from the MOG-2D model developed by LEGOS, CNES, and CLS [25]. This value is subtracted from *ssh_karin* and *ssh_karin_2* when computing *ssha_karin* and *ssha_karin_2*. Only one of *inv_bar_cor* or *dac* should be used.
- *inv_bar_cor*: Model of the static inverse barometer effect on SSH. Above-average pressure lowers the SSH. This value is computed by interpolating atmospheric pressure from the ECMWF meteorological fields in space and time. The value is a part of the dynamic atmospheric correction (*dac*). To use, add *dac* to *ssha_karin* and *ssha_karin_2* and subtract *inv_bar_cor*. Only one of *inv_bar_cor* or *dac* should be used.

4.3.6 Environmental Corrections

These corrections are provided for each sample in the swath, which means that they have been interpolated from lower resolution models or measurements. Including the corrections at the same sampling as the measurement data is intended to allow users to easily remove and/or replace some corrections.

Corrections due to propagation delays from the wet troposphere, the dry troposphere, and the ionosphere are applied during data processing. The reported SSH and geolocation are computed after adding corrections for these propagation delays to the uncorrected range along slant-range paths. The corrections account for the differential delay between the two KaRIn antennas. These corrections are reported in the 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 products can be directly applied to the reported SSH 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 SSH results in the uncorrected SSH. 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 (GIM).

The model-based values of the slant-range wet troposphere correction to range are used to compute *ssh_karin_2*, after which *ssh_karin* is computed using the difference between the reported equivalent wet troposphere corrections from the model and the radiometer (see Section 4.1.3). The corrections for the dry troposphere (*model_dry_tropo_cor*) and the ionosphere (*iono_cor_gim_ka*) are both applied to compute both *ssh_karin_2* and *ssh_karin*.

- *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. The reported *ssh_karin_2* and *ssha_karin_2* have been determined using this model-based correction to ensure continuous availability of SSH and SSHA regardless of availability of radiometer measurements.
- *rad_wet_tropo_cor:* Equivalent vertical wet tropospheric path delay correction from radiometer measurements. This radiometer measurement is likely to have better accuracy and resolution than the model-based correction, *model_wet_tropo_cor*. It has been applied to generate the *ssh_karin* and *ssha_karin* reported quantities.
- *iono_cor_gim_ka*: Equivalent vertical ionospheric path delay correction from the JPL Global Ionosphere Maps (GIM) for the KaRIn Ka-band signal.
- *correction_flag*: Quality indicator for corrections. A value of 0 indicates nominal data. The meaning of other bits/values is TBD.
- *rain_rate*: Rain rate from the ECMWF model.
- *ice_conc:* Ice concentation from the EUMETSAT Ocean and Sea Ice Satellite Applications Facility (OSI SAF) [26]. Ice concentration is computed from atmospherically corrected SSMI brightness temperatures, using a combination of state-of-the-art algorithms.

4.3.7 Sea State Bias Correction

Two sea state bias corrections (*sea_state_bias_cor, sea_state_bias_cor_2*) are provided for each sample in the swath based on the significant wave height (*swh_sea_state_bias*) and other factors such as wind speed (*wind_speed_karin*, *wind_speed_karin_2*), wave period, or wave direction. Sea state bias is an effect on radar-measured height due to the difference in signal reflectivity between the peaks and troughs of ocean waves. Generally, the effect tends to bias the observed height low because troughs reflect more of the radar signal than peaks. The value of *sea_state_bias_cor* (*sea_state_bias_cor_2*) is subtracted from the uncorrected height in generating *ssh_karin* (*ssh_karin_2*).

- *sea_state_bias_cor*: Sea state bias correction, computed using *wind_speed_karin*, that is applied in the computation of *ssh_karin*.
- *sea_state_bias_cor_2*: Sea state bias correction, computed using *wind_speed_karin_2*, that is applied in the computation of *ssh_karin_2*.
- *swh_sea_state_bias*: Estimate of the significant wave height (SWH) that was used to compute the sea state bias corrections. This is the SWH computed from the KaRIn data [TBC]. If that SWH value proves to be inaccurate the SWH computed from the nadir altimeter may be used in the future.

4.4 Unsmoothed SSH File

Unlike the files described in the previous sections, the Unsmoothed SSH file is provided on the native grid of the center KaRIn Doppler beam formed by the OBP (data from the other KaRIn Doppler beams are resampled to the center-beam grid). The measurement data for the left and right half swaths are hence given in separate *left* and *right* NetCDF groups in the Unsmoothed SSH file. The variables in the *left* and *right* groups have identical names and definitions, so the descriptions in this subsection apply to both groups.

As described in Section 3.4, the sampling grids of the left and right half swaths of the Unsmoothed SSH file are finer than the sampling grids of the Basic SSH, Wind and Wave, and Expert SSH with Wind and Wave files.

4.4.1 Time and Location

The time is given in both UTC and TAI for each cross-track line of samples following the conventions in the Basic SSH file.

- *time*, *time_tai*: Time in UTC and TAI of the KaRIn measurement.

The location of each sample in the swath is given following the latitude and longitude representations of the Basic SSH file. These are stored in variables called *latitude* and *longitude.* The samples of the Unsmoothed SSH file correspond to the native sampling locations of Beam 5 (data from other beams are resampled to match Beam 5).

- *latitude*, *longitude*: Latitude in degrees north and longitude in degrees east of the unsmoothed measurement data.
- *latitude_uncert*, *longitude_uncert*: 1-sigma uncertainties in the estimates of the latitude and longitude.

4.4.2 KaRIn Polarization

The variable *polarization_karin* gives the KaRIn signal polarization (see Section 4.2.2). For each of the *left* and *right* NetCDF groups, *polarization_karin* is a 1-D array that varies only with along-track sample and gives the KaRIn polarization for the half swath that is represented by the group.

- *polarization_karin*: Polarization of the KaRIn radar signal for the half swath. The values 'H' and 'V' represent horizontal and vertical polarization.

4.4.3 KaRIn Swath Measurement

The following KaRIn measurement information is provided for each unsmoothed sample.

- *ssh_karin_2*, *ssh_karin_uncert*: Sea surface height (SSH) above the reference ellipsoid and its 1-sigma uncertainty estimate. These quantities are analogous to the *ssh_karin_2* and *ssh_karin_uncert* variables of the Basic SSH file (see Section 4.1.3), except that neither regridding (resampling) nor spatial smoothing after beam combining has been applied. The measurements computed using the model-based wet troposphere correction are given in the Unsmoothed file rather than those computed using a correction based on radiometer data in order to avoid gaps where the radiometer data are not available.
- *sig0_karin_2*, *sig0_karin_uncert*: Fully corrected normalized radar cross section (NRCS or sigma0) estimated from the KaRIn echo power and its 1-sigma uncertainty. These quantities are analogous to the *sig0_karin_2* and *sig0_karin_uncert* variables of the Wind and Wave SSH file (see Section 4.2.3), except that neither regridding (resampling) nor spatial smoothing after beam combining has been applied and that they were computed using the contiguous model-based atmospheric correction rather than a correction based on radiometer data.
- *total_coherence*: Total interferometric coherence. This quantity can be used as an indicator of interferogram quality. The value is a real (not complex) number between 0 and 1.

4.4.4 Geophysical Reference

The mean sea surface for each unsmoothed sample is provided as for the Basic SSH file.

- *mean_sea_surface_cnescls*: Height of the mean sea surface above the reference ellipsoid from the CNES/CLS15 model [10]. This quantity is analogous to the *mean_sea_surface_cnescls* variable of the Basic SSH file (see Section 4.1.3), except that it is given at the locations of the samples of the Unsmoothed SSH file.

4.4.5 Power Measurements

The following power measurements are provided for each sample in the swath as "mitigation" outputs for the detection of small-scale features that might cause artifacts in the KaRIn data. The values are given in linear units, not decibels. Further details are TBD.

- *miti_power_250m*: KaRIn power in the center beam (only) at 250 m resolution.
- *miti_power_var_250m*: KaRIn power variance in the center beam (only) at 250 m resolution.

4.4.6 Flags

The following flags are provided.

- *ancillary_surface_classification_flag*: Surface type flags that has equivalent meaning to the corresponding variable in the Basic SSH file (see Section 4.1.6).
- *ssh_qual*: Flag indicating the quality of the unsmoothed measurement. A value of zero indicates a good measurement. Nonzero values indicate TBD conditions.

5 Detailed Products Description

The L2_LR_SSH product adopts a NetCDF-4 file format and conventions for each of its files. The product includes a global attribute named *Conventions* to indicate the version number number of the Climate for Forecast conventions adopted in the product. This is a self-documenting format that contains metadata as global attributes, dimensions, variables, and attributes for variables. The Unsmoothed SSH file contains two NetCDF groups of data as described in Section 3.2. The global attributes that are defined outside of the groups (i.e., the root netcdf group) apply to all groups in the file, while group attributes that occur within each data group apply only to the data within that single group. Variable attributes only apply to the associated variable. The NetCDF command "ncdump –h product.nc" can be used to view the header of the product, which describes the content of the product.

Sections 5.1 and 5.2 provide information that is common to all four files of the L2_LR_SSH product. Sections 5.3–5.6 then give detailed information for the specific contents of each of the four files.

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_LR_SSH products, 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 (ASCII)
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 file

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. Posssible values of the flag variable.
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 Common Global Attributes and Dimensions

5.2.1 Global Attributes

All four files of the L2_LR_SSH product share a set of common global attributes. These global attributes are provided in Table 6. Note that the string value of the 'title' global attribute differs between the four files to identify the file in the product.

Table 6. Global attributes of all files in the L2_LR_SSH product

Attribute	Format	Description
Conventions	string	NetCDF-4 conventions adopted in this file. This attribute should be set to CF-1.7 to indicate that the file is compliant with the Climate and Forecast NetCDF conventions.
title	string	Level 2 Low Rate Sea Surface Height Data Product - Basic SSH/Wind and Wave/Expert SSH with Wind and Wave/Unsmoothed
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-DD hh:mm:ss : Creation'
platform	string	SWOT
references	string	Published or web-based references that describe the data or methods used to product 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.
time_coverage_start	string	UTC time of first measurement. Format is: YYYY-MM-DD hh:mm:ss.ssssssZ
time_coverage_end	string	UTC time of last measurement. Format is: YYYY-MM-DD hh:mm:ss.ssssssZ
geospatial_lon_min	double	Westernmost longitude (deg) of granule bounding box
geospatial_lon_max	double	Easternmost longitude (deg) of granule bounding box
geospatial_lat_min	double	Southernmost latitude (deg) of granule bounding box
geospatial_lat_max	double	Northernmost latitude (deg) of granule bounding box
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)
wavelength	double	Wavelength (m) of the transmitted signal, which is determined based on the transmitter center frequency of the transmit chirp.
orbit_solution	string	TBD attribute to indicate POE or MOE (also available from CRID).
xref_input_l1b_lr_intf_file	string	Name of input Level 1B Low-Rate Interferogram file.
xref_input_static_karin_cal_file	string	Name of input static KaRIn calibration file.
xref_input_static_geophys_files	string	List of static geophysical parameter files (TBD: to be split into specific input types).
xref_input_dynamic_geophys_files	string	List of dynamic geophysical parameter files (TBD: to be split into specific input types).
xref_input_l1_nalt_gdr_files	string	Name of input L2 Nadir Altimeter Geophysical Data Record files.
xref_input_int_lr_xover_cal_files	string	Name of input crossover calibration files.
xref_input_l2_rad_gdr_files	string	Name of input Level 2 Radiometer Geophysical Data Record files.
ellipsoid_semi_major_axis	double	Semi-major axis of reference ellipsoid in meters.
ellipsoid_flattening	double	Flattening of reference ellipsoid

5.2.2 Dimensions

Variables in the product files use the dimensions with descriptions and lengths given in Table 7. While dimension names (e.g., *num_lines* or *num_pixels*) can be common across multiple files, their values (lengths) are not necessarily the same even for different files within the same granule.

The first and second indices in the *num_sides* dimension correspond to the left and right sides, respectively.

Table 7. Descriptions of variable dimensions for L2_LR_SSH product files.

Name	Description for Basic SSH, Wind and Wave, and Expert SSH with Wind and Wave files	Description for Unsmoothed SSH file
num_lines	Number of along-track samples (approximately 10000)	Number of along-track samples (approximately 80000)
num_pixels	Number of cross-track samples in the full swath (71, indexed from left to right)	Number of cross-track samples per half swath (240 for each half swath)
num_sides	Number of half-swath sides (2, left and right in that order)	Number of half-swath sides (2, left and right in that order)

5.3 Level 2 KaRIn LR Basic SSH File Variables

5.3.1 Global Attributes

Global attributes for the Basic SSH file are provided in Section 5.2.1.

5.3.2 Group Names, Attributes, and Dimensions

As described in Table 2, the Basic SSH file does not contain any NetCDF variable groups. The dimensions of variables in the file are described in Section 5.2.2.

5.3.3 Detailed NetCDF Format Description

This section provides a detailed listing of each of the variables within the Basic SSH file of the L2_LR_SSH product and its associated variable attributes. The descriptions also apply to the same variables that are also provided in the Expert SSH with Wind and Wave file.

Table 8. Variables of the Basic SSH file of the L2_LR_SSH product.

Global Variables		
double time(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in UTC
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]

	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 time_tai(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in TAI
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 [time:tai_utc_difference].
int latitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	latitude (positive N, negative S)
	standard_name	latitude
	units	degrees_north
	scale_factor	0.000001
	valid_min	-80000000
	valid_max	80000000
	comment	Latitude of measurement [-80,80]. Positive latitude is North latitude, negative latitude is South latitude.
int longitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	longitude (degrees East)
	standard_name	longitude
	units	degrees_east
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	comment	Longitude of measurement. East longitude relative to Greenwich meridian.
int ssh_karin(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height
	standard_name	sea surface height above reference ellipsoid
	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude
	comment	Fully corrected sea surface height measured by KaRIn. The height is relative to the reference ellipsoid defined in the global attributes. This value is computed using radiometer measurements for wet troposphere effects on the KaRIn measurement (e.g., rad_wet_tropo_cor and sea_state_bias_cor).
unsigned short ssh_karin_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	sea surface height anomaly uncertainty

	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	60000
	coordinates	longitude latitude
	comment	1-sigma uncertainty on the sea surface height from the KaRIn measurement.
int ssha_karin(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height anomaly
	units	m
	scale_factor	0.000100
	valid_min	-1000000
	valid_max	1000000
	coordinates	longitude latitude
	comment	Sea surface height anomaly from the KaRIn measurement = ssh_karin - mean_sea_surface_cnescls - solid_earth_tide - ocean_tide_fes – internal_tide_hret - pole_tide - dac.
int ssh_karin_2(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height
	standard_name	sea surface height above reference ellipsoid
	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude
	comment	Fully corrected sea surface height measured by KaRIn. The height is relative to the reference ellipsoid defined in the global attributes. This value is computed using model-based estimates for wet troposphere effects on the KaRIn measurement (e.g., model_wet_tropo_cor and sea_state_bias_cor_2).
int ssha_karin_2(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height anomaly
	units	m
	scale_factor	0.000100
	valid_min	-1000000
	valid_max	1000000
	coordinates	longitude latitude
	comment	Sea surface height anomaly from the KaRIn measurement = ssh_karin_2 - mean_sea_surface_cnescls - solid_earth_tide - ocean_tide_fes – internal_tide_hret - pole_tide - dac.
unsigned int ssha_karin_qual(num_lines, num_pixels)		
	_FillValue	4294967295
	long_name	sea surface height quality flag
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for the SSHA from KaRIn.
unsigned short num_pt_avg(num_lines, num_pixels)		
	_FillValue	65535

	long_name	number of samples averaged
	units	1
	valid_min	0
	valid_max	289
	coordinates	longitude latitude
	comment	Number of native unsmoothed, beam-combined KaRIn samples averaged.
unsigned short distance_to_coast(num_lines, num_pixels)		
	_FillValue	65535
	long_name	distance to coast
	source	MODIS/GlobCover
	institution	European Space Agency
	units	m
	scale_factor	1000.000000
	valid_min	0
	valid_max	21000
	coordinates	longitude latitude
	comment	Approximate distance to the nearest coast point along the Earth surface.
unsigned short heading_to_coast(num_lines, num_pixels)		
	_FillValue	65535
	long_name	heading to coast
	units	degrees
	scale_factor	0.010000
	valid_min	0
	valid_max	35999
	coordinates	longitude latitude
	comment	Approximate compass heading (0-360 degrees with respect to true north) to the nearest coast point.
unsigned byte ancillary_surface_classification_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	surface classification
	standard_name	status_flag
	source	MODIS/GlobCover
	institution	European Space Agency
	flag_meanings	open_ocean land continental_water aquatic_vegetation continental_ice_snow floating_ice salted_basin
	flag_values	0 1 2 3 4 5 6
	valid_min	0
	valid_max	6
	coordinates	longitude latitude
	comment	7-state surface type classification computed from a mask built with MODIS and GlobCover data.
unsigned byte dynamic_ice_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	dynamic ice flag
	standard_name	status_flag
	source	EUMETSAT Ocean and Sea Ice Satellite Applications Facility
	institution	EUMETSAT
	flag_meanings	no_ice probable_ice ice
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	longitude latitude
	comment	Dynamic ice flag for the location of the KaRIn measurement.

unsigned byte rain_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	rain flag
	standard_name	status_flag
	flag_meanings	no_rain probable_rain rain
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	longitude latitude
	comment	Flag indicates that signal is attenuated, probably from rain.
unsigned byte rad_surface_type_flag(num_lines, num_sides)		
	_FillValue	255
	long_name	radiometer surface type flag
	standard_name	status_flag
	source	Advanced Microwave Radiometer
	flag_meanings	open_ocean coastal_ocean land
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	comment	Flag indicating the validity and type of processing applied to generate the wet troposphere correction (rad_wet_tropo_cor). A value of 0 indicates that open ocean processing is used, a value of 1 indicates coastal processing, and a value of 2 indicates that rad_wet_tropo_cor is invalid due to land contamination.
int mean_sea_surface_cnescls(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	mean sea surface height (CNES/CLS)
	source	CNES_CLS_15
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	-1500000
	valid_max	1500000
	coordinates	longitude latitude
	comment	Mean sea surface height above the reference ellipsoid. The value is referenced to the mean tide system, i.e. includes the permanent tide (zero frequency).
unsigned short mean_sea_surface_cnescls_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	mean sea surface height accuracy (CNES/CLS)
	source	CNES_CLS_15
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	10000
	coordinates	longitude latitude
	comment	Accuracy of the mean sea surface height (mean_sea_surface_cnescls).
int geoid(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	geoid height
	standard_name	geoid_height_above_reference_ellipsoid
	source	EGM2008 (Pavlis et al., 2012)
	units	m
	scale_factor	0.000100

	valid_min	-1500000
	valid_max	1500000
	coordinates	longitude latitude
	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).
short internal_tide_hret(num_lines, num_pixels)		
	_FillValue	32767
	long_name	coherent internal tide (HRET)
	source	Zaron (2019)
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Coherent internal ocean tide. This value is subtracted from the ssh_karin and ssh_karin_2 to compute ssha_karin and ssha_karin_2, respectively.
int height_cor_xover(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	height correction from KaRIn crossovers
	units	m
	scale_factor	0.000100
	valid_min	-100000
	valid_max	100000
	coordinates	longitude latitude
	comment	Height correction from KaRIn crossover calibration. To apply this correction the value of height_cor_xover should be added to the value of ssh_karin, ssh_karin_2, ssha_karin, and ssha_karin_2.

5.4 Level 2 KaRIn LR Wind and Wave File

5.4.1 Global Attributes

Global attributes for the Wind and Wave file are provided in Section 5.2.1.

5.4.2 Group Names, Attributes, and Dimensions

As described in Table 2, the Wind and Wave file does not contain any NetCDF variable groups. The dimensions of variables in the file are described in Section 5.2.2.

5.4.3 Detailed NetCDF Format Description

This section provides a detailed listing of each of the variables within the Wind and Wave file of the L2_LR_SSH product and its associated variable attributes. The descriptions also apply to the same variables that are also provided in the Expert SSH with Wind and Wave file.

Table 9. Variables of the Wind and Wave file of the L2_LR_SSH product.

Global Variables

double time(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in UTC
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 time_tai(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in TAI
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 [time:tai_utc_difference].
int latitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	latitude (positive N, negative S)
	standard_name	latitude
	units	degrees_north
	scale_factor	0.000001
	valid_min	-80000000
	valid_max	80000000
	comment	Latitude of measurement [-80,80]. Positive latitude is North latitude, negative latitude is South latitude.
int longitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	longitude (degrees East)
	standard_name	longitude
	units	degrees_east
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	comment	Longitude of measurement. East longitude relative to Greenwich meridian.
char polarization_karin(num_lines, num_sides)		
	_FillValue	*
	long_name	polarization for each side of the KaRIn swath
	comment	H denotes co-polarized linear horizontal, V denotes co-polarized linear vertical.
unsigned short swh_karin(num_lines, num_pixels)		
	_FillValue	65535
	long_name	significant wave height from KaRIn
	standard_name	sea_surface_wave_significant_height
	units	m
	scale_factor	0.001000

	valid_min	0
	valid_max	25000
	coordinates	longitude latitude
	comment	Significant wave height from KaRIn volumetric correlation.
unsigned short swh_karin_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	1-sigma uncertainty on significant wave height from KaRIn
	units	m
	scale_factor	0.001000
	valid_min	0
	valid_max	25000
	coordinates	longitude latitude
	comment	1-sigma uncertainty on significant wave height from KaRIn.
float sig0_karin(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	normalized radar cross section (sigma0) from KaRIn
	standard_name	surface_backwards_scattering_coefficient_of_radar_wave
	units	1
	valid_min	-1000
	valid_max	10000000.0
	coordinates	longitude latitude
	comment	Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels). The value may be negative due to noise subtraction. The value is corrected for instrument calibration and atmospheric attenuation. Radiometer measurements provide the atmospheric attenuation (sig0_cor_atmos_rad).
float sig0_karin_uncert(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	1-sigma uncertainty on sigma0 from KaRIn
	units	1
	valid_min	0
	valid_max	1000.0
	coordinates	longitude latitude
	comment	1-sigma uncertainty on sigma0 from KaRIn.
float sig0_karin_2(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	normalized radar cross section (sigma0) from KaRIn
	standard_name	surface_backwards_scattering_coefficient_of_radar_wave
	units	1
	valid_min	-1000
	valid_max	10000000.0
	coordinates	longitude latitude
	comment	Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels). The value may be negative due to noise subtraction. The value is corrected for instrument calibration and atmospheric attenuation. A meteorological model provides the atmospheric attenuation (sig0_cor_atmos_model).
unsigned short wind_speed_karin(num_lines, num_pixels)		
	_FillValue	65535
	long_name	wind speed from KaRIn
	standard_name	wind_speed
	source	TBD
	units	m/s
	scale_factor	0.001000
	valid_min	0

	valid_max	65000
	coordinates	longitude latitude
	comment	Wind speed from KaRIn computed from sig0_karin.
unsigned short wind_speed_karin_2(num_lines, num_pixels)		
	_FillValue	65535
	long_name	wind speed from KaRIn
	standard_name	wind_speed
	source	TBD
	units	m/s
	scale_factor	0.001000
	valid_min	0
	valid_max	65000
	coordinates	longitude latitude
	comment	Wind speed from KaRIn computed from sig0_karin_2.
unsigned int swh_karin_qual(num_lines, num_pixels)		
	_FillValue	4294967295
	long_name	quality flag for significant wave height from KaRIn.
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for significant wave height from KaRIn.
unsigned int sig0_karin_qual(num_lines, num_pixels)		
	_FillValue	4294967295
	long_name	quality flag for sigma0 from KaRIn.
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for sigma0 from KaRIn.
unsigned short num_pt_avg(num_lines, num_pixels)		
	_FillValue	65535
	long_name	number of samples averaged
	units	1
	valid_min	0
	valid_max	289
	coordinates	longitude latitude
	comment	Number of native unsmoothed, beam-combined KaRIn samples averaged.
unsigned short swh_model(num_lines, num_pixels)		
	_FillValue	65535
	long_name	significant wave height from wave model
	standard_name	sea_surface_wave_significant_height
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m
	scale_factor	0.001000
	valid_min	0
	valid_max	30000
	coordinates	longitude latitude

	comment	Significant wave height from model.
unsigned short mean_wave_direction(num_lines, num_pixels)		
	_FillValue	65535
	long_name	mean sea surface wave direction
	source	Meteo France Wave Model (MF-WAM)
	institution	Meteo France
	units	degree
	scale_factor	0.010000
	valid_min	0
	valid_max	36000
	coordinates	longitude latitude
	comment	Mean sea surface wave direction.
unsigned short mean_wave_period_t02(num_lines, num_pixels)		
	_FillValue	65535
	long_name	sea surface wind wave mean period
	standard_name	sea_surface_wave_significant_period
	source	Meteo France Wave Model (MF-WAM)
	institution	Meteo France
	units	s
	scale_factor	0.001000
	valid_min	0
	valid_max	100
	coordinates	longitude latitude
	comment	Sea surface wind wave mean period from model spectral density second moment.
short wind_speed_model_u(num_lines, num_pixels)		
	_FillValue	32767
	long_name	u component of model wind
	standard_name	eastward_wind
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m/s
	scale_factor	0.001000
	valid_min	-30000
	valid_max	30000
	coordinates	longitude latitude
	comment	Eastward component of the atmospheric model wind vector at 10 meters.
short wind_speed_model_v(num_lines, num_pixels)		
	_FillValue	32767
	long_name	v component of model wind
	standard_name	northward_wind
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m/s
	scale_factor	0.001000
	valid_min	-30000
	valid_max	30000
	coordinates	longitude latitude
	comment	Northward component of the atmospheric model wind vector at 10 meters.
unsigned short wind_speed_rad(num_lines, num_sides)		
	_FillValue	65535
	long_name	wind speed from radiometer
	standard_name	wind_speed
	source	Advanced Microwave Radiometer

	units	m/s
	scale_factor	0.001000
	valid_min	0
	valid_max	65000
	comment	Wind speed from radiometer measurements.
unsigned short distance_to_coast(num_lines, num_pixels)		
	_FillValue	65535
	long_name	distance to coast
	source	MODIS/GlobCover
	institution	European Space Agency
	units	m
	scale_factor	1000.000000
	valid_min	0
	valid_max	21000
	coordinates	longitude latitude
	comment	Approximate distance to the nearest coast point along the Earth surface.
unsigned short heading_to_coast(num_lines, num_pixels)		
	_FillValue	65535
	long_name	heading to coast
	units	degrees
	scale_factor	0.010000
	valid_min	0
	valid_max	35999
	coordinates	longitude latitude
	comment	Approximate compass heading (0-360 degrees with respect to true north) to the nearest coast point.
unsigned byte ancillary_surface_classification_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	surface classification
	standard_name	status_flag
	source	MODIS/GlobCover
	institution	European Space Agency
	flag_meanings	open_ocean land continental_water aquatic_vegetation continental_ice_snow floating_ice salted_basin
	flag_values	0 1 2 3 4 5 6
	valid_min	0
	valid_max	6
	coordinates	longitude latitude
	comment	7-state surface type classification computed from a mask built with MODIS and GlobCover data.
unsigned byte dynamic_ice_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	dynamic ice flag
	standard_name	status_flag
	source	EUMETSAT Ocean and Sea Ice Satellite Applications Facility
	institution	EUMETSAT
	flag_meanings	no_ice probable_ice ice
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	longitude latitude
	comment	Dynamic ice flag for the location of the KaRIn measurement.
unsigned byte rain_flag(num_lines, num_pixels)		

	_FillValue	255
	long_name	rain flag
	standard_name	status_flag
	flag_meanings	no_rain probable_rain rain
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	longitude latitude
	comment	Flag indicates that signal is attenuated, probably from rain.
unsigned byte rad_surface_type_flag(num_lines, num_sides)		
	_FillValue	255
	long_name	radiometer surface type flag
	standard_name	status_flag
	source	Advanced Microwave Radiometer
	flag_meanings	open_ocean coastal_ocean land
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	comment	Flag indicating the validity and type of processing applied to generate the wet troposphere correction (rad_wet_tropo_cor). A value of 0 indicates that open ocean processing is used, a value of 1 indicates coastal processing, and a value of 2 indicates that rad_wet_tropo_cor is invalid due to land contamination.

5.5 Level 2 KaRIn LR Expert SSH with Wind and Wave File

5.5.1 Global Attributes

Global attributes for the Expert SSH with Wind and Wave file are provided in Section 5.2.1.

5.5.2 Group Names, Attributes, and Dimensions

As described in Table 2, the Expert SSH with Wind and Wave file does not contain any NetCDF groups. The dimensions of variables in the file are described in Section 5.2.2.

5.5.3 Detailed NetCDF Format Description

As described in Section 3.2, the Expert SSH with Wind and Wave file replicates all of the information in the Basic SSH and Wind and Wave files and has identical structure, variable names, variable definitions, and variable attributes. Table 10 provides a detailed listing of all variables that are provided in the Expert SSH with Wind and Wave file and their associated variable attributes (some information is therefore replicated between Table 8, Table 9. and Table 10).

Table 10. Variables in the Expert SSH with Wind and Wave file of the L2_LR_SSH product including copies of the variables provided in the Basic SSH and Wind and Wave files.

Global Variables		
double time(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in UTC
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 time_tai(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in TAI
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 [time:tai_utc_difference].
int latitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	latitude (positive N, negative S)
	standard_name	latitude
	units	degrees_north
	scale_factor	0.000001
	valid_min	-80000000
	valid_max	80000000
	comment	Latitude of measurement [-80,80]. Positive latitude is North latitude, negative latitude is South latitude.
int longitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	longitude (degrees East)
	standard_name	longitude
	units	degrees_east
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	comment	Longitude of measurement. East longitude relative to Greenwich meridian.
int ssh_karin(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height
	standard_name	sea surface height above reference ellipsoid
	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude

	comment	Fully corrected sea surface height measured by KaRIn. The height is relative to the reference ellipsoid defined in the global attributes. This value is computed using radiometer measurements for wet troposphere effects on the KaRIn measurement (e.g., rad_wet_tropo_cor and sea_state_bias_cor).
unsigned short ssh_karin_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	sea surface height anomaly uncertainty
	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	60000
	coordinates	longitude latitude
	comment	1-sigma uncertainty on the sea surface height from the KaRIn measurement.
int ssha_karin(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height anomaly
	units	m
	scale_factor	0.000100
	valid_min	-1000000
	valid_max	1000000
	coordinates	longitude latitude
	comment	Sea surface height anomaly from the KaRIn measurement = ssh_karin - mean_sea_surface_cnescls - solid_earth_tide - ocean_tide_fes – internal_tide_hret - pole_tide - dac.
int ssh_karin_2(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height
	standard_name	sea surface height above reference ellipsoid
	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude
	comment	Fully corrected sea surface height measured by KaRIn. The height is relative to the reference ellipsoid defined in the global attributes. This value is computed using model-based estimates for wet troposphere effects on the KaRIn measurement (e.g., model_wet_tropo_cor and sea_state_bias_cor_2).
int ssha_karin_2(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height anomaly
	units	m
	scale_factor	0.000100
	valid_min	-1000000
	valid_max	1000000
	coordinates	longitude latitude
	comment	Sea surface height anomaly from the KaRIn measurement = ssh_karin_2 - mean_sea_surface_cnescls - solid_earth_tide - ocean_tide_fes – internal_tide_hret - pole_tide - dac.
unsigned int ssha_karin_qual(num_lines, num_pixels)		
	_FillValue	4294967295
	long_name	sea surface height quality flag
	standard_name	status_flag
	flag_meanings	good bad

	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for the SSHA from KaRIn.
char polarization_karin(num_lines, num_sides)		
	_FillValue	*
	long_name	polarization for each side of the KaRIn swath
	comment	H denotes co-polarized linear horizontal, V denotes co-polarized linear vertical.
unsigned short swh_karin(num_lines, num_pixels)		
	_FillValue	65535
	long_name	significant wave height from KaRIn
	standard_name	sea_surface_wave_significant_height
	units	m
	scale_factor	0.001000
	valid_min	0
	valid_max	25000
	coordinates	longitude latitude
	comment	Significant wave height from KaRIn volumetric correlation.
unsigned short swh_karin_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	1-sigma uncertainty on significant wave height from KaRIn
	units	m
	scale_factor	0.001000
	valid_min	0
	valid_max	25000
	coordinates	longitude latitude
	comment	1-sigma uncertainty on significant wave height from KaRIn.
float sig0_karin(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	normalized radar cross section (sigma0) from KaRIn
	standard_name	surface_backwards_scattering_coefficient_of_radar_wave
	units	1
	valid_min	-1000
	valid_max	10000000.0
	coordinates	longitude latitude
	comment	Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels). The value may be negative due to noise subtraction. The value is corrected for instrument calibration and atmospheric attenuation. Radiometer measurements provide the atmospheric attenuation (sig0_cor_atmos_rad).
float sig0_karin_uncert(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	1-sigma uncertainty on sigma0 from KaRIn
	units	1
	valid_min	0
	valid_max	1000.0
	coordinates	longitude latitude
	comment	1-sigma uncertainty on sigma0 from KaRIn.
float sig0_karin_2(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	normalized radar cross section (sigma0) from KaRIn
	standard_name	surface_backwards_scattering_coefficient_of_radar_wave
	units	1

	valid_min	-1000
	valid_max	10000000.0
	coordinates	longitude latitude
	comment	Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels). The value may be negative due to noise subtraction. The value is corrected for instrument calibration and atmospheric attenuation. A meteorological model provides the atmospheric attenuation (sig0_cor_atmos_model).
unsigned short wind_speed_karin(num_lines, num_pixels)		
	_FillValue	65535
	long_name	wind speed from KaRIn
	standard_name	wind_speed
	source	TBD
	units	m/s
	scale_factor	0.001000
	valid_min	0
	valid_max	65000
	coordinates	longitude latitude
	comment	Wind speed from KaRIn computed from sig0_karin.
unsigned short wind_speed_karin_2(num_lines, num_pixels)		
	_FillValue	65535
	long_name	wind speed from KaRIn
	standard_name	wind_speed
	source	TBD
	units	m/s
	scale_factor	0.001000
	valid_min	0
	valid_max	65000
	coordinates	longitude latitude
	comment	Wind speed from KaRIn computed from sig0_karin_2.
unsigned int swh_karin_qual(num_lines, num_pixels)		
	_FillValue	4294967295
	long_name	quality flag for significant wave height from KaRIn.
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for significant wave height from KaRIn.
unsigned int sig0_karin_qual(num_lines, num_pixels)		
	_FillValue	4294967295
	long_name	quality flag for sigma0 from KaRIn.
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for sigma0 from KaRIn.
unsigned short num_pt_avg(num_lines, num_pixels)		
	_FillValue	65535
	long_name	number of samples averaged
	units	1

	valid_min	0
	valid_max	289
	coordinates	longitude latitude
	comment	Number of native unsmoothed, beam-combined KaRIn samples averaged.
unsigned short swh_model(num_lines, num_pixels)		
	_FillValue	65535
	long_name	significant wave height from wave model
	standard_name	sea_surface_wave_significant_height
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m
	scale_factor	0.001000
	valid_min	0
	valid_max	30000
	coordinates	longitude latitude
	comment	Significant wave height from model.
unsigned short mean_wave_direction(num_lines, num_pixels)		
	_FillValue	65535
	long_name	mean sea surface wave direction
	source	Meteo France Wave Model (MF-WAM)
	institution	Meteo France
	units	degree
	scale_factor	0.010000
	valid_min	0
	valid_max	36000
	coordinates	longitude latitude
	comment	Mean sea surface wave direction.
unsigned short mean_wave_period_t02(num_lines, num_pixels)		
	_FillValue	65535
	long_name	sea surface wind wave mean period
	standard_name	sea_surface_wave_significant_period
	source	Meteo France Wave Model (MF-WAM)
	institution	Meteo France
	units	s
	scale_factor	0.001000
	valid_min	0
	valid_max	100
	coordinates	longitude latitude
	comment	Sea surface wind wave mean period from model spectral density second moment.
short wind_speed_model_u(num_lines, num_pixels)		
	_FillValue	32767
	long_name	u component of model wind
	standard_name	eastward_wind
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m/s
	scale_factor	0.001000
	valid_min	-30000
	valid_max	30000
	coordinates	longitude latitude
	comment	Eastward component of the atmospheric model wind vector at 10 meters.
short wind_speed_model_v(num_lines, num_pixels)		
	_FillValue	32767

	long_name	v component of model wind
	standard_name	northward_wind
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m/s
	scale_factor	0.001000
	valid_min	-30000
	valid_max	30000
	coordinates	longitude latitude
	comment	Northward component of the atmospheric model wind vector at 10 meters.
unsigned short wind_speed_rad(num_lines, num_sides)		
	_FillValue	65535
	long_name	wind speed from radiometer
	standard_name	wind_speed
	source	Advanced Microwave Radiometer
	units	m/s
	scale_factor	0.001000
	valid_min	0
	valid_max	65000
	comment	Wind speed from radiometer measurements.
unsigned short distance_to_coast(num_lines, num_pixels)		
	_FillValue	65535
	long_name	distance to coast
	source	MODIS/GlobCover
	institution	European Space Agency
	units	m
	scale_factor	1000.000000
	valid_min	0
	valid_max	21000
	coordinates	longitude latitude
	comment	Approximate distance to the nearest coast point along the Earth surface.
unsigned short heading_to_coast(num_lines, num_pixels)		
	_FillValue	65535
	long_name	heading to coast
	units	degrees
	scale_factor	0.010000
	valid_min	0
	valid_max	35999
	coordinates	longitude latitude
	comment	Approximate compass heading (0-360 degrees with respect to true north) to the nearest coast point.
unsigned byte ancillary_surface_classification_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	surface classification
	standard_name	status_flag
	source	MODIS/GlobCover
	institution	European Space Agency
	flag_meanings	open_ocean land continental_water aquatic_vegetation continental_ice_snow floating_ice salted_basin
	flag_values	0 1 2 3 4 5 6
	valid_min	0
	valid_max	6
	coordinates	longitude latitude

	comment	7-state surface type classification computed from a mask built with MODIS and GlobCover data.
unsigned byte dynamic_ice_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	dynamic ice flag
	standard_name	status_flag
	source	EUMETSAT Ocean and Sea Ice Satellite Applications Facility
	institution	EUMETSAT
	flag_meanings	no_ice probable_ice ice
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	longitude latitude
	comment	Dynamic ice flag for the location of the KaRIn measurement.
unsigned byte rain_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	rain flag
	standard_name	status_flag
	flag_meanings	no_rain probable_rain rain
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	longitude latitude
	comment	Flag indicates that signal is attenuated, probably from rain.
unsigned byte rad_surface_type_flag(num_lines, num_sides)		
	_FillValue	255
	long_name	radiometer surface type flag
	standard_name	status_flag
	source	Advanced Microwave Radiometer
	flag_meanings	open_ocean coastal_ocean land
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	comment	Flag indicating the validity and type of processing applied to generate the wet troposphere correction (rad_wet_tropo_cor). A value of 0 indicates that open ocean processing is used, a value of 1 indicates coastal processing, and a value of 2 indicates that rad_wet_tropo_cor is invalid due to land contamination.
int sc_altitude(num_lines)		
	_FillValue	2147483647
	long_name	altitude of KMSF origin
	standard_name	height_above_reference_ellipsoid
	units	m
	add_offset	800000.000000
	scale_factor	0.000100
	valid_min	0
	valid_max	2000000000
	coordinates	longitude_nadir latitude_nadir
	comment	Altitude of the KMSF origin.
int latitude_nadir(num_lines)		
	_FillValue	2147483647
	long_name	latitude of satellite nadir point
	standard_name	latitude
	units	degrees_north

	scale_factor	0.000001
	valid_min	-80000000
	valid_max	80000000
	comment	Geodetic latitude [-80,80] (degrees north of equator) of the satellite nadir point.
int longitude_nadir(num_lines)		
	_FillValue	2147483647
	long_name	longitude of satellite nadir point
	standard_name	longitude
	units	degrees_east
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	comment	Longitude (degrees east of Grenwich meridian) of the satellite nadir point.
short orbit_alt_rate(num_lines)		
	_FillValue	32767
	long_name	orbital altitude rate with respect to mean sea surface
	units	m/s
	scale_factor	0.010000
	valid_min	-3500
	valid_max	3500
	coordinates	longitude_nadir latitude_nadir
	comment	Orbital altitude rate with respect to the mean sea surface.
int cross_track_angle(num_lines)		
	_FillValue	2147483647
	long_name	cross-track angle from true north
	units	degrees
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	coordinates	longitude_nadir latitude_nadir
	comment	Angle with respect to true north of the cross-track direction to the right of the spacecraft velocity vector.
int sc_roll(num_lines)		
	_FillValue	2147483647
	long_name	roll of the spacecraft
	standard_name	platform_roll_angle
	units	degrees
	scale_factor	0.000100
	valid_min	-1799999
	valid_max	1800000
	coordinates	longitude_nadir latitude_nadir
	comment	KMSF attitude roll angle; positive values move the +y antenna down.
int sc_pitch(num_lines)		
	_FillValue	2147483647
	long_name	pitch of the spacecraft
	standard_name	platform_pitch_angle
	units	degrees
	scale_factor	0.000100
	valid_min	-1799999
	valid_max	1800000
	coordinates	longitude_nadir latitude_nadir
	comment	KMSF attitude pitch angle; positive values move the KMSF +x axis up.
int sc_yaw(num_lines)		

	_FillValue	2147483647
	long_name	yaw of the spacecraft
	standard_name	platform_yaw_angle
	units	degrees
	scale_factor	0.000100
	valid_min	-1799999
	valid_max	1800000
	coordinates	longitude_nadir latitude_nadir
	comment	KMSF attitude yaw angle relative to the nadir track. The yaw angle is a right-handed rotation about the nadir (downward) direction. A yaw value of 0 deg indicates that the KMSF +x axis is aligned with the horizontal component of the Earth-relative velocity vector. A yaw value of 180 deg indicates that the spacecraft is in a yaw-flipped state, with the KMSF -x axis aligned with the horizontal component of the Earth-relative velocity vector.
int velocity_heading(num_lines)		
	_FillValue	2147483647
	long_name	heading of the spacecraft Earth-relative velocity vector
	units	degrees
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	coordinates	longitude_nadir latitude_nadir
	comment	Angle with respect to true north of the horizontal component of the spacecraft Earth-relative velocity vector. A value of 90 deg indicates that the spacecraft velocity vector pointed due east. Values between 0 and 90 deg indicate that the velocity vector has a northward component, and values between 90 and 180 deg indicate that the velocity vector has a southward component.
unsigned byte orbit_qual(num_lines)		
	_FillValue	255
	long_name	orbit quality flag
	standard_name	status_flag
	valid_min	0
	valid_max	1
	coordinates	longitude_nadir latitude_nadir
	comment	Orbit quality flag.
int latitude_avg_ssh(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	weighted average latitude of samples used to compute SSH
	standard_name	latitude
	units	degrees_north
	scale_factor	0.000001
	valid_min	-80000000
	valid_max	80000000
	comment	Latitude of measurement [-80,80]. Positive latitude is North latitude, negative latitude is South latitude. This value may be biased away from a nominal grid location if some of the native, unsmoothed samples were discarded during processing.
int longitude_avg_ssh(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	weighted average longitude of samples used to compute SSH
	standard_name	longitude
	units	degrees_east
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999

	comment	Longitude of measurement. East longitude relative to Greenwich meridian. This value may be biased away from a nominal grid location if some of the native, unsmoothed samples were discarded during processing.
float cross_track_distance(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	cross track distance
	units	m
	valid_min	-75000
	valid_max	75000
	coordinates	longitude latitude
	comment	Distance of sample from nadir. Negative values indicate the left side of the swath, and positive values indicate the right side of the swath.
float x_factor(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	radiometric calibration X factor as a composite value for the X factors of the +y and -y channels
	units	1
	valid_min	0
	valid_max	1e+20
	coordinates	longitude latitude
	comment	Radiometric calibration X factor as a linear power ratio.
float sig0_cor_atmos_model(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	two-way atmospheric correction to sigma0 from model
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	1
	valid_min	1
	valid_max	10
	coordinates	longitude latitude
	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_karin_2.
float sig0_cor_atmos_rad(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	two-way atmospheric correction to sigma0 from radiometer data
	source	Advanced Microwave Radiometer
	units	1
	valid_min	1
	valid_max	10
	coordinates	longitude latitude
	comment	Atmospheric correction to sigma0 from radiometer data as a linear power multiplier (not decibels). sig0_cor_atmos_rad is already applied in computing sig0_karin.
short doppler_centroid(num_lines, num_sides)		
	_FillValue	32767
	long_name	doppler centroid estimated by KaRIn
	units	1/s
	scale_factor	1.000000
	valid_min	-30000
	valid_max	30000
	comment	Doppler centroid (in hertz or cycles per second) estimated by KaRIn.
int phase_bias_ref_surface(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	height of reference surface used for phase bias calculation

	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude
	comment	Height (relative to the reference ellipsoid) of the reference surface used for phase bias calculation during L1B processing.
int obp_ref_surface(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	height of reference surface used by on-board-processor
	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude
	comment	Height (relative to the reference ellipsoid) of the reference surface used by the KaRIn on-board processor.
short rad_tmb_187(num_lines, num_sides)		
	_FillValue	32767
	long_name	radiometer main beam brightness temperature at 18.7 GHz
	standard_name	toa_brightness_temperature
	source	Advanced Microwave Radiometer
	units	K
	scale_factor	0.010000
	valid_min	13000
	valid_max	25000
	comment	Main beam brightness temperature measurement at 18.7 GHz. Value is unsmoothed (along-track averaging has not been performed).
short rad_tmb_238(num_lines, num_sides)		
	_FillValue	32767
	long_name	radiometer main beam brightness temperature at 23.8 GHz
	standard_name	toa_brightness_temperature
	source	Advanced Microwave Radiometer
	units	K
	scale_factor	0.010000
	valid_min	13000
	valid_max	25000
	comment	Main beam brightness temperature measurement at 23.8 GHz. Value is unsmoothed (along-track averaging has not been performed).
short rad_tmb_340(num_lines, num_sides)		
	_FillValue	32767
	long_name	radiometer main beam brightness temperature at 34.0 GHz
	standard_name	toa_brightness_temperature
	source	Advanced Microwave Radiometer
	units	K
	scale_factor	0.010000
	valid_min	15000
	valid_max	28000
	comment	Main beam brightness temperature measurement at 34.0 GHz. Value is unsmoothed (along-track averaging has not been performed).
short rad_water_vapor(num_lines, num_sides)		
	_FillValue	32767
	long_name	water vapor content from radiometer

	standard_name	atmosphere_water_vapor_content
	source	Advanced Microwave Radiometer
	units	kg/m^2
	scale_factor	0.010000
	valid_min	0
	valid_max	15000
	comment	Integrated water vapor content from radiometer measurements.
short rad_cloud_liquid_water(num_lines, num_sides)		
	_FillValue	32767
	long_name	liquid water content from radiometer
	standard_name	atmosphere_cloud_liquid_water_content
	source	Advanced Microwave Radiometer
	units	kg/m^2
	scale_factor	0.010000
	valid_min	0
	valid_max	2000
	comment	Integrated cloud liquid water content from radiometer measurements.
int mean_sea_surface_cnescls(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	mean sea surface height (CNES/CLS)
	source	CNES_CLS_15
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	-1500000
	valid_max	1500000
	coordinates	longitude latitude
	comment	Mean sea surface height above the reference ellipsoid. The value is referenced to the mean tide system, i.e. includes the permanent tide (zero frequency).
unsigned short mean_sea_surface_cnescls_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	mean sea surface height accuracy (CNES/CLS)
	source	CNES_CLS_15
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	10000
	coordinates	longitude latitude
	comment	Accuracy of the mean sea surface height (mean_sea_surface_cnescls).
int mean_sea_surface_dtu(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	mean sea surface height (DTU)
	source	DTU18
	institution	DTU
	units	m
	scale_factor	0.000100
	valid_min	-1500000
	valid_max	1500000
	coordinates	longitude latitude
	comment	Mean sea surface height above the reference ellipsoid. The value is referenced to the mean tide system, i.e. includes the permanent tide (zero frequency).
unsigned short mean_sea_surface_dtu_uncert(num_lines, num_pixels)		

	_FillValue	65535
	long_name	mean sea surface height accuracy (DTU)
	source	DTU18
	institution	DTU
	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	10000
	coordinates	longitude latitude
	comment	Accuracy of the mean sea surface height (mean_sea_surface_dtu)
int geoid(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	geoid height
	standard_name	geoid_height_above_reference_ellipsoid
	source	EGM2008 (Pavlis et al., 2012)
	units	m
	scale_factor	0.000100
	valid_min	-1500000
	valid_max	1500000
	coordinates	longitude latitude
	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).
short mean_dynamic_topography(num_lines, num_pixels)		
	_FillValue	32767
	long_name	mean dynamic topography
	source	CNES_CLS_18
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	-30000
	valid_max	30000
	coordinates	longitude latitude
	comment	Mean dynamic topography above the geoid.
unsigned short mean_dynamic_topography_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	mean dynamic topography accuracy
	source	CNES_CLS_18
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	10000
	coordinates	longitude latitude
	comment	Accuracy of the mean dynamic topography.
short depth_or_elevation(num_lines, num_pixels)		
	_FillValue	32767
	long_name	ocean depth or land elevation
	source	Altimeter Corrected Elevations, version 2
	institution	European Space Agency
	units	m
	scale_factor	1.000000
	valid_min	-12000
	valid_max	10000

	coordinates	longitude latitude
	comment	Ocean depth or land elevation above reference ellipsoid. Ocean depth (bathymetry) is given as negative values, and land elevation positive values.
short solid_earth_tide(num_lines, num_pixels)		
	_FillValue	32767
	long_name	solid Earth tide height
	source	Cartwright and Taylor (1971) and Cartwright and Edden (1973)
	units	m
	scale_factor	0.000100
	valid_min	-10000
	valid_max	10000
	coordinates	longitude latitude
	comment	Solid-Earth (body) tide height. The zero-frequency permanent tide component is not included.
int ocean_tide_fes(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	geocentric ocean tide height (FES)
	source	FES2014b (Carrere et al., 2016)
	institution	LEGOS/CNES
	units	m
	scale_factor	0.000100
	valid_min	-300000
	valid_max	300000
	coordinates	longitude latitude
	comment	Geocentric ocean tide height. Includes the sum total of the ocean tide, the corresponding load tide (load_tide_fes) and equilibrium long-period ocean tide height (ocean_tide_eq).
int ocean_tide_got(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	geocentric ocean tide height (GOT)
	source	GOT4.10c (Ray, 2013)
	institution	GSFC
	units	m
	scale_factor	0.000100
	valid_min	-300000
	valid_max	300000
	coordinates	longitude latitude
	comment	Geocentric ocean tide height. Includes the sum total of the ocean tide, the corresponding load tide (load_tide_got) and equilibrium long-period ocean tide height (ocean_tide_eq).
short load_tide_fes(num_lines, num_pixels)		
	_FillValue	32767
	long_name	geocentric load tide height (FES)
	source	FES2014b (Carrere et al., 2016)
	institution	LEGOS/CNES
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust. This value has already been added to the corresponding ocean tide height value (ocean_tide_fes).

short load_tide_got(num_lines, num_pixels)		
	_FillValue	32767
	long_name	geocentric load tide height (GOT)
	source	GOT4.10c (Ray, 2013)
	institution	GSFC
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust. This value has already been added to the corresponding ocean tide height value (ocean_tide_got).
short ocean_tide_eq(num_lines, num_pixels)		
	_FillValue	32767
	long_name	equilibrium long-period ocean tide height
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Equilibrium long-period ocean tide height. This value has already been added to the corresponding ocean tide height values (ocean_tide_fes and ocean_tide_got).
short ocean_tide_non_eq(num_lines, num_pixels)		
	_FillValue	32767
	long_name	non-equilibrium long-period ocean tide height
	source	FES2014b (Carrere et al., 2016)
	institution	LEGOS/CNES
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Non-equilibrium long-period ocean tide height. This value is reported as a relative displacement with repsect to ocean_tide_eq. This value can be added to ocean_tide_eq, ocean_tide_fes, or ocean_tide_got, or subtracted from ssha_karin and ssha_karin_2, to account for the total long-period ocean tides from equilibrium and non-equilibrium contributions.
short internal_tide_hret(num_lines, num_pixels)		
	_FillValue	32767
	long_name	coherent internal tide (HRET)
	source	Zaron (2019)
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Coherent internal ocean tide. This value is subtracted from the ssh_karin and ssh_karin_2 to compute ssha_karin and ssha_karin_2, respectively.
short internal_tide_sol2(num_lines, num_pixels)		
	_FillValue	32767
	long_name	coherent internal tide (Model 2)
	source	TBD

	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Coherent internal tide.
short pole_tide(num_lines, num_pixels)		
	_FillValue	32767
	long_name	geocentric pole tide height
	source	Wahr (1985) and Desai et al. (2015)
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Geocentric pole tide height. The total of the contribution from the solid-Earth (body) pole tide height, the ocean pole tide height, and the load pole tide height (i.e., the effect of the ocean pole tide loading of the Earth's crust).
short dac(num_lines, num_pixels)		
	_FillValue	32767
	long_name	dynamic atmospheric correction
	source	MOG2D
	institution	LEGOS/CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	-12000
	valid_max	12000
	coordinates	longitude latitude
	comment	Model estimate of the effect on sea surface topography due to high frequency air pressure and wind effects and the low-frequency height from inverted barometer effect (inv_bar_cor). This value is subtracted from the ssh_karin and ssh_karin_2 to compute ssha_karin and ssha_karin_2, respectively. Use only one of inv_bar_cor and dac.
short inv_bar_cor(num_lines, num_pixels)		
	_FillValue	32767
	long_name	static inverse barometer effect on sea surface height
	units	m
	scale_factor	0.000100
	valid_min	-2000
	valid_max	2000
	coordinates	longitude latitude
	comment	Estimate of static effect of atmospheric pressure on sea surface height. Above average pressure lowers sea surface height. Computed by interpolating ECMWF pressure fields in space and time. The value is included in dac. To apply, add dac to ssha_karin and ssha_karin_2 and subtract inv_bar_cor.
short model_dry_tropo_cor(num_lines, num_pixels)		
	_FillValue	32767
	long_name	dry troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m
	scale_factor	0.000100
	valid_min	-30000
	valid_max	-15000

	coordinates	longitude latitude
	comment	Equivalent vertical correction due to dry troposphere delay. The reported sea surface height, 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 sea surface height results in the uncorrected sea surface height.
short model_wet_tropo_cor(num_lines, num_pixels)		
	_FillValue	32767
	long_name	wet troposphere vertical correction from weather model data
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	m
	scale_factor	0.000100
	valid_min	-10000
	valid_max	0
	coordinates	longitude latitude
	comment	Equivalent vertical correction due to wet troposphere delay from weather model data. The reported pixel height, 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 sea surface height (ssh_karin_2) results in the uncorrected sea surface height.
short rad_wet_tropo_cor(num_lines, num_pixels)		
	_FillValue	32767
	long_name	wet troposphere vertical correction from radiometer data
	source	Advanced Microwave Radiometer
	units	m
	scale_factor	0.000100
	valid_min	-10000
	valid_max	0
	coordinates	longitude latitude
	comment	Equivalent vertical correction due to wet troposphere delay from radiometer measurements. The reported pixel height, 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 sea surface height (ssh_karin) results in the uncorrected sea surface height.
short iono_cor_gim_ka(num_lines, num_pixels)		
	_FillValue	32767
	long_name	ionosphere vertical correction
	source	Global Ionosphere Maps
	institution	JPL
	units	m
	scale_factor	0.000100
	valid_min	-5000
	valid_max	0
	coordinates	longitude latitude
	comment	Equivalent vertical correction due to ionosphere delay. The reported sea surface height, 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 sea surface height results in the uncorrected sea surface height.
int height_cor_xover(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	height correction from KaRIn crossovers
	units	m
	scale_factor	0.000100
	valid_min	-100000
	valid_max	100000
	coordinates	longitude latitude
	comment	Height correction from KaRIn crossover calibration. To apply this correction the value of height_cor_xover should be added to the value of ssh_karin, ssh_karin_2, ssha_karin, and ssha_karin_2.
unsigned byte correction_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	quality flag for corrections
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for corrections.
unsigned byte rain_rate(num_lines, num_pixels)		
	_FillValue	255
	long_name	rain rate from weather model
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	units	mm/hr
	scale_factor	1.000000
	valid_min	0
	valid_max	200
	coordinates	longitude latitude
	comment	Rain rate from weather model.
short ice_conc(num_lines, num_pixels)		
	_FillValue	32767
	long_name	concentration of sea ice
	standard_name	sea_ice_area_fraction
	source	EUMETSAT Ocean and Sea Ice Satellite Applications Facility
	institution	EUMETSAT
	units	%
	scale_factor	0.010000
	valid_min	0
	valid_max	10000
	coordinates	longitude latitude
	comment	Concentration of sea ice from model.
short sea_state_bias_cor(num_lines, num_pixels)		
	_FillValue	32767
	long_name	sea state bias correction to height
	source	TBD
	units	m
	scale_factor	0.000100
	valid_min	-6000

	valid_max	0
	coordinates	longitude latitude
	comment	Sea state bias correction to ssh_karin. Adding the reported correction to the reported sea surface height results in the uncorrected sea surface height. The wind_speed_karin value is used to compute this quantity.
short sea_state_bias_cor_2(num_lines, num_pixels)		
	_FillValue	32767
	long_name	sea state bias correction to height
	source	TBD
	units	m
	scale_factor	0.000100
	valid_min	-6000
	valid_max	0
	coordinates	longitude latitude
	comment	Sea state bias correction to ssh_karin_2. Adding the reported correction to the reported sea surface height results in the uncorrected sea surface height. The wind_speed_karin_2 value is used to compute this quantity.
short swh_sea_state_bias(num_lines, num_pixels)		
	_FillValue	32767
	long_name	SWH used in sea state bias correction
	units	m
	scale_factor	0.001000
	valid_min	0
	valid_max	25000
	coordinates	longitude latitude
	comment	Significant wave height used in sea state bias correction.

5.6 Level 2 KaRIn LR Unsmoothed SSH File

5.6.1 Global Attributes

Global attributes for the Unsmoothed SSH file are provided in Section 5.2.1.

5.6.2 Group Names, Attributes, and Dimensions

As described in Table 2, the Unsmoothed SSH file contains two NetCDF variable groups: *left* and *right*. Each group has a 'description' attribute that elaborates on what the data in the group represents, as described in Table 11 and Table 12.

The dimensions of variables in the file are described in Section 5.2.2; the values (lengths) for each dimension are given in the NetCDF file for each variable group.

Table 11. Attributes of the *left* group of the Unsmoothed SSH file of the L2_LR_SSH product.

Attribute	Format	Description
description	string	Unsmoothed SSH measurement data and related information for the left half swath.

Table 12. Attributes of the *right* group of the Unsmoothed SSH file of the L2_LR_SSH product.

Attribute	Format	Description
description	string	Unsmoothed SSH measurement data and related information for the right half swath.

5.6.3 Detailed NetCDF Format Description

As described in Section 3.2, the *left* and *right* groups of the Unsmoothed SSH file contain the measurements from the KaRIn left and right half swaths, respectively. The two groups have identical structure, variable names, variable definitions, and variable attributes. Table 13 provides a detailed listing of each of the variables within either group. That is, Table 13 is applicable to both the *left* and *right* groups.

Table 13. Variables of the *left* or *right* groups of the Unsmoothed SSH file of the L2_LR_SSH product

Group *left* or Group *right* Variables		
double time(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in UTC
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 time_tai(num_lines)		
	_FillValue	9.969209968386869e+36
	long_name	time in TAI
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[Value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.0
	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 [time:tai_utc_difference].
int latitude(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	latitude (positive N, negative S)
	standard_name	latitude
	units	degrees_north
	scale_factor	0.000001
	valid_min	-80000000
	valid_max	80000000
	comment	Latitude of measurement [-80,80]. Positive latitude is North latitude, negative latitude is South latitude.
int longitude(num_lines, num_pixels)		

	_FillValue	2147483647
	long_name	longitude (degrees East)
	standard_name	longitude
	units	degrees_east
	scale_factor	0.000001
	valid_min	0
	valid_max	359999999
	comment	Longitude of measurement. East longitude relative to Greenwich meridian.
unsigned short latitude_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	1-sigma latitude uncertainty
	units	degrees
	scale_factor	0.000001
	valid_min	0
	valid_max	20000
	coordinates	longitude latitude
	comment	1-sigma latitude uncertainty.
unsigned short longitude_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	1-sigma longitude uncertainty
	units	degrees
	scale_factor	0.000001
	valid_min	0
	valid_max	20000
	coordinates	longitude latitude
	comment	1-sigma longitude uncertainty.
char polarization_karin(num_lines, num_sides)		
	_FillValue	*
	long_name	polarization for each side of the KaRIn swath
	comment	H denotes co-polarized linear horizontal, V denotes co-polarized linear vertical.
int ssh_karin_2(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	sea surface height
	standard_name	sea surface height above reference ellipsoid
	units	m
	scale_factor	0.000100
	valid_min	-15000000
	valid_max	150000000
	coordinates	longitude latitude
	comment	Fully corrected sea surface height measured by KaRIn. The height is relative to the reference ellipsoid defined in the global attributes. This value is computed using model-based estimates for wet troposphere effects on the KaRIn measurement (e.g., model_wet_tropo_cor and sea_state_bias_cor_2).
unsigned short ssh_karin_uncert(num_lines, num_pixels)		
	_FillValue	65535
	long_name	sea surface height anomaly uncertainty
	units	m
	scale_factor	0.000100
	valid_min	0
	valid_max	60000
	coordinates	longitude latitude
	comment	1-sigma uncertainty on the sea surface height from the KaRIn measurement.
float sig0_karin_2(num_lines, num_pixels)		

	_FillValue	9.96921e+36
	long_name	normalized radar cross section (sigma0) from KaRIn
	standard_name	surface_backwards_scattering_coefficient_of_radar_wave
	units	1
	valid_min	-1000
	valid_max	10000000.0
	coordinates	longitude latitude
	comment	Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels). The value may be negative due to noise subtraction. The value is corrected for instrument calibration and atmospheric attenuation. A meteorological model provides the atmospheric attenuation (sig0_cor_atmos_model).
float sig0_karin_uncert(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	1-sigma uncertainty on sigma0 from KaRIn
	units	1
	valid_min	0
	valid_max	1000.0
	coordinates	longitude latitude
	comment	1-sigma uncertainty on sigma0 from KaRIn.
short total_coherence(num_lines, num_pixels)		
	_FillValue	32767
	long_name	total coherence
	units	1
	scale_factor	0.000100
	valid_min	0
	valid_max	10000
	coordinates	longitude latitude
	comment	Total KaRIn interferometric coherence.
int mean_sea_surface_cnescls(num_lines, num_pixels)		
	_FillValue	2147483647
	long_name	mean sea surface height (CNES/CLS)
	source	CNES_CLS_15
	institution	CNES/CLS
	units	m
	scale_factor	0.000100
	valid_min	-1500000
	valid_max	1500000
	coordinates	longitude latitude
	comment	Mean sea surface height above the reference ellipsoid. The value is referenced to the mean tide system, i.e. includes the permanent tide (zero frequency).
float miti_power_250m(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	KaRIn power center beam at 250 m resolution
	units	1
	valid_min	-1
	valid_max	10
	coordinates	longitude latitude
	comment	Center-beam 250 meter resolution power from KaRIn in real, linear units (not decibels).
float miti_power_var_250m(num_lines, num_pixels)		
	_FillValue	9.96921e+36
	long_name	KaRIn power variance center beam at 250 m resolution
	units	1

	valid_min	-1
	valid_max	10
	coordinates	longitude latitude
	comment	Center-beam 250 meter resolution power variance from KaRIn in real, linear units (not decibels).
unsigned byte ancillary_surface_classification_flag(num_lines, num_pixels)		
	_FillValue	255
	long_name	surface classification
	standard_name	status_flag
	source	MODIS/GlobCover
	institution	European Space Agency
	flag_meanings	open_ocean land continental_water aquatic_vegetation continental_ice_snow floating_ice salted_basin
	flag_values	0 1 2 3 4 5 6
	valid_min	0
	valid_max	6
	coordinates	longitude latitude
	comment	7-state surface type classification computed from a mask built with MODIS and GlobCover data.
unsigned byte ssh_qual(num_lines, num_pixels)		
	_FillValue	255
	long_name	quality flag for unsmoothed sea surface height
	standard_name	status_flag
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	longitude latitude
	comment	Quality flag for unsmoothed sea surface height.

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Appendix A. **Acronyms**

ATBD	Algorithm Theoretical Basis Document
CLS	Collecte Localisation Satellites
CNES	Centre National d'Études Spatiales
ECEF	Earth-Centered, Earth-Fixed (frame)
ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GIM	Global Ionosphere Maps
H	Horizontally polarized signal
HPA	High Power Amplifier
HR	High Rate
ITRF	International Terrestrial Reference Frame
JPL	Jet Propulsion Laboratory
KaRIn	Ka-band Radar Interferometer (instrument)
KMSF	KaRIn Metering Structure Frame
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LR	Low Rate
MF-WAM	Metéo France Wave Model
NASA	National Aeronautics and Space Administration
NESZ	Noise-Equivalent Sigma Zero
NRCS	Normalized Radar Cross Section
OBP	On-Board Processor
SAR	Synthetic Aperture Radar
SNR	Signal-to-Noise Ratio

SWOT	Surface Water and Ocean Topography (mission)
TAI	Temps Atomique International / International Atomic Time
TBC	To Be Confirmed
TBD	To Be Determined
UTC	Coordinated Universal Time
V	Vertically polarized signal
X factor	Radiometric normalization and calibration factor (not an acronym)

