Surface Water and Ocean Topography (SWOT) Project

SWOT Product Description
Long Name: Level 2 KaRIn high rate river single pass vector product
Short Name: L2_HR_RiverSP

Revision A (DRAFT)

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August 25, 2020
JPL D-56413

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

CHANGE LOG

VERSION	DATE	SECTIONS CHANGED	REASON FOR CHANGE
Preliminary	2017-03-01	ALL	Preliminary version Approved for export (LRR-028890)
Initial Release	2019-09-11	ALL	Initial Release Approved for public release (CL#19-5718)
Revision A	2020-08-25	ALL	Revision A Approved for public release (URS294326/CL#20-3877)

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1 Introduction

1.1 Purpose

The purpose of this Product Description Document is to describe the Level 2 Ka-band Radar Interferometer (KaRIn) high rate river (HR) single pass (SP) vector data product from the Surface Water Ocean Topography (SWOT) mission. This data product is also referenced by the short name L2_HR_RiverSP.

1.2 Document Organization

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

Section 3 provides the structure of the product, including granule definition, file organization, spatial resolution, temporal and spatial organization of the content, file size, and overall data volume.

Section 4 provides qualitative descriptions of the information provided in the product.

Section 5 provides a detailed identification of the individual data fields within the L2_HR_RiverSP product.

Section 6 provides references.

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

Appendix B provides a description of the format of the product metadata.

1.3 Document Conventions

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

2 Product Description

2.1 Purpose

The L2_HR_RiverSP product provides river data from each continent-pass of the high-rate (HR) data stream of the SWOT KaRIn instrument. These data are generally produced for inland and coastal hydrology surfaces, as controlled by the reloadable KaRIn HR mask.

The L2_HR_RiverSP product specifically provides data for river reaches identified in the prior river database (PRD). Each reach is divided into a number of nodes in the PRD. The content and structure of the PRD are described in [1] (some of the content of the PRD is replicated in the L2_HR_RiverSP product for convenience; see Sections 4.1.10 and 4.2.10). As discussed further in Section 3.2, each L2_HR_RiverSP product granule consists of data for both reaches and nodes.

Only rivers in the PRD are included in the L2_HR_RiverSP product. Information on lakes and unidentified water features is given in the L2_HR_LakeSP science data product [2].

2.2 Latency

The L2_HR_RiverSP 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 or 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, such as an updated version of the PRD.

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_HR_RiverSP product is provided in full-swath pass granules (i.e., including both left and right half swaths) covering individual continents, with continent boundaries defined by the PRD, as described in [3]. These continent boundaries are consistent with the associated Level 2 KaRIn High Rate Lake Single Pass Vector Product (L2_HR_LakeSP) [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. The L2_HR_RiverSP granule covers a swath that is approximately 128 km wide in the cross-track direction, although SWOT performance requirements are only applicable from 10–60 km from nadir on each side; observations may be missing, degraded, and/or flagged over the central 20 km of the swath. A "pass" is a half-revolution of the Earth by the satellite from pole to pole (south to north latitudes for ascending passes, and north to south latitudes for descending passes).

3.2 File Organization

The L2_HR_RiverSP product is distributed in the Esri geographical information system (GIS) shapefile format [4]. Each granule of the product consists of two shapefiles: a reach shapefile and a node shapefile. Each shapefile consists of a set of five files with file name extensions as defined in [4]. A description of these files is provided in Table 1 and Table 2 below.

Table 1. Description of the files representing the L2_HR_RiverSP reach shapefile.

File	Name	Description
1	Main shapefile (reach.shp)	Provides coordinates (linestring shape) of the high-resolution centerline of each reach covered by the product granule.
2	Index file (reach.shx)	Stores the index to each reach in the reach.shp file
3	Attributes file (reach.dbf)	Provides attributes for each reach in the reach.shp file
4	Projection file (reach.prj)	Provides map projection and coordinate reference description
5	Metadata file (reach.shp.xml)	Provides metadata for the reach shapefile

Table 2. Description of the files representing the L2_HR_RiverSP node shapefile.

File	Name	Description
1	Main shapefile (node.shp)	Provides coordinates (point shape) for nodes contained within each reach covered by the product granule.
2	Index file (node.shx)	Stores the index to each node in the node.shp file
3	Attributes file (node.dbf)	Provides attributes for each node in the node.shp file
4	Projection file (node.prj)	Provides map projection and coordinate reference description
5	Metadata file (node.shp.xml)	Provides metadata for the node shapefile

Each file in the shapefile set has the same filename prefix. The .shp file of each shapefile contains the basic geometry of the reaches or nodes as defined by the PRD, so it does not change from pass to pass (unless the PRD is updated). The .dbf file contains the SWOT observations of river water surface elevation (WSE or height), width, slope, and other attributes along with information from the PRD as described in Section 4. The .prj file contains a projection description, using a well-known text (WKT) representation of coordinate reference systems (CRS). The .shp.xml files, which are not defined by the Esri specification [4], carry metadata applicable across reach and node shapefiles (e.g., SWOT pass number), and per-attribute metadata (e.g., units for each attribute). The format of the .shp.xml files is described in Appendix B.

Note that the use of the term “attributes” in this document follows the shapefile nomenclature in referring to the variables associated with each feature in the .shp file. The term should not be confused with attributes as typically used in the context of NetCDF files. This document uses the term “attributes” in reference to the contents of the .dbf file and uses the term “metadata” in reference to characteristics of each attribute of the entire shapefile. Therefore, as an example, in this document the SWOT-observed WSE would be an attribute of a given reach or node, and the metadata of the WSE attribute would indicate that the value is given in units of meters.

Note that the names of attributes in shapefiles can be no more than 10 characters, which explains the abbreviated or truncated names of many reach and node attributes. Owing to this restriction, the naming conventions of attributes in the L2_HR_RiverSP product sometimes differ from the naming conventions of similar variables in other NetCDF-based SWOT data products. Names of variables in the L2_HR_RiverSP product are generally abbreviated more compactly.

3.3 File Naming Convention

The L2_HR_RiverSP product files adopt the following naming convention for the reach and node shapefile:

SWOT_L2_HR_RiverSP_<FileIdentifier>_<CycleID>_<PassID>_<ContinentID>_<RangeBeginningDateTime>_<RangeEndingDateTime>_<CRID>_<ProductCounter>.<extension>

The value of <FileIdentifier> above is either “Reach” or “Node” to indicate whether the file is the reach or the node shapefile. The <continentID> above is described in Table 4. Continent codes for the *reach_id* attribute and corresponding continent IDs for the filename.. The <CRID> above contains the composite release identifier. It contains the version code of the data product, which changes if the processing software and/or the PRD is updated. The <extension> above indicates which of the five parts of the shape file it is (.shp, .shx, .dbf, .prj, or .shp.xml file), per Section 3.2.

Example filename for a reach and corresponding node shapefile, respectively:

```
SWOT_L2_HR_RiverSP_Reach_001_037_NA_20210612T072103_20210612T075103_PGA2_03.shp
SWOT_L2_HR_RiverSP_Node_001_037_NA_20210612T072103_20210612T075103_PGA2_03.shp
```

3.4 Spatial Sampling and Resolution

The L2_HR_RiverSP product contains a record for each reach and for each node in the PRD that is covered by the granule. In addition to other information, the record for each reach or node gives the SWOT measurements of height and area (and slope, for reaches only) over the length of the river covered by that reach or node. In the PRD, each reach and each node has a unique identifier (ID). The reaches and nodes are defined in the PRD based on hydrological, morphological, and observational considerations. Reach lengths of approximately 10 km are typical, but they can vary from 5 to 20 km. Most reaches include a water surface area of at least 1 km^2, to allow for enough spatial averaging of the SWOT observations that the estimated WSEs meet an expected minimum precision. Other considerations for setting reach boundaries include hydrological and morphological features such as tributaries, large islands or channel branching, and edges of the KaRIn measurement swath. Special short reaches are included for known significant WSE changes such as dams. The number of reaches in each L2_HR_RiverSP granule varies, from as few as 50 to as many as 4000.

Figure 1 provides a pictorial representation of one reach. Reaches are divided into nodes along the reach centerline with a node-to-node spacing of approximately 200 meters (approximately 50 nodes per reach). Note that the node shapefile content is a collection of records of shape type *point*, whereas the reach shapefile content is a collection of shape type *polyline*. The coordinates of the polyline correspond to the segment of the high-resolution centerline coordinates (from the PRD) that extends along the reach. Node information is stored in a separate shapefile because there are a variable number of nodes per reach, and the more detailed node information may not be of interest to all product users.

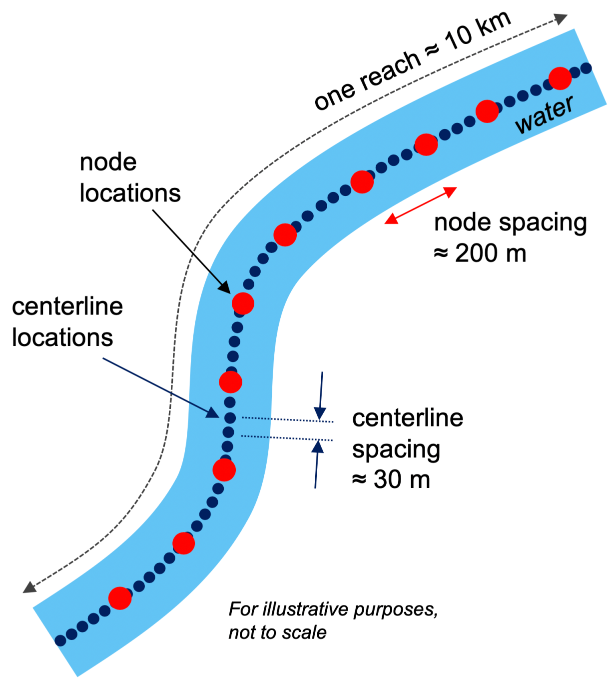

Figure 1. Illustration of the centerline locations (dark blue dots) that define the *polyline* shapes of the reach shapefile and the nodes (red dots) that define the *point* shapes of the node shapefile for a partial segment of one reach, per the PRD.

Reaches are defined in the PRD to end at the cross-track edges (sides) of the half-swaths of the KaRIn measurements. As noted in Section 3.1, there is a narrow 20-km strip centered along the spacecraft nadir track where reaches and their corresponding nodes may be unobserved. Also, the allowed small variations in the SWOT ground track (+/- 1 km) may cause some nodes to be unobserved or reaches to be incomplete for a given pass. Nodes and reaches may also be unobserved or incomplete where the water was not sufficiently reflective of the SWOT radar signal during the pass (so-called "dark water" conditions). Flags indicate unobserved nodes or partial reaches. Nodes are numbered sequentially along each reach.

3.5 Temporal Organization

The observation time is reported for each reach and for each node. As each reach or node is aggregated from many pixels of lower-level SWOT products, the reported observation time corresponds to the average time of the pixel observations contributing to the reach or node. Since the velocity of the spacecraft nadir point along track is approximately 6.5 km/s, it takes about 1.6 sec to cover a 10 km reach oriented along track and only about 30 milliseconds to cover a node. Reach and node records are not necessarily time ordered in the shapefiles. Rather, the reaches are sequentially written to the reach shapefile following the order of the *reach_id* attribute in the PRD (discussed below). Similarly, for node files, the order in the file follows the *node_id*.

3.6 Spatial Organization

As noted above, reaches and nodes are defined in the PRD by hydrological and morphological considerations along each river. For ease of indexing, each reach or node record has as its first data element a unique *reach_id* or *node_id* attribute, respectively (described in Sections 4.1.1 and 4.2.1). The reaches are sequentially written to the reach shapefile according to the order of the *reach_id* attribute. The nodes are sequentially written to follow the *node_id* attribute from the PRD; because the nodes are numbered sequentially in space along the reach, they are written to the file in this order as well. Reach records also give the upstream and downstream *reach_id* attributes (*rch_id_up* and *rch_id_dn*).

3.7 Volume

The list of data elements in Section 5 and general assumptions about the number of reaches and nodes and the SWOT swath geometry allow an estimate of the expected daily number and data product volume of the L2_HR_RiverSP products. The estimated data product volume in Table 3 is based on the following assumptions:

1. There are approximately 350,000 reaches in the PRD.
2. Each reach is observed on average 3 times per (21 day) orbit cycle.
3. There are about 56 L2_HR_RiverSP granules per day, assuming 28 passes per day and approximately 2 PRD continents per pass on average.
4. The average number of reaches per granule is 900 (4000 maximum) over one orbit cycle.
5. Reaches are approximately 10 km long. Centerline points for reach .shp files are spaced at 30 meters (assume 350 points/reach).
6. Nodes are spaced at 200 m; approximately 50 nodes per reach is assumed.
7. To store all data listed in Section 5, a single reach and its associated nodes requires 6.8 and 34.2 kilobytes (KB), respectively.

With these assumptions, the average data volume of each reach and node shapefile is 6 MB and 31 MB, respectively. Using assumption (3) above, the average L2_HR_RiverSP daily global data volume is approximately 2 GB.

Table 3: Description of the data volume of the L2_HR_RiverSP product.

Shapefile	Type	Name	Expected Mean Volume / Granule (MB)	Maximum Volume / Granule (MB)
1	Reach	Reach shapefile (all 5 files)	6	27
2	Node	Node shapefile (all 5 files)	31	138
		Total	37	165

4 Qualitative Description

The L2_HR_RiverSP vector product is derived from associated L2_HR_PIXC product inputs [5], which contain arrays of the measured height, geolocation, and classification data from KaRIn. In the description to follow, the L2_HR_PIXC data that correspond to the geographic area covered by the L2_HR_RiverSP product granule are referred to as the pixel cloud, and individual pixel cloud array elements as pixels. The classification information from the pixel cloud distinguishes water pixels from land pixels (and between different types of water and land) [5]. As discussed in the associated Level 2 KaRIn High Rate River Single Pass Algorithm Theoretical Basis Document (ATBD) [6], this information is used to aggregate high-resolution pixel cloud data to the L2_HR_RiverSP vector products. That is, the pixels are associated with known river features from the PRD and assigned accordingly. Once the pixels are assigned, ensemble measurement quantities for each feature are computed from the pixels that were assigned to the feature. The pixel cloud data are aggregated to the node locations first, and then the corresponding node attributes are further aggregated to generate the reach attributes.

The files that make up the shapefile format are described in Section 3.1. The format of the .shp file is specified in [4]. The .shp file contains the basic geometry (latitudes and longitudes, defined relative to the parameters of the .prj file) defining the shape type (from the PRD, not the SWOT measurement). The reach and node .shp files do not vary with observation for a given instance of the PRD used during processing; the geometry from the SWOT measurement is given in the node.dbf file. Even if a reach is partially observed or a node is missed or is not detected in the SWOT data, the .shp file still contains the reach or node, with fill values in the .dbf file indicating null SWOT measurements (Section 5.1). Descriptions of the .dbf attributes are given below in subsections specific to reaches and nodes.

The following conventions are applied to the names of attributes of polylines (reaches) and points (nodes):

- Prefix "*p_*" indicates that information is taken from the PRD,
- Suffix "*_c*" indicates a correction,
- Suffix "*_f*" indicates a flag,
- Suffix "*_q*" indicates a quality flag,
- Suffix "*_u*" indicates an uncertainty.

Attributes are tagged explicitly as "Basic" or "Expert" in the product metadata. This tag allows the distribution agent to make a subset file of Basic items for users who need only that information. Basic items are intended for users who will use the KaRIn measurements as provided. Expert items are intended for 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. Examples of Basic items include time and location, the main measurements (with uncertainties), flags, and related items from the PRD. Examples of Expert items include additional measurements, instrument and correction information, and additional items from the PRD. Details of the attributes are given in Section 5.

Unless otherwise specified, quantities are given in SI (MKS) units. Units for all reach and node attributes are given in Sections 5.2 and 5.3, respectively.

Unless otherwise specified, all uncertainties represent one-sigma or 68th-percentile uncertainty estimates.

4.1 Reach File

Measured or observed (the terms are used interchangeably in this document) values for reach attributes are calculated from the corresponding node-level attributes (see Section 4.2). The methods for calculating each reach attribute are given in [6].

Each record in the reach.dbf file contains attributes that are conceptually grouped in the subsections below. There is one record for each attribute for each reach in the granule.

4.1.1 Reach Identifier (ID)

Each reach record is associated with a unique identifier *reach_id* from the PRD. The format of the identifier is a 11-character string of the form *CBBBBBRRRRT*, where *C* = continent, *B* = basin, *R* = reach, and *T* = type. The *reach_id* provides the link between the reach location and its corresponding entry in the PRD.

- *reach_id*: Unique reach identifier from the prior river database.

The *reach_id* is based on the Pfafstetter coding system [7] that assigns identifications based on the topology of the river network. The code allows digits 0-9 at each hierarchy level. SWOT *reach_id* values always include six Pfafstetter levels of basins. Continent (*C*) and water body type (*T*) codes are provided in Table 4 and Table 5, respectively. Note that in Table 5, lake water bodies that are connected to the river topology of the PRD (*T* = 3) are processed as river reaches and will appear in the L2_HR_RiverSP product. These connected lakes will typically also appear in the L2_HR_LakeSP product. Disconnected lakes (*T* = 4) are those that are not on the river network defined by the PRD, which excludes very narrow rivers. Therefore, disconnected lakes may or may not be endorheic.

Table 4. Continent codes for the *reach_id* attribute and corresponding continent IDs for the filename.

Continent Code (*C*)	Continent	Continent ID
1	Africa	AF
2	Europe and Middle East	EU
3	Siberia	SI
4	Central and Southeast Asia	AS
5	Australia and Oceania	AU
6	South America	SA
7	North America and Caribbean	NA
8	North American Arctic	AR
9	Greenland	GR

Table 5. Water body type codes for the *reach_id* attribute.

Type Code (*T*)	Water Body Type
1	River
2	Disconnected Lake (not processed)
3	Connected Lake
4	Dam
5	No Topology

The continent code (C) is level 1 in the Pfafstetter code. The continent codes and 2-character continent ID in Table 4 are consistent with the continent coding used in the HydroBASINS product [8]. As indicated in the template above, up to five additional levels of basin (*BBBBB*) are used within each continent. Within each basin level, the reach is numbered in the upstream direction beginning with 001 to a maximum of 999 (i.e., a zero-padded four-digit number, represented as *RRRR* in the *reach_id*).

Within continents, up to 10 second level basins are allowed. Figure 2 shows an example of what the coding might look like at Level 1 ($C = 7$) for the Mississippi River Basin (second level $B = 4$).

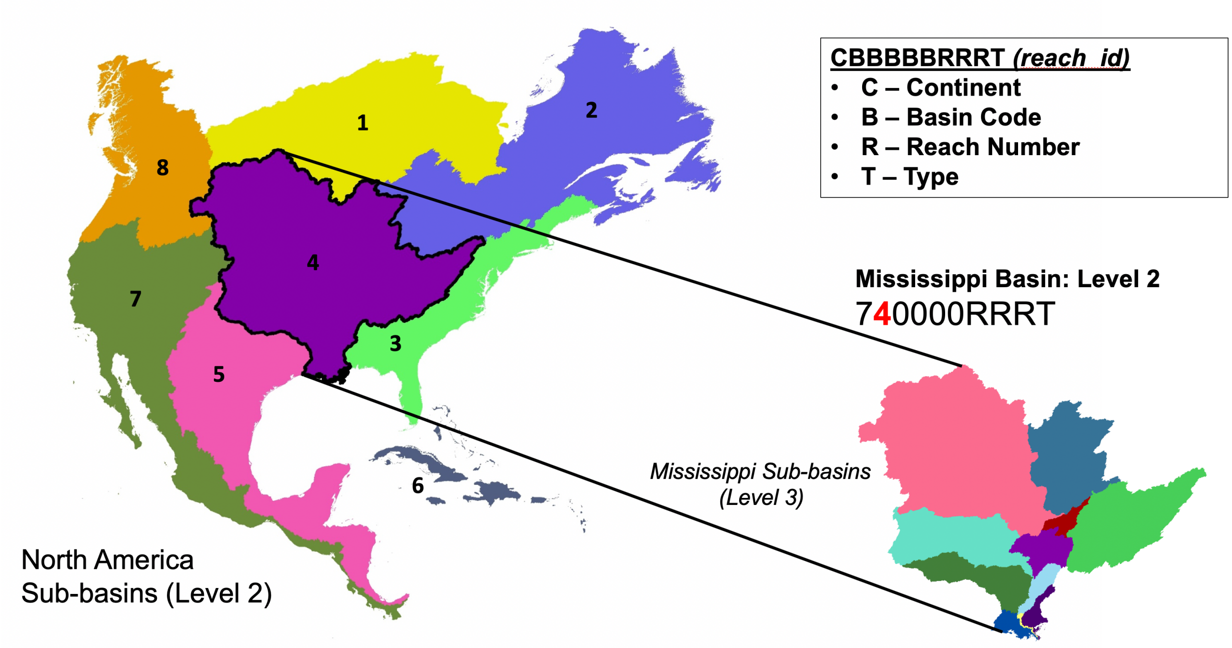

Figure 2. Example of the Pfafstetter basin coding system [7] at Level 2 over North America.

4.1.2 Time

Time tags for each measurement data record are provided in the UTC and TAI time scales using the attributes *time* and *time_tai*, respectively.

- *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 attribute *time* has a metadata field 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 products 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 attribute *time* also has a metadata field named *leap_second* which provides the date at which a leap second might have occurred within the time span of the products granule. The attribute *time* exhibits a jump when a leap second occurs. If no additional leap second occurs within the time span of the product granule, the metadata field *leap_second* of the *time* attribute 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* has a 1 second regression during a leap second transition, while *time_tai* is continuous. That is, when a positive leap second is inserted, two different instances have the same value for the attribute *time*, making *time* non-unique by itself; the difference between *time* and *time_tai*, or the *tai_utc_difference* and *leap_second* metadata 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

The UTC time corresponding to the numeric *time* attribute is also given as a string attribute (*time_str*): YYYY-MM-DDThh:mm:ssZ (with 'Z' suffix to indicate UTC time). The *time* and *time_tai* attributes maintain sub-second precision, but *time_str* is truncated to one-second precision.

4.1.3 Location

A single reference location for each reach is provided in the PRD attributes *p_lat* and *p_lon* (i.e., the reference location is predefined, not a SWOT-measured quantity for a reach). While PRD attributes are listed in Section 4.1.10, these two PRD attributes are listed here for consistency with the description of the node file (Section 4.2).

- *p_lat* (Basic): Geodetic latitude of the reach center in degrees, from the PRD. Positive latitude values increase northward from the equator. The latitude is defined with respect to the reference ellipsoid given by the reach.prj file.

- *p_lon* (Basic): Geodetic longitude of the reach center in degrees, from the PRD. The longitude values become more positive to the east and more negative to the west of the Prime Meridian.

4.1.4 Measured Hydrology Parameters

The basic river hydrological attributes of the SWOT measurement include WSE (*wse*), water surface slope (*slope*), river width (*width*), water surface area (*area_total*), change in cross-sectional area from a reference value (*d_x_area*), and discharge (*dschg_c* and *dschg_gc*; see Section 4.1.5).

Two additional (expert) area attributes (*area_detct* and *area_wse*) are provided for information and for quality-assessment purposes. *area_detct* includes the actual SWOT-detected water surface areas, including open water and area near land-water boundaries [6]. The basic attribute *area_total* is the sum of *area_detct* and the area of any "dark water" (the area of water that was not observed directly by SWOT owing to a low radar echo level, which can occur over very smooth water surfaces, or by significant attenuation of the radar signal due to propagation through rain). Areas of dark water are identified in ground processing through the use of a prior water probability map [5].

The attribute *area_wse* represents the water surface area over which the SWOT measurements of height contribute to the reported WSE (*wse*) and slope (*slope*) for the reach. The value of *area_wse* may be less than *area_total* if some of the measurements fail validity checks during processing [6].

Each attribute that represents a SWOT measurement is associated with an uncertainty estimate, which is given in a corresponding attribute (the uncertainty attribute has "*_u*" appended to its name). The methods for calculating the reach quantities and associated uncertainties from the node values are given in the associated ATBD [6]. For WSE and slope, the random-only component of the total uncertainty (*wse_r_u* and *slope_r_u*) is provided in addition to the total uncertainty (*wse_u* and *slope_u*). The random-only component here is taken to be the component that is independent between reaches, not including systematic errors that would be common from reach to reach within a granule. The WSE systematic uncertainty component can be computed from sqrt($(wse\_u)^2 - (wse\_r\_u)^2$), and similarly for the systematic slope uncertainty.

The WSE and slope given in the product are reported with respect to the provided model of the geoid (*geoid_hght*, see Section 4.1.7), and after using models to accounts for the effects of tides (see Section 4.1.7). Specifically, if *H* represents the geocentric height of the water surface with respect to the reference ellipsoid after applying corrections for media delays (see Section 4.1.8) and the crossover calibration (see Section 4.1.9), then *wse* is computed as follows:

$$wse = H - geoid\_hght - solid\_tide - load\_tidef - pole\_tide$$

The reach-level *wse* and *slope* are evaluated at the PRD along-stream reach center from a polynomial fit applied to the nodes that have a valid WSE [6].

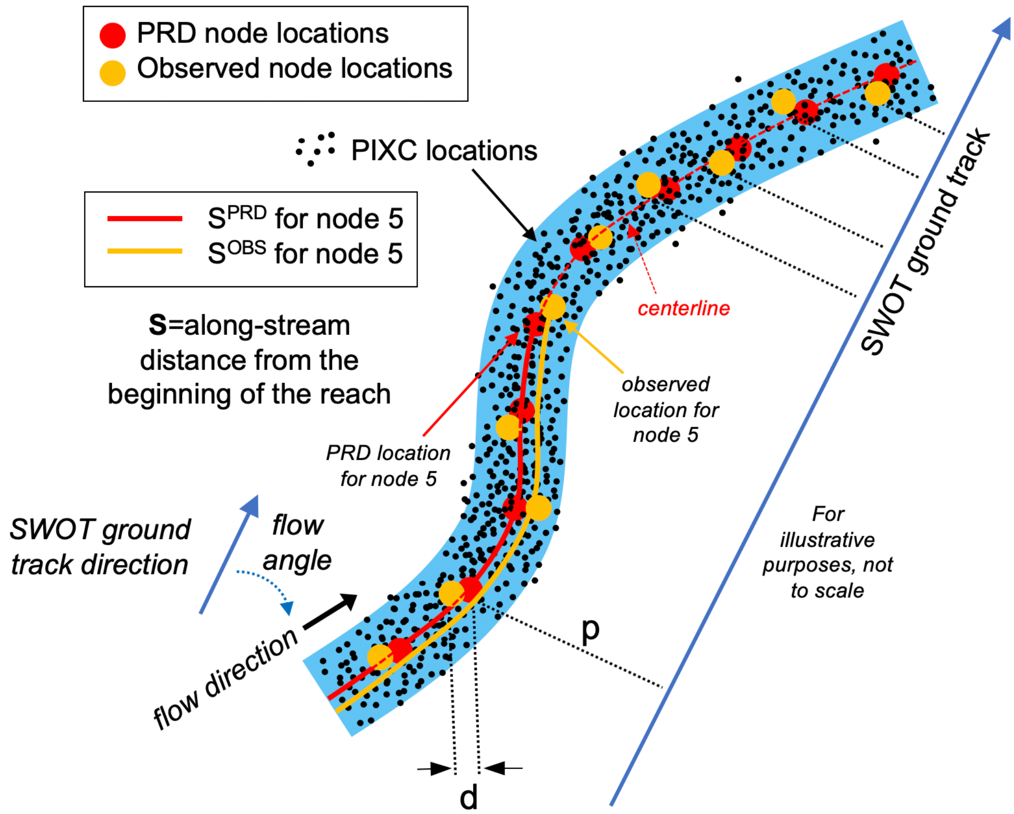

Figure 3. Illustration of quantites use to compute reported node distances for a partial segment of one reach. Definitions of quantities shown are provided in the body text that accompanies this figure.

Referring to Figure 3, **d** refers to the distance (in any direction, as a nonnegative value) between a reported node location (see Section 4.2.3) and its location in the PRD. The attribute *node_dist* is defined as the mean of all **d** values in the reach that have a valid WSE. This quantity characterizes offsets between the observed node geolocations and the predefined node locations from the PRD; large values might indicate river channel migration and/or processing-algorithm errors. The pixel cloud (PIXC) pixels of the L2_HR_PIXC product (from which the L2_HR_LakeSP product is generated) that are assigned to the reach are shown as black points.

In Figure 3, let $\mathbf{s}^{\mathbf{OBS}}$ be the along-stream distance to a given observed (reported) location for a node with a valid WSE in the reach, and let $\mathbf{s}^{\mathbf{PRD}}$ be the along-stream distance to a given node location from the PRD. These quantities are defined for each node; in Figure 3, they are illustrated (only) for the 5$^{\text{th}}$ node in the reach. *loc_offset* is defined as the difference between the mean of all $\mathbf{s}^{\mathbf{OBS}}$ values in the reach and the mean of all $\mathbf{s}^{\mathbf{PRD}}$ values in the reach. Note that $\mathbf{s}^{\mathbf{PRD}}$ is given in the PRD for all nodes in the reach, whereas $\mathbf{s}^{\mathbf{OBS}}$ is computed [6] only for the nodes that were assigned a valid WSE. In other words,

$$loc\_offset = \frac{1}{N_{OBS}} \sum_{k}^{N_{OBS}} s_k^{OBS} - \frac{1}{N_{PRD}} \sum_{k}^{N_{PRD}} s_k^{PRD}$$

where k is an index that goes over all N_{OBS} observed nodes in the reach in the first summation and over all N_{PRD} nodes from the PRD in the reach in the second summation. For example, suppose that a reach were only partially observed, according to the *obs_frac_n* quality attribute (Sec. 4.1.6). If the nodes that were assigned a valid WSE were clumped more at the beginning of the reach than at the end of the reach, *loc_offset* would be negative (and vice versa).

In Figure 3, **p** is defined as the closest distance between a PRD node location and the spacecraft nadir track of the pass. *xtrk_dist* is defined as the mean of the **p** values in the reach. A negative value of *xtrk_dist* indicates that the reach is on the left side of the swath, relative to the spacecraft velocity vector; a positive value indicates that the reach is on the right side of the swath.

- *wse* (Basic): Fitted reach water surface elevation, relative to the provided model of the geoid (*geoid_hght*), with corrections for media delays (wet and dry troposphere, and ionosphere), the crossover correction, and tidal effects (*solid_tide*, *load_tidef*, and *pole_tide*) applied.
- *wse_u* (Basic): Total uncertainty (random and systematic) in the reach WSE. The value includes uncertainties of corrections and variation about the fit. [method for systematic component TBD]
- *wse_r_u* (Expert): Random-only component of the uncertainty in the reach WSE.
- *slope* (Basic): Fitted water surface slope, relative to the provided model of the geoid (*geoid_hght*), and with the same corrections and tidal effects applied as for *wse*. The units are m/m. The downstream direction is defined by the PRD. A positive slope means that the downstream WSE is lower.
- *slope_u* (Basic): Total uncertainty (random and systematic) in the water surface slope, including uncertainties of corrections and variation about the fit. The units are m/m. [method for systematic component TBD]
- *slope_r_u* (Expert): Random-only component of the uncertainty in the water surface slope. The units are m/m.
- *slope2* (Basic): Enhanced water surface slope relative to the geoid, produced using a smoothing of the node *wse*. The units and flow conventions are the same as for *slope*.
- *slope2_u* (Basic): Total uncertainty (random and systematic) in the enhanced water surface slope. The units and conventions are the same as for *slope_u*. [method for systematic component TBD]
- *slope2_r_u* (Expert): Random-only component of the uncertainty in the enhanced water surface slope. The units are m/m.
- *width* (Basic): Reach width. The method used to calculate the width based on *area_total* is described in *[6]*.
- *width_u* (Basic): Total uncertainty (random and systematic) in the reach width. [method for systematic component TBD].

- *area_total* (Basic): Total estimated water surface area, including *area_detct* and any dark water that was not detected as water in the SWOT observation but identified through the use of a prior water probability map.
- *area_tot_u* (Basic): Total uncertainty (random and systematic) in the total estimated water surface area *area_total*. [method for systematic component TBD].
- *area_detct* (Expert): Surface area of the reach that was detected as water by the SWOT observations.
- *area_det_u* (Expert): Total uncertainty (random and systematic) in the surface area of the detected water pixels. [method for systematic component TBD].
- *area_wse* (Expert): Surface area of the reach that contributed to the computation of the WSE.
- *d_x_area* (Basic): Change in the channel cross-sectional area from the value reported in the PRD. This parameter is used in the computation of discharge (see Section 4.1.5).
- *d_x_area_u* (Basic): Total uncertainty (random and systematic) in the change in the cross-sectional area. This parameter is used in the computation of discharge uncertainty (see Section 4.1.5). [method for systematic component TBD].
- *layovr_val* (Expert): TBD value indicating an estimate of the WSE error due to layover.
- *node_dist* (Basic): Mean distance between the observed node locations and the node locations in the PRD. See Figure 3 and the associated discussion.
- *loc_offset* (Basic): Along-stream location offset between the observed and prior reach location. This is defined as the mean of the observed along-stream node distances in the reach, minus the mean of the PRD along-stream node distances in the reach. See Figure 3 and the associated discussion.
- *xtrk_dist* (Basic): Average distance of the observed node locations in the reach from the spacecraft nadir track. A negative value indicates that the reach is on the left side of the swath, relative to the spacecraft velocity vector. A positive value indicates that the reach is on the right side of the swath. See Figure 3 and the associated discussion.

4.1.5 Discharge

The L2_HR_RiverSP product includes estimates from multiple river discharge algorithms as well as consensus values computed over multiple individual algorithms [6]. Five individual discharge algorithms contribute to each consensus value:

1. Metropolis-Manning (MetroMan) [9]
2. Bayesian AMHG-Manning (BAM) [10]
3. Hierarchical Variational Discharge Inference (HiVDI) [11]
4. Modified Manning Method Algorithm (MOMMA) [12]
5. SWOT Assimilated DiScharge (SADS) [13]

Each of these algorithms is run with two different sets parameters (from the PRD), which do and do not incorporate constraints from external streamflow gauge information, respectively [1]. Therefore, the product includes gauge-unconstrained and gauge-constrained discharge values from each individual algorithm, as well as gauge-unconstrained and gauge-constrained consensus values. Below, the gauge-unconstrained and gauge-constrained discharge are referred to as "discharge" and "gauge-constrained discharge," respectively.

Both the discharge estimates and the gauge-constrained discharge estimates are computed from algorithms that estimate flow-law parameters such as river bathymetry and friction coefficient, and both are available for reaches in the PRD. The discharge estimates are based on mass-conserved flow law inversion [14], in which parameters are estimated in order to constrain river discharge to obey continuity as evaluated between adjacent reaches. The (gauge-unconstrained) discharge estimates do not use any other ancillary information such as streamflow measured at streamflow gauges. The gauge-constrained discharge estimates are produced using the same methods, but additional, external information is also taken into account, including measurements from streamflow gauges globally, historical streamflow, and in-situ records. The gauge-constrained discharge estimates spread this information across river networks; therefore they differ from the discharge estimates both in reaches where gauges exist and in other reaches in the same river network. The gauge-constrained discharge estimates are recommended as the most accurate estimates available in the L2_HR_RiverSP product. Users should be advised that these estimates are trained on many streamflow gauges, and therefore their accuracy evaluated against those gauges may not reflect the accuracy in basins where no gauges are available.

Each discharge estimate is accompanied by an associated uncertainty estimate and a quality flag, indicated by the "*_u*" or "*_q*" appended to the attribute name. The consensus estimate and the estimates from each of the five individual algorithms are indicated by the presence of the character "*c*", "*m*", "*b*", "*h*", "*o*", "*s*" in the attribute name, respectively. For the gauge-constrained discharge estimates, each of these algorithm identifiers is preceded by a "*g*" character to indicate that the estimate is based on gauge-constrained parameters.

- *dschg_c* (Basic): Discharge from the consensus algorithm.
- *dschg_c_u* (Basic): Uncertainty in the discharge from the consensus algorithm.
- *dschg_c_q* (Basic): Flag that indicates quality of the consensus discharge. Values of 0, 1, and 2 indicate that the consensus discharge is valid, questionable, and invalid, respectively.
- *dschg_gc* (Basic): Discharge from the gauge-constrained consensus algorithm.
- *dschg_gc_u* (Basic): Uncertainty in the discharge from the gauge-constrained consensus algorithm.
- *dschg_gc_q* (Basic): Flag that indicates quality of the gauge-constrained consensus discharge. Values of 0, 1, and 2 indicate that the gauge-constrained consensus discharge is valid, questionable, and invalid, respectively.

- *dschg_m* (Expert): Discharge from the MetroMan algorithm.
- *dschg_m_u* (Expert): Uncertainty in the discharge from the MetroMan algorithm.
- *dschg_m_q* (Expert): Flag that indicates quality of the MetroMan discharge. Values of 0, 1, and 2 indicate that the MetroMan discharge is valid, questionable, and invalid, respectively.
- *dschg_gm* (Expert): Discharge from the gauge-constrained MetroMan algorithm.

- *dschg_gm_u* (Expert): Uncertainty in the discharge from the gauge-constrained MetroMan algorithm.
- *dschg_gm_q* (Expert): Flag that indicates quality of the gauge-constrained MetroMan discharge. Values of 0, 1, and 2 indicate that the gauge-constrained MetroMan discharge is valid, questionable, and invalid, respectively.

- *dschg_b* (Expert): Discharge from the BAM algorithm.
- *dschg_b_u* (Expert): Uncertainty in the discharge from the BAM algorithm.
- *dschg_b_q* (Expert): Flag that indicates quality of the BAM discharge. Values of 0, 1, and 2 indicate that the BAM discharge is valid, questionable, and invalid, respectively.
- *dschg_gb* (Expert): Discharge from the gauge-constrained BAM algorithm.
- *dschg_gb_u* (Expert): Uncertainty in the discharge from the gauge-constrained BAM algorithm.
- *dschg_gb_q* (Expert): Flag that indicates quality of the gauge-constrained BAM discharge. Values of 0, 1, and 2 indicate that the gauge-constrained BAM discharge is valid, questionable, and invalid, respectively.

- *dschg_h* (Expert): Discharge from the HiVDI algorithm.
- *dschg_h_u* (Expert): Uncertainty in the discharge from the HiVDI algorithm.
- *dschg_h_q* (Expert): Flag that indicates quality of the HiVDI discharge. Values of 0, 1, and 2 indicate that the HiVDI discharge is valid, questionable, and invalid, respectively.
- *dschg_gh* (Expert): Discharge from the gauge-constrained HiVDI algorithm.
- *dschg_gh_u* (Expert): Uncertainty in the discharge from the gauge-constrained HiVDI algorithm.
- *dschg_gh_q* (Expert): Flag that indicates quality of the gauge-constrained HiVDI discharge. Values of 0, 1, and 2 indicate that the gauge-constrained HiVDI discharge is valid, questionable, and invalid, respectively.

- *dschg_o* (Expert): Discharge from the MOMMA algorithm.
- *dschg_o_u* (Expert): Uncertainty in the discharge from the MOMMA algorithm.
- *dschg_o_q* (Expert): Flag that indicates quality of the MOMMA discharge. Values of 0, 1, and 2 indicate that the MOMMA discharge is valid, questionable, and invalid, respectively.
- *dschg_go* (Expert): Discharge from the gauge-constrained MOMMA algorithm.
- *dschg_go_u* (Expert): Uncertainty in the discharge from the gauge-constrained MOMMA algorithm.
- *dschg_go_q* (Expert): Flag that indicates quality of the gauge-constrained MOMMA discharge. Values of 0, 1, and 2 indicate that the gauge-constrained MOMMA discharge is valid, questionable, and invalid, respectively.

- *dschg_s* (Expert): Discharge from the SADS algorithm.
- *dschg_s_u* (Expert): Uncertainty in the discharge from the SADS algorithm.
- *dschg_s_q* (Expert): Flag that indicates quality of the SADS discharge. Values of 0, 1, and 2 indicate that the SADS discharge is valid, questionable, and invalid, respectively.
- *dschg_gs* (Expert): Discharge from the gauge-constrained SADS algorithm.
- *dschg_gs_u* (Expert): Uncertainty in the discharge from the gauge-constrained SADS algorithm.
- *dschg_gs_q* (Expert): Flag that indicates quality of the gauge-constrained SADS discharge. Values of 0, 1, and 2 indicate that the gauge-constrained SADS discharge is valid, questionable, and invalid, respectively.

4.1.6 Quality Indicators

Flags indicating conditions that affect data quality are given as basic attributes. In general, flag values of zero indicate good data.

- *reach_q* (Basic): Summary quality indicator for the reach measurement determined by [TBD]. Values of 0 and 1 indicate nominal and off-nominal measurements, respectively.
- *dark_frac* (Expert): Fraction of *area_total* covered by dark water, equal to 1-(*area_detct*/*area_total*). This value is typically between 0 and 1, with 0 indicating no dark water and 1 indicating 100% dark water. However, the value may be outside the range from 0 to 1 due to noise in the underlying area estimates.
- *ice_clim_f* (Basic): Climatological ice cover flag indicating whether the reach is ice-covered on the day of the observation based on external climatological information *[15]* (not the SWOT measurement). Values of 0, 1, and 2 indicate that the reach is likely not ice covered, may or may not be partially or fully ice covered, and likely fully ice covered, respectively.
- *ice_dyn_f* (Basic): Dynamic ice cover flag indicating whether the surface is ice-covered on the day of the observation based on analysis of external optical satellite data *[15]* (not the SWOT measurement). Values of 0, 1, and 2 indicate that the reach is not ice covered, partially ice covered, and fully ice covered, respectively. Due to the latency of computing the dynamic ice flag, this value may be completely null filled in some processing versions of the data product. When available, *ice_dyn_f* is likely to be more reliable than *ice_clim_f* given that is is based on optical observations.
- *partial_f* (Basic): Flag that indicates only partial reach coverage. The flag is 0 if at least half the nodes of the reach have valid WSE measurements; otherwise, the flag is 1, and reach-level quantities are not computed.
- *n_good_nod* (Basic): Number of nodes in the reach that have a valid node WSE. Note that the total number of nodes from the PRD is given by *p_n_nodes* (see Section 4.1.10).
- *obs_frac_n* (Basic): Fraction of nodes (i.e., *n_good_nod*/*p_n_nodes*) in the reach that have a valid node WSE. The value is between 0 and 1.
- *xovr_cal_q* (Basic): Flag that indicates the quality of the cross-over calibration. [TBD].

4.1.7 Geophysical References

The geoid height, from a model, in meters above the reference ellipsoid (defined by the reach .prj file) is a basic attribute. This information enables the user to convert the observed WSE to a different representation.

Expert attributes provide the tide heights, from models, that were used to calculate the *wse* and *slope* attributes. Note that while the model solution used to account for the effect of the ocean tide loading on the Earth's crust is provided in the attribute *load_tidef*, a second model solution (*load_tideg*) is provided for users who desire to swap these models. These values are first aggregated from pixels to nodes then aggregated to the reach value, as described in the associated ATBD [6].

- *geoid_hght* (Basic): Model for geoid height above the reference ellipsoid whose parameters are given in the reach .prj file. The geoid model is EGM2008 *[16]*. The geoid model includes a correction to refer the value to the mean tide system (i.e., it includes the zero-frequency permanent tide).
- *geoid_slop* (Expert): Geoid model slope in the along-stream direction as defined in the PRD, based upon a least-squares linear fit along the reach. The units are m/m. A positive slope means that the downstream geoid model height is lower.
- *solid_tide* (Expert): Model for the solid Earth (body) tide height. The reported value is calculated using the Cartwright/Taylor/Edden *[17] [18]* tide-generating potential coefficients and consists of the second and third degree constituents. The permanent tide (zero frequency) is not included.
- *load_tidef* (Expert): Model for geocentric surface height displacement from the load tide. The value is from the FES2014b ocean tide model *[19]*. The value is used to compute *wse*.
- *load_tideg* (Expert): Model for geocentric surface height displacement from the load tide. The value is from the GOT4.10c ocean tide model *[20]*. To compute *wse* with this model, add *load_tidef* to *wse* and subtract *load_tideg*.
- *pole_tide* (Expert): Model for the 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 *[21]* and a model for the load pole tide height *[22]*. The value is computed using the reported Earth pole location after correction for a linear drift *[23]*: in milliarcsec,

  $$Xp = 55.0 + 1.677dt$$
  $$Yp = 320.5 + 3.46dt$$

  where dt is years since 2000.0.

4.1.8 Geophysical Range Corrections

Model-based corrections for the dry troposphere, wet troposphere and the ionosphere contributions to the measured range are provided for each reach as expert attributes. These corrections are first aggregated from pixels to nodes then aggregated to the reach value, as described in the associated ATBD [6]. Additional details on these media delays are provided in [5]. Note that while these media delays are corrected during processing along the slanted (non-vertical) radar signal propagation paths, they are provided in these attributes as equivalent vertical quantities after applying a cross-track-dependent obliquity factor. The additional path delay relative to free space results is a negative correction value that is added 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 *wse* value results in the uncorrected reach WSE. 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 sources of the model data used for these corrections are given in the metadata provided in the reach .shp.xml file (see Section 5).

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

4.1.9 Instrument Corrections

Instrument corrections applied to the KaRIn data are provided as expert attributes. The crossover correction is based on repeated SWOT observations over the ocean at orbit-crossing locations to correct for attitude and phase-drift effects. These corrections are provided so that a different or updated calibration can be applied directly to the reach height without regenerating the pixel cloud or river vector products.

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

4.1.10 Prior River Database (PRD) Information

Information from the PRD is provided in the product with the measurements to allow easier connection or comparison. The sources, methods of generation, and accuracy are described in [1]. Different versions of the L2_HR_RiverSP product may be produced with different versions of the PRD.

Note that WSE and slope values for reaches with dams (as indicated by the value of *p_dam_id*) or having widths less than 100 m are not intended to meet nominal SWOT accuracy requirements.

- *n_reach_up*, *n_reach_dn* (Basic): Number of upstream and downstream reaches, respectively, from the PRD. The values may be between 0 and 4, inclusive. A value of 4 indicates 4 or more upstream or downstream reaches.
- *rch_id_up*, *rch_id_dn* (Basic): Values of *reach_id* for the upstream and downstream reaches, respectively, from the PRD. The values are strings of comma-separated lists of at most 4 reach identifiers corresponding to the upstream and downstream reaches.

- *p_wse* (Basic): Reach WSE, relative to the geoid, from the PRD.
- *p_wse_var* (Basic): Reach WSE spatial variability, from the PRD.
- *p_width* (Basic): Reach width from the PRD.
- *p_wid_var* (Basic): Reach width spatial variability from the PRD.
- *p_n_node*s (Basic): Number of nodes in the reach, from the PRD.
- *p_dist_out* (Basic): Along-stream distance from the reach center to the outlet, from the PRD.
- *p_length* (Basic): Length of the reach from the PRD. This value is used to compute the reach width from the water surface area.
- *p_maf* (Expert): Mean annual flow (MAF) from the PRD.
- *p_dam_id* (Expert): Dam ID from the Global Reservoir and Dam (GRanD) database. The value is 0 if there is no influence of dams along the reach. A positive value indicates the influence of a dam along the reach. The value of *p_dam_id* identifies the dam ID in the GRanD database *[24]*. Reaches influenced by dams are also indicated by the type code in *reach_id*.
- *p_n_ch_max* (Expert): Maximum number of channels in the reach from the PRD.
- *p_n_ch_mod* (Expert): Mode of the number of channels in the reach from the PRD.

4.2 Node File

Node shapefiles are organized similarly to reach shapefiles and generally follow the same representation conventions (see the overview of Section 4.1).

The attribute that links each node record to its corresponding entry in the PRD is the *node_id* (Section 4.2.1). As with reaches, the node .shp files are the same for each cycle and pass over a given area, provided that the data are processed with the same version of the PRD. The node .shp file does not change if a node is not observed during a particular pass; the node .dbf file contains fill values for missing nodes (see Section 5.1). Unlike reaches, which are represented as polylines in the reach.shp file, however, nodes are represented as points in the node.shp file.

Each record in the node .dbf file contains attributes that can be conceptually grouped as described in the following subsections. Because the definitions of most of the attributes are the same for reaches and nodes, only the differences are described below. Where reach and node attribute definitions are common, the reach descriptions above generally apply to the node attributes. Note that for reach attributes that involve aggregation of some quantity over all nodes in the reach, the corresponding node attribute involves aggregation of the quantity over all pixel cloud samples in the node. Some of the aggregation methods differ between reaches and nodes (these are described in the associated ATBD [6]), though the differences in processing methodology do not necessarily change the definitions of the attributes.

4.2.1 Node Identifier (ID)

Each node record is associated with a unique identifier *node_id* from the PRD. The format of the *node_id* is the same as the *reach_id* (see Section 4.1.1) with the addition of three additional characters to indicate the node position within the reach. Specifically, the *node_id* identifier is a 14-character string of the form *CBBBBBRRRRNNNT*. The node portion (*NNN*) of the *node_id* indicates the sequential number of the node in the encompassing reach (*RRRR*), starting with node 1 (*NNN* = 001), and increasing in the upstream direction defined by the PRD.

- *node_id*: Unique node identifier from the prior river database.

The identifier of the parent reach is given for each node as the attribute *reach_id* (see Section 4.1.1).

4.2.2 Time

The attributes *time*, *time_tai*, and *time_str* for nodes are as described for reaches in Section 4.1.2.

4.2.3 Location

Unlike reaches, nodes have SWOT-observed locations and corresponding horizontal spatial uncertainty estimates. Figure 3 illustrates conceptually the observed node location and its corresponding PRD location (the PRD location defines the node.shp point).

- *lat* (Basic): Geodetic latitude of the centroid of water-detected pixels assigned to the node, in degrees. Positive latitude values increase northward from the equator. The latitude is defined with respect to the reference ellipsoid given by the node.prj file.
- *lon* (Basic): Geodetic longitude of the centroid of water-detected pixels assigned to the node, in degrees. The longitude values become more positive to the east and more negative to the west of the Prime Meridian.
- *lat_u* (Basic): Uncertainty in the latitude of the centroid of water-detected pixels assigned to the node, in degrees.
- *lon_u* (Basic): Uncertainty in the longitude of the centroid of water-detected pixels assigned to the node, in degrees.

4.2.4 Measured Hydrology Parameters

The basic river hydrological attributes of each SWOT node are WSE (*wse*), width (*width*), and area (*area_total*). Measurements of these quantites for each node are given in the node shapefile following the definitions of Section 4.1.4).

The water surface slope, the various discharge estimates, the change in cross-sectional area (*d_x_area*), and the other attributes related to these quantities (uncertainties and quality) for reaches (Section 4.1.4) are not computed for nodes, so the node shapefile does not include attributes for these quantities.

The along-stream displacement *loc_offset* from the prior location is also not provided. In the node shapefile, the *node_dist* and *xtrk_dist* attributes are defined as in Section 4.1.4 (see Figure 3), except that they represent per-node rather than reach-averaged quantities.

As with the reach product, the node WSE given in the product is reported with respect to the provided model of the geoid (*geoid_hght*), and after using models to accounts for the effects of tides (see Section 4.2.7). For the node product, an additional attribute is included:

- *flow_angle* (Basic): River flow direction for the node relative to the direction of the spacecraft nadir track based on prior data. This value depends on the viewing geometry of the SWOT pass but not the KaRIn observation itself. A value of zero indicates that the flow is in the same direction as the spacecraft velocity direction A value of 90˚ indicates that the flow is toward the right side of the SWOT swath. See Figure 3 and the associated discussion.

4.2.5 Quality Indicators

The definitions of flag attributes are essentially the same for nodes as for reaches (see Section 4.1.6), with the word "reach" replaced with "node". However, there are some quality indicators with subtle differences in the naming and interpretation:

- *node_q* (Basic): Summary quality indicator for the node measurement determined by [TBD]. Values of 0 and 1 indicate nominal and off-nominal measurements.
- *n_good_pix* (Basic): Number of pixel cloud samples that have a valid pixel WSE *[5]* assigned to the node.

4.2.6 KaRIn Sigma0 Information

Expert attributes giving the node-level KaRIn measurement of the normalized radar cross section (NRCS) or backscatter coefficient, commonly referred to as sigma0, are provided for nodes. Reach values of sigma0 are not provided because sigma0 can be highly variable along a reach.

- *rdr_sig0* (Expert): Median of the sigma0 from the pixel cloud samples assigned to the node in determining the node WSE. The value is provided as a dimensionless linear power ratio, not a value in decibels. Note that it is possible for *rdr_sig0* to be negative due to the noise subtraction performed during the estimation of sigma0. While such values are aphysical, they are kept in order to avoid biasing the results. The sigma0 in decibels can be computed as *rdr_sig0_in_dB* = 10*log10(*rdr_sig0*), although care must be taken to avoid taking the logarithm of negative values.
- *rdr_sig0_u* (Expert): Uncertainty of *rdr_sig0*. The value is provided in linear units. This value is an additive (not multiplicative) uncertainty term, which can be added to or subtracted from *rdr_sig0*.
- *rdr_pol* (Expert): Flag indicating whether the node is observed with a horizontal (H) or vertical (V) signal polarization. The KaRIn V half-swath is always on the +y side of the spacecraft, which is to the right of the nadir track if the yaw is near zero (or to the left if the yaw is near 180˚). The KaRIn H half swath is always on the -y side of the spacecraft, which is to the left of the nadir track if the yaw is near zero (or to the right if the yaw is near 180˚).

4.2.7 Geophysical References

The geophysical reference attributes are the same for nodes as for reaches (see Section 4.1.7). The values are aggregated for all pixels assigned to the node. The geoid slope *geoid_slop* is not provided, as slopes are not provided for nodes.

4.2.8 Geophysical Range Corrections

The geophysical range correction attributes are the same for nodes as for reaches (see Section 4.1.8).

4.2.9 Instrument Corrections

The instrument correction attributes are the same for nodes as for reaches (see Section 4.1.9).

4.2.10 Prior River Database Information

Information from the PRD is provided with the node attributes to allow easier connection or comparison. Basic attributes include the prior WSE and width and their variation and the distance to the outlet. Although the main set of attributes is the same for nodes as for reaches (see Section 4.1.10), the node attributes are all listed here as the number is relatively small and the exclusions might be confusing. Note that WSE values for nodes with dams (as indicated by the value of *p_dam_id*) are not intended to meet nominal SWOT accuracy requirements.

- *p_wse* (Basic): Node WSE, relative to the geoid, from the PRD.
- *p_wse_var* (Basic): Node WSE spatial variability from the PRD.
- *p_width* (Basic): Node width from the PRD.
- *p_wid_var* (Basic): Node width spatial variability from the PRD.
- *p_dist_out* (Basic): Along-stream distance from the node to the outlet, from the PRD.
- *p_length* (Basic): Length of the node from the PRD. This value is used to compute the node width from the water surface area.
- *p_dam_id* (Expert): Dam ID from the Global Reservoir and Dam (GRanD) database. The value is 0 if there is no influence of dams at the node. A positive value indicates the influence of a dam at the node. The value of *p_dam_id* identifies the dam ID in the GRanD database *[24]*. Nodes influenced by dams are indicated by the type code in *node_id*.
- *p_n_ch_max* (Expert): Maximum number of channels at the node location, from the PRD.
- *p_n_ch_mod* (Expert): Mode of the number of channels at the node location, from the PRD.

5 Detailed Content

The L2_HR_RiverSP product adopts the Esri shapefile format and conventions [4]. The shapefile format stores geospatial data as primitive geometric shapes like points, polylines, and polygons representing locations, rivers, and lakes, respectively. These shapes, together with data attributes that are linked to each shape, create the representation of the geospatial data. In this section a description of the information in the .dbf file is given. This information is also stored in the .shp.xml files of the reach and node shapefiles. The .shp.xml files provide shapefile metadata information similar to what would be provided as global and per-variable attributes in a NetCDF format file. The format of the .shp.xml files are described in Appendix B.

5.1 Shapefile Information

5.1.1 Dimensions

The headers of the .shp and .shx reach and node files give the number records in the shapefiles. However, the .dbf file does not have an entry for the number of records. All attributes in the .dbf file are scalars (each attribute corresponds to only a single integer, floating-point value, or string). However, some string attributes are used to represent multiple values. For example, in the reach.dbf file, the *rch_id_up* and *rch_id_dn* attributes are given as character strings in a comma-separated list of the *reach_id* values of up to four upstream and four downstream reaches, respectively.

5.1.2 Attributes

The attributes of the .dbf file are assigned a name and a particular data type. Note that .dbf attributes are all stored as space-separated, formatted ASCII (ANSI) character strings rather than binary data types. Table 6 summarizes the type, field width and fill value for each data type.

Table 6. Attribute data types in shapefile products.

Data Type	Description	fill value
int4	integer (4-character storage)	-999
int9	integer (9-character storage)	-99999999
float	floating point (13-character storage)	-999999999999
text	maximum 254-character storage	“no_data”

The unique, descriptive metadata for each attribute (e.g., expected minimum and maximum values) and the global metadata (e.g., SWOT pass number) generally follow the conventions defined for other SWOT products and are given in Tables 7 and 8, respectively. Since metadata cannot be stored internal to the .dbf file, the shapefile .shp.xml file provides the metadata fields that apply to each shapefile attribute in the .dbf file. Not all metadata fields will be used for each shapefile attribute (e.g., the metadata field *leap_second* is unique to the time attributes). A description of the .shp.xml file format is given in Appendix B.

Table 7. Metadata fields used to describe shapefile attributes.

Item	Description
fill_value	The value used to represent missing or undefined data.
basic_expert_tag	Tag to indicate whether the attribute is considered basic or expert.
calendar	Reference time calendar.
comment	Miscellaneous information about the attribute, or the methods to generate it.
coordinates	Coordinate variables associated with the attribute.
flag_meanings	The description of the meaning of each of the elements of flag_values.
flag_values	Values of the flag attribute. Used in conjunction with flag_meanings.
institution	Institution which generates the source data for the attribute, if applicable.
leap_second	UTC time at which a leap second occurs within the time span of the data represented in the attribute.
long_name	A descriptive name that indicates the content of the attribute.
quality_flag	Names of variable quality flag(s) that are associated with this attribute to indicate its quality.
source	Data source (model, author, or instrument).
standard_name	A standard name that indicates the attribute content.
tai_utc_difference	Difference between TAI and UTC reference time.
units	Units of attribute.
valid_max	Maximum theoretical value of the attribute (not necessarily the same as maximum value of actual data)
valid_min	Minimum theoretical value of the attribute (not necessarily the same as minimum value of actual data)
type	Attribute type (int4, int9, float or text)

Table 8. Global metadata fields of the L2_HR_RiverSP product.

Item	Description
Conventions	Esri conventions as given in 'ESRI Shapefile Technical Description, an ESRI White Paper, July 1998' http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf
title	Level 2 KaRIn High Rate River Single Pass Vector Product - Reach/Node
institution	Name of producing agency.
source	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	UTC time when file generated. Format is: 'YYYY-MM-DD hh:mm:ss : Creation'
platform	SWOT
references	Published or web-based references that describe the data or methods used to product it. Provides version number of software generating product.
reference_document	Name and version of Product Description Document to use as reference for product.
contact	Contact information for producer of product. (e.g., 'ops@jpl.nasa.gov').
cycle_number	Cycle number of the product granule.
pass_number	Pass number of the product granule.
continent	Continent the product belongs to.
time_coverage_start	UTC time of first measurement. Format is: YYYY-MM-DD hh:mm:ss.ssssssZ
time_coverage_end	UTC time of last measurement. Format is: YYYY-MM-DD hh:mm:ss.ssssssZ
geospatial_lon_min	Westernmost longitude (deg) of granule bounding box
geospatial_lon_max	Easternmost longitude (deg) of granule bounding box
geospatial_lat_min	Southernmost latitude (deg) of granule bounding box
geospatial_lat_max	Northernmost latitude (deg) of granule bounding box

left_first_longitude	Nominal swath corner longitude for the first range line and left edge of the swath (degrees_east)
left_first_latitude	Nominal swath corner latitude for the first range line and left edge of the swath (degrees_north)
left_last_longitude	Nominal swath corner longitude for the last range line and left edge of the swath (degrees_east)
left_last_latitude	Nominal swath corner latitude for the last range line and left edge of the swath (degrees_north)
right_first_longitude	Nominal swath corner longitude for the first range line and right edge of the swath (degrees_east)
right_first_latitude	Nominal swath corner latitude for the first range line and right edge of the swath (degrees_north)
right_last_longitude	Nominal swath corner longitude for the last range line and right edge of the swath (degrees_east)
right_last_latitude	Nominal swath corner latitude for the last range line and right edge of the swath (degrees_north)
xref_input_l2_hr_pixc_files	List of L2_HR_PIXC files used to generate data in product
xref_input_l2_hr_rivertile_files	List of RiverTile products used to generate data in product
xref_static_river_db_file	Name of static river a-priori database file used to generate data in product
xref_l2_hr_river_sp_param_file	Name of PGE_L2_HR_RiverSP parameter file used to generate data in product

5.2 Reach Attribute Description

Table 9 lists the reach .dbf shapefile attributes (bold left-most column), and their associated metadata fields from Table 7. The attributes are separated into the ten categories listed in Sections 4.1.1 through 4.1.10. Appendix B contains a description of the shp.xml format that was used to generate this table.

Table 9. Attributes of the reach shapefile of the L2_HR_RiverSP product.

Attributes		
reach_id		
	type	text
	long_name	reach ID from prior river database
	tag_basic_expert	Basic
	coordinates	p_lon p_lat
	comment	Unique reach identifier from the prior river database. The format of the identifier is CBBBBBRRRRT, where C=continent, B=basin, R=reach, T=type.
time		
	type	float
	fill_value	-999999999999
	long_name	time (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
	tag_basic_expert	Basic
	units	seconds since 2000-01-01 00:00:00.000
	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 metadata leap_second is set to the UTC time at which the leap second occurs.
time_tai		
	type	float
	fill_value	-999999999999
	long_name	time (TAI)
	standard_name	time
	calendar	gregorian
	tag_basic_expert	Basic
	units	seconds since 2000-01-01 00:00:00.000
	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 metadata [time:tai_utc_difference].
time_str		
	type	text
	fill_value	no_data
	long_name	time (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
	tag_basic_expert	Basic
	comment	Time string giving UTC time. The format is YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time.
p_lat		
	type	float
	fill_value	-999999999999
	long_name	latitude of the center of the reach
	standard_name	latitude
	tag_basic_expert	Basic
	units	degrees_north
	valid_min	-80
	valid_max	80
	comment	Geodetic latitude of the reach center from the prior river database. Positive values increase northward of the equator.
p_lon		
	type	float
	fill_value	-999999999999
	long_name	longitude of the center of the reach
	standard_name	longitude
	tag_basic_expert	Basic
	units	degrees_east
	valid_min	-180
	valid_max	180
	comment	Geodetic longitude of the reach center from the prior river database. The longitude values become more positive to the east and more negative to the west of the Prime Meridian.
wse		
	type	float
	fill_value	-999999999999
	long_name	water surface elevation with respect to the geoid
	tag_basic_expert	Basic
	units	m

	valid_min	-1000
	valid_max	100000
	coordinates	p_lon p_lat
	comment	Fitted reach water surface elevation, relative to the provided model of the geoid (geoid_hght), with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects (solid_tide, load_tidef, and pole_tide) applied.
wse_u		
	type	float
	fill_value	-999999999999
	long_name	total uncertainty in the water surface elevation
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	999999
	coordinates	p_lon p_lat
	comment	Total one-sigma uncertainty (random and systematic) in the reach WSE, including uncertainties of corrections, and variation about the fit.
wse_r_u		
	type	float
	fill_value	-999999999999
	long_name	random-only uncertainty in the water surface elevation
	tag_basic_expert	Expert
	units	m
	valid_min	0
	valid_max	999999
	coordinates	p_lon p_lat
	comment	Random-only component of the uncertainty in the reach WSE, including uncertainties of corrections, and variation about the fit.
slope		
	type	float
	fill_value	-999999999999
	long_name	water surface slope with respect to the geoid
	tag_basic_expert	Basic
	units	m/m
	valid_min	-0.001
	valid_max	0.1
	coordinates	p_lon p_lat
	comment	Fitted water surface slope relative to the geoid, and with the same corrections and geophysical fields applied as wse. The units are m/m. The upstream or downstream direction is defined by the prior river database. A positive slope means that the downstream WSE is lower.
slope_u		
	type	float
	fill_value	-999999999999
	long_name	total uncertainty in the water surface slope
	tag_basic_expert	Basic
	units	m/m
	valid_min	0
	valid_max	0.1
	coordinates	p_lon p_lat
	comment	Total one-sigma uncertainty (random and systematic) in the water surface slope, including uncertainties of corrections and variation about the fit.

slope_r_u		
	type	float
	fill_value	-999999999999
	long_name	random uncertainty in the water surface slope
	tag_basic_expert	Expert
	units	m/m
	valid_min	0
	valid_max	0.1
	coordinates	p_lon p_lat
	comment	Random-only component of the uncertainty in the water surface slope.
slope2		
	type	float
	fill_value	-999999999999
	long_name	enhanced water surface slope with respect to the geoid
	tag_basic_expert	Basic
	units	m/m
	valid_min	-0.001
	valid_max	0.1
	coordinates	p_lon p_lat
	comment	Enhanced water surface slope relative to the geoid, produced using a smoothing of the node wse. The upstream or downstream direction is defined by the prior river database. A positive slope means that the downstream WSE is lower.
slope2_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the enhanced water surface slope
	tag_basic_expert	Basic
	units	m/m
	valid_min	0
	valid_max	0.1
	coordinates	p_lon p_lat
	comment	Total one-sigma uncertainty (random and systematic) in the enhanced water surface slope, including uncertainties of corrections and variation about the fit.
slope2_r_u		
	type	float
	fill_value	-999999999999
	long_name	random uncertainty in the enhanced water surface slope
	tag_basic_expert	Expert
	units	m/m
	valid_min	0
	valid_max	0.1
	coordinates	p_lon p_lat
	comment	Random-only component of the uncertainty in the enhanced water surface slope.
width		
	type	float
	fill_value	-999999999999
	long_name	reach width
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	100000
	coordinates	p_lon p_lat
	comment	Reach width.

width_u		
	type	float
	fill_value	-999999999999
	long_name	total uncertainty in the reach width
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	100000
	coordinates	p_lon p_lat
	comment	Total one-sigma uncertainty (random and systematic) in the reach width.
area_total		
	type	float
	fill_value	-999999999999
	long_name	total water surface area including dark water
	tag_basic_expert	Basic
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	p_lon p_lat
	comment	Total estimated water surface area, including dark water that was not detected as water in the SWOT observation but identified through the use of a prior water likelihood map.
area_tot_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the total water surface area
	tag_basic_expert	Basic
	units	m^2
	valid_min	0
	valid_max	2000000
	coordinates	p_lon p_lat
	comment	Total one-sigma uncertainty (random and systematic) in the total estimated water surface area area_total.
area_detct		
	type	float
	fill_value	-999999999999
	long_name	surface area of detected water pixels
	tag_basic_expert	Expert
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	p_lon p_lat
	comment	Surface area of reach that was detected as water by the SWOT observation.
area_det_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the surface area of detected water
	tag_basic_expert	Expert
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	p_lon p_lat

	comment	Total one-sigma uncertainty (random and systematic) in the surface area of the detected water pixels.
area_wse		
	type	float
	fill_value	-999999999999
	long_name	area used to compute water surface elevation
	tag_basic_expert	Expert
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	p_lon p_lat
	comment	Surface area of the reach that contributed to the computation of the WSE.
d_x_area		
	type	float
	fill_value	-999999999999
	long_name	change in cross-sectional area
	tag_basic_expert	Basic
	units	m^2
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Change in channel cross sectional area from the value reported in the prior river database.
d_x_area_u		
	type	float
	fill_value	-999999999999
	long_name	total uncertainty of the change in the cross-sectional area
	tag_basic_expert	Basic
	units	m^2
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Total one-sigma uncertainty (random and systematic) in the change in the cross-sectional area.
layovr_val		
	type	float
	fill_value	-999999999999
	long_name	metric of layover effect
	tag_basic_expert	Expert
	units	TBD
	valid_min	0
	valid_max	1
	coordinates	p_lon p_lat
	comment	Value indicating an estimate of the height error due to layover (TBD).
node_dist		
	type	float
	fill_value	-999999999999
	long_name	mean distance between observed and prior river database node locations
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	10000
	coordinates	p_lon p_lat

	comment	Mean distance between the observed node locations and the node locations in the prior river database.
loc_offset		
	type	float
	fill_value	-999999999999
	long_name	along-stream location offset between the observed and prior reach location
	tag_basic_expert	Basic
	units	m
	valid_min	-20000
	valid_max	20000
	coordinates	p_lon p_lat
	comment	Location offset between the observed and prior reach locations. This is defined as the mean of the along-stream node distances of only observed nodes in the reach, minus the mean of all prior river database along-stream node distances in the reach.
xtrk_dist		
	type	float
	fill_value	-999999999999
	long_name	distance to the satellite ground track
	tag_basic_expert	Basic
	units	m
	valid_min	-75000
	valid_max	75000
	coordinates	p_lon p_lat
	comment	Average distance of the observed node locations in the reach from the spacecraft nadir track. A negative value indicates the left side of the swath, relative to the spacecraft velocity vector. A positive value indicates the right side of the swath.
dschg_c		
	type	float
	fill_value	-999999999999
	long_name	consensus discharge
	tag_basic_expert	Basic
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the consensus discharge algorithm.
dschg_c_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in consensus discharge
	tag_basic_expert	Basic
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the consensus algorithm.
dschg_c_q		
	type	int4
	fill_value	-999
	long_name	consensus discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Basic
	flag_meanings	valid questionable invalid

	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the consensus discharge. Values of 0, 1, and 2 indicate that the consensus discharge is valid, questionable, and invalid, respectively.
dschg_gc		
	type	float
	fill_value	-999999999999
	long_name	gauge-constrained consensus discharge
	tag_basic_expert	Basic
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the gauge-constrained consensus discharge algorithm.
dschg_gc_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in gauge-constrained consensus discharge
	tag_basic_expert	Basic
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the gauge-constrained consensus algorithm.
dschg_gc_q		
	type	int4
	fill_value	-999
	long_name	gauge-constrained consensus discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Basic
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the gauge-constrained consensus discharge. Values of 0, 1, and 2 indicate that the gauge-constrained consensus discharge is valid, questionable, and invalid, respectively.
dschg_m		
	type	float
	fill_value	-999999999999
	long_name	MetroMan discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the MetroMan discharge algorithm.
dschg_m_u		
	type	float
	fill_value	-999999999999

	long_name	uncertainty in MetroMan discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the MetroMan algorithm.
dschg_m_q		
	type	int4
	fill_value	-999
	long_name	MetroMan discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the MetroMan discharge. Values of 0, 1, and 2 indicate that the MetroMan discharge is valid, questionable, and invalid, respectively.
dschg_gm		
	type	float
	fill_value	-999999999999
	long_name	gauge-constrained MetroMan discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the gauge-constrained MetroMan discharge algorithm.
dschg_gm_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in gauge-constrained MetroMan discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the gauge-constrained MetroMan algorithm.
dschg_gm_q		
	type	int4
	fill_value	-999
	long_name	gauge-constrained MetroMan discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat

	comment	Flag that indicates quality of the gauge-constrained MetroMan discharge. Values of 0, 1, and 2 indicate that the gauge-constrained MetroMan discharge is valid, questionable, and invalid, respectively.
dschg_b		
	type	float
	fill_value	-999999999999
	long_name	BAM discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the BAM discharge algorithm.
dschg_b_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in BAM discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the BAM algorithm.
dschg_b_q		
	type	int4
	fill_value	-999
	long_name	BAM discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the BAM discharge. Values of 0, 1, and 2 indicate that the BAM discharge is valid, questionable, and invalid, respectively.
dschg_gb		
	type	float
	fill_value	-999999999999
	long_name	gauge-constrained BAM discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the gauge-constrained BAM discharge algorithm.
dschg_gb_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in gauge-constrained BAM discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0

	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the gauge-constrained BAM algorithm.
dschg_gb_q		
	type	int4
	fill_value	-999
	long_name	gauge-constrained BAM discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the gauge-constrained BAM discharge. Values of 0, 1, and 2 indicate that the gauge-constrained BAM discharge is valid, questionable, and invalid, respectively.
dschg_h		
	type	float
	fill_value	-999999999999
	long_name	HiVDI discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the HiVDI discharge algorithm.
dschg_h_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in HiVDI discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the HiVDI algorithm.
dschg_h_q		
	type	int4
	fill_value	-999
	long_name	HiVDI discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the HiVDI discharge. Values of 0, 1, and 2 indicate that the HiVDI discharge is valid, questionable, and invalid, respectively.
dschg_gh		
	type	float
	fill_value	-999999999999

	long_name	gauge-constrained HiVDI discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the gauge-constrained HiVDI discharge algorithm.
dschg_gh_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in gauge-constrained HiVDI discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the gauge-constrained HiVDI algorithm.
dschg_gh_q		
	type	int4
	fill_value	-999
	long_name	gauge-constrained HiVDI discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the gauge-constrained HiVDI discharge. Values of 0, 1, and 2 indicate that the gauge-constrained HiVDI discharge is valid, questionable, and invalid, respectively.
dschg_o		
	type	float
	fill_value	-999999999999
	long_name	MOMMA discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the MOMMA discharge algorithm.
dschg_o_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in MOMMA discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the MOMMA algorithm.
dschg_o_q		
	type	int4

	fill_value	-999
	long_name	MOMMA discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the MOMMA discharge. Values of 0, 1, and 2 indicate that the MOMMA discharge is valid, questionable, and invalid, respectively.
dschg_go		
	type	float
	fill_value	-999999999999
	long_name	gauge-constrained MOMMA discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the gauge-constrained MOMMA discharge algorithm.
dschg_go_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in gauge-constrained MOMMA discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the gauge-constrained MOMMA algorithm.
dschg_go_q		
	type	int4
	fill_value	-999
	long_name	gauge-constrained MOMMA discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the gauge-constrained MOMMA discharge. Values of 0, 1, and 2 indicate that the gauge-constrained MOMMA discharge is valid, questionable, and invalid, respectively.
dschg_s		
	type	float
	fill_value	-999999999999
	long_name	SADS discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000

	coordinates	p_lon p_lat
	comment	Discharge from the SADS discharge algorithm.
dschg_s_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in SADS discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the SADS algorithm.
dschg_s_q		
	type	int4
	fill_value	-999
	long_name	SADS discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the SADS discharge. Values of 0, 1, and 2 indicate that the SADS discharge is valid, questionable, and invalid, respectively.
dschg_gs		
	type	float
	fill_value	-999999999999
	long_name	gauge-constrained SADS discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	-10000000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Discharge from the gauge-constrained SADS discharge algorithm.
dschg_gs_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in gauge-constrained SADS discharge
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Uncertainty in the discharge from the gauge-constrained SADS algorithm.
dschg_gs_q		
	type	int4
	fill_value	-999
	long_name	gauge-constrained SADS discharge quality flag
	standard_name	status_flag
	tag_basic_expert	Expert
	flag_meanings	valid questionable invalid
	flag_values	0 1 2

	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Flag that indicates quality of the gauge-constrained SADS discharge. Values of 0, 1, and 2 indicate that the gauge-constrained SADS discharge is valid, questionable, and invalid, respectively.
reach_q		
	type	int4
	fill_value	-999
	long_name	summary quality indicator for the reach
	standard_name	status_flag
	flag_masks	TBD
	tag_basic_expert	Basic
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	p_lon p_lat
	comment	Summary quality indicator for the reach measurement. Values of 0 and 1 indicate nominal (good) and off-nominal (suspect) measurements.
dark_frac		
	type	float
	fill_value	-999999999999
	long_name	fractional area of dark water
	tag_basic_expert	Expert
	units	1
	valid_min	-1000
	valid_max	10000
	coordinates	p_lon p_lat
	comment	Fraction of reach area_total covered by dark water.
ice_clim_f		
	type	int4
	fill_value	-999
	long_name	climatological ice cover flag
	standard_name	status_flag
	source	Yang et al. (2020)
	tag_basic_expert	Basic
	flag_meanings	no_ice_cover uncertain_ice_cover full_ice_cover
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Climatological ice cover flag indicating whether the reach is ice-covered on the day of the observation based on external climatological information (not the SWOT measurement). Values of 0, 1, and 2 indicate that the reach is likely not ice covered, may or may not be partially or fully ice covered, and likely fully ice covered, respectively.
ice_dyn_f		
	type	int4
	fill_value	-999
	long_name	dynamical ice cover flag
	standard_name	status_flag
	source	Yang et al. (2020)

	tag_basic_expert	Basic
	flag_meanings	no_ice_cover partial_ice_cover full_ice_cover
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	p_lon p_lat
	comment	Dynamic ice cover flag indicating whether the surface is ice-covered on the day of the observation based on analysis of external satellite optical data. Values of 0, 1, and 2 indicate that the reach is not ice covered, partially ice covered, and fully ice covered, respectively.
partial_f		
	type	int4
	fill_value	-999
	long_name	partial reach coverage flag
	standard_name	status_flag
	tag_basic_expert	Basic
	flag_meanings	covered not_covered
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	p_lon p_lat
	comment	Flag that indicates only partial reach coverage. The flag is 0 if at least half the nodes of the reach have valid WSE measurements; the flag is 1 otherwise and reach-level quantities are not computed.
n_good_nod		
	type	int4
	fill_value	-999
	long_name	number of nodes in the reach that have a valid WSE
	tag_basic_expert	Basic
	units	1
	valid_min	0
	valid_max	100
	coordinates	p_lon p_lat
	comment	Number of nodes in the reach that have a valid node WSE. Note that the total number of nodes from the prior river database is given by p_n_nodes.
obs_frac_n		
	type	float
	fill_value	-999999999999
	long_name	fraction of nodes that have a valid WSE
	tag_basic_expert	Basic
	units	1
	valid_min	0
	valid_max	1
	coordinates	p_lon p_lat
	comment	Fraction of nodes (n_good_nod/p_n_nodes) in the reach that have a valid node WSE. The value is between 0 and 1.
xovr_cal_q		
	type	int4
	fill_value	-999
	long_name	quality of the cross-over calibration
	flag_masks	TBD
	tag_basic_expert	Basic
	flag_meanings	TBD

	flag_values	T B D
	valid_min	0
	valid_max	1
	coordinates	p_lon p_lat
	comment	Quality of the cross-over calibration.
geoid_hght		
	type	float
	fill_value	-999999999999
	long_name	geoid height
	standard_name	geoid_height_above_reference_ellipsoid
	source	EGM2008 (Pavlis et al., 2012)
	institution	GSFC
	tag_basic_expert	Basic
	units	m
	valid_min	-150
	valid_max	150
	coordinates	p_lon p_lat
	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).
geoid_slop		
	type	float
	fill_value	-999999999999
	long_name	geoid slope
	source	EGM2008 (Pavlis et al., 2012)
	institution	GSFC
	tag_basic_expert	Expert
	units	m/m
	valid_min	-0.001
	valid_max	0.01
	coordinates	p_lon p_lat
	comment	Geoid slope in the along-stream direction, based upon a least-square linear fit along the reach. A positive slope means that the downstream geoid model height is lower.
solid_tide		
	type	float
	fill_value	-999999999999
	long_name	solid Earth tide height
	source	Cartwright and Taylor (1971) and Cartwright and Edden (1973)
	tag_basic_expert	Expert
	units	m
	valid_min	-1
	valid_max	1
	coordinates	p_lon p_lat
	comment	Solid-Earth (body) tide height. The zero-frequency permanent tide component is not included.
load_tidef		
	type	float
	fill_value	-999999999999
	long_name	geocentric load tide height (FES)
	source	FES2014b (Carrere et al., 2016)
	institution	LEGOS/CNES
	tag_basic_expert	Expert
	units	m
	valid_min	-0.2

	valid_max	0.2
	coordinates	p_lon p_lat
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust. This value is used to compute wse.
load_tideg		
	type	float
	fill_value	-999999999999
	long_name	geocentric load tide height (GOT)
	source	GOT4.10c (Ray, 2013)
	institution	GSFC
	tag_basic_expert	Expert
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	p_lon p_lat
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust.
pole_tide		
	type	float
	fill_value	-999999999999
	long_name	geocentric pole tide height
	source	Wahr (1985) and Desai et al. (2015)
	tag_basic_expert	Expert
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	p_lon p_lat
	comment	Geocentric pole tide height. The sum total of the contribution from the solid-Earth (body) pole tide height and the load pole tide height (i.e., the effect of the ocean pole tide loading of the Earth's crust).
dry_trop_c		
	type	float
	fill_value	-999999999999
	long_name	dry troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	tag_basic_expert	Expert
	units	m
	valid_min	-3.0
	valid_max	-1.5
	coordinates	p_lon p_lat
	comment	Equivalent vertical correction due to dry troposphere delay. Adding the reported correction to the reported reach WSE results in the uncorrected reach WSE.
wet_trop_c		
	type	float
	fill_value	-999999999999
	long_name	wet troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	tag_basic_expert	Expert
	units	m
	valid_min	-1
	valid_max	0
	coordinates	p_lon p_lat

	comment	Equivalent vertical correction due to wet troposphere delay. Adding the reported correction to the reported reach WSE results in the uncorrected reach WSE.
iono_c		
	type	float
	fill_value	-999999999999
	long_name	ionosphere vertical correction
	source	Global Ionosphere Maps
	institution	JPL
	tag_basic_expert	Expert
	units	m
	valid_min	-0.5
	valid_max	0
	coordinates	p_lon p_lat
	comment	Equivalent vertical correction due to ionosphere delay. Adding the reported correction to the reported reach WSE results in the uncorrected reach WSE.
xovr_cal_c		
	type	float
	fill_value	-999999999999
	long_name	WSE correction from KaRIn crossovers
	tag_basic_expert	Expert
	units	m
	valid_min	-10
	valid_max	10
	coordinates	p_lon p_lat
	comment	Height correction from KaRIn crossover calibration. The correction is applied before geolocation but reported as an equivalent height correction.
n_reach_up		
	type	int4
	fill_value	-999
	long_name	number of upstream reaches
	tag_basic_expert	Basic
	units	1
	valid_min	0
	valid_max	4
	coordinates	p_lon p_lat
	comment	Number of upstream reaches, from the prior river database. A value of 4 indicates 4 or more upstream reaches.
n_reach_dn		
	type	int4
	fill_value	-999
	long_name	number of downstream reaches
	tag_basic_expert	Basic
	units	1
	valid_min	0
	valid_max	4
	coordinates	p_lon p_lat
	comment	Number of downstream reaches, from the prior river database. A value of 4 indicates 4 or more downstream reaches.
rch_id_up		
	type	text
	fill_value	no_data
	long_name	reach_id of upstream reaches
	tag_basic_expert	Basic

	units	1
	coordinates	p_lon p_lat
	comment	Values of reach_id for the upstream reaches, from the prior river database. The values are strings of comma-separated lists of at most 4 reach identifiers corresponding to the upstream reaches.
rch_id_dn		
	type	text
	fill_value	no_data
	long_name	reach_id of downstream reaches
	tag_basic_expert	Basic
	units	1
	coordinates	p_lon p_lat
	comment	Values of reach_id for the downstream reaches, from the prior river database. The values are strings of comma-separated lists of at most 4 reach identifiers corresponding to the downstream reaches.
p_wse		
	type	float
	fill_value	-999999999999
	long_name	reach water surface elevation
	tag_basic_expert	Basic
	units	m
	valid_min	-1000
	valid_max	10000
	coordinates	p_lon p_lat
	comment	Reach WSE from the prior river database.
p_wse_var		
	type	float
	fill_value	-999999999999
	long_name	reach water surface elevation variability
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	9999
	coordinates	p_lon p_lat
	comment	Reach WSE spatial variability from the prior river database.
p_width		
	type	float
	fill_value	-999999999999
	long_name	reach width
	tag_basic_expert	Basic
	units	m
	valid_min	10
	valid_max	100000
	coordinates	p_lon p_lat
	comment	Reach width from the prior river database.
p_wid_var		
	type	float
	fill_value	-999999999999
	long_name	reach width variability
	tag_basic_expert	Basic
	units	m
	valid_min	10
	valid_max	100000

	coordinates	p_lon p_lat
	comment	Reach width spatial variability from the prior river database.
p_n_nodes		
	type	int4
	fill_value	-999
	long_name	number of nodes in the reach
	tag_basic_expert	Basic
	units	1
	valid_min	1
	valid_max	500
	coordinates	p_lon p_lat
	comment	Number of nodes in the reach from the prior river database.
p_dist_out		
	type	float
	fill_value	-999999999999
	long_name	distance from the reach to the outlet
	tag_basic_expert	Basic
	units	m
	valid_min	-10000
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Along-stream distance from the reach center to the outlet, from the prior river database.
p_length		
	type	float
	fill_value	-999999999999
	long_name	length of reach
	tag_basic_expert	Basic
	units	m
	valid_min	100
	valid_max	100000
	coordinates	p_lon p_lat
	comment	Length of the reach from the prior river database. This value is used to compute the reach width from the water surface area.
p_maf		
	type	float
	fill_value	-999999999999
	long_name	mean annual flow
	tag_basic_expert	Expert
	units	m^3/s
	valid_min	0
	valid_max	10000000
	coordinates	p_lon p_lat
	comment	Mean annual flow from the prior river datavase.
p_dam_id		
	type	int9
	fill_value	-99999999
	long_name	dam ID from GRanD database
	source	Lehner et al. (2011)
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	10000

	coordinates	p_lon p_lat
	comment	Dam ID from the Global Reservoir and Dam (GRanD) database. The value is 0 if there is no influence of dams along the reach, and a positive value indicates there is an influence of a dam along the reach. The value of grand_id identifies the dam ID in the GRanD database. Reaches influenced by dams are indicated by the type code in reach_id.
p_n_ch_max		
	type	int4
	fill_value	-999
	long_name	maximum number of channels detected in the reach
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	100
	coordinates	p_lon p_lat
	comment	Maximum number of channels in the reach from the prior river database.
p_n_ch_mod		
	type	int4
	fill_value	-999
	long_name	mode of the number of channels in the reach
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	100
	coordinates	p_lon p_lat
	comment	Mode of the number of channels in the reach from the prior river database.

5.3 Node Attribute Description

Table 10 lists the node .dbf shapefile attributes (bold left-most column), and their corresponding metadata fields from Table 7. The attributes are separated into the ten categories listed in Sections 4.2.1 through 4.2.10. Appendix B contains a description of the shp.xml format that was used to generate this table.

Table 10. Attributes of the node shapefile of the L2_HR_RiverSP product.

Attributes		
reach_id		
	type	text
	long_name	reach ID with which node is associated
	tag_basic_expert	Basic
	coordinates	lon lat
	comment	Unique reach identifier from the prior river database. The format of the identifier is CBBBBBRRRRT, where C=continent, B=basin, R=reach, T=type.
node_id		
	type	text
	long_name	node ID of the node in the prior river database
	tag_basic_expert	Basic
	coordinates	lon lat

	comment	Unique node identifier from the prior river database. The format of the identifier is CBBBBBRRRRNNNT, where C=continent, B=basin, R=reach, N=node, T=type.
time		
	type	float
	fill_value	-999999999999
	long_name	time (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
	tag_basic_expert	Basic
	units	seconds since 2000-01-01 00:00:00.000
	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 metadata leap_second is set to the UTC time at which the leap second occurs.
time_tai		
	type	float
	fill_value	-999999999999
	long_name	time (TAI)
	standard_name	time
	calendar	gregorian
	tag_basic_expert	Basic
	units	seconds since 2000-01-01 00:00:00.000
	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 metadata [time:tai_utc_difference].
time_str		
	type	text
	fill_value	no_data
	long_name	time (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
	tag_basic_expert	Basic
	comment	Time string giving UTC time. The format is YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time.
lat		
	type	float
	fill_value	-999999999999
	long_name	latitude of centroid of water-detected pixels
	standard_name	latitude
	tag_basic_expert	Basic
	units	degrees_north
	valid_min	-80
	valid_max	80
	comment	Geodetic latitude of the centroid of water-detected pixels assigned to the node. Positive latitude values increase northward from the equator.
lon		
	type	float
	fill_value	-999999999999

	long_name	longitude of centroid of water-detected pixels
	standard_name	longitude
	tag_basic_expert	Basic
	units	degrees_east
	valid_min	-180
	valid_max	180
	comment	Geodetic longitude of the centroid of water-detected pixels assigned to the node. The longitude values become more positive to the east and more negative to the west of the Prime Meridian.
lat_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the node latitude
	tag_basic_expert	Basic
	units	degrees_north
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Total one-sigma uncertainty in the latitude of the centroid of water-detected pixels assigned to the node.
lon_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the node longitude
	tag_basic_expert	Basic
	units	degrees_east
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Total one-sigma uncertainty in the longitude of the centroid of water-detected pixels assigned to the node.
wse		
	type	float
	fill_value	-999999999999
	long_name	water surface elevation with respect to the geoid
	tag_basic_expert	Basic
	units	m
	valid_min	-1000
	valid_max	100000
	coordinates	lon lat
	comment	Fitted node water surface elevation, relative to the provided model of the geoid (geoid_hght), with all corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects (solid_tide, load_tidef, and pole_tide) applied.
wse_u		
	type	float
	fill_value	-999999999999
	long_name	total uncertainty in the water surface elevation
	tag_basic_expert	Basic
	units	m
	valid_min	0.0
	valid_max	999999
	coordinates	lon lat

	comment	Total one-sigma uncertainty (random and systematic) in the node WSE, including uncertainties of corrections, and variation about the fit.
wse_r_u		
	type	float
	fill_value	-999999999999
	long_name	random-only uncertainty in the water surface elevation
	tag_basic_expert	Expert
	units	m
	valid_min	0.0
	valid_max	999999
	coordinates	lon lat
	comment	Random-only uncertainty component in the node WSE, including uncertainties of corrections, and variation about the fit.
width		
	type	float
	fill_value	-999999999999
	long_name	node width
	tag_basic_expert	Basic
	units	m
	valid_min	0.0
	valid_max	100000
	coordinates	lon lat
	comment	Node width.
width_u		
	type	float
	fill_value	-999999999999
	long_name	total uncertainty in the node width
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	10000
	coordinates	lon lat
	comment	Total one-sigma uncertainty (random and systematic) in the node width.
area_total		
	type	float
	fill_value	-999999999999
	long_name	total water surface area including dark water
	tag_basic_expert	Basic
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	lon lat
	comment	Total estimated water surface area, including dark water that was not detected as water in the SWOT observation but identified through the use of a prior water likelihood map.
area_tot_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the total water surface area
	tag_basic_expert	Basic
	units	m^2
	valid_min	0
	valid_max	2000000000

	coordinates	lon lat
	comment	Total one-sigma uncertainty (random and systematic) in the total estimated water surface area area_total.
area_detct		
	type	float
	fill_value	-999999999999
	long_name	surface area of detected water pixels
	tag_basic_expert	Expert
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	lon lat
	comment	Surface area of node that was detected as water by the SWOT observation.
area_det_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the surface area of detected water
	tag_basic_expert	Expert
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	lon lat
	comment	Total one-sigma uncertainty (random and systematic) in the surface area of the detected water pixels.
area_wse		
	type	float
	fill_value	-999999999999
	long_name	area used to compute water surface elevation
	tag_basic_expert	Expert
	units	m^2
	valid_min	0
	valid_max	2000000000
	coordinates	lon lat
	comment	Surface area of the node that contributed to the computation of the WSE.
layovr_val		
	type	float
	fill_value	-999999999999
	long_name	metric of layover effect
	tag_basic_expert	Expert
	units	TBD
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Value indicating an estimate of the height error due to layover (TBD).
node_dist		
	type	float
	fill_value	-999999999999
	long_name	distance between observed and prior river database node location
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	10000
	coordinates	lon lat

	comment	Distance between the observed node location and the node location in the prior river database.
xtrk_dist		
	type	float
	fill_value	-999999999999
	long_name	distance to the satellite ground track
	tag_basic_expert	Basic
	units	m
	valid_min	-75000
	valid_max	75000
	coordinates	lon lat
	comment	Distance of the observed node location from the spacecraft nadir track. A negative value indicates the left side of the swath, relative to the spacecraft velocity vector. A positive value indicates the right side of the swath.
flow_angle		
	type	float
	fill_value	-999999999999
	long_name	river flow direction relative to the satellite ground track
	tag_basic_expert	Basic
	units	degrees
	valid_min	0
	valid_max	360
	coordinates	lon lat
	comment	River flow direction for the node relative to the direction of the spacecraft nadir track based on prior data (not the SWOT observation). A value of zero indicates that the flow is in the same direction as the spacecraft velocity direction. A value of 90 degrees indicates that the flow is toward the right side of the SWOT swath.
node_q		
	type	int4
	fill_value	-999
	long_name	summary quality indicator for the node
	standard_name	status_flag
	flag_masks	TBD
	tag_basic_expert	Basic
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Summary quality indicator for the node measurement. Values of 0 and 1 indicate nominal and off-nominal measurements.
dark_frac		
	type	float
	fill_value	-999999999999
	long_name	fractional area of dark water
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Fraction of node area_total covered by dark water.
ice_clim_f		
	type	int4

	fill_value	-999
	long_name	climatological ice cover flag
	standard_name	status_flag
	source	Yang et al. (2020)
	tag_basic_expert	Basic
	flag_meanings	no_ice_cover uncertain_ice_cover full_ice_cover
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	lon lat
	comment	Climatological ice cover flag indicating whether the node is ice-covered on the day of the observation based on external climatological information (not the SWOT measurement). Values of 0, 1, and 2 indicate that the node is likely not ice covered, may or may not be partially or fully, and likely fully ice covered, respectively
ice_dyn_f		
	type	int4
	fill_value	-999
	long_name	dynamical ice cover flag
	standard_name	status_flag
	source	Yang et al. (2020)
	tag_basic_expert	Basic
	flag_meanings	no_ice_cover partial_ice_cover full_ice_cover
	flag_values	0 1 2
	valid_min	0
	valid_max	2
	coordinates	lon lat
	comment	Dynamic ice cover flag indicating whether the surface is ice-covered on the day of the observation based on analysis of external satellite optical data. Values of 0, 1, and 2 indicate that the node is not ice covered, partially ice covered, and fully ice covered, respectively.
partial_f		
	type	int4
	fill_value	-999
	long_name	partial node coverage flag
	standard_name	status_flag
	tag_basic_expert	Basic
	flag_meanings	covered not_covered
	flag_values	0 1
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Flag that indicates only partial node coverage. The flag is 0 if at least 10 pixels have a valid WSE measurement; the flag is 1 otherwise and node-level quantities are not computed.
n_good_pix		
	type	int9
	fill_value	-99999999
	long_name	number of pixels that have a valid WSE
	tag_basic_expert	Basic
	units	1
	valid_min	0
	valid_max	100000
	coordinates	lon lat

	comment	Number of pixels assigned to the node that have a valid node WSE.
xovr_cal_q		
	type	int4
	fill_value	-999
	long_name	quality of the cross-over calibration
	flag_masks	TBD
	tag_basic_expert	Basic
	flag_meanings	TBD
	flag_values	T B D
	valid_min	0
	valid_max	1
	coordinates	lon lat
	comment	Quality of the cross-over calibration.
rdr_sig0		
	type	float
	fill_value	-999999999999
	long_name	sigma0
	tag_basic_expert	Expert
	units	1
	valid_min	-1000
	valid_max	10000000
	coordinates	lon lat
	comment	Median of the sigma0 from the pixel cloud points assigned to the node in determining the node WSE. The value is provided as a linear power ratio, not a value in decibels. A decibel value may be obtained from: rdr_sig0_in_dB = 10*log10(rdr_sig0).
rdr_sig0_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in sigma0
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	1000
	coordinates	lon lat
	comment	Uncertainty of sig0. The value is provided in linear units. This value is a one-sigma additive (not multiplicative) uncertainty term, which can be added to or subtracted from rdr_sig0.
rdr_pol		
	type	text
	fill_value	no_data
	long_name	polarization of sigma0
	tag_basic_expert	Expert
	coordinates	lon lat
	comment	Flag indicating whether the node is observed with a horizontal (H) or vertical (V) signal polarization.
geoid_hght		
	type	float
	fill_value	-999999999999
	long_name	geoid height
	standard_name	geoid_height_above_reference_ellipsoid
	source	EGM2008 (Pavlis et al., 2012)
	institution	GSFC
	tag_basic_expert	Basic

	units	m
	valid_min	-150
	valid_max	150
	coordinates	lon lat
	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).
solid_tide		
	type	float
	fill_value	-999999999999
	long_name	solid Earth tide height
	source	Cartwright and Taylor (1971) and Cartwright and Edden (1973)
	tag_basic_expert	Expert
	units	m
	valid_min	-1
	valid_max	1
	coordinates	lon lat
	comment	Solid-Earth (body) tide height. The zero-frequency permanent tide component is not included.
load_tidef		
	type	float
	fill_value	-999999999999
	long_name	geocentric load tide height (FES)
	source	FES2014b (Carrere et al., 2016)
	institution	LEGOS/CNES
	tag_basic_expert	Expert
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	lon lat
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust. This value is used to compute wse.
load_tideg		
	type	float
	fill_value	-999999999999
	long_name	geocentric load tide height (GOT)
	source	GOT4.10c (Ray, 2013)
	institution	GSFC
	tag_basic_expert	Expert
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	lon lat
	comment	Geocentric load tide height. The effect of the ocean tide loading of the Earth's crust.
pole_tide		
	type	float
	fill_value	-999999999999
	long_name	geocentric pole tide height
	source	Wahr (1985) and Desai et al. (2015)
	tag_basic_expert	Expert
	units	m
	valid_min	-0.2
	valid_max	0.2
	coordinates	lon lat

	comment	Geocentric pole tide height. The sum total of the contribution from the solid-Earth (body) pole tide height and the load pole tide height (i.e., the effect of the ocean pole tide loading of the Earth's crust).
dry_trop_c		
	type	float
	fill_value	-999999999999
	long_name	dry troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	tag_basic_expert	Expert
	units	m
	valid_min	-3.0
	valid_max	-1.5
	coordinates	lon lat
	comment	Equivalent vertical correction due to dry troposphere delay. Adding the reported correction to the reported reach WSE results in the uncorrected reach WSE.
wet_trop_c		
	type	float
	fill_value	-999999999999
	long_name	wet troposphere vertical correction
	source	European Centre for Medium-Range Weather Forecasts
	institution	ECMWF
	tag_basic_expert	Expert
	units	m
	valid_min	-1
	valid_max	0
	coordinates	lon lat
	comment	Equivalent vertical correction due to wet troposphere delay. Adding the reported correction to the reported reach WSE results in the uncorrected reach WSE.
iono_c		
	type	float
	fill_value	-999999999999
	long_name	ionosphere vertical correction
	source	Global Ionosphere Maps
	institution	JPL
	tag_basic_expert	Expert
	units	m
	valid_min	-0.5
	valid_max	0
	coordinates	lon lat
	comment	Equivalent vertical correction due to ionosphere delay. Adding the reported correction to the reported reach WSE results in the uncorrected reach WSE.
xovr_cal_c		
	type	float
	fill_value	-999999999999
	long_name	WSE correction from KaRIn crossovers
	tag_basic_expert	Expert
	units	m
	valid_min	-10
	valid_max	10
	coordinates	lon lat
	comment	Height correction from KaRIn crossover calibration. The correction is applied before geolocation but reported as an equivalent height correction.

p_wse		
	type	float
	fill_value	-999999999999
	long_name	node water surface elevation
	tag_basic_expert	Basic
	units	m
	valid_min	-1000
	valid_max	10000
	coordinates	lon lat
	comment	Node WSE from the prior river database.
p_wse_var		
	type	float
	fill_value	-999999999999
	long_name	node water surface elevation variability
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	10000
	coordinates	lon lat
	comment	Node WSE spatial variability from the prior river database.
p_width		
	type	float
	fill_value	-999999999999
	long_name	node width
	tag_basic_expert	Basic
	units	m
	valid_min	10
	valid_max	100000
	coordinates	lon lat
	comment	Node width from prior river database.
p_wid_var		
	type	float
	fill_value	-999999999999
	long_name	node width variability
	tag_basic_expert	Basic
	units	m
	valid_min	0
	valid_max	100000
	coordinates	lon lat
	comment	Node width spatial variability from the prior river database.
p_dist_out		
	type	float
	fill_value	-999999999999
	long_name	distance from the node to the outlet
	tag_basic_expert	Basic
	units	m
	valid_min	-10000
	valid_max	10000000
	coordinates	lon lat
	comment	Along-stream distance from the node to the outlet, from the prior river database.
p_length		
	type	float
	fill_value	-999999999999

	long_name	length of node
	tag_basic_expert	Basic
	units	m
	valid_min	10
	valid_max	1000
	coordinates	lon lat
	comment	Length of the node from the prior river database. This value is used to compute the node width from the water surface area.
p_dam_id		
	type	int9
	fill_value	-99999999
	long_name	dam ID from GRanD database
	source	Lehner et al. (2011)
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	10000
	coordinates	lon lat
	comment	Dam ID from the Global Reservoir and Dam (GRanD) database. The value is 0 if there is no influence of dams at the node, and a positive value indicates there is an influence of a dam at the node. The value of grand_id identifies the dam ID in the GRanD database. Nodes influenced by dams are indicated by the type code in node_id.
p_n_ch_max		
	type	int4
	fill_value	-999
	long_name	maximum number of channels detected in node
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	100
	coordinates	lon lat
	comment	Maximum number of channels at the node, from the prior river database.
p_n_ch_mod		
	type	int4
	fill_value	-999
	long_name	mode of the number of channels at the node
	tag_basic_expert	Expert
	units	1
	valid_min	0
	valid_max	100
	coordinates	lon lat
	comment	Mode of the number of channels at the node, from the prior river database.

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Appendix A. **Acronyms**

AD	Applicable Document
API	Application Interface
ATBD	Algorithm Theoretical Basis Document
BAM	Bayesian AMHG-Manning
CNES	Centre National d'Études Spatiales
ECMWF	European Center for Medium-Range Weather Forecasts
GSFC	Goddard Space Flight Center
HiVDI	Hierarchical Variational Discharge Inference
HR	High Rate
JPL	Jet Propulsion Laboratory
KaRIn	Ka-band Radar Interferometer
LR	Low Rate
L2	Level 2
MetroMan	Metropolis-Manning
MOMMA	MOdified Manning Method Algorithm
PIXC	Pixel Cloud
PRD	Prior River Database
RD	Reference Document
SADS	SWOT Assimilated DiScharge
SDS	Science Data System
SP	Single Pass
SWOT	Surface Water Ocean Topography
TAI	International Atomic Time
TBC	To Be Confirmed
TBD	To Be Determined
UTC	Coordinated Universal Time
WSE	Water Surface Elevation
XML	Extensible Markup Language

Appendix B. **Description of Reach and Node XML**

In the L2_HR_RiverSP product, the use of the term “attributes” usually follows the shapefile nomenclature in referring to the variables associated with each feature in the .shp file. Other than in this appendix, this term should not be confused with attributes as typically used in the context of netCDF files. Rather, the L2_HR_RiverSP product uses the term “attributes” in reference to the contents of the .dbf file, and uses the term “metadata” in reference to characteristics of each attribute of the entire shapefile.

However, the Esri shapefile format adopted for the L2_HR_RiverSP product does not have a standard representation for including such metadata. The L2_HR_RiverSP product therefore includes metadata in an extensible markup language (XML) file that is produced alongside each reach and node shapefile (Section 3.2). That is, for the L2_HR_RiverSP product, the reach shp.xml (Table 1) and the node shp.xml (Table 2) XML files convey the information provided in Table 8-10 of this document.

These XML files contain metadata about the entire shapefile (the equivalent of “global attributes” in a netCDF file). The global metadata fields are provided in Table 8. Examples include the starting and ending times of the data contained in the shapefile, and the geospatial bounding box coordinates encompassing the data represented in the shapefile.

These XML files also contain metadata fields, as listed in Table 7, pertaining to specific attributes in the shapefile (the equivalent of per-variable “attributes” in a netCDF file). The reach and node XML files effectively reproduce the specific metadata fields pertaining to attributes that are provided in Tables 9 and 10 of this document, respectively. Examples include metadata such as the allowable minimum and maximum values of an attribute, and the associated units.

Note, however, that the XML files use the word “attributes” in element names following netCDF conventions to refer to metadata fields, not to variables in the shapefile .dbf file. This mix of nomenclature should be clear in context, as variables and metadata fields are named explicitly in the XML file.

These XML files are organized as follows. Following a standard XML declaration, a single top-level XML element *swot_product* always contains exactly two elements *global_attributes* and *attributes*. The *global_attributes* element gives metadata that apply to the entire shapefile, whereas the *attributes* element gives metadata for each shapefile attribute. Child elements of the *global_attributes* element represent individual global metadata fields, with the metadata values as the XML contents between start- and end-tags that define the name of the global metadata field. The *attributes* element has a child element for each attribute of the corresponding shapefile being described; the start- and end-tags of each of these per-attribute elements correspond to the name of the attribute. Each per-attribute element has child elements that give the metadata fields applicable to that attribute, with the metadata values as the contents between start- and end-tags that define the name of the per-attribute metadata field. Not all attributes are associated with the same set of metadata fields. Children of a given element are always unique. While most metadata values will always be the same across different granules of the L2_HR_RiverSP product, some fields do vary between granules (e.g., those involving leap seconds).

Examples are shown below for several XML elements of the .reach.shp.xml file. The attribute-specific metadata differs between the reach and the node XML files where Tables 9 and 10 differ. Note that the XML comments in the example below are included here for descriptive purposes but would not exist in the actual XML file.

```
<swot_product>
    <global_attributes>

        <!-- Global metadata listed in Table 8 here -->
        <!-- Example entries: -->

        <title>Level 2 KaRIn High Rate River Single Pass Vector
        Product</title>
        <continent>EU</continent>.  <!-- From Table 4 -->

        <!-- Other global metadata -->

     <!-- End of global metadata -->


    </global_attributes>

    <attributes>

        <!-- Individual entries for each attribute in Table 5.2 -->
        <!-- Each attribute uses metadata fields from Table 7 -->
        <!-- Example entries for the reach XML file: -->

        <reach_id>
            <type>text</type>
            <long_name> reach ID from prior river database
            </long_name>
            <tag_basic_expert>Basic</tag_basic_expert>
            <coordinates>p_lon p_lat</coordinates>
            <comment> Unique reach identifier from the prior river
            database. The format of the identifier is CBBBBBRRRRT,
            where C=continent, B=basin, R=reach, T=type.</comment>
        </reach_id>

        <wse>
            <type>float</type>
            <fill_value>-999999999999</fill_value>
            <long_name> water surface elevation with respect to the
            geoid</long_name>
            <tag_basic_expert>Basic</tag_basic_expert>
            <units>m</units>
            <valid_min>-1000</valid_min>
            <valid_max>100000</valid_max>
            <coordinates>p_lon p_lat</coordinates>
```

```
            <comment>Fitted reach water surface elevation, relative
            to the provided model of the geoid (geoid_hght), with
            corrections for media delays (wet and dry troposphere,
            and ionosphere), crossover correction, and tidal effects
            (solid_tide, load_tidef, and pole_tide) applied</comment>
        </wse>

        <!-- Metadata fields for other attributes in Table 5.2 -->

      <!-- End of attributes from Table 5.2  -->
    </attributes>
</swot_product>
```

There are a variety of options to display the XML content. For example, many browsers can display XML content directly. Another option is to use XSLT (eXtensible Stylesheet Language Transformations) to transform XML into Hypertext Markup Language (HTML) for a more convenient visualization of the XML content within a browser. To perform this conversion with XLST, there is a tool named “xsltproc” (e.g., http://www.xmlsoft.org/XSLT/xsltproc.html) that can be used to convert the XML files into HTML. For example, to convert the reach XML file on a Linux platform with this tool use the command line:

xsltproc reach.shp.xsl reach.shp.xml > reach.shape.html,

where reach.shp.xsl is an XSLT style sheet of the user’s choosing. An example of a reach.shp.xsl style sheet that a user might choose to use is provided below.

```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
<xsl:variable name="prodtitle" select="swot_product/title"/>
<xsl:template match="swot_product">
  <html>
  <head>
    <title><xsl:value-of select="$prodtitle"/></title>
    <style type='text/css'>
    caption {
      font-weight: bold;
      text-align: center;
    }
    h1 {
      text-align: center;
    }
    th.headcolor {
      background-color: #A9D0F5;
    }
    td.attrcolor {
      background-color: #A9D0F5;
```

```
    }
    </style>
  </head>
  <body>
  <br>
  </br>
  <h1><xsl:value-of select="$prodtitle"/></h1>
  <br>
  </br>
  <xsl:for-each select="global_attributes">
    <table border="1" width="100%" bgcolor="#ffffff" cellspacing="0"
cellpadding="2">
    <caption>Global Metadata of <xsl:value-of
select="$prodtitle"/></caption>
    <tbody>
        <tr>
           <th class="headcolor">Item</th>
           <th class="headcolor">Value</th>
        </tr>
        <xsl:for-each select="*">
          <tr>
            <td>
              <xsl:value-of select="name()"/>
            </td>
            <td>
              <xsl:value-of select="node()"/>
            </td>
          </tr>
        </xsl:for-each>
    </tbody>
    </table>
  </xsl:for-each>
  <br>
  </br>
  <br>
  </br>
  <xsl:for-each select="attributes">
    <table border="1" width="100%" bgcolor="#ffffff" cellspacing="0"
cellpadding
="2">
    <caption>Attributes of <xsl:value-of
select="$prodtitle"/></caption>
    <tbody>
        <xsl:for-each select="*">
          <tr>
            <td colspan="3" class="attrcolor">
              <xsl:value-of select="name()"/>
            </td>
          </tr>
          <xsl:for-each select="*">
```

```
          <tr>
            <td width="40">
            </td>
            <td>
              <xsl:value-of select="name()"/>
            </td>
            <td>
              <xsl:value-of select="node()"/>
            </td>
          </tr>
          </xsl:for-each>
        </xsl:for-each>
    </tbody>
    </table>
   </xsl:for-each>
  </body>
  </html>
</xsl:template>
</xsl:stylesheet>
```