Surface Water and Ocean Topography (SWOT) Project

SWOT Product Description
Long Name: Level 2 KaRIn high rate lake average vector product
Short Name: L2_HR_LakeAvg

Revision B

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December 08, 2023
SWOT-TN-CDM-0676-CNES

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

CHANGE LOG

VERSION	DATE	SECTIONS CHANGED	REASON FOR CHANGE
Preliminary	2017-04-26	All	Preliminary version
Initial Release	2022-02-09	All	Initial Release
Revision A	2022-09-30	All	Revision A following SME review
Revision B	2023-12-08	All	Revision B, minor rewording

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1 Introduction

1.1 Purpose

The purpose of this Product Description Document is to describe the Level 2 Ka-band Radar Interferometer (KaRIn) high rate (HR) lake average (Avg) vector data product from the Surface Water Ocean Topography (SWOT) mission. This data product is also referenced by the short name L2_HR_LakeAvg.

1.2 Document Organization

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

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

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

Section 5 provides a detailed identification of the individual fields within the L2_HR_LakeAvg product.

Section 6 provides references.

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

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

1.3 Document Conventions

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

2 Product Description

2.1 Purpose

The L2_HR_LakeAvg product provides lake data from an aggregate cycle of continent-passes of the high-rate (HR) data stream of the SWOT KaRIn instrument. The aggregate is compiled for lakes in the Prior Lake Database (PLD) [1] using all valid SWOT passes that occur during each observation cycle, and distributed by basin. These data are generally produced for inland and coastal hydrology surfaces, as controlled by the reloadable KaRIn HR mask.

Rivers in the Prior River Database (PRD) [2] are included in the Level 2 KaRIn high rate river average vector product (L2_HR_RiverAvg) [3]. As further discussed in Section 3.2, the L2_HR_LakeAvg product specifically provides data for lakes identified in the PLD [1]. Note that lakes connected to a river topology in the PRD are included in both L2_HR_LakeAvg and L2_HR_RiverAvg science data products.

2.2 Latency

The L2_HR_LakeAvg product is generated with a latency of less than 45 days counted from the end of each 21-day observation cycle. 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 PLD. Note that the L2_HR_LakeAvg product is only generated for the 21-day (actually 20.86) repeat cycles of the SWOT science orbit. It is not generated for the 1-day repeat cycles of the SWOT cal/val orbit.

3 Product Structure

3.1 Granule Definition

The L2_HR_LakeAvg product aggregates all passes in a 21-day observation cycle, with each set of files covering a Pfafstetter level-2 basin as exemplified in Figure 1 and described in [4]. 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). Multiple observations of a lake may be made within the observation cycle, and are labeled separately, as described in section 3.5.

These basin boundaries are consistent with those of the associated L2_HR_RiverAvg product [5].

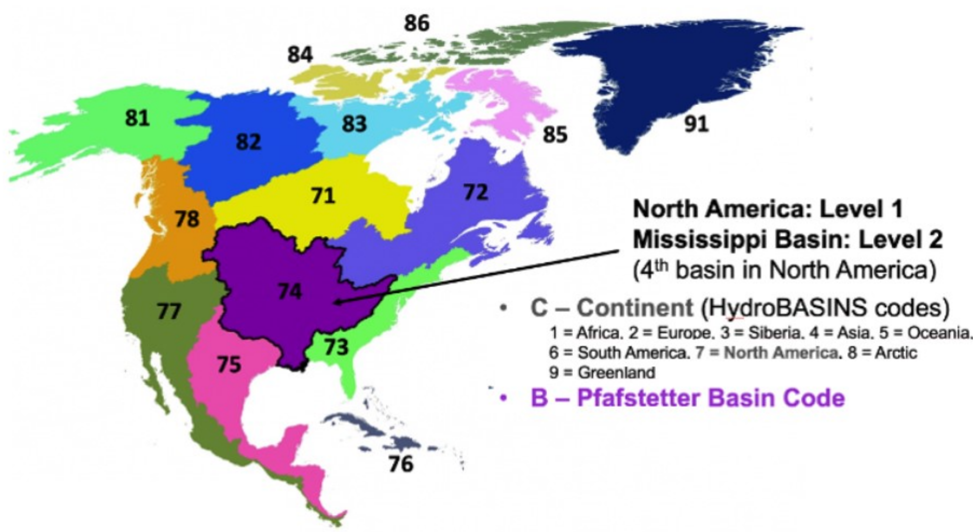

Figure 1. Level-2 Pfafstetter basins in North America, Arctic and Greenland . The Pfafstetter basin organization convention is used to define the spatial extent of each L2_HR_RiverAvg and L2_HR_LakeAvg sets of product files. Basins are organized by continent-level (C) and Pfafstetter basin (B). Level-2 basins therefore refer to the continent-Pfafstetter basin pairs CB. A single granule represents a level-2 region, such as the Mississippi basin, "74". Basins on other continents are defined similarly.

3.2 File Organization

The L2_HR_LakeAvg product is distributed in the Esri Geographical Information System (GIS) vector shapefile format [6]. Each granule of the product consists of one shapefile, with one record per PLD lake.

The PLD lakes may be:

- connected lakes, i.e. lakes that have either an inflow or an outflow or both in the SWOT river network, as defined in the PRD (referenced both in the PLD and the PRD).
- disconnected lakes, i.e. lakes that are not connected to the SWOT river network (referenced in the PLD only).

Each shapefile consists of a set of five files with filename extensions as defined in [6]. A description of these files is provided in Table 1, below.

Table 1. Description of the files representing the L2_HR_LakeAvg shapefile.

File	Name	Description
1	Main shapefile (.shp)	Provides coordinates (polygons shape) delineating a cycle-averaged boundaries of the PLD lakes that have been observed during the cycle
2	Index file (.shx)	Stores the index of each polygon in the .shp file
3	Attributes file (.dbf)	Provides attributes for each polygon in the .shp file
4	Projection file (.prj)	Provides map projection and coordinate reference description
5	Metadata file (.shp.xml)	Provides metadata for the product

Each file in the shapefile set has the same filename prefix. The .shp file contains the basic geometry of the detected water bodies, computed from SWOT observations. The .dbf file contains the SWOT observations of minimum, mean, median, and maximum lake water surface elevation (WSE) for the observation cycle, the corresponding area, and storage change over the observation cycle. It also includes other information from the PLD as described in Section 4. The .prj file contains a map projection description, using a well-known text (WKT) representation of coordinate reference systems (CRS). The .shp.xml file, which is not defined by the Esri specification [6], carries metadata applicable across lake shapefiles (e.g., SWOT cycle number), and per-attribute metadata (e.g., units for each attribute). The format of the .shp.xml file 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 the context of this document, the SWOT-observed average WSE is an attribute of a given lake representing the average water surface elevation in the observation cycle, and the metadata of the *wse_avg* attribute would indicate that the value is given in meters as the unit of measure. A comprehensive list of attributes included in the product is given in Section 5.2.

Note that the names of attributes in shapefiles can be no more than 10 characters, which explains the abbreviated or truncated names of many lake attributes. Owing to this restriction, the naming conventions of attributes in the L2_HR_LakeAvg product sometimes differ from those of similar variables in other NetCDF-based SWOT data products.

3.3 File Naming Convention

The L2_HR_LakeAvg product adopts the following file naming convention:

SWOT_L2_HR_LakeAvg_<CycleID>_<ContinentID>_<BasinID>_<RangeBeginningDateTime>_<RangeEndingDateTime>_<CRID>_<ProductCounter>.<extension>

The two-letter <ContinentID> is described in Table 2.

The two-digit <BasinID> corresponds to the continent code C in Table 2 and Figure 2, followed by the top-level basin number B within the continent, based on the Pfafstetter coding system used in HydroBASINS [7], as illustrated in Figure 1.

The <CRID> is the composite release identifier. It contains the version code of the data system used to generate this product.

The <ProductCounter> identifies the version of product that may have been generated multiple times with the same version of processing software.

The <extension> indicates which of the five parts of the shapefile it is (.shp, .shx, .dbf, .prj, .shp.xml), as described in Section 3.2.

Example:

```
SWOT_L2_HR_LakeAvg_001_EU_23_20210612T072103_20210612T075103_PGA2_03.shp
```

Table 2. Continent codes, and 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 South-East 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

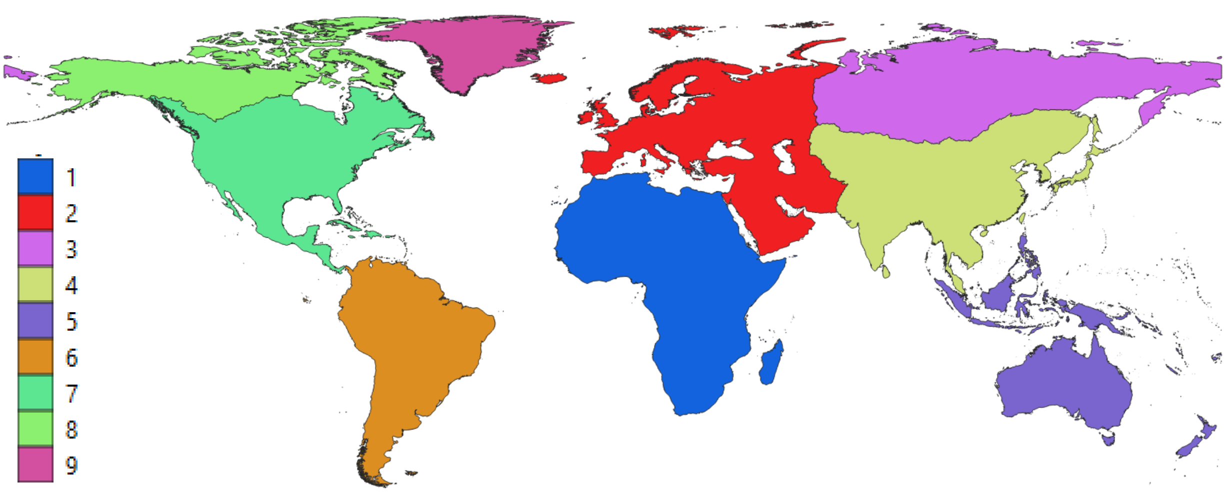

Figure 2. Geograhical delineation of continents from HydroBASINS [7].

3.4 Spatial Sampling and Resolution

The L2_HR_LakeAvg shapefile is a collection of features of shape type *polygon*. The polygon corresponds to the cycle-average extent for PLD lakes that have been observed during the cycle (with some caveats; further details are given in Section 4). If a PLD lake has not been observed during the cycle, its geometry is empty.

The polygons of the individual observations in the L2_HR_LakeSP products are obtained by concave hull vectorization of L2_HR_PIXC (L2_HR_PIXCVec) edge pixels [8]. The polygons of the L2_HR_LakeAvg product can be considered to have similar posting (in the order of 20 m in average) and resolution [8].

The number of lakes in each L2_HR_LakeAvg granule varies from approximately 200 (continent = AU; basin = 55) to 860,000 (continent = NA, basin = 72), with a median of 30,000 (continent = AS; basin = 42).

3.5 Temporal Organization

Each lake is observed multiple times from different orbit passes during each 21-day SWOT cycle. The majority of lakes are observed no more than 5 times per SWOT cycle, though this varies significantly with latitude and is illustrated by Figure 3. A few lakes will never be observed with KaRIn HR data due to the lake's placement within the nadir gap, while other very high latitude (+70°) lakes may have up to 35 observations. Note however that lakes with 0 observations throughout the cycle will have fill values populating all SWOT-derived fields (see Section 5). Refer to section 3.5 of the the L2_HR_LakeSP Product Description Document (PDD) [9] for information on how lake information for individual passes is handled.

The L2_HR_LakeAvg product provides cycle average WSE, area, and storage change. Further details on how the average attributes are computed are given in Section 4. Because WSE is the fundamental measurement of SWOT, the minimum, maximum, and median WSE values are provided to better capture the distribution over the observation cycle (see Figure 4). Area and storage change are also provided for the passes corresponding to minimum, maximum, and median WSE, though of course, the pass with maximum WSE does not necessarily correspond to the maximum of the other quantities over the cycle .

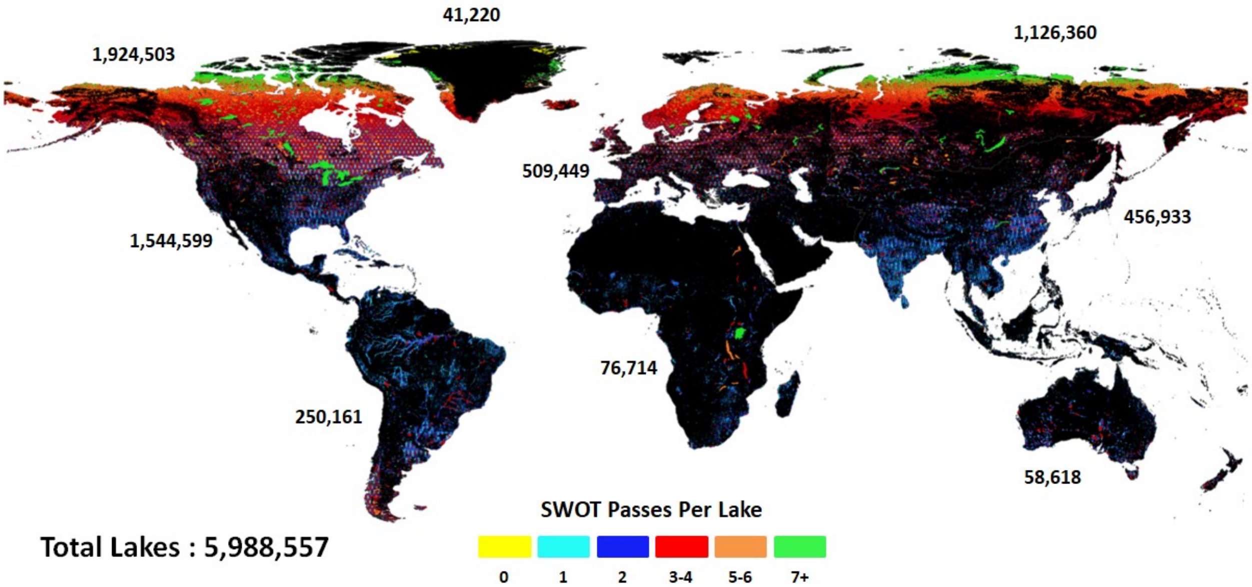

Figure 3. Number of observations per 21-day SWOT cycle for each lake contained in the PLD. Reproduced from [2]. Individual observations for a lake collected during the 21-day SWOT cycle are aggregated to form the lake average product.

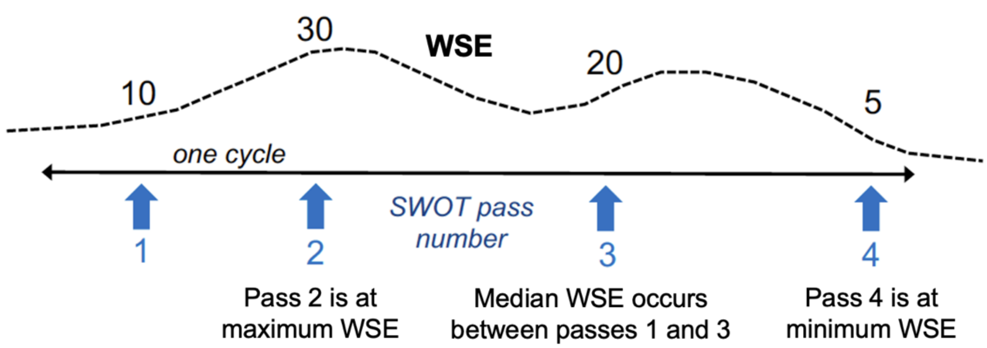

Figure 4. A notional example series of WSE measurements over one SWOT observation cycle. Over the course of one 21-day observation cycle, several SWOT passes will observe the same lake. The L2_HR_LakeAvg product will report the minimum (corresponding to Pass 4 observation), maximum (corresponding to Pass 2 observation), and median (corresponding to Pass 3 observation) WSE, corresponding to a full or a partial observation by SWOT. The area, and storage change values of the passes corresponding to maximum, minimum, and median WSE will also be reported. Furthermore, the mean WSE over all passes with valid WSE is computed .

Consequently, each lake record is associated to four time-tags corresponding to:

- The average time-tag of all measurements contributing to the record,
- The time-tag corresponding to the minimum water surface elevation observed during the cycle,
- The time-tag corresponding to the median water surface elevation observed during

the cycle,

- The time-tag corresponding to the maximum water surface elevation observed during the cycle.

The records are not time-ordered in the shapefile.

3.6 Spatial Organization

As noted above, each feature corresponds to a lake referenced by a geolocated polygon, computed as described in Section 4. This polygon is composed of one or more “rings” (using ESRI terminology); one outer ring defining the lake’s outer edge, and possibly also inner rings, delineating the boundaries of islands within the lake. The lake surface corresponds to the area inside the outer ring and outside any inner rings (Figure 5).

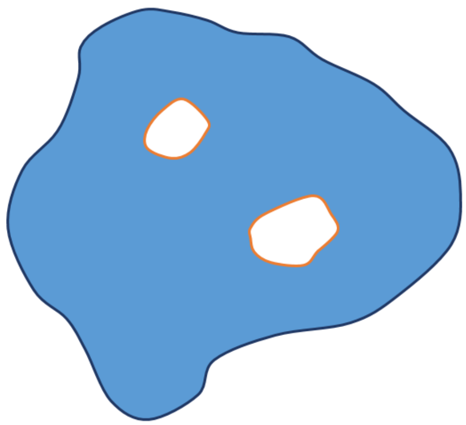

Figure 5. The lake surface (in blue) corresponds to the area comprised between the outer ring (i.e. the lake boundary, in dark blue) and any inner rings (i.e. possible islands, in orange).

The records of the L2_HR_LakeAvg shapefile are ordered by increasing PLD lake identifier (Section 4.2).

3.7 Volume

Table 3 provides the expected volume of the L2_HR_LakeAvg product.

The values provided in Table 3 are based on the following assumptions:

- The .dbf file for attributes represents **~484 bytes / lake**
- The size of the .shp shape file is 144 + 4*[number of lakes] + 16*[number of lakes]*[number of points per lake] bytes
- The .shx index file represents **100 + 8*[number of lakes] bytes**
- The number of points per polygon is considered to be ~100 on the average. As an example, in the lake *a priori* database over Europe, there are ~487 000 lake polygons, with a median number of 23 points, a mean of 51 points, and a maximum of 82 138

points; therefore, **100** points seems to be a conservative average estimate (i.e. with some margin).

- For the computation of the volume per granule (i.e. continent/level-2 basin), the following conservative numbers of lakes over a continent/level-2 basin granule were used:
    - **~30 138 lakes** as a median (continent = AS, basin = 42)
    - **~853 891 lakes** as a maximum (continent = NA, basin = 72)
- There are 60 L2_HR_LakeAvg granules per observation cycle.

Table 3. Description of the data volume of the L2_HR_LakeAvg product.

Shapefile	Name	Expected Median Volume/Granule (MB/basin)	Maximum Volume/Granule (MB/basin)	Expected Volume/cycle (GB)
1	LakeAvg product (all files in Table 1)	60	1707	11.7

4 Qualitative Description

Each L2_HR_LakeAvg vector product granule covers a Level-2 Pfafstetter basin and is derived from all intersecting L2_HR_LakeSP_Prior shapefiles [9] over a 21-day orbit cycle. These L2_HR_LakeSP_Prior products contain, for each observed PLD lake, the measured WSE, area, storage change and associated uncertainties, as well as its extent represented by a concave hull polygon. The principal goal of the L2_HR_LakeAvg product is to provide the corresponding cycle-average attributes and geometry. However, we have to take into account the fact that some of the observations may be partial, i.e. that part of an observed PLD lake may lie outside the effective swath for one or more passes within the cycle.

- The cycle-average WSE, *wse_avg*, is simply the average of all the valid WSE measurements of the lake in the cycle, including both full and partial observations.
  - Averaging of the corresponding time tags, i.e. for both full and partial observations of the lake, yields the cycle-average time tags *t_avg* and *t_tai_avg*.
- For the cycle-average lake geometry (polygon), it is extremely difficult to estimate the true average lake extent, and complicated to combine multiple input polygons in a precise and robust way, especially when some of them correspond to partial observations, so the following simplified approach has been adopted:
  - If the PLD lake has been fully observed at least once during the cycle, which is expected for more that 96% of the ~6 million currently referenced PLD lakes, then the polygon of the full observation whose WSE is closest to *wse_avg* is selected as the cycle-average polygon.
  - If the PLD lake has only been partially observed during the cycle, which is the case for ~20,000 lakes in the current PLD, then the cycle-average feature polygon is the combination (overlap) of all the input polygons.
  - If the PLD lake has not been observed during the cycle, which is expected for ~200,000 PLD lakes, then the cycle-average feature geometry is empty.
- Likewise, the cycle-average area, *area_avg*, is computed in the following way:
  - If the PLD lake has been fully observed at least once during the cycle, *area_avg* is set to the estimated *area_total* of the full observation whose WSE is closest to *wse_avg* (same observation as the retained polygon).
  - If the PLD lake has only been partially observed during the cycle, the area of the reconstructed polygon (overlap of all input polygons) is used.
  - If the PLD lake has not been observed during the cycle, *area_avg* is set to the fill value.
- The cycle-average storage change attributes *ds1_l_avg*, *ds1_q_avg*, *ds2_l_avg* and *ds2_q_avg* are based on the *wse_avg* and *area_avg* attributes as described above.

In addition to cycle average values, the L2_HR_LakeAvg product also includes three sets of measurements for each attribute and associated uncertainty, which are tied to the water surface elevation statistics. The three sets report the values of time, WSE, water surface area, and storage change observed when the WSE was at its minimum, median, and maximum values during the observation cycle. Note that there is no geometry associated with these minimum, median, and maximum attributes.

As an example, the measurement set and associated uncertainties at the time of the minimum observed WSE in the observation cycle contains: time stamp (*t_hmin, t_tai_hmin, t_str_hmin*), WSE (*wse_hmin, wse_hmin_u*), water surface area (*area_hmin, are_hmin_u*), and storage change under different hyptheses (*ds1_l_hmin*, *ds1lhmin_u*, *ds1_q_hmin*, *ds1qhmin_u*, *ds2_l_hmin*, *ds2lhmin_u*, *ds2_q_hmin*, and *ds2qhmin_u*). Further details on all these attributes are provided below.

The files that make up the shapefile format are described in Section 3.2. The format of the .shp file is specified in [6]. The .shp file provides geolocated polygons (latitudes and longitudes) defining lake boundaries as well as any island in it, derived from SWOT measurements. There is one record for each PLD-lake covered by the granule. Each corresponding record in the .dbf file contains attributes that can be conceptually grouped according to the subsections below.

The following conventions are applied to the attribute names:

- Prefix "*p_*" indicates that information is taken from the PLD,
- Suffix *"_f*" indicates a flag,
- Suffix *"_u*" indicates an uncertainty. Unless otherwise stated, all uncertainties represent one-sigma or 68th-percentile uncertainty estimates.
- Suffixes "*_hmin*", "*_hmed*", and "*_hmax*" indicates values respectively corresponding to minimum, median, and maximum water surface elevation.
- Suffix "*_avg*" indicates a cycle-average value.

Unless otherwise specified, quantities are given in SI (MKS) units. Note that surfaces are given in km^2 rather than m^2, and likewise volumes are given in km^3 rather than m^3.

Unlike the L2_HR_LakeSP product, the L2_HR_LakeAvg product does not distinguish between "Basic" or "Expert" attributes. The L2_HR_LakeAvg product was designed with simplicity in mind and is intended for global-scale studies.

4.1 Identifiers

The identifiers attributes are as follows:

- *lake_id*: Principal identifier of the records of the LakeAvg shapefile, corresponding to the PLD lake identifier. The format of the identifier is a 10-character string of the form **CBBNNNNNNT** where **C**=continent code, **BB**=basin code, **NNNNNN**=lake counter in the basin, and **T**=water body type.
- *reach_id*: If this PLD lake is a connected lake, this attribute provides the list of the identifiers of the river reaches (i.e. *reach_id* attribute in the PRD) of type "Connected lake" (i.e. ending with digit 3) that are related to it.

lake_id is based on the Pfafstetter coding system [10] that is constructed using the topology of river networks. The code allows digits 0-9 at each hierarchy level. Continent code (**C**) and water body type (**T**) codes are provided in Table 2 and Table 4, respectively. The geographical delineation of the continents is shown in Figure 2.

As indicated in Table 4, lakes are separated into two types, connected lakes (T=3) and disconnected lakes (T=2). Note that lake water bodies that are connected to the river topology (T=3) are included both in the L2_HR_LakeAvg product and in the L2_HR_RiverAvg product. Connectivity is defined specifically in relation to the PRD, so lakes that are termed disconnected (T=2) here may, in fact, be connected to a river network, but via channels too small to be included in the PRD.

Table 4. Water body type codes for the *lake_id* attribute.

Type Code (T)	Water Body Type
1	River *(not used in this product)*
2	Disconnected lake
3	Connected lake
4	Dam *(not used in this product)*
5	No topology *(not used in this product)*

The continent code (**C**) is Level 1 in the Pfafstetter code. As indicated in the template above, the *lake_id* value is based upon Pfafstetter Level 3, leading to 3 digits (**CBB**). Note that the continent codes in Table 2 are consistent with the continent coding used in the HydroBASINS product [7].

Figure 6 shows an example of what the coding may look like at Level 1 ($C = 7$) for the basin encompassing Mississippi (first level $B = 4$). Within each basin level, the lake is numbered with 000001 to a maximum of 999999 (i.e., a zero-padded six-digit number , represented as **NNNNNN**). Continent and basin polygons are available from [7].

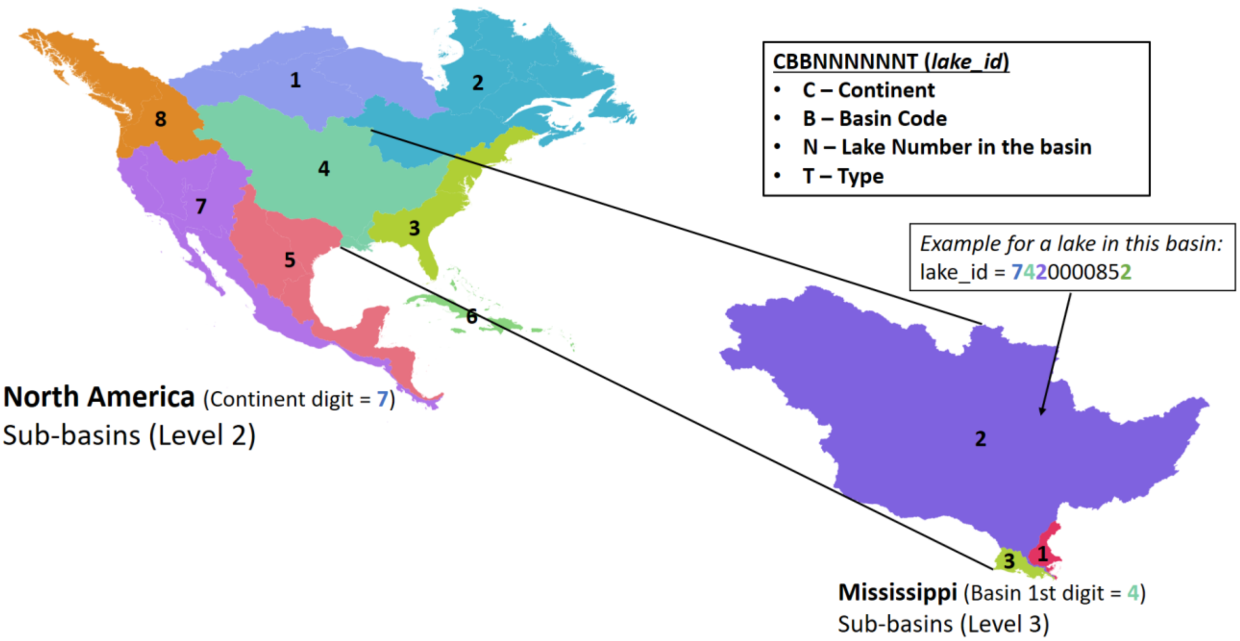

Figure 6. Example of the Pfafstetter basin coding system over North America, limited to the 3 first levels used in the identifiers of the lake products.

4.2 Prior Lake Database (PLD) information

Information from the PLD is provided in the product along with the measurements to allow easier connection or comparison with other data. The information sources, generation methods, and accuracies are described in [1].

- *lake_name*: Name(s) of the lake, retrieved from Open Street Map, IGN Carthage, GLWD and vMap0 databases. In cases where multiple names are given for a lake, these are separated with a semicolon.
- *p_res_id*: Reservoir identifier from the Global Reservoir and Dam (GRanD) database *[11]*. Note that if the PLD lake corresponds to a reservoir, its corresponding lake_id identifier ends with digit 3.

A prior reference location for each lake is provided with the PLD attributes *p_lat* and *p_lon* (i.e., the reference location is predefined, not a SWOT-measured quantity for a lake):

- *p_lon*: Geodetic longitude of the lake reference point, from the PLD. The longitude values become more positive to the east and more negative to the west of the Prime Meridian.
- *p_lat*: Geodetic latitude of the lake reference point, from the PLD. Positive latitude values increase northward from the equator. The latitude is defined with respect to the reference ellipsoid given by the .prj file.

The prior reference point, given by *p_lon* and *p_lat*, lies within the PLD polygon and maximises the distance to its contour (“deepest point”).

In addition, the LakeAvg shapefile contains prior information from the PLD that is needed to compute storage change (Section 4.6).

- *p_ref_wse*: Reference water surface elevation used to compute the storage change.
- *p_ref_area*: Reference water surface area used to compute the storage change.
- *p_date_t0*: UTC time of the first valid measurement for which storage change attributes, as described in Section 4.6, have been computed. Note that this time (date) does not necessarily correspond to the reference water surface elevation and area.
- *p_ds_t0*: Value used to translate the storage change values initially computed with respect to the p_ref_wse and p_ref_area of the PLD lake, to the storage change relative to p_date_t0.
- *p_storage*: Maximum water storage value, computed between the minimum and maximum observed levels of the lake. This field will be filled after one year of SWOT mission.

4.3 SWOT overpasses

The attributes are:

- *npass*: Number of valid SWOT overpasses during the observation cycle, i.e. with *wse* and *area_total* populated in the L2_HR_LakeSP product [9], and that are therefore used to compute the cycle average state. The value may change from one cycle to another, due to the orbit jitter, for example.
- *npass_full*: Number of valid passes fully covering the prior lake during the cycle.
- *pass_full*: List of valid passes fully covering the prior lake during the cycle. The different pass numbers are separated by semicolons.
- *npass_part*: Number of valid passes partially covering the prior lake during the cycle.
- *pass_part*: List of valid passes partially covering the prior lake during the cycle. The different pass numbers are separated by semicolons.

Note that *npass* is the sum of *pass_full* and *npass_part*.

4.4 Time

Numeric time tags for each measurement data record are provided in the UTC and TAI time scales using the attributes beginning with *t_* and *t_tai_* respectively, with a third time tag beginning with *t_str_*, which stores the UTC time as an ISO 8601 date string. A set of three time tags precedes each of the set of measurement statistics. The first set of time tags is associated with the cycle average observations as follows:

- *t_avg*: Average UTC time for the *npass* passes with valid water surface elevation in the observation cycle. The value is the average measurement time in seconds in the UTC time scale since 1 Jan 2000 00:00:00 UTC. The metadata field *tai_utc_difference* in the .shp.xml file gives the difference between the TAI and UTC reference time (in 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.

- *t_tai_avg*: Average TAI time for the *npass* passes with valid water surface elevation in the observation cycle. The value is the average measurement time in seconds in the TAI time scale since 1 Jan 2000 00:00:00 TAI. This time scale contains no leap seconds. The time difference (in seconds) between TAI and UTC at the time of the first measurement of the dataset is given by the metadata property *tai_utc_difference* of the *t_avg* attribute.
- *t_str_avg*: Average UTC time for the *npass* passes with valid water surface elevation in the observation cycle. This value is identical to *t_avg* but is represented as a string in the format YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time.

The second set of time tags represents the time instant when the water surface elevation was at its minimum level in the observation cycle. The three variables are named and defined as follows:

- *t_hmin*: UTC time corresponding to the mininum water surface elevation (*hmin*) in the observation cycle. The UTC time and metadata definitions are identical to that of *t_avg*.
- *t_tai_hmin*: TAI time corresponding to the mininum water surface elevation (*hmin*) in the observation cycle. The TAI and metadata definitions are identical to that of *t_tai_avg*.
- *t_str_hmin*: UTC time corresponding to the minimum water surface elevation (*hmin*) in the observation cycle. The UTC time definitions and string formatting are identical to that of *t_str_avg*.

The third set of time tags represents the time instant when the water surface elevation was at its median level in the observation cycle. The three variables are named and defined as follows:

- *t_hmed*: UTC time corresponding to the median water surface elevation (*hmed*) in the observation cycle. The UTC time and metadata definitions are identical to that of *t_avg*.
- *t_tai_hmed*: TAI time corresponding to the median water surface elevation (*hmed*) in the observation cycle. The TAI and metadata definitions are identical to that of *t_tai_avg*.
- *t_str_hmed*: UTC time corresponding to the median water surface elevation (*hmed*) in the observation cycle. The UTC time definitions and string formatting are identical to that of *t_str_avg*.

The fourth set of time tags represents the time instant when the water surface elevation was at its maximum level in the observation cycle. The three variables are named and defined as follows:

- *t_hmax*: UTC time corresponding to the maximum water surface elevation (*hmax*) in the observation cycle.
- *t_tai_hmax*: TAI time corresponding to the maximum water surface elevation (*hmax*) in the observation cycle.
- *t_str_hmax*: UTC time corresponding to the maximum water surface elevation (*hmax*) in the observation cycle. The UTC time definitions and string formatting are identical to that of *t_str_avg*.

The UTC time attributes have 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. For example, considering the *t_avg* time stamp:

- *t_tai_avg*[0] = *t_avg*[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 products granule. To account for this, the UTC time attributes also have 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 UTC time attributes exhibit 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 “0000-00-00T00:00:00Z”.

Table 5 below provides some examples for the values of *t_avg*, *t_tai_avg*, and *tai_utc_difference*. With this approach, the value of *t* has a 1 second regression during a leap second transition, while *t_tai* is continuous. That is, when a positive leap second is inserted, two different instances have the same value for the UTC time attribute, making UTC time attributes non-unique by themselves; the difference between *t_avg* and *t_tai_avg*, or the *tai_utc_difference* and *leap_second* metadata fields, can be used to resolve this.

Table 5. Examples of how UTC and TAI dates relate to *t_avg*, *t_tai_avg*, and the metadata field *tai_utc_difference.*

UTC Date	TAI Date	*t_avg*	*t_tai_avg*	*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 *t_avg* attribute is also given as string attribute (*t_str_avg*) with the following format: YYYY-MM-DDThh:mm:ssZ (with ‘Z’ suffix to indicate UTC time). The *t_avg* and *t_tai_avg* attributes maintain sub-second precision, but *t_str_avg* is truncated to one-second precision. The same conventions apply to the time stamps associated with *hmin*, *hmed*, and *hmax*.

4.5 Measured hydrological parameters

The L2_HR_LakeAvg product provides four sets of statistics for the hydrological attributes and their associated uncertainties computed over an observation cycle. The first set represents the mean conditions and uncertainties reported during the observation cycle: WSE (*wse_avg*, *wse_avg_u*), water surface area (*are_avg*, *are_avg_u*), and storage change (*ds[1|2]_[l|q]_avg*, *ds[1|2][l|q]_avg_u*; see Section 4.6). The second set reports the values of the hydrological attributes measured at the time of minimum WSE recorded within an observation cycle. These values are identified by the suffixes *_hmin* and *_hmin_u* for each attribute and their associated uncertainty. The remaining two sets provide hydrological attributes measured at the time of median (*_hmed*), and maximum (*_hmax*) WSE recorded within the cycle. Unless otherwise specified, all uncertainties represent one-sigma or 68th-percentile uncertainty estimates.

The WSE provided in this product is reported with respect to the Earth Gravitational Model 2008 (EGM2008) geoid model [15]. For details on the transformations between ellipsoid-relative height and geoid-relative height, the application of geophysical range corrections, and instrument corrections, see Section 4.1.3 of the L2_HR_LakeSP PDD. The attributes included in this product use the corresponding lake attributes in the L2_HR_LakeSP product to which such corrections were already applied.

A list of hydrology parameters, except for storage change-related attributes which are in section 4.6, followed by a short description of each attribute is presented below:

Lake attributes corresponding to average WSE:

- *wse_avg*: Average water surface elevation in the observation cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied. Computed using both full and partial observations.
- *wse_avg_u*: Estimated uncertainty in the average water surface elevation observed in the cycle.
- *area_avg*: Average water surface area in the observation cycle. If the PLD lake has been fully observed at least once during the cycle, area_avg is set to the estimated *area_total* of the full observation whose WSE is closest to *wse_avg*. If the PLD lake has only been partially observed during the cycle (*partial_f* is thus set to 1), the area of the reconstructed polygon is used.
- *area_avg_u*: Estimated uncertainty in the average water surface area in the observation cycle.

Lake attributes at minimum WSE:

- *wse_hmin*: Minimum water surface elevation in the observation cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied.
- *wse_hmin_u*: Estimated uncertainty in the minimum water surface elevation observed in the cycle.
- *area_hmin*: Water surface area measured during the pass containing the minimum water surface elevation in the observation cycle. This variable is corrected for the potential presence of dark water. If the lake has only been partially observed (*part_f_min* is thus set to 1), this corresponds to the area of the observed part of the prior lake.
- *are_hmin_u*: Estimated water surface area uncertainty during the pass containing the minimum water surface elevation in the observed cycle.

Lake attributes at median WSE:

- *wse_hmed*: Median water surface elevation observed in the cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied.
- *wse_hmed_u*: Estimated uncertainty in the median water surface elevation observed in the cycle.
- *area_hmed*: Water surface area measured during the pass containing the median water surface elevation in the observation cycle. This variable is corrected for the

potential presence of dark water. If the lake has only been partially observed (*part_f_med* is thus set to 1), this corresponds to the area of the observed part of the prior lake.

- *are_hmed_u*: Estimated water surface area during the pass containing the median water surface elevation in the observation cycle.

Lake attributes at maximum WSE:

- *wse_hmax*: Maximum water surface elevation observed in the cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied.
- *wse_hmax_u*: Estimated uncertainty in the maximum water surface elevation observed in the cycle.
- *area_hmax*: Water surface area measured during the pass containing the maximum water surface elevation in the observation cycle. This variable is corrected for the potential presence of dark water. If the lake has only been partially observed (*part_f_max* is thus set to 1), this corresponds to the area of the observed part of the prior lake.
- *are_hmax_u*: Estimated water surface area during the pass containing the maximum water surface elevation in the observation cycle.

4.6 Storage change

Cycle-average storage change is computed from the cycle-average water surface elevation and area provided by the *wse_avg* and area *area_avg* attributes (Section 4.5), with respect to the PLD lake's prior reference area and elevation provided in the *p_ref_area* and *p_ref_wse* attributes of the product (Section 4.2). The resulting value is then corrected by *p_ds_t0* to represent the storage change relative to the date of the first valid measurement *p_date_t0* (Figure 7). Note that the cycle-average storage change for a given PLD lake is not the average of the single-pass storage change estimates in the cycle.

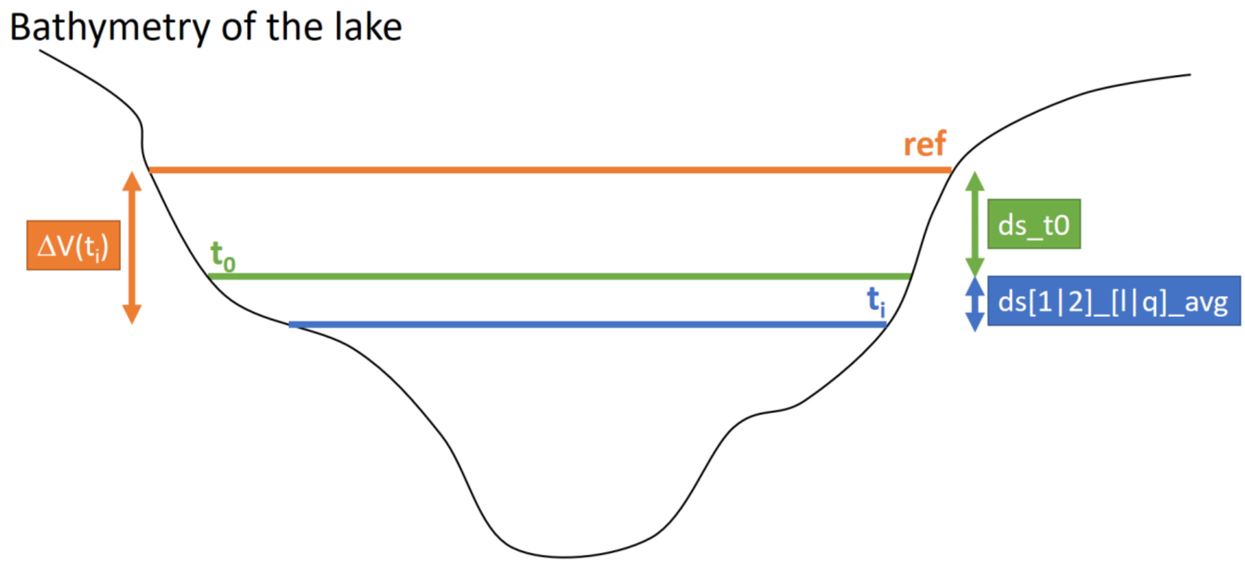

Figure 7. Storage change attributes are given with respect to the date of the first valid measurement *p_date_t0*.

As for single-pass storage change in the L2_HR_LakeSP product [9], cycle-average storage change is computed with two different approaches (directand incremental), and according to two hypotheses concerning the lake bathymetry model (linear and quadratic). This leads to the following attributes for cycle-average storage change:

- *ds1_l_avg*, *ds1l_avg_u*: Storage change and associated uncertainty, computed by the direct approach with the linear hypothesis for the bathymetry model.
- *ds1_q_avg*, *ds1q_avg_u*: Storage change and associated uncertainty, computed by the direct approach with the quadratic hypothesis for the bathymetry model.
- *ds2_l_avg*, *ds2l_avg_u*: Storage change and associated uncertainty, computed by the incremental approach with the linear hypothesis for the bathymetry model.
- *ds2_q_avg*, *ds2q_avg_u*: Storage change and associated uncertainty, computed by the incremental approach with the quadratic hypothesis for the bathymetry model.

The difference between the direct and incremental approaches is illustrated in [9].

As for other hydrological parameters, storage change is also reported at the time of the minimum, median, and maximum observed water surface elevation in the cycle:

- *ds1_l_hmin*, *ds1lhmin_u*: Storage change and associated uncertainty estimated during the pass containing the minimum water surface elevation in the observation cycle; computed by the direct approach with the linear hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*part_f_min* is thus set to 1).
- *ds1_q_hmin*, *ds1qhmin_u*: Storage change and associated uncertainty estimated during the pass containing the minimum water surface elevation in the observation cycle; computed by the direct approach with the quadratic hypothesis for the

bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*part_f_min* is thus set to 1).

- *ds2_l_hmin*, *ds2lhmin_u*: Storage change and associated uncertainty estimated during the pass containing the minimum water surface elevation in the observation cycle; computed by the incremental approach with the linear hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmin* is thus set to 1).
- *ds2_q_hmin*, *ds2qhmin_u*: Storage change and associated uncertainty estimated during the pass containing the minimum water surface elevation in the observation cycle; computed by the incremental approach with the quadratic hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmin* is thus set to 1).
- *ds1_l_hmed*, *ds1lhmed_u*: Storage change and associated uncertainty estimated during the pass containing the median water surface elevation in the observation cycle; computed by the direct approach with the linear hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmed* is thus set to 1).
- *ds1_q_hmed*, *ds1qhmed_u*: Storage change and associated uncertainty estimated during the pass containing the median water surface elevation in the observation cycle; computed by the direct approach with the quadratic hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmed* is thus set to 1).
- *ds2_l_hmed*, *ds2lhmed_u*: Storage change and associated uncertainty estimated during the pass containing the median water surface elevation in the observation cycle; computed by the incremental approach with the linear hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmed* is thus set to 1).
- *ds2_q_hmed*, *ds2qhmed_u*: Storage change and associated uncertainty estimated during the pass containing the median water surface elevation in the observation cycle; computed by the incremental approach with the quadratic hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmed* is thus set to 1).
- *ds1_l_max*, *ds1lhmax_u*: Storage change and associated uncertainty estimated during the pass containing the maximum water surface elevation in the observation cycle; computed by the direct approach with the linear hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmax* is thus set to 1).
- *ds1_q_hmax*, *ds1qhmax_u*: Storage change and associated uncertainty estimated during the pass containing the maximum water surface elevation in the observation cycle; computed by the direct approach with the quadratic hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmax* is thus set to 1).

- *ds2_l_hmax*, *ds2lhmax_u*: Storage change and associated uncertainty estimated during the pass containing the maximum water surface elevation in the observation cycle; computed by the incremental approach with the linear hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmax* is thus set to 1).
- *ds2_q_hmax*, *ds2qhmax_u*: Storage change and associated uncertainty estimated during the pass containing the maximum water surface elevation in the observation cycle; computed by the incremental approach with the quadratic hypothesis for the bathymetry model. Set to _FillValue if the prior lake has only been partially observed (*partf_hmax* is thus set to 1).

4.7 Quality indicators

The product contains flags indicating conditions that affect data quality. In general, flag values of zero indicate good data.

- *quality_f*: Quality flag with two possible states: 0 denotes that at least one valid SWOT observation was present in the cycle, allowing the computation of cycle average quantities, and 1 denotes that no valid SWOT observation was present in the cycle.
- *partial_f*: Flag that indicates whether the prior lake has been fully, partially or not observed during the cycle. 0= Indicates that the prior lake has been entirely covered at least once during the cycle; in this case, the *pass_full* attribute is populated. 1= Indicates that the prior lake has been only partially covered during the cycle; in this case, the *pass_full* attribute is set to “no_data” and the *pass_part* attribute is populated. -999= Indicates that the prior lake has not been observed during the cycle; in this case, the *pass_full* and *pass_part* attributes are set to “no_data”.
- *partf_hmin*: Flag that indicates partial lake coverage during the pass containing the minimum water surface elevation in the observation cycle. 0= Indicates that the observed lake has been entirely covered by the swath. 1= Indicates that the observed lake has been partially covered by the swath.
- *partf_hmed*: Flag that indicates partial lake coverage during the pass containing the median water surface elevation in the observation cycle. 0= Indicates that the observed lake has been entirely covered by the swath. 1= Indicates that the observed lake has been partially covered by the swath.
- *partf_hmax*: Flag that indicates partial lake coverage during the pass containing the maximum water surface elevation in the observation cycle. 0= Indicates that the observed lake has been entirely covered by the swath. 1= Indicates that the observed lake has been partially covered by the swath.

4.8 Geophysical references

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

The associated geophysical reference parameters include:

- *geoid_hght*: Model for geoid height above the reference ellipsoid whose parameters are given in the .prj file. The geoid model is EGM2008 *[12]*. The geoid model includes a correction to refer the value to the mean tide system (i.e., includes the zero-frequency permanent tide).

5 Detailed Content

The L2_HR_LakeAvg product adopts the Esri shapefile format and conventions [6]. 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 geographic data. In this section a description of the information in the .dbf file is given. This information is also stored in the .shp.xml file of the lake shapefile. The .shp.xml file provides 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 file is described in Appendix B.

5.1 Shapefile information

5.1.1 Dimensions

The headers of the .shp and .shx lake files give the number of 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 text). However, some attributes are multi-valued: *reach_id* and *p_name* attributes are given as character strings in a semicolon-separated list of the reaches from the PRD that intersect the PLD lake, and the different names given to the lake, 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”

5.1.3 Metadata

The unique, descriptive metadata for each attribute (e.g., expected minimum and maximum values; e.g., the equivalent of the NetCDF attributes *valid_min*, *valid_max*) and the global metadata (e.g., SWOT pass number) generally follow the conventions defined for other SWOT products and are given in Table 7 and Table 8, respectively. Since metadata cannot be stored inside the .dbf file, the .shp.xml file will provide 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.

Attribute	Description
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.
fill_value	The value used to represent missing or undefined data.
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.
type	Attribute type (int4, int9, float or text)
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)

Table 8. Global metadata fields of the L2_HR_LakeAvg product.

Attribute	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 lake average vector product
short_name	L2_HR_LakeAvg
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	SWOT-DD-CDM-0674-CNES_SAS_Design_L2_HR_LakeAvg - <version> - <date>
reference_document	SWOT-TN-CDM-0676-CNES_Product_Description_L2_HR_LakeAvg - <version> - <date>
product_version	Version identifier of this data file
crid	Composite release identifier (CRID) of the data system used to generate this file
pge_name	PGE_L2_HR_LakeAvg
pge_version	Version identifier of the product generation executable (PGE) that created this file
contact	Contact information for producer of product. (e.g., 'ops@jpl.nasa.gov').
cycle_number	Cycle number of the product.
continent_id	Two-letter continent identifier of the product granule.
continent_code	One-digit (C) continent code of the product granule.
basin_code	Two-digit (CB) basin code of the product granule (from HydroBASINS).
time_granule_start	Nominal starting UTC time of product granule. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ
time_granule_end	Nominal ending UTC time of product granule. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ

Attribute	Description
time_coverage_start	UTC time of first measurement. Format is: YYYY-MM-DDThh:mm:ss.ssssssZ
time_coverage_end	UTC time of last measurement. Format is: YYYY-MM-DDThh: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
xref_l2_hr_lakesp_files	Names of input Level 2 high rate lake single-pass files.
xref_prior_lake_db_file	Name of input prior lake database file.
xref_param_l2_hr_lakeavg_file	Name of input Level 2 high rate lake average processor configuration parameters file.

5.2 Attribute description

Table 9 lists the lake .dbf shapefile attributes (bold left-most column), and their associated metadata fields from Table 7. The attributes are separated into the eight categories listed in Sections 4.1 through 4.8. Appendix B contains a description of the shp.xml format that was used to generate this table.

Table 9. Attributes of the shapefile of the L2_HR_LakeAvg product.

Lake ID		
lake_id		
	type	text
	long_name	lake ID from prior database
	comment	Identifier of prior lake from the prior lake database. The format of the identifier is CBBNNNNNNT, where C=continent code, B=basin code, N=lake counter within the basin, T=type.
reach_id		
	type	text
	fill_value	“no_data”
	long_name	list of reach ID(s) intersecting this lake
	comment	If this prior lake is a connected lake, this attribute provides the list of the identifiers of the river reaches (i.e. reach_id attribute in the prior river database) of type “Connected lake” (i.e. ending with digit 3) that are related to it.
Prior Lake Database (PLD) Information		
lake_name		
	type	text
	fill_value	“no_data”
	long_name	name(s) of the lake
	comment	Name(s) of the lake, retrieved from Open Street Map, IGN Carthage, GLWD and vMap0 databases. The different names are separated by semicolons.
p_res_id		
	type	int9
	fill_value	-999999999999
	long_name	reservoir Id from GRanD database
	source	https://doi.org/10.1890/100125
	valid_min	0
	valid_max	10000
	comment	Reservoir ID from the Global Reservoir and Dam (GRanD) database. 0=The lake is not a registered reservoir.
SWOT overpasses		

npass		
	type	Int4
	fill_value	-999
	long_name	number of valid passes
	comment	Number of valid SWOT overpasses during the observation cycle, i.e. having wse and area_total populated in the LakeSP_Prior shapefiles.
npass_full		
	type	Int4
	fill_value	-999
	long_name	number of passes fully covering the lake
	comment	Number of valid SWOT overpasses fully covering the prior lake during the observation cycle, i.e. having partial_f=0 in the LakeSP_Prior shapefiles. This is the number of passes listed in the pass_full attribute.
pass_full		
	type	text
	fill_value	“no_data”
	long_name	list of passes fully covering the lake
	comment	List of valid SWOT overpasses fully covering the prior lake during the observation cycle. The different pass numbers are separated by semicolons.
npass_part		
	type	Int4
	fill_value	-999
	long_name	number of passes partially covering the lake
	comment	Number of valid SWOT overpasses partially covering the prior lake during the observation cycle, i.e. having partial_f=1 in the LakeSP_Prior shapefiles. This is the number of passes listed in the pass_part attribute.
pass_part		
	type	text
	fill_value	“no_data”
	long_name	list of passes partially covering lake
	comment	List of valid SWOT overpasses partially covering the prior lake during the observation cycle. The different pass numbers are separated by semicolons.
Attributes related to the cycle-average state		
t_avg		
	type	float
	fill_value	-999999999999
	long_name	average UTC time
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.000
	comment	Average UTC time for all passes with valid water surface elevation in the observation cycle. 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.
t_tai_avg		
	type	float
	fill_value	-999999999999
	long_name	average TAI time
	standard_name	time

	calendar	gregorian
	units	seconds since 2000-01-01 00:00:00.000
	comment	Average TAI time for all passes with valid water surface elevation in the observation cycle. 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 time difference (in seconds) between TAI and UTC at the time of the first measurement of the dataset is given by the metadata [t_avg:tai_utc_difference].
t_str_avg		
	type	text
	fill_value	“no_data”
	long_name	average UTC time
	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
	comment	Average UTC time for all passes with valid water surface elevation in the observation cycle. The format is YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time. [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.
wse_avg		
	type	float
	fill_value	-999999999999
	long_name	average water surface elevation with respect to the geoid
	units	m
	valid_min	-1000
	valid_max	100000
	comment	Average water surface elevation observed in the cycle.
wse_avg_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in average water surface elevation
	units	m
	valid_min	0
	valid_max	100
	comment	Uncertainty in the average water surface elevation observed in the cycle.
area_avg		
	type	float
	fill_value	-999999999999
	long_name	average water area
	units	km^2
	valid_min	0
	valid_max	200000
	comment	Average water area observed in the cycle. If the prior lake has only been partially observed during the cycle (“partial_f” is thus set to 1), this corresponds to the area of the reconstructed polygon.
area_avg_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in average water area
	units	km^2
	valid_min	0
	valid_max	200000

	comment	Uncertainty in the average water area observed in the cycle.
ds1_l_avg		
	type	float
	fill_value	-999999999999
	long_name	cycle-average storage change computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Storage change computed from the cycle-average state of the lake (given by “wse_avg” and “area_avg” attributes) with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1l_avg_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in cycle-average storage change computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in cycle-average storage change computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1_q_avg		
	type	float
	fill_value	-999999999999
	long_name	cycle-average storage change computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Storage change computed from the cycle-average state of the lake (given by “wse_avg” and “area_avg” attributes) with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds1q_avg_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in cycle-average storage change computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in cycle-average storage change computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds2_l_avg		
	type	float
	fill_value	-999999999999
	long_name	cycle-average storage change computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000

	valid_max	1000
	comment	Storage change computed from the cycle-average state of the lake (given by “wse_avg” and “area_avg” attributes) with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2l_avg_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in cycle-average storage change computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in cycle-average storage change computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2_q_avg		
	type	float
	fill_value	-999999999999
	long_name	cycle-average storage change computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Storage change computed from the cycle-average state of the lake (given by “wse_avg” and “area_avg” attributes) with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
ds2q_avg_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in cycle-average storage change computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in cycle-average storage change computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
partial_f		
	type	int4
	fill_value	-999
	long_name	partially covered lake flag
	flag_meanings	fully_covered partially_covered
	flag_values	0 1
	valid_min	0
	valid_max	1
	comment	Flag that indicates whether the prior lake has been fully, partially or not observed during the cycle. 0= Indicates that the prior lake has been entirely covered at least once during the cycle; in this case, the pass_full attribute is populated. 1= Indicates that the prior lake has been only partially covered during the cycle; in this case, the pass_full attribute is set to “no_data” and the pass_part attribute is populated. -999= Indicates that the prior lake has not been observed during the cycle; in this case, the pass_full and pass_part attributes are set to “no_data”.

Attributes corresponding to the minimum water surface elevation in the observation cycle (_hmin)		
t_hmin		
	type	float
	fill_value	-999999999999
	long_name	UTC time at the minimum water surface elevation
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.000
	comment	UTC time corresponding to the mininum water surface elevation (hmin) in the observation cycle. Time of measurement in seconds in the UTC time scale since 1 Jan 2000 00:00:00 UTC. [tai_utc_difference] is the difference between TAI and UTC reference time (seconds) for the first measurement of the data set. If a leap second occurs within the data set, the attribute leap_second is set to the UTC time at which the leap second occurs.
t_tai_hmin		
	type	float
	fill_value	-999999999999
	long_name	TAI time at the minimum water surface elevation
	standard_name	time
	calendar	gregorian
	units	seconds since 2000-01-01 00:00:00.000
	comment	TAI time corresponding to the mininum water surface elevation (hmin) in the observation cycle. 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 time difference (in seconds) between TAI and UTC at the time of the first measurement of the dataset is given by the metadata [t_hmin:tai_utc_difference].
t_str_hmin		
	type	text
	fill_value	“no_data”
	long_name	UTC time at the minimum water surface elevation
	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
	comment	UTC time corresponding to the mininum water surface elevation (hmin) in the observation cycle. The format is YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time. [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.
wse_hmin		
	type	float
	fill_value	-999999999999
	long_name	minimum water surface elevation with respect to the geoid
	units	m
	valid_min	-1000
	valid_max	100000
	comment	Minimum water surface elevation in the observation cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied.
wse_hmin_u		
	type	float

	fill_value	-999999999999
	long_name	uncertainty in the minimum water surface elevation
	units	m
	valid_min	0
	valid_max	100
	comment	Estimated uncertainty in the minimum water surface elevation observed in the cycle.
area_hmin		
	type	float
	fill_value	-999999999999
	long_name	water surface area at minimum water surface elevation
	units	km^2
	valid_min	0
	valid_max	200000
	comment	Water surface area measured during the pass containing the minimum water surface elevation in the observation cycle. If the lake has only been partially observed (“partf_hmin” set to 1), this corresponds to the area of the observed part of the prior lake. This variable is corrected for the potential presence of dark water.
are_hmin_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the water surface area at minimum water surface elevation
	units	km^2
	valid_min	0
	valid_max	200000
	comment	Estimated water surface area uncertainty during the pass containing the minimum water surface elevation in the observation cycle.
ds1_l_hmin		
	type	float
	fill_value	-999999999999
	long_name	storage change at minimum water surface elevation, computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the minimal state of the lake (given by “wse_hmin” and “area_hmin” attributes), corresponding to the pass containing the minimum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1lhmin_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at minimum water surface elevation, computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the minimum water surface elevation in the observation cycle, computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1_q_hmin		
	type	float

	fill_value	-999999999999
	long_name	storage change at minimum water surface elevation, computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the minimal state of the lake (given by “wse_hmin” and “area_hmin” attributes), corresponding to the pass containing the minimum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds1qhmin_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at minimum water surface elevation, computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the minimum water surface elevation in the observation cycle, computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds2_l_hmin		
	type	float
	fill_value	-999999999999
	long_name	storage change at minimum water surface elevation, computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the minimal state of the lake (given by “wse_hmin” and “area_hmin” attributes), corresponding to the pass containing the minimum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2lhmin_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at minimum water surface elevation, computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the minimum water surface elevation in the observation cycle, computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2_q_hmin		
	type	float
	fill_value	-999999999999
	long_name	storage change at minimum water surface elevation, computed by incremental approach with quadratic bathymetry model
	units	km^3

	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the minimal state of the lake (given by “wse_hmin” and “area_hmin” attributes), corresponding to the pass containing the minimum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
ds2qhmin_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at minimum water surface elevation, computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the minimum water surface elevation in the observation cycle, computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
partf_hmin		
	type	int4
	fill_value	-999
	long_name	partially covered lake flag at minimum water surface elevation
	flag_meanings	covered partially_covered
	flag_values	0 1
	valid_min	0
	valid_max	1
	comment	Flag that indicates partial lake coverage during the pass containing the minimum water surface elevation in the observation cycle. 0= Indicates that the observed lake has been entirely covered by the swath. 1= Indicates that the observed lake has been partially covered by the swath.
Attributes corresponding to the median water surface elevation in the observation cycle (_hmed)		
t_hmed		
	type	float
	fill_value	-999999999999
	long_name	UTC time at the median water surface elevation
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.000
	comment	UTC time corresponding to the median water surface elevation (hmed) in the observation cycle. Time of measurement in seconds in the UTC time scale since 1 Jan 2000 00:00:00 UTC. [tai_utc_difference] is the difference between TAI and UTC reference time (seconds) for the first measurement of the data set. If a leap second occurs within the data set, the attribute leap_second is set to the UTC time at which the leap second occurs.
t_tai_hmed		
	type	float
	fill_value	-999999999999
	long_name	TAI time at the median water surface elevation
	standard_name	time
	calendar	gregorian
	units	seconds since 2000-01-01 00:00:00.000

	comment	TAI time corresponding to the median water surface elevation (hmed) in the observation cycle. 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 time difference (in seconds) between TAI and UTC at the time of the first measurement of the dataset is given by the metadata [t_hmed:tai_utc_difference].
t_str_hmed		
	type	text
	fill_value	“no_data”
	long_name	UTC time at the median water surface elevation
	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
	comment	UTC time corresponding to the median water surface elevation (hmed) in the observation cycle. The format is YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time. [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.
wse_hmed		
	type	float
	fill_value	-999999999999
	long_name	median water surface elevation with respect to the geoid
	units	m
	valid_min	-1000
	valid_max	100000
	comment	Median water surface elevation in the observation cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied.
wse_hmed_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the median water surface elevation
	units	m
	valid_min	0
	valid_max	100
	comment	Estimated uncertainty in the median water surface elevation observed in the cycle.
area_hmed		
	type	float
	fill_value	-999999999999
	long_name	water area at median water surface elevation
	units	km^2
	valid_min	0
	valid_max	200000
	comment	Water surface area measured during the pass containing the median water surface elevation in the observation cycle. If the lake has only been partially observed (“partf_hmed” set to 1), this corresponds to the area of the observed part of the prior lake. This variable is corrected for the potential presence of dark water.
are_hmed_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the water surface area at median water surface elevation
	units	km^2

	valid_min	0
	valid_max	200000
	comment	Estimated water surface area uncertainty during the pass containing the median water surface elevation observed in the observation cycle.
ds1_l_hmed		
	type	float
	fill_value	-999999999999
	long_name	storage change at median water surface elevation, computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the median state of the lake (given by “wse_hmed” and “area_hmed” attributes), corresponding to the pass containing the median water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1lhmed_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at median water surface elevation, computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the median water surface elevation in the observation cycle, computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1_q_hmed		
	type	float
	fill_value	-999999999999
	long_name	storage change at median water surface elevation, computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the median state of the lake (given by “wse_hmin” and “area_hmin” attributes), corresponding to the pass containing the median water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds1qhmed_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at median water surface elevation, computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the median water surface elevation in the observation cycle, computed by the direct approach with the quadratic hypothesis for the bathymetry model.

ds2_l_hmed		
	type	float
	fill_value	-999999999999
	long_name	storage change at median water surface elevation, computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the median state of the lake (given by “wse_hmed” and “area_hmed” attributes), corresponding to the pass containing the median water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2lhmed_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at median water surface elevation, computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the median water surface elevation in the observation cycle, computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2_q_hmed		
	type	float
	fill_value	-999999999999
	long_name	storage change at median water surface elevation, computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the median state of the lake (given by “wse_hmed” and “area_hmed” attributes), corresponding to the pass containing the median water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
ds2qhmed_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at median water surface elevation, computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the median water surface elevation in the observation cycle, computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
partf_hmed		
	type	int4
	fill_value	-999
	long_name	partially covered lake flag at median water surface elevation

	flag_meanings	covered partially_covered
	flag_values	0 1
	valid_min	0
	valid_max	1
	comment	Flag that indicates partial lake coverage during the pass containing the median water surface elevation in the observation cycle. 0= Indicates that the observed lake has been entirely covered by the swath. 1= Indicates that the observed lake has been partially covered by the swath.
Attributes corresponding to the maximum water surface elevation in the observation cycle (_hmax)		
t_hmax		
	type	float
	fill_value	-999999999999
	long_name	UTC time at the maximum water surface elevation
	standard_name	time
	calendar	gregorian
	tai_utc_difference	[value of TAI-UTC at time of first record]
	leap_second	YYYY-MM-DD hh:mm:ss
	units	seconds since 2000-01-01 00:00:00.000
	comment	UTC time corresponding to the maximum observed water surface elevation (hmax) in the observation cycle. Time of measurement in seconds in the UTC time scale since 1 Jan 2000 00:00:00 UTC. [tai_utc_difference] is the difference between TAI and UTC reference time (seconds) for the first measurement of the data set. If a leap second occurs within the data set, the attribute leap_second is set to the UTC time at which the leap second occurs.
t_tai_hmax		
	type	float
	fill_value	-999999999999
	long_name	TAI time at the maximum water surface elevation
	standard_name	time
	calendar	gregorian
	units	seconds since 2000-01-01 00:00:00.000
	comment	TAI time corresponding to the maximum water surface elevation (hmax) in the observation cycle. 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 time difference (in seconds) between TAI and UTC at the time of the first measurement of the dataset is given by the metadata [t_hmax:tai_utc_difference].
t_str_hmax		
	type	text
	fill_value	“no_data”
	long_name	UTC time at the maximum water surface elevation
	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
	comment	UTC time corresponding to the maximum water surface elevation (hmax) in the observation cycle. The format is YYYY-MM-DDThh:mm:ssZ, where the Z suffix indicates UTC time. [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.
wse_hmax		
	type	float
	fill_value	-999999999999
	long_name	maximum water surface elevation with respect to the geoid

	units	m
	valid_min	-1000
	valid_max	100000
	comment	Maximum water surface elevation in the observation cycle relative to the provided model of the geoid, with corrections for media delays (wet and dry troposphere, and ionosphere), crossover correction, and tidal effects applied.
wse_hmax_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in maximum water surface elevation
	units	m
	valid_min	0
	valid_max	100
	comment	Estimated uncertainty in the maximum water surface elevation observed in the cycle.
area_hmax		
	type	float
	fill_value	-999999999999
	long_name	water surface area at maximum water surface elevation
	units	km^2
	valid_min	0
	valid_max	200000
	comment	Water surface area measured during the pass containing the maximum water surface elevation in the observation cycle. If the lake has only been partially observed ("partfh_max" is thus set to 1), this corresponds to the area of the observed part of the prior lake. This variable is corrected for the potential presence of dark water.
are_hmax_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in the water surface area at maximum water surface elevation
	units	km^2
	valid_min	0
	valid_max	200000
	comment	Estimated water surface area uncertainty during the pass containing the maximum water surface elevation in the observation cycle.
ds1_l_hmax		
	type	float
	fill_value	-999999999999
	long_name	storage change at maximum water surface elevation, computed by direct approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the maximal state of the lake (given by "wse_hmax" and "area_hmax" attributes), corresponding to the pass containing the maximum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by "p_ref_wse" and "p_ref_area" provided by the prior lake database). This attribute is computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1lhmax_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at maximum water surface elevation, computed by direct approach with linear bathymetry model

	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the maximum water surface elevation in the observation cycle, computed by the direct approach with the linear hypothesis for the bathymetry model.
ds1_q_hmax		
	type	float
	fill_value	-999999999999
	long_name	storage change at maximum water surface elevation, computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the maximal state of the lake (given by "wse_hmax" and "area_hmax" attributes), corresponding to the pass containing the maximum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by "p_ref_wse" and "p_ref_area" provided by the prior lake database). This attribute is computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds1qhmax_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at maximum water surface elevation, computed by direct approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the maximum water surface elevation in the observation cycle, computed by the direct approach with the quadratic hypothesis for the bathymetry model.
ds2_l_hmax		
	type	float
	fill_value	-999999999999
	long_name	storage change at maximum water surface elevation, computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the maximal state of the lake (given by "wse_hmax" and "area_hmax" attributes), corresponding to the pass containing the maximum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by "p_ref_wse" and "p_ref_area" provided by the prior lake database). This attribute is computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2lhmax_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at maximum water surface elevation, computed by incremental approach with linear bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000

	comment	Uncertainty in the storage change estimated during the pass containing the maximum water surface elevation in the observation cycle, computed by the incremental approach with the linear hypothesis for the bathymetry model.
ds2_q_hmax		
	type	float
	fill_value	-999999999999
	long_name	storage change at maximum water surface elevation, computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Estimated storage change computed between the maximal state of the lake (given by “wse_hmax” and “area_hmax” attributes), corresponding to the pass containing the maximum water surface elevation in the observation cycle, with respect to the reference state of the lake (given by “p_ref_wse” and “p_ref_area” provided by the prior lake database). This attribute is computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
ds2qhmax_u		
	type	float
	fill_value	-999999999999
	long_name	uncertainty in storage change at maximum water surface elevation, computed by incremental approach with quadratic bathymetry model
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Uncertainty in the storage change estimated during the pass containing the maximum water surface elevation in the observation cycle, computed by the incremental approach with the quadratic hypothesis for the bathymetry model.
partf_hmax		
	type	int4
	fill_value	-999
	long_name	partially covered lake flag at maximum water surface elevation
	flag_meanings	covered partially_covered
	flag_values	0 1
	valid_min	0
	valid_max	1
	comment	Flag that indicates partial lake coverage during the pass containing the maximum water surface elevation in the observation cycle. 0= Indicates that the observed lake has been entirely covered by the swath. 1= Indicates that the observed lake has been partially covered by the swath.
Quality Indicators		
quality_f		
	type	int4
	fill_value	-999
	long_name	summary quality indicator for lake cycle average
	flag_meanings	good bad
	flag_values	0 1
	valid_min	0
	valid_max	1
	comment	Summary quality flag for the lake cycle average. Values of 0 and 1 indicate nominal and off-nominal measurements.
Geophysical References		
geoid_hght		
	type	float

	fill_value	-999999999999
	long_name	geoid height
	standard_name	geoid_height_above_reference_ellipsoid
	source	EGM2008
	institution	GSFC
	units	m
	valid_min	-150
	valid_max	150
	comment	Lake-averaged geoid model height above the reference ellipsoid. The value is computed from the EGM2008 geoid model with a correction to refer the value to the mean tide system (i.e., includes the zero-frequency permanent tide).
Prior Lake Database (PLD) Information (cont.)		
p_lon		
	type	float
	long_name	longitude of the reference point within the prior lake
	units	degrees_east
	valid_min	-180.0
	valid_max	180.0
	comment	Longitude of the reference point within the prior lake.
p_lat		
	type	float
	long_name	latitude of the reference point within the prior lake
	units	degrees_north
	valid_min	-80.0
	valid_max	80.0
	comment	Latitude of the reference point within the prior lake.
p_ref_wse		
	type	float
	fill_value	-999999999999
	long_name	reference water surface elevation
	units	m
	valid_min	-1000
	valid_max	100000
	comment	Reference water surface elevation from the prior lake database, used to compute storage change.
p_ref_area		
	type	float
	fill_value	-999999999999
	long_name	reference water surface area
	units	km^2
	valid_min	0
	valid_max	500000
	comment	Reference water surface area from the prior lake database, used to compute storage change.
p_date_t0		
	type	text
	fill_value	“no_data”
	long_name	reference date for the storage change attributes
	comment	Reference date from the prior lake database for the storage change attributes, corresponding to the date of the first valid measurement. The format is YYYY-MM-DD.
p_ds_t0		
	type	float
	fill_value	-999999999999

	long_name	reference storage change
	units	km^3
	valid_min	-1000
	valid_max	1000
	comment	Reference storage change from the prior lake database used to translate the storage change values initially computed with respect to the p_ref_wse and p_ref_area of the prior lake, to the storage change relative to p_date_t0.
p_storage		
	type	float
	fill_value	-999999999999
	long_name	maximum water storage
	units	km^3
	valid_min	0
	valid_max	30000
	comment	Maximum water storage value from the prior lake database, computed between the minimum (or ground when a bathymetry is available) and maximum observed levels of the lake.

6 References

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Appendix A. **Acronyms**

ATBD	Algorithm Theoretical Basis Document
CNES	Centre National d’Études Spatiales
CRID	Composite Release Identifier
ECMWF	European Center for Medium-Range Weather Forecasts
GSFC	Goddard Space Flight Center
HR	High Rate
JPL	Jet Propulsion Laboratory
KaRIn	Ka-band Radar Interferometer
LR	Low Rate
L2	Level 2
PIXC	Pixel Cloud
PLD	Prior Lake Database
PRD	Prior River Database
RD	Reference Document
SAS	Science Algorithm Software
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
XML	Extensible Markup Language

WSE	Water Surface Elevation

Appendix B. **Description of XML files**

In the L2_HR_LakeAvg 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_LakeAvg 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_LakeAvg product does not have a standard representation for including such metadata. The L2_HR_LakeAvg product therefore includes metadata in an extensible markup language (XML) file that is produced alongside each shapefile (Section 3.2). That is, for the L2_HR_LakeAvg product, a .shp.xml (Table 1) XML file conveys the information provided in Tables 8 and 9 of this document.

This XML file 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.

This XML file also contains 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 XML file effectively reproduces the specific metadata fields pertaining to attributes that are provided in Table 9 and 10, and listed in Section 5.2 of this document. 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.

This XML file is 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_LakeAvg product, some fields do vary between granules (e.g., those involving leap seconds).

Examples are shown below for several XML elements of the .shp.xml file. 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_metadata>

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

   <title>Level 2 KaRIn high rate lake average vector product</title>
   <continent>EU</continent>.  <!-- From Table 2 -->
   <basin_identifier>21</basin_identifier>

   <!-- Other global metadata -->

   <!-- End of global metadata -->
   </global_attributes>

   <attribute_metadata>

   <!-- Individual entries for each attribute in Table 9 -->
   <!-- Each attribute uses metadata fields from Table 7 -->
   <!-- Example entries for the XML file: -->

      <lake_id>
         <type>text</type>
         <long_name>lake ID from prior database</long_name>
         <tag_basic_expert>Basic</tag_basic_expert>
    <comment>Identifier of prior lake from the prior lake database. The
format of the identifier is CBBNNNNNNT, where C=continent code,
B=basin code, N=lake counter within the basin, T=type.</comment>
   </lake_id>

   <wse_avg>
         <type>float</type>
         <fill_value>-999999999999</fill_value>
         <long_name>average water surface elevation with respect to the
geoid</long_name>
         <units>m</units>
         <valid_min>-1000</valid_min>
         <valid_max>100000</valid_max>
         <tag_basic_expert>Basic</tag_basic_expert>
         <comment>Average water surface elevation observed in the
cycle.</comment>
   </wse_avg>

   <!-- Metadata fields for other attributes in Table 9 -->

   <!-- End of attributes from Table 9  -->
   </attribute_metadata>
   </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 XML file on a Linux platform with this tool use the command line:

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

where LakeAvg.shp.xsl is an XSLT style sheet of the user’s choosing. An example of a LakeAvg.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_metadata">
       <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="attribute_metadata">
      <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>
```