HYDROCOASTAL Output Products - Readme file.

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1. Overview – Coverage

1.1 Introduction

Three data sets are available:

- HYDROCOASTAL Final Product: L2 along-track re-tracked product, L3 inland water level time series, L4 river discharge time series.
- HYDROCOASTAL Test Data Set: L2 along-track re-tracked product.
- HYDROCOASTAL CCN2 isardSAT coastal product.

1.2 HYDROCOASTAL Final Product

The HYDROCOASTAL final product is produced using innovative retracking algorithms for the coastal zone (UBonn Statistical STARS type) and inland waters (DTU - Multiple Waveform Persistent Peak -MWaPP), selected as the best performing algorithms tested earlier in the project.

The product is provided at 3 levels:

L2 - Level 2 Extended Product. Along track L2 product – for all regions in Table 1, except 15 (Alps)

L3 - Inland Waters, Water Level Time Series. For all inland water regions

L4 - Inland Waters, River Discharge Time Series for selected inland water regions

The product formats are described in the HYDROCOASTAL Product Specification Document, available at: https://www.satoc.eu/projects/hydrocoastal/docs.html

The Final product covers 25 regions (Table 1).

Table 1. Regions covered in the HYDROCOASTAL Final Product.

	Region Name	Country	Region Type	Re-tracker	Satellites and Mode	Product Available
Coastal Regions						
1	Venice Lagoon (N Adriatic)	Italy	Coastal	DTU / UBonn	S3A, S3B, CS2 SAR	L2E
2	Gulf of Thailand	Thailand	Coastal	DTU / UBonn	S3A, S3B, CS2 SAR	L2E
Coast / Estuaries / Rivers						
3	South Australia	South Australia	Coastal	DTU	S3A, S3B	L2E, L3(AHL)
4	German Bight / S Baltic / Elbe	Germany	Coastal / Estuary	DTU / UBonn	S3A, S3B, CS2 SAR	L2E
5	Severn Estuary	UK	Coastal / Estuary	DTU / UBonn	S3A, S3B, CS2 SAR	L2E

6	Wadden Sea / S North Sea	Germany	Coastal /Estuary	DTU / UBonn	S3A, S3B, CS2 SAR	L2E
7	Ebro Basin	Spain	River /lakes / coast	DTU / UBonn	S3A, S3B, CS2 SAR	L2E, L2WM(AHL), L3(DTU, AHL), L4 (CNR-IRPI)
8	Songhua/ Amur	China/ Russia	River &Estuary	DTU / UBonn	S3A, S3B, CS2 SAR	L2E, L2WM(AHL), L3(DTU, AHL), L4 (NUIM)
Rivers and lakes						
9	River Po	Italy	River	DTU	S3A, S3B, CS2 SAR	L2E, L2WM(AHL), L3(DTU, AHL)
10	Watson River	Greenland	River	DTU	S3A, S3B	L2E, L3(DTU, AHL)
11	Kolyma R	Russia	River	DTU	S3A, S3B	L2E, L3(DTU), L4 (NUIM)
12	Nadym R	Russia	River	DTU	S3A, S3B	L2E, L3(DTU, AHL), L4(NUIM)
13	Mackenzie	Canada	River	DTU	S3A, S3B	L2E, L3(DTU, AHL), L4(NUIM)
14	River Rhine	Germany	River	DTU	S3A, S3B, CS2 SAR	L2E, L2WM(AHL), L3(DTU, AHL), L4 (NUIM)
15	Amazon Basin & Estuary	Brazil	River	DTU	S3A, S3B, CS2 SAR	L2E, L2WM(AHL), L3(DTU, AHL)
16	White Nile	S Sudan	River	DTU	S3A, S3B	L2E, L3(DTU, AHL), L4(CNR-IRPI)
17	Garonne	FR	River	DTU	S3A, S3B	L2E, L3(DTU, AHL), L4(NUIM)
18	River Niger	various	River	DTU	S3A, S3B	L2E, L3(DTU, AHL), L4(CNR-IRPI)
19	Orange	South Africa	River	DTU	S3A, S3B	L2E, L3(DTU, AHL) L4(NUIM)
20	Ganges	Tibet, India, Bangladesh	River	DTU	S3A, S3B	L2E, L3(DTU, AHL) L4(CNR-IRPI)
21	Paraná	Argentina, Uruguay	River	DTU	S3A, S3B	L2E, L3(DTU, AHL) L4(NUIM)
22	Yenisei	Mongolia, Russia	River	DTU	S3A, S3B	L2E, L3(DTU, AHL) L4(NUIM)
23	Murray (S Australia) (subset of 3,	Australia	River	DTU	S3A, S3B	L2E L3(DTU, AHL), L4 (NUIM)

	processed to L4)					
24	Ireland Rivers and lakes	Ireland	River	DTU	S3A, S3B, CS2 SAR	L2E, L2WM(AHL), L3(DTU, AHL)
25	Yakutian Alasses	Russia	River	DTU	S3A, S3B	L2E, L3(DTU, AHL)

The source data are Sentinel 3A and Sentinel 3B SRAL L1a data, for all the operational mission to 30/09/2022 (S3A from 01/04/2016 to 30/09/2022, S3B from 11/05/2018 to 30/09/2022; South Australia starting from 01/01/2017) and Cryosat-2 SAR mode FBR data, for all the operational mission available in Baseline D (from 06/09/2010 to 21/08/2021).
Only Cryosat-2 SAR mode data have been processed. For some regions Cryosat-2 has not been in SAR mode and so no Cryosat-2 data are available.
Cryosat-2 SARIN data have NOT been processed as part of the final data set but were processed for the Test Data Set.
There are no L3 products for CryoSat-2, but subsets of L2 products falling into the water mask (named L2WM). L2WM(AHL) products also contain GSW/Occurrence values, Pfafstetter basin identifier (extracted from HydroBASINS database) and SWORD nodes & reaches metadata (from SWORD v15).

U Porto have provided new GPD+ wet and dry troposphere corrections, and these have been merged with the final products.

All algorithms are described in the HYDROCOASTAL Algorithm Theoretical Basis Document (ATBD), available online at: https://www.satoc.eu/projects/hydrocoastal/docs.html

1.3 HYDROCOASTAL Test Data Set

The HYDROCOASTAL Test Data Set are L2 products generated to evaluate the performance of five innovative new re-trackers. The Product is provided as **L2 - Level 2 Extended Product.** L2 output from all re-trackers implemented for each region is included in this product (See Table 2, column 4.

The product format is described in the HYDROCOASTAL Product Specification Document, available at: https://www.satoc.eu/projects/hydrocoastal/docs.html

The Test Data Set covers 17 regions (Table 2).

Table 2. Regions covered in the HYDROCOASTAL Test Data Set.

	Region Name	Country	Region Type	Re-tracker	Satellites and time coverage
TDS1-01	River Rhine	Netherlands, Germany	River	isardSAT, DTU, TUM, ICC-ER	C-2 SAR, S3A, S3B 2017– 2020
TDS1-02	River Danube	Hungary, Serbia, Romania, Bulgaria	River	isardSAT, DTU, TUM, ICC-ER	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-03	River Amazon	Brazil	River	isardSAT, DTU, TUM, ICC-ER	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-04	River Ob	Russia	River	isardSAT, DTU, TUM, ICC-ER	C-2 SAR, S3A, S3B 2017– 2020
TDS1-05	River Po	Italy	River	isardSAT, DTU, TUM, ICC-ER	C-2 SAR, S3A, S3B 2017– 2020

TDS1-06	River Yangzte	China	River	isardSAT, DTU, TUM	S3A, S3B 2018 – 2020
TDS1-07	Mississippi	USA	River	isardSAT, DTU, TUM	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-08	Nonacho Lake	Canada	Lake	isardSAT, DTU, TUM, ICC-ER	S3A, S3B 2018 – 2020
TDS1-09	River Amur /Songhua	China, Mongolia, Russia	River	isardSAT, DTU, TUM, ICC-ER	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-10	Greece (Aegean)	Greece	Coastal / SARin	Aresys	C-2 SARin 2018 – 2020
TDS1-11	Reindeer Lake	Canada	Lake	isardSAT, DTU, TUM, ICC-ER	S3A, S3B 2018 – 2020
TDS1-12	Zambezi River	Zambia, Mozambique	River	isardSAT, DTU, TUM	S3A, S3B 2018 – 2020
TDS1-13	German Bight, / S Baltic	Germany	Coastal	isardSAT, DTU, TUM, UBonn, ICC-ER	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-14	California Coast	USA	Coastal	isardSAT, DTU, TUM, UBonn	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-15	Gibraltar (Huelva and Bonanza)	Spain	Coastal, Estuary	isardSAT, DTU, TUM, UBonn	S3A, S3B 2018 – 2020
TDS1-16	Cadiz (Tarifa)	Spain	Coastal	isardSAT, DTU, TUM, UBonn	C-2 SAR, S3A, S3B 2018 – 2020
TDS1-17	Caspian Sea	Russia	Inland Sea	isardSAT, DTU, TUM	C-2 SAR, S3A, S3B 2018– 2019

The source data are Sentinel 3A and Sentinel 3B SRAL L1a data, and Cryosat-2 SAR mode FBR Baseline D data. The Test Data Set contain 3 years' data (June 2017 to May 2020) for the Rhine, Ob, and Po regions, 1 year's data for the Caspian (December 2018 to November 2019) and 2 years' data (June 2019 to May 2020) for all other regions.

U Porto have provided new GPD+ wet and dry troposphere corrections, and these have been merged with the test data set products.

All algorithms are described in the HYDROCOASTAL Algorithm Theoretical Basis Document (ATBD), available online at: https://www.satoc.eu/projects/hydrocoastal/docs.html

1.4 HYDROCOASTAL CCN2 isardSAT Coastal Data Set

The third data set is a coastal data set produced by isardSAT, generated from Sentinel-6 data. There are two components, an L2 data set produced by the isardSAT CORS Delay Doppler (DD) Coastal Processor for three regions: Aegean Sea, Baltic Sea, California Coast, from cycle 5 to cycle 42, and a Fully Focused SAR data set for a single Sentinel-6 track in the Aegean Sea, from cycle 37 to cycle 41. Fully Focused SAR data set includes L1b FF products, L2 data produced from L1b FF by the isardSAT's CORS retracker, and L2 data produced from L1b FF by the isardSAT's analytical retracker.

2. How to Access

The HYDROCOASTAL Final Data Products are available through the Altimeter Virtual Laboratory Web Pages, at:

https://avl-repo.earthconsole.eu/sarvatore/Hydrocoastal/

2.1 Folder Structure

The parent folder (“Hydrocoastal”) contains 5 top-level folders "L2E", "L3", "L4", "Test Data Set" and “HYDROCOASTAL_CCN2”.

Final Product L2E (Level 2 Extended Format)
All final L2E product data are under the top-level folders “s3_full” (Sentinel 3A and 3B data), and “cs2_full” (Cryosat-2 SAR mode data). Under these top-level folders are zip files containing all the data for each region.

L3 (Level 3 Inland Water Time Series)
All final L3 products are under top level folders “L3_DTU” and “L3_AHL”.
Under the L3_DTU are separate zip files for River level time series from Sentinel-3 data (S3_Rivers.zip), River level time series from Cryosat-2 data (C2_Rivers.zip), and lake water level time series from both Sentinel-3 and Cryosat-2 data (S3_C2_Lakes.zip).
Under the L3_AHL are separate zip files for River level time series from Sentinel-3 data (S3_Rivers.zip) and River level time series from Cryosat-2 data (C2_Rivers.zip).

L4 (Level 4 Inland Water River Discharge Time Series)
Final L4 River Discharge products are under folders
“L4_NUIM_Global_Product”, “L4_NUIM_TestSites_ResearchProduct”,
“L4_CNR_Global_Product”, and “L4_CNR_TestSites_ResearchProduct”.

The products are provided as netcdf files, contents and processing as described below in Section 4.

Test Data Set Product L2E (Level 2 Extended Format)
The Test Data Set L2E product is under the top-level folder “Test Data Set”. Under here are two folders “s3_combined_reduced” and “cs2_combined_reduced”, containing Sentinel-3 and Cryosat-2 data respectively. Under these folders are zip files containing all the data for each region.

CCN2 isardSAT Coastal Data Set L2 Product
The CCN2 isardSAT Coastal Data Sets are under the top-level folder “HYDROCOASTAL_CCN2”. Under here are two folders “FF coastal” and “DD coastal”. Under these folders are zip files containing L1b and L2 products from the Fully Focused SAR, and L1b and L2 products from Delay Doppler respectively. L2 data produced by the isardSAT’s CORS retracker are under the sub folder “coastal_processing” for Delay Doppler and under the sub folder “L2_isd_coastal” for Fully Focused SAR. L2 data produced by the isardSAT’s analytical retracker are under the sub folder “L2_isd” for Delay Doppler and under the sub folders “SL04_ML300_fromL1B”, “SL04_10”, and “SL1_ML10” for the different configurations of Fully Focused SAR.

3. Final Product L2 Data Format and content

L2 data are provided in HYDROCOASTAL L2E format. See the HYDROCOASTAL Product Specification Document at: https://www.satoc.eu/projects/hydrocoastal/docs.html

Final Product

For regions which include coastal / estuary parts, both DTU and U Bonn re-trackers have been implemented. Where they have provided a valid solution, L2 output from both re-trackers are included in the merged final product, together with the operational ESA L2 solution (resp. L2 LAND for S3 mission and L2 ICE Baseline D for CryoSat-2 mission; L2 WAT for South Australia), interpolated on to the HYDROCOASTAL along-track locations.

For regions only over inland water, only the DTU re-tracker has been applied. For these regions the L2E merged product includes the DTU and operational ESA L2 output.

4. L3 Data Format and content

L3 products are processed using two different L3 processors: one from AltiHydroLab.fr (AHL) and another one from DTU Space. We provide outline format content descriptions below, for full details read the Product Specification Document at: https://www.satoc.eu/projects/hydrocoastal/docs.html

4.1 DTU

DTU provide the inland water data processed into four formats, which are described in full in the HYDROCOASTAL Product Specification Document:

A: river water level time series (L3) for Sentinel-3A (S3A) and -3B (S3B)
B: extracted river water levels (L2) for S3A and S3B
C: extracted and reduced river water levels from CryoSat-2
D: a combined S3A, S3B, and Cryosat-2 lake level time series (L3) (so far just for Ireland)

4.2 AHL

a. CryoSat-2 / L2WM (AHL)

The CryoSat-2 L2WM products from AHL are organised as concatenated subsets of L2E products coordinates (time, lon, lat) for the L2E measurement falling into the Water Mask.
There are as many L2WM files as L2E files, except for locations where the L2E files do not intersect the HydroBASINS and/or the SWORD databases.
Inside a L2WM file, each block of data, called an “overflight”, is assigned an “overflight identifier” and metadata from various databases.

b. Sentinel-3 A&B / L3 (AHL)

The Sentinel-3 A&B L3 products from AHL are organised as one file per ROI/basin (some ROI spans two basins and thus have two files). The basin information is extracted from HydroBASINS database making each file hydrologically consistent (i.e., the data in one file never crosses basin’s boundaries).
Inside the L3 AHL files are a series of Virtual Stations data. For each virtual station, there are two time series of the river water level: one based on the DTU re-tracker and one based on the original ESA re-tracker.

5. L4 Data Format and content

5.1 NUIM

NUIM provides two types of L4 products:

1) Research product for three test sites: Salekhard (Ob), Memphis (Mississippi) and Pontelagoscuro (Po). For these sites the discharge was estimated by three methods: rating

curve (RC), Bjerklie method (BJ) and Manning method (Man), using DTU L3 test dataset and river width retrieved by NUIM from Landsat-8 and Sentinel-1 images. This product does not contain the information about uncertainties.

2) Global L4 product for 11 sites on large, medium and small rivers: Arctic Red River (Mackenzie), Igarka (Yenissey), Chapeton (Parana), Pella Mission (Orange), Lock 1 Downstream (Murray), La Reole (Garonne), Salekhard (Ob), Mainz (Rhine), Nadym (Nadym), Khabarosk (Amur), Kolymskoe (Kolyma).

The discharge values for these sites, located in different climate conditions, were retrieved using the rating curve method, which demonstrated the lowest errors among the methods evaluated on the test sites. The Q retrievals from several VS located within ~200 km river stretch were merged in one time series and sorted by **time**. The Q for an individual VS can be extracted based on **vs_id** variable. The VS ID corresponds to the VS ID of Global L3 product.

It is worth noting that the calculated discharge is referred to the location of the ground station used for calibration and not to the location of the satellite virtual stations. The ground station name and coordinates can be found in the Global L4 product only in the **Station information** global attribute.

5.2 CNR-IRPI

CNR-IRPI provides two types of L4 products:

1) Research product for 12 test sites: Salekhard (Ob R.), Chester, Thebes, Memphis (Mississippi R.), Piacenza, Cremona, Borgoforte, Sermide, Pontelagoscuro (Po R.), Worms, Kaub, Mainz (Rhein R.).

2) Global L4 product for 12 sites: Tortosa, Zaragoza, Gelsa, Ascò (Ebro R.), Bahadurabad, Baruria, Hardinge Bridge (Gange and Brahmaputra R.), Lokoja, Makurdi, Onitsha (Niger R.), Abu Tong, Malakal (White Nile R.).

For these sites the discharge was estimated by three methods: rating curve starting from the altimetry water level (RC), rating curve from the CM indices (CM), merge approach from altimetry and reflectance combination (Merge). The water level from altimetry is derived by DTU L3 dataset, whereas CM indices from MODIS Aqua and Terra and Sentinel-2 images provided by CNR-IRPI.

It is worth noting that the calculated discharge is referred to the location of the ground station used for calibration and not to the location of the satellite virtual stations. The ground station name and coordinates can be found in the Global L4 product only in the **Station information** global attribute.

6. L2 Test Data Set Format and Content

For the Test Data Set, Table 2 lists which re-trackers were implemented in which regions. L2 outputs from all re-trackers used are included in the output product.

7. L2 CCN2 isardSAT Coastal Data Set Format and Contents

There are two components to the CCN2 isardSAT Coastal Data Set:

- L2 data set produced by the isardSAT CORS Delay Doppler (DD) Coastal Processor for three regions: Aegean Sea, Baltic Sea, California Coast. The data processed are Sentinel-6 cycles 5-42.
- Fully Focused SAR processed data set for a single Sentinel-6 track in the Aegean Sea (pass 94), cycles 37-41

The data are described in two HYDROCOASTAL documents:
Coastal and FF-SAR processing of S6 data -*Test Data Set,* CCN#2, deliverable D1
Coastal and FF-SAR processing of S6 data - *Technical Note,* CCN#2, deliverable D2
Both documents are available online at
https://www.satoc.eu/projects/hydrocoastal/docs.html