HYDROCOASTAL

SAR/SARin Radar Altimetry for Coastal Zone and Inland Water Level

Input Output Data Definitions
Deliverable D2.1

Sentinel-3 and Cryosat SAR/SARin Radar Altimetry for Coastal Zone and Inland Water

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1 Introduction

1.1 The HYDROCOASTAL Project

The HYDROCOASTAL project is a project funded under the ESA EO Science for Society Programme, and aims to maximise the exploitation of SAR and SARin altimeter measurements in the coastal zone and inland waters, by evaluating and implementing new approaches to process SAR and SARin data from CryoSat-2, and SAR altimeter data from Sentinel-3A and Sentinel-3B.

One of the key objectives is to link together and better understand the interactions processes between river discharge and coastal sea level. Key outputs are global coastal zone and river discharge data sets, and assessments of these products in terms of their scientific impact.

1.2 Scope of this Report

This is the Input Output Data Definitions (IODD) report for HYDROCOASTAL and represents D2.1 of the project.

The scope of this document is to describe the Input and Output Products' definitions of each of the processors in the HYDROCOASTAL project. The detailed output product format parameters are included in HYDROCOASTAL Deliverable 2.3 PSD (Product Specification Document) (RD-08).

For more details regarding the algorithms of the processor, please refer to the HYDROCOASTAL Delivery 1.3 ATBD document (RD-06). For an extensive description of the configuration and options, please refer to the HYDROCOASTAL Delivery POCCD (RD-07).

1.3 Applicable Documents

AD-01 Sentinel-3 and CryoSat SAR/SARin Radar Altimetry for COASTAL ZONE and INLAND WATER - Statement of Work, V1.0 10/01/2019 Ref: EOP-SD-SOW-2018-089

1.4 Reference Documents

RD-01 HYDROCOASTAL Technical Proposal. V1.1 28/11/2019, SatOC and HYDROCOASTAL team.

RD-02 HYDROCOASTAL Implementation Proposal. V1.1 28/11/2019, SatOC and HYDROCOASTAL team.

RD-03 HYDROCOASTAL Management Proposal. V1.3 26/11/2019, SatOC and HYDROCOASTAL team

RD-04 HYDROCOASTAL Financial Proposal. V1.2 28/11/2019, SatOC and HYDROCOASTAL team

RD-05 HYDROCOASTAL Contractual Proposal. V1.2 26/11/2019, SatOC and HYDROCOASTAL team

RD-06 HYDROCOASTAL Deliverable 1.3 ATBD (Algorithm Theoretical Basis Document). V1.1 08/10/2020, isardSAT and HYDROCOASTAL team.

RD-07 HYDROCOASTAL Deliverable POCCD (Processing Options Configuration Control Document). V1.1 08/10/2020, isardSAT and HYDROCOASTAL team.

RD-08 HYDROCOASTAL Deliverable 2.3 PSD (Product Specification Document). V1.1 08/10/2020, isardSAT and HYDROCOASTAL team.

RD-09 CryoSat characterisation for FBR users, C2-TN-ARS-GS-5179 v2. (https://wiki.services.eoportal.org/tiki-download_wiki_attachment.php?attId=4233&page=CryoSat%20Technical%20Notes&download=y)

RD-10 CryoSat Ice netCDF L2 Product Format Specification, CRYOSAT Ground Segment Instrument Processing Facility L2 (https://earth.esa.int/documents/10174/125273/CryoSat-Ice-L2-Product-Specification.pdf)

RD-11 Product Data Format Specification SRAL/MWR Level 2 Land products, Preparation and Operations of the Mission Performance Centre (MPC) tor the Copernicus Sentinel-3 Mission (https://earth.esa.int/documents/247904/2753172/Sentinel-3-Product-Data-Format-Specification-Level-2-Land)

RD-12 Sentinel 3 Product Data Format Specification Level 1 (https://sentinel.esa.int/documents/247904/2753172/Sentinel-3-Product-Data-Format-Specification-Level-1-products)

RD-13 CryoSat Ice netCDF L1B Product Format Specification [PFS-I-L1B] (https://earth.esa.int/documents/10174/125273/CryoSat-netCDF-L1b-Product-Format-Specification.pdf)

RD-14 HYDROCOASTAL Deliverable 2.2 PDL (Parameter Data List). V1.1 08/10/2020, isardSAT and HYDROCOASTAL team.

RD-15 Pekel J-F, Cottam A, Gorelick N, Belward AS (2016) High-resolution mapping of global surface water and its long-term changes. Nature 540:418–422. (https://doi.org/10.1038/nature20584)

1.5 Document Organisation

This document is organised as follows:

- Section 1 (this section) is a short introduction defining the scope of this report.
- Section 2 includes the general definition of ESA products and variable types.
- Section 3 includes the definition of the empty L2 Enhanced Master product.
- Section 4 details the L2 Processors Inputs & Outputs specification.
- Section 5 details the final merging of L2 intermediate products.
- Section 6 details the L3 River Processor (AHL) input and output specifications.
- Section 7 details the L3 River Level (DTU Space) input and output specifications.
- Section 8 details the L4 River Discharge (NUIM) input and output specifications.

- Section 9 details the L4 River Discharge (CNR) input and output specifications.
- The last section includes the list of acronyms.

2 General Definitions

2.1 General Product Definitions

Based on the ESA product definition and more specifically on Sentinel-3 Mission, five levels of data can be found:

- Level-1A products containing unpacked L0 complex echoes that have been sorted and calibrated. Geo-location information is included in this product.
- Level-1B-S contain geo-located, calibrated, azimuth processed complex echoes after geometric correction application arranged in stacks and before power averaging (multilooking). Relevant ancillary data (e.g., beam angles, calibration information, statistical description of stack,…) are included.
- Level-1B products include the SAR averaged measurements (20 Hz).
- Level-2 products are the Level 1 products re-tracked and with the geophysical corrections applied to give the final altimeter parameters including range, backscatter coefficient, wind speed and significant wave height.
- Level-3 River Level products are the Level 2 products processed to produce River Level Time Series, or space-time series.
- Level-4 HYDROCOASTAL products are the Level 3 products processed to produce Time Series of River Discharge.

2.2 Variable Types

Table 2.1 Variable Types

Variable Type	Description	Range
uc	8-bit unsigned integer (ubyte)	0 to 255
sc	8-bit signed integer (byte)	-128 to 127
us	16-bit unsigned integer	0 to 65535
ss	16-bit signed integer	-32768 to 32767
ul	32-bit unsigned integer	0 to 4294967295
sl	32-bit signed integer	-2147483648 to 2147483647
sll	64-bit signed integer	-9223372036854775808 to 9223372036854775807
fl	32-bit single precision floating point	1.17549e-38 (min) 3.4028e+38(max)
do	64-bit double precision floating point	2.22e-308(min) 1.79e+308(max)

3 Definition of the empty L2 Enhanced Master product

3.1 Overview of Processing Scheme

This module is in charge of processing radar altimeter satellite data either from L1A (S3), from FBR (CS2-SAR) or from L1B (CS2-SARIN). Its aim is to process this data in order to obtain an *empty* L2 enhanced Master product, which includes essentially the L1B/L1B(s) waveforms and some parameters of the official L2 products. These official L2 products are integrated to the *empty* L2 enhanced Master product file after an interpolation process as described in the HYDROCOASTAL Deliverable 1.3 ATBD [RD-06], Section 11.

Figure 3.1 shows a block diagram of this module.

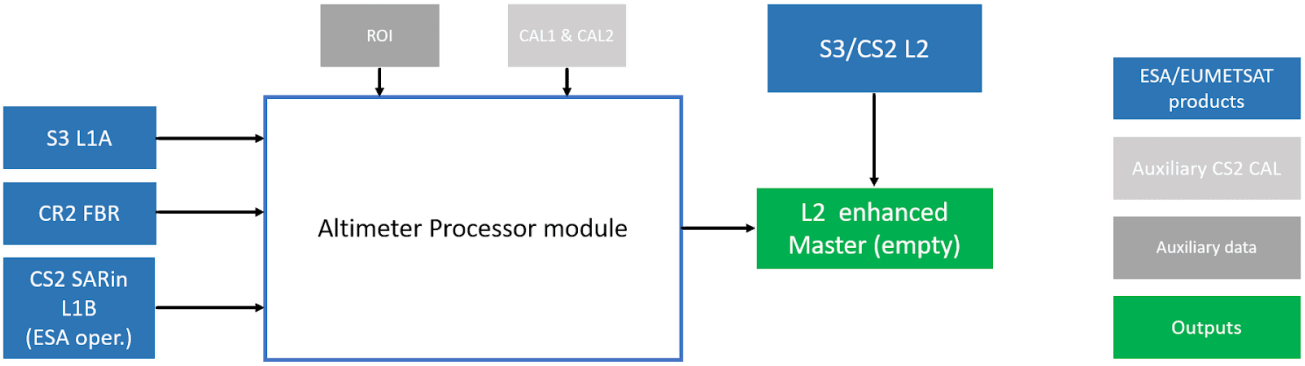

Figure 3.1. Block diagram of the L2 data flow.

3.2 Input Data Specification

This module requires the following list of input files.

3.2.1 Altimer burst mission products

The radar altimeter burst data is found in different files depending on the satellite (Sentinel-3 or Cryosat-2) and on the operating mode (SAR or SARin). The inputs required depending on the kind of input file are described in the following sections.

3.2.1.1 Sentinel 3 L1A data

The list of variables from the S3 L1A input file that are of interest for this module are presented in Table 3.1. Full details are found in the Sentinel 3 Product Data Format Specification Level 1[1] [RD-12].

Table 3.1: List of inputs of interest from S3 L1A file.

Variable name	Description
echo_sample_ind	Number of samples in I2+Q2, I and Q echoes
sar_ku_pulse_burst_ind	Number of Ku-band pulses per burst in SAR mode
sar_c_pulse_burst_ind	Number of C-band pulses per burst in SAR mode
ltm_max_ind	Maximum number of LTM Cal1 or Cal2 tables
time_l1a_echo_sar_ku	TAI seconds since 2000-01-01 00:00:00.0
UTC_day_l1a_echo_sar_ku	Days since 2000-01-01 00:00:00.0
UTC_sec_l1a_echo_sar_ku	Seconds in the day UTC
UTC_time_20hz_l1a_echo_sar_ku	UTC seconds since 2000-01-01 00:00:00.0
isp_coarse_time_l1a_echo_sar_ku	ISP coarse time
isp_fine_time_l1a_echo_sar_ku	ISP fine time
flag_time_status_l1a_echo_sar_ku	Time status flag (synchronisation / no_synchronisation)
sral_fine_time_l1a_echo_sar_ku	ISP SRAL fine datation
lat_l1a_echo_sar_ku	Latitude
lon_l1a_echo_sar_ku	Longitude
surf_type_l1a_echo_sar_ku	Surface type flag
burst_count_prod_l1a_echo_sar_ku	Bursts counter within the product
seq_count_l1a_echo_sar_ku	Source sequence count
burst_count_cycle_l1a_echo_sar_ku	Bursts counter within the tracking cycle

[1] Sentinel 3 Product Data Format Specification Level 1 [RD-12] available in: https://sentinel.esa.int/documents/247904/2753172/Sentinel-3-Product-Data-Format-Specification-Level-1-products

nav_bul_status_l1a_echo_sar_ku	Navigation bulletin status
nav_bul_source_l1a_echo_sar_ku	Navigation bulletin source identifier
oper_instr_l1a_echo_sar_ku	Operating instrument
SAR_mode_l1a_echo_sar_ku	SAR mode identifier
cl_gain_l1a_echo_sar_ku	Tracking configuration - closed loop gain
acq_stat_l1a_echo_sar_ku	Tracking configuration - acquisition status
dem_eeprom_l1a_echo_sar_ku	Tracking configuration - DEM EEPROM read access
weighting_l1a_echo_sar_ku	Altimeter configuration - weighting function
loss_track_l1a_echo_sar_ku	Loss of track criterion
h0_nav_dem_l1a_echo_sar_ku	Altitude command H0 computed with nav DEM
h0_applied_l1a_echo_sar_ku	Applied altitude command H0
cor2_nav_dem_l1a_echo_sar_ku	Altitude command COR2 computed with nav DEM
cor2_applied_l1a_echo_sar_ku	Applied altitude command COR2
dh0_l1a_echo_sar_ku	Distance error computed on the echo of the cycle (N-2) in open loop mode
agccode_ku_l1a_echo_sar_ku	AGCCODE for Ku band
agccode_c_l1a_echo_sar_ku	AGCCODE for C band
alt_l1a_echo_sar_ku	Altitude of satellite
orb_alt_rate_l1a_echo_sar_ku	Orbital altitude rate
x_pos_l1a_echo_sar_ku	Satellite altitude - x component
y_pos_l1a_echo_sar_ku	Satellite altitude - y component
z_pos_l1a_echo_sar_ku	Satellite altitude - z component
x_vel_l1a_echo_sar_ku	Satellite velocity - x component
y_vel_l1a_echo_sar_ku	Satellite velocity - y component
z_vel_l1a_echo_sar_ku	Satellite velocity - z component
roll_sat_pointing_l1a_echo_sar_ku	Satellite pointing angle - roll
pitch_sat_pointing_l1a_echo_sar_ku	Satellite pointing angle - pitch

yaw_sat_pointing_l1a_echo_sar_ku	Satellite pointing angle - yaw
roll_sral_mispointing_l1a_echo_sar_ku	SRAL mispointing angle - roll
pitch_sral_mispointing_l1a_echo_sar_ku	SRAL mispointing angle - pitch
yaw_sral_mispointing_l1a_echo_sar_ku	SRAL mispointing angle - yaw
range_ku_l1a_echo_sar_ku	Corrected range for ku band
int_path_cor_ku_l1a_echo_sar_ku	Internal path correction for ku band
uso_cor_l1a_echo_sar_ku	USO frequency drift correction
cog_cor_l1a_echo_sar_ku	Distance antenna-CoG correction
agc_ku_l1a_echo_sar_ku	Corrected AGC for ku band
scale_factor_ku_l1a_echo_sar_ku	Scaling factor for sigma0 evaluation for ku band
sig0_cal_ku_l1a_echo_sar_ku	Internal calibration correction on Sigma0 for ku band
i_meas_ku_l1a_echo_sar_ku	Ku band echoes, i measurements
q_meas_ku_l1a_echo_sar_ku	Ku band echoes, q measurements
gprw_meas_ku_l1a_echo_sar_ku	Ku band samples of the normalized GPRW (cal2)
cal2_ku_ind_l1a_echo_sar_ku	Index of the cal2 ltm table (normalized GPRW)
burst_power_cor_ku_l1a_echo_sar_ku	Ku band burst power corrections (cal1)
burst_phase_cor_ku_l1a_echo_sar_ku	Ku band burst phase corrections (cal1)
cal1_ku_ind_l1a_echo_sar_ku	Index of the cal1 ltm tables (power and phase corrections)

3.2.1.2 CS2 FBR data

The variables from the input file that are of interest for this module are presented in Table 3.2. Full details can be found in the Cryosat-Ice-L1B Product Specification document[2] [RD-13].

Table 3.2: List of inputs of interest from CS2 FBR file.

Variable name	Description
agc_1_85_ku	Gain command for the AGC stage 1 for both the Rx channels. It does not include the calibration corrections that are specific for each Rx channel.
agc_2_85_ku	Gain command for the AGC stage 2 for both the Rx channels. It does not include the calibration corrections that are specific for each Rx channel.
alt_85_ku	Altitude of the Satellite CoM above reference ellipsoid [WGS84] corresponding to the MDSR Time Stamp - FBR SAR."
beam_dir_vec_85_ku	Real beam direction vector described in the CryoSat Reference Frame. The 3 components are given according to the 'space_3d' dimension: [1] x, [2] y, [3] z - FBR SAR Mode.
cor2_applied_85_ku	COR2 is the 2-way on-board tracker height rate over the radar cycle, forwarded from telemetry - FBR SAR.
cplx_waveform_ch1_i_85_ku	FBR sar complex waveforms i samples. The in-phase component of each complex echo waveform in the burst received by antenna 1 (Tx-Rx). Instrument calibrations not applied.
cplx_waveform_ch1_q_85_ku	FBR sar complex waveforms q samples. The quadrature component of each complex echo waveform in the burst received by antenna 1 (Tx-Rx). Instrument calibrations not applied.
dop_cor_85_ku	This is the Doppler range correction due to the satellite altitude rate. It is computed for the component of satellite velocity in the nadir direction.
h0_applied_85_ku	The H0 (initial altitude instruction) forwarded from telemetry - FBR SAR.
h0_fai_word_85_ku	This is the Fine Altitude Instruction (FAI), computed from

[2] Cryosat Ice netCDF L1B Product Format Specification [RD-13] available in: https://earth.esa.int/documents/10174/125273/CryoSat-Ice-L1B-Product-Specification.pdf

	H0 and COR2 - FBR SAR.
h0_lai_word_85_ku	This is the Coarse Altitude Instruction (LAI), computed from H0 and COR2 - FBR SAR.
instr_cor_gain_rx_85_ku	Instrument Gain Correction (Rx only chain). It includes the power variation from CAL1 and the AGC calibration values - FBR SAR.
instr_cor_gain_tx_rx_85_ku	Instrument Gain Correction (Tx-Rx chain). It includes the power variation from CAL1 and the AGC calibration values - FBR SAR.
instr_cor_range_rx_85_ku	2-way instrument Range Correction (Rx only chain). It includes: the internal path delay from CAL1, the external group delay from ground characterisation and the vertical component of the CoM – Antenna distance - FBR SAR.
instr_cor_range_tx_rx_85_ku	2-way instrument range correction (tx-rx chain). Instrument Range Correction (Tx-Rx chain) - Calibration correction to range on channel 1 applied at L1B. It includes the internal path delay from CAL1, the external group delay from ground characterisation and the CoM – Antenna distance - FBR SAR.
inter_base_vec_85_ku	Interferometric Baseline direction vector. This is the direction vector from Tx-Rx antenna reference point to Rx only antenna reference point described in the CryoSat Reference Frame. The 3 components are given according to the 'space_3d' dimension: [1] x, [2] y, [3] z - FBR SAR.
lat_85_ku	Latitude of nadir location [-90,+90]. Positive latitude is North latitude, negative latitude is South latitude. Note the scale factor - FBR SAR.
lon_85_ku	Longitude of nadir location [-180,+180]. Positive longitude is East relative to Greenwich meridian. Note the scale factor - FBR SAR.
noise_power_85_ku	Noise power to be the noise floor of FBR measurement echoes. In SAR it is estimated on the L1B 20Hz multilooked power waveform. This field is set to the default value equal to -9999.99 when the telemetry contains zero - FBR SAR.
orb_alt_rate_85_ku	Instantaneous altitude rate of the satellite CoM with respect to the reference ellipsoid [WGS84] - FBR SAR.
sat_vel_vec_85_ku	Satellite velocity, described in the International Terrestrial Reference Frame in the International Earth Fixed System. This is not a unit vector as the velocity magnitude is also required. The 3 components are given according to the

	'space_3d' dimension: [1] x, [2] y, [3] z - FBR SAR.
seq_count_85_ku	Source Sequence Counter read from the L0 echo telemetry packet - FBR SAR.
surf_type_01	A 4-state surface type mask for Cryosat2 data for the surface type at the nadir location. Computed by combining data from different sources: GMT, GlobCover, Modis Mosaic of Antarctica, and Water body outlines from LEGOS.
time_85_ku	TAI time counted in seconds since 2000-01-01 00:00:00. Time corresponding to ground bounce time of the middle of the burst - FBR SAR.
time_cor_01	"TAI time counted in seconds since 2000-01-01 00:00:00. Time refers to the instant which the corrections are referred to.
tot_gain_ch1_85_ku	Total Fixed Gain On Channel 1 - total fixed instrument gain to be applied on channel 1, this is the gain applied by the RF unit - FBR SAR.
tot_gain_ch2_85_ku	Total Fixed Gain On Channel 2 - total fixed instrument gain applied on channel 2, this is the gain applied by the RF unit.
transmit_pwr_85_ku	The altimeter transmitted power - FBR SAR.
uso_cor_85_ku	USO correction factor defined as the ratio between the nominal and the modelled value. This correction accounts for the difference between the nominal frequency provided in the IPFDB and the modelled frequency deviation provided by the DORIS USO drift file. Correction to be applied by the user - FBR SAR."
window_del_85_ku	2-way window delay: distance from CoM to middle range window (at sample ns/2 from 0). It does not include range corrections, which are given in the variable instr_cor_range_tx_rx_85_ku - FBR SAR.

3.2.1.3 CS2 SARin L1B data

There are two retrackers (the Specialised SARin retracker and the ICC-ER) that are going to use CS2 SARin L1B Operational ESA products as input. The main reason for this is that only the operational SARin L1B products can be correctly calibrated for the phase difference between the two rx chains since the SIRAL calibration characterization is not publicly available.

As a consequence, differently from SAR acquisitions and from SARin acquisitions limiting to the power waveforms, it is not possible to develop an in-house Level1 processor able to compute Level1 phase difference and coherence waveforms with the same (or higher) level of accuracy of the L1B Operational ESA products. Aiming at obtaining from SARin retrackers geophysical parameters with the best available quality, it has been decided to start the processing from the CS2 SARin L1B BaselineD Operational ESA products.

The variables from the CS2 SARin L1B BaselineD Operational ESA products that are of interest for the SARin retrackers are detailed in Section 4.2, Table 4.2.

3.2.2 Official L2 mission products

The record locations from the official L2 mission products are likely to be different from the ones generated by the Delay-Doppler Processor (DDP). Therefore, official L2 products need to be interpolated to the DDP grid. The criteria of “closest-value” is considered valid here for the interpolation process. In the following subsections details for both Sentinel 3 and CS2 official L2 variable products are introduced. For more details please refer to [RD-06].

3.2.2.1 Sentinel 3 official L2 mission data

The variables from the input file that are of interest for this module are presented in Table 3.3. They are extracted from the Product Data Format Specification - SRAL/MWR Level 2 Land products[3] [RD-11]. Full details regarding units and other parameters can be found there.

Table 3.3: List of inputs for the official L2 mission products to be added to the L2 enhanced master file for S3 files.

Variable name	Description	Equivalent variable name in L2 enhanced product
time_20_ku	Seconds since 2000-01-01 00:00:00.0 (20Hz time vector)	--
lat_20_ku	Latitude in degrees North	--
lon_20_ku	Longitude in degrees East	--
amplitude_ocean_20_ku	Amplitude / 'ocean' retracking (FFT power unit). The retracked power is obtained by computing the product of this parameter by the scale_factor_20_ku.	retracked_Pu_ESA
scale_factor_20_ku	This scaling factor represents the	--

[3] Product Data Format Specification -SRAL/MWR Level 2 Land products, Preparation and Operations of the Mission Performance Centre (MPC) for the Copernicus Sentinel-3 Mission [RD-11], available in: https://earth.esa.int/documents/247904/2753172/Sentinel-3-Product-Data-Format-Specification-Level-2-Land

	backscatter coefficient for a waveform amplitude equal to 1. It is corrected for AGC instrumental errors and internal calibration	
range_ocean_20_ku	Corrected 'ocean' altimeter range. ocean/coastal retracking. Instrumental corrections included : USO drift correction , internal path correction, distance antenna-COG, Doppler correction, modeled instrumental errors correction and system bias	retracked_range_ESA
sig0_ocean_20_ku	Corrected 'ocean' backscatter coefficient. ocean/coastal retracking. Instrumental corrections included : AGC instrumental errors correction , internal calibration correction, modeled instrumental errors correction, atmospheric attenuation correction and system bias	retracked_sig0_ESA
swh_ocean_20_ku	Corrected 'ocean' significant wave height. Instrumental corrections included : modeled instrumental errors correction and system bias.	swh_ESA
ssha_20_ku	Sea surface height anomaly, defined as ssha = altitude of satellite -Ku band corrected ocean altimeter range -altimeter ionospheric correction on Ku band -model dry tropospheric correction -radiometer wet tropospheric correction -sea state bias correction in Ku band -solid earth tide height -geocentric ocean tide height (solution 2= FES) -geocentric pole tide height -inverted barometer height correction -high frequency fluctuations of the sea surface topography -mean sea surface	ssha_ESA
epoch_ocean_20_ku	Epoch of the 'ocean' retracking.	retracked_epoch_ESA

range_ocean_qual_20_ku	Quality flag for the ‘ocean’ altimeter range. Flag indicating the use or not of the 20-Hz estimate of the 'ocean' altimeter range in the computation of 1Hz estimate	flags_ESA
time_01	Seconds since 2000-01-01 00:00:00.0 (1Hz time vector)	--
mod_dry_tropo_cor_zero_altitude_01	Model dry tropospheric correction at zero altitude. Computed from 3d meteorological fields at zero altitude, at the altimeter time-tag from the interpolation of 2 meteorological fields that surround the altimeter time-tag. A dry tropospheric correction must be added (negative value) to the instrument range to correct this range measurement for dry tropospheric range delays of the radar pulse	mod_dry_tropo_cor_zero_altitude
mod_dry_tropo_cor_meas_altitude_01	Model dry tropospheric correction at measurement altitude. Computed from 3d meteorological fields at measurement altitude, at the altimeter time-tag from the interpolation of 2 meteorological fields that surround the altimeter time-tag. A dry tropospheric correction must be added (negative value) to the instrument range to correct this range measurement for dry tropospheric range delays of the radar pulse	mod_dry_tropo_cor_meas_altitude
mod_wet_tropo_cor_zero_altitude_01	Model wet tropospheric correction at zero altitude. Computed from 3d meteorological fields at zero altitude, at the altimeter time-tag from the interpolation of 2 meteorological fields that surround the altimeter time-tag. A wet tropospheric correction must be added (negative value) to the instrument range to correct this range measurement for wet tropospheric range delays of the radar pulse	mod_wet_tropo_cor_zero_altitude

mod_wet_tropo_cor_meas_altitude_01	Model wet tropospheric correction at measurement altitude. Computed from 3d meteorological fields at measurement altitude, at the altimeter time-tag from the interpolation of 2 meteorological fields that surround the altimeter time-tag. A wet tropospheric correction must be added (negative value) to the instrument range to correct this range measurement for wet tropospheric range delays of the radar pulse	mod_wet_tropo_cor_meas_altitude
rad_wet_tropo_cor_01	Radiometer wet tropospheric correction. A wet tropospheric correction must be added (negative value) to the instrument range to correct this range measurement for wet tropospheric range delays of the radar pulse. This correction is valid over ocean surfaces only	rad_wet_tropo_cor
rad_wet_tropo_cor_sst_gam_01	Radiometer wet tropospheric correction. Computed at the altimeter time-tag from the radiometer brightness temperatures, the Ku-band backscatter coefficient, the sea surface temperature and the lapse rate (decreasing rate of the atmosphere temperature with altitude). A wet tropospheric correction must be added (negative value) to the instrument range to correct this range measurement for wet tropospheric range delays of the radar pulse.	rad_wet_tropo_cor_sst_gam
tb_238_01	23.8 GHz main beam brightness temperature:	tb_238
tb_365_01	36.5 GHz main beam brightness temperature	tb_365
sig0_ocean_20_ku	Corrected 'ocean' backscatter coefficient. SAR mode : ocean/coastal retracking. Instrumental corrections included : AGC instrumental errors correction (agc_cor_20_ku), internal	sig0_ocean

	calibration correction (sig0_cal_20_ku), modeled instrumental errors correction (mod_instr_cor_sig0_20_ku), atmospheric attenuation correction (atm_cor_sig0_01_ku) and system bias.	
rad_surf_type_01	Radiometer-derived surface type	rad_surf_type
rain_flag_01_ku	Altimeter rain flag	rain_flag
open_sea_ice_flag_01_ku	Open sea-ice flag	open_sea_ice_flag
rad_along_track_avg_flag_01	Radiometer along-track averaging flag	rad_along_track_avg_flag
tb_238_quality_flag_01	Quality flag of 23.8 GHz main beam brightness temperature based on mean and standard deviation thresholds	tb_238_quality_flag
tb_365_quality_flag_01	Quality flag of 36.5 GHz main beam brightness temperature based on mean and standard deviation thresholds:	tb_365_quality_flag
sig0_ocean_qual_20_ku	Quality flag for the 'ocean' backscatter coefficient: SAR mode: ocean/coastal retracking. Flag indicating the use or not of the 20-Hz estimate of the 'ocean' backscatter coefficient in the computation of 1Hz estimate	sig0_ocean_qual
inv_bar_cor_01	Inverted barometer height correction	inverse_baro
atm_cor_sig0_01_ku	Atmospheric attenuation correction on the backscatter coefficient	atm_cor_sig0
iono_cor_gim_01_ku	GIM ionospheric correction	GIM_iono
iono_cor_alt_20_ku	Altimeter ionospheric correction	altimeter_iono
ocean_tide_sol1_01	Geocentric ocean tide height (solution 1 = GOT). Includes the corresponding loading tide (load_tide_sol1_01) and equilibrium long-period ocean tide height (ocean_tide_eq_01). The permanent tide (zero frequency) is	ocean_tide_got

	not included in this parameter because it is included in the geoid and mean sea surface (geoid_01, mean_sea_surf_sol1_01).	
ocean_tide_sol2_01	Geocentric ocean tide height (solution 2 = FES). Includes the corresponding the short-period part of the loading tide (load_tide_sol2_01) and equilibrium long-period ocean tide height (ocean_tide_eq_01). The permanent tide (zero frequency) is not included in this parameter because it is included in the geoid and mean sea surface (geoid_01, mean_sea_surf_sol1_01).	ocean_tide_fes
load_tide_sol1_01	Load tide height for geocentric ocean tide (solution 1 = GOT). This value has already been added to the corresponding ocean tide height value recorded in the product (ocean_tide_sol1_01).	load_tide_got
load_tide_sol2_01	Load tide height for geocentric ocean tide (solution 2 = FES). This value contains the total load tide height (short-period and long-period) for the geocentric ocean tide (solution 2). To get only the pure ocean tide height (solution 2), do: ocean_tide_sol2_01 + ocean_tide_non_eq_01 - load_tide_sol2_01. This value has already been added to the corresponding ocean tide height value recorded in the product (ocean_tide_sol2_01).	load_tide_fes
ocean_tide_eq_01	Equilibrium long-period ocean tide height	ocean_tide_eq
ocean_tide_non_eq_01	Non-equilibrium long-period ocean tide height	ocean_tide_non_eq
solid_earth_tide_01	Solid earth tide height	solid_earth_tide
pole_tide_01	Geocentric tide height	geocentric_polar_tide
hf_fluct_cor_01	High frequency fluctuations of the	hf_fluct_cor

	sea surface topography. Provided as a correction to the inverted barometer correction (inv_bar_cor_01).	
sea_state_bias_01_ku	Sea state bias correction. A sea state bias correction must be added (negative value) to the instrument range to correct this range measurement for sea state delays of the radar pulse.	sea_state_bias
geoid_01	Geoid height. Computed from the geoid model with a correction to refer the value to the mean tide system i.e. includes the permanent tide (zero frequency)	geoid
mean_sea_surf_sol1_01	Mean sea surface height above reference ellipsoid	MSS
surf_type_20_ku	Surface type	surf_type

3.2.2.2 CS2 official L2 mission data

The variables from the input file that are of interest for this module are presented in Table 3.4. They are extracted from the CryoSat Ice netCDF L2 Product Format Specification[4] [RD-10].

Table 3.4: List of inputs for the official L2 mission products to be added to the L2 enhanced master file for CS2 files.

Variable name	Description	Equivalent variable name in L2 enhanced product
time_20_ku	Time @20Hz (sec. since 2000-01-01)	--
lat_20_ku	Latitude in degrees North	--
lon_20_ku	Longitude in degrees East	--
range_1_20_ku	Range to surface (retracker 1)	retracked_range_ESA
sig0_1_20_ku	Backscatter coefficient (retracker 1)	retracked_sig0_ESA

[4] CryoSat Ice netCDF L2 Product Format Specification, CRYOSAT Ground Segment Instrument Processing Facility L2 [RD-10], available in: https://earth.esa.int/documents/10174/125273/CryoSat-Ice-L2-Product-Specification.pdf

swh_ocean_20_ku	Significant wave height	swh_ESA
ssha_20_ku	Sea-surface height anomaly	ssha_ESA
flag_retracker_20_ku	Retracker flag	flags_ESA
time_cor_01	Time @1Hz (sec. since 2000-01-01)	--
mod_dry_tropo_cor_01	Dry tropospheric correction	mod_dry_tropo_cor
mod_wet_tropo_cor_01	Wet tropospheric correction	mod_wet_tropo_cor
inv_bar_cor_01	Inverse barometric correction	inverse_baro
iono_cor_gim_01	GIM ionospheric correction	GIM_iono
ocean_tide_01	Elastic ocean tide height	ocean_tide_non_eq
load_tide_01	Ocean loading tide height	load_tide_fes
ocean_tide_eq_01	Long-period ocean tide height	ocean_tide_eq
solid_earth_tide_01	Solid earth tide height	solid_earth_tide
pole_tide_01	Geocentric pole tide height	geocentric_polar_tide
hf_fluct_total_cor_01	Dynamic atmosphere correction	hf_fluct_cor
sea_state_bias_01_ku	Sea state bias correction	sea_state_bias
geoid_20_ku	Geoid height	geoid
mean_sea_surface_sea_ice_20_ku	Mean sea surface height above reference ellipsoid	MSS
surf_type_20_ku	Surface type from mask	surf_type

3.2.3 Calibration files

For CS2-SAR, a calibration file is required as described in the document CryoSat characterisation for FBR users [RD-09], Section 2.1, containing the parameters defined in Table 1.

Regarding S3 data processing, no calibration files are required since calibration data is already included in the L1A files.

3.2.4 Region of interest mask

The mask for each region of interest is defined as a polygon of coordinates in kml a file. Figure 3.2 shows the mask for the Elbe Estuary region as an example. These masks are used from the first stage of processing, when selecting the satellite passes to be downloaded.

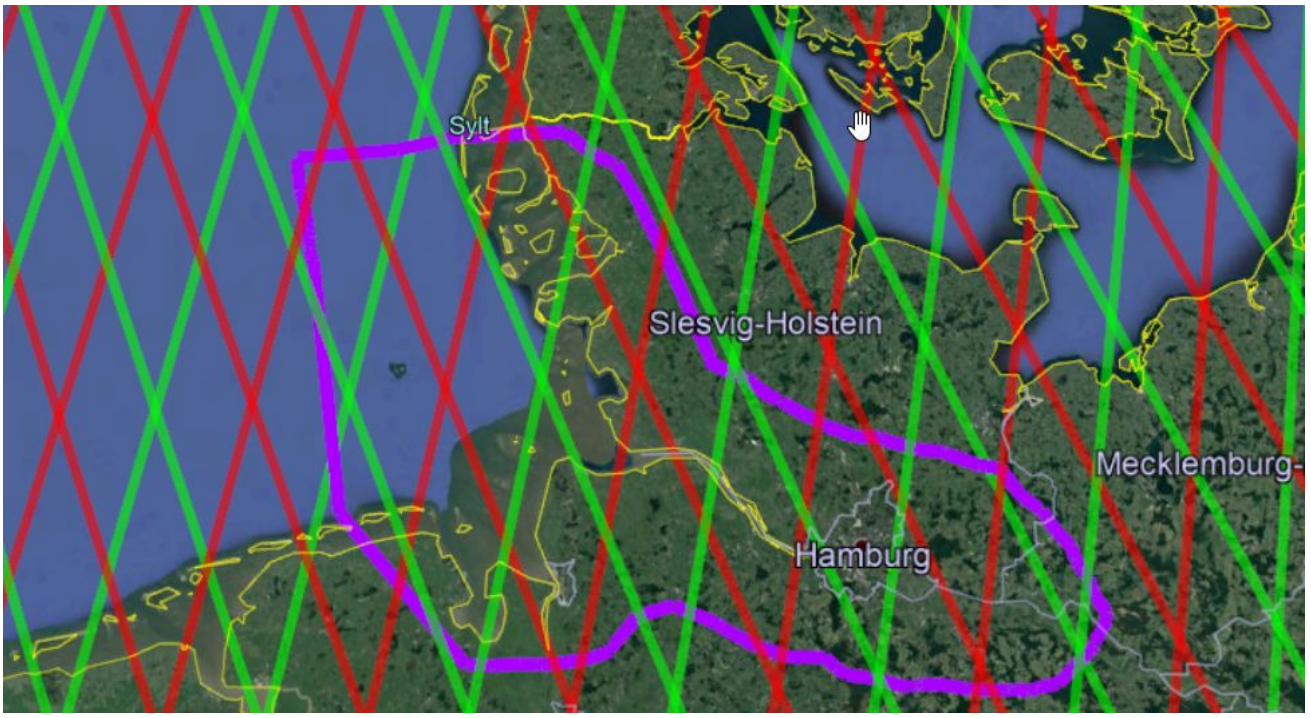

Figure 3.2. Example of mask over the region of interest "Elbe Estuary".

3.2.5 Configuration file

This file contains the definition of all the processing options as defined in the HYDROCOASTAL deliverable POCCD (Processing Options Configuration Control Document), Section 2.1.3 (RD-07).

3.2.6 Characterisation file

This file contains the definition of all the mission, mode and performance parameters that are of interest for this module. Detailed lists of parameters and values for both S3 and CS2 can be found in Section 3.1 and 3.2 of the HYDROCOASTAL deliverable POCCD (Processing Options Configuration Control Document) (RD-07).

3.2.7 Constant parameters file

This file contains the definition of all the constant parameters required for the processing of this step. The content of this file is the list of constant variables presented in the HYDROCOASTAL deliverable D2.2 PDL (Parameter Data) List document, Section 3 (RD-14).

3.3 Output Data Specifications

This module produces an *empty* L2 Enhanced Master file which contains the output variables as defined in the HYDROCOASTAL Delivery 2.3 PSD document (RD-08), Section 3.2.

The filename of this file will be defined according to this pattern: “HCA_<mission_code>_L2E_<acq_period>_<abs_orbit>_<rel_orbit>_<pass_num>.nc”

- Mission code
- <acq_period> : Acquisition period, following the notation [start time, end time] as YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS
- <abs_orbit>: Absolute orbit
- <rel_orbit>: Relative orbit
- <pass_num>: Pass number

  File name example:
  HCA_S3A_L2E_20200517T204039_20200517T204046_20200611T220610_3029_058_213.nc

4 L2 Processors Inputs & Outputs

4.1 Overview of Processing Scheme

This module is in charge of applying the whole subset of retrackers to the Delay-Doppler waveforms. For more details about the algorithms of each retracker please refer to the HYDROCOASTAL Delivery 1.3 ATBD (RD-06).

The processing scheme is as follows: the input to each L2 processor is an *empty* L2 Enhanced Master file, which includes essentially the L1B/L1B(s) waveforms and some parameters of the official L2 products. Regarding the outputs, each processor processes this input file in order to generate an L2 Intermediate file. Consequently, different L2 Intermediate files can be expected from this module.

Figure 4.1 shows a diagram of this processing stage.

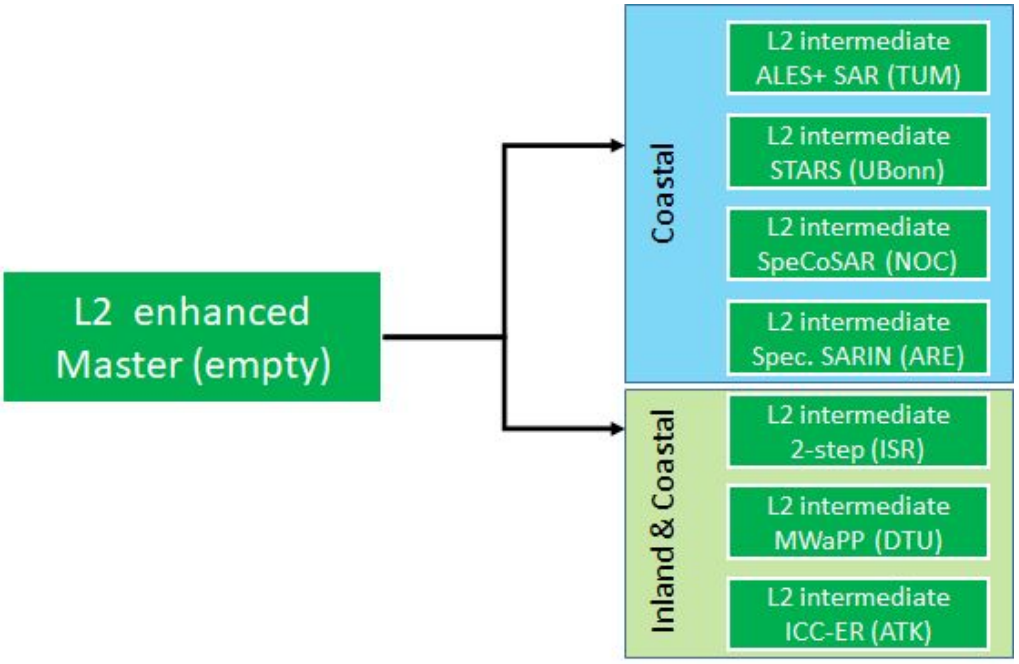

Figure 4.1. Block diagram of the L2 data flow.

The specifications of the *empty* L2 Enhanced Master file can be found in the HYDROCOASTAL Delivery 2.3 PSD (Product Specification Document) (RD-08), Section 3.2.

The set of retrackers to be applied (*Coastal* or *Inland*) varies depending on the ROI chosen.

4.2 Input Data Specifications

This section specifies the variables from the L2 Enhanced Product Master product *Empty file* that are required as inputs by each L2 processor. The detailed description of each variable is included in the L2 Enhanced product Format Specifications of the HYDROCOASTAL Delivery 2.3 PSD document, Section 3 (RD-08).

The list of input variables for each retracker using SAR mode is found in Table 4.1.

Table 4.1: List of inputs variables for SAR mode.

Variable name	Two Step Analytical isardSAT	MWaPP DTU	ICC-ER ATK	STARS UBonn	ALES+ TUM	SpeCo SAR NOC
time	X	X		X	X	
seq_count				X		
lat	X	X		X	X	
lon	X	X		X	X	
alt	X	X		X		
range	X	X	X	X	X	
roll	X			X		
pitch	X			X		
yaw	X			X		
scale_factor	X	X	X	X		
doppler_freq_sar	X			X		
velocity_x	X			X		
velocity_y	X			X		
velocity_z	X			X		
range_migration_corr				X		
altitude_rate	X			X		

RIP_sar				X		
look_angle_start	X					
look_angle_stop	X					
burst_nb_start	X					
burst_nb_stop	X					
looks_i_masked			X			
looks_q_masked			X			
waveform_i2q2	X	X	X	X	X	
waveform_scale_factor	X	X		X		
mod_dry_tropo_cor	X (CS2)	X (CS2)		X (CS2)		
mod_wet_tropo_cor	X (CS2)	X (CS2)		X (CS2)		
mod_dry_tropo_cor_zero_altitude	X (S3)	X (S3)		X (S3)		
mod_dry_tropo_cor_meas_altitude	X (S3)	X (S3)		X (S3)		
mod_wet_tropo_cor_zero_altitude	X (S3)	X (S3)		X (S3)		
mod_wet_tropo_cor_meas_altitude	X (S3)	X (S3)		X (S3)		
rad_wet_tropo_cor	X (S3)	X (S3)		X (S3)		
inverse_baro	X			X		
atm_cor_sig0	X (S3)			X (S3)		
GIM_iono	X	X		X		
altimeter_iono				X (S3)		
ocean_tide_got	X (S3)			X (S3)		
ocean_tide_fes	X (S3)			X (S3)		
load_tide_got	X (S3)			X (S3)		
load_tide_fes	X			X		
ocean_tide_eq	X			X		
ocean_tide_non_eq	X			X		
solid_earth_tide	X	X		X		

geocentric_polar_tide	X	X		X		
hf_fluct_cor	X			X		
sea_state_bias				X		
geoid		X				
MSS				X		
surf_type	X					

Table 4.2 includes the input variables for retrackers using SARin mode. It is worth recalling here that the SARin retrackers are going to use as input CS2 SARin L1B BaselineD Operational ESA products. The full description of the products is provided in the CryoSat Ice netCDF L1B Product Format Specification[5] [RD-13].

Table 4.2: List of input variables for SARin mode.

Variable Name	Description	Specialised SARIN retracker Aresys	ICC-ER ATK
time_20_ku	TAI time counted in seconds since 2000-01-01 00:00:00. Time refers to the instant the L1B 20Hz power waveform touches the surface.	X	
rec_count_20_ku	Record counter - progressive counter incremented by 1 for each record. Surface Sample counter for SAR/SARin L1B products.		X
lat_20_ku	Latitude of nadir location [-90,+90]. Positive latitude is North latitude, negative latitude is South latitude.	X	X
lon_20_ku	Longitude of nadir location [-180,+180]. Positive longitude is East relative to Greenwich meridian	X	X
alt_20_ku	Altitude of the satellite Centre of Mass above the reference ellipsoid.	X	X
off_nadir_roll_angle_str_20_ku	Roll angle with respect to the nadir pointing,	X	X

[5] CryoSat Ice netCDF L1B Product Format Specification document [RD-13], available in: https://earth.esa.int/documents/10174/125273/CryoSat-netCDF-L1b-Product-Format-Specification.pdf

	measured by the STRs and post-processed by the ground facility.		
off_nadir_pitch_angle_str_20_ku	Pitch angle with respect to the nadir pointing, measured by the STRs and post-processed by the ground facility.	X	X
off_nadir_yaw_angle_str_20_ku	Yaw angle with respect to the nadir pointing, measured by the STRs and post-processed by the ground facility.	X	X
echo_scale_factor_20_ku	The 20Hz power waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B 1Hz average power waveform into Watts, is applied as follows: pwr_waveform_20_ku(time_20_ku,ns_20_ku)* echo_scale_factor_20_ku(time_20_ku)*2^ech o_scale_pwr_20_ku(time_20_ku).	X	
look_angle_start_20_ku	Value of Look Angle for the first single look echo in the stack. It is the angle between: (a) nadir direction from the satellite CoM to the surface, (b) direction from satellite to surface location. The look angle depends purely on geometry.	X	
look_angle_stop_20_ku	Value of Look Angle for the last single look echo in the stack. It is the angle between: (a) nadir direction from the satellite CoM to the surface, (b) direction from satellite to surface location. The look angle depends purely on geometry.	X	
ph_diff_waveform_20_ku	L1b 20Hz phase difference waveform is a fully-calibrated, high resolution, multi-looked phase difference computed from the complex echoes on the two receiving channels	X	X
coherence_waveform_20_ku	The L1b 20Hz coherence waveform is a fully-calibrated, high resolution, multi looked coherence computed from the complex echoes on the two receiving channels	X	X
mod_dry_tropo_cor_01	ECMWF dry tropospheric correction (1-way)		X
mod_wet_tropo_cor_01	ECMWF wet tropospheric correction (1-way)		X
iono_cor_01	Model ionospheric correction (1-way)		X
solid_earth_tide_01	Solid earth tide (1-way)		X

surf_type_01	A 4-state surface type mask for Cryosat2 data for the surface type at the nadir location. Computed by combining data from different sources: GMT, GlobCover, Modis Mosaic of Antarctica, and Water body outlines from LEGOS.	X	
echo_numval_20_ku	It is the number of single look echoes in the Surface Sample Stack that have been multi-looked to compute the corresponding L1B 20Hz power waveform. This variable includes only one receiving channel however, in SARIn, single looks from both channels are averaged in order to reduce the SNR.	X	
echo_scale_pwr_20_ku	The 20Hz power waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B 1Hz average power waveform into Watts, is applied as follows: pwr_waveform_20_ku(time_20_ku,ns_20_ku)* echo_scale_factor_20_ku(time_20_ku)*2^ech o_scale_pwr_20_ku(time_20_ku).	X	
flag_mcd_20_ku	Measurement confidence flags. Generally the MCD flags indicate problems when set. If the whole MCD is 0 then no problems or non-nominal conditions were detected. Serious errors are indicated by setting the most significant bit, i.e. block_degraded, in which case the block must not be processed. Other error settings can be regarded as warnings.	X	X
pwr_waveform_20_ku	L1B 20Hz power waveform is a fully-calibrated waveform.	X	X
sat_vel_vec_20_ku	Satellite velocity vector, described in the International Terrestrial Reference Frame in the International Earth Fixed System. This is not a unit vector as the velocity magnitude is also required. The 3 components are given according to the 'space_3d' dimension: [1] x, [2] y, [3] z.	X	
time_cor_01	TAI time counted in seconds since 2000-01-01 00:00:00. Time refers to the instant which the corrections are referred to.	X	
window_del_20_ku	Calibrated 2-way window delay: distance from CoM to middle range window (at sample ns/2 from 0). It includes all the range instrument	X	X

	corrections.		
noise_power_20_ku	Noise power measurement to be the noise floor of measurement echoes. In SAR/SARIn it is estimated on the L1B 20Hz multi-looked power waveform. In LRM it is converted from telemetry units and scaled according to the proper AGC value. This field is set to the default value equal to -9999.99 when the telemetry contains zero.		X
stack_kurtosis_20_ku	Gaussian power fitting: kurtosis wrt beam number		X
stack_peakiness_20_ku	Stack peakiness computed from the range integrated power of the single look echoes within a stack.		X
stack_skewness_20_ku	Gaussian power fitting: skewness wrt beam number		X
stack_std_20_ku	Gaussian power fitting: std dev wrt beam number		X

4.3 Output Data Specifications

This module produces a set of L2 intermediate files which contains the output variables as defined in the HYDROCOASTAL Delivery 2.3 PSD document (RD-08), Section 3.2.
The filename notation of the output files is “<master_file_name>_<retracker_code>.nc”, where the <master_file_name> is the filename of the input file of this module and the <retracker_code> is defined according to:

- “ISR”, for the 2-Step retracker
- “ARE”, for the Specialised SARIN retracker
- “DTU”, for the MWaPP retracker
- “ATK”, for the ICC-ER retracker
- “UBO”, for the STARS retracker
- “TUM”, for the ALES+ for SAR retracker
- “NOC”, for the SpeCoSAR retracker.

5 Final merging of L2 intermediate products (isardSAT)

5.1 Overview of Processing Scheme

This module is in charge of merging all the L2 intermediate products generated by the different retrackers in the previous module together with the geophysical corrections from UPorto, which are added in parallel. Figure 5.1 shows the diagram of this module:

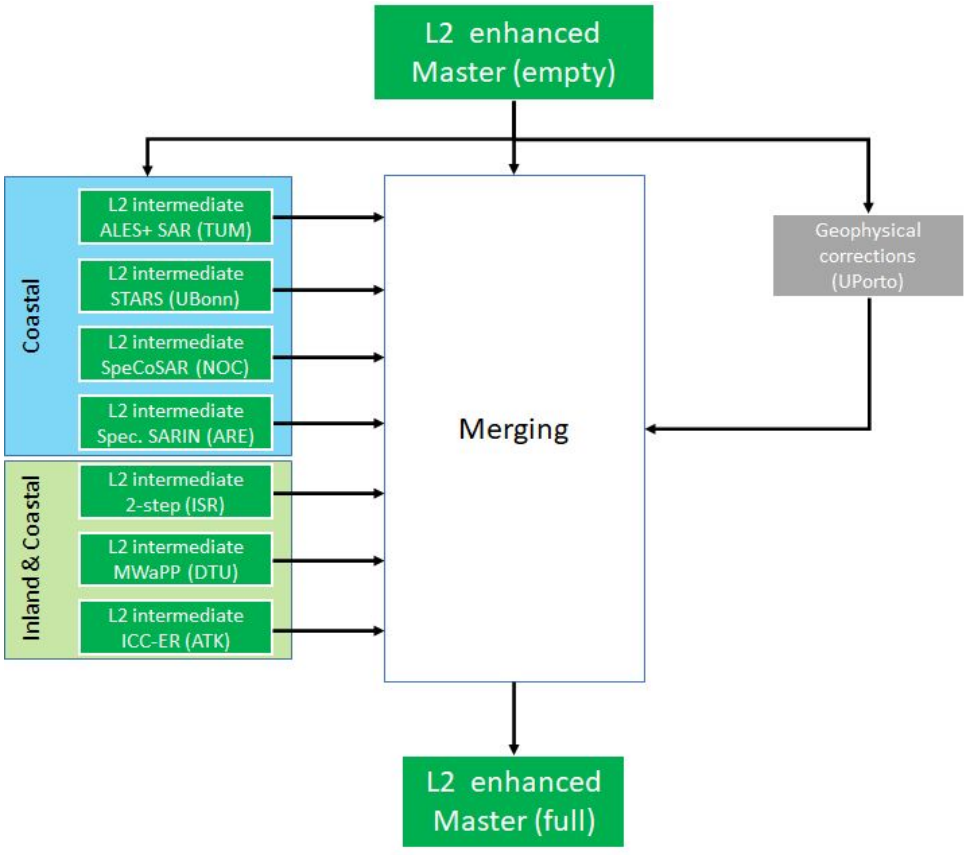

Figure 5.1. Block diagram of the L2 Merging module.

5.2 Input Data Specifications

This module requires a variable number of files as input. This number of files depends on the type of target observed, that can be *coastal* or *inland*, and also on the operational mode of the satellite in case of CS2, which can be SAR or SARin.

Also, the data from official L2 files is incorporated to the final L2 Enhanced Master product.

5.2.1 L2 intermediate products

The exact number of L2 intermediate files depends of the kind of target of the file:

- For *coastal* regions, the files to be eventually included are:
  - <master_file_name>_ISR.nc
  - <master_file_name>_ARE.nc
  - <master_file_name>_DTU.nc
  - <master_file_name>_ATK.nc
  - <master_file_name>_TUM.nc
  - <master_file_name>_UBO.nc
  - <master_file_name>_NOC.nc

- For *inland* regions, the files to be eventually included are:
  - <master_file_name>_ISR.nc
  - <master_file_name>_ATK.nc
  - <master_file_name>_DTU.nc

Since all the variables from each L2 intermediate file are to be included in the final L2 Master Enhanced file, no further details are copied here in order not to overlap information. For more details on the outputs of the L2 intermediate files please refer to HYDROCOASTAL Delivery 2.3 PSD (RD-08).

5.2.2 Geophysical corrections (UPorto)

The input variables from the Geophysical corrections Uporto file that are of interest for this module are presented in Table 5.1.

Table 5.1: List of inputs from the Geophysical corrections file.

Variable name	Description	Units	Type	Dims
h_surf	Altitude above sea level at which the DTC (upt_dry_tropo) and WTC (gpd_wet_tropo) have been computed	m	fl	time
upt_dry_tropo	Dry Tropospheric Correction from UPorto	m	fl	time
gpd_wet_tropo	Wet Tropospheric Correction from UPorto	m	fl	time
gpd_wet_tropo_flag	Data source flag for the Wet Tropospheric Correction from UPorto	--	uc	time
geoid_EIGEN_6C4	Geoid heights from EIGEN-6C4 model	m	fl	time

5.3 Output Data Specifications

This module produces a final L2 enhanced product file which contains the output variables as defined in the HYDROCOASTAL Delivery 2.3 PSD (RD-08), Section 3.2. The filename of this file is defined as “<master_file_name>_FULL.nc”.

6 L3 River Processor (AHL)

6.1 Overview of Processing Scheme

This module is in charge of processing radar altimeter satellite data from L2 (Sentinel-3A/B SARM, CryoSat-2 SARM/SARINM) in order to produce River Water Level time series (for repeat orbit Sentinel-3 missions) and space-time series (from non-repeat orbit CryoSat-2 mission). Figure 6.1 shows a block diagram of this module.

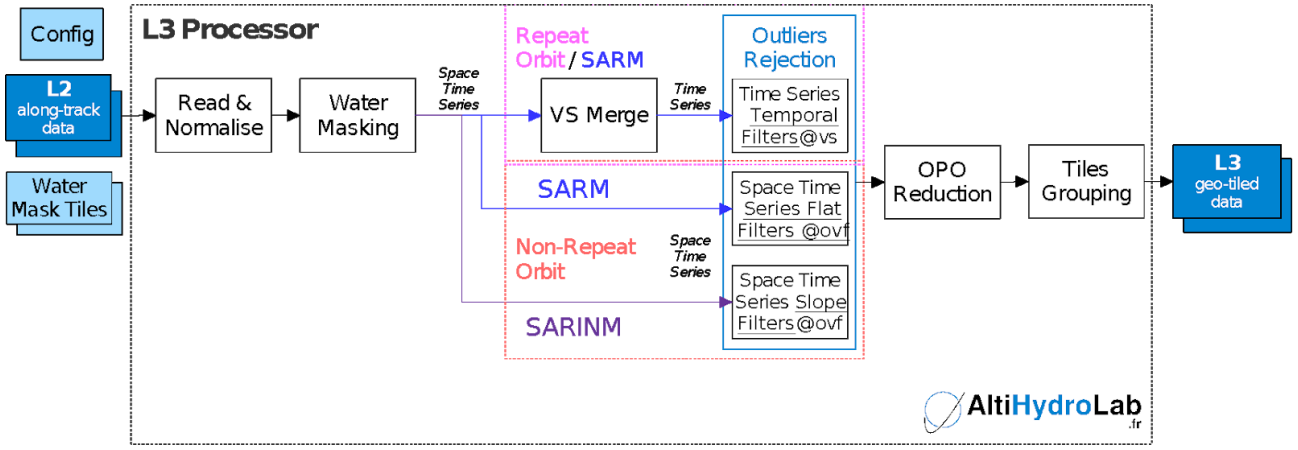

Figure 6.1. Block diagram of the L3 Rivers Processor data flow.

6.2 Input Data Specifications

The L3 River Processor accepts in input:

- One or more L2 enhanced files (netCDF files) as described in the PSD (RD-08)
- One configuration file (JSON file) as described in the POCCD (RD-07), Section 2.3.2.3.
- Water Mask files (as described in section 6.2.2 “Water Mask”) as ShapeFile or GeoTiff files

6.2.1 L2 Master enhanced mission products

Table 6.1 below describes the list of variables from the L2 enhanced product files that are necessary to the L3 River Processor. Full variable details can be found in the HYDROCOASTAL Deliverable 2.3 PSD (Product Specification Document) (RD-08) Section 3.2.

Table 6.1: List of inputs from the L2 Master enhanced mission products.

Variable name	Description
time	Time of measurement

lon	Longitude of measurement at nadir [-180, +180]: Positive at East, Negative at West
lat	Latitude of measurement [-90, +90]: Positive at North, Negative at South
lon_p	Longitude of satellite platform (CryoSat-2/SARINM only).
lat_p	Latitude of satellite platform (CryoSat-2/SARINM only).
alt	Satellite antenna altitude
retracked_range_<RTK>	Range as computed by retracker <RTK>
GIM_iono	GIM Ionospheric Correction
gpd_wet_tropo	Wet Tropospheric Correction from UPorto
gpd_wet_tropo_flag	Data source flag for the Wet Tropospheric Correction from UPorto
upt_dry_tropo	Dry Tropospheric Correction from UPorto
mod_dry_tropo_cor	Dry tropospheric correction (Only for CS2)
mod_wet_tropo_cor	Wet tropospheric correction (Only for CS2)
mod_dry_tropo_cor_zero_altitude	Model dry tropospheric correction at zero altitude (Only for S3)[6]
mod_dry_tropo_cor_meas_altitude	Model dry tropospheric correction at measurement altitude (Only for S3)
mod_wet_tropo_cor_zero_altitude	Model wet tropospheric correction at zero altitude (Only for S3)
mod_wet_tropo_cor_meas_altitude	Model wet tropospheric correction at measurement altitude (Only for S3)
rad_wet_tropo_cor	Radiometer wet tropospheric correction (Only for S3)
rad_wet_tropo_cor_sst_gam	Radiometer wet tropospheric correction using SST and Gamma (Only for S3)
solid_earth_tide	Solid Earth Tide
geocentric_polar_tide	Geocentric Polar Tide
geoid	Geoid Height

[6] Note that S3 provides dry/wet troposphere corrections at two altitudes in L2 official products, while CS2 L2 products only provide dry/wet troposphere corrections at one altitude.

geoid_EIGEN_6C4	Geoid heights from EIGEN-6C4 model
water_fraction_atk	Fraction of water within the Doppler footprint of the altimetric measurement. This is the ratio, within the Doppler footprint, of the water surface vs. the surface of the Doppler footprint itself. It is computed by intersecting the ground projected Doppler footprint and the water mask.

6.2.2 Water Mask

The River L3 Processor is using Water Mask auxiliary data in order to isolate inland water surface from land surface.
Supported Water Mask data are: SWBD, GSW (Pekel et al., 2016, RD-15) and possibly others. Supported Water Mask file formats are either Shapefiles or georeferenced binary images (e.g., GeoTiff).

6.3 Output Data Specifications

This module produces L3 River Level netCDF product files which contain the output variables as defined in D2.3 Product Specification Document (PSD) (RD-08).

7 L3 River Level (DTU Space)

7.1 Overview of Processing Scheme

The DTU level 3 water level time series product is contracted via a state-space time series model. The process part is a simple random walk. The error distribution in the observation part is a mixture between a Cauchy and a Normal distribution limiting the effect of erroneous measurements. The main steps in the processing is outlined below.

- Data extraction using a water mask
- Crude outlier identification
- Preparation of data input format
- Estimation of Water level time series
- Constructing output file

For details the algorithm is specified in HYDROCOASTAL deliverable D1.3 ATBD (RD-06) and the data output format is specified in HYDROCOSTAL Product Specification Document D2.3 (RD-08).

7.2 Input Data Specifications

To reconstruct the water level time for one target (here it is assumed that the applied L2 data related to the inland water body have been extracted by a mask) the following parameters are needed:

- Time in decimal years
- L2 surface elevation
- Track number
- Satellite id (more than one mission is applied in the reconstruction)

A confidence indicator from the individual waveform could be applied as a weight to the L2 surface elevations.

7.2.1 Input Files

The following files are necessary to prepare and reconstruct the L3 water level time series:

- L2 Master enhanced mission product file. The required input variables are the same as ones specified in Table 6.1.
- Lake and river mask (both in raster and vector format).

7.3 Output Data Specifications

For each target the following columns are provided by the L3 algorithm “tsHydro”:

- Time in decimal years

- Surface water elevation
- Standard deviation of water surface elevation

The L3 algorithm also provides the estimated standard deviation of the L2 surface elevations.

The full description of the L3 parameters is given in the HYDROCOASTAL Product Specification Document (PSD) Deliverable D2.3 (RD-08).

8 L4 River Discharge (NUIM)

Three algorithms of different complexity are proposed for discharge estimation.

- Rating curve method
- Bjerklie equation based method
- Manning equation based method

8.1 Overview of Processing Scheme

- RATING CURVE method is based on relations established between simultaneously measured altimetric water heights and in situ water discharges.
- BJERKLIE EQUATION method is a simplified empirical equation based on hydraulic laws for parabolic river channels.The discharge is estimated as a function of width (B), depth (D) and water slope (S).
- MANNING EQUATION method is based on hydraulic laws and relates the discharge to width (B), depth (D), water slope (S) and bottom friction (n) via a full system of equations. A particular interest of the use of the hydraulic equations consists in their potential application for ungauged rivers.

8.2 Input Data Specifications

This L4 River Discharge method requires as input two files:

- L3 River Level enhanced product
- File with auxiliary parameters.

8.2.1 L3 River level enhanced product

Table 8.1 below describes the list of variables from the L3 River Level enhanced product files, which are common for all methods used for providing the L4 River Discharge product. Full variable details can be found in Section 4.2 of the HYDROCOASTAL Deliverable 2.3 PSD (Product Specification Document) (RD-08).

Table 8.1: List of inputs from the L3 River Level products.

Variable name	Description
time	Time of measurement
lon	Longitude of measurement [-180;+180]
lat	Latitude of measurement [-90;+90]
water_level_<mission>_<band>_<mode>_<retracker>	L3 river level. Estimated Water Level w.r.t. geoid height variable.

sd_l2_meas_<mission>_<band>_<mode>_<retracker>	Uncertainty in the L3 River Level. Standard Deviation of L2 measurements involved in the computation of this L3 Water Level.
vs_id	ID for the Virtual Station
geoid_height	Geoid Height from model

8.2.2 Auxiliary parameters file

Table 8.2 below describes the list of variables derived from L3 River Level enhanced product and Water Mask files (as described in section 6.2.2 “Water Mask”), which are necessary for Bjerklie and Manning methods of L4 River Discharge product.

Table 8.2: List of inputs from other HydroCoastAl products.

Variable name	Description	Units	Type	Dims
time	Time of measurement	decimal year	do	time
lon	Longitude of measurement [-180;+180]	degrees	do	time
lat	Latitude of measurement [-90;+90]	degrees	do	time
water_slope	Water slope retrieved from L3 DTU state-space time series model [0; 0.00010]	km/km	do	time
water_width	Dynamic channel water width estimated from river mask product [0; 10000]	m	do	time

8.3 Output Data Specifications

The output file is a L4 River Discharge product. List and specification of output variables are defined in D2.3 Product Specification Document (PSD) (RD-08).

9 L4 River Discharge (CNR)

9.1 Overview of Processing Scheme

This module is in charge of merging the L3 River Level datasets and the Reflectance Ratio from imaging sensors to derive L4 River Discharge. For more details about the merging algorithm, please refer to the Section 15.2 of the HYDROCOASTAL Delivery 1.3 ATBD (RD-06). Figure 9.1 shows the diagram of this module.

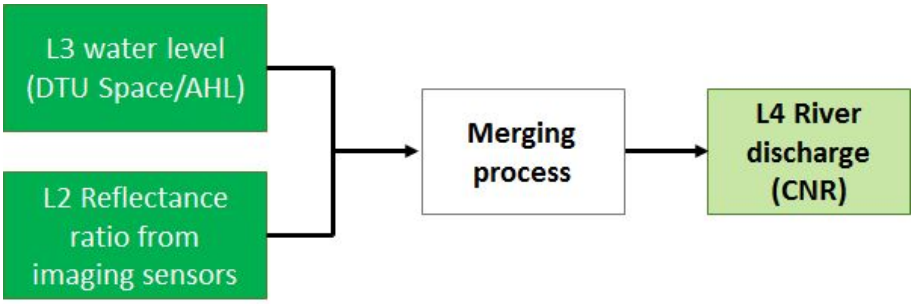

Figure 9.1. Block diagram of the L4 Merging module.

9.2 Input Data Specifications

The L4 River Discharge merging method accepts in input:

- L3 river level (netCDF files)
- Reflectance ratio from imaging sensors (netCDF files)

9.2.1 L3 River Level product

Table 9.1 below described the list of variables from the L3 River Level enhanced product files that are necessary to the merging method for providing the L4 River Discharge product. Full variable details can be found in the HYDROCOASTAL Deliverable 2.3 PSD (Product Specification Document).

Table 9.1: List of inputs from the L3 River Level products.

Variable name	Description
time	Time of measurement
lon	Longitude of measurement [-180;+180]
lat	Latitude of measurement [-90;+90]
water_level_<mission>_<band>_<mode>_<retracker>	L3 river level. Estimated Water Level w.r.t. geoid height variable.
sd_l2_meas_<mission>_<band>_<mode>_<retracker>	Uncertainty in the L3 River Level. Standard Deviation of L2 measurements involved in the computation of this L3 Water Level.
vs_id	ID for the Virtual Station
geoid_height	Geoid Height from model

9.2.2 Reflectance Ratio product

Table 9.2 below described the list of variables from the NIR images analysis necessary to the merging method for providing the L4 River Discharge product.

Table 9.2: List of inputs from the Reflectance Ratio products.

Variable name	Description	Units	Type	Dims
time	Time of measurement	days	do	time
lon	Longitude of measurement [-180;+180]	degrees	do	time
lat	Latitude of measurement [-90;+90]	degrees	do	time
reflec_ratio	Reflectance Ratio value	NA	do	time

9.3 Output Data Specifications

This module produces L4 River Discharge netCDF product files, which contain the output variables as defined in D2.3 Product Specification Document (PSD) (RD-08).

10 List of Acronyms

AD	Applicable Documents
AGC	Automatic Gain Control
AHL	AltiHydroLab
ARE	Aresys
ATBD	Algorithm Technical Basis Document
ATK	Along Track SAS
CNR	(Italian acronym) Consiglio Nazionale delle Ricerche
CoG	Centre of Gravity
CryoSat-2	Altimetry satellite for the measurement of the polar ice caps and the ice thickness
CS2	CryoSat-2
DDP	Delay-Doppler Processor
DEM	Digital Elevation Model
DTC	Dry Tropospheric Correction
DTU	Danmarks Tekniske Universitet (Technical University of Denmark)
ECMWF	European Centre for Medium-Range Weather Forecasts
EO	Earth Observation
ESA	European Space Agency
FBR	Full Bit Rate
FFT	Fast Fourier Transform
GIM	Global Ionospheric Maps
GPD	GNSS-derived Path Delay
GSW	Global SurfaceWater
IDAN	Intensity-Driven Adaptive-Neighbourhood
IGS	International GNSS (Global Navigation Satellite Systems) Service
IODD	Input Output Data Document
IPF	Integrated Processing Facility
ISR	isardSAT
KML	Keyhole Markup Language
L1A	Level-1A
L1B	Level-1B
L1B-S, L1BS	Level-1B-S (aka, Stack data)
L2	Level-2
L3	Level-3
L4	Level-4
LEGOS	(french acr.) Laboratoire d'Études en Géophysique et Océanographie Spatiale (Laboratory for Studies in Geophysics and Spatial Oceanography)
LRM	Low Resolution Mode
MPC	Mission Performance Centre
MSS	Mean Square Slope
MSS	Mean Sea Surface
MWR	Microwave Radiometer
netCDF	Network Common Data Form
NOC	National Oceanography Centre
NUIM	National University of Ireland Maynooth
POCCD	Processing Options Configuration Control Document
PSD	Product Specification Document
RD	Reference Document
RF	Random Forest
RIP	Range Integrated Power (of the MLD) sometimes referred as Angular Power Response (APR)
ROI	(geographical) Region(s) Of Interest
S3	Senti
SARIn	SAR Interferometric (CryoSat-2/SIRAL mode)
SAR	Synthetic Aperture Radar
SNR	Signal to Noise Ratio
SOW	Statement Of Work
SRAL	SAR Radar Altimeter
Stack	Matrix of stacked Doppler beams
STD	Standard Deviation
STR	Star Tracker
SWBD	SRTM Water Body Data
SWH	Significant Wave Height
TAI	Temps Atomique International (International Atomic Time)
TN	Technical Note
TUM	Technische Universität München
UBO	University of Bonn
UPort	Universidade do Porto / University of Porto
USO	Ultra Stable Oscillator
UTC	Coordinated Universal Time
VS	Virtual Station(s)
w.r.t.	with respect to
WTC	Wet Tropospheric Correction

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