HYDROCOASTAL

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

Product Specification Document
Deliverable D2.3 -

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

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Written by:	Albert Garcia-Mondéjar, Ferran Gibert, Ester Vendrell	08/10/20
Checked by	David Cotton	08/10/20
Approved by:		

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Author	Organisation	Internal references
Albert Garcia-Mondejar, Ferran Gibert, Ester Vendrell	isardSAT	HYDROCOASTAL_ESA_PSD
Joana Fernandes	UPorto	
Michele Scagliola	Aresys	
Ole Andersen, Karina Nielsen, Heidi Ranndal	DTU Space	
Pierre Fabry	Along Track	
Luciana Fenoglio-Marc	U Bonn	
Marcello Passaro	TUM	
Christine Gommenginger	NOC	
Nicolas Bercher	AltHydroLab	

Angelica Tarpanelli	CNR-IRPI	
Elena Zakharova	NUIM	

	Signature	Date
For HydroCoastAL team		
For ESA		

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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 Document

The scope of this document is to identify and specify the format of the data products generated within the HYDROCOASTAL project

1.3 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 products, variables and file formats.
- Section 3 includes L2 products format specifications
- Section 4 includes L3 products format specifications
- Section 5 includes L4 products format specifications
- Last sections include references and the list of acronyms.

1.4 Reference Documents

RD-1 HydroCoastAL Proposal: SAR/SARin Radar Altimetry for Coastal Zone and Inland Water Level. Proposal, January 2020.

RD-2 ESA. “Sentinel-3 Product Data Format Specification - SRAL/MWR Level 2 products”, ref. S3IPF.PDS.003.2, issue 2.12, 05 March 2018.

RD-3 Advanced Computer Systems (ACS). CryoSat Ice netCDF L2 Product Format Specification [PFS-I-L2], C2-RS-ACS-ESL-5265 Issue: 1.6, 2019

RD-4 HYDROCOASTAL Deliverable 1.3 ATBD (Algorithm Theoretical Basis Document). V1.1 08/10/2020, isardSAT and HYDROCOASTAL team.

RD-5 HYDROCOASTAL Deliverable 2.1 IODD (Input Output Data Definitions). V1.1 08/10/2020, isardSAT and HYDROCOASTAL team.

2 General definitions

2.1 Product definitions

A block diagram with the main input and output products is shown in Figure 2.1.

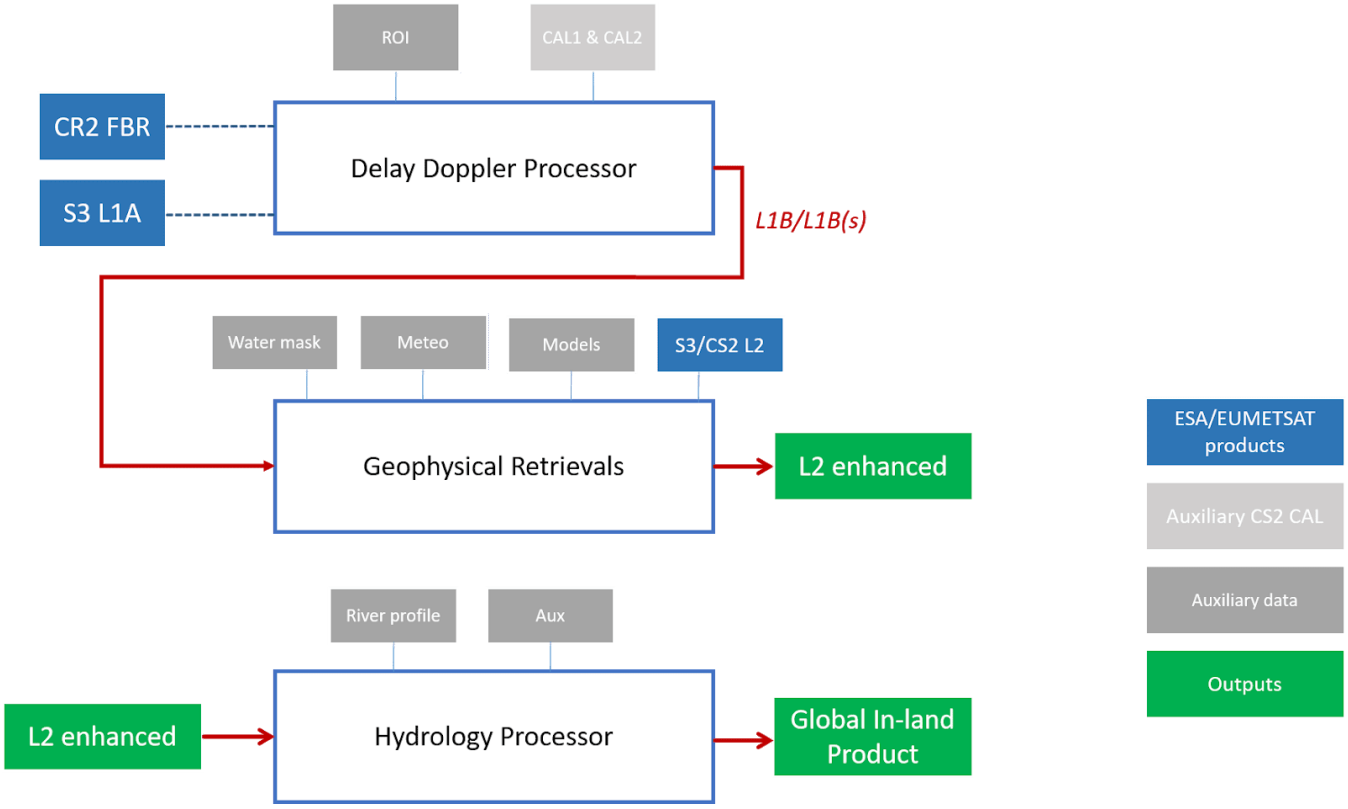

Figure 2.1. Block diagram of the whole process.

2.1.1 Master L2 enhanced product

The master output product is the main product where all the partners will be contributing with the outputs of their algorithms. It will initially be defined as an *empty* product, including essentially the L1B/L1B(s) waveforms and some parameters of the official L2 products. After integrating the contribution from each L2 partner and some geophysical corrections, the final product will be labeled L2 Master enhanced *full* product. Depending on the ROI, the final Master L2 enhanced will include outputs from either Coastal retrackers or Inland retrackers, as shown in Figure 2.2.

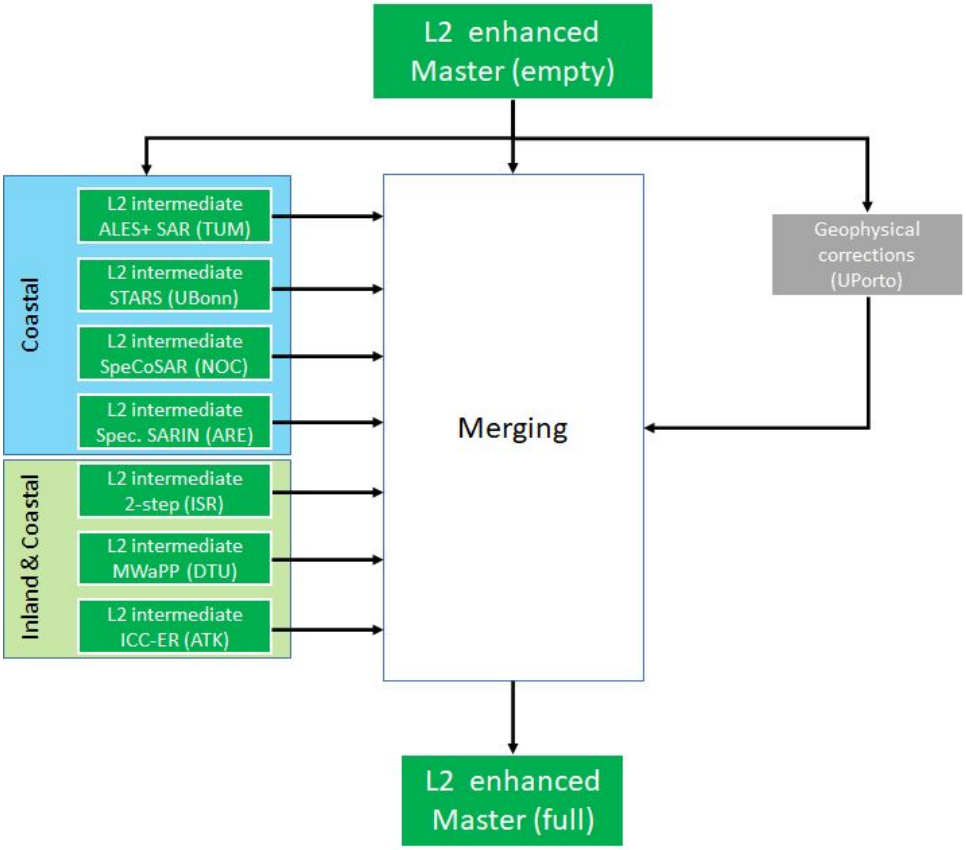

Figure 2.2. Block diagram of the L2 data flow.

2.1.2 Intermediate L2 enhanced product

The products that each of the partners involved in the Retracking needs to generate. The list of parameters will be different depending on the contribution that each of them will need to do. A block diagram with the interaction of the Intermediate L2 enhanced products and the Master L2 enhanced product is found in Figure 2.2.

2.1.3 Auxiliary products

2.1.3.1 Sentinel 3 L2 standard

It will be used as an input to get the geophysical corrections that are not covered by the HydroCoastAL team and to get the outputs from the ocean retracker. The specific geophysical corrections are specified in Table 3.2. Its product format can be checked in the following link: Sentinel 3 L2 Product Format Specification [RD-2].

2.1.3.2 CryoSat-2 L2

It will be used as an input to get the geophysical corrections that are not covered by the HydroCoastAL team and to get the outputs from the ocean retracker. The specific geophysical corrections are specified in Table 3.2. Its product format can be checked in the following link: CryoSat Ice netCDF L2 Product Format Specification [RD-3].

2.1.3.3 Other products that may be used (on the global production)

Global River Widths from Landsat (GRWL) Database (Allen et al., 2018). A line layer shapefile with river centerlines and information regarding the width of the river.

2.1.3.3.1 Water Masks

Available global water mask products:

The occurrence product from the Global Surface Water Explorer https://global-surface-water.appspot.com/download (Pekel et al., 2016). This product is based on Landsat imagery and contains the likelihood of water as a percentage with a pixel resolution of 30 m.

HydroLakes https://hydrosheds.org/page/hydrolakes (Lehner et al., 2008). A polygon layer shapefile mask of 1.4 million global distributed lakes.

2.2 Variable types

Variable type	Description	Range
bl	boolean	True, False
str	string of characters	--
uc	8-bit unsigned integer (ubyte)	0 to 255
sc	8-bit signed integer (byte)	-128 to 127
us	16-bit unsigned short integer	0 to 65535
ss	16-bit signed short integer	-32768 to 32767
ul	32-bit unsigned long integer	0 to 4294967295

sl	32-bit signed long integer	-2147483648 to 2147483647
sll	64-bit signed “long long” 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)

2.3 NetCDF format file

The NetCDF format has been lately widely used to provide remote sensing data, especially in the oceanographic framework. The main advantages of such encapsulating data format are its flexibility in the definition/creation/access of data, its transversal capability to share machine/platform-independent data and their self-describing characteristics. Thanks to such potentialities and ease in data sharing such format has been selected to provide the official distributed L1A, L1BS, L1B, and L2 for the Sentinel 3 and Sentinel 6 missions and it has been incorporated in the CryoSat-2 Baseline D production.

A NetCDF file is composed by the following elements:

- Dimensions: used to represent a real physical dimension (e.g., time, latitude, longitude, or height) of to index other quantities (e.g., number of waveforms or samples). A dimension has both a name and a length.
- Variables: used to store the data in a NetCDF file. A variable corresponds to an array of values of the same type. Each variable is completely defined by its name, data type and shape (described by the list of dimensions). A scalar value is defined as a 0-dimensional array. A variable can also contain related attributes, which can be added, deleted or modified once the variable has been created.
- Attributes: used to keep information of the data (metadata). Generally, they provide information about a specific variable. These are identified by the name of the variable, jointly with the name of the attribute (e.g., units, scale factor, or offset to be added).
- General attributes: used to provide a global description of the dataset as a whole.

2.4 Files alignment

L2 master and intermediate product files from the HydroCoastAL processor are synchronized/aligned in (1) files number and (2) number of records per files (i.e., variables share dim 0 of same length). Time, location and record number variables are used to link records from these product files.

3 L2 enhanced product Format Specifications

3.1 L2 enhanced NetCDF format

L2 products are compliant with the NetCDF-4 format, following similar variable convention names as the ones provided in Sentinel-3 format product specifications [RD-2]. A NetCDF file contains dimensions, variables, attributes, and global attributes as described in Section 2.3. The global attributes description can be found in Section 3.3.

Table 3.1 Dimensions for Level 2 enhanced product

Dimension name	Description	Value
time	Number of along track records (L2 measurements) in the file. Record frequency is 20Hz.	# of Ku records
Ns	Number of samples in a waveform. It is 128*zp for SAR and 512*zp for SARIn (SARIn always has zp=2).	128*zp (SAR) 1024 (SARIn)
Nl	Maximum number of looks per stack	256 (SAR) 64 (SARIn)

3.2 L2 enhanced product variables

A description of the L2 Master Enhanced product variables is found in Table 3.2. Variables are thematically grouped. For the group called "*Common parameters for each retrackers*", each variable suffix "<RET>" is to be replicated for each retracker developer according to the following notation:

- **ISR** for isardSAT 2-step analytical retracker
- **ARE** for Aresys, for Specialised SARin retracker
- **DTU** for DTU's MWaPP retracker
- **ATK** for Along-Track's ICC-ER empirical retracker
- **UBO** for UBonn's Statistical STARS retracker
- **TUM** for TUM's ALES+ for SAR retracker
- **NOC** for NOC's Specialised Coastal SAR retracker
- **ESA** for the ocean retracker extracted from official products.

It is important to remark the differences between the different L2 Enhanced Master file versions:

1. The *empty* version of the product contains only the variables tagged as *DDP*, *ESA* and *GeoCor* in Table 3.2. This is the version provided as input to each L2 retracker partner.
2. Each L2 Enhanced Master *intermediate* file is the result of adding the output parameters of a specific L2 retracker to an *empty* L2 Enhanced Master file. The number of L2 *intermediate* files depends on the number of L2 retrackers: each L2 tracker produces its own L2 *intermediate* file. The list of variables inside a specific L2 *intermediate* file is the number of variables in the *empty* version plus the variables added by the specific retracker as identified in the column "Filled by" in Table 3.2. Each L2 *intermediate* file name must include the L2 retracker identifier, as defined in HYDROCOASTAL Deliverable 2.1 IODD [RD-5] Section 4.3.
3. The *full* version of the product integrates all the L2 *intermediate* files generated from a specific L2 *empty* file and incorporates the Geophysical corrections from UPorto.

For the geophysical corrections module, the value "Uporto" in the "Filled by" column corresponds to the variables generated by the University of Porto while "GeoCor" means that the variables are extracted from the L2 official products. Details of the L2 variables selected and the process applied to them can be found in the HYDROCOASTAL Deliverable 2.1 IODD [RD-5] and in the HYDROCOASTAL Deliverable 1.3 ATBD respectively [RD-4].

Table 3.2 L2 netCDF product variables. The colors are indicative of the variable provider.

Var name	Description	units	Type	Dims	Filled by
time	Time at surface of the along track measurement (at the reference point of the tracking window position).	seconds	do	time	DDP
seq_count	Record sequence counter	count	us	time	DDP
lat	Latitude of measurement at nadir [-90, +90]: Positive at North, Negative at South	degrees	sl	time	DDP
lon	Longitude of measurement at nadir [-180, +180]: Positive at East, Negative at West	degrees	sl	time	DDP
alt	Altitude of the satellite Centre of Mass	meters	sl	time	DDP
range	Reference tracker range corrected for USO frequency drift and internal path correction	meters	sl	time	DDP
roll	Roll mispointing measured by STRs and post-processed by AOCS or by ground	degrees	sl	time	DDP

	facility.				
pitch	Pitch mispointing measured by STRs and post-processed by AOCS or by ground facility.	degrees	sl	time	DDP
yaw	Yaw mispointing measured by STRs and post-processed by AOCS or by ground facility.	degrees	sl	time	DDP
scale_factor	Scaling factor in order to retrieve sigma-0. It includes antenna gains and geometry satellite - surface. It is not applied to waveforms	dB	sl	time	DDP
doppler_freq_sar	Doppler frequencies used to calculate the Doppler beams	degrees	sl	time* Nl	DDP
velocity_x	Satellite velocity vector: x component	m/s	fl	time	DDP
velocity_y	Satellite velocity vector: y component	m/s	fl	time	DDP
velocity_z	Satellite velocity vector: z component	m/s	fl	time	DDP
range_migration_corr	Slant range correction for each beam in the stack	m	do	time* Nl	DDP
altitude_rate	Altitude rate at 20Hz	m/s	sl	time	DDP
RIP_sar	Integrated stack in fast time dimension	Watt	fl	time* Nl	DDP
look_angle_start	Look angle of the first contributing look/beam (Look angle is defined as angle between nadir satellite and the given surface for that beam or look)	radians	ss	time	DDP
look_angle_stop	Look angle of the last contributing look/beam (Look angle is defined as angle between nadir satellite and the given surface for that beam or look)	radians	ss	time	DDP
burst_nb_start	Burst index of the first contributing look	count	ss	time	DDP
burst_nb_stop	Burst index of the last contributing look	count	ss	time	DDP
looks_i	I component for the looks of the stack	count	sc	time	DDP

				* Ns* Nl	
looks_q	Q component for the looks of the stack	count	sc	time * Ns* Nl	DDP
i_scale_factor	The i-samples scaling factor, computed in order to best fit the i-samples within 1 byte. The scaling, needed to convert the looks_i into sqrt(watt), is applied as follows: looks_i_sqr_watt (ku_rec,Nl, Ns) = looks_i (ku_rec,Nl, Ns) * i_scale_factor(ku_rec,Nl)	sqrt Watt / count	fl	time *Nl	DDP
q_scale_factor	The q-samples scaling factor, computed in order to best fit the q-samples within 1 byte. The scaling, needed to convert the looks_q into sqrt(watt), is applied as follows: looks_q_sqr_watt (ku_rec,Nl, Ns) = looks_q (ku_rec,Nl, Ns) * q_scale_factor(ku_rec,Nl)	sqrt Watt / count	fl	time *Nl	DDP
looks_i_masked	I component for the looks of the stack after masking.	count	sl	time * Ns* Nl	DDP
looks_q_masked	Q component for the looks of the stack after masking.	count	sl	time * Ns* Nl	DDP
waveform_i2q2	The fully calibrated, multi-looked power waveform. The final scaling is given in the variable "waveform_scale_factor", in order to best fit the waveform into 2 bytes	count	sl	time * Ns	DDP
waveform_scale_factor	The waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the waveform into Watt, is applied as follows: waveform_i2q2_watt(ku_rec,	Watt / count	fl	time	DDP

	Ns) = waveform_i2q2 (ku_rec, Ns) * waveform_scale_factor (ku_rec)				
phase_difference	Phase difference **(Only for SARIn mode)**	rad	fl	time* Ns	ESA
coherence	Coherence **(Only for SARIn mode)**	count	fl	time* Ns	ESA
lon_p	Longitude of satellite platform [-180;+180] **(Only for SARIn mode)**	degrees	do	time	ESA
lat_p	Latitude of satellite platform [-90;+90] **(Only for SARIn mode)**	degrees	do	time	ESA
Geophysical Corrections and metadata					
h_surf	Altitude above sea level at which the DTC (upt_dry_tropo) and WTC (gpd_wet_tropo) have been computed	m	fl	time	UPorto
upt_dry_tropo	Dry Tropospheric Correction from UPorto	m	fl	time	UPorto
gpd_wet_tropo	Wet Tropospheric Correction from UPorto	m	fl	time	UPorto
gpd_wet_tropo_flag	Data source flag for the Wet Tropospheric Correction from UPorto		uc	time	UPorto
geoid_EIGEN_6C4	Geoid heights from EIGEN-6C4 model	m	fl	time	UPorto
mod_dry_tropo_cor	Dry tropospheric correction **(Only for CS2)**	m	ss	time	GeoCor.
mod_wet_tropo_cor	Wet tropospheric correction **(Only for CS2)**	m	ss	time	GeoCor.
mod_dry_tropo_cor_zero_altitude	Model dry tropospheric correction at zero altitude **(Only for S3)**	m	ss	time	GeoCor.
mod_dry_tropo_cor_meas_altit	Model dry tropospheric correction at measurement altitude	m	ss	time	GeoCor.

ude	**(Only for S3)**				
mod_wet_tropo_cor_zero_altitude	Model wet tropospheric correction at zero altitude **(Only for S3)**	m	ss	time	GeoCor.
mod_wet_tropo_cor_meas_altitude	Model wet tropospheric correction at measurement altitude **(Only for S3)**	m	ss	time	GeoCor.
rad_wet_tropo_cor	Radiometer wet tropospheric correction **(Only for S3)**	m	ss	time	GeoCor.
rad_wet_tropo_cor_sst_gam	Radiometer wet tropospheric correction using SST and Gamma **(Only for S3)**	m	ss	time	GeoCor.
tb_238	Channel 1 main beam BT **(Only for S3)**	K	ss	time	GeoCor.
tb_365	Channel 2 main beam BT **(Only for S3)**	K	ss	time	GeoCor.
sig0_ocean	Corrected « ocean » backscatter coefficient **(Only for S3)**	dB	ss	time	GeoCor.
rad_surf_type	Radiometer-derived surface type (S3)		sc	time	GeoCor.
rain_flag	Altimeter rain flag (S3)		sc	time	GeoCor.
open_sea_ice_flag	Ocean/sea-ice flag **(Only for S3)**		sc	time	GeoCor.
rad_along_track_avg_flag	Radiometer along-track averaging flag **(Only for S3)**		sc	time	GeoCor.
tb_238_quality_flag	Quality flag for Channel 1 main beam BT **(Only for S3)**		sc	time	GeoCor.
tb_365_quality_flag	Quality flag for Channel 2 main beam BT **(Only for S3)**		sc	time	GeoCor.
sig0_ocean_qual	« Ocean » backscatter coefficient validity flag **(Only for S3)**		sc	time	GeoCor.

inverse_baro	Inverse Barometric Correction	m	sl	time	GeoCor.
atm_cor_sig0	Atmospheric Attenuation Correction **(Only for S3)**	dB	ss	time	GeoCor.
GIM_iono	GIM Ionospheric Correction	m	sl	time	GeoCor.
altimeter_iono	Ionospheric Correction from the altimeter **(Only for S3)**	m	sl	time	GeoCor.
ocean_tide_got	Ocean Tide: Includes the corresponding the short-period part of the loading tide and equilibrium long-period ocean tide height (only for S3) **(Only for S3)**	m	sl	time	GeoCor.
ocean_tide_fes	Ocean Tide: Includes the corresponding the short-period part of the loading tide and equilibrium long-period ocean tide height (only for S3) **(Only for S3)**	m	sl	time	GeoCor.
load_tide_got	Load tide height for geocentric ocean tide (GOT solution) **(Only for S3)**	m	sl	time	GeoCor.
load_tide_fes	Load tide height for geocentric ocean tide (FES solution)	m	sl	time	GeoCor.
ocean_tide_eq	Equilibrium long-period ocean tide height	m	sl	time	GeoCor.
ocean_tide_non_eq	Non-equilibrium long-period ocean tide height	m	sl	time	GeoCor.
solid_earth_tide	Solid Earth Tide	m	sl	time	GeoCor.
geocentric_polar_tide	Geocentric Polar Tide	m	uc	time	GeoCor.
hf_fluct_cor	High frequency fluctuations of the sea surface topography	m	ss	time	GeoCor.

sea_state_bias	Sea state bias correction	m	ss	time	GeoCor.
geoid	Geoid Height	m	uc	time	GeoCor.
MSS	Mean Sea Surface	m	uc	time	GeoCor
surf_type	0 open_ocean or semi-enclosed_seas, 1 enclosed_seas or lakes, 2 continental_ice, 3 land		sc	time	GeoCor.
Common parameters for each retracker					
retracked_epoch_<RET>	Estimated epoch in meters w.r.t center of the window (tracker range is given to the center of the window) using the <RET> retracker. (no geophysical corrections applied)	m	sl	time	Retrack
retracked_range_<RET>	Corrected range by the retracker offset (using <RET> retracker), the reference range includes already the USO frequency drift and the internal/instrument corrections. (no geophysical corrections applied)	m	sl	time	Retrack
retracked_Pu_<RET>	Retrieved power using the <RET> retracker.	dB	sl	time	Retrack
retracked_sig0_<RET>	Backscattering coefficient computed from the retracked power once corrected by the sigma0 scaling factor (scale_factor)	dB	sl	time	Retrack
flags_<RET>	Flag indicating successful or failed retracking		sl	time	Retrack
Specific parameters for the retrackers					
swh_ESA	Significant wave height	m	sl	time	Retr. ESA
ssha_ESA	Sea surface height anomaly	m	sl	time	Retr. ESA
swh_isr	Significant wave height	m	sl	time	Retr. ISR

misfit_analytical_isr	Correlation between the real waveform and the fitted one. It is the Pearson correlation coefficient expressed as percentage. Waveforms with values below 90% should be discarded.	percent	sl	time	Retr. ISR
swh_are	Significant Wave Height	m	sl	time	Retr. ARE
misfit_are	Misfit computed according to the following formula: sqrt(sum((L1B_wave-fitted_wave).^2))/sqrt(sum((L1B_wave).^2))	unitless	sl	time	Retr. ARE
num_peaks_dtu	Number of peaks in waveform	count	uc	time	Retr. DTU
dif_height_dtu	Difference from average peak height	m	sl	time	Retr. DTU
num_peaks_atk	Number of processed peaks in the waveform (math notation : M_{PWF}) ; this number being 0 or 1 for LRM and SARM.	count	uc	time	Retr. ATK
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.	--	ui	time	Retr. ATK
ind_pk_start_atk	first peak start indexe.	count	uc	time	Retr. ATK
ind_pk_stop_atk	first peak stop index.	count	uc	time	Retr. ATK
elv_rtk_atk	elevation of the retracked point above the reference ellipsoid (for SARIn mode	metres	ss	time	Retr. ATK

	only)				
lat_rtk_atk	geodetic latitude of the retracked point	degrees	sl	time	Retr. ATK
lon_rtk_atk	longitude of the retracked point	degrees	sl	time	Retr. ATK
swh_ubo	Significant Wave Height	m	sl	time	Retr. UBO
ssb_ales_20_ku_tum	Sea State Bias correction specific to the ALES+ SAR Range output	m	[data type]	time	Retr. TUM
swh_noc	Significant Wave Height	m	sl	time	Retr. NOC
misfit_noc	misfit between SAR Waveform Model and SAR Waveform Data has been computed as: sqrt(1/128*sum(residual)^2)*100, where residuals are the differences between the fitted model waveform power and the data waveform power, normalized for the waveform power maximum value.	percent	sl	time	Retr. NOC

3.3 L2 global attributes

Table 3.3: L2 enhanced product Global attributes

Attribute name	Description	Format
Conventions	NetCDF convention	string
project_name	Name of the project (HydroCoastAL)	string
mission_name	Name of the mission	string
operation_mode	Name of the altimeter mode	string
altimeter_sensor_name	Name of the altimeter sensor	string
gnss_sensor_name	Name of the GNSS sensor	string

doris_sensor_name	Name of the DORIS sensor	string
acq_station_name	Identification of the acquisition station	string
first_meas_time	UTC Date of the first measurement of the data set (YYYY-MM-DD HH:MM:SS.mmmmmm)	string
last_meas_time	UTC Date of the first measurement of the data set (YYYY-MM-DD HH:MM:SS.mmmmmm)	string
xref_altimeter_level1a	Name of the altimeter level 1a / FBR data file	string
ellipsoide_name	Ellipsoid name	string
semi_major_ellipsoid_axis	Semi-major axis of the reference ellipsoid (meters)	UL
ellipsoid_flattening	Flattening coefficient of the reference ellipsoid	do
orbit_cycle_num	Cycle number (set to +000 if not used)	ss
orbit_REL_Orbit	Relative Orbit Number at sensing start time. If not used set to +00000	sl
orbit_ABS_Orbit_Start	Absolute Orbit Number at Product Start time	ul
orbit_Rel_Time_ASC_Node_Start	Relative time since crossing ascending node time relative to start time of data sensing (seconds)	do
orbit_ABS_Orbit_Stop	Absolute Orbit Number at Product Stop Time	ul
reference_tracking_gate	Index of the gate where the tracking window is referenced. It is 43, starting from 0, in for the products from Sentinel 3, 63 for the ones coming from SAR CryoSat-2 and 255 for SARIn. No zero padded waveforms considered.	us
DDP_processor	Indicates the DDP processor used.	string
Retrackers	Indicates the list of retrackers used in the L2 processor.	string

4 L3 Inland water Format Specifications

L3 products are Water Level data derived from L2 measurements confined by the auxiliary data sets such as global lake and river water masks. Each L3 record provides an estimation of river/lake water level for a given overflight over the waterbody as made by the satellite. Mean measurement location coordinates and mean overflight time of the involved L2 measurements are the space time coordinates of the L3 records.
For the Sentinel-3 repeat orbit missions, this leads to time series of water level.
For the CryoSat-2 non-repeat mission this leads to space-time series of water level.
L3 product files are organised as geographical tiles of squares of 10° square. A L3 product file may cover several unrelated waterbodies and basins, different sections of the same river, etc. L3 products are also waterbody/basin-agnostic.

4.1 L3 NetCDF format

L3 products are compliant with the NetCDF-4 format, following as much as possible similar variable convention names as the ones provided in Sentinel-3 format product specifications [RD-2]. A NetCDF file contains dimensions (this section), variables and their attributes (cf. section 4.2), and global attributes (cf. section 4.3).

The final L3 file format is not totally defined and is going to be agreed after PM1.

Table 4.1 Dimensions for Level 3 product

Dimension name	Description	Value
time	Number of water height values in the file (all time series merged), with a frequency related to the revisit period of the satellite over the water body.	# of points

4.2 L3 Products variables

L3 products are processed from various L2 datasets, including: CryoSat-2 SARM or CryoSat-2 SARINM and Sentinel-3 SARM L2 products, using outputs from various retrackers. In the tables below, variables which depend upon a specific so called “altimetric context” (i.e., specific: mission and/or altimeter frequency band and/or altimeter mode and/or retracker) are named using the following convention:

“<variable_name>_<mission>_<band>_<mode>_<retracker>”

E.g., for Water Level estimation derived from CryoSat-2 operating in Ku band, in SARIN mode and using outputs of the OCOG retracker, the variable name would be:

"water_level_cryosat2_ku_sin_ocog"

- Possible mission names are : 'cryosat2', 'sentinel3a', 'sentinel3b'
- Possible band names are : 'ku' (C-band from the Sentinel-3 satellites is not addressed in the frame of this project)

Possible retracker ID are : 'isr' (SHAPE 2-Step, isardSAT), '' (Specialised SARIN), 'algo3' (Empirical Narrow Peak), 'algo4' (SHAPE Empirical), 'algo5' (Stats STAR), 'algo6' (ALES+ for SAR), 'algo7' (SAR Coastal Zone)

Table 4.2: L3 NetCDF product variables

Var name	Description	units	Type	Dims	Filled by
time	Mean Time at waterbody overflight.	decimal year	do	time	AHL or DTU
lat	Mean Latitude of waterbody overflight [-90, +90]: Positive at North, Negative at South.	degrees	sl	time	AHL or DTU
lon	Mean Longitude of waterbody overflight [-180, +180]: Positive at East, Negative at West.	degrees	sl	time	AHL or DTU
mission_id	Identifier of the mission 1=CryoSat-2 ; 2=Sentinel-3.	n.a.	ui	time	AHL or DTU
altimeter_mode	Name of the altimeter mode: 1=LRM ; 2=SAR ; 3=SARIN ; 4=Degraded SARIN.	n.a.	ui	time	AHL or DTU
track_id	Sentinel-3 track number, FillValue for CryoSat-2.	NA	us	time	AHL or DTU
vs_id	Virtual station ID Sentinel-3 over rivers or lakes and CryoSat-2 over lakes. . There are usually several vs_id per river while there is always only one vs_id value per lake. Set to FillValue otherwise, for the case of CryoSat-2 over rivers.	n.a.	uc	time	AHL or DTU

lake_name	DTU products only: Lake name taken from the lake mask, FillValue over rivers.	NA	uc	time	DTU
lake_area	DTU products only: Lake area taken from the lake mask, FillValue over rivers.	km	us	time	DTU
water_level_<mission>_<band>_<mode>_<retracker>	Estimated Water Level w.r.t. geoid height variable.	m	sl	time	AHL or DTU
no_l2_meas_<mission>_<band>_<mode>_<retracker>	Number of L2 measurements involved in the computation of this L3 Water Level.	n.a.	ui	time	AHL or DTU
sd_l2_meas_<mission>_<band>_<mode>_<retracker>	Standard Deviation of L2 measurements involved in the computation of this L3 Water Level.	m	sl	time	AHL or DTU
geoid_height	Geoid Height from Eigen-6C4 model.	m	sl	time	AHL or DTU

Special note for the CryoSat-2/Rivers cases: Constructing a L3 time series product for CryoSat-2 is not a standard procedure and is not straight forward. As a global data product, we therefore suggest constructing and defining a CryoSat-2 based river L3 product. Here we suggest 3 candidate products. 1) Simply providing extracted L2 water levels based on a river mask. 2) Provide L2 water levels projected to the centerline of the river. 3) construct water level time series based on measurement from a river segment e.g. 50km. Whatever the selected option, the CryoSat-2/Rivers product shall be compatible with, and use, the present L3 product format. Agreement will be made during PM1.

4.3 L3 Global attributes

Table 4.3: L3 product Global attributes

Attribute name	Description	Format
Conventions	NetCDF convention	string
provider	Name of the product provider (AHL or DTU)	string

project_name	Name of the project (HydroCoastAL)	string
ellipsoid_name	Ellipsoid name	string
semi_major_ellipsoid_axis	Semi-major axis of the reference ellipsoid (meters)	UL
ellipsoid_flattening	Flattening coefficient of the reference ellipsoid	do
water_mask_tiles	Name of Water Mask Tile(s) used for this L3 product	string
first_meas_time	UTC Date of the first measurement of the data set (YYYY-MM-DD HH:MM:SS.mmmmmm)	string
last_meas_time	UTC Date of the first measurement of the data set (YYYY-MM-DD HH:MM:SS.mmmmmm)	string

4.4 L3 Processing variants

L3 products are processed using two different L3 processors: one from AltiHydroLab.fr (AHL) and another one from DTU Space. Each processor uses different auxiliary datasets. This section describes these auxiliary datasets and the way they are used in the respective processors.

L3 Processing by AHL

L3 products are confined by e.g. the Global Surface Water Explorer (Pekel et al., 2016) and satellite tracks. More details are provided in the ATBD document of the project [RD-4], Section 6.

L3 Processing by DTU Space

L3 products are confined by e.g. the Global Surface Water Explorer (Pekel et al., 2016), the Sentinel-3A/B ground track locations and a subset of a river mask/river centerline product e.g. The Global River Widths from Landsat (GRWL) Database (Allen et al., 2018). The second global product is a CryoSat-2 + Sentinel-3A/B Lake product also provided in 10 by 10 degree tiles. This product will be confined by a subset of a lake shapefile mask e.g. the hydroshed hydroLakes product https://hydrosheds.org/page/hydrolakes (Lehner et al., 2008).

5 L4 River discharge Format Specifications

L4 water discharge product will include the information from the L3 River product relevant to the discharge retrieving site.

5.1 L4 NetCDF format

There is one L4 file for each water body (or ROI) addressed by the HydroCoastAL project:

Table 5.1: Dimensions for Level 4 product

Dimension name	Description	Value
time	Number of water height values in the file (all time series merged), with a frequency related to the revisit period of the satellite over the water body.	# of points

5.2 L4 Products variables

Table 5.2: L4 NetCDF product variables

Var name	Description	units	Type	Dims	Filled by
time	Time of crossing	decimal year	do	time	DTU
lat	Mean Latitude of waterbody crossing [-90, +90]: Positive at North, Negative at South.	degrees	do	time	DTU
lon	Mean Longitude of waterbody crossing [-180, +180]: Positive at East, Negative at West.	degrees	do	time	DTU
geoid_height	Geoid Height from model	m	do	time	DTU
vs_id	Virtual station id. This will contain an A/B to indicate the mission. The same as in L3 “Virtual Station” product	NA	uc	time	DTU

water_level	Estimated Water Level w.r.t. Geoid height.	m	do	time	DTU
water_discharge_RC	Water Discharge estimated by Rating Curve approach	m3/s	do	time	NUIM
water_discharge_BJ	Water Discharge estimated by Bjerklie approach. The field contains NaN if the retrievals fail	m3/s	do	time	NUIM
water_discharge_Man	Water Discharge estimated by Manning approach. The field contains NaN if the retrievals fail	m3/s	do	time	NUIM
flag_floodplain_MAN	flag[0,1], ==1 if floodplain flow is included	NA	ui	time	NUIM
water_discharge_Merg	Water Discharge estimated by merging altimetry and reflectance ratio C/M approach. The field contains NaN if the retrievals fail	m3/s	do	time	CNR
water_width	Water Width used in Bjerklie and Manning equations, retrieved from dynamic masks or from width- height relations. The field will contain NaN if both retrievals fail.	m	do	time	NUIM, ATK
water_slope	Water slope used in Bjerklie and Manning equations, retrieved from L3 river product.The field will contain NaN if both retrievals fail.	m/m	do	time	DTU
reflectance ratio_CM	Reflectance ratio C/M extracted by multispectral imageries	NA	do	time	CNR

5.3 L4 Global attributes

Table 5.3: L4 product Global attributes

Attribute name	Description	Format
Conventions	NetCDF convention	string
project_name	Name of the project (HydroCoastAL)	string

provider	Name of the product provider	string
Altimetric Missions	mission used for retrievals	string
Auxiliary Missions	missions and products used for retrievals	string
RC method	short description, reference to the document	string
Bjerklie method	short description, reference to the document	string
Manning method	short description, reference to the document	string
Merging method	short description, reference to the document	string
Water level method	short description, reference to the document	string

6 References

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Pekel, J. F., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. Nature, 540(7633), 418–422. https://doi.org/10.1038/nature20584

7 List of Acronyms

ACE2 Altimeter Corrected Elevations (vers. 2)
AD Applicable Documents
AGC Automatic Gain Control
AH Alti-Hydro
AHP Alti-Hydro Product(s)
AI Action Item
AIM Action Item Management (tool)
AltiKa Altimeter in Ka band and bi-frequency radiometer instrument
AMSR-E Advanced Microwave Scanning Radiometer-Earth Observing System
ANA Agência Nacional de Águas (National Water Agency, Brazil)
AoA Angle of arrival
API Application Programming Interface
AR Acceptance Review
ASAP As Soon As Possible
ASCII American Standard Code for Information Interchange
ATBD Algorithm Technical Basis Document
ATK ALONG-TRACK S.A.S.
AVISO Archivage, Validation et Interprétation des données des Satellites Océanographiques
BIPR Background Intellectual Property Right
CASH Contribution de l'Altimetrie Spatiale à l'Hydrologie (Contribution of Space Altimetry to Hydrology)
CCN Contract Change Notice
CFI Customer Furnished Item
CLASS NOAA/Comprehensive Large Array-Data Stewardship System
CoG Centre of Gravity
CPP CryoSat-2 Processing Prototype (CNES)
CryoSat-2 Altimetry satellite for the measurement of the polar ice caps and the ice thickness
CRISTAL Copernicus polaR Ice and Snow Topography ALtimeter
CRUCIAL CRyosat-2 sUCcess over Inland wAter and Land
CSV Comma Separated Values
CTOH Centre de Topographie des Océans et de l'Hydrosphère (Centre of Topography of the Oceans and the Hydrosphere)
DAO Data Access Object
DARD Data Access Requirement Document
DDM Delay-Doppler Map
DDP Delay-Doppler Processor
DEM Digital Elevation Model
DGC Doppler Ground Cell
DPM Detailed Processing Model
DPP Data Procurement Plan
DTC Dry Tropospheric Correction
DTU Danmarks Tekniske Universitet (Technical University of Denmark)
DVT Data Validation Table
ECMWF European Centre for Medium-Range Weather Forecasts
ECSS European Cooperation for Space Standardisation
EGM Earth Gravitational Model
ENVISAT ENVIronment SATellite
EO Earth Observation
EOEP Earth Observation Enveloppe Programme
EOLi Earth Observation Link
EOLi-SA EOLi-Stand Alone
EPN EUREF Permanent Network
ERA ECMWF ReAnalysis
ESA European Space Agency
EUREF IAG Reference Frame Sub-Commission for Europe
FBR Full Bit Rate
FFT Fast Fourier Transform
FR Final Review
FTP File Transfer Protocol
FCUP (from portuguese) *"Faculdade de Ciências da Universidade"*, Science faculty of the University of Porto
GDAL Geospatial Data Abstraction Library
GDR, [I-,S-] Geophysical Data Record, [Interim-, Scientific-]
GFZ Deutsche GeoForschungsZentrum (German Research Centre for Geosciences)

GNSS Global Navigation Satellite System
GOCE Gravity field and steady-state Ocean Circulation Explorer
GPD GNSS-derived Path Delay
G-POD Grid Processing on Demand
GPT2 Global Pressure and Temperature model (vers. 2)
GPP Ground Processing Processor
GPS Global Positioning System
GRACE Gravity Recovery And Climate Experiment
GRDC Global Runoff Data Centre
GRGS Groupe de Recherche de Géodésie Spatiale (Space Geodesy Research Group)
GRLM Global Reservoir and Lake Monitor
GTN-L Global Terrestrial Network - Lakes
HDF-EOS Hierarchical Data Format - Earth Observing System
HGT A SRTM file format
HWS High Water Stage
HYCOS Hycos Hydraulics & Control Systems
HYPE Hydrological Predictions for the Environment model
IAG International Association of Geodesy
IDAN Intensity-Driven Adaptive-Neighbourhood
IE Individual Echoes
IGS International GNSS (Global Navigation Satellite Systems) Service
IM Internal Meeting (e.g. not with the client)
IODD Input Output Data Document
IPF Integrated Processing Facility
ISD isardSAT
ITRF International Terrestrial Reference Frame
IRF Impulse Response Function
Jason-1 Altimetry satellite, T/P follow-on
Jason-2 Altimetry satellite, also known as the « Ocean Surface Topography Mission » (OSTM), Jason-1 follow-on
Jason-3 Altimetry satellite, Jason-2 follow-on
Jason-CS Jason Continuity of Service
KML Keyhole Markup Language
KO Kick Off
L1A Level-1A
L1B Level-1B
L1B-S, L1BS Level-1B-S (aka, Stack data)
L2 Level-2
L3 Level-3
L4 Level-4
LAGEOS Laser Geodynamics Satellite
LEGOS (french acr.) Laboratoire d'Études en Géophysique et Océanographie Spatiale (Laboratory for Studies in Geophysics and Spatial Oceanography)
LOTUS Preparing Land and Ocean Take Up from Sentinel-3
LPS Living Planet Symposium
LRM Low Resolution Mode
LSE Least Square Estimator
LWL Lake Water Level
LWS Low Water Stage
MARS Meteorological Archival and Retrieval System
MDL Minimum Description Length
MMSE Minimum Mean Square Error
MNDWI Modification of Normalised Difference Water Index
MoM Minutes of Meeting
MPC Mission Performance Centre
MRC Mekong River Commission
MTR Mid Term Review
MSS Mean Square Slope
MSS Mean Sea Surface
MWR Microwave Radiometer
NAVATT Navigation and Attitude
NDVI Normalised Difference Vegetation Index
NDWI Normalised Difference Water Index
netCDF Network Common Data Form
NOAA National Oceanic and Atmospheric Administration
NR New Requirement (w.r.t. the SoW)
NRT Near Real-Time
NWM Numerical Weather Model
OCOG Offset Centre of Gravity
OPC One per Crossing
OSTM Ocean Surface Topography Mission (also known as Jason-2), is also the name of the satellites series T/P, Jason-1, Jason-2 and Jason-3
OVS Orbit State Vector
PDF Probability Density Function
PEACHI Prototype for Expertise on AltiKa for Coastal, Hydrology and Ice
PEPS Sentinel Product Exploitation Platform (CNES)
PISTACH (french acr.) Prototype Innovant de Système de Traitement pour les Applications Cotières et l'Hydrologie
PMP Project Management Plan

POCCD	Processing Options Configuration Control Document
PR	Progress Report
PRF	Pulse Repetition Frequency
PSD	Product Specification Document
PTR	Point Target Response
PVP	Product Validation Plan
PVR	Product Validation Report
PVS	Pseudo Virtual Station(s)
PWF	Pseudo Waveform
RADS	Radar Altimeter Database System
RB	Requirements Baseline (document)
RCMC	Range Cell Migration Curve
RCS	Radar Cross Section
RD	Reference Document
RDSAR	Reduced SAR (also known as Pseudo-LRM)
RF	Random Forest
RGB	Red, Green, Blue
RID	Review Item Discrepancy
RIP	Range Integrated Power (of the MLD) sometimes referred as Angular Power Response (APR)
RMS	Root Mean Square
ROI	(geographical) Region(s) Of Interest
RP	Report Period (a month that is being reported into a Progress Report)
RSS	Remote Sensing Systems
RWD	River Water Discharge
RWL	River Water Level
SAMOSA	SAR Altimetry MOde Studies and Applications
SARAL	In Indian "simple", in english "SAtellite for ARgos and AltiKa.
SARIn	SAR Interferometric (CryoSat-2/SIRAL mode)
SAR	Synthetic Aperture Radar
SARvatore	SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation
SCOOP	SAR Altimetry Coastal & Open Ocean Performance
SDP	Software Development Plan
SEOM	Scientific Exploitation of Operational Missions
SHAPE	Sentinel-3 Hydrologic Altimetry PrototypE
SI-MWR	Scanning Imaging MWR
SME	Small and Medium-sized Enterprise
SMHI	Swedish Meteorological and Hydrological Institute
SNAP	SeNtinel Application Platform
SOA	State Of the Art
SOW	Statement Of Work
SPR	Software Problem Reporting
SPS	Sentinel-3 Surface Topography Mission System Performance Simulator
SRAL	SAR Radar Altimeter
SRTM	Shuttle Radar Topography Mission
SSB	Sea State Bias
SSMI/IS	Special Sensor Microwave Imager (SSM/I) Sounder
SSO	Single Sign-On
Stack	Matrix of stacked Doppler beams
STD	Standard Deviation
STM	Sentinel-3 Surface Topography Mission
STR	Star Tracker
SUM	Software User Manual
SWBD	SRTM Water Body Data
SWH	Significant Wave Height
TAI	Temps Atomique International (International Atomic Time)
TBC	To Be Confirmed
TBD	To Be Done
TCWV	Total Column Water Vapour
TDS	Test Data Set
TMI	Tropical Rainfall Measuring Mission (TRMM) Microwave Imager
TN	Technical Note
T/P	Topex/Poseidon (altimetry satellite)
TR	Technical Risk
UNESCO	United Nations Educational, Scientific and Cultural Organization
URL	Uniform Resource Locator
USGS	United States Geological Survey
USO	Ultra Stable Oscillator
UTC	Coordinated Universal Time
UWM	Updated Water Mask
VS	Virtual Station(s)
VH	Vertical-Horizontal polarisation
VV	Vertical-Vertical polarisation
WBS	Work Breakdown Structure
WF	Waveform
WFR	Water Fraction Ratio
WMO	World Meteorological Organization
WP	Work Package(s)
w.r.t.	with respect to
WTC	Wet Tropospheric Correction

XML eXtensible Markup Language
ZP Zero Padding