SARvatore Altimetry Virtual Lab Migration and Integration in the EarthConsole Platform

Software User Manual

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Applicable Documents

Doc Ref	Title
AD1 [ESA-EOP-SD-SOW-0222]	SARvatore Altimetry Virtual Lab Migration and Integration in the EarthConsole Platform
AD2 [ESA RFP/3-17173/21/I-DT-lr Detailed Proposal]	ALTIMETRY VIRTUAL LAB SARvatore Migration

Reference Documents

Doc Ref	Title
RD01	Guidelines for the SAR (Delay-Doppler) L1b Processing, ESA, 2013, https://earth.esa.int/eogateway/documents/20142/37627/Guidelines-for-the-SAR-Delay-Doppler-L1b-Processing.pdf?sortby=NEWEST_FIRST
RD02	(SAMOSA Model Paper) Ray, Chris & Martin-Puig, Cristina & Clarizia, M.P. & Ruffini, Giulio & Dinardo, Salvatore & Gommenginger, Christine & Benveniste, Jerome. (2015). SAR Altimeter Backscattered Waveform Model. Geoscience and Remote Sensing, IEEE, 10.1109/TGRS.2014.2330423
RD03	Dinardo, Salvatore & Fenoglio, Luciana & Buchhaupt, Christopher & Becker, Matthias & Scharroo, Remko & Joana Fernandes, M & Benveniste, Jérôme. (2017). Coastal SAR and PLRM altimetry in German Bight and West Baltic Sea. Advances in Space Research. https://doi.org/10.1016/j.asr.2017.12.018
RD04	Guccione, P., Scagliola, M., Giudici, D. 2D Frequency Domain Fully Focused SAR Processing for High PRF Radar Altimeters. Remote Sens. 2018,10, 1943. https://doi.org/10.3390/rs10121943
RD05	Davis C. H., A robust threshold retracking algorithm for measuring ice-sheet surface elevation change from satellite radar altimeters, in IEEE Transactions on Geoscience and Remote Sensing, vol. 35, no. 4, pp. 974-979, July 1997, https://doi.org/10.1109/36.602540.
RD06	Passaro, M., et al., Absolute Baltic Sea Level Trends in the Satellite Altimetry Era: A Revisit. Frontiers in Marine Science 2021. https://doi.org/10.3389/fmars.2021.647607
RD07	Buchhaupt C., Fenoglio-Marc L., Dinardo S., Scharroo R., Becker M (2018). A fast convolution based waveform modell for conventional and unfocused SAR altimetry, Advanced Space Research Special Issue CryoSat-2, https://doi.org/10.1016/j.asr.2017.11.039

RD08	Buchhaupt, C., (2019). Model Improvement for SAR Altimetry, PhD Thesis, University of Darmstadt, tuprints.ulb.tu-darmstadt.de/9015/
RD09	Fenoglio L. and Buchhaupt C. (2020). TUDaBo SAR-RDSAR for G-POD Altimetry Coastal and Open Ocean Performance -Algorithm Theoretical Basis Document (ATBD), ESA Reference number: EOEP-SEOM-EOPSTN-17-046, Version 1.6, 30-01-2020

Acronyms

Acronym	
AOI	Area of Interest
AVL	Altimetry Virtual Lab
CE	Computing Element
CF	Climate & Forecast
EOP-SER	Earth Observation Programmes: Science, Exploitation, Research
EOP-SER	Earth Observation Programmes: Science, Exploitation, Research
ESA	European Space Agency
FBR	Full Bit Rate
FF-SAR	Fully Focused SAR
G-POD	Grid Processing on-Demand
GPP	Ground Processor Prototype
GRS	Geodetic Reference System
L1a	Level 1a
L1A	Level 1A
L1b	Level 1b
L1B	Level 1B
L1B-S	Level 1B-S
L2	Level 2

LRMC	Low resolution mode with range cell migration correction
LUT	Look-Up Table
NoR	Network of Resources
NRT	Near Real Time
OGC	Open Geospatial Consortium
PDGS	Payload Data Ground Segment
PI	Principal Investigator
PO	Processor Owner
P-Pro	Parallel Processing environment
RA	Rolling Archive
RADS	Radar Altimeter Database System
RDS	Reference Data Set
RDSAR	Reduced SAR (also known as Pseudo-SAR)
RDSAR	Reduced SAR SAR Synthetic Aperture Radar
RSS	Research and Service Support
SAMOSA	SAR Altimetry model developed for Sentinel-3
SAR	Synthetic Aperture Radar
SARIN	Synthetic Aperture Radar Interferometry
SARvatore	SAR versatile altimetric toolkit for research & exploitation
SE	Storage Element
SINC	Signal model involving numerical convolutions
SINC2	SINC based conventional altimetry retracker
SINCS	SINC based SAR altimetry retracker
SINCS-OV	Extension of SINCS introducing orbital wave velocities
SMAP	Standalone Multi-mission Altimetry Processor
WCS	WEB COVERAGE SERVICE
WFS	WEB FEATURE SERVICE
WGS	World Geodetic System
WGS	World Geodetic System

WMS	WEB MAP SERVER
WN	Worker Node
WP	Work Package
WxS	WMS, WCS, WFS

Table of Contents

1. Introduction

The purpose of this document is to provide a collection of the Software User Manuals of the Altimetry processors integrated in EarthConsole within the framework of the project: SARvatore Altimetry Virtual Lab Migration and Integration in the EarthConsole Platform.

2. Altimetry processors integrated in EarthConsole: overview

2.1 ALES+ SAR Retracker – TUM

ALES+ SAR Retracker – TUM is a subwaveform retracker for open ocean and coastal zone SAR altimetry data. It adopts a simplified version of the Brown-Hayne functional form (which is the functional form for pulse-limited altimetry) as an empirical retracker to track the leading edge of the waveform. A specific sea state bias correction is also computed and shall be used when correcting the estimated range to compute the sea surface height.

2.2 SARvatore for CryoSat-2

SARvatore (SAR Versatile Altimetric TOolkit for Research and Exploitation) for CryoSat-2 is a Software Processor Prototype developed by ESA/ESRIN (RD01) to experiment with SAR processing from L1A (FBR) to L2 using the SAMOSA retracking model and the Delay-Doppler principle. It can be used over open ocean or coastal zones, as well as over more difficult targets such as rivers, lakes, and sea-ice & ice leads/floes. This toolkit is made available to the user community as an EarthConsoleTM P-PRO Service. The toolkit takes in input Cryosat-2 SAR FBR data products and produces in output geophysical L2 products in standard NetCDF format. This output can be manipulated and visualized with BRAT (the Broadview Altimetry Radar Toolbox, http://www.altimetry.info/toolbox/).

2.3 SARvatore for Sentinel-3

SARvatore (SAR Versatile Altimetric TOolkit for Research and Exploitation) for Sentinel-3 is a Prototype Software Processor developed by ESA/ESRIN to experiment with Sentinel-3 SAR Altimetry processing exploiting the SAMOSA retracking model and the Delay-Doppler principle. It can be used over open ocean or coastal zone, as well as over more difficult targets such as rivers, lakes, and sea-ice & ice leads/floes. This toolkit, similar to the one developed for CryoSat-2, is made available to the user community as an EarthConsole® P-PRO Service. It takes in input L1A Sentinel-3 SAR Altimetry data products and produces in output L2 data products in standard NetCDF format. The content of these output files can be manipulated, displayed and further post-processed with BRAT (the Broadview Altimetry Radar Toolbox, http://www.altimetry.info/toolbox/).

2.4 SARINvatore for CryoSat-2

SARINvatore (SARIN Versatile Altimetric TOolkit for Research and Exploitation) for CryoSat-2 is a Software Processor Prototype developed by ESA/ESRIN to experiment with SARin processing from L1A (FBR) to L2 using the SAMOSA retracking model and the Delay-Doppler principle. It can be used over open ocean or coastal zones, as well as over more difficult targets such as rivers, lakes, and sea-ice & ice leads/floes. This toolkit is made available to the user community as EarthConsole® P-PRO Service. The toolkit takes in input Cryosat-2 SARin FBR data products and produces in output geophysical L2 products in standard NetCDF format. This output can be manipulated and visualized with BRAT (the Broadview Altimetry Radar Toolbox, http://www.altimetry.info/toolbox/).

2.5 Fully-Focused SAR for CryoSat-2 – Aresys Srl

FF-SAR (Fully-Focused SAR) for CryoSat-2 by Aresys (https://www.aresys.it/) is a web service that provides the capability to process on line and on demand CryoSat-2 SAR data, from FBR data products to Level1B FF-SAR products. The service is based on the AREALT-FF1 Processor Prototype that has been developed by Aresys in the framework of ESA contracts for Sentinel-6 and CryoSat-2. The AREALT-FF1 Processor produces FF-SAR altimetry waveforms exploiting the focusing technique in the 2D transformed frequency domain proposed in RD04. Additionally, FF-SAR can be coupled with the ALES+ retracker to produce additional L2 estimates.

2.6 TUDaBO SAR-RDSAR – U.Bonn

TUDaBO SAR-RDSAR – U.Bonn is a processor prototype developed by C. Buchhaupt and L. Fenoglio-Marc at TU Darmstadt (https://www.tu-darmstadt.de/index.en.jsp) and U Bonn (https://www.uni-bonn.de/en) to experiment with SAR mode data from L1A (FBR) to L2. Reduced SAR, unfocused SAR, and LRMC data can be generated for both CryoSat-2 and Sentinel-3A. For each mode, dedicated signal processing options and retrackers are available, which allow the user to experiment with different configurations. All L1B/L2 products for reduced SAR, unfocused SAR, and LRMC have the same geolocations and time tags, allowing a direct comparison without the need for interpolation.

2.7 Sentinel-6 GPP L1 – isardSAT

Sentinel-6 P4 L1 Ground Prototype Processor service in EarthConsole makes available the HR processor for Sentinel-6A Poseidon 4 Level 1A High Resolution products developed by isardSAT (https://www.isardsat.cat/ca).

2.8 Fully-Focused SAR for Sentinel-6 and Sentinel-3 – Aresys Srl

FF-SAR (Fully-Focused SAR) for Sentinel-6 and Sentinel-3 by Aresys (https://www.aresys.it/) is a web service that provides the capability to process on line and on demand Sentinel-6 Poseidon-4 L1A High-Resolution SAR and Sentinel-3 L1A SAR products, to produce Level1B FF-SAR products. The service is based on the AREALT-FF1 Processor Prototype that has been developed by Aresys in the framework of ESA contracts for Sentinel-6 and CryoSat-2. The AREALT-FF1 Processor produces FF-SAR altimetry waveforms exploiting the focusing technique in the 2D transformed frequency domain proposed in RD04. Additionally, FF-SAR for Sentinel-3 can be coupled with the ALES+ retracker.

2.9 SMAP for Sentinel-3 – CLS

The Standalone Multi-mission Altimetry Processor (SMAP) for Sentinel-3 service is a standalone altimeter data processor written in Python 3 (3.7.3). SMAP implements in particular the fully-focused SAR (FF-SAR) processing using the time-domain back-projection algorithm. SMAP is currently able to process Sentinel-3 L1A PDGS products and also includes a few retrackers. An open source version of the processor is available at: https://github.com/cls-obsnadir-dev/SMAP-FFSAR.

3. ALES+ SAR Retracker – TUM

ALES+ SAR Retracker – TUM is a subwaveform retracker for open ocean and coastal zone SAR altimetry data developed at the Technical University of Munich (https://www.tum.de/en/). It adopts a simplified version of the Brown-Hayne functional form (which is the functional form for pulse-limited altimetry) as an empirical retracker to track the leading edge of the waveform. A specific sea state bias correction is also computed and shall be used when correcting the estimated range to compute the sea surface height.

Provider

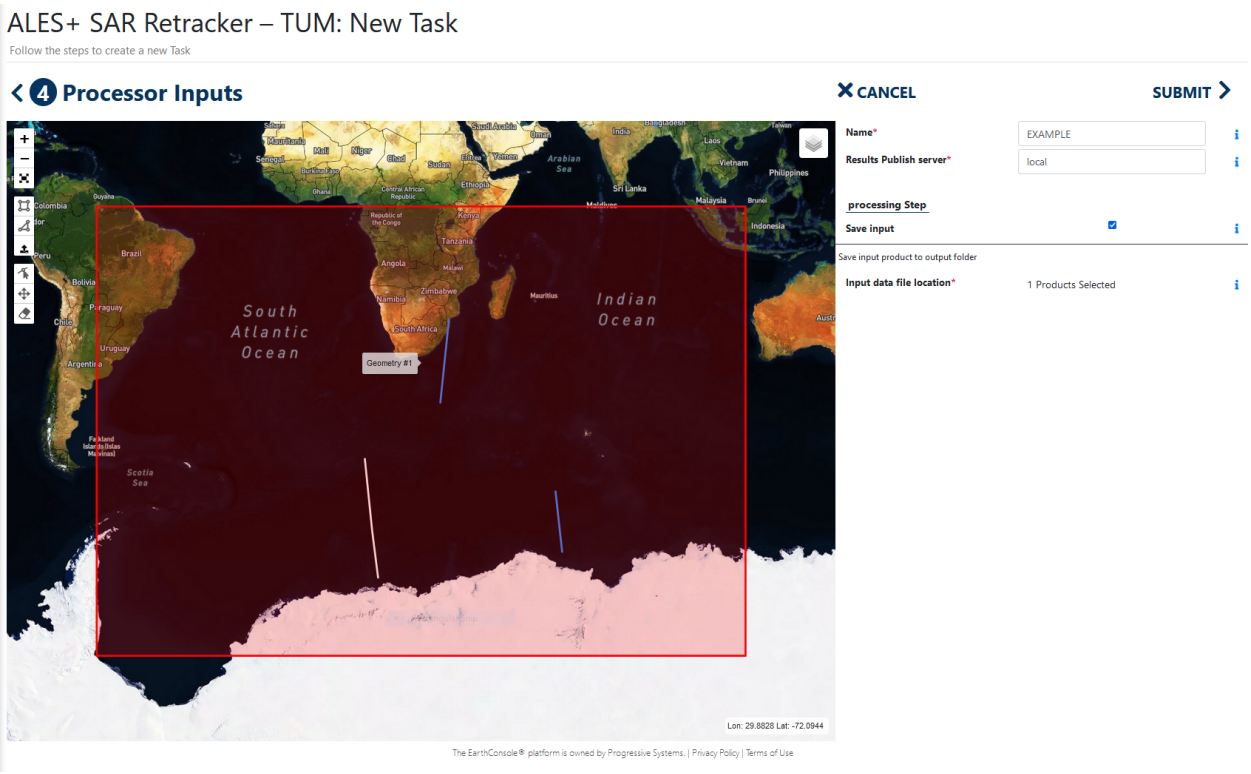
Technical University of Munich (TUM) – Marcello Passaro

Description

The P-PRO Service ALES+ SAR Retracker – TUM (Adaptive Leading Edge Subwaveform retracker, version +, for SAR), is a web platform that provides the capability to process on line and on demand either official CryoSat-2 L1b products or Sentinel-3 WAT L1b products to produce ALES+ SAR L2 NetCDF products.
ALES+ SAR Retracker – TUM is a subwaveform retracker for open ocean and coastal zone SAR altimetry data. It adopts a simplified version of the Brown-Hayne functional form (which is the functional form for pulse-limited altimetry) as an empirical retracker to track the leading edge of the waveform. A specific sea state bias correction is also computed and shall be used when correcting the estimated range to compute the sea surface height.
ALES+ SAR Retracker – TUM is an algorithm under research & development, which is subject to updates.

Different phases of the ALES+ SAR Retracker – TUM development have been funded by the following ESA Projects:
* Sea Level Climate Change Initiative (ESA Contract No. 4000126561/19/I-NB)
* Baltic+ Sea Level (ESA Contract No. 4000126590/19/I/BG)
* HYDROCOASTAL (ESA Contract No. 4000129872/20/I-DT)

The processing service is available on EarthConsole platform, where a user-friendly and intuitive interface allows to create and submit processing tasks.



4. SARvatore for CryoSat-2

SARvatore (SAR Versatile Altimetric TOolkit for Research and Exploitation) for CryoSat-2 is a Software Processor Prototype developed by ESA/ESRIN (RD01) to experiment with SAR processing from L1A (FBR) to L2 using the SAMOSA retracking model. It can be used over open ocean or coastal zones, as well as over more difficult targets such as rivers, lakes, and sea-ice & ice leads/floes. This toolkit is made available to the user community as an EarthConsoleTM P-PRO Service. The toolkit takes in input Cryosat-2 SAR FBR data products and produces in output geophysical L2 products in standard NetCDF format. This output can be manipulated and visualized with BRAT (the Broadview Altimetry Radar Toolbox, http://www.altimetry.info/toolbox/).

Provider

ESA/ESRIN

Description

The P-PRO SARvatore (SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation) for CryoSat-2 service is a web platform that provides the capability to process on line and on demand CryoSat-2 SAR data, from L1a (FBR) data products to SAR Level-2 geophysical data products.
The service is based on the SARvatore Processor Prototype that has been developed entirely by Salvatore Dinardo in the scope of the EOP-SER Altimetry Team (Salvatore Dinardo, Bruno Manuel Lucas, Jerome Benveniste) at ESA-ESRIN.
The processor will make use of the EarthConsoleTM P-PRO distributed computing platform to deliver timely the output data products.
These output data products are generated in standard NetCDF format (using CF Convention), and they are compatible with BRAT (Broadview Radar Altimetry Toolbox, http://www.altimetry.info/toolbox) and other NetCDF tools.

List of option entries and adopted conventions

The processor prototype is versatile in the sense that the users can customize and adapt the processing, according to their specific requirements, by setting a list of configurable options. The configurable options are divided according to the processing level they refer to (L1b and L2). Here, you find them listed with a basic description of their significance.

L1b Processing Options:

Option Name	Option Value	Option Description
[Pre-Processing] Filter out Duplicated CryoSat-2 Products during the processing time	• Enable • Disable	Enable to filter out duplicated products during the processing. If activated, duplicated products (from different baselines) will not be processed: only the product with highest baseline rank will be processed.
Data Posting Rate 20Hz/80Hz	• 20 Hz • 80 Hz	Flag to set the data posting rate: 20 Hz (canonical posting rate) or 80 Hz (finer posting rate). 20 Hz corresponds to a distance between samples of about 320 m and 80 Hz to about 80 m.

Hamming weighting Window	• Apply only in coastal zone • Yes, apply it • No, do not apply it	Users can decide here whether to apply or not a Hamming weighting window on the SAR burst data or to apply it only for surface locations in coastal area (more info in RD01).
Beam-Forming	• Approximated • Exact	Users can decide here whether to operate an exact Beam-Forming or an approximated Beam-Forming (more info in RD01).
FFT Zero-Padding	• Yes, apply Zero-Padding • No, don't apply Zero-Padding	Users can decide here whether to operate the Zero-Padding prior to the range FFT (section 4.8 in RD01). Zero-Padding is indicated for coastal zone and sea-ice analysis.
Radar Receiving Window Size	• 128 Range Bins • 256 Range Bins	Users can select here the size of the radar receiving window: 128 range bins (standard) or 256 range bins (extended). Extended window is indicated for coastal zone analysis.
Antenna Pattern Compensation	• NO • YES	Flag to activate the antenna pattern compensation on the Stack Data.
Dump SAR Stack Data in output	• NO • YES, with only power • YES, with power and phase	Users can choose here to post in output SAR/SARIN Stack Data Products for each selected pass. Beware: SAR/SARIN Stack Data Products are quite bulky (usually one GB for medium-size product); we recommend to process SAR/SARIN Stack Data singularly or max 5 passes at a time: contact the P-PRO team for a massive production of SAR/SARIN Stack Data.

L2 Processing Options:

Option Name	Option Value	Option Description
Restrict the re-tracking on specific surfaces	• Process all • Process only open sea points • Process only water points	Users can decide here whether to process the whole pass, only points in open sea or only water points (i.e., points in open sea, coastal zone and inland water).
PTR width alphap parameter	• LUT • Constant	Users can decide here whether to use a LUT (Look-Up Table) or a constant for the PTR (Point Target Response) alphap parameter.
SAMOSA Model Generation	• Use SAMOSA 2 • Use SAMOSA 3 • Use SAMOSA+	Users can decide here which SAMOSA retracking model to use in the processing (SAMOSA 2 or SAMOSA 3 or SAMOSA+). The SAMOSA 3 is a truncated version of SAMOSA 2 (only zero-order term); more info in RD02. SAMOSA+ is the SAMOSA2 model tailored for inland water, sea ice and coastal zone domain; more info in RD03.
Single-Look or Multi-Look Model	• Single-Look • Multi-Look	Users can decide here to retrack the waveform with the multi-look waveform model or the single-look waveform model. The Single-Look option is indicated for quick runs over sea ice and inland water whereas the Multi-Look option is the most accurate and is advised for ocean applications.
Dump RIP in output	• NO • YES	Flag to append Range Integrated Power (RIP) in the output NetCDF data product.
Dump SAR Echo Waveforms in Output	• NO • YES	Users can choose here to append the SAR Echo Waveforms in the output product.

Choose the Default Tide Model	• FES2004 • FES2014b • TPXO8 • TPXO9	Flag to command the Default tide model used in the product (choose between FES2004, FES2014b, TPXO8, TPXO9).
Choose the Default Mean Sea Surface Model	• DTU15 • DTU18 • CLS-CNES15	Flag to choose the Default mean sea surface model used in the product (choose between DTU15, DTU18,CLS-CNES15).
[Post-processing] Append the ALES+ SAR output to the output NetCDF product	• NO • YES	Flag to append the ALES+ SAR retracker estimates to the output NetCDF product.

Adopted Conventions

- The Reference Time for the TAI Datation is 01/01/2000 00:00:00.
- The Vertical Datum for altitude reference is the WGS84 Ellipsoid.
- The Curve Best-Fitting Scheme, used in the re-tracking stage, is a Bounded Levenberg-Marquardt Least-Squares Estimation Algorithm (LEVMAR-LSE).
- The SAR Power Return Waveform Model, used in the re-tracking stage, is the SAMOSA Model (RD02)
- Static bias has been applied to the range, sigma nought and antenna mispointing measurements. The values of the static biases are reported in the output NetCDF data products.
- The orbital altitude has been corrected for a Time Tag Bias. The value of the applied time tag bias is reported in the output NetCDF data products.
- The measurements are posted both at rate of 20 Hz/80 Hz and of 1 Hz.
- The sea state bias correction has not been applied to the sea level anomaly estimates.
- All the default geophysical path corrections are from the CryoSat-2 FBR products; refer to CryoSat-2 mission handbook to know the exact source of these corrections
- No a priori data editing has been applied to the 20 Hz/80 Hz measurements.
- The 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 model's waveform power and data's waveform power, normalized for the waveform power's maximum value.

Output Format

The L2 data products generated in output are in standard NetCDF format (CF-convention), fully compatible with the Broadview Radar Altimetry Toolbox (BRAT, http://www.altimetry.info/).
The file naming convention for these files is : **RES_FBR_INPUT_FILENAME.nc** where: **FBR_INPUT_FILENAME** is the filename of the SAR FBR data file given in input
(for more details on the input filename, please check the product specification)
The NetCDF format is self-explanatory with all the data field significance described in the attributes.
Along with the NetCDF file, it is provided in output a .png picture of the radar data image (Radar Echogram) and a .kml file of the satellite pass ground-track.
By selecting the corresponding option, user can decide to post in output also the SAR Stack Data Products, still in NetCDF format.
The naming convention for those stack data products is :
STK_FBR_INPUT_FILENAME.nc
They will be held in the STACK folder inside the .tgz output package.

Opening SARvatore products in BRAT

Please refer to Appendix A.

5. SARvatore for Sentinel-3

SARvatore (SAR Versatile Altimetric TOolkit for Research and Exploitation) for Sentinel-3 is a Prototype Software Processor developed by ESA/ESRIN (RD01) to experiment with Sentinel-3 SAR Altimetry processing exploiting the SAMOSA retracking model and the Delay-Doppler principle. It can be used over open ocean or coastal zone, as well as over more difficult targets such as rivers, lakes, and sea-ice & ice leads/floes. This toolkit, similar to the one developed for CryoSat-2, is made available to the user community as an EarthConsoleTM P-PRO Service. The toolkit takes in input L1A Sentinel-3 SAR Altimetry data products and produces in output L2 data products in standard NetCDF format. The content of these output files can be manipulated, displayed and further post-processed with BRAT (the Broadview Altimetry Radar Toolbox).

Provider

ESA/ESRIN

Description

The P-PRO SARvatore (SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation) for Sentinel-3 service is a web platform that provides the capability to process on line and on demand Sentinel-3 SRAL L1A data products in SAR mode to Level-2 geophysical data products.

The service is based on the Sentinel-3 SARvatore Processor Prototype, heritage of the CryoSat-2 SARvatore Processor Prototype.
The data products in input to the service are the Sentinel-3 SRAL L1A data products.
The Sentinel-3 SARvatore Processor has two stages: L1b (SAR) & L2 (retracking).
The processor makes use of the EarthConsoleTM P-PRO distributed computing platform to deliver timely the output data products.
These output data products are generated in standard NetCDF format (using CF Convention) and are compatible with BRAT (Basic Radar Altimetry Toolbox, http://www.altimetry.info/toolbox/) and other NetCDF tools.

List of option entries, adopted conventions and limitations

The processor prototype is versatile in the sense that the users can customize and adapt the processing, according to their specific requirements, by setting a list of configurable options.
The configurable options are divided according to the processing level they refer to (L1b and L2). Here, you find them listed with a basic description of their significance.

Option Name	Option Value	Option Description
[Pre-Processing] Pass Direction	• ALL • Ascending • Descending	Flag to select whether to process all or only ascending/descending passes.
Data Posting Rate 20Hz/80Hz	• 20 Hz • 80 Hz	Users can decide here the posting rate (20 Hz or 80 Hz) of the L2 data published in output. 20 Hz corresponds to a distance between samples of about 320 m and 80 Hz to about 80 m.
Range Walk Correction	• NO • YES	Flag to set the application of the Range Walk on the burst data (remember to set exact-beam steering when Range Walk is activated).
Hamming weighting Window	• Apply only in coastal zone • Yes, apply it • No, do not apply it	Users can decide here whether to apply or not a Hamming weighting window on the SAR burst data or to apply it only for surface locations in coastal area (more info in RD01).
Beam-Forming	• Approximated • Exact	Users can decide here whether to operate an exact Beam-Forming or an approximated Beam-Forming (more info in RD01).

FFT Zero-Padding	• Yes, apply Zero-Padding • No, don't apply Zero-Padding	Users can decide here whether to operate the Zero-Padding prior to the range FFT (section 4.8 in RD01). Zero-Padding is indicated for coastal zone and sea-ice analysis.
Radar Receiving Window Size	• 128 range bins (No Extension) • 128X2 range bins (Extension by factor of 2) • 128X3 range bins (Extension by factor of 3) • 128X4 range bins (Extension by factor of 4)	Users can select here the size of the radar receiving window: 128 range bins (standard) or 128XN range bins (extended N times). Extended window with N=2 is indicated for coastal zone and sea ice analysis. N>2 may be indicated only for inland water over very steep topographic regions.
Stack Subset	• ALL • 100 • 120 • 140 • 160 • 180	Subset the Stack to Looks: [100, 120, 140, 160, 180, ALL].
Antenna Pattern Compensation	• NO • YES	Users can decide here whether to apply the Antenna Pattern Compensation on Stack Data prior to perform the multi-looking.
Dump SAR Stack Data in output	• NO • YES, with only power • YES, with power and phase	Users can choose here to post in output SAR Stack Data Products for each selected pass. Users can select whether to dump just the power of the Stack data or the power and phase. Beware: SAR Stack Data Products are quite bulky (usually 2 GB for 10 minutes of data); we recommend to process SAR Stack Data singularly or max 5 passes at a time: contact the P-PRO team for a massive production of SAR Stack Data.

L2 Processing Options

Option Name	Option Value	Option Description
Restrict the re-tracking on specific surfaces	• Process all • Process only open sea points • Process only water points	Users can decide here whether to process the whole pass, only points in open sea or only water points (i.e., points in open sea, coastal zone and inland water).
PTR width alphap parameter	• LUT • Constant	Users can decide here whether to use a LUT (Look-Up Table) or a constant for the PTR (Point Target Response) alphap parameter.
SAMOSA Model Generation	• Use SAMOSA2 • Use SAMOSA3 • Use SAMOSA+	Users can decide here which SAMOSA retracking model to use in the processing (SAMOSA2, SAMOSA3, SAMOSA+). The SAMOSA 3 is a truncated version of SAMOSA 2 (only zero-order term); more info in RD02. SAMOSA+ is an enhancement of the SAMOSA2 solution providing better performances over inland water, coastal zones and sea ice; more info in RD03.
Dump RIP in output	• NO • YES	Flag to append the Range Integrated Power (RIP) in the output NetCDF data product.
Dump SAR Echo Waveforms in Output	• NO • YES	Users can choose here to append the SAR Echo Waveforms in the output product.
Single-Look or Multi-Look Model	• Multi-look • Single-look	Users can decide here to retrack the waveform with the Multi-look waveform model or the single-look waveform model. Single-look waveform model is an acceptable approximation over inland water or sea-ice scenario. The Single-Look option is quicker than Multi-Look option.
Choose the Default Tide Model	• FES2014b • TPXO8 • TPXO9	Users can decide here which tide model to use as default in the product between FES2014b, TPXO8-ATLAS, TPXO9-ATLAS.

Choose the Default Mean Sea Surface Model	• DTU18 • DTU15 • CLS-CNES15	Users can decide here which mean sea surface model to use as default in the product between DTU18, DTU15, CLS-CNES15.
[Post-processing] Append the ALES+ SAR output to the output NetCDF product	• NO • YES	Flag to append the ALES+ SAR retracker estimates to the output NetCDF product.

Adopted Conventions

- The Reference Time for the TAI Datation is 01/01/2000 00:00:00
- The Vertical Datum for altitude reference is the WGS84 Ellipsoid
- The Curve Best-Fitting Scheme, used in the re-tracking stage, is a Bounded Levenberg-Marquardt Least-Squares Estimation Algorithm (LEVMAR-LSE).
- The SAR Power Return Waveform Model, used in the re-tracking stage, is the SAMOSA Model (RD02).
- Static bias has been applied to the range, sigma nought and antenna mispointing measurements. The values of the static biases are reported in the output NetCDF data products.
- The product orbit latency/source is the one coming from the SAR L1A data file used in input.
- The orbital altitude has been corrected for a Time Tag Bias. The value of the applied time tag bias is reported in the output NetCDF data products.
- The measurements are posted both at rate of 20 Hz/80 Hz and of 1 Hz.
- The sea state bias correction has not been applied to the sea level anomaly estimates.
- No a priori data editing has been applied to the 20 Hz/80 Hz measurements.
- The 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 model's waveform power and data's waveform power, normalized for the waveform power's maximum value.

Known Limitations of Sentinel-3 EarthConsole P-PRO Products

The Sentinel-3 products feature the following limitations:

- The Dual Frequency Ionosphere Correction (Ku&C) is not computed. Instead, the ionosphere correction from the JPL GIM model is provided in the L2 product.
- The MWR wet tropospheric correction is not computed. Instead, the wet tropospheric correction from the ECMWF model is provided in the L2 product.
- The sea state bias solution in the L2 product is the CLS 2012 Jason-2 SSB solution.

Output Format

The L2 data products generated in output are in standard NetCDF format (CF-convention), fully compatible with BRAT (http://www.altimetry.info/toolbox/).

The file naming convention for those files is: **RES_INPUT_FILENAME.nc** where: **INPUT_FILENAME** is the filename of the SAR L1A data file given in input (for more details on the input filename, please check the product specification).

The NetCDF format is self-explanatory with all the data field significance described in the attributes. Along with the NetCDF file, it is provided in output a .png picture of the radar data image (Radar Echogram) and a .kmz file of the satellite pass ground-track.

By selecting the corresponding option, users can decide to post in output also the SAR Stack Data Products, still in NetCDF format.

The naming convention for those stack data products is:**STK_INPUT_FILENAME.nc**

They will be held in the STACK folder inside the .tgz output package.

Opening SARvatore products in BRAT

Please refer to Appendix A.

6. SARINvatore for CryoSat-2

SARINvatore (SARIN Versatile Altimetric Toolkit for Research and Exploitation) for CryoSat-2 is a Software Processor Prototype developed by ESA/ESRIN (RD01) to experiment with SARin processing from L1A (FBR) to L2 using the SAMOSA retracking model. It can be used over open ocean or coastal zones, as well as over more difficult targets such as rivers, lakes, and sea-ice & ice leads/floes. This toolkit is made available to the user community as EarthConsoleTM P-PRO Service. The toolkit takes in input Cryosat-2 SARin FBR data products and produces in output geophysical L2 products in standard NetCDF format. This output can be manipulated and visualized with BRAT (the Broadview Altimetry Radar Toolbox, http://www.altimetry.info/toolbox/).

Provider

ESA/ESRIN

Description

The P-PRO SARvatore (SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation) for CryoSat-2 service is a web platform that provides the capability to process on line and on demand CryoSat-2 SAR data, from L1a (FBR) data products to SAR Level-2 geophysical data products.
The service is based on the SARvatore Processor Prototype that has been developed entirely by Salvatore Dinardo in the scope of the EOP-SER Altimetry Team (Salvatore Dinardo, Bruno Manuel Lucas, Jerome Benveniste) at ESA-ESRIN.
The processor has been further upgraded (SARINvatore) to accept in input L1a (FBR) SARIN data products and build SARIN Level-2 geophysical data products as well.
The processors will make use of the EarthConsole P-PRO distributed computing platform to deliver timely the output data products.
These output data products are generated in standard NetCDF format (using CF Convention), and they are compatible with BRAT (Broadview Radar Altimetry Toolbox, http://www.altimetry.info/toolbox/) and other NetCDF tools.

List of option entries and adopted conventions

The processor prototype is versatile in the sense that the users can customize and adapt the processing, according their specific requirements, by setting a list of configurable options. The configurable options are divided according to the processing level they refer to (L1b and L2). Here, you find them listed with a basic description of their significance.

L1b Processing Options:

Option Name	Option Value	Option Description
[Pre-Processing] Filter out Duplicated CryoSat-2 Products during the processing time	• Enable • Disable	Enable to filter out duplicated products during the processing. If activated, duplicated products (from different baselines) will not be processed: only the product with highest baseline rank will be processed.
Data Posting Rate 20Hz/80Hz	• 20 Hz • 80 Hz	Flag to set the data posting rate: 20 Hz (canonical posting rate) or 80 Hz (finer posting rate). 20 Hz corresponds to a distance between samples of about 320 m and 80 Hz to about 80 m.
Hamming weighting Window	• Apply only in coastal zone • Yes, apply it • No, do not apply it	Users can decide here whether to apply or not a Hamming weighting window on the SAR burst data or to apply it only for surface locations in coastal area (more info in RD01).
Beam-Forming	• Approximated • Exact	Users can decide here whether to operate an exact Beam-Forming or an approximated Beam-Forming (more info in RD01).

FFT Zero-Padding	• Yes, apply Zero-Padding • No, don't apply Zero-Padding	Users can decide here whether to operate the Zero-Padding prior to the range FFT (section 4.8 in RD01). Zero-Padding is indicated for coastal zone and sea-ice analysis.
Radar Receiving Window Size	• 512 Range Bins • 1024 Range Bins	Users can select here the size of the radar receiving window: 512 range bins (standard) or 1024 range bins (extended). Extended window is indicated for coastal zone analysis.
Antenna Pattern Compensation	• NO • YES	Flag to activate the antenna pattern compensation on the Stack Data.
Dump SAR Stack Data in output	• NO • YES, with only power • YES, with power and phase	Users can choose here to post in output SAR/SARIN Stack Data Products for each selected pass. Beware: SAR/SARIN Stack Data Products are quite bulky (usually one GB for medium-size product); we recommend to process SAR/SARIN Stack Data singularly or max 5 passes at a time: contact the P-PRO team for a massive production of SAR/SARIN Stack Data.

L2 Processing Options:

Option Name	Option Value	Option Description
Restrict the re-tracking on specific surfaces	• Process all • Process only open sea points • Process only water points	Users can decide here whether to process the whole pass, only points in open sea or only water points (i.e., points in open sea, coastal zone and inland water).
PTR width alphap parameter	• LUT • Constant	Users can decide here whether to use a LUT (Look-Up Table) or a constant for the PTR (Point Target Response) alphap parameter.

SAMOSA Model Generation	• Use SAMOSA 2 • Use SAMOSA 3 • Use SAMOSA+	Users can decide here which SAMOSA retracking model to use in the processing (SAMOSA 2 or SAMOSA 3 or SAMOSA+). The SAMOSA 3 is a truncated version of SAMOSA 2 (only zero-order term); more info in RD02. SAMOSA+ is the SAMOSA2 model tailored for inland water, sea ice and coastal zone domain; more info in RD03.
Single-Look or Multi-Look Model	• Single-Look • Multi-Look	Users can decide here to retrack the waveform with the multi-look waveform model or the single-look waveform model. Single-Look option is indicated for quick runs over sea ice and inland water while Multi-Look is the most accurate and is advised for ocean applications.
Dump RIP in output	• NO • YES	Flag to append Range Integrated Power (RIP) in the output NetCDF data product.
Dump SAR Echo Waveforms in Output	• NO • YES	Users can choose here to append the SAR Echo Waveforms in the output product.
Choose the Default Tide Model	• FES2004 • FES2014b • TPXO8 • TPXO9	Flag to command the Default tide model used in the product (choose between FES2004, FES2014b, TPXO8, TPXO9).
Choose the Default Mean Sea Surface Model	• DTU15 • DTU18 • CLS-CNES15	Flag to choose the Default mean sea surface model used in the product (choose between DTU15, DTU18, CLS-CNES15).

Adopted Conventions

- The Reference Time for the TAI Datation is 01/01/2000 00:00:00.
- The Vertical Datum for altitude reference is the WGS84 Ellipsoid.
- The Curve Best-Fitting Scheme, used in the re-tracking stage, is a Bounded Levenberg-Marquardt Least-Squares Estimation Algorithm (LEVMAR-LSE).

- The SAR Power Return Waveform Model, used in the re-tracking stage, is the SAMOSA Model (RD02).
- Static bias has been applied to the range, sigma nought and antenna mispointing measurements. The values of the static biases are reported in the output NetCDF data products.
- The orbital altitude has been corrected for a Time Tag Bias. The value of the applied time tag bias is reported in the output NetCDF data products.
- The measurements are posted both at rate of 20 Hz/80 Hz and of 1 Hz.
- The sea state bias correction has not been applied to the sea level anomaly estimates.
- All the default geophysical path corrections are from the CryoSat-2 FBR products; refer to CryoSat-2 mission handbook to know the exact source of these corrections.
- No a priori data editing has been applied to the 20 Hz/80 Hz measurements.
- The 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 model's waveform power and data's waveform power, normalized for the waveform power's maximum value.

Output Formats

The L2 data products generated in output are in standard NetCDF format (CF-convention), fully compatible with BRAT (http://www.altimetry.info/toolbox/).

The file naming convention for those files is: **RES_FBR_INPUT_FILENAME.nc** where **FBR_INPUT_FILENAME** is the filename of the SAR FBR data file given in input (for more details on the input filename, please check the product specification).

The NetCDF format is self-explanatory with all the data field significance described in the attributes.
Along with the NetCDF file, it is provided in output a .png picture of the radar data image (Radar Echogram) and a .kml file of the satellite pass ground-track.

Selecting the corresponding option, users can decide to post in output also the SAR Stack Data Products, still in NetCDF format.

The naming convention for those stack data products is: **STK_FBR_INPUT_FILENAME.nc.**
They will be held in the STACK folder inside the .tgz output package.

Opening SARvatore products in BRAT

Please refer to Appendix A.

7. Fully-Focused SAR for CryoSat-2 – Aresys Srl

The P-PRO Service FF-SAR (Fully Focused SAR) for CryoSat-2 is a web service that provides the capability to process on line and on demand CryoSat-2 SAR data, from FBR data products to Level1b FF-SAR products.

Provider

Aresys srl (https://www.aresys.it/) – Michele Scagliola

Description

The P-PRO Service FF-SAR (Fully Focused SAR) for CryoSat-2 is a web service that provides the capability to process on line and on demand CryoSat-2 SAR data, from FBR data products to Level1b FF-SAR products. The service is based on AREALT-FF1 Processor Prototype that has been developed by Aresys in the framework of ESA contracts for Sentinel-6 and CryoSat-2. The AREALT-FF1 Processor produces L1b FF-SAR altimetry waveforms exploiting the focusing technique in the 2D transformed frequency domain proposed in RD04
The AREALT-FF1 Processor will make use of the P-PRO (Parallel Processing) distributed computing platform to deliver timely the output Level1b products. These output data products are generated in standard NetCDF format.
The output Level1b product includes the variable uncorrected_retracked_height, that contains the surface height computed by the threshold retracker described in RD05. It is worth underlining that the threshold is set to 60% and that the geophysical corrections are not applied, but included in variables geophysical_correction_ocean, geophysical_correction_land and geophysical_correction_seaice.

User can also decide whether to fit the waveform using the ALES+ FF-SAR empirical retracking algorithm to estimate range. ALES+ FF-SAR is an adaptation of the ALES+ SAR algorithm described in RD06.

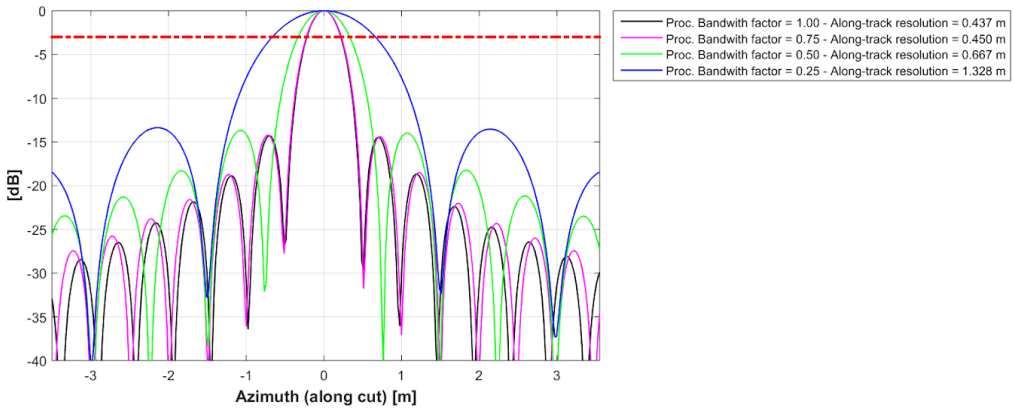
List of processing parameters and constraints

The processor prototype is versatile in the sense that the users can customize and adapt the processing, according their specific requirements, setting a list of configurable options.

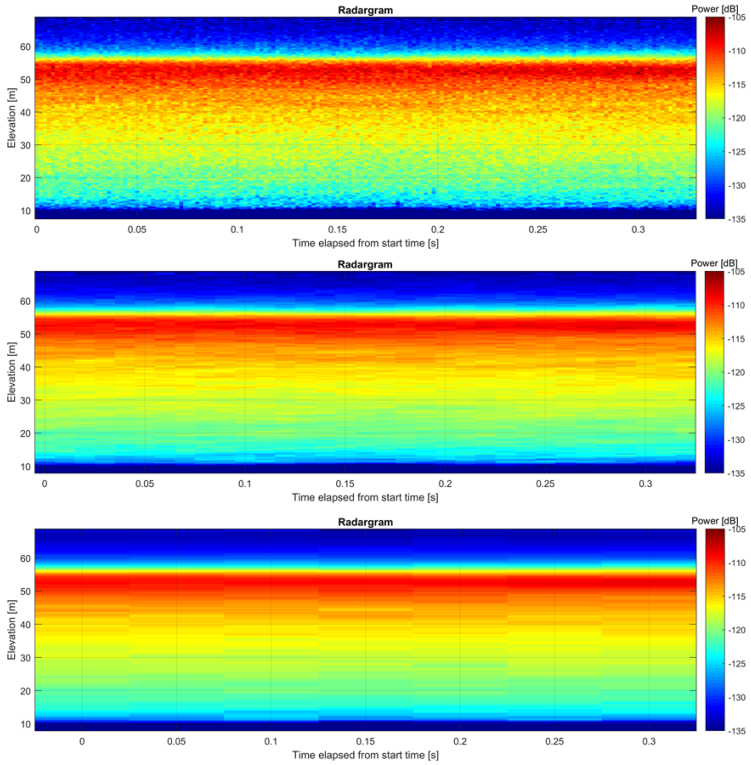
Processing Parameter	Values	Description
Range oversampling factor	• 1 • 2	User can decide whether to apply zero padding prior to range compression: 1 if the zero padding has not to be applied, 2 if a zero padding by a factor of 2 has to be applied. It is worth recalling that the instrument samples the waveforms with a 320 MHz clock, providing a nominal_sampling = c / 320e6 / 2 = ~0.468m (with c = speed of light). Applying an oversampling factor waveform_sampling = nominal_sampling / range_oversampling_factor. Note that the altimeter range resolution is fixed and given by the chirp bandwidth of 320 MHz: c / 320e6 / 2 = ~0.468m.
Processed bandwidth factor	• 0.25 • 0.50 • 0.75 • 1.00	User can decide the fraction of the Doppler bandwidth that is processed to generate the FF-SAR single look waveforms, allowing to control the along-track resolution. Under some approximation the theoretical along-track resolution at -3dB is at_resolution = 1.073*velocity/processed_bandwidth (with velocity the satellite velocity and processed_bandwidth equal to the processed bandwidth factor multiplied by the instrument Pulse Repetition Frequency).
Multilook posting rate	• 1 • 20 • 80 • 100 • 200 • 500	User can decide the posting rate of the FF-SAR multi look waveforms. The processing parameter represents the approximate waveform spacing in frequency (Hz). The actual spacing will vary slightly along the orbit depending on orbital parameters.
Append the ALES+ FF-SAR output to the output NetCDF product	• Yes • No	User can decide whether to fit the waveform using the ALES+ FF-SAR empirical retracking algorithm to estimate range. Note that this processing parameter, as the algorithm oversamples the multilook waveform by a factor 2, can be selected only if the Processing Parameter "Range oversampling factor" is set to 1 RD04ALES+ FF-SAR is an adaptation of the ALES+ SAR algorithm, see section 2.1.2 of RD06.

It is worth recalling here that along-track resolution is different from along-track sampling rate (i.e. posting rate). The along-track resolution is to be intended as the width at -3dB with respect to the peak power of

the along-track point target response. The user can select the along-track resolution by tuning the processed bandwidth factor. In the following figure, the FF-SAR along-track point target response of CryoSat is shown for different values of the processed bandwidth factor, so that the effect on the along-track resolution can be noticed.



The multilook posting rate determines how many waveforms per unit of time are in the output product so that, as the multilook posting rate increases, less single look waveforms at instrument Pulse Repetition Frequency rate are averaged together. The user can select how many single look waveforms are averaged together by tuning the multilook posting rate. In the following figure, it is shown the radargram for a same CryoSat acquisition after FF-SAR processing at different multilook posting rate. It can be noticed that at higher posting rates, the number of waveforms is larger but the speckle noise is more visible.



Multilooked waveforms
Posting rate 500 Hz

Multilooked waveforms
Posting rate 100 Hz

Multilooked waveforms
Posting rate 20 Hz

Processing constraints

The AREALT-FF1 Processor has to be executed providing as input an acquisition segment longer than 2 seconds, that corresponds to the along-track antenna aperture of the CryoSat instrument. This constraint is due to the fact that the AREALT-FF1 Processor exploits the focusing technique in the 2D transformed frequency domain, which operates in a block-by-block basis where the lower limit for a block length is the along-track antenna aperture.

Additionally, the maximum number of products allowed in one single task is 250. This constraint is set in order to limit the duration of a task to less than 72 hours. Tasks longer than this are automatically terminated.

Output Format

The FF-SAR Level1b data products generated in output are in standard NetCDF format. The NetCDF format is self-explanatory with all the data field significance described in the attributes.

The file naming convention for the output files is **L1B_FF_ML_starttime_stoptime.nc**

where:

- starttime is the time of the first sample in the Leve1b product in the format YYYYMMDDThhmmss
- stoptime is the time of the last sample in the Level1b products in the format YYYYMMDDThhmmss

In the Level1b product, the following conventions are adopted

- The Reference Time for the TAI Datation is 01/01/2000 00:00:00
- The Vertical Datum for altitude reference is the WGS84 Ellipsoid

The Level1b product includes the variable uncorrected_retracked_height, that contains the surface height computed by threshold retracker in RD05. It is worth underlining that the threshold is set to 60% and that the geophysical corrections are not applied, but included in the variables: geophysical_correction_ocean, geophysical_correction_land and geophysical_correction_seaice.

8. TUDaBO SAR-RDSAR – U.Bonn

TUDaBO SAR-RDSAR – U.Bonn is a processor prototype developed by C. Buchhaupt and L. Fenoglio-Marc at TU Darmstadt and U Bonn to experiment with SAR mode data from L1A (FBR) to L2. Reduced SAR, unfocused SAR, and LRMC data can be generated for both CryoSat-2 and Sentinel-3A. For each mode, dedicated signal processing options and retrackers are available, which allow the user to experiment with different configurations. All L1B/L2 products for reduced SAR, unfocused SAR, and LRMC have the same geolocations and time tags, allowing a direct comparison without the need for interpolation.

Provider

TU Darmstadt and University of Bonn – Luciana Fenoglio

Introduction

The EarthConsoleTM P-PRO TUDaBo SAR-RDSAR (Technical University Darmstadt – University Bonn SAR-Reduced SAR) service is a web service that provides the capability to process on line and on demand SAR mode Full Bit Rate (FBR or L1A) data to Level-1B and Level-2 geophysical data products. The service is based on a SAR-RDSAR Processor Prototype that has been developed and tested by Christopher Buchhaupt and Luciana Fenoglio-Marc in TU Darmstadt and at the University of Bonn. Available modes to generate L1B and L2 data are reduced SAR, unfocused SAR and LRMC, whereas several signal processing options and retrackers are available. The output data products are in standard NetCDF format and follow in large part the format and variable names of RADS products (http://rads.tudelft.nl/rads/rads.shtml).

List of option entries, output options and adopted conventions

The users can customize and adapt the processing, according to their specific requirements, setting a list of configurable options grouped according to the processing level (L1B and L2). More information can be found in RD07-09.

General Options

Mission	CryoSat-2	Satellite mission which L1A data is going to be processed.
	Sentinel-3A	
Reference ellipsoid	WGS84	Reference ellipsoid used for the vertical datum.
	TOPEX	
	GRS80	

L1B Processing Options:

Option Name	Option Value	Option Description
Use RADS bias	No	Flag to determine if the RADS roll/pitch and range bias shall be used in the L1B processing. Alternatively the biases for roll/pitch and range are treated as in CryoSat-2 Baseline-C products. For Sentinel-3A no biases exist.
	Yes	
Process RDSAR	Yes	Flag to determine if RDSAR L1B data shall be processed.
	No	
Process unfocused SAR	Yes	Flag to determine if unfocused SAR L1B data shall be processed.

	No	
Process LRMC	Yes	Flag to determine if LRMC L1B data shall be processed.
	No	
Distribution of pulse/beam samples	Exponential	Stochastic distribution of the L1B data before the averaging, which is in state-of-the-art processing exponential. By selecting "Zero skewness Weibull" a transformation is applied to achieve a sample power distribution close to normal.
	Zero skewness Weibull	
Use Hamming window	No	Flag to determine if a Hamming window shall be applied before each FFT.
	Yes	
Apply zero padding	Yes	Flag to determine if zero padding shall be applied before each FFT.
L1B sampling frequency	20 Hz	Sampling rate of L1B data. 20 Hz corresponds to a distance between samples of about 320 m, 40 Hz to about 160 m and 80 Hz to about 80 m.
	40 Hz	
	80 Hz	
Local surface approximation	Sphere	Surface representation used in the processing. "Sphere" assumes a globally constant curvature, "Ellipsoid" applies latitude dependent curvatures, "Slopes" includes geoid slopes and "Geoid" adds additionally the geoid curvatures.
	Ellipsoid	
	Slopes	

	Geoid	

L2 Processing Options:

Option Name	Option Value	Option Description
Retracked surface	Water	Flag to determine the surface which is going to be retracked. "Water" are locations which are flagged by the MODIS water-land mask as water and "Ocean" are water locations with a distance to coast greater than 10km.
	Ocean	
	All	
	None	
Retracker RDSAR	BMLE3	Retracker used to generate RDSAR L2 data. BMLE3 is a state-of-the-art conventional altimetry retracker based on the Brown-Hayne model. SINC2 is a fast convolution based adaption of BMLE3, which does not use a PTR approximation. TALES is SINC2 using an ALES approach to lessen land contamination effects on L1B data.
	SINC2	
	TALES	
	NONE	
Retracker unfocused SAR	SINCS	Retracker used to generate unfocused SAR L2 data. SINCS is a fast convolution based SAR waveform retracker, which does not apply a PTR approximation. SINCS-OV is an adaption of SINCS including vertical wave orbital velocities by retracking the stack or L1B-S data.

	SINCS-OV	
	NONE	
Retracker LRMC	SINCS	Retracker used to generate LRMC L2 data. SINCS is a fast convolution based SAR waveform retracker, which does not apply a PTR approximation. SINCS-OV is an adaption of SINCS including vertical wave orbital velocities by retracking the stack data.
	SINCS-OV	
	NONE	

Output Options:

Option Name	Option Value	Option Description
Dump waveforms	Yes	Flag to determine if the waveforms (L1B) shall be stored in the NetCDF output file.
	No	
Store Stack Data	Yes	Flag to determine if the stack data (L1B-S) shall be stored in the NetCDF output file.
	No	

Adopted Conventions

- The Reference Time for UTC is 01/01/1985 00:00:00
- The Curve Best-Fitting Scheme, used in the retracking stage, is a Levenberg Marquardt Least-Squares Estimation Algorithm (LEVMAR-LSE).
- Static bias has been applied to the range, sigma nought and antenna mispointing measurements. The values of the static biases are reported in the output NetCDF data products.
- The orbital altitude has been corrected for a Time Tag Bias. The value of the applied time tag bias is reported in the output NetCDF data products.
- The measurements are posted both at a rate of 20 Hz/40 Hz/80 Hz and of 1 Hz.
- The sea state bias correction has not been applied to the sea level anomaly estimates.
- All the default geophysical path corrections are from the FBR products.
- No a priori data editing has been applied to the 20 Hz/40 Hz/80 Hz measurements.
- The misfit between a waveform model and waveform data has been computed as:

$$Misfit = \frac{100}{N}\sum_{k=1}^{N} r_k^2$$

where rk are the differences between model's waveform power and data's waveform power, normalized for the waveform power's maximum value and N is the number of sampled considered during retracking.

Output Format

The L2 data products generated in output are in standard NetCDF format (RADS-convention) The file naming convention for the files is: PSG_FBR_INPUT_FILENAME.nc where FBR_INPUT_FILENAME is the filename of the SAR FBR data file given in input. The NetCDF format is self-explanatory with all of the data field's meaning described in the attributes.

9. Sentinel-6 GPP L1 – isardSAT

The Sentinel-6 P4 L1 Ground Prototype Processor service in EarthConsole makes available the HR processor for Sentinel-6A Poseidon 4 Level 1A High Resolution products.

Provider

isardSAT

List of option entries, output options and adopted conventions

The users can customize and adapt the processing, according to their specific requirements, setting a list of configurable options.

Option Name	Option Value	Option Description
Processor	HR	
Debug	Yes	Enable or Disable debug mode
	No	
Start from L1A	Yes	Only Yes value possible in the current version
	No	
Orbit file type	OrbitEocfi	Indicates what type Orbit file is to be used. Only OrbitEocfi possible in the current version
	SimOsv	
	OrbitDorNav	
Attitude file type	SimAttitude	Indicates what type Attitude file is to be used. Only AttitudeEocfi possible in the current version
	AttitudeEocfi	
	PlatformAttitude	
Transfer function correction (Ku-band)	ChdArrays	Indicates the source of the transfer function correction (Ku-band). Only ChdArrays possible in the current version
	Cal2L1B	

Altimeter power drift correction (Ku-band)	Chd Cal1L1BPulse Cal1L1BLrm Cal1L1BSar	Indicates the source of the altimeter power drift correction (Ku-band). Only Chd possible in the current version
Internal delay range correction (Ku-band)	Chd Cal1L1BPulse Cal1L1BLrm Cal1L1BSar	Indicates the source of the internal delay range correction (Ku-band). Only Chd possible in the current version
Attenuator tables (Ku-band)	ChdArrays Cal1L1BAtt	Indicates the source of the attenuator tables (Ku-band). Only ChdArrays possible in the current version
Intra-burst corrections, phase and power (Ku-band)	ChdArrays Cal1L1BSar	Indicates the source of the Intra-burst corrections (Ku-band). Only ChdArrays possible in the current version

10. Fully-Focused SAR for Sentinel-6 and Sentinel-3 – Aresys Srl

The P-PRO Service FF-SAR (Fully Focused SAR) for Sentinel-6 and Sentinel-3 is a web service that provides the capability to process on line and on demand Sentinel-6 Poseidon-4 L1A High-Resolution SAR data and Sentinel-3 L1A SAR data, from L1A data products to Level1b FF-SAR products.

Provider

Aresys srl (https://www.aresys.it/) – Michele Scagliola

Description

The P-PRO Service FF-SAR (Fully Focused SAR) for Sentinel-6 and Sentinel-3 is a web service that provides the capability to process on line and on demand Sentinel-6 Poseidon-4 L1A High-Resolution SAR data and Sentinel-3 L1A SAR data, from L1A data products to Level1b FF-SAR products.
The service is based on AREALT-FF1 Processor Prototype that has been developed by Aresys (http://www.aresys.it) in the framework of ESA contracts for Sentinel-6 and CryoSat-2. The AREALT-FF1 Processor produces L1b FF-SAR altimetry waveforms exploiting the focusing technique in the 2D transformed frequency domain proposed in RD04.
The AREALT-FF1 Processor will make use of the P-PRO (Parallel Processing) distributed computing platform to deliver timely the output Level1b products. These output data products are generated in standard NetCDF format.
The output Level1b product includes the variable uncorrected_retracked_height, that contains the surface height computed by the threshold retracker described in RD05. It is worth underlining that the threshold is set to 60% and that the geophysical corrections are not applied, but included in the variables: geophysical_correction_ocean, geophysical_correction_land and geophysical_correction_seaice.

User can also decide whether to fit the waveform using the ALES+ FF-SAR empirical retracking algorithm to estimate range (only for Sentinel-3 data). ALES+ FF-SAR is an adaptation of the ALES+ SAR algorithm described in RD06.

List of processing parameters and constraints

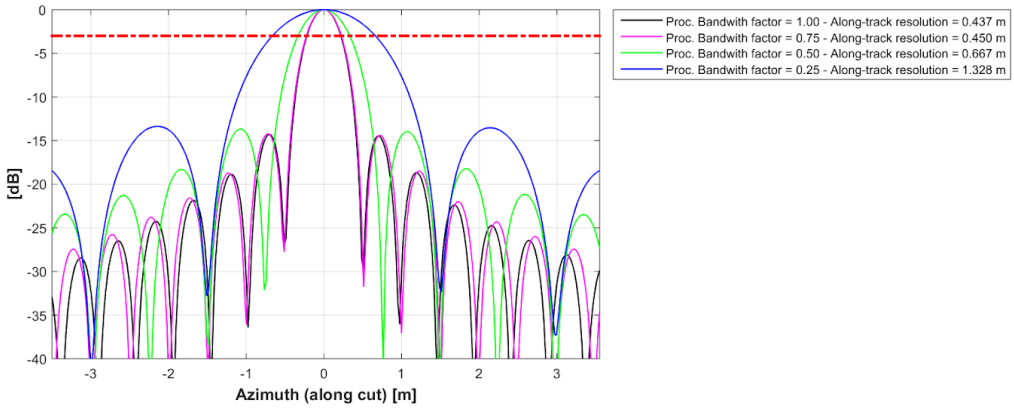
The processor prototype is versatile in the sense that the users can customize and adapt the processing, according their specific requirements, setting a list of configurable options.

Processing Parameter	Values	Description
Range oversampling factor	• 1 • 2	User can decide whether to apply zero padding prior to range compression: 1 if the zero padding has not to be applied, 2 if a zero padding by a factor of 2 has to be applied. It is worth recalling that the instrument samples the waveforms with a 320 MHz clock, providing a nominal_sampling = c / 320e6 / 2 = ~0.468m (with c = speed of light). Applying an oversampling factor waveform_sampling = nominal_sampling / range_oversampling_factor. Note that the altimeter range resolution is fixed and given by the chirp bandwidth of 320 MHz: c / 320e6 / 2 = ~0.468m.

Processed bandwidth factor	• 0.25 • 0.50 • 0.75 • 1.00	User can decide the fraction of the Doppler bandwidth that is processed to generate the FF-SAR single look waveforms, allowing to control the along-track resolution. Under some approximation the theoretical along-track resolution at -3dB is at_resolution = 1.073*velocity/processed_bandwidth (where 'velocity' equals the satellite velocity and 'processed_bandwidth' equals the processed bandwidth factor multiplied by the instrument Pulse Repetition Frequency).
Multilook posting rate	• 1 • 20 • 80 • 100 • 200 • 500	User can decide the posting rate of the FF-SAR multi look waveforms. The processing parameter represents the approximate waveform spacing in frequency (Hz). The actual spacing will vary slightly along the orbit depending on orbital parameters.
Append the ALES+ FF-SAR output to the output NetCDF product	• Yes • No	User can decide whether to fit the waveform using the ALES+ FF-SAR empirical retracking algorithm to estimate range. Note that this processing parameter, as the algorithm oversamples the multilook waveform by a factor 2, can be selected only if the Processing Parameter "Range oversampling factor" is set to RD041. ALES+ FF-SAR is an adaptation of the ALES+ SAR algorithm, see section 2.1.2 of RD06.
L1b FF SL product flag	• true • false	Advanced option, either true or false.
Grating lobes mitigation flag	• true • false	Advanced option, either true or false, allows the user to set a threshold for grating lobes.

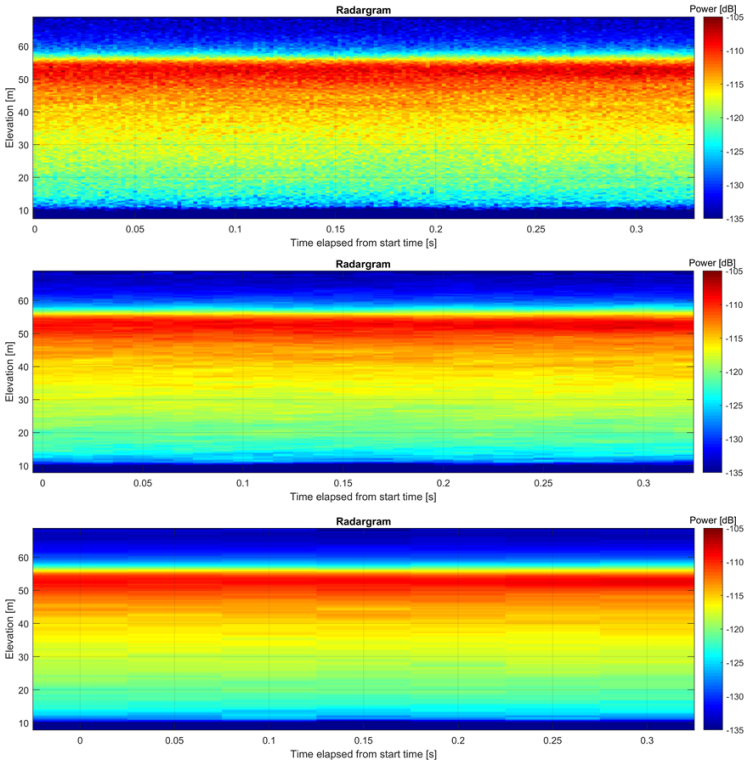
Grating lobes mitigation threshold	• Int	Advanced option, set the mitigation threshold for grating lobes, default is 35.
Data block length	• Float	Advanced option, set the data block length, default is 4.
Data block margin	• Float	Advanced option, set the data block margin value, default is 2.

It is worth recalling here that along-track resolution is different from along-track sampling rate (i.e. posting rate). The along-track resolution is to be intended as the width at -3dB with respect to the peak power of the along-track point target response. The user can select the along-track resolution by tuning the processed bandwidth factor. Its effect on the along-track resolution can be noticed in the figure below (which shows the FF-SAR along-track point target response for CryoSat-2).



The multilook posting rate determines how many waveforms per unit of time are in the output product so that, as the multilook posting rate increases, less single look waveforms at instrument Pulse Repetition

Frequency rate are averaged together. The user can select how many single look waveforms are averaged together by tuning the multilook posting rate. At higher posting rates, the number of waveforms is larger but the speckle noise is more visible.



Multilooked waveforms
Posting rate 500 Hz

Multilooked waveforms
Posting rate 100 Hz

Multilooked waveforms
Posting rate 20 Hz

Processing constraints

The AREALT-FF1 Processor has to be executed providing as input an acquisition segment longer than the along-track antenna aperture of the satellite instrument. This constraint is due to the fact that the AREALT-FF1 Processor exploits the focusing technique in the 2D transformed frequency domain, which operates in a block-by-block basis where the lower limit for a block length is the along-track antenna aperture.

The FF-SAR for Sentinel-6 processor is particularly heavy, and it is recommended to use it on small areas of interest for few products at a time.

Output Format

The FF-SAR Level1b data products generated in output are in standard NetCDF format. The NetCDF format is self-explanatory with all the data field significance described in the attributes.

The file naming convention for the output files is: **L1B_FF_ML_starttime_stoptime.nc**

where:

- starttime is the time of the first sample in the Leve1b product in the format YYYYMMDDThhmmss.
- stoptime is the time of the last sample in the Level1b products in the format YYYYMMDDThhmmss.

In the Level1b product, the following conventions are adopted

- The Reference Time for the TAI Datation is 01/01/2000 00:00:00.
- The Vertical Datum for altitude reference is the WGS84 Ellipsoid.

The Level1b product includes the variable uncorrected_retracked_height, that contains the surface height computed by threshold retracker in RD05. It is worth underlining that the threshold is set to 60% and that the geophysical corrections are not applied, but included in the variables: geophysical_correction_ocean, geophysical_correction_land and geophysical_correction_seaice.

11. SMAP for Sentinel-3 - CLS

The Standalone Multi-mission Altimetry Processor (SMAP) for Sentinel-3 service is a standalone altimeter data processor written in Python 3 (3.7.3). SMAP implements in particular the fully-focused SAR (FF-SAR) processing using the time-domain back-projection algorithm. SMAP is currently able to process Sentinel-3 L1A PDGS products. An open source version of the processor is available at: https://github.com/cls-obsnadir-dev/SMAP-FFSAR.

Provider

CSL (https://www.cls.fr/en/) – Pierre Rieu and Samira Amraoui

Description

The Standalone Multi-mission Altimetry Processor (SMAP) for Sentinel-3 service is a standalone altimeter data processor written in Python 3 (3.7.3). SMAP implements in particular the fully-focused SAR (FF-SAR) processing using the time-domain back-projection algorithm. SMAP is currently able to process Sentinel-3 L1A PDGS products.

List of processing parameters and constraints

The processor prototype is versatile in the sense that the users can customize and adapt the processing, according their specific requirements, setting a list of configurable options.

Processing Parameter	Values	Description
Surface type	• 0 • 1 • 2 • 3	User can decide a combination of surface type to be processed, can be stacked (separated with commas, without spaces); possible values are open_ocean_or_semi-enclosed_seas : 0 / enclosed_seas_or_lakes : 1 / continental_ice : 2 / land : 3 (e.g., "0,1,2,3"); the geographical selection is based on the Level-1A surface type flags.
L2 processing	• OCOG_SAR • PTR • MultiPTR	User can decide a selection of L2 retrackers to be applied to the waveforms, can be stacked (separated with commas, without spaces), between OCOG_SAR, PTR, and MultiPTR (e.g., "OCOG_SAR,PTR,MultiPTR"); OCOG_SAR is the standard threshold peak retracker [Wingham, (1986)] (threshold can be configured with ocog_threshold); PTR retracker fits the main peak of the waveform with the range PTR (least-square criterion); MultiPTR retracker fits multiple peaks of the waveform with PTR retracking, with a number of peaks to retrack indicated in the configuration field multiptr_n and return retrack parameters for each individual peak; note that the MultiPTR option is experimental and it is only available for bulk processing (not in the on-demand GUI).
Illumination time	• Float	User can decide the illumination time in seconds (the integration time associated with the synthetic aperture). This shall be a floating number between 0.08 and 2.3.

Posting rate	• Float	User can decide the posting rate in Hz related to the FFSAR along-track multi-looking of the single-looks, the spacing on ground between two multi-looks is equal to "satellite_velocity/posting_rate" meters. This shall be a floating number between 20 and 17825.
Zero padding	• 1 • 2	User can set the oversampling factor in range, an integer between 1 and 2.
Hamming range	• yes • no	User can decide whether to apply Hamming weighting in range, either yes or no.
Hamming azimuth	• yes • no	User can decide whether to apply Hamming weighting in azimuth, along the burst, either yes or no.
Range extension	• 1 • 2	User can set the extension factor in range; processing is done on 128 * range_ext_factor * zp range gates to be truncated into 128 * zp central range gates at the end of the processing; can be an integer between 1 and 2.
OCOG threshold	• Float	User can set the threshold for the OCOG retracker, a floating number between 0.0 and 1.0 (parameter applied when the field "L2 processing" includes "OCOG_SAR").

Multiptr N	• 1 • 2 • 3 • 4 • 5 • 6 • 7 • 8 • 9 • 10	User can set the number of peaks to be retracked with the Multi PTR retracker, an integer between 1 and 10 (parameter applied when the field "L1 processing" includes "MultiPTR").

Shapefiles to delimit the processing geographically can be provided in the form presented at https://github.com/cls-obsnadir-dev/SMAP-FFSAR/tree/main/shp & https://github.com/cls-obsnadir-dev/SMAP-FFSAR/blob/main/doc/NOTES.pdf and adopted in processing campaigns only.

Processing constraints

The SMAP FF-SAR processor is quite heavy, and it is recommended to use it on small areas of interest for few products at a time.

Output Format

The SMAP FF-SAR data products generated in output are in standard NetCDF format. The NetCDF format is self-explanatory with all the data field significance described in the attributes.

SMAP gives four subdirectories as output, containing respectively: L1b netCDF files, L2 netCDF files, log files, and command files (bash scripts launching l1b and l2 programs).

The tracker range and range values in the output product are corrected for USO drift and internal path delay. The COG distance is also included. Additionally, the AGC correction is included in the calibration of the data, all the other calibrations applied (like CAL1, CAL2, π-shift between bursts,...) can be found in the files available at: https://github.com/cls-obsnadir-dev/SMAP-FFSAR.

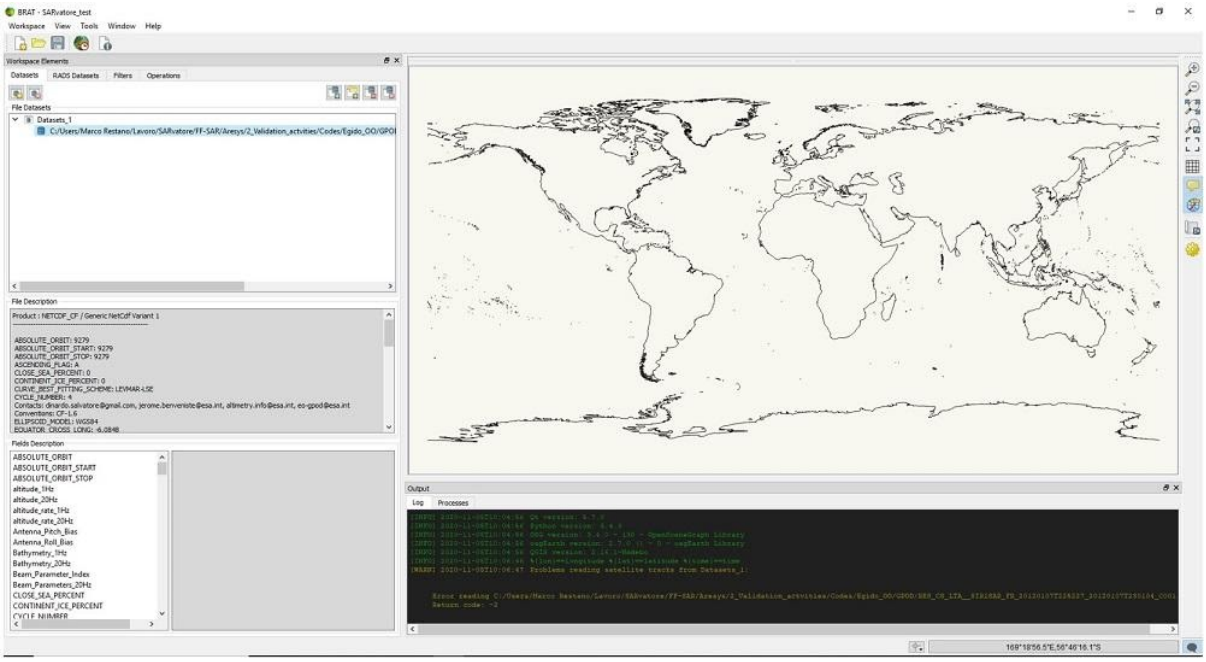
The surface height is computed as *alt_ffsar* - *range_ffsar* (range_ffsar depends on the retracker that is used). It does not include any geophysical correction on the range. The user can find geophysical corrections in official L2 PDGS products. The variable alt_ffsar is relative to the reference ellipsoid WGS84 (not to the geoid).

Users can apply their own empirical & physical retrackers by using data fields in the L1b products. These also include the tracker range and the scaling factor for sigma0 evaluation. The nominal tracking gate number for Sentinel 3 is 44.

Appendix A

Opening SARvatore products in BRAT

SARvatore products can also be opened in the Broadview Radar Altimetry Toolbox (BRAT). However, when products are loaded, the track is not correctly displayed on the BRAT map and an error is reported:

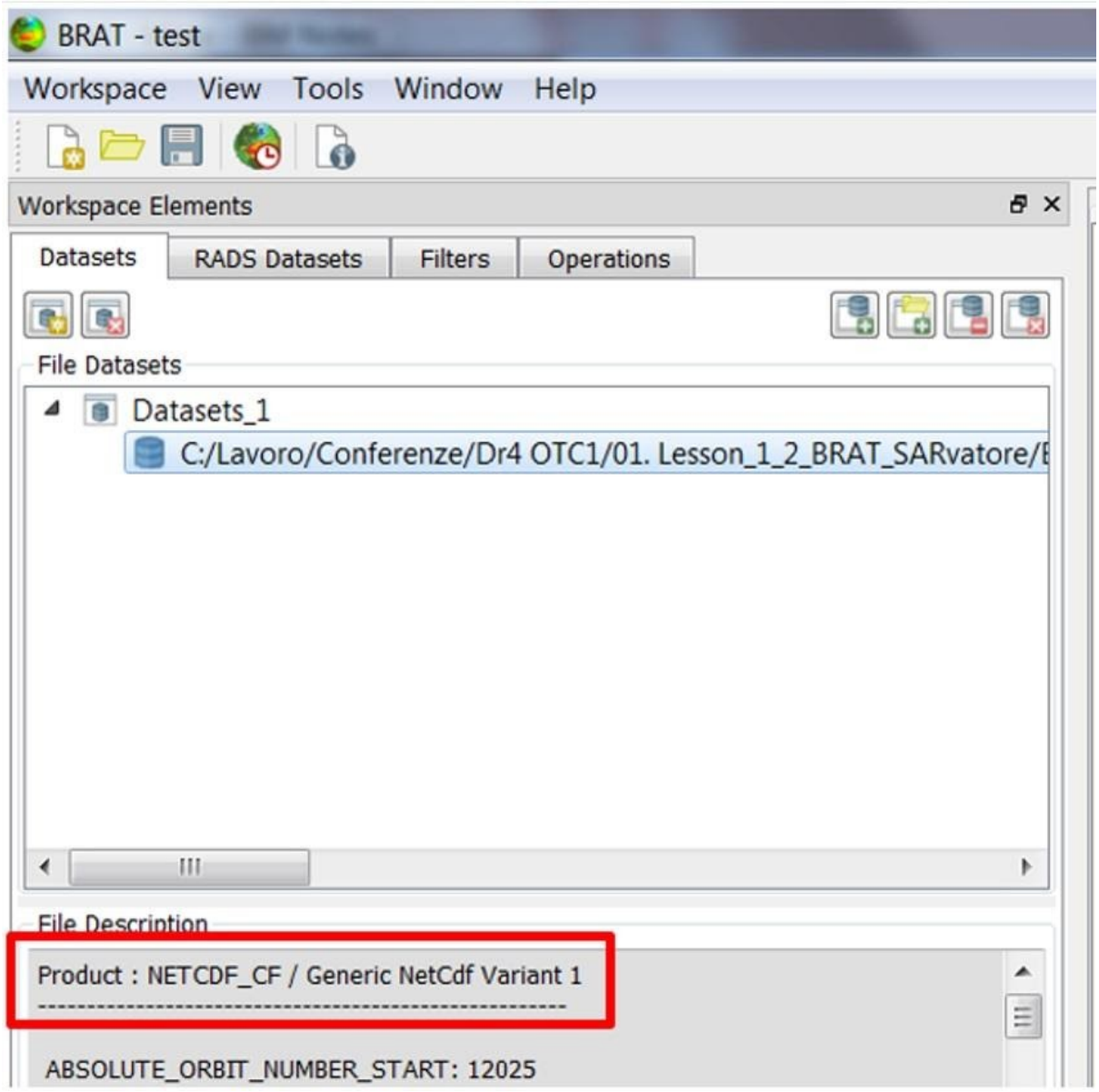


The toolbox is able to read:

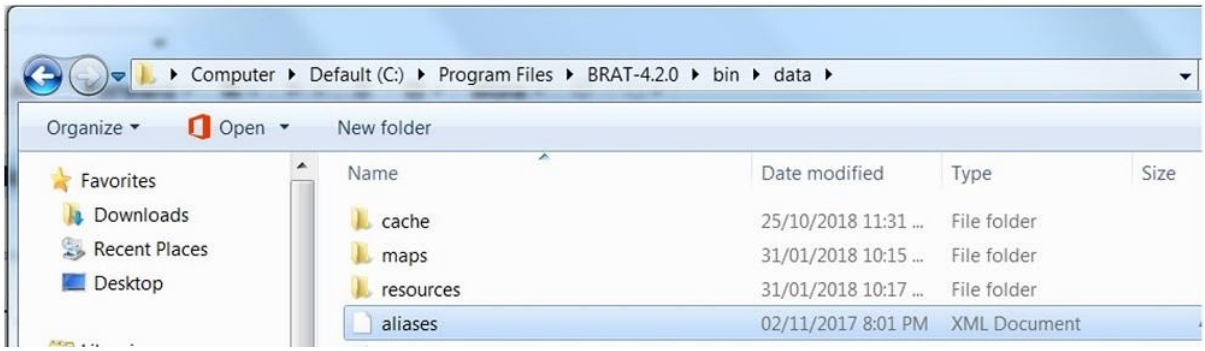
- all altimetry data from official data centres (from ERS-1 and 2, Topex/Poseidon, Geosat Follow-on, Jason-1, Envisat, Jason-2, Cryosat and Sentinel-3, from Sensor Geophysical Data Record to gridded merged data);
- any NetCDF file.

In the latter case, a small edit is needed to correctly visualize the track associated with the input products.

Considering SARvatore products, the NetCDF file is associated with the **NETCDF_CF / Generic NetCdf Variant 1** format:



Therefore, to correctly display the track on the BRAT map, users shall close the program, open the **bratXX/bin/data** folder:



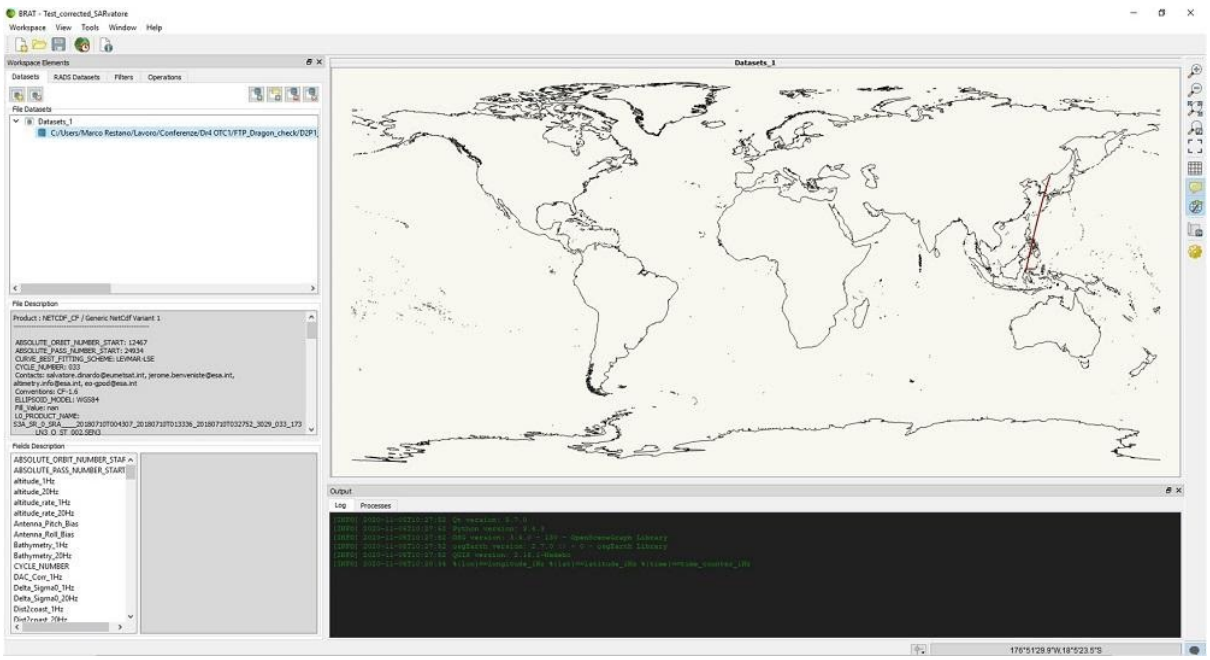
and edit the aliases.xml file as follows in the Generic NetCdf Variant 1 section:

- change the latitude to latitude_1Hz ;
- change the longitude to longitude_1Hz;
- change the time to time_counter_1Hz (or those at 20Hz).

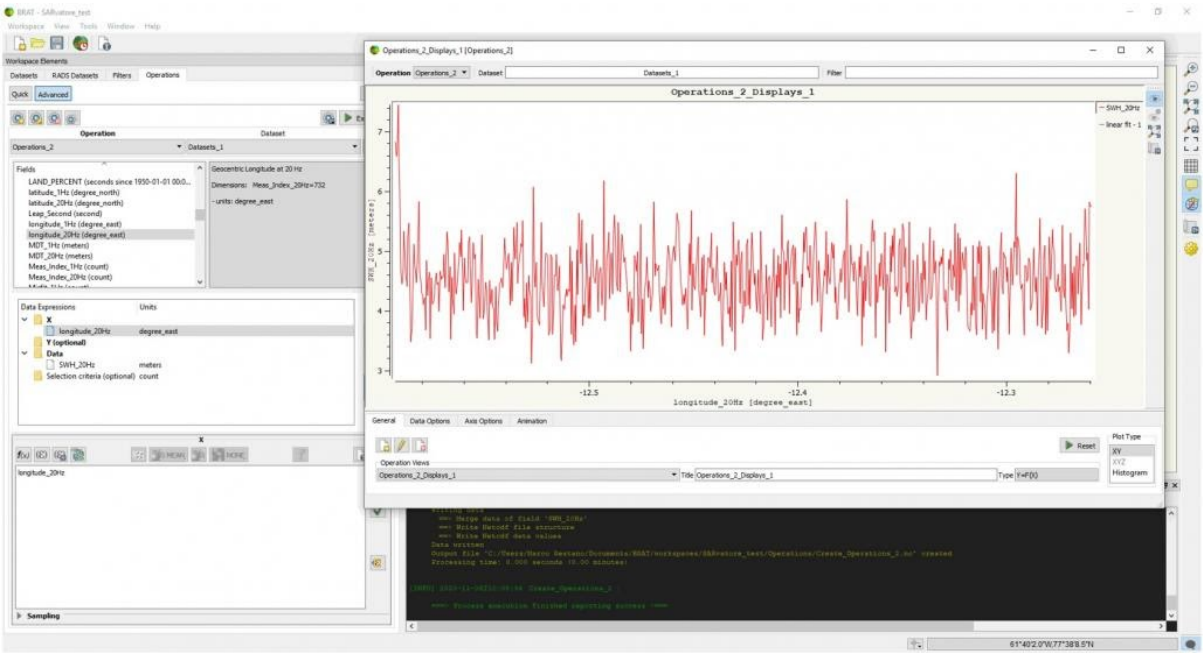
```
<aliases productType="Generic NetCdf Variant 1" description="Generic Netcdf Dataset - Aliases Variant 1">
  <alias name="lat">latitude</alias>
  <alias name="lon">longitude</alias>
  <alias name="time">time</alias>
</aliases>
```

```
<aliases productType="Generic NetCdf Variant 1" description="Generic Netcdf Dataset - Aliases Variant 1">
  <alias name="lat">latitude_1Hz</alias>
  <alias name="lon">longitude_1Hz</alias>
  <alias name="time">time_counter_1Hz</alias>
</aliases>
```

Once the track is loaded again in BRAT, it will be correctly displayed and no error will be reported:



More information can be found in Chapter 5 of the BRAT user manual available here.
Afterwards, SARvatore products can be processed in BRAT using the Advanced option in the Operations menu.



To learn how to use BRAT, please consider the material available at the following links:

- https://youtu.be/PdnSalcOUHA
- https://www.youtube.com/watch?v=ya2NeqFDvo8&t=6s