ESA–MOST China Dragon 4 Cooperation

→ ADVANCED TRAINING COURSE IN OCEAN AND COASTAL REMOTE SENSING

12 to 17 November 2018 | Shenzhen University | P.R. China

Principles of SAR altimetry & The ESA GPOD SARvatore on-line and on-demand processing service for the advanced exploitation of Sentinel-3 and CryoSat-2

Hosted by

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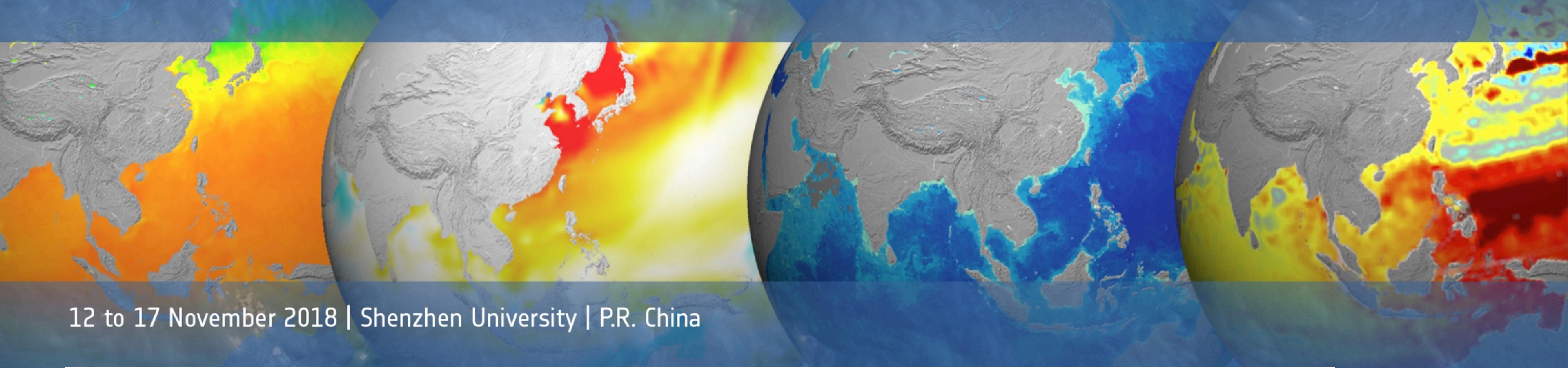

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Principles of SAR altimetry

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Limits of LRM Altimetry

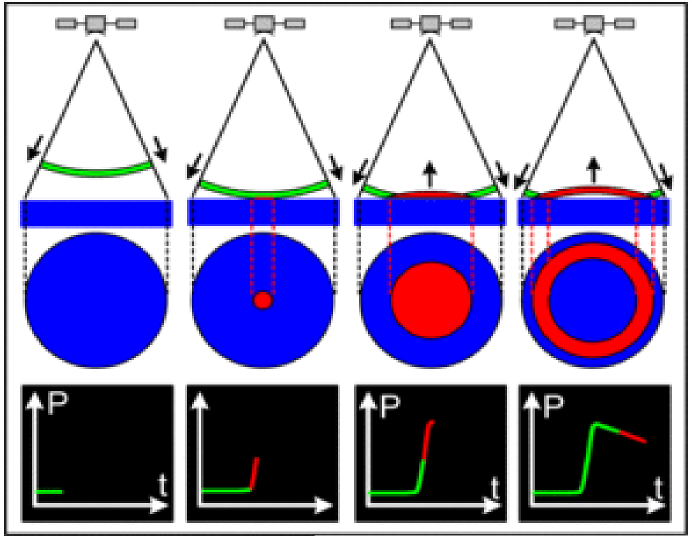
- Conventional altimeters discussed so far use returns from the pulse limited footprint (forming the leading edge) to estimate the minimum radar range at nadir.

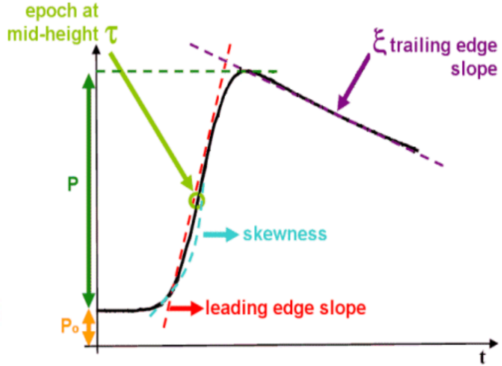
- A radar altimeter is pulse limited when the tx signal duration is short enough that the entire target within the antenna beam is not simultaneously illuminated.

- The mean return pulse is mainly the convolution of the radar system point target response (PTR), the sea surface height distribution (typically Gaussian) and the antenna pattern.

- By looking at the **trailing edge**, it is clear that echoes from scatterers located outside the pulse limited footprint appear at a relative greater delay.

- Therefore, a significant amount of power is wasted in receiving echoes that cannot be used for range estimation.

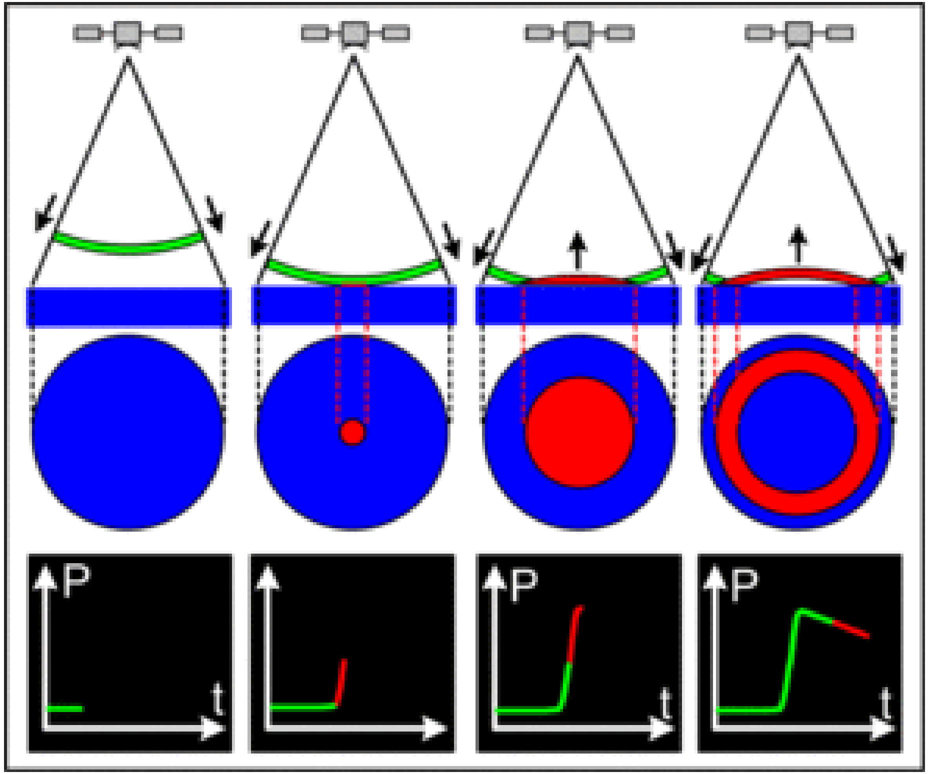




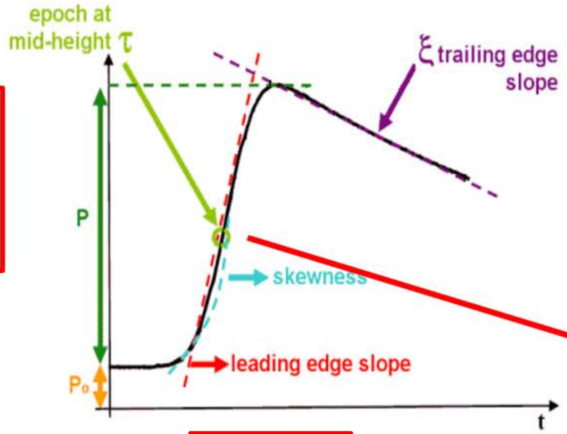
Limits of LRM Altimetry (1)

- As an example, (Raney, 1998) indicated that for GEOSAT the pulse limited footprint **(from which the leading edge is created)** was less than 1/10 of the antenna pattern when a quasi-flat surface was considered.

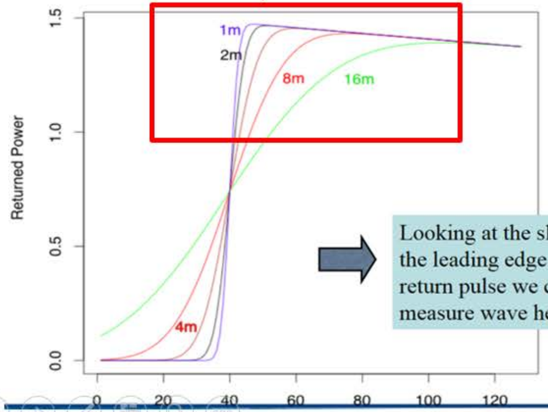
- Another disadvantage of LRM altimetry is the increase in footprint dimension as the surface become rougher (SWH>>) leading to a degraded estimation of range and SWH.



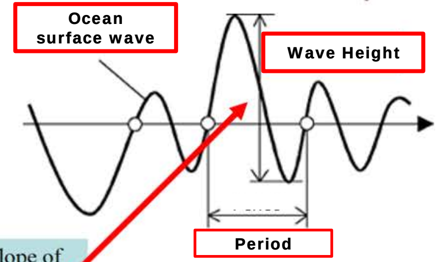
Limits of LRM Altimetry (2)

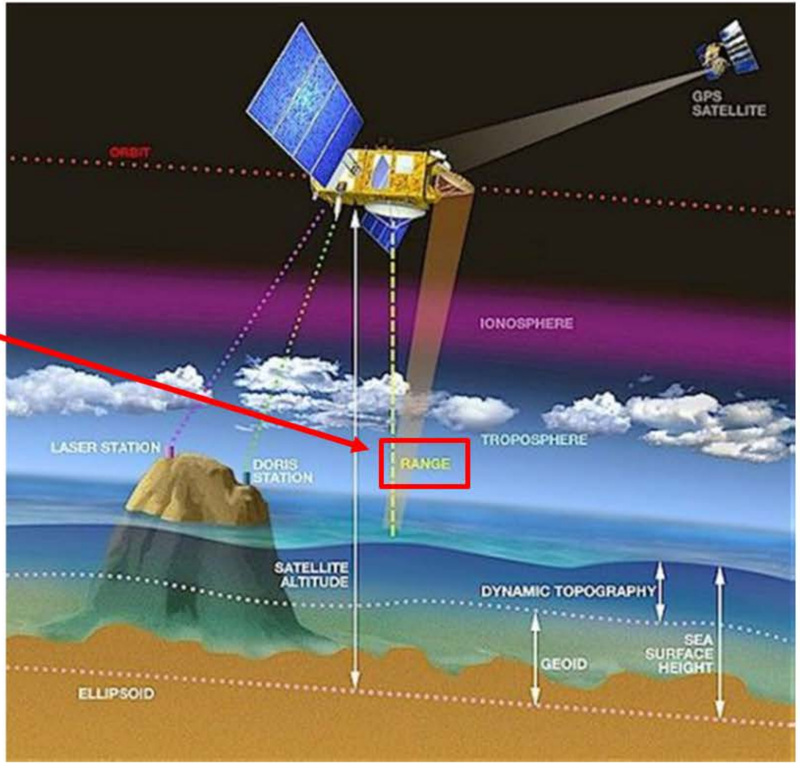


The Power amplitude (sigma0) of the signal can be related to the wind speed.



Looking at the slope of the leading edge of the return pulse we can measure wave height!





Why SAR Altimetry?

Starting from these limitations, the Delay/Doppler processing *(Raney, 1998*) aims at:

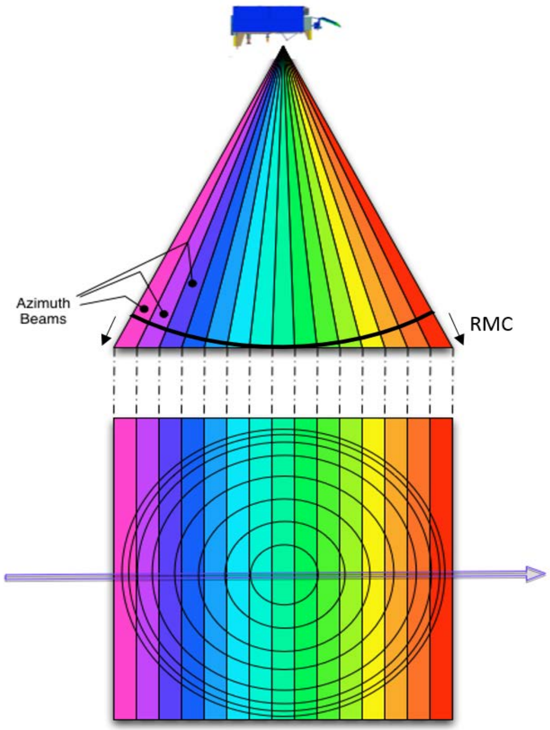
1) Better exploiting the transmitted energy by <u>using the entire beam-limited along-track signal history</u> instead of only the small pulse limited footprint.

2) Using the Doppler selectivity to decrease the extension of the footprint in <u>along-track</u> limiting also the influence of an increasing SWH.

A Doppler shift f in the frequency of the received signal is present anytime the sensor and the scatterer are moving with respect to each other:

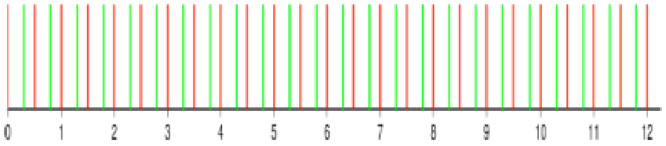
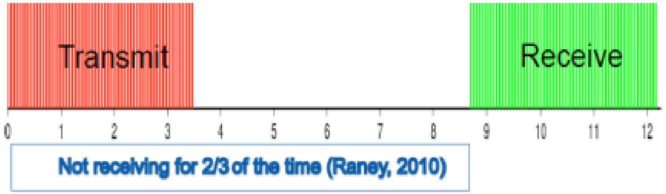
$$f = \frac{2|\vec{V}|cos\theta_n}{\lambda}$$

where $\vec{V}$ is the velocity vector, λ is the wavelength and θ_n is the angle between the the sensor and the surface scatterer. **<u>The Doppler shift is null when the scatterer is observed at nadir as no relative movement exists</u>**



Transmission Scheme

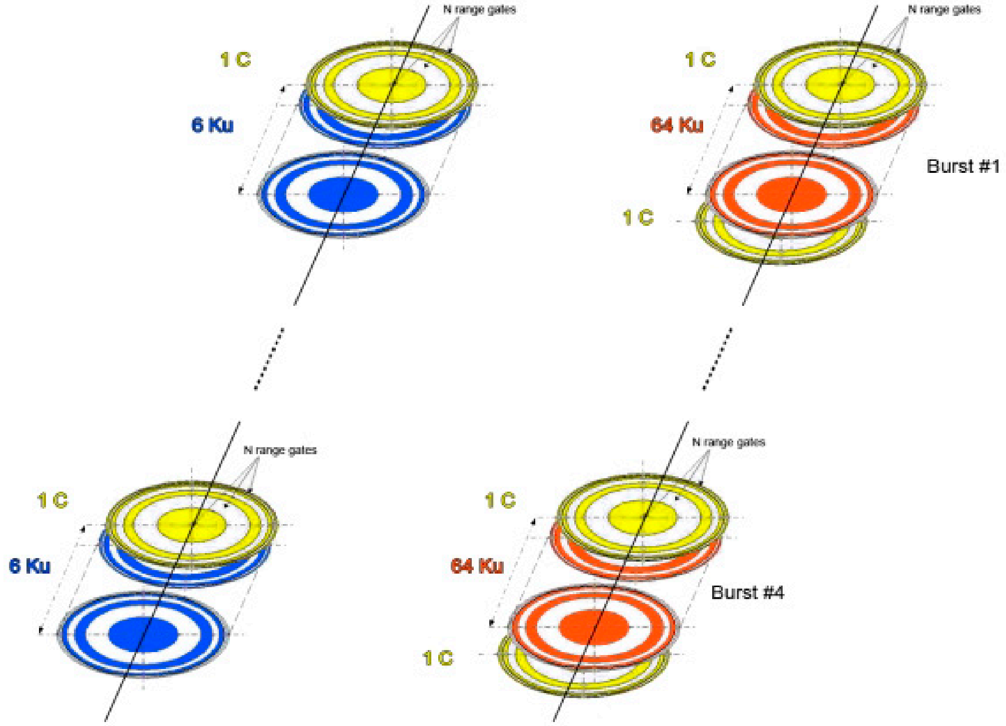
- To be performed, this processing requires a different transmission scheme in comparison to LRM altimeters:

OPERATION MODE	CHRONOGRAM	ALTIMETRIC MISSIONS
Low Resolution Mode (LRM) Low PRF (1-4kHz) Continuous Tx/Rx		All past ocean altimeter missions Cryosat-2 LRM AltiKa Jason-3
SAR Closed-Bursts High PRF (~20 kHz) Tx/Rx in bursts		Cryosat-2 SAR Sentinel-3

- No single pulses but **bursts of pulses are transmitted** guaranteeing, through a higher PRF $(\sim 18Khz)$, the **coherent correlation** among pulses of each burst *(*the transmitted *pulses* of a *coherent* radar have all *defined* phase angles to a reference). The **coherency** is needed to support the **along-track FFT** discussed in the next slides.

Transmission Scheme (2)

- Old Design: Sentinel-3 LRM radar cycle transmitting pattern (left) and SAR radar cycle transmitting pattern (right).
- The LRM mode was dismissed.
- SAR radar cycles contain four bursts
- Each burst has a sequence of 1 C - 64 Ku -1 C pulses.

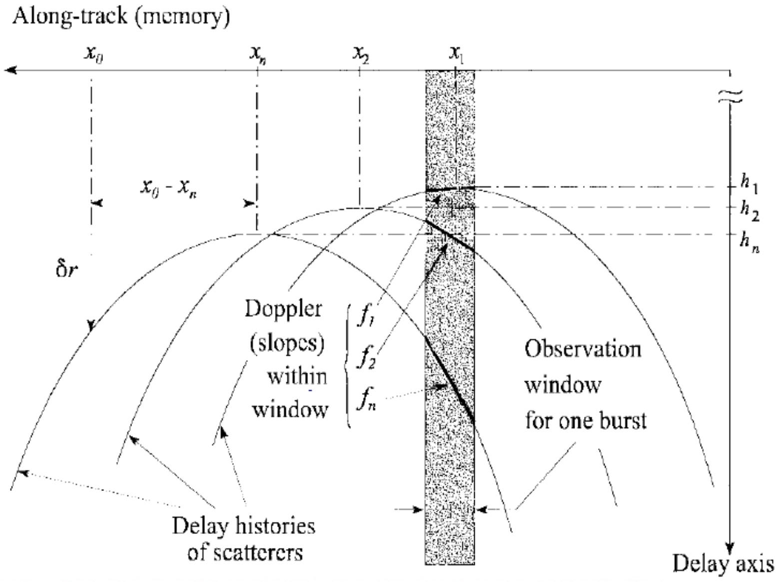


(Figure credit: Thales Alenia Spazio)

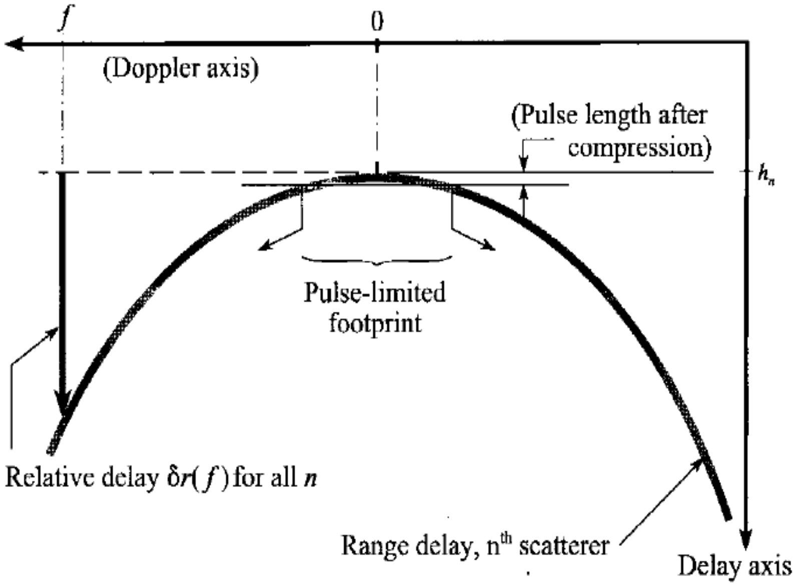
How to perform Doppler Processing?

- The altimeter is said to operate in the **time domain** in **along-track** and in the **range**, or **Delay**, **domain** in **across-track**.
- A **Fast Fourier Transform (FFT)** is applied to signals received from each burst **to transform the time domain** into the **Doppler domain**. Here a comparison between Delay-Time and Delay-Doppler Domain:

Delay-Time (multi-valued correspondence)



Delay-Doppler (single-valued correspondence)

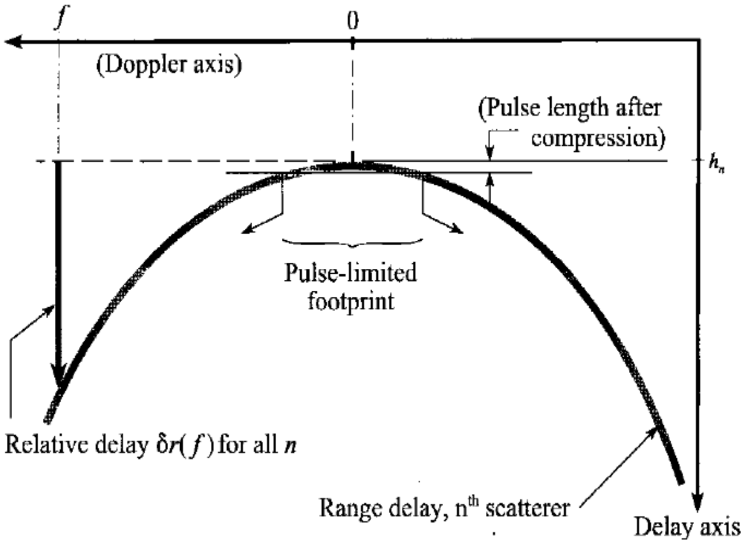


How to perform Doppler Processing? (1)

Following the application of the FFT in along-track, **the relative delay becomes function of Doppler frequency ($\delta_r(f)$)**.

The **Delay/Doppler relation** is **now single-valued** and the relative delay $\delta_r(f)$ can be eliminated from all signals simultaneously *(Raney, 1998)*.

The new domain can be geometrically interpreted as it includes by mathematical construction a 1:1 correspondence between the observed Doppler frequency f (relative to zero) and the individual scatterer's position in along-track.

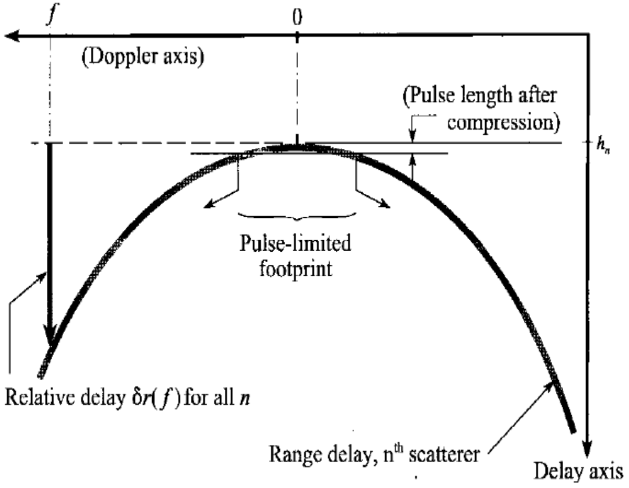


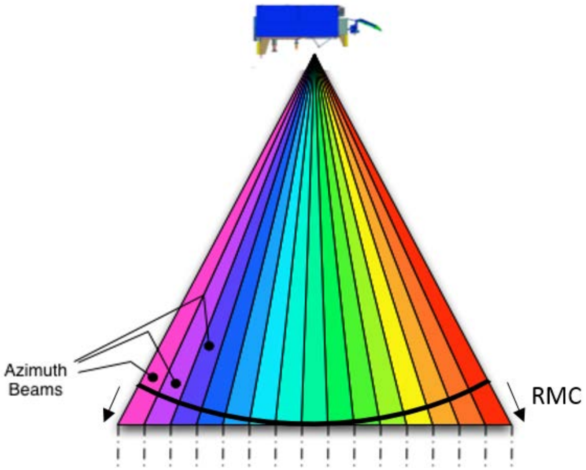
$$f \approx \frac{2V_{S/C}}{\lambda}\frac{x_n - x_0}{h_n}$$

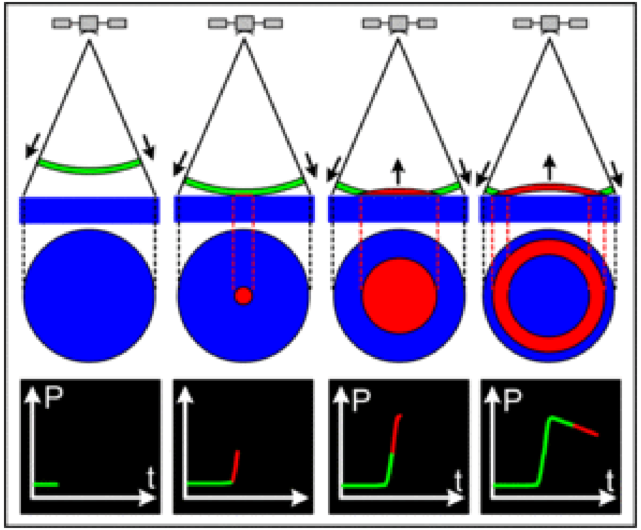
x_n: individual scatterer's position in along-track (relative to the x_0 altimeter along-track position). h_n is the minimal height of the scatterer.

How to perform Doppler Processing? (2)

The processing continues by **eliminating the curvature of the range delay** (unwanted extra delay with respect to the nadir direction for which the Doppler frequency $f = 0$) by the **application of multiplicative phase shifts** and partitioning the data in Doppler frequency bins.





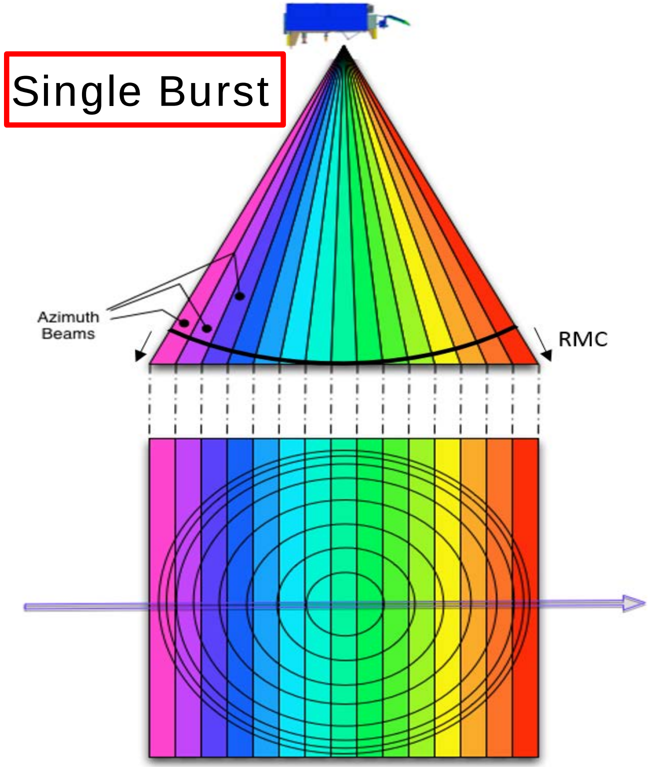


How to perform Doppler Processing? (3)

During the overfly of the scatterer, the height estimate spans the Doppler range from the highest Doppler bin to the lowest until the scatterer is no more illuminated.

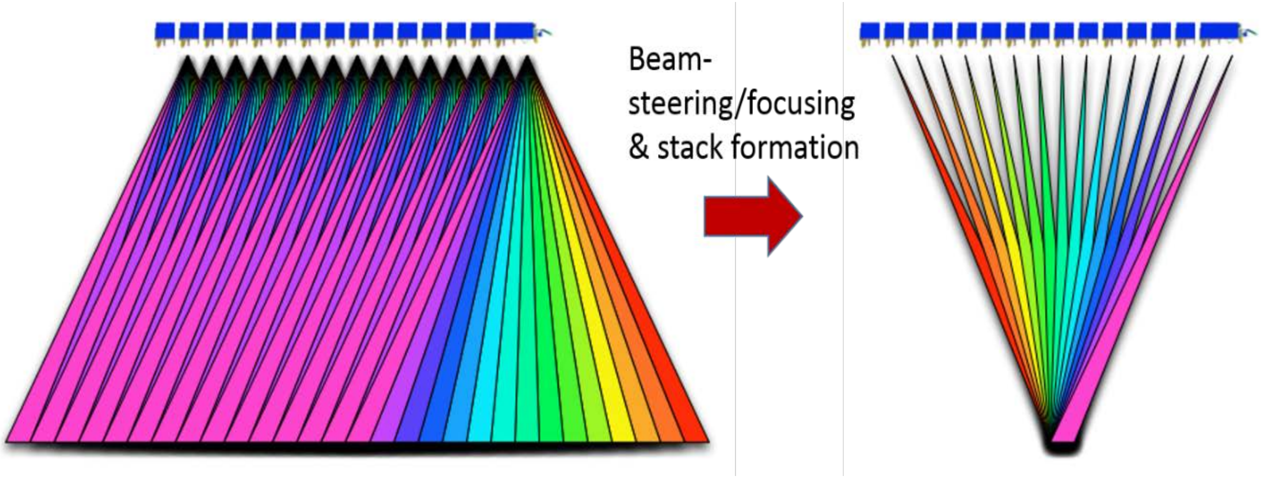
In other words, height estimates are sorted by the Doppler frequency as if the beam-limited antenna pattern would be split into many narrower Doppler beams (looks) looking at the same scatterer from different angles during the overfly.

After the compensation, the scatterer appears at its minimum nadir distance over all its delay history and all the area illuminated by the antenna pattern is exploited.



How to perform Doppler Processing? (4)

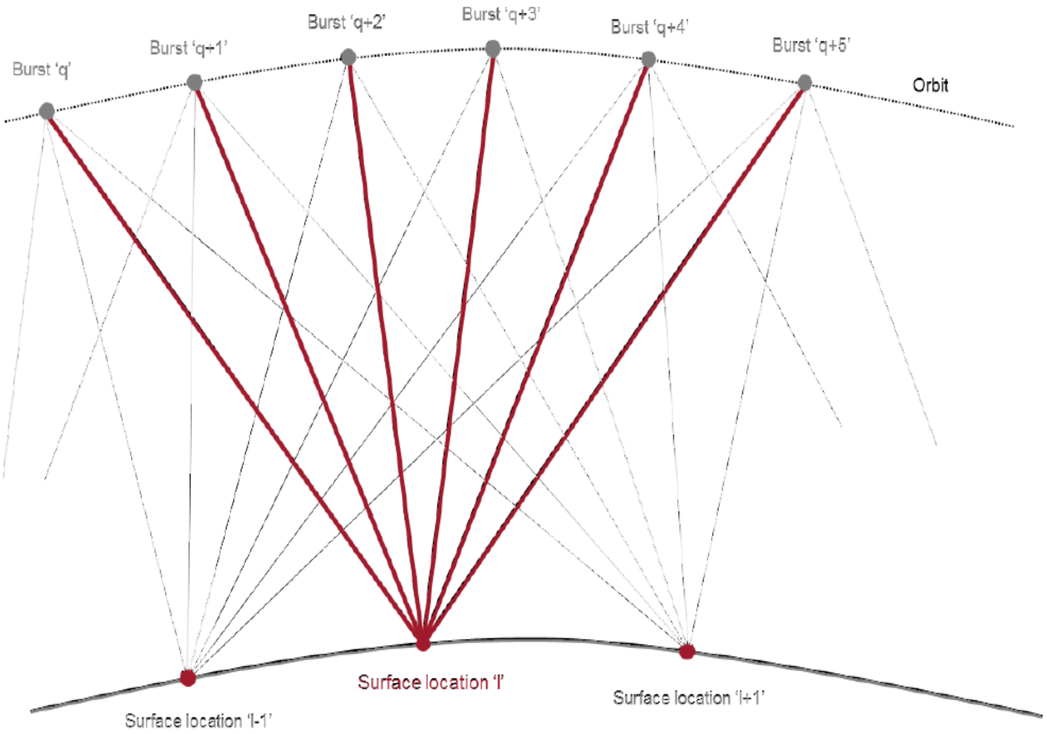
- The process is **repeated over subsequent bursts**.
- Several bursts are transmitted during the overfly of each surface point and each burst provides one single look to a surface point.



Stacking

- Afterwards, **data collected in each Doppler bin** are inverse Fourier transformed by applying an **IFFT** (Inverse Fast Fourier Transform) and **power detected** (losing the phase information, no more needed after that the range delay has been compensated using phase shifters).

- Data are accumulated to **form stacks** of **many "looks"** at specific surface positions.



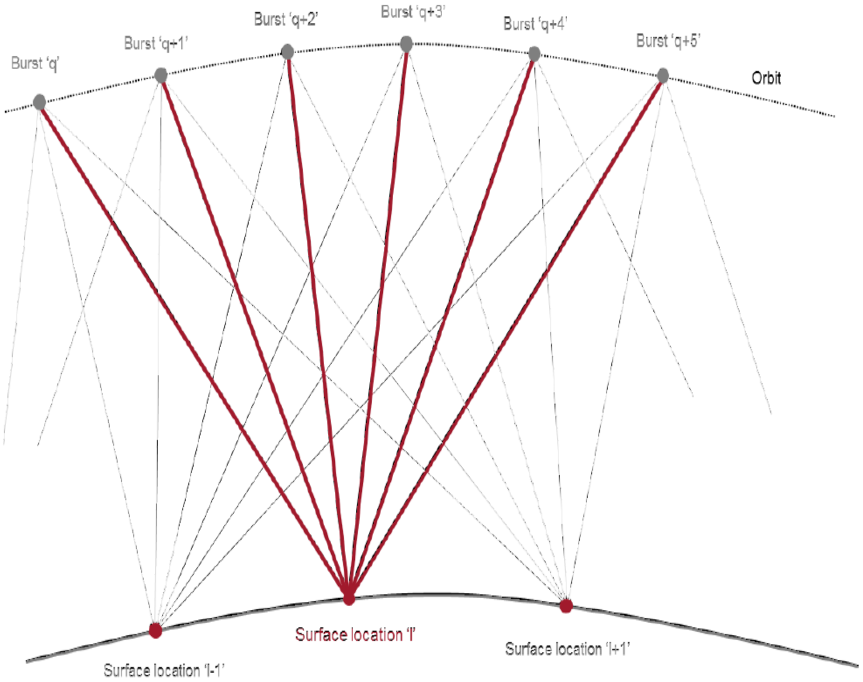
Formation of 3 stacks on predetermined surface locations. Each burst provides one single look to a surface point (Credit: isardSAT).

Incoherent Averaging

The final height estimate (retracking) is made on the L1b waveform resulting from the **incoherent averaging of waveforms (looks)**, composing the stack, that point a specific surface location (e.g. 6 looks from 6 different bursts are reported in the figure).

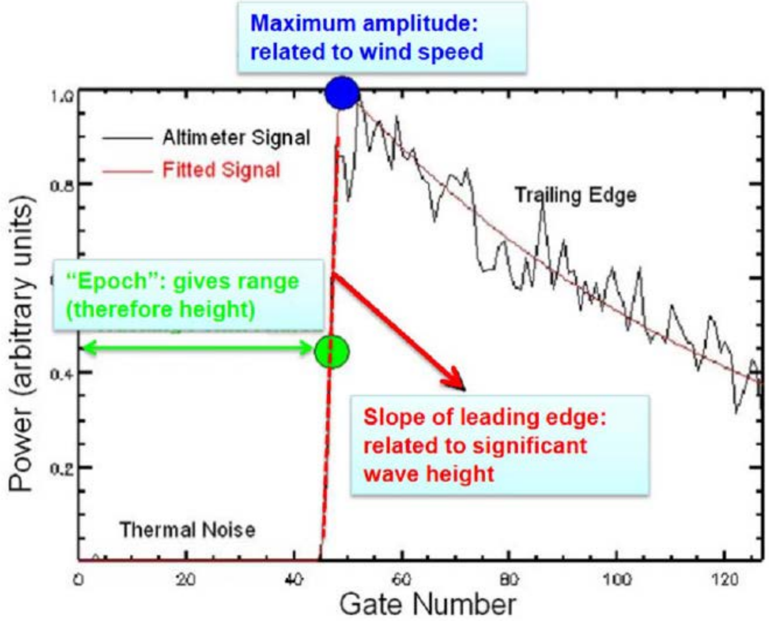
If Doppler bins cover the entire along-track antenna beam-width, all data acquired contribute to the height estimate (up to ~230 looks can be averaged).

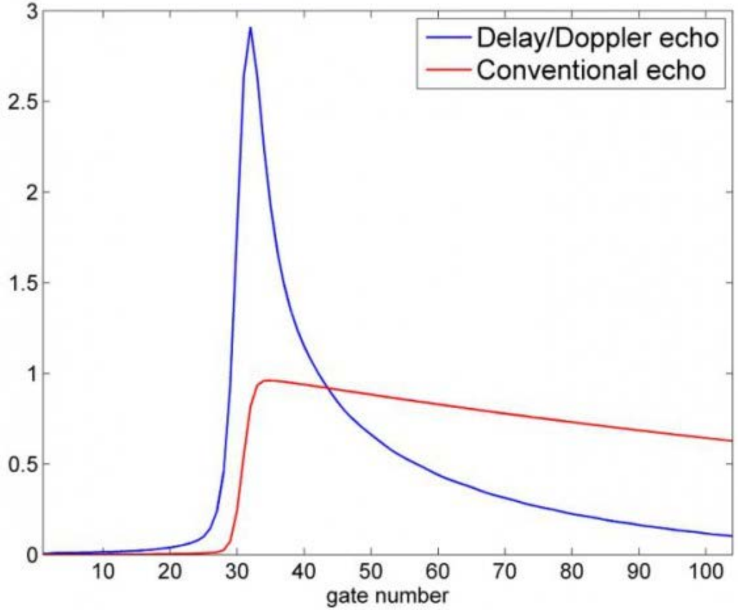
The possibility of using a reduced number of looks will be discussed later.



Incoherent Averaging

The resulting waveform is named “**L1b echo waveform**” and shall be retracked either by using empirical retrackers or physical retrackers **specifically developed for SAR (Delay / Doppler) waveforms**.



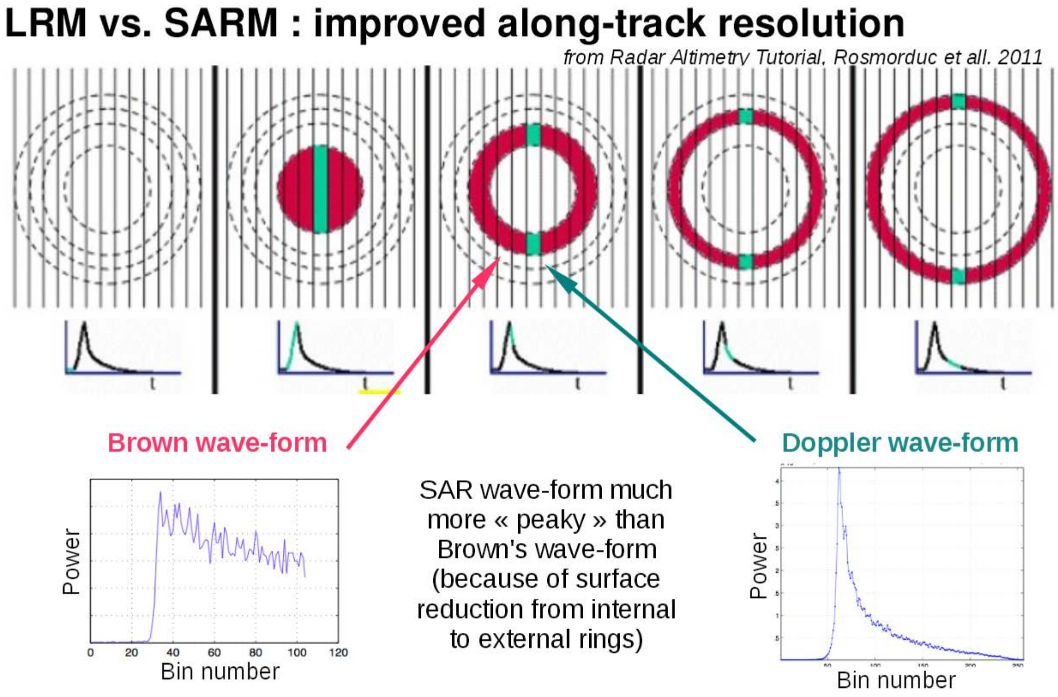


Footprint reduction in Along-Track

The incoherent averaging (multi-looking) of the individual echoes in the stack leads to a different result, if compared to the incoherent averaging made on LRM altimeters.

Footprint reduction in along-track up to 300 m **(fixed value!)**.

The **SAR L1b waveform is peakier** than the LRM one (S/N increases) and the **footprint dimension is no more dependent on surface roughness (SWH).**



Important considerations

Following the Walsh bound (*Walsh, 1982*), the transmitted pulses (PRF = 17Khz for CryoSat-2 in Delay/Doppler SAR mode) are **coherent within the burst** and **incoherent from burst to burst**.

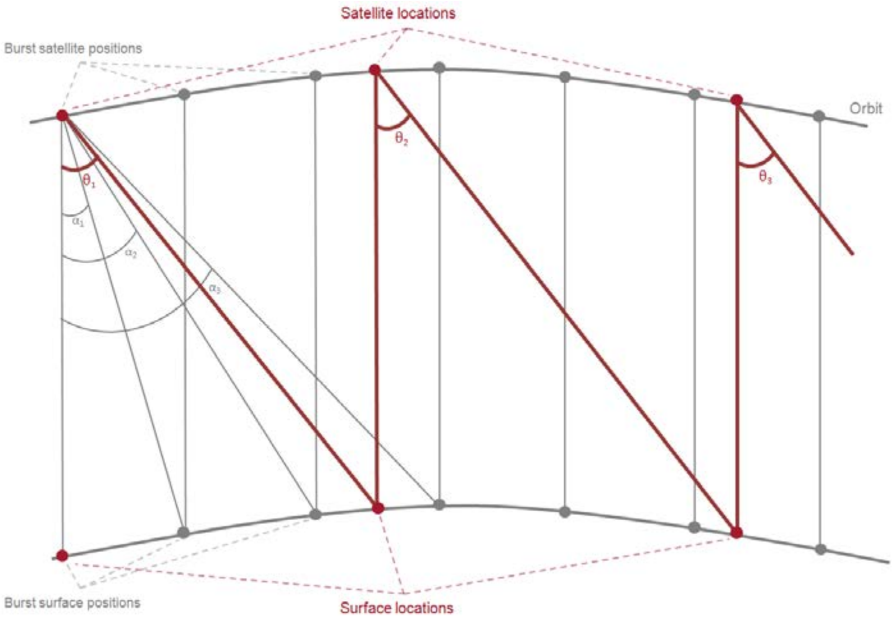
The **coherency** is needed to support the **along-track FFT** leading to the 2D Delay/Doppler domain, whereas the burst period separating the transmission of two consecutive bursts is set both to map overlapping surface locations in successive bursts and to **guarantee that in the multi-looking incoherent returns are averaged to reduce the speckle** as in conventional LRM altimeters.

Important considerations (2)

Surface along-track locations are derived from **satellite burst locations** projected on ground.

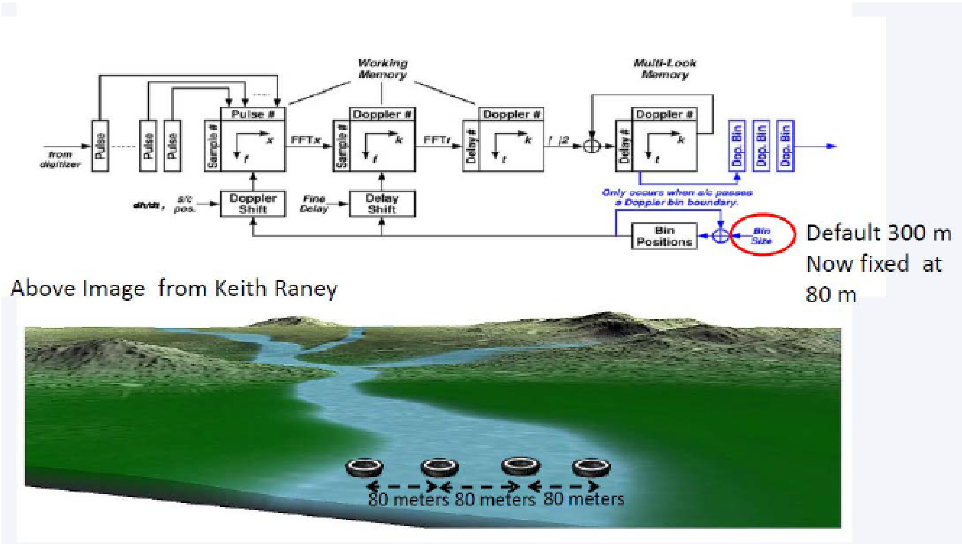
The **burst repetition frequency is typically ~80Hz** leading to an **on-ground cell spacing of 80m** with each grid cell co-located with the burst center.

However, standard **SAR L1b 20 Hz products** are formed by **averaging four consecutive 80 Hz SAR waveforms** resulting in an increase of cell size to **~300 m (no dependent on SWH!)**.

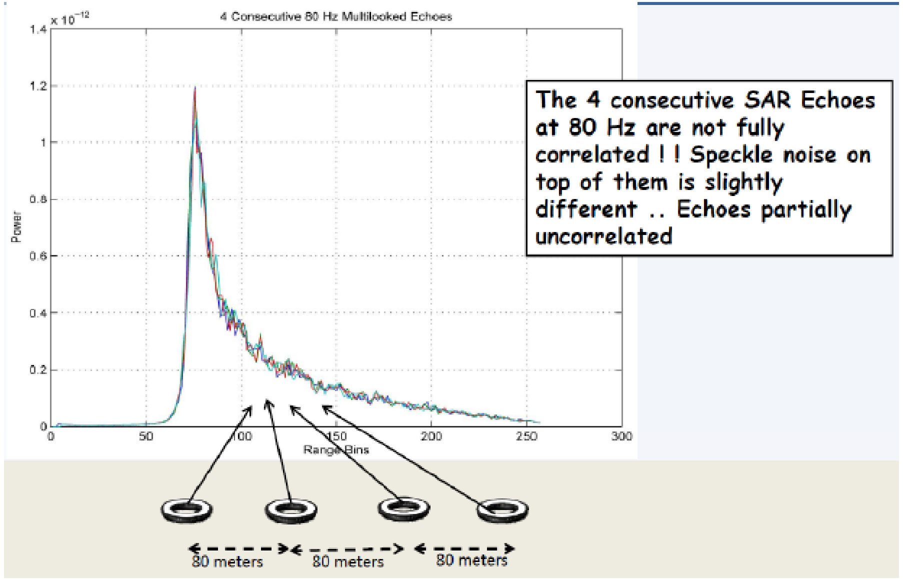


Important considerations (2)

Altimetric geophysical parameters from 80 Hz data can be also used (see option in SARvatore)



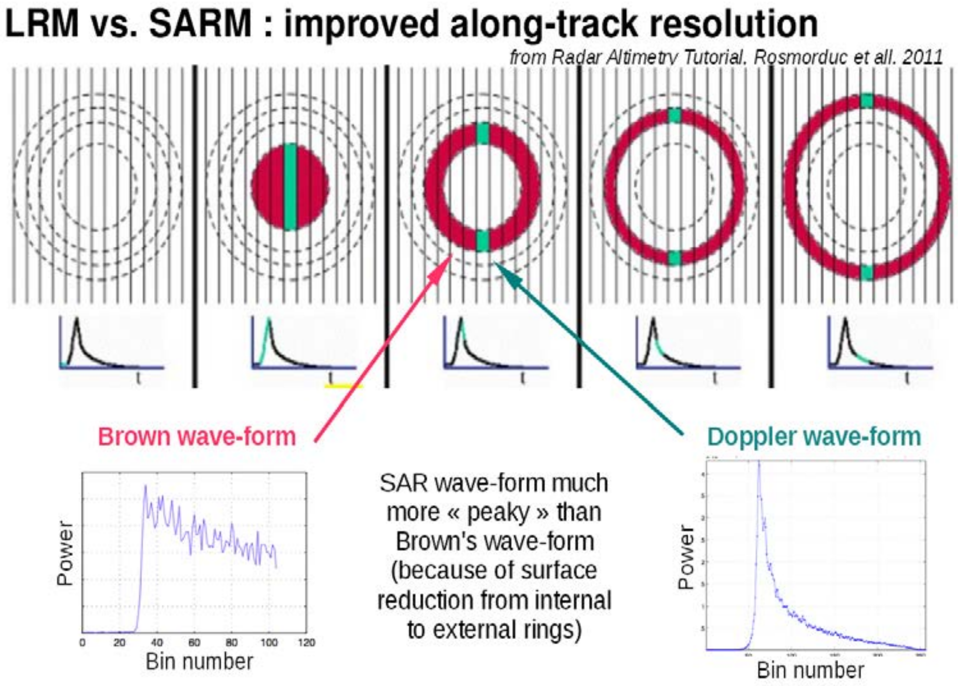
WE DONT CHANGE THE ALONG TRACK RESOLUTION, ONLY THE GRID STEP SIZE!



Important considerations (3)

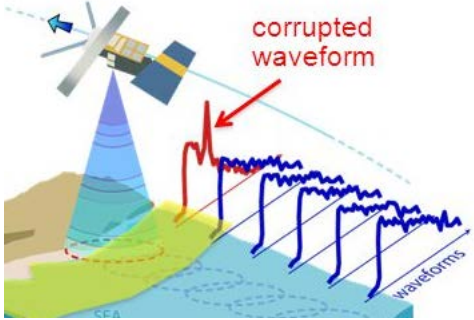
Although the SAR altimeter design curtails the along-track footprint, **the across-track footprint remains large**.

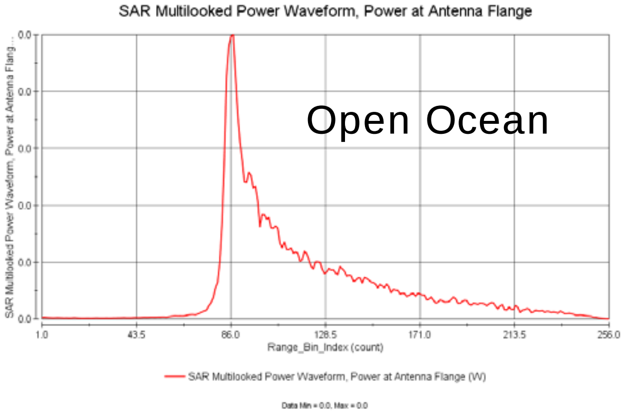
Researchers (see CRUCIAL project later) are now moving towards working with **Level-1BS data** (stack data before multi-looking), tailoring the processing to optimise signal retrieval from the desired target.

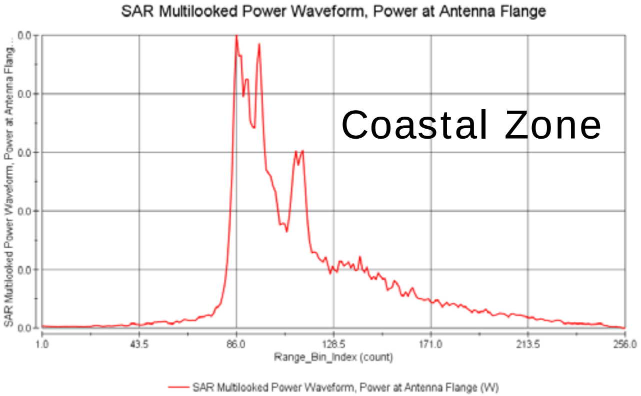


Important considerations (4)

L1b products contain L1b waveforms (records) from each 20 Hz surface location.







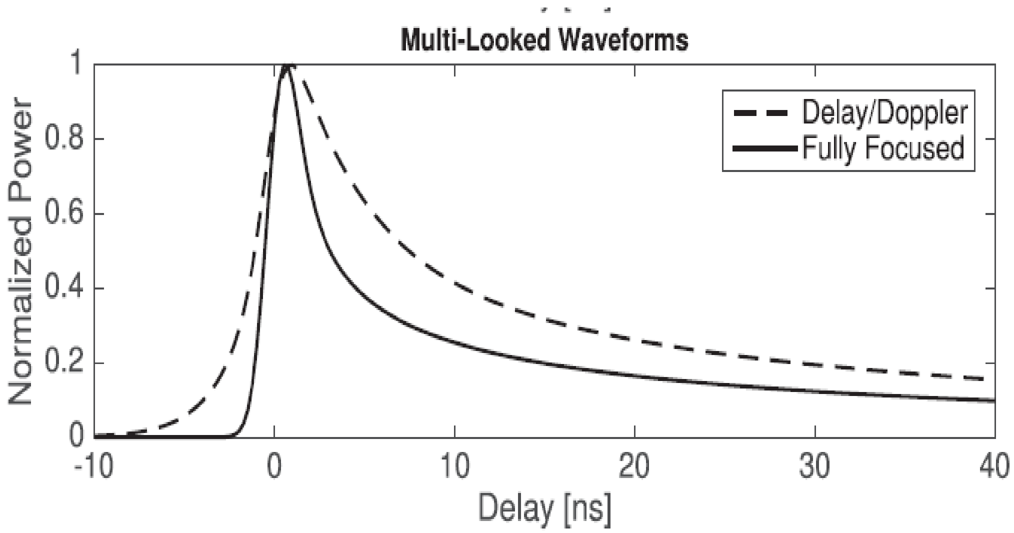
Appended to each record is the **number of looks** used in the averaging and the correspondent Doppler angles identifying the displacement of the looks. **They are needed to support the retracking phase** (only analytical retracking). Empirical retrackers do not need any additional information (not an advantage in case of mispointing).

A detailed description of the processing can be found in *(Raney, 1998*).

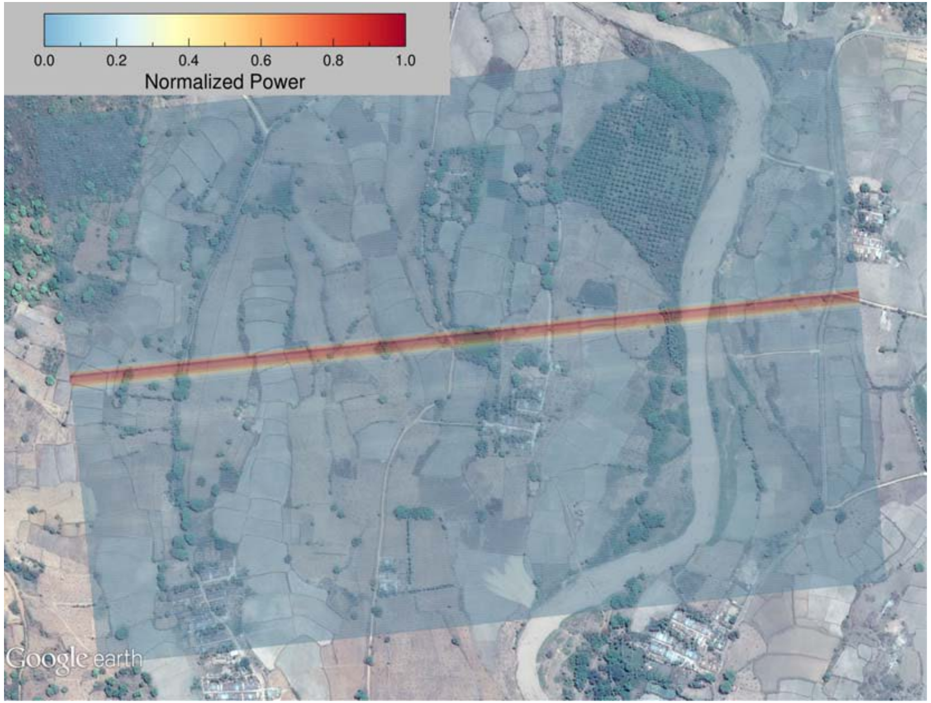
Fully-Focused SAR

The recent developed Fully-Focused SAR processing (*Egido and Smith, 2017*) is currently **capable of reducing the along-track resolution** down to the theoretical limit equal to half the antenna length (**0.5 m for typical SAR altimeters**).

This is accomplished thanks to **an enhanced multi-looking** capability leading both to a significant **increase in the effective number of looks (ENL)** with respect to the delay/Doppler altimetry and to a **peakier multi-looked waveform (S/N>>)**

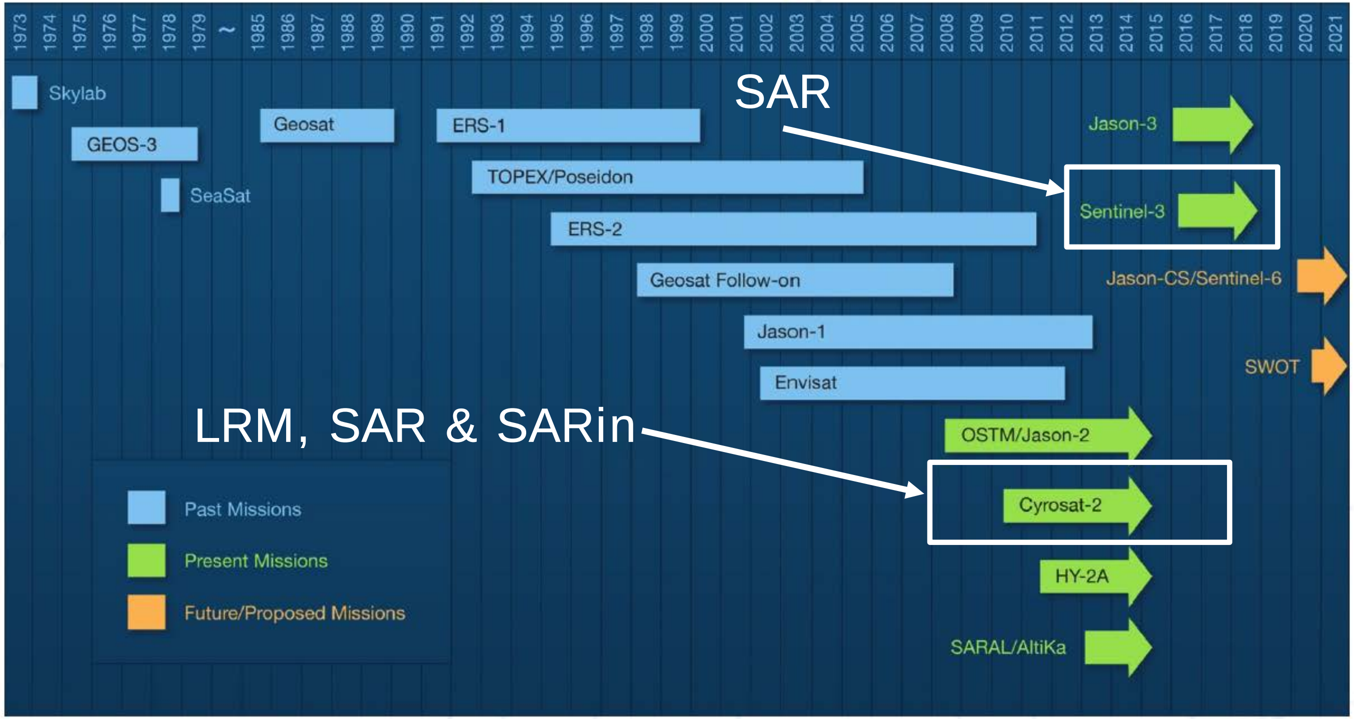


Fully-Focused SAR (2)



Delay / Doppler response (left) and FF-SAR response (right) of a 40 x 40 m irrigation pond

Altimetry Missions (1973-2017)



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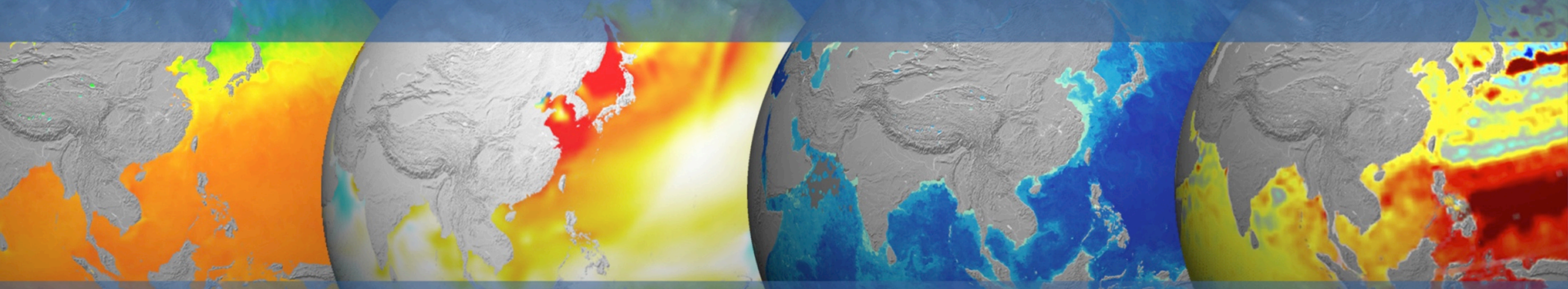

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Contents

- Introduction to the ESA/ESRIN GPOD Platform
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- SARvatore Data in Projects & Peer-Reviewed Papers

Introduction to the ESA/ESRIN GPOD Platform

G-POD Distributed Environment

The **ESA Grid Processing on Demand (**G-POD**)** system is a generic GRID-based operational computing environment providing users with a fast computational facility without the need to handle bulky data.

The G-POD system hosts high-speed connectivity, distributed processing resources and large volumes of data to provide scientific and industrial partners with a shared data processing platform fostering the development, validation and operations of new Earth Observation applications.

G-POD Distributed Environment (2)

In particular, the G-POD environment consists of:

- Over **600 CPUs** in about **90 Working Nodes**
- Over **400 TB** of **local on-line Storage** + flexible capacity of EO data accessed directly from the PACs
- Access to Cloud processing and data resources on demand
- **Internal dedicated 1 Gbit LAN** at ESRIN and at UK-PAC archives & 1 Gbps external connection
- **Software Resources on-line**: IDL, MATLAB, BEAT, BEAM, BEST, CQFD, NEST, **BRAT**, Python, Gamma
- System: GRID Globus on Linux

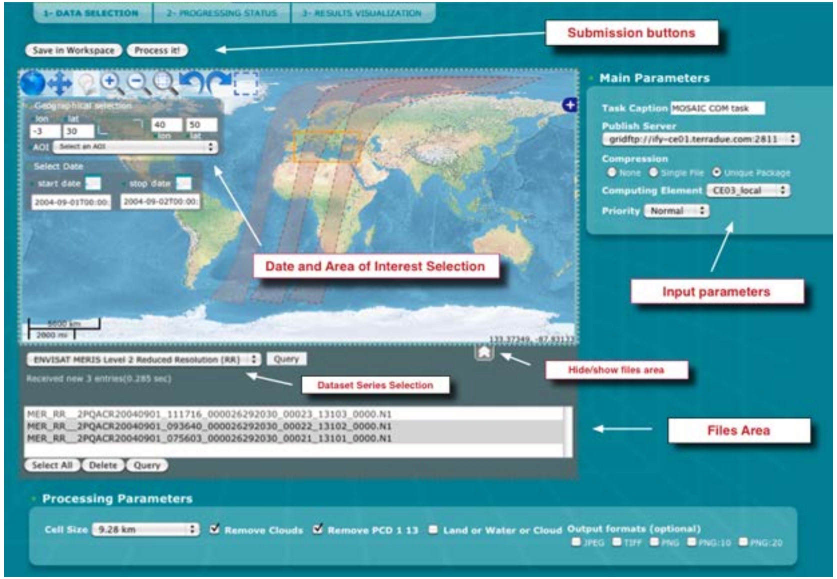
EO Data available to G-POD services come from both ESA and non-ESA missions.

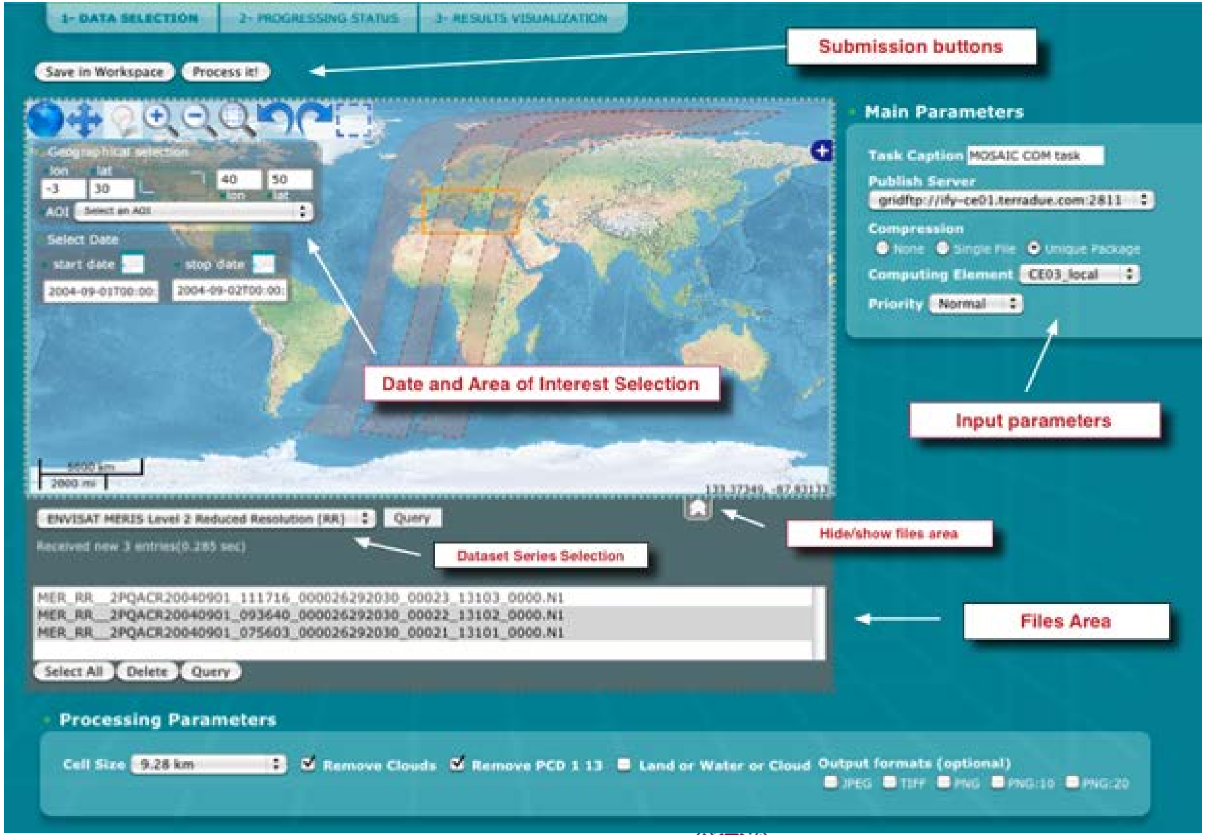
G-POD Web Portal

The G-POD web portal is a flexible, secure, generic and distributed web platform.

From the creation of a new task to the output/publication, passing through the data selection and the job monitoring, the user goes trough a friendly and intuitive user interface accessible from everywhere.

More info on the G-POD Web Portal are available here: http://wiki.services.eoportal.org/tiki-index.php?page=GPOD+User+Manual#Annex




1- DATA SELECTION
2- PROCESSING STATUS
3- RESULTS VISUALIZATION
Submission buttons
Save in Workspace
Process it!
Main Parameters
Task Caption
MOSAIC COM task
Publish Server
Compression
Computing Element
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Priority
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Date and Area of Interest Selection
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Files Area
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Land or Water or Cloud
Output formats (optional)

G-POD Services Portfolio

AARDVARC
aeromeris
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AMORGOS
Antarctica
ASARP
BEAMARITHM
BeamReproject
BIOMASAR-II
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GEOFIT

GlobTemperature
GMESCQC
GUT
Imager
INSAR
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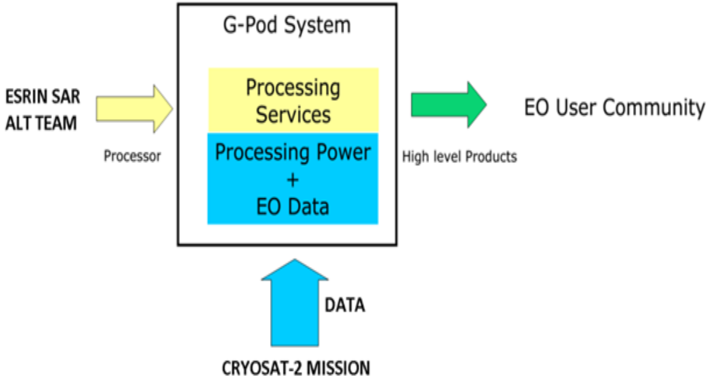
SARINvatore for CryoSat-2
SARvatore for Sentinel-3
SMOSL1
SMOSL2OS
SMOSL2SM
SOIL MAPPER
SSEGridFAPAR
VASD
vomit
WACMOS

The GPOD Processing Service

The ESA G-POD Service, SARvatore (**SAR** **V**ersatile **A**ltimetric **T**oolkit for **O**cean **R**esearch & **E**xploitation) for Sentinel-3 & CryoSat-2 is an Earth-Observation application that provides the capability to process remotely and on demand **Sentinel-3** SAR and **CryoSat-2** SAR/SARin data, from L1A (FBR) data products to SAR/SARin L2 geophysical data products.



Processor Prototype

- The service is based on the SAR Processor Prototype that was developed by the ESRIN R&D Altimetry Team for CryoSat-2 validation purposes and preparation for Sentinel-3 mission.

System features:

- SAR/SARin L1b Processor Prototype (Standard Delay-Doppler Processing).
- SAR/SARin L2 Retracker Prototype (with SAMOSA Analytical Model and LEVMAR Least Square Estimator).
- Input: CryoSat-2 SAR/SARIN FBR Data or Sentinel-3 L1A Data.
- Output L1b → Radar Echogram.
- Output L2 → SSH, SLA (W/O SSB), SWH, sigma0, wind speed.

Processor Prototype (2)

- ESRIN R&D ALT team compiled the processor's MATLAB source code into a 64-bit Linux binary and delivered to ESA G-POD team the executables, the input archive (FBR/L1A data) and satellite footprints (ASCII tracks). The toolkit has been fully integrated in the GPOD System for grid on-demand computing.

The objectives of the service integration in GPOD are:

- to experiment in-house research themes that will be further exploited in the ESA-funded R&D projects.
- to validate CryoSat-2 & Sentinel-3 and support the exploitation of the data.
- to provide scientists with the access to SAR/SARin processing to get acquainted with the novelties and specificities of SAR/SARin Altimetry and to build their own customized products.

DATA Catalogues in G-POD

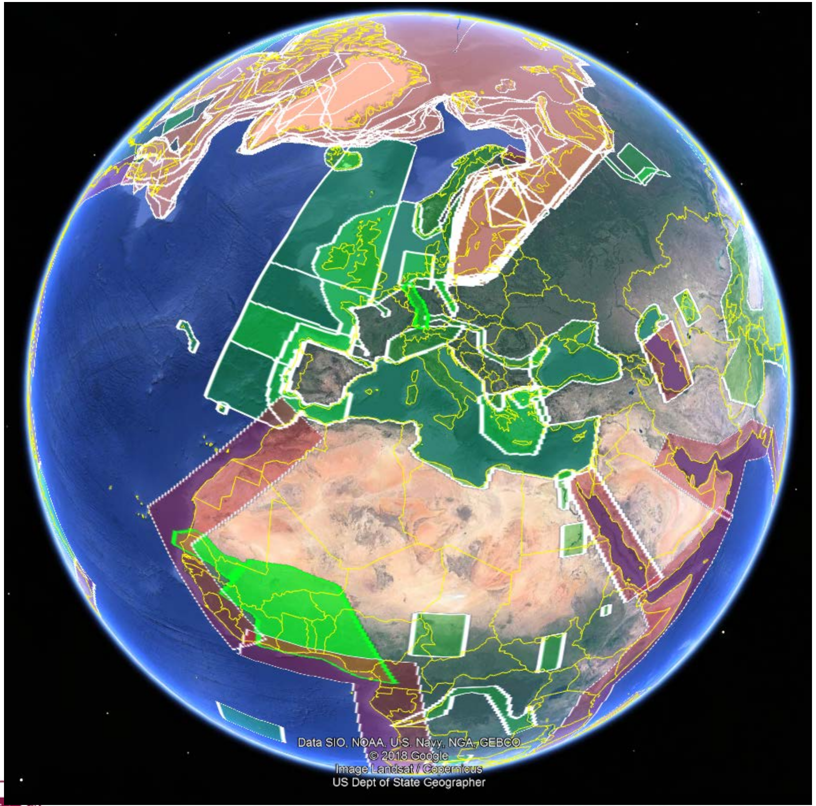
- The current GPOD service offers SAR (SARvatore) and SARin (SARinvatore) services to process **Cryosat-2** data.

- **439,184 SAR** passes and **367,592 SARin** passes have been stored in the service catalogue.

- An amount of **190.1 TB** of **CryoSat-2 FBR data** has been archived into the G-POD storage*****.

- Data obtained from the ESRIN R&D ALT Team (historical) and CryoSat-2 FTP servers (current).

*****Partial historical archive (<2012/05) were provided by NOAA/RADS and ESA/ESTEC.

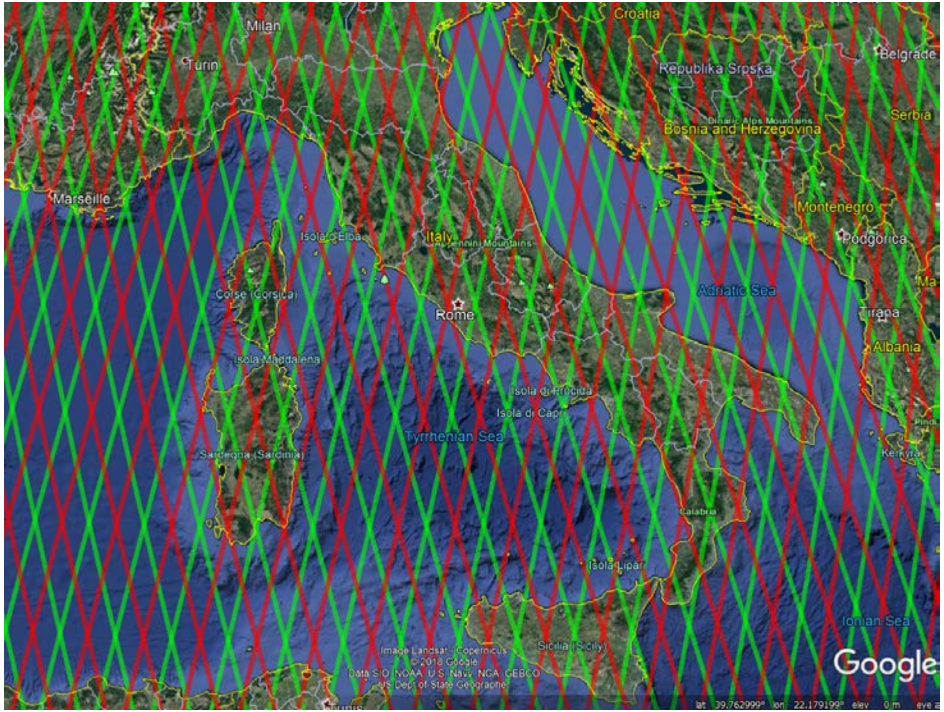


DATA Catalogues in G-POD (2)

- The current GPOD service also offers a SAR (SARvatore) service to process **Sentinel-3** data.

- **39,001 SAR** passes have been stored in the service catalogue.

- An amount of **82.4 TB** of **Sentinel-3 L1A data** have been archived into the G-POD storage.



SARvatore Usage Statistics

Users in last 4 years:

97 **SARvatore for CS-2** **94** **SARINvatore for CS-2** **52** **SARvatore for Sentinel-3**

375.280 CPU hours (that's **42.8** years);

190.1 TB of CryoSat-2 data storage & **82.4** TB of Sentinel-3 data storage.

Number of processing tasks submitted for SARvatore / SARINvatore for CryoSat-2 : **21393 / 3179**

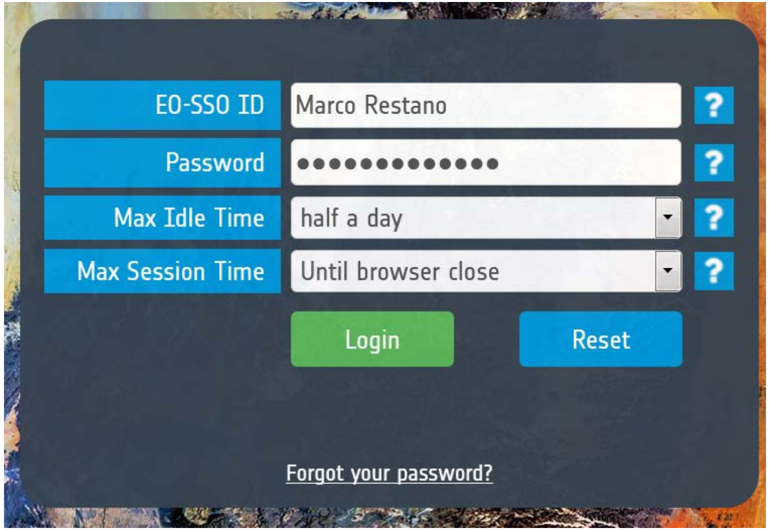
Number of processing tasks submitted for Sentinel-3: **11838**

Input processed by SARvatore / SARINvatore tasks: **106.7 TB / 28.8 TB**

Input processed by Sentinel-3 tasks: **182.5 TB**

Service Registration and Access

- The service is **open, free of charge** and **accessible online from everywhere**.
- In order to be granted the **access to the service**, you need to have an **EO-SSO** (Earth Observation Single Sign-On) **ID.**
- For the **EO-SSO registration**, go at https://earth.esa.int/web/guest/general-registration.
- Afterwards, you need to **send an e-mail** to the G-POD team (to eo-gpod@esa.int), requesting the activation of the SARvatore service for your EO-SSO user account.



Service Registration and Access (2)

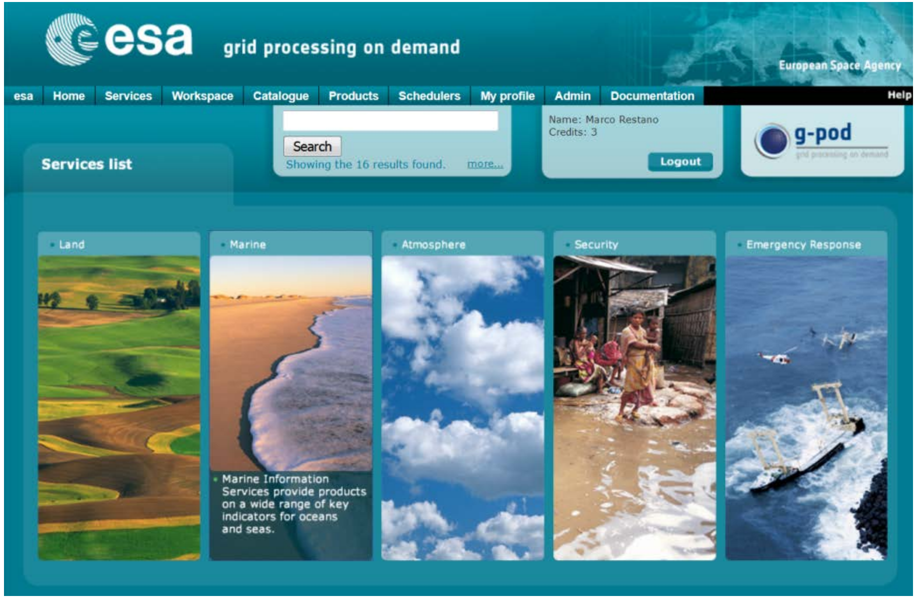
- After the registration to EO-SSO, users can freely access the services at:

https://gpod.eo.esa.int/services/CRYOSAT_SAR/

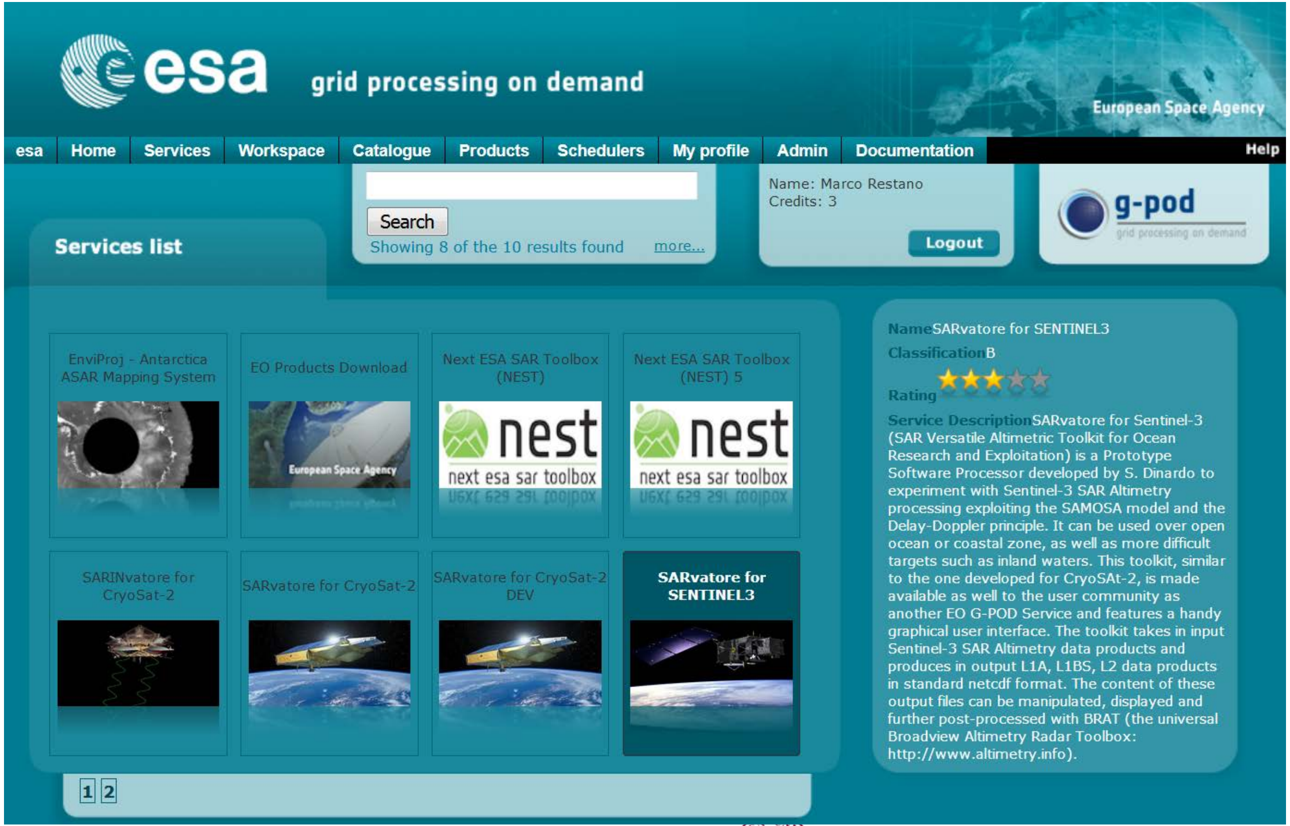
https://gpod.eo.esa.int/services/CRYOSAT_SARIN/

https://gpod.eo.esa.int/services/SENTINEL3_SAR

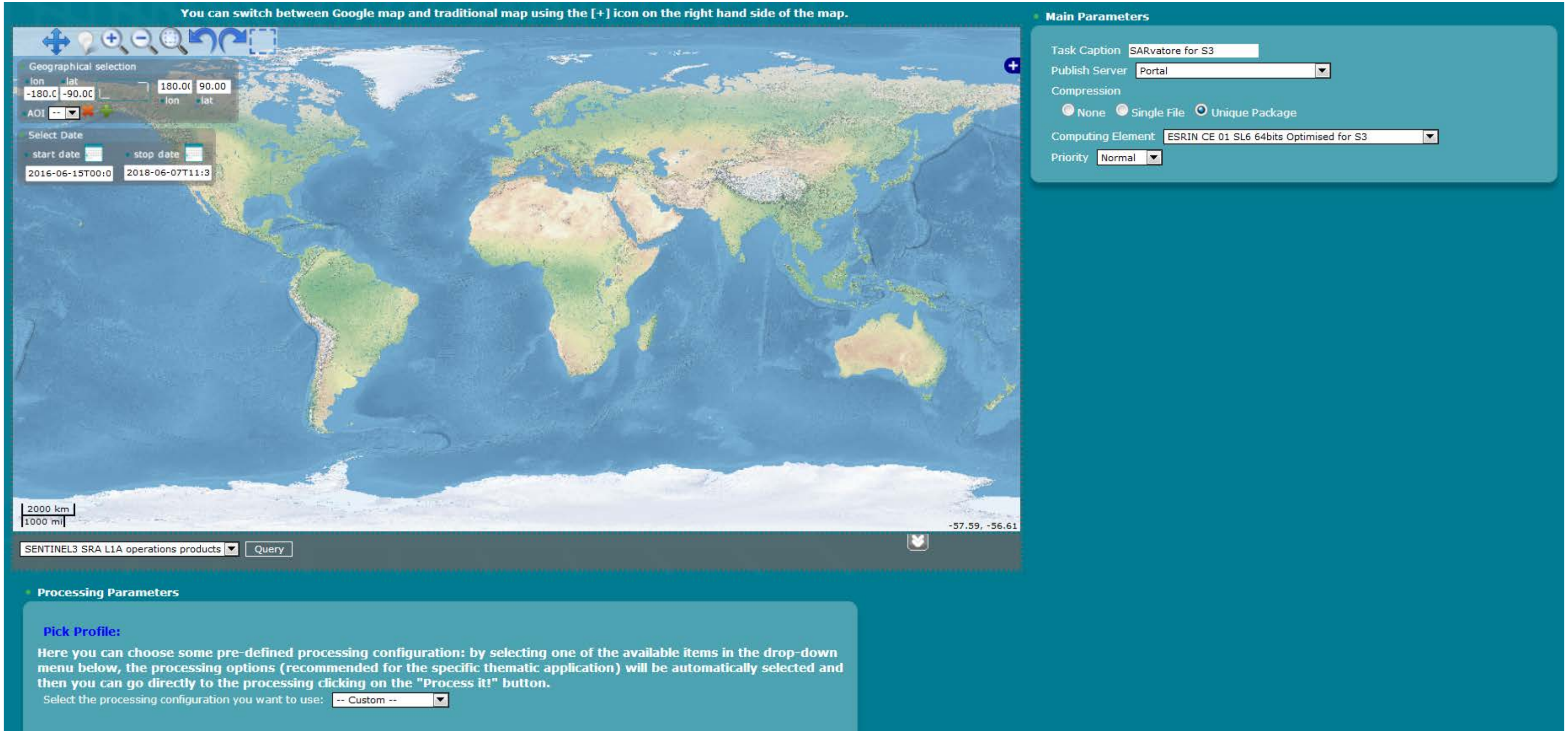
- These services are listed under the **Marine Theme** and can be found through the search bar.



The SARvatore Service for CryoSat-2 and Sentinel-3



esa
grid processing on demand
European Space Agency
esa
Home
Services
Workspace
Catalogue
Products
Schedulers
My profile
Admin
Documentation
Help
Search
Showing 8 of the 10 results found
more...
Name: Marco Restano
Credits: 3
Logout
g-pod
Services list
EnviProj - Antarctica ASAR Mapping System
EO Products Download
Next ESA SAR Toolbox (NEST)
Next ESA SAR Toolbox (NEST) 5
nest
next esa sar toolbox
SARINvatore for CryoSat-2
SARvatore for CryoSat-2
SARvatore for CryoSat-2 DEV
SARvatore for SENTINEL3
1 2
Name SARvatore for SENTINEL3
Classification B
Rating
Service Description SARvatore for Sentinel-3 (SAR Versatile Altimetric Toolkit for Ocean Research and Exploitation) is a Prototype Software Processor developed by S. Dinardo to experiment with Sentinel-3 SAR Altimetry processing exploiting the SAMOSA model and the Delay-Doppler principle. It can be used over open ocean or coastal zone, as well as more difficult targets such as inland waters. This toolkit, similar to the one developed for CryoSAt-2, is made available as well to the user community as another EO G-POD Service and features a handy graphical user interface. The toolkit takes in input Sentinel-3 SAR Altimetry data products and produces in output L1A, L1BS, L2 data products in standard netcdf format. The content of these output files can be manipulated, displayed and further post-processed with BRAT (the universal Broadview Altimetry Radar Toolbox: http://www.altimetry.info).

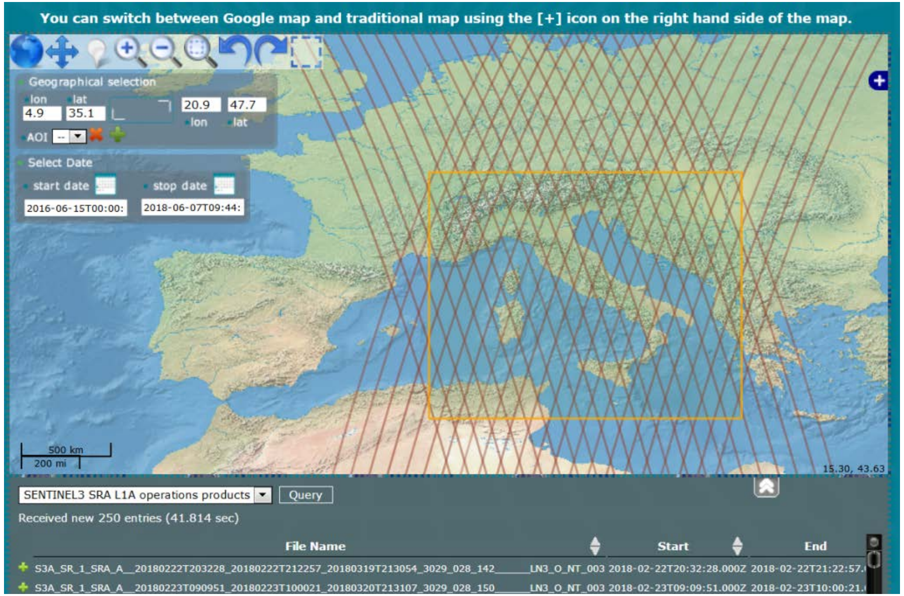


You can switch between Google map and traditional map using the [+] icon on the right hand side of the map.
Geographical selection
lon lat
-180.0 -90.00
180.00 90.00
lon lat
AOI --
Select Date
start date stop date
2016-06-15T00:0
2018-06-07T11:3
2000 km
1000 mi
-57.59, -56.61
SENTINEL3 SRA L1A operations products
Query
Main Parameters
Task Caption SARvatore for S3
Publish Server Portal
Compression
None Single File Unique Package
Computing Element ESRIN CE 01 SL6 64bits Optimised for S3
Priority Normal
Processing Parameters
Pick Profile:
Here you can choose some pre-defined processing configuration: by selecting one of the available items in the drop-down menu below, the processing options (recommended for the specific thematic application) will be automatically selected and then you can go directly to the processing clicking on the "Process it!" button.
Select the processing configuration you want to use: -- Custom --

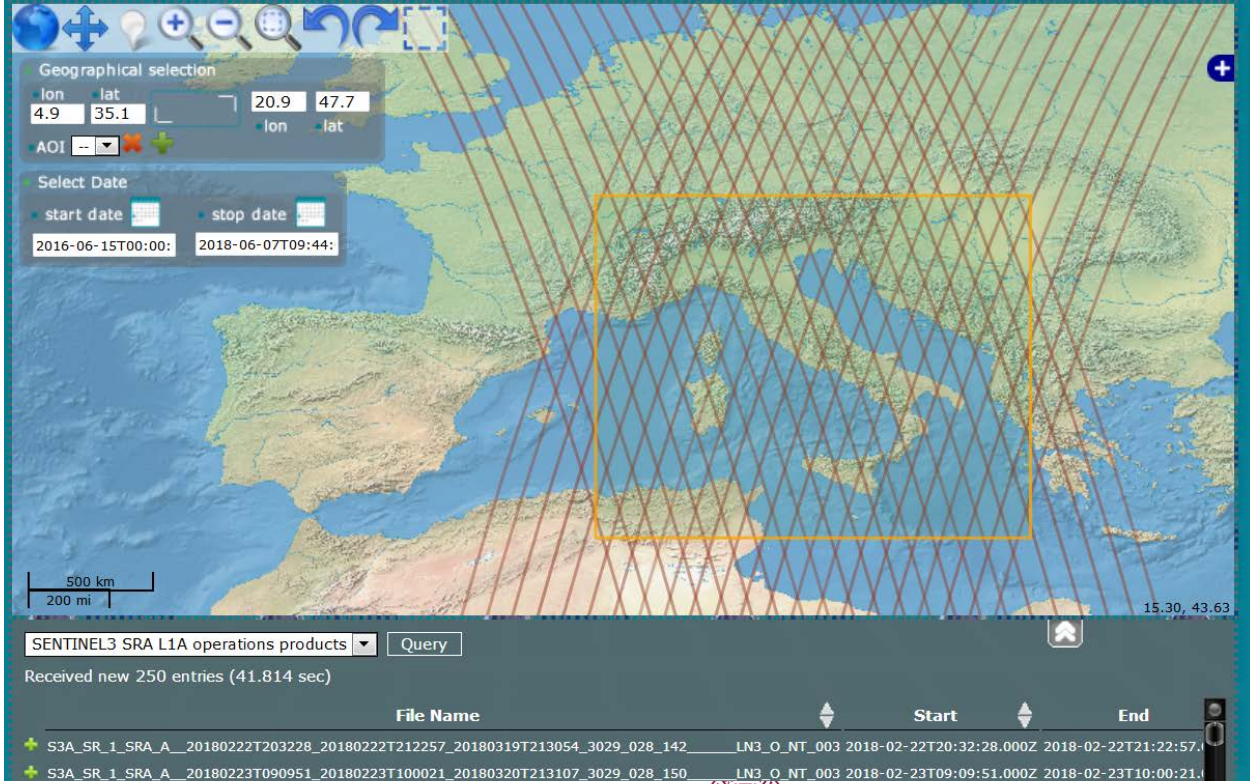
In the service page, the first action is to select the zone of interest (by either drawing a rectangle or typing coordinates) and the time of interest for the run (start–stop date).

By default, the start date is the launch date of CryoSat-2 and Sentinel-3, respectively.

The GUI embeds standard buttons for image browsing (panning, zoom-in zoom-out, centering, undo, redo, reset, etc.).



You can switch between Google map and traditional map using the [+] icon on the right hand side of the map.



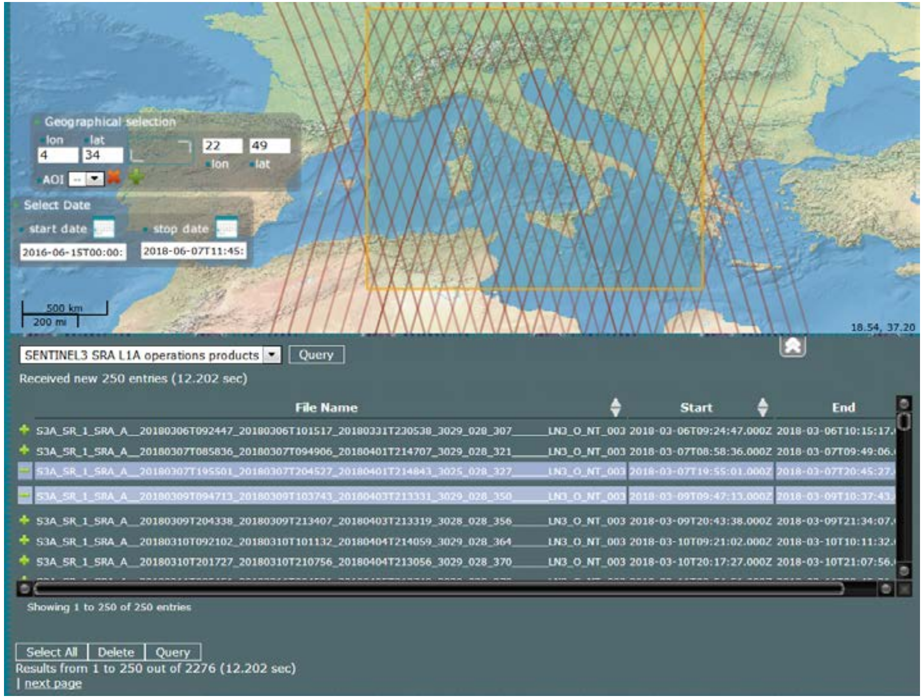
Data Selection

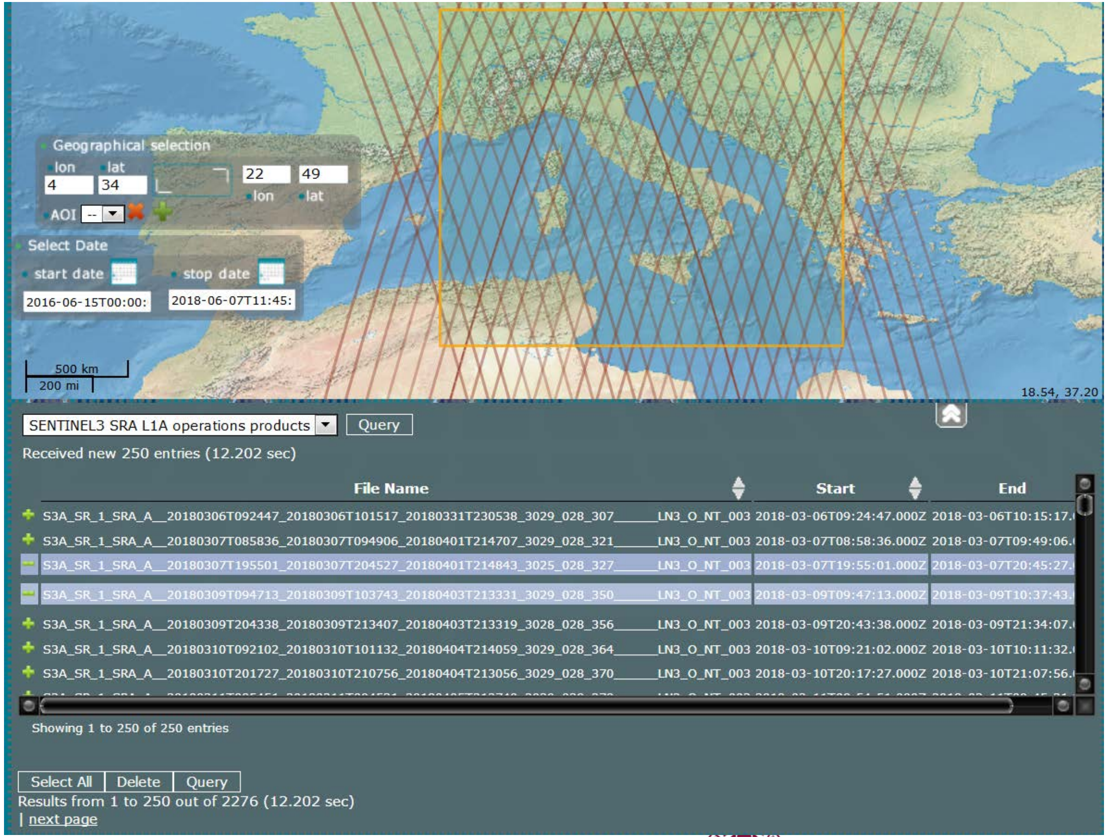
After the temporal/spatial selection, by clicking on the "**QUERY**" button, the service lists all passes matching the temporal/spatial requirements.

Sentinel-3 (or CryoSat-2) tracks, crossing the area of interest, are then overlaid on the world map.

The graphical interface lists up to 250 FBR products per page and informs users on the total number of passes found.

The user can select products by: clicking on specific passes. A 'Select All' option is available.



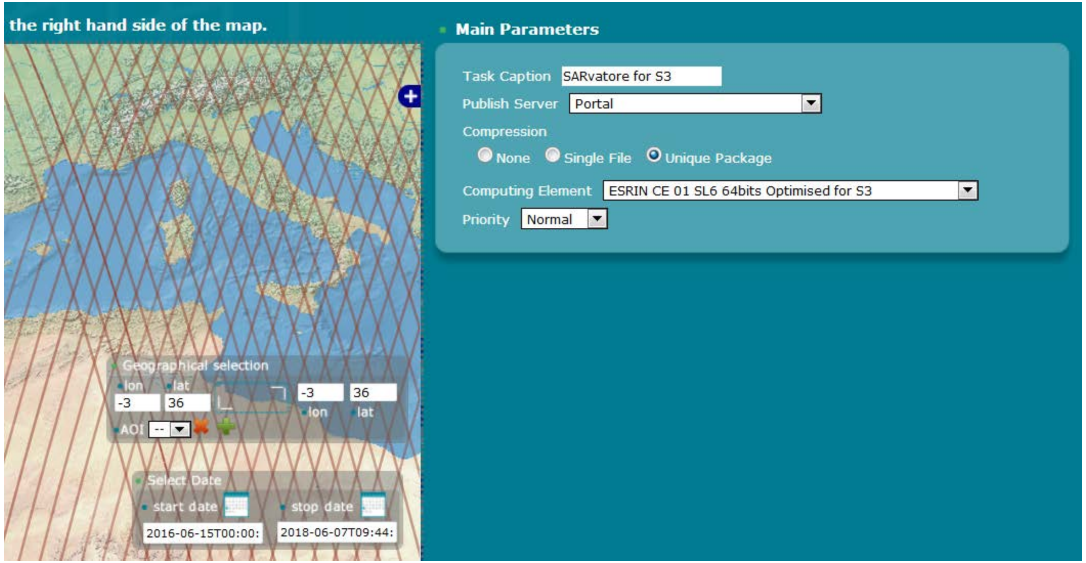


Geographical selection
lon
lat
4
34
22
49
lon
lat
AOI
Select Date
start date
stop date
2016-06-15T00:00:
2018-06-07T11:45:
500 km
200 mi
18.54, 37.20
SENTINEL3 SRA L1A operations products
Query
Received new 250 entries (12.202 sec)
File Name
Start
End
S3A_SR_1_SRA_A__20180306T092447_20180306T101517_20180331T230538_3029_028_307______LN3_O_NT_003 2018-03-06T09:24:47.000Z 2018-03-06T10:15:17.
S3A_SR_1_SRA_A__20180307T085836_20180307T094906_20180401T214707_3029_028_321______LN3_O_NT_003 2018-03-07T08:58:36.000Z 2018-03-07T09:49:06.
S3A_SR_1_SRA_A__20180307T195501_20180307T204527_20180401T214843_3025_028_327______LN3_O_NT_003 2018-03-07T19:55:01.000Z 2018-03-07T20:45:27.
S3A_SR_1_SRA_A__20180309T094713_20180309T103743_20180403T213331_3029_028_350______LN3_O_NT_003 2018-03-09T09:47:13.000Z 2018-03-09T10:37:43.
S3A_SR_1_SRA_A__20180309T204338_20180309T213407_20180403T213319_3028_028_356______LN3_O_NT_003 2018-03-09T20:43:38.000Z 2018-03-09T21:34:07.
S3A_SR_1_SRA_A__20180310T092102_20180310T101132_20180404T214059_3029_028_364______LN3_O_NT_003 2018-03-10T09:21:02.000Z 2018-03-10T10:11:32.
S3A_SR_1_SRA_A__20180310T201727_20180310T210756_20180404T213056_3029_028_370______LN3_O_NT_003 2018-03-10T20:17:27.000Z 2018-03-10T21:07:56.
Showing 1 to 250 of 250 entries
Select All
Delete
Query
Results from 1 to 250 out of 2276 (12.202 sec)
| next page

Session Main Parameters Panel

On the top right, a main parameters panel allows users to set the:

- Name of the current task.
- FTP Server to publish results (portal or personal).
- Data compression format (.tgz, none).
- Grid Computing Resources.
- Task Priority.



List of Processing Options

The last step, before the task submission, is to set the list of processing options.

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

In the G-POD interface, users can easily set processing options via a series of drop-down menus.

The configurable options are divided according to the processing level they refer to (L1b and L2).

Processing Parameters

Pick Profile:

Here you can choose some pre-defined processing configuration: by selecting one of the available items in the drop-down menu below, the processing options (recommended for the specific thematic application) will be automatically selected and then you can go directly to the processing clicking on the "Process it!" button.

Select the processing configuration you want to use: [-- Custom --]

Here you find a list of processing options that you can select according to the processing level

For a wiki user manual of the service, go here: wiki

For a hands-on presentation, go here: slides

L1B Processor:

- Select the data type NT/ST you want to process

Flag to process only ST (Short Time Critical) or only NT (Non Time Critical) or both data types [only NT]

- Data Posting Rate

Flag to set the data posting rate: 20 Hz (canonic posting rate) or 80 Hz (finer posting rate) [20 Hz]

- Hamming Weighting Window

Flag to set the application of the Hamming Weighting Window on the burst data (section 4.4 in REF1) [Apply only in coasta]

- Exact Beam-Forming

Flag to set the application of exact or approximated Doppler Beam Steering (section 4.4 in REF1) [Approximated]

- FFT Zero-Padding

Flag to operate the Zero-Padding prior to the range FFT (section 4.8 in REF1). Zero-Padding is indicated for coastal zone analysis [Yes, apply Zero-Pad]

- Radar Receiving Window Size

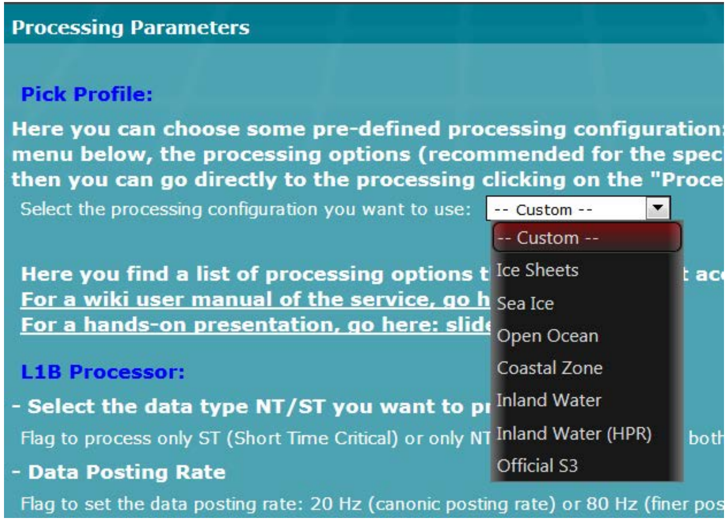
Flag to select the size of the radar receiving window: 128 range bins (standard) or 256 range bins (extended). Extended window is indicated for coastal zone analysis [128 range bins]

- Antenna Pattern Compensation

Flag to activate the antenna pattern compensation on the Stack Data [No]

- Dump SAR Stack Data in output

Flag to dump the SAR Stack Data in the output package. Be aware that SAR Stack Data are bulky data products (around 1 GB for single pass); do not process them massively but limit yourself at around 10/20 passes at the time [No]



L2 Processor:

- Restrict the re-tracking on specific surfaces

Flag to limit the processing on open sea or on water (open sea, coastal zone and inland water) or to process the full pass

Process only water

- PTR width alphap parameter

Use a LUT (Look-Up Table) or a constant for PTR (Point Tartet Response) alphap parameter

LUT

- SAMOSA Model Generation

Flag to select the generation of the SAMOSA model to use in the re-tracking. SAMOSA3 is a truncated version (only zero order term) of SAMOSA2 (REF2), SAMOSA+ is the SAMOSA2 model tailored for inland water, sea ice and coastal zone domain

Use SAMOSA2

- Dump RIP in output

Flag to append Range Integrated Power (RIP) in the output netCDF data product

No

- Dump SAR Echo Waveforms in output

Flag to append the SAR Echo Waveforms in the output netCDF data product

No

- Single-look or Multi-look Model

Flag to set the application of the Model Multilooking (Single-Look or Multi-Look). Single-Look option is indicated for quick look operations while Multi-Look is the most accurate

Multi-look

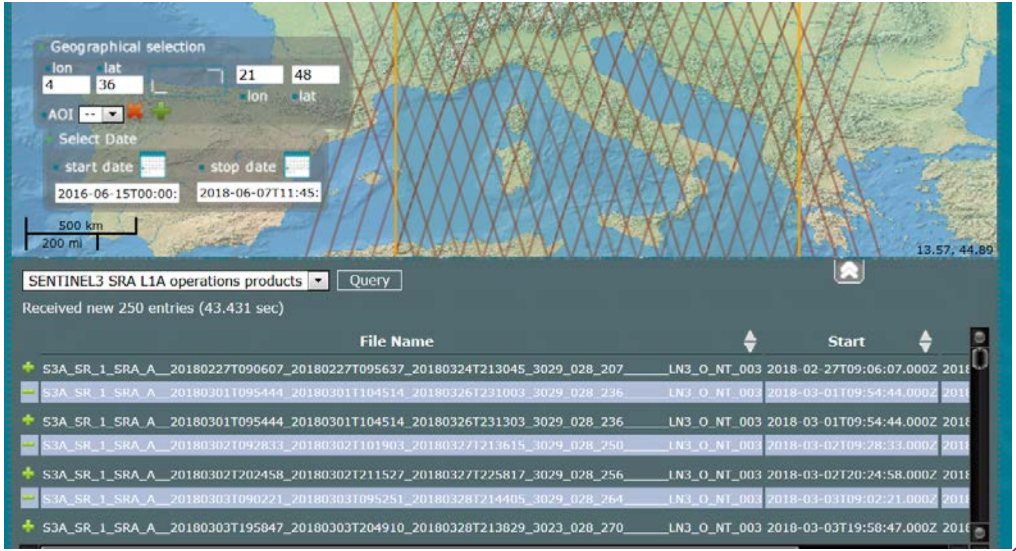
REF1: Guidelines for the SAR (Delay-Doppler) L1b Processing
REF2: SAR Altimeter Backscattered Waveform Model (SAMOSA Model Paper), IEEE-TGARSS, Geoscience and Remote Sensing, IEEE Transactions on (Volume:53, Issue: 2)

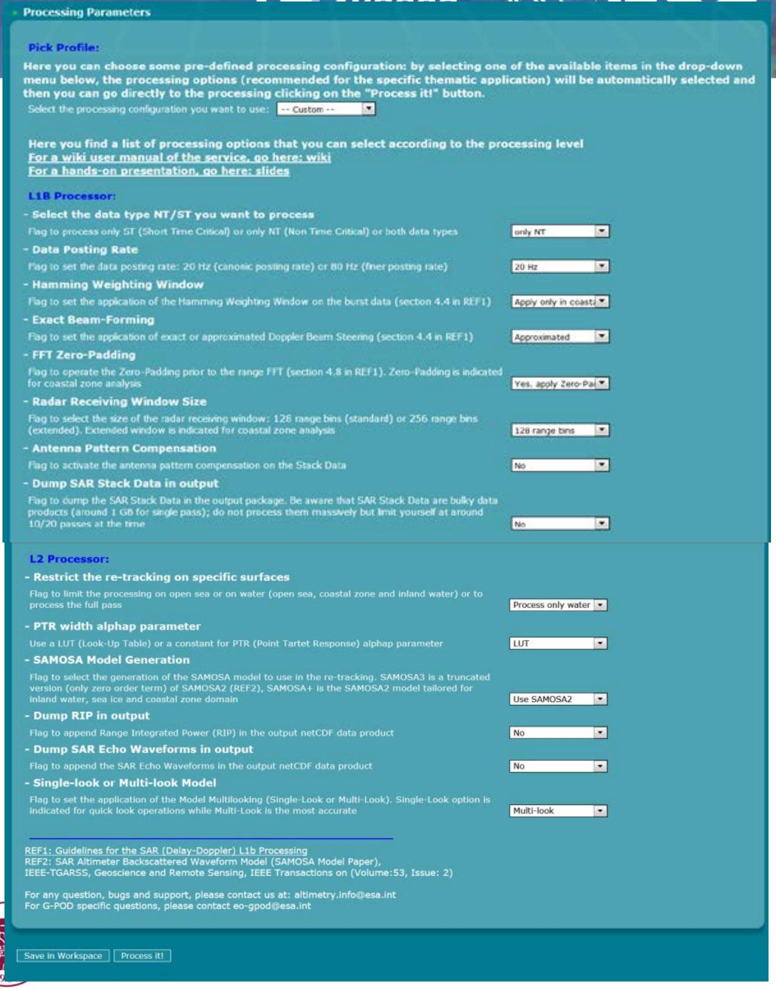
For any question, bugs and support, please contact us at: altimetry.info@esa.int
For G-POD specific questions, please contact eo-gpod@esa.int

Save in Workspace | Process it!

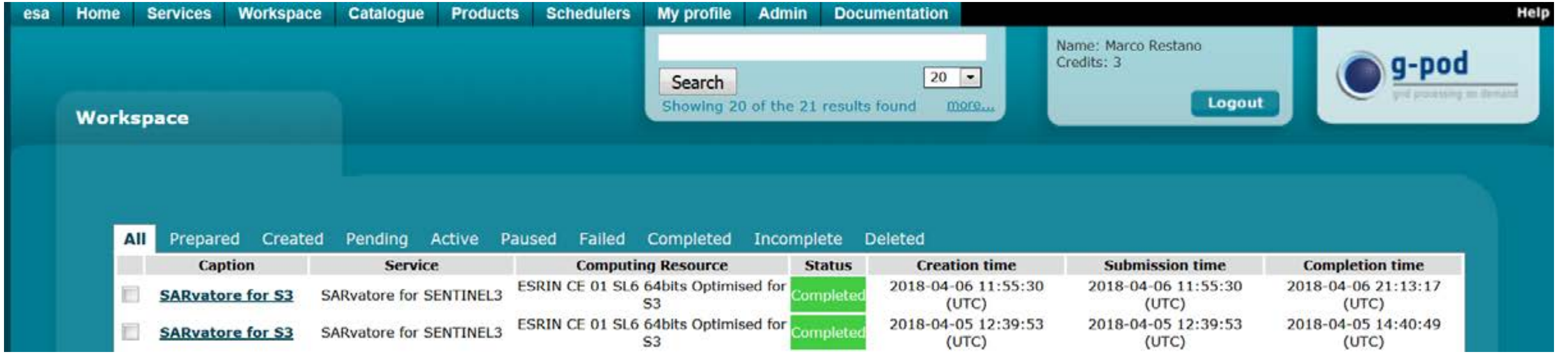
Task Submission

Once the user has operated the selection of the tracks & processing options, the user has to click on the “PROCESS IT” button to submit the task to G-POD Computing Elements.





Task Viewer / Workspace

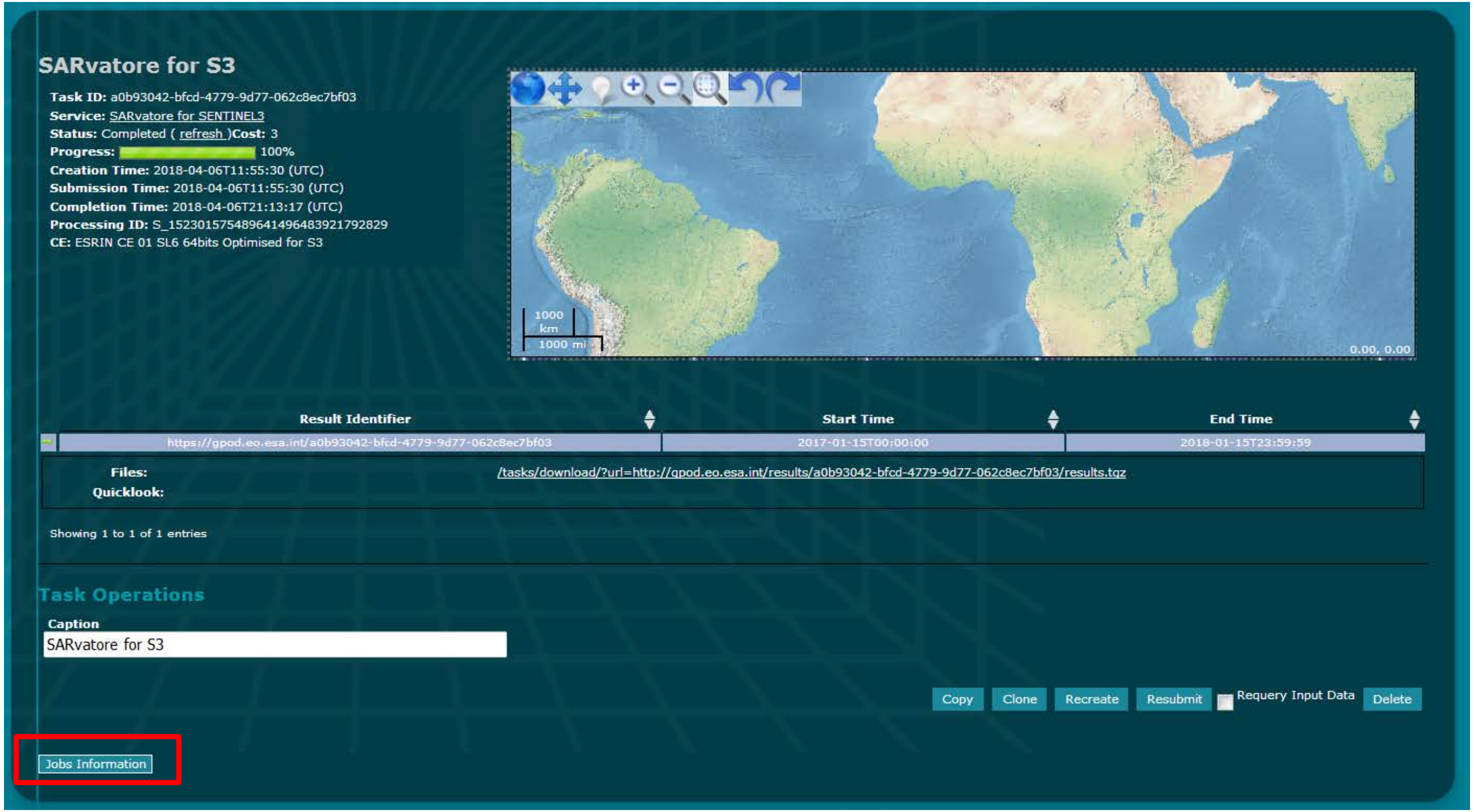


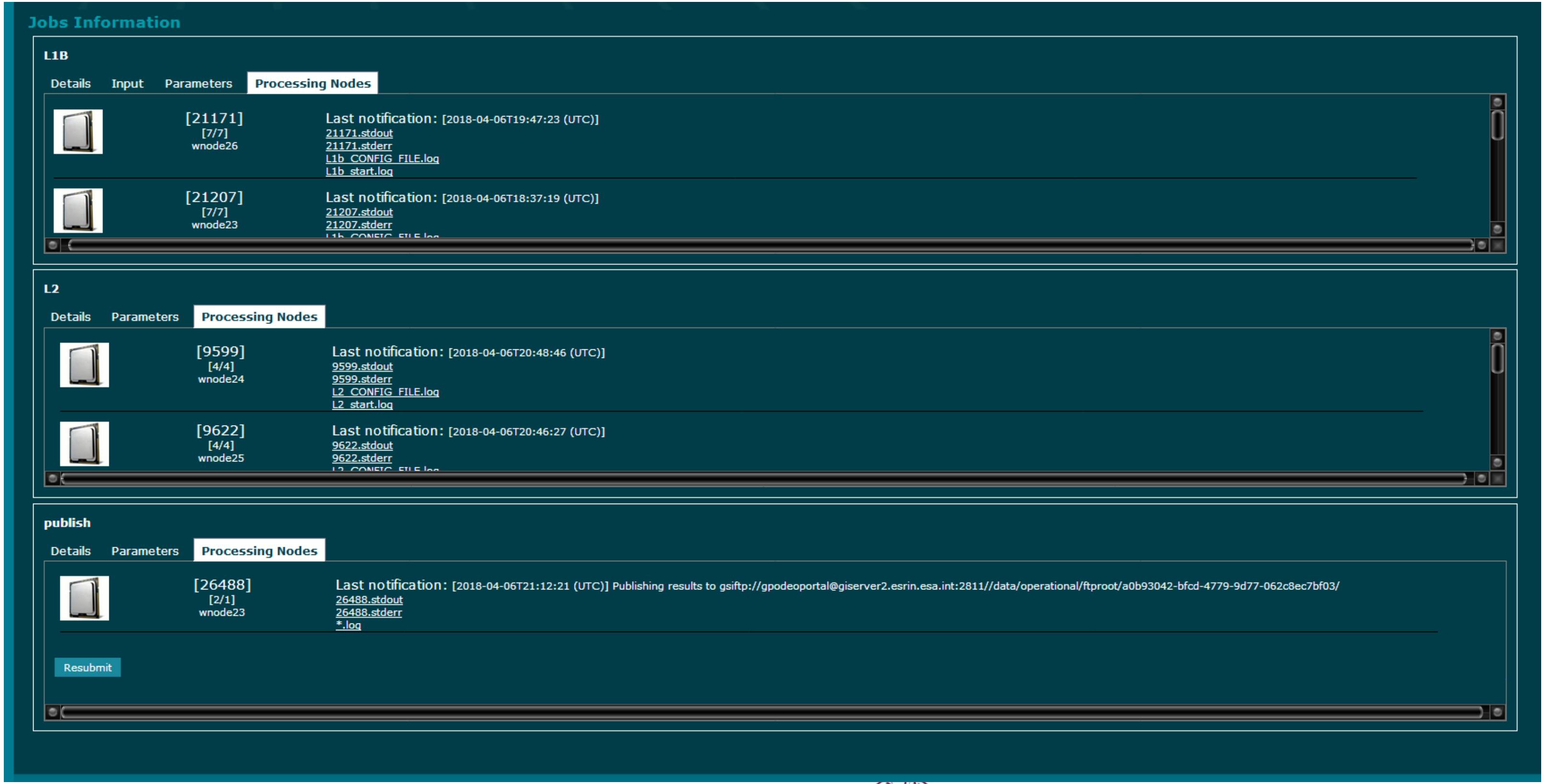
After the submission of the job, users are directed to the workspace page where they can **check in real time the status of the run**. The color code is:

Orange → run under processing
Green → run completed
Red → run failed

Further, **clicking on the task**, the user can have more information on the processing task:

- Task Id — Processing Id — Grid Working Node Id
- Task Progress (data retrieving, data processing, data publishing) — Task Creation Time

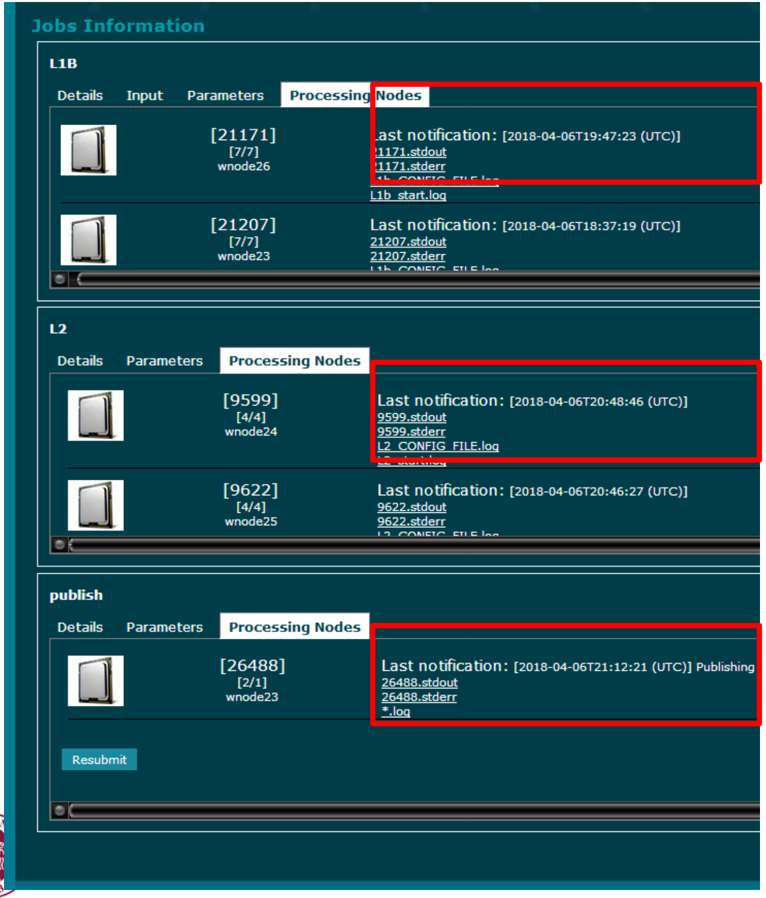

SARvatore for S3
Task ID: a0b93042-bfcd-4779-9d77-062c8ec7bf03
Service: SARvatore for SENTINEL3
Status: Completed (refresh)Cost: 3
Progress: 100%
Creation Time: 2018-04-06T11:55:30 (UTC)
Submission Time: 2018-04-06T11:55:30 (UTC)
Completion Time: 2018-04-06T21:13:17 (UTC)
Processing ID: S_1523015754896414964839217928 29
CE: ESRIN CE 01 SL6 64bits Optimised for S3
1000 km
1000 mi
0.00, 0.00
Result Identifier
Start Time
End Time
https://gpod.eo.esa.int/a0b93042-bfcd-4779-9d77-062c8ec7bf03
2017-01-15T00:00:00
2018-01-15T23:59:59
Files:
/tasks/download/?url=http://gpod.eo.esa.int/results/a0b93042-bfcd-4779-9d77-062c8ec7bf03/results.tgz
Quicklook:
Showing 1 to 1 of 1 entries
Task Operations
Caption
SARvatore for S3
Copy
Clone
Recreate
Resubmit
Requery Input Data
Delete
Jobs Information


Jobs Information
L1B
Details Input Parameters Processing Nodes
[21171]
[7/7]
wnode26
Last notification: [2018-04-06T19:47:23 (UTC)]
21171.stdout
21171.stderr
L1b_CONFIG_FILE.log
L1b_start.log
[21207]
[7/7]
wnode23
Last notification: [2018-04-06T18:37:19 (UTC)]
21207.stdout
21207.stderr
L2
Details Parameters Processing Nodes
[9599]
[4/4]
wnode24
Last notification: [2018-04-06T20:48:46 (UTC)]
9599.stdout
9599.stderr
L2_CONFIG_FILE.log
L2_start.log
[9622]
[4/4]
wnode25
Last notification: [2018-04-06T20:46:27 (UTC)]
9622.stdout
9622.stderr
publish
Details Parameters Processing Nodes
[26488]
[2/1]
wnode23
Last notification: [2018-04-06T21:12:21 (UTC)] Publishing results to gsiftp://gpodeoportal@giserver2.esrin.esa.int:2811//data/operational/ftproot/a0b93042-bfcd-4779-9d77-062c8ec7bf03/
26488.stdout
26488.stderr
*.log
Resubmit

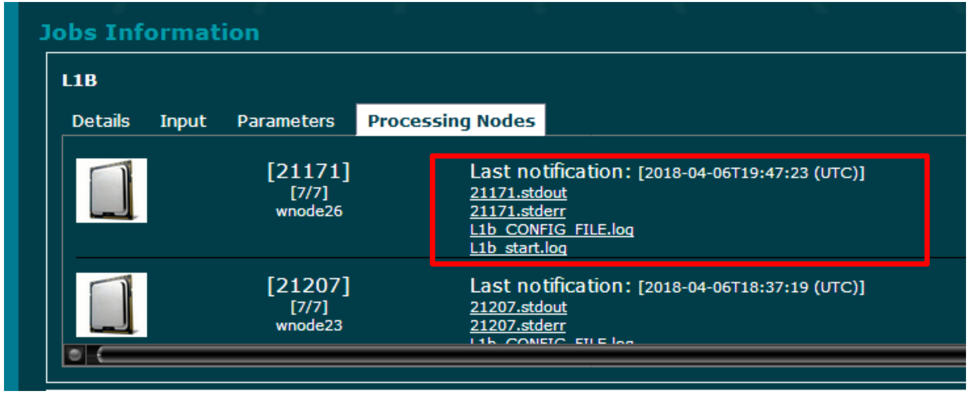
Task Viewer / Workspace

After run completion, clicking on the button "Jobs Information", the user can inspect:

- The GPOD **log file** (.stdout or .stderr) where **eventual errors on data retrieving or data storing** are reported.
- The prototype **configuration file** (L1b_CONFIG_FILE.log and L2_CONFIG_FILE.log) where all the **processing options** are reported.
- The prototype **log files** (L1b_start.log and L2_start.log) where **eventual prototype processing errors** are reported.
- Users can also decide to **change one or more processing options** and then **re-submit the task**.



Example of Config File (L1b)

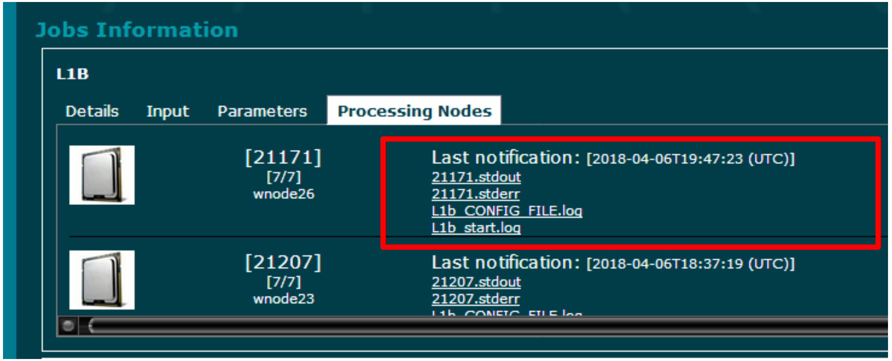



```
#################### SARvatore L1b PROCESSOR PROTOTYPE CONFIGURATION FILE ##############################

####################          SYSTEM PATHS          ##############################

DATA_FOLDER=/gpfs/gpfs01/RDIR/S_14126896661282889214708256 5778/SARvatore/20624/L1b_WDIR/

AUX_FOLDER=/gpfs/gpfs01/RDIR/AUX_DATA/

############################################################################################

####################          CONFIGURATION FLAGS          ##############################

Weight_Flag=D
Beam_Forming_EXACT=N
Mean_Profile=N
Save_Stack=N
Gridding_Flag=LR
Extended_Window=Y
Zero_Padding_Flag=Y
############################################################################################

####################          GEOGRAPHICAL SUBSETTING          ##############################

NORTH_LAT=-3
SOUTH_LAT=-13
EAST_LON=-32
WEST_LON=-38

############################################################################################
```

You don't need to care about it

(if everything goes ok)

Example of Log File (L1b)



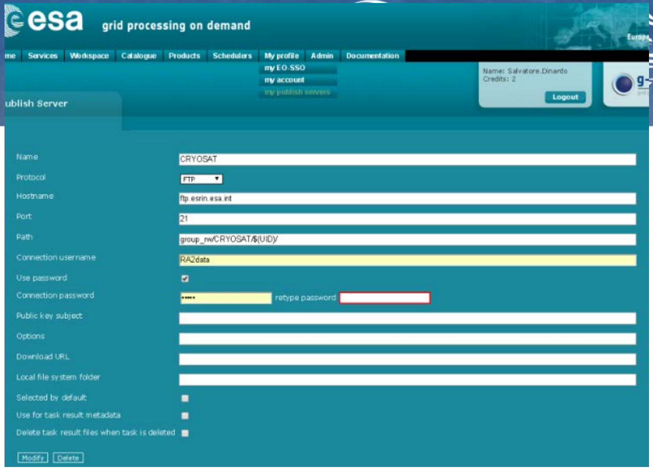
You don't need to care about it
(if everything goes ok)

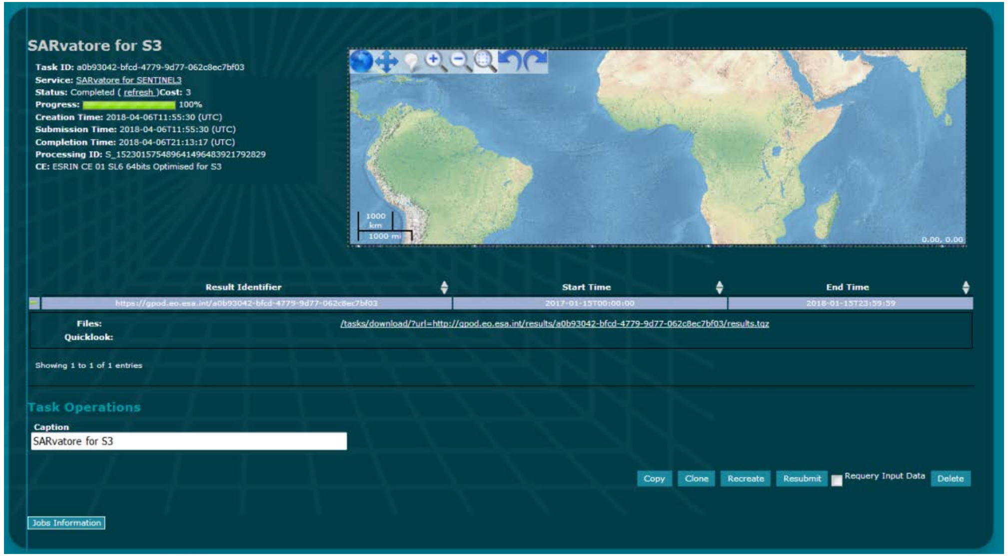
```
##########################################################################################
SARvatore Processor Prototype
SAR Versatile Altimetry Toolkit for OLIW (Ocean-Land-Inland Water) Research and Exploitation

Current Run: CryoSat-2 SAR Mode L1b Processor
Current Version: 1.52

##########################################################################################

Found 3 Passes to Process

----------------------------------------------------

Processing the Pass: CS_OFFL_SIR1SAR_FR_20140619T042952_20140619T043016_B001.DBL

Pass with 537 Records to Process

BLOCK START: 1 --> 200
Scenario Recovery: 1 --> 200
Gain and Calibration Correction: 1 --> 200
Beam Pointing: 1 --> 200
Beam Forming (Approximated): 1 --> 200
Beam Stacking: 1 --> 200
Scenario Recovery: 1 --> 200
Alignment and Range Compression: 1 --> 200
Elapsed time is 35.847286 seconds.
BLOCK END: 1 --> 200

BLOCK START: 201 --> 400
Scenario Recovery: 201 --> 400
Gain and Calibration Correction: 201 --> 400
Beam Pointing: 201 --> 400
Beam Forming (Approximated): 201 --> 400
Beam Stacking: 201 --> 400
Scenario Recovery: 201 --> 400
Alignment and Range Compression: 201 --> 400
Elapsed time is 27.736071 seconds.
BLOCK END: 201 --> 400

BLOCK START: 401 --> 537
Scenario Recovery: 401 --> 537
Gain and Calibration Correction: 401 --> 537
Beam Pointing: 401 --> 537
Beam Forming (Approximated): 401 --> 537
Beam Stacking: 401 --> 537
Scenario Recovery: 401 --> 537
Alignment and Range Compression: 401 --> 537
Extrapolation going on with more than 4 samples
Extrapolation going on with more than 4 samples
Extrapolation going on with more than 4 samples
Extrapolation going on with more than 4 samples
Extrapolation going on with more than 4 samples
Extrapolation going on with more than 4 samples
Elapsed time is 14.332029 seconds.
BLOCK END: 401 --> 537

Generating Output in kml, png and mat format

Output Generated -> Moving to Next Pass ...

Completed L1b Processing for the Pass: CS_OFFL_SIR1SAR_FR_20140619T042952_20140619T043016_B001.DBL

----------------------------------------------------

Processing the Pass: CS_OFFL_SIR1SAR_FR_20140619T042952_20140619T043016_B001.HDR

No CryoSat-2 L1b File for: CS_OFFL_SIR1SAR_FR_20140619T042952_20140619T043016_B001.HDR -> File Skipped

----------------------------------------------------

Processing the Pass: CS_OFFL_SIR1SAR_FR_20140619T042952_20140619T043016_B001.TGZ
```

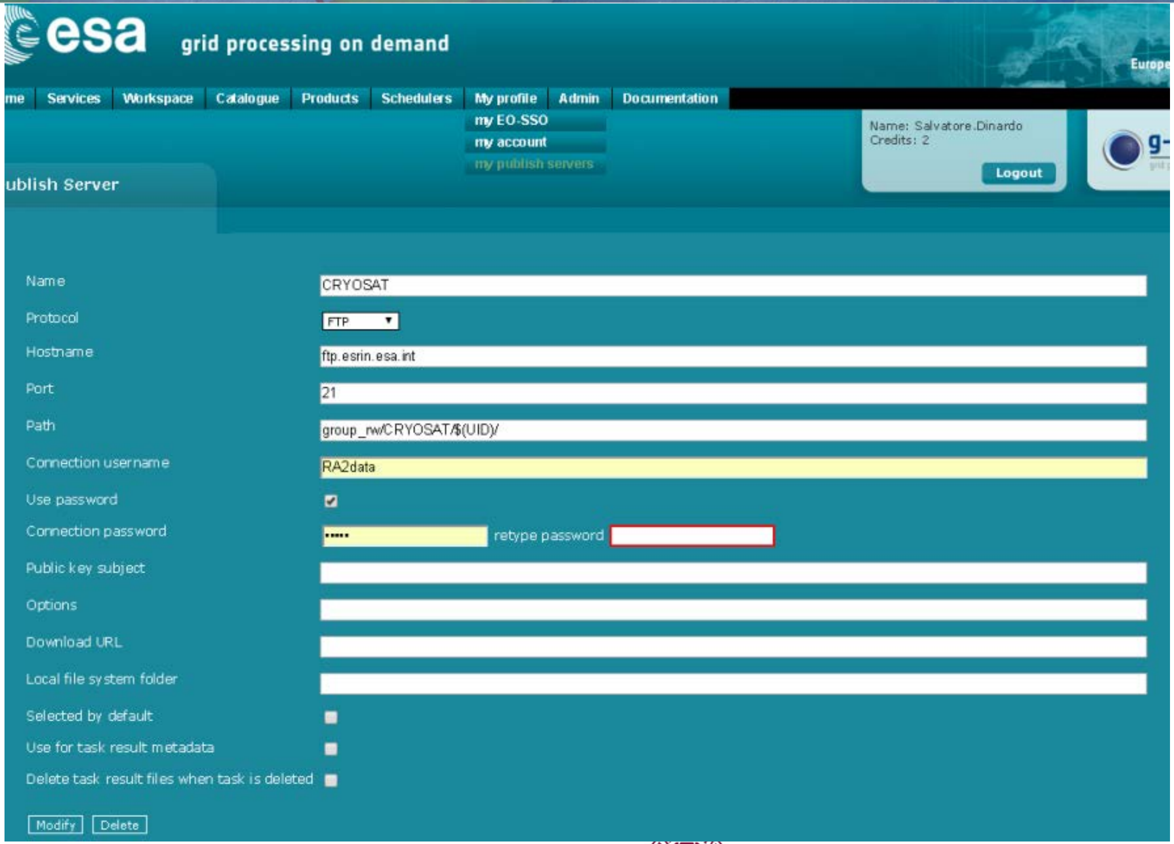
Output Package Publishing

- In case of successful run completion (green status), the portal will provide the user with a http link from where to download the output package on own local drive.

- The user can order to post the package directly on his **own personal ftp server** once the ftp server credentials have been inserted (through my “publish servers” sub-menu).This is the recommended option






esa grid processing on demand
me
Services
Workspace
Catalogue
Products
Schedulers
My profile
Admin
Documentation
my EO-SSO
my account
my publish servers
Name: Salvatore.Dinardo
Credits: 2
Logout
ublish Server
Name
CRYOSAT
Protocol
FTP
Hostname
ftp.esrin.esa.int
Port
21
Path
group_rw/CRYOSAT/$(UID)/
Connection username
RA2data
Use password
Connection password
retype password
Public key subject
Options
Download URL
Local file system folder
Selected by default
Use for task result metadata
Delete task result files when task is deleted
Modify
Delete

SARvatore for S3

Task ID: a0b93042-bfcd-4779-9d77-062c8ec7bf03
Service: SARvatore for SENTINEL3
Status: Completed (refresh)**Cost:** 3
Progress: 100%
Creation Time: 2018-04-06T11:55:30 (UTC)
Submission Time: 2018-04-06T11:55:30 (UTC)
Completion Time: 2018-04-06T21:13:17 (UTC)
Processing ID: S_152301575489641496483921792829
CE: ESRIN CE 01 SL6 64bits Optimised for S3

Result Identifier	Start Time	End Time
https://gpod.eo.esa.int/a0b93042-bfcd-4779-9d77-...		...18-01-15T23:59:59

Files: /tasks/download/?url=http://gpod.eo.esa.int/results/a0b93042-bfcd-4779-9d77-062c8ec7bf03/results.tgz
Quicklook:

Showing 1 to 1 of 1 entries

Task Operations

Caption

SARvatore for S3

Copy | Clone | Recreate | Resubmit | Requery Input Data | Delete

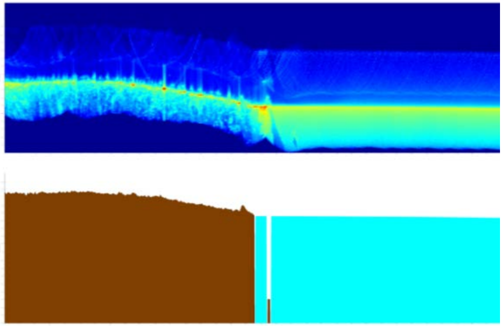
Jobs Information

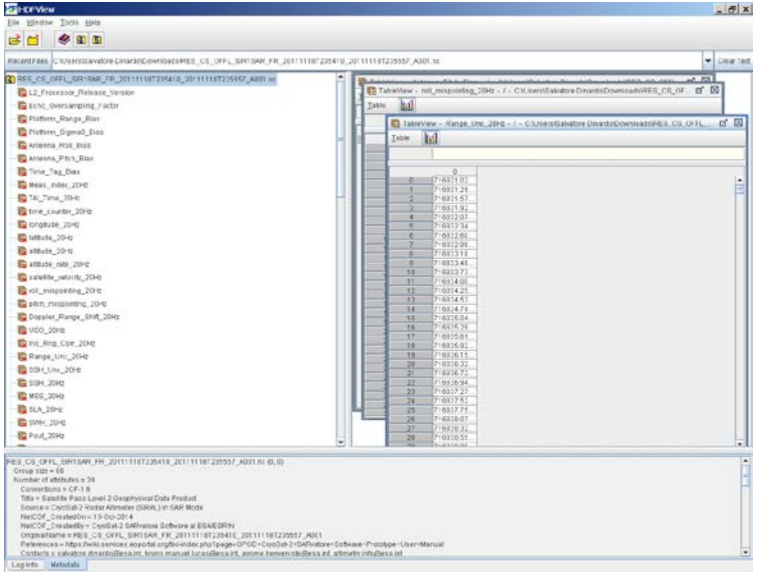
Output Package Content

The output package consists of :

- Pass Ground-Track in .kml format.
- Radar Echogram Picture in PNG format.
- L2 data product in NetCDF format with all the scientific results.

The NetCDF format is self-explanatory with all the data field significance described in the attributes.





OFF LINE GPOD Processing

For massive processing (years of data in large area of interest), it is recommended to request an off line processing: the GPOD team is available to process the data for you in an off line configuration and post the output L2 data in a personal ftp repository.

To request an order of processing, please write your order description (time of interest, region of interest, processing baseline) at:

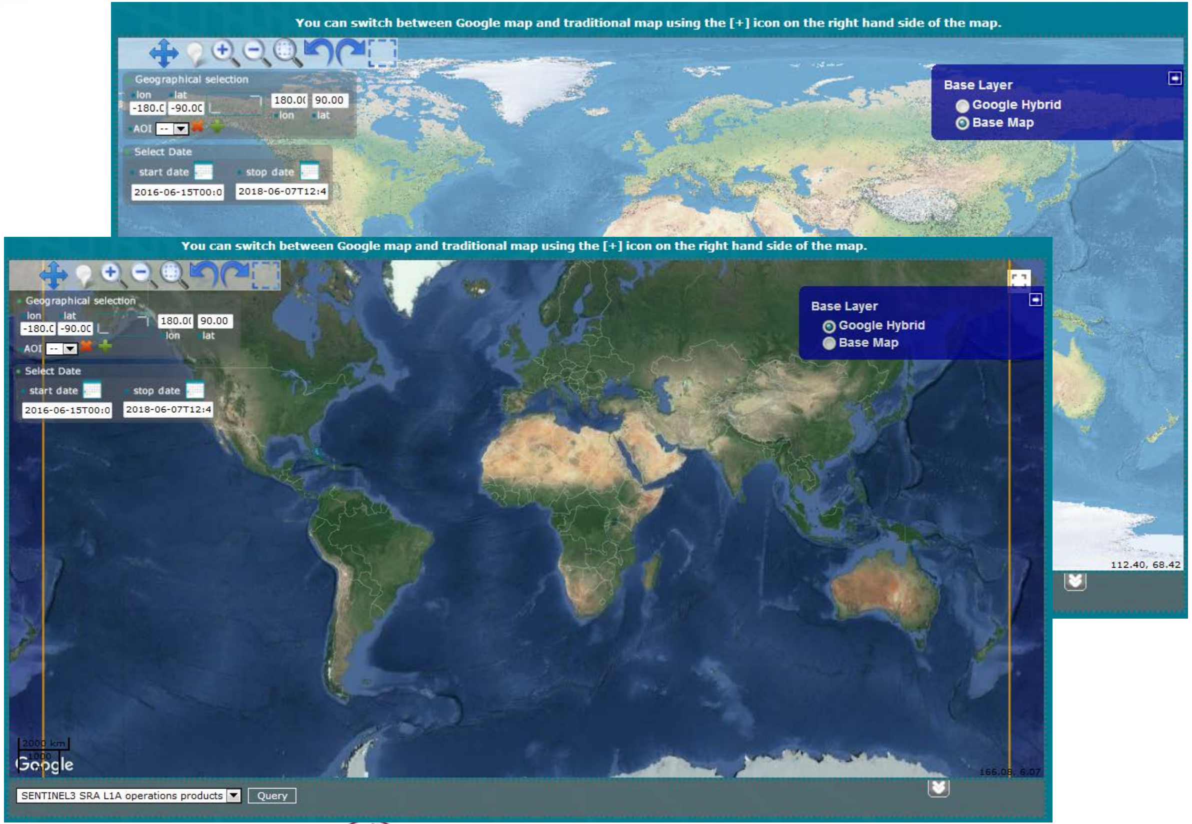
eo-gpod@esa.int **altimetry.info@esa.int**

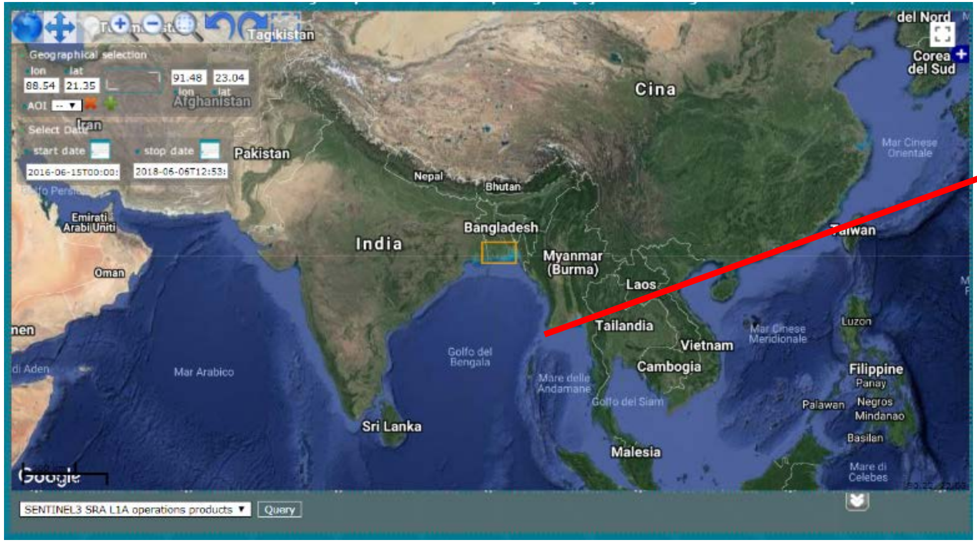
Recent & Future Updates

Google Earth Map Layer

- New Map Layer (Google Earth Map) to support coastal and inland water communities.

- Use the Base Layer menu to switch between the Google Hybrid and the Base Map layer.




Geographical selection
lon
lat
88.54
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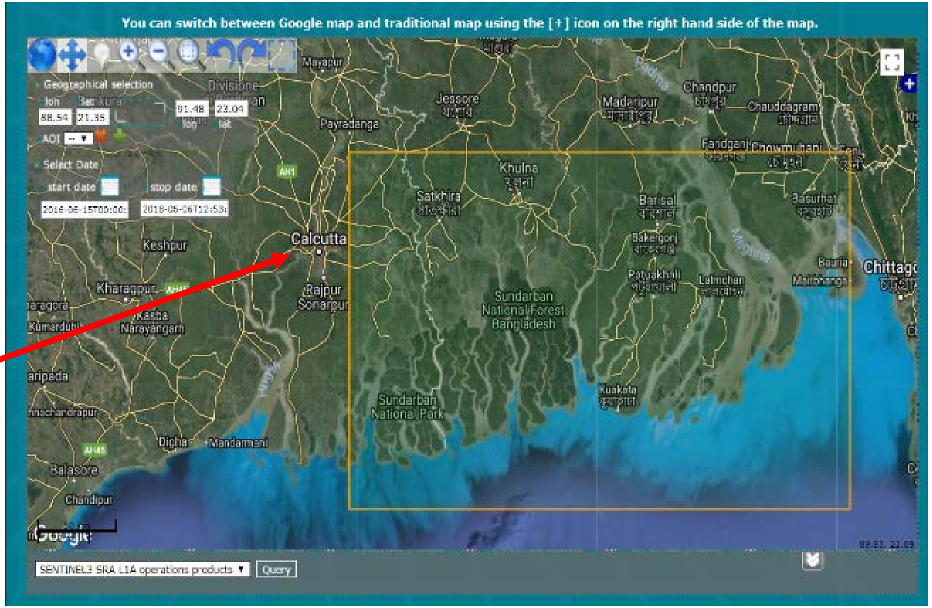
91.48
23.04
AOI
Select Date
start date
stop date
2016-06-15T00:00:
2018-06-06T12:53:
Cina
India
Bangladesh
Pakistan
Nepal
Bhutan
Myanmar (Burma)
Laos
Tailandia
Vietnam
Cambogia
Filippine
Malesia
Sri Lanka
Oman
Mar Arabico
Golfo del Bengala
SENTINEL3 SRA L1A operations products
Query


You can switch between Google map and traditional map using the [+] icon on the right hand side of the map.
Geographical selection
88.54
21.35
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AOI
Select Date
start date
stop date
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2018-06-06T12:53:
Calcutta
Khulna
Barisal
Jessore
Satkhira
Keshpur
Kharagpur
Rajpur Sonarpur
Sundarban National Forest Bangladesh
Sundarban National Park
Chandpur
Chittagong
SENTINEL3 SRA L1A operations products
Query

New Models and Options

Recently made available in the products:

- CNES-CLS MSS 2015
- CLS Jason-2 Sea State Bias Solution
- ECMWF SWH and Wind Speed
- NSIDC Sea Ice Concentration
- NSIDC Sea Ice Age
- NCEP Sea Surface Temperature
- NCEP Precipitable Water

Soon to come:

- UPorto GPD Wet Tropo Solutions
- LEGOS FES14b Tide Model
- TPX09 Tide Model
- SAMOSA++
- STACK PHASE
- RETRACKER EPOCH

Support to Near Real Time Applications with Sentinel-3 data and Support to S3-B

-SARvatore for Sentinel-3 allows to process L1A Short Time Critical (STC) Data (48h latency).

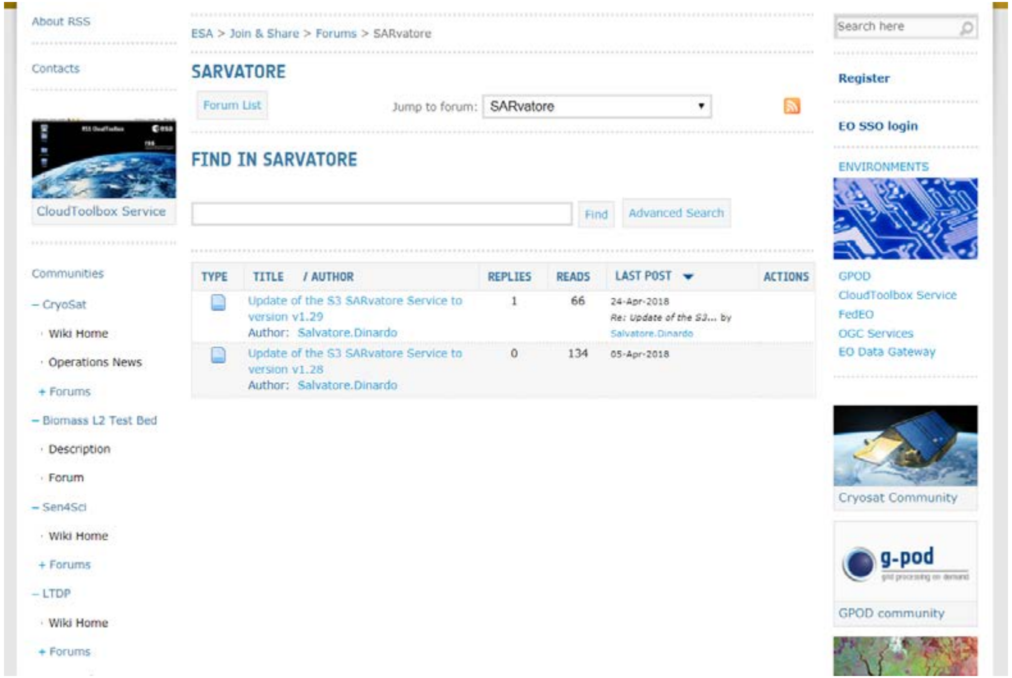
-The latest available Geophysical Corrections and Models are ingested daily in the GPOD system and appended to the GPOD Sentinel-3 STC products.

- System ready to process S3-B data when they will be made available to users

Joins & Share SARvatore Forum

- J/S Forum: users can get here the last updates & releases and report issues, ask questions, share & discuss results:

[*https://wiki.services.eoportal.org/tiki-view_forum.php?forumId=105*](https://wiki.services.eoportal.org/tiki-view_forum.php?forumId=105)



Data Repository

Data Repository: The **SARvatore Data Repository** is now online. Datasets processed for the users are available to the Altimetry Community at:

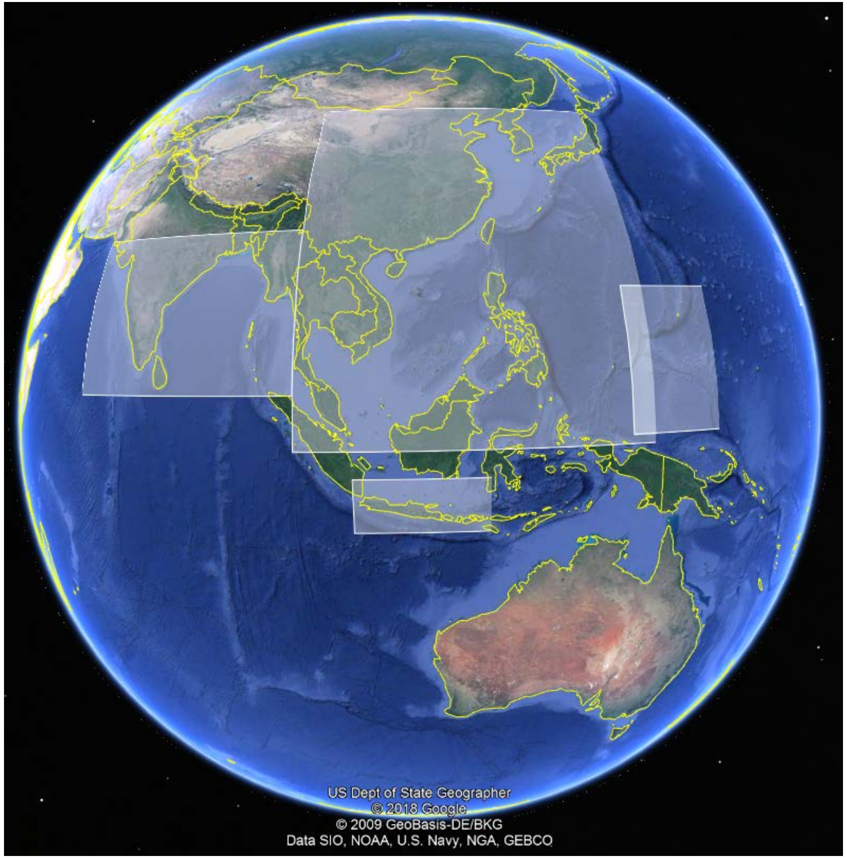
https://wiki.services.eoportal.org/tiki-index.php?page=SARvatore+Data+Repository&highlight=repository

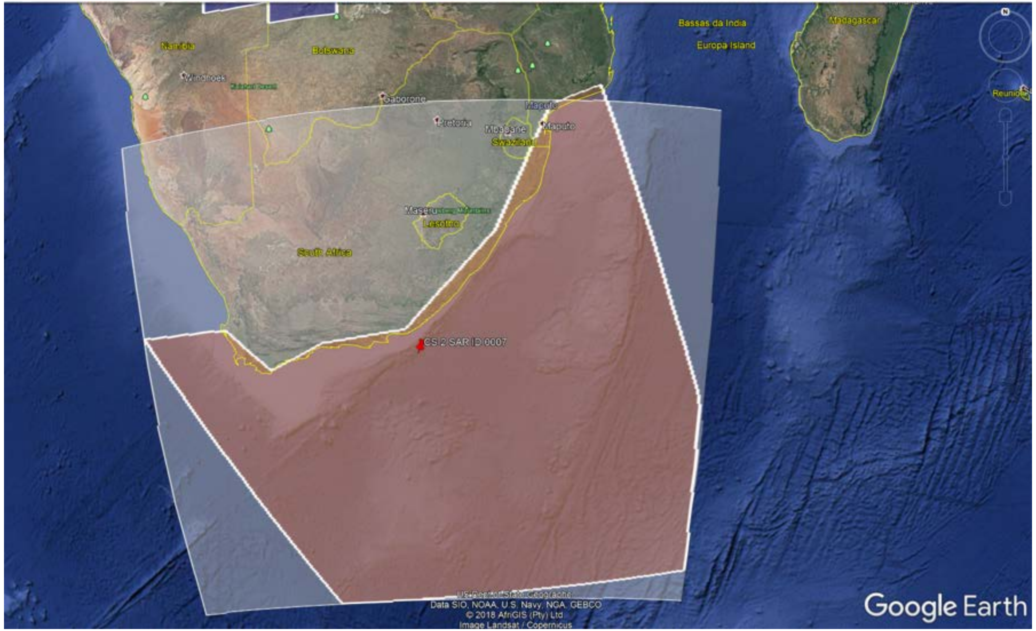
- A .kmz file can be downloaded to visualize in Google Earth the processed regions and compare, for example, to the CS-2 geographical mode mask.

SARVATORE DATA REPOSITORY

This page is a repository of Data processed in G-POD with SARvatore service. Data are available for download.

USER	SERVICE	PROFILE	REGION	COORDINATES	START-STOP TIME	PURPOSE OF THE PROCESSING	DATA
S. Dinardo	SARvatore for S3	Custom	Atlantic - North East	60N 35N 12W 16E	15/06/2016 09/05/2018		0001
SCOOP Team	SARvatore for CS-2	Sentinel-3	Pacific - West	17.1N 0N 137E 150E	01/10/2012 31/12/2013	Support to the SCOOP project	0002
SCOOP Team	SARvatore for CS-2	Sentinel-3	Pacific - Central	25.2N 15N 180W 167W	01/10/2012 31/12/2013	Support to the SCOOP project	0003
SCOOP Team	SARvatore for CS-2	Sentinel-3	Pacific - East	4.6S 25S 140W 85W	01/10/2012 31/12/2013	Support to the SCOOP project	0004
SCOOP Team	SARvatore for CS-2	Sentinel-3	Atlantic - North East	70.3N 32.9N 20.1W 0.5E	01/10/2012 31/12/2013	Support to the SCOOP project	0005
SCOOP Team	SARvatore for CS-2	Sentinel-3	North Sea	70N 50N 6W 16E	01/10/2012 31/12/2013	Support to the SCOOP project	0006
SCOOP Team	SARvatore for CS-2	Sentinel-3	Agulhas	25S 44S 13.8E 40.2E	01/10/2012 31/12/2013	Support to the SCOOP project	0007
SCOOP Team	SARvatore for CS-2	Sentinel-3	North Indian Coast	24.4N 5.2N 66.9E 98.1E	01/10/2012 31/12/2013	Support to the SCOOP project	0008
SCOOP Team	SARvatore for CS-2	Sentinel-3	Indonesia	4S 10.1S 104.6E 120E	01/10/2012 31/12/2013	Support to the SCOOP project	0009
SCOOP Team	SARvatore for CS-2	Sentinel-3	Harvest	38.1N 31N 124W 119W	01/10/2012 31/12/2013	Support to the SCOOP project	0010
D. Martínez Sanchis	SARvatore for S3	Custom (STACK)	Greenland Sea	83N 72N 30W 30E	15/06/2016 15/06/2018	Comparing Stack peakiness with OLCI data for tunning lead detection Algorithm	0011
ID=1671	SARvatore for S3	Coastal Zone	Europe - North West	64N 44N 15W 13E	11/07/2017 28/10/2017	Research purpose	0012
ID=1671	SARvatore for S3	Coastal Zone	Arctic Pole	90N 70N 180W 180E	11/07/2017 28/10/2017	Research purpose	0013
ID=1671	SARvatore for CS-2	Default	Europe - North West	64N 44N 15W 13E	01/01/2016 01/01/2018	Research purpose	0014
ESA	SARvatore for CS-2	Inland Water	Mississippi mouth	32N 28.9N 92.9W 89.8W	13/10/2014 26/06/2018	Dataset for Community	0015


US Dept of State Geographer
© 2018 Google
© 2009 GeoBasis-DE/BKG
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


Namibia
Botswana
Windhoek
Gaborone
Pretoria
Maputo
Mbabane
Swaziland
Maseru
Lesotho
South Africa
Bassas da India
Europa Island
Madagascar
CS 2 SAR ID 0007
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2018 AfriGIS (Pty) Ltd
Image Landsat / Copernicus
Google Earth

Users Contribution to GPOD

Implementation of Processors Developed by the Users

- The ESA-ESRIN Altimetry Team and the ESA GPOD Team support users who want to include their processors in GPOD.

- If interested, please send an email to:

eo-gpod@esa.int **altimetry.info@esa.int**

SARvatore Data in Projects

&

Peer-Reviewed Papers

R&D Projects using CryoSat-2 GPOD Data

- CP40 (Paolo Cipollini and Marcello Passaro, NOC & TUM)
- GOCE++ (Ole Andersen, DTU)
- SCOOP (Luciana Fenoglio, TU Bonn)
- SeaNice (Sara Fleury, LEGOS)
- SHAPE (Pierre Fabry & Nicolas Bercher, Along Track)
- Iceberg Detection (Jean Tournadre, IFREMER)
- Swell Detection (Saleh Abdallah, ECMWF)
- CRUCIAL (Philip Moore, NU)
- SAR SSB Study (Christine Gommenginger, NOC)
- ....

Peer Review Papers using CryoSat-2 GPOD Data in the coastal zone

- *Salvatore Dinardo, Luciana Fenoglio-Marc, Christopher Buchhaupt, Matthias Becker, Remko Scharroo, M. Joana Fernandes, Jérôme Benveniste,Coastal SAR and PLRM altimetry in German Bight and West Baltic Sea, Advances in Space Research,2017,ISSN 0273-1177,https://doi.org/10.1016/j.asr.2017.12.018. (http://www.sciencedirect.com/science/article/pii/S0273117717308943)*
- *Cipollini, Paolo; Calafat, Francisco M.; Jevrejeva, Svetlana; Melet, Angelique; Prandi, Pierre. 2017 Monitoring sea level in the coastal zone with coastal altimetry and tide gauges. Surveys in Geophysics, 38 (1). 33-57.https://doi.org/10.1007/s10712-016-9392-0*
- *Passaro, Marcello; Dinardo, Salvatore; Quartly, Graham D.; Snaith, Helen M.; Benveniste, Jerome; Cipollini, Paolo; Lucas, Bruno. 2016 Cross-calibrating ALES Envisat and CryoSat-2 Delay-Doppler: a coastal altimetry study in the Indonesian Seas. Advances in Space Research, 58 (3). 289-303.10.1016/j.asr.2016.04.011*
- *Bonnefond, P.; Laurain, O.; Exertier, P.; Boy, F.; Guinle, T.; Picot, N.; Labroue, S.; Raynal, M.; Donlon, C.; Féménias, P.; Parrinello, T.; Dinardo, S. Calibrating the SAR SSH of Sentinel-3A and CryoSat-2 over the Corsica Facilities. Remote Sens. 2018, 10, 92.*
- *Gómez-Enri, J.; Scozzari, A.; Soldovieri, F.; Coca, J.; Vignudelli, S. Detection and Characterization of Ship Targets Using CryoSat-2 Altimeter Waveforms. Remote Sens. 2016, 8, 193.*
- *Gomez-Enri, Jesus & Vignudelli, S & Cipollini, P & Coca, Josep & González, Carlos. (2017). Validation of CryoSat-2 SIRAL sea level data in the eastern continental shelf of the Gulf of Cadiz (Spain). Advances in Space Research. . 10.1016/j.asr.2017.10.042.*
- *Idžanović, M., V. Ophaug, and O. B. Andersen (2017), The coastal mean dynamic topography in Norway observed by CryoSat-2 and GOCE, Geophys. Res. Lett., 44, 5609–5617, doi:10.1002/2017GL073777.*

Contacts & References

- For any question, bugs and support, please contact us at:
  altimetry.info@esa.int
- For G-POD platform specific questions and get access to the service, please contact:
  eo-gpod@esa.int
- Service Manuals available at:

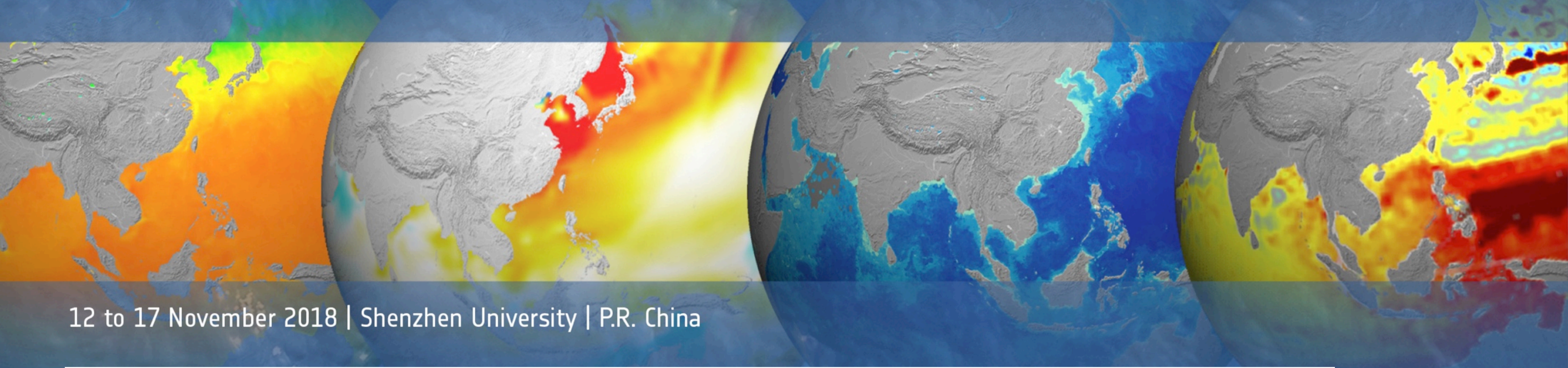
http://wiki.services.eoportal.org/tiki-index.php?page=GPOD+CryoSat-2+SARvatore+Software+Prototype+User+Manual

http://wiki.services.eoportal.org/tiki-index.php?page=GPOD+SENTINEL-3+SARvatore+Software+Prototype+User+Manual

- Services available at:
  https://gpod.eo.esa.int/services/CRYOSAT_SAR/
  https://gpod.eo.esa.int/services/CRYOSAT_SARIN/
  https://gpod.eo.esa.int/services/SENTINEL3_SAR/

ESA–MOST China Dragon 4 Cooperation

→ ADVANCED TRAINING COURSE IN OCEAN AND COASTAL REMOTE SENSING



12 to 17 November 2018 | Shenzhen University | P.R. China

SAR & SARin Altimetry for Coastal Zone and Inland water

Hosted by

GPOD Data Contribution to SAR analyses (Open Ocean & Coastal Zone)

CryoSat Plus for Oceans (CP4O)

GPOD products processed with the coastal zone profile were used in the CryoSat Plus for Oceans (CP4O) Project and compared to the CNES CPP Data from CNES.

The **TWLE (total water level envelope)**, i.e. the total sea level inclusive of ocean tides and atmospheric forcing (due to pressure and wind effects) has been investigated:

TWLE = Orbit Latitude - Corrected Range - Mean Sea Surface + - (Solid Earth Tide + Load Tide)

SAR L1b Processing Options	CPP	GPOD
Hamming Weighting Function	Not Applied	Applied only in Coastal Zone
Beam Steering	Approximated	Approximated
Radar Window Size	Normal (128 bins)	Extended (256 bins)
Range pre-FFT Zero Padding	Not Applied	Applied
SAR L2 Processing Options	**CPP**	**GPOD**
SAR Return Waveform Model	Numerical Solution with real antenna pattern & real PTR	SAMOSA 2 with LUT for alpha_p (PTR width)

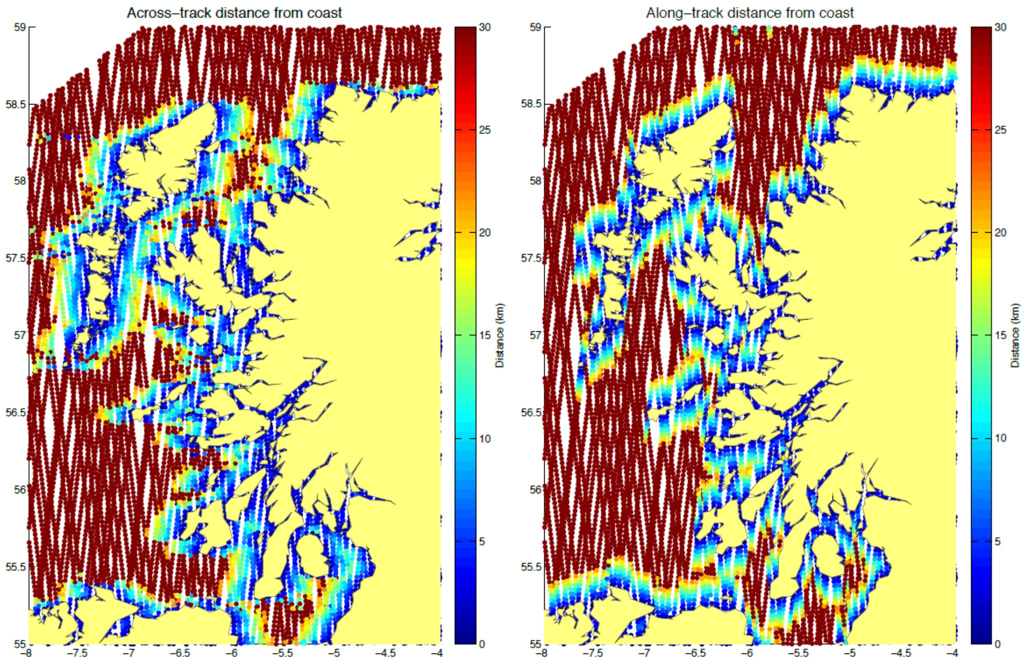


Figure 5: across-track and along-track distance from coast for CryoSat-2 passes around the Western coast of Scotland.

Report of Project results (1)

The **noise proxy** has **been evaluated as a function of along & across-track distance** from the coast for the CPP and GPOD datasets, respectively.

It can be noticed that the specific **coastal processing used in the GPOD** run gives only a slight reduction of the noise (~5 to ~4.5 cm) away from the coast, but **improves it significantly in the last 5 km yielding a noise of ~9cm at 3 km from the coast**.

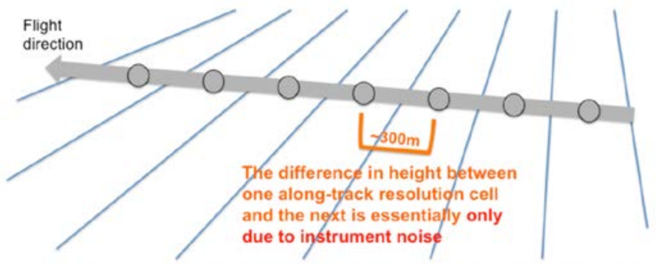


Figure 1: schematics of the use of difference in height between adjacent resolution cells as a proxy for instrumental noise.

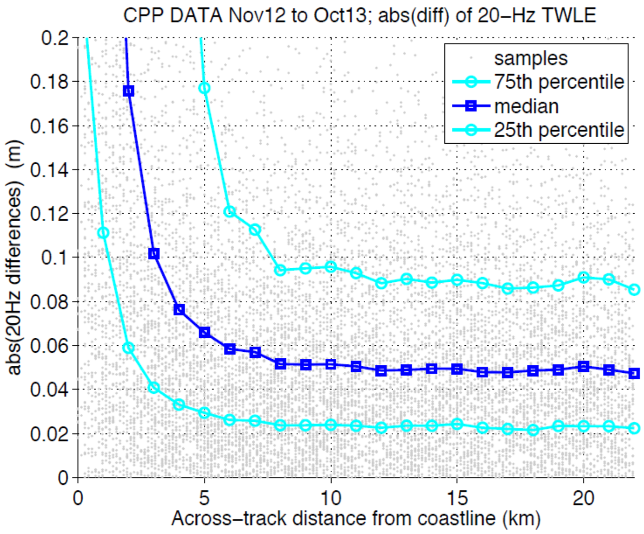


*Figure 6: scatterplot of the absolute value difference between consecutive TWLE measurements against **across-track** distance from coast, and the statistics of its distribution in 1-km distance bins, for the CPP dataset.*

Hosted by

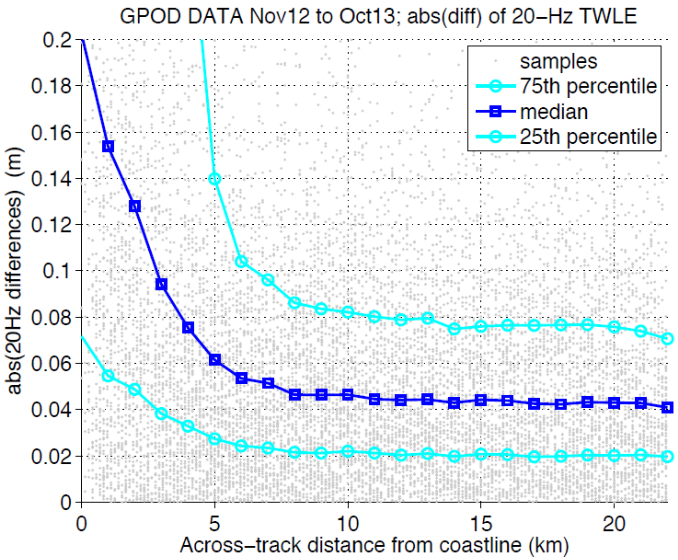


Figure 7: as in figure 5, for the GPOD dataset.

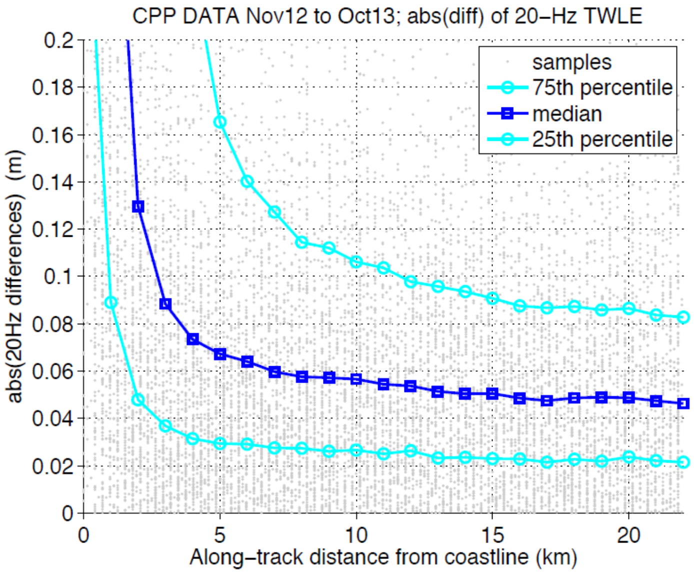


*Figure 8: scatterplot of the absolute value difference between consecutive TWLE measurements against **along-track** distance from coast, and the statistics of its distribution in 1-km distance bins, for the CPP dataset.*

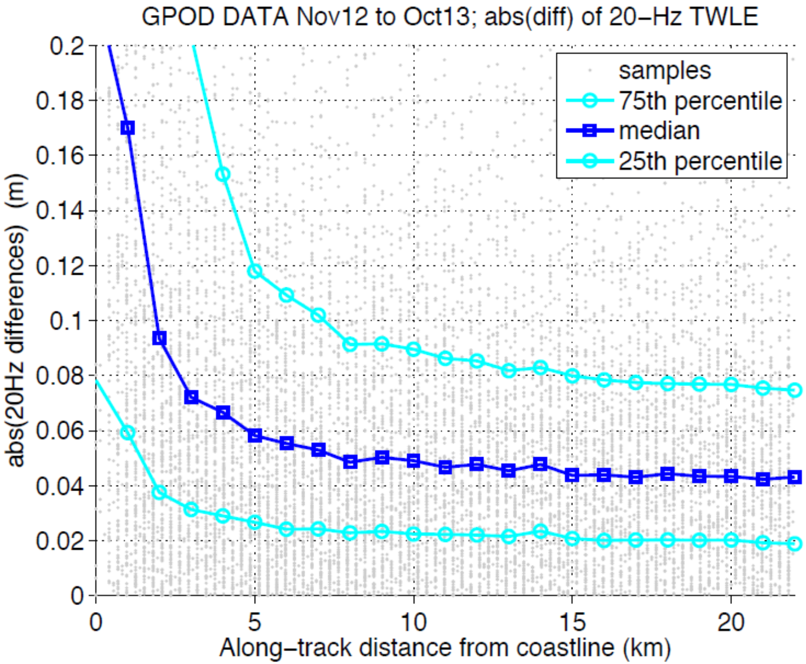


Figure 9: as in figure 7, for the GPOD dataset.

SAR analyses & Stack Editing

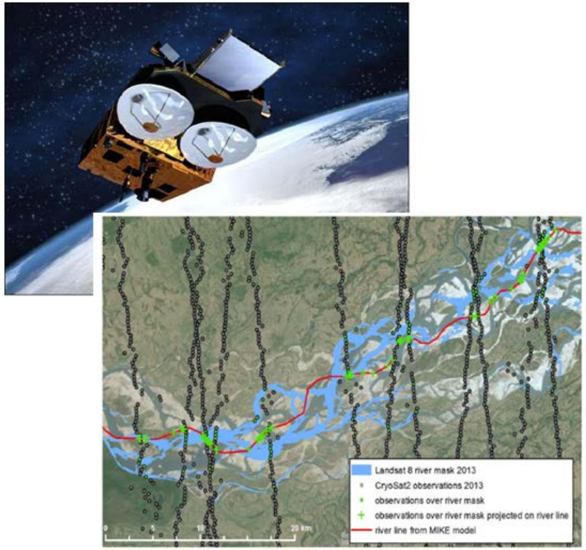
(Inland Water domain)

CryoSat-2 Success over Inland Water and Land (CRUCIAL)

- **CRUCIAL** was funded by the **ESA's Support To Science Element (STSE)** Programme.

- **Goal**: investigate the application of **CryoSat-2 data over inland water** with a forward-look component to the Sentinel-3 mission.

- The high along-track sampling of Cryosat-2 altimeter in SAR/SARin modes offers the opportunity to recover high frequency signals.



Part 1: Process bursts (Q, I data)

SAR $\sim 80\ Hz, 80\ m\ along\ track$

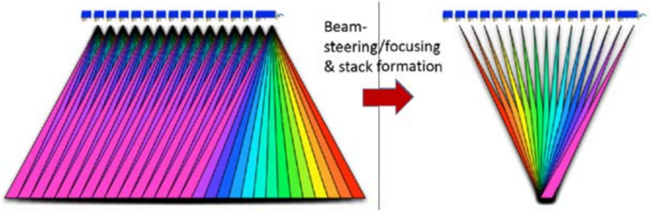
SARin $\sim 20\ Hz, 320\ m\ along\ track$

- Range FFT over 64 pulses in burst
- Beam formation and steered to nadir direction
- Heights from OCOG/Threshold retracker
- Orthometric heights using EGM08
- Coarse orthometric surface recovered from polynomial fit to ocean/inland water heights
- Improved ellipsoidal surface height by reinstating geoid

Part 2: Multi-look

$(\sim 300\ m\ along\ track)$

- Form sequence of ground points at beam angle using coarse approximate steering
- Beam formation and steered to ground points
- Stack beams pointing at ground points
  - max 240 beams in SAR mode and 60 for SARin in stack for multi-look
- Apply slant range correction, tracker range correction, Doppler range correction
- Heights from empirical and OCOG/Threshold retrackers



CryoSat-2 Success over Inland Water and Land (CRUCIAL)

- Selected regions of interest (Rivers)

  Tonlé Sap river, Cambodia (SAR)
  Mekong River (SAR)
  Amazon (SAR)
  Ocean off Amazon estuary (SARin)
  Amazon (SARin)
  Brahmaputra (SARin

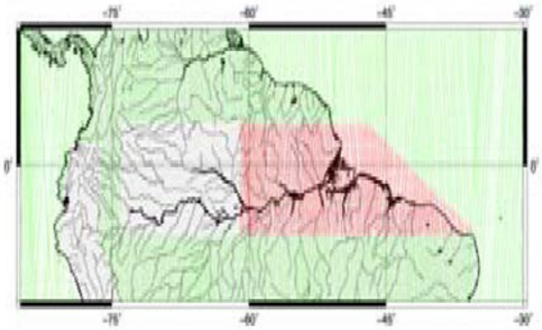
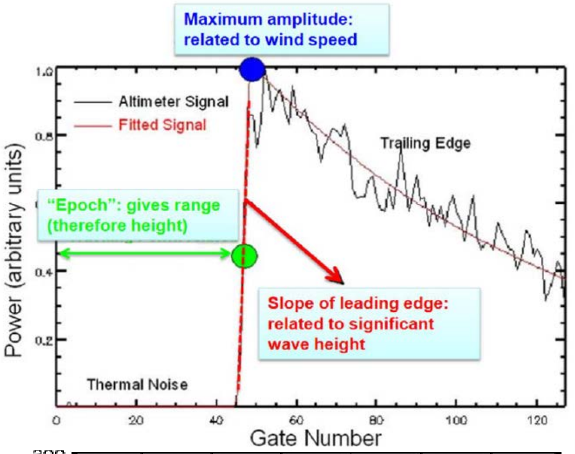


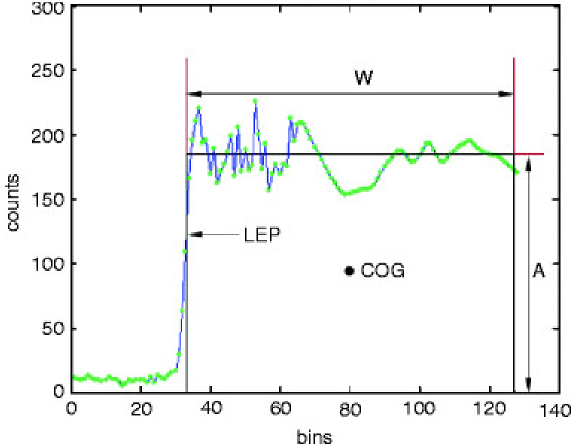
Figure 1. Amazon Basin: LRM (green), SAR (red) and SARIN(blank) tracks. Blank area is SARIN.



- Processing Baselines & Retrackers

FBR to L1B: Innovative processing **optimizing the number of beams** in the stack for ML. CS-2 Baseline B SAR & SARin data as input.

Retrackers: OCOG/Threshold retrackers, re-adapted within the project, and SAMOSA2.



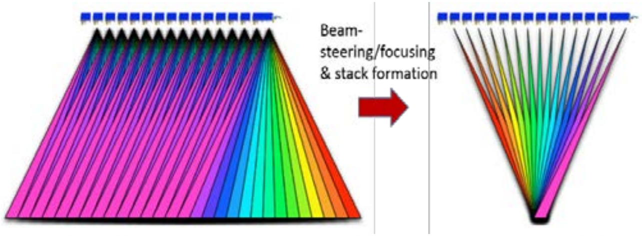
- ESA G-POD **SAR**vatore & **SARin**vatore service data.
- Auxiliary dataset for validation: a) River Gauges data, b) Jason-2, Envisat and SARal-AltiKa data, c) LANDSAT data for river masks computation. D) ACE2 and other GDEM data to estimate river slope.

CRUCIAL - Results (1) – SAR

- The **speckle in the burst echoes** affects the recovered heights from the **80 Hz SAR data** and multi-look waveforms <u>are essential for precise heights when CRUCIAL retrackers are considered (**empirical retrackers**)</u>.

- A **reduction** from the maximum possible number in the stack of approximately **240 to 81 looks** centred on the beam directed closest to nadir reduced the variability in derived heights across Tonlé Sap.

- **N=40 (2N+1=81 looks) was selected for all ROI in SAR mode.**



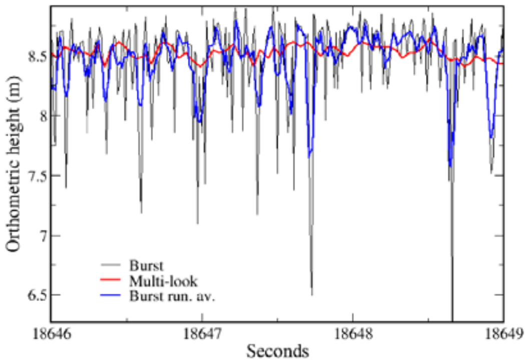
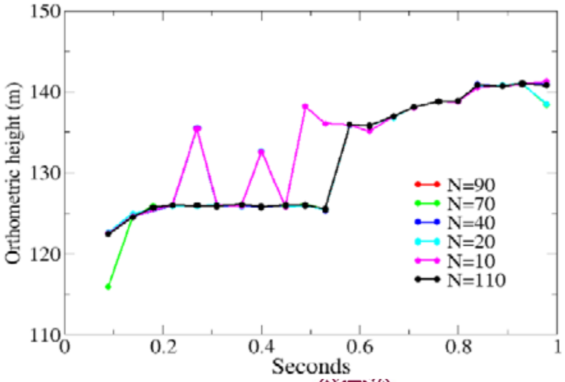
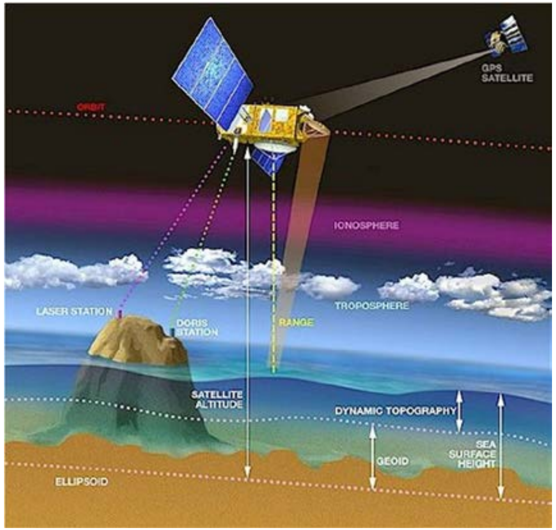


Figure 1: Pass across Tonlé Sap of 3 Dec 2011. 80 Hz burst data (black); running average over 4 points of burst data (blue) and multi-look with N=40 (red). The orthometric height is the height on the surface above the EGM96 geoid.





CRUCIAL – Results (2) – Validation for the Mekong ROI (SAR)

- SAR FBR heights along the Mekong **(N=40)**. Gauges and range identified by lines/circles. Circles at gauge show low water level (Dec-Apr) and high water level (Aug-Sep).
- Validation of Cryosat-2 inland water heights along the Mekong are severely affected by the non-repeating orbit.
- **RMS errors at the Kratie gauge are equal to 67.8 cm (N=40) and 91.9 cm (N=110), respectively**.
- These differences are comparable to those of Birkinshaw et al (2010) where an RMS of **76 cm** was seen **for ERS-2** for the years 1995-2003 and **57 cm for Envisat** for the years 2002-2008.

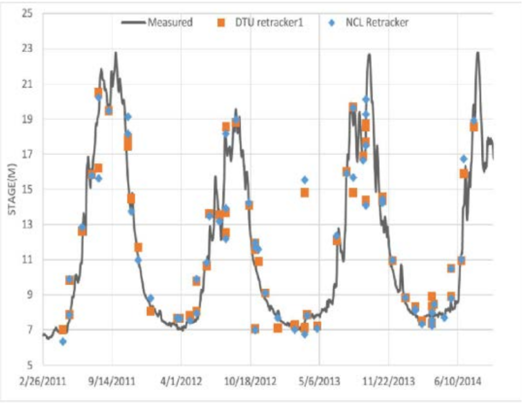


Figure 19: Comparison of Kratie gauge data with heights from near-by altimetric points from NCL (this study; N=110) and DTU. RMS 91.9 cm (NCL, empirical retrackers) and 96.8 cm (DTU).

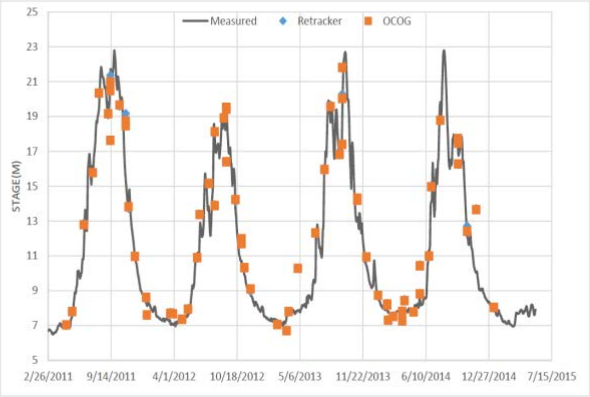


Figure 20: Comparison of Kratie gauge data with heights from near-by altimetric points from NCL (this study) waveforms using N=40. RMS 67.8 cm (empirical retrackers) and 66.9 cm (OCOG/Threshold) using 3σ rejection level.

SARin analyses for Coastal Zone and Inland Water

SARin for Coastal Zone and Inland Water

- Waveforms transmitted from two antennae illuminating the same surface area.
- If the satellite roll is accounted for, heights from the two antennae should be near identical over flat terrain and inland waters.
- The **Coherence** calculated from the waveforms collected by both antennae can be used to investigate the **ground slope** (if the roll angle is not biased).
- The **angle of arrival (AoA)** can be used to **identify off nadir clutter returns.**

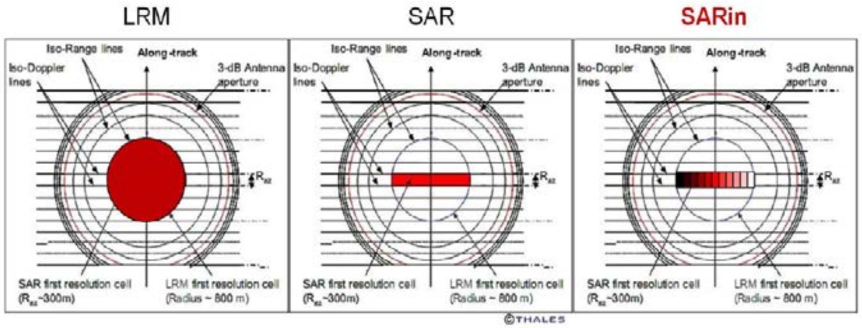


Figure 2-1. The three CS2 possible modes: LRM, SAR & SARin (courtesy of Thales Alenia Space).

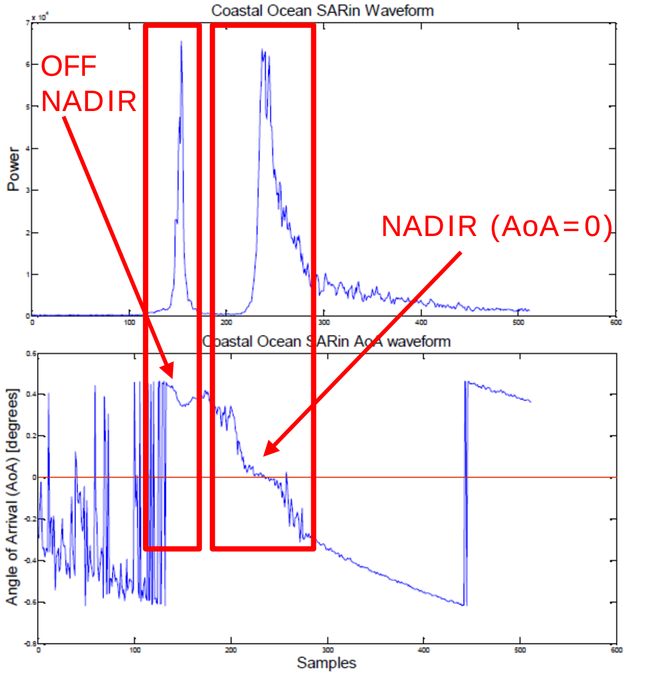


Figure 2-2. Example of a Coastal Ocean contaminated waveform. TOP: Power waveform. BOTTOM: Angle of Arrival waveform.

SARin for Coastal Zone in CP4O

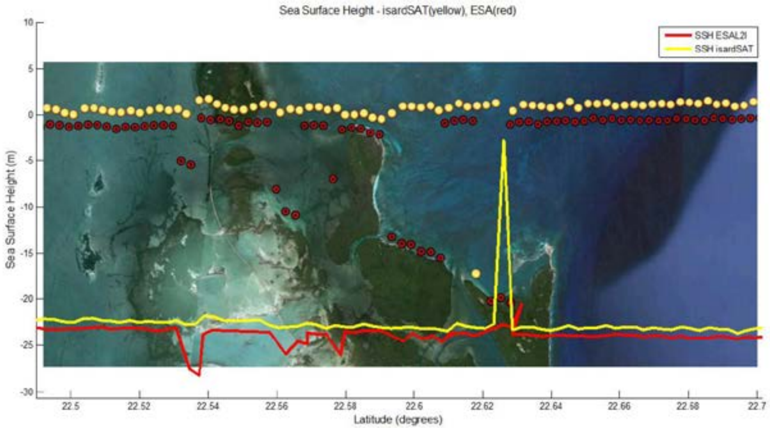


Figure 3-9. Example of processing results on Cuban North East Islands, descending pass. Retracked geolocations are marked with points, and the SSH estimates (in meters) are marked with lines. Red colour is used for ESA L2I outputs, yellow colour is used for CP4O processing outputs.

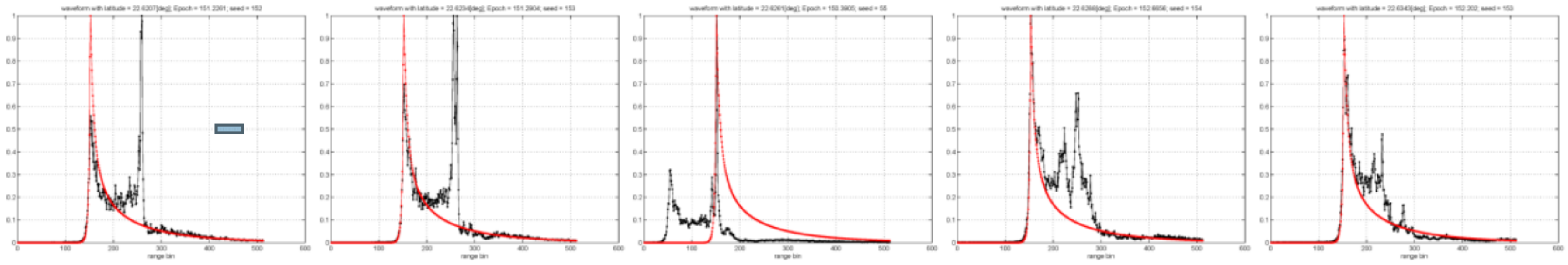


Figure 3-10. Five consecutive Power Waveforms corresponding to the track of Figure 3-9 around the CP4O processing SSH jump. The retracking fitted waveform is shown in red.

SARin Analyses of Ground Slope in CRUCIAL

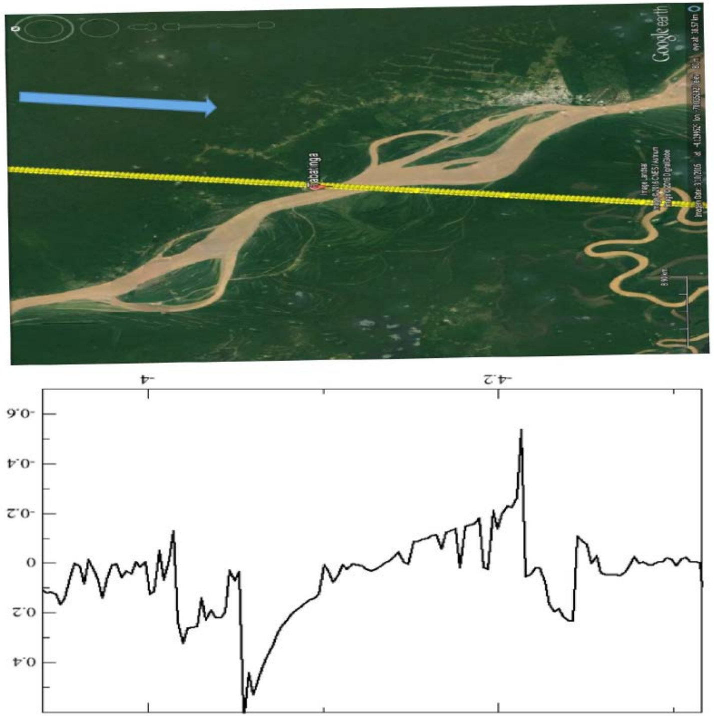


Figure 45: Google earth plot of descending pass on 8 September 2012 across Amazon near Tabatinga (upper). Cross angles from SARin mode (lower). The blue arrow points along direction of flight.

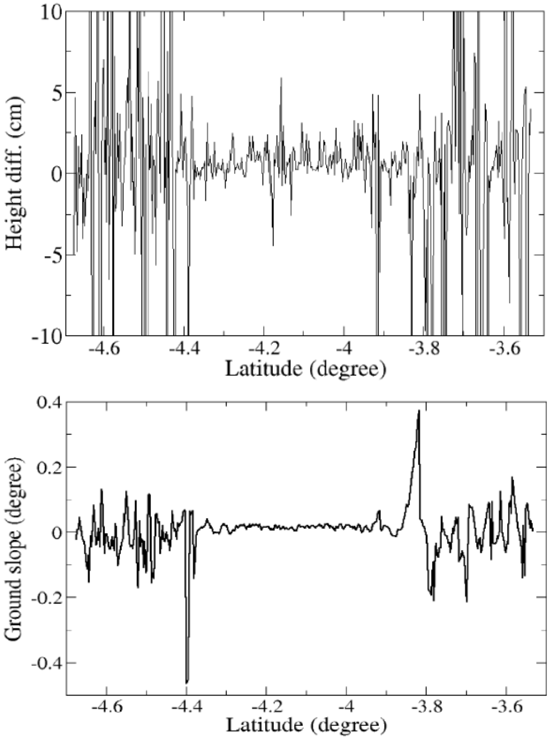


Figure 22: (Upper) Difference between heights from two antennae; (lower) ground slope across.

SARin Amazonas 5 May 2012. (Latitude -4.2˚ corresponds to longitude 70.179˚W)

Validation for the Amazon ROI (SARin)

- Comparison against data from Tabatinga gauge along a river stretch of 160 km (**N=60)**
- Passes 2 days apart used to adjust for river slope.
- Heights from SARin data at Tabatinga yielded an **RMS of 29.9 cm**. This is an improvement on the best results of Birkett et al. (2002) for the Amazon (for Topex/Poseidon: for 1992-1999 were in the range **0.4–0.6 m**).

The **SAMOSA2 analytical retracking** in G-POD **SARin**vatore is inappropriate for inland waters (**SAMOSA+ performs better, see slides about Lake Bracciano**). Retracking G-POD waveforms using the empirical trackers developed in CRUCIAL or with the OCOG/Threshold retracker yields enhanced results.

Figure 38: Google earth image of Amazon near Tabatinga. Gauge marked in red. Yellow markers denote centre line of stretch considered for Cryosat-2 crossings.

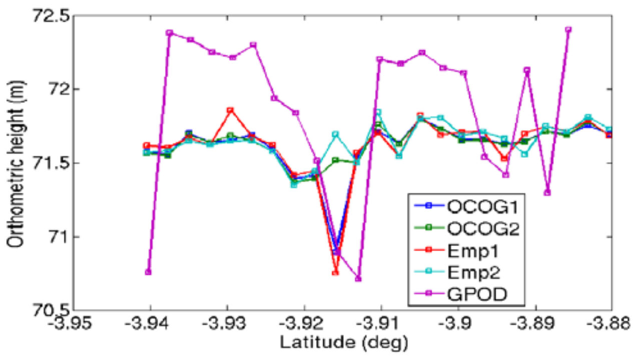


Figure 36: Heights derived by retracking multi-look SARin waveforms (N=60) across Amazon on 5 May 2012. G-POD heights from SARinvatore.

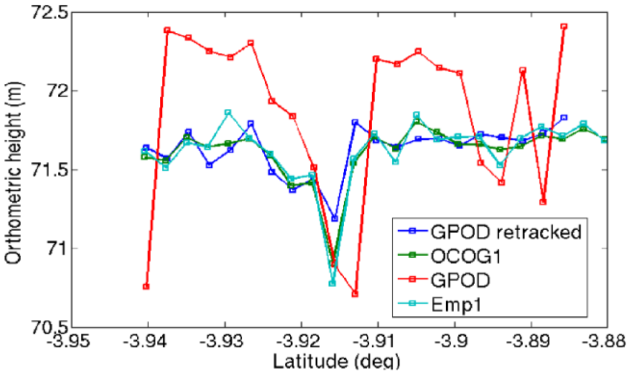


Figure 37: As Figure 36 but with G-POD waveforms retracked.

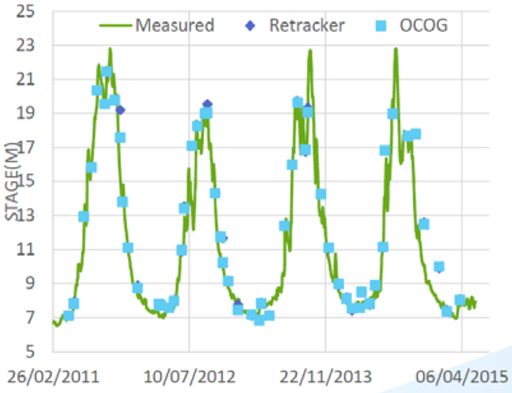


Fig. 13. Comparison of Cryosat-2 and gauge data near Tabatinga, Amazonas.

GPOD Data Contribution:

20 Hz & 80 Hz analyses with the SAMOSA+ Retracker

Lake Bracciano: 20 Hz & 80 Hz analyses with SAMOSA+ (1)

Lake Bracciano is a lake of volcanic origin located in the Italian region of Lazio 32 km northwest of Rome. It is one of the major lakes of Italy and has a circular perimeter of approximately 32 km with a diameter of roughly 9 Km. Its inflow is from precipitation only as there are no inflowing rivers.

As the lake serves as a drinking water reservoir for the city of Rome, it has been under control since 1986 to avoid the pollution of its waters. For this reason, Bracciano is among the cleanest lakes of Italy.

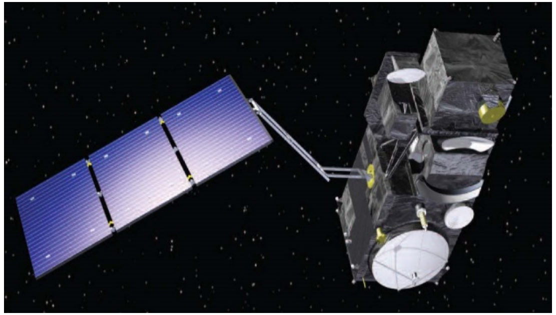
The absence of motorized navigation favors sailing, canoeing and swimming

In the first six months of 2017 less than half of average rainfall in central Italy was recorded.

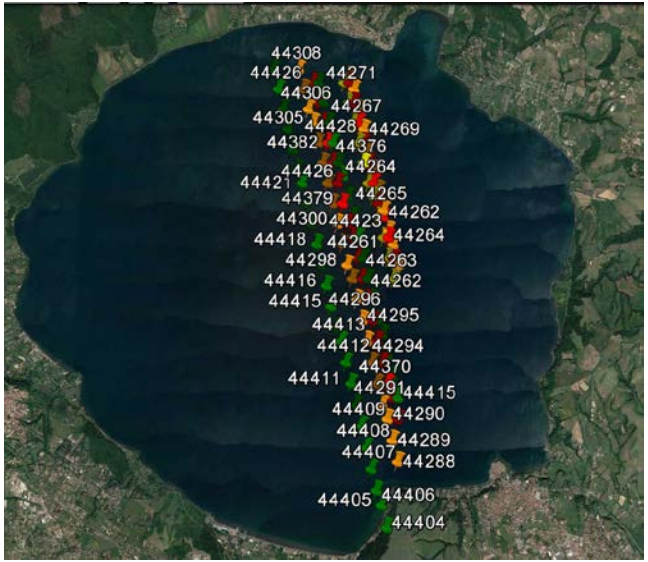
Lake Bracciano has seen a significant drop in water level. The receding shoreline was so prominent that it became visible in optical satellite data. While this may mean more beach space for holidaymakers, it indicated a depleted supply of water for the Italian capital.

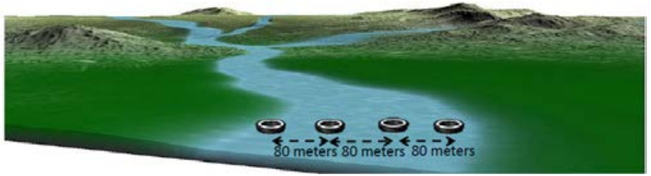
Lake Bracciano's water level is closely monitored by local authorities but, in remote parts of the world, water levels of other large lakes can also be monitored by satellite radar altimeters, helping governments better manage water resources.

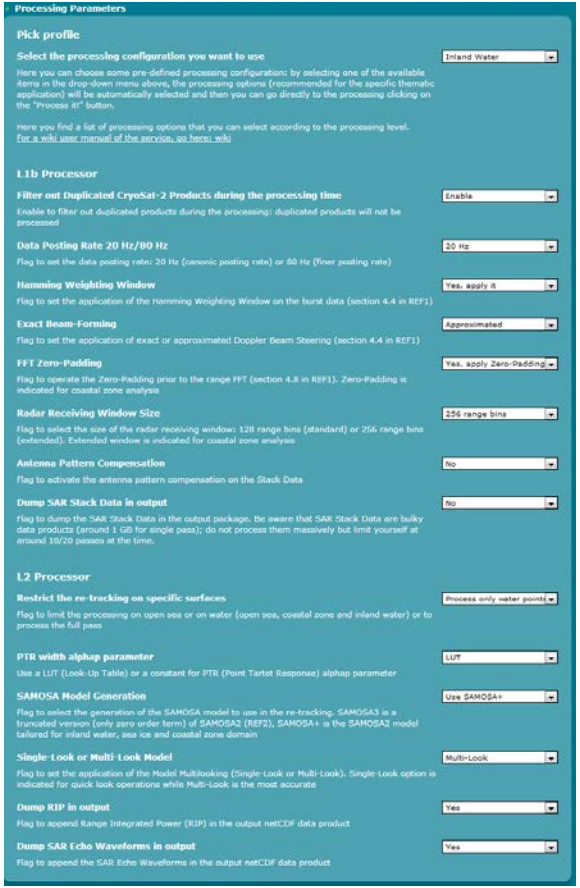
Lake Bracciano: 20 Hz & 80 Hz analyses with SAMOSA+(3)



- In this study, **Sentinel-3** products made available by the ESA GPOD SARvatore for Sentinel-3 online and on-demand processing service (**https://gpod.eo.esa.int/services /SENTINEL3_SAR**) have been analyzed.
- The scope is to maximize the exploitation of Sentinel-3 data over all surfaces providing user with specific processing options not yet available in the official Sentinel-3 processing chain.







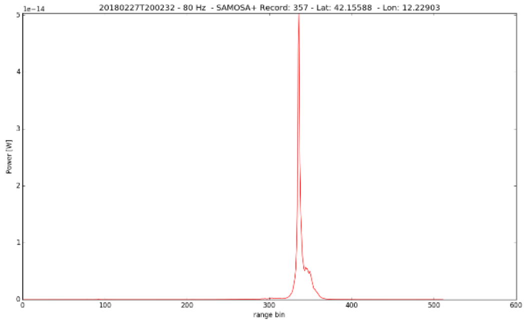
Lake Bracciano: 20 Hz & 80 Hz analyses with SAMOSA+(4)

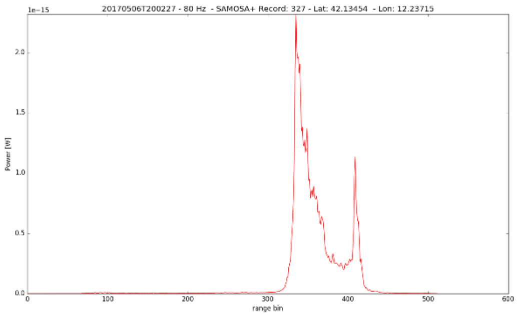
A preliminary check indicated that the majority of the data is corrupted (multi-peaks, top figures). Two independent approaches have been used:

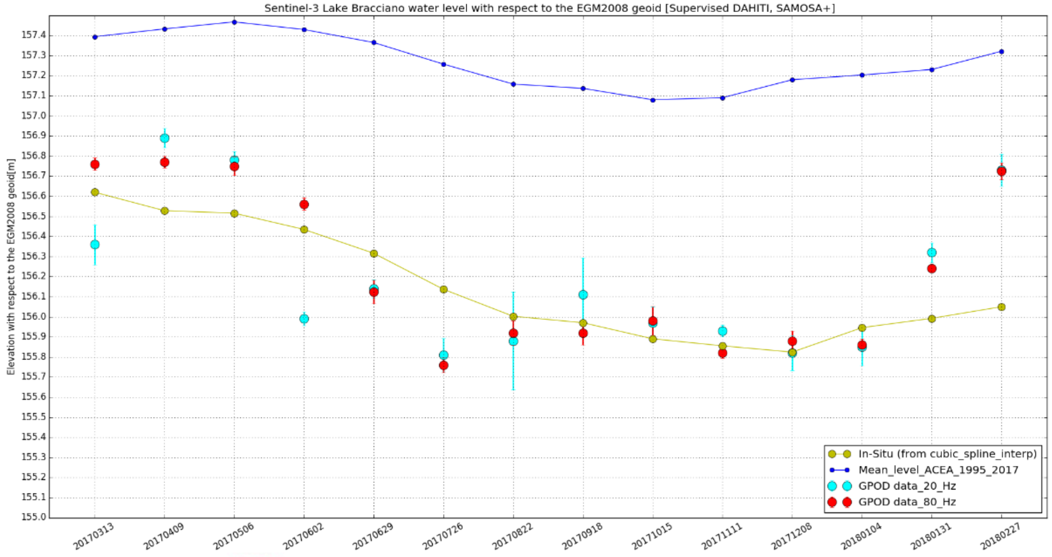
1 - The DAHITI approach has been adopted to filter outliers [Schwatke et al., 2015]. Thresholds on water height, height error (ADM: “absolute deviation around the median”) and Sigma0 have been applied. These have been applied after a supervised selection of regions (latitude threshold) in which water height, sigma0 and ADM error were stable and within the bounds suggested in [Schwatke et al., 2015].

Some tuning has been performed to optimize the thresholds. **These are similar but not identical for the 20Hz and 80Hz cases**.

The median and 2*std (error bar) of the selected values have been considered to build the final time series.







C. Schwatke et al., DAHITI – an innovative approach for estimating water level time series over inland waters using multi-mission satellite altimetry. Hydrol. Earth Syst. Sci., 19, 4345–4364, 2015. https://doi.org/10.5194/hess-19-4345-2015