ICCER - A new robust empirical retracker for non homogeneous surfaces

ALONG-TRACK
pfabry@along-track.com

Pierre Fabry(1), Marco Restano(2), Américo Ambrosio(3), Jérôme Benvéniste(4)
(1) ALONG-TRACK SAS, (2) Serco/ESRIN, (3) Deimos/ESRIN, (4) ESA/ESRIN

Sentinel-3 Hydrologic Altimetry Processor prototypE

1. A robust retracker in multi-peak context

We describe a new emprirical retracker that we have designed and implemented in the frame of the ESA funded SHAPE project that aims at making the best use of SAR (delay-Doppler) altimetry data in hydrology. It addresses both CryoSat-2 and Sentinel-3 SARM products. The SHAPE project is part of SEOM, the Scientific Exploitation of Operational Missions initiative.

Inland water bodies tend to have a specular scattering response to incident radar waves. Multi-peak beams in the Stack and therefore multi-peak **waveforms** (**WF**s) are statistically frequent in areas with a dense hydrological surface networks or in inundated plains. The width and the power of the peaks can hardly be modelled as it depends at least on the water roughness, its area, its across track extent and location within the altimeter footprint. Some of the peaks may also appear at few Doppler Beams when strongly reflective targets (e.g. calm waters) re-appear in the radar echoes through the side lobes of the antenna.

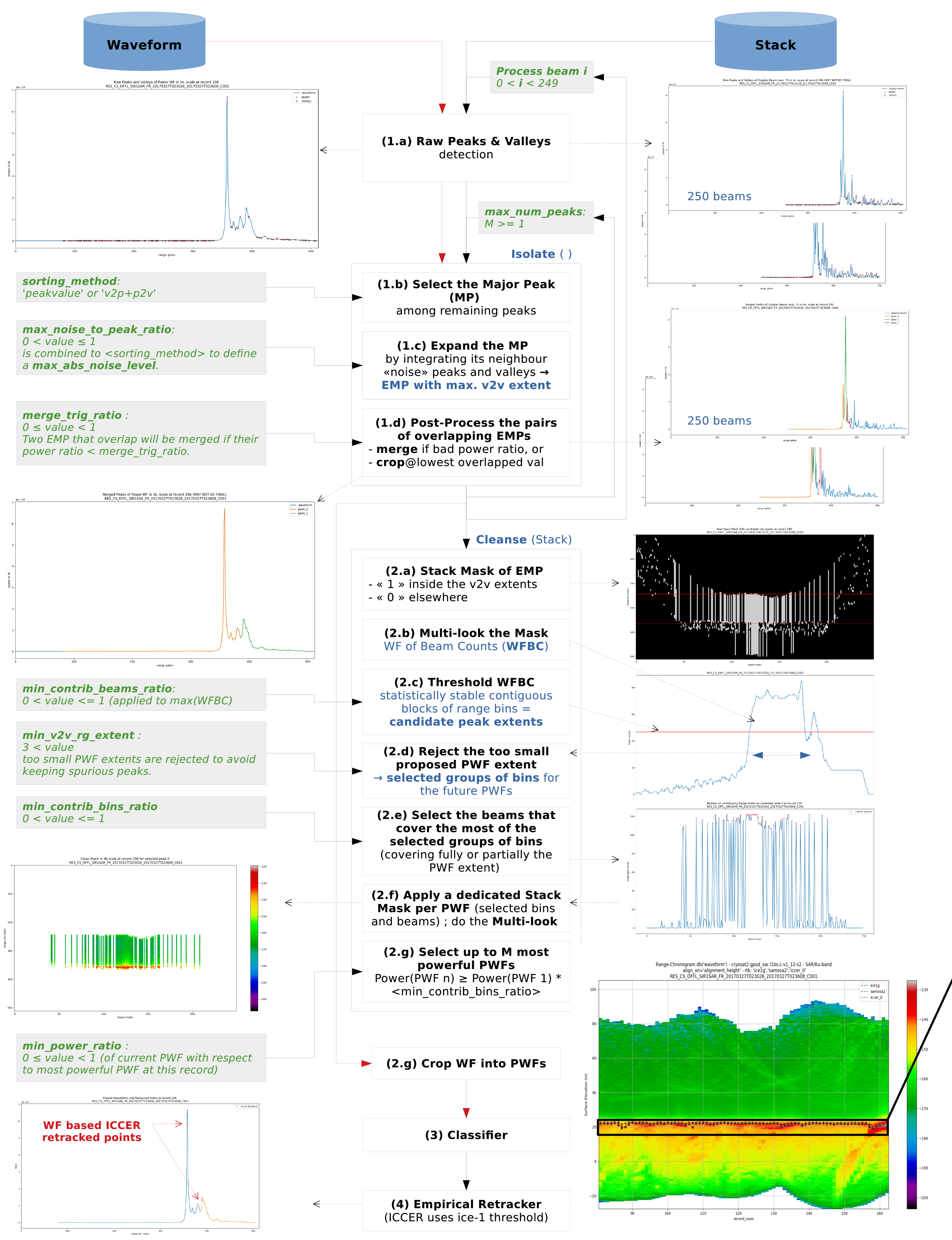
The ICCER retracker addresses the issue of noisy multi-peak echoes potentially corrupted by spurious (ghost) peaks. The driving idea is to cleanse the Stack before multi-looking it, in order to deliver better WFs to the sub-WF retracking scheme. This is achieved by first isolating all peaks in all beams and then filtering out the peaks that are not persistent over a sufficient number of beams. The peaks of interest may be selected either from their absolute maximum value or from their cumulated bin to bin amplitudes. As they are searched individually two peaks may overlap each-other ; in this case they are merged when their respective integrated powers are similar, or split at the lowest valley in between their maximums. In the end the most powerful peak is selected among the ones that are persistent in the Stack. Only the range gates that define this peak over the persistent beams are kept in the stack.

The **pseudo-WF** (**PWF**) that is obtained after multi-looking the masked Stack is then classified as 'Water' or 'Non Water' by a simple threshold on its Pulse Peakiness. In the absence of surface water over homogeneous surfaces (like primary forests) the resulting peak may well have a Brownian like shape, while the presence of water is characterized by peaky PWFs. By isolating the peaks of interest the retracker is less perturbed as it is not influenced by the spread of energy all over the tracking window, but simply on the selected range gates. A simple ice-1 threshold is used to determine the epoch of interest. This new scheme is robust by design and it can deal with most WFs including Multi-peak WF, Brownian WF with peak in the trailing edge.

This new retracker has initially been design to provide multi-epoch outputs on SARINM products over sea ice. Sea ice and Hydrology offer very similar Stacks and WF even if there is a much wider type of targets involved in Hydrology. In order to join efforts with a similar poster on the cryosphere (poster number 10) , we illustrate here the step by step results over sea ice.

3. Step by Step ICCER algorithm outputs

ICCER - Isolate Cleanse Classify Empirical Retracker



2. ICCER retracker overview

The **ICCER (Isolate, Cleanse, Classify - Empirical Retracker)** is a software suite developed by ALONG-TRACK to address non Brownian radar altimeter echoes. But Brownian WF are properly handled. The suite exploits multi-peak L1B-S data acquired in continental hydrology and sea ice.

***peak** (definition): group of contiguous range gates associated to powerful echo returns.*

Multi-peak WFs are frequent over non homogeneous surfaces. They are hard to model as they combine the size, location, morphology and backscattering coefficient of a large and unknown number of targets. This is not in favor of geophysical retrackers. Our new empirical retracker looks for stable peaks of energy over the Stack beams and cleanse them prior to multi-looking. Therefore, the final stage benefits from 'denoised' **pseudo-WF**s (**PWF**). Each PWF is classified for a surface type. Multiple targets per record can be exploited in SARINM. In SARM the ICCER addresses the first "major" peak. In the end, the ice-1 threshold is applied to each PWF.

We illustrate the step by step outputs on GPOD SARvatore 2.08 products over the Lincoln sea.

HIGH LEVEL ALGORITHM DESCRIPTION

1. Isolate the M major peaks, in a **valley-to-valley** (**v2v**) definition of the peaks :

for each *beam* in ***L1BS_Stack*** :

- **1a. detect peaks & valleys**: peak = local max. delimited by the 2 closest valleys (fore & aft)
- **1b. sort peaks** by desc. order upon the ***sorting_method*** in ['peakvalue', 'v2p+p2v'] :
  - 'peakvalue': sort with the values of the WF at the peaks range bin,
  - 'v2p+p2v': sort with the sum of the bin to bin amplitudes from fore to aft valley,
- **1c. expand** the v2v extent of the major peaks ($1 < m \leq M$) to account for local noise: Browse the vicinity of the *m*-th peak (backward & forward) and change the peak's limits (valleys) to integrate all neighbor peaks that are below the noise threshold (***max_noise_to_peak_ratio*** x highest_peak_value). The expansion of the *m*-th peak ends, in each direction, as soon as it meets a peak that is too big to be 'noise'. when the expansion ends in both directions, the extent (list of bins) of the *m*-th **Expanded Major Peak** (**EMP**) is held in *EMP_bins*(*m*, *beam*).
- **1d. merge or split** the overlapping EMPs two by two:
  - *if* *EMP_bins*(*m1*, *beam*) overlap *EMP_bins*(*m2*, *beam*):
    - *if* they have similar power (v2v_power_ratio < ***merge_trig_ratio***): **merge** them,
    - *else*: **split them** at the lowest valley in between the 2 maximums (the 2 peaks)

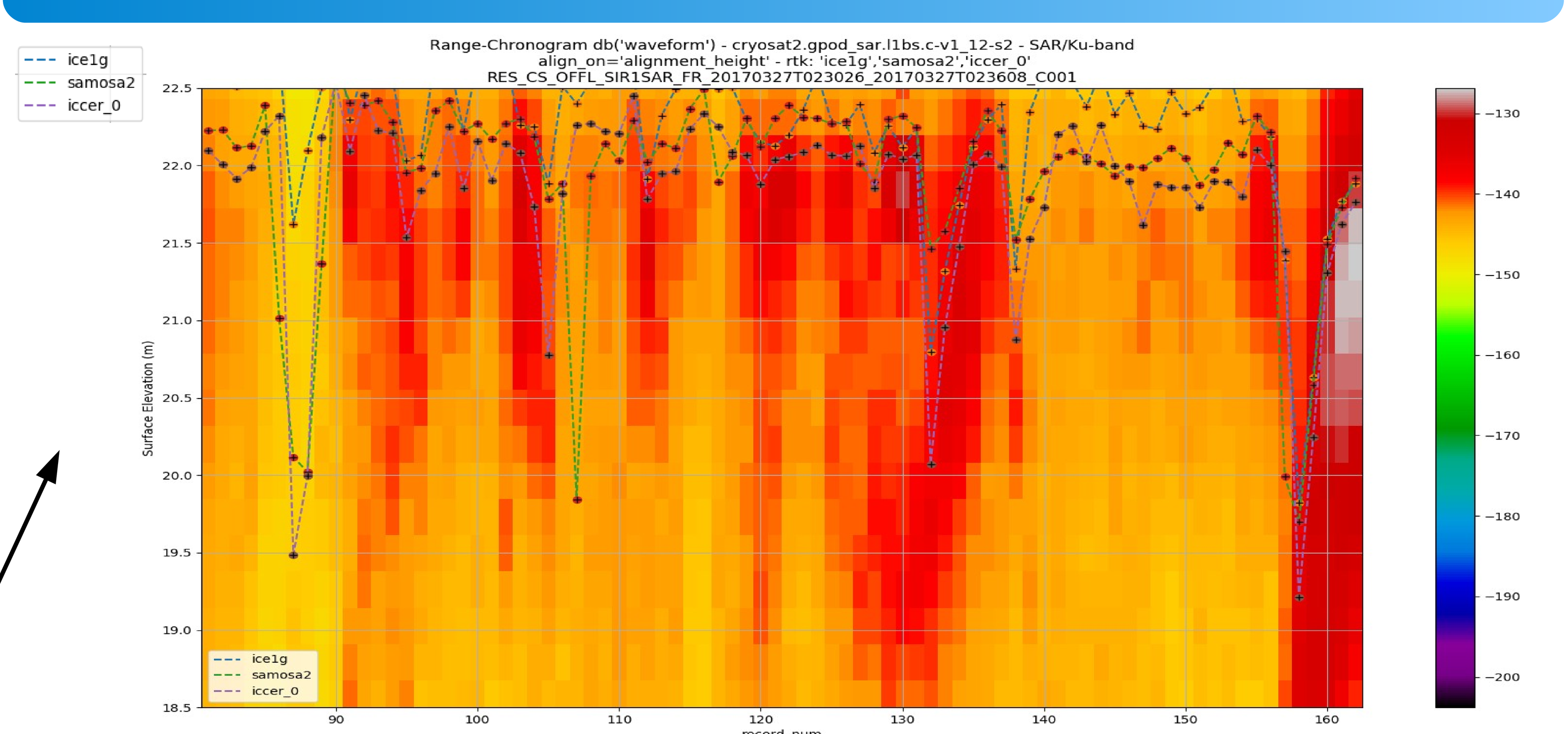
2. Cleanse the L1BS_Stack to get "clean" PWF from the consistent beams of the L1BS_Stack:

- **2a. build** one **Temprary Stack Mask** (**TSM**) per *EMP (EMP==m)*:
  - *for* each *beam* in *L1BS_Stack*:
    - *TSM*(*beam*, :)=*0*
    - *for* *m* in [*1*, *M*]:
      - *TSM*(*beam*, *EMP_bins*(*m*, *beam*))=*1*
- **2b. multi-look** the *TSM* → bin-wise histogram of consistent (contributing) beams: *WFBC*
- **2c. threshold** *WFBC* and keep the *M* most powerful contiguous groups of bins for which *WFBC* > floor(***min_contrib_beams_ratio*** x *number_of_beams*). These bins contribute to the EMPs over a significant number of beams. Store them into *static_EMP_bins*(*m*) *for* *m* in [*1*, *M*].
- **2d. discard** the static EMPs that exhibit a too small extent:
  - *for* *m* in [*1*, *M*],
    - *for* each *beam* in *L1BS_Stack*,
      - *if* size(*static_EMP_bins*(*m*)) < ***min_v2v_range_extent***:
        - *M*←*M*-1,
        - *next* (*m* | *beam*)
      - *else*: for m loop on (2e, 2f, 2g)
- *for* *m* in [*1*, *M*] (for each EMP):
  - **2e. create mask** by selecting which bins of *L1BS_Stack* can contribute to the *m*-th PWF :
    - *for* each *beam* in *L1BS_Stack*:
      - *bins*(*m*, *beam*) = *L1BS_Stack*(*beam*, :) ⋂ *static_EMP_bins*(*m*)
      - *Stack_Mask*(*beam*, :) = 0
      - *if* size(*bins*(*m*, *beam*)) > ***min_contrib_bins_ratio*** x size(*static_EMP_bins*(*m*)):
        - *Stack_Mask*(*beam*, *bins*(*m*, *beam*)) = 1
  - **2f. apply the mask**: *L1BS_pseudo_Stack*(*m*) = *L1BS_Stack*(*Stack_Mask*)
  - **2g. multi-look** *L1BS_pseudo_Stack*(*m*) to obtain the *PWF*(*m*)

3. **Classify**: apply a threshold to PulsePeakiness(*PWF*(*m*)), classes in ['Water', 'Non Water']

4. **Retrack**: apply ice-1 threshold to *PWF*(*m*).

4. Comparison with Ice1 and Samosa-2



5. Conclusions

We have designed and implemented a new empirical retracker. The preliminary results on CryoSat-2 baseline-C products from the GPOD SARvatore 2.08 processor are very encouraging. The ICCER retracker seems to be at least as pertinent and robust as the Ice-1 and the Samosa-2 retrackers, if not better. Being also used in the HYDROCOASTAL ESA funded project (costal and inland water) the ICCER retracker will soon be evaluated in terms of statistical performances thanks to a complete validation exercise based on gauging stations data. In this poster we have described the very first version of the ICCER which is able to process either Waveforms or Stacks. A new version has been designed since then with simplifications that should improve its processing speed, now combining the early use of Waveforms and Stacks afterwards. The new version still permits to process waveforms only. The classification scheme is being tested and improved thanks to a dedicated analysis tool (SWAT) that displays a wide variety of pseudo-waveforms and Stack derived parameters like peakiness, skewness, kurtosis ...

[R-1] R. Ricker, S. Hendricks, V. Helm, H. Skourup, M. Davidson, Sensitivity of CryoSat-2 Arctic sea-ice freeboard and thickness on radar-waveform interpretation, The Cryosphere, vol. 8, 2014, num. 4, p. 1607-1622, url http://www.the-cryosphere.net/8/1607/2014/, DOI 10.5194/tc-8-1607-2014.
[R-2] Helm, V., Humbert, A., and Miller, H.: Elevation and elevation change of Greenland and Antarctica derived from CryoSat-2, The Cryosphere Discuss., 8, 1673-1721, doi:10.5194/tcd-8-1673-2014, 2014.

http://chronos.along-track.com/
https://cryosat10years.org/NikalWebsitePortal/cryosat-10th-anniversary-science-conference/esa

CryoSat 10th Anniversary Conference
VIRTUAL EVENT | 14–17 JUNE 2021
esa