ICCER - A new multi-epoch empirical retracker dedicated to freeboard measurement.

ALONG-TRACK
pfabry@along-track.com

Pierre Fabry(1), Jérôme Bouffard(2).

(1) ALONG-TRACK SAS, (2) ESA-ESRIN.

Cryo-SEANICE

1. The need for a multi-epoch empirical retracker

We describe a new emprirical retracker that we have designed and implemented in the frame of the ESA funded **Cryo-SEANICE** project. This project aims at improving the measurement of **freeboard** (**FB**) from CryoSat-2 **SARM** products and testing the potential of CryoSat-2 **SARINM** to provide qualitative FB. In this communication we consider radar-FB which is the elevation of the main scattering horizon (within the snow+ice layer) above the local sea level (leads) as defined in [R-1].

Leads are calm water areas sheltered by the surrounding sea ice. They have a specular scattering response to incident radar waves. Their powerful and peaky echo returns can cause **tracker snagging** (reference gate shifted away from nadir but nadir still within the tracking window). In LRM and SARM the tracking window is only 60m wide. The leads that are away from nadir can cause **tracker off-nadir hookings** (no range bin related to NADIR anymore). Snagging and hookings are hard to detect from a single **waveform** (**WF**) as the bright target peak is likely to be near the reference gate. Range is overestimated → sea level is underestimated → FB is overestimated. To reduce FB noise classifiers do reject (m)any exotic WF and a robust outlier rejection filter is used at L3 processing stage.

However, in the Arctic seas, CryoSat-2 WFs often receive signatures from both floes and leads. These WFs are considered as ambiguous and they are often rejected. This is acceptable in LRM and SARM but would be a huge waste of measurements in the case of SARINM where the phase difference permits to precisely locate 1 to many retracked points that offer sufficient coherence and power even if they are located far away from the reference gate. Some of the existing retrackers, like TMFRA (Threshold First Maximum Retracker Algorithm) [R-2], are able to handle the first peak in multi-peak waveforms.

Our goal was to further increase the number of measurements out of SARINM records. Our new classifier-retracker can deal with Multi-peak WF, Brownian WF with peak in the trailing edge that would be flagged as ambiguous by some existing schemes. In SARINM. the ability to exploit multi-peak and multi-classes WF brings the hope to densify the measurements after they have been corrected from slant-range geometry to an equivalent NADIR geometry by use of the phase difference. By densifying the number of measurements in both classes we expect to reduce noise freeboard.

With densified measurements from a multi-peak retracker, the SARIN FB methodology shall be revisited as well compared to methods that deal with less measurements after heavy WF rejection at the classifier, single epoch and single class per processed WF. We will discuss the SARIN FB method in a future communication.

This poster is linked to poster 158 where the introduction provides more insights on the ICCER principles and why it is also useful in SARM in the presence of ghost signals from the sidelobes of the antenna pattern.

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. The suite exploits multi-peak L1B-S data acquired in continental hydrology and over 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:

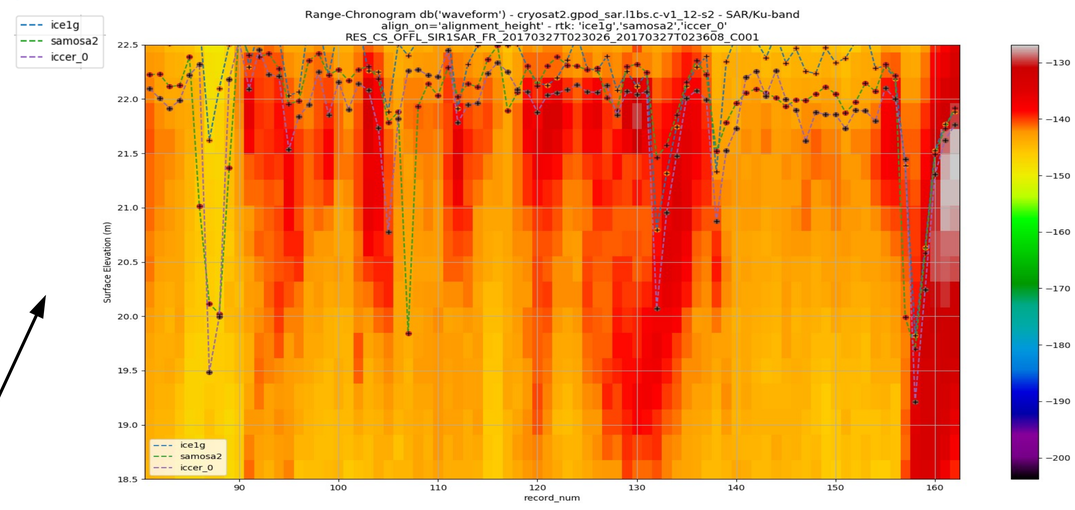
- **2a. build** one **Temprary Stack Mask** (**TSM**) per *EMP (EMP==m)*:
  - *for* each *beam* in *L1BS_Stack*:
    - *TSM*(*beam*, :)=*0*
    - *for* m in [*1*, *M*]:
      - *TSM*(*beam*, *EMP_bins*(m, *beam*))=*1*
- **2b. multi-look** the *TSM* → bin-wise histogram of consistent (contributing) beams: *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).

3. Step by Step ICCER algorithm outputs

ICCER - Isolate Cleanse Classify Empirical Retracker

4. Comparison with Ice1 and Samosa-2



5. Conclusions

In the frame of the Cryo-SEANICE ESA contract we have designed a new empirical retracker. The preliminary results obtained 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. The new empirical retracker is also involved in the HYDROCOASTAL ESA project (costal and inland water) where its statistical performances will be determined thanks to 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 use of Waveforms and Stacks. The new version still permits to process only waveforms. 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