Leads Detection with Fully-Focused SAR in Antarctica

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ABSTRACT

Leads between ice floes are key elements to determine the sea surface height in sea ice scenarios since they provide a sea-level reference for the freeboard height measurements. A lead detector with Fully-Focused SAR back-projection algorithm has been implemented with the aim of detecting leads in the Antarctica with high resolution.

Frequently, due to defrost and other environment events, ice in polar areas break, forming leads where water is accumulated. The objective of this activity is to develop an algorithm to detect the leads and estimate environmental parameters with very high resolution. The current along track sampling provided by the Delay Doppler processing limits the lead detection ~300 meters, but with Fully-Focussed we can get reliable measurements every ~0.5 meters. The detection of leads with that enhanced resolution will reduce the uncertainty of the sea ice freeboard retrievals.

Fully-Focused SAR back-projection algorithm, published by A. Egido and W. Smith (2018), improves the along-track resolution of current operational algorithms (delay-Doppler) up to the theoretical, half of the length antenna. In the case of CryoSat-2, along-track resolution of 0.5 meters can be achieved by using Fully-Focused algorithms.

The Fully-Focused SAR back-projection algorithm has been implemented and tested with CryoSat-2 data. It has been validated using different data set processed using transponder, inland waters and ocean scenarios.

With the aim of evaluating the performance of the lead detection algorithm, images from Sentinel-1 have been used in order to locate natural areas with a huge number of leads. Issues with the synchronization between Sentinel-1 and CryoSat-2 data have been found, as they do not share the same orbital tracks. Yet, images from Sentinel-1 were useful to evaluate the quality of the results.

METHODOLOGY

Fully-Focused issues with CryoSat-2 data: Replicas

CryoSat-2 uses closed-burst mode. Due to the effective PRF of the altimeter, along-track replicas appear at ~92 meters after processing the data with the Fully-Focused algorithm. This problem can be minimized if other pulse emission pattern is used. For example, Sentinel-6 uses an interleave mode, increasing the effective PRF and minimizing the effect of replicas.

Fully-Focused issues with CryoSat-2 data: Phase irregularities

Intra-burst phase jumps were found when correcting the along-track phase. Also, inaccuracy in the telemetry attitude data (position quantization errors, imprecise datation…) introduces defocusing in the along-track phase. Those errors can be fixed by interpolating the telemetry data.

Evaluating the Fully-Focused algorithm over transponder passes

In order to evaluate the performance of the Fully-Focused algorithm, multiple tracks over transponder locations have been processed. This evaluation is useful to understand the behaviour of CryoSat-2 data when processed by the Fully-Focused algorithm. When processing data over transponder, the apparition of replicas can be noticed. Also, processing transponder data is important to determine the real along-track resolution that is obtained by the algorithm.

Approach:

1. Process Fully-Focused algorithm.
2. Obtain the along-track signal of maximum energy range samples.
3. Correlating along-track signal with a model of sinc replicas.
4. Windowing average.
5. Determine a power threshold.
6. Find peak pattern to classify leads.

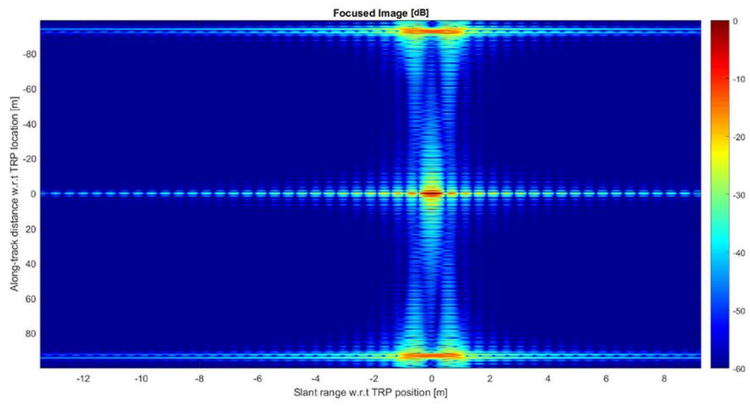
Cleaning replicas and reducing noise to estimate leads

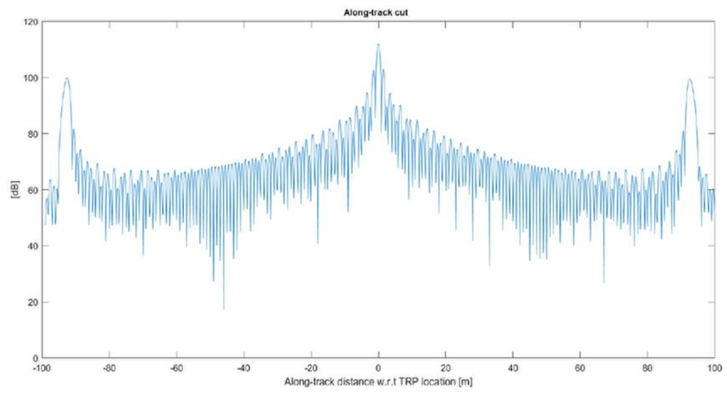
In Antarctica, leads can be of the order of hundreds of kilometres, which means that replicas can interfere the along-track lead signal, making more difficult to estimate the lead position and its width. The real challenge of the lead detection algorithm for CryoSat-2 data is to clean the replicas and reduce the noise.

Correlation with a theoretical model of replicas, power averaging and peak detection

By correlating the along-track signal with a theoretical model of replicas, the noise is reduced considerably, and the pattern of replicas in the along-track signal can be easy identified. Applying a power averaging window softens the along-track signal and helps to determine the position of the leads. To estimate the position of the leads, parameters such as the peak prominence, the peak power threshold and peak bandwidth have to be determined. In order to improve the accuracy of the results, the algorithm has to be trained in order to estimate the optimum values for the processing parameters.

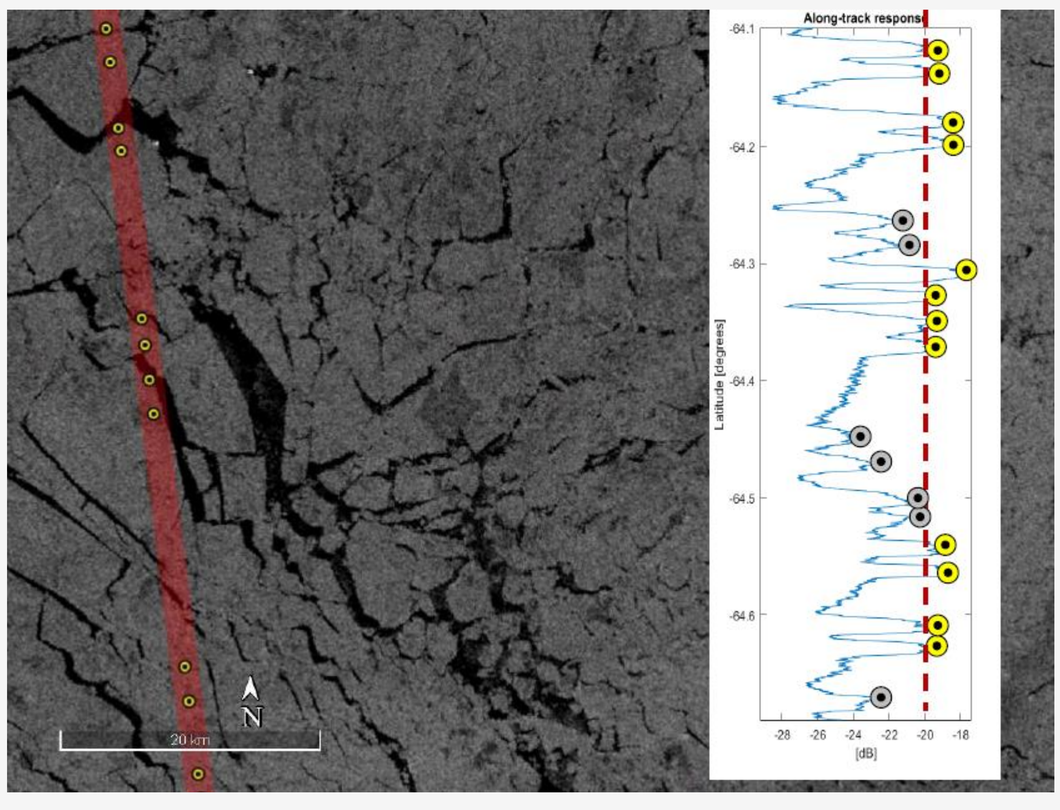
Fully-Focused 2-D response over transponder (CryoSat-2 data)



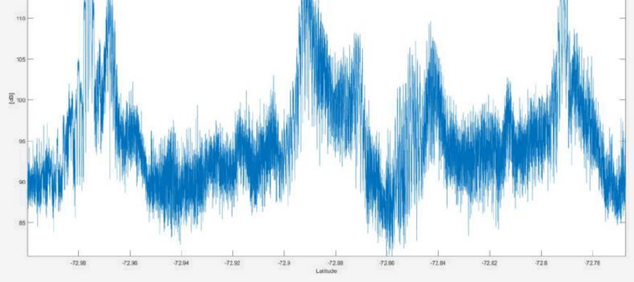


RESULTS

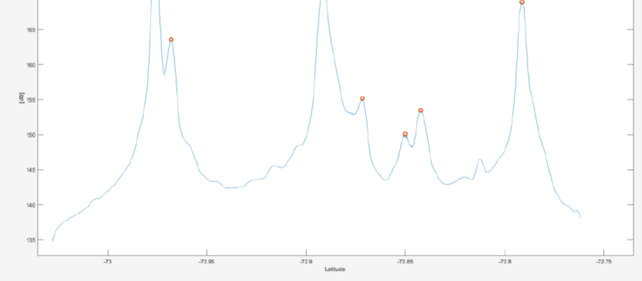
CryoSat-2 Along-Track processed signal with Sentinel-1 image



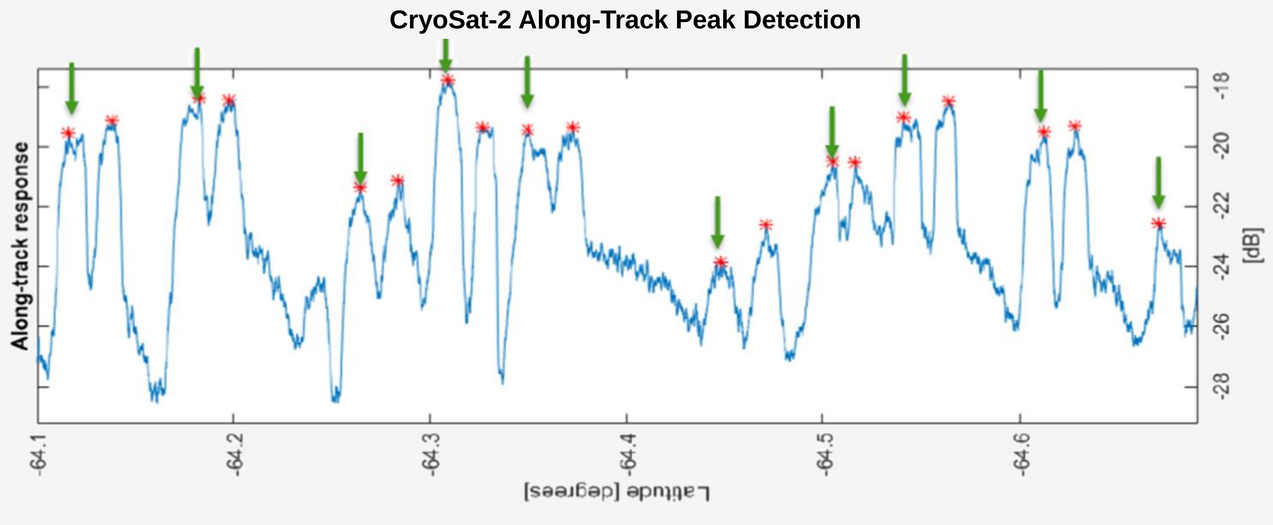
CryoSat-2 Fully-Focused 2-D Along-Track signal over ice



Post-processed Along-Track signal



CryoSat-2 Along-Track Peak Detection



CONCLUSIONS

A lead detection algorithm using Fully-Focused processed data has been developed. This algorithm is able to determine the position of leads and estimate its width despite the fact that along-track replicas interfere the main signal due to the closed-burst mode of the altimeter instrument.

The detection algorithm has to be trained in order to estimate processing parameters such as the peak prominence, the peak power threshold or the peak bandwidth. In order to train the algorithm, validation data has to be recollected and processed.

Since maximum range power is taken, off-nadir detections cannot be determined. Leads detected seem to appear in pairs, due to the interference of the replicas. As the along-track signal is obtained by taking the maximum energy of each range samples, the position of leads off-nadir cannot be determined.

References

[1] Egido, A.; Smith, W. Fully Focused SAR Altimetry: Theory and Applications. IEEE Trans. Geosci. Remote Sens. 2017, 1–15.