Fully-Focussed iceberg detection with Sentinel-6 data and prospects for CRISTAL

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ABSTRACT

Sentinel-6 is an operational oceanography programme consisting of two satellites that will map the sea surface levels with great precision. Sentinel-6 includes two identical satellites with the first launched on November 21, 2020 (Sentinel-6 Michael Freilich) and the second scheduled for launch in 2025 (satellite B). Following its launch, the Sentinel-6 Validation Team (S6VT) has carried out validation activities with Sentinel-6 Michael Freilich data for more than a year to ensure the best possible outcome of the mission.

Thanks to the transmission pattern of the Sentinel-6 Poseidon-4 altimeter (continuous transmission at 9kHz PRF, Open Burst mode), the data can be processed using Fully-Focussed SAR techniques, which enables a much better along track resolution and also better scene focussing. This is highly beneficial over sea ice areas, where the coherence of the scene is kept during the illumination time and very detailed features, such as small leads and icebergs, can be precisely acquired.

This work will show how we can use Sentinel-6 Poseidon-4 radar altimeter data over sea ice waters to detect the presence of small icebergs and extract useful parameters from them. Furthermore, we will show the improvement obtained in resolution when analysing the data using Fully-Focussed techniques over conventional unfocussed SAR processing.

Nevertheless, carrying a single radar antenna (as it happens in the Sentinel-6 Poseidon-4 radar altimeter) severely reduces the number of parameters we can extract from the detected icebergs using this technique, as well as not allowing us to locate them with precision.

The future Copernicus Polar Ice and Snow Topography Altimeter mission (CRISTAL), with an expected launch on 2027, will carry on-board as its main payload the IRIS altimeter. Amongst other improvements with respect to previous missions, a key feature from the IRIS altimeter will be the use of 2 antennas in the Ku band allowing the determination of the across track location using the SAR interferometric (SARIn) information. The use of an interferometric mode greatly improves the information we can extract from the small icebergs detected, as well as to locate them with great precision with respect to the satellite track.

To finalise this work, we will show which are the future prospects regarding iceberg detection for CRISTAL, and how it will allow us to combine the Fully-Focussed analysis techniques used during the S6VT activities with the SARIn mode to maximise the information and resolution we can obtain detecting icebergs.

SCENARIO

Sentinel-2 image taken on 07/01/2021. It corresponds to an open waters region northeast of South Georgia populated with icebergs. Sentinel-6 track from 08/01/2021 is drawn in red.

On July 2017, A68 iceberg calved from the Larsen-C ice shelf. After a year of barely moving, it started its slow drift towards the north. By the end of 2020, and close to the dates when Sentinel-6 lifted off, it approached the coast of South Georgia. It slowly broke down into pieces during the following months, spreading its fragments into the southern seas.

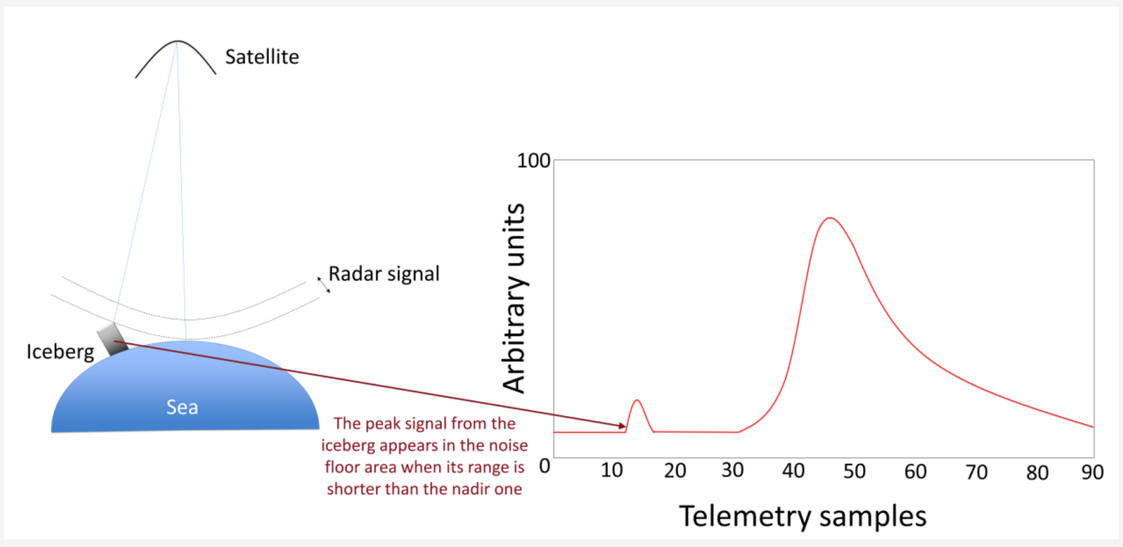
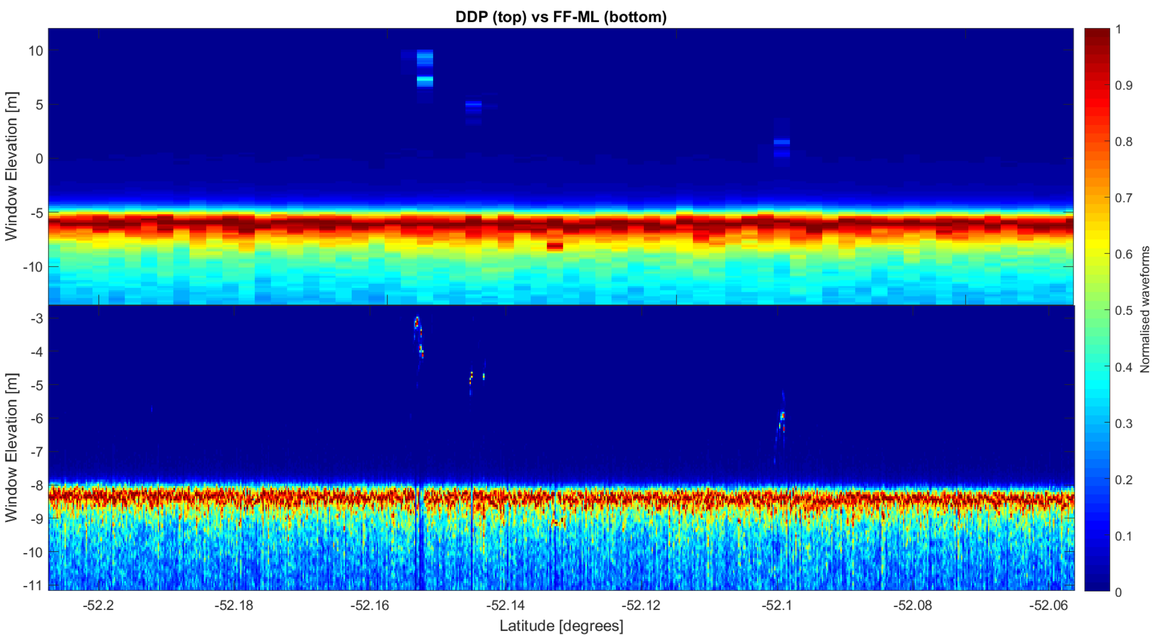


Diagram explaining how the iceberg signature is found in the thermal noise part of the altimetry waveform when the signal range is shorter than the nadir one.

As indicated by Tournadre, J. et al. [1], small icebergs leave a signature in the thermal noise part of altimetry waveforms over open ocean. This happens when the range of the radar signal bouncing on the iceberg is shorter than the nadir range.

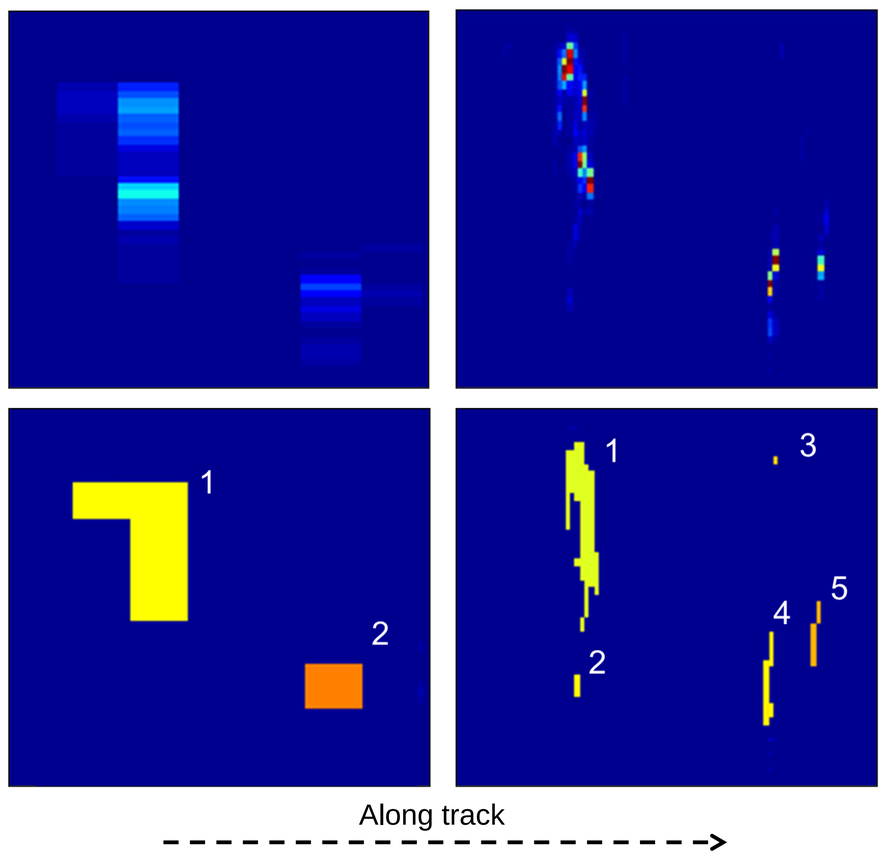
ANALYSIS



*Along-track waveforms of Sentinel-6 near iceberg fragments shown on previous image on 08/01/2021. (*Top*) Conventional unfocussed SAR processed waveforms, with an along-track resolution of ~300 m. (*Bottom*) Fully-Focussed Multi-Looked processed waveforms, with an along-track resolution of ~25 m.*

In the upper figure we can observe the comparison of the signature of icebergs in the thermal noise part of the Sentinel-6 altimetry waveforms for conventional unfocussed SAR processing and Fully-Focussed Multi-Looked processing.

During the analysis of this segment, a total of 8 regions/icebergs could be differentiated in the unfocussed SAR waveforms, in contrast with 34 regions/icebergs in the FF-ML waveforms.



*Zoom in an iceberg detection area of the Sentinel-6 waveforms, and comparison of the resolution between unfocussed SAR, with along-track resolution of ~300 m (*left*) and Fully-Focussed Multi-Looked, with along-track resolution of ~25 m (*right*).*

Here we can see how the improvement in along-track resolution allow us to differentiate between icebergs that appeared to be the same in unfocussed SAR waveforms, and even to detect new ones which could not be detected before.

CONCLUSIONS

- The method has been implemented and preliminary results are obtained with Sentinel-6 FF SAR products.
- The improved along-track resolution (from ~300 m down to ~25 m) allows to better detect small icebergs and the surface of the big ones can be better determined.
- Thanks to the interferometric capabilities of CRISTAL, the uncertainty of the iceberg location, surface and volume can be improved when compared with the current results obtained in Sentinel-6.
- The polar orbit of CRISTAL will enable the monitoring over the most common iceberg paths.

References

[1] Tournadre, J., Whitmer, K., and Girard-Ardhuin, F. (2008), Iceberg detection in open water by altimeter waveform analysis, *J. Geophys. Res.*, 113, C08040, doi:10.1029/2007JC004587.