DeDop

Fully Adaptable and Configurable Altimeter Delay Doppler Processor

Sentinel 3 For Science – SAR Altimetry Studies

SEOM Study 1. SARAE

DeDop Case Study Report Arctic Sea Ice

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1 Introduction

1.1 Purpose

This document is the case study report for an investigation into the use of DeDop as a tool for the rapid prototyping of different methods of L1 SAR-mode altimetry data processing and assessing the impact of the different methods on the recovery of sea-ice parameters in L2 processing.

As an example of how this can be achieved, this document presents the results of processing a track of Cryosat-2 data used in the commissioning of the sea-ice processing chains. The track is processed multiple times, with different configurations of L1 processing in DeDop. The impact on the L2 results is shown.

The contents of this document are distilled into a set of Powerpoint slides suitable for use in teaching others how to replicate this processing – see the annex.

1.2 Document structure

This section should provide a brief overview of the outline structure of the document.

1.3 Acronyms

AD	Applicable Document
DDP	Delay-Doppler Processor
DMP	Data Management Plan
ESA	European Space Agency
HRM	High Resolution Mode
ISP	Instrument Source Packet
L1A	Input file with geo-located bursts of Ku echoes. The calibrations are not applied. Each record contains 1 SAR burst of aligned but not-calibrated echoes
L1B-S	Output file with fully processed and calibrated SAR complex echoes, arranged in stacks after slant range correction and prior to echo multi-looking
L1B	Output file with fully calibrated multi-looked power echoes (SAR)
L2	Output file with geophysical measurements
MSS	Mean Sea-Surface
RD	Reference Document
SAR	Synthetic Aperture Radar
SHA	Surface Height Anomaly

1.4 References

1.4.1 Applicable Documents

AD. 1

1.4.2 Reference Documents

RD. 1 S. W. Laxon and C. G. Rapley, “Radar altimeter data quality flagging,” *Advances in Space Research*, vol. 7, no. 11, pp. 315–318, 1987

RD. 2 Wernecke, A., Kaleschke, L., 2015. Lead detection in Arctic sea ice from CryoSat-2: quality assessment, lead area fraction and width distribu- tion. Cryosphere 9, 1955–1968.

RD. 3 M. Passaro, F. L. Müller, and D. Dettmering, “Lead detection using Cryosat-2 delay-doppler processing and Sentinel-1 SAR images,” *Advances in Space Research*, vol. 62, no. 6, pp. 1610–1625, 2017.

2 Case Study Description

2.1 Scientific / Technical Context

The discrimination of the surface type is a key stage in sea-ice processing of altimetry data. Ocer sea-ice, the most important measurement required is sea-ice freeboard. To compute this, we must derive both the height of sea-ice floes, and what the height of the ocean surface would have been if the sea-ice floes were not present. Subtracting one from the other gives the sea-ice freeboard. To compute what the height of the ocean surface would have been, we must interpolate between available measurements of the sea surface where it is free from sea-ice. We therefore need a method of discriminating between what are measurements of the sea-ice and what are measurements of the ocean. Crucially, we need to reject any measurements for which we are not sure, as incorrectly classified records will badly contaminate the results.

To discriminate correctly, we need to derive metrics from the altimetry data that differentiate clearly between different surface types. Waveform peakiness [R1], backscatter [R2] and other metrics based on the shape of the stack of SAR beams [R3] have all been used for this purpose in the past.

The configuration of the L1 processing is therefore crucial in optimising the retrieval of geophysical parameters in L2 processing as it has a major impact on waveform shape. For Cryosat, it was found to be optimal to zero-pad the waveforms and apply Hamming weighting within the L1 processing. Performing a study to determine the best combination of processing parameters (or implement new options for testing) using the operational processing chains is cumbersome. An agile processing tool such as DeDop makes performing such a study much easier.

2.2 Objective / Purpose of Case Study

The purpose of this case study is to show that DeDop is a useful tool for investigating the performance of different methods of processing altimetry data to extract metrics necessary to perform the sea-ice discrimination

2.3 Input Data Sets (including auxiliary and validation data sets)

The input dataset for this study is a single track of Cryosat FBR data that was used for validation purposes during the Cryosat commissioning phase. This track of data is of particular use, because there is a co-temporal (only a few hours difference) ASAR image that clearly shows leads in the sea ice, and the leads are wide enough that several surface samples are formed while the satellite overflies them.

The Cryosat FBR file is:

`CS_LTA__SIR1SAR_FR_20120329T112952_20120329T113436_C001.DBL`

The ASAR file is:

ASA_WSM_1PNPDE20120329_183748_000002323113_00128_52728_7536.N1

2.4 DeDop Tool Processing Specifications and Description

The input FBR data is passed through the DeDop processor once for each of the numbered configurations listed below. The configurations state which parameters have been altered from their default state:

1. No alterations
2. x2 zero padding
3. 32 bin Hamming weighting
4. 32 bin Hamming weighting and x2 zero padding
5. 64 bin Hamming weighting
6. 64 bin Hamming weighting and x2 zero padding

The zero padding is configured by editing this parameter in the CNF.json file:

```
  "zp_fact_range_cnf": {
    "value": 2,
    "units": null,
    "description": "Zero padding factor used during range
compression"
  },
```

The Hamming weighting is controlled by the following parameters:

```
  "flag_azimuth_windowing_method_cnf": {
    "value": "hamming",
    "units": "flag",
    "description": "Flag the sets the azimuth windowing method:
Disabled ('none'); Boxcar ('boxcar'); Hamming ('hamming'); Hanning
('hanning')"
  },
  "azimuth_window_width_cnf": {
    "value": 32,
    "units": "count",
    "description": "Width of Azimuth window (minimum value: 32,
maximum value: 64)"
  },
```

2.5 Additional Post DeDop Processing

Post-processing is performed in IDL. The routine used are:

- dedop_discriminate(), performs a discrimination of the surface types.

- dedop_retrieve(), retrieves a surface height anomaly by retracking and subtracting the mean sea surface, and an interpolated surface height anomaly between leads in the sea-ice
- dedop_zscope_shifted(), used to plot a zscope image of the radar waveform that has been aligned to surface height anomaly values

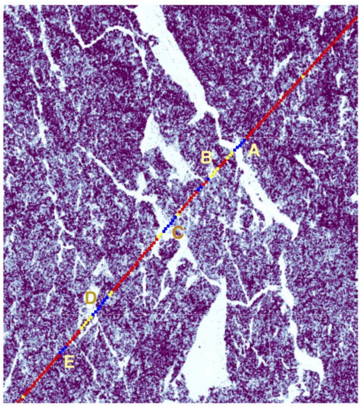
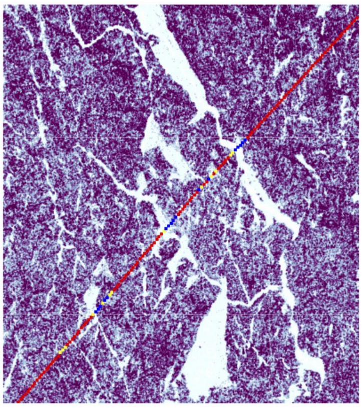
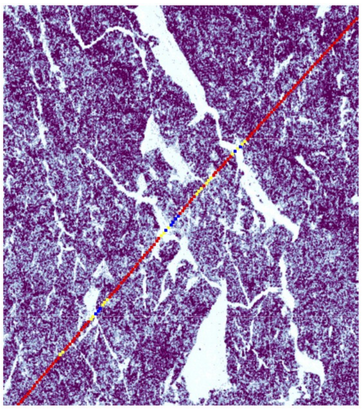
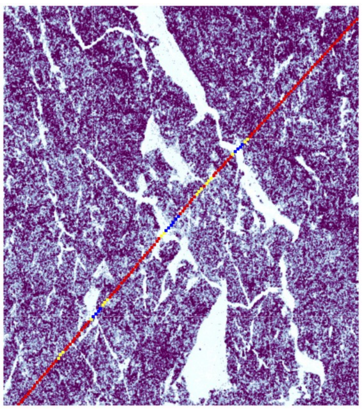
3 Analysis of Case Study Output

3.1 Technical / Scientific Results

The netCDF format L1b data output by DeDop was read into an IDL program that performs a discrimination of the surface types present in the data. The surface type is then over-plotted on an ASAR image of the surface:

- Red Sea-ice floe
- Blue Lead in sea-ice
- Yellow Indeterminate, rejected

There is an approximately 7h difference in time, so an exact match is not expected, however all of the images in Figure 1 show a clear correspondence.

	No ZP	x2 ZP
0 Ham		
32 Ham		

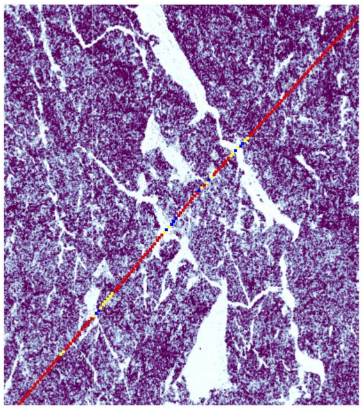
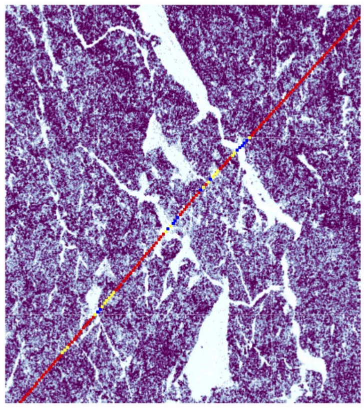
64 Ham		

Figure 1: Discrimination results by processing options chosen

Reviewing the results of changing the processing options, it is apparent that applying the Hamming weighting has converted the incorrect lead detection at ‘E’ into unknown returns. Overall, the move from 32-bin Hamming to 64-bin reduces the number of lead detections over the primary crossings and introduces some near ‘B’ that had been removed by the introduction of weighting. Since this is a complex region, rejecting those detections is the better option. Therefore the 32-bin weighting is performing best at this stage.

It is also immediately apparent that the discrimination result is significantly dependant on the processing options chosen. The default options of no zero-padding or weighting has done well. All three major lead crossings are detected, and the major traverses of the sea-ice are all detected as such (red). However, there is also a lead detection in a region of sea-ice (marked ‘E’) and the lead detections cover the entire lead, including contaminated regions with complex echoes near the edges. The ideal result would sacrifice the number of lead detections for a few, high-quality results towards the middle of the leads.

Comparing the surface height anomaly retrieval and surface type discrimination for the default case (no weighting or zero padding) against the best performing case (32 bin Hamming weighting and x2 zero padding) shows that the weighting reduces power ahead of the leading edge aliased from bright leads.

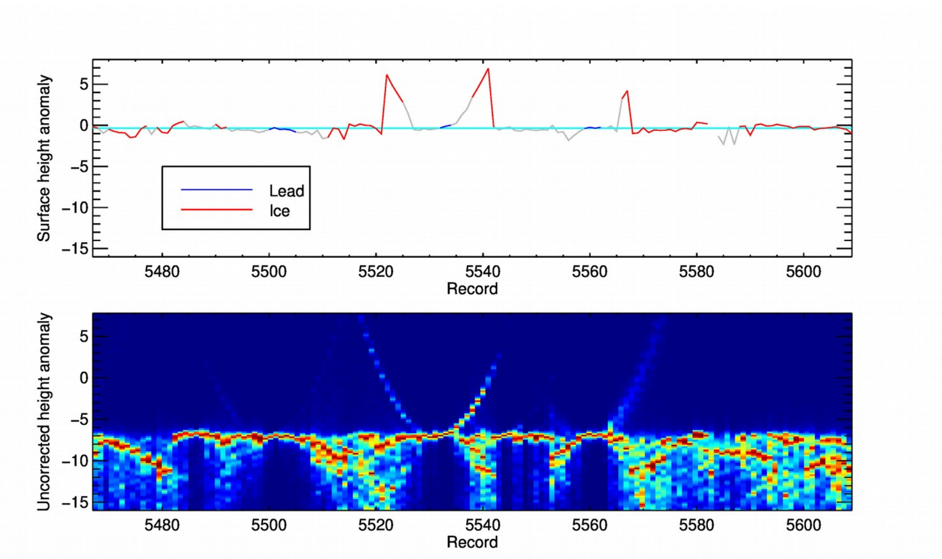


Figure 2: DeDop Default configuration

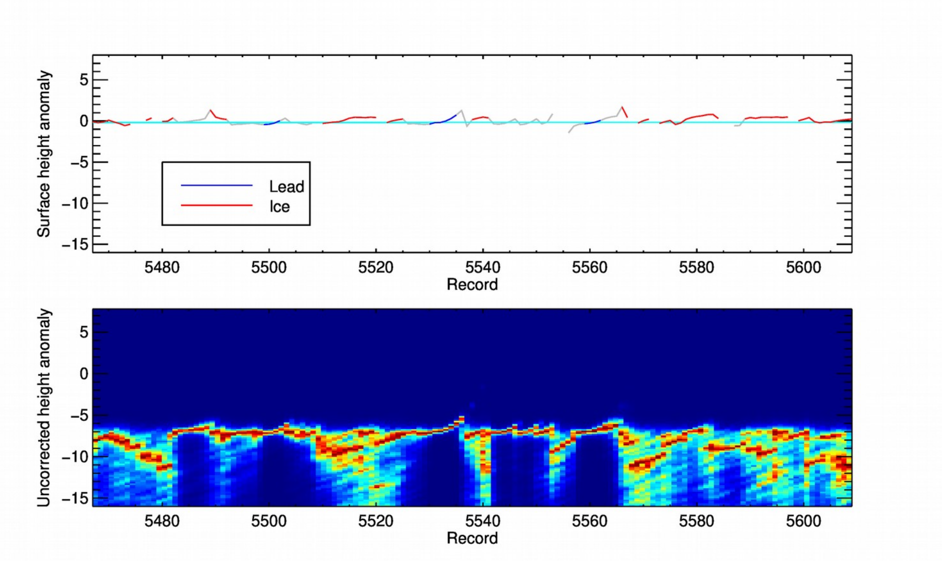


Figure 3: Dedop configured for 32 bin weighting and zero-padding

Figure 2 shows the upturned 'U' shape of the lead power and it has been removed in Figure 3. The improved resolution has also had an effect on the retrieved height of the sea-ice compared to the interpolated sea-surface height anomaly, giving a generally positive freeboard for records discriminated as sea-ice. The cyan line is an interpolated SHA that is subtracted from sea-ice SHA values to give sea-ice freeboard.

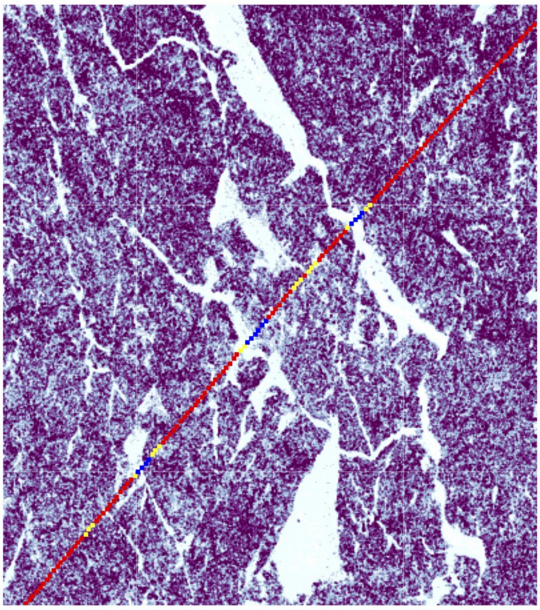
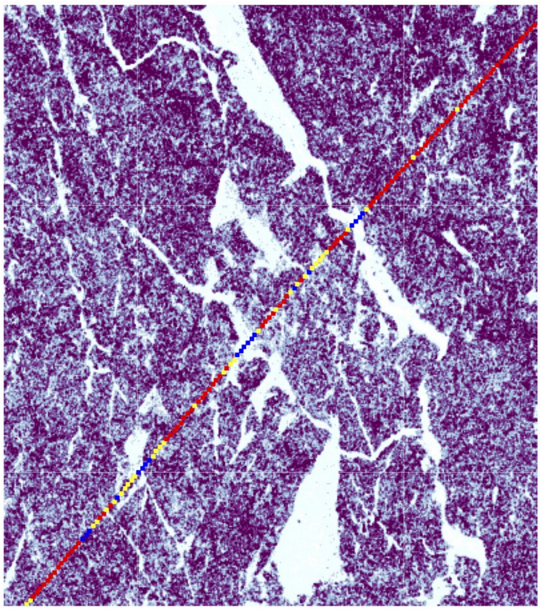
3.2 Impact of Different DeDop Processing Configurations

This case study shows that manipulating the available processing options in the DeDop processor configuration file has a demonstrable effect on the processing of the waveforms in L2 sea-ice processing. Altering the zero-padding and the Hamming weighting options has a similar effect to the corresponding changes that were made to the Cryosat L2 processing.

A plug-in architecture for the DeDop processor would allow users to add new forms of weighting, as needed for a study but (as DeDop is open-source) users can just modify the processor directly if needed, so a defined architecture would only provide a minimal simplification.

3.3 Product Validation Report

The following images compare the best of the DeDop produced results against released Cryosat data.

DeDop (32 bin Hamming and 2x zero-padding)	CS2 reference results
	

The DeDop processing is actually causing fewer spurious detections that the Cryosat processing. It is possible that this is due to the tuning of the discrimination parameters, as the DeDop results do not have the same numerical values of peakiness as the Cryosat results. Also, the Cryosat processing places the surface samples in slightly different locations along the track, so it is not an exact 1:1 comparison.

3.4 DeDop Processor and Tool Performance

The DeDop tool was simple and quick to configure and allowed multiple different L1 processing configurations to be tested. This case study produced no recommendations for necessary changes or improvements to the tool.

4 Conclusions / Recommendations

DeDop is an effective tool for prototyping L1 processing changes and assessing the impact of those changes on L2 processing.

Continuing to develop DeDop and expanding the design to include the ability to process data from other missions is recommended.

Annex A. Presentation of Case Study: Sea-Ice Case Study

A presentation, suitable for use as a teaching resource, is contained in the Powerpoint file DeDop_UCL_Sea_Ice_Case_Study.pptx delivered with this report.

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