Improved Waveform Classification in the Arctic

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sea level cci

Introduction

There are now almost two decades of near-continuous radar altimetry from ERS-1, ERS-2 and ENVISAT satellites, enabling long-term studies of changes in sea level and ocean circulation. The ESA-funded Sea Level Climate Change Initiative (CCI) had recognised that the Arctic Ocean is one region where further research is required to fully exploit the altimetric record.

Specifically, the challenge is to distinguish between altimeter signals coming from open ocean, sea ice and narrow cracks within sea ice known as leads.

Figure 1 (left): Leads observed in the sea ice on 26/03/2011 (NASA Earth Observatory).

Sea Ice Classification

An altimeter return from a flat ocean surface will result in a Brown-like waveform. A reflection from pure sea ice may be something similar, but with a greater reflectance. However, in the case of leads within the sea ice, providing very flat water, the signal is expected to consist of a sharp peak without a declining tail.

One way of recognising such waveforms is through the large variability in power (P) characterised by pulse peakiness (pp). For the RA-2 altimeter on ENVISAT, Lillibridge et al. (2004) define peakiness as:

$$pp = \frac{82 \times P_{max}}{\sum_{i=0}^{127} P_i}$$

At PML we are working on improving existing classification and retracking techniques originally developed for the Sea Ice CCI project. The structure for the new sea level retracker, is shown in Figure 2.

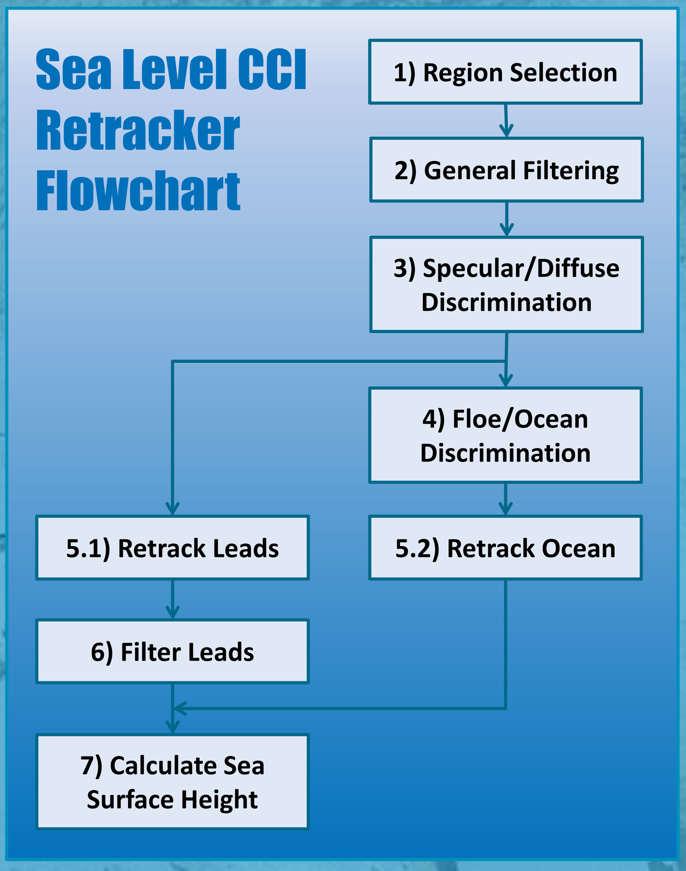

Figure 2: Flowchart for the Sea Level CCI retracker (based on an earlier figure from the Sea Ice CCI ATBDv0, 2012).

Implementing a New Retracker

The power in a Brown-like waveform is given by:

$$P(t) = P_{PTR}(t) * P_{PSF}(t) * PDF(t)$$

where:

$$P_{PSF}(t) = F[\sigma_0(\varphi)]$$

By using a non-coherent backscattering model for surface roughness to give a new expression for σ_0, waveforms which are in-between highly specular and Brown-like returns can be more accurately modelled.

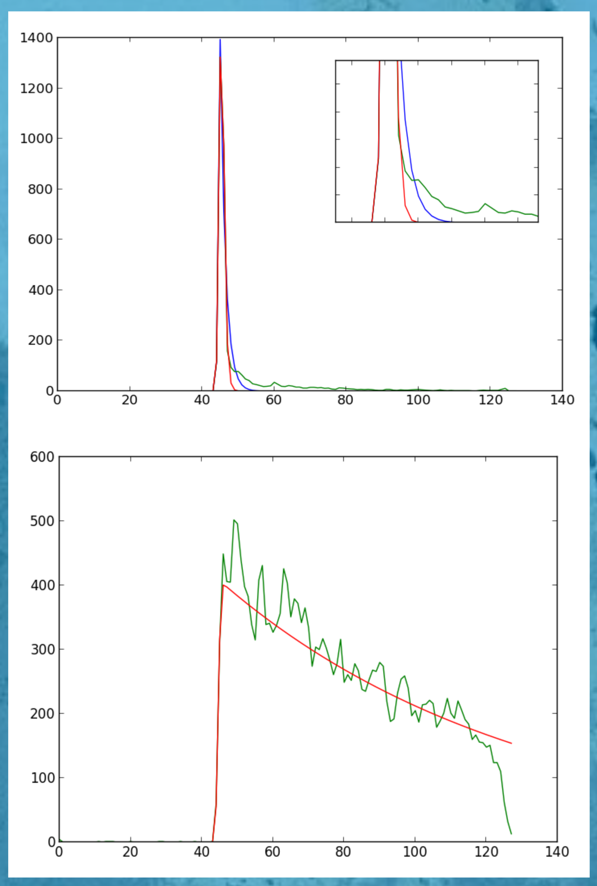

Figure 3: (Top) Lead retracking: measured waveform (green), simulated waveform (blue) and extended Brown model (red). (Bottom) Floe retracking: measured waveform (green) and extended Brown model (red).

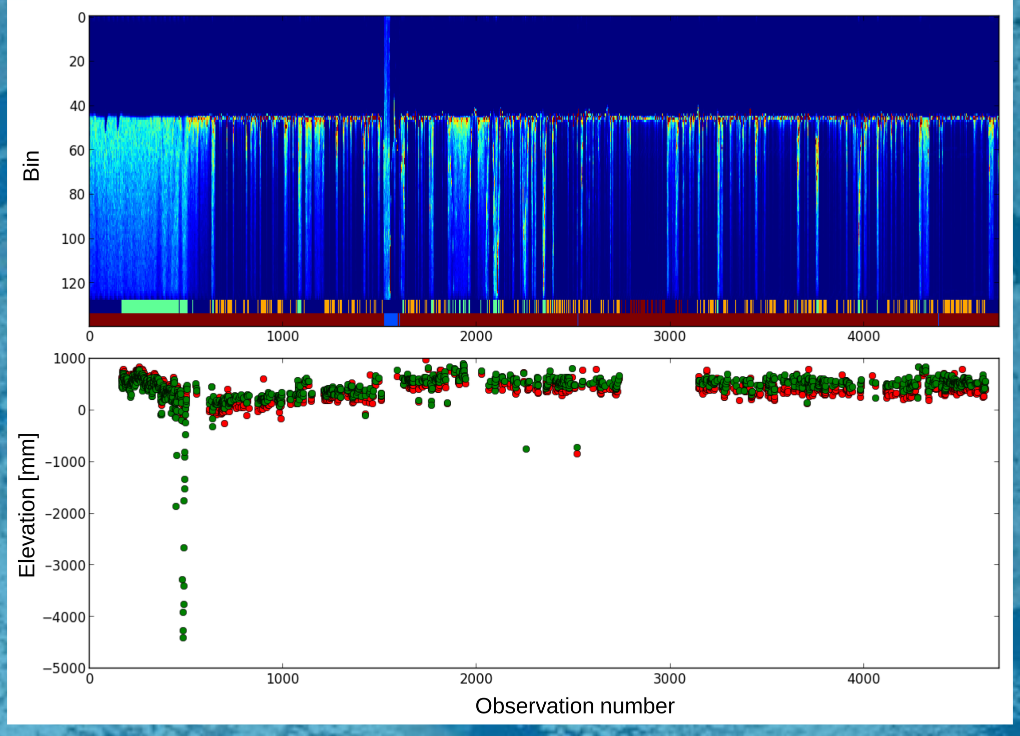

Figure 4: 2D waveform and corresponding elevations from the original (red dots) and new (green dots) retracker algorithms.

A 2D waveform plot of a RA-2 track from May 2009 is shown in Figure 4, along with a comparison of elevations from the existing retracker and the new retracker algorithm.

Lead Classification

Figure 5 show the percentage of altimeter returns classified as leads for the period Jan-June 2009. As the months progress there is a distinct increase in leads, particularly around the spring melt in April.

However, by June the majority of sea ice surfaces are classified as leads; this is likely to be the result of melt ponds forming on the surface of the ice during the summer months which result in specular returns, similar to those resulting from leads. Further work is required to discriminate between these two types of specular return.

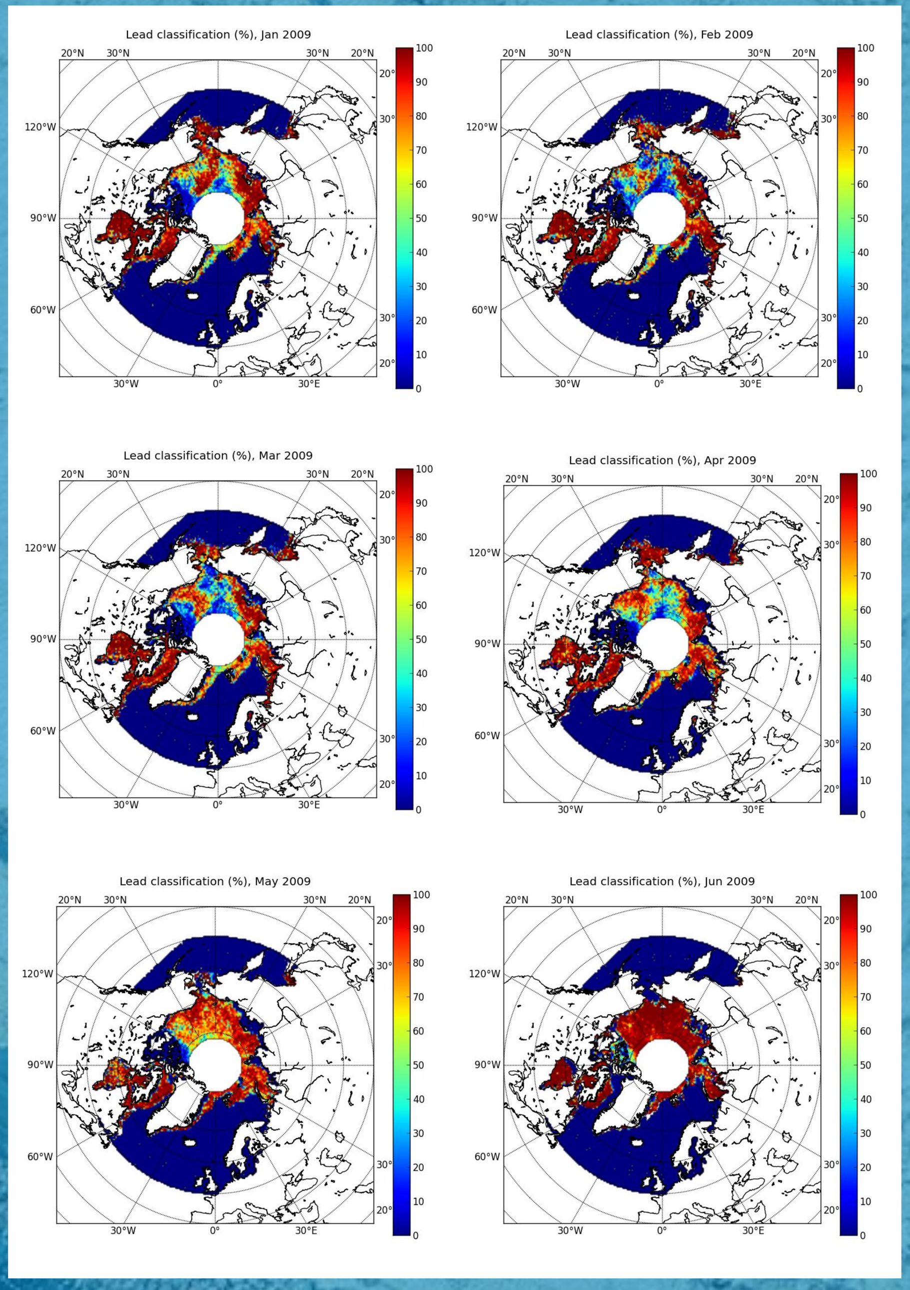

Figure 5 (right): Lead classification maps showing the percentage of RA-2 returns classified as leads per month, for the period Jan-June 2009.

Multi Sensor Match-Ups

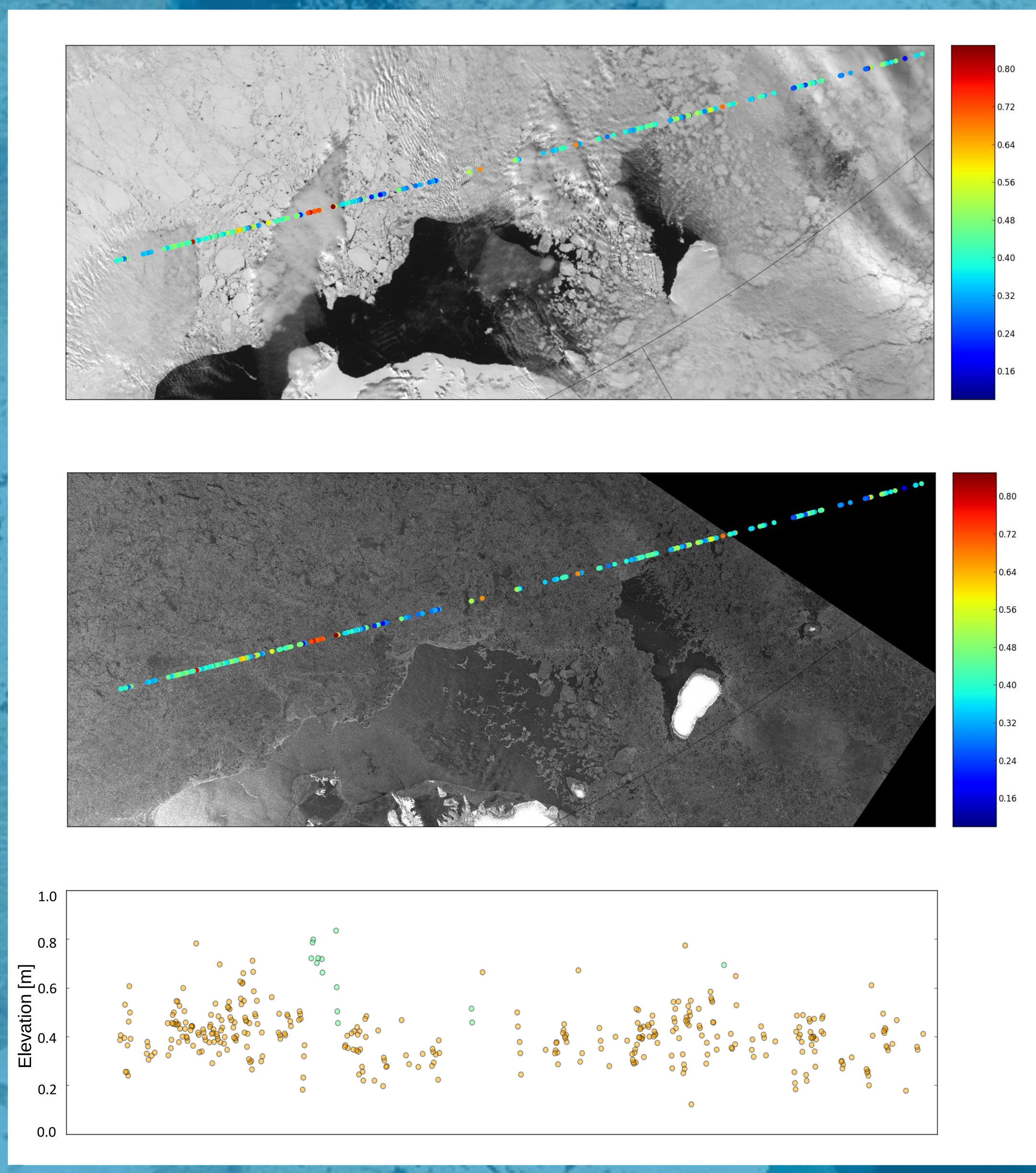

Figure 6: Match up of a RA-2 track from 09/05/2009 with coincident MERIS (top panel) visible data and SAR (centre panel) data. The lower panel shows elevation, coloured by the surface classification type (leads yellow, floes green).

In order to validate classification results, we have begun to match RA-2 altimetry data to coincident Synthetic Aperture Radar (SAR) data and data from optical sensors such as MERIS.

MERIS full resolution (300 m) optical imagery allows the identification of fine scale topographic features, such as ice ridges, and can be used to easily distinguish ice from ocean. However, optical images can be obscured by thick cloud, particularly at northern latitudes, whereas SAR data are not. Using a combination of data from both sensors therefore allows a comprehensive validation of the altimeter surface type classification.

Future Work

We intend to process several years of RA-2 data using the extended Brown model retracker, to obtain a new sea level dataset for the Arctic. To validate our results we will perform further RA-2 track match-ups with MERIS and SAR scenes.

We also intend to investigate the source of parabolic features seen in some 2D waveform plots (see Figure 7), which hint at strong reflectors on the surface, such as ice ridges. This will help to improve the accuracy of the current lead and floe classification scheme.

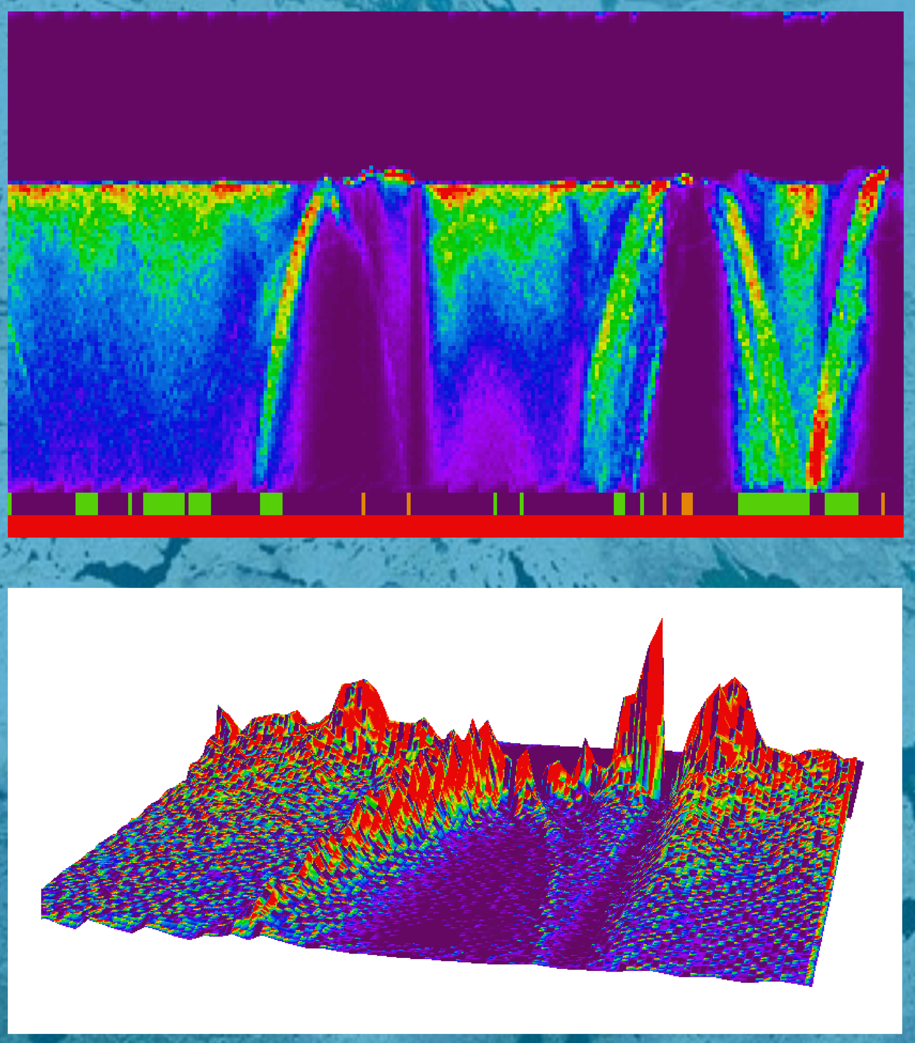

Figure 7: (Top) 2D waveform plot showing two well defined parabolic features, with lead (orange) and floe (green) classifications shown. (Bottom) The corresponding 3D representation.

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References:
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Laxon, S., 1994, Sea ice extent mapping using the ERS-1 radar altimeter, EARSeL Advances in Remote Sensing, Vol. 3, No.2 – XII.
Lillibridge, J., Scharroo, R., and Quartly, G., 2004, Rain and ice flagging of ENVISAT altimeter and MWR data, Proc. of the 2004 ENVISAT and ERS Symposium, Salzburg, Austria, pp 6.
Background image: ESA (http://www.esa.int/spaceinimages/Images/2008/02/The_Canadian_Arctic_Archipelago).

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