Sea ice melt pond fraction estimation from dual-polarisation C-band SAR – Part 2: Scaling in situ to Radarsat-2

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General Comments

The paper reports on retrieval of melt pond fraction on first-year ice (FYI) using SAR using Radarsat-2 (RS-2) quad-polarisation images. The study finds that the two co-polarized (HH and VV) channels, when used to calculate the polarization ratio VV/HH, can indicate the melt pond fraction during the middle part of the melt season. The authors suggest this may offer a means of providing wide-scale melt pond fraction mapping for process studies, but there are a couple of issues that limit its practicality:

1. At present it is not common to have HH and VV supplied together except in limited coverage (25x25 km) quad-polarization scenes, and the widespread coverage of most operational users is wide swath (400 km) dual-polarization HH+HV or VV+VH. To be widely applicable, this approach will have to wait until full polarimetric data becomes more widely available, perhaps with the future Radarsat Constellation Mission (RCM) around 2018.

2. The algorithm exploits the dominant effect of high dielectric free-water ponds on the polarization ratio at moderate to high incidence angles (about 40° and above). This again limits its applicability as wide swath images, with the demise of Envisat typically ScanSAR Wide (SCWA) on Radarsat-2, cover the approximate range 20 to 49 degrees incidence angle.

The title of the paper is slightly misleading. On reading, this reviewer and anyone from the operational community reading it, would assume that by dual-polarization SAR the authors are referring to the large volumes of wide swath data that are being acquired. It is a bit of disappointment to find on reading the paper, that these are in fact quad-pol images from which an uncommon channel subset has been extracted.

The algorithm was applied to images acquired at 5 discrete points in time during May-June 2012 at one location in the Canadian Archipelago. The question is how representative are these for ice conditions across the whole Arctic. Because there are only 5 time points, it is difficult to compare the temporal evolution of the melt ponds observed using this technique with the supporting environmental data or to see if the technique is sufficiently robust. As each of the images over the Parry Channel were 4 of the 25x25 km scenes mosaiced together, there were a total of 17 RS-2 scenes used in this study. It would have been better to have acquired these at 17 different times over the field site so as to better evaluate whether the technique is really capturing melt-pond fraction. The study would have benefited from a larger number of images from different locations and years to see if the history of the ice plays any role in the results, and to increase the reliability of the error statistics. The Canadian Ice Service is acknowledged as providing support, and it is surprising that more areas featuring undeformed first-year ice during the melt season could not be identified for analysis given that organizations large ice chart and RS-2 image archive.

In general the paper is well written, and the data acquisition, processing, and analysis methods are scientifically sound and described in sufficient detail. The technique looks promising, and it would be good to see this study expanded to see if the results are still valid for different areas where there are differing environmental conditions.

Specific comments

Abstract

P846/L14 - The abstract says the algorithm was developed in 4 images, not 5.

P846/L17 - Expand root-mean-square error (RMSE) here rather than leaving it until section 3.3 (P858/L18).

Introduction

P848/L20 - "Data from these sensors have been used to identify pond formation...". Passive microwave and scatterometer data is generally more applicable to providing a synoptic estimation of melt pond formation that could then be used in large-scale models. Yes, it would be nice to have high resolution data from SAR but the coverage is limited.

2.2 Bragg scattering model

P852/L5 – The validity criterion $k\,s < 0.3$ but the roughest ponds exceed this limit (P848/L28). Whilst a simple wind speed threshold is unsatisfactory due to the contribution of the ice morphology, is it possible to also introduce a sea ice type classification into the filtering to identify area where this may occur?

3.2 Data processing

P858/L3 - "A 75 by 75 pixel square...". Give dimensions in meters. Same for "60 by 60" at P858/L6.

3.3 Pond fraction retrieval

P859/L8 – What does "Full-resolution" mean here? In the context, I think it means the undersampled RS-2 scenes described in the pre-processing (P856/L11), but it could be confused with use of the original image data at full resolution.

4.1 Seasonal evolution of pond coverage and SAR backscatter

P859/L23 – Quantify how much variation is due to incidence angle.

4.2 Spatially distributed polarization ratios and pond fractions

P861-P862 – The change in relationship due to a possible slight refreezing is interesting. This makes it difficult to see how the method could be applied to a wider scale study, using operational SAR coverage, without good supporting meteorological and optical satellite data to get surface temperatures and cloud cover.

4.3 Pond fraction retrievals

P863/L9 - "Spatial patterns of retrieved melt pond fractions, created by globally applying Eq. (8) to the PR bands from the RS-2 dataset, are shown in Fig. 6.". The caption for Figure 6 says that the maps are constructed using the cross-validation retrieval method. However, this is Eq. 9 in the text, Eq. 8 refers to the scatterometer PR function.

P864/L18 – What is "the Cscat PR model"? Is this the scatterometer PR model from 3.3?

5 Discussion

P865/L10 – Sentinel-1 will be dual-polarisation with HH+HV or VV+VH. It will not have an HH+VV mode. The only potential C-band SAR satellite constellation that addresses the need for HH+VV is the RCM with its compact polarimetry mode.

6 Conclusions

P867/L23 – The methods are only applicable to FY undeformed ice. In the Arctic Ocean , with more deformation processes occurring, it will difficult to find large larges of level ice except in

some of the fast ice around northern Greenland and the Russian shelf seas.

Technical corrections

P856/L23 – Should be “method”, not “metods”?

P883 – R1, R2, R4, and R5 panels could do with being enlarged, and less space taken up with the R3 panel and legend.