Potential of RADARSAT-2 for Sea Ice Classification

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Abstract – **Polarimetric data acquired by the CCRS CV-580 airborne SAR is used to assess the capability of RADARSAT-2 for operational sea ice classification. The information content of the polarimetric data is illustrated by showing how specific scattering mechanisms are portrayed by the entropy, anisotropy and α-angle features. Ice type classes are derived from the full pol data set using a complex Wishart classifier. The classes are then mapped into 2-D scatterplots to compare the information content between dual and fully polarimetric data. While dual pol data is an improvement over single channel data, it is found that fully polarimetric data is needed to provide accurate ice classification performance.**

I. Introduction

Because of its all-weather operation, sensitivity to surface roughness and wide coverage, satellite SAR has proven to be an ideal instrument for sea ice monitoring. RADARSAT-1 has met most of the operational requirements of the sea ice community [1] and the Canadian Ice Service (CIS) is one of the world's largest users of its data [2]. Current operational satellite SAR sensors only provide single polarisation data, and image classification is based on the received intensity. However, uncertainties are often present that make reliable and accurate classification a difficult task if no additional data is available.

The next generation satellite, RADARSAT-2, will have increased capabilities such as dual and fully polarimetric modes. To help assess the capabilities of these channels for sea ice classification, the Canada Centre for Remote Sensing (CCRS) acquired fully polarimetric (quad pol) airborne SAR data off the north coast of Prince Edward Island in March 2001. The sensor was the C-band polarimetric SAR on the Canadian government's Convair-580 aircraft.

This paper will discuss the potential of dual and fully polarimetric SAR data for operational sea ice classification. Using the Convair data, possible dual and fully pol data of satellite SARs are emulated. Starting with a classification result obtained with the complete data set, we show how dual pol data cannot provide the same degree of class separation.

II. Description Of The Test Data

The scene (L5P2) contains first year ice (FYI) in various stages of development. Land-fast ice with a smooth surface is present near the coast and deformed and ridged ice is found further off shore. A RADARSAT-1 scene covering the same area is also available, as well as a limited amount of ground truth. The average air temperature was reported to be approximately –5°C. A detailed ice map provided by the Canadian Ice Service shows thin FYI between 30 and 70 cm as the main cover, occurring in large ice floes with a width between 500 m and 2000 m. Two other ice types, grey ice (10-15 cm thick) and medium FYI (70-120 cm thick) are also present in the scene.

III. Analysis of the Data

We use an unsupervised classifier based on the complex Wishart distribution to assess the information content of the data [3]. This classifier showed promising results with AIRSAR sea ice data [4]. The classifier used eight initial classes, and a minimum distance metric completely separates the final classes. The classification result is shown in Figure 1, using the classes and corresponding colour assignment described in Table I. The classes were then manually interpreted with respect to ice types and the spatial distribution of classes suggested that a reasonable classification was made.

In a second step, scatterplots of the co- and cross-polarised backscatter magnitudes were produced. Two data pairs were chosen: VH-VV representing the dual polarisation capability of RADARSAT-2 and HH-VV representing the alternating polarisation mode of ENVISAT ASAR. Five of the eight classes derived by the Wishart classifier from quad pol data were chosen to colour code the scatter plots. They included the four most prominent ice classes and one land class. As the five classes were completely separated by the fully pol classifier, the class overlap in the scatter plots can be used to illustrate the discrimination capability of the dual channel intensities for each class.

Figures 2 and 3 show the coloured scatterplots (please see the CD-ROM or our web site for the colour versions of the figures). The HH-VV scatterplot of Figure 2 indicates high correlation between these two parameters. Classes overlap significantly and confusion between sea ice and land is likely. In this case, the ability of the data to separate ice classes is probably little better for these two co-pol channels than it would be for single channel data.

Figure 3 shows that there is a wider data spread in the VH-VV cross-pol space, indicating that the correlation between these two parameters is relatively low compared to the co-pol channels. Although there is still some overlap between the classes (*i.e.* blue-red, red-magenta, magenta-cyan), a reasonable separation of the main ice types (Fast Ice and rough FYI) seems feasible. However, the fully pol result is more detailed, and allows a sub-classification into more specific ice types.

TABLE I

COLOUR ASSIGNMENT

Colours	Description
blue	Smooth, thin Fast Ice
red	Fast Ice with rough surface
magenta	Rough FYI
cyan	Rough, thicker FYI
white	Rough, thicker FYI / Land
green	Land
dark green	Land
black	Land
grey	Classes not used for comparison in the scatterplots (white dark green and black)

An eigenvalue decomposition can be used to illustrate the extra information content of the fully pol data [5]. Figure 4 shows the entropy, H, the anisotropy, A, and the alpha angle for the scene, representing the main features obtained from the decomposition. Smooth ice shows the lowest *entropy* (in the centre of the image), while land has the highest entropy (bottom of the image). This indicates that the scattering mechanisms of ice are more homogeneous than those of land.

The *anisotropy* is lowest for land scatterers and higher for the ice. The contrast between land and ice, and between different ice types, seems to be the best of the three features.

The *α-angle* is low over smooth ice which, in combination with low entropy, indicates that surface scattering dominates the backscatter in these areas. Over rough FYI (top of the image) the α-angle is slightly higher and so is the entropy. This indicates a contribution from another scattering mechanism. The high HV backscatter in these regions is an indication for volume scattering.

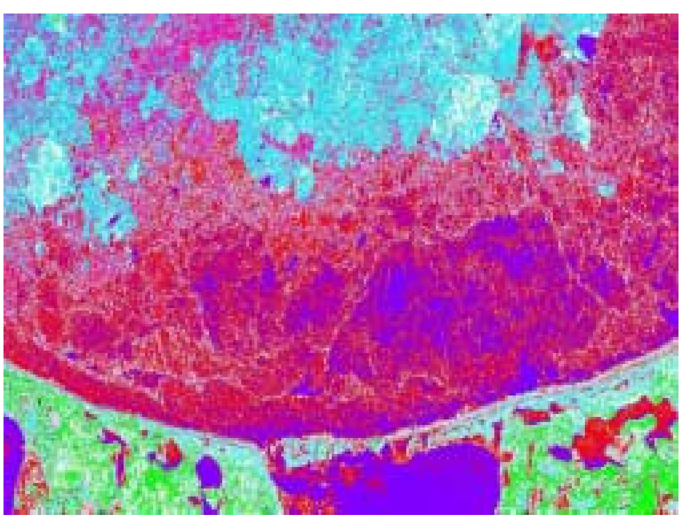

Fig. 1: Classified image of the north shore of PEI and offshore ice, using the complex Wishart classifier with 8 initial classes and 12 iterations

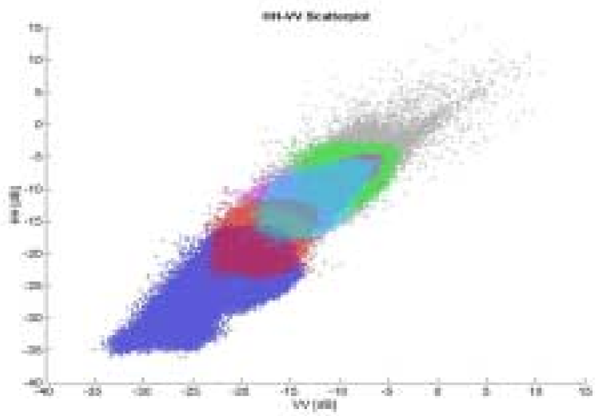

Fig. 2: HH-VV scatterplots with five classes derived using the iterative Wishart classifier

From this analysis, we can see that the information in each feature derived from the quad pol data is different from the other features, and that each of the three features provides some degree of ice type discrimination. Then, when the three features are used together in the classifier, a high degree of ice type discrimination can be obtained.

IV. CONCLUSIONS

An analysis of classes derived from the iterative Wishart classifier clearly shows the high information content of fully polarimetric SAR data. While sea ice exhibits a more homogeneous scattering than land, the fully polarimetric data provided enough discrimination to allow an effective classification of the ice types.

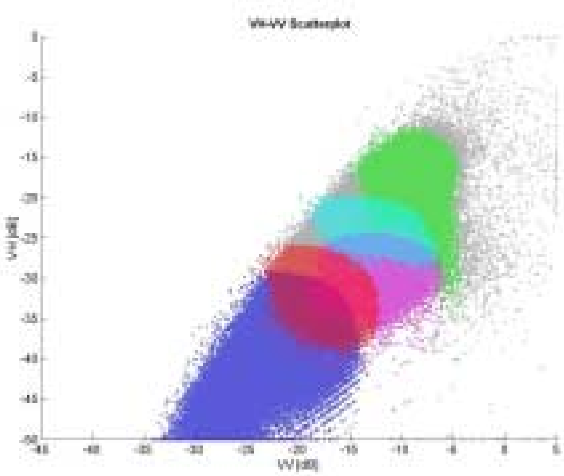

Fig. 3: VH-VV scatterplot with five classes derived using the iterative Wishart classifier

In contrast, the ice classes obtained from the fully pol data were quite confused in the dual pol data, as illustrated by overlap in scatter plots.

In the future, we will provide a more detailed comparison of the classification results using the dual and fully polarimetric data channels. This assessment will be presented at IGARSS 2002 in a poster session, and the results will be posted in colour on our web site http://www.ece.ubc.ca/sar/.

ACKNOWLEDGMENTS

This work was funded by MacDonald Dettwiler and Associates under contract to the Canadian Space Agency (No. 9F028-0-4902/06) as part of the Earth Observation Applications Development Program.

The authors thank the Canada Centre for Remote Sensing for providing the airborne SAR data and the Canadian Ice Service for providing meteorological data.

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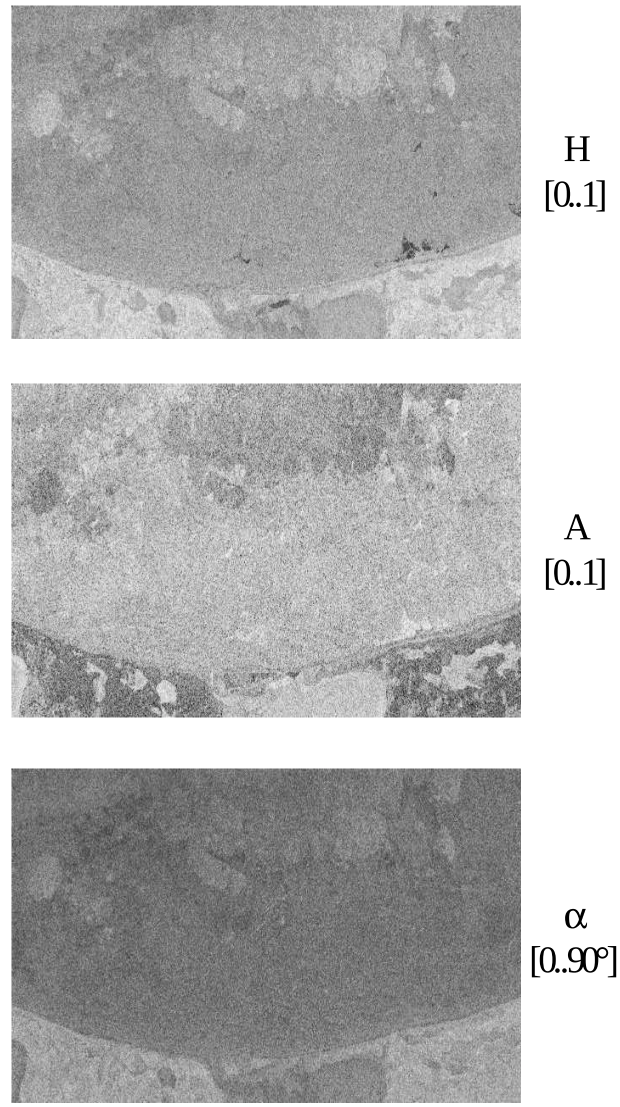

Fig. 4: Entropy H, Anisotropy A and α-angle for CV-580 polarimetric data.
(Image bottom: Land; Image centre: Fast Ice; Image top: Rough FYI)