ENVISAT ASAR AP Data for Operational Sea Ice Monitoring

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***Abstract*— The information content of ENVISAT ASAR alternating polarization data is evaluated with respect to operations at the Canadian Ice Service. A data set covering an entire ice season is shown to have a higher information content compared to single polarization data. The potential for automated information extraction is also investigated, in particular problems caused by system noise and its variation over the swath.**

Keywords- ASAR; cross-polarization; sea ice

I. Introduction

Spaceborne Synthetic Aperture Radar (SAR) data have significantly changed the way national ice services around the world work and operate. First generation single polarization spaceborne SAR instruments provide cloud cover independent coverage of areas affected by sea ice. RADARSAT-1 in particular, with its ScanSAR modes, is currently the primary data source for frequent wide area coverage of sea ice. A description of the operational use of RADARSAT-1 data by the Canadian Ice Service (CIS) is provided in [1].

The benefits of polarization diversity for SAR sea ice monitoring have been studied extensively since the late 80's based on airborne polarimetric data [2]. The general conclusion is that polarization diversity provides increased information content resulting in higher classification performance as well as the opportunity to estimate ice parameters. Airborne data acquisitions generally are one off events failing to address the temporal changes of ice signatures during an ice season. The benefits and tradeoffs of polarization diversity in spaceborne SAR data are discussed in [3]. The potential of RADARSAT-2 for operational sea ice monitoring is evaluated in [4].

The Advanced SAR instrument (ASAR) on the European Space Agency (ESA) ENVISAT satellite provides the first opportunity to investigate multi-polarization sea ice signatures over an entire ice season. The Alternating Polarization (AP) mode of ASAR provides both co-polarized (HH+VV) channels or one co- and one cross-polarized (HH+HV or VH+VV) channel. The ASAR AP mode can only provide a 100 km swath. This is less attractive for operational monitoring than 400 km ScanSAR swaths. However, ASAR data are very useful for application development in advance of RADARSAT-2, which will provide dual-polarization (HH+HV or VH+VV) ScanSAR data.

This paper reports the analysis of ENVISAT ASAR AP data covering an entire season over an area in the Canadian Arctic near Resolute. The objectives were to:

- Evaluate the additional information content provided by the cross-polarization channel for ice type classification and ice edge detection.
- Determine how this information can be most appropriately visualized for operator interpretation.

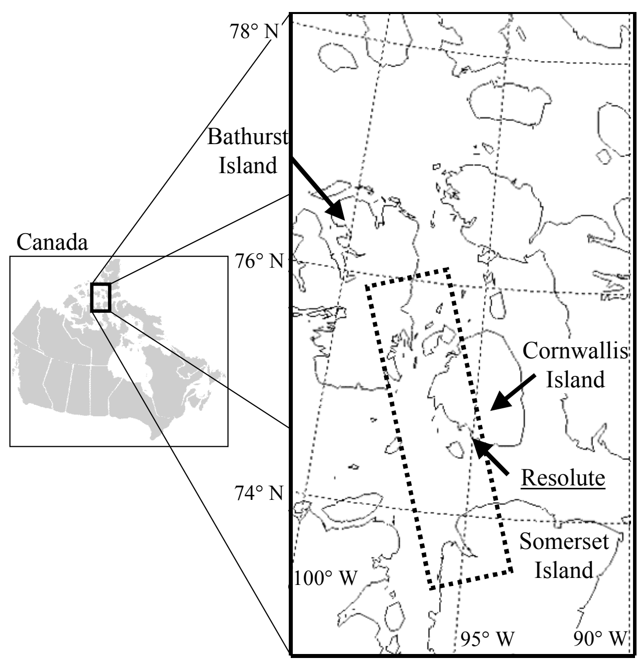

Figure 1. Area of interest for ENVISAT ASAR AP data analysis. The IS6 APM swath coverage is shown by the dotted rectangle.

The work was conducted by MacDonald Dettwiler under contract (#KM149-3-85-039) to the Canadian Ice Service.

TABLE I. DATA AVAILABILITY

Acquisition Date (2003)	ASAR Data		Aux. Data	
	Beam	***Pol.***	***Ice chart type***	***RADARSAT***
Apr. 3	IS6	HV+HH	Monthly	N/A
May 8	IS6	HV+HH	Weekly	May 6
June12	IS6	HV+HH	Weekly	Same day
June 20	IS1	VH	Weekly	Same day
July 17	IS6	HV+HH	Weekly	Same day
July 25	IS1	VV+VH	Daily	July 24
July 27	IS5	VH	Daily	Same day
Aug. 3	IS3	VV+VH	Daily	Same day
Aug. 21	IS6	HV+HH	Daily	Same day
Aug. 31	IS5	HV+HH	Daily	Same day
Sept. 25	IS6	HV+HH	Weekly	N/A
Oct.5	IS5	VV+VH	Daily	Same day
Oct.18	IS4	VV+VH	Daily	Same day
Oct 30	IS6	HV+HH	Weekly	Oct.31
Nov. 5	IS4	HH	Weekly	Nov.4
Nov. 9	IS5	VV+VH	Weekly	Same day

N/A: Not available

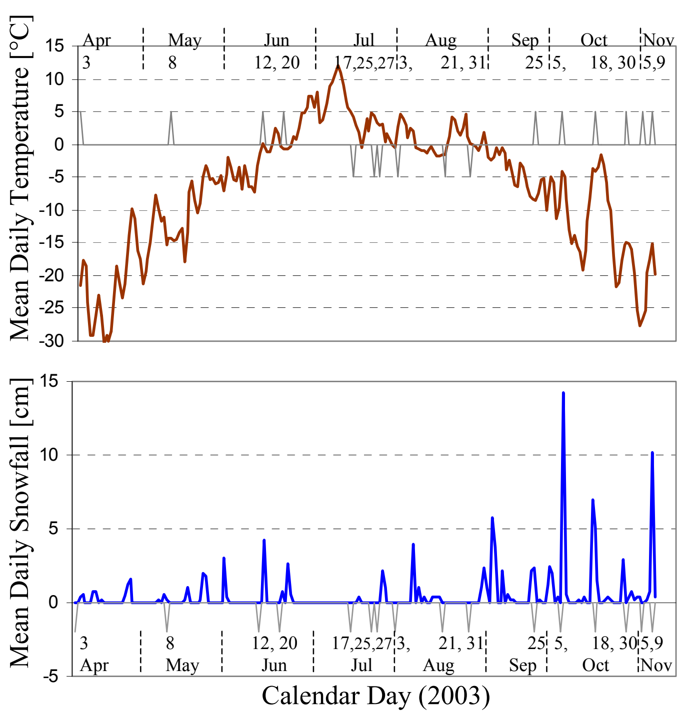

Figure 2. Temperature and snowfall record for Resolute with ASAR acquisition dates indicated.

II. DESCRIPTION OF THE DATA SET

A. *Full Season ASAR AP Data*

Between April and November 2003, ESA regularly acquired ASAR AP data over Resolute, one of the official calibration sites. As part of a research agreement with ESA, CIS obtained all data acquired in that period. Only combinations of co- and cross-polarization data are available. None of the images provide both co-polarizations. In order to provide more area coverage, the medium resolution product (APM) was selected thus allowing for longer acquisition lines. Fig. 1 shows a sketch map of the area as well as an approximate outline of an IS6 ascending swath. Table I lists details of all acquisitions.

B. *Auxiliary Data*

In addition to the ASAR data available for the area, CIS acquired RADARSAT-1 data and produced ice charts as part of their regular operation. These are also listed in Table I. Daily meteorological data (temperature, snowfall and wind speed) collected by Environment Canada, are also available.

The data set covers a wide range of environmental conditions including calm and high wind as well as melting and freezing conditions. The CIS ice charts identify mostly thick first year ice and old ice for the region of interest. Several scenes contain areas of open water.

Fig. 2 shows the temperature and snowfall record for the area. The data acquired between mid June and late August were acquired in melting conditions. Few significant snowfall events are reported, most of them occurred in the fall with temperatures well below zero. Winds above 30 km/h were reported for April 3, October 5 and 18 as well as November 5 and 9. Calm winds (below 10 km/h) are reported for May 8, June 20, August 3 and 31, September 25 and October 30.

III. DATA VISUALIZATION

CIS operations are heavily based on human expert analysis. Data visualization is therefore an important aspect. Brightness variations due to incidence angle or season make visual analysis of sea ice SAR data challenging. The availability of a second polarization promises higher information content, at the same time analysts need to evaluate more data in the same limited time frame. The use of color is a good way to visualize multiple channels.

The analysis of the ASAR data focussed on the marine region of the area observed. In a first step, a land mask was therefore created for each data set. The mask served in the evaluation of the dynamic range of the various channels available as well as for classification purposes.

Histograms for all scenes showed that the dynamic range of cross-polarization data is significantly shorter than that of co-polarization data. The dynamic range of the cross-polarization data is restricted at its lower limit by the sensor noise level. Co-polarized backscatter also varies more with incidence angle than cross-polarized backscatter. In an effort to achieve a consistent visualization, a common scaling scheme was established for this data set:

- Co-polarization: -22 dB to -10 dB
- Cross-polarization: -25 dB to -19 dB

These values are based on the combined histograms of all scenes and are used for the upper and lower limits in data visualization. This can be used for gray scale images as well as for color representations.

Fig. 3 shows all cross-polarized images acquired in beam IS6 (39.1° to 42.8° incidence angle). The data cover almost the entire season and therefore show significant change. There is very little change between the April and May acquisitions. Both scenes were acquired during stable, late winter ice conditions. There is a consistent across-swath intensity variation over lower backscatter areas.

The June 12 image clearly shows a more unified signature over the entire ice region thus indicating surface melt. Here more than in any other image a variation of the cross-polarization component over the swath can be observed. This variation (approx. 1.5 dB) can be attributed to the variation of the noise level over the swath and is therefore system related. More detailed analysis of IS4 data reveals a more significant variation for this beam with an increase of up to 4 dB in far range.

The breakup of the ice can be seen in the July image whereas in August, September and October the various stages of freeze-up are shown. Generally, the cross-polarization channel offers good contrast between old ice or deformed ice and first year ice as compared to the co-polarization image. With the exception of the June and July images, old and deformed ice can easily be identified.

Fig. 4 shows the HH image for September 25, 2003, an RGB color representation of both channels, and a four class classification result. The HH image differs from the HV image. In this case, the backscatter of large flows is lower relative to the rest of the scene. In absolute terms HH is about 10 dB higher than HV. The RGB image reveals the relative differences and provides a powerful tool for visual analysis.

For both gray level and RGB images, each scene provides more spatial detail when the data range is adapted to the scene content (marine region only), however, a comparison of different scenes is not easily possible. For analysis purposes, both a common and a scene content dependent visualization option should be provided with an option to toggle between them.

IV. CLASSIFICATION

Based on the assumption that co- and cross-polarization channels are not correlated, a modified Wishart classifier for two channels was used to classify the scene. The main objective is the separation of sea ice and open water, a task important for ice edge delineation, the location of leads as well as ice concentration estimation. Initial tests show promising results for ASAR AP data [4].

The Wishart classifier is used in three iterations and is automatically initialized using the median values of the marine areas for the two channels resulting in four classes. The interpretation of the final result is a manual task. A reduction to two classes proved unsuccessful, mostly due to the large variation of the ice signatures present. Land areas are masked out, the classification is performed for the marine areas of the image only.

The example classification result presented in Fig. 4 shows good visual resemblance with the RGB image, and it appears that the open water / thin ice in the area is well identified. From the data set at hand, it cannot be shown that thin ice and open water can automatically be separated.

While the classification results are good for many images, for selected scenes the variation of HV over the swath shows in the classification result. Further research is needed to address the issue. The approach shows potential for use as an ice type concentration estimator to aid ice chart generation.

V. CONCLUSIONS

The use of spaceborne multi-polarization SAR data will be beneficial for operational sea ice monitoring in the future. While ENVISAT ASAR does not provide wide spatial coverage for its AP modes, RADARSAT-2 will be capable of acquiring dual-polarization ScanSAR data. Benefits include higher information content, which can be visualized relatively easy using color representation. Automated information retrieval algorithms can be based on at least two channels resulting in better performance.

Spaceborne systems generally have a higher noise level compared to many airborne systems; this is particularly the case for wider swaths. Combined with a variation of the noise level over the swath this may result in problems for visualization as well as for automated information retrieval and research is required to counter these effects.

ACKNOWLEDGMENT

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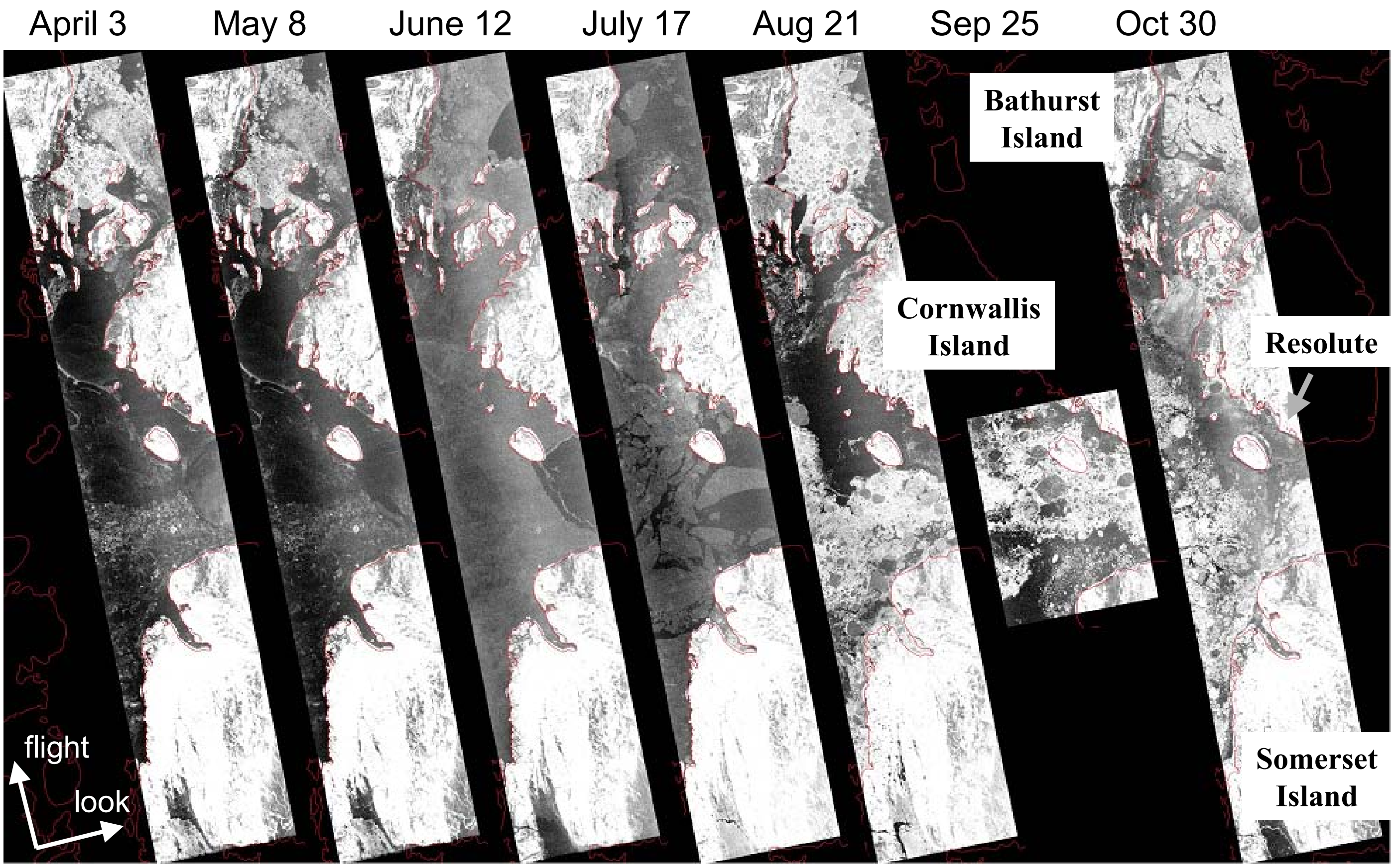

Figure 3. ASAR APM IS6 HV examples acquired in 2003 (scaled from -25 dB to -19 dB).

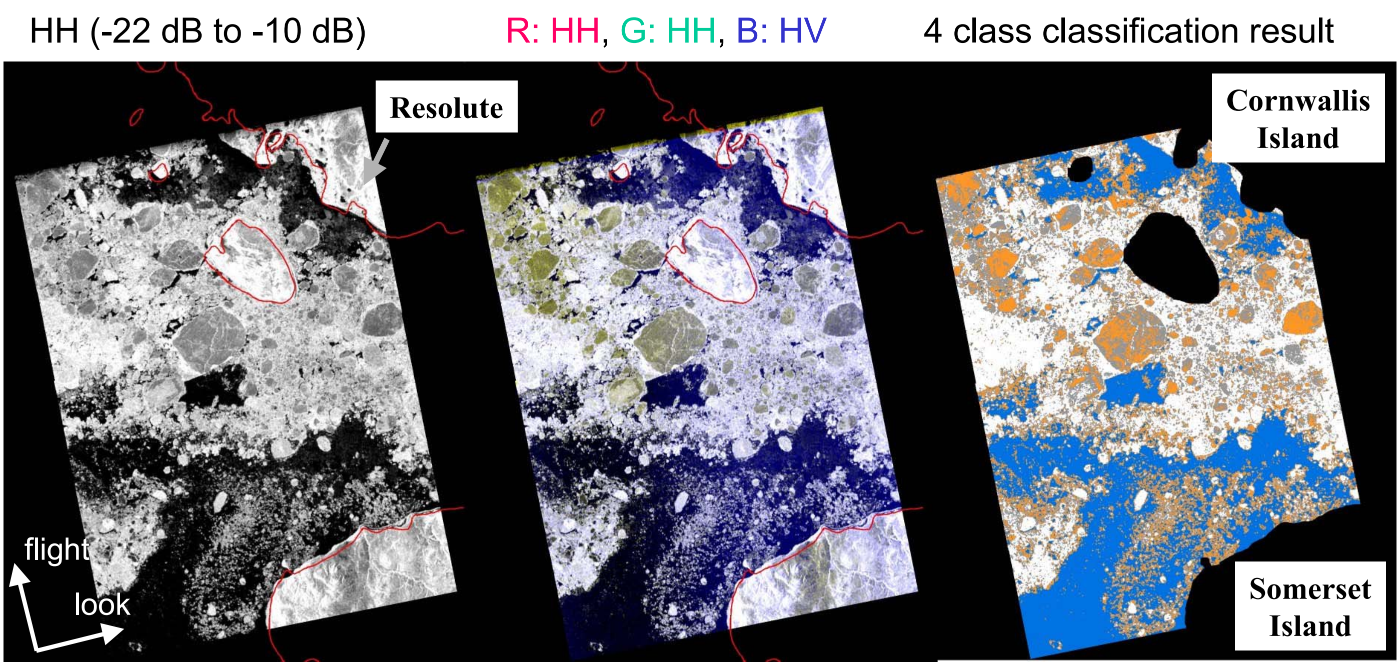

Figure 4. September 25, 2003 acquisition. HH, RGB, and classification result. The color assignment in the classification result is as follows: white: deformed ice, gray and orange: first year ice (slight differences in roughness), blue: thin ice or possibly open water. (Land is shown in black.)