Algorithm development for operational satellite SAR classification and mapping of Great Lakes ice cover

G.A. Leshkevich[1] and S.V. Nghiem[2]

[1]Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration
2205 Commonwealth Blvd., Ann Arbor, Michigan 48105, U.S.A.
Tel: 734-741-2265, Fax: 734-741-2055, E-mail: george.leshkevich@noaa.gov

[2]Jet Propulsion Laboratory, California Institute of Technology, MS 300-235
4800 Oak Grove Drive, Pasadena, California 91109, U.S.A.
Tel: 818-354-2982, Fax: 818-393-3077, E-mail: son.v.nghiem@jpl.nasa.gov

ABSTRACT

During the 1997 winter season, shipborne polarimetric backscatter measurements of Great Lakes (freshwater) ice types using the Jet Propulsion Laboratory (JPL) C-band scatterometer, together with surface-based ice physical characterization measurements and environmental parameters were acquired. This polarimetric data set, measured at incident angles from 0^o to 60^o for all polarizations, was processed to radar cross-section to establish a library of signatures (look-up table) for different ice types. Using this library of signatures, computer analysis of calibrated ERS-2 and RADARSAT ScanSAR images of Great Lakes ice cover using a supervised classification technique indicates that different ice types in the ice cover can be identified and mapped, and that wind speed and direction can have an influence on the classification of water as ice based on single frequency, single polarization data.

Keywords: Synthetic Aperture Radar (SAR), satellite, ice, classification, Great Lakes, RADARSAT, ERS-2

1 INTRODUCTION

The all-weather, day/night viewing capability of satellite Synthetic Aperture Radar (SAR) makes it a unique and valuable tool for Great Lakes ice identification and mapping provided that data analysis techniques and capability for using SAR data in an operational setting can be developed. Previous computer analysis of ERS-1 and RADARSAT ScanSAR Narrow images of the Great Lakes using a supervised (level slicing) classification technique has shown that different ice types in the ice cover can be identified and mapped and that wind speed and direction can have a strong influence on the backscatter from open water. However, for image-to-image classification, a library of backscatter signatures for different ice types is needed for use with calibrated SAR imagery.

2 ERS-2 SAR

During the 1997 winter season, shipborne polarimetric backscatter measurements (0^o to 60^o) of Great Lakes ice types using the Jet Propulsion Laboratory (JPL) C-band scatterometer, together with surface-based ice physical characterization measurements and environmental parameters were acquired concurrently with RADARSAT and ERS-2 overpass [1] Nghiem and Leshkevich (submitted). Measured vertical-polarization (VV) backscatter values (converted to dB) for three ice types and calm water were applied to an 8 x 8 pixel-averaged ERS-2 calibrated SAR image. However, a problem with saturation within the analog to digital converter (ADC) of the ERS-1 and ERS-2 SARs leads to a power loss resulting in an underestimation of the normalized radar cross

section (NRCS). To correct for power loss, the ERS-2 image (22 March 1997) was recalibrated as described in [2] Rosenthal *et al.* (1998). In addition, to account for the effects of local incidence angle, the measured (calibrated) backscatter values for the three ice types and calm open water used as "training data" were interpolated every 0.5^{o} between incident angles 19.5^{o} and 26.5^{o}. These "training data" sets were then used to classify the 8 x 8 pixel-averaged recalibrated image. As there were rather low power loss corrections to perform in this image, the results are similar to the first classification. Two notable differences are that 1) there is more area classified as patchy snow cover on snow ice covered black ice, and 2) a small area of open water is classified in this image as the result of the more accurate calibration and "training data" sets.

3 RADARSAT SAR

When applied to a calibrated (using software written at John Hopkins University/Applied Physics Laboratory (JHU/APL), [3] Monaldo (2005)) RADARSAT ScanSAR Wide A (SWA) scene of the same area on the same day, the library of horizontal-polarization (HH) backscatter signatures produced classification results similar to those of the ERS-2 scene. The RADARSAT scene (22 March 1997) was also calibrated by Satlantic, Inc. using their SentrySAR processor [4] Dragosevic and Plache (2000). To obtain the most accurate classification results, the calibrated RADARSAT scene was classified by incidence angle of each pixel using training data for six ice types and open water [5] Leshkevich and Nghiem (submitted). Moreover, the polarimetric radar backscatter measurements acquired over Great Lakes ice types during our 1997 Great Lakes Winter Experiment (GLAWEX 1997) reveal that multi-polarization backscatter data (such as that from ENVISAT or RADARSAT-2) can be used to map ice and open water without the ambiguity encountered in single polarization data due to variations in wind speed over water.

4 CONCLUSIONS AND FUTURE PLANS

Despite some differences, the overall classification of ice types in each scene was very similar. The measured library of signatures (both for HH and VV polarizations) appears to classify most ice types in the ERS-2 re-calibrated scene and the RADARSAT scene collected on the same day. Differences in the classification results between the JHU/APL and Satlantic RADARSAT scenes can be mainly attributed to differences in calibration, in classification methodology, and to the additional training data (ice types) used for the Satlantic classification, but emphasizes the need for an accurately calibrated data.

RADARSAT-2 SAR will have polarimetric capability in single-beam modes [6] Morena *et.al.* (2004). Furthermore, RADARSAT-2 SAR has dual-polarization ScanSAR modes and a large range of incidence angles. In anticipation of these advanced SAR capabilities, the 1997 GLAWEX library was obtained with the JPL polarimetric C-band shipborne scatterometer for all polarization combinations and incidence angle up to 60^{o}. Thus, this library will be applicable to both ENVISAT and RADARSAT-2 SAR data for Great Lakes ice classification and mapping.

ACKNOWLEDGMENTS

SAR data for this study were provided by the European Space Agency (ESA) and the Canadian Space Agency (CSA)/RADARSAT International (RSI). The authors gratefully acknowledge individuals at the Ice Center Environment Canada and the U.S. National Ice Center for their efforts in obtaining and making available the RADARSAT and ERS-2 SAR imagery, to Dr. J. Horstmann of the GKSS Research Center (Germany) for his help in recalibrating the ERS-2 image to correct for power loss, and to Dr. F.M. Monaldo of the Johns Hopkins University/Applied Physics Laboratory for use of his SAR calibration software and processing assistance. Our appreciation and thanks go to the U.S. Coast Guard, Ninth District for providing the ship, helicopter, and ground support essential to the success of this study. The research in this paper performed by Jet Propulsion Laboratory, California Institute of Technology, was sponsored by the National Oceanic and Atmospheric Administration (NOAA), through an agreement with the National Aeronautics and Space Administration (NASA). GLERL Contribution Number 1415.

REFERENCES

[1] NGHIEM, S.V. and LESHKEVICH, G.A., 2006: Satellite SAR Remote Sensing of Great Lakes Ice Cover Part 1. Ice Backscatter Signatures at C Band. *Remote Sens. Environ.* (submitted).

[2] ROSENTHAL, W., HORSTMANN, J., LEHNER, S., SCHULZ-STELLENFLETH, J., and WEINREICH, I., 1998: The spatial resolution of marine meteorological and marine biological parameter fields in coastal areas with ERS SAR. SARPAK Final Report. GKSS Research Center, Geesthacht, Germany.

[3] MONALDO, F. M., 2005: ANSWRS: APL/NOAA SAR Wind Retrieval System-Software Documentation Version 3.0. Report: SRO-05-13. Johns Hopkins University/Applied Physics Laboratory, Laurel, MD 20723-6099, 36 pp.

[4] DRAGOSEVIC, M. and PLACHE, B., 2000: Doppler tracker for a spaceborne ScanSAR system. *IEEE Transactions on Aerospace and Electronic Systems*, 36(3), pp. 907-924.

[5] LESHKEVICH, G.A. and NGHIEM, S.V., 2006: Satellite SAR Remote Sensing of Great Lakes Ice Cover Part 2. Ice Classification and Mapping. *Remote Sens. Environ.* (submitted).

[6] MORENA, L.C., JAMES, K.V., and BECK, J., 2004: An introduction to the RADARSAT-2 mission. *Canadian Journal of Remote Sensing*, 30(3), pp. 221,234.