Comparison of Texture From Multi-resolution SAR and In-situ Data for Surface State Estimation of Decaying Landfast First-year Sea Ice

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Theme 3.1 Ocean-Ice-Atmosphere Coupling and Climate Variability

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Abstract

Our understanding of the spatial variation in regional sea ice albedo during its summer decay is poorly understood despite the importance of albedo as a tuning parameter in climate models. This work presents a coupling between *in-situ* geophysical measures of decaying first-year sea ice, with linkages to surface albedo, and texture measures derived from coincident synthetic aperture radar (SAR) overpasses from sensors RADARSAT-1 and ENVISAT-ASAR over two field sites near Churchill, Manitoba in 2005. Early results suggest that relatively homogeneous regions of ice surface morphology and melt pond distribution can be discriminated in SAR images by way of identifying regions with similarly varying pixel intensities.

Scientific Rationale

Repeat coverage synthetic aperture radars (SARs) such as RADARSAT-1 and ENVISAT-ASAR, as well as non-imaging scatterometers such as QuickSCAT have demonstrated utility in providing proxy information on the climate state of sea ice from its stable winter state through its summer decay. This has primarily been acheived through the temporal analysis of changes in calibrated microwave backscattering coefficients (σ^o) from radars [1-2]. In a climate-modeling context, attempts to utilize σ^o to quantify regional albedo [3] during melt season have proven rather elusive due to dynamic and subscale changes - in both the horizontal and vertical dimensions within an ice matrix - that confuse the spatial interpretation of σ^o across an image scene and negate the implementation of automated image classification techniques [4].

Research Questions

1. Can spatial variations in σ^o (i.e., image texture) from a time-series of SAR image scenes be utilized to discriminate relatively homogeneous regions of first-year sea ice of varying climate state[1]?

2. What effect does SAR pixel resolution have on our ability to discriminate regions of varying climate state across image scenes?

[1] *By "climate state" here we refer to the usage of statistics to identify homogeneous geographical units that define deviations about a mean climate state for the end purpose of regionalization [5].*

Study Site

A spring-summer sea ice surface geophysical sampling program was conducted between May 7 and May 26, 2005 as part of the Hudson Bay System Study (BaySys) - project 3.1 of Theme 3 of ArcticNet - on the landfast first-year sea ice adjacent to Churchill, Mantioba (Figure 1).

Figure 1. Map showing spring-summer sampling locations on landfast first-year sea ice in Button Bay (LF-1) and adjacent to Churchill, MB (LF-2). Also shown are wind and temperature logging stations and the approximate landfast ice-pack ice boundary prior to break-up.

Methods - In Situ Data

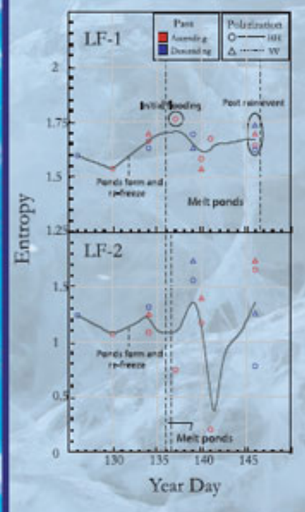
In-situ measurements were made coincident to satellite SAR overpasses for the purpose of resolving ambiguities in the interpretation of image scenes. Every 1-3 days a set of measurements was conducted at LF-1 and/or LF-2 (see Figure 1) for the purpose of characterising changes in the horizontal dimension (i.e., the distribution of dominant surface types such as bare ice and melt pond) and the vertical dimension (i.e., physical properties of surface types) on the ice surface (Figure 2). At each site visit, measurements of (1) surface type and (2) depth were recorded along 100 m long E-W and S-N profiles while (3) temperature, (4) conductivity, and (5) salinity measurements were taken as conditions allowed. Wind speed and direction (2m height) and temperature (1m) were continuously logged at a 5-minute interval in LF-2, while only wind wind speed (1m) was logged at LF-2 when liquid melt ponds were present.

Figure 2. Digital photos taken at standing height showing contrasting surface conditions at LF-2. The photo on the left shows snow-covered sea ice as the dominant feature, while the photo on the right reveals a mixture of snow, bare ice and melt pond (35%). Photos were taken only 2.5 hours apart.

Methods - Satellite Data

28 RADARSAT-1 and ENVISAT-ASAR SAR image scenes of 12.5m, 100m and 400 m resolution covering the study region were acquired along with two Quickbird high-resolution (0.6 - 2.4 m) optical scenes over LF-1. SAR images were calibrated to σ^o and their texture measures derived. Average texture values for LF-1 and LF-2 were derived from each image for the purpose of time series analysis, while the derived texutre images were retained for visual and spatial analyses.

Results - Change Over Time



Initial testing shows that texture statistics *entropy* and *contrast*, when determined using a directionally invariant 3 by 3 GLCM, are most useful in discriminating between different observed ice states in time series' from LF-1 and LF-2.

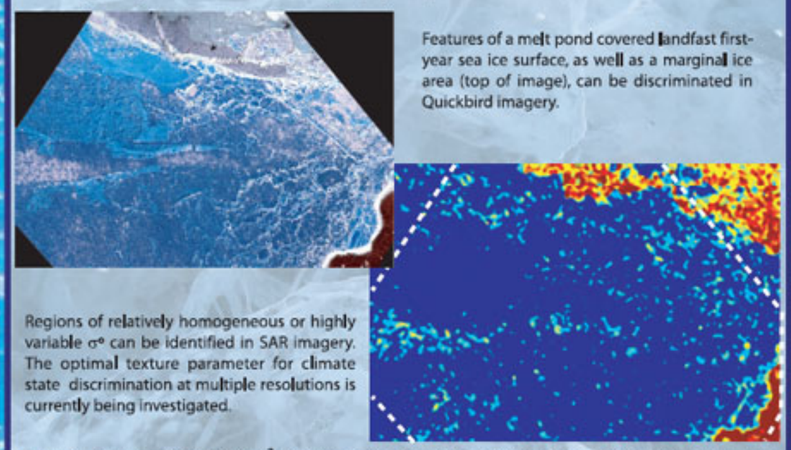
Entropy (left) provides a measure of the local variability of σ^o, which changes with time as the surfaces move from a cold, winter-like state to a flooded, melt- pond covered surface, and finally to a drained, bare-ice surface.

As expected, those SAR images acquired at 12.5 m resolution are best able to resolve changes in ice states, as predominant surface features like melt ponds are typically subresolution of coarser SARs.

Figure 3. Time series of entropy from 12.5 m resolution SAR over LF-1 and LF-2. Entropy values from ascending and descending SAR overpasses, as well as horizontal (HH) and vertical (VV) SAR transmit-receive polarization states, are discrminated.

Results - Change Over Space

Currently, the high resolution Quickbird optical images obtained on two cloud-free days over LF-1 are guiding the visual texture analysis (Figure 4).



Features of a melt pond covered landfast first-year sea ice surface, as well as a marginal ice area (top of image), can be discriminated in Quickbird imagery.

Regions of relatively homogeneous or highly variable σ^o can be identified in SAR imagery. The optimal texture parameter for climate state discrimination at multiple resolutions is currently being investigated.

Figure 4. An approximately 64 km^2 Quickbird optical image at 2.4 m resolution (left) is shown in contrast to a temporally near-coincident, 12.5 m resolution ENVISAT-ASAR (HH) overpass (right) that has been texture-filtered for entropy values. In the ASAR image, homogeneous regions of σ^o are showin in blue while areas of high σ^o variability are yellow-red.

Future Research

This is very much a work in its infancy. More work is being done to statistically quantify field-measured changes in the surface geophysical variables that influence observed σ^o in coincident SAR imagery. The sensor effects, such as incidence angle and polarization, on our ability to discrminate different climate states is being investigated. A comprehensive melt season *in-situ* σ^o dataset, obtained during BaySys 2005 using a portable C-band polarimateric scatterometer, will aid this research. Collaboration with other sea ice research participants in BaySys 2005 from the Centre for Earth Observation Science (CEOS), Faculty of the Environment, University of Manitoba, as well as the Department of Fisheries and Oceans (DFO) Canada, will significantly augment this research.

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