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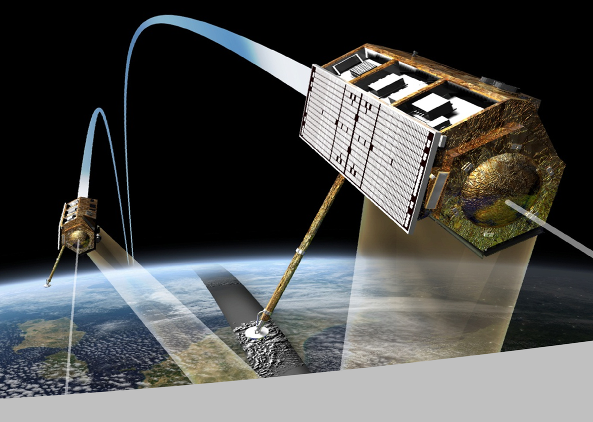

Modelling and Interpretation of Polarimetric Scattering from Subarctic Lakes at L-Band

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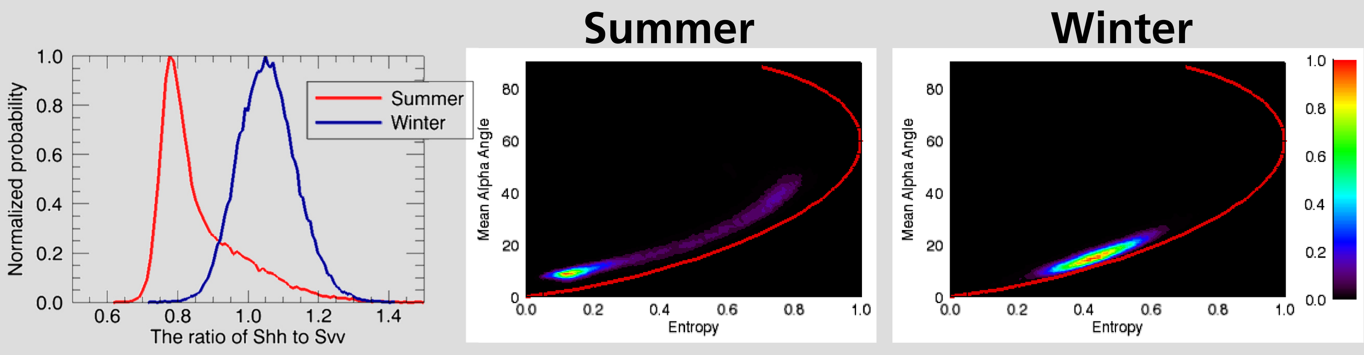
Abstract

This work is focused on investigating the capabilities of fully polarimetric SAR (Synthetic Aperture Radar) at low frequencies (L-Band) in revealing facts about the subsurface and the inhomogeneities above it which are dominated mainly by methane bubbles for the case of frozen subarctic lakes. A model for the polarimetric backscattering is developed in [1]. The forward simulations of the model are compared to experimental quad-pol data obtained by ALOS-PALSAR over frozen shallow sub-arctic lakes in several regions in the northern wetlands.
Based on those comparisons, an entropy-alpha colour scheme is generated and entropy-alpha colour coded maps (power normalised) are presented.

Test Sites

1. Churchill (N58.5°, E-94°)
   - At 27/07/2010 (summer) and 10/05/2009 (winter)
   - Ice thickness during winter acquisition is around 1.6m.
2. Baker Lake (N64.3°, E-96°)
   - At 15/03/2007 and 30/04/2007
   - Ice thickness increased from 1.5m to 1.85m during the two winter acquisitions.
3. Inuvik (N68°, E-132°)
   - At 11/03/2007 and 26/04/2007
   - Ice thickness measurements are not available. Average temperatures above 0°C during a week before the second acquisition. (ice melting)

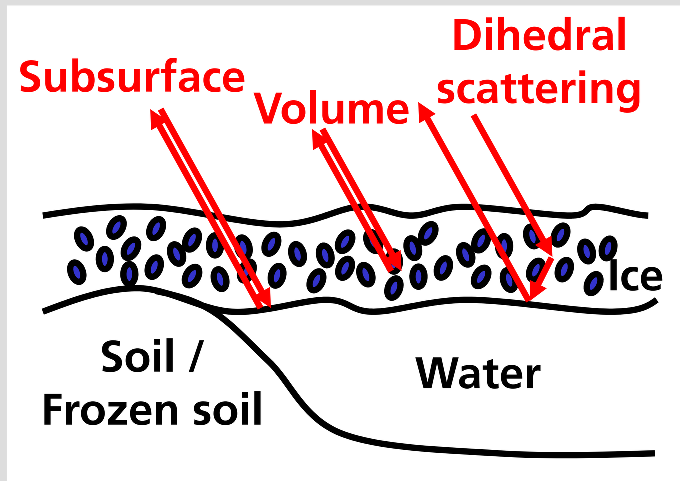
Summer versus winter (Churchill)



With ice presence: Shh/Svv increases, no change in the co-polarisation phase difference (0°), and Entropy-Alpha increases (summer values matches X-Bragg predictions).

Theory and Model

- The sub-arctic lakes can be in different conditions:
  - A. Unfrozen
  - B. Floating ice: Ice above water
  - C. Grounded ice: frozen to the lake bed
- Two layer system:
  1. Subsurface scattering
  2. Upper layer inhomogeneity (volume)
  3. Dihedral scattering (volume-subsurface)



- Model equation:

$$P_D = \left|\frac{R_\perp + R_\parallel}{2}\right|^2 P_{V\_forward}$$

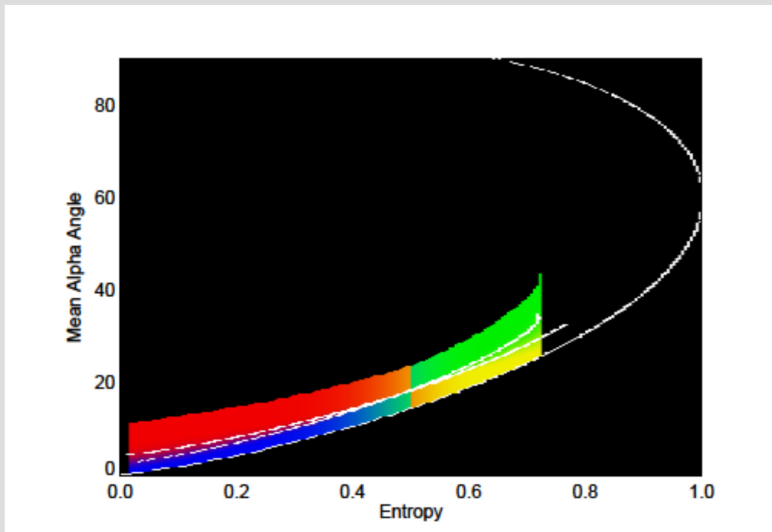
$$[T_S] = P_{SS}\begin{bmatrix} T_{11}^{SS} & T_{12}^{SS} & 0 \\ T_{12}^{*SS} & T_{22}^{SS} & 0 \\ 0 & 0 & T_{33}^{SS} \end{bmatrix} + P_V\begin{bmatrix} T_{11}^{V} & T_{12}^{V} & 0 \\ T_{12}^{*V} & T_{22}^{V} & 0 \\ 0 & 0 & T_{33}^{V} \end{bmatrix} + P_D\begin{bmatrix} T_{11}^{D} & T_{12}^{D} & 0 \\ T_{12}^{*D} & T_{22}^{D} & 0 \\ 0 & 0 & T_{33}^{D} \end{bmatrix}$$

X-Bragg | Partially oriented prolate volume | Dihedral volume-surface scattering

- The mathematical formulation of dihedral volume-surface scattering mechanism is introduced in [1], and predicts Shh>Svv with a 0° phase difference. The volume that contributes to the dihedral backscattering is the same that is responsible for the volume backscattering, such that the shape and the orientation distribution of the particles within the volume is assumed to be identical for both mechanisms and the backscattered powers (P_D, P_V) are related by the Fresnel coefficient of the subsurface ($R_\perp, R_\parallel$). The model has the same number of unknowns as without the Dihedral mechanism.

Model predictions and results

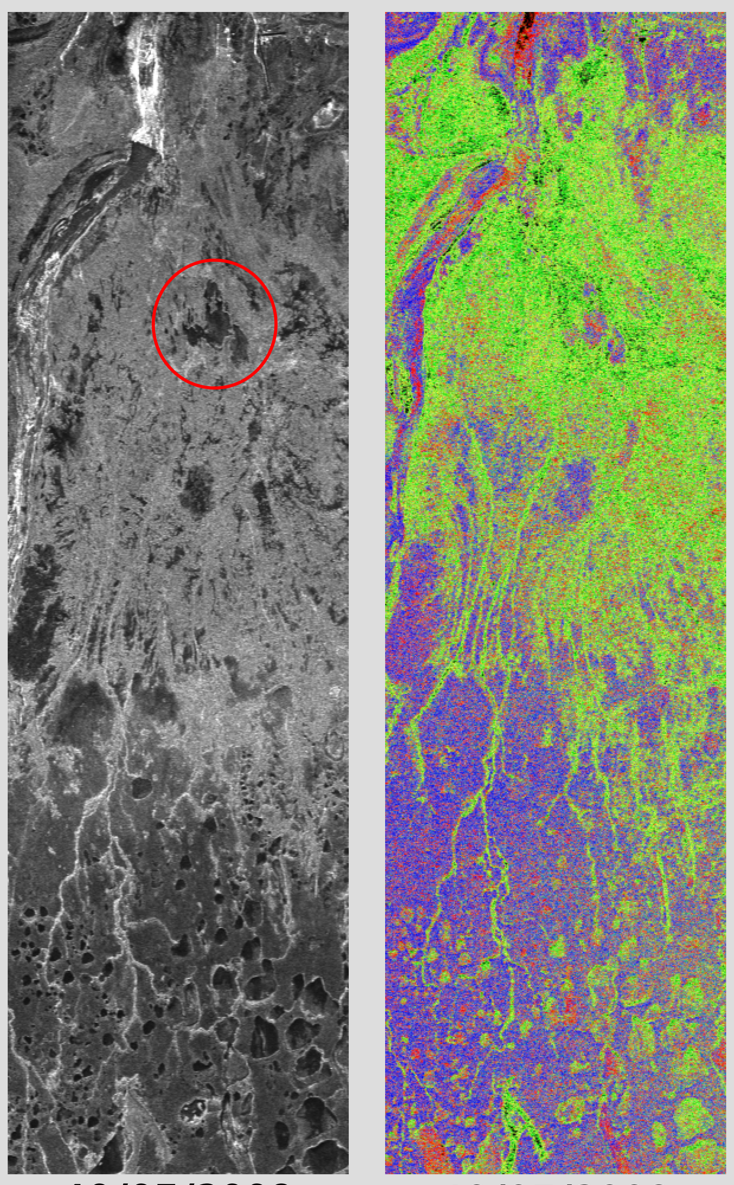
	Dominating mechanism	Backscattered power	Co- polarisation power ratio Shh/Svv	Position in the entropy-alpha plane
Water surface/ Water + thin layer of ice	Surface	Low	Low (< 0.9)	Between close to far from the boundary line
Thin layer of grounded ice	Surface + volume	Low / medium (if subsurface is rough)	Low (≤ 0.9)	Close to the boundary line (further away for higher volume)
Medium thickness layer of floating ice	Surface + volume + dihedral	High	High (≈ 1.1)	Close to the boundary line (closer for higher volume)
Medium thickness layer of grounded ice	Surface + volume	Low (for smooth subsurface)	Low (≈ 0.9)	Far from the boundary line
Thick layer of floating ice	Surface + volume + dihedral	High	High (≈ 1.2)	Very close to the boundary line



Power normalised colour scheme generated from the forward simulation of the model for two lines, one for floating ice and the other for grounded ice.

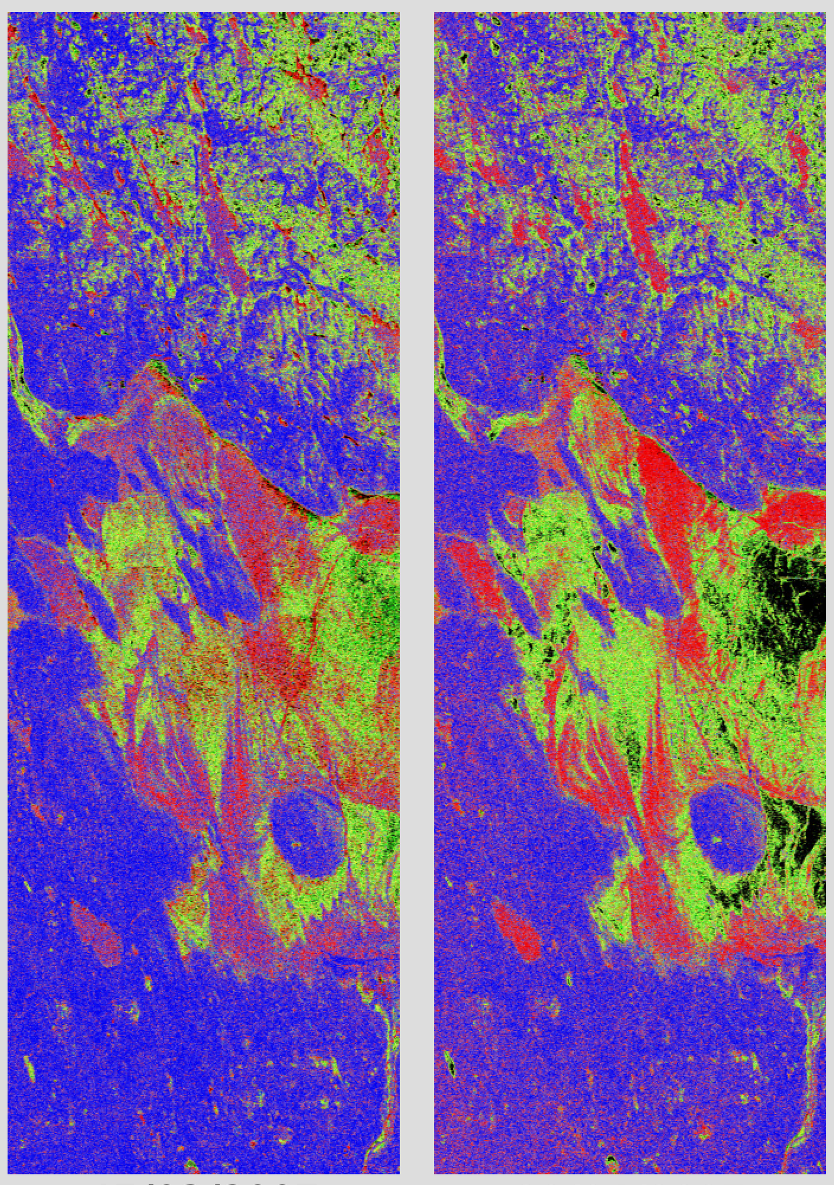
1. Churchill: Power versus entropy-alpha colour coded map for floating and grounded ice
   Lakes with low power appear green while lakes with high power appear red except the lake indicated with a red circle.
2. Baker Lake: Increase in red and green colour indicating an increase in the volume and dihedral contribution, and accordingly the inhomogeneities within the ice (increase in ice thickness).
3. Inuvik: Some lakes indicated by the numbers 1 to 4 change their colour from green standing for grounded ice to red standing for floating ice because of melting.

Churchill site



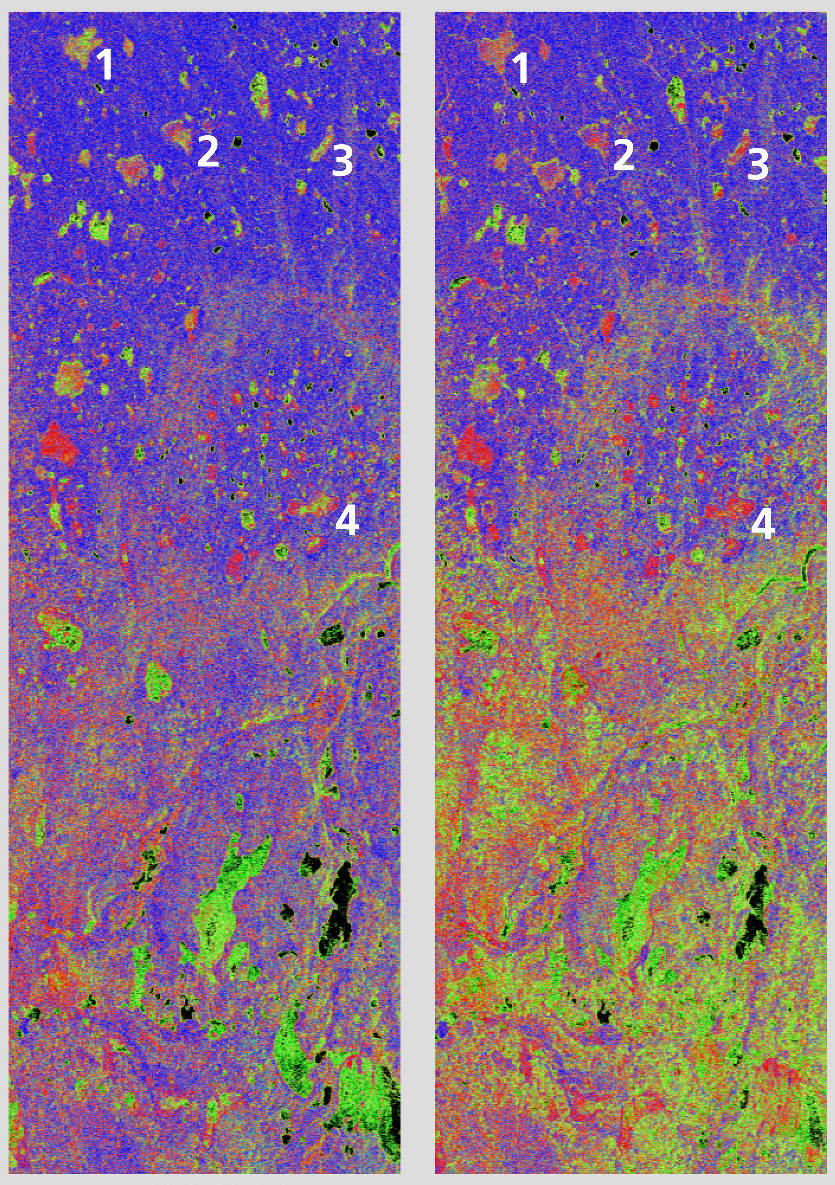
10/05/2009 | 10/05/2009

Baker Lake site



15/03/2007 | 30/04/2007

Inuvik site



11/03/2007 | 26/04/2007

[1] Al-Kahachi, N.; Papathanassiou, K.; , "Polarimetric scattering model for methane bubbles trapped in the ice of sub-arctic lakes," *Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International* , vol., no., pp.1485-1488, 22-27 July 2012.