A NOVEL CONTEXTUAL SPECKLE REDUCTION METHOD OF POLSAR IMAGES: EVALUATION OF SPECKLE REDUCTION EFFECTS ON SEA ICE CLASSIFICATION

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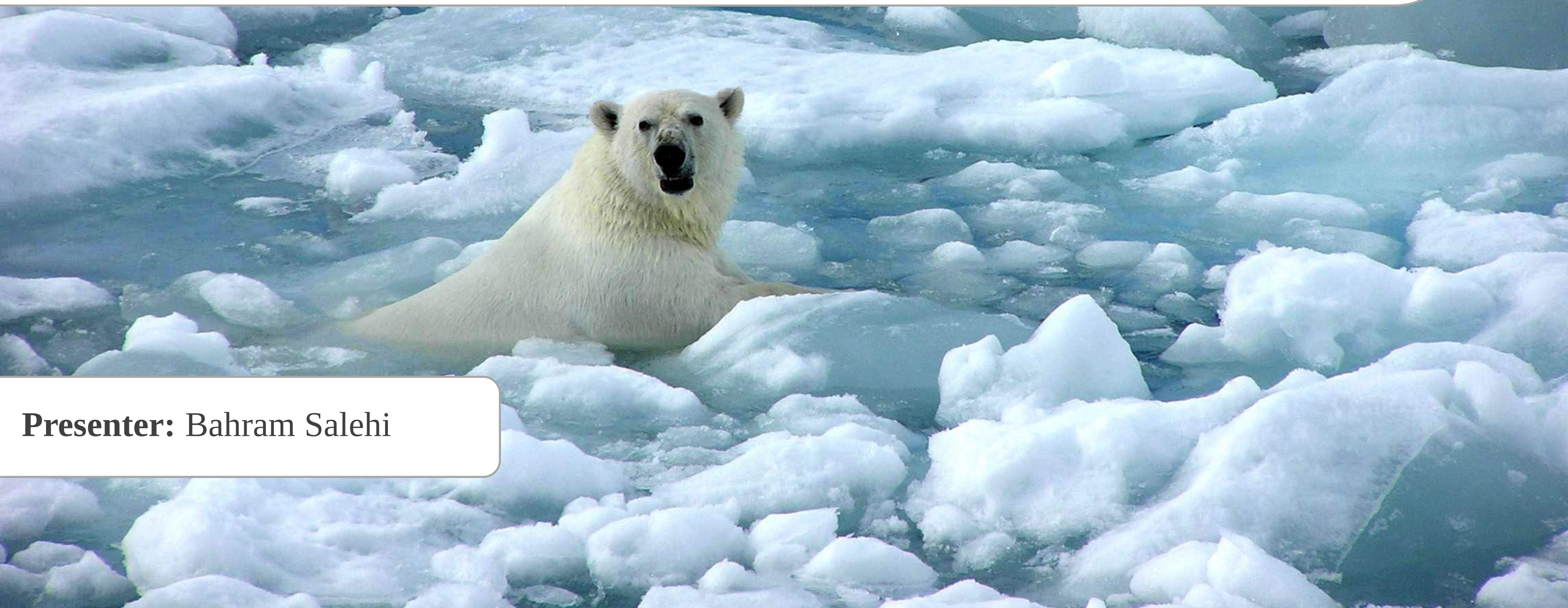


Presenter: Bahram Salehi

Content

- Introduction
- Sea ice monitoring importance
- PolSAR Data
- Case Study
- Methodology
- Experimental Results
- Conclusion

Introduction

Why sea ice monitoring is important?

- One of the most dramatic environmental changes over the Arctic.
- The increasing temperature & degradation of ice thickness makes more navigation routs in the Arctic.
- Optimum ways to access to this valuable resources in the Arctic and safety issues (e.g. near sea ice edge)
- Arctic region is a habitat for Arctic creatures such as seals and polar bears.

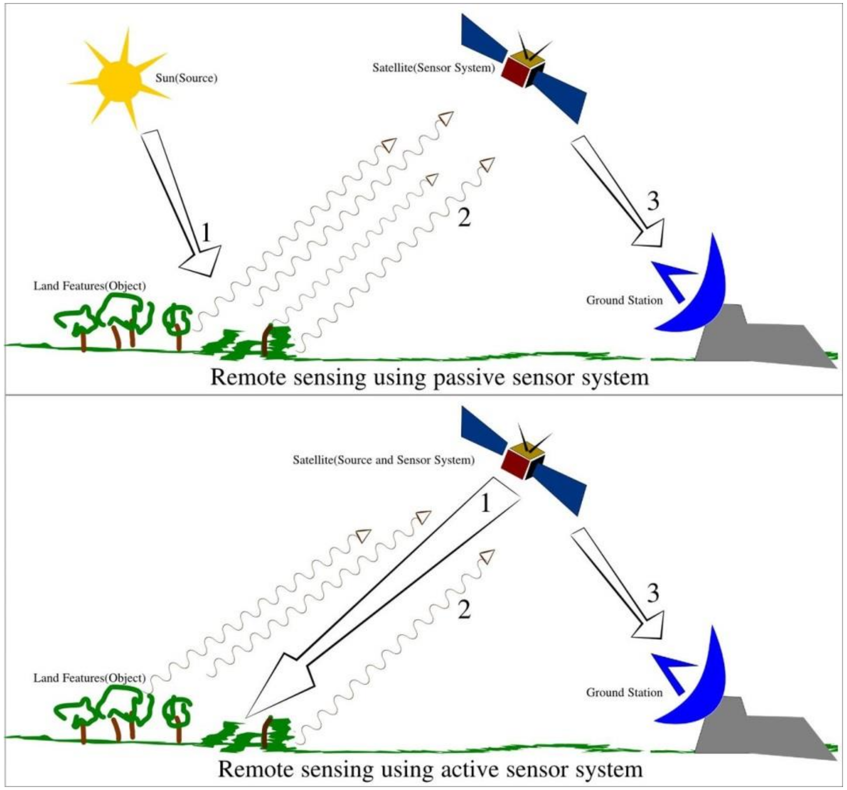
Remote Sensing Sensors

Passive

- Optical sensors
- Require to sun illumination:
- World view2, Sentinel 2,ASTER, Landsat, AVHRR.

Active

- Radar sensors
- Independent of sun illumination and cloud cover:
- ALOS PALSAR, RADARSAT, TerraSAR-X.



Remote sensing using passive sensor system

Remote sensing using active sensor system

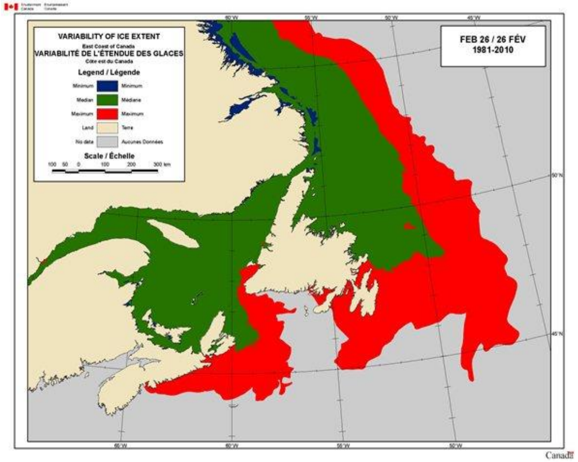
PolSAR Data

- Synthetic Aperture Radar (SAR) observation with very high resolution is extensively used for the monitoring of changes in Arctic ice.

- Currently, for the production of ice charts the Canadian Ice Service alone processes ten to twelve thousand SAR images every year manually (Moen et al., 2013).

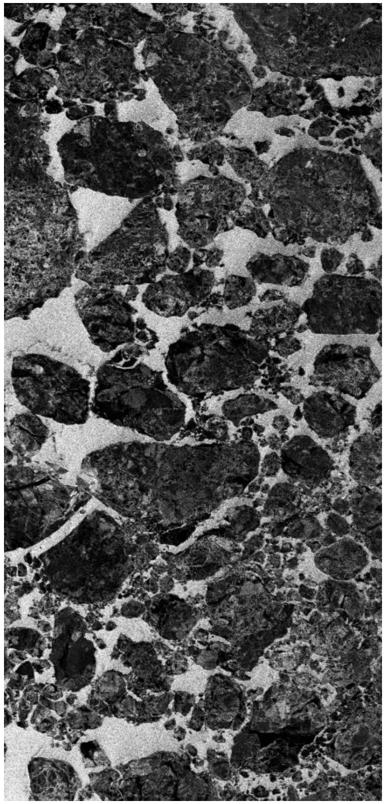
- A sea ice classification algorithm is able to provide the ice charts automatically with less human involvement while it is more time efficient.

- In this study, PolSAR data has been used for sea ice classification.

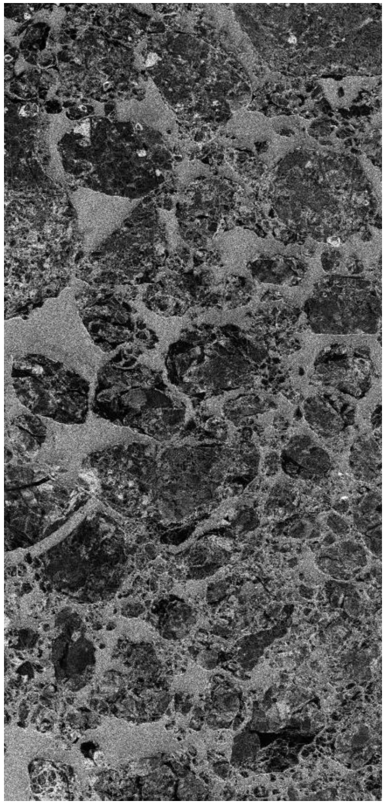


PolSAR Data

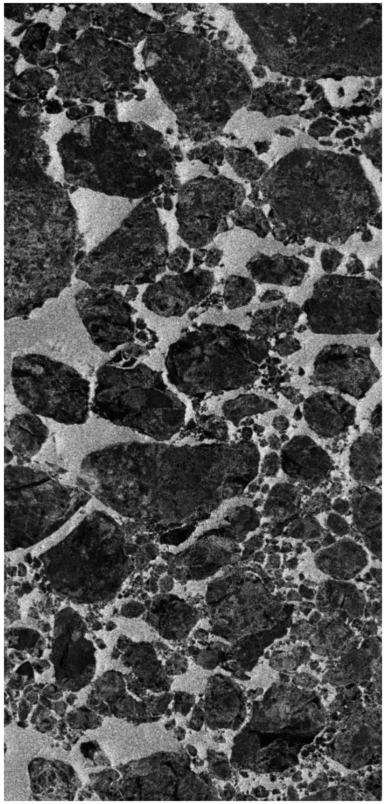
- **What does the PolSAR data show?**



HH

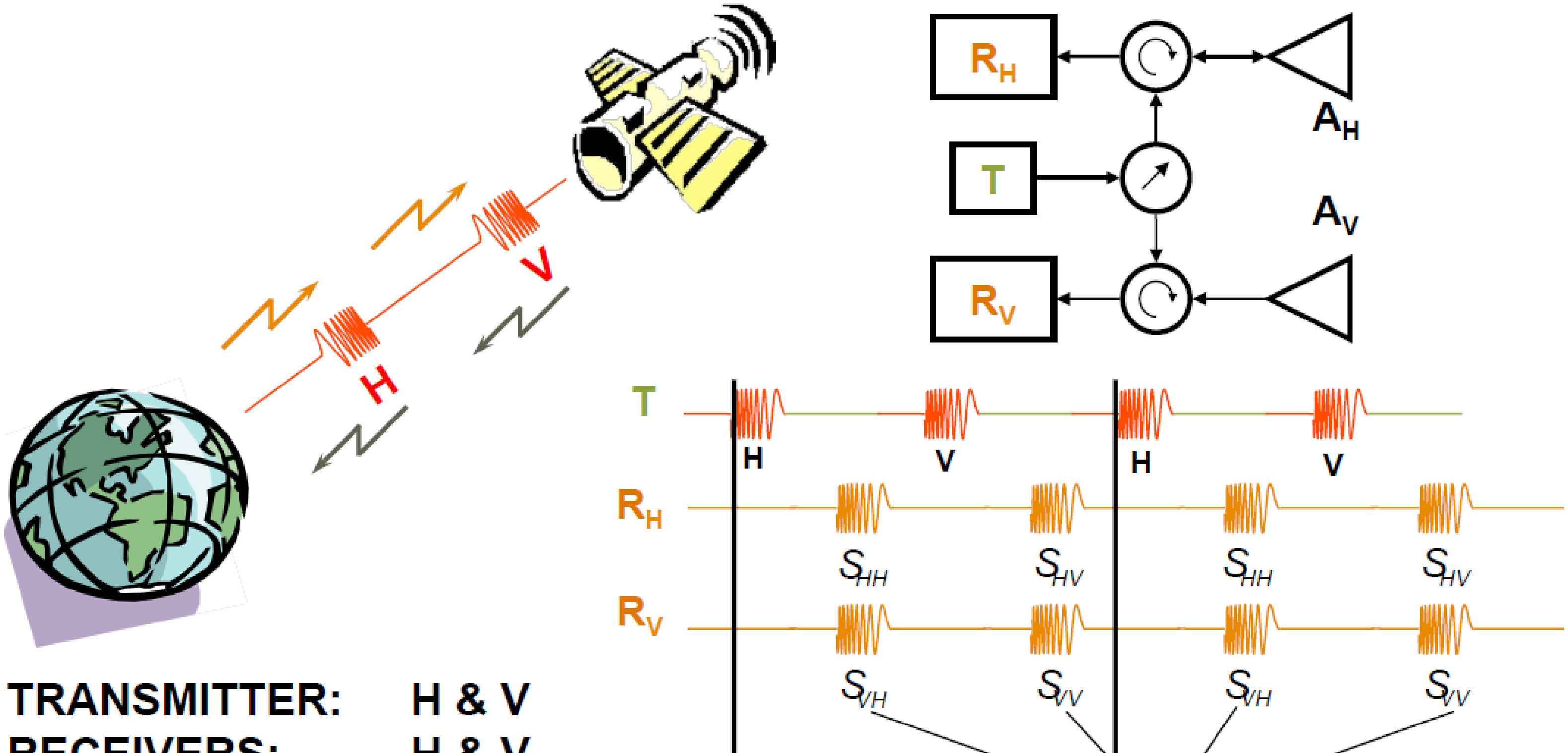


HV



VV

PolSAR Data



TRANSMITTER: H & V
RECEIVERS: H & V

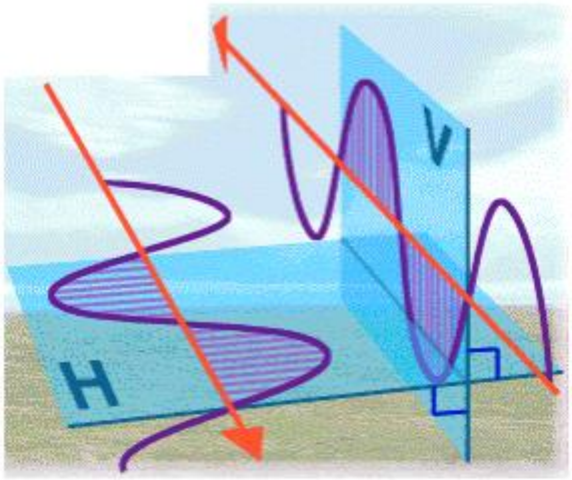
(BACK)SCATTERING MATRIX

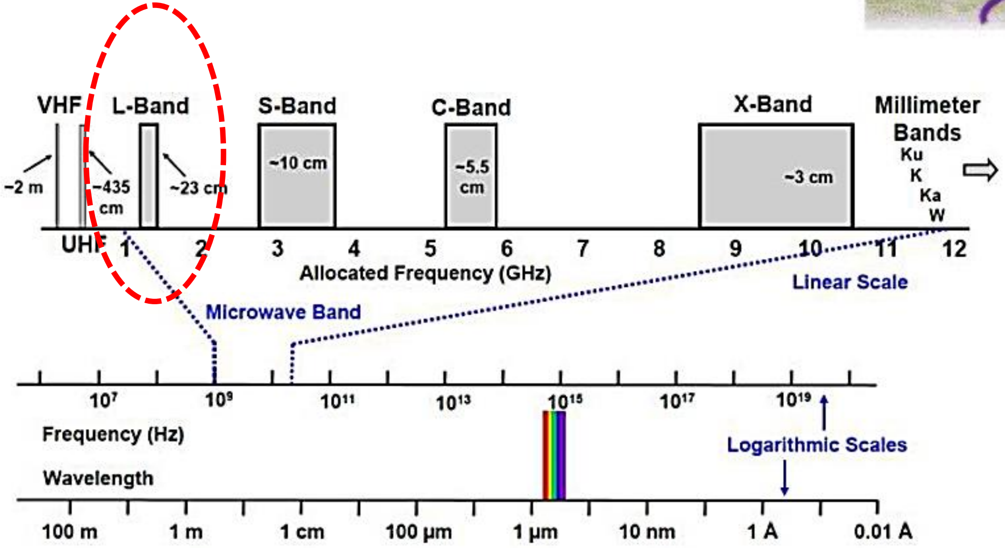
$$\left\{ [S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix} \right\}$$

PolSAR Data

PolSAR data is a function of:

- Wavelength
- Polarization





PolSAR Data Wavelength

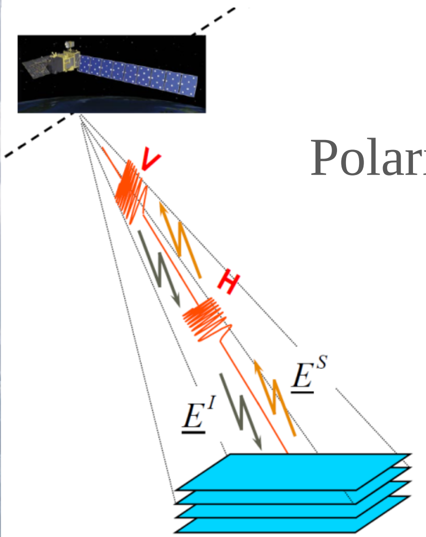
- L-band has deeper penetration capability,
- Improved separation of ice types in summer,

Radarsat2, C-band

ALOS PALAR, L-band

RDC Statoil

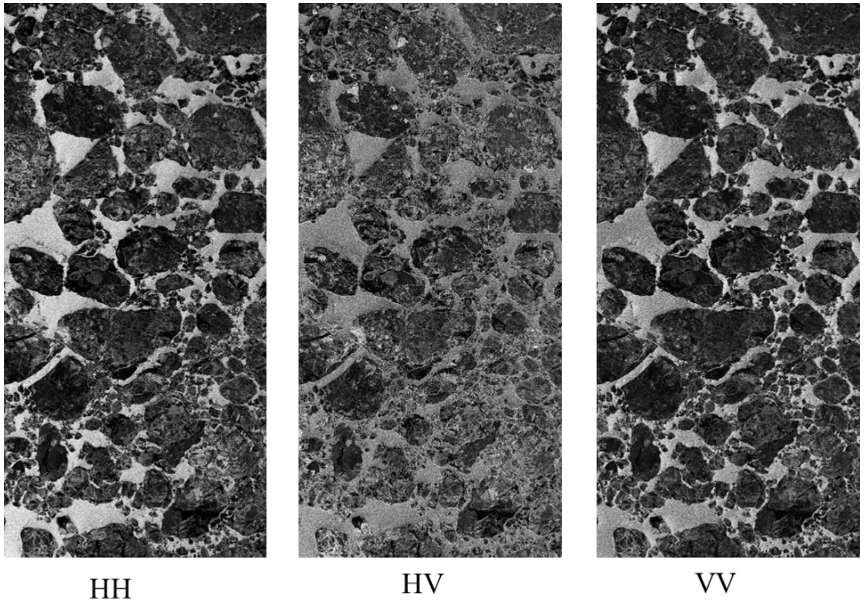
PolSAR Data Polarization



Polarimetric channels:

- single pol
(HH v VV v HV v VH)
- dual pol
(HH & HV v VV & VH)
- full pol
(HH & HV & VH & VV)

HH v VV – co-polarized channels
HV v VH – cross-polarized channels



We applied our proposed method to fully polarimetric L-band SAR data, ALOS PALSAR satellite.

PolSAR Data

The scattering matrix, which is the simplest representation of PolSAR data, can be defined as:

$$S = \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix}$$

The polarimetric scattering information can be represented by scattering vector using the Pauli basis (k) or lexicographic basis (Ω):

$$k = \frac{1}{\sqrt{2}} [S_{hh} + S_{vv} \quad S_{hh} - S_{vv} \quad 2S_{hv}]^T$$

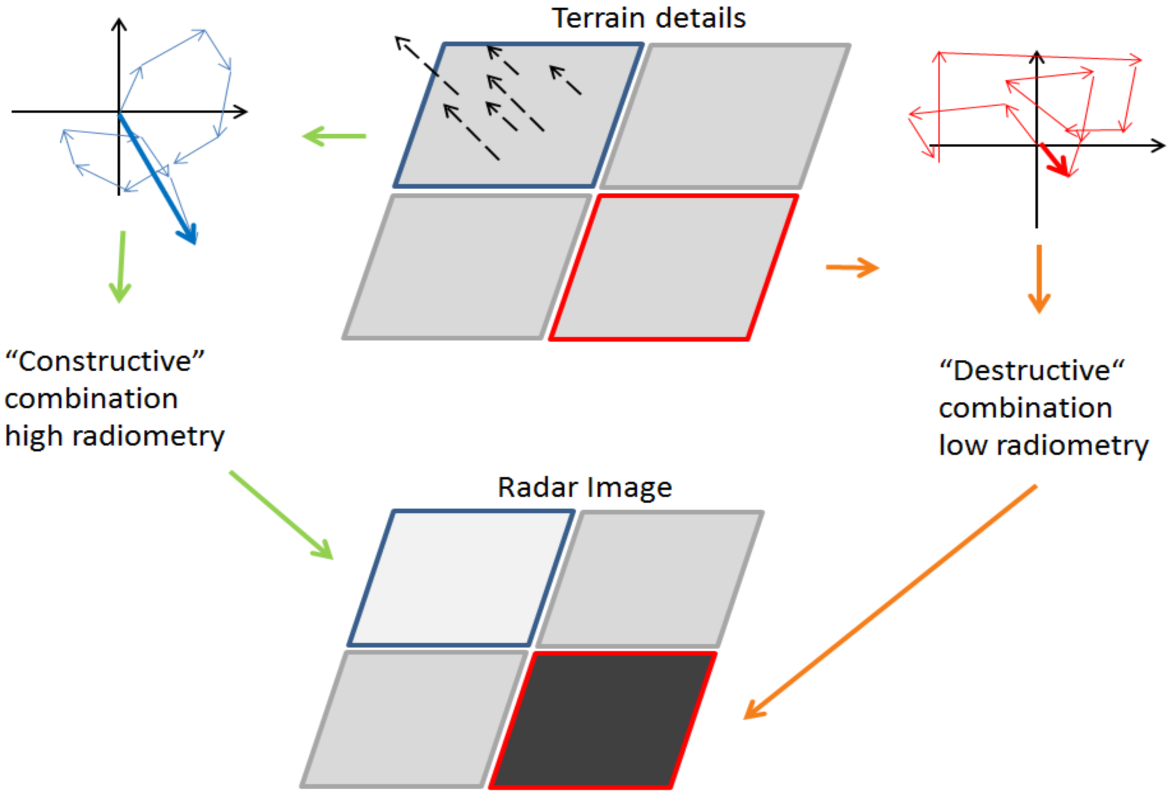
$$\Omega = [S_{hh} \quad \sqrt{2}S_{hv} \quad S_{vv}]^T$$

Thus, the covariance and coherency matrix can be determined by:

$$C = \Omega\, \Omega^{*T}; \quad T = K\, K^* = \begin{bmatrix} \boldsymbol{T11} & \boldsymbol{T12} & \boldsymbol{T13} \\ \boldsymbol{T21} & \boldsymbol{T22} & \boldsymbol{T23} \\ \boldsymbol{T31} & \boldsymbol{T32} & \boldsymbol{T33} \end{bmatrix}$$

Speckle and filtering techniques

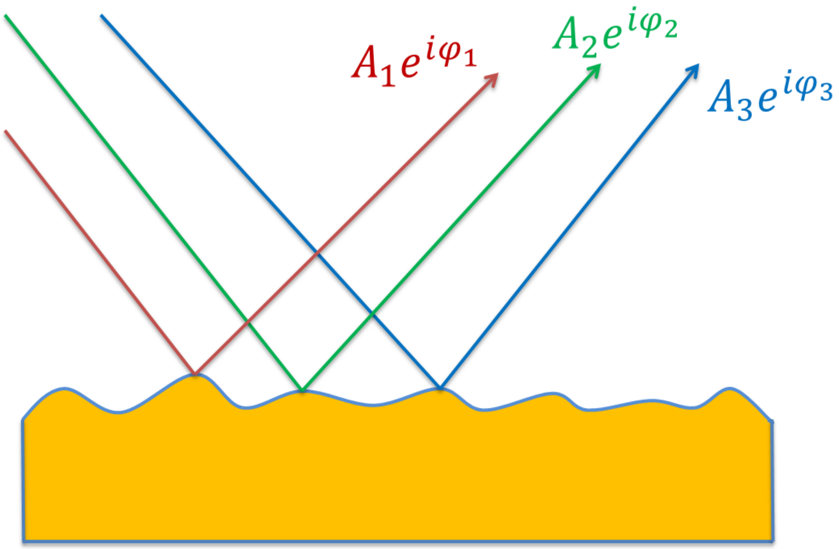
Addition of backscatter from a collection of targets produces randomly constructive or destructive interference.



Speckle and filtering techniques

Scattering model addressing fully developed speckle.

$$A_t\, e^{\,i\varphi_t} = \sum\nolimits_k A_k\, e^{\,i\varphi_k}$$



Speckle and filtering techniques

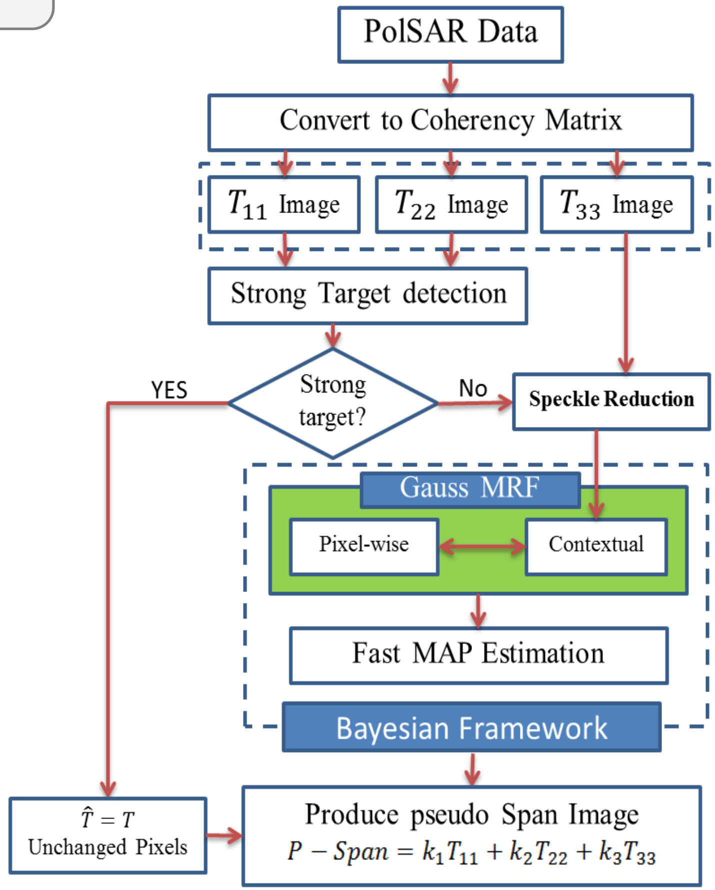
The polarimetric speckle filter should have the following characteristics:

- Preserves polarimetric properties,
- Avoids cross-talk between polarization channels. Each element of the covariance matrix has to be filtered independently,
- Preserves scattering characteristics, edge sharpness and point targets (be adaptive).

Proposed method for speckle reduction

- The strong point targets have been detected by T_{11} for surface scattering and T_{22} for double bounce scattering.

- Strong point targets are not affected by speckle phenomena and, thus, they should be excluded from the de-speckling process.



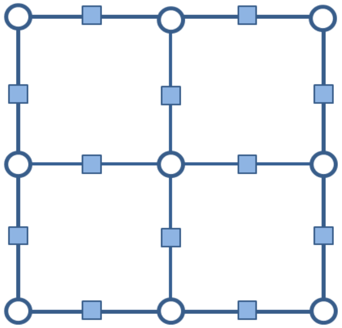
Proposed method for speckle reduction

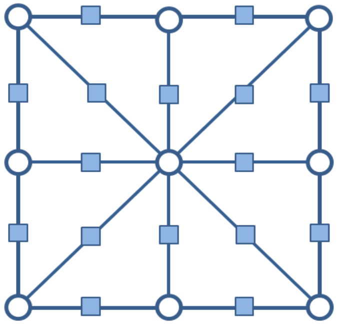
- Bayesian Framework

$$p(x|y,\theta) = \frac{p(y|x,\theta)p(x|\theta)}{p(y|\theta)}$$

- Gaussian Markov Random Field model

$$U(z) = \sum_{i\in\xi} D(x_i) + \lambda \sum_{i\in\xi} \sum_{(i,j)\in\eta} V(x_i, x_j)$$

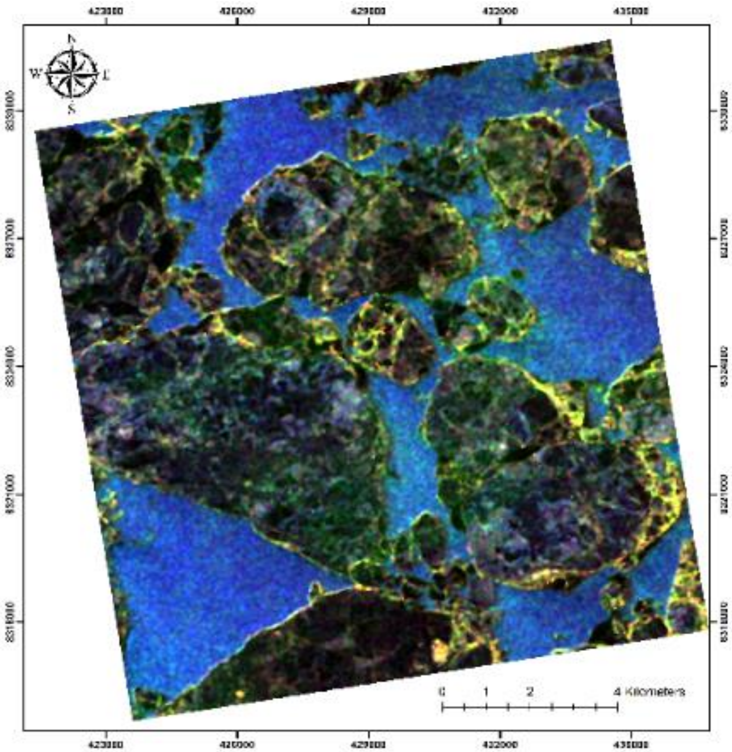




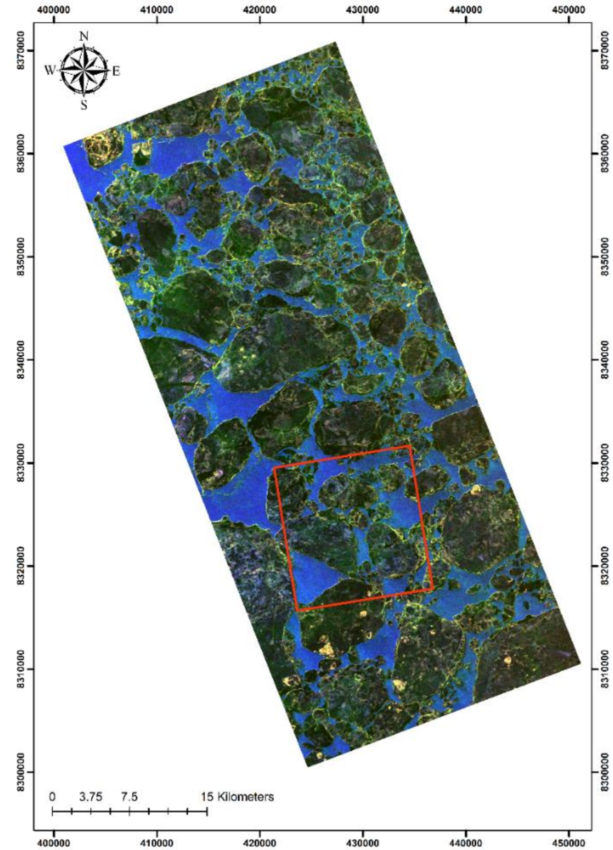
Proposed method for speckle reduction

- Kuan
- Enhanced Lee
- Nonlocal Means
- Proposed method based on a Gaussian Markov Random Field model (GMRF)

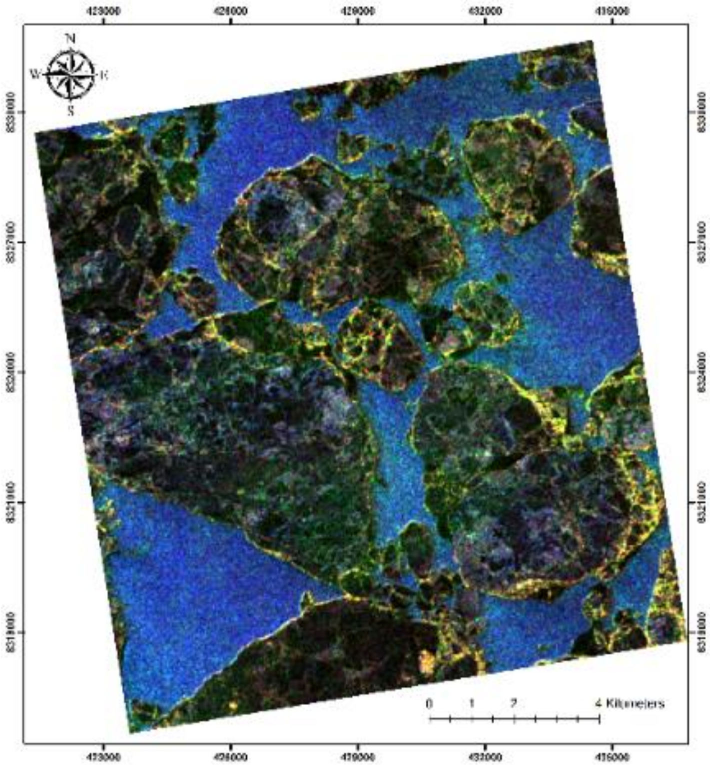
Evaluating de-speckling methods



Proposed method

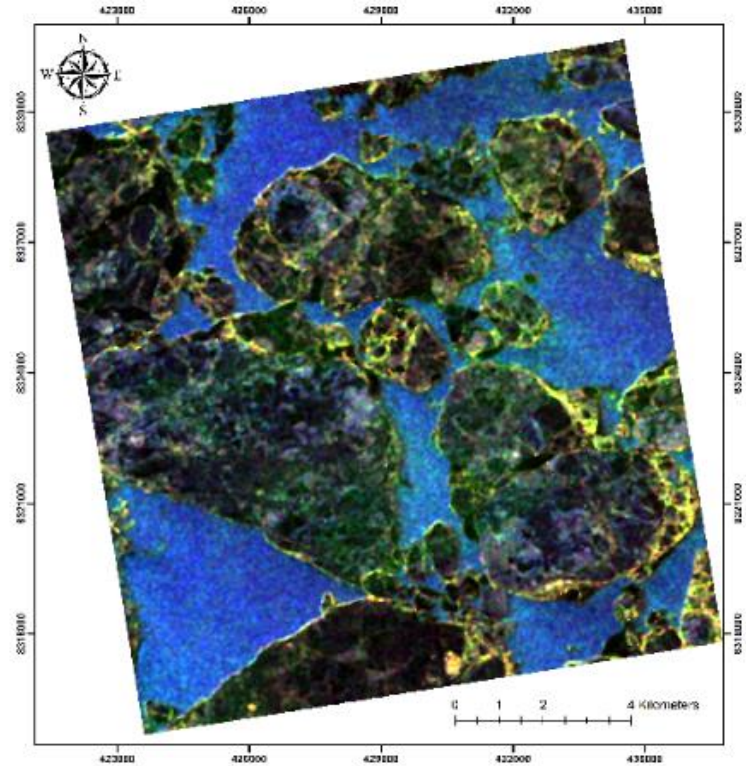


Evaluating de-speckling methods



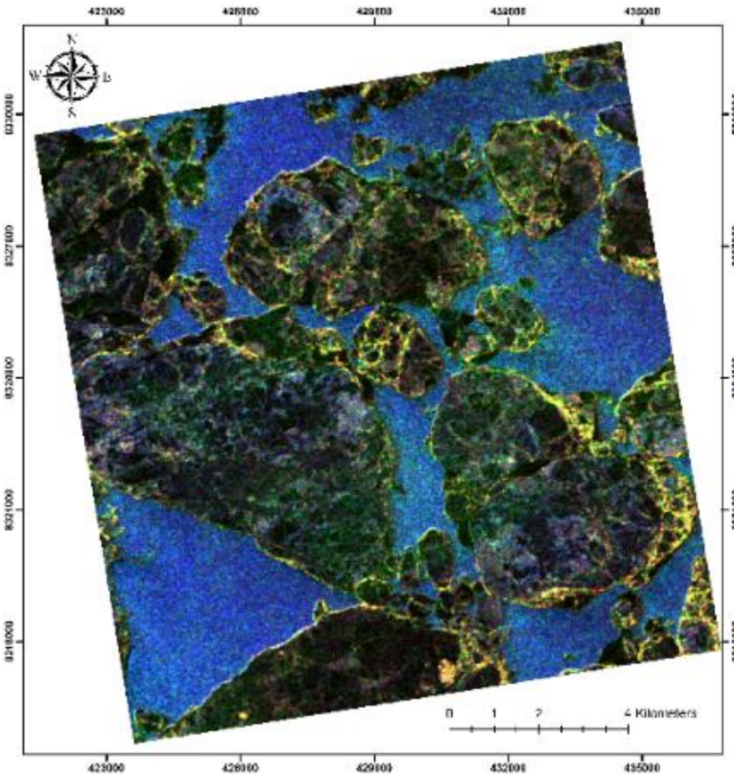
Kuan

- High speckle level.
- Maintains the mean value of the original image in homogenous areas.



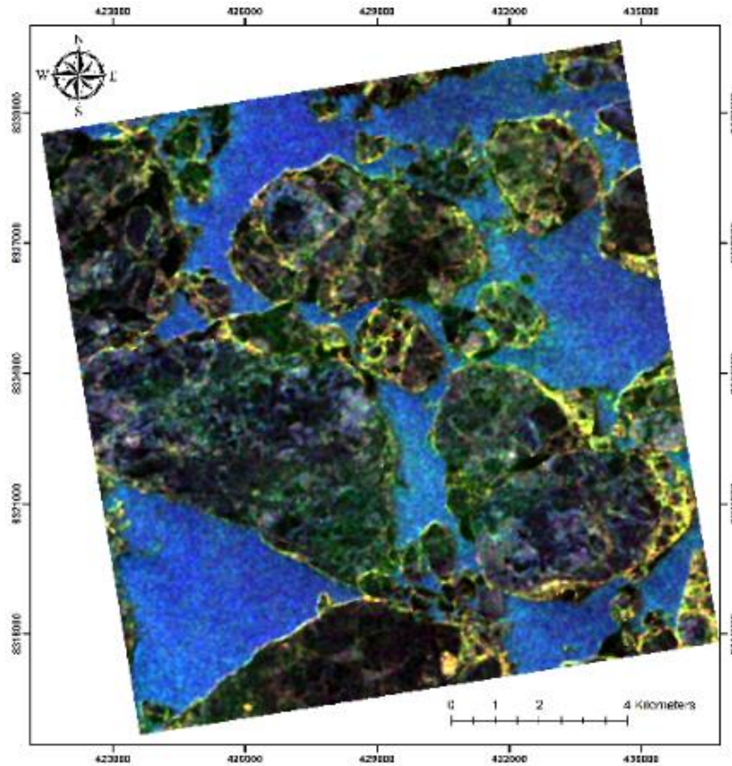
Proposed method

Evaluating de-speckling methods



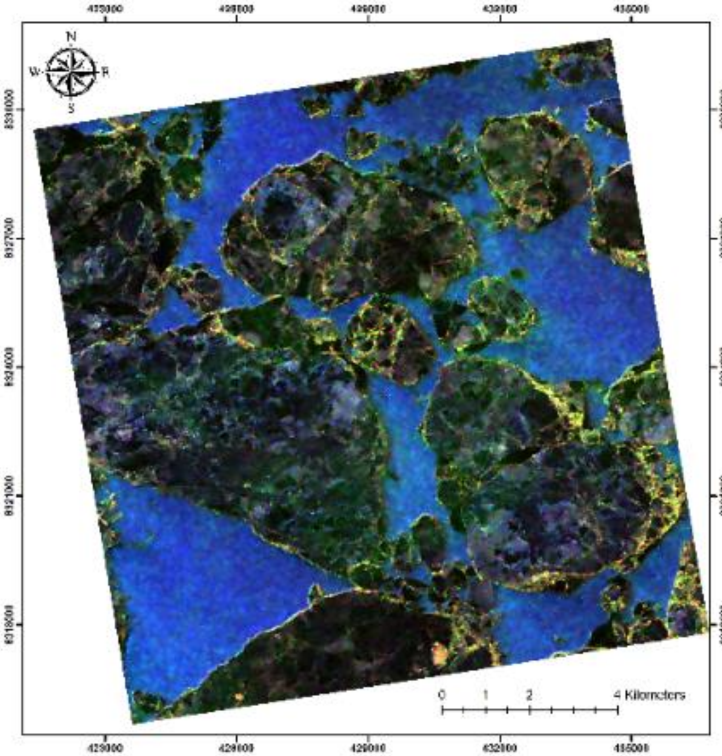
Enhanced Lee

- Moderate speckle level.
- Maintains the mean value of the original image in homogenous areas.
- Preserves the edges.



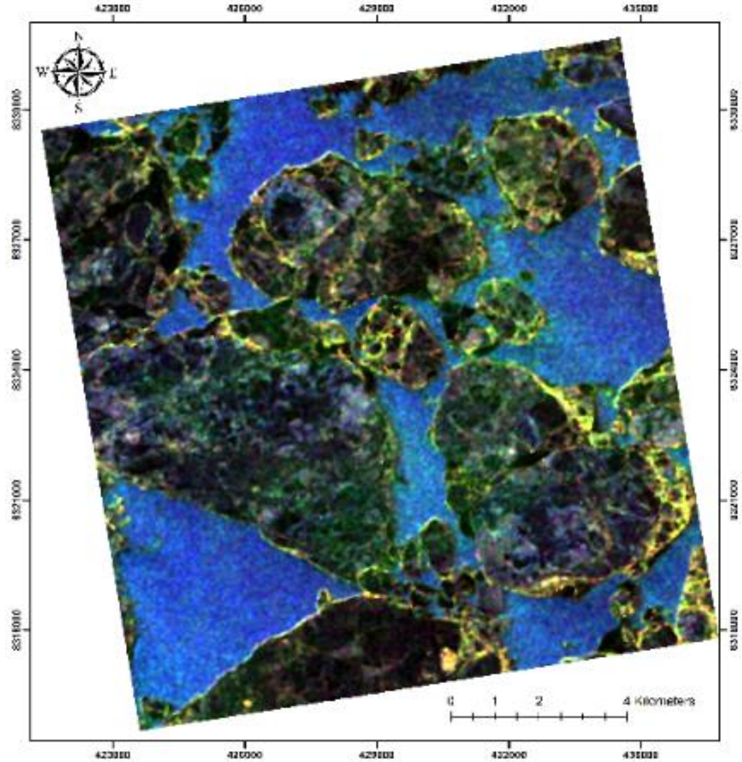
Proposed method

Evaluating de-speckling methods



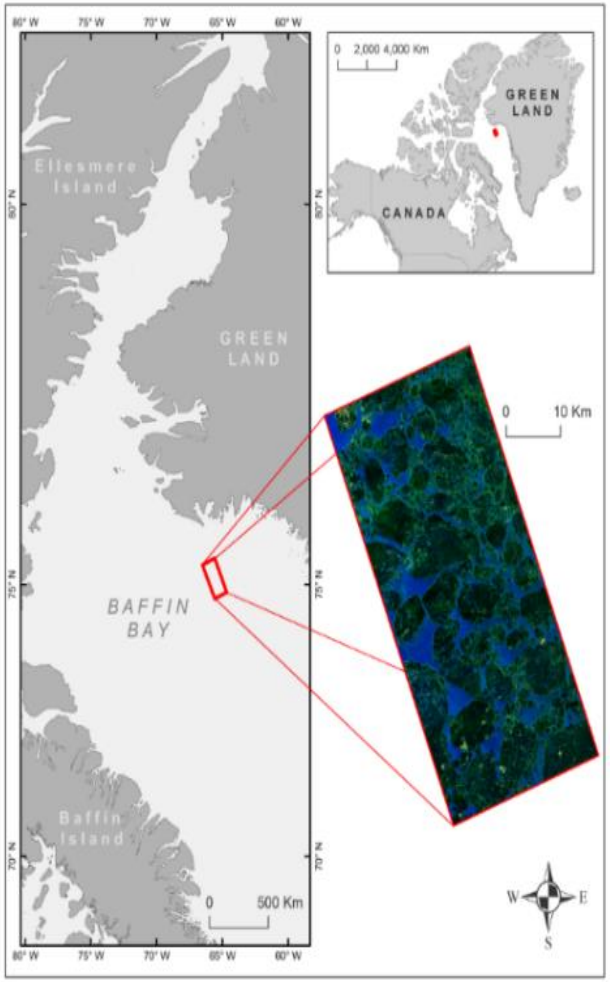
Nonlocal Means and Refined Lee method

- Low speckle level.
- High blurring effect.
- Can not maintains the mean value of the original image.

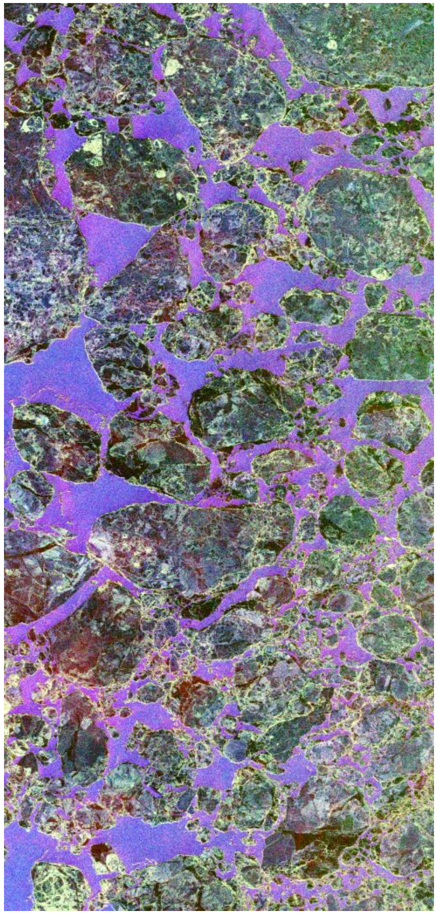


Proposed method

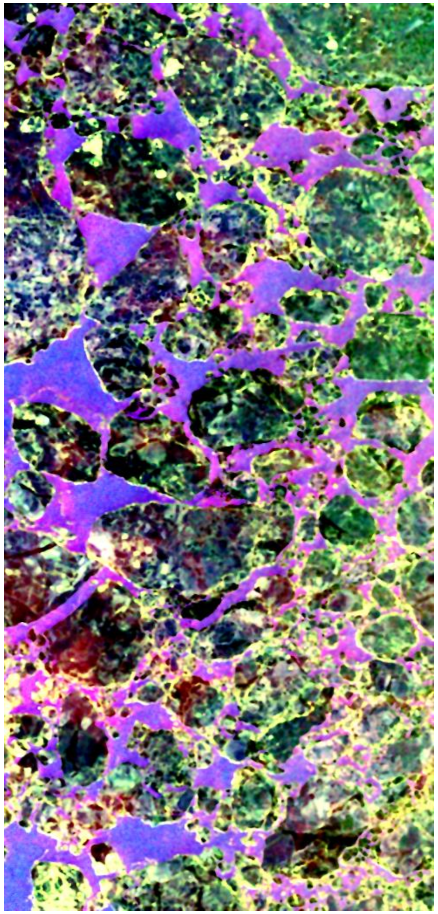
Case Study *Baffin Bay*



Evaluating de-speckling methods



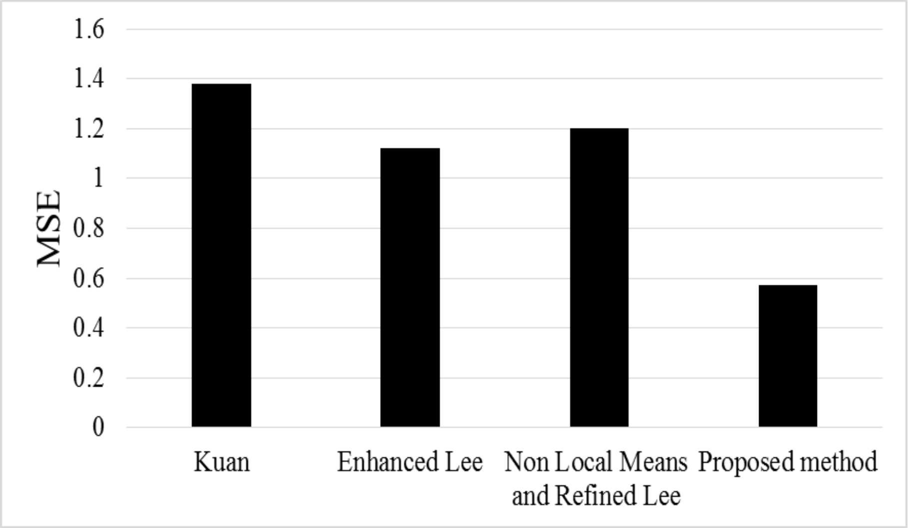
Original Pauli image



De-speckled Pauli image

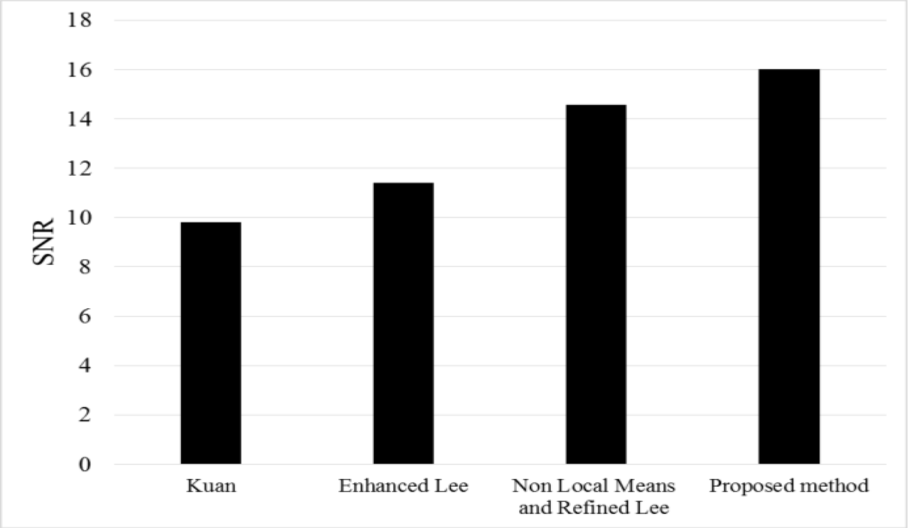
De-speckling filters

The MSE parameter represents the global assessment of de-speckling performance. The Kuan and proposed method indicated the highest and lowest MSE. In particular, a MSE of about 1.39, 1.1, 1.19, and 0.58 were obtained by the Kuan, Enhanced Lee, Nonlocal, and the proposed method, respectively.



De-speckling filters

A SNR value of about 15.9, 14.3, 11.3, and 9.7 was obtained by the proposed method, Nonlocal, Enhance Lee, and Kuan filter, respectively. Again, the Kuan filter was shown to be the least successful filter with a lower SNR value than other filters.



De-speckling filters

The results illustrated that both the proposed method and the enhanced Lee method were successful for edge preservation in horizontal and vertical directions. However, the proposed method demonstrated a slightly better capability. The nonlocal filter method also showed comparable results with the first two successful filters.

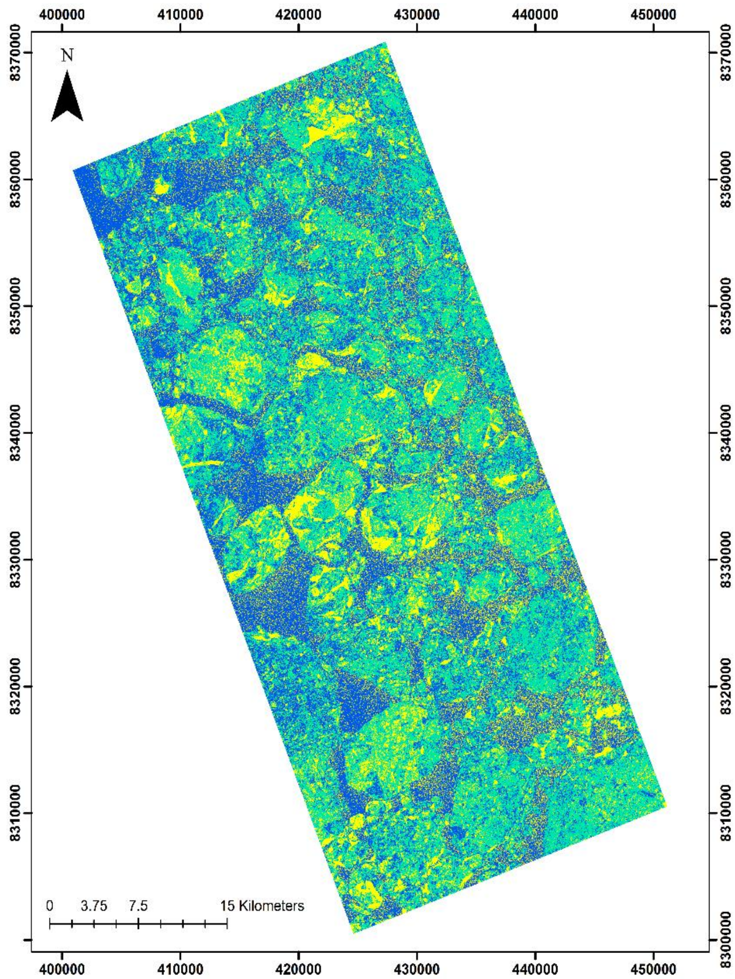
De-speckling methods	ESI-H	ESI-V
Kuan	0.41	0.43
Enhanced Lee	0.64	0.66
Non Local Means and Refined Lee	0.58	0.61
Proposed method	0.65	0.69

Sea ice classification

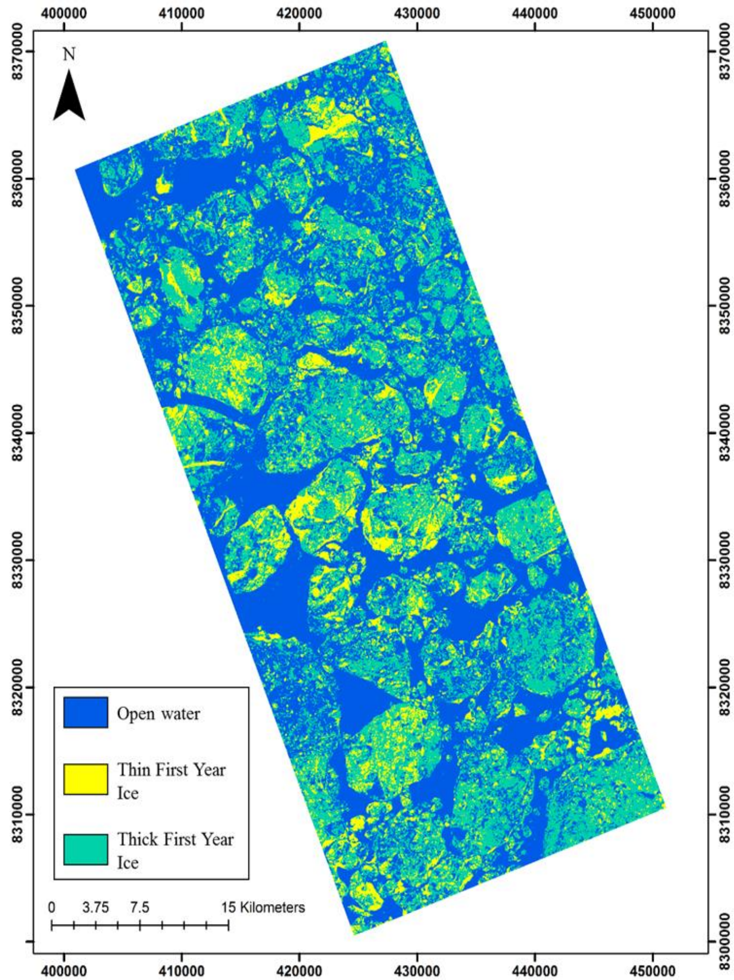
Next, all de-speckled images using different de-speckling methods were applied into a supervised Maximum Likelihood Classifier. Particularly, we evaluated the capability of different de-speckling methods based on the overall classification accuracy.

De-speckling methods	OA (%)	K
Kuan	61	0.49
Enhanced Lee	68	0.54
Nonlocal Means and Refined Lee	64	0.51
Proposed method	79	0.68

Classified map



Kuan filter



Proposed method

Conclusion

- A new de-speckling method based on an adaptive Gaussian Markov Random Field (GMRF) model was proposed, and its efficiency was evaluated compared to other well-known de-speckling methods, including the Kuan method, the enhanced Lee method, and the Nonlocal Means and Refined Lee method.
- Several de-speckling indices were used to evaluate the capability of the proposed method as well as other methods.
- Overall, the proposed method illustrated to be more efficient in terms of both mean signal preservation and speckle reduction.
- Particularly, the de-speckled images obtained by the Kuan and enhanced Lee methods exhibited signs of noise after applying the filter.
- Although, the Nonlocal Means and Refined Lee method was better able to remove noise, it was still unsuccessful in mean signal preservation.
- The de-speckled PolSAR images were further used in the Maximum Likelihood Classifier for sea ice classification.
- It was observed that the de-speckled image obtained by the proposed method resulted in the most accurate classified map.
- An overall classification accuracy of about 79% was obtained by the proposed method, which was 11%, 15%, and 18% higher than the enhanced Lee method, the Nonlocal Means and Refined Lee method, and the Kuan method, respectively.

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