# DEPENDENCE OF SIGNATURE CONTRAST BETWEEN ICEBERGS AND SEA ICE ON ICE CONDITIONS AND RADAR PARAMETERS

**Laust Færch[1], Rida Bokhari[2], Genwang Liu[2], Xi Zhang[2], Wolfgang Dierking[1,3]**
1 UiT The Arctic University of Norway, Tromsø
2 First Institute of Oceanography, Ministry of Natural Resources, Qingdao, China
3 Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

## Abstract

Images from satellite Synthetic Aperture Radar (SAR) are widely used for iceberg monitoring. Icebergs can be detected in SAR images if the difference (the "contrast") between the backscattered radar intensities from an iceberg and from the surface around it is statistically significant. In our presentation, we focus on sea ice surfaces. For test sites from Greenland, we used L-and C-band SAR systems and found that the intensity contrast depends on the radar frequency, the incidence angle and the sea ice surface characteristics. Moreover, iceberg detection based on L-band Compact Polarimetric SAR (CP) was investigated. CP features were evaluated for sea ice conditions by using three indices of Euclidean distance, Bhattacharyya distance and target-background contrast. The CP feature with best iceberg detection potential was the second eigenvalue λ2 of covariance matrix. Therefore, λ2 was used to detect iceberg by the generalized gamma distribution CFAR method. Compared with the single-polarization (HV-CFAR) and full-polarization (GNF) detection methods, the proposed method reveals a good detection performance for icebergs of different sizes in sea ice conditions and has a good application prospect in the use and combination of recent and upcoming SAR satellite missions.

## Introduction

- C-band SAR is regularly used for monitoring icebergs in open water. Detecting icebergs in sea ice has only received little attention in the literature.
- L-band SAR has shown the potential to improve detections, but very few comparisons between C- and L-band have been published in the literature until now.
- Sea ice exhibit a highly varying backscatter depending on ice type, incidence angle, polarization, and season. This makes the separation of icebergs from sea ice more difficult.
- Quad-polarimetric SAR may solve some challenges but has limited swath widths and is therefore not suitable for operational monitoring.
- Circular Polarization (CP) SAR can provide scattering information similar to quad-pol SAR over wider swaths.

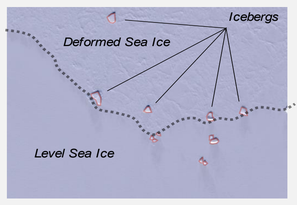
## Objectives

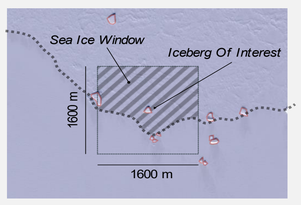
- Compare backscatter from icebergs and surrounding sea ice for C- and L-band SAR
- Investigate the relationship between the contrast and incidence angle
- Evaluate the potential of numerous CP SAR polarization features in iceberg detection
- Test the detection of icebergs using the most suitable features for CP SAR

## Methods

Backscatter comparison between C and L band SAR of Iceberg

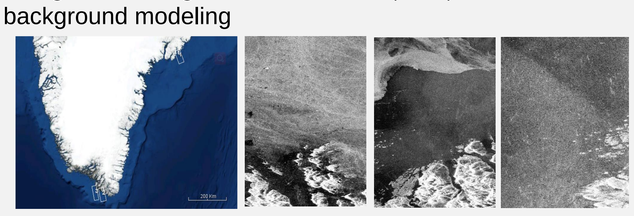
- Backscatter from 657 icebergs (301 from 2019 and 356 from 2020) were extracted
- 41 ALOS-2 images (22 from 2019 and 19 from 2020) and 31 Sentinel-1 images (14 from 2019 and 17 from 2020) were available
- For each iceberg we extracted the average iceberg backscatter and the average background (sea ice) backscatter



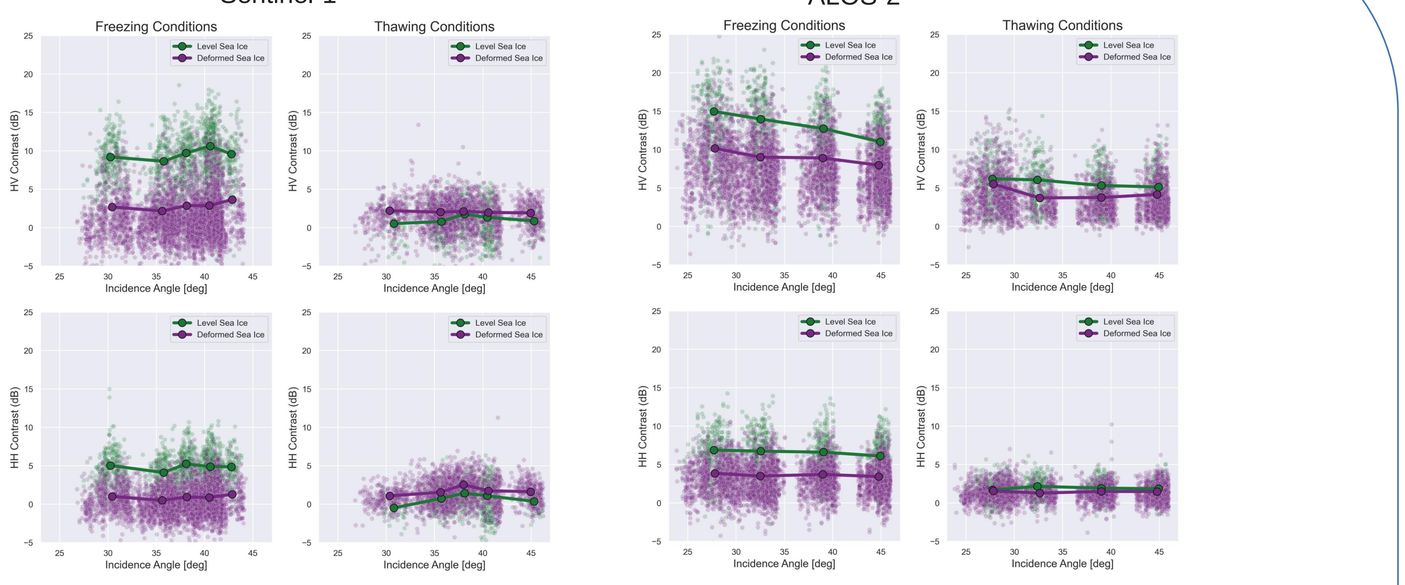

Iceberg detecion for CP SAR

- 3 ALOS images with 100 icebergs were used.
- 39 different CP SAR polarization features were evaluated.
- 3 indexes of Euclidean distance, Bhattacharyya distance and target-background contrast were used to compare features.
- The generalized gamma distribution (GΓD) is used for background modeling

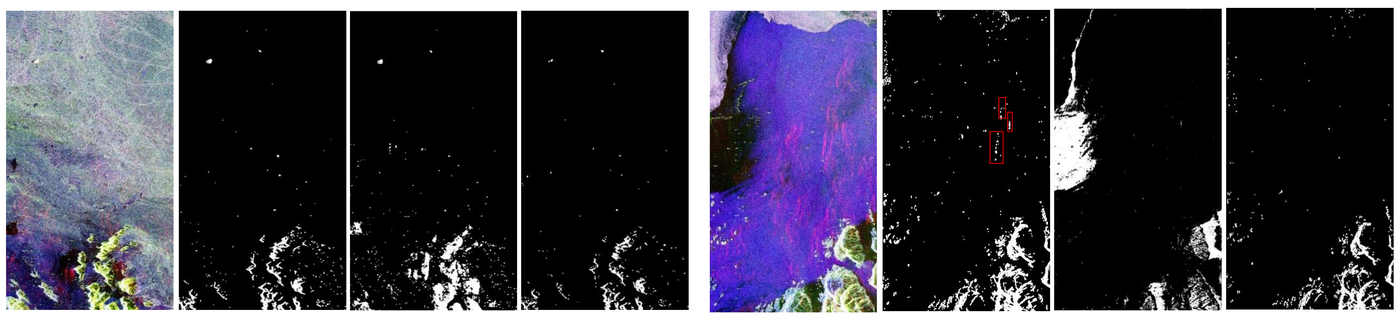


## Results

Backscatter comparison between C and L band SAR of Iceberg




Detection results for CP SAR



**RGB image** | FOM=0.79 **$\lambda_2$-GΓD-CFAR** | FOM=0.62 **GNF** | FOM=0.69 **HV-GΓD-CFAR**

**RGB image** | FOM=0.72 **$\lambda_2$-GΓD-CFAR** | FOM=0.54 **GNF** | FOM=0.57 **HV-GΓD-CFAR**

## Discussion

Backscatter with incidence angle in thawing and freezing conditions

- The iceberg – sea ice backscattering contrast is higher under freezing than under thawing conditions.
- The contrast at L-band is generally higher than at C-band, and higher at HV- than at HH-polarization.
- L-band shows a decrease of the contrast with incidence angle in particular under freezing conditions and at HV-polarization.

Iceberg detection using CP SAR

- There are differences in the variation patterns of the three indicators on 39 features
- Compact λ2, pv, H, α, and Raney_Rnd are the feature that show larger distance and contrast values.
- The generalized gamma distribution model (GΓD) is suitable for the modeling of complex sea ice conditions.

## Conclusion

Iceberg Sea Ice Contrast

- L-band appears to have a large advantage over C-band SAR for detecting icebergs in sea ice.
- Low incidence angles and freezing conditions offer the best conditions for detecting icebergs in sea ice with L-band SAR.

Iceberg detection for CP SAR

- 39 different CP SAR features in complex sea conditions was evaluated by using three indexes.
- The CP SAR features with the best iceberg detection potential is the second eigenvalue λ2 of the covariance matrix.
- The λ2-GΓD-CFAR method for iceberg detection has a good application prospect in complex sea conditions.

## References

Amdal, F., & Hughes, N. (2022). Multi-Sensor Ice Analysis Data: Analysis for Belgica Bank, North East Greenland 2019-20 (1.0.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7053975
G. Liu, J. Zhang, X. Zhang, J. Meng, M. Bao and C. Cao, "Iceberg Detection Based on L-band Compact Polarimetric SAR," 2021 CIE International Conference on Radar (Radar), Haikou, Hainan, China, 2021, pp. 586-589

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