THE CHALLENGE OF YEAR-LONG HIGH RESOLUTION ICE CLASSIFICATION

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The remoteness and environmental hostility of the arctic region greatly impacts polar remote sensing research, because collecting in-situ measurements is arduous and expensive. In the case of sea ice property or class retrieval, the research becomes heavily reliant on human annotated datasets. Due to the limited time that a human observer can spend on a scene and the difficulty of labelling sea ice from the backscatter alone, these annotations suffer from a range of drawbacks. Apart from possible mislabelling and human bias, they are also either coarse or not covering the large span of possible ice conditions. By coarseness it is meant that the class polygons are drawn without attention to detail, like in operational ice charts. Here little to no effort is made to for example separate individual floes, leads or young ice inclusions. If the time is taken to produce a high resolution dataset, the number of scenes that can be labelled at this standard is low. Because of the large diversity of ice conditions and resulting SAR signatures across the seasons, the span of sea ice signatures is usually not covered by these types of datasets. The fast evolving climate further increases the difficulty, as the ice type distributions and signatures are changing and thus arises the need to update these datasets frequently.

Data-driven algorithms, like neural network based approaches, cannot learn anything that is not represented in the data. To realise the potential of a reliable classifier near pixel resolution, that SAR offers, human annotated datasets as mentioned above are thus not sufficient on their own. The challenge is to extract additional local sea ice information at high resolution which does not need any human interaction. One observational sea ice property that could fulfil these requirements is the incidence angle dependence of different ice classes' backscatter.

From a number of observations we know that different ice classes' backscatter signatures behave differently under change of incidence angle in the HH band (fig. 1). The amount of energy returned to the sensor depends on the incidence angle because the observed structure is not symmetrical under change of angle. The most dominant symmetry breaking feature is of course the orientation of the earth's surface. Secondary effects arise because of oriented features, such as brine channels, air bubbles or surface deformations. As these correlate with different stages of ice development, the difference in incidence angle dependencies is to be expected. The HV band backscatter is lower generally over sea ice, and so are the incidence angle dependent changes ($magnitude < 0.02$ dB/Deg as reported by [3]). However, one would also expect diverse relations for different ice classes here - their smaller magnitude just makes them more difficult to observe. Research by Gill et al. [6] found significant gradients over land fast first-year ice for the HV backscatter.

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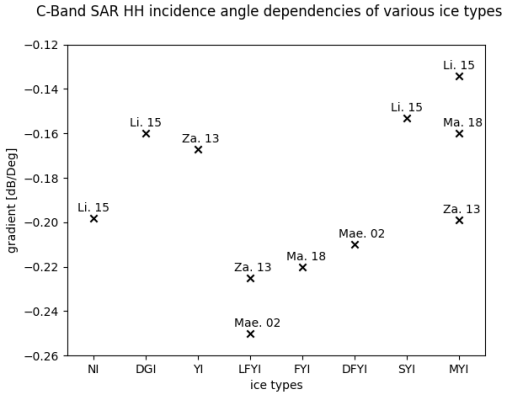

Fig. 1. C-Band IA dependency measurements at HH from Satellite SAR during freeze-up and winter seasons until 2018. Summary in [1]. Originally published [2, 3, 4, 5]

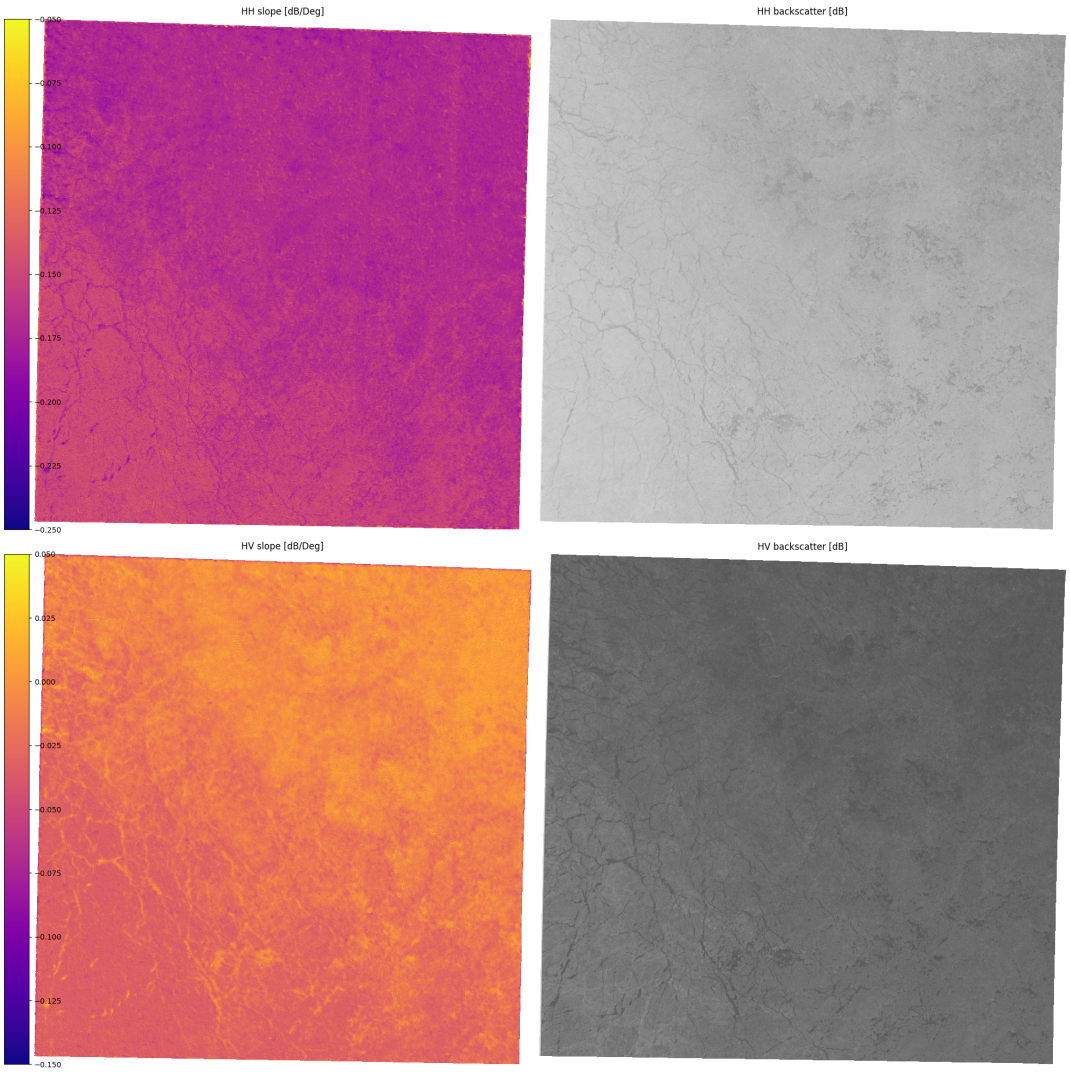

Fig. 2. Predicted backscatter gradients using a GAN based approach show of clear differences between older (bottom left) and younger (top right) ice sheets.

Predicting these dependencies from a single scene is a difficult but feasible process, because we know the incidence angle for every pixel in the scene. A physics constrained neural network GAN setup allows to train an algorithm that produces reasonable results for the local incidence angle dependence (fig. 2), where predictions are in line with previous observations (fig. 1). The GAN setup is trained with only the SAR data, meaning it can easily be scaled to a pan-arctic and multi-seasonal algorithm. Solving this prediction task forces the algorithm to implicitly learn about ice classes, without needing any labels. As this can be trained and used with any and all acquisitions it could prove a valuable asset to provide the high resolution information for the complete span of possible backscatter signatures of sea ice, that we are missing from human annotated ice charts.

In summary, the sparseness of coincident in-situ measurements for sea-ice observations necessitates the extraction of additional information that does not rely on labels to improve retrieval methods. Incidence angle dependence has a high correlation with different ice classes and can be predicted from the SAR scene alone with reasonable results. Improving the extraction and integrating the information into a classifier could help complete the sea ice class retrieval puzzle and can offer sustainable support for the future as it does not rely on measurements other than SAR.

1. REFERENCES

[1] Marko Mäkynen and Juha Karvonen, "Incidence angle dependence of first-year sea ice backscattering coefficient in sentinel-1 sar imagery over the kara sea," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 55, no. 11, pp. 6170–6181, 2017.

[2] Natalia Zakhvatkina, Vitaly Alexandrov, Ola Johannessen, Stein Sandven, and Ivan Frolov, "Classification of sea ice types in envisat synthetic aperture radar images," *Geoscience and Remote Sensing, IEEE Transactions on*, vol. 51, pp. 2587–2600, 05 2013.

[3] Huiying Liu, Huadong Guo, and Lu Zhang, "Svm-based sea ice classification using textural features and concentration from radarsat-2 dual-pol scansar data," *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of*, vol. 8, pp. 1601–1613, 04 2015.

[4] Mallik S. Mahmud, Torsten Geldsetzer, Stephen E. L. Howell, John J. Yackel, Vishnu Nandan, and Randall K. Scharien, "Incidence angle dependence of hh-polarized c- and l-band wintertime backscatter over arctic sea ice," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 56, no. 11, pp. 6686–6698, 2018.

[5] M.P. Makynen, A.T. Manninen, M.H. Simila, J.A. Karvonen, and M.T. Hallikainen, "Incidence angle dependence of the statistical properties of c-band hh-polarization backscattering signatures of the baltic sea ice," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 40, no. 12, pp. 2593–2605, 2002.

[6] Jagvijay Gill, J.J. Yackel, Torsten Geldsetzer, and M. Christopher Fuller, "Sensitivity of c-band synthetic aperture radar polarimetric parameters to snow thickness over landfast smooth first-year sea ice," *Remote Sensing of Environment*, vol. 166, 09 2015.