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Evaluation of River and Lake Ice Cover, Based on SENTINEL-1 Backscatter Values in VV and VH Polarizations

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Introduction

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This research will evaluate if Sentinel-1 data is suitable for monitoring ice phenomena in Lithuania and territories of similar climate and if satellite image analysis is accurate enough to determine exact boundaries of ice cover.

The main aim of this study is to create ice detection method for rivers and lakes based on Sentinel-1 SAR signal dual polarization (VV and VH) backscatter values.

Data and methods

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Our areas of interest were two biggest rivers of Lithuania – Nemunas and Neris, and a few lakes where ice thickness measurements are still being conducted by local observers: Tauragnas, Žuvintas, Sartai, Kaunas reservoir, lake Totoriškiai, Stervas, Paršežeris.

We used Sentinel-1 A and Sentinel-1 B satellite data. They were launched on 3rd of April 2014 and 25th of April 2016 respectively. Therefore, in order to analyse territories with sufficient temporal resolution, 2016 – 2017 winter was the first season applicable for more reliable analysis.

To process raw satellite imagery, SNAP (Sentinel application platform) was used. It allows to modify imported images by applying various pre-processing steps in order to get an image that can be used for further analysis

Data from Lithuanian hydrometeorological service and Sentinel-2 images were used to validate our findings.

Polarization

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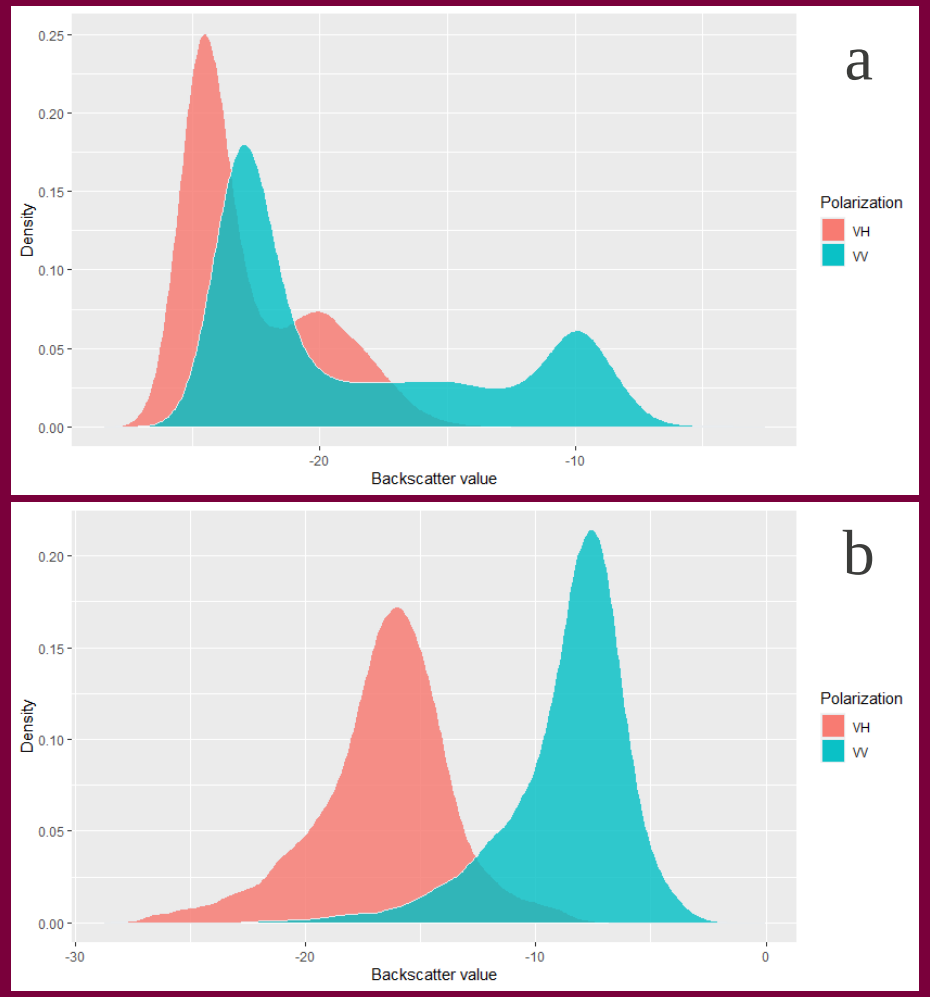

Fig. 1 Distribution of polarization values in Nemunas river section from Smalininkai to river delta in 2018-02-19 (a) and 2018-02-26 (b)

Sentinel-1 satellite can transmit a signal in either horizontal (H) or vertical (V) polarization, and then receive in both H and V polarisations. Orientation of the objects on the surface influence the polarization backscattered field and we can use this information to interpret what the surface characteristics are. In our case, Sentinel-1 images were only available at VH and VV polarizations.

Distribution of pixels when river section was almost fully covered in ice (Figure 1a) shows a clear single peaks in both polarizations, giving us a possibility to determine a backscatter value range that we can consider to be ice surface.

When only part of the river is covered (Figure 2b), we can isolate 2 peaks in pixel distribution map. Pixel distribution of VV and VH polarizations had noticeable differences. VV polarization pixels have bigger value spread compared to VH polarization. We suspect that VV polarization is more sensitive to floating ice which has its backscatter values mixed with water around it, therefore it could be more suitable for precise ice phenomena observations.

Ice detection

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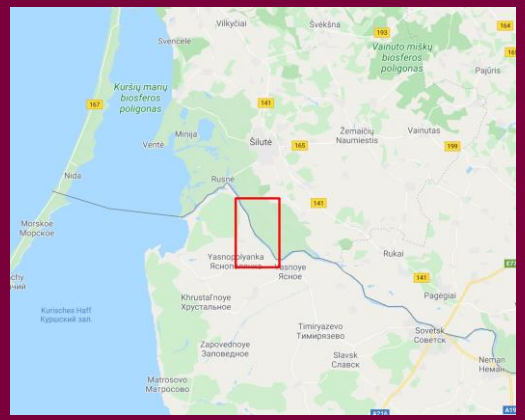

Fig. 3 River section of inerest

Fig. 4 Potencial ice cover (white) in Nemunas river section in 2018-02-02

After analyzing multiple histograms and scatter plots of both polarizations we have set boundary values for ice in both polarizations. >-11 for VV and >-19 for VH. Using these values, we have marked the pixels that meet either one of these margins in white and pixels that do not, in black (Figure 4). This gives us a potential area of ice.

This is only a beginning stage of ice detection algorithm construction. In the next stages we will overlap Sentinel-1 and Sentinel-2 data and use larger number of images to improve the accuracy of determining ice boundaries.

Conclusions

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- VV polarization images appear to have a higher value diapason between open water surface and ice cover. In VH polarization images, ice and water values are closer to each other, but this polarization type may still be useful for ice identification. The combination of both polarizations seems like the best approach to determine accurate ice boundaries
- River surface values above -11 in VV polarization can be classified as continuous ice, while in VH polarization this value is around -19. These are only approximate values which will change after improvements to the algorithm.
- Poor image resolution complicates detection of floating ice and extraction of correct river boundaries. Backscatter values of different surfaces mix in the same pixels and gives misleading results.