

Improved lead detection with Sentinel-1 SAR images in the Arctic

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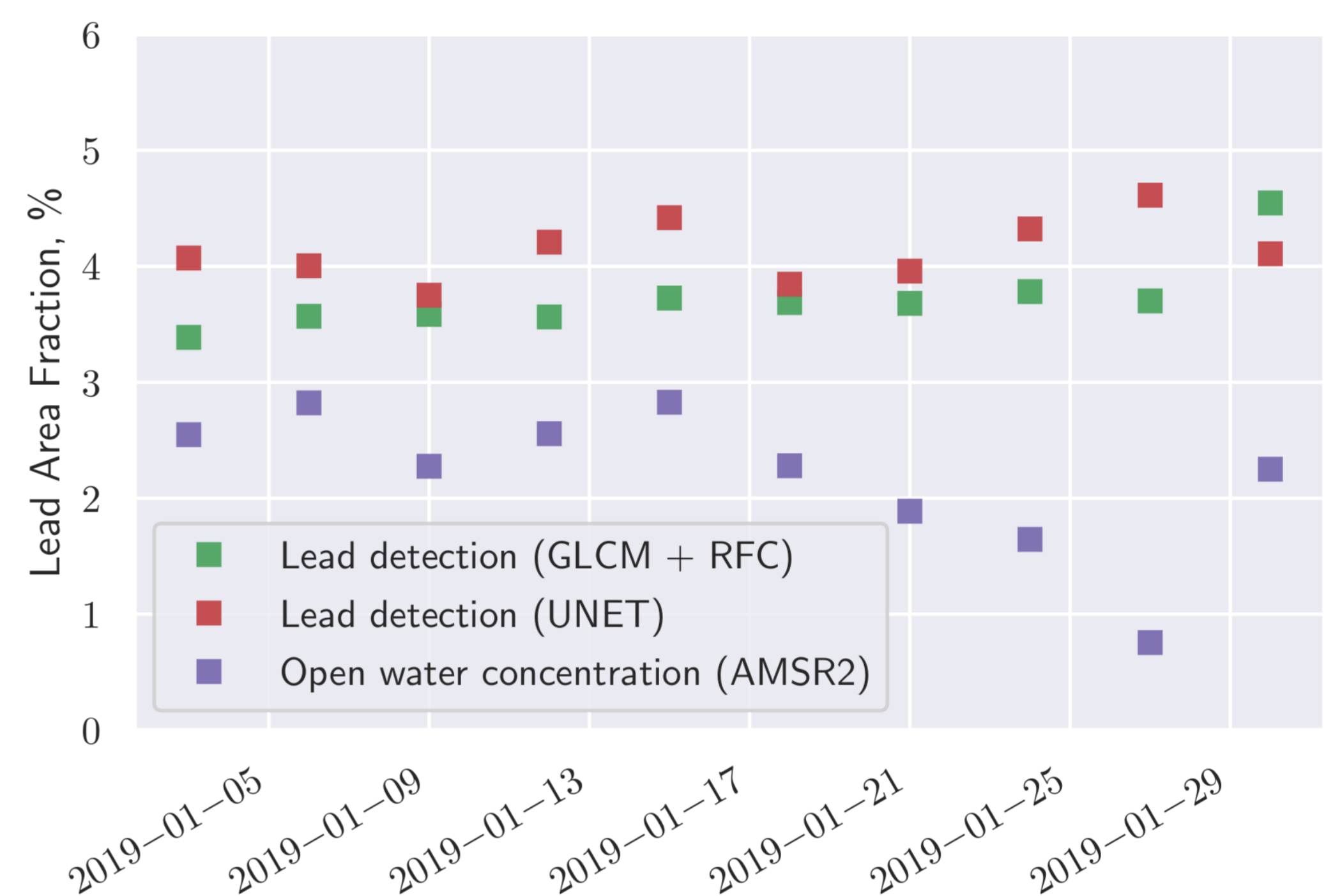
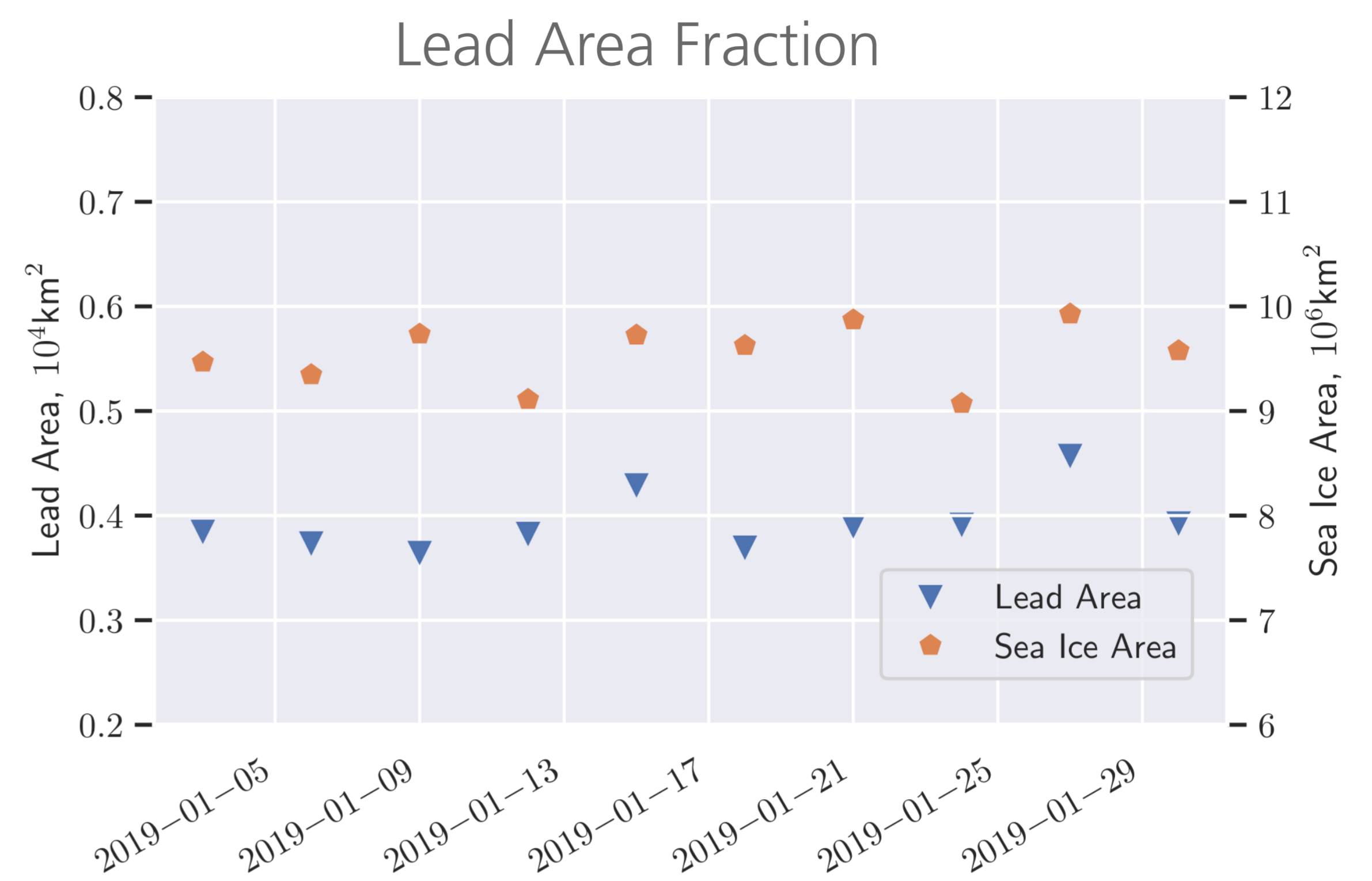
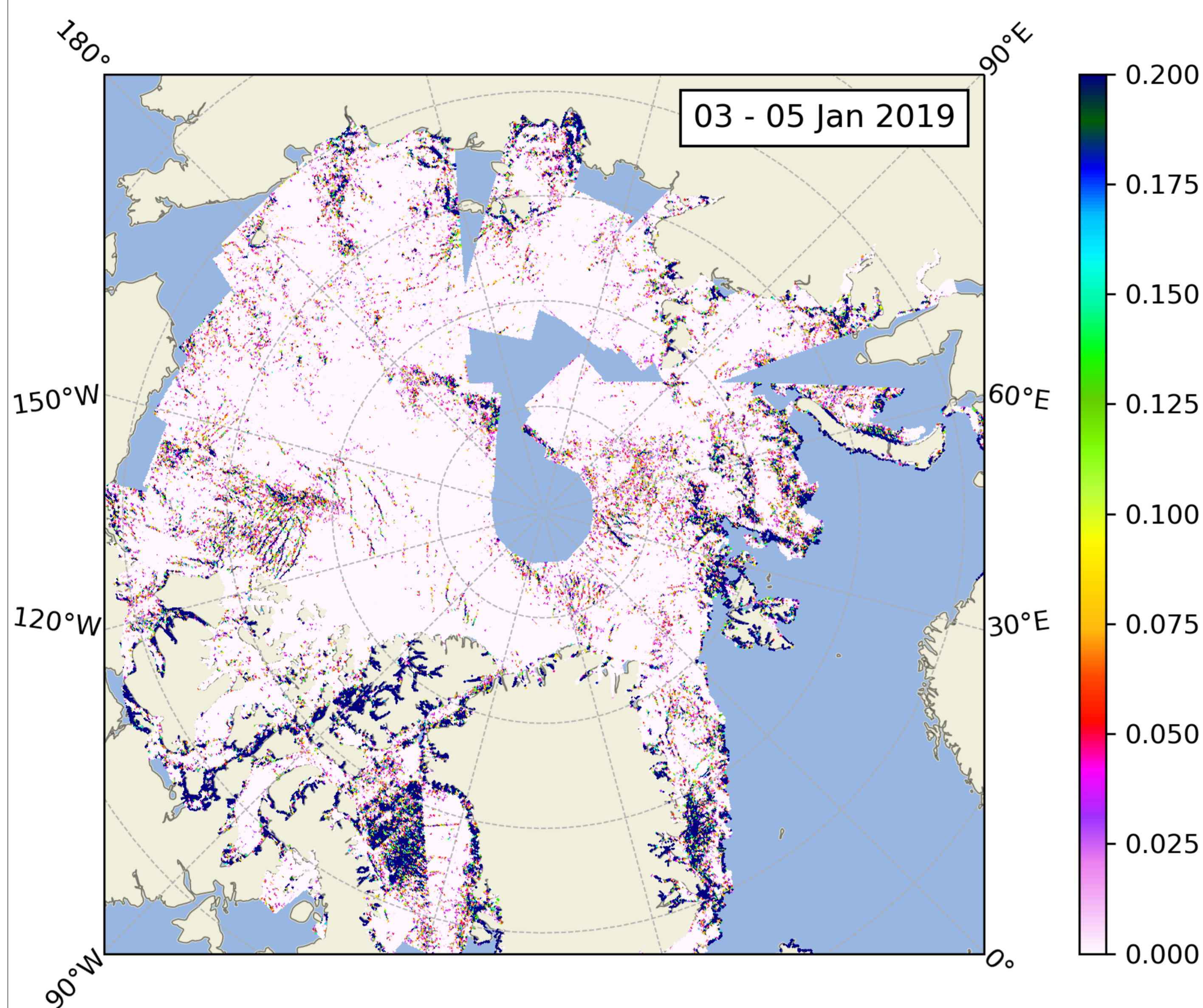
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Abstract

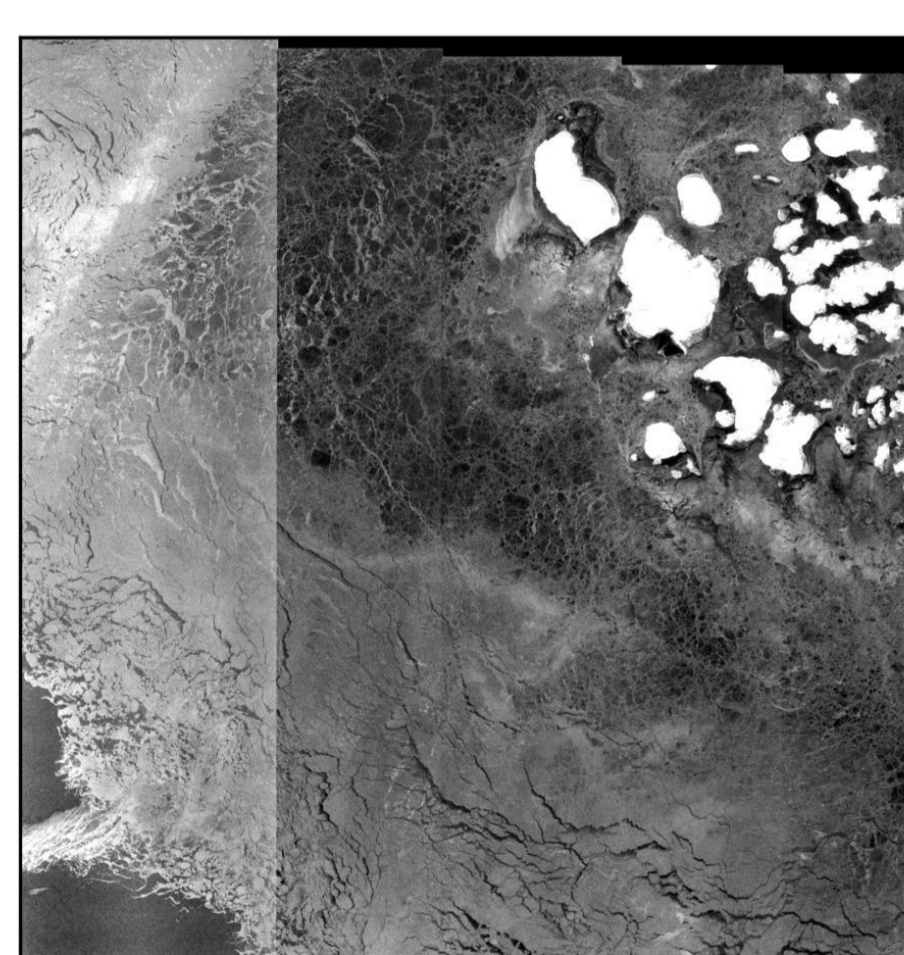
The Sentinel-1 SAR Extra Wide swath mode with its 40 meters resolution allows accurate lead mapping in the Arctic Ocean. Here we describe the improved lead detection algorithm based on a modified UNET convolutional neural network [1]. We introduce a preprocessing procedure that balances normalized radar cross section (NRCS) values between subswaths and, thus, provides a more consistent Sentinel-1 SAR images, which is especially important for the cross-polarization HV channel. In turn, image consistency is essential for automatic image semantic segmentation.

As the result, the algorithm is applicable over the entire Arctic Ocean. We produce pan-Arctic binary lead maps at 40 meters resolution. Below is the lead area fraction derived from binary lead maps on a 12 km grid. Arctic-wide maps are produced for every three days in January 2019, the lead area fraction is calculated (shown on the right). We compare lead area fraction with previously suggested algorithm [2] and with open water fraction derived from AMSR2 data [3].

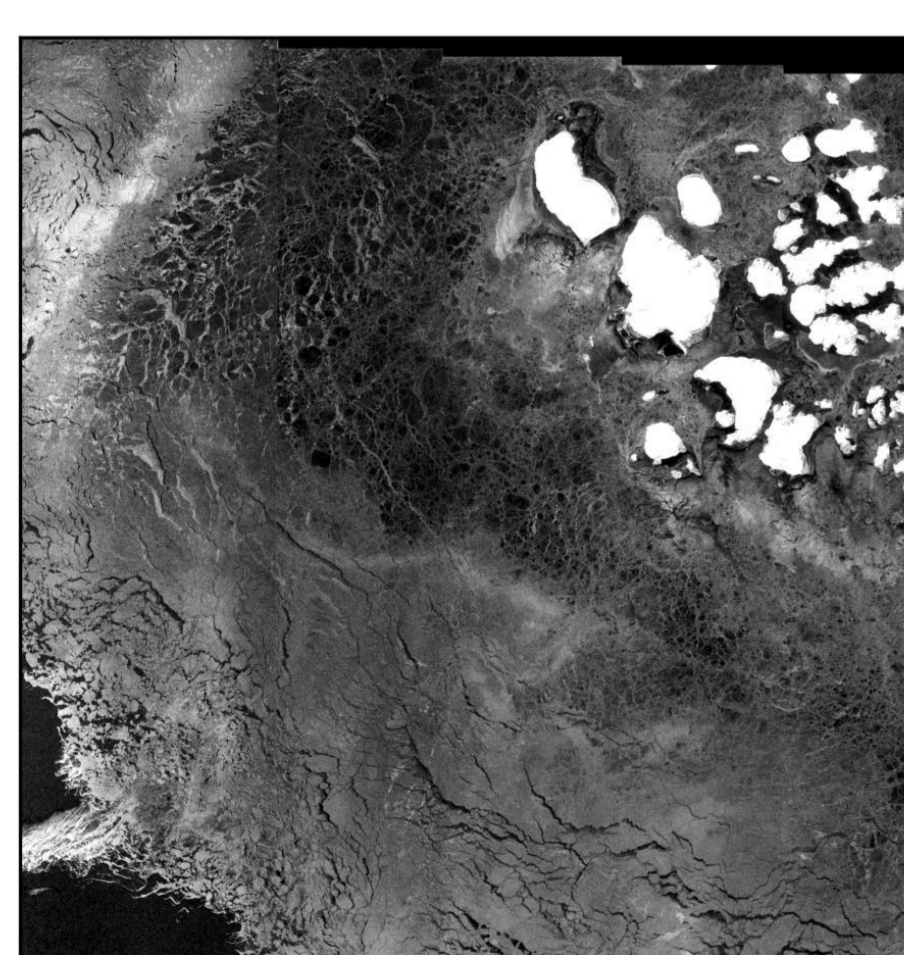


Three-day composite binary lead maps are produced for January 2019. The top figure shows total lead area (in blue), derived from binary maps. Changes in sea ice extent during the month and variations in Sentinel-1 coverage influence the total lead area, therefore we also show total sea ice area (sea ice extent within covered by Sentinel-1 scenes). The ratio of the two, the lead area fraction, is shown in the second image. Three plots correspond to the previously suggested algorithm (GLCM + RFC, in green) [2], the improved lead detection algorithm described here (UNET) and open water concentration derived from sea ice concentration maps based on passive microwave data (AMSR2) [3].

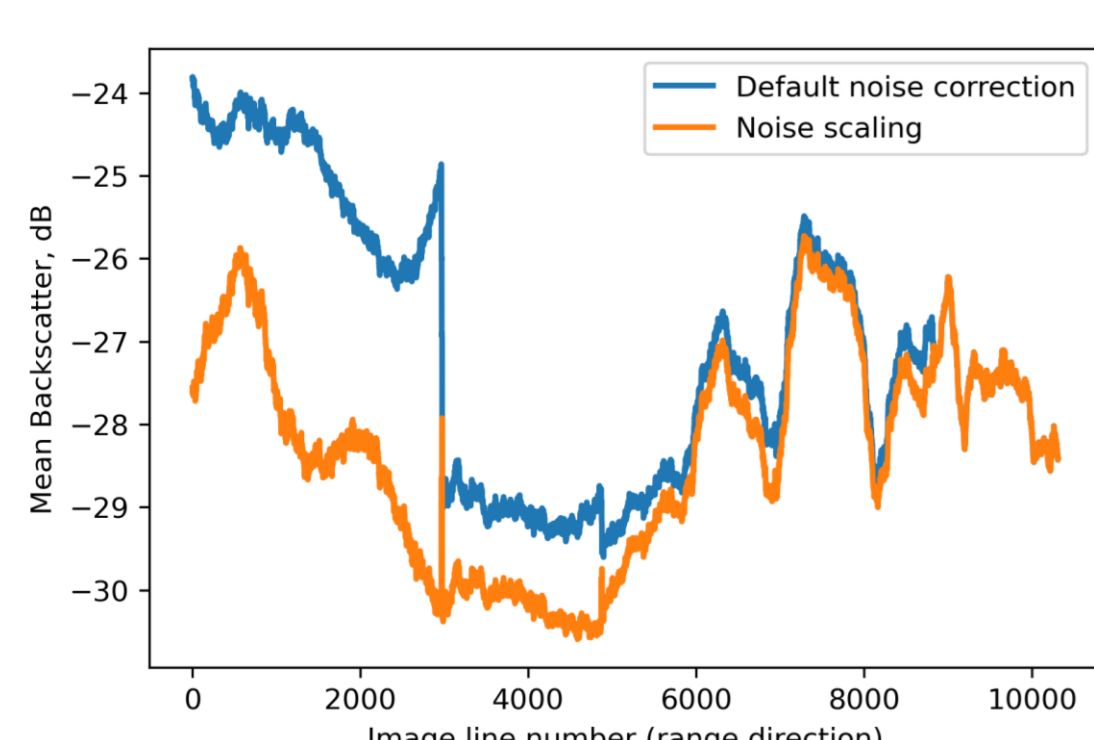
Sentinel-1 preprocessing



Standard noise correction



Thermal noise scaling



Information on thermal and scalloping noise is provided with Sentinel-1 scenes. On the left we show the HV channel of a Sentinel-1 scene after the standard noise correction applied. Although decreased, the thermal noise is still present on the image, which is clearly visible between the first and the second subswaths.

To reduce the remaining thermal noise, we assume the thermal noise distribution within a subswath to have little discrepancy, whereas the thermal noise absolute value has some error and can be corrected with a scale factor. We also assume Sentinel-1 scenes to be homogeneous at the subswath border. Therefore average NRCS values should not change drastically. In other words, the SAR NRCS values averaged in along track direction should be continuous in the range direction. Based on these assumptions we calculate scale factor for each subswath of a scene. We apply denoising with the subswath balancing technique to the same Sentinel-1 scene shown on the left middle image instead of the standard denoising suggested by ESA. The figure at the bottom shows comparison of average NRCS values across the range direction with the two preprocessing procedures.

Lead detection algorithm

Lead detection algorithm is based on UNET convolutional neural network [1]. The depth of the encoder and the decoder has been increased to six layers compared to four in the original paper. The size of input tiles is 512x512x2 pixels. Two channels, HH and HV, are normalized to [-1.0; 1.0]. The data set used for algorithm training consists of 21 manually labels Sentinel-1 scenes with the following classes: sea ice, dark leads, bright leads. The dataset is split into training (80%) and test (20%) parts. Finally, to avoid border effects between single tiles, we apply semantic segmentation four times with 0%, 25%, 50%, and 75% offsets and then average results.

The figure on the right illustrates the lead detection results on a small scale. The top two images show the input HH and HV channels. Second row shows classification results with the previously suggested algorithm (GLCM + RFC) [2] for dark leads and bright leads. The third row presents classification results with the improved lead detection algorithm (UNET). The last row shows binary images derived from probabilistic results, from the second row – on the left, from the third row – on the right. The new algorithm shows higher confidence in detected leads and is less prone to errors coming from presence of noise on Sentinel-1 images.

