Arctic Sea Ice Extent Mapping Using Artificial Intelligence

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Overview

The Advanced Scatterometer (ASCAT) mounted on the MetOp satellite series is a specialized radar instrument that measures the normalized radar backscatter σ_0 from Earth's surface. Although ASCAT's primary function is to measure ocean vector wind vector, its data has proven valuable across multiple geoscience applications. As a wind scatterometer, ASCAT precisely measures σ_0, which is then processed to determine the speed and direction of near-surface ocean winds. Beyond wind applications, ASCAT also collects σ_0 measurements on land and ice surfaces.

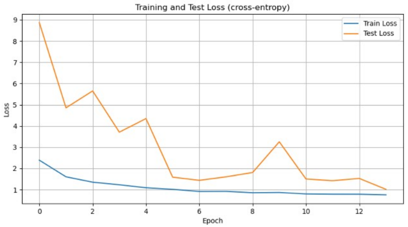
ASCAT's unique capabilities make it particularly well-suited for sea ice classification, especially in distinguishing between first-year and multi-year ice. The C-band frequency (5.255 GHz) at which ASCAT operates can penetrate surface of the sea-ice and thus can provide information about both surface and subsurface characteristic. This is crucial for differentiating sea-ice types. For example, multi-year ice typically has lower salinity and a rougher surface compared to first-year ice, resulting in distinct backscatter responses. This enables mapping of these ice types.

Approach

The UNet architecture that we employ uses a series of convolutional neural networks to extract high-level features of the image, then up-samples the embeddings back to the original image size using transposed convolutions. We use the outputs of a bayesian model as our labelled data and calculate accuracy by comparing the outputs of the two models. This labelled data is accurate enough to “teach” the AI model, with the hope that it learns the trends and begins generalizing to make segmentation decisions on its own.

Results

Figure 1: Train (blue) and test (orange) loss during training process. Model clearly quickly overfits to training set but learns to generalize.



Training and testing loss curves demonstrate that the model successfully learned to segment sea ice types from ASCAT imagery. Minor discrepancies are visible along the ice edge and coastal regions, where class transitions are inherently more ambiguous. Overall, the UNet model effectively captures the primary spatial patterns of Arctic sea ice in ASCAT data, with room for improvement during complex seasonal transitions.

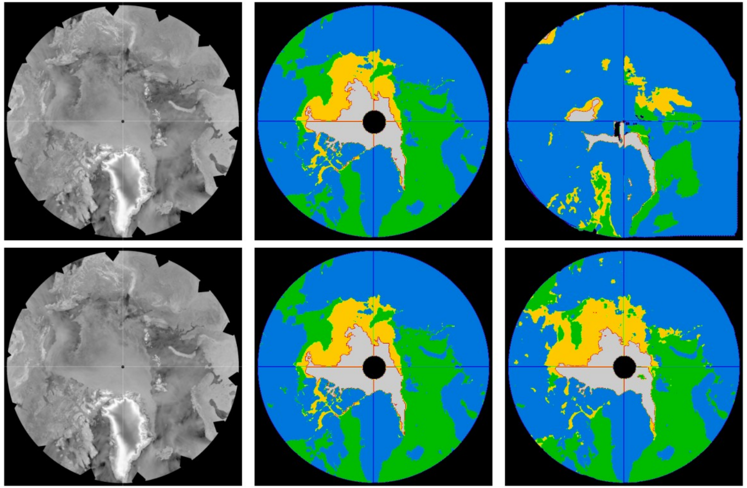


Figure 2: Starting from left to right shows original grayscale sigma-0 image, labelled image, and prediction from our model. First row is after one epoch of training, second is after 14 epochs.

Applications

The model enables detailed tracking of Arctic sea ice age over time by quantifying the coverage of first-year ice, multi-year ice, ocean, and land. We can generate monthly or seasonal trends showing changes in sea ice types, offering insights into seasonal melt, freeze-up cycles, and long-term shifts in ice dynamics in a computationally-effective way with little overhead.

Beyond simple tracking, this model could also be integrated into large-scale climate models or reanalysis datasets to improve the accuracy of sea ice boundary conditions. Incorporating higher-resolution, automatically segmented sea ice maps could enhance forecasting efforts for shipping routes and ecosystem modeling.

Figure 3: Smoothed time series of the percentage of Ocean, First-Year Ice (FY Ice), and Multi-Year Ice (MY Ice) across all test images..