**Titel:**

Detecting Hydrofracturing Events on Ice Sheets Using Sentinel-1 SAR Imagery: A Deep Learning approach

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**Abstract**

Climate change, with global temperatures rising over the past decades, is a primary driver of sea level rise through the thermal expansion of seawater and the melting of the Antarctic and Greenland Ice Sheets (AIS and GIS). These ice sheets are crucial for predicting future sea level changes, as increased melting forms supraglacial lakes. These lakes can induce hydrofracture, leading to ice shelf instability and accelerated ice flow into the ocean, further elevating sea levels and affecting global climate systems. This study focuses on the AIS and GIS, emphasizing the development and application of a deep learning model to detect and classify the behavior of summer supraglacial lakes using Sentinel-1 SAR satellite data.

The methodology involved normalizing SAR imagery data to enhance data consistency, training a deep learning model using a U-Net architecture on a labeled dataset of Greenland lakes for semantic segmentation, and evaluating its performance on both Greenland and Antarctic datasets using metrics such as accuracy, precision, recall, F1-score, and SSIM. The model is trained to distinguish between draining and refreezing lakes based on backscatter intensity patterns captured in the satellite images. Furthermore, a sensitivity analysis is conducted by creating ten different perturbations of the testing dataset, which included variations in intensity, rotation, and zoom levels. The trained model is then applied to Antarctic data to create an Antarctic-wide map of lake behavior.

The deep learning model exhibited high performance, achieving an accuracy of 90.6%, precision of 90.9%, recall of 90.6%, and an F1-score of 90.0%. It showed high classification accuracy for non-lake pixels (97.5%) and draining lake pixels (84.4%), but lower accuracy for refreezing lake pixels (55.4%) due to class imbalance. Sensitivity analysis revealed optimal performance on the 'zoomed out' dataset with an overall accuracy of 92.9%. Applying the model to Antarctic data successfully identified regions of draining and refreezing lakes, providing a starting point for monitoring ice sheet dynamics and their implications for climate change.

This study underscores the potential of deep learning models to enhance supraglacial lake monitoring, contributing to a better understanding of ice sheet stability and the impacts of climate change. Future work should address class imbalance and explore further model optimizations to improve classification accuracy across both lake types.