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Detection of Supraglacial Lakes using Gaofen-3 data and Advanced Attention U-Net

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Detecting supraglacial lakes is becoming increasingly crucial in the rising of global warming. Serving as vital indicators of glacier surface runoff storage and loss, these lakes provide significant insights to the understanding of glacier mass balance and global sea-level changes. Synthetic Aperture Radar (SAR) images have been used in numerous automatic detection algorithms due to their unique advantages of being independent from weather and illumination conditions. However, most SAR-based algorithms primarily use SAR backscattering intensities, which limits detection accuracy due to the high sensitivity of backscattering intensities to varying surface dielectric and geometric properties. To address this problem, it becomes essential to incorporate the polarization information to better distinguish different surface properties.

In this work, we introduced an innovative automated lake detection method that integrated a dual-polarization decomposition approach in a deep learning scheme. We enhanced the traditional decomposition method for HH and HV polarizations by segmenting the Stokes vector into fully and partially polarized sections to isolate volume and surface scattering components. The alpha angle, derived through eigenvalue decomposition of the covariance matrix, was further determined to quantify the degree of polarization. Subsequently, the decomposed SAR images were used to train an Attention U-Net deep learning model for lake segmentation. The Atrous Spatial Pyramid Pooling (ASPP) technique was introduced to the Attention U-Net to facilitate end-to-end training with limited datasets.

The proposed method was applied to the Gaofen-3 dual-polarization SAR imagery over expansive study regions in Greenland. Results indicated that the proposed decomposition approach was effective in detecting lakes in areas of complex surface conditions and discriminating frozen lakes in winter months. The method significantly reduced misidentification and inaccuracy in distinguishing various surface features such as dark ice, blue ice, wet snow, and actual lakes. Compared to existing methods, the proposed method provided improved attention to the finer details, exhibiting higher accuracy in identifying small lakes. More importantly, comprehensive physical interpretations of the data were also provided based on the polarization decomposition, offered valuable insights into the future development of lake detection algorithms.

In summary, this work introduces an effective and innovative methodology combining SAR dual-

polarization decomposition and deep learning for accurate supraglacial lake detection. The proposed method shows promising potential for an operational supraglacial lake mapping on a large scale and is expected to provide valuable insights into the understanding of ice sheet and glacier runoff dynamics.