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Automated glacier extraction using a Transformer based deep learning approach from multi-sensor remote sensing imagery

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Glaciers serve as sensitive indicators of climate change, making accurate glacier boundary delineation crucial for understanding their response to environmental and local factors. However, traditional semi-automatic remote sensing methods for glacier extraction lack precision and fail to fully leverage multi-source data. In this study, we propose a Transformer-based deep learning approach to address these limitations. Our method employs a U-Net architecture with a Local-Global Transformer (LGT) encoder and multiple Local-Global CNN Blocks (LGCB) in the decoder. The model design aims to integrate both global and local information. Training data for the model were generated using Sentinel-1 Synthetic Aperture Radar (SAR) data, Sentinel-2 multispectral data, High Mountain Asia (HMA) Digital Elevation Model (DEM), and Shuttle Radar Topography Mission(SRTM) DEM. The ground truth was obtained for a glaciated area of 1498.06 km^2 in the Qilian mountains using classic band ratio and manual delineation based on 2 m resolution GaoFen (GF) imagery. A series of experiments including the comparison between different models, model modules and data combinations were conducted to evaluate the model accuracy. The best overall accuracy achieved was 0.972. Additionally, our findings highlight the significant contribution of Sentinel-2 data to glacier extraction.