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Draining or Refreezing? Investigating Meltwater Lake Evolution through Deep Learning

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Antarctic ice shelves are becoming more vulnerable as a warming atmosphere leads to surface melting and the formation of meltwater lakes. Some meltwater lakes in Antarctica refreeze, but others drain into ice fractures, potentially destabilizing ice shelves and thereby contributing to rising sea levels. Conventional monitoring, using optical satellites, tracks lake changes during a melt season if data is accessible. However, cloud cover in Antarctica limits the use of optical imagery, creating a shortage of useful images and making it challenging to track lake progression. Unlike optical imagery, radar data from sources like Sentinel-1 offers frequent coverage of Antarctic ice shelves, because Sentinel-1 works independently from sun illumination and weather conditions. However, interpreting it is complex due to factors such as looking geometry, polarization, and speckle noise. By training our model on optical imagery from both refreezing and draining lakes—serving as ground truth—we applied a spatiotemporal deep learning technique to extract meaningful information from the Sentinel-1 images. Our results show that the majority of Antarctic meltwater lakes underwent refreezing from 2017 to 2023. However, a significant number of draining lakes were also identified, many of which had not been previously discovered through optical imagery. As the vulnerability of Antarctica's ice shelves intensifies, Sentinel-1's ability to provide insights into surface lake dynamics presents a promising avenue for research, enhancing our understanding of these crucial systems in the context of climate change and sea level rise.