EGU22-10119, updated on 14 Aug 2022
https://doi.org/10.5194/egusphere-egu22-10119
EGU General Assembly 2022

Life cycles of glacial lakes in Norway: Insights from machine learning algorithms on Landsat series and Sentinel-2

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The observed retreat of mountain glaciers on a global scale promotes the formation and growth of glacial lakes across newly exposed ice-free areas. In mainland Norway, this process drives the rise in glacial lake outburst floods (GLOFs), posing a considerable threat to people and infrastructure downstream. Moreover, many glacial lakes are used as reservoirs for hydropower production and thus represent an important energy source, emphasizing the need for continuous monitoring of glacial lake life cycles.

Remote sensing is currently the most efficient technique for tracking changes in glacial lakes, understanding their responses to climate change and observing lakes prone to GLOFs. Recent advances in machine learning techniques have presented new opportunities to automatize glacial lake mapping over large areas. For the first time, this study presents a Norway-wide reconstruction of glacial lake changes through the last three decades using machine learning algorithms and long-term satellite observations. It contrasts the performance of two classification methods - maximum likelihood classification (MLC) and support vector machine (SVM) - to outline glacial lakes and study their evolution using the Landsat series and Sentinel-2 images.

This study zooms into the pros and cons of each classification method and satellite product through the prism of glacial lake processes occurring over disparate temporal and spatial scales - from lake formation, growth and dissociation from the proximal glaciers to the aftermath of rapid GLOF events. Based on this analysis, I conclude that the recognition skills of supervised classification methods largely depend on the quality of satellite images and careful selection of training samples. Some of the factors that adversely affect the classification results are unfavourable weather conditions such as cloud, snow and ice cover, image disturbances through atmospheric corrections and shadows on slopes that lead to misclassifications. Regardless of higher spatial and temporal resolution, Sentinel imagery has not revealed significant advantages over Landsat but has shown a potential for their complementary use to continue glacial lake observations in the future. The performance of SVM is clearly superior to MLC, but it is difficult to use over large spatial scales, at least in the form it is currently implemented in ENVI.