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Inventorying Retrogressive Thaw Slumps along the Qinghai-Tibet Engineering Corridor using a deep-learning-aided semi-automatic method

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Permafrost in the Tibetan plateau is undergoing warming and degradation due to thermal and anthropogenic disturbance. As visible indicators of permafrost degradation, retrogressive thaw slumps (RTSs) are slope failures resulting from thawing of ice-rich permafrost, which can retreat and expand in thawing seasons, and may destroy infrastructure, change ecosystems and release carbon preserved in permafrost. However, the distribution of RTSs over Tibet is seldom investigated and poorly understood.

In this study, we used optical images collected by the Planet CubeSat constellation in 2019 to identify RTSs over a vast area of ~45000 km^2 along the Qinghai-Tibet Engineering Corridor, where the main highways and railways across the plateau are running through and a new highway is under planning. We planned to use the deep learning model DeepLabv3+, which can classify every pixel in the entire study area. However, with limited training data (300 RTSs) centered in a relatively small subregion (Beiluhe Region), it is infeasible to delineate all RTSs accurately in such a large and diverse area by using deep learning alone. Therefore, we proposed an iteratively semi-automatic method. In each iteration, we used DeepLabv3+ to automatically identify and delineate all possible RTSs, then manually checked them and selected newly-found RTSs based on their geomorphic features and temporal changes. To minimize the chance that DeepLabv3+ may miss some RTSs in each iteration, we added newly-found RTSs into the positive training dataset for the next iteration. We stopped iteratively mapping until no new RTSs could be identified.

Eventually, our method identified and delineated 877 RTSs which affect a total area of 17 km^2. They tend to spread out across the region, while Beiluhe is characterized as a cluster. Among these, 57 RTSs are within 500 m from major roads and the railway and potentially threaten their safety. This study demonstrates the applicability of using our deep-learning-aided method to obtain a comprehensive inventory of RTSs in large areas such as the engineering corridor, give us an overall understanding of RTS distribution, and provide an important benchmark dataset and knowledge for further quantifying temporal changes of RTSs.