Spatiotemporal Dynamics of Retrogressive Thaw Slumps in the Shulenanshan Region, Western Qilian Mountains (Postprint)

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Date: 2025-07-17T00:00:00+00:00

Abstract

In the context of global climate warming, permafrost degradation in mid- and low-latitude regions has significantly intensified, leading to widespread development of thermokarst landforms (such as retrogressive thaw slumps, RTS). These landforms, primarily formed by the thawing of ice-rich permafrost, have been proven to exert significant impacts on topography, hydrology, and ecosystem dynamics. However, systematic studies on the spatiotemporal patterns of RTS distribution and development in mid- and low-latitude permafrost regions are still lacking. This study systematically analyzed the spatiotemporal dynamics of RTS in the Heshenling area of the western Qilian Mountains based on multi-temporal PlanetScope imagery, Google Earth historical imagery, and Sentinel-1 Interferometric Synthetic Aperture Radar (InSAR) data from 2014–2023. The results indicate that: a total of 20 RTS were identified in the study area, with an average area of 3.7 ha, concentrated in slope zones at elevations of 3455–3651 m with slopes of 7–23°. RTS deformation rates ranged between -54 and 27 mm/yr. Through analysis of surface deformation, they were classified into three developmental stages: development stage, stable stage, and mature stage. RTS in the development stage exhibited accelerated headward retreat and debris tongue expansion, with expansion of some slump bodies reaching up to 35%. High temperature and precipitation serve as potential factors promoting accelerated RTS development in arid alpine mountainous environments, and their activity may intensify with continued climate change.

Full Text

Preamble

Spatiotemporal Dynamics of Retrogressive Thaw Slumps in the Shule South Mountain Region, Western Qilian Mountains

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Abstract

In the context of global climate warming, permafrost degradation in mid- and low-latitude regions has significantly intensified, leading to widespread development of thermokarst landforms such as retrogressive thaw slumps (RTS). These features, primarily formed by the thawing of ice-rich permafrost, have been shown to exert substantial impacts on topography, hydrology, and ecosystem dynamics. However, systematic investigations into the spatiotemporal patterns of RTS distribution and evolution in mid- and low-latitude permafrost zones remain limited. This study systematically analyzed the spatiotemporal dynamics of RTS in the Heshenling area of the western Qilian Mountains using multitemporal PlanetScope imagery, Google Earth historical imagery, and Sentinel-1 Interferometric Synthetic Aperture Radar (InSAR) data from 2014 to 2023. The results identified a total of 20 RTS features in the study area, with an average area of 3.7 ha, concentrated in slope zones between 3455–3651 m elevation and 7–23° gradients. RTS deformation rates ranged from -54 to 27 mm/yr. Based on surface deformation analysis, three developmental stages were distinguished: development, stable, and mature. RTS in the development stage exhibited accelerated retrogressive headwall retreat and debris tongue expansion, with some slump bodies expanding by up to 35%. High temperatures and precipitation represent potential drivers of accelerated RTS development in arid alpine environments, and their activity may intensify under continued climate change.

Keywords: climate change; retrogressive thaw slump; permafrost; Qinghai-Tibet Plateau

Note: Figure translations are in progress. See original paper for figures.