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Analysis of Precursors and Collapse of June 15, 2023, Brienz/Brinzauls Rockslide in Switzerland: Integrating Seismic and Remote Sensing Observations

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The early detection of slope instability and the monitoring of frequent hazard processes in mountainous regions is of paramount importance due to their sudden occurrence, and the risk of causing numerous fatalities and significant economic damage. The recent collapse of the Brienz/Brinzauls rockslide on June 15, 2023, in an active, deep-seated mountain slope deformation complex in Switzerland, provides a unique opportunity to investigate the evolution of precursors leading up to the collapse. Early identification of accelerating rockmass enabled us to set up a network of five broadband seismometers, strategically deployed to systematically record seismic signals in close proximity, reducing information loss due to attenuation of seismic waves.

The internal rock damage dynamics in the displacing rock mass were interacting with external seasonal forcings, such as snow melt and rainfall, for years preceding the collapse at approximately 21:38:00 UTC on June 15, 2023. Seismic events of various types have been detected in the entire landslide complex, characterised by the recurrence of identical seismic events that aggregate prominently within the most rapid compartment, referred to as the "Insel," positioned directly above the village of Brienz. This study aims to investigate the influence of seasonal forcings on accelerating the rate of displacements and to understand how the nature of detected precursors changes over time. We systematically examine the feedback loop between seasonal triggers and gravity-driven internal rock damage under changing stress conditions during fluctuations in compartment velocity. Initially, events exhibit accelerations following periods of precipitation, but subsequently, a runaway acceleration in seismic events was noted even during dry periods. The locations detected reveal communication between the upper and lower parts of the “Insel” mass in the build-up to the main collapse. From June 1 onward, there is a consistent and gradual increase in the mean spectral power of the recurring seismic events, with a rapid

escalation observed in the three days leading up to the collapse. Interestingly, on the final day preceding the main collapse, a significant decrease in the mean spectral power was identified. To complement seismic observations, the spatial and temporal changes in pre-failure slope instability for the period 05.2014-06.2023 were also analyzed using Sentinel-1 synthetic aperture radar (SAR) data using a multi-temporal interferometric (MTI) approach. MTI analysis indicates several patches of instability and surface deformation on the slope, along with signs of significant surface displacement of a few centimetres per year, also manifesting in the village of Brienz. To facilitate automatic detection and classification, we apply data science methods to various statistical seismic attributes of the identified precursors. This study contributes to advancing our understanding of the mechanisms leading to rockslide collapses, with the potential to significantly enhance warning system effectiveness.