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Integration of DInSAR, climatic, and morphometric data through data-driven models for regional-scale activity classification of rock glaciers in South Tyrol (Italy)

Chiara Crippa[1], Stefan Steger[2], Giovanni Cuozzo[1], Francesca Bearzot[3], and Claudia Notarnicola[1]
[1]EURAC, Institute for Earth Observation, Bolzano, Italy
[2]GeoSphere, Wien, Austria
[3]University of Calgary, Calgary Alberta, Canada

High-altitude regions serve as crucial indicators of climate change, with the Alps acting as a natural laboratory for studying glacial and periglacial processes. In situ and remote sensing techniques reveal permafrost degradation, coinciding with accelerated rates of rock glacier creep, potentially leading to destabilization.

Our study, focused on South Tyrol (North-East Italy), aims to screen and classify rock glaciers, thus pinpointing hotspots and unraveling the factors influencing their activity through the integration of remote sensing approaches and data-driven models. Our analyses are based on an existing inventory of periglacial landforms (1779 in total) across South Tyrol, mapped using LIDAR DTMs (2.5 m GSD) and orthophotos. The dataset already includes a descriptive attribute of activity from independent morphological observations and a DInSAR coherence-based estimation (Bertone et al., 2019). However, it lacks a comprehensive definition of activity based on climatic drivers, displacement rate, and morphometric parameters.

To quantify the velocity for each feature, we adopted a replicable workflow utilizing Sentinel 1A/B C-band images (2020-2022). This workflow involves three main steps: i) SAR pairs selection, filtering and processing using the Alaska Satellite Facility's Hybrid Pluggable Processing Pipeline (ASF HyP3); ii) atmospheric correction through a CNN (convolutional neural network) approach (Brencher et al., 2023); iii) time series inversion to produce mean LOS (Line-of-Sight) displacement rate maps through the MintPy algorithm (Yunjun et al., 2019).

We processed geomorphological (slope, aspect, insolation, curvature, etc.) and climatic maps (precipitation, temperature, snow cover duration) from both in situ (weather stations) and remote sensing products (MODIS, Landsat) to extract 19 descriptive parameters potentially influencing the development and state of activity of rock glaciers. These parameters served as predictor variables in a multiclass GAM classifier (Generalized Additive Mixing Models) to categorize all mapped landforms in active, relict, or transitional classes (RGIK, 2022).

After training the model on a subset of confidently classified features, we applied it to the entire rock glacier dataset, including features without an activity definition. Quantitative assessment of

the model's performance, using the area under the ROC curve, consistently yielded results exceeding 0.86 across various k-fold cross-validation approaches.

Our analysis not only enhanced classification accuracy but also provided insights into the factors influencing activity classes. A final classification using the Bulk Creep Factor (BCF) indicator (Cicioira et al., 2021), describing the dynamic state and rheology of large-scale rock glacier datasets, facilitated the selection of key case studies for a detailed local-scale investigation.

This comprehensive approach refines the categorization of mapped features and contributes to a more detailed understanding of the factors controlling rock glacier activity in the alpine environment, particularly in South Tyrol.