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Integration of SAR and machine learning methods to improve rock glacier classification

Christian Kofler (1,2), Aldo Bertone (2,3), Stefan Steger (2), Mattia Callegari (2), Carlo Marin (2), Giovanni Cuozzo (2), Marc Zebisch (2), Claudia Notarnicola (2), Volkmar Mair (4), Roberto Seppi (3), Francesco Zucca (3), Francesco Comiti (1), and Stefan Schneiderbauer (2)

(1) Free University of Bozen-Bolzano, Faculty of Science and Technology, Bozen, Italy (christian.kofler@eurac.edu), (2) Eurac Research, Institute for Earth Observation, Bozen, Italy, (3) University of Pavia, Department of Earth and Environment Sciences , Pavia, Italy, (4) Office for Geology and Building Materials Testing, Autonomous Province of Bozen-Bolzano, Kardaun, Italy

Rock glacier inventories have been created for many mountainous regions in Europe and outside in the past decades. These GIS-based catalogues are an important source of information to investigate periglacial landscapes, such as exploring associations between permafrost phenomena and environmental conditions. In this context, a crucial information stored in rock glacier inventories are the activity status and the related ice content of the mapped landforms (“active”, “inactive”, “intact” or “relict”, and “fossil”). The assignment of the activity status is mostly done by individual operators based on morphological evidences found in the field, on aerial images and on digital terrain models, in some cases by field measurements with different methods. Even though this expert-based approach has proven to be highly valuable, it is also known to be time consuming and somewhat subjective concerning especially the definition of the status of the rock glaciers. Recent technological advances in satellite remote sensing techniques - coupled to new algorithms for multiple variable analysis - offer new possibilities for improving rock glacier classification.

This study presents a novel, two-step approach to divide first moving from not moving rock glaciers, and subsequently to separate ice-cored from ice-free rock glaciers. This approach combines remote sensing with statistical computing and proposes an integration scheme that enables to combine the advantages of these both methodologies. The study was conducted in South Tyrol (Northern Italy), a region for which a comprehensive rock glacier inventory was made available by the local administration.

In the first step, a stack of multi-temporal SAR Sentinel 1A/B-images were processed to obtain coherence changes within each rock glacier present in the inventory. Exploiting the relation between coherence and displacement, an unsupervised classification has been developed. Rock glaciers were divided into “non-moving” forms (i.e. those without detectable displacement and thus including inactive, intact, relict or fossil categories) and “moving” ones (i.e. those with detectable displacement and corresponding to active rock glaciers). This first step takes into account only the kinematic aspects, without considering the permafrost ice content.

The second step is based on a supervised classification of the rock glacier status using statistically-based and machine-learning algorithms. A set of environmental variables, which in literature were found to be indicative about the ice content of rock glaciers, were used to build several multiple-variable models. This operation produces a binary classification of rock glaciers: those featuring a relevant ice content (i.e. including both active and intact types) and those with only sparse to null ice (i.e. relict and fossil types).

Finally, the integration of the two steps described above leads to the following classification: “currently moving” and “high ice content” = “active”; “not moving” and “high ice content” = “intact”; “not moving” and “sparse ice content” = “relict”; “not moving” and “no ice content” = “fossil”.