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# A novel methodology to classify rock glaciers using Sentinel-1 data

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Rock glaciers are the most common geomorphological evidence of permafrost in alpine regions and are characterized by creeping processes that generate a downstream displacement, with speed rates ranging from a few cm to more than 1 meter per year. This displacement varies from year to year and seasonally and is influenced by several environmental factors. The slope instability related to rock glacier and permafrost dynamics is monitored for a proactive management of natural hazards. Moreover, as permafrost is sensitive to climate change, observing its dynamics is a key issue in alpine environment.

Remote sensing is a modern technology to study remote areas at a large spatial scale and variable time scales. Airborne and satellite data, integrated with ground techniques such as GPS or UAV, can be used to detect and monitor rock glaciers, in order to inventory them and to study their activity.

In this work we propose a novel automatic methodology to detect the rock glacier activity by exploiting Sentinel-1 SAR multitemporal images , with the aim to update and refine an existing inventory developed in South Tyrol (Eastern Alps, Italy).

South Tyrolis an alpine region characterized by a widespread presence of rock glaciers, which were recently inventoried using remote sensing and field observations. In this inventory, the rock glacier activity was defined by visual interpretation of the available data. As in alpine areas the winter snow cover restricts the number of usable SAR images, making difficult the use of the multitemporal interferometry, we detected the terrain deformation by using amplitude and coherence information from Sentinel-1 data.

In order to take into account, the ground changes (e.g. snowfall), we computed the amplitude variation between each pair of images,within each rock glacier. The pairs of images with a low variation in amplitude were then used for the classification. Subsequently, in order to detect the status of the rock glaciers (i.e. active or inactive), we addressed the coherence information. A low coherence inside the rock glacier area suggest that the landform has changed between the pairs of images, and this provide a good probability that the landform is active (i.e. in motion). This information is exploited in an unsupervised way using an expectation maximization algorithm to classify active and inactive rock glaciers.

The new methodology developed enabled us to automatically define the activity status of rock glaciers. Of the 1542 landforms already inventoried in South Tyrol, 1147 have been re-classified by using our methodology. The number of rock glaciers has shown an agreement of about 84% with the existing inventory, of which 245 rock glaciers were listed as active. To validate the proposed methodology, the results were compared with an independent dataset of active landforms classified by the interpretation of geomorphic evidences visible in a digital orthophoto and a DTM from 2006. The unsupervised classification shows an agreement with the validation dataset of 74%, confirming the applicability of the new methodology.