Sources of uncertainty and variability in rock glacier inventories

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Abstract

We report preliminary findings of a mapping test that aims to evaluate the inherent sources of uncertainty and variability associated with the compilation of a rock glacier inventory from remotely sensed imagery. In particular, we compare rock glacier inventories conducted by five operators on Google Earth (GE), and on a combination of orthophoto and LiDAR-derived shaded relief rasters (LO) in Kaiserberg Valley, Austria. Results show that: (i) the number of detected rock glaciers among operators can vary up to a factor of 3; (ii) all operators consistently mapped a larger number of rock glaciers in LO compared to GE imagery, due to the identification of additional landforms as well from the disentangling of previously merged features. Similar discrepancies in mapping outcomes are likely to affect environmental evaluations and applications that rely on rock glacier inventories.

Keywords: Rock glaciers; Geomorphological mapping; Periglacial landforms; Remote sensing

Introduction

The last decade has witnessed a blooming of rock glacier-based studies for assessing present and past spatial distribution of permafrost (e.g., Scotti et al., 2013), post-LGM landscape response to climate change (e.g., Zasadni & Kłapyta, 2016), and water storage potential (e.g., Jones et al., 2018). This revived interest for rock glaciers has been fostered by increasingly available high-resolution, remotely sensed imagery and digital topography, which are crucial for detecting and mapping such landforms. The compilation of a rock glacier inventory typically requires some expert-based image interpretation, therefore its completeness and areal extent depends not only on image quality, but also on the experience and training of the operator. This study presents preliminary results on a mapping exercise that evaluates rock glacier inventories compiled by five operators in Kaiserberg Valley, a 14-km^2 hanging valley located in western Kaunertal, Ötztal Alps, Austria.

Methods

Rock glacier mapping, including evaluation of the degree of activity (Barsch, 1996), was performed in two independent steps, first using Google Earth™ imagery (GE), and subsequently using higher resolution 1-m LiDAR-derived shaded relief and a 0.2-m orthophoto mosaic (LO) (Fig.1). Critical topographic attributes, such as rock glacier maximum and minimum elevations were extracted from a 1-m LiDAR DTM.

Findings

Results display high variability in the number of rock glaciers identified, which ranges from 11 to 31 in GE-based inventories, and from 22 to 40 in LO-based ones (Fig. 1). This variability reflects different mapping styles in terms of rock glacier identification i.e., whether a given lobate landform is considered a rock glacier or not, and delineation i.e., polymorphic rock glaciers vs single-lobe overlapping ones. The increase in image resolution from GE to LO produces an increase in identified rock glaciers across operators.

The greater number of landforms mapped on LO imagery chiefly derives from: (i) the identification of previously undetected rock glaciers, from a minimum of 6 to a maximum of 13, and (ii) the subdivision of single, large rock glaciers into smaller ones i.e., from no changes to 6 rock glaciers being split into 17 new ones.

Changes in rock glacier dynamic classification due to higher resolution imagery involves, on average, 37 % of the rock glacier sample, ranging from 14 % to 50 %. The most frequent classification changes concern the "intact" category, from active-to-inactive and vice versa.

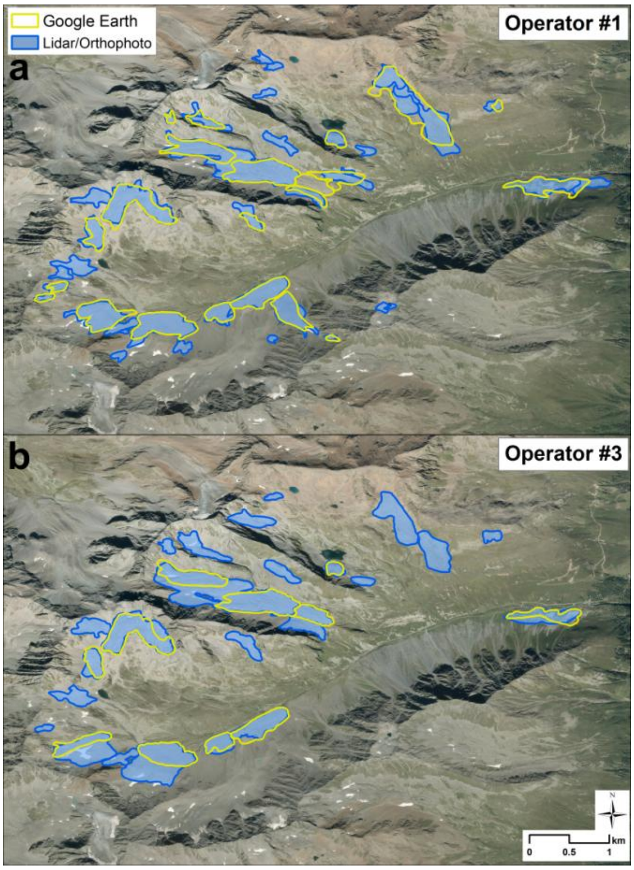

Figure 1. Sample inventory maps of rock glaciers delineated by (a) operator 1, and (b) operator 3 using Google Earth (yellow outline) and Lidar & Orthophoto (solid blue polygons).

With respect to the minimum and maximum elevation changes of rock glaciers stratified by dynamic classification, relict rock glaciers exhibit higher variability between GE and LO and across operators, compared to intact rock glaciers (Fig. 2b, c). In particular, we observe the largest discrepancies between operators for minimum and maximum elevation of relict rock glaciers mapped on GE images. By contrast, minimum elevations of intact rock glaciers mapped on LO imagery are the most consistent. Since rock glacier minimum elevation has been used as a proxy for assessing the lower limit of alpine permafrost (e.g., Boeckli *et al.,* 2012), our preliminary finding reinforces the robustness of such approach. Conversely, the high variability associated with the minimum elevation of relict rock glaciers potentially poses a question on the reliability of paleo-permafrost reconstructions, especially when based on low-resolution imagery.

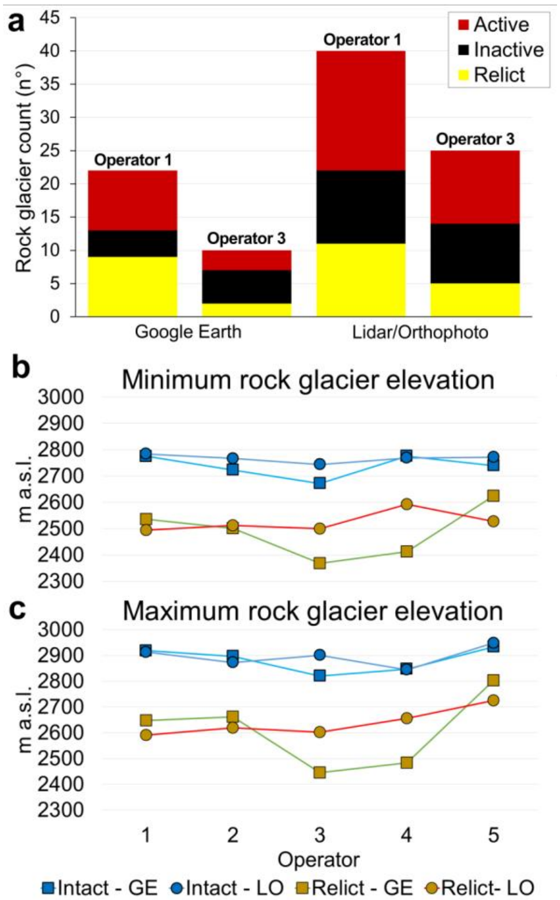

Figure 2. (a) Number of rock glaciers mapped by operators 1 and 3. Average minimum (b) and maximum (c) rock glacier elevation across the 5 operators. Data are stratified by rock glacier degree of activity and type of imagery used.

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