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Rock glaciers – prominent landforms in (protected areas of) Austria

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Abstract

About 5500 rock glaciers, permafrost-related debris accumulations in alpine environments, exist in the Austrian Alps, of which 837 are found in three National Parks. Among them, active (moving, widespread permafrost), inactive (stable, rather widespread permafrost), pseudo-relict (stable, permafrost lenses) and relict (stable, permafrost free) rock glaciers are distinguished. Permafrost existence, as a thermal phenomenon, is controlled by climatic conditions. Hence a change in climate influences its ice content und movement behavior which is also of relevance for other fields of research.

Keywords

Rock glacier; cryospheric landform; warming climate

Introduction

Rock glaciers are the most prominent permafrost-related landforms in alpine environments (e.g. BARSCH, 1996). Depending on the content of permafrost-ice, these debris accumulations can be classified as active (moving, widespread ice-bearing permafrost), inactive (stable, rather widespread ice-bearing permafrost), pseudo-relict (stable, ice-bearing permafrost lenses) and relict (stable, permafrost and ice free) ones. Permafrost is a thermal phenomenon and mainly controlled by climatic conditions. Therefore, climate change will influence ice content and activity of rock glaciers.

Research on rock glaciers, especially of relict ones, comprises their distribution (e.g., HARRISON et al. 2008; KELLERER-PIRKLBAUER et al. 2012; KRAINER & RIBIS 2012) as a base of their relevance as markers of sudden climate changes during the late glacial period (e.g., PUTNAM & PUTNAM 2009). Additional research issues are related to rock fall hazard of the destabilizing rock-ice mixture (with blocks of up to a size of several m³) due to a warming climate and in particular the impact on the discharge pattern of springs related to rock glaciers which is of interest concerning water management in alpine catchments (e.g., KRAINER et al. 2007; PAURITSCH et al. 2017; ROGGER et al. 2017; WAGNER et al. 2016; WINKLER et al. 2016). This might be of high relevance for prognosis as the intensity of droughts as well as heavy rainfall events might increase due to climate warming.

Within an Austrian wide research project (WINKLER et al. 2017) a rock glacier inventory is currently conducted and attributed based on airborne-laser-scan data (ALS) with a resolution of 1 meter compiling and incorporating already existing inventories (KRAINER & RIBIS 2012; KELLERER-PIRKLBAUER et al. 2012; WINKLER et al., 2016). Preliminary results show a large number of these prominent landforms in the Austrian Alps: more than 5500 rock glacier-suspected landforms (WINKLER et al. 2017) are depicted (Fig. 1), of which 837 are found in three Austrian National Parks (Fig.1, green polygons). These will be the focus of the following analysis: the distribution of intact versus relict landforms is investigated.

Methods

Classification of rock glaciers regarding permafrost existence or absence in four alpine national parks of Austria (Kalkalpen, Gesäuse, Hohe Tauern and Nockberge; see Fig. 1) was carried out in ArcGIS by combining our elaborated rock glacier inventory for the federal provinces of Salzburg, Carinthia, Styria (based on LIEB et al. 2012) as well as Tyrol (based on KRAINER & RIBIS 2012) and Upper Austria (LIEB et al. 2012). In a first step all rock glaciers within the national park boundaries were selected for further analysis. In a second step these rock glaciers were combined with the regional permafrost model of BOECKLI et al. (2012) and classified into 'relict' and 'intact' rock glaciers.

Rock glaciers were considered as relict when absence of permafrost was indicated by the regional permafrost model (BARSCH 1996). Furthermore, rock glaciers were also classified as relict if only the uppermost part of the entire rock glacier surface was slightly within the modeled permafrost area. In this case the term pseudo-relict can be used because visually such rock glaciers look relict but permafrost in the uppermost part of the rock glacier is very likely (cf. KELLERER-PIRKLBAUER 2016). A clear distinction between relict and pseudo-relict is only feasible in case of subsurface permafrost data (e.g. ground temperature or geophysics).

In contrast, rock glaciers were classified as intact if the entire rock glacier body is entirely within modeled permafrost or if at least most of the rock glacier was in the model class 'permafrost only in very favorable conditions'. The former intact rock glacier-type might be regarded as an active rock glacier because widespread permafrost existence might cause downslope displacement. The latter intact rock glacier-type might be regarded as a climatic inactive rock glacier implying no present movement (cf. Barsch 1996). A clear distinction between active and inactive is only possible if a surface displacement analysis was carried out using multitemporal rock glacier surface data.

Preliminary Results

In total, 837 rock glacier-suspected landforms were identified within three NPs (NP Gesäuse, NP Nockberge and NP Hohe Tauern). As no ALS-data for the NP Kalkalpen was available for this analysis, the rock glacier inventory of Lieb et al. (2012) was used, but no rock glacier-suspected landforms were identified there. Only one single relict rock glacier was identified in the NP Gesäuse; 66 relict rock glaciers in the NP Nockberge. In contrast, a total of 770 rock glacier-suspected landforms were identified in the NP Hohe Tauern; 321 of them were classified as relict, 449 as intact. For the Carinthian part of the NP Hohe Tauern, 77 relict and 111 intact rock glaciers were identified. In Tyrol, a total of 311 rock glaciers, 90 relict and 221 intact, were recognized. For Salzburg, 154 relict and 117 intact rock glaciers were mapped, summing up to 271 landforms.

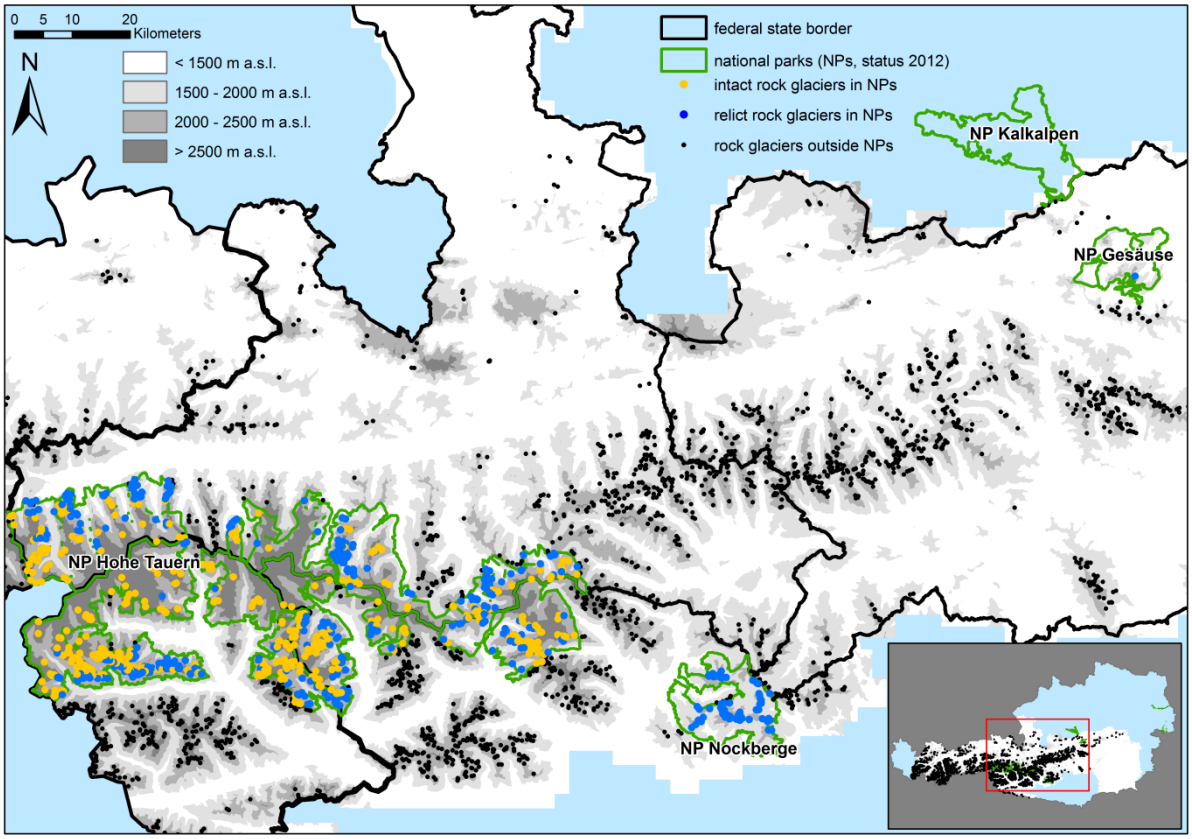

Figure 1: Distribution of rock glacier-suspected landforms in and outside of the national parks (NPs) Gesäuse, Kalkalpen, Nockberge and Hohe Tauern and their potential activity status (intact versus relict) within the NPs boundaries.

national park	rock glaciers			rock glacier data source
	relict	intact	total	
Gesäuse	1	0	1	this study
Nockberge	66	0	66	this study
Hohe Tauern	321	449	770	this study
Kalkalpen	0	0	0	Lieb et al. (2012)
total	388	449	837	this study

Table 1: number of rock glacier-suspected landforms in various national parks.

Conclusion and Outlook

The 837 rock glacier-suspected landforms within the 3 NPs represent 15% of the total number of landforms mapped so far within this project in Austria. Almost 54% of rock glaciers in NPs are intact rock glaciers, and are therefore ice-bearing landforms. Due to the expected climate warming and consequently ice-melt within intact landforms, it is expected that the discharge dynamics and storage capacities of these landforms will change accordingly. This will have an impact on the runoff of alpine catchments and will be of general water management interest as these landforms will alter the runoff pattern further downstream.

An important aspect to further quantify these ongoing changes in discharge dynamics and storage capacities is the appropriate monitoring of various intact and relict rock glaciers.

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