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The impact of rock glaciers on the runoff of alpine catchments in protected areas of Austria

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Abstract

Due to the coarse blocky surface debris layers, surface flow is usually absent on rock glaciers. Water infiltrates into these landforms from their respective catchment and is released at springs in a more dampened/modified way due to storage capacities of rock glaciers. Research of the recent years has indicated that the storage capacities of especially relict rock glaciers can have important impacts on the downstream sections of an alpine headwater and the fragile ecosystem therein. Here we report on these findings with a focus on the alpine environments protected by the National Parks of Austria.

Keywords

Rock glacier; storage capacity; runoff; alpine catchment; protected areas

Introduction

More than 5500 rock glacier related landforms were identified in the Austrian Alps and their related hydrological catchments cover a total area of more than 1200 km² (WINKLER et al. 2017). Based on the content of permafrost-ice, rock glaciers are divided into intact (active and inactive that means moving, widespread ice-bearing permafrost and stable, rather widespread ice-bearing permafrost, respectively), and relict (stable, permafrost and ice free) ones including all crossovers between these types. All the water of their respective catchments infiltrates into these landforms and is released with some delay at springs at the rock glaciers front. Springs with considerable discharge are consequently relevant for water resources management issues in (non-karstified) alpine regions composed of metamorphic rocks and are mainly related to landforms such as rock glaciers.

Research of the last two decades showed the complexity of the runoff of rock glaciers and identified e.g. three different flow components (snow melt/rain, melting of permafrost-ice and longer stored groundwater below the rock glaciers) for active rock glaciers (e.g. KRAINER & MOSTLER 2002; KRAINER et al. 2007). Relict rock glaciers are heterogeneous, complex aquifers (PAURITSCH et al. 2015, 2017; WINKLER et al. 2016) and, as shown by WAGNER et al. (2016), have potential storage/buffer capacities that might be of interest as the intensity of droughts as well as heavy rainfall events might increase due to climate warming (e.g. GOBIET et al. 2014). Moreover, ROGGER et al. (2017) investigated the impact of the reduction of permafrost ice in a permafrost-dominated part of the Kaunertal (Ötztal Alps, North Tyrol). They showed that melting of permafrost-ice will potentially increase the storage capacities and therefore cause a more dampened discharge pattern. In addition to the quantitative hydrological issues the process-based understanding of mobilization and transport of dissolved solids in and downstream of these landforms is another important aspect. Recent research in Southern Tyrol (ca. 2700 rock glacier-suspected landforms mapped by BOLLMANN et al. (2012)) indicates some potential heavy metal pollution related to permafrost ice (KRAINER et al. 2015). An Austrian-wide project currently investigates the hydrochemical background of rock glacier related spring waters (WINKLER et al. 2017).

These recent findings indicate that rock glaciers are likely to be important debris accumulations that are going to influence in various ways the runoff of alpine catchments and are of high water management relevance in particular for drinking water supply and small power plants. Moreover, a better understanding of the related discharge dynamics will allow a better predictability of changes in alpine headwaters.

Methods

The classification of rock glaciers has been described in this conference volume by WAGNER et al. (2017). The related catchments were computed using standard ArcGIS hydrology tools. All grid cells (using ALS data with 1m of horizontal resolution) flowing towards the rock glacier-suspected landforms were considered as contributing to the catchment area. This is an approach that assumes that the orographic catchment area coincides with the actual one; although this is a simplification, it is a suitable first approach for crystalline areas. Moreover, the catchment delineation has been manually checked for outliers (e.g. forest roads may create artificial flow paths). The following analysis is focused on rock glaciers and their related catchments within the boundaries of the National ParksGesäuse, Nockberge and Hohe Tauern.

Preliminary Results

Rock glaciers within protected areas of Austria were the focus of this work. Fig. 1 shows a representative part of the National Park (NP) Hohe Tauern, the rock glacier-suspected landforms mapped in that area and their related catchment areas.

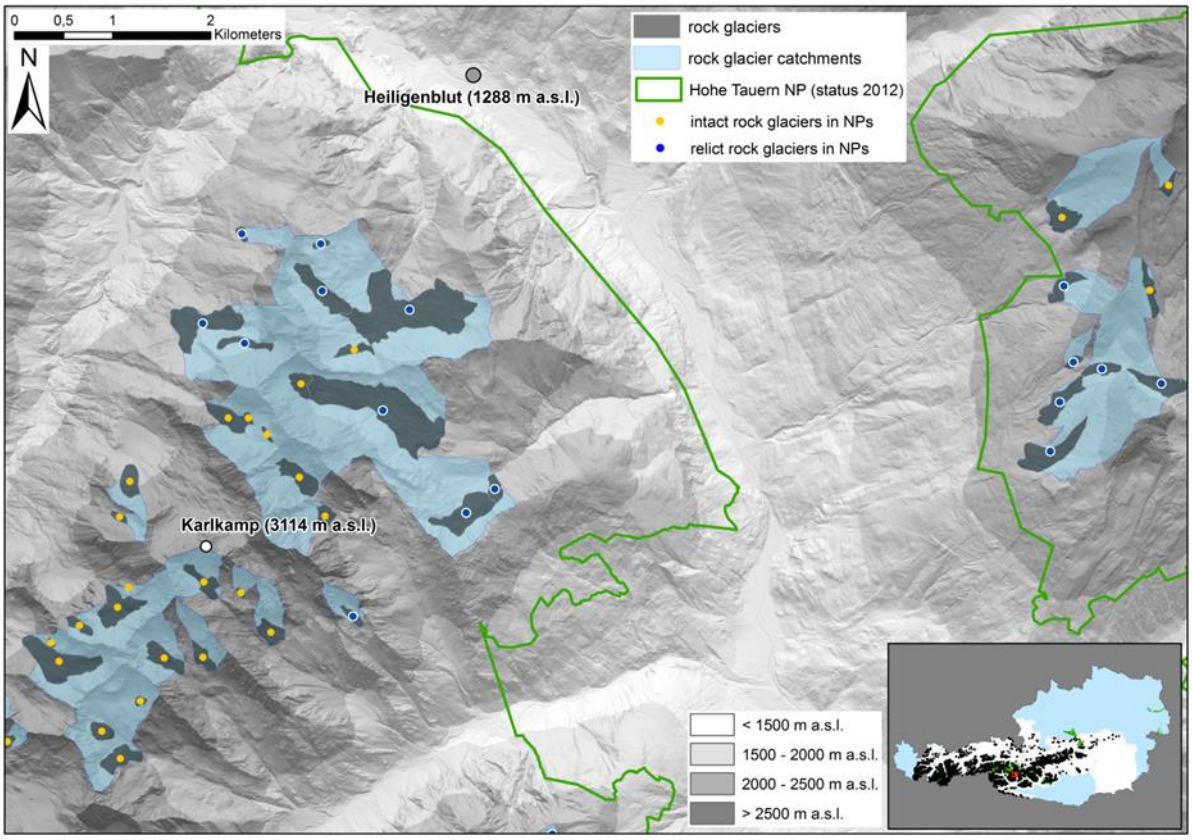

Figure 1: Rock glacier-suspected landforms (RGs) and their related catchments of a representative region of the National Park Hohe Tauern: parts of the Schober and the Goldberg Mountain Ranges south of Heiligenblut (1288 m. a.s.l.).

Tab. 1 shows the areal contribution of rock glaciers and their hydrological catchments referred to the total area of the National Parks (NPs) and to elevations above 1500 m, 2000 m and 2500 m a.s.l.. In total, only 2% of the NP areas are covered by rock glaciers, however this number increases to 7,4% if the catchment areas of the rock glaciers are considered. For elevations above 1500 m a.s.l., this value increases only slightly (8%), rises to 9,7% for elevations above 2000 m a.s.l. and further to 11,7% for elevations above 2500 m a.s.l. The Gesäuse NP contributes only very little to this analysis (a single relict rock glacier); in the Nockberge NP, 66 relict rock glaciers have been mapped. Compared to the total area of this NP (184,5 km²), the area influenced by rock glaciers (water that is drained through relict rock glaciers) is only 10,8 km², which is about 5,9%. For the Hohe Tauern NP these numbers are higher, as rock glaciers are more abundant there (770 out of 837 in total). Nevertheless, compared to the Seckauer Tauern Range (22% of areal share above 1500 m a.s.l. and 51% above 2000 m a.s.l.; WAGNER et al. 2016), these values are not exceptionally high. The highest areal share within the NPs is found in the NP Nockberge for elevations above 2000 m a.s.l. with almost 17% draining through relict rock glaciers. For the Hohe Tauern NP, a value of 9,7% is calculated, however there is a large number of intact rock glaciers that might change their discharge pattern as climate warming proceeds.

national park (NPs)	NP area [km²]	rock glaciers (RGs)			RG area	RG catchment area	RG catchment area ≥ 1500 m a.s.l.	RG catchment area ≥ 2000 m a.s.l.	RG catchment area ≥ 2500 m a.s.l.
		relict	intact	total	[km² / % of total area]	[km² / % of total area]	[km² / % of total area]	[km² / % of total area]	[km² / % of total area]
Gesäuse	110,3	1	0	1	0.1/ 0.1	0.7 / 0.6	0.7 / 2.1	0.1/ 2.1	0 / -
Nockberge	184,5	66	0	66	2.4 / 1.3	10.8 / 5.9	10.8 / 6.9	7.3 / 16.9	0 / -
Hohe Tauern	1857,1	321	449	770	39.7 / 2.1	148.4 / 8.0	148.2 / 8.3	144.1/ 9.7	83.7 / 11.7
total	2151,8	388	449	837	42.1/ 2.0	160.0 / 7.4	159.7 / 8.1	151.5 / 9.9	83.7 / 11.7

Table 1: statistics of rock glacier-suspected landforms (RGs) and their respective catchments in various national parks (for details on the RGs see Wagner et al. (2017), in this conference volume).

Conclusion

Research of recent years has shown that the storage capacities and discharge pattern of rock glaciers have an impact on the runoff of alpine catchments and will be of general interest for water management as these landforms will alter the runoff behavior further downstream. Rock glaciers provide groundwater as an important resource for water management issues in alpine catchments such as drinking water supply and/or small hydropower plants. This might be of high relevance for the supply of huts with drinking water and/or electricity in alpine headwaters. However, a better understanding of the hydro(geo)logical properties of these landforms (as they might degrade from an intact state to a relict one by melting of permafrost ice and a change in storage capabilities) is crucial for the prognosis of the hydrological evolution of alpine catchments due to climate warming. Thus, the appropriate monitoring at various intact and relict rock glaciers is essential to quantify the ongoing changes in discharge dynamics and storage capacities.

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