# Vegetation on Alpine rockglaciers

**Lorenzo Rieg, Rudolf Sailer & Johann Stötter**

## Abstract

To analyze the vegetation cover and patterns on four active rockglaciers in the Stubai and Ötztal Alps (Tyrol, Austria), total vegetation cover and cover of each distinct species as well as grain size and the percentage of fine-grained material were assessed along several longitudinal and transversal transects on each rockglacier. The floristic composition in each study area and the differences between the four areas were analyzed as well as the relation of total vegetation cover to the availability of fine-grained substrate. Results show that vegetation cover and composition on rockglaciers are divers and inhomogeneous, even in a relatively delimited area.

**Keywords:** rockglaciers, permafrost, vegetation cover

## 1 Introduction

Active rockglaciers are widespread features in alpine environments and are commonly regarded as indicators of discontinuous permafrost (Barsch 1996). Vegetation on rockglaciers has been investigated mainly by Burga (1987 and 1999), Cannone (1997), Cannone & Gerdol (2003) and Burga et al. (2004). Due to the special edaphic and climatic conditions, active rockglaciers are environments hostile to plant growth, but they still show some vegetation cover and are inhabited by different species, of which most are also typical for scree slopes. Vegetation cover can be used alongside other methods to determine the status of activity of rockglaciers or differences in activity at different parts of a rockglacier. Over longer terms, changes in vegetation patterns and cover can be used as indicators for changes in rockglacier activity.

## 2 Study areas and field work

All four study areas are high alpine cirques, containing one or several active rockglaciers, located in the Stubai and Ötztal Alps, Tyrol (Austria) (see Figure 1). The rockglacier Äusseres Hochebenkar (AHK) is located in the Gurgler Tal, a few kilometers south of Obergurgl. It is a big, tongue shaped rockglacier, with a length of about 1,600 m, which fills the whole cirque.

According to Schneider & Schneider (2001), it is the best-investigated rockglacier in Austria. The history of investigations goes back to the 1930s (Pillewitzer 1938), with a long record of flow velocity and other data (Vietoris 1958, 1972; Haeberli & Patzelt 1982; Schneider & Schneider 2001).

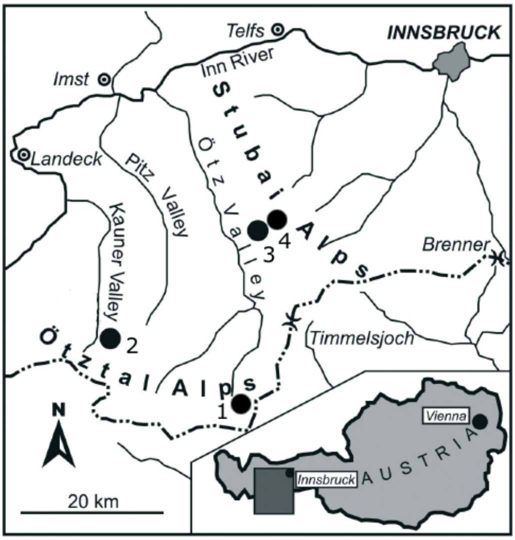


*Figure 1: Location of the study sites: Äusseres Hochebenkar (1), Innere Ölgrube (2), Inneres Reichenkar (3) and Schrankar (4).*

The rockglacier Äusseres Hochebenkar covers relatively steep terrain and is one of the fastest moving rockglaciers known with velocities of up to 5 m/a (Barsch 1996: 126). It reaches from 2,830 m to ca. 2,360 m. The Innere Ölgrube (OGR) is a small side valley of the Kaunertal, containing a composite rockglacier. This rockglacier has been thoroughly investigated recently (Berger et al. 2004; Krainer & Mostler 2002, 2006; Hausmann et al. 2007a; Krainer et al. 2007). It consists of two separate, tongue-shaped rockglaciers, which lie side by side and therefore appear as one (see Figure 2). The study areas Inneres Reichenkar (RKR) and Schrankar (SKR) are located in the westernmost part of the Stubai Alps, in the Sulztal, a small side-valley of the Ötztal. The rockglacier Reichenkar is not only one of the longest and most active rockglaciers in Austria (Hausmann et al. 2007b); it has also been intensively investigated, especially during the last decade (Chesi et. al. 1999, 2003; Krainer & Mostler 2000, 2002 and 2006; Hausmann et al. 2007b; Krainer et al. 2002, 2007).

The Schrankar is a large cirque enclosed by high peaks with a steep cirque threshold to the south, containing several rockglaciers of different activity and material. In this study, two rockglaciers were investigated (see Figure 2), which are both significantly smaller and less active than the rockglaciers at the other study sites.

The high surrounding mountain ranges in combination with the central location close to the alpine main ridge cause a relatively dry and cold climate in the study areas (Fliri 1975).

For this study, the total vegetation cover as well as the cover of each distinct species was assessed in squares of 3 x 3 m along several longitudinal and transversal transects on each rockglacier, using the Braun-Blanquet method (Braun-Blanquet 1964) with a percentualscale (Dierschke 1994). In addition, the percentage of fine-grained material (silt, clay and sand combined) was estimated visually in each square.

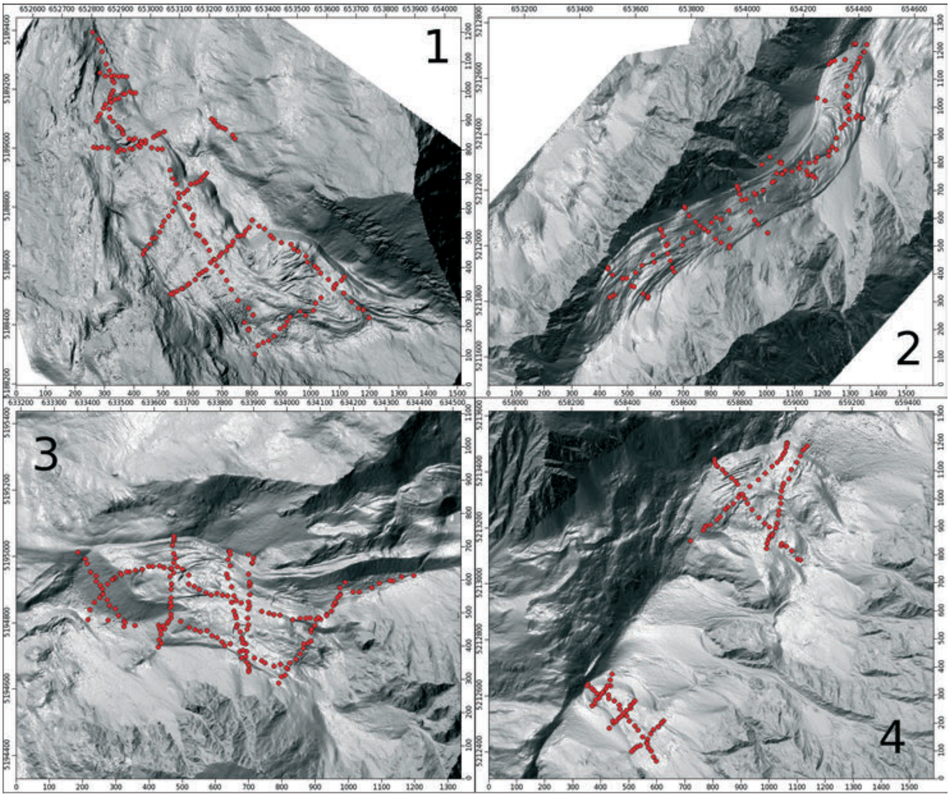


*Figure 2: Mapped squares in the study sites. 1 Äusseres Hochebenkar, 2 Reichenkar, 3 Ölgrube and 4 Schrankar.*

For comparison, adjacent stable areas alongside the rockglaciers were also mapped. In total, over 600 squares were mapped during August and September 2010.

## 3 Vegetation cover and frequency

Vascular plants were found in 45% of all squares, with a total mean cover of 3.5% (see Table 1). The most frequent species over all was *Poa laxa*, with a mean cover of 0.86% and a frequency of 32%, followed by *Cerastium uniflorum* with a mean cover of 0.73% and a frequency of 21%. Of all other species, only *Saxifraga bryoides* showed a frequency of over 10% with a mean cover of 0.3%, all other species showed much lower vegetation cover and were less frequent (see Table 2).

### 3.1 Äusseres Hochebenkar

On two rockglaciers, 161 squares were mapped (see Figure 2). On the main rockglacier, vascular plants were only found in 37% of the squares, while the mean vegetation cover of all squares on the rockglacier is only 3.2%. Both are the lowest values

*Table 1: Number of different species and average values for fine-grained material and total vegetation cover in the squares on rockglaciers for all study areas (Äusseres Hochebenkar AHK, Ölgrube OGR, Reichenkar RKR and Schrankar SKR).*

| Area (Nr. Of Squares) | Species | Fine-grained material (%) | Vegetation cover (%) |
|---|---|---|---|
| AHK (161) | 9 | 8.45 | 3.19 |
| OGR (160) | 15 | 13.49 | 5.57 |
| RKR (110) | 15 | 9.62 | 4.17 |
| SKR (110) | 14 | 13.51 | 4.77 |

*Table 2: Average cover (Cov.) and frequency (Fr.) of all species in the different study areas and combined for all areas in percent. Äusseres Hochebenkar (AHK), Innere Ölgrube (OGR), Inneres Reichenkar (RKR) and Schrankar (SKR).*

| Study area | AHK | | OGR | | RKR | | SKR | | All | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Cov. | Fr. | Cov. | Fr. | Cov. | Fr. | Cov. | Fr. | Cov. | Fr. |
| *Poa laxa* | 0.7 | 20 | 1.69 | 44 | 1.08 | 32 | 0.85 | 34 | 0.86 | 32 |
| *Cerastium uniflorum* | 1.28 | 26 | 0.81 | 17 | 0.72 | 28 | 0.83 | 14 | 0.73 | 21 |
| *Saxifraga bryoides* | 0.02 | 1.3 | 0.01 | 0.6 | 0.6 | 25 | 1.31 | 26 | 0.39 | 11 |
| *Oxyria digyna* | 0.42 | 0.6 | 0.16 | 4.4 | 0.45 | 17 | 0.28 | 11 | 0.26 | 7 |
| *Leucanthemopsis alpina* | 0.38 | 10 | 0.58 | 11 | 0.09 | 4.6 | 0.16 | 6 | 0.24 | 8.5 |
| *Minuartia sedoides* | 0 | 0 | 1.02 | 29 | 0 | 0 | 0 | 0 | 0.2 | 8.5 |
| *Geum reptans* | 0.02 | 1.3 | 0.28 | 9 | 0.12 | 7 | 0.11 | 6 | 0.11 | 5 |
| *Taraxacum alpinum* | 0 | 0 | 0 | 0 | 0 | 0 | 0.25 | 6 | 0.05 | 1.3 |
| *Sedum alpestre* | 0.2 | 4.5 | 0.04 | 1.9 | 0 | 0 | 0.3 | 2.7 | 0.05 | 2.4 |
| *Rhododendron ferrugineum* | 0 | 0 | 0 | 0 | 0.24 | 3.6 | 0 | 0 | 0.05 | 0.7 |
| *Veronica alpina* | 0 | 0 | 0.18 | 5 | 0 | 0 | 0 | 0 | 0.04 | 1.5 |
| *Senecio incanus* | 0 | 0 | 0.15 | 6 | 0.01 | 1.8 | 0 | 0 | 0.03 | 2 |
| *Saxifraga moschata* | 0.09 | 2 | 0.01 | 0.6 | 0 | 0 | 0 | 0 | 0.02 | 0.7 |
| *Salix repens* | 0 | 0 | 0.04 | 1.2 | 0.04 | 0.9 | 0 | 0 | 0.02 | 0.5 |
| *Poa alpina* | 0 | 0 | 0 | 0 | 0.06 | 1.8 | 0.04 | 1.8 | 0.02 | 0.7 |
| *Erigon uniflorum* | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | 2.7 | 0.02 | 0.5 |
| *Doronicum clusii* | 0 | 0 | 0.06 | 1.8 | 0.04 | 1.8 | 0 | 0 | 0.02 | 0.7 |
| *Campanula barbata* | 0 | 0 | 0.02 | 0.6 | 0.04 | 0.9 | 0 | 0 | 0.02 | 0.4 |
| *Loiseleuria procumbens* | 0 | 0 | 0.3 | 1.9 | 0 | 0 | 0.3 | 1.9 | 0.01 | 1.1 |
| *Linaria alpina* | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 2.7 | 0.01 | 0.5 |
| *Carex curvula* | 0 | 0 | 0 | 0 | 0.03 | 0.9 | 0 | 0 | 0.01 | 0.5 |
| *Androsace alpina* | 0.06 | 0.6 | 0 | 0 | 0.01 | 0.9 | 0 | 0 | 0.01 | 0.4 |
| *Artemisia mutellina* | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 1.8 | 0 | 0.2 |

of all investigated active rockglaciers. There were also only 9 different species found, with *Cerastium uniflorum* being the most frequent with a mean cover of 1.3% and a frequency of 26% (see Table 2).

The mean grain size of the rock debris is the biggest of all investigated rockglaciers at 88 cm, while the percentage of fine-grained material with a mean of only 8.1% is lower than at the other investigation sites.

No vascular plants were found at the small rockglacier, which also misses any fine-grained material. It is completely covered with lichens (mainly *Rhizocarpon geographicum*) and therefore assumed to be fossil.

## 3.2 Innere Ölgrube

160 squares were mapped on the composite rockglacier (see Figure 2). The mean vegetation cover of approximately 5.6% on the rockglacier Innere Ölgrube was the highest of all study sites. Vascular plants were found in 48.1% of the squares. The total of 15 different species was also high (see Table 2). The most frequent species was *Poa laxa*, with 1.7% average cover over all squares and an appearance in 44.4% of the squares. This also makes *Poa laxa* at the study site Ölgrube the most frequent species in all of the study sites. Two species, *Minuartia sedoides* and *Veronica alpina* were exclusively found at Innere Ölgrube, with *Minuartia sedoides* even being the species with the second highest mean cover and frequency.

## 3.3 Inneres Reichenkar

110 squares were mapped on the rockglacier (see Figure 2). 15 different species were found (see Table 2), with a total mean cover of 4.2%. Vascular plants were found in 48.2% of the squares, with *Poa laxa* being the most frequent species. It appears in 32% of the squares with a mean cover of 1.1%. Furthermore, *Rhododendron ferrugineum* and *Carex curvula* were found on the rockglacier. Those species are common on the stable areas at all study sites, but only at Reichenkar do they grow on the rockglacier itself. They inhabit mainly the ridges on the tongue, close to the front, which may indicate a relative stability of those areas. They are not found in the furrows, where long snow cover requires different strategies for plant growth.

## 3.4 Schrankar

110 squares were mapped on the two rockglaciers (see Figure 2). The mean vegetation cover is 4.8%, vascular plants were found in 49% of the squares, which is the highest value of all study sites. 14 different species were found, with *Poa laxa* being again the most frequent (see Table 2). It appears in over a third of the squares, but only has a mean cover of 0.8%. *Artemisia mutellina*, *Linaria alpina*, *Erigeron uniflorus* and *Taraxacum alpinum* only appear in the Schrankar.

## 3.5 Differences and similarities in vegetation at the different study areas

Although the vegetation cover and patterns show certain similarities on all studied rockglaciers, there are significant differences (see Table 1 and 2). Äusseres Hochebenkar shows the lowest number of different species, which might be explained by the scarcity of fine-grained substrate and therefore low vegetation cover, while the high vegetation cover at Innere Ölgrube is related to the high percentage of fine-grained material.

Schrankar and Reichenkar show comparable mean values of vegetation cover (see Table 1), while the amount of fine-grained material is significantly lower at Reichenkar. This could be an explanation for the slightly lower vegetation cover, especially in combination with the high surface velocities at Reichenkar (Hausmann et al. 2007a).

Only six species, *Poa laxa*, *Cerastium uniflorum*, *Saxifraga bryoides*, *Oxyria digyna* and *Geum reptans*, occur at all study sites (see Table 2). These are also the most frequent species, except from *Minuartia sedoides*, which was only found at Ölgrube, but in such high amounts that it is still one of the most frequent species overall. These species are all well-adapted to surface movement. *Geum reptans* spreads laterally over debris with long creeping stolons, *Cerastium uniflorum* creeps over scree (Cannone & Gerdol 2003), *Poa laxa* is relatively fast growing and undemanding and therefore able to colonize even moving surfaces relatively quickly, while *Oxyria digyna* is believed to play a role in creating more stable patches on instable slopes, due to its long and thin roots.

All other species occur rarely overall, probably due to individual site-specific factors or coincidental germination. More field data would be needed to seriously compare the vegetation patterns of the different study areas.

## 4 Vegetation cover in relation to fine-grained substrate

The occurrence of plants on active rockglaciers is related to the availability of fine-grained substrate. As shown in Figure 3, vegetation cover is low or very low in all squares with little amounts of fine-grained substrate, but can reach amounts of over 50% in squares with a good availability of fine material.

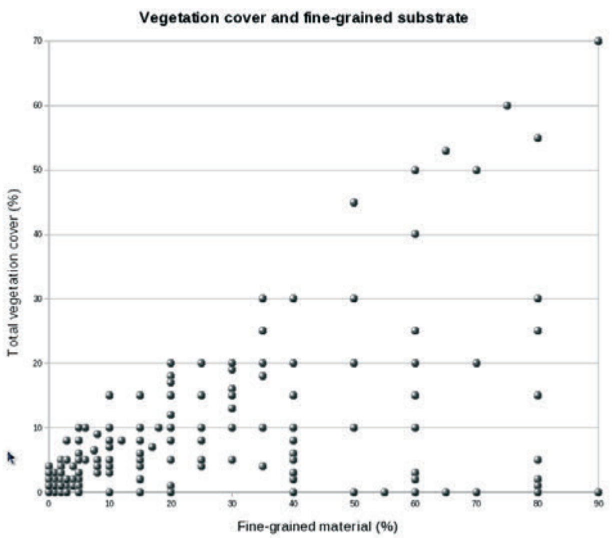


*Figure 3: Total vegetation cover in relation to fine-grained material for the squares on all four rockglaciers.*

The maximum values for vegetation cover increase with the percentage of fine-grained material, but lots of squares with high amounts of fine-grained substrate show relatively low or no vegetation cover. The availability or absence of fine-grained substrate is therefore a limiting, but no triggering factor for plant growth and vegetation cover on rockglaciers. Other factors limiting plant growth are micro-climatic parameters, such as surface temperature and humidity, surface instability and long snow cover. Most squares with a high proportion of fine-grained material but no or very low vegetation cover are located in very active areas of the rockglaciers with high surface instability or in small depressions or furrows, which hold perennial snow patches and therefore prohibit or at least hinder plant growth.

## 5 Discussion

Altogether, results show that vegetation cover and composition on different active rockglaciers are divers and inhomogeneous, even if only rockglaciers in a delimited area of the eastern Alps are compared.

All species, which occur on rockglaciers in the study areas have also been found on other rockglaciers in the Alps (Cannone 1997; Cannone & Gerdol 2003; Burga et al. 2004). Especially *Cerastium uniflorum*, *Saxifraga bryoides*, and to a lesser extent *Geum reptans* and *Loiseleuria procumbens* occur frequently on all botanically investigated rockglaciers and can therefore be assumed to be typical species of active rockglaciers in the eastern Alps. Due to the transect-approach, less different species were found than in other studies. On the other hand, the complete rockglacier surfaces could be investigated, albeit in a less detailed way, while the majority of other studies focus on the easily accessible rockglacier tongues. This might also be the reason for the relatively low vegetation cover in comparison to other studies. For example Cannone & Gerdol (2003) showed vegetation covers of over 10%, but only investigated the lower parts of the rockglaciers.

The vegetation cover generally increases with an increasing availability of fine-grained substrate, but cannot be explained by that variable alone, since other factors, especially surface instability and the micro-climatic conditions are also very decisive. Topographic factors, such as slope, exposition and elevation do not correlate with the vegetation cover at the studied sites.

Since the presented method gives an overview of the floristic composition of investigated rockglaciers, it could be used for monitoring vegetation on rockglaciers if done repeatedly at the same study sites.

## Acknowledgements

This study was embedded in the project C4AUSTRIA (Climate Change Consequences for the Cryosphere), which is funded by the Austrian Climate Research Program (ACRP).

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