

Glaciers and glaciation changes in the Hohe Tauern National Park (Austria): From early research initiatives to glacier preservation

Gerhard Karl Lieb & Andreas Kellerer-Pirklbauer

Keywords: glaciers; glacier research; glacier monitoring; glacier preservation; Hohe Tauern National Park

Abstract

The Hohe Tauern National Park (HTNP) is Austria's largest (1,856 km²) and oldest (1981) national park with some of the highest peaks in the Eastern Alps. Some 19% of the present national park was covered by glaciers during the Little Ice Age maximum circa ad 1850. One third of this area is still covered by glaciers. This paper presents a short overview of the long glaciological research tradition and the monitoring activities on glaciers starting in 1879 and presents selected results from the HTNP. In addition, the importance of glaciers for the HTNP is discussed with special emphasis on educational trails. Some considerations on aspects of glacier protection conclude the article.

Profile

Protected area

Hohe Tauern

National Park

Mountain range

Alps, Austria

Introduction

The United Nations has declared 2025 the International Year of Glaciers' Preservation to point out the global importance of glaciers. This declaration is accompanied by the proclamation of 21 March of each year as the World Day for Glaciers starting in 2025. The aim is to raise awareness of the crucial role of glaciers, snow and ice in the global climate system and water cycle and to increase awareness of the economic, social and ecological impacts of impending changes in the Earth's cryosphere (UNESCO 2025). Numerous events and publications all over the world contribute to this effort, as for instance listed by the World Glacier Monitoring Service (WGMS 2025a). As glaciers are endangered by climate change, glacier protection and preservation may first mean climate change mitigation – including all well-known societal, political and economic challenges. However, a second aspect of glacier preservation, which plays a crucial role in this text, is tied to the aspect of nature conservation. This implies protecting glaciers and surrounding areas from being changed or even destroyed for economic reasons. In the European Alps (hereinafter referred to as Alps), these primarily comprise the construction and maintenance of power plants and touristic infrastructure. Like other ecosystems, only (high) mountains with no or little technical impact ensure the supply of the ecosystem services of glaciers such as water release, natural hazard mitigation, aesthetic values and tourism.

Against this background, this article is dedicated to an exemplary Austrian mountain region in which glaciers are frequent, important for society and well protected in terms of nature protection. The widespread glaciation is due to high elevations along the central crest of the Alps, including Austria's highest summit (Großglockner, 3,798 m asl). This is among the aspects which aroused the interest of scientists

and alpinists at the turn of the 18th and 19th centuries. Glacier research began in the mid-19th century and glacier monitoring a few decades later. The latter has continued ever since. This resulted in long time series of monitoring data giving detailed insights into glaciation changes since the last glaciation maximum during the Little Ice Age (LIA) circa 1850. The idea of nature conservation intensified from the 1970s onwards and led to the establishment of the Hohe Tauern National Park (HTNP) in 1981 with substantial expansions in 1984 and 1992. This paper presents a short outline of different topics on glaciers and their variations based above all on long-term monitoring results and ends with some remarks on glacier preservation.

Glaciers in the Hohe Tauern National Park

Glaciers are widespread in the HTNP (Figure 1). At the glaciation peak of the LIA, all glaciers in the present-day national park covered an area of 352.8 km² (100%), in 1969 of 206.5 km² (58.5%) and in 2015 of 126.6 km² (35.9%). The percentage of glacier areas in the HTNP (overall area 1,856 km²) amounts to 6.8% in 2015 compared to 11.1% in 1969 and 19.0% in 1850. Thus, only one third of the former glaciated areas are still left (and substantially less of the volume). For comparison, between the LIA maximum and 2015 the glaciated area in all of Austria was reduced from 941 km² (Fischer et al. 2015) to 330 km² (Buckel & Otto 2018), i.e., by about two thirds. For the same time period, Reinthaler & Paul (2025) show that for the entire European Alps the glaciated area has shrunk from 4,244 km² to 1,806 km² (–57%) and the volume has decreased from 280 km³ to 100 km³ (–64%). The mountain areas with the largest glaciers are around the summits of Großglockner, Großvenediger, Hoher Sonnblick and Hochalm Spitze (Figure 1b). Some of the glaciers are famous due to their size and scenic beauty in combination with mountain summits which

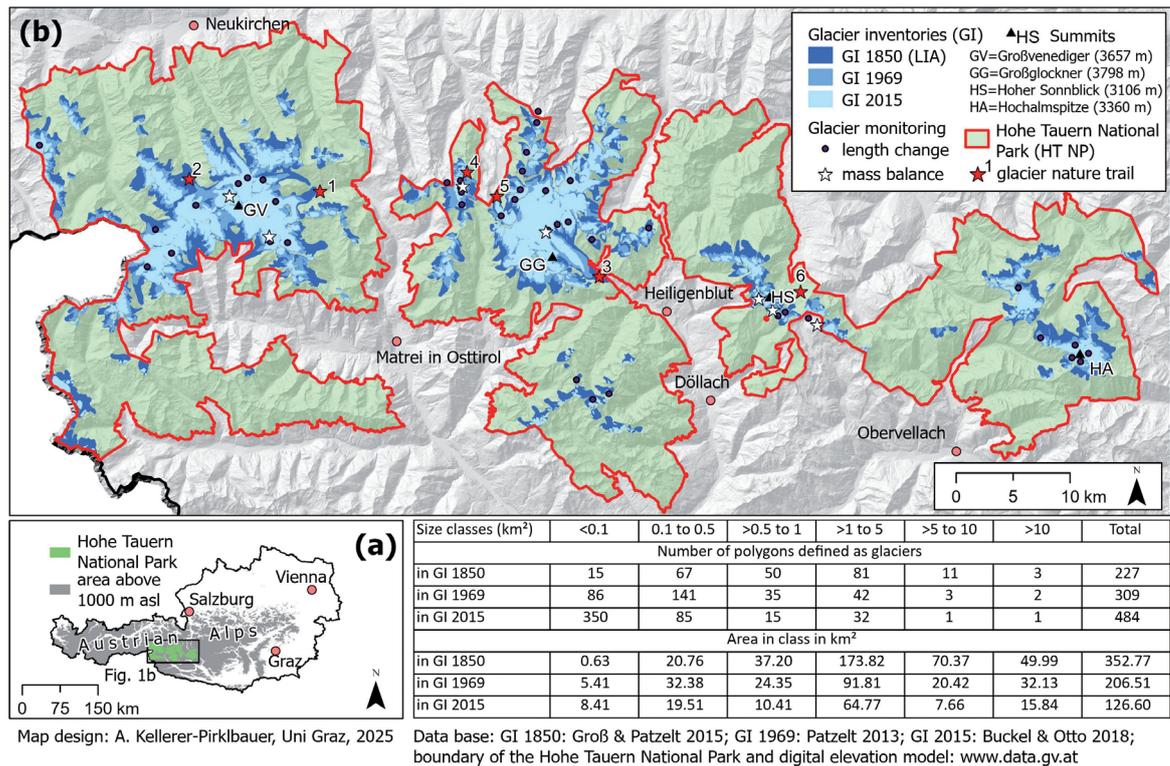


Figure 1 – Map of Hohe Tauern National Park (HTNP) in Austria (a) and its glacier extents (b) according to different glacier inventories (GI) for 1850, 1969, and 2015. The absolute number and area of glaciers per size class are given in the inset table. Glaciers with length changes and/or mass balance is monitored are indicated. Educational glacier nature trails: 1 = Schlatenkees (Innergschlöß), 2 = Obersulzbachkees, 3 = Pasterze, 4 = Stubacher Sonnblickkees, 5 = Ödenwinkelkees, 6 = Goldbergkees.

are among the highest in Austria. As will be explained in the section *History of glaciological research* of this article, those glaciers attracted early scientific attention – above all the Pasterze Glacier, Austria's largest, situated beneath Großglockner. During the LIA, valley glaciers were widespread. In the central part of the Venediger and Glockner mountains, almost every valley was covered by a mighty glacier tongue. Meanwhile, most of the glacier tongues have disappeared so that mountain glaciers covering high-elevated cirques became the typical glacier type.

History of glaciological research

The first reports about the glaciers of today's HTNP date back to the 17th century. In the LIA period, 15 large glaciers tongues advanced to elevations lower than 2,000 m asl even affecting pastures there (Groß 2018). Some glaciers – above all the Nördliches Bockkarkees (*Kees* is the regional term for glacier) – caused damage by ice avalanches (Kellerer-Pirklbauer et al. 2012), whereas lake outburst floods (like in the Ötztal Alps) only occurred at small scales due to less critical topography (i. e., no damming of main valleys). The first glacier which attracted scientific attention was the Pasterze glacier. A. & H. Schlagintweit (1850) published a book with a map of this glacier. The map depicts the glacier extent in 1846 and is considered to be one of the oldest maps of a glacier in the Eastern

Alps. In 1879, F. Seeland set up control points in the proglacial area to quantify the annual front variation of Pasterze. Since then, those measurements have been carried out annually, except for in three years, resulting in the longest data series of glacier length changes in the entire Alps based on on-site measurements (Lieb & Kellerer-Pirklbauer 2018). More details about the glacier's cultural and research history can be found in the monograph by Lieb & Slupetzky (2011).

Examples of other large glaciers with a long research tradition are the Obersulzbachkees, the Schlatenkees and the Karlinger Kees. The names of the two famous Austrian researchers F. Simony and E. Richter are associated with glaciers in the HTNP. A glacier and two mountains in the Venediger Mountains were named for instance after Simony in his honour. All these activities contributed significantly to the glaciers becoming known. Furthermore, after the opening of the meteorological observatory on the summit of Hoher Sonnblick (3,105 m asl) in 1886, the glaciers in the surrounding Goldberg Mountains became objects of early glaciological research. The uninterrupted meteorological time series of this observatory serves as a frequently used reference for correlating glaciation changes with measured temperature and precipitation data (e. g., Kellerer-Pirklbauer et al. 2008).

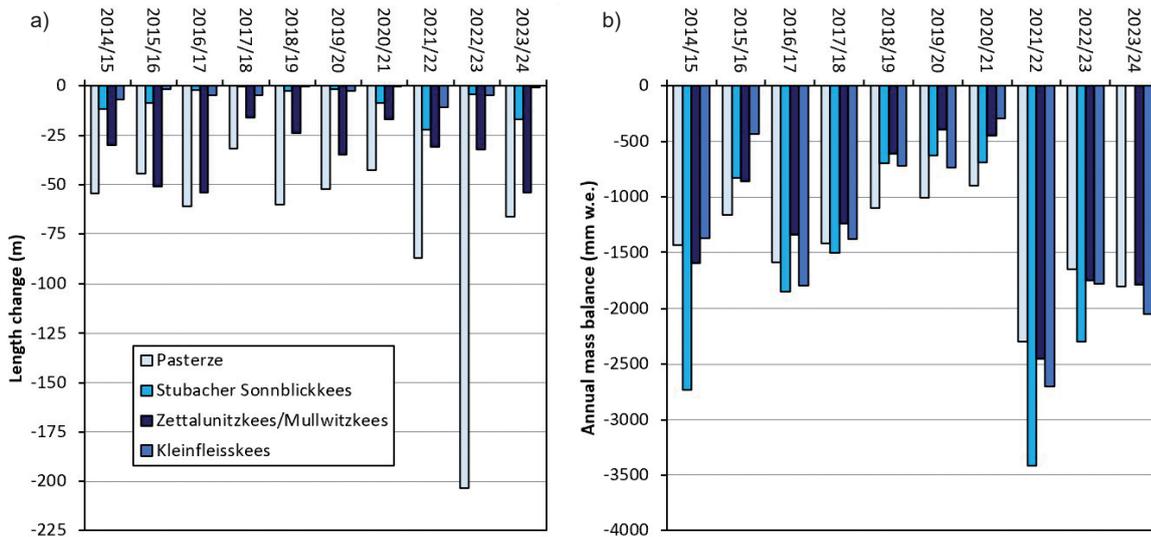


Figure 2 – Glacier monitoring results in the HTNP: (a) Length variation (in m) of four selected glaciers and (b) specific annual mass balances (in mm water equivalent/m.e.) of the same glaciers in the 10-year period 2014/15 to 2023/24. Data sources: (a) Austrian Alpine Association; (b) WGMS (2025b).

Modern glacier monitoring and its results

F. Seeland's pioneering work in setting up control points in front of the Pasterze Glacier in 1879 marks the beginning of modern glacier monitoring. At the turn of the 19th and 20th centuries already 26 glaciers in the later HTNP had control points for annual measurements of the length variations in their forelands (Groß 2018). This was basically the result of a letter published in 1891 by the former German and Austrian Alpine Association which encouraged its members to measure the glaciers regularly. Over time, this developed into the glacier monitoring service (*Gletschermessdienst*) organized and financed by what is now the Austrian Alpine Association (*Österreichischer Alpenverein, OeAV*). In 2024, the volunteers working for this service made available the results for 38 glaciers in the HTNP (Lieb & Kellerer-Pirklbauer 2025). Between 2023 and 2024, 37 glaciers retreated and only one did not significantly change the position of its terminus during this one-year observation period. The length variations of four selected glaciers are shown in Figure 2a. In addition to length variation, at the Pasterze Glacier variations in thickness and surface movement are also measured (Lieb & Kellerer-Pirklbauer 2025).

In 1963, H. Slupetzky for the first time measured the glacier mass balance at Stubacher Sonnblickkees. Over the years, the number of sites where mass balance measurements were carried out expanded. In 2025, mass balance data for seven glaciers in the HTNP were available from the World Glacier Monitoring Service (WGMS 2025b). Results for the last decade are shown in Figure 2b, which allows the comparison of length variations and mass balances for the same glaciers. Both diagrams impressively depict massive glacier shrinkage mainly as a result of exceptionally warm summers without snowfall events, in some years also

combined with little snow accumulation even in winter. The glaciers of the HTNP are no exception in the ongoing global deglaciation (WGMS 2025b).

The importance of glaciers

Numerous large and small glaciers are a characteristic feature of the HTNP. Glaciers have shaped and transformed the landscape for millennia. Even though these ice bodies are shrinking significantly due to climate change, they remain something very special. In addition, the glacier forelands are a primeval landscape that is repopulated by animals and plants (HTNP 2025). With a similar text content, the HTNP introduces visitors to the topic of glaciers and water. The text covers various aspects of the significance of glaciers:

- Glaciers shape the relief of the Alps – not just for millennia, but for at least 2.6 million years.
- Great number and spatial distribution make glaciers one of the dominant surface types of the HTNP (Figure 1).
- Glaciers are indeed *something very special* in terms of their rapid and very visible response to a changing climate.
- Not only the moraines, but the entire proglacial areas or glacier forelands are *primeval landscapes* in which geomorphological, hydrological and biological processes of high scientific value take place.

From a societal perspective, glaciers act as landmarks, are tourist attractions and contribute to creating regional identity. Therefore, they already played a crucial role in the period in which the HTNP was established – together with famous mountains and natural rivers, as well as animals and plants worth protecting. Thus, it may not be surprising that the core area

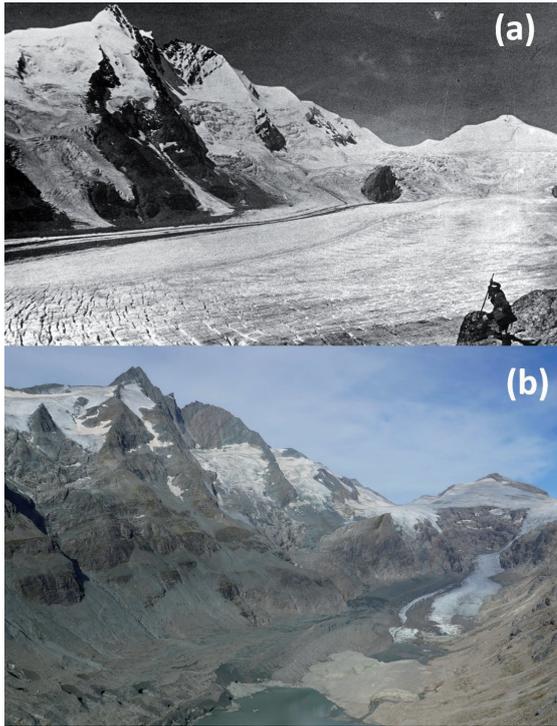


Figure 3 – The Pasterze Glacier, as it can be seen from the famous observation spot at Franz-Josefs-Höhe: (a) circa 1920 (Source: archive Gerhard Lieb) and (b) in September 2024. © Gerhard Lieb

of the oldest part of HTNP, which was declared a national park in 1981, was the Pasterze Glacier (Figure 3) and its at that time still widely glaciated vicinity. Aside from that, the HTNP celebrated its 30th anniversary among others with the publication of a book about the same glacier (Lieb & Slupetzky 2011).

Besides nature protection, the HTNP aims at scientific research, environmental education and regional development. The latter is to a minor extent the focus of the NP authorities, but more the focus of the local and regional stakeholders who try to make economic profit with the help of the HTNP. This is not necessarily a contradiction as the example of glaciers shows. Glaciers are valuable objects for environmental education as they make the relationship between climate and ice, as well as other natural processes, clearly visible. Moreover, glacial landscapes provide impressive scenery, not least due to the presence of water and the already mentioned natural dynamics in the proglacial areas. For this reason, of the first five educational trails established between 1978 and 1987 in the present-day area of the HTNP, no fewer than three led through the foreland of glaciers (1978 Innergschlöß; 1984 Pasterze; 1986 Obersulzbachtal). The educational trail to the Pasterze Glacier (the first version of the trail in 1984; two updates afterwards) was one of the first educational projects to vitalize the young protected area of the HTNP in Carinthia, founded in 1981. Meanwhile there are six educational trails dedicated to glaciers and glaciation change in the park (Figure 1), each

of them offering guide books or comparable information. From a nature protection perspective, trails of this kind are considered a positive contribution to visitor guidance. From an economic point of view, they are tourist attractions. Educational trails are among the most important facilities of the HTNP because they provide authentic nature experiences outside the visitor centers.

Final remarks on glacier preservation

The conservation regime in HTNP – as in other IUCN Category I or II areas – makes special conservation measures for glaciers unnecessary, as all glaciers are located in the park's core zone, where no direct human intervention is permitted. However, this cannot, of course, prevent the glaciers from being exposed to global climate change. It should additionally be noted that large areas of the HTNP are owned by the OeAV. As Austria's largest environmental protection NGO, the OeAV guarantees the intact preservation of nature including glaciers on its property. As mentioned above, this cannot, however, reduce glacier retreat. Therefore, both the HTNP and the OeAV (together with other environmental organizations) use their facilities, publications and programs to enhance public awareness of climate change (together with other environmental challenges) and the necessity of climate change mitigation at all spatial scales from local to global.

Learning about climate change as a contribution to education for sustainable development is promoted in glacial environments: the experience of hiking combined with the acquisition of knowledge in an impressive landscape may allow for a deeper reflection on society-environment relationships, the recognition of personal responsibility and a sharpening of the view of political necessities. The latter encompass measures for both climate change mitigation and protection of near-natural areas, not only in the high mountains and beyond glacier and climate preservation. The well-investigated and well-protected yet shrinking glaciers of HTNP may convey this message to society.

Acknowledgements

The authors acknowledge the long-term financial support by the Austrian Alpine Association (OeAV) which established the long-term glacier monitoring service in Austria in 1891. In addition, the HTNP administration has been supporting the authors' team's glacier research in various projects for more than two decades. The projects are also funded by the Hohe Tauern National Park and the Earth System Sciences funding program of the Austrian Academy of Sciences.

References

- Buckel, J. & J.C. Otto 2018. The Austrian Glacier Inventory GI 4 (2015) in ArcGis (shapefile) format [dataset]. *PANGAEA*. <https://doi.org/10.1594/PANGAEA.887415>
- Fischer, A., B. Seiser, M. Stocker-Waldhuber, C. Mitterer & J. Abermann 2015. Tracing glacier changes in Austria from the little ice age to the present using a lidar-based high-resolution glacier inventory in Austria. *Cryosphere* 9: 753–766. <https://doi.org/10.5194/tc-9-753-2015>
- Groß, G. 2018. Die Geschichte der Gletscherbeobachtung und -messung in den Österreichischen Alpen. In: Fischer A., G. Patzelt, M. AchRAINER, G. Groß, G.K. Lieb, A. Kellerer-Pirklbauer & G. Bendler, *Gletscher im Wandel. 125 Jahre Gletschermessdienst des Alpenvereins*: 53–96. Berlin. <https://doi.org/10.1007/978-3-662-55540-8>
- Groß, G. & G. Patzelt 2015. The Austrian Glacier Inventory for the Little Ice Age Maximum (GI LIA) in ArcGIS (shapefile) format [dataset]. *PANGAEA*. <https://doi.org/10.1594/PANGAEA.844987>
- HTNP (Hohe Tauern National Park) 2025. *Glaciers and water*. Available at: <https://hohetauern.at/en/nature/glaciers-water.html> (accessed 30/03/2025)
- Kellerer-Pirklbauer, A., G.K. Lieb, M. Avian & J. Gspurning 2008. The response of partially debris-covered valley glaciers to climate change: the example of the Pasterze Glacier (Austria) in the period 1964 to 2006. *Geografiska Annaler* 90/4: 269–285. <https://doi.org/10.1111/j.1468-0459.2008.00345.x>
- Kellerer-Pirklbauer, A., H. Slupetzky & M. Avian 2012. Ice-avalanche impact landforms: The event in 2003 at the glacier Nördliches Bockkarkees, Hohe Tauern Range, Austria. *Geografiska Annaler* 94/1: 97–115. <https://doi.org/10.1111/j.1468-0459.2011.00446.x>
- Lieb, G.K. & A. Kellerer-Pirklbauer 2018. Die Pasterze, Österreichs größter Gletscher, und seine lange Messreihe in einer Ära massiven Gletscherschwundes. In: Fischer, A., G. Patzelt, M. AchRAINER, G. Groß, G.K. Lieb, A. Kellerer-Pirklbauer & G. Bendler, *Gletscher im Wandel. 125 Jahre Gletschermessdienst des Alpenvereins*: 31–51. Berlin. <https://doi.org/10.1007/978-3-662-55540-8>
- Lieb, G.K. & A. Kellerer-Pirklbauer 2025. Gletscherbericht 2023/24. Sammelbericht über die Gletschermessungen des Österreichischen Alpenvereins im Jahr 2024. *Bergauf 1/2025*: 13–25. https://www.alpenverein.at/bk/bergauf/bergauf2025/Bergauf_1_2025/html5/index.html?&locale=DEU
- Lieb, G.K. & H. Slupetzky 2011. *Die Pasterze. Der Gletscher am Großglockner*. Salzburg.
- Patzelt, G. 2013. Austrian glacier inventory 1969 (GI I) [dataset]. *PANGAEA*. <https://doi.org/10.1594/PANGAEA.807098>
- Reinthaler, J. & F. Paul 2025. Reconstructed glacier area and volume changes in the European Alps since the Little Ice Age. *The Cryosphere* 19: 753–767. <https://doi.org/10.5194/tc-19-753-2025>
- Schlagintweit, A. & H. Schlagintweit 1850. *Untersuchungen über die physicalische Geographie der Alpen; in ihren Beziehungen zu den Phänomenen der Gletscher, zur Geologie, Meteorologie und Pflanzengeographie*. Leipzig.
- UNESCO 2025. *2025 International Year of Glaciers' Preservation*. <https://www.un-glaciers.org/en>
- WGMS (World Glacier Monitoring Service) 2025a. *International year... of glaciers' preservation 2025*. <https://wgms.ch/iygp/>
- WGMS (World Glacier Monitoring Service) 2025b. *Latest glacier mass balance data*. <https://wgms.ch/latest-glacier-mass-balance-data/>

Authors

Gerhard Karl Lieb^{1,2}

is a retired associate professor of Geography at the University of Graz. He has experience in physical geography with special regard of high mountains (glaciers, permafrost, geomorphic processes) as well as in regional geographies and geography didactics.

Andreas Kellerer-Pirklbauer^{1,2}

is a senior scientist at the University of Graz. He conducts research on the impacts of global change on the environment, particularly in relation to geomorphology and the cryosphere, as well as on human-environment interactions at various spatiotemporal scales.

¹ Department of Geography and Regional Science, Cascade – The mountain processes and mountain hazards group, University of Graz, Graz, Austria

² Together they lead the glacier monitoring service of the Austrian Alpine Association (OeAV)