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Glacier tourism without ice: Envisioning future adaptations in a melting world

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Climate change is causing profound changes in high mountain environments, including the rapid retreat of glaciers. The retreat and potential disappearance of Alpine glaciers during the twenty-first century raises questions about the future of glacier tourism sites. This perspective article reflects on these changes with a desk-based approach to suggest three possible ways glacier tourism can adapt to anticipated glacier loss. These three strategies include further developing geotourism, transforming last-chance tourism into "dark tourism," and using virtual reality to "virtually" reconstruct disappearing glaciers. This paper draws on three cases to discuss the potential of these strategies. The first is the Aletsch Glacier, the largest in the Alps, which is listed as a UNESCO World Heritage Site. It has also been the subject of recent work on geotourism. The second case is Mer de Glace, the largest glacier at the Montenvers site in France. This glacier has been studied in the context of last-chance tourism. The final case is the Mortaretsch Glacier in Switzerland, which can be reached from Diavolezza and has not been the subject of many studies. However, this site is one of the first to incorporate virtual reality technology into the tourist experience of the glacier.

KEYWORDS

glacier tourism, climate change, deglaciation, adaptation, environmental changes, future, geotourism, last-chance tourism

1. Introduction

Glaciers have been the objects of human fascination for centuries (Carey, 2007). Glaciers possess spiritual qualities and have often been used in rituals (Cruikshank, 2005). However, glaciers have become tourist destinations (Salim et al., 2021b) since the middle of the eighteenth century and have served as attractions and travel destinations (Joutard, 1986). Glaciers have been developed into tourist destinations in many countries worldwide, including Canada, Austria, and France (Groulx et al., 2016; Salim et al., 2021a). These sites sometimes rely on heavy infrastructure and have high operating costs that must be sustained by attracting numerous visitors. For example, the Bashui Glacier in China attracts up to 3 million visitors annually (Wang et al., 2010).

However, mountain environments are vulnerable to climate change (Einhorn et al., 2015), and glaciers have been some of the first to be affected by it. Consequently, many glaciers have retreated at an unprecedented rate for the last two millennia (IPCC, 2021), and mountain glaciers have experienced rapid and dramatic mass losses globally (Roe et al., 2017). A glacier's equilibrium line is a crucial marker of its mass balance; the equilibrium lines of European Alpine glaciers rose by an average of 114 m from 1901–1930 and 1971–2000 (Žebre et al., 2021). Contemporary global glacier mass loss is now considered entirely anthropogenic (Roe et al., 2021). Moreover, this glacier mass loss has intensified the processes that began from the paraglacial period, including moraine destabilization and post-glacial decompression (e.g., Cody et al., 2020; Glueer et al., 2020). Modeling indicates that ice masses from 2015 are expected to decrease from 26% (±6%) to 41% (±11%) by

2100, depending on the climate scenario (Rounce et al., 2023). The same study suggests that, in the case of SSP5-8.5, the ice mass in the European Alps could decrease by 99% by 2100 compared to 2015 levels.

Climate change will also affect glacier tourism, especially access to glaciers (Salim et al., 2021c). Climate change will make glacier tourism more dangerous because it destabilizes the glacial terrain and increases the frequency of rockfalls (Purdie et al., 2015). Some activities will no longer be possible or need to be conducted in poorer conditions; one example is glacier tours and ice cave visits in Iceland (Welling and Abegg, 2021). In the European Alps, retreating glaciers are also making it difficult to reach high mountain huts (Mourey and Ravanel, 2017), and warming permafrost is making some parts of the tourist infrastructure unstable (Duvillard et al., 2015). In addition, profound changes in the landscape of mid-altitude glacier sites can negatively influence visitor satisfaction (Stewart et al., 2016).

Tourism operators are developing strategies to adapt to these changes. Some consist of reactive strategies, such as limiting the rate of glacier retreat in a particular area by covering it with blankets (Carver and Tweed, 2021). Salim et al. (2021c) demonstrated that adaptation strategies in the European Alps can be divided into the following categories: heritage, diversification, mitigation, technical responses, access and itinerary maintenance, management changes, transformation projects, and stakeholder planning. Their research also revealed that although the adaptation strategies developed by glacier tourism stakeholders may allow glacier tourism to continue, these strategies are mainly reactive. That is, they do not allow for the proactive management of future changes (Fedele et al., 2019).

In some cases, adaptations have become maladaptations, such as when glacier hikes were replaced by helicopter glacier hikes in New Zealand's Glacier Country. This maladaptation increased the vulnerability of the operators by creating changes in demand and operating costs (Espiner et al., 2017). However, transformative adaptation strategies (c.f. Fedele et al., 2019) that involve the development of glacier interpretation centers have transformed glacier sites, which formerly attracted visitors based on their beautiful landscapes, into sites that enable visitors to engage in geotourism and landscape interpretation (Nesur et al., 2022).

Although several adaptation strategies have emerged that allow glacier tourism stakeholders to continue their current operations, the future of glacier tourism is still in jeopardy, particularly when considering a future where glaciers entirely disappear. For example, the Aletsch Glacier will likely no longer be visible from the vantage point by 2100 (Jouvet and Huss, 2019; see Figure 1). Moreover, Peyaud et al. (2020) proposed a model for the retreat of the Mer de Glace that suggests that by the 2050s, the glacier will no longer be visible from the Montenvers vantage point (see Figure 2). Accordingly, this paper assessed the pathways glacier tourism stakeholders could take to enhance the visitor experience when the glaciers are almost or entirely gone. This paper explores the future possibilities of Alpine glacier tourism in a world without ice.

2. Possible future

Research by Salim et al. (2021a) identified over 70 Alpine glacier tourism sites. These sites are in diverse natural environments and employ a variety of tourism models. For this perspective article, three glacier sites were analyzed to explore the future of glacier tourism. The three case studies are analyzed using a desk-based approach employing grey literature and previous scientific publications. The Mer de Glace and Aletsch glaciers were chosen because they exemplify glaciers in the Alps and have been the subject of previous research related to glacier tourism. The Morteratsch Glacier was selected because it is one of the few sites in the Alps where stakeholders have been developing tourism strategies incorporating virtual reality (VR). These three sites are not necessarily representative of Alpine glacier tourism; however, they allow for a discussion of three potential paths for glacier tourism: geotourism, last-chance tourism (LCT), and VR-enhanced tourism. Therefore, these three descriptive case studies are used to better understand the current challenges facing glacier tourism (Urioste-Stone et al., 2018) and identify potential solutions. Other pathways that are not represented by the three case studies examined in this paper may exist.

2.1. From glacier tourism to geotourism: Aletsch Glacier

Geotourism refers to nature-based tourism in a geographically localized ecosystem, such as mountainous areas, coastlines, or glacial environments (Newsome et al., 2012). Glacier tourism has long focused on the aesthetic appeal of ice environments; however, tourism stakeholders are now emphasizing their scientific value (Bussard et al., 2021). Consequently, glacier tourism can be considered a form of geotourism (based on geosystems) and a form of scientific tourism through interpretation elements (or *médiation scientifique*; Vialette et al., 2021). In this context, the Aletsch Glacier, the largest glacier in the Alps, is an interesting case. The UNESCO World Heritage List has included this entire area under the criteria of outstanding aesthetics (vii), geological and geomorphological interest (viii), and ecosystem diversity (ix). Geoscientific interpretation is provided for the entire tongue of the glacier through brochures, mobile applications, educational trails, and museums (Bussard and Reynard, 2022).

The Valais side of the Aletsch Glacier (Figure 1) is primarily used for winter activities, predominantly skiing. These activities accounted for 87.9% of the ~9.5 million annual lift visits to the area in 2019 (Aletsch Bahnen AG, 2019). Skiing does not occur on the glacier itself but on the southern side of the left slope of the mountain and is not directly affected by the glacier's disappearance. However, it could potentially reduce the attractiveness of the destination as a whole. During the summer season, around 1.1 million people use the lift to reach three main viewpoints (Moosfluh, 2,333 m a.s.l., Bettmerhorn, 2,647 m a.s.l., and Eggishorn, 2,869 m a.s.l.), and the glacial scenery is a major attraction for visitors, particularly for those visiting the main viewpoint (Eggishorn; Salim et al., 2022).

The disappearance of this glacier during the second half of the twenty-first century (Jouvet and Huss, 2019) may force operators to change how they advertise the glacier to the public. Therefore, this paper considers promoting geotourism as a strategy that meets the goals of tourism stakeholders and UNESCO. Although glacial UNESCO sites are considered under threat from climate change

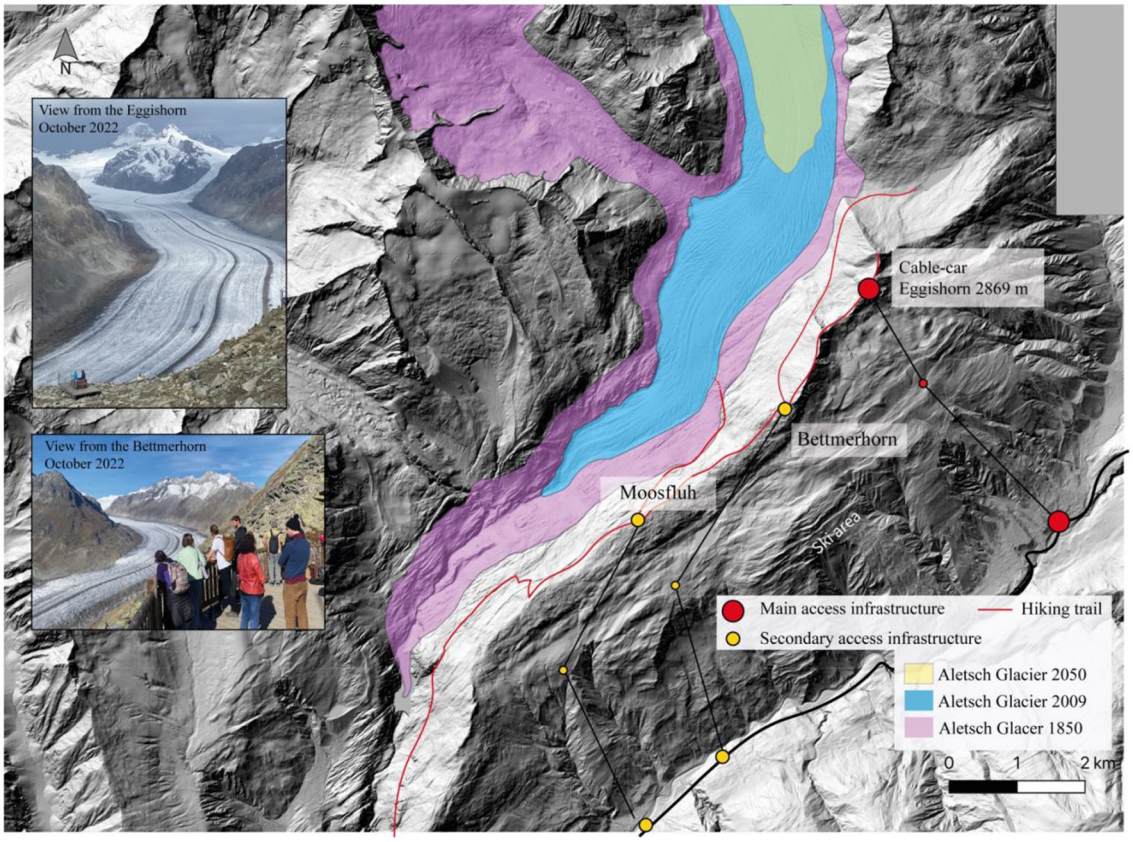

FIGURE 1
Map of the tourist site of the Aletsch Glacier. The glacier extensions for 1850 and 2009 are based on GLAMOS-Glacier Monitoring Switzerland (2019) and the 2050 Projection on Jouvet and Huss (2019). Pictures are from the author.

and glacial retreat, the IUCN evaluation report notes that, while the threat is real, its consequences should be "recognized among the ongoing ecological and geomorphological/glaciological processes (criteria viii and ix) of which the property provides an outstanding example" (IUCN, 2007, p. 91). In this context, the retreat of the Aletsch Glacier makes it an ideal site for witnessing the effects of climate change, which can be used to promote geotourism in the area.

In the case of the Aletsch Glacier, although the glacier's retreat decreases its aesthetic beauty, it also increases its scientific significance, creating the potential for developing it into a geotourism site. A similar dynamic can be observed in the interventions made by the ProNatura Association at the Aletsch site. This Swiss nature conservation organization has been active at the site for many years and offers numerous glaciology, geology, and biodiversity tours.[1] As Nesur et al. (2022) suggested, strengthening interpretation activities through the reinforcement of territorial geo-resources could serve as a form of tourism diversification. Examples of post-glacial geotourism already exist, including tours that explore the Pyramides d'Euseigne, the traces of the ancient Herens Glacier (Wallis, Switzerland), and geotraces of past glaciation in Norway (e.g., Jamorska et al., 2020). Although these tourism products have been developed around traces of past glaciations (e.g., Würm), this approach can also be applied to sites of ongoing deglaciation.

Therefore, increasing the importance of geotourism activities and products can transform the visitor experience by focusing on scientific interpretation rather than aesthetic beauty. Such geotourism would focus not only on the glacier itself but also on the knowledge of it.

2.2. Glacier retreat as an attraction: Mer de Glace glacier

Another possible strategy involves transitioning from LCT, which allows tourists to witness a natural feature before it disappears (Lemelin et al., 2010), to a post-LCT scenario when a glacier eventually vanishes. This strategy is particularly relevant to the Mer de Glace Glacier in France. With around 400,000 visitors yearly, the Montenvers site is one of the most-visited glaciers in France (Figure 2). It is also clearly threatened by climate change, and by 2050, it may no longer be visible from the Montenvers viewpoint (Peyaud et al., 2020). Salim and Ravanel (2020) demonstrated that visitors come to the site to witness the glacier before it disappears. However, they also revealed that,

1 Interview with Aletsch ProNatura representative (October 2022).

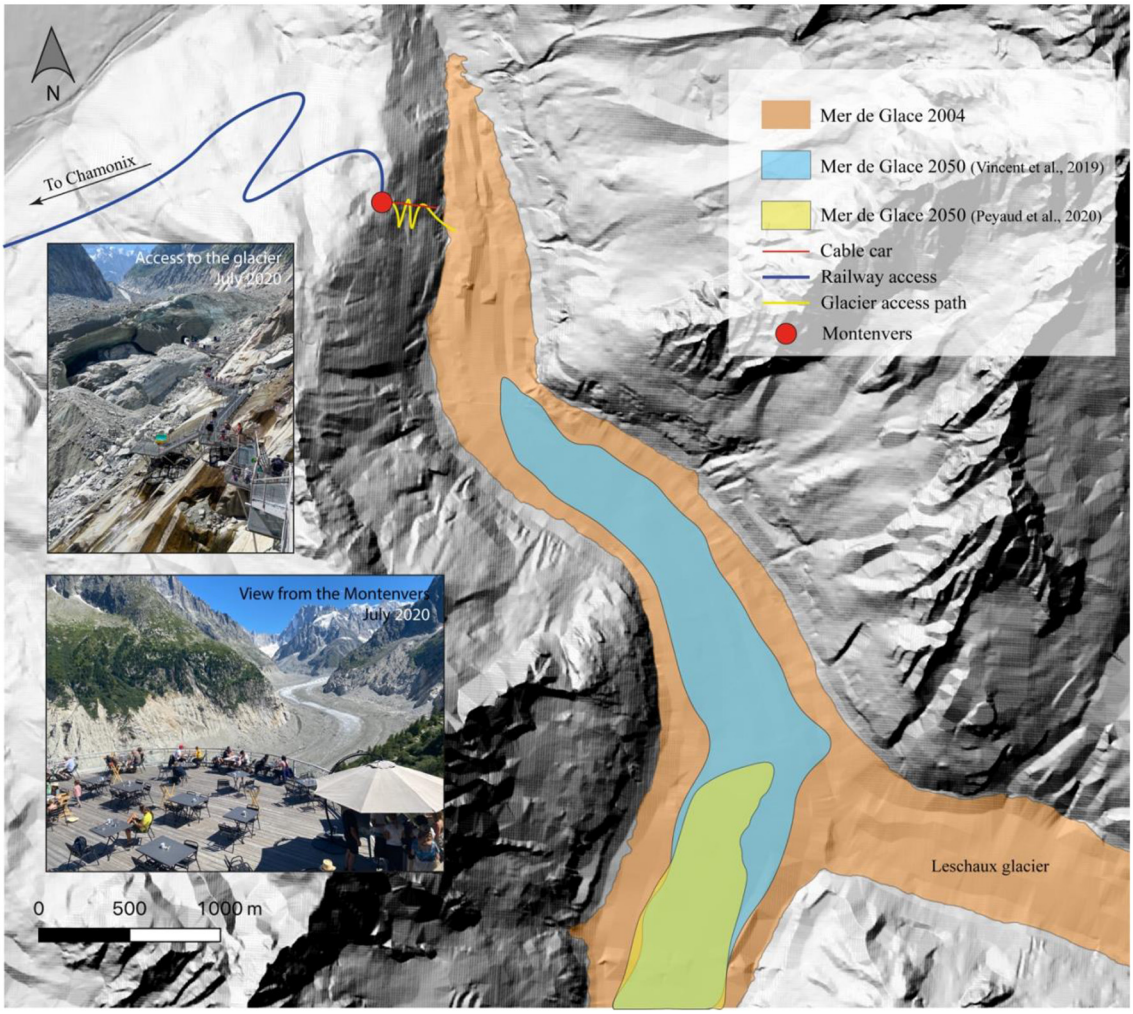

FIGURE 2
The evolving state of the Montenvers Mer de Glace. The glacier extension from 2004 is based on Vincent et al. (2007), the 2050 extension represented by the color blue is based on Vincent et al. (2019), and the yellow-colored extension is based on Peyaud et al. (2020). Pictures were taken by the author.

beyond wanting to obtain a final glimpse of the glacier, visitors were also motivated to understand the phenomenon of climate change and observe the evolution of the glacier. The findings suggests that visitors' motivations are complex and involve diverse motivations, such as wanting to better understand tragic events and "see to believe" or commemorate it. These motivations are often related to the concept of "dark tourism" (e.g., Poria et al., 2004), which refers to visiting disaster areas or sites of commodified death (Foley and Lennon, 1996).

This shift from LCT to dark tourism could be supported by the general ubiquity of post-apocalyptic narratives, which emphasize the collapse of existing systems (e.g., glacial landscapes; Varnajot and Saarinen, 2021). In this context, the site "where the Mer de Glace used to be" would reflect the destruction of the Anthropocene era and its accompanying "climate apocalypse" (Swyngedouw, 2019). The tourism industry could take advantage of the new image of these sites to overcome the loss of the glacial landscape and rebrand them as ideal sites for witnessing the consequences of climate change. Varnajot and Saarinen (2022) discussed this concept in the context of Arctic tourism, and it is possible to apply it to glacier tourism, particularly in the context of scientific education on glaciers (Salim et al., 2021c).

When the ice disappears, glacier tourism stakeholders could turn to post-glacial tourism as an alternative. Such dark tourism would enable tourism stakeholders to commemorate these vanished glaciers. Examples of such commemorative acts already exist, such as the ceremonies on the Okjokull Glacier in Iceland (Hall and Saarinen, 2020) and the Swiss Pizol Glacier (RTS, 2019) in 2019. Therefore, as the Mer de Glace recedes, the Montenvers site could become a site to commemorate the disappearing glacier.

With such a shift toward dark tourism, the visitor experience would become oriented toward understanding the effect of humans on the environment. The focus would not be on the glacier but on what it represents. That is, the experience would be based on the "Specters" of past glaciers.

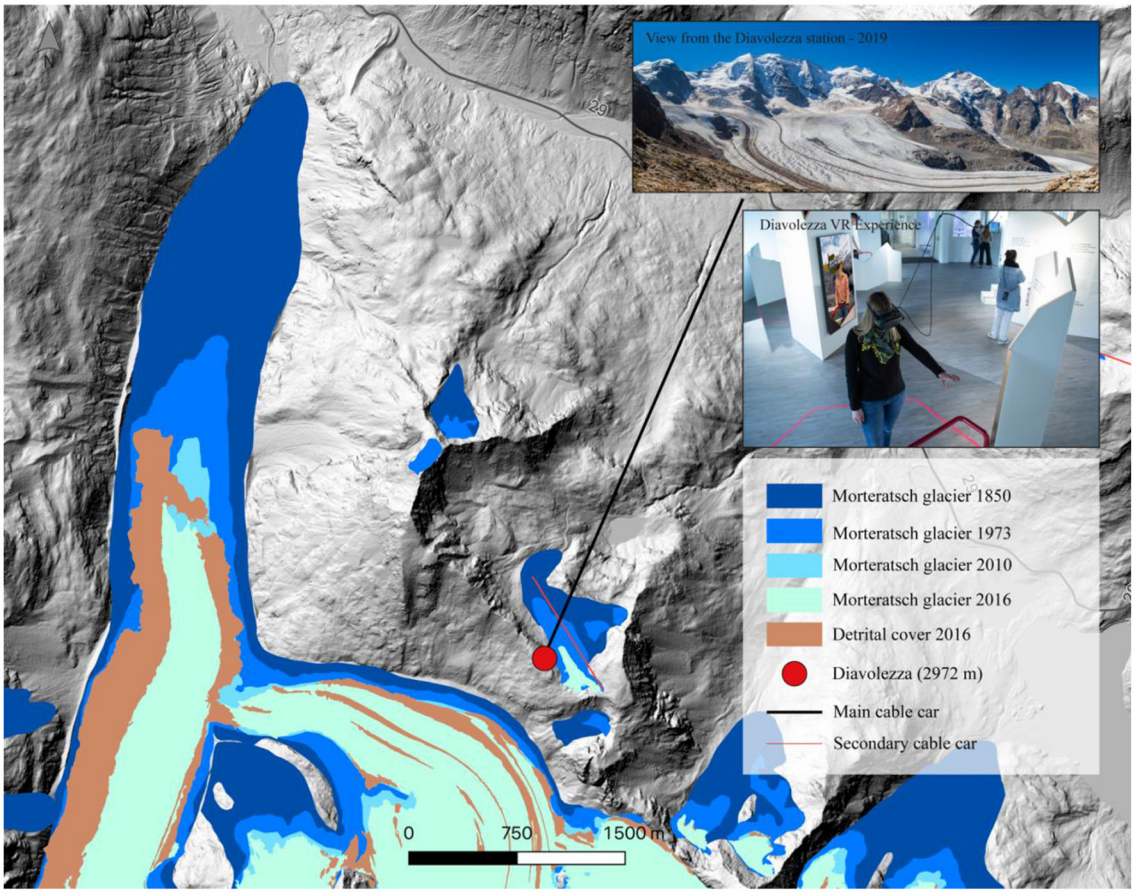

FIGURE 3
Evolving state of the Diavolezza site and the Morteratsch Glacier. The glacier extensions are based on GLAMOS-Glacier Monitoring Switzerland (2019). Pictures of the Diavolezza Glacier VR Experience room were taken by Peter Stein (2019).

2.3. From natural to virtual glaciers: Morteratsch Glacier

The third scenario involves the development of "virtual glacier tourism." In such a scenario, the attraction of the physical glacier would be replaced by its representation using digital technologies. Tourist sites have already begun incorporating such technology as VR, augmented reality (superimposing computer-generated information on the real world) and mixed reality (Beck et al., 2019). These different forms of "technological tourism" can augment visitor experiences. For example, Han et al. (2019) proposed that VR technology can enhance visitor engagement, emotion, reflective observation, and learning experiences. Other studies have highlighted the potential for VR to enhance learning, authenticity, and emotional experiences in the context of dark tourism (e.g., Fisher and Schoemann, 2018). Due to climate change, glaciers are constantly changing in size and appearance. Thus, applying VR technology to post-glacier tourism could help tourism operators preserve the history of the glacier and develop its appeal as a virtual object.

The "VR Experience" attraction at the Diavolezza site in the Grisons, a canton in Switzerland, is an example of how VR technology can be applied to glacier tourism and LCT more generally. This site offers a view of the Mortaretsch Glacier and enables visitors to experience a visual representation of the glacier's past and future states (Figure 3). The site is accessible by a cable car that carries an average of 375,000 people per year, with 180,000 rides occurring in the summer (Diavolezza LAGALB AG, 2019). Unlike classical interpretation devices, these devices provide visitors with a visual representation of the evolution of the glacier. Therefore, instead of promoting the actual glacier itself, operators of glacier sites can promote their virtual representation. In this sense, VR is a tool that stakeholders can use to develop the future of glacier tourism. Few studies have assessed the use of VR for cryosphere-related tourism. However, studies on its use for preserving archaeological sites in the Arctic (Dawson and Levy, 2016) indicate that it could be an appropriate tool for conveying a powerful message. It remains to be seen to what extent a "virtual glacier" will be perceived as authentic and what meaning it will bring to visitors.

3. Concluding remarks

This study analyzed three existing glacier tourism sites to reflect on potential strategies that could be used to adapt to the

challenges presented by climate change. This study identified three unique approaches that glacial tourism operators could implement in response to the inevitable disappearance of glaciers.

The first approach involves focusing on the scientific value of glaciers through the development of geotourism. Stakeholders could advocate for including a glacier in the UNESCO World Heritage List, create geoparks, and develop an interpretive tourist approach to experiencing the glacier and its history. Geotourism development would facilitate a shift in focus from the aesthetic beauty of the glacier to its scientific significance. Such an approach has already been employed at several glacier sites (Bussard et al., 2021). This transfer of value could help to diversify the appeal of tourist sites and ultimately reduce vulnerability for tourism stakeholders, as Loehr (2020) pointed out in a study of a small island developing states tourism initiative.

The second scenario concerns the development of post-glacial tourism, where LCT is progressively substituted with dark tourism. In such a scenario, contemporary glacial sites would be converted into places that commemorate glaciers and highlight the consequences of the Anthropocene. This approach is comparable to the nostalgic elements of dark tourism that have previously been highlighted in the literature (Christou, 2020). Because such dark tourism approaches focus on the memory of past glaciers, such a tourism model would not be threatened by the retreat of glaciers. This pathway would encourage visitors and operators to engage in new experiences responsive to ongoing environmental changes.

Finally, the third scenario involves applying VR technology to glacial tourism. Although this scenario does not specify whether stakeholders should focus on the glacier's aesthetic or scientific value, it implies a shift in interest from the physical glacier to the glacier as a virtual object. When installed at current glacier sites, VR technology would allow operators to reduce their vulnerability to glacier retreat by offering a virtual representation of the glacier's past, present, and future. As suggested in the literature, VR would complement and eventually replace experiences of the actual glacier (Loureiro et al., 2020). Once the VR experience replaces the experience of the actual glacier, it would be possible to imagine scenarios where glacier tourism occurs far from any actual glacier, as is the case with the Expedition 2 Grads in several Swiss cities (see https://www.expedition2grad.ch/).

These scenarios are not mutually exclusive and could easily be combined by tourism stakeholders seeking to adapt to climate change. Additionally, other forms of glacier tourism adaptation remain possible. For example, VR tools could be coupled with the development of a form of hyper-tourism (e.g., Salim et al., 2021a), the main characteristics of which would be an upmarket approach, a strong focus on the unique aesthetic value of a glacier, and an acceleration of approaches aimed at international markets. Another strategy could be developing tourism activities in proglacial environments, especially around future lakes formed by the glacier retreat. However, tourism activities could conflict with other interests, such as hydropower, in such scenarios. Moreover, the need to protect these sensitive areas will require, among other things, sustainable adaptation and management (Zimmer et al., 2022). These scenarios, although futuristic, can help us imagine future possibilities and stimulate debate on the ethical, theoretical, and conceptual issues raised by the disappearance of glaciers in the context of glacial tourism.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

ES prepared, wrote, and reviewed the manuscript.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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