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Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie

GLAMOS Glacier Monitoring Switzerland

GCOS Switzerland Project

"Discovering forgotten glacier images in a new glance (DEFOGGING)"

Final Report

Project period:	01.08.2021 – 31.07.2023
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Institutions:	WSL Birmensdorf and ETH Zurich
Funding:	MeteoSwiss, in the framework of GCOS Switzerland

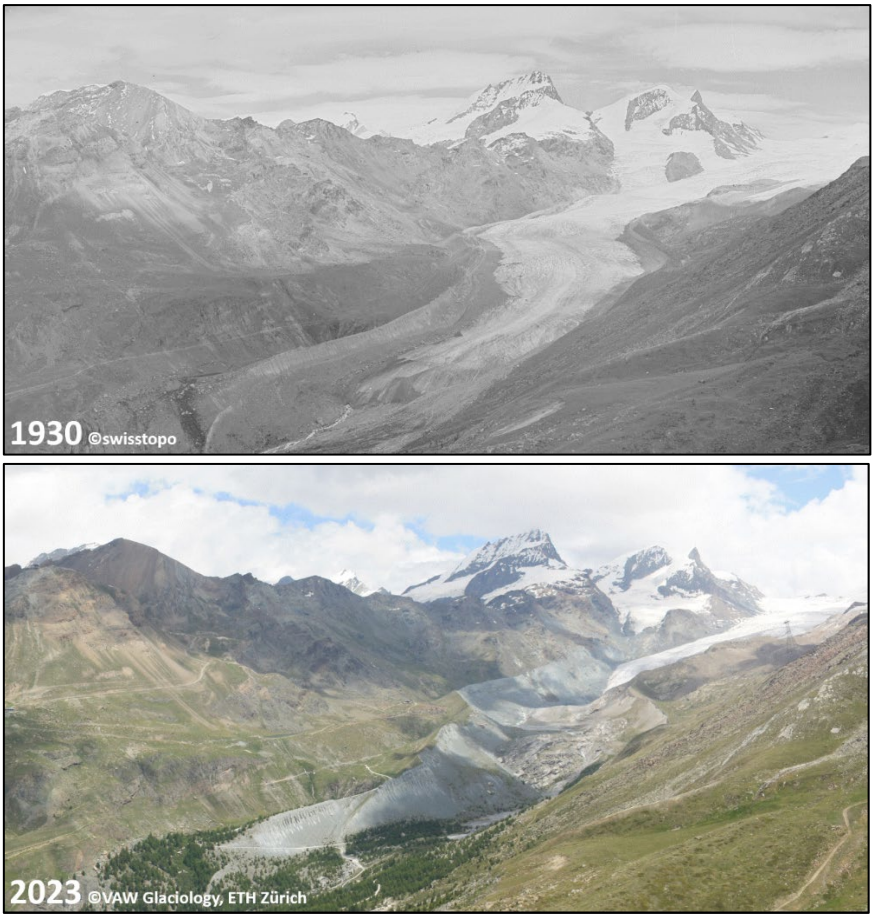

Figure 1: An example of repeated glacier photography acquired during the project. The example refers to Findelgletscher, VS. Image credits and years of acquisition are given.

1. Summary

Repeated glacier photography is possibly one of the most impressive ways to visualize the alarming pace of ongoing climate change. Such photography does not only speak to the general public but al-so to the scientific community across disciplines. Whilst some well-curated, excellent examples of repeated photography exist, the case of old photographs being lost through time is far more common. Sometimes, such images re-emerge years later, e.g. when some archives are moved, or when the personal photos of some ancestor are rediscovered in the family's attic.

During the past decades, the project team and their institutes had latently collected such old glacier photographs. The result was a large pool of images that document the historical evolution of Swiss glaciers over a century or so. The project "DEFOGGING" set out to valorise these incredible documents.

Based on a close collaboration between the ETH Library and the Glaciology group jointly affiliated to both WSL Birmensdorf and ETH Zurich, the project inventoried, digitized, and completed with metadata a total of almost 35,000 glacier images. Based on the positive experience gained during previous image-archiving efforts, roughly 10,800 of the most insightful images were geolocated by leveraging "the crowd", i.e. a set of volunteers recruited amongst the general public. While the original intent was to aim at a quantitative analysis of the images too, the focus was on the power of images to speak for by them-selves. With the active promotion of such type of images amongst the media and the general public, the project aimed at contributing in communicating the importance of long-term monitoring.

More specifically, the project was structured around six work packages (WPs), dealing with the triaging and inventorying of the images (WP1), their digitization (WP2), their geolocation through crowdsourcing (WP3), the quantitative evaluation of the relevant glaciological information (WP4), the dissemination of the project results (WP5), and the operationalization of the developed procedures (WP6). The geolocation happened through the established platform "sMapshot", while the infrastructure of ETH's Library was leveraged to ensure that the inventoried images will remain accessible to the larger public in the long term.

Based on the project's success, it was decided to integrate part of the project workflows into the operations of the Glacier Monitoring Switzerland (GLAMOS) initiative. This will ensure that up-to-date glacier repeat photographs will continue to remain available for effective communication of glacier changes.

2. Scientific Report

2.1. Introduction

Glacier changes are amongst the most visible signs of environmental responses to long-term climate fluctuations. The GCOS Implementation Plan underpins this, and defines “glacier area”, “glacier elevation change”, and “glacier mass change” as three of the Essential Climate Variables (ECV) in the Terrestrial domain. Whilst the monitoring of ECVs can be both informative and effective, the visual comparison of images (Figure 1) might be even more powerful when communicating climatic changes to the general public.

Repeated photography of the same place is widely used to visualize any sort of environmental change, ranging from the temporal migration of three lines to the expansion of urban areas. In the context of climatic change, repeated photography of glaciers has established itself as one of the most popular ways to inform about the magnitude and speed of currently ongoing changes.

Sometimes, such repeated photography of glaciers is done specifically, i.e. with the precise purpose of documenting the glacier changes. In such cases, contemporaneous photographers often aim at re-finding the exact position from which a historic image was taken – sometimes investing considerable efforts to do so. Much more common, however, is the situation in which glaciers are photographed once, as an element characterizing the landscape in which the non-scientific photographer happened to be in the very moment. In Switzerland and other Alpine countries with long-standing touristic activities, such glacier photographs have now been taken for almost two centuries, i.e. since the development of photographic techniques that are portable enough to be brought to mountains.

With the project “DEFOGGING”, we set out to create a framework by which such historic photographs can be both preserved in the long term and repeated when deemed of interest. The idea was to pool the expertise in the archiving of historic materials hold by the ETH Library with the disciplinary expertise carried by WSL/ETH’s glaciology group, and to establish a platform through which historic glacier photographs can be (i) collected, (ii) geolocated, and (iii) made available to the wider public. More precisely, the project aimed at establishing a process through which duly triaged images are complemented with the necessary meta information, and stored within ETH’s Image Archive.

2.2. Methods and activities

The project was conceived around six work packages (WPs) dedicated to the triaging and inventorying of the available images (WP1), image digitization (WP2), image geolocation through crowdsourcing (WP3), quantitative evaluation of the retrieved glaciological information (WP4), dissemination of the project results (WP5), and development of procedures for handling similar images after the project’s conclusion (WP6). The activities performed in the various WPs are briefly described hereafter while some of the main results are summarized in Section 2.3.

WP 1: Inventorying and triage

The project’s starting point was a pool of >30’000 glacier images that were “accumulated” through time by the project partners and their institutes. The pool ranged from single-shot images taken by occasional tourists to time series of repeated photographs collected during former research projects. The images were available in a multitude of formats ranging from

Figure 2: Non-exhaustive overview of the images that were available at the start of the project. The collection included (a) sorted, printed photographs, (b) diapositives, (c) photographs contained in reports, and (d) unsorted photographs from private persons.

separately printed photographs, over diapositives and illustrations within reports, to individual photo-panoramas composed of pictures manually glued together on paper (Figure 2).

WP1 gained an in-depth overview of the available materials, and triaged them based their glaciological information content (cf. WP4) or their outreach potential. The images were grouped into four categories of priority representing images to be treated with high priority ("Priority A" images), images to be treated with medium and low priority (Priority B and C, respectively), and images that can be discarded (Priority D) because of insufficient quality or lacking the possibility of any geolocation due to a too narrow field of view.

For all retained images (see WP2), a detailed inventory of metadata was compiled. These metadata included information on the image's format (e.g. film, diapositive, printed copy, …), image quality (i.e. resolution, sharpness, …), photographer or copy-right holder, approximate location and view field, and time stamp of the acquisition.

WP 2: Scanning and preparatory work for geolocation

Based on the triage of WP1, WP2 scanned the individual images and matched them with the corresponding metadata. The scanning process was performed through the facilities provided by ETH's Library. As anticipated, the scanning of small-format slides (diapositives) preceded quickly and with good quality, while the digitising of older prints and medium formats (e.g. negatives, glass plates) was more time consuming. Although attention was paid to preserve the colour quality of the images, some images required post-processing in terms of lighting conditions and contrast. In total, the project scanned some 34,800 images, of which 16,200 were post-processed.

The scanned images were all ingested into ETH's Image Archive, hosted by ETH's Library. In this process, every image was given a DOI and assigned a CC BY-SA 4.0 license (https://creativecommons.org/licenses/by-sa/4.0/), thus ensuring free access for any type of use. Scanned images with "Priority A" were additionally released in the form of so-called "Collections" on the sMapshot platform (https://smapshot.heig-vd.ch/), i.e. the platform used for image geolocation (cf. WP3). This process was facilitated by the ETH Library having access to an own branch of the platform itself (https://smapshot.heig-vd.ch/owner/ethz).

WP 3: Image geolocation via crowdsourcing

WP3 followed a crowdsourcing approach for geolocating (a part of) the images scanned in WP2. The overarching challenge for extracting information from the images was that, in general, the images were not acquired with a documentative usage in mind. In particular, this means that the position from which a photograph was taken and the view angle displayed by the image were rarely kept track of. The implication is that, a priori, it is also unknown which locations the images show – an obvious problem when envisioning a quantitative evaluation.

To solve the above, the project leveraged the very positive experiences that the ETH Library gained by using the platform "sMapshot" (https://smapshot.heig-vd.ch) – a platform developed by the School of Management and Engineering Vaud (HEIG-VD) which allows to outsource the time-consuming, manual georeferencing work to an active pool of volunteers ("the crowd"; Produit and Ingensand, 2018). The georeferencing is based on so-called monophotogrammetry (or monoplotting; Bozzini et al., 2012), i.e. a photogrammetrical process by which geographic data are extracted from single, non-metric images with arbitrary orientation. Loosely speaking, monoplotting can be understood as being opposed to stereo-photogrammetry: whilst in the latter a set of overlapping images is used to compute a three-dimensional (3D) model of the portrayed surface, monoplotting uses a pre-existing 3D model to reconstruct the location of individual points on a given image. The prerequisite is to have the image correctly aligned with the 3D model. sMapshot provides an environment in which the above alignment can be performed in an iterative, intuitive, and interactive way (Figure 3).

The release of the images scanned in WP2 happened through two distinct campaigns (campaigns "Glacier II" and "Glacier III" under https://smapshot.heig-vd.ch/owner/ethz). Through them, about 5,000 images were released at a time. By the end of the project, roughly 80% of all released images (i.e. ~8,500 out of ~10,800) were successfully georeferenced, thus allowing for a unambiguous reconstruction of the image position. For most of the remaining cases, the relatively narrow field of view proved to be the bottleneck.

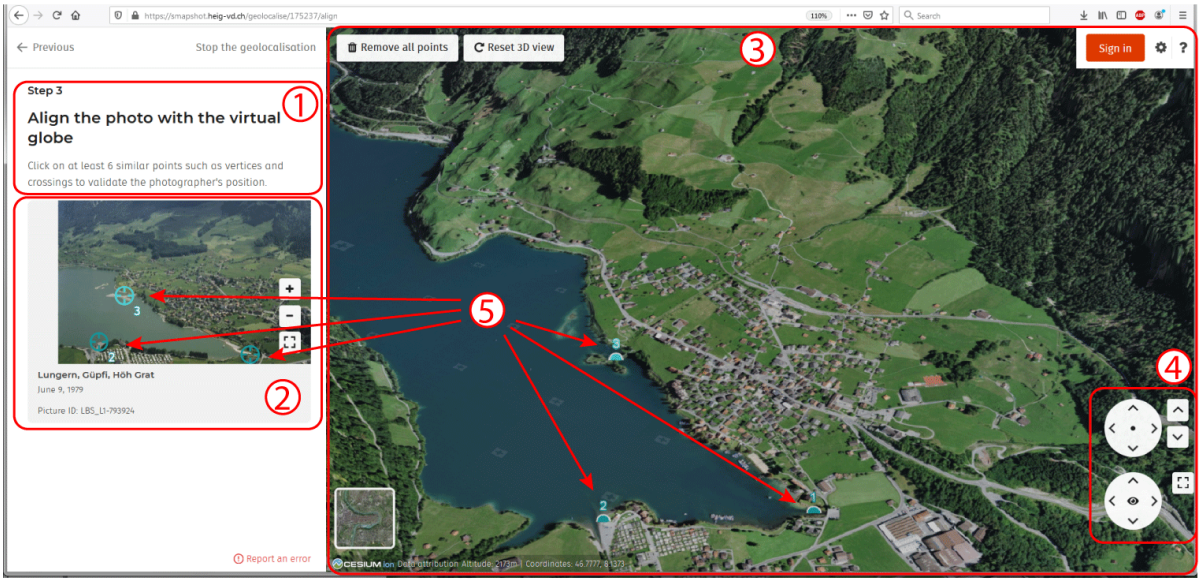

Figure 3: Screenshot of ongoing georeferencing within the sMapshot platform. The following elements are labelled: (1) brief instructions, (2) image to be aligned with corresponding metadata, (3) main window with 3D terrain model, (4) navigation panel, (5) visualized, already-aligned points.

WP 4: Analyse the potential for quantitative evaluation

The archived and geolocated images emerging from WPs 1–3 have great value, both as historic documents and as signs of change that are easily interpretable by the general public. The idea of this work package was however to additionally explore the images' potential for retrieving quantitative information about glacier changes. To explore this potential, three different approaches were attempted, unfortunately with little success.

The first approach relied on the "Monoplotting Tool" (MPT) developed at WSL (https://www.wsl.ch/en/services-and-products/software-websites-and-apps/wsl-monoplotting-tool.html). The tool was tested for a set of a few dozen of images but satisfactory results could only be obtained for individual images. The reason for this was the difficulty in georeferencing the individual images within the MPT, as the work needed to be repeated independently of WP3 (Figure 4a). The insufficient quality of the geolocation became particularly evident when reproducing any glacier outline digitized within the MPT (Figure 4b) on a topographic map or orthophoto (Figure 4c). In this case, in fact, clearly erroneous projections emerged. These unsatisfactory results let us eventually to abandon the idea of using the MPT for larger sets of images.

The second attempted was based on sMapshot directly. Here, the intention was to being able to digitize glacier outlines within the platform, and to then extract the corresponding coordinates from there. Discussions with the developers revealed that such a solution would be possible in principle but that the necessary developments were not feasible within the scope of the project. This forced us to abandon this solution too.

A final attempt was performed with "Photgeoref", a somewhat older research software originally developed at ETH Zurich and written in the programming language "IDL" (Corripio, 2004). Unfortunately, also this attempt provided unsuccessful. In this case, the necessity of providing the software with a viewshed (i.e. a map defining the field of view from the location of the photographer) proved to be the bottleneck as the information is (i) relatively laborious to obtain for a large set of points and (ii) the location of the photographer was not always known at that stage.

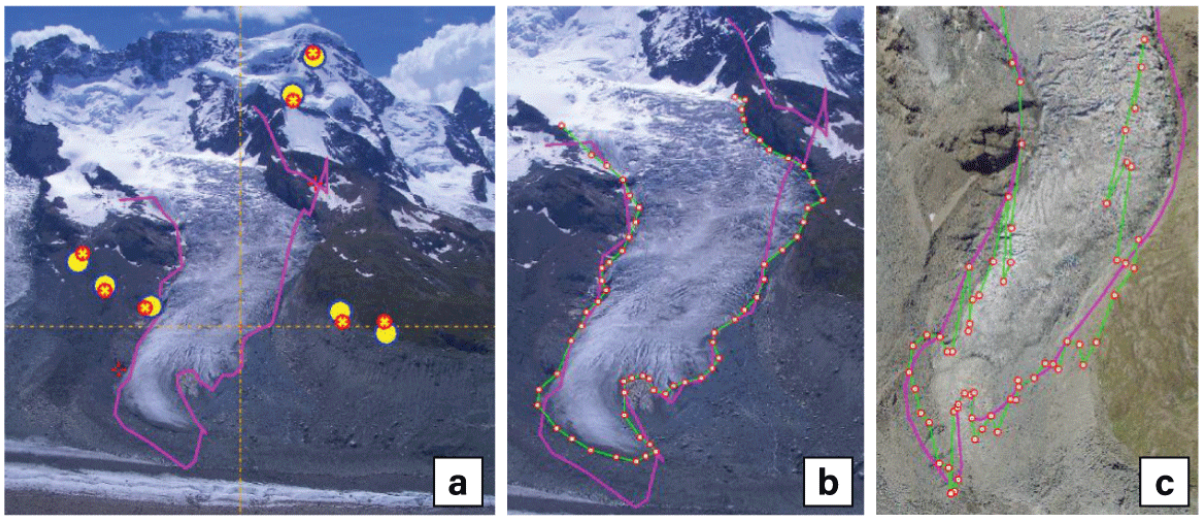

Figure 4: Visualization of the monoplotting procedure in WSL's Monoplotting Tool. (a) Manual georeferencing of individual, known positions (yellow and red markers) for a given, oblique image. (b) Manual digitization of the glacier outline (green outline with yellow markers). (c) Resulting projection on an orthophoto (Swissimage). The example refers to Breithorn, VS, and an image of 2005. The purple outline is an independent outline derived from a topographic map and used for cross-validation.

Combined, the above meant that the plan of utilizing the archived photographs in a quantitative fashion had to be abandoned, at least within the project lifetime. We remain confident that the information contained within the various images is of value and will become accessible at a later stage.

WP 5: Dissemination of results and outreach

The active promotion and dissemination of the project results was an important component of the project itself. Indeed, the recruiting of the volunteers necessary for the georeferencing performed in WP 3 relied on an active and interested community. The activities included, amongst other, the active participation in the frame of ETH's and University of Zurich's "Scientifica 2021" (https://scientifica.ch/impressionen/), a biannual science-communication event that took place on 04-05 September 2021. Here, a glaciology stand entitled "Can our glaciers still be saved?" (https://scientifica.ch/en/ausstellungen/sind-unsere-gletscher-noch-zu-retten/) did not only present the project as such but used the opportunity to inform about glacier research and glacier monitoring activities in general.

Even more active engagement happened through both social media and the conventional media, the project being able to capture significant attention (Figure 5). In this context, large interest was sparked by the repeat photographs which were generated by selectively repeating the most promising images acquired via WPs 1–3. These repeat acquisitions were conducted in the field with the help of various project members, and proved to be a significant but worthwhile investment.

Further outreach activities were initiated in the form of individual expositions or collaborations with artists, the results of these efforts being expected to bear fruit after the official termination of the project (see also Sec. 2.5 "Outlook").

Figure 5: Examples of outreach activities facilitated by glacier repeat photography. (left) Animated ".gif" posted on twitter by @VAW_glaciology (https://twitter.com/VAW_glaciology/status/1540205578835861507), and (right) the Japanese newspaper "Chugoku_Shimbun" picking up a similar repeat photograph on 04.09.2022.

WP 6: Operationalization of the procedures

The experience of the project partners shows that newly discovered, historic glacier photographs become available from time to time. From the start, the project's intention was thus to devise a set of procedures by which such newly emerging images can be taken up and preserved in the long term.

In this respect, the workflow given by the sequence of WPs 1 to 3 (i.e. triaging; scanning and preparation of metadata; importing into ETH's Image Archive; and batch-wise georeferencing) proved its value, and the intention is to continue similar activities in the context of the Glacier Monitoring Switzerland (GLAMOS) initiative. Indeed, a corresponding proposal has been put forward in the frame of the new GLAMOS financing period, which is due to run from 2024 to 2027. Here, the focus was put on the element of repeat photography as this proved to be the most valuable element in terms of both acquired information and communication potential.

2.3. Results

The project's main result is the extensive set of images that has been permanently archived in ETH's Image Archive. This set of almost 35,000 glacier images is probably unique, especially when it comes to the richness in its metadata (for an impression, see Figure 6). Indeed, we are unaware of any similar collection existing anywhere else.

We attribute similar value to the number of repeat photographs that have been acquired through the project (a selection is shown in Figure 7) – an impression that we gained through both the very positive feedback received for them and the number of requests related to them.

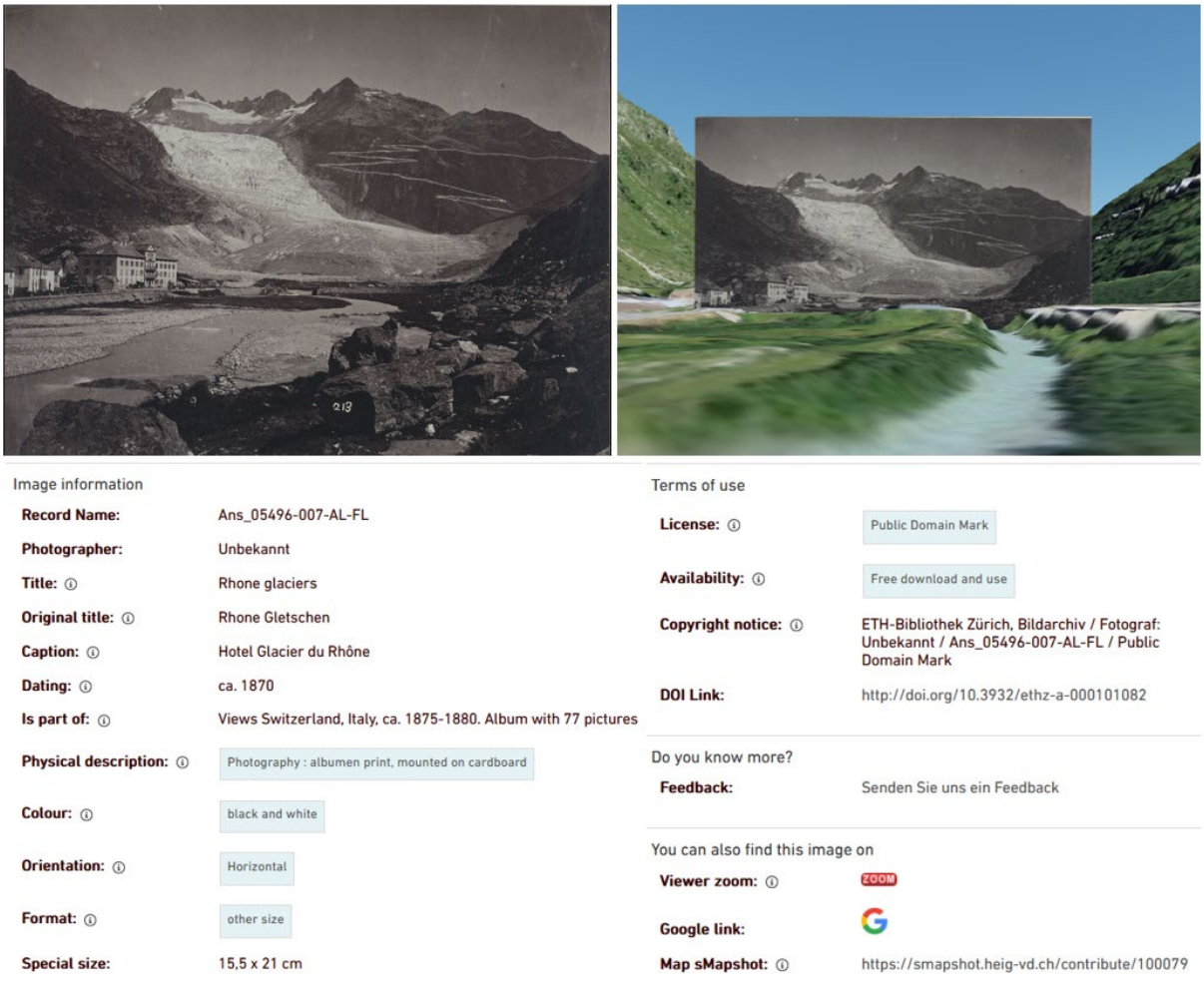

Figure 6: Example of an archived image. The original image (top left) is shown together with its metadata (bottom), and a visualization of the image embedded in the modern landscape (top right). The original figure and metadata are found at http://doi.org/10.3932/ethz-a-000101082. The visualization at top right is directly taken from the sMapshot platform: https://smapshot.heig-vd.ch/contribute/100079 (note that the link is given in the image's metadata).

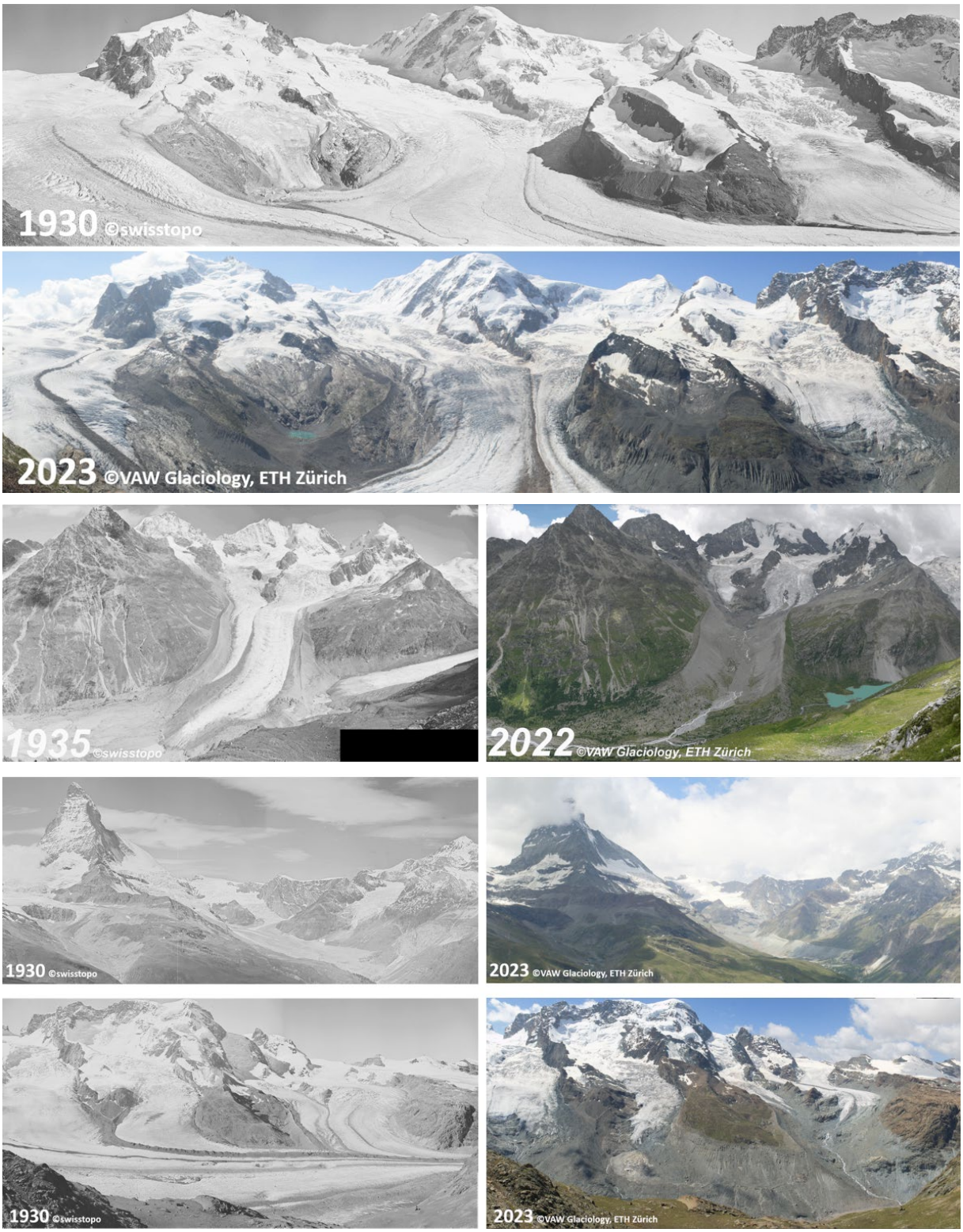

Figure 7: Examples of repeat photographs acquired during the course of the project. The changes are striking. From top to bottom, the examples refer to Gorner- and Grenzgletscher, VS (first two rows); Vadret da Tschierva e da Roseg, GR (third row); Zmuttgletscher, VS (second row from the bottom); Unterer Theodul- and Breithorngletscher, VS (last row). Images from the 1930s were acquired by swisstopo, in the frame of their "TerrA" survey (© swisstopo). Images from 2022/2023 were acquired in the frame of our project (© VAW Glaciology, ETH Zurich).

2.4. Conclusion and limitations

The project set out to secure that an invaluable source of information, such as are historic glacier photographs, can be preserved in the long term. This goal was achieved for a set of almost 35,000 images from various sources, which we rate as a success.

Of particular value proved to be the effort of repeating a selected set of these images with contemporary counterparts. Indeed, the emerging repeat photographs impressively illustrate the magnitude and speed at which a sensible part of our environment is evolving in response to climate change. Such visualizations have not only proven their value in the realm of scientific communication but also in the more ample dissemination of climate-related information to the broader public.

Most of the activities originally envisioned within the project could be completed successfully. This notably also includes the intention of georeferencing the individual photographs with the help of crowdsourcing, an approach that was not attempted so far by ETH/WSL's Glaciology group. In this respect, the collaboration amongst the project partners (ETH Library and HEIG-VD in particular) proved to be very fruitful.

The main limitations relate to (1) the attempt of using the archived images in a quantitative manner, (2) the volume of the available image materials, and (3) the difficulty in retrieving a complete set of meta data for all images.

The difficulties encountered with respect to point "(1)" have been discussed under "WP 4" in Section 2.2, and are thus not repeated here. For point "(2)", we are confident that the experience gained during the project and the envisioned continuation of the activities in a longer-term framework (see notes under "WP 6", again in Section 2.2) will allow for processing any of the remaining images with glaciological value at least in the medium term. For point "(3)", finally, it must be noted that certain limitations are virtually impossible to overcome. If a given image is not dated, or if the image's author is unknown, the effort that would be needed to reconstruct this information is often disproportionate. Similar goes for the possibility of reconstructing the location at which a given picture was taken: if the field of view is too narrow, i.e. if the image background does not feature sufficiently distinct topographic features as to allow for recognizing the surroundings, geolocating the image becomes virtually impossible. In such cases, we often preferred an incomplete set of metadata to a complete information loss so far, but this strategy can be questioned, especially if the activity is to be regularly continued in future.

2.5. Outreach work, publication of data and results

Engaging in outreach work was an integral part of the project's activities (see also "WP 5" in Section 2.2). This engagement entailed frequent communication over the twitter accounts @VAW_glaciology and @ETHBildarchiv, the dissemination of project results (especially the repeat photographs) over the media, the presence at science-divulgation events such as ETH and the University of Zurich's "Scientifica" (https://scientifica.ch/en/ausstellungen/sind-unsere-gletscher-noch-zu-retten/), or the engagement with artists and museums (see also Section 2.6).

For what the mediatic interest is concerned, the activities peaked in summer and fall 2022, when the first repeat images became available from the project and when it became clear that the year 2022 would be the worst on records in terms of glacier loss in Switzerland (the hydrological year ended with an unprecedented ~6% glacier volume loss; SCNAT, 2022). The

corresponding images have been used by a large number of national and international media outlets, with requests still reaching the project team on a regular basis.

In terms of publications, the project concentrated on a systematic and open release of the inventoried images. This happened via ETH's Image Archive "E-Pics" (https://ba.e-pics.ethz.ch) and by making use of a CC BY-SA 4.0 license (https://creativecommons.org/licenses/by-sa/4.0/). A peer-reviewed publication on the topic was not foreseen, and the possibility was further discarded in light of the difficulties encountered when trying to extract quantitative information from the images (cf. "WP 4" in Section 2.2, and Section 2.4).

2.6. Outlook

With climate change causing global mean temperatures to rise further, further glacier retreat is unavoidable. The interest in documenting and visualizing such changes will thus remain pressing. It is for this reason that the activities initiated with this project – notably including the selected, repeated photography of individual glaciers – will be continued also after the termination of the project. In particular, this will happen through the proposed embedding of the element "repeated glacier photography" in the GLAMOS activities for the period 2024-2027.

Similar continuation is anticipated for a set of outreach activities that have been initiated already. These include, among other, (i) the participation to the next "Scientifica", jointly organized by ETH Zurich and the University of Zurich between 28 August and 03 September 2023, (ii) a collaboration with the Musée Historique Lausanne, which should result in an exposition in 2024, and (iii) a further exhibition in ETH Zurich's Collections and Archives new exhibition space "extract" (https://extract.ethz.ch/en/exhibition.html), planned for summer 2025. We are confident that such activities will further increase the visibility and value of an already very successful project.

2.7. Acknowledgements

We would like to thank GCOS Switzerland for providing funding for this project. The support was instrumental to realize a project that has sparked much interest in the glaciological community and beyond. Special thanks go to the team of the ETH Library, notably including Caroline Ingold, Gina Meili, Barbara Giezendanner, and Flurina Huonder. Similar thanks go to the persons involved from ETH/WSL's Glaciology group, notably Guillem Carcanade, Leo Hösli, Lilian Turpin, Barthelemy Anhorn, Julien Cuzzocrea, Pia Neuburger, Kaja von Rotz, and others. Finally, we would like to thank the sMapshot team from HEIG-VD, without which help the project could not have been realized.

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