

GCOS Switzerland Project

Harnessing the Power of Crowdsourcing to tackle 21st century mountain observation challenges (POC21): User Need Assessment & Feasibility Study

FINAL REPORT

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1 Summary

As captured by the recent Call for Action of the World Meteorological Organization (WMO High-Mountain Summit 2019), addressing high-mountain challenges requires the provision of actionable information on Alpine changes. Swiss national monitoring programmes for glaciers and permafrost, GLAMOS and PERMOS, play a fundamental role in the provision of this information, however often lack sufficient real-time in-situ information to develop timely monitoring products.

This feasibility study is about exploring the potential of modern observation methods to fill this information gap, and in particular evaluating the power of crowdsourcing for long-term mountain monitoring. To this end, MountainNow – a collaborative platform for sharing mountain observations in real-time – is built upon to provide both GLAMOS and PERMOS with a set of representative crowdsourced observations featuring for instance the position of glacier snouts or of rock-falls from permafrost areas.

This is made possible by enhancing national collaboration between the public and private sectors, building on existing infrastructure and technology, and putting together a strong multidisciplinary consortium with in-depth experience in the science, technology, communication, and policy components of mountain monitoring.

Key outcomes and activities include: Tasks were successfully fulfilled following the proposal plan – without any deviation. First, a detailed analysis of user requirements was performed, focusing on the potential of real-time crowdsourced observations to document the state and changes of glaciers and permafrost in the Swiss Alps. Second, pilot digital platforms building on the latest technology were developed to collect and analyse crowdsourced observations and meet these requirements. Third, an observation campaign – including diverse outreach – was launched to collect representative crowdsourced observations and enable a significant evaluation by GLAMOS and PERMOS of the collected data. Fourth, relevance and added-value of these crowdsourced observations were evaluated by GLAMOS and PERMOS, leading to a recommendation for a follow-on phase 2 project.

The project drew interest from research institutions beyond Switzerland (France and Italy) and received communication support from a major Swiss commercial sports brand (Baechli Bergsport), as well as from a world-famous mountain athlete (Kilian Jornet Foundation).

Project milestones and deliverables contributed directly to the implementation of the GCOS Switzerland Strategy 2017-2026 as well as of GEOSS (Global Earth Observation System of Systems), also helping to address mountain-related challenges of the Sustainable Development Goals (SDGs).

Importantly also, the project responded to the recent WMO Call for Action to contribute to “an Integrated High-mountain Observation, Prediction and Services Initiative with user-centred goals, building on existing knowledge and activities, with international coordination and multidisciplinary approaches”.

2 Scientific Report

2.1 Introduction

In recent decades, a general decline in glaciers, permafrost, and snow-cover has been observed (Huss et al. 2017; Beniston et al. 2018; Biskaborn et al. 2019; IPCC SROCC 2019, PERMOS 2021) – increasing the probability of natural hazards and affecting high-mountain infrastructure as well as local/downstream agriculture, forestry, hydropower production, and domestic water supply. Adaptation to these changes requires sound knowledge and baseline data while posing new observation challenges to the high-mountain Earth system – of which Swiss mountains are an integral part.

One rising approach to address these challenges, and get fit-for-purpose in-situ data, is to involve citizens in data collection (Haklay 2015; Flanagan and Metzger 2008; ETH-UZH Citizen Science Centre initiative 2018).

In line with these drivers, the present project aims to evaluate the power of crowdsourcing for mountain monitoring building on key assets, including: MountaiNow, a crowdsourcing platform with a proven track-record for providing fit-for-purpose mountain data; ExoLabs, advanced products based on near real-time satellite data processing; and the Swiss monitoring networks GLAMOS and PERMOS, authoritative observations and data/information on glaciers and permafrost together with expertise in applicability and policy applications (see brief description below). Further assets relate to communication resources from project partners’ networks (e.g. ETH, Universities, citizen associations, Alpine Clubs).

The present project primarily addresses Pillar 2 (“Promote collaboration nationally, regionally, and globally”) and Pillar 3 (“Ensure applicability of Swiss GCOS data and products”) of the GCOS Switzerland Strategy 2017–2026, and in particular Priority 2.1 “Enhance collaboration at national level: make better use of existing infrastructure and identify new partner institutions” and Priority 3.1 “Ensure that requirements of the Swiss science community, policy makers, and the public are taken into account”.

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Brief Description of the Project Partners

MountaiNow is a collaborative platform for sharing mountain observations in real-time. Designed for use by the public, MountaiNow offers a live map of the latest mountain conditions and hazards (e.g. crevasses, rock falls) – to improve mountain safety and better adapt to climate change. The App (see Fig.1) is live on PlayStore, AppStore and the website on www.mountainnow.net

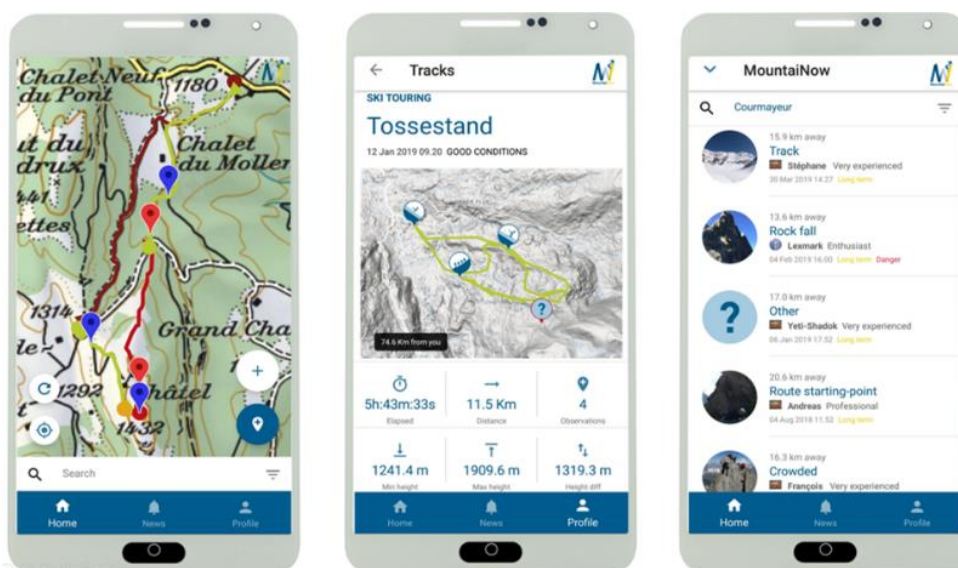


Fig. 1: Screenshot examples from the MountaiNow App

MountaiNow Facts

- Fast growth since 2017: over 20'000 users and tracks/observations shared on the platform
- Proof of technology: MountaiNow was successfully used worldwide e.g. in Europe, Himalaya
- User feedback that MountaiNow is unique and truly useful – meeting a growing need in a climate change context (SAC 2019, RTS 2019)
- Authoritative organizations have been working with MountaiNow since its creation, e.g. Alpine Clubs and Safety-, Mapping-, and Tourism-bodies
- The mobile app and webapp are available free of charge in German, French, Italian, and English

GLAMOS (Swiss Glacier Monitoring Network) is responsible for maintaining measurement series of glaciers in the Swiss Alps, evaluating and archiving the data, and making them available to both the scientific community and the public. Data acquired in the frame of GLAMOS are stored in a database and documented metadata are available for the more recent measurements.

PERMOS (Swiss Permafrost Monitoring Network) on its end is responsible for documenting the state and changes of mountain permafrost in the Swiss Alps – focusing on in-situ observations of ground temperatures, changes in ice content, and rock-glacier creep velocities. PERMOS also documents special events originating from permafrost areas and maintains a rockfall database together with the WSL Institute for Snow and Avalanche Research SLF.

ExoLabs is a start-up from the University of Zurich producing tailored software solutions, data products and scientific know-how in the field of environmental monitoring. Products are based on geospatial and remote sensing data to support the private and public sector in gaining insight and efficiency at reducing costs. Within the POC21 project, ExoLabs provides maps on snow coverage and snow depth based on satellite images, ground observations, and weather model outputs.

2.2 Methods and Activities

The main method used in this project is “crowdsourcing” or “citizen science”. Aimed at involving citizens in data collection (Haklay 2015; Flanagin and Metzger 2008; ETH-UZH Citizen Science Centre initiative 2018), citizen science builds on strong quality controls and collaboration between scientists and the public to collectively solve real world problems (Bonney 2009). The public or “citizen scientists” use their own portable devices (e.g. smartphones, laptops) to “crowdsource” – i.e. to observe, collect, report and exchange vital data to complement existing environmental monitoring systems.

As part of the project and as planned in the proposal, the following activities were successfully completed:

- (i) GLAMOS and PERMOS Offices performed an analysis of user requirements, focusing on the potential of real-time crowdsourced information to document the state of glaciers and permafrost in the Swiss Alps. One important conclusion is that: “In general, there is a lack in real-time observations at a wide spatial scale. Operational measurements in the framework of the monitoring programmes are obtained for a few selected variables at a limited number of landforms or sites, where long time series (> 10y) are measured. Crowd-sourcing has the potential to fill in for additional variables, more timely observations, as well as broad geographical coverage“.
- (ii) The four project partners devised crowdsourcing solutions to fill the above-mentioned observation gaps. Solutions were then translated into technical specifications for the MountaiNow mobile App and related extensions to the MountaiNow Core-System. Priorities were set according to the feasibility study objectives and related budget.

As part of the enhancements made to the MountaiNow app and core-system, two quality-control methods were integrated: (i) Moderation from Admin: Members of MountaiNow, ExoLabs, GLAMOS, and PERMOS (aka Admin) checking new observations as they come in, also responding to flags

from users (see next point); and (ii) Moderation from users: users having the option to “flag” inappropriate content as they consult observations on the MountainNow’s live map.

- (iii) An [observation campaign](#) (see Fig. 2) was launched in early summer 2021 to collect representative crowdsourced glacier/permafrost observations. The campaign focused on the following observation types: Landscape; Rock fall; Glacier melt; Snow depth; Seracs/Ice avalanche; Glacial lake; and on the following target regions: Aletsch, Morteratsch/Diavolezza, Orny/Trient, and Zinal; the dual objective being to collect representative crowdsourced observations and enable a significant evaluation by GLAMOS and PERMOS.



Fig. 2: Poster presenting the summer observation campaign

To encourage participation in the campaign, targeted communication plans were developed and implemented – building on various communication channels (see Section 2.5).

The observation campaign and related communication activities continued throughout the summer and came to an end on 30 September 2021. Following this, GLAMOS and PERMOS proceeded with the evaluation of the collected data – testing in particular the relevance and added-value of the crowdsourced observations to their information production-chain.

Crowdsourced information was first quality-controlled, and then qualitatively and quantitatively considered for integration into the GLAMOS/PERMOS databases. Usability and potential for long-term monitoring in remote high Alpine areas was also evaluated.

2.3 Results

GLAMOS and PERMOS identified a number of observation gaps with a potential for crowd-sourcing, including on glaciers (e.g. mass balance stakes, snow probing, glacier hazards); and on permafrost (e.g. rock falls, rock glaciers photography, snow distribution patterns on permafrost slopes).

Building on these descriptions, adjustments were made to the MountainNow App with a view to enable the collection of glacier/permafrost observations (see Fig. 3).

These include:

- New observation icons: Glacier melt, Snow depth, Glacial lake, Landscape
- New map layers such as ExoLabs snowdepth and the OFEV potential permafrost distribution
- In-app tutorials, also available off-line, giving tips on how to make a useful observation

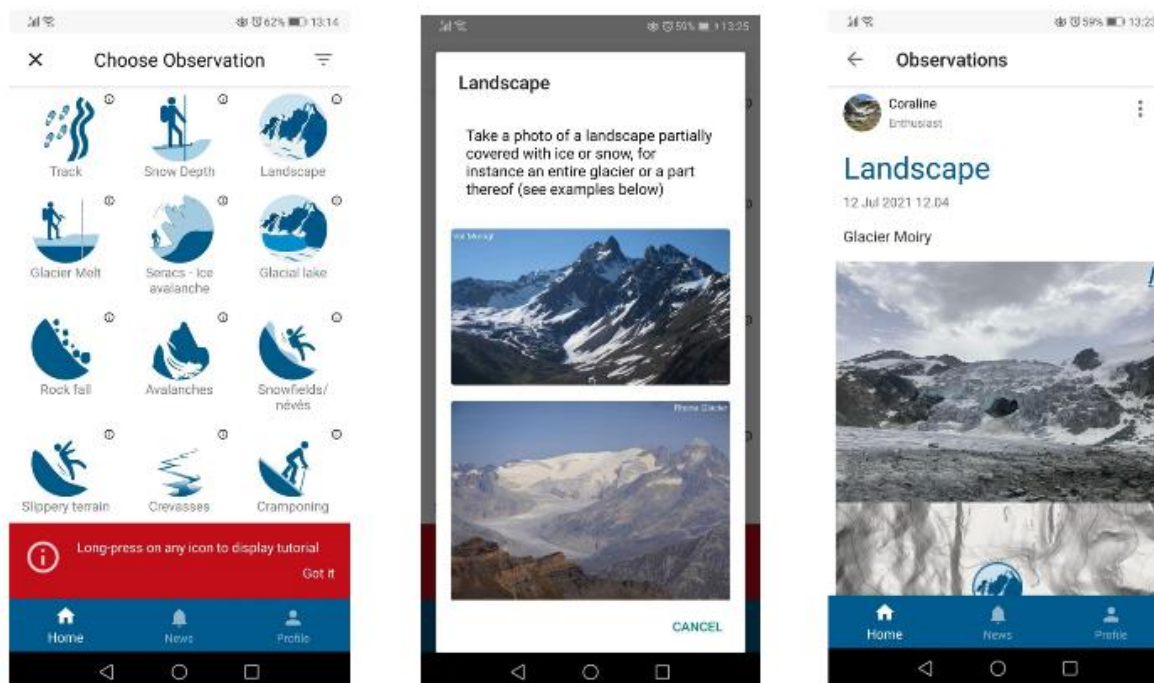


Fig. 3: Examples of adjustments made to the MountainNow App: (left) icons; (center) tutorials, (right) observation outlook

With regard to the MountainNow Core-System, extensions were implemented with a view to enable GLAMOS and PERMOS to easily access the collected glacier/permafrost observations. These include a demonstration dashboard featuring trailblazing pilot functionalities and showcasing the potential for quick and efficient analysis of crowdsourced observations (see Fig. 4).



Fig. 4: MountainNow dashboard enabling quick analysis of crowdsourced observations

The dashboard builds on, and offers interoperability with, the operational cloud-based geo-service Rheticus (rheticus.eu) as well as on a tailored Graphical User Interface (GUI) enabling fast and easy consultation/analysis of data. Pilot features include: (i) filters; (ii) quality control checks; (iii) overlay of ExoLabs snow layers, the OFEV potential permafrost distribution [map](#) and the permafrost and ground ice map (PGIM) developed by SLF (Kenner et al. 2019), and (iv) download of observation data.

As planned in the proposal, enhancements to the MountainNow platform (mobile App and Core System) were fully functional by May 2021, ready for the start of the summer observation campaign.

The observation campaign enabled the collection of observations providing valuable insights on how to strengthen crowdsourcing for cryosphere observation in the future. Between 1 April 2021 and 30 September 2021, a total of 138 observations relating to variables of potential interest to GLAMOS and PERMOS were collected. Many of these observations were accompanied by photos, see examples in Figures 5, 6, and 7.



Fig. 5: Observation examples for the (left) “snow depth” variable: snow probe on Glacier du Tsanfleuron; and (right) “glacier melt” variable: ablation stake on Silvrettagletscher

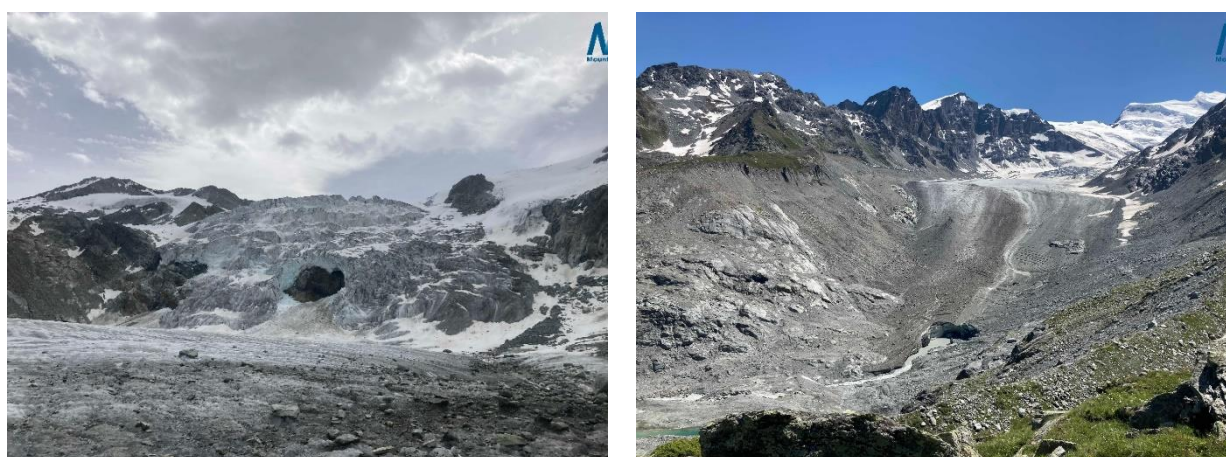


Fig. 6: Observation examples for the “landscape” variable: (left) state of glacier front at Glacier de Moiry; and (right) glacier snout of Glacier de Corbassière



Fig. 7: Observation examples for the (left) “rock fall” variable at Gran Cornier; and (right) “seracs/ice avalanche” variable at Wellenkuppe

The total number of collected observations remained relatively limited. Two reasons for this may be put forward:

First, communication resources – commensurate with a feasibility study – proved insufficient to efficiently reach large numbers of mountain goers and related communities (e.g. associations, Alpine Clubs, hut keepers, mountain guides) and maintain continuous participation throughout the whole summer. In other words, the experience of the observation campaign shows that targeted communication material and sustained communication activities are required to generate large numbers of observations and spread the word on the unique opportunity to collect real-time high-mountain observations via crowdsourcing.

Second, weather was notoriously wet over the period of the observation campaign. As reported by MeteoSwiss (MeteoSwiss-Blog 2021), summer 2021 was the fifth wettest on average in the northern Alps since measurements began. Moreover in central Alps, summer was locally the wettest ever measured. As a result, many mountaineering activities were cancelled and opportunities for crowdsourcing observations reduced.

With regard to observations collected over the campaign, two main types may be distinguished: (1) Quantitative observations (e.g. snow depth, glacier melt) that can directly be transformed to be used in monitoring products; and (2) Qualitative observations (e.g., landscape images, text descriptions) that can provide valuable information on the state of glaciers and permafrost but cannot be integrated into long- or short-term monitoring measurement data sets as such.

Whereas about 10% of the collected data were quantitative, most of the contributions relevant to GLAMOS or PERMOS were qualitative. Of the 10% of quantitative contributions, most were actually directly observed by members of the monitoring programmes in the frame of testing the MountainNow App. This does not come as a surprise considering that the collection of hard/measurement data is more difficult and requires some knowledge; also for some variables, some gear is required (snow probe). Therefore, the typical mountaineer with no direct relation to scientific data collection typically contributes qualitative observations.

Overall, about one third of the collected observations could be rated as “good” and exploitable for cryosphere monitoring. This is a promising result considering that MountainNow users also use the “Landscape” variable to report on low-mountains (about 45% of the “landscape” photos were not related to high-mountains).

Nearly all exploitable landscape photos show glaciers as their main theme. Considering the visibility and, hence public awareness of glaciers compared to permafrost, this is not surprising. There was no photo showing permafrost landforms (i.e., rock glaciers) or observations of permafrost ice. However, since glaciers and permafrost occur in the same areas, permafrost-related features were also visible in many photos.

2.4 Conclusions and limitations

Throughout the project, Work Packages and related Tasks were successfully fulfilled, following the proposal plan without any deviation. In particular: identifying key observation gaps, delivering pilot platforms for collecting/analysing observations to fill these gaps, organizing a limited-area observation campaign in Switzerland, and collecting representative crowdsourced observations to enable a significant evaluation by GLAMOS and PERMOS of the collected data.

The outcome of the evaluation indicates that crowdsourcing potential for supporting glacier and permafrost observation in the context of GLAMOS and PERMOS is considerable. However, this potential can only be fully realized if (i) a critical mass of observations is collected every year including several hundreds of quantitative observations, and (ii) methodology like geo-referencing is mainstreamed to automatize the exploitation of qualitative observations. This conclusion leads to the recommendation to develop and implement a follow-on project phase 2 addressing the above requirements – paving the way for crowdsourcing to become an integral part of a modern monitoring network.

The project also demonstrates great interest in the topic of crowdsourcing for cryosphere monitoring. The feasibility study received support from research institutions beyond Switzerland (France and Italy), a major Swiss commercial sports brand (Baechli Bergsport), and a world-famous mountain athlete (Kilian Jornet Foundation).

Main limitations relate to the collection of (1) quantitative observations and (2) direct permafrost observations, and (3) to the conversion of qualitative observations into data:

- (1) Most of the observations crowdsourced over the summer were qualitative (rather than quantitative). This is to be expected considering that the collection of hard/measurement data is more difficult and requires some knowledge and, for some variables, also some gear (snow probe). Therefore, the typical mountaineer with no direct relation to scientific data collection tends to contribute qualitative observations. Development and dissemination of user-friendly tutorials explaining how to quickly proceed with measurement and why this is important to science and society as a whole could help overcome this limitation.
- (2) Permafrost is a sub-surface phenomenon and thus invisible to the eye, its typical occurrence and landforms are less known than glaciers. Also rock-falls originating from permafrost slopes (and having a volume >1000 m³), which are documented in the framework of PERMOS, are also not frequently observed. This makes permafrost observation more difficult to perform for the public. Again, user-friendly tutorials providing guidelines on permafrost landforms/sites and the kind of information to contribute could be very helpful in encouraging permafrost observations.
- (3) Qualitative observations can be highly valuable as they contain a lot of information that can be extracted (e.g., state of snow cover, type and date of glacier or rock-fall hazard events). However, at present, converting these observations into data that can support time series of relevant variables is often difficult and time-consuming. One approach for overcoming these obstacles could be geo-referencing.

2.5 Outreach work, publication of data and results

Numerous communication activities were carried out during the project by partners, including:

- (i) 4 [landing pages](#) – describing in detail how to best contribute to the observation campaign – were developed in German, French, Italian, and English, and published on the MountainNow website and social media accounts
- (ii) 6 video tutorials – showcasing key MountainNow functionalities (e.g. “how to add an observation”) were completed and made available on the website
- (iii) 45+ newsletters and blog articles were shared with the MountainNow community
- (iv) 125+ news were posted on social networks (Facebook, Instagram, Twitter, LinkedIn) together with dedicated advertising campaigns on Facebook and Instagram
- (v) Articles about the POC21 project were published in the Swiss Alpine Club official magazine (150'000+ copies), Swiss Alpine Club Diablerets magazine and newsletters (3000+ copies)
- (vi) Presentations were made as part of public events, e.g. “Traces du Climat”, 4 July 2021
- (vii) New partnerships were developed with two major groups who decided to get engaged and encourage participation in the observation campaign: [Baechli Bergsport](#) featuring blog articles and various online announcements to their customers across Switzerland; and the [Kilian Jornet Foundation](#) sharing posts on their social media accounts with their 25'000+ worldwide followers.

These communication activities helped raise awareness of the POC21 project, climate observations, and GCOS Switzerland. Drawing conclusions from the observation campaign as well as from the evaluation work of GLAMOS and PERMOS did, and will continue to, represent opportunities to communicate broadly on long-term cryosphere observations in the Swiss Alps and beyond.

Data collected within the scope of the project and observation campaign in particular (e.g. crowdsourced photos) are available free of charge to any research institution, nationally or internationally. Requests to access this data should be made to info@mountainow.net

2.6 Outlook

MountainNow is a 360-day live platform and as such will continue to collect crowdsourced observations relevant to cryosphere monitoring beyond the end of the project. With regard to the integration of these observations into national databases and crowdsourcing becoming an integral part of the cryosphere monitoring network, GLAMOS and PERMOS recommend that a follow-on project phase 2 be implemented (see Section 2.4).

2.7 Acknowledgement

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