WP23_25: Global Network for Observations and Information in Mountain Environments

1242,245

Basic Information

Full title of the Initiative

Global Network for Observations and Information in Mountain Environments

Short Title or Acronym

GEO Mountains

Current category in the 2020-2022 GWP

GEO Initiative

Proposed category in the 2023-2025 GWP

GEO Initiative

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Purpose

Objective

To increase the discoverability, accessibility, and usability of a wide range of data and information pertaining to mountains globally, and to apply these data to have positive impacts across key areas of science, policy, and practice.

Please provide a short description of the Initiative

GEO Mountains is a global network that brings together the providers and users of data and information on the world's mountain regions. It considers mountains as complex social-ecological systems, and therefore takes a highly interdisciplinary approach that integrates multiple thematic areas. A main objective is seeking to compile and hence ease access to existing mountain data and information resources (in situ, remotely sensed, and modelled), which it achieves on an ongoing basis via the curation and provision of inventories to the community. GEO Mountains also seeks to contribute to wider debates and actions around mountain monitoring and data generation (e.g. the concept of Mountain Observatories and Essential Variables applicable to mountains); the identification of key data gaps (including via the consultation of data users); the organization of sessions at

scientific conferences, meetings, thematic workshops and other fora; activities that can translate data into knowledge (e.g. hackathons); and training / capacity building events. It also engages extensively with regional or thematic initiatives and networks that have overlapping objectives. The initiative is underpinned by strong Open Data and Open Science principles, and was requested to contribute to the IPCC AR6 process. Launched as an activity of the GEO Work Programme in 2016, the Initiative is co-led by the Mountain Research Initiative (MRI) and the National Research Council of Italy (CNR). Outputs of the Initiative have increased substantially since 2020, when funding from the Swiss Agency for Development and Coordination enabled a dedicated Scientific Project Officer to be employed in support of the co-leads and wider network. GEO Mountains has a dedicated website (www.geomountains.org).

Why is this Initiative needed?

Mountains host complex social-ecological systems that provide numerous important goods and services to wider human populations and societies. They are also considered "hotspots" of global change (including climate and biodiversity change), and so understanding and predicting how these systems will evolve is crucial to adapt to changes / mitigate risks with a view towards sustainable mountain development. However, for various reasons, the components of mountain systems are difficult both to observe comprehensively using in situ and remote techniques and to model. Those observational datasets that do exist are typically extremely "scattered" (e.g. obtained by a very large number of different organizations) and/or non- comparable/standardised. A global, interdisciplinary network is therefore required to bring together the data and information resources generated by more regional/thematic efforts, and provide "thought leadership" and evidence that can be applied in practice with respect to monitoring and data (e.g. helping to set priorities, protocols, and data gaps), and to provide a coherent mountain voice, informed by evidence, in global assessments and policy processes.

What evidence is there to support this need?

Over the last few years, we have engaged extensively with the user communities of data and resources in several different mountain regions. These consultations have demonstrated that, whilst some excellent progress has been / is being made, key data gaps or challenges (e.g. data sharing) remain that impinge upon an integrated approach to the application of relevant data and information to address knowledge needs. By compiling our inventories and analyzing existing datasets more generally, we have also developed an appreciation of – and in some cases more quantitative evidence for – deficiencies in the coverage of mountain data. This includes by variable (e.g. current remote monitoring approaches do not allow us to obtain spatially distributed data on Snow Water Equivalent or permafrost extent), as well as by region, elevation, and time period (see e.g. Thornton et al., Frontiers in Climate with respect to in situ climatological observations).

Is this Initiative open to participation by representatives of any GEO Member, Participating Organization, and GEO Associate?

Yes

Are you aware of other projects or initiatives at a global or regional scale (both in GEO and externally) that provide similar products or services?

Yes

Please describe.

Several other networks or initiatives exist, including ICIMOD, CONDESAN, the GMBA, the iLTER, GLORIA, and MIREN. However, many of these efforts are either region-specific or cover only some specific themes or components of mountain social-ecological systems. Many of GEO Mountains' members also belong to one or more of these networks / initiatives. In some cases, these efforts also have their own data portals or other tools via which associated resources and information can be accessed, e.g. the ICIMOD Regional Database System (RDS: https://rds.icimod.org/), the iLTER's DEIMS-SRD (https://deims.org/), the GMBA's Mountain Portal, although others do not currently.

How is this Initiative unique?

When it comes to data and information, the aforementioned networks or initiatives generally have a much more constrained focus than GEO Mountains, be that regionally, thematically, or both – and in some cases

place less explicit emphasis on fundamental “upstream” considerations like data availability and usability. In this sense, GEO Mountains can be considered unique in its integration of multiple disciplines (including the interactions and feedbacks between them) spanning both biophysical and social-economic aspects on a global scale, and also covering different time horizons, from the past to the future. In taking such a perspective, GEO Mountains is uniquely placed to respond to growing calls / the realization that mountains should be considered as complex systems by providing a convening platform for integration and collaboration, given that highly inter- and/or transdisciplinary approaches are required to tackle key societal questions (e.g. around climate change impacts on water, biodiversity, and natural hazards, population pressured on mountain regions, agriculture, energy, etc.). At a fundamental level, our interdisciplinary inventories (https://www.geomountains.org/resources/resources- surveys/general-inventory; https://www.geomountains.org/resources/resources-surveys/inventory-of-in-situ-observational-infrastructure) seek to make it easier for data users to identify existing datasets (from a range of disciplines) in a given study region as a basis for such work. This is achieved primarily by providing easily searchable / filterable web links to external resources. In the case of our in situ inventory, we also provide an interactive web mapping tool.

Thanks in part to the MRI's own established networks and relationships with key organizations such as the WMO, UNEP, and UNESCO, we are also unique in being able to "straddle" both the research and policy-oriented communities dealing with questions around how changes in mountain systems affect the environment and people effectively, i.e. taking an integrated systems approach to such questions. For instance, we have recently helped relaunch UNESCO's World Network of Mountain Biosphere Reserves, and sit as a co-convenor of the eLTER Expert Group on Mountains. GEO Mountains is able to benefit from the MRI's regular and high-quality outreach and communication activities (e.g. with a dedicated GEO Mountain segment in the MRI's Monthly Newsletter, as well as a member mailing list), and deliver inputs on mountains into broader discussions at GEO (including the various Working Groups in which we are represented, and at the GEO Symposiums and Plenary sessions).

Please identify the most important actual and/or intended outputs (products, services, etc.) produced by the Initiative, along with their intended and/or actual users. This list does not need to be comprehensive but should identify the outputs which are most used and are expected to have the greatest potential impact.

Output	Status	Users	Additional info
The GEO Mountains In Situ Inventory	Occasionally updated	Predominantly researchers and practitioners	https://www.geomountains.org/resources/resources-surveys/inventory-of-in-situ-observational-infrastructure
The GEO Mountain General Inventory	Occasionally updated	Predominantly researchers and practitioners	https://www.geomountains.org/resources/resources-surveys/general-inventory
GEO Mountains' Knowledge Package on Human Populations in Mountains	Available but not updated	Predominantly researchers and practitioners, but may also be relevant for policy-makers	https://gkhub.earthobservations.org/search?q=GEO%20Mountains&f=geo_work_programme_activity%3Ageo-activities-geo-mountains&l=list&p=1&s=10&sort=bestmatch
GEO Mountains' Compilation of Training / Capacity Development Materials	Regularly updated	Students / Educators / Researchers / Practitioners / Decision Makers	https://www.geomountains.org/resources/training-capacity-development; We will add resources we will develop ourselves through our Implementation Plan

			going forward
Toward a definition of Essential Mountain Climate Variables	Available but not updated	Researchers, policy-makers, pracitioners	https://www.sciencedirect.com/science/article/pii/S2590332221002487
Coverage of in situ climatological observations in the world's mountains	Available but not updated	Authorities / organisations responsible for in situ climate monitoring (national, regional, international)	https://www.frontiersin.org/articles/10.3389/fclim.2022.814181/full
GEO Mountains Regional Data Consultations Report	In development	Data providers and users in selected regions, researchers, policy-makers, practitioners	Workshop summaries can be accessed via: https://www.geomountains.org/implementation-plan-get-involved/surveys
Policy brief: State of observations and information in mountain environments (exact title tbc). This policy brief is a contribution to the observance of the International Year of Sustainable Mountain Development 2022, proclaimed by the UNGA in December 2021.	In development	Policy-makers, donors, authorities / organisations responsible for supporting or developing monitoring campaigns	Expected by GEO Plenary 2022
GEO Mountains Website (as a service to the community)	Regularly updated	Network community and general public	www.geomountains.org

If needed, please provide additional comments or explanation to accompany the outputs table

Several of the Tasks listed under the "Technical Synopsis" section of this form will likely result in additional important outputs or products. Furthermore, we also have the capability to seek input and contributions from members of our network on behalf of other organizations (e.g. FAO Taskforce for the Review of the SDG Indicator 15.4.2 – Mountain Green Cover Index; currently in progress).

What kinds of decisions are the outputs of this Initiative primarily intended to support?

The Initiative seeks to support a wide range of various decisions across diverse spatial scales and stakeholder groups. These include decisions around where to prioritise our monitoring efforts (e.g. which variables to focus on, where investments in station installation and maintenance are required, etc.), how to overcome (sometimes sensitive) existing barriers to more extensive data sharing, and helping to inform decisions required in the context of the development of novel data and associated research agendas (e.g. in relation to UNESCO's Man and Biosphere World Network of Mountain Biosphere Reserves). In addition, the Initiative seeks to help contribute data and foundational support for global assessment exercises such as those of the IPCC, which in turn inform policy decisions.

How will these decisions benefit from the outputs of this Initiative?

These decisions will be supported and substantiated, as far as possible, by rendering relevant data and evidence findable, open, and accessible. More specifically, data, calculations / computations, and inferred knowledge / conclusions will be presented in an open, transparent, and reproducible fashion, with uncertainties quantified, to the greatest extent possible. It is important that data and information to be used in

decision-making contexts possesses these attributes, since decision makers increasingly demand them.

What kinds of impacts (for example, reduced loss of life, monetary savings, conservation of biodiversity, etc.) are anticipated as a result of the use of the outputs of this Initiative?

The appropriate use of the Initiative's outputs is expected to support sustainable mountain development. This includes, inter alia, healthy and well-functioning hydrological and ecological systems (including conservation of biodiversity), effective mitigation of mountain natural hazards (e.g. avalanches, floods, landslides, debris flows, drought), effective adaptation to and mitigation of adverse impacts of climate change, in support for human livelihoods and societies (e.g. sustainable agriculture and tourism). We plan to develop a “success stories” section of our website to communicate examples of data and information being applied in the value chain (use cases), even if some of these applications (e.g. research activities) will themselves require further work or uptake by others before they are translated into the kind of ultimate impacts listed above.

Has this Initiative been asked to provide specific information (for example, reports, data, services) on an ongoing basis to an international convention, organization, or other multilateral body?

Yes

Please identify the requesting organization.

The Intergovernmental Panel on Climate Change (IPCC)

Describe the nature of the request.

GEO Mountains was requested to contribute the analytical skills, knowledge of data resources, and more general expertise of members of the network to provide transparent and defensible estimates of the number of people living in and near mountain areas, which were reported in the Cross Chapter Paper "Mountains" (recently published as part for of the WGII contribution to AR6). Further requests of this nature are expected during the course of the AR7 cycle.

Please provide supporting documentation of the request.

- ipcc_ar6_wgii_crosschapterpaper5.pdf (link)
- ipcc_ar6_wgii_crosschapterpaper5_supplementarymaterial.pdf (link)

Technical Synopsis

Please provide a brief description of the methods used by the Initiative to produce its (actual or planned) outputs.

GEO Mountains applies, and will continue to apply, a variety of methods to generate its outputs. Firstly, we will continue to conduct technical tasks to update and improve our data inventories. This will likely involve developing improved front-ends / user experiences, as well as working to make ensure that the dataset metadata is programmatically-discoverable (e.g. following Science on Schema.Org guidelines). We will also conduct a variety of iterative consultative activities (surveys, online discussions, conference sessions etc.) to receive inputs from network members on key data gaps / barriers, key research questions that GEO Mountains could help address, key data and information required for policy and assessment exercises, and whether the resources provided to date generally meet the needs of the user community. Such consultative activities are particularly important to provide focus, given the vast possible scope of the Initiative. More practically, we will attempt to mobilise resources (financial/time/expertise) to implement new ideas with regards to fundamental monitoring of mountain systems (e.g. further the concept of "Mountain Observatories", and launch the Unified High Elevation Observing Platform, UHOP). We will also seek to conduct projects to digitize or otherwise “rescue” mountain datasets, and make them freely available. Meanwhile, capacity-sharing activities and generating knowledge insights from the datasets compiled by the Initiative (including dataset intercomparison exercises) will likely take the form of regional "hackathons", whereby various stakeholders are brought together

over a period of a few days to work collaboratively on a given topic. During these events, and elsewhere in our programme, we will seek to exploit the capabilities of the latest Machine Learning (ML) and other data-driven algorithms to gain insights from large and complex datasets. Co-funding for these events will be provided by GEO Mountains. We will continue to hold bi-annual General Meetings as well as other ad-hoc meetings as needed, to which all participants are welcome. We will continue to propose and host sessions focusing on relevant themes at scientific conferences. We will also continue to remain alert to third parting funding opportunities that fit with our objectives. We may seek to nominate a series of regional representatives or focal points, to increase and drive regional engagement. We will continue to work as closely as possible, and share and distribute tasks where applicable, with partner organizations both within and beyond GEO (e.g. WMO, UNEP, eLTER, WNMRBs, GEO BON, GEO Human Planet, CONDESAN, ICIMOD, GMBA etc). We particularly welcome the growing involvement of private sector organisations, such as the WTW Research Network, in GEO – and feel that we could be well placed to take advantage of such connections for the benefit of sustainable development in mountains.

If you would like to provide further details on the technical methods, you may upload one or more documents here.

- no supporting documents provided -

Are there any significant scientific or technical challenges that need to be resolved by the Initiative during the 2023-2025 period?

Yes

Please describe these challenges and the steps being taken to solve them.

One key challenge relates to ensuring the currency of the links contained in our data inventories, given the constant release of new versions and entirely new datasets by data providers. To help solve this challenge, we have set up a process by which members of our community can contribute either new datasets or update information pertaining to existing entries. We are still however largely reliant on their goodwill and time to do this, which is a risk. The large number of different data providers (especially for in situ data) is another challenge. In addition, at the moment, we provide links to various datasets, but do not advise to what extent they agree with one another, their respective strengths and weaknesses, or whether they would be most suitable for a given application. To address this, we plan to conduct some "data intercomparison" exercises over the next period. We will seek to improve the geospatial visualisation and filtering capabilities of our inventories, although as mentioned in the GEO Symposium session to which we contributed (GEOSS EAG), some advancements in the GEOSS Portal functionality would be required if this system is to provide a full solution. In particular, to our understanding, at present, GEOSS is only capable of mirroring data that are hosted on a geospatial server elsewhere. More generally, there is growing interest in mountain science (and indeed acknowledgement of the need to) in developing methods / algorithms to extract maximal information content from complementary in situ and remotely sensed datasets (numerical modelling, calibration, data fusion, assimilation, evaluation etc.). Depending on the interests of our network, we could be well placed to work on such themes in mountain regions, potentially in collaboration with dedicated modelling organizations such as ECMWF.

Does the Initiative expect to complete any key new outputs, improvements to existing outputs, or improvements to the methods of producing outputs, in the 2023-2025 period?

Yes

Please describe these new outputs or improvements.

We will maintain and improve our inventories (e.g. add geospatial capabilities to our General Inventory), where applicable provide entirely new datasets to the community (e.g. those arising from our AI4EBVs project), build our library of mountain relevant capacity development / education resources and other "knowledge resources" (via the GEO Knowledge Hub), and identify other areas of engagement in which our products and resources could have a positive impact (to be confirmed, but hopefully other assessment exercises besides the IPCC, such as IPBES and/or Sendai Framework).

Please identify the key tasks that must be implemented to ensure delivery of these changes, with target dates for completion.

Task	Task description	Expected completion (month/year)
1.1a) Provide an inventory containing links to general datasets for use by the community	Maintain and update the GEO Mountains General Inventory. Ideally this should increasingly become inter-operable with other data inventories in order to ensure currency and comprehensiveness. We will work closely with the developers of GEOSS to hopefully also share these datasets via the Portal. We will place particular emphasis on increasing the proportion of socio-economic data coverage.	Periodic releases (~annual / biannual) throughout the implementation period
1.1b) Provide an inventory of in situ mountain monitoring infrastructure metadata GEO Mountains In Situ Inventory	Maintain and update the GEO Mountains In Situ Inventory. Ideally this should increasingly become inter-operable with other data inventories, potentially including the WMO's OSCAR Surface, in order to ensure currency and comprehensiveness.	Periodic releases (~annual / biannual) throughout the implementation period
1.2 Conduct interdisciplinary and multi-type data gap analysis	Identify deficiencies in mountain data coverage (including availability and in relation to the protocols followed), based on the GEO Mountains data inventories. Will consider data corresponding to multiple different disciplines, and of various different types (in situ, remotely sensed, modelled). Builds on the recent (limited) analysis of Thornton et al. (2022).	12/2023
1.3. Translate data into scientific knowledge	Exploit the available data to response to key scientific questions and predefined assessment knowledge requirements / mandates. Ensure the derivation of knowledge from data is transparent and reproducible, and share the resultant knowledge packages via the GKH. This task is likely to revolve largely around data inter-comparison, integration, and application projects (some of which will be undertaken via regional "hackathons"). For example, we may aim to provide data quality or utility flags or other recommendations to guide users'	Ongoing effort

	data choices, where these have not already been specified by the data providers. A project is underway on machine learning and cloud computing for landslide / avalanche hazard / risk assessment in Europe in collaboration with Accenture (private sector). We also hope to develop a tools for the extraction of (regional) climate model scenario data for a given area of interest, time period, model, and pathway combinations. This would likely be widely used across a range of subsequent climate change impact studies. This activity could also involve modelling activities with organizations such as ECMWF, in particular the integration of mountain-specific data. User knowledge needs must be well identified and met.	
2.2. Improve fundamental monitoring of mountain systems.	Support and help co-design efforts around the coordination and standardization of interdisciplinary mountain in situ monitoring (e.g. further the concept of "Mountain Observatories"), plus the initial steps towards the practical implementation of novel approaches / frameworks for mountain climatological monitoring (e.g. UHOPs as a protocol to integrate in situ data measured in various ways). Note that information on elevation dependent climate change (EDCC) could be included in the mountain range “fact sheets” mentioned below, or a dedicated set of factsheets could be developed on this topic.	Identify and showcase 15 globally distributed "Mountain Observatories" (MOs) by 12/2023; Hold an international workshop on UHOPs in 2023, plus receive feedback from “pioneer” transects (e.g. in BC, Canada).
2.3. Define and advocate for the use of Essential (Shared) Variables in Mountains	Where possible, take steps to i) further the implementation of the proposed concept of "Essential Mountain Climate Variables" (EMCVs); ii) Publish a perspective article on priority variables for biodiversity monitoring in mountains (currently in prep); iii) Hold a workshop and prepare associated publication on Essential Socio-economic variables in mountains; all	i) (EMCVs) – Ongoing; ii) (biodiversity variables) – Submit paper by 12/2022; iii) (Socio-economic variables) – Hold workshop by 12/2022 or early 2023.

	potentially with a view to the definition of an integrated set of Essential Mountain Variables.	
2.4. Develop a map of mountain social-ecological systems	Develop (a) novel spatial representation(s) / layer(s) of mountain socio-ecological systems. This should include bi-directional dependencies / connections between mountains and connected lowlands, including via flows of ecosystem goods and services.	12/2023
2.5. Increase the availability and use of paleodata from mountain environments	Increase the number of paleo datasets in the GEO Mountains data inventories, and seek to apply those data to inform forward looking climate modelling exercises. We will work in collaboration with relevant networks such as PAGES to achieve this.	Ongoing effort
3.4. Develop educational, training, and capacity development materials	Ideally these should respond to a pre-identified requirement / lack / request. Projects are underway with CONDESAN (vegetation data in the Andes) and Sea to Sky Gondola (more general educational materials). User training / education / capacity development needs must be well identified and met. We also plan to conduct capacity sharing workshops on the installation / maintenance of high elevation in situ monitoring infrastructure and associated data management, sharing knowledge and experiences from different regions. Likely in collaboration with selected MRI working groups and partners from the GEO Mountains network.	Ongoing effort
3.5. Provide data and information for policy and decision making applications	Similar to 1.3, but here focusing specifically on data and knowledge provision to policy applications.	Ongoing effort

Resources

Have all resources required to implement the Initiative's planned work in the 2023-2025 period been secured?

- Gap in human resources
- Gap in access to data

What are the essential skill sets needed by the Initiative but are not currently resourced?

Core and co-funding is secured to the end of 2023, funding to cover the remaining period to end of 2025 is under negotiation pending a detailed proposal and successful completion of key tasks in 2022, as well as MRI's own core funding bid for the period 2023-2027.

What data sets are needed by the Initiative but are not currently available?

Greater access (in particular) to in situ observations made in and near mountains by national hydrometeorological agencies and other authorities. Ideally, all of these observations should be fed into a single portal from where they can be accessed, such as the GEO Mountains In Situ Inventory and/or the WMO's OSCAR (surface) portal. There are other key data gaps, some of which we are working to address (e.g. lack of systematic spatio-temporal data on mountain snowpacks, currently being developed via the Joint Body on the Status of Mountain Snow Cover), and others which are more challenging to address (e.g. socio-economic data, reliable data on permafrost and soils).

What actions is the Initiative taking to obtain the required resources?

A Proposal is under preparation by the MRI for the continued support of GEO Mountains under the Adaptation at Altitude programme, funded by the Swiss Agency for Development and Cooperation (SDC). The proposal covers a second phase for this programme (2024-2027). Additional contributions and resources will be invited from members of GEO Mountains.

Please list all financial and non-financial contributions to the Initiative (other than in-kind, voluntary participation by individual contributors) having a value of more than USD 50,000.

Contributing Organization	GEO Status	Type of Resource	Value	Currency
Swiss Agency for Development and Cooperation (SDC)	Switzerland	Financial	~1,000,000 (over 4 years, 2020-2023)	CHF

Lessons from the 2020-2022 Period

Were all planned activities for the 2020-2022 period implemented as expected?

No

Please describe which activities were delayed or not implemented and how has this affected plans for 2023-2025.

The COVID-19 pandemic (2020-2022) has had, and continues to have, a considerable impact on the Initiative. In particular, it meant that almost all planned in person engagements, including consultations / workshops regarding data availability and gaps across the world's main mountain regions, had to be held remotely rather than in person. This naturally limited the duration of these engagements, as well as the ease with which concrete next steps could be agreed. Scientific conferences were likewise limited to online-only, which likely reduced the speed with which individuals / institutions interested in joining the network and contributing to key activities could be identified. Perhaps somewhat associated to the pressures imposed by the pandemic, we also found that the members of our network had limited capacity to contribute sufficient time to the Initiatives activities, leaving the GEO Mountains Secretariat to conduct / lead many of the technical tasks ourselves (rather than them being "community led", as originally envisaged). We will have to carefully monitor and track the time that our members can commit to GEO Mountain on an in-kind basis, and probably provide funding to individuals / institutions / teams for the execution of key tasks that they would not have necessarily conducted independently of GEO Mountains. In this sense, going forward, there may be some potential to align the Initiative's Implementation Plan with tasks that our members are planning to complete

anyway, but this will not be feasible in all cases. Finally, given that GEO Mountains is a geographically rather than a thematically focused Initiative we also feel that there is great scope to work far more extensively with many other WP Activities. Likewise, given that mountains are globally distributed and present in all contents of the world, there is still untapped potential to work more concretely with the regionally oriented Activities (e.g. AmeriGEO, AfriGEO). Of course, to achieve this, these has to be willingness and time dedicated to such inter-GEO collaboration from all partners. In the slightly longer term, given that GEO is considering taking an increasingly "Nexus-oriented" approach post-2025, and given the highly integrated nature of mountain systems and their well-established importance in global societies, GEO Mountains could be well-placed to provide this nexus on mountains (rather than spread ourselves thinly by contributing to a number of other nexuses).

Were there any key challenges faced by the Initiative in the 2020-2022 period?

Yes

Please describe.

The key challenges have largely been described above. In addition, staff capacities at the MRI Coordination Office also meant that some coordination support for GEO Mountains was at times challenging to sustain.

Were there any impacts or changes to operations due to COVID-19?

Yes

Please describe.

Yes, the main impact of COVID-19 has been outlined above. In addition, it meant that the Co-Leads and Scientific Project Officer had to undertake remote working strategies, although the overall impacts of this on outputs / productivity were minimal. Indeed, some impacts may have been positive (reduced time lost commuting / travelling, reduced carbon emissions, more time to focus on fundamental inventory development and paper writing tasks). We therefore take a balanced view of the impacts of the pandemic.

Please describe the key changes proposed for the 2023-2025 period, for example, new projects, new areas of focus, or adjustments to the activity governance.

At a high level, given our previous work on the delivery of inventories of data, software and tools, we will increasingly shift our emphasis from the provision of data to actionable information and knowledge, including education and capacity building materials that exploit the compiled data. This includes data intercomparison and integration activities. That said, with relevant partners, we will follow through on our findings and advice regarding key data gaps / areas of deficient coverage (see Thornton et al., 2022, Frontiers in Climate), as well as conduct similar but more comprehensive and interdisciplinary "gap analyses" using our data inventories, once they have been further augmented by contributions from the community. Furthermore, we will expand our work on identifying key climate-related variables for monitoring (Essential Mountain Climate Variables) into the areas of biodiversity monitoring and socio-economic monitoring. Indeed, we will seek to place greater emphasis on the availability / provision of socio-economic data more generally, as this has repeatedly been identified as a key gap to better understand, predict, and managed / adapt / mitigate climate change impacts in mountains (including in the form of planned contributions to IPCC AR7). These efforts will be undertaken in close collaboration with our members/participants (and the partner networks and other institutions many of them represented within GEO Mountains). To strengthen our governance, the Initiative intends to appoint a "Core Group" (which could fulfil a strategic and operational advisory role, pending some simple ToRs which are yet to be co-designed). We do not intend to make the process of appointments to this group unduly formal or bureaucratic at this stage, however.

Does the Initiative have outputs (products, services, etc.) available to users now, even if only on a pilot or testing basis?

Yes

Please provide any available information describing this usage (for example, user statistics, results of user testing) and/or feedback from users (for example, user

comments, evaluations).

The website presenting our In Situ inventory has received 772 hits to date. We also regularly seek feedback from our members and users during our biannual general meetings. Finally, we often run short feedback surveys following our events, receiving generally very positive feedback. For example, an online lecture we gave on the subject of Essential Mountain Climate Variables was evaluated as 19/20 in terms of usefulness of the content, and 19/20 in terms of technical quality (e.g. registration process, quality of video and sound, etc.). We may seek to develop more extensive and rigorous impact tracking and evaluation capabilities during the 2023–2025 period.

Please provide supporting documentation if available.

- no supporting documents provided -

Do you have evidence of any impacts that have occurred in part as a result of using the outputs of the Initiative (for example, policy decisions taken, behaviour changes by users, risks mitigated)?

Yes

Please provide examples, with evidence where available.

GEO Mountain to the IPCC are an example of our Initiative contributing to high profile assessments and subsequent associated policy decisions and implementation actions. However, our work has been instrumental in a successful bid to have the MRI officially be part of the WMO Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS) as a member, with Carolina Adler invited to Co-Chair the development of High-Level Ambitions position on observations to the WMO Congress. For further details, please see here: https://community.wmo.int/governance/executive-council/executive-council/panel-polar-and-high-mountain-observations-research-and-services-ec-phors

Please provide supporting documentation if available.

- no supporting documents provided -

Have there been any internal or external reviews or evaluations of the Initiative since 2019?

No

Please indicate any GEO Work Programme activities with which you have ongoing collaboration.

- AFRIGEO - African Group on Earth Observations
- AMERIGEO - Americas Group on Earth Observations
- DE-AFRICA - Digital Earth Africa
- GEO BON - GEO Biodiversity Observation Network
- GEO-EV - GEO Essential Variables
- HUMAN-PLANET - GEO Human Planet
- GEO Secretariat Operations - GEO Secretariat Operations
- GEO Work Programme Support - GEO Work Programme Support
- GEOSS Data, Information and Knowledge Resources - GEOSS Data, Information and Knowledge Resources

Please indicate any additional GEO Work Programme activities with which you would like to establish new collaborations.

- AOGEO - Asia-Oceania Group on Earth Observations
- CLIMATE-OBS - Climate Observation, Simulation and Impacts
- C3S - Copernicus Climate Change Service
- GEO-DARMA - Data Access for Risk Management
- DIAS - Data Integration and Analysis System

- EO4SENDAI-MONITORING - Earth Observation and Copernicus in support of Sendai Monitoring
- EO4DRM - Earth Observations for Disaster Risk Management
- EO4EA - Earth Observations for Ecosystem Accounting
- EO4HEALTH - Earth Observations for Health
- EO4SDG - Earth Observations for the Sustainable Development Goals
- EO4WEF - Earth Observations for the Water-Energy-Food Nexus
- EUROGEO - European Group on Earth Observations
- GEO-CITSCI - GEO Citizen Science
- GEO Engagement Priorities Coordination - GEO Engagement Priorities Coordination
- GEOGLAM - GEO Global Agricultural Monitoring
- GEO-ECO - GEO Global Ecosystems
- GEOGLOWS - GEO Global Water Sustainability
- GEO-LDN - GEO Land Degradation Neutrality
- GEO-WETLANDS - GEO Wetlands
- GEO Work Programme Support - GEO Work Programme Support
- GEOSS Data, Information and Knowledge Resources - GEOSS Data, Information and Knowledge Resources
- GEOSS Infrastructure Development - GEOSS Infrastructure Development
- GDIS - Global Drought Information System
- GLOFAS - Global Flood Awareness System
- GFRM - Global Flood Risk Monitoring
- GFOI - Global Forest Observation Initiative
- LAND-COVER - Global Land Cover
- GWIS - Global Wildfire Information System
- IN-SITU-ESC - In-Situ Observations and Applications for Ecosystem Status of China and Central Asia
- MUSYQ - Multi-source Synergized Quantitative Remote Sensing Products and Services
- NEXT-EOS - Next Generation Earth Observation Services
- OEA - Open Earth Alliance
- GEO-VALUE - Understanding the Impacts and Value of Earth Observations
- UHCO - Urban Heritage Climate Observatory

Stakeholder Engagement and Capacity Building

Are there specific countries or organizations that your Initiative would like to engage?

Yes

Please list these countries, regions or organizations.

We firstly wish to strengthen links / work more closely with organisations with whom we already work to some extent, including both GEO members and GEO Participating Organisations (such as WMO, UNESCO, UNEP, iLTER, USGS, ICIMOD, Future Earth, SAEON), and non-GEO members (such as GLORIA, MIREN, GMBA, CONDESAN), and others, on mutually beneficial projects / tasks. We likewise seek to develop further collaborations with GEO WP Activities with whom we have worked previously, such as GEO BON and GEO Human Planet. Secondly, we wish to explore potential links with the many other GEO WP Activities, either regional or thematic, that could have synergies with GEO Mountains (see previous check box). In terms of geographical scope, we work across the mountains of the world, but with a particular focus on East Africa, the Caucasus, the Hindu Kush Himalayas, the Andes, and the mountains of Central Asia. Therefore, we are seeking to engage with the relevant GEO members and GEO WP activities in those regions as well as agencies of any country with a considerable mountain extent, but particularly in these focal regions.

What are your plans to engage them?

We are quite well placed to deepen our collaborations with our existing partners. With respect to both the engagement of other GEO WP Activities and national authorities, we plan to make written contact in the first instance and set up meetings to discuss potential synergies. The influence and reach of the GEO Secretariat also has the potential to help us greatly in facilitating discussions with national agencies in member countries in particular. (On this point, we would like to highlight the fact that in becoming members of GEO, countries

have theoretically made a "best effort" commitment to share data etc., but our experiences in consultation exercises have shown that this is often not realised in practice / on the ground, especially for in situ data; if the GEO Secretariat can facilitate a dialogue to incentivize all members / organisations to apply the Data Sharing Principles to the greatest extent possible, that would also be much appreciated). The return of GEO events (Symposium, Plenary) to presential format will certainly help these efforts.

Does your Initiative engage users in the work of the Initiative (for example, consultation, testing, co-design)?

Yes

Please briefly describe the Initiative’s approach to engaging users.

We host regular workshops on issues related to data in our focal regions, and complement these consultations with more systematic exercises. We also welcome our partners to help us host similar workshops in other mountain regions (e.g. Europe, North America). Data users will also be invited to forthcoming "hackathons" which will have a joint purpose: i) to translate data into knowledge and insights for policy and practical decisions, ii) to educate and build capacity around interdisciplinary data analysis / computation for a range of applications across the world's mountains. In addition to keeping our website updated, we regularly email members of our network and other potential users with updates that are also widely shared via out social media channels (e.g. events, funding, calls for input), and host bi-annual meetings at which all stakeholders can share their inputs and views on the Initiative's progress. Via the recent establishment of several Task Groups, we have attempted to decentralise parts of the work and give a certain degree of autonomy to participants to pursue tasks related to their areas of expertise. Success of this approach has been mixed so far, however.

Does the Initiative have a user engagement strategy or similar kind of document?

No

Are there categories of users that are not represented at this time, but you would like to engage?

Yes

Please list these user categories or regions.

Practitioners are perhaps the least represented user group at present, likely because of their large number and heterogenous foci. We could perhaps identify and seek to engage key practitioner representatives.

What are the plans for further engagement of users in the Initiative?

We will seek stronger involvement (potentially including financial or by committing other resources) from the organisations represented in the Core Group. We also plan to conduct a general survey to obtain insights on whether the community / our users feel that we are currently meeting their needs, and what improvements could be made going forward.

Does the Initiative have a documented capacity development strategy?

No

Please describe the approach to capacity development that is being implemented by the Initiative?

We are firstly seeking to compile links to existing useful capacity development resources: https://www.geomountains.org/resources/training-capacity-development. Secondly, we endeavour to follow the principles of Open Science in all projects led / heavily involving the Initiative. For instance, in Thornton et al. (2022), we provide all of the input data and code. To accompany a paper on population distributions in human mountains, we have developed a GEO Knowledge Package. These outputs can help capacity development. We are also seeking to fund and develop our own dedicated training / education / capacity development resources. For instance, we are currently planning (and co-financing) a workshop with

colleagues from CONDESAN to build local capacity around the analysis of ecological and biodiversity data in the Andes. Furthermore, given the strong interest shown by younger people around the world in climate-related issues, we plan to develop specifically targeted educational and other materials for children and youngsters on topics related to mountain change (e.g. via the journal Frontiers Young Minds or similar).

Are there any commercial sector organizations participating in this Initiative?

No

Are there opportunities for commercial sector uptake of the outputs of the Initiative?

Yes

Please describe these opportunities.

Our data and information services could potentially be useful to a range of organisations operating in or near mountains including in sectors such as energy (especially hydropower), agriculture, leisure and tourism, and insurance, although this is not our primary focus at present.

Is there already commercial uptake occurring?

No

Are there opportunities for further commercial sector participation in the Initiative?

Yes

Please describe these opportunities.

We could foresee potential links with the (re)insurance industry around DRR, commercial EO providers (in specific cases), and technology companies to help provide proxy data / close gaps on socio-economic data, to provide a few examples.

Does the Initiative have a plan for commercial sector engagement?

No

Governance

Please describe the roles of each of the key leadership positions, as well as any team structures involved in day-to-day management.

Dr. Carolina Adler (MRI): Co-lead
Dr. Elisa Palazzi (CNR): Co-lead
Dr. James Thornton (MRI): Scientific Project Officer
Other MRI staff: assist with events planning and reporting.

Is there a steering committee or other governance bodies that advise the Initiative but are not involved in day-to-day management?

Yes

Please describe the roles of each body. If there are multiple governance bodies, please describe the relationships among them (such as through a governance structure diagram).

There is an informal "Core Group" that provides ad hoc advice and feedback to the GEO Mountains Secretariat (Co-leads and Scientific Project Officer).

- no supporting documents provided -

What methods does the Initiative use to communicate with its participants?

- Email / e-newsletters
- Regular conference calls
- Website
- Regular events

Please describe the key risks that could delay or obstruct the completion of the planned activities and outputs of the Initiative, along with any actions taken to mitigate these risks.

Description of the hazard	Description of the possible impacts	Scale of impact	Likelihood of occurrence	Mitigation measures
Unsuccessful funding application.	Unsuccessful (or partially successful) in securing requested core funds beyond 2023, potentially reducing our available budget for core activities.	Severe	Not very likely	Identify potential donor or funding agencies to support core coordination/networking tasks.

What methods are used by the Initiative to monitor its effectiveness?

- Informal discussions with users / beneficiaries
- User or beneficiary surveys
- Website statistics
- Consultations or events
- Other

Please describe.

Social media.

Would the Initiative be interested in assistance from the GEO Secretariat for developing an impact plan?

Yes

How are the results of the monitoring and evaluation activities shared with participants and the wider GEO community?

N/A at present, but we will use emails and general meetings (and the reporting of those outcomes) to share this information if such activities are conducted in the future.

Are any monitoring or evaluation activities required by funders/contributors?

Yes

Please describe and provide reports if available.

We are required to report on progress against a logframe agreed with the funder, with activity reports provided every 6 months.

- no supporting documents provided -

Participants

Please list the active individual participants in the Initiative

First name	Last name	Email address	Member	Org
Daniele	Ehrlich	daniele.ehrlich@ec.europa.eu	European Commission	JRC - Joint Research Center
Davnah	Urbach	davnah.payne@ips.unibe.ch		GMBA - Global Mountain Biodiversity Assessment
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Jörg	Balsiger	joerg.balsiger@unige.ch	MRI - The Mountain Research Initiative	University of Geneva - University of Geneva
Luis Daniel	Lambi	luis.llambi@condesan.org		
Maria	Shahgedanova	m.shahgedanova@reading.ac.uk	MRI - The Mountain Research Initiative	University of Reading - University of Reading
Mandira	Shrestha	mandira.shrestha@icimod.org	ICIMOD - International Centre for Integrated Mountain Development	ICIMOD - International Centre for Integrated Mountain Development
Marc	Zebisch	marc.zebisch@eurac.edu	Italy	- EURAC
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Yves-Alain	Roulet	yves-alain.roulet@meteoswiss.ch	MRI - The Mountain Research Initiative	

Other information

Please provide any other comments or information that was not included in the previous sections, but you would like to appear in the Implementation Plan.

Please note that the list of 21 Participants given only includes the proposed "Core Group". As of 23 May 2022, in addition to this group, our list of Participants / Members and other potentially interested parties (enlisted in our mailing list) contains 313 individuals from diverse regions around the world.

- no supporting documents provided -

Co-Editor Management

List of co-editors for this initiative

First name	Last name	Email address
James	Thornton	james.thornton@unibe.ch
Elisa	Palazzi	e.palazzi@isac.cnr.it