Implementation Plan
2020-2022 GEO Work Programme

Version 2.1

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Background to the current version (10 October 2020)

The previous GEO-GNOME Implementation Plan for the GEO Work Programme 2020-2022 (dated 29 July 2019, and submitted to GEO for endorsement at the GEO Plenary in 2019), outlined four objectives: 1) To accurately delineate mountain regions using best available data; 2) To identity data providers and user knowledge needs; 3) To improve monitoring and understanding of mountain processes; and 4) to communicate, link, and develop reporting capacity that responds to policy needs.

Since the 2019 GEO Plenary, significant funding has been awarded to the Mountain Research Initiative (MRI) by the Swiss Agency for Development and Cooperation (SDC) in order to strengthen GEO-GNOME over the period 2019-2023 as part of the first phase of the SDC's global Adaptation at Altitude Programme[1]. The objectives and activities stated under that contract had to be combined with those already existing under GEO-GNOME. Hence, this revised Implementation Plan was prepared.

This revision was also important to ensure that tasks previously completed (i.e. over 2017-2019) are identified as such here, and that any ongoing and pending activities are carried over and integrated into this new plan appropriately. For instance, the previous Objective 1 (delineating mountain regions) has been removed here because many of the tasks therein are complete.

This revised Implementation Plan was submitted to the GEO Executive Committee in September 2020 for their information and endorsement ahead of the GEP Plenary 2020.

More recently, a decision has been taken to re-brand the Initiative. Whilst the official title remains the same, instead of GEO-GNOME, a new short title will be used in all communications going forward: **GEO Mountains**. A new logo has also been prepared to reflect this.

Carolina Adler and Elisa Palazzi
GEO Mountains Co-Leads

20 October 2020

[1] https://www.mountainresearchinitiative.org/activities/projects/adaptation-at-altitude

Executive Summary

Full title of the Initiative

Global Network for Observations and Information in Mountain Environments

Short title or acronym

GEO Mountains

Existing or proposed category

Initiative (existing)

Overview

GEO Mountains was launched as a GEO Initiative in 2016 (as GEO-GNOME). It seeks to identify, collate and make accessible transboundary and inter- and transdisciplinary data and information – from a variety of providers – pertaining to environmental, ecological, and societal change in mountainous regions globally. In so doing, the ease with which the scientific research community, local, national, and regional decision makers, and other interested parties can access and use such data and information will be greatly enhanced. More broadly, such work intends to ensure that mountains as a context will assume and retain a prominent position in all major global policy agendas, including the 2030 UN Agenda and its Sustainable Development Goals (SDGs), reporting on climate change through the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Convention on Climate Change (UNCCC), and the Sendai Framework for Disaster Risk Reduction (DRR).

Planned activities

The main activities planned for the current Work Programme period (2020-2022) are listed as Tasks under three main objectives, as follows:

Objective 1: *Identify the needs of diverse users of data and information pertaining to global mountain environments and, as far as possible, satisfy these needs by making relevant data freely discoverable, accessible, and usable*

1.1. Create, maintain, and make available up-to-date registries/databases of i) GEO Mountains Members/Participants and representatives of affiliated organisations (including GEO Flagships, Initiatives, Community Activities, and Regional GEOs, ii) potential or actual data providers and metadata describing their datasets, and iii) mountain observatory infrastructure (again with metadata describing the corresponding data). Relevant open datasets published “stand alone” in data journals or in community repositories (e.g. PANGAEA, *figshare* etc.).

1.2. Conduct surveys of data and information users to gain insights into i) requirements regarding ideal functionality and specifications for an online mountain data portal (i.e. the GEOSS GEO Mountains Community Portal), and ii) data/information/knowledge needs, including thoughts on the extent to which they can already be met (i.e. by datasets and information that are discoverable, accessible, and usable). Regional similarities and differences should be considered.

1.3. Make the three alternative delineations of global mountain areas (K1, K2, and K3) that are currently accessible via the Global Mountain Explorer (https://rmgsc.cr.usgs.gov/gme/) accessible on the GEOSS GEO Mountains Community Portal, and ensure that corresponding subsets of global data layers can be created and exported. This is to be supplemented by an additional layer or layers containing socio-economic data (see also task 2.4).

1.4. Guided by the outcomes of Tasks 1.1 and 1.2, make as much relevant inter- and transdisciplinary data and information as possible freely accessible via the GEOSS GEO Mountains Community Portal (see also Task 3.4).

Objective 2: *Improve monitoring and understanding of mountain processes*

2.1 Investigate the extent to which existing in situ meteorological and other instrumental infrastructure in global mountain areas currently meet internationally agreed standards (e.g. those of the World Meteorological Organisation; WMO, for meteorological stations), and whether additional information/data is provided to render non-compliant data more useable (e.g. indications of the magnitudes of any biases and/or uncertainties, instrument inter-comparisons, complementary measurements, etc.).

2.2 In collaboration with the Mountain Research Initiative's (MRI's) Mountain Observatories (MOs) and Elevation Dependent Climate Change (EDCC) Working Groups, support the development of the Unified High Elevation Platform (UHOP), for instance by helping to identify appropriate sites/regions and evaluating existing infrastructure and associated gaps.

2.3 Convene further workshops seeking to define "Essential Mountain Variables", i.e. those variables which should form high priority targets for observation across various disciplines (e.g. climate change and impacts, biodiversity change and impacts, and socio-ecological system change and impacts)

2.4 Develop the conceptual foundations for a new mountain layer (K4) that integrates key relevant aspects of mountain social-ecological systems.

2.5 Establish deeper links with paleoscience research communities with a view to improving the availability of relevant proxy data in global mountain regions.

Objective 3: *Communicate, link, and develop reporting capacity that responds to policy needs*

3.1 Establish a dedicated GEO Mountains website which communicates the governance structure (e.g. Co-leads, Core Group, and Scientific Officer) and Members/Participants, and gives prominence to data providers and their resources (including a link to the GEOSS GEO Mountains Community Portal), news, and impact stories.

3.2 Make quarterly communications by email / newsletter will all Members/Participants and other affiliated parties to update them on progress, forthcoming (note: this is in addition to the monthly Mountain Research Initiative (MRI) Newsletter; ad hoc correspondence will also be sent as necessary).

3.3 Undertake a regular series of webinars to enhance the interaction, communication, and progress of the GEO Mountains community and other interested parties, including data providers, users, and GEO Flagships, Initiatives, Community Activities, and Regional GEOs.

3.4 Develop training and educational materials related to the drivers, processes, and impacts of environmental, ecological, and societal change in mountain areas, and how to access and use relevant data and information, to inform and build capacity in local communities.

The degree of temporal dependence between these tasks is fairly limited, except that survey related tasks (e.g. 1.2) should be undertaken as soon as possible, whilst the development of training and educational material for deployment in mountain communities is likely to occur later. Many tasks will be ongoing throughout the Work Programme period (e.g. data continually added into GEOSS).

Note that additional activities are also planned beyond 2022 as part of the "Adaptation at Altitude" programme supported by SDC.

A General Meeting will be held on 27 November 2020 to provide an update of this new plan and progress towards its objectives to all participants. During this meeting, we will seek to establish Task Groups to assist in completing various tasks (under the three objectives).

Primary points of contact

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Purpose

Rationale for the Initiative

Mountains are globally distributed environments which produce significant societal benefits. However, the ability of these regions to provide goods and services to both their inhabitants as well as to adjacent lowland populations is seriously threatened by climatic changes, environmental pollution, large-scale political and socio-economic transformations, unsustainable management of natural resources, and major gaps in fundamental system understanding.

Indeed, despite numerous focused research efforts, links between mountain researchers in different disciplines, the availability, accuracy, and spatial representativeness of high-elevation environmental observations, and models capable of generating reliable future predictions and projections all remain somewhat limited. This situation is hindering reporting and decision-making that numerous policy contexts require.

GEO Mountains seeks to collate and make accessible transboundary and inter- and transdisciplinary data and information – from a variety of providers, including research institutes and mountain observation networks – pertaining to environmental, ecological, and societal change in mountainous regions globally. In so doing, the ease with which the scientific research community, local, national, and regional decision makers, and other interested parties can access and use such data and information will be greatly enhanced.

More broadly, through such activities it is hoped that mountains as a context will assume and retain a prominent position in all major global policy agendas, including the 2030 UN Agenda and its Sustainable Development Goals (SDGs), reporting on climate change through the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Convention on Climate Change (UNCCC), and the Sendai Framework for Disaster Risk Reduction (DRR). Furthermore, through the connections and participation of GEO Mountains partners and contributing organisations, additional contributions to advocacy on mountain relevant-issues are envisaged for the post-2020 process under the Convention on Biological Diversity (CBD) and the Land Degradation Neutrality under the United Nations Convention to Combat Desertification (UNCCD).

Description of any direct policy mandate received from an international body – required for GEO Flagships, optional for Initiatives

No direct policy mandate from an international convention or UN Agency has been received by GEO Mountains at present. However, GEO Mountains has been tasked with contributing a key task – that on mountain observations – within a new global programme supported by SDC, titled “Adaptation at Altitude”.

Actual and/or planned outputs of the Initiative (i.e. data sets, open methods, information products or services, or other openly available results intended for external users) and their geographical scope

Planned future outputs of the Initiative fall into two main categories: i) numerous relevant datasets spanning many disciplines, along with inventories of observational infrastructure, will be made freely available to all interested parties via the GEOSS GEO Mountains Community Portal, and ii) various “knowledge-related” outputs, including scientific articles in peer-reviewed journals, reports (e.g. conference summaries or proceedings). Similarly, the Initiative has been invited to be part of the initial design activities by the GEO Knowledge Hub (GKH) team at the GEO Secretariat, thereby paving the way for GEO Mountains to make an early contribution to the GKH,

whose development has recently been approved by the GEO Executive Committee (July 2020). In terms of communication and engagement, a new dedicated website for the Initiative will be developed, and a quarterly GEO Mountains newsletter will be sent to all participants. (Note: all participants in GEO Mountains activities are automatically, with their permission, considered Members). Geographically, the activities will focus on the following major mountain regions: the Andes, the Caucasus, the Hindu Kush Himalaya (HKH), Central Asia, Eastern Africa, the European Alps, and the North American Cordillera. Below, specific intended outputs corresponding to each of the tasks listed above under "Planned activities" are provided.

Objective 1: *Identify the needs of diverse users of data and information pertaining to global mountain environments and, as far as possible, satisfy these needs by making relevant data freely discoverable, accessible, and usable*

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1.2. Conduct surveys of data and information users to gain insights into i) requirements regarding ideal functionality and specifications for an online mountain data portal (i.e. the GEOSS GEO Mountains Community Portal), and ii) data/information/knowledge needs, including thoughts on the extent to which they can already be met (i.e. by datasets and information that are discoverable, accessible, and usable). Regional similarities and differences should be considered.

1.3. Make the three alternative delineations of global mountain areas (K1, K2, and K3) that are currently accessible via the Global Mountain Explorer (https://rmgsc.cr.usgs.gov/gme/) accessible on the GEOSS GEO Mountains Community Portal, and ensure that corresponding subsets of global data layers can be created and exported. This is to be supplemented by an additional layer or layers containing socio-economic data (see also task 2.4).

1.4. Guided by the outcomes of Tasks 1.1 and 1.2, make as much relevant inter- and transdisciplinary data and information as possible freely accessible via the GEOSS/GEO MOUNTAINS Community Portal (see also Task 3.4).

Objective 2: *Improve monitoring and understanding of mountain processes*

2.1 Investigate the extent to which existing in situ meteorological and other instrumental infrastructure in global mountain areas currently meet internationally agreed standards (e.g. those of the World Meteorological Organisation; WMO, for meteorological stations), and whether additional information/data is provided to render non-compliant data more useable (e.g. indications of the magnitudes of any biases and/or uncertainties, instrument inter-comparisons, complementary measurements, etc.).

2.2 In collaboration with the Mountain Research Initiative's (MRI's) Mountain Observatories (MOs) and Elevation Dependent Climate Change (EDCC) Working Groups, support the development of the Unified High Elevation Platform (UHOP), for instance by helping to identify appropriate sites/regions and evaluating existing infrastructure and associated gaps.

2.6 Convene further workshops seeking to define “Essential Mountain Variables”, i.e. those variables which should form high priority targets for observation across various disciplines (e.g. climate change and impacts, biodiversity change and impacts, and socio-ecological system change and impacts)

2.7 Develop the conceptual foundations for a new mountain layer (K4) that integrates key relevant aspects of mountain social-ecological systems.

2.8 Establish deeper links with paleoscience research communities with a view to improving the availability of relevant proxy data in global mountain regions.

Objective 3: *Communicate, link, and develop reporting capacity that responds to policy needs*

3.1 Establish a dedicated GEO Mountains website which communicates the governance structure (e.g. Co-leads, Core Group, and Scientific Officer) and Members/Participants, and gives prominence to data providers and their resources (including a link to the GEOSS GEO Mountains Community Portal), news, and impact stories.

3.2 Make quarterly communications by email / newsletter will all Members/Participants and other affiliated parties to update them on progress, forthcoming (note: this is in addition to the monthly Mountain Research Initiative (MRI) Newsletter; ad hoc correspondence will also be sent as necessary).

3.3 Undertake a regular series of webinars to enhance the interaction, communication, and progress of the GEO Mountains community and other interested parties, including data providers, users, and GEO Flagships, Initiatives, Community Activities, and Regional GEOs.

3.4 Develop training and educational materials related to the drivers, processes, and impacts of environmental, ecological, and societal change in mountain areas, and how to access and use relevant data and information, to inform and build capacity in local communities.

Actual and/or intended users of the outputs and the expected types of decisions these outputs are expected to inform

GEO Mountains intends to provide suitable data and information to serve the needs of several diverse user groups.

Firstly, research scientists must be able to quickly identify suitable in situ and remotely sensed datasets for purposes such as better monitoring and understanding fundamental physical processes/phenomena (e.g. elevation dependent climate change; EDCC) as well as informing and evaluating numerical models in complex mountainous environments. For example, investigations into EDCC require that lengthy records (> 20 years) of a minimum set of variables (including, but not limited, to air temperature, shortwave and longwave radiation, and specific humidity) are available and accessible at several locations along elevational gradients. As such, GEO Mountains hopes to facilitate and expedite research in such fields.

Many scientific outputs (e.g. publications, new datasets) should in turn feed through to global assessment efforts, such as those conducted by the IPCC, which themselves ultimately inform negotiations and decisions under the auspices of organisations like the UNFCCC (e.g. The Paris Agreement). Hence, GEO Mountains should also make crucial indirect, yet relevant contributions.

Through the coordination and reporting of workshops and conference, the Initiative seeks to drive progress and develop consensus amongst experts with regards to future monitoring and scientific priorities in mountain regions so that major challenges can ultimately be addressed.

The Initiative likewise seeks to meet the knowledge and information needs of governments at various spatial scales (i.e. local, regional, and national), environmental managers, and those looking to invest in mountain environments.

Finally, the outputs will provide a powerful means to communicate drivers, processes, and impacts of environmental, ecological, and societal change in mountainous regions. In this regard, training and teaching resources will be developed for use in local communities, schools, and universities. “In region” and/or online training courses on the use of Earth Observation (EO) and numerical modelling to understand ongoing change in mountainous regions and explore future scenarios, for instance, will be organised by GEO Mountains-affiliated researchers; such activities will contribute greatly to capacity building.

Looking forward, any new GEO Mountains tasks will be co-designed in collaboration with key stakeholders including practitioners, decision makers, research scientists, and policy makers (as applicable) to ensure that the foreseen results and outputs align closely with their requirements and expectations. As part of this process, regular meetings, webinars, workshops, and surveys will be organised. The recently launched “Adaptation at Altitude” programme of the SDC provides one platform in which such crucial dialogues with practitioners and policymakers can occur.

Expected outcomes, impacts and beneficiaries from adoption of the outputs from the Initiative

The expected general benefits from adoption of the outputs are largely summarized in the above section; essentially, easier access to high quality and appropriately documented mountain data, community led efforts to define monitoring and scientific priorities, increased support for data and information end users, and a tighter, more informed community of mountain researchers and practitioners.

Background and Previous Achievements

Status of implementation of planned activities and outputs for the 2017-2019 period

Whilst some of the tasks planned for the 2017-2019 period were successfully completed, a lack of resources for effective coordination meant that certain others were not. For the most part, those tasks in the latter category have simply been transferred and re-stated as part of the present Implementation Plan.

In summary, perhaps the most significant achievements of the Initiative during the Work Programme period 2017-2019 was the creation of the Global Mountain Explorer (GME); an online tool enabling the visualization and comparisons of three alternative spatial delineations of mountains globally (in the form of shapefiles). The constituent layers were also compared by Sayer et al. (2018).

In addition, a successful workshop on Essential Climate Variable (ECVs) in mountain environments was held in June 2019. (A complementary workshop on Essential Biodiversity Variables (EBVs) was held at the start of the current Work Programme period, in February 2020).

Evidence of use of the outputs of the Initiative, particularly by end users

The shapefiles referred to above have already been used in various contexts, including:

1. In a pilot, desk-based study that was conducted by the MRI and the CDE to identify a subset of Sustainable Development Goal (SDG) indicators that are relevant in the context

of sustainable mountain development and explore indicator data availability, including the extent to which it can be spatially disaggregated (Bracher et al., 2018)

2. In an issue brief by the MRI and the CDE. This document proposes some initial steps towards the "localisation" of the 2030 Agenda to mountainous regions. Common development priorities in mountains such as sustainable resource use, climate action, and strengthening peoples' livelihoods and resilience were highlighted. However significant differences also emerged due to the global diversity of mountains, as outlined in this policy brief (Wymann et al., 2018). A scientific paper was also published to expand on this analysis (Kulonen et al. 2019).

3. In the "High Mountains" chapter of the IPCC's Special Report on the Ocean and Cryopshere in a Changing Climate (Hock et al., 2019), as well as the current assessment of the IPCC Working Group II contribution to the Sixth Assessment Report (AR6) in its Cross-Chapter Paper "Mountains", expected to be published in 2021.

In addition, the IPCC Working Group I and Working Group II contributions to the AR6 Atlas, author team are using the shapefiles to overlay trends of observed climate impacts in mountains regions and well as their associated impacts in mountains (currently under development).

Examples or evidence of outcomes and/or impacts based on use of outputs (e.g. policy decisions taken, behaviour changes by users, risks mitigated)

Since the Initiative presently remains at a relatively early stage of development (see the section immediately below), besides the applications of the shapefiles outlined above, there has not yet been the opportunity for our outputs to feed through to such impacts (e.g. policy decisions). That said, we will carefully monitor these outcomes and report them as "success stories" in a dedicated section of the new GEO MOUNTAINS website.

Reflection on the effectiveness of the Initiative's governance structure and resourcing strategy

GEO Mountains began its activities with few resources for effective the coordination and overview/delivery of tasks; those tasks that were completed were largely achieved through in-kind contributions. Additionally, in the original GEO Mountains proposal, little emphasis was placed on establishing a governance structure that could be implemented in practical terms. These difficulties were exacerbated by the fact that "membership" of the Initiative remained rather aspirational and informal.

Consequently, commitments towards contributions were often not effectively followed through, and much of the burden regarding key decisions rested on the co-leads (i.e. without an effective mechanism in place for consultation and validation of measures or suggestions for moving forward).

Subsequently, based on their interest and active participation in the Initiative (e.g. in key calls and virtual meetings), a "core" group of individuals was identified to serve as a de facto "advisory body".

As part of the present Work Programme (2020-2022), a formal registry of members will be generated and much increased visibility given to them (including the core group) on a new, dedicated GEO Mountains website.

The governance structure will also be adapted to include a rotating role for advisory board members that will be filled by representatives of a mixture of GEO Participating Organisations, GEO Member Countries, and other external GEO Mountains Members/Participants.

Summary of the results of any internal or external reviews or evaluations of the Initiative

The previous Implementation Plan (corresponding to the Work Programme period 2017-2019) discussed the reviews of the Initiative that were conducted upon its inception; readers are referred to that document for more details. The next review is scheduled for 2022/23. Lessons learned from (or challenges experienced in) the previous implementation period and proposed actions for amendments or improvements.

Key lessons learnt during the lifespan of the Initiative to date include the following:

- A dedicated and resourced "project manager" role is crucial for ensuring that tasks are effectively coordinated and, where members/participants have volunteered to pursue them, followed through. Since May 2020, thanks to the SDC funding, such a position (80% FTE) has been filled (by Dr. James Thornton).
- Regular virtual meetings are needed to ensure communication among those working on joint tasks/activities and to ensure sufficient dialogue between co-leads and participants/members.
- Physical meetings at least once a year are also important to maintain momentum and relevance. Ideally, these meetings should be combined with thematic workshops and represent major opportunities to define and organize tasks, providing impetus to the Initiative. In addition, smaller meetings (e.g. splinter meetings) at international conferences are also important.
- Active participation in GEO-led events is crucial. Through attendance and by making contributions at such events, we will be able to i) communicate progress to the GEO community, and ii) develop links with other GEO Initiatives, Flagships, and Community Activities. These exchanges will be bi-directions, i.e. engagement will help GEO Mountains achieve its goals, but we should also be able to offer useful input to the efforts of others.

Relationship to GEO Engagement Priorities and to other Work Programme Activities

GEO Mountains is currently focused on ensuring that the right base layers, structures, and protocols are in place (2020-2022 Work Programme) to subsequently overlay information for visualisation and reporting. Following such groundwork, we hope to be more explicit with regards to specific SDGs that could be reported upon in pilot/demonstration projects in the latter part of the next work plan (i.e. looking at the 2023-2025 horizon). On this longer timescale, supporting the provision of relevant mountain-specific data and information for the following SDGs will form priorities:

- **SDG Target 1.4**, specifically the capability to map, for Indicator **1.4.2**: *The proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure*

- **SDG Target 2.4**, specifically the capability to map, for Indicator **2.4.1**: *The proportion of agricultural area under productive and sustainable agriculture*
- **SDG Target 3.9**, specifically the capability to map, for Indicator **3.9.1**: *The mortality rate attributed to household and ambient air pollution*
- **SDG Goal 6**, specifically the capability to map for, Indicator **6.3.2**: *The proportion of bodies of water with good ambient water quality, for* **6.4.2:** *The level of water stress: freshwater withdrawal as a proportion of available freshwater resources,* and for **6.6.1:** *The change in the extent of water-related ecosystems over time*
- **SDG Target 7.1**, specifically the capability to map for, Indicator **7.1.1:** *The proportion of population with access to electricity*
- **SDG Target 9.1**, specifically the capability to map for, Indicator **9.1.1**: *The proportion of the rural population who live within 2 km of an all-season road*
- **SDG Target 31.1**, specifically the capability to map for, Indicator **13.1.1**: *The number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population*
- **SDG Goal 15**, specifically the capability to map for, Indicator **15.1.1**: *Forest area as a proportion of total land area*, for **15.3.1**: *The proportion of land that is degraded over total land area*, for **15.4.1**: *Coverage by protected areas of important sites for mountain biodiversity*, and for **15.4.2:** *Mountain Green Cover Index* (linking to GEO-ECO and the outcomes of the recently concluded ECOPOTENTIAL project).

Description of which activities or outputs of the Initiative, if any, are expected to support the Paris Agreement and identify which pillars are implicated

Through its involvement in SDC's global "Adaptation at Altitude" programme, GEO Mountains will develop the means to provide access to data and information that is directly relevant to assessments such as those conducted by the Intergovernmental Panel on Climate Change (IPCC). By extension, this work will also provide relevant and information inputs to UNFCCC policy dialogues like the Paris Agreement and discussions at Conferences of Parties (CoPs).

More specifically, as an outcome of the 2020-2022 Work Programme, via the provision of inputs relevant for IPCC and for regional dialogues in mountain regions, we envisage to be able to report on the following pillars of the Paris Agreement in the lead up to the Global Stocktake in 2023:

- Adaptation;
- Loss and Damage; and
- National Reporting / Global Stocktake

Description of which activities or outputs of the Initiative, if any, are expected to support achievement of the targets of the Sendai Framework and which targets are implicated

While no activities in the 2020-2022 Work Programme specifically target the information needs of the Sendai Framework, we envisage being able to provide data and information that would allow the research and practitioner community to report, from a "mountains perspective", on at least the following targets in time for the next UN Disaster Risk Reduction Global Platform at the next Global Assessment Report event in 2022:

- **A: Substantially reduce global disaster mortality by 2030**, aiming to lower the average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015
- **C: Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030**
- **D: Substantially reduce disaster damage to critical infrastructure and disruption of basic services**, among them health and educational facilities, including through developing their resilience by 2030
- **G: Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments** to the people by 2030

List of Flagships, Initiatives and Community Activities in the 2020-2022 GEO Work Programme that are relevant to this Initiative and a brief description of the relationship or plans for future engagement / collaboration

As GEO Mountains is thematically focused (on mountains), several disciplinarily and regionally focused GEO entities with the potential to make important contribution to our objectives, and to which we hope to in turn be able to contribute to, have been identified. These include AmeriGEO, GEO Human Planet, GEO Eco, GEO4SDGs, EO4EA, GEO EVs (GEO Community Activity on Essential Variables), and Himalayan GEOSS.

In addition, GEO MOUNTAINS Mountains is developing stronger bonds with GEO BON, having recently been one of few “outside” Initiatives to present at the GEO BON Open Science Meeting in July 2020. GEO Mountains also led a consortium granted funding as part of the 1st GEO BON - Microsoft Joint Call "EBVs on the Cloud” and looks forward to establishing closer ties with GEO BON (especially relevant Working Groups) going forward. GEO MOUNTAINS greatly values the potential for such collaborative working and complementary synergies that participation in GEO brings.

Furthermore, GEO Mountains has confirmed representation in all four GEO Working Groups, with the following individuals listed as members:

- GEO Capacity Development Working Group (CD-WG)
  Yves-Alain Roulet, Switzerland (MeteoSwiss)
- Climate Change Working Group (CC-WG)
  Shawn Marshall, Canada (Environment Canada, University of Calgary and MRI Science Leadership Council member)
- Disaster Risk Reduction Working Group (DRR-WG)
  Carolina Adler, Switzerland (MRI)
- Data Working Group (Data-WG)
  James Thornton, Switzerland (MRI).

Stakeholder Engagement and Capacity Building

Description of key organisations and stakeholders, particularly at the international level, which are relevant to this Initiative (operating environment of the Initiative)

Key international organisations in this domain are:

- The **IPCC.** It is important that GEO Mountains continues to develop links and interactions with members of the IPCC community, including its Lead Authors. This will provide an opportunity for co-designing suitable Initiative outputs and ensuring that they contribute to

systematic, up-to-date global climate change assessment reporting and, ultimately, support policy decisions;

- The **WMO.** Close links already exist, in part through the High Mountain Summit, which took place in October 2019 and sought to address the global paucity of high-elevation meteorological measurements (Carolina Adler was one of the co-chairs of this event). Close interactions with the WMO's Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS) should also developed and maintained. GEO Mountains is also expected to make contributions to the WMO Data Conference, scheduled for November 2020; and

- The United Nations Environment Programme **(UNEP);** a partner in the "Adaptation at Altitude" programme, and a close collaborator on the Convention on Biological Diversity (CBD).

Strategy for engaging stakeholders in the co-development / co-production of the Initiative, including determining user needs, and for building individual, organisational, and institutional capacity to use the outputs of the Initiative

The task listed above involving consultations/surveys are relevant here; the results and outcomes will directly inform decisions related to priorities for functionality of the GEOSS GEO Mountains Community Portal, which datasets and types of datasets to focus on making available first, etc. In addition, task in the current Implementation Plan have been co-developed with the SDC, and there will be able opportunity for other stakeholders to contribute to the priorities of the Initiative moving forward.

Current and/or planned activities to engage stakeholders and/or strengthen individual, organisational and/or institutional capacity and the expected outputs and outcomes of these activities

Due to the situation surrounding the COVID-19 pandemic in 2020, several of the stakeholder engagement activities that were planned to take place in person have been transferred to a virtual format for the foreseeable future. Nevertheless, this should not fundamentally affect the validity of the outcomes or impede progress. Some of the more specific expected outputs and outcomes have been listed already in the relevant section above

Current and/or planned activities to strengthen the capacity of the participants in the Initiative for successful implementation

Please see the relevant section above.

Governance

Description of the governance structure for the Initiative, including the mandates of steering/advisory/management committees, if applicable

GEO Mountains is currently co-led by the Mountain Research Initiative (MRI) and the Italian National Research Council (CNR), and is driven by a core group comprising representatives of the MRI (Switzerland), CNR (Italy), EURAC (Italy), University of Bern (Switzerland), the Global Mountain Biodiversity Assessment (GMBA) network (Switzerland), University of Geneva (Switzerland), University of Portsmouth (UK), University of Reading (UK), CONDESAN (Ecuador/Peru), and USGS (US).

Shortly, the current "core group" shall be formally appointed as the steering committee to guide and advise on matters related to the GEO Mountains Work Programme. Likewise, a registry of "members" (i.e. participants) will be established and, with the appropriate permissions, listed publicly. Members will include representatives of current GEO Members, Participating Organisations, and other representatives of institutions and individuals with the expertise and capacity to contribute to GEO Mountains' objectives.

Description of the roles of key leadership positions

The organisation leading GEO Mountains, the MRI, is an international global change research network focused on mountain regions that consists of more than 10,000 members from 154 countries. The MRI acts as a research and network coordination facility that also engages key actors and stakeholders in mountainous regions themselves. The MRI is supported by the Swiss Academy of Science and is hosted by the Centre for Development an Environment (CDE) at the University of Bern, Switzerland. MRI makes both in-kind contributions to GEO Mountains and, through a contract with the SDC, hosts and finances the Initiative Coordinator / Secretariat. MRI is also a Participating Organisation in GEO and is currently appointed to the GEO Work Programme Board 2019-2022 and is Observer to the GEO Executive Committee 2020-2023.

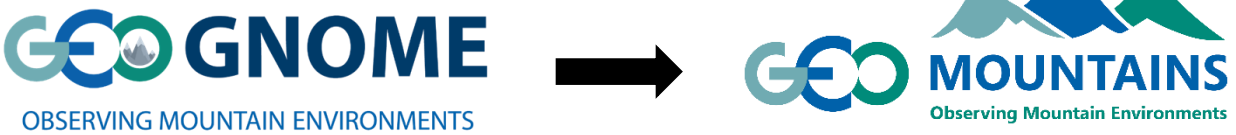
CNR is the co-leading organisation of GEO Mountains. It supports the initiative through the provision of in-kind scientific and research input and expertise, and on projects dealing with high-elevation mountain regions (especially those related to climate change impacts). For example, the NextData project (http://www.nextdataproject.it/), which ended in December 2018, was an Italian national research project devoted to collecting existing data on mountains, implementing measurement networks in remote areas, and developing web portals to access meteo-climatic and atmospheric composition data in mountains. The ECOPOTENTIAL project, meanwhile, (http://www.ecopotential-project.eu/) explored the use of Earth Observations to monitor changes in European ecosystems and support their management, with mountain ecosystems as a specific sub-category.

Strategy for communication with participants and stakeholders, including the main communications channels used

GEO Mountains currently has a simple webpage hosted by the MRI[2] where a general description and updates on new publications and events are posted. A Twitter feed (@GEO_Mountains) and regular updates via the monthly MRI Newsletter also serve to keep the community informed. Other communications currently take place by email. Going forwards, regular webinars will be held, and in the coming months a dedicated mailing list and more extensive website will also be developed, replicating some of the approaches taken by successful GEO Flagships and Initiatives. These aspects related to communications, online presence, and outreach should now be achievable given that the Secretariat/Project Manager is now in position.

In another important change, we will announce the new short name (GEO Mountains) and logo at GEO Week 2020. The new logo allows us to comply with GEO branding guidelines for GEO activities. This launch will hopefully coincide with the new branding webpages to be developed by the GEO Secretariat in the GEO website (to be confirmed). We will, however, maintain the Initiative's formal name; The Global Network for Observations and Information in Mountain Environments.

[2] https://www.mountainresearchinitiative.org/activities/projects/geo-gnome



Monitoring and evaluation activities to be undertaken within the Initiative or required by funders/contributors, including how the effectiveness of user engagement and capacity building activities will be assessed. Include a brief description of how the results of the monitoring and evaluation activities will be shared with the GEO community

To fulfil the requirements of the principal GEO funder during the current Work Programme period (2020-2022), standard monitoring activities will be undertaken. For instance, the hours spent by the coordinator will be reported, and regular updates will be provided on progress with respect to the agreed timeline.

In terms of user engagement, if the capacities of GEOSS allow, the number of dataset downloads from the GEOSS GEO Mountains Community Portal will also be recorded. Depending on technical solution taken with regards to the new GEO Mountains website, we are also hopeful of being able to record and report the number of "hits" (via Google Analytics).

Developing the means to evaluate the effectiveness of capacity building activities still require some consideration but will be addressed before these activities commence.

Towards the end of the period, we will seek feedback on the activities and contributions of the Initiative from the community; this should serve to refine the aims and working methods of the Initiative beyond then.

Risk management: description of the key risks that could prevent the full realization of the intended outcomes of the Initiative and the strategy for managing and/or mitigating the identified risks

Key risks that could affect the project and undermine the achievement of the key objectives include:

- Funding constraints from single source donors. This risk will be mitigated as far as possible by ensuring that both funding sources and inputs/contributions from GEO members and participating organisations are diverse.
- Personnel changes among key leading individuals managing specific tasks/activities, which may undermine continuity. This risk will be mitigated as far as possible by identifying institutional capacities that go beyond individuals (to ensure others can take over tasks, for instance), and by ensuring that adequately detailed documentation of all processes and results/outcomes is made available to all GEO Mountains contributors.
- As with other GEO entities, certain tasks are dependent on the "best efforts" and "good will" of external organisations contributors.

Resources

Summary of the estimated resources required to implement the proposed activities for the 2020-2022 period, including financial, in-kind participation, and other in-kind resources (e.g. data, equipment, computing capacity, office space)

The **MRI** will make in-kind contributions of staff time equivalent to 140,000 CHF/year. In addition, funding from the SDC to the MRI as a contribution to GEO Mountains of 250,000 CHF/year (initially for four years) has enabled the employment of a dedicated GEO Mountains Scientific Officer / Secretariat to coordinate activities, and will additionally support the organisation and participation in various workshops, conferences, etc.

CNR-DTA will make in-kind contributions of staff time equivalent to 15,000 CHF/year. In addition, the EU Horizon 2020-funded project ECOPOTENTIAL, which was coordinated by CNR-DTA, explored the use of Earth observations for the management of ecosystems, with mountain ecosystems as a specific sub-category. It was conceived as an EU contribution to GEO.

The **USGS** Land Change Science Program provided support for specific activities in the past and continues to engage in the development and design of future activities.

Description of the extent to which confirmed contributions to the Initiative meet the identified requirements

With the contributions listed above, the leadership, oversight, and coordination functions of the Initiatives can be met. Note that there remains a certain dependence on participants to voluntary conduct specific activities as in-kind contributions.

Strategy for mobilizing additional resources, either to meet gaps in confirmed contributions or to support future requirements

GEO Mountains is continuing to check to calls of the European Commission's Horizon 2020 programme, not least because some of the projects are flagged as requiring the Initiative's involvement.

Summary of existing commercial sector engagement in the Initiative, if any, and the strategy for engaging commercial sector organisations in future

To date, the Initiative has no active commercial sector engagement, but is open to the prospect.

Technical Synopsis

There is little to add in terms of technical information beyond that which has already been provided above. Essentially, this is due to the broad scope of the scope of the initiative, encompassing as it does an extremely wide range of potentially relevant multi-disciplinary datasets pertaining to mountainous regions globally. Nevertheless, certain aspects are expanded upon somewhat in the sub-sections below.

Description of the principal data sets used by the Initiative (including space-based and in situ observations as well as non-EO data sets, such as socio-economic data), the sources from which the data are obtained, and whether the data are openly and freely accessible

It is impractical at this stage to provide a list of the principal datasets that will be used, since i) we do not intend to take a limited amount of data as input and then generate operational products, for example, but are rather hoping to compile and make available a large amount of diverse data

(i.e. we hope to include all potentially relevant datasets, and ii) the resultant list (alongside the data availability itself) will in fact be a major outcome of the Initiative during the period under consideration. Regarding access, only open and freely available datasets will be generally considered, although if extremely important and unique proprietary datasets are identified then attempts may be made to influence the future data policy of the corresponding data provider organisation.

Description of the key methods used to transform the source data into the products and/or services that are or will be provided, including any workflows or open algorithms

As noted above, at least initially, the Initiative is less concerned with transforming source data into products or services than simply making relevant data and information discoverable, accessible, and usable. That said, it can be envisaged that numerous opportunities will arise for all interested parties, including GEO Mountains members and the mountain research and policy communities more generally, to combine the various datasets that are made available via the initiative, perhaps with numerical models and/or data-driven algorithms, to answer a range of pressing scientific and policy questions. Where such activities, we will of course advocate that workflows and any derived data be shared according to Open Science principles.

Description of any significant scientific or technical issues that need to be resolved by the Initiative and the strategy to address them

The scientific and technical issues that must be overcome are numerous and varied, but include the following:

- Interested parties having the ability, via GEOSS, to clip large global datasets down to only regions of interest (e.g. a specific sub-category of mountain regions).
- Better understanding the complex mechanism and their interactions that could lead to EDCC – the concept that climate change and its impacts might be accelerated/augmented at higher elevations that lower ones in the same climatic regions, with the ultimate goal of generating more reliable future predictions of environmental system change.
- Establishing methodologies to optimise the locations and instrumentation of interdisciplinary high-mountain observatories, including UHOPs (i.e. identify observation strategies that are likely to yield the most informative data and information with respect to their costs (up front plus maintenance).
- Devise improved methods to integrate diverse, often complementary data types, both in situ and remotely sensed, pertaining to physical processes in mountains in order to better understand and predict them under changed conditions
- Identifying the requisite spatio-temporal resolution required for monitoring environmental processes in steep, rugged terrain, given the considerable dynamism and spatial variability in physical phenomena encountered in such settings; and
- Better exploiting available paleo / proxy data to understand the nature of the climate and other physical processes (e.g. floods) in mountainous areas prior to the advent of instrumental and satellite records, and potentially link with numerical models that are employed to make future predictions.

Data Policy

Policy of the Initiative regarding data availability, including degree of adherence to the GEOSS Data Sharing Principles and GEOSS Data Management Principles

The initiative will align fully with the GEOSS Data Sharing and Data Management Principles, although it must be recognised that there is a strong dependence on the position that data providers take in relation to this. As a partner in the World Data System of the International Science Council, MRI is also subscribed to the FAIR principles and open data policies that need to be promoted as part of all MRI activities, including GEO Mountains.

If key datasets are managed by the Initiative, a description of how the data are/will be managed

It is not anticipated that datasets will be explicitly managed by the Initiative. Rather, the intention is to "mirror" the datasets and databases hosted at other locations via the GEOSS GEO Mountains Community Portal.

Strategy for longer-term preservation of data and information produced by the Initiative

If any data is generated or managed by the Initiative, care will be taken to ensure that it is made available at a persistent repository with DOI according to FAIR principles. The precise repository, data formats and suchlike will be agreed with the principal funder (the SDC). Furthermore, once the dedicated GEO Mountains website is created, a dedicated page from which users will be able to download relevant resources (e.g. reports etc.) will be provided.

Tables

Please note the updated version of the following accompanying Table:

A. Individual Participants (new registry updated in September 2020, with 163 individuals listed)

The following tables are yet to be updated, but ale largely already described in this new version of the Implementation Plan:

B. Confirmed Contributions
C. Task / Work Package Structure
D. Deliverables / Milestones

These will be updated and incorporated into this Plan in time for the GEO Plenary 2020.

Annexes

I. Acronyms and abbreviations

II. List of key scientific references describing the basis for the work of the Initiative

III. Brief CV of Project Leader(s)

Annexes

I. Acronyms and abbreviations

EC PHORS	Executive Council Panel of Experts of Polar & High Mountain Observations, Research, & Services
EDCC	Elevation-Dependent Climate Change
EDW	Elevation Dependent Warming
ESA	European Space Agency
EVs	Essential Variables
ECVs	Essential Climate Variables
EBVs	Essential Biodiversity Variables
EO	Earth Observations
EU	European Union
EMVs	Essential Mountain Variables
ESVs	Essential Social Variables
FAO	Food and Agricultural Organization
FOEN	Swiss Federal Office for the Environment
GEO	Group on Earth Observations
GEOSS	GEO Systems of Systems
GMBA	Global Mountain Biodiversity Assessment
GME	Global Mountain Explorer
H2020	Horizon 2020
ICC	Implementation Coordination Committee
ICIMOD	International Centre for Integrated Mountain Development
ICS	International Science Council
IPCC	Intergovernmental Panel on Climate Change
MRI	Mountain Research Initiative
NSF	US National Science Foundation
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
SES	Social-ecological system
SLC	Science Leadership Council (MRI)
SNSF	Swiss National Science Foundation
SROCC	IPCC Special Report on Ocean and Cryosphere
UHOP	Unified High Elevation Observing Platform
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

II. List of key scientific references describing the basis for the Initiative's work

Most recent papers relevant to GEO-GNOME Work Plan:

Adler, C., Palazzi, E., Kulonen, A., Balsiger, J., Colangeli, G., Cripe, D., Forsythe, N., Goss-Durant, G., Guigoz, Y., Krauer, J., Payne, D., Pepin, N., Peralvo, M., Romero, J., Sayre, R., Shahgedanova, M., Weingartner, R. & Zebisch, M. (2018). Monitoring Mountains in a Changing World: New Horizons for the Global Network for Observations and Information on Mountain Environments (GEO-GNOME). *Mountain Research and Development*, 38 (3), 265-269. DOI: 10.1659/mrd-journal-d-8-00065.1

Sayre, R., Frye, C., Karagulle, D., Krauer, J., Breyer, S., Aniello, P., Wright, D. J., Payne, D., Adler, C., Warner, H., Van Sistine, D. Paco & Cress, J. (2018). A New High-Resolution Map of World Mountains and an Online Tool for Visualizing and Comparing Characterizations of Global Mountain Distributions. *Mountain Research and Development*, 38 (3), 240-249. DOI: 10.1659/mrd-journal-d-17-00107.1

Other papers of reference:

Becker, A. and Bugmann, H. (eds.), 2001. Global Change and mountain regions: The Mountain Research Initiative. Implementation Plan, IGBP Report #49 / IHDP Report #13 / GTOS Report #28, IGBP Secretariat, Stockholm, Sweden, 86 pp.

Kapos,V., Rhind, J., Edwards, M., Ravilious, C. and Price, M.F. 2000. Developing a map of the world's mountain forests in Sustainable Mountain Development: A State of Knowledge Report 2000. Wallingford, UK : CAB International

Körner, C., Paulsen, J., Spehn, E. 2011. A definition of mountains and their bioclimatic belts for global comparisons of biodiversity data. Journal of Alpine Botany. DOI 10.1007/s00035-011-0094-4

Ostrom, E. 2009. Social-Ecological Systems:A General Framework for Analyzing Sustainability. Science 325, 419-422. DOI: 10.1126/science.117213

Palazzi E., L. Mortarini, S. Terzago, J. von Hardenberg. (2018). Elevation-dependent warming in global climate model simulations at high spatial resolution, accepted for publication on Climate Dynamics, DOI: 10.1007/s00382-018-4287-z

Pepin, N. and the MRI Elevation Dependant Warming Working Group. 2015. Elevation-Dependent Warming in Mountain Regions of the World. Nature Climate Change 5:424-430. http://dx.doi.org/10.1038/nclimate2563

Renwick, J. 2014. MOUNTerrain: GEWEX Mountainous Terrain Precipitation Project. GEWEX News 24(4):5-6.

Sayre, R., J. Dangermond, C. Frye, R. Vaughan, P. Aniello, S. Breyer, D. Cribbs, D. Hopkins, R. Nauman, W. Derrenbacher, D.Wright, C. Brown, C. Convis, J. Smith, L. Benson, D. Paco VanSistine, H. Warner, J. Cress, J. Danielson, S. Hamann, T. Cecere, A. Reddy,D. Burton, A. Grosse, D. True, M. Metzger, J. Hartmann, N. Moosdorf, H. Durr, M. Paganini, P. DeFourny, O. Arino, S. Maynard, M. Anderson, and P. Comer. 2014. A New Map of Global Ecological Land Units — An Ecophysiographic Stratification Approach. Washington, DC: Association of American Geographers. 46 pages.

III. Brief CV of Project Leader(s)

Carolina Adler

Nationality: Dual national of Chile (birth) and Australia (citizenship); residency in Switzerland.
Mountain Research Initiative, c/o Centre for Development and Environment, University of Bern, Mittelstrasse 43, 3012 Bern, Switzerland.
Contact: carolina.adler@unibe.ch | T: +41 (0)31 631 51 41

Professional Biography

Carolina Adler, a dual national from Chile and Australia, is an Environmental Scientist and Geographer with an international career spanning both research and practice in the public and private sectors. She obtained her PhD at Monash University (Australia) in 2010, focusing on climate change adaptation and relevant policy processes for sustainable development in mountain regions, receiving the Harold D. Lasswell Prize in 2010 for best thesis. Following a passion for mountaineering, she also shares her environmental expertise as a delegate to the International Mountaineering and Climbing Federation (Union International des Associations d'Alpinisme - UIAA) Mountain Protection Commission, assuming the role of President in 2016. Since living in Switzerland, she has been a Research Fellow at the Transdisciplinarity Lab (TdLab), at ETH Zurich in Switzerland, where she focussed her research on participatory approaches, particularly in the assessment and evaluation of such research on questions related to sustainable development in mountains. As Executive Director of the Mountain Research Initiative (MRI), hosted by the Swiss Academies of Arts and Sciences in Bern, she is tasked with coordinating scientific research agendas and support regional and thematic networks on global change research in mountains. She is a Lead Author for the “High Mountains” chapter of the Intergovernmental Panel on Climate Change (IPCC) special report on oceans and cryosphere (SROCC), published in 2019, and serves as Lead Author for Working Group II on Impacts Vulnerability and Adaptation and co-leads the coordination of the Cross-Chapter Paper on ‘Mountains’ for the Sixth Assessment Report (AR6).

Professional Experience

2017- E*xecutive Director*, Mountain Research Initiative, Bern, Switzerland;
2011-17 *Research Associate*, Department of Environment Systems Science, ETH Zurich:
2010-11 - *Research Fellow*, Climate Change Adaptation Program, RMIT University, Australia.
2007-10 - *PhD*, School of Geography & Environmental Science, Monash University, Australia:
2004-10 - *Research Assistant & Lecturer*, Australian School of Business, UNSW, Australia.
2001-04 - *Environmental and Management Consultant*, ENVIRON Australia Pty Ltd, Australia.
1998 - *Ministerial Liaison Officer* – Sydney Water Corporation, Australia.

Academic qualifications

2010 Ph.D. (Geography & Environmental Science), Monash University, Australia.
2009 Graduate Certificate (Research Management), Southern Cross University, Australia.
2003 Graduate Certificate (Environmental Management), UNSW, Australia.
2001 MSc. (Environmental Sciences), Wageningen University, The Netherlands.
1999 BSc. Honours (Geography), UNSW, Australia.

Recent projects, consultancies and practical experience (selection)

2016-2018: Project (main investigator) "*What counts for transferability of knowledge across cases in transdisciplinary research?*" Funded by the Swiss National Science Foundation (SNF), in collaboration with the Centre for Development and Environment of the University of Bern, Switzerland;

2015-2018: Project (collaborator) "*New risks: trade-offs in switching from nuclear electricity to renewables in Switzerland*", funded by the SNF under the National Research Programme "Energy Turnaround" (NRP 70), in collaboration with ETH Climate Policy Group;- · 2016: Consultancy "*Mountain Waste Management Outlook: 'Mountaineering'* ", GRID Arendal and UNEP;

2015-2016: "*Teaching transdisciplinarity for sustainable development*". Funded by Innovedum, (ETH Zurich), in collaboration with Department of Environment Systems Science "Transdisciplinarity Lab" (DUSYS TdLab);

2014-2017: "Moving towards adaptation to climate change: current practices developed in Chile, their usefulness, barriers to implementation, and opportunities for improvement [*Desarrollo e implementación del prototipo de una herramienta participativa para la evaluación de prácticas de adaptación al cambio climático a escala local]".* Funded by CONICYT Chile, in collaboration with the University of Chile;

2014-2015: Consultancy "Evaluation of National Action Plan on Climate Change [*Plan de Acción Nacional de Cambio Climático, PANCC*] 2008-2012 and development of new action plan 2016-2021". Funded by the Environment Ministry, Chile, with University of Chile and partners;

2011-2013: "*Learning from Indigenous Natural Resources Management in the Barmah-Millewa, Australia*". Capacity building, training facilitation, and research on community participation for policy on climate change adaptation;

2010-2011: Principal Field Specialist, capacity building and workshop design and facilitation, "Tourism and Climate Change", Kailash Sacred Landscape Conservation Initiative (Nepal), ICIMOD/GIZ, with RMIT University, Australia.

Publications (recent relevant peer-reviewed publications, as first author)

Adler, C., *et al.* (2018). Monitoring Mountains in a Changing World: New Horizons for the Global Network for Observations and Information on Mountain Environments (GEO-GNOME). *Mountain Research and Development,* 38(3): 265-269.

Adler, C., Hirsch Hadorn, G., Breu, T., Wiesmann, U., Pohl, C. (2017). Conceptualizing the transfer of knowledge across cases in transdisciplinary research. *Sustainability Science*.

Adler, C.E., Aldunce, P., Indvik, K., Bórquez, R., Galaz, V. (2015). "Resilience". In K. Bäckstrand & E. Lövbrand (eds.) *Research Handbook on Climate Governance*. Edward Elgar.

Adler, C.E., & Hirsch Hadorn, G. (2014). The IPCC and treatment of uncertainties: topics and sources of dissensus. *WIREs Climate Change*, 5(5): 663–676.

Adler, C.E., McEvoy, D., Chhetri, P., & Kruk, E. (2013). The role of tourism in a changing climate for conservation and development. A problem-oriented study in the Kailash Sacred Landscape, Nepal. *Policy Sciences*, 46(2): 161-178.

Roman, C.E., Lynch, A.H., & Dominey-Howes, D. (2011). What is the goal? Framing the climate change adaptation question through a problem-oriented approach. *Weather, Climate & Society*, 3(1): 16-30.

Publications (other top 5 relevant peer-reviewed contributions)

Lillo-Ortega, G., Aldunce, P., Adler, C., Vidal, M., & Rojas, M. (2018). On the evaluation of adaptation practices: a transdisciplinary exploration of drought measures in Chile. *Sustainability Science;*

Diaz, P., Adler, C., Patt, A. (2017). Do stakeholders' perspectives on renewable energy infrastructure pose a risk to energy policy implementation? A case of a hydropower plant in Switzerland. *Energy Policy;*

Patterson, J., Schulz, K., Vervoort, J., van der Hel, S., Widerberg, O., Adler, C., Hurlbert, M., Anderton, K., Sethi, M., & Barau, A. (2017). Exploring the governance and politics of transformations towards sustainability. *Environmental Innovation and Societal Transitions*, 24: 1-16

Borquez, R., Aldunce, P., Adler, C. (2017). Resilience to climate change: from theory to practice through co-production of knowledge in Chile. *Sustainability Science*, 12(1): 163-176.

Sword-Daniels, V., Eriksen, C., Hudson-Doyle, E., Alaniz, R., Adler, C., Schenk, T., & Vallance, S. (2016). Embodied uncertainty: living with complexity and natural hazards. *Journal of Risk Research,;*

Professional Services (selected)

2018: Lead Author IPCC AR6 WGII “Chapter 17: Decision-making options for managing risk” and Co-Lead Cross-Chapter Paper on Mountains;

UNISDR Global Platform 2019: member of Organizing Team for High Level Dialogue on Achieving the SDGs through Climate and Disasters

2017: Lead Author IPCC Special Report on Oceans and Cryosphere in Changing Climate (SROCC), ‘High Mountains’;

Co-Editor for Special Issue in the journal *Regional Environmental Change* titled “Impacts of climate change on the high-mountain cryosphere and associated responses”;

2016: New Directions Team (Contributing Author), Earth System Governance Project;

2016: Member -IUCN World Commission on Protected Areas (WCPA) Tourism and Protected Areas Specialist Group;

2015: Community of Practice Moderator (facilitating a dialogue between science and policy), Global Environment Outlook (GEO-6) Assessment, UNEP;

2014: Steering Committee and Chair (Curriculum Work Group) - Policy Sciences Academy, Society of Policy Scientists;

2012: Member and President (since 2016), Mountain Protection Commission, UIAA;

2011: External Reviewer, Scientific Capacity Building and Enhancement for Sustainable Development, Asia-Pacific Network for Global Change Research;

2011: Fellow & Europe Regional Coordinator, Earth System Governance Project, Future Earth.

Other Memberships and Networks (selected)

Society of Policy Scientists (invited), member of the Executive Council; International Society for the Scientific Study of Subjectivity (Q-methodology); UZH/ETH Zürich Network for Interdisciplinary Climate Change Research; Mountain Research Initiative; ProClim-Swiss Forum for Climate and Global Change.

Prizes and acknowledgements

PhD thesis awarded the 2010 *Harold D. Lasswell Prize* by the Society of Policy Scientists Inc. in the USA, for best dissertation in the field of public policy on climate change adaptation.

Appointed ISSC World Social Sciences Fellow on Risk Interpretation and Action (2013).

Elisa Palazzi

Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR)
ORCID ID: orcid.org/0000-0003-1683-5267

Education

June 2003: Laurea (degree) in Physics, Dept. of Physics - University of Bologna, Italy (110/110L), on the development of the Radiative Transfer Model "PROMSAR" (Processing of Multiple Scattered Atmospheric Radiation) for the simulation of radiation transport in the Earth's atmosphere.

June 2008: PhD in Physical Modeling for Environmental Protection, Dept. of Earth Sciences – University of Bologna, Italy, on the retrieval of the vertical profile of atmospheric constituents in the lower troposphere from remote sensing measurements performed using the Multiple-AXis Differential Optical Absorption Spectroscopy (MAX-DOAS) technique

Employment

2008-2009: Postdoctoral fellow at ISAC-CNR, Bologna, Italy. Diagnostics of mixing and transport mechanisms in the tropical tropopause layer (TTL) and across other dynamical barriers in the atmosphere (subtropical barrier and polar vortex barrier).

2009-2011: Short-term researcher at ISAC-CNR, Bologna, funded by the European Space Agency (ESA). Principal Investigator of the ESA-funded project "DIMITRI (Diagnostics of Mixing and Transport in the Atmospheric Interfaces)", on the use of satellite data to study transport and mixing processes in the atmosphere and across dynamical barriers

Since October 2011: Researcher at ISAC-CNR, Torino. Study of the climate system processes and interactions, with a particular focus on the hydrological cycle in the mountain regions, climate change and its impacts in the high-altitude cryosphere system and study of the elevation-dependent warming (amplification of warming with elevation) and its driving mechanisms.

Specific scientific interests

My research topics in the recent years have been mostly addressed to the study of the climate variability and changes in the mountain regions, with a particular focus on the changes in the hydrological cycle (including the analysis of precipitation, snow, and temperature).The specific activities include:

1. Study of the climate system and Earth-System processes, with a focus on the current and future evolution of the hydrological cycle in mountain regions. In particular, analysis of the precipitation climatology, characteristics, and changes in the Alpine region and in the Karakoram-Himalaya-Tibetan Plateau using in-situ observations, observation-based gridded datasets, satellite and reanalysis data, and the output of regional and global climate models (e.g. from the CORDEX and CMIP5 experiments, and the EC-Earth global model run at ISAC-CNR).

2. Study of elevation-dependent warming (EDW), the mechanism by which mountain regions are experiencing more rapid and intense warming than the surrounding areas or compared to the global mean, similar to the Arctic (or polar) amplification. Analysis of the factors driving EDW in

different mountain regions of the world (in particular in the Alpine Region, the Rocky mountains and the Himalayas-Tibetan Plateau), and in the different seasons, using observations and climate model simulations.

3. Downscaling of climate scenarios: in particular, application of the stochastic rainfall downscaling procedure called RainFARM, developed at ISAC-CNR, for the generation of ensembles of high-resolution precipitation fields from coarser datasets. Recent advancements include the implementation in the model of an orographic correction accounting for the dependence of precipitation on orography.

4. Analysis of climate change hot-spots, i.e. geographical regions which display the largest variations in multiple statistics (mean, variability, and extremes) of key climate variables (e.g., temperature and precipitation) in historical data and future scenarios. This also includes the investigation of climatic and environmental changes in specific protected areas.

5. Use of earth system models of intermediate complexity to perform equilibrium and transient climate sensitivity experiments; analysis of possible tipping points in the climate system.

6. Study of the earth critical zone (ECZ) in mountain areas, through in-situ campaigns measuring CO2 fluxes and exchange between the soil and the atmosphere and defining models for future changes in the ECZ characteristics.

Relevant publications since 2013

- Lefebvre, G., L. Redmond, C. Germain, E. Palazzi, S. Terzago, L. Willm, B. Poulin, Predicting the vulnerability of seasonally-flooded wetlands to climate change across the Mediterranean Basin, Science of The Total Environment, Volume 692, 546-555, 2019.
- Hoke, W., Swierczynski, T., Braesicke, P., Lochte, K., Shaffrey, L., Drews, M., Gregow, H., Ludwig, R., Nilsen, J. E. Ø., Palazzi, E., Sannino, G., Smedsrud, L. H., and ECRA network: The European Climate Research Alliance (ECRA): Collaboration from bottom-up, Adv. Geosci., 46, 1-10, https://doi.org/10.5194/adgeo-46-1-2019, 2019.
- Adler C., E Palazzi, A Kulonen, J Balsiger, G Colangeli, D Cripe, N Forsythe, G Goss-Durant, Y Guigoz, J Krauer, D Payne, N Pepin, M Peralvo, J Romero, R Sayre, M Shahgedanova, R Weingartner and M Zebisch, "Monitoring Mountains in a Changing World: New Horizons for the Global Network for Observations and Information on Mountain Environments (GEO-GNOME)," Mountain Research and Development 38(3), (1 August 2018). https://doi.org/10.1659/MRD-JOURNAL-D-8-00065.1
- Terzago, S., Palazzi, E., and von Hardenberg, J.: Stochastic downscaling of precipitation in complex orography: a simple method to reproduce a realistic fine-scale climatology, Nat. Hazards Earth Syst. Sci., 18, 2825-2840, https://doi.org/10.5194/nhess-18-2825-2018, 2018.
- Palazzi E., L. Mortarini, S. Terzago, J. von Hardenberg. Elevation-dependent warming in global climate model simulations at high spatial resolution, accepted for publication on Climate Dynamics, DOI: 10.1007/s00382-018-4287-z, 2018
- Pasetto D., S. Arenas-Castro, J. Bustamante, R. Casagrandi, N. Chrysoulakis, A. F. Cord, A. Dittrich, C. Domingo-Marimon, G. El Serafy, A. Karnieli, G. A. Kordela, I. Manakos, L. Mari, A. Monteiro, E. Palazzi, D. Poursanidis, A. Rinaldo, S. Terzago, A. Ziemba, G. Ziv. Integration of satellite remote sensing data in ecosystem modelling at local scales:

practices and trends, Accepted for publication on Methods in Ecology and Evolution, doi: 10.1111/2041-210X.13018, 2018

- Massimiliano Alvioli, Massimo Melillo, Fausto Guzzetti, Mauro Rossi, Elisa Palazzi, Jost von Hardenberg, Maria Teresa Brunetti, Silvia Peruccacci, Implications of climate change on landslide hazard in Central Italy, Science of The Total Environment, 630, 1528-1543, https://doi.org/10.1016/j.scitotenv.2018.02.315, 2018.
- Terzago, S; J von Hardenberg; E. Palazzi, A. Provenzale, Snow water equivalent in the Alps as seen by gridded data sets, CMIP5 and CORDEX climate models, The Cryosphere, 11, 1625-1645, https://doi.org/10.5194/tc-11-1625-2017, 2017.
- Palazzi E., Filippi L., von Hardenberg J., Insights into elevation-dependent warming in the Tibetan Plateau-Himalayas from CMIP5 model simulations, Clim. Dyn., 48 (11-12), 3991-4008, 2017.
- Palazzi E., Provenzale A., Water in the climate system, in “The Fluid Dynamics of Climate”, pp: 161-182, Springer Vienna, 2016.
- Norris, J., Carvalho, L.M.V., Jones, C. Cannon, F., Bookhagen, B., Palazzi, E., Tahir A. A., The spatiotemporal variability of precipitation over the Himalaya: evaluation of one-year WRF model simulation, Clim Dyn., doi:10.1007/s00382-016-3414-y, 2016.
- Pepin, N., Bradley, R.S., Diaz, H.F., Baraer, M., Caceres, E.B., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M.Z., Liu, X.D., Miller, J.R., Ning, L., Ohmura, A., Palazzi, E., Rangwala, I., Schöner, W., Severskiy, I., Shahgedanova, M., Wang, M.B., Williamson, S.N., Yang, D.Q., Elevation- dependent warming in mountain regions of the world (2015) Nature Climate Change, 5 (5), pp. 424-430. DOI: 10.1038/nclimate2563, 2015.
- Turco, M., E. Palazzi, J. von Hardenberg, and A. Provenzale, Observed climate change hotspots. Geophys. Res. Lett., 42, 3521–3528. doi: 10.1002/2015GL063891, 2015
- Soncini, A., Bocchiola, D., Confortola, G., Bianchi, A., Rosso, R., Mayer, C., Lambrecht, A., Palazzi, E., Smiraglia, C., Diolaiuti, G. Future hydrological regimes in the upper Indus basin: A case study from a high-altitude glacierized catchment, Journal of Hydrometeorology, 16 (1), pp. 306-326. DOI: 10.1175/JHM-D-14-0043.1, 2015.
- Palazzi, E., Von Hardenberg, J., Terzago, S., Provenzale, A. Precipitation in the Karakoram- Himalaya: a CMIP5 view, Climate Dynamics, Vol 45, pp. 21-45, DOI: 10.1007/s00382-014- 2341-z, 2015.
- Filippi, L., Palazzi, E., Von Hardenberg, J., Provenzale, A. Multidecadal variations in the relationship between the NAO and winter precipitation in the Hindu Kush-Karakoram, Journal of Climate, 27 (20), pp. 7890-7902. DOI: 10.1175/JCLI-D-14-00286.1, 2014.
- D'Onofrio, D., Palazzi, E., Von Hardenberg, J., Provenzale, A., Calmanti, S. Stochastic rainfall downscaling of climate models, Journal of Hydrometeorology, 15 (2), pp. 830-843. DOI: 10.1175/JHM-D-13-096.1, 2014.
- Terzago, S., von Hardenberg, J., Palazzi, E., Provenzale, A. Snowpack changes in the Hindu Kush- Karakoram-Himalaya from CMIP5 global climate models, Journal of Hydrometeorology, 15 (6), pp. 2293-2313. DOI: 10.1175/JHM-D-13-0196.1, 2014.
- Garcia-Aristizabal, A., Bucchignani, E., Palazzi, E., D’Onofrio, D., Gasparini, P., Marzocchi, W. Analysis of non-stationary climate-related extreme events considering

climate change scenarios: an application for multi-hazard assessment in the Dar es Salaam region, Tanzania, Natural Hazards, 75 (1), pp. 289-320. DOI: 10.1007/s11069-014-1324-z, 2014.

- Palazzi, E., Von Hardenberg, J., Provenzale, A. Precipitation in the hindu-kush karakoram himalaya: Observations and future scenarios, Journal of Geophysical Research: Atmospheres, 118 (1), pp. 85-100. DOI: 10.1029/2012JD018697, 2013.

Synergistic Activities

- Teaching: Course “Physics of Climate”, University of Turin, Department of Physics, since 2013 (CFU 6); Teaching at the “Scuola di Studi Superiori” of the University of Turin Ferdinando Rossi (SSST), an institution of excellence and higher education for University Studies, since 2012; Series of seminars at the University of Pisa, within the course: “Meteoclimatology”, since 2018

- Teaching experiences in summer schools: 1) Alpine Summer School on "Fundamental processes in geophysical fluid dynamics and the climate system", Valsavarenche, Valle d’Aosta, Italy (2012, 2013); 2) ENVIMAT International Summer School on Environment-Material Interaction (2014, 2015)

- Reviewer for the following journals: Climatic Change, Journal of Geophysical Research, Climate Dynamics, Nature Geoscience, Mountain Research and Development, Atmospheric Measurement Techniques, Earth System Dynamics, International Journal of Water Resources Development, Science of the Total Environment, International Journal of Climatology, Climate.

Relevant Projects

1) Co-coordinator from November 2011 to 2013 of the Italian PAPRIKA-Karakorum project focused on the evolution of water resources in the Kararoram/Himalaya region.

2) Coordinator of Subproject 2 on future projections and responsible of WP2.6 in the Italian NextData project (A national system for the retrieval, storage, access and diffusion of environmental and climate data from mountain and marine areas, 2012-2018) - ended December 2018.

4) Participant to the H2020 EU projects ECOPOTENTIAL (Improving future ecosystem benefits through earth observations, Task Leader of the Task on downscaling and future scenarios) and CRESCENDO (COORDINATED RESEARCH IN EARTH SYSTEMS AND CLIMATE: EXPERIMENTS, KNOWLEDGE, DISSEMINATION AND OUTREACH, participant) - ongoing.

3) Partner of the project “Innovative methods for water resources management under hydro-climatic uncertainty scenarios”, PRIN 2010-2011 (D.M. 1152/ric del 27/12/2011) - closed

Assignments

1) Co-lead, along with the Mountain Research Initiative (MRI), of GEO Mountains – The Global Network for Observations and Information in Mountain Environments; a Group on Earth Observations (GEO) Initiative.

2) Member of the Working Group for Italy in the Belmont Forum (International Group of Funding Agencies) and GPC (Group of Program Coordinators) member of the Belmont Collaborative Research Action (CRA) “Mountains as Sentinels of Change”

3) Co-coordinator of the European Climate Research Alliance (ECRA) Collaborative Programme “Changes in the Hydrological Cycle”.

5) Member, since May 2018, of the Italian working Group on “Dynamics of the Paleoclimate” within CNR.

6) Since 2014 to 2017 in the Scientific Council of the Italian-French Alpine summer school on "Fundamental processes in geophysical fluid dynamics and the climate system" organized each year by the Institute of Atmospheric Sciences and Climate (ISAC) - CNR (Turin, Italy) and by the Centre national de la recherche scientifique (France).