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Monitoring Mountains in a Changing World: New Horizons for the Global Network for Observations and Information on Mountain Environments (GEO-GNOME)

MOUNTAIN RESEARCH INITIATIVE

Mountains are globally distributed environments that provide significant societal benefits, a function that is increasingly compromised by climatic change, environmental stress, political and socioeconomic transformations, and unsustainable use of natural resources. Gaps in our understanding of these processes and their interactions limit our capacity to inform decisions, where both generalities of mountain regions (eg climate processes) and specificities (eg context-specific manifestations of climate risks) matter. The Global Network for Observations and Information on Mountain Environments (GEO-GNOME), a Group on Earth Observations initiative, aims to fill these gaps through accessible Earth Observation (EO) as well as in-situ data and information on global change drivers, conditions, and trends. A workshop convened by the Mountain Research Initiative (MRI) revised GEO-GNOME's work plan, galvanizing a network that promotes relevant monitoring of global change in mountains and is responsive to the integrated knowledge needs of policy, research, and management.

Background

Established in 2005, the Group on Earth Observations (GEO) is a partnership of 105 national governments and 125 participating organizations. It works to ensure that decisions and actions for the benefit of humankind are informed by coordinated, comprehensive, and sustained Earth Observation (EO) information and services (GEO 2018). Within the scope of GEO's work, the Mountain Research Initiative (MRI) fulfills 3 key roles: as a participating organization, as member of the GEO program board, and as colead of the Global Network for Observations and Information on Mountain Environments (GEO-GNOME), a GEO initiative.

As a GEO initiative in the current GEO Work Program 2017–2019, GEO-GNOME supports the GEO vision and aims at facilitating access to diverse sources of mountain-specific EO data, as well as in-situ data and other forms of information. Through this facilitation, its aims are twofold. On the one hand, it seeks to support monitoring of global change in mountains, for research that enhances an understanding of drivers, conditions, and trends in biophysical and socioeconomic processes of change at different temporal and spatial scales. On the other, it supports decisions for policy and management. GEO-GNOME treats mountains as complex socioecological systems where dynamic interactions occur. To this end, the ability to integrate biophysical and socioeconomic data and information is, ultimately, its desired outcome and overarching purpose.

In 2017, GEO-GNOME launched an online visualization tool for spatial delineation of mountains according to different mountain definitions (Sayre et al 2018, in this issue), thereby completing its first task as depicted in the original GEO-GNOME work plan. In the same year, the GEO-GNOME coleads, MRI in Switzerland and the Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR) in Italy, revised the original GEO-GNOME work plan to redefine time frames and align tasks with available human and other resources. The revised work plan was submitted to the GEO Secretariat in July 2017 and subsequently approved at the GEO plenary meeting in Washington DC in October 2017, where GEO-GNOME was presented at the UNEP-chaired side event "Earth Observation for Achieving and Monitoring Mountain-Related SDGs: ECOPOTENTIAL, GEO-GNOME, and GEO-ECO."

However, to bring the work plan to fruition during 2018–2019, the GEO-GNOME coleads, in collaboration with the Institute for Earth Observation at EURAC Research, Italy, convened the "GEO-GNOME Status and Scoping Workshop," hosted by MRI and held on 23–25 May 2018, in Bern, Switzerland (MRI 2018). The main objective of the workshop was to review the GEO-GNOME work plan with active participants of the GEO-GNOME effort, as well as other key experts and knowledge holders. The workshop provided an opportunity to review achievements to date and reflect on the role of GEO-GNOME in providing policy-relevant information on mountain regions and global policy contexts where GEO has identified a priority, such as the Paris Agreement (UNFCCC 2015), Sendai Framework for Disaster Risk Reduction (UNISDR 2015), and 2030 Agenda (UN 2015). Workshop participants also embraced the opportunity to identify new research

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prospects that support observations in mountains, a continuous process that MRI steers and mobilizes.

Workshop format

The workshop program was structured around 2 half days and a full day. The first afternoon served to set the scene, and to take stock of and reflect on mountain observations, with diverse expert inputs. Douglas Cripe (GEO Secretariat) updated participants on the large-scale aims and initiatives of the GEO work program and the role of GEO-GNOME in this constellation. Davnah Payne (Global Mountain Biodiversity Assessment [GMBA]) spoke on achievements in the delineation of mountain areas using examples from the GMBA. Roger Sayre (US Geological Survey [USGS]) then presented the Global Mountain Explorer (GME) (GEO-GNOME 2017), a mountain visualization tool and key GEO-GNOME output (Sayre et al 2018, in this issue). Guido Colangeli (European Space Agency [ESA]) guided participants through the potential and functions of the Global Earth Observation System of Systems (GEOSS 2018) data portal and plans for the development of the GEO-GNOME GEOSS portal, which is currently in beta and expected to be launched in time for the next GEO plenary meeting in Kyoto, Japan, in October 2018.

Nicholas Pepin (University of Portsmouth) followed with scientific advances and open questions that remain since a key scientific publication on elevation-dependent warming (EDW) in mountain regions (Mountain Research Initiative EDW Working Group 2015), which was a product of an MRI-supported workshop. He also discussed the global need for a coordinated network of in-situ data over elevation gradients as a means to complement data and information from EO sources. Finally, Marc Zebisch (EURAC Research) provided a detailed and updated account on the opportunities and challenges for EO in the mountain context, providing examples from the European Alps. For the remainder of the workshop, participants discussed these inputs in relation to the GEO-GNOME work plan and the science of mountain observations more generally, including proposed revisions to specify and identify future tasks for GEO-GNOME and new research prospects.

Deliberations on EO infrastructures, information, and science of mountain observations

The discussion that ensued during the second day of the workshop centered on 2 different but complementary topics that served to justify a rationale for a new work plan for GEO-GNOME (day 3). These topics were: (1) EO infrastructures and information, and debating the demand for and supply of data, information, and knowledge needs from a user perspective; and (2) science of mountain observation data and processes.

EO infrastructure and information

It was deemed important to formulate the storylines that clarify the need for, and relevance and purpose of, types of mountain observation data and information. Three examples served to illustrate different data requirement scenarios. The first example illustrated how governmental and scientific stakeholders in the Caucasus mountain region express a need for a spatial and temporal data infrastructure for risk management (Scientific Network for the Caucasus Mountain Region 2017). The Sendai Framework on Disaster Risk Reduction was likely one factor motivating these demands at national and regional levels, alongside new national policy mandates and regional donor initiatives. Therefore, a good starting point is to understand the types and formats of data and information required to address reporting needs under specific policy frameworks.

The second example referred to a pilot study conducted by MRI and the Centre for Development and Environment (CDE) for Promoting Sustainable Mountain Development for Global Change (SMD4GC) program (SDC 2017). The key aim of this pilot study was to assess the feasibility of reporting globally on sustainable development in mountains using the Sustainable Development Goals (SDGs) framework, which would depend on the availability of mountain-disaggregated data and accurate delineation of mountain regions (Bracher et al 2018). The GME was used to visualize and compare the extent of mountain surface area covered by different mountain definitions in specific contexts, enabling a comparison of results that each definition would have for reporting on the SDGs. The visualizations also clarified the type and format of data needed, and the functions that a GEOSS portal for GEO-GNOME should provide to export these visualizations for reporting purposes. On the SDGs, workshop participants also reflected on the need to explore other possible mountain-specific sustainable development targets and indicators that may not be captured within the current SDG framework.

The third storyline centered on the needs of the research community to produce the types of review and synthesis publications that are useful in the context of global assessments, such as those conducted by the Intergovernmental Panel on Climate Change (IPCC). Access to high-quality global data is often cited as a limitation, more specifically, a lack of density and quality with some in-situ and/or EO data used to conduct analyses on essential climate variables (ECVs) in mountains. This issue also points to certain mountain regions where monitoring capacity is lacking

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or that global assessments fail to include. Here, participants suggested that GEO-GNOME play a significant role in helping address these gaps.

A key conclusion of this discussion round centered on the need to update current contacts and identify other initiatives and networks that produce and provide data and information on these and other examples of policy knowledge needs. Connecting and integrating these efforts would be a cost-effective way to make data discoverable and accessible, as well as encourage collaborations.

Science of mountain observation

Discussion took place on the need to better understand key change processes and mechanisms in mountain environments such as climate change. This requires measurement data (in-situ and EO) and model simulations, bearing in mind their associated uncertainties. There are direct research needs for improving and homogenizing observations, as well as for a better design of metadata on existing observations, to ensure realistic parameterization schemes and thus model outputs. Participants also suggested a role for GEO-GNOME in facilitating meaningful exchange and collaboration between field scientists and modelers, thereby advancing the science of monitoring and observations in mountains.

A transect network of in-situ climate data over elevation gradients (Unified High Elevation Observing Platform [UHOP]) was suggested as a means to better understand the processes of elevation-dependent climate change (EDCC). This would build on the scientific work on EDW and produce a standard way of observing change in mountains. Such transect data would also serve in combining and standardizing EO data with in-situ climate data. Including data on other environmental processes, in addition to climate, would further strengthen GEO-GNOME's ability to provide knowledge for management problems, for instance, related to disaster risk reduction. Participants agreed that since climate is a key driver of environmental change in mountains, monitoring and collecting data on ECVs in the mountain context are important efforts. However, the type of climate data collected, catalogued, and made accessible has to be relevant and combined to serve a variety of end users' information needs and purposes, addressing questions and queries from different fields or problem types. Examples discussed at the workshop included natural hazards, water resources, and ecosystem accounting.

The planned network of transect data could also serve as a suitable template approach to combine other mountain-relevant parameters and variables (eg ecosystems and essential biodiversity variables [EBVs]). Defining "essential mountain variables" (a possible combination of ECVs and EBVs) would be useful in the development of sound protocols for collecting and combining these data. Furthermore, the template would also help structure and facilitate access to, and integration with, key socioeconomic data and information on societal change in mountains (eg demographics, migration, governance, land-use change), including the potential to capitalize on citizen science data.

Key outcomes for GEO-GNOME

Based on the output and ideas from these discussions, the participants defined a revised GEO-GNOME work plan, while examining prospects for the subsequent GEO work program 2020–2023. The objectives and tasks of the revised GEO-GNOME work plan are summarized in Figure 1, with a detailed document to be prepared and made available in time for the GEO plenary meeting in October 2018.

Outlook: Mountain observations for society

The insightful workshop discussions generated a new and focused GEO-GNOME work plan that streamlines objectives and tasks. Participants also considered it important to align tasks with limited resources and capacities available from GEO-GNOME collaborators, recognizing the great potential for joint delivery, which could achieve far more than anyone could individually. At the same time, securing resources and delivery capacity are essential for the realization of the desired products, outputs, and information services to be made discoverable and accessible for policy, management, and research.

The planned workshops to be organized by the GEO-GNOME coleaders (tasks 3.2 and 3.3) were designed to generally serve the development of content and processes in GEO-GNOME and mountain observations. However, they also serve as a platform to identify and secure the required resources to sustain this large collaborative effort into the 2020–2023 GEO work program. The great spirit and collegiality experienced at this workshop, not to mention the collective desire to advance mountain observations in a meaningful way for society, are testaments to the types of efforts that need to be supported, precisely at a time of rapid global change that demands new capacities to respond to these challenges.

The workshop has paved a way towards the desired outcome and overarching purpose for GEO-GNOME, mobilizing a collaborative community to make key data and information accessible to monitor and observe processes of global change in mountain regions, and to assist in the decisions for policy, management, and investment in mountains and society. For MRI, the workshop also sharpened a strategy and focus to ensure the mountain

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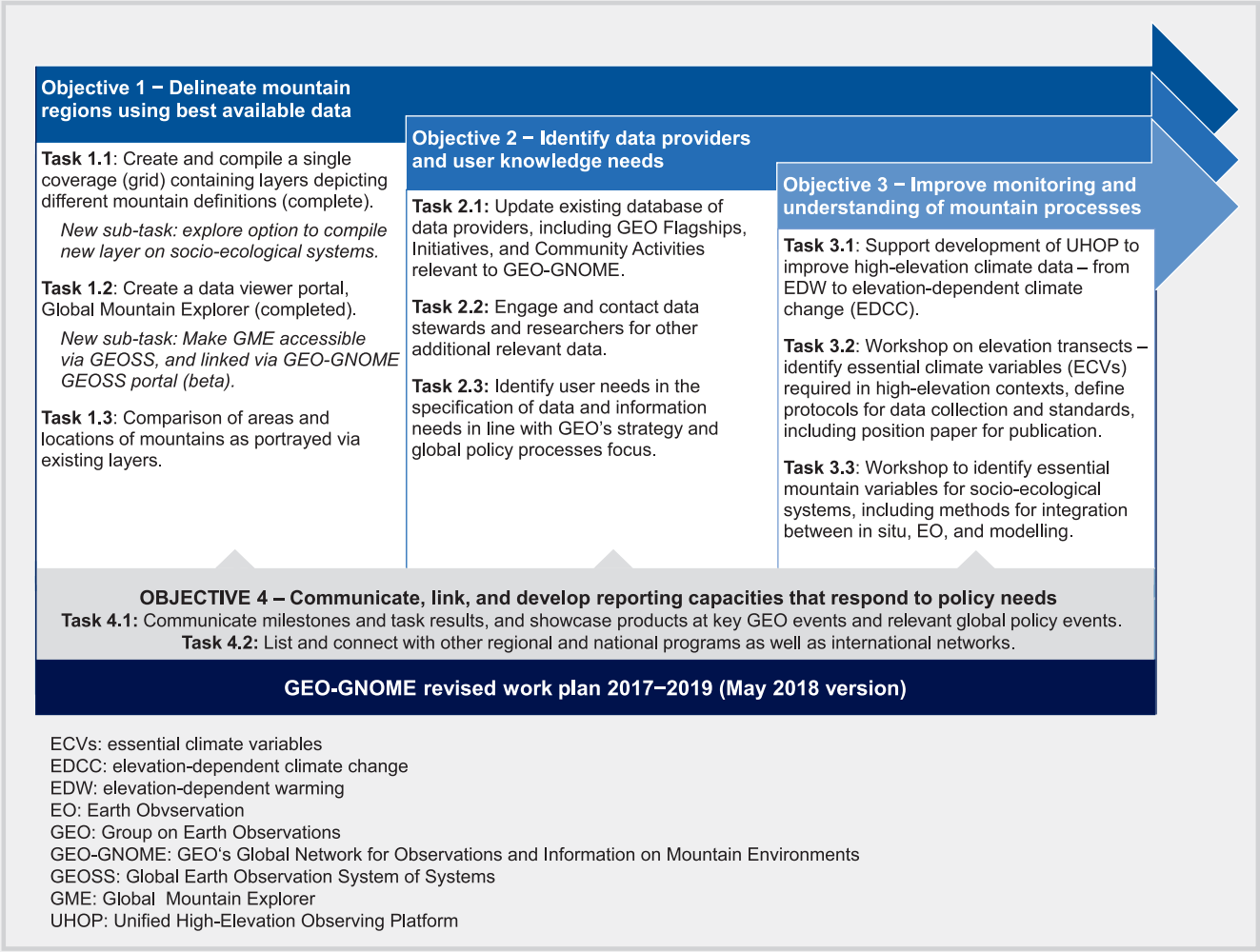
FIGURE 1 Overview of key objectives and tasks in the new revised GEO-GNOME work plan 2018–2019 (May 2018 version).



ECVs: essential climate variables
EDCC: elevation-dependent climate change
EDW: elevation-dependent warming
EO: Earth Obvservation
GEO: Group on Earth Observations
GEO-GNOME: GEO's Global Network for Observations and Information on Mountain Environments
GEOSS: Global Earth Observation System of Systems
GME: Global Mountain Explorer
UHOP: Unified High-Elevation Observing Platform

research community participates and contributes to this endeavor.

For more information on GEO and the GEO work program, including GEO-GNOME, see https://www.earthobservations.org.

WEBSITES

Mountain Research Initiative (MRI): www.mountainresearchinitiative.org
Group on Earth Observations: www.earthobservations.org
Global Network for Observations and Information on Mountain Environments (GEO-GNOME): www.earthobservations.org/activity.php?id=117

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