20 YEARS

OF MAKING CONNECTIONS
FOR OUR CHANGING
MOUNTAINS

MOUNTAIN RESEARCH INITIATIVE

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20 YEARS
MOUNTAIN RESEARCH INITIATIVE

2022
International Year of
SUSTAINABLE MOUNTAIN DEVELOPMENT

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WELCOME

In 2021, the Mountain Research Initiative (MRI) Coordination Office celebrated its 20th anniversary. By the standards of the ancient mountains that inspire and connect the work of the thousands of individuals who make up the MRI network, this two-decade milestone may seem insignificant. During this time, however, the MRI has achieved a great deal; testament to the efforts of mountain researchers worldwide who have come together across borders and disciplines to advance our understanding of global change in mountain social-ecological systems.

Through the convening role of the MRI Coordination Office, our network has instigated numerous successful collaborations. In doing so, we have not only added to a growing body of important scientific knowledge, but also raised the profile of mountains on the international stage, and integrated and synthesized the results of our research to inform key stakeholders of their implications for policy and practice. Perhaps the best example of our network connecting mountain science with policy is the significant contribution we have made to global assessments, such as the recent Intergovernmental Panel on Climate Change reports. Together, we have worked to ensure that mountains and mountain people have a voice in these important, policy-relevant documents – while also making efforts to build capacity among early-career researchers to support their participation in these processes (more on page 16). Through the MRI co-led GEO Mountains initiative, we also continue to open up access to mountain data for researchers and decision-makers alike, building on the strong foundations laid by the Global Network of Mountain Observatories and the many other activities undertaken by the research community over the years that have made such vital contributions to improving the data landscape across mountain regions (more on page 18).

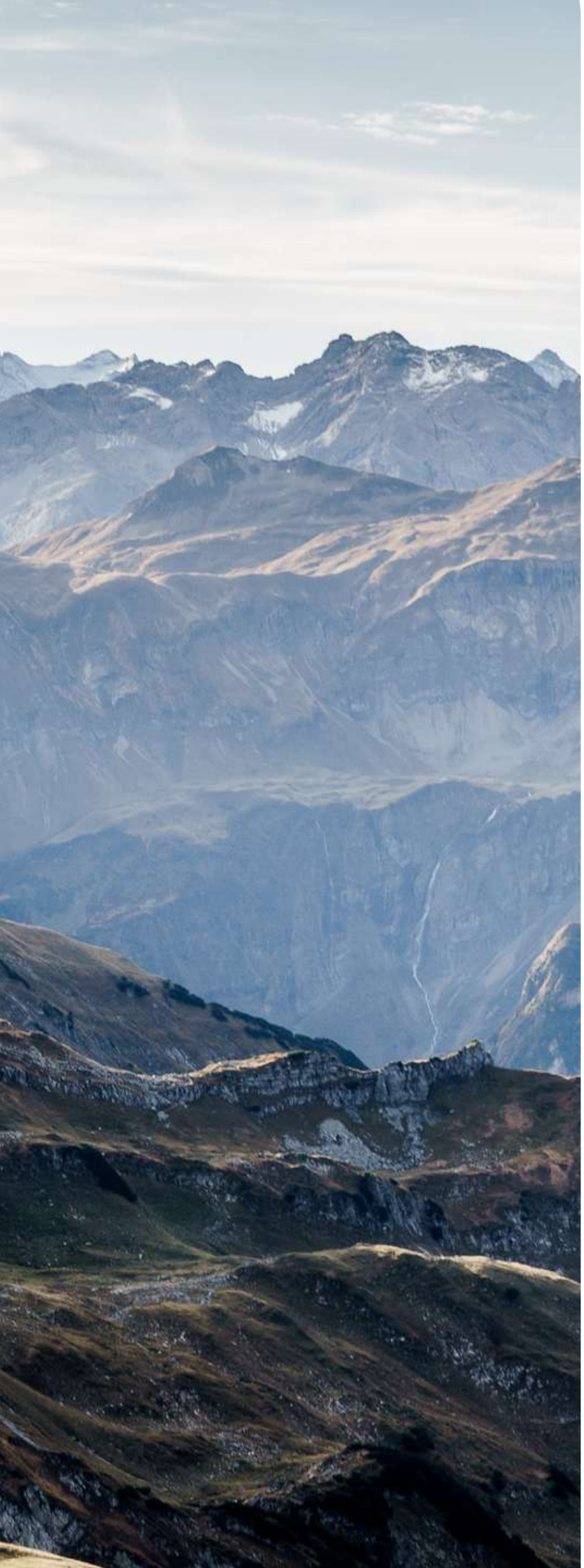
And our community-led Working Groups and Synthesis Workshops have also resulted in important outputs. These include the development of valuable frameworks – such as to help evaluate how Nature-based Solutions may contribute to transformative change, and to link alpine-treeline ecotone patterns to underlying processes – and the publication of the much-cited article 'Elevation-dependent warming in mountain regions of the world' in *Nature Climate Change* in 2015 (more on page 23).

Taking stock of these successes, this publication celebrates the collective effort that has made the MRI what it is today. It showcases just a few of the many key contributions made by the MRI community, and invites those that have been part of our 20-year history to share their reflections on the past, present, and future of our network. Of course, our work together is by no means complete. Global change is occurring at pace, and mountain regions, the remarkable biodiversity they host, and the millions of people that call the mountains home are particularly exposed to its impacts. Communities living in and around mountains are already bearing witness to rapid changes in our cryosphere (more on page 31). They are also facing cascading risks and other emerging challenges, and finding new and innovative ways to adapt to them (more on page 45).

As we look to the future, there are clearly important challenges ahead with significant and far-reaching implications. We hope that, with the ongoing active and engaged participation of the global mountain research community, the MRI will evolve to meet them – and continue making connections for our changing mountains.

With very best regards,

DR. CAROLINA ADLER,
MRI EXECUTIVE DIRECTOR



"Scientists and practitioners devoting their work to mountains are tied together by a strong sense of identity and belonging. They are all part of a larger family: the MRI community. Ancient, awesome, and rather complicated mountains serve as a common anchor for an otherwise highly diverse and scattered group [...] Obviously, the mountain research community existed long before the establishment of the MRI and its networks - but the MRI has been instrumental in giving the research community, and mountains, a voice."

DR. ASTRID BJÖRNSEN GURUNG, DEPUTY HEAD WSL RESEARCH PROGRAM EXTREMES, MRI PROGRAMME MANAGER 2003-2014.

OUR HISTORY

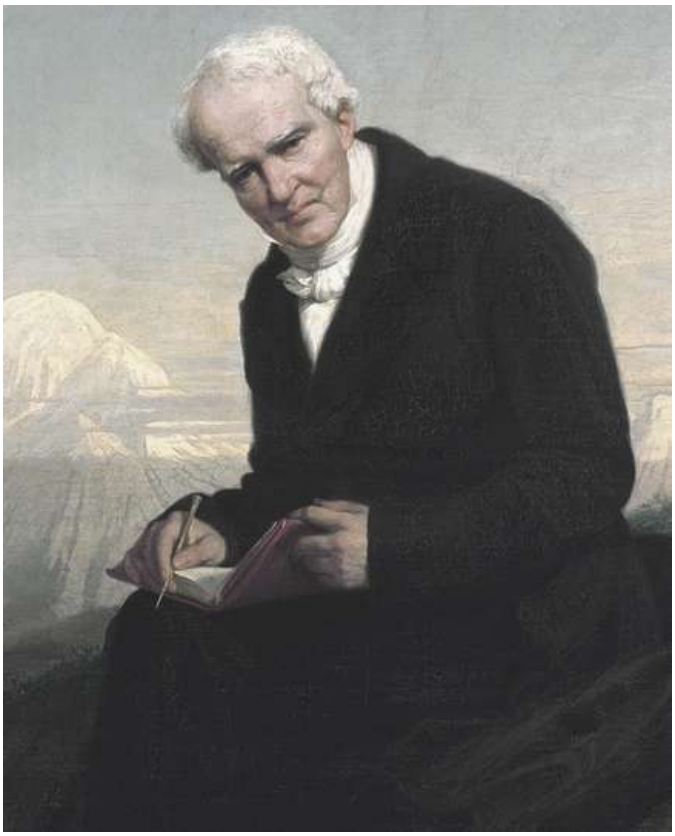
THE MRI IN CONTEXT: THE GROWTH OF MOUNTAIN RESEARCH BEYOND BORDERS & DISCIPLINES

1700s–1800s | EARLY MOUNTAIN RESEARCH

Mountain research as an endeavour of individual scientists has a long tradition going back to at least the 1700s, with scientists such as Horace Bénédict de Saussure, Alexander von Humboldt, and Louis Agassiz paving the way for those that would follow. Indeed, it was while contemplating the Andes from the heights of Ecuador's Chimborazo mountain in 1802 that von Humboldt, a German naturalist and explorer, found inspiration for the central paradigm of his scientific legacy: that nature is a web of connections, and disrupting a single link will therefore impact the whole.

Despite this, it was well over a century before mountains gained wider attention as a field of research with important implications for policy and society, both nationally and internationally.

> *"In this great chain of causes and effects, no single fact can be considered in isolation."*
>
> ALEXANDER VON HUMBOLDT.



1913 | *REVUE DE GÉOGRAPHIE ALPINE* LAUNCHED

The *Revue de géographie alpine / Journal of Alpine Research* [1] was initiated by the French geographer Raoul Blanchard. At the time of its launch, the journal was focused on the European Alps (and the French Alps in particular), with the goal of making this research accessible to a broader scientific public.

1968 | IGU COMMISSION ON HIGH-ALTITUDE GEOECOLOGY FOUNDED

The German geographer Carl Troll, himself inspired by von Humboldt, founded the International Geographical Union Commission on High-Altitude Geoecology in 1968, laying the foundations for interdisciplinary and international mountain research.

Pictured: Carl Troll. Photo credit: Czasopismo Geograficzne/Geographical Journal, PTG, Wrocław, tom XLVII, zeszyt 2/1976

Pictured: Königssee in the Berchtesgadener Land Biosphere Reserve, Berchtesgaden National Park, Germany. Photo credit: Kordula Vahle.

1971 | UNESCO MAN AND THE BIOSPHERE PROGRAMME LAUNCHED

The launch of the UNESCO Man and the Biosphere (MAB) Programme [2] raised the profile of mountains and provided a basis for more integrated mountain research; among the 14 projects initiated to reconcile conservation and biological diversity with socio-economic demands and cultural integrity was 'Impact of Human Activities on Mountain Ecosystems [3].

"In the years that followed, that project provided a great stimulus to overcome the large gap between the natural and the social sciences and to develop methods and models for inter- and transdisciplinary approaches and collaboration."

BRUNO MESSERLI, PROGRAMME DIRECTOR, IMPACT OF HUMAN ACTIVITIES ON MOUNTAIN ECOSYSTEMS [3].

Pictured: 5 June 1972 - United Nations Conference on the Human Environment, Stockholm, Sweden. A general view of the opening meeting of the Conference. Photo credit: UN Photo/Yutaka Nagata.

1972 | UN CONFERENCE ON THE HUMAN ENVIRONMENT

In June 1972, the United Nations (UN) Conference on the Human Environment was held in Stockholm, Sweden. It was the very first UN conference to be devoted entirely to environmental issues, stressing the need for international collaboration to prevent environmental problems going beyond international borders.

> *"Cooperation through multilateral or bilateral arrangements [...] is essential to effectively control, prevent, reduce, and eliminate adverse environmental effects"*

UNITED NATIONS, 1972 [4].

This gave further impetus to the UNESCO MAB Programme, and subsequently led to a series of mountain-focused events and initiatives, such as a conference exploring 'The Future of the Alps' that took place in Trento, Italy, in 1974, or an international workshop held in the same year in Munich, Germany, focused on 'The Development of Mountain Environment: An Interdisciplinary Approach for a Future Strategy' [5].

1981 | *MOUNTAIN RESEARCH AND DEVELOPMENT* FOUNDED

The quarterly journal *Mountain Research and Development* [6] was founded by Jack Ives and published its first issue in 1981. This journal subsequently became an important instrument of communication [3] as regional and global cooperation on mountain research and development grew.

The subsequent founding of the *Journal of Mountain Science* [7] in 2004 and the *Journal on Protected Mountain Area Research and Management* [8] in 2008 further served to bring together and strengthen knowledge and debate regarding mountain-specific challenges and opportunities.

1992 | MOUNTAINS INCLUDED IN UN *AGENDA 21*

The Rio Declaration on Environment and Development, *Agenda 21* [9], was adopted by 178 Governments at the UN Conference on Environment and Development held in Rio de Janeiro, Brazil, in June 1992. Crucially, Agenda 21 placed mountains in the context of sustainable development with the inclusion of Chapter 13 on 'Managing Fragile Ecosystems: Sustainable Mountain Development.'

The inclusion of this key mountain-focused chapter in Agenda 21 was, in part, thanks to the commitment of a group of mountain scientists, dubbed the 'Mountain Mafia' [10]. The Mountain Mafia – among them Yuri Badenkov, Jayanta Bandyopadhyay, Lawrence Hamilton, Jack Ives, Bruno Messerli, Peter Stone, and Maurice Strong – worked tirelessly to raise the profile of mountains in research and policy, promoting the idea of interdisciplinary research cooperation to address the challenges posed to mountain ecosystems at the global level.

1998 | UN GENERAL ASSEMBLY DESIGNATES INTERNATIONAL YEAR OF MOUNTAINS

In recognition of the importance of mountain regions, a draft resolution adopted at the 1998 United Nations General Assembly [11] proclaimed 2002 as the International Year of Mountains. This reinforced the implementation of the mountain-focused Chapter 13 of Agenda 21, placing mountains on an equal footing with climate change, tropical deforestation, and desertification.

Among other objectives, the International Year of Mountains aimed to initiate new mountain research programmes. As a precondition for the successful follow-up of the International Year of Mountains [12], the implementation of Chapter 13 of Agenda 21, the development of national strategies for sustainable development, and the formulation of mountain-specific policies, the UN highlighted the need for a solid knowledge base regarding mountain ecosystems and their responses to global change.

It is against this backdrop that the origins of the MRI can be found.

"Wherever we may come from, however high or small the hills or mountains may be in the land of our birth, we are all mountain people. We are all dependent on mountains, connected to them, and affected by them, in ways we may never have previously imagined."

FAO DIRECTOR-GENERAL JACQUES DIOUF, SPEAKING AT THE GLOBAL LAUNCH OF THE INTERNATIONAL YEAR OF MOUNTAINS IN DECEMBER 2001.

OUR HISTORY

THE MOUNTAIN RESEARCH INITIATIVE

Pashupatinath Temple, Kathmandu. Image Credit: Bijay Yadavweden.

1996-1998 | PUTTING THE PIECES TOGETHER

An interdisciplinary team of mountain scientists gathered in April 1996 at the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu (Nepal) to discuss a new initiative that would bring together ecological, hydrological, and socio-economic research and would push an interdisciplinary research agenda to enhance sustainable development in mountain regions.

At a follow-up workshop in Pontresina (Switzerland) in April 1998, a draft work plan for such an initiative was developed. These two meetings were initiated and convened by Alfred Becker († 2010) and Harald Bugmann, both then at the Potsdam Institute for Climate Impact Research.

2000 | MRI PROPOSED AT UN GENERAL ASSEMBLY

In view of the increasing recognition of the significance of the world's mountains, the International Geosphere Biosphere Programme, the International Human Dimensions Programme, and the Global Terrestrial Observation System proposed a joint initiative to "achieve an integrated approach for observing, modelling and investigating Global Change phenomena and processes in mountain regions, including the impacts of these changes and of human activities on mountain ecosystems" (UN Assembly 2000: 8) [13]. The idea was not that this initiative would direct such a research programme itself, but rather facilitate the emergence of such research by creating a community of mountain researchers and promoting and coordinating research conducted by various groups and individuals worldwide.

A small group of dedicated scientists – including, but not limited to, Alfred Becker, Bill Bowman, Harald Bugmann, Georg Grabherr, Lisa Graumlich, Wilfried Häberli, Michael Kuhn, and Martin Price – further developed the work plan from the 1998 Pontresina workshop into an integrated interdisciplinary approach [14] spanning a range of activities: monitoring, process studies, modelling, as well as providing guidance to policy and management.

"[The Mountain Research Initiative] strives to achieve an integrated approach for observing, modelling, and investigating global change phenomena and processes in mountain regions, including their impacts on ecosystems and socio-economic systems."

ALFRED BECKER & HARALD BUGMANN, 2001 [14].

2001 | MRI COORDINATION OFFICE ESTABLISHED

The MRI Coordination Office was established in 2001 under Executive Director Mel Reasoner, and hosted by the Swiss Academy of Sciences (SCNAT) in Bern, Switzerland. The Swiss ecologist Harald Bugmann served as the first Chair of the MRI's Scientific Advisory Board (now Co-Principal Investigators).

Under the tenure of Bugmann and Reasoner, the publication *Global Change and Mountain Regions: An Overview of Current Knowledge* [15] was initiated. Published in 2005, 67 mountain researchers contributed to this comprehensive summary of the state of the science at that time and provided their recommendations for future research.

Pictured: Early Mountain Research Initiative logo. Image credit: MRI

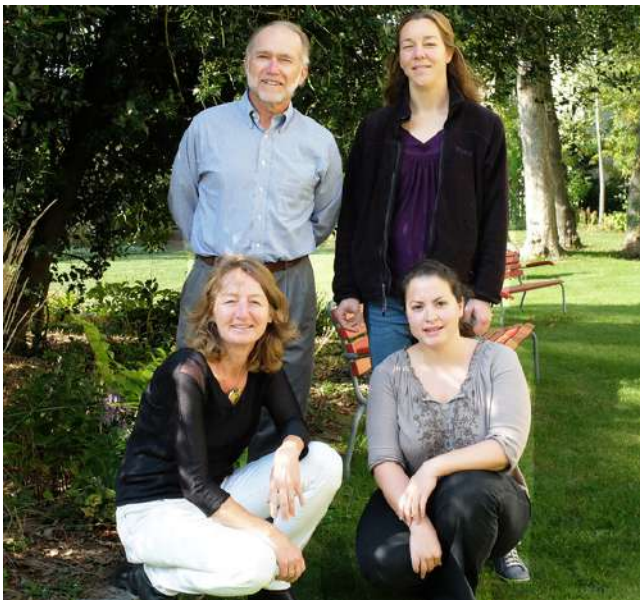
2003 | GLOCHAMORE LAUNCHED

The launch of the Global Change in Mountain Regions (GLOCHAMORE) [16] project took place in 2003. This project, coordinated by the MRI and the University of Vienna, looked at global change in UNESCO Biosphere Reserves around the world. With the collaboration of over 250 scientists and Biosphere Reserve managers, GLOCHAMORE developed a targeted research strategy [17], which recommends specific actions to detect, monitor, and react to signals of global change at local and regional scales. This research strategy was subsequently used as the basis for UNESCO's Global and Climate Change in Mountain Sites (GLOCHAMOST) [2] initiative.

2004 | MRI NETWORKS INITIATED

In 2004, following a successful proposal to the Swiss National Science Foundation led by Harald Bugmann, the MRI Coordination Office moved to ETH Zürich, Switzerland. During that same year, Gregory Greenwood joined the MRI as its new Executive Director. Under Greenwood's guidance, the MRI initiated regional networks and networking events. These served to bring the mountain research community together, enabling collaboration and synthesis.

Over time, these efforts blossomed into a community of 10,000 global change researchers that was – under Greenwood – organized into regional networks in North and South America (American Cordillera Transect), Africa (AfroMont), and Europe (MRI-Europe), with regional initiatives in the Carpathians (S4C) [18] and South-Eastern Europe (SEEmore).



Pictured: Gregory Greenwood, MRI Executive Director 2004-2017, pictured with other members of the MRI Coordination Office team in 2015. Image credit: MRI

2005 | PERTH I: GLOCHAMORE OPEN SCIENCE CONFERENCE

In October 2005, many issues relevant to mountain areas were addressed during the Open Science Conference of the GLOCHAMORE project [16] in Perth, Scotland. This event was organised by the Centre for Mountain Studies, Perth College UHI [19] in collaboration with the MRI and other GLOCHAMORE project partners, and funded principally by the EU Sixth Framework Programme, with further support from UNESCO.

The GLOCHAMORE Open Science Conference was attended by 210 people from 41 countries, and proved to be the starting point for a series of conferences focused specifically on global change in mountain regions.

Pictured: MRI Europe Programme Coordinator Astrid Björnsen Gurung, MRI Chair Harald Bugmann, and Martin Price of the Centre for Mountain Studies, UHI in discussion during the 2005 Perth conference. Photo credit: MRI

2007 | MRI COORDINATION OFFICE MOVES TO UNIVERSITY OF BERN

In 2007, the Swiss hydrologist Rolf Weingartner succeeded Harald Bugmann as MRI Chair, and the MRI Coordination Office moved to the Institute of Geography at the University of Bern, Switzerland.

> *"The MRI is a unique, worldwide network which has fantastic potential."*
>
> ROLF WEINGARTNER,
> MRI CHAIR 2007-2019 [20].

2009 | MOUNTAINTRIP PROJECT LAUNCHED

'Mountain Sustainability: Transforming Research Into Practice (MountainTRIP)' [21], was a project funded by the European Union under its Seventh Framework Programme. It was developed and implemented by the MRI and its European partners from 2009 to 2011.

MountainTRIP produced a series of short videos that translated scientific results into guidance for practitioners of sustainable mountain development.

The aim of this project was to inspire scientists to find new and effective ways of communicating their research results by providing examples of best practice.

Video: Professor Harald Bugmann, MRI Chair 2001-2007, providing an overview of the Advanced Terrestrial Ecosystem Analysis & Modelling (ATeam) project for MountainTRIP.

Pictured: Perth, View of the River Tay from Perth Bridge. Photo credit: Eugene Birchall.

2010 | PERTH II: GLOBAL CHANGE AND THE WORLD'S MOUNTAINS

Following on from the GLOCHAMORE Open Science Meeting in 2005, the MRI collaborated with the Centre for Mountain Studies, Perth College UHI [19] to organize a second conference focused on global change in mountains. It took place in Perth, Scotland and was attended by 450 people from 60 countries. This conference provided an unparalleled opportunity for mountain scientists from a range of natural and social science disciplines to come together and present and discuss their research.

This conference resulted in the publication of a Special Issue [22] of the peer-reviewed journal *Mountain Research and Development*. A one-day strategy session organized by the MRI took place after the conference in order to explore future research activities and means to ensure a high profile for mountain issues in the Rio+20 process and other global assessment and policy processes.

2013 | MRI COLLABORATES ON GLOBAL QUANTITATIVE ASSESSMENT OF SUSTAINABLE MOUNTAIN DEVELOPMENT

As part of the Sustainable Mountain Development for Global Change (SMD4GC) [23] programme, which ran from 2013 to 2018, the MRI collaborated with the University of Bern's Centre for Development and Environment (CDE) in order to develop an approach for assessing sustainable mountain development using the UN Sustainable Development Goals framework. The aim was to help contextualize and highlight the specific needs and challenges for mountain communities and ecosystems in addressing sustainable mountain development, thereby also informing policy and decision-making at the global, national, and subnational level. Work concluded on this project in 2018 with the publication of the Issue Brief *Leaving No One in Mountains Behind* [24], presenting initial steps towards localization of the 2030 Agenda to mountain areas. This Issue Brief was complemented by the publication *Sustainable Development Goals: Reflections Based on Research in Mountain Regions* by Kulonen et al [25].

2014 | MRI LOBBIES FOR MOUNTAINS FOR EUROPE'S FUTURE

As the Swiss representative of the Swiss Austrian Alliance for Mountain Research (CH-AT), in 2014 the MRI led a lobbying effort to increase mountain research in the European Union. The short term aim was to get more mountain research topics into Horizon 2020 [26] calls; the long-term goal was to increase awareness among decision-makers about the importance of mountains for the whole of Europe.

These efforts resulted in the publication of *Mountains for Europe's Future: A Strategic Research Agenda* [27].

2015 | PERTH III: MOUNTAINS OF OUR FUTURE EARTH

The third and last of the Perth mountain

conferences took place in 2015, co-organized by the Centre for Mountain Studies, Perth College UHI, the Global Mountain Biodiversity Assessment, and the MRI. This conference was intended as a contribution to the global Future Earth [28] programme. It aimed to present, evaluate, and synthesize progress in our understanding of global change in mountain regions; refine and agree on agendas for collaborative research; and foster effective interdisciplinary collaboration between participants.

The conference resulted in Special Issues of the journals *Mountain Research and Development* [29] and *Regional Environmental Change* [30].

Photo: Winner of the 'Dynamic Mountains' category of the Perth III photo competition – Sarah Bittel with her photograph 'Alpine Artefact.' Photo credit: Sarah Bittel

2016 | GEO MOUNTAINS LAUNCHED

GEO Mountains [31] (formerly known as GEO-GNOME) was launched in 2016, and is co-led by the MRI and the National Research Council of Italy. A Group on Earth Observations (GEO) Work Programme Initiative, GEO Mountains seeks to bring together research institutions and mountain observation networks to collate and make available transboundary and inter- and transdisciplinary environmental and socio-ecological data and information on global change in mountains. In so doing, it hopes to increase 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.

"How can we plan a sustainable future without good information? The MRI's work connecting observatories and opening up access to mountain data is very important."

ROLF WEINGARTNER, MRI
CHAIR 2007-2019

2017 | THE MRI BUILDS ON PAST SUCCESSES

In 2017, after 13 years of successful service to the MRI, Gregory Greenwood retired and was succeeded as MRI Executive Director by Carolina Adler. With this change in leadership came an opportunity for an internal strategic review. The MRI Chair and Co-Principal Investigators collaborated with Adler on the development of a strategy for the future of the MRI, designed to build on past successes and harness the considerable social and intellectual wealth fostered via the network over the years. The decision was taken to establish a decentralised coordination approach to mountain research and the MRI's own activities in the regions. The aim was to focus on the global coordination effort and offer better support for the regions in the longer term.

As part of this new approach, establishing closer coordinated links with regional and local entities, networks, and individuals was prioritised. Among others, the MRI facilitated the transition from MRI Europe to the

the Network of European Mountain Research (NEMOR) [32], as well as securing support for a transition from MRI Latin America to the new Cluster of Cooperation Conectate Andes+ [33]. In both cases, the MRI continues to be part of these networks' activities and provides the strategic links and connections to support regional to global efforts, as well serving as a focal point for interregional exchange and collaboration. Other similar efforts are being carried out with local partners in other regions via existing projects such as the Adaptation at Altitude [34] global programme (see page 14).

This new direction for the MRI was heralded with the introduction of a new logo to represent the MRI and its mission: Making Connections for Our Changing Mountains.

"Co-production of knowledge is a social process, where enablers provide the conditions and the means for the research community to connect and thrive. The MRI is you and I!"

CAROLINA ADLER,
MRI EXECUTIVE DIRECTOR 2017-PRESENT

2018 | MOUNTAIN #VANISHINGGLACIERS HIGHLIGHTED AT COP24

Mountain Glaciers: Vanishing Sources of Water and Life (#VanishingGlaciers) [35] was an evidence-based communications campaign that ran on social media during, and was presented at, the 2018 UN Climate Change Conference (COP24) to highlight the large-scale environmental transformation occurring in the world's mountains as glaciers melt – and to call for tougher action on emissions to mitigate their loss.

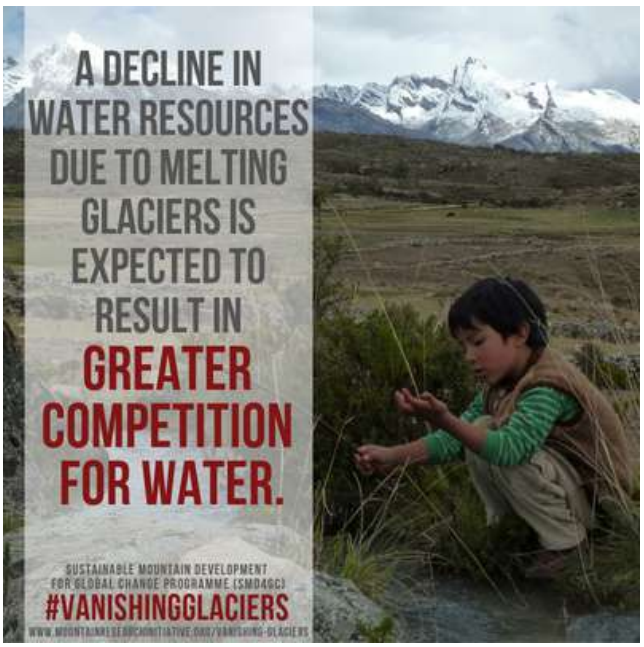


Image: One of the ten evidence-based key messages ran on social media as part of the #VanishingGlaciers campaign during COP24. Image credit: MRI / SMD4GC Project Partners

This project was coordinated by the MRI and brought together the mountain research community involved in the Sustainable Mountain Development for Global Change (SMD4GC) [23] programme, condensing their research into the campaign's 10 key messages.

2019 | FUNDING SUPPORT FOR THE FUTURE

In 2019, the MRI Coordination Office moved to its current host, the University of Bern's Centre for Development and Environment (CDE) [36], and bade farewell to Rolf Weingartner as MRI Chair following his retirement. Weingartner was succeeded in his role as MRI Chair by Jörg Balsiger, Director of the Institute and Hub for Environmental Governance and Territorial Development at the University of Geneva [37].

Importantly, during this period the MRI also secured continued support from the Swiss Academy of Sciences (SCNAT) [38] for the next four years (2019-2023), with additional

support for the MRI's activities and projects provided by the Swiss Agency for Development and Cooperation (SDC) [39], the swissuniversities Development and Cooperation Network (SUDAC) [40], the Office of Foreign Affairs of the Principality of Liechtenstein [39], and Future Earth [28].

In the same year, the MRI received funding under the Adaptation at Altitude (A@A) [34] global program to strengthen its coordination capacity and implement the GEO Mountains Work Plan. In doing so, the MRI continues to support long-term observations and information in mountain social-ecological systems, as envisioned by Bugmann and Becker in the MRI's 2001 founding proposal [14].

Photo: Building containing the University of Bern's Centre for Development and Environment (CDE). Photo credit: Rolf Siegenthaler / Universität Bern

2020 | MAKING CONNECTIONS FOR OUR CHANGING MOUNTAINS

By 2020, the MRI continued to maintain and established new links with key international and strategic partnerships to enhance the value of and support for mountain research globally (e.g., Group on Earth Observations, Belmont Forum, WMO, Future Earth, UNESCO MAB Mountain Biospheres programme, IPCC, UN Environment, among others).

Towards the end of 2020, the paper 'Making Connections for Our Changing Mountains: Future Directions for the Mountain Research Initiative (MRI)' [42] was published in the journal *Mountain Research and Development*. This paper outlines the objectives of the network and the flagship [43] and community-led [44] activities that will help the mountain research community to realize their potential and the MRI vision in future years.

"Our scientific work in mountains continues to advance scholarship and strengthen the value of global change research, considerably improving our knowledge base and understanding of mountains as social-ecological systems. However, it also plays a key role in identifying the diverse human values and goals that underpin desired outcomes for sustaining mountain ecosystems and people, and support transformative actions and pathways to sustainability through co-production of knowledge."

ADLER ET AL, 2020 [42]

OUR ACTIVITIES

Three principles guide how the MRI implements its activities: (1) mountains are unique social-ecological systems; (2) diversity is valued in terms of knowledge, disciplines, cultural, generational, and gender aspects; and (3) knowledge is shared to fulfill an important social role.

The MRI structures and distinguishes between flagship and community-led activities: flagship activities are mainly led and coordinated by the MRI Coordination Office, with network participation, whereas community-led activities are primarily led by researchers, with the MRI Coordination Office supporting administration and communications.

The MRI Governing Body [45] oversees and provides strategic direction and advice to support the implementation and development of both flagship and community-led activities.

Proposed flagship and community-led activities connect researchers in mountain-related fields in natural and social sciences and humanities, as well as practitioners and broader society, helping to address shared research goals and knowledge needs. Enabling coproduction of knowledge, empowering the next generation of researchers, and facilitating diverse participation are key considerations for all the MRI's activities. The following pages showcase just a few examples.

SPOTLIGHT ON MRI FLAGSHIP ACTIVITIES

CONTRIBUTIONS TO SCIENCE-POLICY

Actively participating in multi-stakeholder dialogues and assessments at the science-policy interface is one way for the MRI community to contribute relevant research findings and connect those to policy knowledge needs, while also guiding future research and synthesis activities to better address these needs. Active participation at this interface is not only important in the MRI's pursuit of knowledge to "support decision, actions, and transformations to sustainable mountain development" (Adler et al, 2020) [42], but also to support and substantiate advocacy efforts to raise the profile of mountains and mountain research for international policymaking.

As part of the MRI's vision and priorities in the 2019-2023 period [42], the MRI is participating in, and in some cases coordinating, a number of activities to help facilitate the identification and/or compilation of inputs from across the mountain research community for various science-policy knowledge needs, such as global and/or regional scientific assessments.

These activities [46] include, among others, contributions to the UN 2030 Agenda for Sustainable Development [47] and the Intergovernmental Panel on Climate Change Sixth Assessment, including the *Special Report on the Ocean and Cryosphere in a Changing Climate* [48] and 'Cross-Chapter Paper 5: Mountains' in *Climate Change 2022: Impacts, Adaptation, and Vulnerability* [49].

"At the level of raising awareness of the importance of fragile mountain socio-ecological systems at the science-policy interface, the activities of the MRI have been vital. These include within the IPCC via several of their regular Assessment Reports and, for example, the Special Report on the Ocean and Cryosphere in a Changing Climate that featured a dedicated chapter on High Mountain Areas. This may appear to be - and sometimes actually is - tedious work, but it is important so as to ensure that the livelihoods of millions of people in the mountains as well as those downstream are not forgotten in policymaking."

PROFESSOR HARALD BUGMANN, MRI CO-FOUNDER AND FIRST MRI CHAIR 2001-2007.

SPOTLIGHT ON MRI FLAGSHIP ACTIVITIES

GEO MOUNTAINS

The Global Network for Observations and Information in Mountain Environments (now known as GEO Mountains for short) was first presented [50] to the Group on Earth Observations (GEO) at its 10th Plenary Session (GEO-X) by Antonello Provenzale [51] (National Research Council of Italy) in 2014. Its initial appearance in the GEO Work Plan came in the update of the 2012-2015 version [52] that was released shortly thereafter. At this stage, GEO-GNOME, as it was then known, was listed as one of three activities under the section 'EC-01 Global Ecosystem Monitoring'.

In setting out GEO-GNOME's *raison d'être*, a compelling case was made for the global importance of mountains. A demonstration of the high levels of disagreement / variability between recent observed historical and projected future precipitation estimates served as an effective tangible example as to why the quality of data and information from the planet's high elevation areas had to be urgently improved.

From the outset, in recognition of the complex and multi-faceted nature of mountain systems, the proposed scope was extremely broad, integrative, and ambitious; air pollution, land use changes, the presence of alien species, ecosystem function and services (including water quality and quantity), food production / agriculture, and economic growth were all identified as intended focal areas, with the broader themes of climate and environmental change providing an overarching umbrella.

The need to effectively monitor mountain environments and project their future

responses was effectively articulated, with specific emphasis being placed on the need for application-driven research (i.e., research related to the various societal benefits of mountains). Equally importantly, and very much in accordance with the position of GEO as a whole (which was arguably fairly pioneering at the time), the nascent activity committed itself to open data, models, information, and 'minds' (i.e., to promote an inclusive and open philosophy).

Specific foreseen tasks included taking global cooperative action, making effective use of existing remotely sensed and ground-based datasets, expanding monitoring networks to answer specific questions (with a special emphasis on sensitive areas, UNESCO Biosphere Reserves, natural heritage sites, and internally relevant protected areas), and developing models that were specifically suited to mountain environments.

Further intended activities related to capacity building and education activities on mountain monitoring and sustainable development focused on developing countries with fragile mountain ecosystems, providing observational and data support in response to monitoring frameworks of regional and international conventions and agreements, and providing a platform for interactions between researchers, stakeholders, and policy makers to ultimately bring about action at various levels. These objectives were to be achieved by establishing a comprehensive partnership of key stakeholders and developing a network of existing mountain measurement sites to collate and make available the corresponding data.

Somewhat in parallel, in July 2014, a workshop entitled the Global Fair and Workshop on Long-Term Observatories of Mountain Social-Ecological Systems [53], co-convened by the MRI and the University of Nevada, Reno, was held in Reno, USA.

Logo from the 2014 Reno workshop from which the Global Network of Mountain Observatories (GNOMO) developed, later to be integrated into the Group on Earth Observations' Global Network for Observations and Information in Mountain Environments (GEO Mountains).

A year later, a follow up workshop was held at the Rocky Mountain Biological Lab in Crested Butte, Colorado, USA, at which the Global Network of Mountain Observatories (GNOMO) was officially inaugurated. The planning team consisted of Jeff Brown (Sagehen), Greg Greenwood (Mountain Research Initiative), Art McKee (Flat Head Lake), Faerthen Felix (Sagehen), and Ian Billick (Rocky Mountain Biological Laboratory). A draft mission statement was proposed:

"Teams of researchers, covering the range of pertinent disciplines, work together in a finite number of sites representative of the diversity of mountain regions around the world to develop their understanding of the current structure and function as well as the longer-term evolution of mountain social-ecological systems using protocols that support comparative analysis, at a detail sufficient to support forecasts of likely outcome, given sufficiently defined boundary conditions, and in ways that engage a wide range of actors and contribute significantly to public and private decision-making."

GREG GREENWOOD,
MRI EXECUTIVE DIRECTOR 2004-2017

Since GNOMO was organised as an ad hoc Committee of the Organization of Biological Field Stations (OBFS), membership entailed the payment of a small fee.

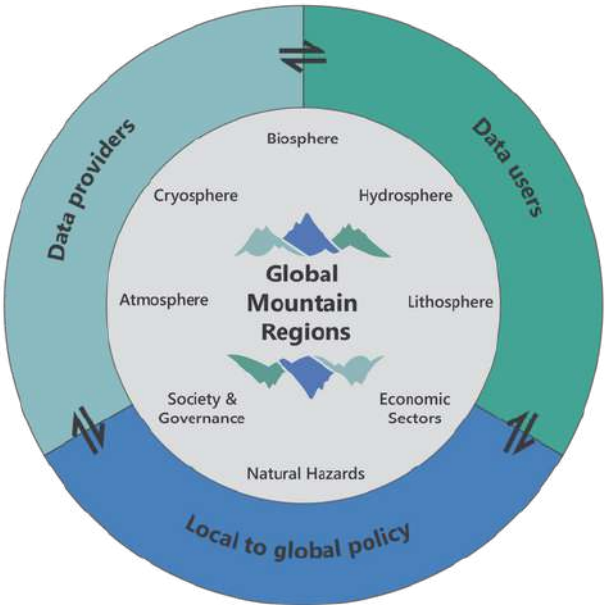
In the first evidence of a link between GEO-GNOME and GNOMO – which despite their similar acronyms and objectives were originally independent – was the formation of a GEO-GNOME Working Group as one of several such groups within GNOMO.

By 2016, under the Directorship of Greg Greenwood, the MRI had become engaged in the leadership of GEO-GNOME along with Elisa Palazzi, then of the National Research Council of Italy. It was at the 2016 GEO Plenary (GEO-XIII) that GEO Members voted to accept GEO-GNOME into the GEO Work Programme as a GEO Initiative, with GNOMO being explicitly listed as one of the activities. The key challenge of finding sufficient time and funding to sustain the ambitious programme was already identified as a potential barrier to progress at this stage, especially given the voluntary contributions-based model of GEO. Indeed, progress was rather modest between 2016 and 2018 largely due to these constraints; although some crucial progress was made (see e.g., Sayre et al., 2018) [54].

In 2017, Carolina Adler took over from Greg Greenwood as Executive Director of the MRI, and shortly after coordinated a workshop, along with Elisa Palazzi and Marc Zebisch (EURAC Research) to reassess and streamline the GEO-GNOME implementation plan in light of the available resources. The outcomes of this meeting were summarised by Adler et al. (2018) [55]. During this period, GNOMO also became entirely embedded within GEO Mountains.

In 2019, GEO-GNOME was successful in being granted substantial funding from the Swiss Agency for Development and Cooperation (SDC) [39], to contribute – along with several other institutional partners – to its Adaptation at Altitude [56] programme. This programme runs in a first phase from 2019 to 2023. The support provided enabled the MRI to employ a dedicated staff member to coordinate and implement GEO Mountains.

Whilst the Initiative retains its full official name, a rebranding exercise was undertaken in late 2020 which led to GEO-GNOME being known simply as GEO Mountains going forward, and a dedicated website [31] was released. The Initiative's Implementation Plan was further revised, with the current version being accessible here [57]. In 2021, the following figure was developed in an attempt to conceptually summarise, at a high level, the scope of the Initiative as currently conceived.



High level diagram summarising the scope of GEO Mountains (as of 2021); an Initiative that seeks to connect data providers, data users, and policy makers from range of disciplines – and working across disciplines – with one another, and doing so across all mountain regions globally.

The Initiative's current objectives are to:

1. Identify and satisfy the data and

information needs of a diverse range of stakeholders operating in the mountain sphere.

2. Improve monitoring and scientific understanding of mountain processes and phenomena, especially under change.
3. Build, connect, and communicate with the community of mountain researchers, practitioners, and policy makers.
4. Develop collective reporting capacity that responds to pre-identified assessment and policy needs.

Given the Initiative's current more secure financial future, another key objective is to support the longevity and persistence of resources, outputs, and outcomes developed from relevant short-term research projects and other activities.

Of late, activities and outputs have increased, with progress (and regular updates) being provided via the MRI's Monthly Newsletter [58]. Progress over 2020 and 2021 was summarised in two articles (here [59] and here [60]). We are pleased that our momentum and visibility appear to be gradually increasing.

Reflecting back, it is remarkable that that our current Implementation Plan retains so much similarity with the early visions of GEO-GNOME and GNOMO, with most issues and objectives still remaining extremely pertinent today. This is certainly testament to the vision of those who initially developed the concepts of and founded these activities. It may also reflect the challenges that were encountered in making substantial progress against these ambitious objectives; this is an area in which we should arguably collectively re-double our efforts, to ensure that mountain regions receive the investments they deserve!

Looking ahead, we gratefully thank all those who have contributed their time and expertise to date, and are excited for what the future may hold. We warmly encourage anyone who may be thinking of doing so in future to get involved. Collaboration with our community of members/participants is essential as we co-develop the next version of our Implementation Plan (2023-2025).

On behalf of the co-leads,

DR. JAMES THORNTON, GEO MOUNTAINS SCIENTIFIC PROJECT OFFICER

"You can't conduct productive research that generates useful practical results in isolation [...] We need to develop a network that generates multidisciplinary data using the key complimentary techniques: in situ measurements, remote sensing, and modelling. We need to put these data into a longer historical context by using palaeo reconstructions. We need to remember that science is for people. This means that socio-economic and human sciences data are also equally important, and it is this type of data that are often missing. It also means that we need to share our data freely."

PROFESSOR MARIA SHAHGEDANOVA, MRI SLC MEMBER & MOUNTAIN OBSERVATORIES WORKING GROUP LEAD

SPOTLIGHT ON MRI COMMUNITY-LED ACTIVITIES

ELEVATION-DEPENDENT CLIMATE CHANGE WORKING GROUP

Mountains hold most of the world's snow and ice outside of polar regions and play an essential role [61] in supplying water to meet the needs of both fragile ecosystems and a significant proportion of the world's population. By the mid-21st century, it is anticipated that about 1.5 billion people in lowland areas – almost a quarter of the world's lowland population – will critically depend upon water from mountains [61]. The retreat of glaciers, rising snow lines, and changes in precipitation as a result of climate change, both now and in future, therefore have serious implications.

In order to help us anticipate and respond to future challenges, quantifying rates of climate change in mountain regions is essential. In view of this, the MRI's Elevation-Dependent Warming (EDW) Working Group [62] was established in 2012. It began its activities by assessing if, where, to what extent, and why mountains and other high elevation regions are warming more rapidly than lowlands. This ultimately resulted in the 2015 publication 'Elevation-Dependent Warming in Mountain Regions of the World' [63] in *Nature Climate Change*, which reviewed the evidence for elevation-dependent warming and examined the mechanisms that may account for this phenomenon.

"Elevation-dependent warming occurs when a systematic and statistically significant change in warming rates with elevation is found. And though this change may, in principle, not always be positive - meaning that warming rates can both increase or decrease with elevation - this is often the case."

DR. ELISA PALAZZI, CO-AUTHOR OF 'ELEVATION-DEPENDENT WARMING IN MOUNTAIN REGIONS OF THE WORLD.'

From Elevation-Dependent Warming to Elevation-Dependent Climate Change

In 2020, the EDW Working Group expanded its scope, moving beyond a focus on warming in order to include additional climate processes specific to mountains and high elevation regions. In doing so, it changed its name to the Elevation-Dependent Climate Change (EDCC) Working Group.

"For most of the last decade, this MRI working group has played a major role in highlighting the importance of warming in mountain areas for the international community. We now realise that many aspects of future climate change may be enhanced in mountain regions, including sensitivity to changes in precipitation, changes in the state of the cryosphere, and mountain hazards. Thus the name change is an indication of the importance of understanding the response of the whole mountain climate system," explains Dr. Nick Pepin [64], EDCC Working Group lead.

Among its activities in recent years, the EDCC Working Group has collaborated with GEO Mountains and the MRI's Mountain Observatories Working Group [65] on developing a set of potential Essential Mountain Climate Variables to support the monitoring and understanding of key climate change-related mountain processes. This culminated in the 2021 publication 'Toward a Definition of Essential Mountain Climate Variables' [66] in the journal *One Earth*. In addition, many members of the EDCC Working Group contributed to the high mountain analysis and specific section on elevation-dependent warming in the High Mountain Areas Chapter of the *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [48].

"For most of the last decade, this MRI working group has played a major role in highlighting the importance of warming in mountain areas for the international community."

DR. NICK PEPIN, EDCC WORKING GROUP LEAD.

Photo: Participants at an MRI-sponsored workshop and splinter meeting with members of the MRI Elevation Dependent Climate Change Working Group at AGU 2019. This meeting led to the publication 'Climate Changes and Their Elevational Patterns in the Mountains of the World' in Reviews of Geophysics. Photo credit: Aino Kulonen.

Pictured: Rainfall on Switzerland's Aletsch Glacier.

Latest EDCC Working Group Research Finds More Rapid Decline in Mountain Snow and Ice Likely

In its latest research, published in *Reviews of Geophysics* in January 2022, the EDCC Working Group turned its attention towards examining evidence of elevation dependency in precipitation trends, in addition to updating its earlier analysis of temperature changes.

As the authors point out, whilst the concept of elevation-dependent warming is widely accepted, no consistent elevation-dependent warming profile at the global scale has been identified. What is more, past assessments have also neglected elevation-dependent changes in precipitation. In order to address this, the researchers undertook a comprehensive analysis of in situ station temperature and precipitation data from mountain regions worldwide. This was coupled with an extensive analysis of global gridded datasets (observations, reanalyses, and model hindcasts) to examine the elevation dependency of temperature and precipitation changes since 1900.

"This research looks at recent climate changes in mountains and compares them with simultaneous changes in lowland regions using weather station data, large global datasets, and climate models. We examine changes since 1900, but also concentrate on the last 40 years since this is when many changes have started to accelerate."

PEPIN ET AL. 2022 [67]

The researchers found that, worldwide, nearly all mountain regions are getting warmer. Moreover, in their local comparisons they found that the rate of warming that mountain

sites are experiencing is more rapid than in adjacent lowlands. However, once they averaged the data from all mountains globally and compared this with data from all lowland areas, the researchers found no significant difference in warming between the two.

"These results may appear confusing, but we must remember that mountains exist in a whole range of environments and climates and are unevenly distributed across the globe," says Pepin. "When we compare all mountains and lowlands on a global scale there may be many other factors, such as variable geography, which explain why there is no difference between overall warming rates. The simpler comparisons are those made within a local region, and in nearly all of these studies the high elevations are warming faster."

"Temperature increases at sea-level are likely to be amplified in high mountains - and this can only be bad news for mountain snow and glaciers, which are continuing to melt at a rapid rate."

DR. NICK PEPIN, EDCC WORKING GROUP LEAD.

When looking at precipitation, the researchers found that rainfall and snowfall is decreasing in some areas and increasing in others. Globally, precipitation is on average increasing, but in nearly all cases the strongest increases are occurring in lowland areas. Increases in the mountains, meanwhile, tend to be more subdued (if occurring at all).

"Our work identifies, for the first time, preliminary evidence of a potential weakening elevation-dependency of precipitation. As the planet warms, precipitation increase in mountainous regions may not occur as rapidly as in lowland regions."

PEPIN ET AL. 2022 [67]

There may be multiple reasons for this, including changing wind patterns and atmospheric moisture content. One key consequence could be that snow and ice stores in mountain regions could be lost even more rapidly than previously anticipated – with significant implications for the ecosystems and populations that rely on these vital resources.

"It is therefore critical that we improve our observations and modelling of changing mountain temperatures and precipitation patterns," says Dr. Pepin. "Our current network has many gaps, because mountain areas are challenging to research. Along with improved data, we must strengthen interdisciplinary research on the impacts of such enhanced changes, since changes in mountain climates have widespread physical and human/social consequences."

For more information about the EDCC and other MRI Working Groups, including details of how to get involved in their activities, please see the MRI website [44].

IN FULL TRANSITION: ADDRESSING THE CHALLENGES OF OUR CHANGING MOUNTAINS

The Mountain Research Initiative was established 20 years ago, and no doubt there are important challenges ahead that extend far beyond another 20 years of this organisation. Even at the highest (altitudinal) levels…

Indeed, one striking example of such a challenge concerns the highest altitudes, with their icy peaks, highly climate-sensitive glaciers, and deeply frozen rocks. Conditions and processes in these regions are in full transition, with important consequences for humans, their infrastructure, and livelihoods at scales from local (new landscapes), regional (catastrophic events), continental (water supply), and even to global (sea level). Many mountain ranges are rapidly losing large parts, if not all, of their glacier cover. New lakes continue to form closer and closer to steep rock walls, whose permafrost has already been warmed tens of meters below the surface. Due to slow heat diffusion at depth, this profound thermal anomaly will continue to penetrate deeper still into frozen mountainsides. Decreasing slope stability of icy peaks caused by permafrost degradation and vanishing glaciers represents an unavoidable commitment for the future.

Catastrophic mass flows like the recent Chamoli event in the Indian Himalaya are likely to increase in frequency and to become especially dangerous in connection with new lakes as risk multipliers. In order to adequately deal with such system reactions under conditions of growing imbalance, the International Association of Cryospheric Sciences (IACS) [68] and the International Permafrost Association (IPA) [69] established the Scientific Standing Group Glacier and Permafrost Hazards in Mountains (GAPHAZ) [70]. This organisation recently issued technical guidelines and comprehensive analyses of extraordinary events.

While hazard and risk considerations have first priority, other interests related to new landscapes and, in particular, to new lakes in deglaciating mountains are also at play. These include hydropower development, freshwater supply, tourism, and landscape protection. Potential synergies, but also conflicts, exist and give rise to basic legal questions: who

Pictured: Syphoning for lake level lowering and flood protection at Laguna Palcacocha, Cordillera Blanca, Peru. Rock and ice avalanches from the surrounding icy peaks can directly impact the lake. Photo credit: H. Frey, April 2015.

owns the new landscapes, who is responsible for them, who can make use of them, what are the overall targets, and how can diverging interests be harmonized? Participatory planning must start without delay because environmental change is happening fast. Such planning needs to be based on integrative, transdisciplinary, and scenario-based quantitative as well as qualitative research, taking a larger, regional perspective in addition to focusing on individual cases. In unprotected areas, e.g., outside national parks, landscape protection tends to have a comparably difficult position. It must come in at an early stage, with strong arguments concerning realistic goals to be reached, and by referring to constructive strategies rather than limiting itself to a naysayer function.

Decisions concerning safe, economically sustainable, and socio-politically acceptable developments of new landscapes in deglaciating mountain regions must be taken soon, and will have effects for generations to come.

An international scientific organisation like the MRI is optimally suited to help develop the necessary integrative and transdisciplinary scientific basis for successful adaptation by furthering international exchange of knowledge.

Fortunate, then, that we have the MRI with its 20 years of experience!

PROFESSOR WILFRIED HAEBERLI
MRI PRINCIPAL INVESTIGATOR 2007-2010.

"Mountain regions lacking disaster risk management will face more severe impacts of climate change. Growing populations, rapid urbanization, inequality, poverty, marginalization, and stressed ecological systems are synonymous with increasing levels of vulnerability and exposure, and are also considered as some of the major drivers of disaster risk and disasters. If the mountain research community is fully engaged with the translation of mountain research into solving societal problems, disaster risk reduction becomes one of the key ingredients for achieving sustainable mountain regions - and one of the main challenges for regional networks of mountain researchers."

PROFESSOR IRASEMA ALCÁNTARA-AYALA, MRI SLC MEMBER

OUR CHANGING GLACIER: ÁAK'W T'ÁAK SÍT'

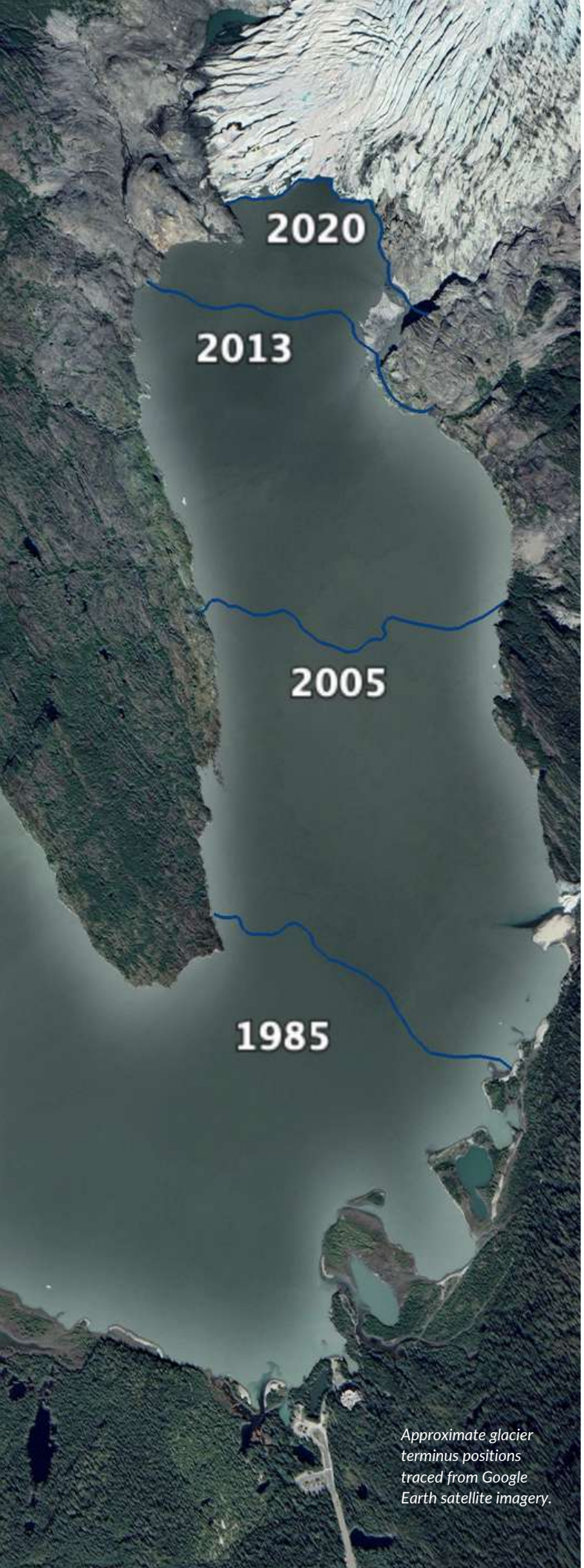
A photo essay by members of the Juneau community in Alaska, curated by Gabrielle Vance and Grace Goss-Durant.

How does a glacier impact the people whose lives are lived in the landscape it shapes? In this photo essay, members of the Juneau community in Alaska reflect on life shared with the Áak'w T'áak Sít' (or Mendenhall) glacier – and how it feels to witness it receding as a result of climate change.

According to glaciologists at the University of Alaska Southeast, the Áak'w T'áak Sít' Glacier receded about three kilometres over the course of the twentieth century. During the last two decades, it receded more than a kilometre and thinned by as much as 150 meters.

They predict it will continue receding during the twenty-first century.

See here for the full, interactive photo essay [71].



Approximate glacier terminus positions traced from Google Earth satellite imagery.

Photo credit: Glenn Miller

"This pair of photos shows me and [my daughter] toddler Gwenn and then Gwenn with [her son] Isaac: These images taken 30 years apart at the same spot show the appalling retreat of a once mighty ice face. Clearly my great-grandchildren will not be able to view the glacier from that location."

GLENN MILLER

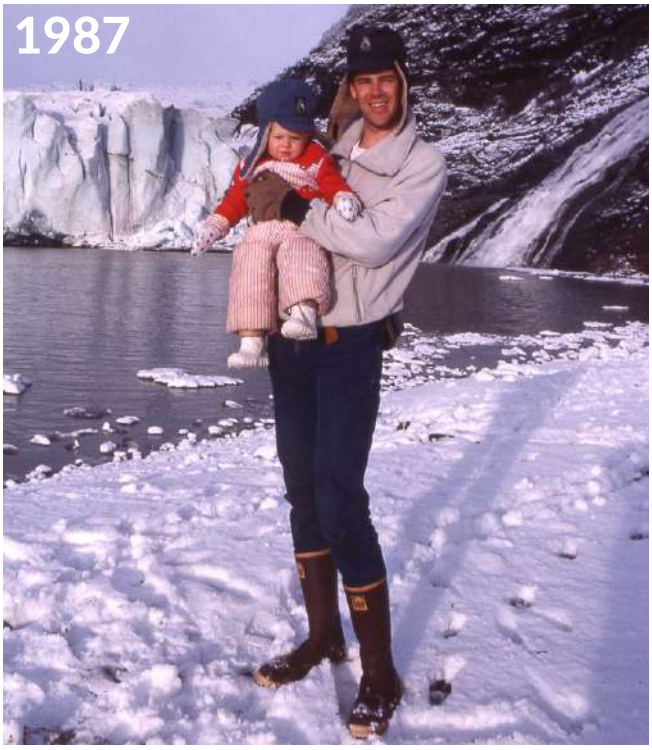


Photo credit: Glenn Miller

1992

Photo credit: Teri Robus

Photo credit: Gabrielle Vance

1995

"The glacier shrank as the children grew, but it always remained a reliable, rewarding destination for their adventures and education."

LEON VANCE

2000

"The Mendenhall makes me think about swimming in a sports bra in the shallow pools by the visitors center and at the secret deep pool in the woods on warm days during track and field workouts. It was hard to know how much it meant until I lived in landscapes not dominated by glaciers. Oh to be cradled by a U-shaped valley and a cool mist! It taught me the awesome power of nature, its ability to crush a fragile human if the iceberg they are sitting on turns over. The other lesson: humans can melt glaciers. Global warming is making a beloved glacier uglier, but worse, it's damaging the health and well-being of Alaskans and people around the world. I hope we rise to the challenge, but it may be too late for the Mighty Mendy."

LEIGH CLARK

Pictured: Leigh Clark in front of the glacier. Photo credit: Glenn Miller

Photo credit: Teri Robus

Photo credit: Sarah Conarro

Photo credit: Stephanie Joyce

2004

Photo credit: Glenn Miller

Photo credit: Gayle Trivette

2005

"At a superficial level the Mendenhall Glacier is our local 'pride and joy.' It has been the backdrop for endless family photos and recreation and the biggest 'must see' for visitors. It also represents my personal reminder of the enormous ice field that shelters our community from the encroachment of what passes for 'civilization.' The rapid retreating and shrinking of our view of the Mendenhall coincides with my own aging and diminishing abilities, as well as the loss of family and friends smiling in old photos in front of a much closer Mendenhall. Change is a certainty in life, but change at a 'glacial pace' doesn't mean it's slow!"

GAYLE TRIVETTE

2007

Between 2003 and 2007, a black wolf [72] lived around the Áak'w T'áak Sít' Mendenhall glacier. He was nicknamed Romeo due to his friendly interactions with local people and their dogs.

"This image showing a black wolf and a woman on skis was an extra special moment for my wife Joan and I. It was truly a rare treat to visit with Romeo."

GLENN MILLER

Photo credit: Glenn Miller

2009

Pictured: Gwenn and Tyler Hennon, who got married at the Mendenhall Glacier Visitor Center. Photo credit: Glenn Miller

"When we were little it seemed like this dangerous towering cliff, I remember the signs that warned people about being too close to calving icebergs, but over the years it just kept retreating and diminishing so that it was harder to get close to and touch. I remember when I was doing bike tours with Cycle Alaska and a couple of tourists said 'seen one glacier, seen 'em all' and I was sort of personally offended because seeing it is not something I ever took for granted; I always felt the awe of being in the presence of something great. Whenever I'm in town we always have to go see 'the glacier.' It's sad to come back and see it now because it's like visiting a grandparent who is dying. Tyler and I got married at the glacier visitors' center, but it makes me sad to think of our kids going back there and seeing it so diminished from its former glory."

GWENN HENNON

2011

Photo credit: Glenn Miller

Photo credit: Jonathan Rupp

2012

"I only lived in Juneau for one year, but it was very apparent the effect of Mendenhall Glacier. There are happy neighborhoods where the ice had retreated long ago, then the pleasant park areas in the moraine and lake, and then the treacherous alder thickets in the more recently exposed land. My friend is one of many who became so lost in that area they needed to be rescued. The departing ice leaves sadness but also new beginnings."

JONATHAN RUPP

2015

Photo credit: Rob Clark

"The 'Mendy' was the first Alaskan glacier I spent time on. I spent a season walking tourists around on the ice 6 days a week, telling them about the cracks, the accumulation of snow, how the rocks of the moraine got to be there, on and on. On my days off I would... hike to the glacier. It was basically the center of my world then. That was less than a decade ago and already the changes are quite stark. I'll miss it when it's gone."

ROB CLARK

Photo credit: Rob Clark

Photo credit: Sydney Akagi

2016

"Frozen toes, numb fingers, red noses, and a whole lot of excellent photos during a morning canoe at the glacier!"

SYDNEY AKAGI

Photo credit: Will Elliott

Photo credit: Ricky Tagaban

2018

"'Unnncle! I don't wanna go to the glacier'... has fun once we're there."

RICKY TAGABAN

Photo credit: Christy NaMee Eriksen

2019

"My son complained almost the entire hike and at some point I said the phrase 'you know, many people wait their whole lives and travel thousands of miles to come here to do this' and as the last word left my mouth I knew this was it, there was no turning back, I had certainly and finally and unregrettably become my parents. Fitting that my parents were there!"

CHRISTY NAMEE ERIKSEN

Photo credit: Grace Petersen

2019

"Touristing / advertisement for Carhartt"

GRACE PETERSEN

Photo credit: Janelle Quimpo

2020

"Snack break for Benny after an eventful trek to the receding glacier behind us. Appreciating her presence, especially to remind us to slow down."

JANELLE QUIMPO

2020

"The Mendenhall Glacier in Juneau, Alaska flows into our town's largest suburban area and is the backdrop for everything from baby photos to beer advertisements. The trails that used to access the glacier itself, now access different areas along the lake where the glacier can still (barely) be seen. My dog Theo doesn't care much about the view, but he loves the small spit of land at the base of a large waterfall which is now the closest a hiker can get to the glacier from the visitors center 45 minutes behind us. We visit this spot at all times of the year except the peak of the tourist season. Here he's telling me to throw another poor stick into the shallow lake."

PETER NAVE

Photo credit: Peter Nave

"The environment has changed dramatically over the last 20 years. I have been particularly struck by the dramatic shrinkage of glaciers over the last two decades. When I visited the Trift Glacier in the Bernese Oberland a few years ago, I saw a picture of the glacier on the wall of the lower cable car station. That picture had been taken in the early 2000s, but there was no resemblance with the current glacier, such that I was fooled into believing that they had posted the picture of another glacier in the cable car station [...] Global change is real and is progressing at a fast pace. The MRI is also real and has proven its importance over the past 20 years. I am convinced that the MRI will continue to contribute to a sustainable future for humans and ecosystems in mountains, for the benefit of humankind in general."

PROFESSOR HARALD BUGMANN,
MRI CO-FOUNDER AND FIRST
MRI CHAIR 2001-2007.

GLOBAL CHALLENGES, LOCAL CHALLENGES

CREATIVE SOLUTIONS FOR THE FUTURE

The future of Guttannen, a small village in the Swiss Alps, hangs in the balance. Population decline, ever decreasing numbers of schoolchildren, and, due to climate change, an increase in dangerous natural processes such as debris flows threaten the village, which has existed for centuries. But Guttannen is facing up to these challenges. The municipal council has founded a working group. Its mandate is clear and unambiguous: to plan and implement measures that will strengthen the village's resilience and thus make it fit for the future.

After my resignation as MRI Chair, I joined Guttannen's working group by a stroke of luck. This engagement rewards me richly, as it allows exclusive insights into the 'soul' of a mountain village and enables me to contribute to creative solutions for the future. And it is precisely this local level, the 'ground truth', that I missed or – somewhat more self-critically – neglected at the MRI.

Pictured: Rolf Weingartner onsite in Guttannen. Photo credit: MRI / Grace Goss-Durant.

Pictured: The Swiss mountain village of Guttannen faces numerous challenges, and is taking action to address them. Photo credit: MRI / Grace Goss-Durant.

Over the years, the MRI has been able to strengthen the global level, promote networking among researchers, and successfully lobby for the Earth's mountains. The Cross-Chapter Paper on Mountains in the WGII contribution to the *IPCC Sixth Assessment Report*, published this year, is testament to the enhanced profile of mountains in research, policy, and the public consciousness.

But the MRI's motto should really be: continue to successfully cultivate or even expand at the global level, and do not (any longer) neglect the regional to local level. I therefore urge you to look for your 'Guttannen' in your mountain region, to discuss problems and challenges locally, to jointly develop practical research projects, and to include the implementation of the results locally. Your research will gain in quality, sustainability, and practical relevance… and it will be even more fun!

During my time at the MRI, we often thought about the acronym MRI – and about the 'I' in particular. 'I' stands, it is clear to all of us, for initiative. But can you spend years, or even decades, just initiating things? Hardly. 'I' becomes integration. Bringing research results together leads to added value for everyone (see the IPCC Report). But only when it comes to 'implementation' of research results are we ultimately successful.

Your 'Guttannen' is waiting for you!

PROFESSOR ROLF WEINGARTNER, MRI CHAIR 2007-2019

Pictured: An avalanche on the edge of Guttannen. Photo credit: Daniel Bürki

VOICES FROM OUR CHANGING MOUNTAINS

A VILLAGE UNITES FOR ITS FUTURE

The Swiss mountain village of Guttannen is under threat. Climate change is melting the glaciers, thawing the permafrost, and destabilizing the mountainsides. This has resulted in multiple severe debris flow and flooding events in recent years. Combined with outmigration, an isolated location, and limited employment opportunities, Guttannen faces an uncertain future. A future the village has come together to fight for.

Nestled between the snowy peaks of the Swiss Alps, the village of Guttannen in the Bernese Oberland is picture-postcard perfect; a place of wooden chalets and lush Alpine meadows, the gentle scenery of the valley gradually giving way to the jagged mountains above.

With a name that stems from the phrase 'ze den guoten tannen,' meaning by the good firs, Guttannen can be traced as far back as 1377 [73] and, over the centuries, the people that have called the village home have weathered and adapted to the often challenging conditions that life at 1,057 meters above sea level can bring.

One of the main hazards the region has faced has been avalanches and, over time, the villagers have developed an understanding of them, and identified avalanche-safe areas for construction. As a result, the risk posed by avalanches to the present settlement area is currently considered to be low [74].

"One must simply have respect for avalanches. And when you've always lived here… I would say that I am beginning to get a bit of a sense for when they are coming. But you can always be wrong. You can never say I have this under control, nothing is going to happen to me. That is what shapes the people here somewhat: dangers. And one can't avoid them, in a way."

However, as climate change increases precipitation, melts the glaciers, and thaws the permafrost, the mountainsides are becoming less stable – with the result that new hazards are arising in areas that were previously considered safe.

"When it snows heavily, then you tell the small children that they can't go beyond the village. For them, that is self-evident: you know you stay within the village."

Unstable Slopes

In August 2005, following days of heavy rain, a debris flow of over 500,000 cubic meters [75] swept down the channel of the Rotlouwi creek and into the valley below, covering the cantonal road and landing in the bed of the Aare river just downstream from the village of Guttannen. The subsequent backlog of water in the Aare caused a new channel to form, directing the water towards the village. While fortunately nobody was injured, the cost of the damage was several million francs [75].

Pictured: The Aare river from above. Photo credit: Daniel Bürki

"The masses… the masses were coming and coming and coming. And then the water came into the village, and at [our house] it was in the cellar relatively quickly. At this point, people were already being evacuated to the Bären [Hotel]. That was at 10 o'clock in the evening, and we couldn't have gone down on foot then. A pretty torrential stream was flowing down. And then they came with a giant behemoth of a machine, and we all stepped into the front loader with our backpacks, and they drove us down to the Bären [Hotel]. I do still think about it sometimes. There was no fear, somehow. We just acted."

A number of subsequent debris flows [75] have occurred at Rotlouwi, while a little further downstream from Guttannen at Spreitgraben – a steep channel situated on the northeastern flank of the Ritzlihorn mountain – approximately twenty debris flows have occurred since July 2009 [75]. These flows have resulted in a cumulative volume of 700,000 cubic meters of material being deposited into the Aare River, with boulders of over 700 tonnes being dislodged from the mountainside.

Photo credit: Daniel Bürki

"I was scared once, and it was on a Sunday. We were all here, and then my daughter said "Oh, look! Look there!" And then Hans, my husband, shouted "Lay on your stomach!" He sprang over to our eldest son and told him to "Get up! Be quick! Be quick!" And then a dust avalanche came. Just as we were hidden in the back and we were holding each other, it went WHOOMPH! And we didn't know whether the windows would hold."

This hazard also poses a threat to the cantonal road to the north that, for much of the year, is the only route linking Guttannen to the outside world; the Grimsel pass that connects the village to the south is usually closed between October and May due to heavy snowfall.

For an already isolated village of under 300 inhabitants where, due to sustained outmigration of younger generations seeking employment and other opportunities, every third person is over 65 [76], any such road closure could have severe consequences.

"There has been an excitement, there has been a unity in the village… a freedom. Nobody comes, we are for ourselves. There have been festivities in the Bären [Hotel] from time to time. No closing time. No one could come to check. We were among ourselves. That, especially as a young person, is the excitement. Later on, maybe, you think about it more. If someone would fall ill… Today, you can go by helicopter. But if the weather is really bad, even a helicopter can't fly. Then it might look a bit different. Then you worry more. But it never scares me."

Photo credit: Daniel Bürki

Safeguarding a Community

In the face of evolving threats to Guttannen's future, the local community has come together. When the Grimsel Region Climate Adaptation Strategy [77] was launched in 2016 – part of a pilot project by the Swiss federal government on addressing and managing climate change – the village founded the association Guttannen Bewegt [78] to further develop and implement the measures formulated there.

Central to these adaptation measures has been constant hazard monitoring and regular risk assessments. Based on the data and information gathered, decisions are then taken regarding which safety measures to introduce, such as reinforcing protective structures or updating the natural hazard zoning of the area to account for changing risks. There is also an early warning system [79] in place to alert residents to any danger, which extends to automatically changing traffic lights in the vicinity to red to prevent motorists from entering the hazard area.

"I've been told that if we do something now, we won't notice it for another 30 years. We don't do it for ourselves, we do it for the next generation. And now [humanity] is at a stage where I think we have to go over the books a little bit in the world, [think about] what we really do. If we keep going like this, it's not just us here in the mountains who have a problem, others will have a problem too."

However, it is not only against natural hazards that the community is fighting; Guttannen is also rallying against its declining population and, in particular, the absence of families and young people. In 2019, with fewer than ten pupils enrolled in Guttannen's primary school, the Canton of Bern took the decision to close it. Thanks to the efforts of the local community, a private school was found to step into the breach and secure the school's short-term future. In the hope of attracting young families to the area and keeping the school open in the longer term, the community subsequently invested in four chalets to offer as affordable housing. It went into debt to do so, but the gamble paid off: towards the end of 2021, the first family moved in [76]. Recent world events have also had an impact on the local population. In March 2022, the number of pupils at the primary school increased significantly with the arrival of 12 Ukrainian refugee children [80].

And Guttannen is opening up its community in other ways, too. It has installed an Ecocapsule [81], the first micro hotel of its kind in Switzerland, in order to welcome tourists. What is more, the village is now home to an ice stupa; this small artificial glacier serves both as an attraction for winter visitors and is central to a research project [82] being conducted by the University of Fribourg that aims to study freezing and melting processes. The findings of this project are being applied in Ladakh, an arid region in the Indian Himalayas, in order to help tackle future water shortages and support local climate change adaptation.

Photo credit: Daniel Bürki

"I wish that here in the village, which is actually experiencing climate change very strongly, people would also make the connection to their own everyday lives. In other words, [people would] see what is happening here… the slopes that are sliding are to do with our behavior, our everyday behavior. Of course, not that one points the finger at a mountain village. We live like the others. But that one says, we see this [climate change] so directly and we want to contribute to doing something about it through own behavior."

By holding symposia [83] and hosting excursions [84] for university research groups and other stakeholders learning about and developing solutions to issues around climate change in mountain regions, Guttannen has also positioned itself as a useful knowledge partner – and not just for scientists and practitioners. Most recently, Guttannen launched an audio theme trail, *Das Wetter und Wir* [85], inviting visitors to the village to listen to local residents reflect on how they deal with weather extremes and climate change, and

how weather shapes their everyday lives. The village hopes that, by sharing their collective experience, they might serve as a positive example of climate-resilient development.

The path ahead for Guttannen may be uncertain, but its long history is testament to the strength and ingenuity of the people who have lived there over the centuries. Now, as the villagers come together to secure their community for the future, they are learning to live alongside new challenges and create new opportunities, continuing to adapt to life in our changing mountains.

With thanks to the community of Guttannen for their kind permission to share their translated voices from Das Wetter und Wir in text form here. Das Wetter und Wir [86] can be experienced in Guttannen year-round.

One knows the problems here and lives with them. And can deal with them. And when it has to be that way, then I'll leave too. I'll leave in good time, but I won't immediately. I won't immediately run away. Because for those who live here, we are actually attached to this place Guttannen. And it is just… home."

Photo credit: Daniel Bürki

"Many mountain peoples face a set of conundrums reflecting geographic, political, and socioeconomic marginalization. Yet mountains attract powerful external actors. A key example is that of mining operations, which can degrade the environment while generating profits for outsiders rather than local people. External interventions and global processes exceed the capacity of local governance to address alone. Therefore, resolving major governance conundrums requires cross-level coordination, development of partnerships, and participatory processes in which mountain peoples have a strong voice."

PROFESSOR CATHERINE TUCKER, MRI SLC MEMBER 2016-2019 & MRI MOUNTAIN GOVERNANCE WORKING GROUP LEAD.

LAST WORD

This publication celebrates 20 years of the Mountain Research Initiative Coordination Office. Twenty years of existence is an important achievement. It warrants gratitude to the many women and men who have contributed time, effort, and vision. Thanks to their commitment, some 12,000 mountain scientists and otherwise interested parties have been able to make the MRI one of their homes.

For twenty years, we have worked to draw attention to the special plight of mountains. The message is increasingly heard but the writing has been on the wall for twenty years, loud and clear. In fact, a recently published re-analysis of MIT's 'World3' model, which was at the heart of the Club of Rome's 1972 book Limits to Growth (LtG), suggests that the worst-case scenarios accurately predicted real-world developments; while this study was carried out by a KPMG director, previous re-analysis obtained similar results. While the business-as-usual scenario 'BAU2' points to societal collapse some time around 2040, the comprehensive technology 'CT' scenario allows for a 'softer landing' once economic growth grinds to a halt in a decade or so. Is this but hyperbole?

LtG redux and other Cassandra-like moments (remember those warnings of a second, third,

and fourth Covid-19 wave?) give cause for serious concern. They take concepts such as adaptation and resilience to entirely new levels of relevance, especially in mountain regions. And yet, faced with an apparently limitless capacity of collective forgetfulness, I believe it is worth questioning the ultimately passive, or at best reactive (and often veering into reactionary), posture of adaptation and resilience, properties of systems we sometimes forget are composed of individuals like you and I.

This is what I wish for the MRI's next 20 years, alongside all the great things it already offers and will continue to do so. I wish that we can make an important and timely contribution to transformation and that this transformation be fundamentally humanist, in the tradition of the Brundtland definition of sustainable development, which emphasizes intra- and intergenerational equity and nature's regenerative capacity.

It's a tall order but I am positive we can do it, one connection at a time.

PROFESSOR
JÖRG
BALSIGER
MRI CHAIR

REFERENCES AND SOURCES CITED

1. https://journals.openedition.org/rga/?lang=en
2. https://en.unesco.org/mab
3. Messerli, B. (2012). 'Global Change and the World's Mountains.' Mountain Research and Development, 32(S1). https://doi.org/10.1659/MRD-JOURNAL-D-11-00118.S1
4. https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=6471
5. https://portals.iucn.org/library/node/19860
6. https://www.mrd-journal.org/
7. https://www.springer.com/journal/11629
8. https://ecomont.mountainresearch.at/
9. https://sustainabledevelopment.un.org/outcomedocuments/agenda21
10. Ives, J. D., Messerli, B., and Sarmiento, F. (2016) 'Obituary for a Mountain Champion: Lawrence Hamilton, 1925–2016.' Mountain Research and Development, 36(4):569-570. 12. https://doi.org/10.1659/MRD-JOURNAL-D-16-00obit.1
11. https://www.un.org/press/en/1998/19981110.ga9499.html
12. Hofer, T. (2005). 'The International Year of the Mountains: Challenge and Opportunities for Mountain Research' in Huber U. et al (eds), Global Change and Mountain Regions: An Overview of Current Knowledge. Springer, Dordrecht, pp. 1-8. https://link.springer.com/chapter/10.1007/1-4020-3508-X_1
13. UN General Assembly 2000. Status of Preparations for the International Year of Mountains, 2002. Report of the Secretary-General A/55/218. New York. https://digitallibrary.un.org/record/430338
14. Becker, A. and Bugmann, H. (eds.) (2001). Global Change and Mountain Regions: The Mountain Research Initiative. IGBP Report Series 49; GTOS 28; IHDP Report Series 13. Stockholm. https://www.mountainresearchinitiative.org/images/About_MRI/Our_History /Global_Change_and_Mountain_Regions.pdf
15. Huber, U.M., Bugmann, H., and Reasoner, M, (eds.), (2005). Global Change and Mountain Regions. An Overview of Current Knowledge. Springer, Dordrecht, 650pp. https://link.springer.com/book/10.1007 /1-4020-3508-X
16. https://www.mountainresearchinitiative.org/activities/mri-publications/global-change-in-mountain-regions-glochamore
17. Björnsen Gurung, A, ed. (2006). Global Change and Mountain Regions: A Research Strategy. MRI/UNESCO Publication, ADAG Copy AG, Zürich. https://unesdoc.unesco.org/ark:/48223/pf0000147170
18. http://carpathianscience.org/
19. https://www.perth.uhi.ac.uk/subject-areas/centre-for-mountain-studies/events/archived-events/perth-iii-mountains-of-our-future-earth/about/history-of-the-conference/
20. https://www.mountainresearchinitiative.org/news-page-all/129-mri-news/2444-a-farewell-to-mri-chair-professor-rolf-weingartner
21. https://www.mountainresearchinitiative.org/activities/communication-campaigns/mountain-trip
22. https://bioone.org/journals/mountain-research-and-development/volume-32/issue-S1
23. https://www.eda.admin.ch/deza/en/home/themes-sdc/climate-change/finanzierung-des-klimaschutzes.html /content/dezaprojects/SDC/en/2013/7F08758/phase1
24. https://www.mountainresearchinitiative.org/images/MRI_Publications /Issue_Brief_Leaving_No_One_in_Mountains_Behind.pdf
25. Kulonen, A., Adler, C., Bracher, C., & Dach, S.W.v. (2019). Spatial context matters in monitoring and reporting on Sustainable Development Goals: Reflections based on research in mountain regions. GAIA - Ecological Perspectives for Science and Society, 28(2), 90-94. https://doi.org/10.14512/gaia.28.2.5
26. https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en
27. Drexler, C., et al. (2016). Mountains for Europe‘s Future: A Strategic Research Agenda. https://www.mountainresearchinitiative.org/activities/mri-publications/mountains-for-europe-s-future
28. https://futureearth.org/
29. https://bioone.org/journals/mountain-research-and-development/volume-36/issue-4
30. https://link.springer.com/journal/10113/volumes-and-issues/17-8?page=1

31. https://www.geomountains.org/
32. https://nemor.creaf.cat/
33. https://mountainresearchinitiative.org/activities/projects/conectate-a
34. https://mountainresearchinitiative.org/activities/projects/adaptation-at-altitude
35. https://mountainresearchinitiative.org/activities/communication-campaigns/vanishingglaciers
36. https://www.cde.unibe.ch/
37. https://www.unige.ch/gedt/
38. https://scnat.ch/en
39. https://www.eda.admin.ch/sdc
40. https://www.swissuniversities.ch/themen/entwicklung-und-zusammenarbeit/p-6-swissuniversities-development-and-cooperation-network-sudac
41. https://www.llv.li/inhalt/11842/amtsstellen/amt-fur-auswartige-angelegenheiten
42. Adler, C. et al., 2020. 'Making Connections for Our Changing Mountains: Future Directions for the Mountain Research Initiative.' Mountain Research and Development, 40(3): https://doi.org/10.1659/MRD-JOURNAL-D-20-00045.1
43. https://mountainresearchinitiative.org/activities/projects
44. https://mountainresearchinitiative.org/activities/community-led-activities
45. https://www.mountainresearchinitiative.org/who-we-are/team/principal-investigators
46. https://www.mountainresearchinitiative.org/activities/projects/contributions-to-science-policy
47. https://www.mountainresearchinitiative.org/activities/projects/completed-flagship-activities
48. Hock, R., G. Rasul, C. Adler, B. Cáceres, S. Gruber, Y. Hirabayashi, M. Jackson, A. Kääb, S. Kang, S. Kutuzov, Al.
Milner, U. Molau, S. Morin, B. Orlove, and H. Steltzer, 2019: High Mountain Areas. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 131–202. https://doi.org /10.1017/9781009157964.004
49. Adler, C., P. Wester, I. Bhatt, C. Huggel, G.E. Insarov, M.D. Morecroft, V. Muccione, and A. Prakash, 2022: Cross-Chapter Paper 5: Mountains. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/
50. https://www.earthobservations.org/index.php
51. https://www.cnr.it/it/istituto/043/direttore/istituto-di-geoscienze-e-georisorse-igg
52. https://www.earthobservations.org/documents/work%20plan/geo_wp1215_rev3_140123.pdf
53. https://www.unr.edu/nevada-today/news/2014/mountain-observation-conference
54. Sayre, R., Frye, C., Karagulle, D., Krauer, J., Breyer, S., Aniello, P., Wright, D.J., Payne, D., Adler, C., Warner, H., VanSistine, D.P., & 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, 210. https://doi.org/10.1659/MRD-JOURNAL-D-17-00107.1
55. 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, 265. https://doi.org/10.1659/MRD-JOURNAL-D-8-00065.1
56. https://adaptationataltitude.org/adaptation-at-altitude
57. https://earthobservations.org/documents/gwp20_22/GEO-MOUNTAINS.pdf
58. https://www.mountainresearchinitiative.org/news
59. https://www.geomountains.org/news-page-all/138-geo-mountains/2743-geo-mountains-update-and-outlook
60. https://www.geomountains.org/news-page-all/138-geo-mountains/2833-geo-mountains-annual-summary-2021
61. Viviroli, D., Kummu, M., Meybeck, M. et al. Increasing dependence of lowland populations on mountain water resources. Nat Sustain 3, 917–928 (2020). https://doi.org/10.1038/s41893-020-0559-9
62. https://mountainresearchinitiative.org/activities/community-led-activities/working-groups/2098-elevation-dependent-warming
63. Pepin et al. 'Elevation-Dependent Warming in Mountain Regions of the World' in Nature Climate Change (2015): https://doi.org/10.1038/nclimate2563
64. https://researchportal.port.ac.uk/en/persons/nick-pepin
65. https://mountainresearchinitiative.org/activities/community-led-activities/working-groups/2097-mountain-observatories

66. https://www.mountainresearchinitiative.org/news-page-all/129-mri-news/2871-towards-a-definition-of-essential-mountain-climate-variables
67. Pepin et al. 'Climate Changes and Their Elevational Patterns in the Mountains of the World' in Reviews of Geophysics (2022): https://doi.org/10.1029/2020RG000730
68. https://cryosphericsciences.org/
69. https://www.permafrost.org/
70. https://www.gaphaz.org/
71. https://uploads.knightlab.com/storymapjs/1a92d3359d7d5572e32c02791c4ef0da/our-changing-glacier-aakw-taak-sit/index.html
72. https://www.nationalgeographic.com/animals/article/150322-romeo-wolf-dog-animals-wildlife-alaska-ngbooktalk
73. https://hls-dhs-dss.ch/de/articles/000468/2014-10-15/
74. https://www.friedrich-verlag.de/geographie/klima-wetter/umgang-mit-risiken-in-zeiten-des-wandels-7404
75. https://interpraevent2016.ch/wp-content/uploads/2019/03/IP16_EX8_Guttannen_digital.pdf
76. https://www.srf.ch/news/schweiz/abwanderung-im-bergdorf-wie-guttannen-mit-voller-kraft-gegen-das-aussterben-kaempft
77. https://www.nccs.admin.ch/dam/nccs/de/dokumente/klima/externe-studien-berichte/klimaadaptionsstrategiegrimselgebiet.1.pdf.download.pdf/klimaadaptionsstrategiegrimselgebiet.pdf
78. https://www.guttannen-bewegt.ch/
79. https://www.swissinfo.ch/eng/natural-hazards-_an-alpine-village-on-the-frontline-of-climate-change/44361602
80. http://www.schuleguttannen.ch/
81. https://www.guttannen-bewegt.ch/hintergrund/aktivitaeten/ecocapsule
82. https://eisstupa.jimdosite.com/
83. https://www.berneroberlaender.ch/es-bewegt-sich-was-in-guttannen-743550248314
84. https://www.jungfrauzeitung.ch/artikel/175350/
85. https://www.guttannen-bewegt.ch/themenpfade/pfade/klima
86. https://www.guttannen-bewegt.ch/themenpfade

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