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Joint Endeavor Toward Sustainable Mountain Development: Research at the Institute for Interdisciplinary Mountain Research of the Austrian Academy of Sciences

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The sustainable development of mountain regions requires inter- and transdisciplinary knowledge. The Institute for Interdisciplinary Mountain Research contributes to this global endeavor as part of the Austrian Academy of Sciences and as a member of international scientific networks, together with local partners and stakeholders. As a joint effort of individual researchers covering multiple fields, this article highlights our views on mountains as research objects, the phenomena we investigate as parts of entire mountain systems, and the synergies and differences of the disciplinary frames within which we work.

Alles ist Wechselwirkung [Everything is interaction]

(A. von Humboldt, 18XX, 27r)

Sustainable development as the overarching goal of the 21st century

Sustainable development, a major global goal of the early 21st century, requires that wellbeing should not decrease over generations (Matson et al 2016) and that tipping points be avoided (Lenton et al 2008). This clearly requires scientific effort (Independent Group of Scientists 2019) and knowledge transfer. Mountain areas are complex systems with great geodiversity, steep gradients, and high variability in their hydro-climate systems, topography, ecosystems, and societies. To work out future sustainable pathways in mountains, we thus need to capture processes and feedback in these complex systems through interdisciplinary research that can investigate past development paths, system properties, and present management capabilities.

Founded in 2006, the Institute for Interdisciplinary Mountain Research of the Austrian Academy Sciences (IGF/ÖAW) is dedicated to investigating the imprints of global change on mountain systems. With a historically strong background in geography and vegetation ecology, the team members cover a wide range of scientific disciplines (see Figure S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-22-00002.1.S1). The strength of the interdisciplinary research lies in scientific cooperation, enabling us to work on a great variety of individual research topics (see Box S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-22-00002.1.S1). Mountain science as a field has an uninterrupted (Glass et al 2013; Messerli 2012) and ongoing (eg Otero et al 2020; Sarmiento et al 2020) tradition of joint interdisciplinary research, which is an excellent basis for coping with the societal challenges of the 21st century.

Heading toward trans- and interdisciplinary mountain research

The evolution of the disciplinary philosophies of science in the 19th and 20th centuries (Lohse and Reydon 2017) has resulted in greatly differing definitions of material objects and scholarly framings of research questions. This is

illustrated by the various meanings of "mountains" for the researchers of the IGF/ÖAW (Figure 1A). The focus on mountains as objects of analysis enables us to develop our interdisciplinary research by emphasizing their various aspects and interconnections. Mountains allow us to investigate very specific physical and social settings, as well as greatly varied land use and cultural techniques related to these specific livelihoods (Figure 1B). The individual scientific disciplines provide the framings (Figure 1A) and define the views on the real-world phenomena studied (Figure 1B) to develop basic understanding and theoretical concepts in the world of science (Figure 1C).

Our research in the European Alps builds on long-term datasets and benefits from in-depth studies of a partly glacierized mountain system surrounded by a highly populated region of Europe. Given their complexity, which arises from the coexistence of diverse near-natural and heavily anthropogenized areas, the Alps are an internationally outstanding mountain region for long-term and interdisciplinary research. Even though most of our researchers struggle with short-term contracts and soft money, their field of research requires long-term data and concepts. As major challenges in interdisciplinary research, the IGF team lists understanding the conventions of different disciplines, finding a common language, scale, and accuracy, and building a common theoretical framework (joint ontological and epistemological positions) without losing the power of disciplines or knowledge considered self-evident in some disciplines. The task of understanding research from these many different perspectives by leaving one's own comfort zone and seeking compromise in the definition of research objectives and work methodologies is made even more challenging by the difficulty in funding interdisciplinary projects.

A typical example of the challenges encountered is found in the temporal and spatial scale used and the corresponding terminology. These depend on specific research contexts: "now and here" is an obvious baseline for comparing past and present pathways, but these can be interpreted very differently (Figure 2A).

"Now" can mean the latest measured data point or measurement campaign, this decade, a window of a couple of years around the present, or the current growing season. There is a clear range of variability even in the context of a specific research question, for instance, if one compares the current state of a glacier with its Holocene variability. The process knowledge of present mass balance comes from energy balance records at hourly resolution, annual mass balance data, and a comparison with centennial means, with "now" referring to the last period of 1 hour, 1 year, or 100 years. More conceptual definitions understand "now" as a contextual result of the past or as the subjective current living situation.

"Here" can be interpreted as coordinates, within a grid point, an area around an observed entity, the habitat, or ecological community, within the head catchment, a vegetation plot, or sampling site, the study area defined by the data available, or a specific ecological niche/ecotone. More conceptual definitions are the ethnographic concept of "field" (places, regions, or settings) and their extent defined by local communities, traditions, culture, or political or administrative boundaries.

Based on the various phenomena investigated and their properties in terms of responses in time and space, the data types investigated at the IGF vary from gridded data to point measurements, from in situ to historical records or even numerical modeling data and polls (Figure 2B).

Thus, setting the frame for interdisciplinary research is challenging, even if we focus on only "here and now," and even more so if we are studying coevolutionary pathways.

Contributions of the IGF to a transformation toward a sustainable mountain future

Researchers at the IGF contribute to scientific efforts for sustainable development by aiming for a better understanding of human–nature/nature–culture connectedness, adding knowledge about landscape, regional, and urban development, finding new systems of human land use in mountains, and revealing past development paths. Awareness building on global climate change and climate change impacts is key to any transition toward sustainability. Understanding the subjective meaning of "sustainable" and "development" and learning from experiences (best practice examples) adds knowledge about the high complexity and variability of processes in mountains. Specific research topics in our sustainability research portfolio include investigating environmentally sustainable alternatives in landslide management, enhancing our understanding of slope movements as a solid basis for a sustainable future, supporting protected mountain areas, and adding to knowledge on climate change effects of toxicant contamination in fish populations.

Recent studies by IGF researchers on the environmental conditions during the Holocene and their impact on mankind have discussed the paleo-perspective on 3500 years of sustainable development in Hallstatt (Festi et al 2021), revealed glaciers as climate archives (Bohleber et al 2020), and pointed out the historical impact of climate change on Alpine topography at high elevations (Hohensinner et al 2021).

Risk and landscape research at the IGF, for instance, correlates simulated hydro-meteorological input with a measured response of landslide velocity (Pfeiffer et al 2021) and aims for a better understanding of human–landscape interactions and of natural hazards (Hossain et al 2020).

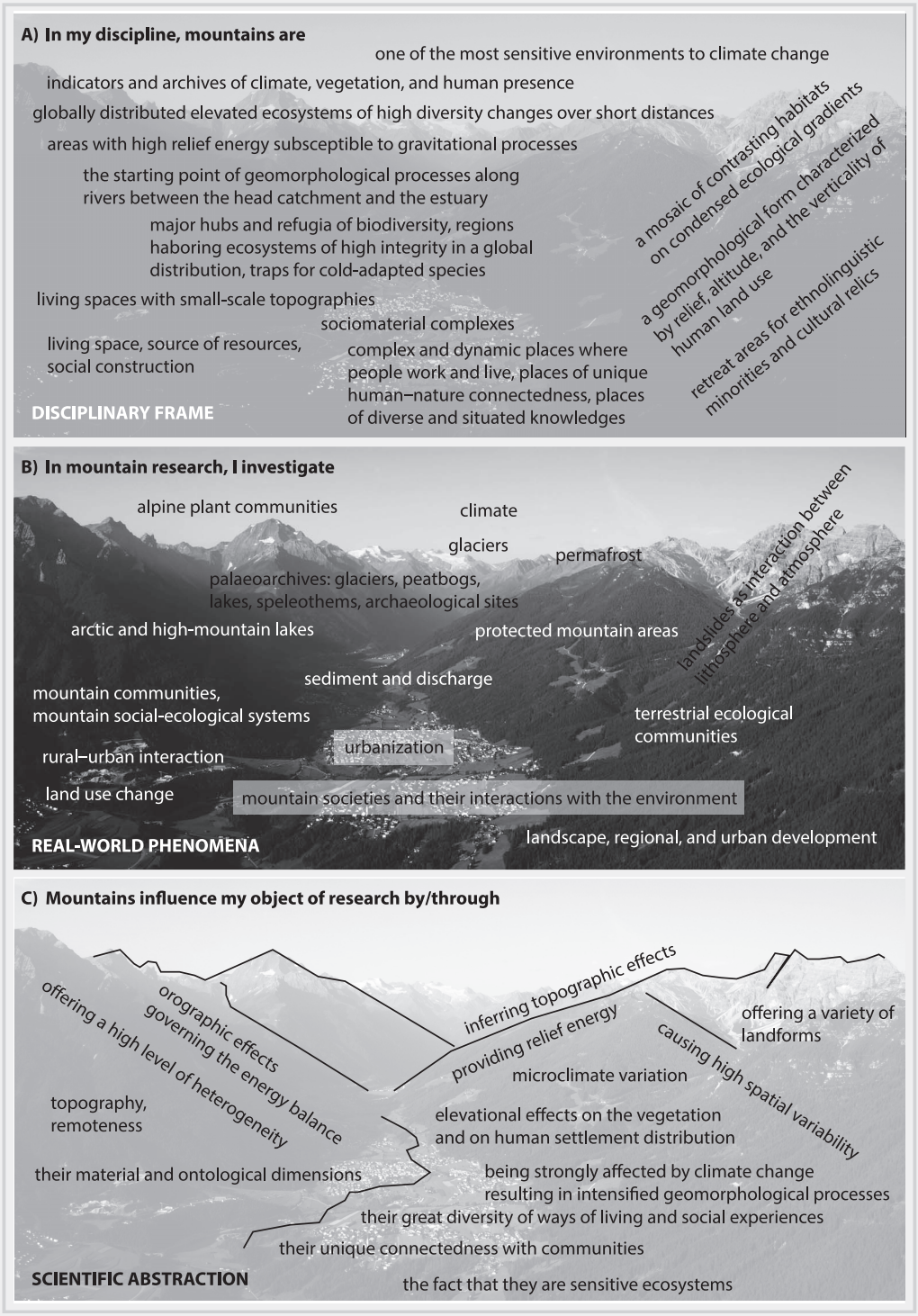
Human geography researchers at the IGF have analyzed the impacts of urbanization and local responses to it (Haller and Branca 2020), found new systems of human land use in mountains (Borsdorf and Haller 2020), expanded knowledge on landscape, regional, and urban development (Bender and Haller 2017), and presented best-practice examples to learn from (Wymann and Ruiz Peyré 2020).

Our ecological research, finally, has added to knowledge on climate change effects of toxicant contamination in fish populations (Lehnherr et al 2017) and enhanced knowledge on biodiversity declines and their impact on the integrity of near-natural ecosystems (Cuesta et al 2020).

Global efforts require work within international networks

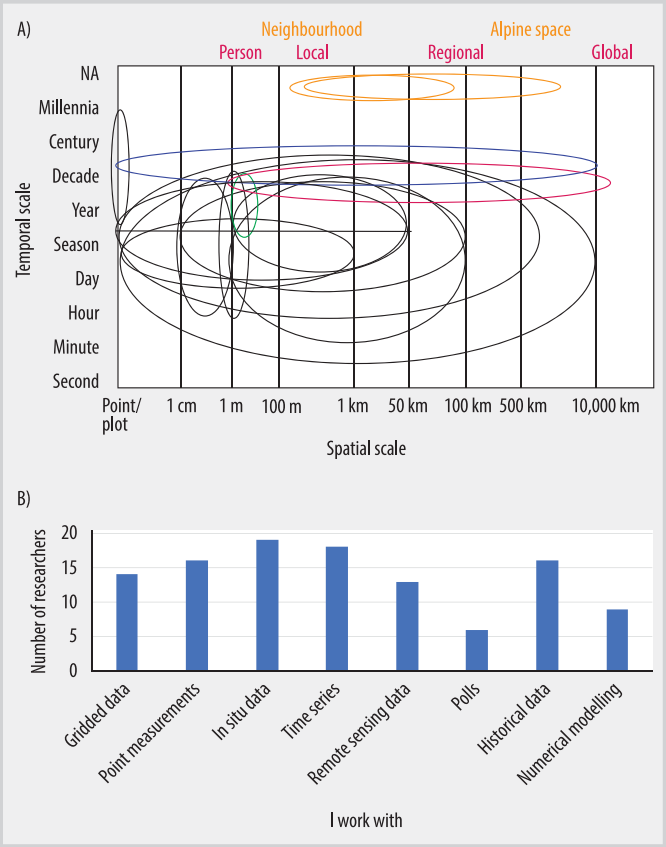
In the context of local and global sustainable development, international research networks are important for sharing knowledge and creating transformative energy. International long-term research is a major strength of the

FIGURE 1 Diversity of mountain areas: (A) perspectives on mountains in the research fields of the IGF/ÖAW vary just like (B) the investigated physical, socioecological, and cultural phenomena. Mountains present great diversity and variability in the investigated phenomena within the respective fields, with some phenomena (C) found in mountains only, for example, because they require relief energy.



IGF at the Austrian Academy of Sciences. The Global Observation Research Initiative in Alpine Environments (GLORIA, https://gloria.ac.at/), which investigates mountain biodiversity changes, is coordinated at our institute. IGF researchers observe glaciers as indicators and archives of climate change in detail within the frameworks of the World Glacier Monitoring Service (https://wgms.ch/), Global Terrestrial Network for Glaciers (https://www.gtn-g.ch/), and Global Climate Observing System (https://gcos.wmo.int/). The GLORIA master site of Schrankogel, as well as the glacier research sites of Jamtalferner and Kesselwandferner, are also part of the Long-Term Ecological Research (LTER) network. The IGF coordinates the Horizon 2020 Marie Skłodowska-Curie Research and Innovation Staff Exchange (MSCA-RISE) project Highlands.3 (https://www.highlands3.eu/), which involves 42 academic and nonacademic

FIGURE 2 (A) The different temporal and spatial scales used in the current research demonstrate the specific approaches to the natural (black), social (red), and cultural (orange) space—among many other aspects of space, including language, political districts, and religion. (B) The variety of investigated phenomena and their different extents and response times require a great variety of empirical evidence to create scientific knowledge on humans and the environment in mountain regions.



institutions in 25 countries on 4 continents. The project promotes inclusive sustainable development in highlands through comparative transdisciplinary research in different mountain ranges of the world. These networks make data and research results easily available for researchers from other mountain regions, encouraging comparative studies. With climate change and global change as major challenges, we are happy to cooperate with researchers across the globe on our pathway toward sustainable and resilient mountain regions.

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Supplemental material

FIGURE S1 Pathways of academic development and cooperation within the team of the Institute for Interdisciplinary Mountain Research (IGF).
BOX S1 Main research questions guiding current research efforts of the IGF team.

Found at: https://doi.org/10.1659/MRD-JOURNAL-D-22-00002.1.S1