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Editorial: Water and hazards in mountainous regions in a changing climate

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Editorial on the Research Topic
Water and hazards in mountainous regions in a changing climate

Mountainous regions receive and store more precipitation than downstream areas due to the orographic effect and the lower temperatures at altitude which favor the storage of this water as snow and in glaciers. This stored water is released more gradually than it would be otherwise, delaying runoff and providing a more constant water supply during dry periods. Thus, mountains are often depicted as natural "water towers" that store and supply water to sustain human and ecosystems needs downstream (Viviroli et al., 2007; Immerzeel et al., 2020; Figure 1).

These "water towers" are, however, sensitive to climate change. Reduced snow cover, glacier volume, and permafrost thaw have been observed in recent decades and attributed to climate change (Hock et al., 2019). Warming reduces the storage potential of water as snow and in glaciers, increases evapotranspiration, and thus increases water insecurity downstream. The impacts are of particular importance for regions that are water-scarce and heavily populated, such as dryland areas of the Andes and parts of High Mountain Asia (e.g., the Indus, Amu Darya and Syr Darya River basins), and models capable of accurately simulating these factors are needed to enable planning and management of water resources.

Water in liquid and frozen forms in mountain environments not only represents a critical resource but also a potential hazard. For example, flash floods can result in soil erosion, river overflow, landslides, and loss of lives (Godara et al.). In steep mountainous regions flash floods can be particularly destructive since the landscape facilitates a rapid rise in discharge and water velocities (Moraru et al., 2021). Likewise, the rapid downslope movement of a glacier (e.g., surging glaciers or glacier detachments) or water generated via glacial melt (e.g., Glacier Lake Outburst Floods) can be devastating to communities downstream. In recent decades, the stability of mountain slopes has decreased due to glacier retreat and permafrost thaw, and flash floods have increased at high elevations in winter (Hock et al., 2019).

This Research Topic (RT) provides a range of approaches and perspectives on understanding change in mountain systems. These include two novel contributions that incorporate more advanced glacier modeling and evapotranspiration parameters in hydrological models, both of which have large impacts on streamflow levels. Pesci et al. make use of an open-source distributed hydrological model (Water Flow and Balance

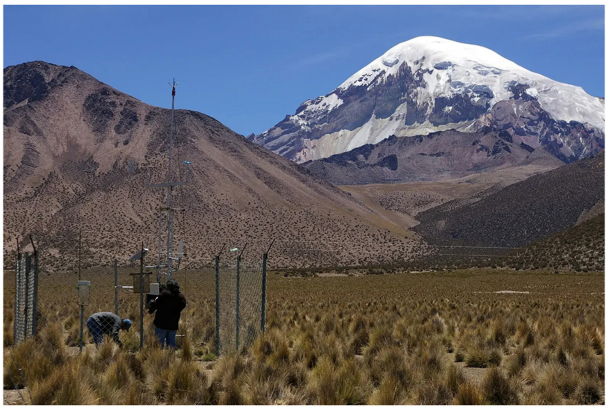

FIGURE 1
Meteorological station maintained by Instituto de Hidraulica e Hidrologia (based in La Paz) in front of Nevado Sajama, the highest peak in Bolivia (6,542 m). Photograph by S. Gascoin.

Simulation Model, WaSiM) and couple this with the Open Global Glacier Model (OGGM) which includes the physics of glacier dynamics. Their approach is novel since many glacio-hydrological models at the catchment-scale emphasize the processes for non-glacierized parts of the catchment while applying relatively simple glacier models that do not account for the dynamic movement of glaciers. The coupled model projects a glacier that is ∼19.5% smaller and an additional ∼19% reduction in peak streamflow compared to projections without glacier dynamics by 2,100 for an Austrian catchment. This study provides a benchmark for improved catchment scale modeling in mountainous environments. In a similar vein, Tran et al. test a new diagnostic tool to understand the heterogeneity of streamflow loss to evapotranspiration in headwater catchments. The study shows the utility of the Budyko Shape Parameter (ω) which reflects the characteristics of a basin such as climate, vegetation, topography, and combinations of these. Tran et al. fit ω to 37-years of hydrological simulation outputs in the Upper Colorado River Basin and find that ω can be used to describe the severity of streamflow loss during dry years. This methodology will be useful for effective planning and management of water resources, particularly in mountainous regions where streamflow losses are heterogenous due to the complex topography.

Flash floods in mountainous regions are complex to model due to the topography and large variability in meteorological variables (Li et al., 2020; Maqtan et al., 2022). Usually, flood events are modeled with separate hydrological and hydraulic models, with more accurate coupled model approaches, being very limited. In this RT, Godara et al. apply the two existing coupled models which are suitable for steep terrain (TELEMAC-2D and HEC-RAS 2D) to a mountain catchment in Norway to compare their performance. This study highlights the possibilities and limitations of existing models and provides important insights to help engineers and researchers evaluate model use for flood events in steep catchments.

Mountain hazards also include the sudden collapse of low-angle mountain glaciers resulting in massive ice-rock avalanches, or glacier detachments, which were relatively undocumented pre-2016. Since 2016 at least 18 glacier detachments have been reported prompting an investigation to understand the driving factors to eventually predict their occurrence (Kääb et al., 2021). Here Ugalde et al. provide a wealth of information for the detachment of the Aparejo Glacier in Chile in 1980. As well as characterizing the detachment event, they elucidate causes of the glacier detachment, as well as possible warning signs pre-detachment, which likely has important implications for glacier monitoring programmes generally.

The importance of glaciers as a strategic water resource has been formally recognized through the approved Argentinian and proposed Chilean Glacier Protection Laws. In a contribution to this RT, Fox et al. present an analysis of how environmental campaigns, scientific research, and policy came to strategically frame glaciers as a water resource. They conclude that this limits their protection because it is conditional on how glaciers are valued as a water resource, their protection could be discarded if water can be obtained from another source (e.g., a desalination plant), and this narrow focus excludes their protection based on other important factors such as potential hazards or their cultural importance.

Finally, Zeballos et al. connect science and society through data collection, which can act to both strengthen monitoring programmes and empower communities in the decision-making process. The study highlights the potential and caveats with participatory monitoring techniques, and advocates for long-term relationships to ensure the collection of continuous, high-quality data.

We have enjoyed editing this Research Topic, as it shows the wide array of research currently underway in mountain region hydrology and hazard research, and speaks to the importance of connecting science, technology and people together to address complicated challenges.

Author contributions

NS: Writing – original draft, Writing – review & editing, Conceptualization. SG: Writing – review & editing. SM: Writing – original draft, Writing – review & editing. SS: Writing – review & editing. WI: Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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