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Editorial: Hydrological and chemical effects of a changing cryosphere on mountain freshwaters

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Editorial on the Research Topic
Hydrological and chemical effects of a changing cryosphere on mountain freshwaters

Introduction

Billions of people depend upon mountains for water supply. Snow, glaciers and permafrost (and related landforms) are key elements of the mountain cryosphere, and represent relevant water sources (and storage systems) for downstream areas. In the last decades, most of the global mountain areas have undergone a snow-cover decline, the majority of mountain glaciers have been receding, and mountain permafrost has suffered degradation and ice loss due to warming climate. These changes affect the quantity and quality of mountain freshwaters. Snow-cover reduction can have multiple implications on water resources and related ecosystem services. Glacier recession can modify the hydrological regime of headwater catchments and influence the water supply of lowland areas. In turn, permafrost degradation and the cryospheric changes of rock glaciers - and other mountain landforms - may partially offset water shortages by increasing the water storage capacity of mountain terrains. Permafrost degradation and glacier recession can also increase the content of solutes and trace elements, including heavy metals, in mountain freshwaters.

This Research Topic gathers eight original articles describing how changes in mountain cryosphere influence hydrological systems (Figure 1).

Glaciers and snow melt provide high quantities of water to the river networks. Changes in seasonal glacier ablation and snowfall control year-to-year variations in streamflow and impact the water availability in downstream areas. Adnan et al. (this Research Topic) and

Budhathoki et al. (this Research Topic) dealt with the application of hydrological models (UBC-WM, HBV-light) and estimated the contributions of the different runoff components and their seasonal variations. The two studies showed that the snow and glacier melt contributions in the Gilgit River (snowmelt 25%; glacier melt 46%) in the Upper Indus basin were much higher than the monsoon-dominated Tamakoshi River (snowmelt 5%; glacier melt 13%) in the Central Himalaya. Such modelling approaches provide essential insights into the ongoing rapid hydrological changes occurring in glacierised river basins.

While most of research on glacier hydrology has hitherto focused on their key role as water resources, very little is known on the relative contribution from snow, ice, firn, and rainfall on the glacier meltwater itself. To address this knowledge gap, Penn et al. (this Research Topic) used chemical (sulphate) and isotopic (δ^2H, δ^{18}O, d-excess) tracers to investigate the contribution from snow and ice to the supraglacial flows and the glacier outflow in a glacierised catchment in the Canadian Rockies. The seasonality of the relative contribution from these water sources was related to cryospheric and hydrological processes occurring on the glacier surface, and beneath the glacier where the authors found indirect evidence of internal water storage.

Rock glaciers are common geomorphic features in alpine landscapes. They are slowly creeping mixtures of debris and ice which form by processes on a continuum from glacial to periglacial. Rock glaciers comprise a potentially significant but poorly quantified water resource. To address this knowledge gap, Navarro et al. (this Research Topic) investigated the internal structure of the transition zone of a debris-covered glacier and an active rock glacier in Chile (Tapado glacier complex) using a combination of three geophysical techniques. A potentially important hydrological role of the active rock glaciers was argued based on the observed heterogeneous internal structure of the rock glacier zone, which was further associated with enhanced vertical infiltration processes compared to the debris-covered glacier area. Thus, rock glaciers may have an increasing impact on the hydrological system in a warming climate due to their ability to effectively transfer and store water.

Rock glaciers are also known to act as a solute-concentrating site and are capable to strongly influence the quality of surface waters. Nickus et al. (this Research Topic) analysed the chemical composition of the ice matrix of an active rock glacier in the Central Eastern Alps (Lazaun, Italy). The 10,000-year-old core had layers characterised by high concentrations of major ions and trace elements, mostly driven by enhanced geochemical weathering of bedrock minerals. Superimposed prehistoric atmospheric deposition from metal ore mining, wood (biomass) burning and large volcanic eruptions may have potentially added up to increased substance loads in certain depths of the core. In addition, Del Siro et al. (this Research Topic) found that outflows from active rock glaciers were more enriched in solutes when compared with those from inactive rock glaciers and non-glacial locations. Building on their findings in the Swiss Alps, they suggested that the higher concentrations of sulphates, calcium, and magnesium in permafrost influenced springs were provided by ice melt. The authors supported the hypothesis that airborne chemical compounds were deposited with snow during a period of permafrost accretion (1960s–1980s), and therefore became part of the rock glacier ice during the refreezing of the snowmelt water.

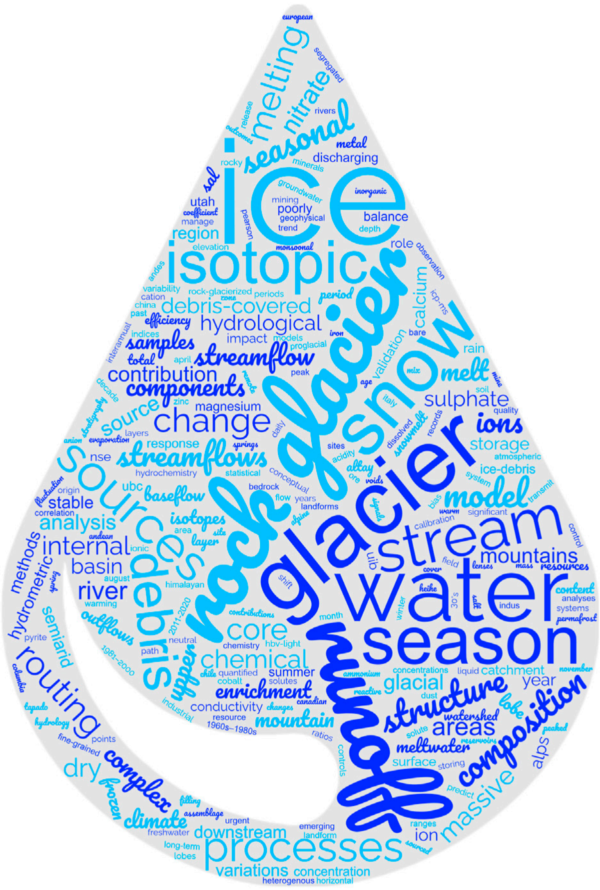

FIGURE 1
Word cloud of the abstracts of the contributions to this Research Topic (software: WordClouds.com).

Finally, Munroe and Handwerger (this Research Topic) analysed the hydrochemical and stable water isotope characteristics of surface waters in two rock-glacierised mountain ranges in Utah (United States). In late summer, rock glacier water was distinguished by enriched isotope values along with elevated electric conductivity and high cation concentrations (e.g., calcium and magnesium). A clear hydrochemical influence from rock glacier stream on the receiving stream water was demonstrated. These findings underscore the significant role played by rock glaciers in shaping the hydrochemistry of high-elevation watersheds.

Snow is an important atmospheric deposition. Unravelling the source and transport of major water-soluble inorganic ions in snow cover is relevant for understanding hydrological and chemical processes. Zhang et al. (this Research Topic) analysed the major water-soluble inorganic ions in snow at two field sites in Heihe and Altay (Northwest China). The concentrations of soluble inorganic ions in snow were higher at the Altay region than at the Heihe region and other remote areas at high elevation and latitude. The chemical composition of snow was mostly influenced by terrestrial sources, although anthropogenic and marine sources were also relevant.

These studies from Asia, Europe, and North and South America present traditional and modern methods and techniques, and their combination, such as field-based chemical and hydrological analyses, glacio-hydrological modelling, and geophysical measurements. Considering all contributions, this Research Topic will help the scientific community understand and quantify the role of the cryosphere in shaping the hydrological and geochemical dynamics of mountain watersheds.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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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