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Editorial: Climatic and Associated Cryospheric and Hydrospheric Changes on the Third Pole

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Editorial on the Research Topic

Climatic and Associated Cryospheric and Hydrospheric Changes on the Third Pole

The Third Pole (TP), known as the “Asian Water Tower,” is a high-elevation region of Asia centered on the Tibetan Plateau. The TP is home to around 100,000 km^2 of glaciers, comprising the largest volume of ice outside the Antarctic and Arctic. The TP lies at the headwaters of many large Asian rivers (e.g., Ganges, Brahmaputra, Indus, Yangtze, Yellow, Mekong, Salween, Amu Darya, and Syr Darya) and serves as the main water supply for millions of inhabitants in downstream countries. The high-elevation region is widely covered by snow, glaciers, lakes, permafrost, and seasonally frozen ground, and exerts a profound climatic influence on adjacent and distant regions.

The TP has been getting warmer and wetter during the past several decades, as indicated by significant air temperature rises, and spatiotemporally, heterogeneous precipitation increases–particularly since the 1980s. The TP warming, which is above the global average rate, could be associated with variations in precipitation and decreases in snow depth, extent, and persistence. The warming and wetting climate has been closely associated with glacier retreat, lake expansion, permafrost thawing, and thickening of the active layers over the permafrost.

This research topic aims to cover recent climate changes over the TP and its associated impacts on the cryosphere and hydrosphere. The studies address changes in surface air temperature, precipitation, seasonal snow cover, mountain glaciers, permafrost, lakes, and river runoff, and examine how these changes are linked to climate change across different spatial scales (from a catchment to the whole TP). Results from these studies will improve our understanding of cryosphere–hydrosphere–atmosphere interactions over the TP.

This research topic includes three comprehensive reviews in TP cryohydrology (one about the discipline as a system, and two about permafrost), which describe research progress in these topics and provide insightful perspectives on the recent advancement of *in situ* observations, satellite remote sensing, as well as process-based modeling. This is a multidisciplinary special issue bridging the gaps in climatology, hydrology, cryosphere, geochemistry, and remote sensing sciences.

Dai et al. suggest that a large alpine lake (Lake Nam Co.) can be an important regulator of regional climate (e.g., precipitation) over the TP, based on the WRF (weather research forecasting model) sensitivity experiments for the year 2008. Their study indicates that the lake cooling effect can cause a reduction in the over-lake summer precipitation by 45–70%, while the lake warming effect can enhance the autumn precipitation by 60% over the lake and surroundings.

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Wood et al. demonstrate that glacier retreat and snowpack loss threaten high-altitude communities that rely upon seasonal melting water for domestic water resources. They indicate that 34–90% of water comes from ice and snow melt during the dry pre-monsoon season, accounting for an average discharge contribution of 65% in the Khumbu Valley, Nepal (a highly glaciated catchment with elevations ranging from 2,000 to 8,848 m). With as much as two-thirds of the dry-season domestic water supply at risk, the communities of the Khumbu Valley are extremely vulnerable to the cryospheric effects of climate change.

Chevallier et al. examine the headwater geochemistry of Mount Everest (Upper Dudh Koshi River, Nepal). They aim to address three parallel topics: 1) the dynamics of the water geochemistry, major ions, and trace elements; 2) the stable water isotopes of precipitation and rivers; and 3) water use by the inhabitants.

Chen et al. illustrate an atmospheric bridge that connects the Barents Sea ice and snow depth in the midwest Tibetan Plateau. They reveal that a positive anomaly of the Barents Sea ice can enhance the meridional air temperature gradient to the south and hence accelerate the polar front westerly jet. Consequently, an anomalous Rossby wave propagating upward and equatorward is generated, resulting in a dipole pattern of the atmospheric circulation anomaly over the polar region and Eurasian continent.

Different from previous studies on the TP snow using coarse-resolution microwave data (25 km × 25 km), Smith and Bookhagen assess multi-temporal snow–volume trends in the TP from 1987 to 2016 with high-resolution (3.125 km × 3.125 km) passive microwave data from the special sensor microwave imager (SSM/I) instrument family at refined spatial details. They find that changes in the high percentile monthly snow–water volume exhibit steeper trends than changes in low percentile snow–water volume, which suggests a reduction in the frequency of high snow–water volumes in much of TP. Regions with positive snow–water storage trends generally correspond to regions of positive glacier mass balances.

Under accelerated warming on the TP, permafrost degradation is dramatically altering regional hydrological regimes. Jiang et al. review the progress and challenges in studying the TP permafrost, with a focus on remote sensing approach, while Gao et al. review the state-of-the-art understanding of permafrost hydrological processes in hydrological models of varying complexity. They both emphasize the importance of long-term field measurements and recommend the integration of satellite remote sensing retrievals together with process-based permafrost-hydrology models to deepen the understanding of permafrost hydrological processes and to enhance the ability to predict the future response of permafrost hydrology to climate change.

Finally, Ding et al. review the evolution of the concept of cryohydrology, and analyzes its hydrological basis and discipline system. Three points are concluded in this study. 1) Cryohydrology was developed based on traditional hydrology for a single element of the cryosphere, focusing on the hydrological functions of the cryosphere and their impacts on the water cycle and water supply to other spheres. 2) The hydrological function of cryohydrology is further subdivided into water conservation, runoff recharge and hydrological regulation. 3) The key research issues of cryohydrology include the principal research method, hydrological process, watershed function, and regional impact. Cryohydrology aims to deepen the theoretical and cognitive levels of the associated mechanisms and processes, to accurately quantify the hydrological functions of the basin, and to promote the understanding of the ecological and environmental impacts of the cryosphere.

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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