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Editorial: Cryospheric changes in Eurasian water towers: cloud-platform-aided mapping, monitoring, and model-prediction

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Editorial on the Research Topic
Cryospheric changes in Eurasian water towers: cloud-platform-aided mapping, monitoring, and model-prediction

The cryosphere and its changes are important for the sustainability of the human community, especially in the background of fast climate change and increasing anthropogenic activities. The Qinghai-Tibet Plateau (QTP), Central Asian mountains, Alps, Carpathia and Caucasus, Da, Xiao, and Outer (Stanovoy) Xing'anling (Khinggan), Yablonovy, Khenti, Sayan, and Changbai mountains, and other mountain chains in Eurasia are in the source areas of large/major rivers, i.e., Eurasia Water Towers (EWTs), which experience 2–3 times more climate warming than the global average. The multi-system coupling of cryosphere dynamics with related eco-environmental and hydrological processes is vital for the security of human communities in Eurasia, as well as many other parts of the Northern Hemisphere, in the 21st and 22nd centuries.

Over the past several decades, the components in the EWTs have undergone serious degradation at wide spatiotemporal scales, which was evidenced by sparsely and unevenly distributed observations at some long-term monitoring sites and occasional investigations at some temporal plots. For example, permafrost was reported to degrade severely across all three poles, including the Qinghai-Tibet Plateau, Arctic and Subarctic regions, and the surrounding Antarctic, in the aspects of rising of ground temperature, shrinkage of permafrost areal extent, deepening of active layer thickness, and decreasing of maximum depth of seasonal frost penetration, as revealed by *in situ* observations or simulations driven by reanalysis products or future climate scenarios. Variations in some geomorphologic features in permafrost regions, such as rock glaciers, frost mounds, patterned ground, and ice wedges, which were synthetically analyzed with the facilitation of the increasing of remote sensing images, demonstrated the sensitivity of permafrost to climate change as well.

With the growth of field observational, laboratory experimental, and remote sensing data and reanalysis products, the features and dynamics of various elements of the cryosphere in the EWTs have been comprehensively analyzed. The implementations of some continuous monitoring points, slope/transect, watershed/basin, and regional to continental scales, have greatly increased the possibilities for analyzing the diurnal, seasonal, and yearly dynamics of geomorphologic features and the thermal state of the land surface in near real-time. With the increasing knowledge and the rapid advances in information technologies, there is an increasing interest by the worldwide scientific community to fully justify the variations of the cryospheric elements. They want to more accurately reproduce the state of evolution of physical processes of the earth through high-fidelity computer models, with the aim of understanding, simulating behaviors, and evaluating them under changing conditions.

The Qinghai-Tibet Plateau, the Central Asian Mountains, the Sayan and Changbai Mountains, the Da and Xiao Xing'anling Mountains and Stanovoy Mountains, the Yablonov Mountains, the Khenti Mountains, Caucasus, Alps, and other parts of the EWTs also transport, sequester, and emit large amounts of carbon and nitrogen to the atmosphere, hydrosphere, and pedosphere, which likely further accelerates the global warming. The change of landscapes in the cryosphere as a result of the degradation of permafrost, glaciers, and other elements will have deep influences on the related eco-environment, biogeochemical cycles, and engineering construction structures built in the cryosphere. The variations in water resources resulting from the degradation of the cryosphere will deeply affect agriculture, industry, and people's daily lives. Therefore, the cryospheric part of EWTs is key to multi-system coupling from source areas of large rivers and from point, slope/transect, watershed/basin, regional to continental scales, and is concerned with the security of the human community in the 21st–22nd centuries.

At present, research in this field mainly focuses on the mapping of spatial and temporal distribution patterns of cryospheric elements, monitoring, and simulation of changes, and the impacts of changes in cryospheric elements on point, slope, basin, regional, continental to global ecological environment and water resources, and the reciprocal feedbacks of the multi-sphere such as the atmosphere, hydrosphere, pedosphere and biosphere. However, there is still much room for improvements in how to integrate massive *in situ* observation data, increasing laboratory experimental data into the Earth system and multiple models, and how to standardize *in situ* and remote sensing-based data, and reanalysis products from different sources, different accuracy, different spatial scales and observation time.

In recent years, based on increasing funding, field *in situ* observations, laboratory experiments, and remote sensing technology, have been widely used in the study of Eurasian water towers, and numerous high-quality research results have been achieved worldwide. Therefore, *Frontiers in Earth Science* has invited experts in the fields of permafrost, remote sensing, and computing as guest editors to contribute to a Research Topic of *Frontiers in Earth Science* in collaboration with international experts in the field to promote the further application of remote sensing, integration of laboratory experiments and massive multi-source data to the study of Eurasian water towers, improve accessibility of researchers to the *in situ* observational, experimental, satellite and reanalysis products data, and promote the intersection of cryosphere, remote sensing, laboratory, and computing disciplines. This *FiES* collective topic aims to provide a conveyor for cloud-based research on the cryosphere part of EWTs. It is expected to promote research related to the impacts of cryospheric changes on the Eurasian water towers to enhance the understanding of the rapidly changing cryosphere of the EWTs. The collective topics consequently attract four pieces of papers, which likely shed light on the progress of the integration of massive observation data into computer platforms, although they are not closely tied to the main idea of the topic—the four papers of the collective topic report on the progress or reviews of cryospheric elements.

Deng et al. studied and evaluated the impact of climate change on the long-term water balance in the Yalung Zangbo River Basin (YZRB). The regions of the Himalayas and QTP serve as the core of "Asian water towers". Originated from the Jiema Yangzong (Gyama Langdzom) Glacier in the Shiquanhe (Seng-ge Kambab) River Valley in Zhongba County, Shigatse (Xigaze), the YZRB is the upper stream of the Brahmaputra River, one of the most important major rivers in South Asia Subcontinent, including those most populated nations such as India and Bangladesh, sustaining a population of 163 million and numerous other lives in the downstream. Climate change, shrinking glaciers and snow cover, and degrading permafrost have substantially impacted the hydrological and carbon cycles in alpine regions. However, the temporal and spatial trends of runoff and the water balance have not yet been adequately and quantitatively assessed and effectively managed. In this paper, the snowmelt module of the Soil and Water Assessment Tool (SWAT) has been optimized for the YZRB to quantify the historical and future variability in the runoff, snowmelt water, and other water balance components. According to the results of the Coupled Model Intercomparison Project (CMIP) Five and Six (CMIP5 and CMIP6), in comparison with that of the historical reference period of 1980–2019, the CMIP6- and CMIP5-projected values of annual precipitation (2020–2099) may increase by 2.7% and 10.2%, respectively. The increase in CMIP6-projected annual average air temperature (2.4°C) exceeds that of CMIP5-projected value (1.9°C). The river runoff during 2020–2050 may be reduced by 12.7% in comparison with the historical reference, and it would further decline by 9.2% during 2060–2099. Based on the average results of CMIP5 and CMIP6, the water balance deficit may increase primarily due to an increase of 42.4% in evaporation. In contrast, snowmelt, water yield, soil water, and groundwater recharge would decline by 32.1%, 9.4%, 19.8%, and 17.8%, respectively. The results of this evaluation for the long-term water balance suggest that mid- and upper-reaches of the YZRB could undergo a higher risk of drought, potentially threatening the sustainability of local alpine grassland ecosystems.

Chen et al. featured the distributive patterns of summer raindrops in a nival-glacial zone in the eastern/Chinese Tianshan Mountains in Central Asia. As a key component of the hydrological cycle, precipitation is critical to understanding the formation and evolution of a water system. In this study, based on the observation data of the Present Weather Sensor PWS100 set at the meteorological observation site at the terminal of Glacier No. 1 in the Headwater Area of the Urumqi River (HAUR), eastern/Chinese Tianshan Mountains, statistical characteristics of the summer raindrop size distribution (DSD) were analyzed, and features for the DSD of five different rainfall rates (R) and two rainfall types (convective and stratiform) were investigated at the daytime and nighttime. The average spectral width of raindrops was the largest in class III ($1 < R < 5\ mm\ h^{-1}$). The raindrop concentration increased with R, with the maximum raindrop concentration at class IV ($5 < R < 10\ mm\ h^{-1}$) when the raindrop diameter was >1.74 mm. Small- and medium-sized raindrops dominated (98%) the rainfall composition in the HAUR, where convective precipitation was divided into continental clusters. The stratiform/convective D_m-$log_{10}N_w$ was characterized by a large mass-weighted mean diameter $D_m = 0.584$ mm, and a generalized intercept $log_{10}N_w = 0.819$. Between the day- and night-time, *N(D)* of convective precipitation differed significantly, while that of stratiform precipitation, was almost the same. The constraint relationship between R-D_m and R-$log_{10}N_w$ of the two precipitation types was deduced, with a negative exponent of the R-$log_{10}N_w$ relationship of the two precipitation types, and a more stable D_m of stratiform precipitation at a larger rainfall rate (1–2 mm). Finally, in the HAUR, the power-law relationship between radar reflectivity (Z) and R, *i.e.*, $Z = A{\times}R^b$, was deduced for stratiform ($Z = 698.8\ R^2$) and convective ($Z = 47.1\ R^2$) rainfall types. For the first time, these research results provide insights into the microphysical nature of summer raindrops in the HAUR and give out essential information for precipitation retrievals based on weather radar observations.

Lu et al. conducted an experimental study on the hydrothermal-deformational features of cement-stabilized soils under freeze-thaw cycles, which are key to mitigating the hazardous deformation of foundation soils in cold regions. This study took six groups of cement-stabilized soil specimens with different cement contents (3%, 6%, 9%, 12%, 15%, and 18%) for understanding the variability in temperature, volumetric unfrozen water content (UWC_v), deformation, freezing temperature, and dry density of the tested soils. The results have revealed a three-staged time-temperature curve of the cement-stabilized soils during the freezing and thawing processes and lowering soil freezing temperature with increasing cement content. Additionally, soil cement content and ambient temperature significantly affect the UWC_v of cement-stabilized soils during the freeze–thaw cycles, and; soil temperatures corresponding to the peak hysteresis degree are relatively consistent with freezing temperatures of soils. The residual UWC_v is determined by soil cement content and soil freezing conditions. In spite of the similar variations in UWC_v during the soil freezing and thawing processes, ranges in temperature change differ significantly in the tested soils, particularly in the zone of intense phase transition. In addition, adding cement into soils effectively mitigates soil deformation, mainly due to the dual positive effects of the reduced UWC_v as a combined result of hydration reaction and structural compaction.

Bi et al. investigated UWC_v models for freezing soils. In cold regions, UWC_v is a significant hydrothermal parameter in numerical modeling of soil physical processes. Although many models have been developed to simulate and predict the variations in UWC_v with subzero soil temperature (SST), comprehensive evaluation of UWC_v models is scarce. This study collected a total of 29 models and divided them into four categories: theoretical, soil water characteristic curve (SWCC)-based models, empirical, and estimation models. They were evaluated with 1278 experimental points from 16 studies covering multiple soil types, including 24 clays, 18 silty clays, 7 silts, 19 sands, and 10 sandstones. Root mean square error and average deviations were applied to judge the performance of these models. Most UWC_v models can well simulate the relationship between UWC_v and SST. Among the aforementioned four categories of UWC_v models, Lizhm *et al.* model, Fredlund and Xing (C=1)-Wen model, Kozlowski empirical model, and Kozlowski estimation model performed the best in their respective categories. Compared to the rest three categories, estimation models can be applied to predict the variations in UWC_v with SST by some readily available soil physical parameters and to guide the building and improvement of UWC_v models.

This collective topic of the FiES is just an attempt in providing a preliminary survey on the mapping, monitoring, and model-prediction of cryospheric changes in the Eurasia Water Towers (EWTs). However, there are still a long way to go. In the future, the improvement of the quality of datasets stored in multiple platforms with the incorporation of high accurate *in situ* observations of cryospheric elements will be an incessant, ongoing effort. Moreover, the migration of some traditional simulations and model methods about the cryospheric elements, such as the permafrost models, TTOP model and Stefan Equation, into the state-of-art computing platforms should be continued.

Author contributions

HJ: Conceptualization, Funding acquisition, Project administration, Writing–original draft, Writing–review and editing. AF: Writing–review and editing. GB: Writing–review and editing. DL: Conceptualization, Funding acquisition, Project administration, Writing–original draft, Writing–review and editing. MF: Writing–review and editing. YR: Writing–review and editing. IG: Writing–review and editing. YY: Writing–review and editing.

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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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