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Editorial

Energy and Water Cycles in the Third Pole

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The energy and water cycles in the Third Pole have great impacts on the atmospheric circulation, Asian monsoon system and global climate change. On the other hand, as the largest high-elevation part of the cryosphere outside the polar regions, with vast areas of mountain glaciers, permafrost and seasonally frozen ground, the Third Pole is characterized as an area sensitive to global climate change [1–3]. The Tibetan Plateau (TP) and the surrounding higher elevation area are experiencing evident and rapid environmental changes, such as glacial retreat, snow melting, lake expanding and permafrost degradation. All these changes pose potential long-term impacts to water resources of local and surrounding regions. A better understanding of the water and energy cycles is essential for assessing and understanding the causes of changes in the cryosphere and hydrosphere in relation to changes of plateau atmosphere in the Asian monsoon system and for predicting the possible changes in water resources in South and East Asia [3].

To this end, the aim of this Special Issue was to present recent advances in quantifying (1) land–atmosphere interactions, (2) the water cycle and its components, (3) energy balance components, (4) climate change, and (5) hydrological feedbacks by in-situ measurements, remote sensing or numerical modelling approaches in the TP.

Ten articles (nine research articles and one review) are published in this Special Issue, covering the quantitative assessments of land surface radiation fluxes, evapotranspiration, water vapor transport and runoff, as well as the distinct surface processes over lake and glacier driven by warming climate. Besides, the coupling mechanism between the vertical motion of air with the near-surface meteorological variables is analyzed. Additionally, the pollution characteristics and possible sources of PFASs (per- and poly-fluoroalkyl substances) in both surface water and precipitation are also discussed.

Analysis of long-term, ground-based radiation budgets on the TP help to enhance scientific understanding of land-atmosphere interactions and their influence on weather and climate change in this region. Wang et al. (2021) [4] systematically analyzed the in situ measurements from 2006 to 2019 at six research stations over the TP. Despite the differences in climate and land cover, both land surface albedo and upwelling shortwave radiation decreased at all sites, while the downwelling and upwelling longwave radiation, net radiation, surface temperature and air temperature presented increasing trends at most stations.

Evapotranspiration (ET) is a key parameter in the surface energy and water balance, whose accurate estimation is important but still challenging. The ET estimates from one satellite merged dataset (EB), one assimilation product (GLDAS), two reanalysis datasets (ERA5 and ERA-Interim) and two WRF simulations (DDM and CPM) were intercompared by Dan et al. (2021) [5] in detail. The temporal and spatial variations and driving factors of ET were discussed by Song et al. (2022) [6]. As the air temperature, precipitation and NDVI (normalized difference vegetation index) increased at a rate of 0.07 °C/decade, 24.73 mm/decade and 0.02/decade in Qinghai Province from 2000 to 2020, respectively, the actual ET presented a significant increasing rate of 37.26 mm/decade, which is nearly three times of the increasing rate in China. The results also revealed that the air temperature is the dominant driving factor of ET, followed by NDVI and precipitation. Additionally, ET increased by 2.84 mm/100 m with increasing altitude, which also exhibited distinct heterogeneity in its driving factors across the altitude gradient, where the influence of precipitation, NDVI, and air temperature dominated at 1700–2600 m, 2600–3800 m, and 3800–6000 m, respectively.

Changes in the surface energy and water fluxes can induce the transport of water vapor. The variation patterns of water vapor budget and its relationship with precipitation were reported by Qi et al. (2021) [7], and the relationships between the sensible/latent heat and the water vapor flux divergence were revealed by Li et al. (2021) [8]. The height of the water vapor transportation channel of the western air flow was found to be higher than 3000 m, while that for the southwestern and southeastern air flows was about 2000 m. A negative correlation between the surface fluxes and the water vapor flux divergence was depicted. The southwest boundary of southeast TP was found to be the key area affecting the water vapor flux divergence. Determination of the location and density of water vapor sources is of great importance to the improvement of extreme precipitation forecasts. The relation of the atmospheric vertical motion with the climate was discussed by Tian et al. (2021) [9] via climate diagnosis and statistical analysis. Moreover, Li et al. (2021) [10] evaluated the runoff simulation skills via WRF-Hydro, and achieved an improvement of 6.6% in root mean square error against in situ measurements. The enhanced WRF-Hydro simulated an increase in latent heat flux, but a decrease in sensible heat flux and soil surface temperature due to the moist soil.

The TP preserves a sufficient amount of lakes and glaciers, which are both experiencing hydrological change in the context of climate warming. The surface processes and ice phenology of lakes on the TP were investigated by Lang et al. (2021) [11], and an increasing trend in lake surface temperature and latent heat flux, as well as a decreasing trend in sensible heat flux and ice thickness, were illustrated. Based on surface mass balance parameterizations, the mean glacier volume loss of Da Anglong Glacier during 2016–2098 was simulated by Zhao et al. (2022) [12] to be 38% and 83% of the volume in 2016 under RCP2.6 and RCP8.5.

Finally, the characteristics and possible sources of PFASs in surface water and precipitation in China were reported by Wang et al. (2022) [13]. The concentration of PFASs in the surface water in different areas of China varied from 0.775 ng/L to 1.06×10^6 ng/L, while that in precipitation was lower, ranging from 4.2 ng/L to 191 ng/L. Although the concentrations of PFASs in surface water and precipitation in the TP were lower comparably (0.115–6.34 ng/L and 0.115–1.24 ng/L, respectively), influenced by the southeast monsoon in summer, PFASs can reach the TP through long-distance transportation and finally enter the surface water of this area through depositions.

In summary, this Special Issue mainly presents the up-to-date advances on the quantitative assessments of surface radiation fluxes, ET, water vapor transport, runoff, and the typical surface processes over lake and glacier on the TP. These selected papers are novel and timely for the understanding of land–atmosphere interactions driven by climate warming over the TP.

We trust that the collation of these papers will provide quantitative references for better assessment and prediction of the energy and water cycle processes in the "Third Pole".

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