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EDITORIAL

Integrated Disaster Risk Research of the Qinghai-Tibet Plateau Under Climate Change

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The Qinghai-Tibet Plateau and its adjacent mountainous areas are characterized by significant climate differences, diverse geomorphology, active glaciers, and strong crustal uplift and river incision. The complex natural environment has led to a variety of natural hazards and disasters, including earthquakes, rock/glacier falls, landslides, debris flows, flash floods, snow avalanches, and thaw slumps. These hazards coexist, overlap, and interact, creating complex chains of disasters and cascading and compound events, and imposing great threat to the local people and socioeconomic activities. Climate change is altering the cycles of water, energy, and mass on the Qinghai-Tibet Plateau. It is of paramount importance to understand the dynamics of these processes and their impacts on the exposed population and socioeconomic systems under climate change.

For a better understanding of the climate change and its effects on ecological, environmental, and other natural hazards on the Qinghai-Tibet Plateau, a national research program—the Second Tibetan Plateau Scientific Expedition and Research Program (STEP)—was launched in 2017, which includes ten major projects. Among the ten projects, the key focus of Project #9—*Geological Environment and Disasters*—is the hazards and risks of earthquakes, landslides, debris flows, flash floods, permafrost, disaster chains, and multi-hazards. This special issue, entitled *Integrated Disaster Risk Research of the Qinghai-Tibet Plateau under Climate Change*, mainly results from the latest research outcomes under Project #9.

The Guest Editors selected the papers in order to give thematic coherence to the topic of integrated disaster risk research, climate change and the Qinghai-Tibet Plateau. The final collection includes 13 articles that can be divided into three parts: (1) changes in cryosphere-related disasters driven by the warming climate; (2) changes in susceptibility to debris flows and landslides that are highly related to precipitation intensity and the driving factors of climate change; and (3) exposure and vulnerability of populations, buildings, and highway infrastructure, as well as insurance solutions to the disaster risks.

The first part—changes in cryosphere-related disasters driven by the warming climate—provides latest insights on the changes related to snow avalanches and thaw slumps of permafrost on the plateau, driven by climate change. Hao et al. tried to understand how the risk of snow avalanche activity during the snow season would likely change under a warming climate. They investigated long-term observed meteorological and snowpack data and the snow avalanche activity data along a transportation corridor in the central Tianshan Mountains. They found that the active period of wet snow avalanches triggered by temperature surges and high solar radiation has gradually moved forward from the second half to the first half of March with climate warming, which is important for rationally organizing snow avalanche relief resources to improve the risk management of snow avalanche disasters. Zhang et al. proposed an automatic identification algorithm to map thaw slumps based on neural network methods by using GaoFen-1 remote sensing imagery and fused multi-source feature data. Their method showed reasonable overall accuracy when applied in the Beilu River Basin of the Qinghai-Tibet Plateau, and provided a new insight for the potential

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feasibility of applying the designed edge detection method to map diverse thaw slumping landforms in larger areas with high-resolution images. Focused on the detection of thaw slumps, Jiao et al. applied a multi-temporal Interferometric Synthetic Aperture Radar (MT-InSAR) method to map the spatiotemporal variations in surface deformation of retrogressive thaw slumps (RTSs) in the Beilu River region. Their method captured the retrogressive dynamics of the thaw slumps by offering metrics of annual deformation rates and three typical motion stages of the thaw slumps. Fan et al. investigated the effect of slope aspects on the thermal conditions of thaw slumps by using ground measurement data at two slope sites with opposing aspects in a warming permafrost region in the central Qinghai-Tibet Plateau. Significant differences were found in ground temperatures and moisture content in the active layer of the two sites. Niu et al. developed a three-dimensional hydro-thermal coupled numerical model of retrogressive thaw slumps. Model-simulated ground ice ablation and turbidity events between 2011 and 2021 were highly correlated with climatic warming and wetting. Their results offered a valuable approach to assessing the effects of RTS on infrastructure and the environment, especially in the context of a changing climate.

The second part focuses on the susceptibility to debris flows and landslides, the occurrence of which is closely related to precipitation intensity and therefore driven by climate change. Tian et al. focused on the mechanism of silent large-scale landslides, a special type of landslides that occur without significant triggers such as earthquakes or heavy rainfall. Using the case study in Zhaobishan on the Qinghai-Tibet Plateau, they found that silent large-scale landslides were jointly controlled by weak-soil (fractured rock mass) and strong-water (abundant water replenishment) conditions under the impact of active tectonism and complex hydraulic properties. Zou et al. focused on rainfall-triggered shallow landslides, with special attention to the positive effects of vegetation canopy interception and plant-root reinforcement and the negative effects of plant gravity loading and preferential flow of root systems. Yang et al. examined the sampling strategy for landslide susceptibility modeling. To avoid the overestimation of susceptibility in the epicenter area by using equal numbers of landslide and non-landslide samples, they proposed a spatially heterogeneous non-landslide sampling strategy by considering the uneven distribution of local ratios of landslide to non-landslide area. Their results indicated that the proposed strategy outperforms the traditional one when compared to landslide inventory data. Li et al. used debris flow data, historical meteorological data, and future climate projection data to assess the debris flow risk of the Karakoram Highway region. Their results showed that the risk of debris flows increased with climate change, and the upper reaches of the Ghez River and the second half of Tashkurgan-Khunjerab region are the sections with the highest risk.

The third part shifts from hazards to exposed elements on the plateau. Spatiotemporal distribution of exposed elements is a fundamental consideration in risk assessments. Wei et al. offered a method to generate high-resolution and dynamic assessments of the spatiotemporal distribution of populations by introducing six days of mobile phone user-location signal data. Their attempt successfully captured strong temporal regularity and downtown-suburban attenuation patterns of the population of Xining City, Qinghai Province. Zheng et al. focused on the physical vulnerability of residential buildings, bringing a novel perspective to regarding earthquake-debris flow disaster chains rather than single hazards. They considered debris flow triggered by a rainstorm in a short aftermath of a major earthquake that occurred in Beichuan County, China, in 2008. Focusing on critical infrastructure, He et al. conducted a field survey of 440 bridges with embankment–bridge transition sections along the Qinghai-Tibet Railway. The top three types of distresses of the transition sections due to permafrost activity included differential settlement, subsidence of the protection-cone slopes, and longitudinal dislocation. The occurrence of those distresses differed significantly with temperature. Yang et al. offered one of the first estimates of rural residents' preferences for rural housing disaster insurance attributes in the central and western Tibetan Plateau. The empirical findings from their discrete choice experiment revealed consistent need of insurance products with higher sums insured, higher subsidy rates, and a wider range of insured objects. But residents also showed strong heterogenous preferences on the peril insured, closely related to local disaster occurrence and personal experience.

This Special Issue is a collection of multidisciplinary research efforts to understand the dynamics of hazards and disaster risks on the Qinghai-Tibet Plateau under climate change. The articles cover the physical mechanisms, large-scale retrieval of locations via remote sensing, and susceptibility modeling of hazards, distribution and vulnerability of major types of exposed elements, as well as insurance solutions. The research outcomes collected in this Special Issue can improve our understanding of disaster risk in this unique region. The Guest Editors and the journal editorial team extend their sincere appreciation to all contributors and reviewers for their admirable effort and insightful knowledge, support, and assistance, and we look forward to further enrichment of our knowledge about disaster risks on the Qinghai-Tibet Plateau.