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Editorial

The Impacts of Climate Change on the Hydrological Cycle and Water Resource Management

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Global warming can alter the hydrological cycle in various forms such as increased cloudiness and latent heat fluxes, leading to more intensive and frequent precipitation extreme events (e.g., droughts, storms, and floods). These extreme events have received increased attention in the past few decades because of the associated economic loss, deaths, and many other severe consequences for human society. Climate change can also cause significant shifts in the spatial and temporal patterns of precipitation, bringing many unprecedented challenges for water resource management at regional and local scales. In addition to these common hydrological challenges, coastal communities are further threatened by rising sea levels and increasing storm surge and erosion. Adapting to these challenges requires a thorough understanding of the potential impacts of climate change from a long-term and systematic perspective.

As the world is facing unprecedented climate uncertainties, a more rigorous understanding of the impacts of climate change is gaining higher significance. A growing body of knowledge is centered on the multidimensional perspectives of the impacts of climate change on the hydrological cycle, water-related hazards, and water management at various scales for understanding the short- and long-term consequences in different parts of the world. This Special Issue focuses on the latest research advances in modeling hydroclimatic conditions, river, and coastal hydrology; hydrological extremes such as floods and droughts; and sustainable water resource management. A total of twelve articles are published in this Special Issue: Six of them involve modeling the impacts of climate change on the hydrological cycle, two are focused on how climate change impacts hydrometeorological hazards, and four articles highlight the water security issues in the watershed and their impacts on ecosystems. A brief highlight of these articles is presented here.

Modeling climate change impacts on the hydrological cycle:

While global climate models predict the potential changes that may occur at the global scale, the impacts of such global changes on the hydrological cycle at both the regional and local scales are still not well understood. New research is emerging around the world. In this Special Issue, six articles involve the investigation of climate change at the local scale and its impact on precipitation, temperature, and stream flow in Asia, Africa, Europe, and Australia. Doi and Kim [1] examined the projected future climate and estimated uncertainty for South Korea using results from the global climate model (GCM) and compared the differences in outcome between the fifth and sixth phases of the Coupled Model Intercomparison Project (CMIP5 and CMIP6). They concluded that the models in CMIP6 performed better than those in CMIP5 in reproducing the climatic patterns during the control period. In their other article, Doi and Kim [2] established future associations between rainfall intensity (*RI*) and the duration and frequency of rainfall (called the IDF curve) by using the climate internal variability (CIV) and identifying the characteristics concerning rainfall frequency at fine scales across South Korea. This study shows that future *RI* will increase significantly for most locations, especially near the end of this century, and the spatial distribution of RI across the countries is similar to those of the climatological mean (CM) and CIV. The study also provides some other interesting results related to uncertainties of rainfall patterns under different scenarios. In a European case, López et al. [3] analyzed the effects of climate change on the long-term rainfall pattern (1927–2016) in Igeldo–Gipuzkoa, Spain, and found no significant change in rainfall characteristics throughout the year except for maximum winter precipitation.

Three articles specifically involve the impacts of climate change on stream flow and water availability in watersheds. Chakilu, Sándor, and Zoltán [4] evaluated the impact of changes in temperature and rainfall on high and low flow in the major watersheds of the Lake Tana Basin in the upper Blue Nile Basin under the Representative Concentration Pathway (RCP) highest emission scenario (RCP8.5). Their results suggest both increasing and decreasing change patterns concerning inter-annual rainfall variability due to changes in maximum and minimum temperature over the projection periods (i.e., the 2020s, 2050s, and 2080s). As a result, watersheds are expected to receive decreased low flow and increased high flow in the future. Wrzesiński et al. [5] investigated changes in the low-flow regime of rivers in Poland resulting from climate change in 1987–1989. Their analysis reveals that the number of days with low flow (ND_{FL}) significantly increased in around two-thirds of Poland during 1989–2020, mainly located in the western and southwestern regions of the country. By contrast, during 1951–1988, the low-flow regions were located in the eastern parts of Poland. Chiew et al. [6] compared future streamflow projections for 133 catchments in the Murray–Darling Basin, Australia, and predicted a 20% decline in streamflow across the basin during the 2046–2075 period relative to 1981–2010 using a high global warming scenario.

The impacts of climate change on hydrometeorological hazards:

Despite extensive research, new evidence on the impacts of climate change on hydrometeorological hazards such as floods, droughts, and cyclones is still emerging, and studies continue to provide insights into location-specific variability and the magnitude of hazards and their impacts on society and nature. In this collection, two cases from Ethiopia and Canada are presented. Orke and Li [7] assessed the impacts of hydrometeorological variability due to climate change on drought characteristics in the Ethiopian Bilate watershed. Analyzing climate projections for the near future (2021–2050) and far future (2071–2100) under RCP4.5 and RCP8.5 scenarios, this study shows that the annual average rainfall is expected to decrease significantly in the far future, leading to a reduction in streamflow in the Bilate watershed. The study also indicates that the probability of drought occurrence could be doubled in the far future, with increased intensities of droughts, which would exacerbate water scarcity and threaten food security in the watershed. Jardine, Wang, and Fenech [8] presented evidence of coastal flooding in Prince Edward Island, Canada, caused by post-tropical storm Dorian in 2019. Based on the high water marks collected just after the storm event, they found that the floods reached elevations above 3.4 m at some locations, posing threats to local infrastructure and causing damage to natural features such as sand dunes in these areas. The findings of this study could help enhance public understanding of the potential impacts on the island and can guide planners toward better preparation and adaptation for future storm events.

Climate change impacts on water security:

Water security for fulfilling social and ecological demands remains a key challenge in different parts of the world in the face of climate uncertainties. Detailed investigations of local watersheds provide a crucial understanding of the impacts of climate change on water availability under different scenarios, which are essential for the implementation of sustainable management measures. This Special Issue includes four articles involving the analysis of the impacts of climate change on water security in social, agricultural, and ecological contexts. Goyburo et al. [9] assessed the potential water scarcity under socioeconomic and climate change scenarios in the Vilcanota–Urubamba Catchment, Cusco, Perú during 2010–2099. Using the water evaluation and planning system (WEAP) model, they predicted that although water availability will increase under future climate change scenarios, the water demand will not be met in all sub-basins owing to the uneven distribution of water availability in all parts of the basin. They suggested that a reduction in population growth and improving agricultural water use efficiency may reduce the demand and suppress the level of water scarcity in the area. Rahim et al. [10] examined the degree of hydrologic alteration at seven flow gauge stations in the Mangla watershed, Pakistan, between the pre-impact (1967–1994) and post-impact (1995–2014) periods, using the "indicators of hydrologic alteration" method. The study reveals a moderate hydrological alteration in the whole watershed, which may adversely affect the aquatic ecosystem of the Mangla watershed. Bhatti et al. [11] analyzed the impacts of climate change on temperatures, precipitation, stream flow, and groundwater recharges across Prince Edward Island, Canada, between 1991 and 2080 using the observed and projected data, and the SWAT model. Based on the findings of their study, more attenuated stream flow and groundwater recharge are expected, with higher quantities in late winter and early spring than in summer, which could decrease water supplies during the growing season. Moreover, precipitation uncertainty between dry and wet years continues to be a major water management challenge, which requires special attention from adaptation planners. Lastly, Cárdenas Castillero et al. [12] investigated the global perspectives on climate change and aquifer recharge presented in the recent scientific literature. Based on a systematic literature review, their study reveals that the worst cases of reductions in groundwater recharge occur in arid and desert areas; the highest recharge areas are located in northern regions and in areas at high altitudes, where rapid snow and glacial melting resulting from temperature increases play a crucial role in maintaining or increasing the recharge capacity.

The articles published in this Special Issue contribute to closing critical knowledge gaps in understanding the impacts of climate change on the hydrological cycle and the issues related to water resource management in various contexts. We hope this will encourage further investigation in this area, in order to improve methods and techniques and provide a better understanding of the impacts of climate change on the water sector as well as on society as a whole.

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