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Editorial

Hydroclimatic Variability at Local, Regional and Global Scales

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Abstract: Hydroclimate is non-stationary and varies in often unpredictable ways on local, regional and global scales, which can lead to water insecurity. This editorial relates the advances and challenges in our understanding of the spatio-temporal relationship between climate variability and change and the components of the hydrologic cycle through the lens of six articles, which contributed to the *Water* Special Issue: Hydroclimatic Variability at Local, Regional and Global Scales. The relationship between the El Niño/Southern Oscillation and precipitation, temperature, and evapotranspiration is examined within the Indian Summer monsoon, gauge-based precipitation datasets are intercompared over Pakistan, trends in precipitation, temperature, and streamflow are investigated in Ethiopia and China, alternate configurations of hydroclimate modeling are assessed over Canada, and finally, future limitations in groundwater supply are presented for Italy.

Keywords: hydroclimate; precipitation; streams; lakes; groundwater; climate variability; climate change

1. Introduction

Long-term water resource planning is a necessity, especially in areas of community development and population growth. Fresh water supply is often sourced from an easily accessible and/or abundant local reservoir(s) of the hydrologic cycle. However, this cycle is often vulnerable to local, regional and global climate variability, and too much or too little of one component of the cycle (e.g., rainfall) has cascading effects in time and space, ultimately impacting other components (e.g., groundwater). Thus, hydroclimatology is an important field of study that attempts to understand these interactions among water, climate and society in a holistic sense [1–3]. There has been a rapid growth in relating climate variability and change to fresh water supply and hazards and this Special Issue, co-edited with Dr. Glenn McGregor from Durham University, UK contributes to the body of literature, with six significant peer-reviewed papers covering advances in trend analysis and hydroclimate modeling. While all contributions can be considered as local to regional, the Special Issue is truly global, with four continents represented. The studies are also linked in that they hypothesize relationships among multiple hydroclimatological variables.

2. Contributed Papers

Several studies have related the El Niño/Southern Oscillation (ENSO) with Indian Summer Monsoon rainfall (e.g., [4]), yet the paper by Tamaddun et al. [5] is somewhat unique in that it focuses on interlinked components of the hydrologic cycle: temperature, precipitation, and potential evapotranspiration in northern states of India. Furthermore, they examine how the relationship between these variables and ENSO changes over time using concepts of entropy. Hydroclimatological anomalies were more prevalent under El Niño conditions as compared to La Niña or neutral years.

Interestingly, ENSO led to a change in trend (or shift) in the monsoon season hydroclimate for some districts.

While hydroclimatological data are abundant in India, [5] reporting monthly values from 1901–2002 for 146 districts, data sparsity is a problem for much of Pakistan [6]. Ahmed et al. [6] use mean bias error, mean absolute error, and modified index of agreement to assess the ability of several gauge-based data sets to estimate precipitation totals over the arid Balochistan province of Pakistan. This province is water-stressed and climate models project an increase in droughts with global warming [6,7]. Therefore, in addition to adequately describing the mean conditions, the authors note the importance of gauge-based datasets to accurately describe the temporal variability and distribution of precipitation for better estimating surface water resources [6,8]. They find that the Global Precipitation Climatology Centre (GPCC) [9] out-performs the other gauge-based datasets that they examined. This was likely due to the fact that GPCC incorporated the largest number of Balochistan gauge observations during the period of study, and its interpolation method accounts for the region's rough terrain.

Another country that struggles with a lack of precipitation is Ethiopia. According to Jaweso et al. [10], "unmitigated hydrometeorological variability increases poverty rates by about 25 percent and costs the economy about 38 percent of its growth potential". Similar to [5], their paper examines trends in multiple hydroclimatological variables: temperature, precipitation and stream flow. However, unlike the previous two papers, where the study areas comprised political jurisdictions, this study considers the upper Omo-Ghibe River Basin [10]. Within the basin, they find an increasing trend in temperature, decreasing trend in stream flow and a mixed signal in rainfall, which agrees with previous studies. Change points are identified in the time series (1981–2008) but are not consistent across the hydroclimatological variables. The authors are not able to specify the causes of the trends and change points, but suggest a combination of climate variability and land use change.

While most papers in this Special Issue are observational, Ricard et al. [11] explore alternate configurations of the hydroclimatological modeling chain that links climate change to a future hydrologic regime of a watershed. Climate observations are used to both force hydrologic models and adjust climate simulations. Here, the authors propose an alternative configuration which "forces and calibrates the hydrologic model directly with post-processed climate simulations" [11] avoiding the redundant use of sometimes questionable climate observations. Their method is tested over three river basins (515–633 km^2) in Quebec, Canada. While more experiments need to be performed, the authors' preliminary results are promising. Compared to the standard modeling chain, the hydrologic response to frozen precipitation is comparable to the historical record and the model-generated interannual variability and extremes are realistic.

The fifth paper [12] closely follows Jaweso et al. [10] by examining trends in temperature, precipitation and stream flow over a river basin. Zhang et al. [12] choose to study the high elevation (>4000 m) Yarlung Zangbo River (YLZR) basin located in the Tibetan Plateau in China. The basin contains many glaciers and is vulnerable to climate change. The authors use Mann–Kendall tests, Sen's slope estimate, cross wavelet transform, and wavelet coherence to identify significant increasing trends in temperature and precipitation, with non-significant mixed signals in stream flow trends. The study further examines reanalysis data and concludes that rapid warming from 1957–1970 to 1971–1990 could be partially explained by a low-pressure anomaly over the region. The authors also find that the Pacific Decadal Oscillation (PDO) is negatively correlated with annual precipitation within the YLZR basin, significant at the 0.05 level. Finally, similar to [10], change points identified are not consistent across the hydroclimatological variables.

Another aspect of the water cycle that is sensitive to climate change and on which society depends is groundwater. Citrini et al. [13] investigate the future drinking water supply from the Nossana Spring in Northern Italy, which currently serves about 300,000 people. The objective of their study is to quantify changes in temperature and precipitation over the 80 km^2 hydrogeological basin using statistical downscaling of regional climate models based on a representative concentration pathway (RCP) scenarios and use this information in a groundwater model to project limits on the future use of the karst spring. The maximum change in spring discharge is −39% for the time period 2041–2060, resulting from a decrease in precipitation and increase in evapotranspiration, in agreement with previous studies [14]. Finally, "after 2060 the length of periods with discharge lower than the length of thresholds is expected to increase" [13], prompting the need for additional sources of water.

3. Conclusions

This special section of the journal *Water* advances the field of hydroclimatology, through six significant contributions covering various parts of the world. The methodologies are transferrable and should be considered for future studies.

All the articles demonstrate the challenges of relating historical changes and future projections of climate to water availability. Many of the studies link climate teleconnections (e.g., ENSO, PDO) and global warming to local changes in temperature and precipitation which drive fresh water availability, but there still needs to be a better understanding of the intervening processes. As noted previously by Dr. McGregor, more attention needs to be given to "diagnosing the relationships in terms of atmosphere and ocean physics and dynamics" [2]. This is difficult because of the cascading temporal and spatial scales and feedback in the hydrologic cycle. Advances in hydroclimate modeling which more fully couple climate models and hydrologic models (see [11]) may be one way forward.

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