The Impact of Climate on Hydrological Extremes

Salvatore Manfreda [1],* , **Vito Iacobellis [2]**, **Andrea Gioia [2]** , **Mauro Fiorentino [1]** and **Krzysztof Kochanek [3]**

[1]   Department of European and Mediterranean Cultures: Architecture, Environment and Cultural Heritage (DiCEM), University of Basilicata, 75100 Matera, Italy; mauro.fiorentino@unibas.it
[2]   Department of Civil, Environmental, Land, Construction and Chemistry (DICATECh), Polytechnic University of Bari, 70125 Bari, Italy; vito.iacobellis@poliba.it (V.I.); andrea.gioia@poliba.it (A.G.)
[3]   Institute of Geophysics, Polish Academy of Sciences, 01-452 Warsaw, Poland; kochanek@igf.edu.pl
*   Correspondence: salvatore.manfreda@unibas.it; Tel.: +39-0971-20-5139

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Abstract: High and low flows and associated floods and droughts are extreme hydrological phenomena mainly caused by meteorological anomalies and modified by catchment processes and human activities. They exert increasing on human, economic, and natural environmental systems around the world. In this context, global climate change along with local fluctuations may eventually trigger a disproportionate response in hydrological extremes. This special issue focuses on observed extreme events in the recent past, how these extremes are linked to a changing global/regional climate, and the manner in which they may shift in the coming years.

Introduction to the Special Issue

The present special issue focuses on the impact that climate has on hydrological extremes. This is a critical issue not been fully understood due to the complex interactions between climate and hydrological systems, e.g., [1,2]. Climate change is producing significant alterations in hydrological dynamics, with a general tendency to amplify hydrological extremes [3,4]. Therefore, there is a growing need to modify the general perspective of hydrologists in order to solve this issue at different scales and in different environments.

Current hydrological research is inhibited when identifying clear trends and patterns due to using only ground observations. Nevertheless, we believe that investigating physical dependencies between global (climatic) and local (hydrologic) processes may help in understanding the key factors controlling changes and future scenarios. Therefore, this Special Issue focuses on the physical mechanisms underlying past, present, and future climatic extremes, both from the observational and the modeling points of view.

For the present call, we received a significant number of contributions that offer an interesting overview of the state of the art and the interplay between climate and extreme events in different contexts. In particular, the manuscripts can be grouped into the following four topics: (1) precipitation and weather predictions; (2) extreme precipitation and regime; (3) drought indices and low flow; (4) flood management and weather predictions.

The first group of papers deals with precipitation and weather predictions. In particular, Wu et al. [5] propose the use of a self-organizing map (SOM), based on the cluster analysis technique, in order to integrate the ensemble numerical weather prediction system in Taiwan. By means of this technique, ensemble forecasts of similar features were clustered in order to provide better typhoon rainfall forecasts. The application was conducted during five typhoon events, showing that the

integrated typhoon rainfall forecasts resulting from the proposed strategy were more accurate when compared to those from the conventional methods.

The second group of papers deals with extreme precipitation. In particular, Su et al. [6] investigated the spatiotemporal variability of seasonal extreme precipitation over the Yangtze River Basin. The authors observed that the El Niño Southern Oscillation (ENSO) index is a controlling factor for rainfall events above the average, while the Atlantic Multi-decadal Oscillation (AMO) contributes most to below-average precipitation events. Li et al. [7] exploited the methods of climatic diagnosis (e.g., the Modified Mann–Kendall method, principal component analysis and correlation analysis) to analyze the spatial and temporal variations of six extreme precipitation indices on the eastern part of the Inner Mongolian Plateau. They also analyzed and described the relationship between ENSO and the observed extreme precipitation.

Tao et al. [8] investigated the spatial and temporal variations of precipitation extremes, total precipitation, seasonality of precipitation using the Mann–Kendall trend test, Pettitt change-point test, and the correlation analysis using a gridded Chinese ground precipitation dataset from 1961–2013. They observed positive and negative trends of extreme precipitation across the country, but a significant consistency as to the total precipitation. This was justified by the fact that the temporal heterogeneity of daily precipitation is dominated by heavy rainfall.

Finally, in the context of frequency analysis, Pei et al. [9] analyzed the frequency and intensity of extreme daily precipitation for 1961–2012 on the Yangtze River in China, showing overall increasing trends that could be associated with a weakened East Asian summer monsoon in recent decades and some local factors such as lake regulation, hydrologic engineering, and topography. Extreme precipitation intensity revealed an enhanced trend in the western part of the middle reach of the Yangtze River, while extreme precipitation frequency shows a decreasing trend in this region.

In the context of the investigation of the precipitation regime, Pensieri et al. [10] presented the analysis of a five-year time series of in situ precipitation and near-surface atmospheric and marine data, collected in the open Ligurian Sea (from the fixed platform W1M3A and coastal stations). The study characterized the main features of the precipitation over this area and its seasonal and annual variability. Furthermore, the work included a description of the main atmospheric and oceanic surface parameters observed from the platform during some intense events that occurred in 2009–2013 and suggested to what extent the offshore observations may contribute to improving the forecasting of rainfall events.

The third group of papers deals with drought indices and low flow. Sun et al. [11] investigated the behavior of hydrological droughts in the Tarim River Basin (China). They found that the Wakeby distribution satisfactorily describes the probabilistic behavior of the low flow regime. In particular, they observed that the low flow volume has been increasing in recent years due to the temperature-induced increase of snowmelt and increasing precipitation.

Jang [12] used the temperature and precipitation data extracted from the Representative Concentration Pathway (RCP) 8.5 scenario provided by the Korea Meteorological Administration (KMA) for drought prediction up to the year 2100, exploiting the Standardized Precipitation Index (SPI) and the Reconnaissance Drought Index (RDI) estimated at 73 observatories in Korea. Results highlighted the limitations in the use of the SPI for the description of climatic changes with respect to the RDI.

In water level reconstruction, Fok et al. [13] investigated a methodology for reconstructing water levels based on the hydrological Palmer's Drought Severity Index (PDSI), the ENSO Index, and their combination in the lower Mekong River Basin. The results demonstrated that the use of ENSO information could lead to a potential improvement in water level reconstruction and prediction of hydrological extremes.

The fourth group of papers deals with flood management. In particular, Romanescu et al. [14] investigated extreme flood events that occurred in the summer of 2010 in the Siret Basin (NE Romania). They emphasized the role played by the local heavy rains at the onset of floods and the importance of large reservoirs for the mitigation of flood waves. Judi et al. [15] used climate projections to drive high-resolution hydrology and flood models able to evaluate social, economic, and infrastructure

resilience for the Snohomish Watershed (WA, USA). The authors found that the peaks of precipitation and streamflow shifted from spring and summer to earlier winter.

Wang et al. [16] derived a design rainstorm using the Pilgrim and Cordery method [17] combined with the fuzzy identification of different hyetographs considering single-peak and double-peak rainstorms. The design of areal rainfall amounts derived with the proposed methodology were compared with the outcomes of the classic Chicago rainstorm method [18], demonstrating the reliability of the method.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Manfreda, S.; Smettem, K.; Iacobellis, V.; Montaldo, N.; Sivapalan, M. Preface of the special issue: Coupled ecological-hydrological processes. *Ecohydrology* **2010**, *3*, 131–132. [CrossRef]
2. Manfreda, S.; Caylor, K.K. On the vulnerability of water limited ecosystems to climate change. *Water* **2013**, *5*, 819–833. [CrossRef]
3. Fischer, E.M.; Knutti, R. Observed heavy precipitation increase confirms theory and early models. *Nat. Clim. Chang.* **2016**, 6. [CrossRef]
4. Schleussner, C.F.; Pfleiderer, P.; Fischer, E.M. In the observational record half a degree matters. *Nat. Clim. Chang.* **2017**, *7*, 460–462. [CrossRef]
5. Wu, M.C.; Hong, J.S.; Hsiao, L.F.; Hsu, L.H.; Wang, C.J. Effective Use of Ensemble Numerical Weather Predictions in Taiwan by Means of a SOM-Based Cluster Analysis Technique. *Water* **2017**, *9*, 836. [CrossRef]
6. Su, Z.; Hao, Z.; Yuan, F.; Chen, X.; Cao, Q. Spatiotemporal variability of extreme summer precipitation over the Yangtze River basin and the associations with climate patterns. *Water* **2017**, *9*, 873. [CrossRef]
7. Li, W.; Duan, L.; Luo, Y.; Liu, T.; Scharaw, B. Spatiotemporal Characteristics of Extreme Precipitation Regimes in the Eastern Inland River Basin of Inner Mongolian Plateau, China. *Water* **2018**, *10*, 35. [CrossRef]
8. Tao, Y.; Wang, W.; Shuang, S.; Ma, J. Spatial and temporal variations of precipitation 2 extremes and seasonality over China during 3 1961–2013. *Water* **2018**, *10*, 719. [CrossRef]
9. Pei, F.; Wu, C.; Qu, A.; Xia, Y.; Wang, K.; Zhou, Y. Changes in Extreme Precipitation: A Case Study in the Middle and Lower Reaches of the Yangtze River in China. *Water* **2017**, *9*, 943. [CrossRef]
10. Pensieri, S.; Schiano, M.E.; Picco, P.; Tizzi, M.; Bozzano, R. Analysis of the Precipitation Regime over the Ligurian Sea. *Water* **2018**, *10*, 566. [CrossRef]
11. Sun, P.; Zhang, Q.; Yao, R.; Singh, V.P.; Song, C. Low Flow Regimes of the Tarim River Basin, China: Probabilistic Behavior, Causes and Implications. *Water* **2018**, *10*, 470. [CrossRef]
12. Jang, D. Assessment of Meteorological Drought Indices in Korea Using RCP 8.5 Scenario. *Water* **2018**, *10*, 283. [CrossRef]
13. Fok, H.S.; He, Q.; Chun, K.P.; Zhou, Z.; Chu, T. Application of ENSO and Drought Indices for Water Level Reconstruction and Prediction: A Case Study in the Lower Mekong River Estuary. *Water* **2018**, *10*, 58. [CrossRef]
14. Romanescu, G.; Mihu-Pintilie, A.; Stoleriu, C.C.; Carboni, D.; Paveluc, L.E.; Catalin Ioan Cimpianu, C.I. A Comparative Analysis of Exceptional Flood Events in the Context of Heavy Rains in the Summer of 2010: Siret Basin (NE Romania) Case Study. *Water* **2018**, *10*, 216. [CrossRef]
15. Judi, D.R.; Rakowski, C.L.; Waichler, S.R.; Feng, Y. Integrated Modeling Approach for the Development 2 of Climate-Informed, Actionable Information. *Water* **2018**, *10*, 775. [CrossRef]
16. Wang, A.; Qu, N.; Chen, Y.; Li, Q.; Gu, S. A 60-Minute Design Rainstorm for the Urban Area of Yangpu District, Shanghai, China. *Water* **2018**, *10*, 312. [CrossRef]
17. Pilgrim, D.H.; Cordery, I. Rainfall temporal patterns for design floods. *J. Hydraul. Div.* **1975**, *101*, 81–95.
18. Keifer, C.J.; Chu, H.H. Synthetic storm pattern for drainage design. *J. Hydraul. Div.* **1957**, *83*, 1–25.