Journal of Hydrology 608 (2022) 127615

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Editorial

Hydroclimatic extremes and impacts in a changing environment: Observations, mechanisms, and projections

1. Introduction

The frequency and intensity of hydroclimatic extremes such as droughts, floods, and heatwaves have been increasing in many countries around the world due to anthropogenic climate change, posing severe threats to human and natural systems. In particular, compound events that result from a combination of climate drivers and/or hazards across different spatial and temporal scales have been receiving increasing attention from the hydroclimate community in recent years (Zscheischler et al., 2018). Compound events such as concurrent droughts and heatwaves may lead to more devastating impacts than individual hazards, which are becoming more frequent and severe due to the intensification of the hydrological cycle under a warming climate. It is thus necessary to explore the spatiotemporal characteristics and driving factors of hydroclimatic extremes for improving societal resilience and for supporting adaptation planning.

It is difficult to explain the changes in the frequency and severity of observed hydroclimatic extremes. Thus, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change brings together the latest advances in climate science, observations, and climate simulations to improve our understanding of physical mechanisms causing hydroclimatic extremes in a changing climate. As the occurrence and magnitude of hydroclimatic extremes vary across regions and have significant socio-economic and environmental impacts, future projections of hydroclimatic extremes under different climate scenarios are urgently needed to develop mitigation and adaptation strategies.

The aim of this special issue is to gather the most significant contributions to theoretical development and scientific advancement relating to hydroclimatic extremes and impacts in a changing environment. This special issue is a timely collection of 47 articles that cover a variety of topics in the field of hydroclimatic extremes, which presents recent advances in methodologies, modeling techniques and physical mechanisms. The main contributions are summarized as follows.

2. Scientific advances

Chen et al. (2021) performed a quantitative assessment on the potential relationships between the negative/positive effects of forest cover changes on water yields and the biophysical cooling/warming effects of forest cover on local temperatures across 12 paired watersheds globally. Domínguez-Tuda and Gutiérrez-Jurado (2021) assessed the hydrologic responses to climatic variability globally during the period of 2001–2016 and then examined the role of major topographic factors in modulating hydrologic responses. Kumar et al. (2021) assessed the spatiotemporal variability and the complex dependence of climate extremes for 24 major river basins of India, using a copula-based probabilistic approach. Li et al. (2021) investigated the future changes in rainfall erosivity in mainland China under the Paris Agreement (1.5 °C and 2 °C) global warming targets based on statistically downscaled and bias-corrected Community Earth System Model (CESM) low-warming ensemble simulations. Nury et al. (2021) assessed the change in streamflow owing to the changing snow resources for the climate-sensitive Brahmaputra basin and surrounding areas in the Tibetan Plateau. Nygren et al. (2021) assessed the impact of hydroclimate on groundwater with a focus on seasonal frost cover in a region (Sweden and Finland) dominated by cold climate. Paltán et al. (2021) used river flow simulations derived from a multi-model ensemble to estimate future changes in potential water risks, which the current and planned global hydropower generation capacities may need to face in their contribution towards the Paris Agreement global warming targets. Qi et al. (2021) investigated the interannual variations and trends of water bodies as well as their responses to the interaction of driving factors over recent decades (1984–2018) in the high-latitude water tower, Changbai Mountain. Wang et al. (2021) examined the temporal and spatial variability of annual and extreme precipitation between permafrost and non-permafrost zones across the Siberian lowlands during 1959–2018. Zhang et al. (2021b) used the Hybrid Single-Particle Lagrangian Integrated Trajectory model to investigate the moisture sources and pathways that supply precipitation over the Sichuan Basin in southwestern China.

To investigate climate change impacts on hydrological extremes (floods and droughts), Elagib et al. (2021) used photographs and satellite images to analyze the recent pluvial and fluvial flood hazards as well as their potential causes in the Sahel region of Africa. Kourgialas (2021) evaluated the climate change impacts on hydrological extremes in the northwestern part of Greece, which represents one of the most important agricultural regions in the Mediterranean, dominated by tree cultivations for the period of 1960–2019. Ndehedehe et al. (2021) assessed the large-scale variability of hydrological stores (terrestrial water storage, soil moisture, surface water, and groundwater) and their responses to drought intensities over large semi-arid areas in Australia. Pandey et al. (2021) examined the historical and projected future trends in hydroclimatic extremes and their spatial variations for a rain-fed Extended East Rapti watershed in Central-Southern Nepal, based on an ensemble of regional climate model simulations. Wasko et al. (2021a) explained the changing characteristics of droughts and floods over Australia by evaluating historical trends in key hydroclimatic variables including rainfall, soil moisture, evapotranspiration, and runoff. Wasko et al.

https://doi.org/10.1016/j.jhydrol.2022.127615

Available online 18 February 2022

(2021b) further investigated the influence of changes in extreme rainfall and soil moisture on flood magnitude on a global scale, improving our understanding of how rainfall and streamflow extremes are changing under climate change. Yin et al. (2021) identified the hydrometeorological and hydrological controls of the extreme inland flooding caused by Hurricane Florence in 2018 over the Cape Fear River basin, based on both observations and numerical simulations using WRF-Hydro.

In terms of compound event detection and attribution, Feng et al. (2021) evaluated and compared the changes in compound dry and hot events over global maize-producing areas based on different drought indicators. Hao et al. (2021) investigated different categories of compound dry and hot events in northeast China during July-August from 1952 to 2012 based on antecedent El Niño-Southern Oscillation (ENSO). Shi et al. (2021) analyzed the spatiotemporal characteristics and future changes of drought-flood abrupt alternation events over the Wei River basin located in northern China for the period of 1960–2010.

3. Methodological advances

Nerantzaki and Papalexiou (2022) conducted a comprehensive review on probabilistic methods used in the analysis of hydroclimatic extremes, aiming to highlight their strengths and weaknesses. In terms of methodological advances in drought analysis, Afroz et al. (2021) developed a new method, termed the Residual Mass Severity Index (RMSI), to assess hydroclimatic extremes based on precipitation time series, and then compared the RMSI with the well-known Standardized Precipitation Index for different drought durations across Australia. Chang et al. (2022) proposed an integrated drought indicator based on a combination of three hydrometeorological variables (precipitation, runoff, and soil moisture) to identify drought events, and also developed a Principal Component Analysis (PCA)-Copula based approach for assessing the frequency of drought events for the upstream Nanpan River in China. Ho et al. (2021) proposed a new framework for calculating the spatial propagation time from meteorological to hydrological droughts, which provided insights in drought propagation through different hydrologic variables. Zhao et al. (2021a) proposed a nonstationary standardized precipitation index to detect droughts and then used copula functions to construct links between drought characteristics in three major grain production zones of China under a changing environment.

In terms of methodological advances in extreme precipitation and flood analysis, Luo et al. (2021) introduced a new hydrologic and hydraulic coupled modeling program–MetroFlow that integrated multiple models for improving the simulation of urban drainage systems in response to a full spectrum of storm conditions. Ma et al. (2021) proposed an Extreme Gradient Boosting (XGBoost) based approach for flash flood risk assessment and then produced a county-level flash flood risk map for Yunnan Province of China. Mohanty and Simonovic (2021) investigated the suitability of various reanalysis datasets as hydraulic forcings for simulating flood inundation over six selected flood-prone basins in Canada. Ossandón et al. (2021) developed a multivariate semi-Bayesian Hierarchical framework, which was capable of capturing the spatial structure and correlation between model parameters through Gaussian multivariate processes, for conducting nonstationary frequency analysis of precipitation extremes at 73 stations over the Southwest United States. Roksvåg et al. (2021) proposed two post-processing methods for adjusting the return level of extreme precipitation estimated by Bayesian inference, improving the accuracy and consistency of intensity–duration frequency curves across different durations and return periods. Thorndahl and Andersen (2021) proposed a novel method, CLIMACS (CLImate projection of MeAsured preCipitation Series), for stochastic projection of long-term continuous rain series for urban drainage design under different climate scenarios. Yin and Park (2021) integrated the Terrestrial water storage anomaly (TWSA) retrieved from the Gravity Recovery and Climate Experiment (GRACE) mission with model-based TWSA estimates based on an optimal least square merging method across North America, improving flood potential analysis with increased accuracy and reduced uncertainty at sub-regional to local scales. Zhao et al. (2021b) proposed a new transfer learning-based approach to improve urban flood susceptibility mapping in two urban catchments located in the metropolitan areas of Beijing in China, improving conventional machine learning based hazard assessments.

4. Ways forward

The frequency and intensity of hydroclimatic extremes have been increasing in a warming world, which pose a growing threat to the environment, human life, and socioeconomic development. In previous studies, considerable efforts have been made to detect the spatial and temporal changes in hydroclimatic extremes from local to global scales, but there is a lack of in-depth analysis of the underlying physical causes of extreme events and their real-world consequences. It remains unclear 1) how anthropogenic-induced warming promotes the occurrence of individual and interrelated hydroclimatic extremes and 2) how hydroclimatic extremes can translate into quantitative impacts on the environment, society, and infrastructure. Thus, more efforts are expected in future studies to explore the mechanisms causing hydroclimatic extremes associated with land–atmosphere–ocean interactions and feedbacks across local, regional and global scales, and to explicitly quantify their impacts on different sectors such as water resources, agriculture, environment, human health, and infrastructure.

From the perspectives of methodologies and modeling techniques, we need to propose innovative methods and guidelines for improving the detection and attribution of hydroclimatic extremes. For instance, conventional univariate analysis should be extended to multivariate assessments with a main focus on the interactions between potential drivers and/or hazards, thereby improving the characterization of hydroclimatic extremes and advancing our understanding of occurrence mechanisms (Raymond et al., 2020; Zscheischler and Lehner, 2021; Zhang et al., 2021a). In addition, convection-permitting models (CPMs) with horizontal grid spacing $\leq$ 4 km can be used as a promising tool to better resolve local-scale forcing and hydroclimatic processes associated with complex topography and land use/cover (e.g., urban, mountainous, and coastal regions) in response to variability in the large-scale atmospheric circulation (Prein et al., 2015; Liu et al., 2017; Wang and Wang, 2019). CPMs are useful for improving the representation of hydroclimatic dynamics and associated variables, especially hydroclimatic extremes such as the short-duration (subdaily) rainfall extremes on a local scale. Various sources of uncertainty, including observations, initial and boundary conditions, climate scenarios, parameterization schemes, model parameters and structures, should also be explicitly addressed to improve the reliability of hydroclimatic projections. Since various types of datasets, including high-resolution satellite-based products, in situ observations, reanalysis products, and model simulations, have become publicly available in recent years, high-quality datasets from different sources should be utilized and combined to increase the robustness in the detection, attribution, and projection of hydroclimatic extremes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to express our sincere gratitude to all the authors for their contributions to this special issue and also the reviewers for their efforts dedicated to providing valuable comments and feedbacks.

References

Afroz, R., Johnson, F., Sharma, A., 2021. The residual mass severity index – A new method to characterize sustained hydroclimatic extremes. J. Hydrol. 602, 126724. https://doi.org/10.1016/j.jhydrol.2021.126724.

Chang, W., Li, W., Ma, H., Wang, D., Bandala, E.R., Yu, Y., Rodrigo-Comino, J., 2022. An integrated approach for shaping drought characteristics at the watershed scale. J. Hydrol. 604, 127248. https://doi.org/10.1016/j.jhydrol.2021.127248.

Chen, X., Liu, L., Su, Y., Yuan, W., Liu, X., Liu, Z., Zhou, G., 2021. Quantitative association between the water yield impacts of forest cover changes and the biophysical effects of forest cover on temperatures. J. Hydrol. 600, 126529. https://doi.org/10.1016/j.jhydrol.2021.126529.

Domínguez-Tuda, M., Gutiérrez-Jurado, H.A., 2021. Global analysis of the hydrologic sensitivity to climate variability. J. Hydrol. 603, 126720. https://doi.org/10.1016/j.jhydrol.2021.126720.

Elagib, N.A., Zayed, I.S.A., Saad, S.A.G., Mahmood, M.I., Basheer, M., Fink, A.H., 2021. Debilitating floods in the Sahel are becoming frequent. J. Hydrol. 599, 126362. https://doi.org/10.1016/j.jhydrol.2021.126362.

Feng, S., Hao, Z., Wu, X., Zhang, X., Hao, F., 2021. A multi-index evaluation of changes in compound dry and hot events of global maize areas. J. Hydrol. 602, 126728. https://doi.org/10.1016/j.jhydrol.2021.126728.

Hao, Y., Hao, Z., Feng, S., Wu, X., Zhang, X., Hao, F., 2021. Categorical prediction of compound dry and hot events in northeast China based on large-scale climate signals. J. Hydrol. 602, 126729. https://doi.org/10.1016/j.jhydrol.2021.126729.

Kourgialas, N.N., 2021. Hydroclimatic impact on Mediterranean tree crops area – Mapping hydrological extremes (drought/flood) prone parcels. J. Hydrol. 596, 125684. https://doi.org/10.1016/j.jhydrol.2020.125684.

Kumar, N., Kumar Goyal, M., Kumar Gupta, A., Jha, S., Das, J., Madramootoo, C.A., 2021. Joint behaviour of climate extremes across India: Past and future. J. Hydrol. 597, 126185. https://doi.org/10.1016/j.jhydrol.2021.126185.

Ho, S., Tian, L.u., Disse, M., Tuo, Y.e., 2021. A new approach to quantify propagation time from meteorological to hydrological drought. J. Hydrol. 603, 127056. https://doi.org/10.1016/j.jhydrol.2021.127056.

Li, D., Qi, Y., Zhou, T., 2021. Changes in rainfall erosivity over mainland China under stabilized 1.5 ℃ and 2 ℃ warming futures. J. Hydrol. 603, 126996 https://doi.org/10.1016/j.jhydrol.2021.126996.

Liu, C., Ikeda, K., Rasmussen, R., Barlage, M., Newman, A.J., Prein, A.F., Chen, F., Chen, L., Clark, M., Dai, A., Dudhia, J., Eidhammer, T., Gochis, D., Gutmann, E., Kurkute, S., Li, Y., Thompson, G., Yates, D., 2017. Continental-scale convection-permitting modeling of the current and future climate of North America. Clim. Dyn. 49 (1-2), 71–95. https://doi.org/10.1007/s00382-016-3327-9.

Luo, H., Oberg, N., Landry, B.J., García, M.H., 2021. Assessing the system performance of an evolving and integrated urban drainage system to control combined sewer overflows using a multiple-layer based coupled modeling approach. J. Hydrol. 603, 127130. https://doi.org/10.1016/j.jhydrol.2021.127130.

Ma, M., Zhao, G., He, B., Li, Q., Dong, H., Wang, S., Wang, Z., 2021. XGBoost-based method for flash flood risk assessment. J. Hydrol. 598, 126382. https://doi.org/10.1016/j.jhydrol.2021.126382.

Mohanty, M.P., Simonovic, S.P., 2021. Fidelity of reanalysis datasets in floodplain mapping: Investigating performance at inundation level over large regions. J. Hydrol. 597, 125757. https://doi.org/10.1016/j.jhydrol.2020.125757.

Ndehedehe, C.E., Ferreira, V.G., Agutu, N.O., Onojeghuo, A.O., Okwuashi, O., Kassahun, H.T., Dewan, A., 2021. What if the rains do not come? J. Hydrol. 595, 126040. https://doi.org/10.1016/j.jhydrol.2021.126040.

Nerantzaki, S.D., Papalexiou, S.M., 2022. Assessing extremes in hydroclimatology: A review on probabilistic methods. J. Hydrol. 605, 127302. https://doi.org/10.1016/j.jhydrol.2021.127302.

Nygren, M., Giese, M., Barthel, R., 2021. Recent trends in hydroclimate and groundwater levels in a region with seasonal frost cover. J. Hydrol. 602, 126732. https://doi.org/10.1016/j.jhydrol.2021.126732.

Nury, A.H., Sharma, A., Marshall, L., Cordery, I., 2021. Modelling climate change impacts on the Brahmaputra streamflow resulting from changes in snowpack attributes. J. Hydrol. 603, 126998. https://doi.org/10.1016/j.jhydrol.2021.126998.

Ossandón, Á., Rajagopalan, B., Kleiber, W., 2021. Spatial-temporal multivariate semi-Bayesian hierarchical framework for extreme precipitation frequency analysis. J. Hydrol. 600, 126499. https://doi.org/10.1016/j.jhydrol.2021.126499.

Pandey, V.P., Shrestha, D., Adhikari, M., 2021. Characterizing natural drivers of water-induced disasters in a rain-fed watershed: Hydro-climatic extremes in the Extended East Rapti Watershed, Nepal. J. Hydrol. 598, 126383. https://doi.org/10.1016/j.jhydrol.2021.126383.

Paltán, H.A., Pant, R., Braeckman, J.P., Dadson, S.J., 2021. Increased water risks to global hydropower in 1.5 °C and 2.0 °C Warmer Worlds. J. Hydrol. 599, 126503 https://doi.org/10.1016/j.jhydrol.2021.126503.

Prein, A.F., Langhans, W., Fosser, G., Ferrone, A., Ban, N., Goergen, K., Keller, M., Tölle, M., Gutjahr, O., Feser, F., Brisson, E., Kollet, S., Schmidli, J., Lipzig, N.P.M., Leung, R., 2015. A review on regional convection-permitting climate modeling: demonstrations, prospects, and challenges. Rev. Geophys. 53 (2), 323–361. https://doi.org/10.1002/2014RG000475.

Qi, P., Huang, X., Xu, Y.J., Li, F., Wu, Y., Chang, Z., Li, H., Zhang, W., Jiang, M., Zhang, G., Feng, M., Tang, X., 2021. Divergent trends of water bodies and their driving factors in a high-latitude water tower, Changbai Mountain. J. Hydrol. 603, 127094. https://doi.org/10.1016/j.jhydrol.2021.127094.

Raymond, C., Horton, R.M., Zscheischler, J., Martius, O., AghaKouchak, A., Balch, J., Bowen, S.G., Camargo, S.J., Hess, J., Kornhuber, K., Oppenheimer, M., Ruane, A.C., Wahl, T., White, K., 2020. Understanding and managing connected extreme events. Nat. Clim. Change 10 (7), 611–621. https://doi.org/10.1038/s41558-020-0790-4.

Roksvåg, T., Lutz, J., Grinde, L., Dyrrdal, A.V., Thorarinsdottir, T.L., 2021. Consistent intensity-duration-frequency curves by post-processing of estimated Bayesian posterior quantiles. J. Hydrol. 603, 127000. https://doi.org/10.1016/j.jhydrol.2021.127000.

Shi, W., Huang, S., Liu, D., Huang, Q., Han, Z., Leng, G., Wang, H., Liang, H., Li, P., Wei, X., 2021. Drought-flood abrupt alternation dynamics and their potential driving forces in a changing environment. J. Hydrol. 597, 126179. https://doi.org/10.1016/j.jhydrol.2021.126179.

Thorndahl, S., Andersen, C.B., 2021. CLIMACS: A method for stochastic generation of continuous climate projected point rainfall for urban drainage design. J. Hydrol. 602, 126776. https://doi.org/10.1016/j.jhydrol.2021.126776.

Wang, P., Huang, Q., Tang, Q.i., Chen, X., Yu, J., Pozdniakov, S.P., Wang, T., 2021. Increasing annual and extreme precipitation in permafrost-dominated Siberia during 1959–2018. J. Hydrol. 603, 126865. https://doi.org/10.1016/j.jhydrol.2021.126865.

Wang, S., Wang, Y., 2019. Improving probabilistic hydroclimatic projections through high-resolution convection-permitting climate modeling and Markov chain Monte Carlo simulations. Clim. Dyn. 53 (3-4), 1613–1636. https://doi.org/10.1007/s00382-019-04702-7.

Wasko, C., Shao, Y., Vogel, E., Wilson, L., Wang, Q.J., Frost, A., Donnelly, C., 2021a. Understanding trends in hydrologic extremes across Australia. J. Hydrol. 593, 125877. https://doi.org/10.1016/j.jhydrol.2020.125877.

Wasko, C., Nathan, R., Stein, L., O'Shea, D., 2021b. Evidence of shorter more extreme rainfalls and increased flood variability under climate change. J. Hydrol. 603, 126994. https://doi.org/10.1016/j.jhydrol.2021.126994.

Yin, G., Park, J., 2021. The use of triple collocation approach to merge satellite- and model-based terrestrial water storage for flood potential analysis. J. Hydrol. 603, 127197. https://doi.org/10.1016/j.jhydrol.2021.127197.

Yin, D., Xue, Z.G., Warner, J.C., Bao, D., Huang, Y., Yu, W., 2021. Hydrometeorology and hydrology of flooding in Cape Fear River basin during Hurricane Florence in 2018. J. Hydrol. 603, 127139. https://doi.org/10.1016/j.jhydrol.2021.127139.

Zhang, B., Wang, S., Wang, Y., 2021a. Probabilistic projections of multidimensional flood risks at a convection-permitting scale. Water Resour. Res. 57, e2020WR028582 https://doi.org/10.1029/2020WR028582.

Zhang, S., Liu, B.o., Ren, G., Zhou, T., Jiang, C., Li, S., Su, B., 2021b. Moisture sources and paths associated with warm-season precipitation over the Sichuan Basin in southwestern China: climatology and interannual variability. J. Hydrol. 603, 127019. https://doi.org/10.1016/j.jhydrol.2021.127019.

Zhao, R., Wang, H., Hu, S., Zhan, C., Guo, J., 2021a. Joint probability of drought encounter among three major grain production zones of China under nonstationary climate. J. Hydrol. 603, 126995. https://doi.org/10.1016/j.jhydrol.2021.126995.

Zhao, G., Pang, B.o., Xu, Z., Cui, L., Wang, J., Zuo, D., Peng, D., 2021b. Improving urban flood susceptibility mapping using transfer learning. J. Hydrol. 602, 126777. https://doi.org/10.1016/j.jhydrol.2021.126777.

Zscheischler, J., Lehner, F., 2021. Attributing compound events to anthropogenic climate change. Bull. Am. Meteorol. Soc. 1–45 https://doi.org/10.1175/BAMS-D-21-0116.1.

Zscheischler, J., Westra, S., van den Hurk, B.J.J.M., Seneviratne, S.I., Ward, P.J., Pitman, A., AghaKouchak, A., Bresch, D.N., Leonard, M., Wahl, T., Zhang, X., 2018. Future climate risk from compound events. Nat. Clim. Change 8 (6), 469–477. https://doi.org/10.1038/s41558-018-0156-3.

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This manuscript was handled by Marco Borga, Editor-in-Chief, with the assistance of Nadav Peleg, Associate Editor