



Editorial Statistical Approach to Hydrological Analysis

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Despite the extensive body of research on the topic, the physical processes leading to the formation of extreme hydrological phenomena are still not fully understood, and robust deterministic models that would reliably describe them are yet to be developed [1]. Meanwhile, due to the random nature of hydrological processes, a statistical approach has been used for decades [2,3]. Of special interest to researchers, policymakers, and natural-event risk managers is hydrological extremes, such as heavy precipitations, floods, droughts, or storm surges, due to their profound effects. Hence, the most pressing recent challenge is to create a new generation of more accurate and reliable models that may include the estimation of the impact of environmental changes on the frequency and magnitude of natural extremes.

A wide range of statistical methods can be useful for the modelling of hydrological extremes, including both uni- and multivariate extreme value theory, times series analysis, copulas, Bayesian theory, and others. Past hydrological information detected by palaeohydrological techniques can be incorporated into studies to supplement the observed data; among other data, paleoflood data can expand and challenge flood frequency analysis and influence the links between event sequences and global changes [4]. This subject also covers the study of compound events, which combines the physical processes leading to hazards such as floods and droughts. Examples include extreme precipitation, river peak discharge, and storm surge, which change the interactions in the face of climate change and make it difficult to project future hazards based on single drivers.

The current Special Issue contains interesting proposals for analyzing and modeling hydrological phenomena, in particular for hydrological extremes, by new methods or by the improvement of existing methods. The contributions covered three main issues: (1) regular and extreme precipitation, (2) regular and extreme flows, (3) low flows and droughts. The research area covers Europe, Asia, and North and South America.

The first group of papers deals with regular and extreme precipitation. The contribution to the establishment of multiscale methods based on information theory was given by Silva et al. [5], who applied the modified multiscale entropy method (MMSE) to the identification of the rainfall regularity across a wide range of temporal scales, from one month to one year, for various types of regions in the state of Pernambuco, northeastern Brazil.

Espinoza et al. [6] employed the extremogram and cross-extremogram techniques to find the relationship between the North Atlantic Oscillation index (NAOI) and rainfall extremes in a small North Atlantic island, Madeira, Portugal, taking into account the negative and positive NAOI dominance sub-periods.

Furthermore, a pronounced spatial heterogeneity of short-duration extreme rainfall was detected in the four megacities in China [7] and a closely link of the rainfall characteristics as location, range, and directions with various urban development in individual cities. Interesting is, that the research considers urban area but located in highly diversified mountain-plain environment, which generates additional hydrological and meteorological issues to be addressed.

A similarly diversified but less urbanized area was studied by Markiewicz [8]. A case study covers the Upper Vistula Basin (Poland), where there is a high risk of flooding in



Citation: Kochanek, K.; Markiewicz, I. Statistical Approach to Hydrological Analysis. *Water* 2022, 14, 1094. https://doi.org/10.3390/ w14071094

Received: 22 March 2022 Accepted: 28 March 2022 Published: 30 March 2022

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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). the summer season due to intensive rainfall. An analysis of the variability of maximum precipitation series showed their stationarity, which supports the conclusion that there is no increase in the risk of flooding from rainfall in the summer season. The proposed new approach to determining the depth-duration-frequency (DDF) relationship of extreme precipitation provided a more accurate estimation of the DDF curves for individual stations than the commonly used approach.

The next subject considers discharges in the rivers, ranging from average up to inundation-provoking ones. In this section, El Hannoun et al. [9] proposed the application of Regular Vine (R-vine) copulas to assess composite risk generated in the cascade of five reservoirs built in the Saint John River basin in Eastern Canada. The approach presented proved to be flexible in the choice of distributions used to model heavy-tailed marginal and co-dependencies, which results in a more accurate estimation of risk parameters in dam-controlled rivers.

Gulakhmadov et al. [10] assessed the long-term changes in streamflow in snow-fed and glacier-fed rivers that were vulnerable to climatic variations in alpine mountainous regions. They used non-parametric tests to determine the trends and variability of magnitude in the Kofarnihon River Basin in Central Asia. The research confirmed strong spatial patterns and altitude-dependent, and, obviously, seasonal diversity of climatic parameters influencing the flow of rivers and thus water-management policies in the region.

Since the classical approach to flood frequency analysis (FFA) may result in significant jumps in the estimates of design (flood) quantiles along with the lengthening series of maximum flows, Markiewicz et al. [11] presented a new variant of a multi-model approach in FFA. The newly proposed probability mixture model as well as the previously proposed quantile mixture model mitigates the problem of unstable design quantiles of maximum flows. Furthermore, this provides a promising tool for parameter estimation in various areas, especially in the life sciences, e.g., when the experiment cannot be repeated under the same conditions or the experimental parameters are out of the control.

The last group of papers addresses the ninth problem of the UPH [1]: *How do flood-rich and drought-rich periods arise, are they changing, and if so, why?*' Heidari et al. [12] developed a probabilistic approach to improve the characterization of -duration-frequency relationships of sub-annual socioeconomic drought intensity under shifts in water supply and demand conditions. As the case study, they chose the City of Fort Collins (Colorado, USA) water supply system. The results showed that the mixture of Gamma-Generalized Pareto models supported by the deterministic modelling techniques leads to enhanced estimation of sub-annual socioeconomic drought frequencies, particularly for extreme events within the context of scenarios with a changing climate.

Additionally, in Central Europe, it can be noticed that the problem of droughts is growing at an alarming rate. Vlach et al. [13] analyzed the long-term variability and seasonality of low flows and streamflow droughts in fifteen headwater catchments of three regions in Central Europe. In their study, the authors revealed a substantial increase in the proportion of summer low flows during the analyzed period (1968–2019), with an apparent shift, recognized mainly in higher altitudes (800–1000 m.a.s.l.), in the average date of low flow occurrence towards the start of the year. The results of the study help to identify the vulnerable near-natural catchments that are prone to summer water scarcity.

To sum up, the Special Issue of journal *Water*, 'Statistical Approach to Hydrological Analysis', addresses significant issues of the contemporary hydrology and water management policies throughout the world. The methodology developed by the authors fits into the current trends visible in the scientific literature, and the authors propose practical solutions that can be easily applied by hydrological services. Unfortunately, the picture presented by the research results is not comforting. The demonstrated increase in both the frequency and magnitude of extreme hydrological phenomena in the face of climate change prompts us to rethink the current economic policy of the regions and to take steps to change the water management method. It is significant that the problems and the solutions suggested by the authors relate to the entire world.

Author Contributions: Conceptualization, K.K. and I.M.; resources, K.K. and I.M.; data curation, K.K. and I.M.; writing—original draft preparation, K.K. and I.M.; writing—review and editing, K.K. and I.M. All authors have read and agreed to the published version of the manuscript.

Funding: The work was funded by the Ministry of Science and Higher Education of Poland within the statutory activities No. 3841/E-41/S/2022.

Acknowledgments: The authors would like to thank the journal editors, all authors submitting papers and the anonymous reviewers who have contributed to the quality improvement of the present Special Issue.

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

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