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Editorial

Developments In Water Resources Management And Hydrologic Forecasting.

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Abstract

Global attention has been drawn to the effects of climate change on the management of water supplies as well as the rise in catastrophic natural catastrophes in recent decades. Effective management of water resources and the prevention of natural disasters depend on precise and dependable hydrological forecasts. Accurate forecasting is extremely difficult due to the infamously nonlinear hydrological processes, but developing accurate forecast models and dependable management systems calls for sophisticated methodologies. Artificial intelligence (AI) is one of the newest methods for modeling complicated systems. AI has the amazing capacity to effectively extract important information from vast volumes of data in order to solve complicated issues, and it can mimic how people learn. By utilizing the most recent cutting-edge methods, like artificial intelligence, the fourteen research papers included in this Special Issue greatly aid in the assessment of operational hydrologic forecasting uncertainty under shifting environmental conditions and the advancement of water resources management. The fourteen contributions fall into four main research areas: (1) hydrological forecasting using machine learning techniques; (2) assessing and analyzing uncertainty in hydrological modeling in dynamic environments; (3) artificial intelligence techniques for optimizing multi-objective reservoir operation; and (4) hazard mitigation adaptation strategies for extreme hydrological events. In addition to advancing the field of water sciences, the articles in this issue can help decision-makers manage water resources in a more efficient and sustainable manner.

Keywords : *Water resources management, multi-objective reservoir operation, hydrologic forecasting, artificial intelligence, machine learning, uncertainty, and risk.*

INTRODUCTION

Because of climate change, natural catastrophes have tended to occur more frequently and with greater severity in recent decades. Flood forecasting in each river basin serves as a preventative measure to deal with future floods, warning those involved and reducing damage and fatalities. Effective management of water resources and the prevention of natural disasters like floods and droughts depend on hydrological forecasting. It takes a combination of hydrological and meteorological data, forecasting techniques, and skilled forecasters to create a workable hydrological forecasting model for populations that are at risk. Forecasts need to be precise enough to inspire confidence so that users and communities respond appropriately to warnings. For water planning and management, multidisciplinary research and sophisticated hydrological forecasting techniques—particularly during extreme floods and droughts—are widely used. This eventually results in better optimum management of water resources and efficient control in a changing environment. These include artificial intelligence (AI) approaches, which are widely utilized to address a variety of hydrological issues, including flood forecasts, and are effective tools for gleaning the most important information from intricate, highly dimensional input-output patterns in this Special Issue[1–14]. Numerous research conducted over the past few decades have shown that artificial intelligence (AI) approaches, such as machine learning (ML) methods, can generate flood forecasts in a matter of hours [15–19], and for larger river basins, they can extend to seasonal forecasts several months in advance [20–24]. Water utility administrators may efficiently maximize multi-objective water resources revenues with AI, which can also be a perfect tool for managing water resources in a constantly changing environment [25–30].

To manage floods and increase the effectiveness of streamflow forecasts used for real-time reservoir operation, it is essential to have accurate and dependable streamflow forecasts with lead times ranging from hours to days. However, all forecasts have some degree of uncertainty, which may be related to the model's forecast mistakes, hydrological model mechanics and parameters, or meteorological data. We must address

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the uncertainty associated with streamflow estimates in order to apply them to real-time reservoir operation. There are relatively few studies addressing the impact of prediction uncertainty on real-time reservoir operations, despite the fact that forecast uncertainty is crucial to reservoir operation and has been well examined in hydrology [31–36]. Overcoming these obstacles, discussing ongoing initiatives to learn more about hydrological processes, addressing the impact of forecast uncertainty, and implementing more effective water management techniques in a changing environment are the goals of this special issue.

SYNOPSIS OF THE SPECIAL ISSUE PAPERS

The papers in this Special Issue cover a wide range of topics, including uncertainty analysis, water resources management, and hydrological forecasts. Three articles [1–3] use a variety of machine learning (ML) techniques to address operational hydrological forecasts. In order to predict the average regional flood inundation depth in a river basin in Taiwan, the authors of [1] suggest an Internet of Things (IoT) machine learning-based flood forecast model. They also show how to online modify the machine learning models to improve the models' accuracy and suitability for multi-step-ahead flood inundation forecasts. They also point out that flood prediction may benefit from the integration of IoT and machine learning techniques. The authors of [2] present a general framework for probabilistic flood forecasting conditional on point forecasts that combines a recurrent neural network with an unscented Kalman filter (UKF) post-processing approach. They assert that the suggested method could greatly increase model dependability and forecast accuracy for future horizons by overcoming the under-prediction phenomenon and reducing the uncertainty present in data-driven flood forecasting. The authors of [3] suggest using a random forest (RF) model to forecast the Normalized Difference Vegetation Index (NDVI) and investigate how it relates to climate variables. The findings show that RF can clarify biological processes in the Yarlung Zangbo river basin and be included into the management of water resources. These studies unequivocally show that IoT sensors are helpful tools for monitoring natural environments and improving hydrological forecasts, and machine learning techniques have a great capacity to model the nonlinear dynamic features in hydrological processes, such as flood forecasts and NDVI.

Research on uncertainty assessment and analysis in hydrological modeling and forecasting is reported in papers [4–6]. In [4], Hong's approach is used to carry out the point estimate method (PEM) in a case study that uses the ANUGA hydrodynamic model to simulate water runoff for a region in Glasgow, UK. The authors show that the Hong's method, which only requires three 11-minute simulation runs instead of the 500 needed for the Monte Carlo (MC) simulation, could more effectively create probabilistic flood-inundation maps in the same areas as those of the MC simulation. The authors of [5] present the Generalized Likelihood Uncertainty Estimation-Technique for Order Preference by Similarity to Ideal Solution (GLUE-TOPSIS), a multi-criteria decision analysis method. The suggested approach was applied to the Dahongmen catchment in Beijing, China, using the Storm Water Management Model (SWMM). They come to the conclusion that the suggested GLUE-TOPSIS is a legitimate method for evaluating the urban hydrological model's uncertainty from a variety of objective angles, which enhances the dependability of model output in the urban catchment. The Snowmelt Runoff Model (SRM) parameter uncertainty is assessed by the authors in [6] using various calibration techniques and its effects on a deglaciating Yurungkash watershed in China with limited data. The findings indicate that there is a great deal of uncertainty in the runoff projection for the future, that the discharge during the snowmelt season is expected to grow, and that the start of snowmelt runoff is probably going to move earlier in the year.

The reliable use of hydrological models with time-invariant parameters has been severely hampered by hydrological nonstationary. The robustness and prediction power of a hydrological model in dynamic situations are examined in two articles [7, 8]. The authors of [7] suggest a novel approach based on empirical mode decomposition (EMD) for creating and synthesizing data that is tampered with by non-stationary issues. The water supply system of Taiwan's Hushan reservoir was simulated using both fresh synthetic and historical flow data, and the comparison of the two shows that the synthetic data closely resembles the historical flow distribution. The authors of [8] examine the robustness and predictive power of a conceptual hydrological model (GR4J) with a time-varying parameter in dynamic situations. The outcomes demonstrate that using the time-varying parameters enhanced the streamflow simulation's performance. Additionally, by increasing the model's robustness, the GR4J model with time-varying parameters performed better than the original GR4J model. All things considered, these studies highlight how crucial it is to take into account the parameter uncertainty of time-varying hydrological processes when modeling hydrology and assessing the effects of climate change.

Reservoirs are expected to become more crucial as a result of climate change, not just for storing water but also for optimizing water use advantages and reducing climate extremes. In order to determine reservoir operating rules for multi-reservoir systems and/or optimize multi-objective reservoir operation, four studies [9–12] use sophisticated optimization techniques. The authors of [9] use the genetic algorithm (GA) and an enhanced non-dominated genetic algorithm (NSGA-II) to solve the single-objective and multi-objective optimal schema in a multi-target single dispatching study on ecology and power generation in the lower Yellow River. The findings have significant practical implications for future enhancements to the ecological health of the lower Yellow River and serve as a foundation for decision-making on the multi-objective dispatching of the Xiaolangdi reservoir. The authors of [10] combine the Mahalanobis–Taguchi System (MTS) and the gray entropy technique (GEM) to choose the best water level plan for the Pankou reservoir during flood season. The findings confirm the viability and validity of the model by demonstrating that the best plan chosen by the suggested model can maximize advantages within a reasonable risk range and, as a consequence, more effectively balance risk and benefit. The authors of [11] demonstrate how reservoir operators may be able to determine the early impoundment operation rules (EIOR) in the upper Yangtze river basin as a result of the development of seasonal flow forecasts. According to their findings, the suggested GloFAS-Seasonal forecasts are adept at predicting the streamflow condition based on the chosen 20th and 30th percentile thresholds. The seasonal forecasts that are produced, along with the early reservoir impoundment, may improve water use and hydropower production. A new enhanced gravitational search algorithm (EGSA) is put out in [12] to solve the multi-objective optimization model while taking into account the peak operation requirements of a power system situated on China's Wujiang River and the electricity generation of a hydroelectric firm. The findings demonstrate that the EGSA approach might produce satisfactory scheduling schemes for the multi-objective operation of hydropower systems in various scenarios.

For the purpose of reducing hazards, early warning and post-assessment of extreme hydrological occurrences are essential. The best flood management method for small and medium-sized rivers in densely populated areas is examined by the authors in [13]. Building two additional tributaries to move floodwater from the Shegong River's midstream and downstream into the Tieshan River's downstream is likely the most economical flood management plan. According to their findings, flood control for small and medium-sized rivers in densely populated areas should take into account both tributary and mainstream flood characteristics from a regional perspective, rather than only tributary flood regimes. The authors of [14] provide emergency disposal methods for appropriately managing the landslide and dammed lake in a matter of hours to days in order to reduce the risk of flooding. They outline a general plan for dealing with the hazardous situation caused by a massive dammed lake with 770 million m3 of water volume and develop an emergency disposal solution for the 25 million m3 of debris. This plan consists of both non-engineering measures for the operation of reservoirs and hydropower stations and engineering measures for the excavation of floodgates. In addition to lowering the danger of a large-scale flood (10,000-year return period, 0.01%) to a small-scale flood (10-year return period, 10%), the disposal option also lowers the risk of a massive landslide killing anyone.

CONCLUSION

Global warming has caused significant changes in the climate during the past few decades.Additionally, we observe that artificial intelligence has been effectively applied to improve our understanding, learn about hydrological processes, and implement more effective water management techniques in response to shifting environmental conditions. The research articles included in this Special Issue provide a substantial contribution to our comprehension of water resources management and hydrological modeling techniques.

They fall under four major topic categories: AI tools for optimizing multi-objective reservoir operation; (2) uncertainty analysis and assessment on hydrologic forecasts; (3) machine learning methods for hydrologic forecasting; and (4) adaptation strategies for extreme hydrological events to mitigate hazards.These studies provide cutting-edge techniques for understanding intricate hydrological processes, simulating hydrological forecasts, lowering model uncertainty, and improving the management of water resources. Along with case studies from around the globe, the chosen manuscripts included in this Special Issue offer unique insights into the state-of-the-art in artificial intelligence techniques, offering a high degree of research and useful information on putting AI methods and strategies into practice for precise flood forecasts and reservoir operation.

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