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Editorial: Risk analysis of hydrological extremes — spatio-temporal dynamics, interdependence, and uncertainty

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Editorial on the Research Topic
Risk analysis of hydrological extremes: spatio-temporal dynamics, interdependence, and uncertainty

Hydrology-related catastrophes have wide-ranging impacts across the world. The increasing risks of hydrological extremes are driven by global warming and socioeconomic drivers. Analysis of risk of hydrological extremes is a difficult task given the complex interactions among several pertinent aspects including exposure, sensitivity, adaptive capacity, vulnerability, and resilience of systems which are directly or indirectly affected by natural hazards especially floods and/or droughts. Furthermore, interpretations of some of the key terms pertaining to the floods and droughts such as resilience, sensitivity and vulnerability are diverse (see e.g. Gallopin, 2006; Nelson et al., 2007, 2010; Willner et al., 2018; Hall and Leng, 2019; Hughes et al., 2020; Ward et al., 2020) thereby complicating the clear-cut description, characterization and quantification of natural hazard risk challenging. This topic collection explores the risk analysis of hydrological extremes, with a focus on investigating flood risk drivers in a data-scarce region, constructing a multi-risk assessment framework, improving the approach for estimating building-specific average annual losses due to flood hazards, and applying an interdisciplinary approach to analyse biophysical and socio-institutional casualties of increasing flood events.

The first study in this topic collection by Wetzel et al. investigated key flood risk drivers in the Lower Mono River Basin of Benin, a data-scarce region in West Africa. It aimed at addressing the limitations of current risk assessment methods which do not comprehensively capture the dynamic nature of flood risks and the principal drivers. The study highlighted the importance of using an impact chain model to explore flood risk dynamics and especially the interactions among flood risk drivers through what-if-scenarios. However, they concluded that the reliability of risk assessment results from such models depends on the availability of large quantitative observations to test and validate the model and any inconsistencies in the system's representation can lead to unreliable and illogical interactions among the risk drivers. Thus, validation of the risk assessment model is crucial before using the results to support actionable policy for planning adaptation measures against hydrological hazards.

Realizing that most studies on hydrological risk assessment concentrate on a single hazard while the approaches for analyzing complex risks are not yet well established, the second study of this topic collection by Cotti et al. constructed a multi-risk assessment framework for the Marrakech-Safi region of Morocco in North Africa. The framework comprised information from multiple consultations of stakeholders and an array of single-risks pertaining to flood and drought hazards. A composite vulnerability indicator was constructed using weights of relevant information from experts and stakeholders as well as an array of vulnerability indicators. The study result showed that up to 28% of the municipalities exhibited very high multi-risk levels, with drought-related risks being the major contributor. The authors recommended further research to explore the best way to disentangle the complexity and uncertainty in the results from final multi-risk assessments before using them to support actionable policy for risk management from floods and/or droughts.

The third study by Gnan et al. aimed at improving the approach for estimating average annual losses (AAL) for buildings from flood hazards. The authors used the Gumbel distribution to estimate the flood hazard for a building and included a wide range of quantiles from shorter (frequent) to longer (rare) return periods to improve the relationship between annual exceedance probability and flood depths. For a case study in Louisiana, USA they found that flood risk reduction of over $1,000 and about $2,000 can be achieved annually using one foot and four feet freeboard, respectively. Furthermore, their sensitivity analysis demonstrated that the choice of depth-damage function substantially influences the estimation of building-specific AAL (Gnan et al.). The authors recommended that future work should take into account climate change impacts in flood risk models especially in updating annual exceedance probability of flood events.

The last paper of this topic collection (Sahani et al.) applied an interdisciplinary approach to analyse biophysical and socio-institutional casualties of increasing flood events in the Kosi sub-basin in India. The study found that vulnerability of the community to flood hazards in the study area cannot only solely be linked to precipitation and that other socio-institutional factors are also relevant. Results from interviews of affected communities and field observations confirmed that the post-embankment period is characterized by more frequent and intense floods than those for the sub-period before the embankment. Furthermore, the flood hazard outside the embankment in Kosi sub-basin is exacerbated by the breaching of the river embankments.

This topic collection showcases a variety of studies regarding the risk analysis of hydrological extremes. However, many challenges continue to exist in risk analysis of hydrological extremes especially regarding uncertainty, attribution of extreme events, data limitation, and handling and processing of big data. For developing countries, risk analyses of floods and droughts are mainly challenged by the limitation and low quality of observed weather and climatic data. The quality and number of weather stations across developing countries are often very low and small, respectively, and the few stations that do exist may not remain continuously operational due to a lack of maintenance of the recording equipment (Onyutha, 2018). Furthermore, it is too expensive for scientific researchers in developing countries to afford observed climatic time series from the few weather stations (Onyutha, 2020). Data limitation leads to large uncertainties in future climate change projections, as a sparse observational network hampers model tuning and evaluation (Tabari et al., 2019). One solution to this issue is the use of available high-resolution satellite and reanalysis products of relevant climatic data (Golian et al., 2019). However, their validity against observations needs to be determined before they can be used to quantify risks of hydrological natural hazards (Zhang et al., 2011). This calls for investments in data collection especially regarding recording of observed weather and climatic data in developing countries.

The limited availability of detailed and consistent data on exposure and vulnerability components of natural hazards and their evolution over the following decades presents another significant challenge for conducting future risk assessments of hydrological extremes. As exposure and vulnerability play important roles in shaping risk (Knorr and Arneth, 2016; Tabari et al., 2021), there is an urgent need to develop more comprehensive data to support risk analysis for the future.

There have been remarkable recent advances in big data, coupled with progress in artificial intelligence. These aspects offer commendable opportunities to improve predictions and outputs of data-driven risk models in the future. However, big data can be typified by multiple variables that are substantially heterogeneous and comprise complex inherent patterns. We believe that a commitment from scientists to maximize the application of big data analytics in risk analysis of hydrological extremes will improve reliability of information to support actionable policies for flood and drought risk mitigation. In addition to big data analysis, we see artificial intelligence as a potential game-changer in conventional approaches to uncertainty analysis, modeling, and risk prediction of hydrological extremes. It can help to enhance our understanding of the complex interactions among exposure, sensitivity, vulnerability, and resilience of society and environmental systems.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

SG was employed by the SRK Consulting, GeoHydro Group, Cardiff, United Kingdom.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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