Approaches to analyse and model changes in impacts: reply to discussions of "How to improve attribution of changes in drought and flood impacts"

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Abstract

We thank the authors, Brunella Bonaccorso and Karsten Arnbjerg-Nielsen for their constructive contributions to the discussion about the attribution of changes in drought and flood impacts. We appreciate that they support our opinion, but in particular their additional new ideas on how to better understand changes in impacts, and to challenge us to think a step further on how to foster the collection of long data time series and how to use these to model and project changes. Here, we elaborate on the possibility to collect time series data on hazard, exposure, vulnerability and impacts and how these could be used to improve e.g. socio-hydrological models for the development of future risk scenarios.

Keywords: hydrological extremes; damage; dynamic risk; new data; projecting risk

The Panta Rhei opinion paper series intents to foster scientific discussion about approaches to increase our knowledge of interactions and feedbacks between hydrology and society (https://think.taylorandfrancis.com/panta-rhei-collection; Kreibich et al. 2017). Thus, we are grateful to the authors, Bonaccorso (2019) and Arnbjerg-Nielsen (2019), supporting our view and for their constructive comments to our opinion paper "How to improve attribution of changes in drought and flood impacts" (Kreibich et al. 2019). Both authors back up our appreciation that droughts and floods have much in common and that flood risk management measures may influence drought risk, and vice-versa, partly because of inadequate land management practices. Furthermore, both authors agree on the need for a closer cooperation between drought and flood experts to do joint analysis of the effects of flood and drought management on impact changes, which is important for scientific advancement in this area. Bonaccorso (2019) stresses that in addition to interdisciplinary teamwork of experts with a natural sciences or engineering background, a broader debate and closer cooperation with water resources economists and socio-political scientists is necessary for sustainable, pro-active risk management, which focuses on adaptive solutions to cope with droughts and floods in the future. There are convincing examples of such successful cooperation in practice as well as in science. We cannot provide an overview here, particularly not about the many good activities happening in practice, but we give some examples. For instance, hydrologists, economists and geographers developed together the cost assessment cycle, which involves the continuous monitoring and reduction of the total costs associated with natural hazard impacts and risk management, thus enabling the early detection of inefficient risk mitigation strategies (Kreibich et al. 2014). Psychologists, economists, political scientists, physical geographers and urban planners are working together to better understand relocation decisions to reduce flood risks (Bukvic et al. 2015, Botzen et al. 2016). In a collaboration between human and physical geographers, international development specialists, and hydrological modellers, Rangecroft et al. (2018) explored interdisciplinary ways to increase preparedness for drought. And in Breyer et al. (2018) an engineer and a geographer modelled the feedbacks between drought and urban water use restrictions. They conclude that "adapting to anthropogenic drought requires sustained engagement between hydrology and social sciences to integrate socioeconomic status and political feedbacks into the water cycle." In the EU-funded project DROUGHT-R&SPI (http://www.eu-drought.org/), economists and political scientists worked together with weather-related hazard experts on economic losses in Southern European agriculture (Musolino et al., 2018). The study reveals that drought does not have only "losers", but also "winners". In their case, farmers were the winners, while the consumers were the losers. These findings also refer to Arnbjerg-Nielsen (2019) suggestion to investigate how stakeholders are differently affected, e.g. citizens versus agriculture.

However, we agree that interdisciplinary cooperation should be further strengthened in drought and flood research. This is especially crucial if we want to model drought and flood risks using improved scenarios for exposure and vulnerability as suggested by Arnbjerg-Nielsen (2019). Such scenarios cannot be developed without a strong collaboration with social scientists. In recent years, a rethinking towards the need for more inter- and transdisciplinary research projects began. Nevertheless, collaboration between physical and social scientists requires extra time that needs to be invested in order to gain sufficient mutual understanding of concepts, approaches and models, which is often difficult to justify in research proposals. The well-established inclusion of some social scientists in the Panta Rhei initiative and working groups is a step in the right direction (https://iahs.info/Commissions--W-Groups/Working-Groups/Panta-Rhei/Working-Groups.do). However, it is unclear if and how this cooperation will continue after the end of this scientific decade in 2022 (Montanari et al. 2013, McMillan et al. 2016). The European Commission should include in their RTD programme (e.g. upcoming Horizon Europe) calls for projects addressing interdisciplinary cooperation on changes in risk of weather-related natural hazards, incl. floods and droughts due to global change.

Arnbjerg-Nielsen (2019) acknowledges the challenge to compile matching data of impacts and their potential drivers for catchments or regions, which is especially true for droughts where impacts are not always directly attributable to the hazard (Kreibich et al. 2019). Recently a global inventory was made for drought risk assessment, of over 200 datasets, tools, indicators, text-based information, etc. (WorldBank, 2019; Deltares, 2018), which shows that most available data is on the (historical) drought hazard, whereas impact data is very limited or even lacking. Bonaccorso (2019) provides hope, that impact and other data will become increasingly available through private initiatives of big on-line service providers, such as Google, or insurance companies. Indeed, in recent years, new data sources such as data derived from satellite images, from crowed sourcing of social media, from measurements of innovative sensors or data gained in a participative way, e.g. when citizens provide information, are gaining more and more importance in science and application domains. Several studies showed the significant potential that data science can enfold for natural hazards research. For instance, crop data derived from a multi-year satellite image analysis and ancillary soil data was analysed with data mining Net Bayesian Classifiers to support the estimation of flood losses to agricultural crops. The approach was validated in flood retention areas at the Havel River, which were used for temporary storage of flood water during the extreme flood event in August 2002 in Germany (Tapia-Silva et al. 2011). Sieg et al. (2019) developed an approach for seamless damage estimation including uncertainty quantification which is based on open access building data from openstreetmap.org, which is collected in a participatory way, in combination with random forest based loss modelling. In Florida, USA, citizens are helping to collect information on flooded locations and other data during flooding in high tide events (SLSC, 2019). News media data are also increasingly used in flood and drought risk studies. For example, Quesnel and Ajami (2017) used news media coverage and Google search frequency to study drought awareness in California between 2005 and 2015. They found that residential water use was strongly related to the news media coverage. A promising governmental tool of the European commission is the Europe Media Monitor (EMM), which was initially developed to globally monitor outbreaks of diseases. “Monitoring thousands of news sources in over 70 languages, the system uses advanced information extraction techniques to automatically determine what is being reported in the news” and could be adapted to scan for impacts of natural hazards (Steinberger et al. 2013).

Bonaccorso (2019) stresses the need for international standards for impact data collection, and she suggests that the scientific community should be in charge of developing general guidelines. There are several scientific studies aiming to define which data should be collected for which purpose, and how (e.g. Van Lanen et al., 2016; Molinari et al., 2018, Elmer et al. 2010). Impact data collections are undertaken by different stakeholders after drought and flood events: scientists collect impact data to gain knowledge about damage processes, governmental agencies and insurance companies collect data in the framework of loss compensation. Scientific assessments contain often a lot of details, but suffer from a relatively small sample size (Blong, 2004; Mazzorana et al. 2014). Data collected by governmental agencies and insurance companies is often classified, and not accessible for research. Thus, a closer cooperation between these different stakeholders is advantageous. Important developments are the EU initiatives for recording and sharing disaster damage and loss data (https://drmkc.jrc.ec.europa.eu/partnership/Science-Policy-Interface/Disaster-Loss-and-Damage-Working-Group; JRC 2013), and the OECD initiative to develop a framework for accounting risk management expenditures and losses of disasters (OECD, 2014). NGOs also play an important role as intermediaries, including aid and other relief organisations in developing countries, where public authority capacities are lower compared to developed countries. For instance, the Red Cross is active in collecting disaster event data, and also in developing algorithms to predict where and when impacts can be expected in future events (Van den Homberg et al., 2018).

With reference to the proposed paired-event approach, Bonaccorso (2019) suggests that it would be essential for better detecting changes in vulnerability, to go back in time to find a baseline scenario, where almost no-risk reduction intervention has been put in place yet. We are not so sure about the possibility of such a baseline scenario, since humans have been managing water already for centuries to millennia in many areas around the world, and often no data predating human interventions exist (e.g. Kuil et al., 2016 and Ochoa-Tocachi et al., 2019). However, we agree that the paired-event data would gain significantly in value if the data at the two points in time (i.e. at the two events) would be extended with longer time series of hazard, exposure, vulnerability and impact data, indicators or proxies. That means, it would be interesting to check the availability of time series of the variables which have been collected for paired event case studies (Table 2 in Kreibich et al. 2019). As suggested by Arnbjerg-Nielsen (2019), processes and variables that are difficult to monitor might be represented via modelling approaches, i.e. constructed time series data, such as from regional climate models. Such an extended dataset would enable time series analyses of impacts and its drivers (e.g. Bubeck et al.

2012; Safavi et al. 2014; Blauhut et al. 2016) to gain more knowledge about the temporal dynamics of drought and flood risk processes, causes and consequences. Also, Erfurt et al. (2019) proved the added value of long-term data going back to the early 19th century, showing that severities of recent drought events are nothing novel, but underlying vulnerabilities might have changed as indicated by drought impact reports.

Arnbjerg-Nielsen (2019) stresses the need to develop modelling approaches to enable the projection of drought and flood risk. He suggests that many regions of the world are very likely to experience more water extremes in the future, i.e. an increase in the occurrence and magnitude of both droughts and floods in the same catchments. Using historical data might underestimate the linkages that are important for risk management even in the near future (Arnbjerg-Nielsen 2019). Indeed, more quantitative knowledge about possible future developments together with an adaptable risk management strategy are urgently needed (Kreibich et al. 2014). One of the big challenges is developing the "reasonable scenarios for exposure and vulnerability" that Arnbjerg-Nielsen (2019) mentions. To make plausible future scenarios, more quantitative analysis of dynamic vulnerability of historic events is needed, so that past trends may be extrapolated into the future, assuming different trends in vulnerability reductions (see e.g. Jongman et al., 2015). Additionally, the application of stress test scenarios is a promising novel approach to gain insights for possible future conditions (e.g. Guillod et al., 2018, Zischg et al. 2018, Stölzle et al. 2019). Such stress test scenarios will "help to explore the resilience of socio-ecological systems to droughts" (Hall and Leng, 2019). Additionally, the above mentioned long-term datasets might be used to improve socio-hydrological models (e.g. Barendrecht et al. 2019) or other models which could be used to project the dynamics of drought and flood risk for the future. According to Barendrecht et al. (2017) and Aerts et al. (2018) other models which are able to describe the interaction of hydrological and anthropogenic processes are system-of-systems models (e.g. Falter et al. 2016; Metin et al. 2018; O'Connell and O'Donnell 2014), or agent-based models (e.g. Haer et al. 2016; 2019, Jenkins et al. 2017). For example, Barreteau et al. (2014) developed an agent-based model to evaluate the suitability of different drought indicators for different stakeholders. Examples are, however, very limited and more research in this direction would certainly be very valuable. This can help answer the question "How can we extract information from available data on human and water systems in order to inform the building process of socio-hydrological models and conceptualisations?", which is listed by Blöschl et al. (2019) as one of the twenty-three unsolved problems in hydrology.

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