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Climate change and floods – the importance of assessing uncertainty

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ABSTRACT

This study discusses the estimates of uncertainty for projected future changes of maximum flows using a number of case study catchments in Poland, and provides arguments towards changing social expectations from total security towards "living with floods". We argue that due to the large range of uncertainty for future floods it is necessary to improve flood warning systems and to minimize flood losses using integrated planning of flood defenses.

1. Introduction

Challenges related to flood risk management have now been multiplied due to ongoing climate change. Urbanization is another factor influencing flood risk. A number of studies deal with flood risk projections in the future, globally and locally. These projections differ depending on the scale of the region, the methods used, and the future climate projections applied. Examples from the literature show that different precipitation-runoff simulation models give different results, even for the same input variables (Piniewski et al. 2017). Despite the known and widely acknowledged uncertainty in flood risk estimates, there is still a need for informed decisions to be made on the adaptation of flood risk management to climate change. Flood forecasting and flood risk management are related to each other even though they have different goals. Both problems require flood – prone areas to be identified.

The aim of this study is to evaluate the estimates of present and future changes in flow regime and, in particular, maximum flows, obtained by researchers in a number of recently published studies, with the main focus on Polish rivers. Different aspects of the derivation of flood risk maps, following the procedures described by the EU Floods Directive and implemented already in Poland, are scrutinized.

This study tries to answer the following questions: (i) Why should we take uncertainty into account in the adaptation to future floods? What are the pros and cons? (ii) Which factors are important for society? (iii) Why is it important to introduce reliable flood warning systems? (iv) Why is it important to educate society about understanding uncertainty?

2. Methods

Flood Risk has many meanings, but usually contains two factors: (i) the probability that the event will happen, and (ii) the consequences of that event (impact). A risk-based approach allows for informed choices to be made on the basis of a comparison of the expected outcomes and the costs of alternative courses of action. Flood risk management is a process of decision-making under uncertainty. Traditional approaches have assumed determinism using the concepts of "design floods", the uncertainty being taken into account through safety factors. On the contrary, in a risk-based approach the unpredictability is fundamental in decisions on how to deal with floods. Uncertainties have to be revealed, analyzed and taken into account in decision- making. A discussion of those issues based on work by the author on various case studies provides an answer to the first of the research questions posed in the introduction.

The second research question deals with the complex interactions between society and natural hazards. Among challenges that flood defense systems must address are the natural variability of rainfall and sea surge processes, the fact that the severity of flooding results from a combination of different conditions (breaching of flood defense embankments, vulnerability of habitants of floodplain, timing of rainfall and runoff in different locations), spatial interactions (the improvement of embankments in one area may result in increased erosion in other parts of the river reach), the response of the river, coast or man-made structures

is highly uncertain, and flooding systems change with time over a range of scales (precipitation patterns and amounts may change, long-term geomorphological processes, human intervention, dynamics of ecosystems).

Both the loading of flood defense systems (rainfall and marine waves) are naturally variable and cannot be forecast beyond a few days into the future. For the design purpose those loads have to be described in statistical terms. It is argued that a reliable flood warning system is the possible way forward (the third research question).

The discussion on uncertainty of future flood projections is illustrated using a simple case study which consists of eight semi-natural catchments from Poland (Table 1). We applied two rainfall-runoff models, HBV and GR4J, to illustrate the uncertainty of maximum flow projections related to different model structures. These catchments were part of the CHIHE project (Romanowicz et al., 2016). Following the standard procedures described, the models are calibrated and validated using available observations and subsequently used to derive a number of high flow indices and their changes for the future climate projections for the years 1971-2100. We show that large uncertainty of those projections makes a synthesis of the estimated future changes of maximum flow using standard procedures extremely difficult to perform in a satisfactory way.

Table 1. Calibration and validation results for the study catchments (Nash-Sutcliff efficiency criterion [ ])

River(Gaugin station)	GR4J		HBV	
	Cal	Val	Cal	Val
Dunajec(Nowy Targ)	0.77	0.80	0.77	0.80
Wisła(Skoczów)	0.72	0.75	0.65	0.75
Biała Tarnowska(Koszyce Wielkie)	0.79	0.74	0.79	0.75
Nysa Kłodzka(Kłodzko)	0.72	0.70	0.72	0.70
Oleśnica(Niechmirów)	0.66	0.67	0.72	0.52
Narewka(Narewka)	0.72	0.60	0.71	0.54
Flinta(Ryczywół)	0.62	0.61	0.70	0.61
Myśla(Myślibórz)	0.62	0.52	0.71	0.52

To illustrate the fourth research question we use the Biala Tarnowska catchment case study to show that flood risk management should be performed in an integrated way. Lowering the flood risk in one part of the river (upstream) usually leads to an increase of flood risk downstream. This rather obvious conclusion is not obvious to the residents of local communities who demand full safety at a local scale. Unfortunately, an integrated approach is not always present in flood risk management plans prepared by water authorities. An on-line forecasting system supported by reliable long-term weather forecasts and a modern flood warning system based on the most advanced technologies may be the best way forward.

3. Conclusions

In conclusion, the study argues that both aspects of flood risk management, i.e., an integrated system approach and uncertainties related to flood risk, should be taken into account in the adaptation of management plans to future floods. At the same time, those two aspects of flood risk management should be explicitly communicated to the public. The latter requires cooperation with social scientists and media and the education of society.

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