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POLICY BRIEF

The importance of including compound events in the implementation of the Floods Directive

MAIN MESSAGES

- The phenomenon known as compound flooding, caused by the coincident occurrence of multiple flood drivers such as high precipitation events, storm surges or high runoff rates, has caused some of the most destructive flooding in Europe. To date, however, the compounding nature of multiple drivers has not been given sufficient consideration in current flood hazard and risk scenarios developed, for example, in the context of the Floods Directive. This may lead to a biased assessment of flood risk, both for current and future climate conditions.

- IMPREX puts forward a host of reasons as to why it is important to incorporate compound events into flood hazard and risk assessments, providing related methods and tools:

  - Incorporation of compound events can enhance the reliability of flood statistics and consequently flood hazard maps

  - Probability of compound events may change in the future climate

  - Compound events may call for different flood measures, making it imperative to factor them into the flood risk management plans drawn up

→ Better understanding of the emergence and impact of compound events is needed. Particular attention should be paid that the correlation between flood drivers is quantified more clearly. More emphasis on and support for related research is needed.

→ Awareness and knowledge of compound events needs to be increased at all levels of river basin management.

→ Compound events should be factored in at every stage of implementation of the Floods Directive. The explicit mention of compound events in the Floods Directive as well as in related Guidance Documents should be given proper consideration.

BACKGROUND

In October 1998 and January 2012 in Delfzijl in the north of The Netherlands, discharge of heavy precipitation on the polder to the sea was blocked due to storm surges happening at the same time, leading to unprecedented flooding. The 2013/2014 flood in the South West of the UK was caused by heavy precipitation on an already saturated soil in combination with high ocean water levels. A common feature of these events was that they were caused by the joint occurrence of two or more drivers, such as heavy precipitation, storm surges at sea or increased water levels in a river, which ultimately led to these extreme events. Even though compound events are known for causing some of the worst flood events, they have often been viewed as an ancillary issue in hazard and risk assessments towing to the difficulties in characterizing and predicting them. Research has shown, however, that compound floods are not only among the most destructive but are also far more common in Europe than often perceived, which is why it is all the more imperative that they be taken into account in flood statistics as well.

Within the framework of the Floods Directive all Member States are obligated to put in place flood risk management plans to prevent, prepare for and ensure protection from flooding. In line with the Directive, flood hazard and risks are assessed in order to define flood scenarios for different return periods. The Floods Directive accounts for the great variety of flood causes by urging Member States to prepare for different types of floods that are relevant in their territory. Neither in the Floods Directive nor in related Guidance Documents, however, are compound events mentioned. Further, compound events are not sufficiently taken into account when developing flood hazard maps in the Member States. In light of the current debate on how to make Europe fit for future climate and weather conditions, compound events could well become even more relevant, especially given the potential impact that changes in weather patterns and the projected sea level rise - a new flood driver - have on the probability of occurrence of compound events.

The research project IMPREX has explored the occurrence of diverse examples of compound flood events for the current as well as the future climate in five case studies in the Netherlands and in the UK. The results underline the need to factor in compound events in implementing the Floods Directive.

RELEVANCE OF COMPOUND EVENTS

Compound events can cause extreme flood events even if individual drivers are not extreme in themselves

Compound events can be found in any areas of natural hazards, for example, droughts, wildfires, storms and floods. Multiple definitions of compound events have been proposed. The common denominators of most definitions are, however, the coincident or consecutive occurrence of more than one driver, resulting in amplified risk and, ultimately, an extreme (e.g. flood) event. It is important to mention that the individual drivers of compound events in themselves do not necessarily have to be extreme to cause an extreme hazard. Even average precipitation, for example, can cause flooding if it occurs in combination with previously saturated ground.
IMPREX has developed methods to estimate the likelihood of different cases of compound flood events.

Incorporation of compound events can enhance the reliability of flood statistics and consequently the reliability of flood hazard maps

One of the challenges faced in implementing the Floods Directive in Member States is the development of reliable flood statistics as the basis for flood hazard maps. Usually flood probabilities are derived from historical flood data that is integrated into hydrological models used to derive useful statistics. Future climate conditions are mapped by manipulating or replacing the input data with information from future climate projections. For events that are governed by multiple drivers, assumptions are made on the statistical correlation between these drivers, which have a big impact on the outcome of the flood probability estimate.

A difficulty that stands in the way of an accurate derivation of the correlation structure is that observational records are only available for limited time spans, which may not cover very extreme events driven by a rare combination of multiple drivers with an unknown mutual dependence. This in turn may lead to biases in the derived flood statistics and risks. On the basis of a number of case studies of compound flood events, IMPREX has enhanced the understanding of the statistical dependence of flood drivers. For instance it provided a method involving a high resolution regional climate model simulation for current and future climate conditions, which was coupled with hydrological and/or hydraulic models. It provided much longer time-series of relevant variables than available from observations. This approach was used to analyze statistical dependencies between drivers of flood events when deriving flood risk. This method was applied to different case studies in order to quantify the effect of the dependency between flood drivers and how this might change in future climate. The method was thus shown to be transferable to other applications.

The results highlight not only the need to incorporate compound events into flood hazard assessments. In fact, they also show that it is possible and should be further explored for the implementation of the Floods Directive.

Probability of occurrence of compound events may change in future climate

One of the biggest unknowns in climate research is the effect of the changing climate on weather patterns. This leads to great uncertainty in future climate scenarios and, consequently, flood scenarios. This also gives rise to challenges for Member States when it comes to drawing up flood hazard maps in the context of implementation of the Floods Directive. When considering changing weather patterns it is important not only to look at changing patterns of isolated flood drivers but also to explore more deeply how climate change alters the correlation structure between such drivers, as this may affect the probability of compound events. A change in the correlation between drivers can be caused by altered large-scale atmospheric circulation patterns affecting storm statistics, or changes in hydrological phenomena that affect flood risk, increasing or decreasing it accordingly; in both cases, the potential impact on the financial risk and preparatory measures is substantial. For this reason, a better understanding of the driving forces behind compound events is paramount.

The current debate on how to give greater consideration to climate change impacts in flood hazard and risk maps should not leave out the potential changes in the probability of extreme events due to compound scenarios.

Compound events may call for different flood measures, making it imperative to factor them into the flood risk management plans drawn up

The Floods Directive requires Member States to select appropriate flood measures based on a prior assessment of flood hazard and risk. When it comes to choosing flood measures that also take compound scenarios into account, however, there is limited understanding and experience. This becomes especially critical if flood measures designed to counteract flooding caused by individual drivers, fail in compound events. IMPREX has investigated a few such cases which show that compound events may require different flood measures than those that would be necessary if the driver were to occur on its own. One case study shows how the coincidence of extremely high river discharges of River Rhine and Meuse in combination with storm surge off the Dutch coast and projected sea level rise does not allow for the water to be discharged to the sea, which in turn leads to a huge flood risk resulting from the fact that the flood measures can no longer work here. The same holds true for another case study, where the simultaneous occurrence of peak flows meant two rivers (Dommel and Aa) were no longer able to discharge into the River Meuse, resulting in severe flooding

The outcome here shows how vital it is to take the risk of compound events into account when evaluating suitable flood measures, for example, when putting together programmes of measures as part of flood risk management plans.

RECOMMENDATIONS

IMPREX not only provides evidence on why proper consideration of compound events is much needed also in the context of implementation of the Floods Directive, but also shows how compound events can be incorporated into flood statistics, enabling better preparation and protection from some of the most destructive floods ever seen. Based on the work conducted within IMPREX, the following recommendations are made:

- **Improve the understanding of compound flood events and the correlation between drivers through research.** The integration of compound events into flood scenarios is crucial to be able to accurately gauge the probability of extreme events and improve flood statistics. Better understanding of underlying meteorological and hydrological processes of compound events is needed. A first step has been taken in the form of the European COST action DAMOCLES, a recent initiative (involving IMPREX partners) that seeks to coordinate research and improve the assessment of compound events.

- **Raise awareness of compound events with policy and decision makers and strengthen related management capacities.** Several EU Member States have had hands-on experience with compound events. This experience should be actively shared in order to deepen our knowledge and bridge the gap between research and practice.

- **Include compound events in the European policy framework for flood risk management.** Flood risks resulting from compound events need to be taken into account at every stage of implementation of the Floods Directive, from deriving flood statistics and developing flood hazard maps to determining flood measures. Proper consideration should therefore be given to the possibility of explicitly specifying compound events as a potential flood source in the Floods Directive as well as in related Guidance Documents.

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IMPREX is designed to help reduce Europe's vulnerability to hydrological extremes by achieving a better understanding of the intensity and frequency of potential disrupting events. Enhancing our forecasting capability will increase the resilience of European society as a whole, while reducing costs for strategic sectors and regions at the same time. The research project brings together 23 partners from 9 countries and has received funding from the European Union's Horizon 2020 Research and Innovation Programme.

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