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New insights into flood warning and emergency response from the perspective of affected parties

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Abstract. Early warning is essential for protecting people and mitigating damage in case of flood events. However, early warning is only helpful if the parties at risk are reached by the warning, if they believe the warning and if they know how to react appropriately. Finding suitable methods for communicating helpful warnings to the "last mile" remains a challenge. To gain more knowledge, surveys were undertaken after the August 2002 and the June 2013 floods in Germany, asking affected private households and companies about warnings they received and emergency measures they undertook. Results show that in 2002 early warning did not work well: in many areas warnings came late or were imprecise. Many people (27%) and companies (45%) stated that they had not received any flood warning. Additionally, preparedness of private households and companies was low before 2002, mainly due to a lack of flood experience. After the 2002 flood, many initiatives were launched and investments undertaken to improve flood risk management including the flood warning systems in Germany. In 2013 only a small share of the affected people (7%) and companies (7%) were not reached by any warning. Additionally, also private households and companies were better prepared. For instance, the share of companies which have an emergency plan in place has increased from 10% in 2002 to 26% in 2013. However, there is still room for improvement. Therefore, integrated early warning systems from monitoring through to the reaction of the affected parties as well as effective risk and emergency communication need continuous further improvement.

1 Introduction

Flood warning systems are implemented to reduce material, human and cultural damage (Parker and Fordham, 1996). Their potential to significantly reduce direct tangible damage is long time known (e.g. Lustig et al., 1988; Thieken et al., 2005; Meyer et al., 2012; Molinari et al., 2013). For instance, already during the flood in Lismore (Australia) in 1974 with a warning time of about 12 hours, damage in the residential sector were only 50% and in the commercial sector only 24% of the economic damage expected without emergency measures (Smith, 1981). A successful flood early warning system consists of several interacting components: continuous monitoring, developing forecasts, activating emergency response organisations, warning affected people and taking the correct action and behaviour adapted to the situation (Parker et al., 1994). However, often

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investments are undertaken in the development of flood forecasting systems without adequately taking into consideration the dissemination of warnings (Grünewald et al., 2001). Flood early warning systems often underperform because warning dissemination and response are unsatisfactory (Parker and Fordham, 1996). A recent review confirms these evaluations and concludes that "despite substantial technical progress, major challenges remain to achieve the potential benefits of flood early warning systems, in particular in communicating risk information and early warnings to emergency services and the population at-risk and consequently trigger response actions" (Cools et al., 2016).

Important factors influencing the effectiveness of flood early warning systems in reducing damage are the lead time, the water depths, and the ability of affected parties to undertake emergency measures effectively (Lustig et al., 1988; Penning-Rowsell and Green, 2000; Kreibich et al., 2007a). The longer the lead time, the longer the time for undertaking emergency measures. For shallow water levels, damage can be reduced easily by sealing the building or by moving contents higher e.g. onto shelves or higher storeys. With high water levels, water barriers are overtopped and the ingress of water can often not be prevented. The ability to undertake effective measures is again dependent on different factors, e.g. recent flood experience, preparedness, availability of emergency plans (Thieken et al., 2007; Kreibich et al., 2007b). People who have witnessed a flood recently tend to be better prepared and tend to know better what to do when a warning reaches them.

In the case of the extreme flood in 2002 in Germany, the weather warnings came too late or were too imprecise (Rudolph and Rapp, 2003). Additionally, there was strong criticism regarding the flood reports and their dissemination (von Kirchbach et al., 2002). Integrated early warning systems from monitoring through to the reaction of the affected parties were insufficiently developed and hardly evaluated (Thieken et al., 2016). Many initiatives were introduced after 2002 to improve the flood warning systems. For instance, the German Weather Service (DWD) has improved its numerical weather forecast models and its warning management (Kreibich et al., 2007a; DKKV, 2015). The federal states have improved the flood alerting gauges as well as the flood routing and forecast models. Flood centres have partly been restructured, e.g. in Saxony and Lower Saxony (Kreibich et al., 2007b; DKKV, 2015). Even complementary local solutions were developed: for instance the town council of Grimma decided to install an autonomous local warning system, which consists of components including: a central flood announcement system including sirens, autonomous SMS information network and 24-h flood information to the television media (Meyer et al., 2012). Collaboration across administrative departments and federal states as well as disaster control was improved (DKKV, 2015). By June 2013, clear progresses in the technical systems and the organization of warnings were discernible at all levels. Cross-departmental and transnational collaboration across the federal states have been achieved. Dissemination and communication pathways were clearly defined and feedback loops were established to avoid interruptions of the alerting process (DKKV, 2015). But also the evolution and dynamics of the floods differed: in August 2002 flash floods in the Ore Mountains led to a critical isolation of valleys and municipalities and caught those affected in the middle of the night (DKKV, 2015). In contrast, the event in June 2013 developed over several days, so that disaster response had fewer life threatening situations to deal with and affected people had more time for emergency measures. Additionally, due to intensive risk communication campaigns, and repeated flooding in the Elbe and Danube catchments in 2005, 2006, 2010 and 2011 people and companies were highly aware of the flood risk and better prepared (Kreibich et al., 2011; Kienzler et al., 2015).

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The objective of this study is to investigate the improvements of the early warning systems in Germany in respect to the dissemination and response part. It is particularly interesting whether warning and emergency response worked well during the flood in 2013, since the event was from a hydrological point of few even more extreme than the flood in 2002 (Schröter et al., 2015). Thus, we compare the perception of early warning and deployment of emergency measures by private households and companies during the floods in 2002 and 2013.

2 Surveys and data

In order to gain more knowledge on how private households and companies were warned and how they undertook emergency measures before and during the 2002 and 2013 floods in Germany, computer-aided telephone interviews (CATI) were conducted (Table 1). On the basis of information from affected districts or municipalities, flood reports, press releases, as well as with the help of flood masks derived from satellite data (DLR, Centre for Satellite Based Crisis information, www.zki.caf.dlr.de) lists of affected streets were compiled. These provided the basis for generating property-specific random samples of households and companies (i.e. their telephone numbers). For the survey on the 2002 flood, households from the list were sampled randomly. For the survey on the 2013 event, a comprehensive survey was conducted, i.e. all the researched telephone numbers were contacted. To overcome the lack of large companies in the sample, additional effort was undertaken to identify and interview also large companies, e.g. expert interviews, analyses of flood reports and press releases, were undertaken. After the 2002 flood large-scale companies were additionally interviewed in May 2004 (Table 1). After the 2013 flood all companies irrespective of their size were interviewed between May and July 2014. Always the person in the household or in the company with the best knowledge of the flood damage was interviewed. In total, 1697 households and 415 companies were interviewed about the 2002 flood event and 1652 households and 557 companies about the 2013 flood event (Table 1). All questionnaires addressed the following topics: flood impact (e.g., water depth, contamination), flood warning, emergency measures, evacuation, cleaning up, characteristics of and damage to household contents and buildings / characteristics of and damage to company assets (buildings, equipment, goods, products or stock, etc.), recovery, precautionary measures, flood experience and awareness as well as socioeconomic variables / characteristics of the company (sector, number of employees, etc.). Further details about the surveys and the data processing are published by Thieken et al. (2007), Kreibich et al. (2007b) and DKKV (2015).

Table 1: Surveys: computer-aided telephone interviews with private households and companies affected by flooding in 2002 and 2013.

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3 Results and discussion

3.1 Warnings and emergency measures of private households

To gain knowledge about the warning situation, private households were asked "How did you become aware of the imminent flood danger?". The given answers show that in 2002, more than a quarter of the respondents (27%) stated that they were not warned at all; in 2013 this fraction was only 7% (Figure 1). Warnings by public authorities were most important for becoming aware of the flood danger (Figure 1). In 2002, 42% of respondents indicated that they had received a warning by public authorities, in 2013, this fraction was 56%. Interesting is, that also the fraction of private households who became aware of the flood via own observations has increased from 2002 to 2013. This might be due to an increase in awareness and preparedness after 2002 (Kreibich et al., 2011; Kienzler et al., 2015). Additionally important for the warning of private households is the general trans-regional media coverage.

Additionally, private households were asked about warning lead times, i.e. how many hours before the flood reached their house, they became aware of the flood danger. For both flood events there are large differences between regions, i.e. warning times were between one hour and 14 days (data not shown). The average warning time in August 2002 was 30 hours (median: 10 hours), in June 2013, it was 38 hours (median: 24 hours).

The significant improvement of the warning situation has probably two reasons: firstly, the flood warning systems in Germany have been significantly improved after 2002 (Thieken et al., 2016; DKKV 2015) and secondly, the flood characteristics differed. In August 2002 severe flash floods occurred in the Ore Mountains, whereas the flood event in June 2013 developed slowly over several days (Conradt et al., 2013; Schröter et al., 2015).

Figure 1: Answers of the interviewed private households in response to the question of how they became aware of the imminent flood danger.

Early warning is only effective, if the people at risk believe the warning and know what to do when they receive the warning. Helpful are for example check lists indicating what should be done and which things should be available in case of an emergency (Kreibich et al., 2007a). Respondents who had received a warning through public authorities were asked whether they knew how they could protect themselves and their household from the flood. Figure 2 shows that in 2002 only 14% of the interviewed households stated that it was totally clear to them what to do when the waning reached them; in 2013 this fraction was 46%. Increased flood experience and improved risk communication e.g. via information campaigns presumably contributed to this development (Kienzler et al., 2015; Thieken et al., 2016).

Figure 2: Answers of the households that had received a public authority warning, in response to the question whether they knew how to protect themselves and their household from the flood.

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Figure 3 provides an overview of the emergency measures undertaken and Figure 4 presents their perceived effectiveness. The fraction of households who had not undertaken any emergency measures decreased from 17% in 2002 to 8% in 2013 (Figure 3). The effectiveness of all emergency measures implemented in 2013 received higher ratings than the ones implemented in 2002 (Figure 4). Maybe the measures have been implemented in a more effective way due to longer lead times, improved experience, better risk communication and preparedness before the 2013 event (Kreibich et al., 2011; Kienzler et al., 2015).

Simple measures were implemented very often and their effectiveness was rated very high. Among these measures are: safeguard documents and valuables, put movable contents upstairs and drive vehicles to flood-safe place (Figures 3 and 4). Although also frequently implemented, more complicated measures like protect building against inflowing water or pump out water achieved lower effectiveness ratings (Figure 4). The effectiveness of emergency measures depend not only on the correct implementation but also on the flood impact, e.g. water depth. For instance, in cases where the water level increases higher than expected, water barriers are overtopped and are not at all able to prevent water from entering the building (Kreibich et al., 2005).

Figure 3: Overview of the emergency measures undertaken by the interviewed households (semi-open question, multiple answers possible).

Figure 4: Perceived effectiveness of undertaken emergency measures by interviewed households.

In summary, the warning situation for private households was much better during 2013 in comparison to 2002 and they were more effective in undertaking emergency measures.

3.2 Warnings and emergency measures of companies

Generally, a similar picture emerges from the surveyed companies as in the case of the private households. The warning situation was much better in 2013 in comparison to 2002: while in 2002, 45% of the companies responded that they had not been warned at all, this was the case for only 7% of the companies in 2013 (Figure 5). Flood warnings by public authorities played a considerable role during the floods of 2002 and 2013 (Figure 5). In 2013, more than 23% of the surveyed companies received warnings from public authorities that had been directed specifically at the company. In 2002 this was only 7%. However, during both floods (even increasing from 2002 to 2013) most companies also became aware of the flood through their own observation. Additionally important for the warning of companies is the general trans-regional media coverage (Figure 5).

Also for companies lead times were very different from region to region. However, the average lead time of the warnings to companies in 2002 was 20 hours (median: 8 hours); in 2013 the lead time comprised 38 hours on average (median: 24 hours).

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Figure 5: Answers of the interviewed companies in response to the question of how they became aware of the imminent flood danger.

The clearly improved warning situation in 2013 lead to the situation that also more companies implemented emergency measures: 91% in 2013 compared to 67% in 2002 (Table 2). In the case of the 2002 flood, 74% of the companies would have been able to implement (more) emergency measures if they had been warned earlier; in 2013 only 38% of the surveyed companies indicated this (Table 2). This means that in 2002, 74% of the interviewed companies had too little time to implement emergency measures, while in 2013 most companies had sufficient time to implement all necessary emergency measures. Therefore, in 2013 far more companies were able to protect the most important part of their equipment as well as of goods, products, etc. (Table 2). Reasons for this higher effectiveness of the emergency measures are probably longer lead times, more experience and better preparedness of the companies (Kreibich et al., 2011).

Besides emergency measures, like protecting equipment, goods etc. as well as protecting the vehicles, other measures were carried out, like the setting up of water barriers, mainly using sandbags, the deployment of pumps, as well as securing any other movable objects. The share of companies, which had an emergency plan in place already before the flood had increased from 10% in 2002 to 26% in 2013 (Table 2). The share of those who had undertaken emergency exercises before the flood increased from 4% to 13% (Table 2). However, in this respect there is still room for improvement.

Table 2: Information by the respondents on emergency measures implemented

In summary, the warning situation also for companies was much better during 2013 in comparison to 2002 and they were more effective in undertaking emergency measures.

5 Conclusions

The warnings received and the emergency measures undertaken by private households and companies before and during the 2002 and 2013 flood events show a clear improvement. The warning reached significantly more affected parties and reached them sooner in 2013 in comparison with 2002. Also, the share of official warnings through public authorities increased from 2002 to 2013. Besides early warning by the responsible public authorities, also personal observations and warnings via media coverage played an important role. Probably, the marked decline of affected parties who had not received any warning is due to the improvements in the warning systems. However, in 2013 the evolution of the flood event was clearly less dynamic than in 2002 when flash floods did play an important role. The boost in information and awareness campaigns after the flood in 2002 may have led to an improved knowledge of households and companies about how they can protect themselves against flooding. Furthermore, increased flood experience also played a significant role. This became apparent in the amount of emergency measures implemented as well as in the evaluation of their effectiveness by private households and companies. In

the case of companies the increase in available emergency plans and regularly conducted emergency exercises points to an increased preparedness. However, particularly in respect to emergency plans and exercises there is still room for improvement. The maintenance and advancement of integrated early warning systems from monitoring through to the reaction of the affected parties as well as effective risk and emergency communication is a continuous task in order to protect people and mitigate residual risks in case of floods.

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Table 1: Surveys: computer-aided telephone interviews with private households and companies affected by flooding in 2002 and 2013.

Flood events	August 2002 flood		June 2013 flood	
Target groups	households	companies	households	companies
Survey method	Computer-aided telephone interviews			
Survey period	April to June 2003	October 2003 and May 2004	February to March 2014	May to July 2014
Survey area, i.e. catchments	Elbe and Danube	Elbe (only in Saxony)	Elbe, Danube, Rhine, Weser	Elbe, Danube, Rhine, Weser
Number of completed interviews	1697	415	1652	557
Length of interviews	About 180 questions	About 90 questions	About 180 questions	About 90 questions
Surveying institute	SOKO institute for social research and communication (www.soko-institut.de)		Explorare institute for marketing research (www.explorare.de)	SOKO institute (www.soko-institut.de)
Project partners	German Research Centre for Geosciences (GFZ), Deutsche Rückversicherung		University of Potsdam, German Research Centre for Geosciences (GFZ), Deutsche Rückversicherung	

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Table 2: Information by the respondents on emergency measures implemented.

Fraction of interviewed companies, that …	**2002** (n=415)	**2013** (n=557)
… had implemented emergency measures	67%	91%
… could have implemented (more) emergency measures, if they had been warned earlier	74%	38%
… were able to protect their equipment in its entirety or the most important part thereof	19%	54%
… were able to protect their goods, products and stock in their entirety or the most important part thereof	17%	47%
… were able to protect their vehicles in their entirety or the most important part thereof *	-	73%
… already had an emergency plan before the flood	10%	26%
… already conducted flood emergency exercises before the flood	4%	13%

* question only asked for 2013 flood

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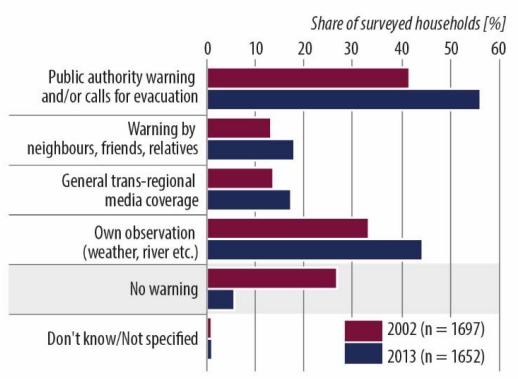

Figure 1: Answers of the interviewed private households in response to the question of how they became aware of the imminent flood danger.

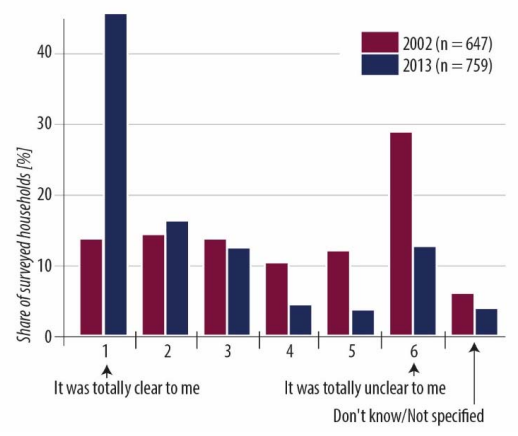

Figure 2: Answers of the households that had received a public authority warning, in response to the question whether they knew how to protect themselves and their household from the flood.

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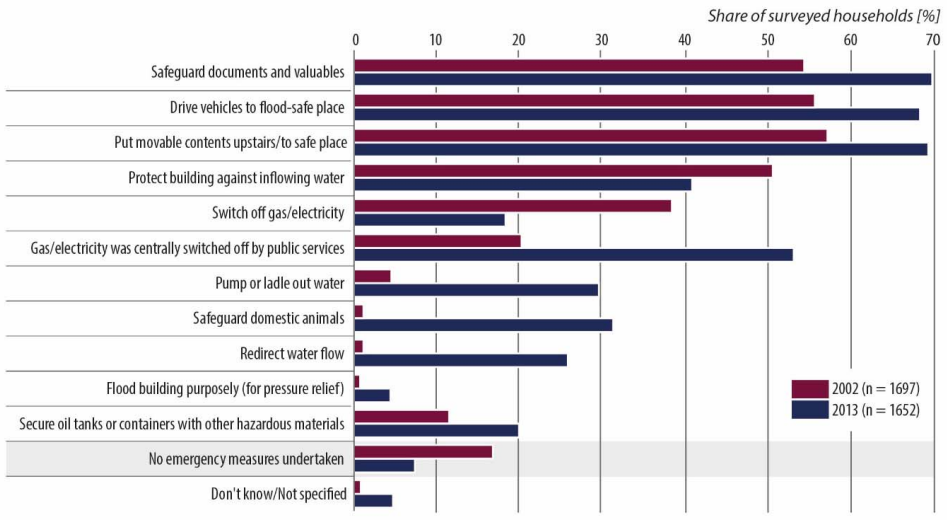

Figure 3: Overview of the emergency measures undertaken by the interviewed households (semi-open question, multiple answers possible).

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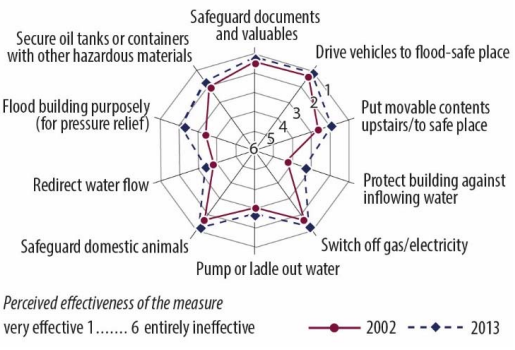

Figure 4: Perceived effectiveness of undertaken emergency measures by interviewed households.

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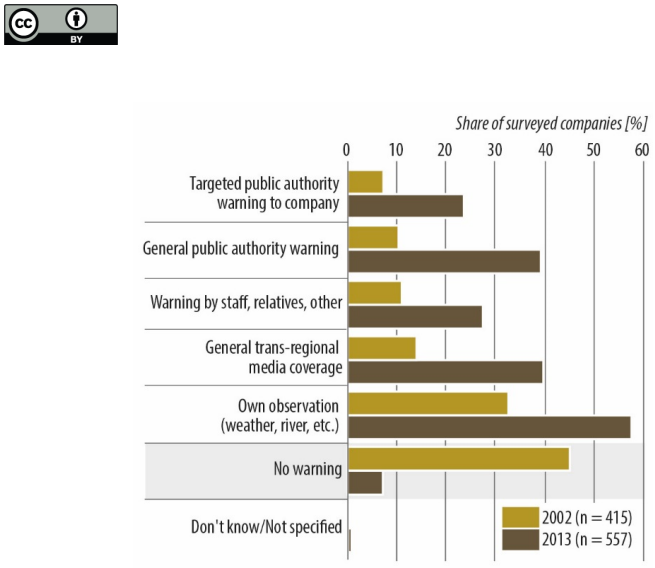

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