

Final Author comments to:

Anonymous Referee #1 RC1: nhess-2016-387-RC1, 2017

Anonymous Referee #2 RC2: nhess-2016-387-RC2, 2017

5 Author: Jonas Laudan¹

Co-authors: Viktor Rözer², Tobias Sieg^{1/2}, Kristin Vogel¹, Annegret H. Thieken¹

¹University of Potsdam, Institute of Earth and Environmental Science, Karl-Liebknecht-Strasse 24-25, 14476 Potsdam, Germany

10 ²GFZ German Research Centre for Geosciences, Department of Hydrology, Telegrafenberg, 14473 Potsdam, Germany

Referee #1

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General answer:

We thank the reviewer for the helpful and constructive comments as well as the reasonable overall suggestion to transform the Brief Communication into a Research paper. We acknowledge the reviewer's suggestions, which in many cases could not be implemented in the submitted version due to the chosen paper format. That especially holds for a more comprehensive literature review and an embedding of existing studies as well as a detailed outline of our methods and results. Thus, we followed the reviewer's suggestion to transform the Brief Communication into a Research paper, addressing all helpful comments.

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General comments of the reviewer 1

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Reviewer1 quote 1:

It is not very clear for which process the research has been conducted for. The title refers to "flash floods", however, in the text the term "debris flow" is often used for the process under investigation (e.g. p. 2, line 31). Are these two processes identical for the authors? What is the difference of these processes regarding their impact on buildings? Were all the buildings under investigation impacted by the same process?

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Answer 1:

- 35 The presented research aims to identify damaging processes related to flash floods, which can trigger debris flows to a certain degree. The flash flood in Braunsbach, was accompanied by a considerable amount of sediment, boulders and rubble, potentially showing flow characteristics of debris flows as defined by Fuchs et al. (2010) and Borga et al. (2014). Yet, a clear distinction between flash floods and debris flows is not always straightforward. In the revised version of the paper, we clearly defined flash floods and debris flows and we aimed for consistency and adequate wording for the process.
- 40 All buildings under investigation were affected by the same primary process, namely flash flood. However, the damage patterns are highly influenced by the amount and force of transported debris colliding with building walls and damaging the building structure.

45 **Reviewer1 quote 2:**

The article should refer to similar studies and their connection to them, for example:

Papathoma-Köhle M., Zischg A., Fuchs, S. Glade T., Keiler M. 2015. Loss estimation for landslides in mountain areas- An integrated toolbox for vulnerability assessment and damage documentation. *Environmental Modelling and Software*, 63, 156-169

- 50 Papathoma-Köhle M. 2016. Vulnerability curves vs vulnerability indicators: application of an indicator-based methodology for debris-flow hazards. *NHESS*, 16(8): 1771-1790.

Thouret et al., 2014. Assessing physical vulnerability in large cities exposed to flash floods and debris flow: the case of Arequipa (Peru). *Natural Hazards*, 73: 1771-1815
Leelawat, N. Suppasri A., Charvet I., Imamura F., 2014. Building damage from the 2011 Great East Japan tsunami: quantitative assessment of influential factors. *Natural hazards*, 73: 449-471.

- 55 But also similar studies looking at the connection of social variables to the consequences of natural hazards:

Adger N., 1998. Indicators of social and economic vulnerability to climate change in Vietnam. CSERGE Working Paper GEC 98-02

Cutter S. 2003. Social vulnerability to environmental hazards

Adger et al., 2004. New indicators of vulnerability and adaptive capacity. Tyndall Project IT 1.11: July 2001-June 2003.

- 60 Final project report.

Connection to these works is essential for two reasons: first the existing literature review gap will be filled and second the aim of the study will be better understood since the results of the study may have a direct practical application.

Answer 2:

- 65 Thank you for your suggestions. As stated above, while converting the brief communication to a research paper, we took more existing literature into account to integrate our work into an up-to-date, scientific framework. A review section is included in the introduction.

Reviewer1 quote 3:

70 The authors refer to the implementation of the European flood directive in Germany. This is an interesting point which
remains which may be connected to the first comment above: Flash floods and surface water flooding are according to the
authors neglected by the directive. How can the presented research fill this gap? Debris flow is actually a landslide type so
naturally is not covered by the flood directive. Moreover, it has been often pointed out that during an event more than one
processes may affect the elements at risk. See and refer to Totschnig et al (2011) who claim that: “During one individual
75 event, the respective processes in the torrent often change due to the temporal and spatial variability of sediment
concentration”.

Totschnig R., Sedlacek W., Fuchs S., 2011. A quantitative vulnerability function for fluvial sediment transport. *Natural Hazards*, 58: 681-703.

Answer 3:

80 Thank you for your suggestions. The implementation of the European Floods Directive 2007/60/ EC in Germany and the
implications according to the German Federal Water Act (e.g. the obligation for flood adapted spatial planning and the
creation of flood risk maps) is shortly mentioned in the revised paper. The consideration of flash floods as a “significant
risk” would have serious implications on mapping, planning and risk management. This holds especially for the not yet
mandatory creation of flood hazard risk and risk maps, which, in case of flash floods, do currently not exist nationwide and
85 would have to be generated. As a further consequence, German Federal Water Act intends a building ban in all areas that are
affected by a 100-year flood event. Therefore, the consideration of flash floods or surface water flooding could have serious
consequences for local planning.

As already mentioned, the particular flash flood in Braunsbach revealed the complexity and the high impact of such events.
Even if flash floods are technically not considered as significant hazards in the German Federal Water Act, it is possible to
90 include measures for reducing their impacts (e.g. potential tangible as well as intangible damage) in flood risk management
plans.

Reviewer1 quote 4:

95 According to the authors, the intensity of the process derives from the following two factors: -The inundation depth -The
exposition of the building in flow direction. In my opinion the second factor is not relevant to the process and should not be
considered in the process intensity (the intensity of the rain is the same either a person holds an umbrella or not, right?).
Moreover, the intensity of the “flash flood” or “debris flow” also depends on other factors such as the velocity, the viscosity
and the material that the flow contains, their size and percentage in the water.

Answer 4:

With process intensity we refer to potential (external) factors affecting the building and resulting in damage, which are independent from the building characteristics and can be surveyed in the aftermath of the event. Since these factors (i.e. the inundation depth as well as the exposition) relate to the buildings relative position, a combined value - “process intensity” - should indicate the potential physical impact and intensity of the flash flood at the particular house or in a specified area for that matter (i.e. process intensity map). With this term we do not refer to the physical characteristics of the flash flood itself or flood inherent processes (flow velocities, duration), since these processes could not be determined on site. Instead, we give a proxy for the flow impacts and the impact forces of flow and debris on a building. However, to differentiate from flood inherent processes, we use the term “local impact” in the revised paper.

Specific comments of the reviewer 1

115 Reviewer1 quote on the title and abstract:

Title: The title is too general and does not reflect the content of the paper.

Abstract: why is the understanding of damage so important? What can you do with the expected results? Who may use them and how?

120 Answer on the title and abstract:

Title: Thank you for the hint. The paper title has been revised that it reflects the content of the paper in a more elaborate way. The title is now: “Damage assessment in Braunsbach 2016: A data collection and analysis for an improved understanding of damaging processes during flash floods.”

Abstract: The understanding of damage caused by flash floods is of great interest because we observe changing weather patterns in Central Europe and Germany due to the climate change. Further, an increased risk for higher damage due to flooding can be detected, which is mainly influenced by urbanization, economic growth as well as changing land use patterns (see European Environment Agency: Climate change, impacts and vulnerability in Europe 2016 - An indicator-based report, 1, Luxembourg, doi:10.2800/534806, 2017).

Thieken, A. H., Cammerer, H., Dobler, C., Lammel, J., and Schöberl, F.: Estimating changes in flood risks and benefits of non-structural adaptation strategies - a case study from Tyrol, Austria, *Mitig Adapt Strateg Glob Change*, 21, 3, 343-376, doi:10.1007/s11027-014-9602-3, 2014.

Murawski, A., Zimmer, J. and Merz, B. 2016: High spatial and temporal organization of changes in precipitation over Germany for 1951-2006. *International Journal of Climatology*, 36, 6, 2582-2597. doi:10.1002/joc.4514.

Volosciuk, C., Maraun, D., Semenov, VA., Tilinina, N., Gulev, SK. and Latif, M. 2016: Rising Mediterranean Sea Surface
135 Temperatures Amplify Extreme Summer Precipitation in Central Europe. Scientific Reports, 6, 32450.
doi:10.1038/srep32450.

Beniston, M., Stephenson, DB., Christensen, OB., Ferro, CAT., Frei, C., Goyette, S., Halsnaes, K., Holt, T., Jylha, K., Koffi,
B., Palutikof, J., Scholl, R., Semmler, T. and Woth, K. 2007: Future extreme events in European climate: an exploration of
regional climate model projections. Climatic Change, 81, 71-95. doi: 10.1007/s10584-006-9226-z.).

140 As an effect of higher precipitation intensities within shorter time periods, flash floods might occur more frequently in
future. In combination with changing land use patterns and urbanisation, the damage mitigation, insurance and risk
management in flash flood prone regions become increasingly important. We hope that our results contribute to a better
understanding of damage driving factors with regard to those extreme events and thus enable the implementation of adequate
risk reduction measures.

145

Reviewer1 quote on the introduction:

Introduction: Page 2, last paragraph. The authors claim that the aim of this brief communication is twofold, however, they
present three aims in the following paragraphs: 1) identifying factors that govern damage, 2) the methods and the analysis of
150 the factors 3) advantages of open source software. Additionally, the practical application of the results should also be
included here. The aim of the brief communication is not clear and my feeling is that the authors do or actually present too
much for a brief communication but not enough for a full research paper.

Answer on the introduction:

155 The aims of the brief communication were stated to be twofold, since we present two major topics.

1. The identification and discussion of factors and processes that govern the damage caused by this particular flash
flood to improve the general process understanding.
2. The use of open source software, how it was implemented, carried out on site and presenting advantages as well as
disadvantages.

160 We did not declare the methods and also subsequent analysis and processing of identified factors (i.e. the process
intensity/local impact map) as an aim on its own because they eventually lead to a better understanding of damage processes,
what is seen as the actual aim. In the following, we present our option of choice to revise the last introduction paragraph and
express our aims in a clearer way:

“Consequently, we present Braunsbach as a case study, having collected and analysed data in order to add to the knowledge
165 in this field. This research paper follows two major objectives. Using the flash flood in Braunsbach as a case study, it is
aimed at identifying, analysing, comparing and discussing factors that govern damage caused by this event, applying
different linear and non-linear methods. As a second issue, the methods used for the ex-post damage data collection in

Braunsbach and the creation of this database are presented and discussed to demonstrate accompanying challenges as well as advantages.”

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Reviewer1 quote on the methods:

175 Methods: -In the first paragraph there is a reference to debris flow. Please, clarify what is the process that is investigated here. -Structural precaution: how can we check the correlation here? Shouldn't each precaution measure be a variable itself with YES/NO? -Higher ground level: Is the higher ground level always related to low damages? What about the effects of erosion during such an event? In a paper (partly by the same authors) describing the event (Agarwal et al 2016. Die Sturzflut in Braunsbach, Mai 2016. Eine Bestandsaufnahme und Ereignisbeschreibung) we can see pictures (page 3, figure 1, central photo) showing houses that have been damaged not because of a high debris level but because of erosion. In this case even if the ground floor is elevated the damage is still significant. How do you address this issues here? This also connects to a
180 previous comment. I believe that the choice of variables has to be explained and discussed at the beginning.

Answer on the methods:

As mentioned above, we are now consistent in the use of terms in the revised paper. The flash flood of Braunsbach, as well as several other flash floods that occurred in spring 2016, were accompanied by high erosion rates leading to high sediment
185 and debris loads in the surface runoff. See Answer 1 at “General comments of the reviewer”.

Indeed, the variables for each structural precaution measure exist in a binary format, allowing for basic correlation tests.

The Spearman's rho correlation of -0.09 (p 0.43) between higher ground floor and the damage class only indicates a minor damage reducing effect of higher ground levels. Yet, this effect is assumed to predominantly hold for water levels below a certain threshold (e.g. the height of the elevated ground floor) and potentially avoids the infiltration of water and sediments
190 in these cases.

As can be seen in the figure the reviewer refers to, processes such as flow velocities or erosion contribute to the building damage. However, since variables as the flow velocity and amount of transported material could not reliably be observed in the aftermath of the event, the exposition of the building was used as a proxy instead. Low exposition is often related to reduced flow velocities and to a lesser degree of sediment/debris load, which in turn leads to smaller erosion rates and less
195 collision damage. The overall damage pattern implies that higher damage is mainly governed by higher expositions in flow direction (and probably higher flow velocities) and higher water levels. In the revised paper, we analysed all recorded variables (see “Answer on tables and figures”). Further, we stated our motivation and variable choice for particular tests in the beginning.

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Reviewer1 quote on the results:

205 Results: -Page 3, line 30: how is this database unbiased? A large proportion of the characteristics of each variable depends on expert judgement. Why does this have a minor impact (p.4, line 2)? -page 4, line 22: delete repeated word (“this”). – Why so many methods for the correlation tests? Why these specific ones and not another one (e.g. Mann Whitney U test)? (explain in the “Methods” chapter) -In subchapter 3.1 reference to Figure 1 is needed. -p.5, line 3: the authors refer to the intensity of the process which is characterized by the “inundation depth” and the “exposition of building in flow direction”. What about other characteristics such as flow velocity or sediment content? Aren’t these characteristics related to the impact on buildings? The exposition of the building in flow direction has to do with the orientation of the building itself and not
210 with the process: : Is it correct to consider it as a defining factor for the intensity?

Answer on the results:

215 With “unbiased” we refer to variations in the dataset caused by intersubjective differences in classification. An alternative description such as “consistency among different team members during the data collection” might be better to describe this issue. We consider the data to be consistent in a way that the team members had very similar opinions e.g. on the damage classes or exposition in flow direction. Thus, a bias in the dataset due to personal variations in expert judgement is expected to be low.

220 We chose the Spearman’s rho correlation test, since we are interested in a correlation measurement of variables with different measurement scales and distributions. The Mann Whitney U test is primarily used to compare two datasets from the same population which does not seem to be beneficial for our purposes to describe variable coherences.

225 As described above, flow velocity and sediment load could not be determined on site. Instead, exposition of the building was used to respect both parameters. Yet, the used term “process intensity” has been revised. We use the term “local impact” to differentiate from flood inherent processes. However, as a difference to riverine flooding, we revealed that, during this flash flood, the physical impact (caused by debris, boulders and/or rubble) on buildings holds great importance as a damage driving factor and is dependent on both, the buildings relative position to the stream and probably shielding effects of neighbouring buildings. In general it can be said that, with “process intensity”/“local impact”, we do not focus on the hazard itself but rather analyse the consequences of flash floods and circumstances which are related to higher damage.

230 **Reviewer1 quote on tables and figures:**

Table 1: why do you include categories with no representative buildings? (e.g. Rubber or steel buildings and terraced houses, conservatory, greenhouse, chemical and sewage contamination). Is the list of variables exhaustive? Figure 1: Are all the variables for table 1 included in the correlation test? If not, why not? What is with the “cellar”? The “estimated construction year”? In page 3, line 27 you refer to 21 variables, yet in Figure 1 there are only 14. Figure 2: it is not clear how the process

235 intensity map has derived. Is the inundation depth and the exposition of building in flow direction equally important in defining the intensity? Is the intensity lower where there is no building to be exposed to the flow direction? How can this map use and what do we learn out of this map? Please refer to the following:

Fuchs S., Ornetsmüller C., Totschnig R. 2012. Spatial scan statistics in vulnerability assessment: an application to mountain hazards. *Natural Hazards*, 64: 2129-2151.

240 Fuchs et al. (2012) also detected spatial distribution patterns of loss ratios in four torrent fans in Austria.

Answer on tables and figures:

To avoid offline and unsynchronised modifications, several variable categories were included in the questionnaire beforehand, without knowledge about the specific situation in the research area. We consider the presentation of the complete set of possible answers to be relevant for comparisons with followup studies. The table represents the complete survey, as it was designed and the distribution of occurrences, categories with zero cases are thus included as well.

245 Due to the paper format, not all variables were included in the correlation tests. Our main objectives were to analyse the damage driving factors of flash floods and to reveal potential differences compared to riverine flooding. E.g. Maiwald et al. 2015 give an overview of known factors which influence structural damage on buildings. Especially the building material, condition (before the event) and the age are important factors related to the buildings resistance potential. Factors such as inundation level and contamination relate to “action” parameters (Maiwald et al. 2015) and describe external forces. Thus, the choice of the analysed variables was based on both, existing literature as well as expert judgement, i.e. including the exposition in flow direction, the abundance of large shop windows on the ground level or the sealing of the near environment as well. However, we analysed but not necessarily discussed all recorded variables in the revised paper.

255 Factors such as inundation level, flow velocity, specific energy and contamination relate to “action” parameters and describe external forces (Maiwald and Schwarz, 2015). Thus, in our study, the inundation depth measured at the building and the building’s exposition in flow direction were combined to create a local impact, which can be seen as a proxy for local flood related impact and hydrostatical forces at the building. Consequently, we chose a combination of these factors where both contribute to equal extents. While the inundation depth has continuous values, which are roughly uniformly distributed between 2 and 360 cm, the exposition in flow direction is recorded in three classes (low, medium, high). To achieve comparable variable ranges, the exposition classes “low”, “medium” and “high” are transformed into the mean values of the lower, middle and upper third of recorded water levels. The derived values 57, 133 and 230 fit into the range of observed water levels, enabling a combination of both attributes (Figure 5). The calculated local impact corresponds to the sum of water level and transformed exposition value. Please note that the exposition values are not used to replace water levels, but are only transformed into a comparable range.. In the revised paper, we support the explanation of this particular method with a graphic.

265 The “process intensity”/“local impact”-map was created in QGIS and is used to visualize the “local impact” indicator. However, it has to be noted that the local impact is measured on buildings itself and therefore hypothetical for the areas

around. In the framework of the paper, the map is further used to illustrate the flash flood process in Braunsbach and to underline the impact of water depth and exposition on the resulting damage. Overall the estimation of a local impact could be used in strategic planning of mitigation measures against future hazards in Braunsbach. The same approach can also be used for similar villages in that region, given that information about the potential flash flood (e.g. inundation depth) is available either from observations of an actual event or from flash flood models. The consideration of exposition as damage driver fits to the statement by Fuchs et al. (2012), saying that the general land use and settlement patterns play an important role in the geographical distribution of building damage. Thus, our map may contribute to the identification of potentially vulnerable locations on a small scale and within case studies.

280 **Referee #2**

General answer:

We thank the reviewer for the constructive comments. As stated by referee 1 as well, we agree with the reviewer that the Brief Communication had to be transformed into a Research paper, in which we extend our analysis and discussion.

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Comments of the reviewer 2

Reviewer2 quote, paragraph 1, 2, 3 & 4:

290 The paper describes the field survey and some first results after the flash flood event of Braunsbach in Baden-Württemberg in Germany. This type of event and the analyses are an interesting and relevant topic in the field of building damage due to extreme flood events. The complex characteristic of these extreme flood events and the resulting, in some cases, very heavy structural damage is not only in Germany an insufficient understood problem.

The aims of the paper are the identification of the damage relevant parameter due to flash floods and a discussion about the benefits of the use of the open source software “KoBoCollect” for the data acquisition.

295 The paper gives a short overview about the process of the event and the investigation area. The relevant aspects of preparation and realization of the data collection during the field survey are described.

300 During the field survey, the authors classified the damaged buildings into a damage classification system developed by other authors. A damage grade as a measure for the structural damage was assigned to each damage case. These damage grades and the documented impact and building parameter are the basis for the statistical analyses for the identification of the damage-relevant parameters. These statistical analyses are a further focus of the paper. From the viewpoint of the referee, the linkages between the individual steps of the described procedure are logical and comprehensible.

Answer 1, 2, 3 & 4:

Thank you for acknowledging the relevance of our work.

305 In our research we used the damage classification scheme developed by Schwarz and Maiwald (2007) in order to ensure comparability to other studies. In the revised version, we keep the general outline and extended our research as well as literature review.

310 Reviewer2 quote, paragraph 5 & 6:

The principle problem of the paper is mentioned by the first referee. A “brief communication” should represent a significant contribution to science, ground breaking and new results...

In its present form the paper would be in principle a good damage report after correcting some inaccuracies. But in the present form it fulfils not the demand for a brief communication. In general there are two possibilities: to find a journal that
315 accepts a report form or like suggested by the first referee, to extend the work to a research paper including a detailed analysis with more graphs and figures. In the latter case also more topic related literature should be cited. In each case the type of impact (flash flood, debris flow or mud flow) should be clearly separated with respect to the involved material components.

320 **Answer 5 & 6:**

Thank you for this suggestion. As also stated in our response to the comments of reviewer 1, we agree that the conversion of the Brief Communication into a Research paper was a helpful suggestion. We included more graphics supporting our methods and analysis. These are

1. Graphics to explain our methods (i.e. the derivation of the process intensity/local impact in the revised paper)
- 325 2. Graphics related to more detailed analysis

Our detailed analysis includes correlation tests with all recorded variables. We perform an additional analysis (i.e. multinomial logistic regression) to obtain additional outcomes and deepen the discussion. Further, we discuss our work in the context of existing studies on this topic.

The flash flood in Braunsbach was accompanied by a considerable amount of sediment and building rubble, potentially
330 showing flow characteristics of debris flows such as defined by Fuchs et al. 2010 and Borga et al 2014. Yet, a clear distinction between flash floods and debris flows is not always straightforward. In the revised version of the paper, we clearly define flash floods and debris flows and we aim for consistency and adequate wording for the process.

335 **Reviewer2 quote, paragraph 7:**

Some other comments are necessary: By the application of the damage classification system, the authors speak from the assignment of damage classes or degree of damage. In contrast, the original publication refers to the term “damage grades”.

Answer 7:

340 Thank you for the comment, we have been more careful and consistent with the terms we use to describe the damage classification. In the revised version, we use the term “damage grades”.

Reviewer2 quote, paragraph 8:

345 According the paper, the team was in the field first one week after the event. This is related with the careful preparations before the survey. However, it should be discussed whether the damages a week after the event still clearly assessable due to

the advanced clean-up work. It could be also discussed, whether the water level measurements with the thermographic camera the ascending humidity in the walls was taken into account.

350 **Answer 8:**

One week after the event, the structural damage on buildings and building characteristics was still assessable, since the main work within this period was mainly focused on clearing the roads, establishing paths for large construction machinery as well as removing and cleaning the interior of affected buildings. Some areas of the village were even not accessible before, since roads were blocked by debris and buildings in danger of collapse had to be secured. The progress of the clean-up work
355 was further beneficial for the damage assessment, as a thick layer of debris and rubble previously covered big parts of the building damage. However, few buildings could not be reliably examined, since debris and rubble were still hampering the access.

The use of the thermographic camera is better presented and discussed in the revised paper, since it offered advantages in such cases, where the inundation depth could not be reliably estimated. We agree with the reviewer, that the ascending
360 humidity in the walls is a point to consider when using a thermographic camera for water level estimations. For that reason the thermal images were mainly used to verify estimations based on visible mud contamination and marks caused by water and transported debris. Since the thermally derived water levels matched well with visible traces, thermal images were also used to estimate the inundation depth for buildings with no or little visible traces.

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Reviewer2 quote, paragraph 9:

A discussion about the topic process intensity seems also necessary. The first referee has here the opinion that the exposition belongs not to intensity. I believe at the end this is a question of the understanding of the meaning of intensity. Should the intensity considered only as a combination of impact parameter (water level, velocity, material density and debris impact)?
370 Or has it an extended meaning like for earthquake according to EMS-98 (Grünthal et al. 1998), where also the effects on humans, nature and building were considered for the assignment of the intensity? Clear, for the damage also the exposition of the building can be relevant (Maiwald & Schwarz, 2015). A high exposition leads by such dynamic impact characteristics to higher loads on the buildings. With respect to these dynamic impacts especially the legitimation of the replacement of mean water level for some calculated percentiles with the exposition classes is unclear. Is there really a meaningful
375 correlation?

Answer 9:

We agree with the statement of the reviewer that the attributes of intensity are determined by different meanings and can include exposition grades as well. In our case, the process intensity includes factors which are independent from building

380 characteristics and do not only represent flood inherent parameters. As stated in the answer on the first referee comment as well, we replaced the term “process intensity” with “local impact”, to reflect the actual meaning in a better way.

The exposition classes needed to be transformed in order to derive the process intensity. Still, the inundation depth and the exposition classes contribute independently to the process intensity. In the following paragraph, the methods are described in detail (copy from the answers on referee comment RC1):

385 “Factors such as inundation level, flow velocity, specific energy and contamination relate to “action” parameters and describe external forces (Maiwald and Schwarz, 2015). Thus, in our study, the inundation depth measured at the building and the building’s exposition in flow direction were combined to create a local impact, which can be seen as a proxy for local flood related impact and hydrostatical forces at the building. Consequently, we chose a combination of these factors where both contribute to equal extents. While the inundation depth has continuous values, which are roughly uniformly distributed
390 between 2 and 360 cm, the exposition in flow direction is recorded in three classes (low, medium, high). To achieve comparable variable ranges, the exposition classes “low”, “medium” and “high” are transformed into the mean values of the lower, middle and upper third of recorded water levels. The derived values 57, 133 and 230 fit into the range of observed water levels, enabling a combination of both attributes (Figure 5). The calculated local impact corresponds to the sum of water level and transformed exposition value. Please note that the exposition values are not used to replace water levels, but
395 are only transformed into a comparable range.” In the revised paper, we support the explanation of this particular method with a graphic.

Reviewer2 quote, paragraph 10:

400 It could be not expected, that these complex topic can be analysed in a really detailed form from a limited study of 96 damage cases. Therefore is more comprehensive data base necessary. But after a major revision of this paper and its extension to a research paper we can expect more detailed insights in the topic. I look forward to the further progress of the work.

405 **Answer 10:**

We thank the reviewer and aim to contribute to a better understanding of flash floods and related damage processes in general. Considering the fact that our research in Braunsbach resembles a case study, the 96 damage cases represent an almost complete inquiry. Thus, we do not claim to perform an extensive study of this complex topic. However, we will add to the knowledge within this field of research. Especially since further research is planned and an additional survey related to
410 flash floods will be carried out soon, connecting to our results.

Summary of major paper changes:

Since the paper format has changed from a “Brief Communication” to a full research paper, the changes in the text and graphics are very comprehensive and poorly to be shown by track changes of the former version. I therefore decided to list all major changes below:

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- Included an elaborate literature review in the introduction.
- Added a new method to analyse the “local impact” indicator (multinomial logistic regression).
- Included new graphics (RF and RGLM model results, multinomial logistic regression, explanatory graphics).
- “local impact”-map update, change in the method of local impact “interpolation” (Voronoi diagrams instead of IDW interpolation were used).
- Elaborate discussion of significant variables, referring to literature.
- Less focus on open source software discussion and presentation of “KoBoCollect”.

425