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Interactive comment on "Brief communication: On-site data collection of damage caused by flash floods: Experiences from Braunsbach, Germany, in May/June 2016" *by* Jonas Laudan et al.

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Discussion paper

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 would like to follow the reviewer's suggestion to transform the Brief Communication into a Research paper, addressing all helpful comments.

General comments of the reviewer

Reviewer 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?

Answer 1: 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 will clearly define flash floods and debris flows and we aim for consistency and adequate wording for the process. 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.

Reviewer quote 2: The article should refer to similar studies and their connection to

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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 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. 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. 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: Thank you for your suggestions. As stated above, when converting the brief communication to a research paper, we will take more existing literature into account to integrate our work into an up-to-date, scientific framework. This will include a review section

Reviewer quote 3: 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 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: 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) will be discussed 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 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 include measures for reducing their impacts (e.g. potential tangible as well as intangible damage) in flood risk management plans. The current state of the still ongoing discussion will be addressed in the revised paper.

Reviewer quote 4: 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.

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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 will use the term "local impact" in the revised paper.

Specific comments of the reviewer

Reviewer 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?

Answer on the title and abstract: Title: Thank you for the hint. The paper title will be revised that it reflects the content of the paper in a more elaborate way. One option could be: "Damage assessment after the flash flood 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 (see 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 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.). As an effect of higher precipitation intensities within shorter time periods, flash floods, such as seen in Braunsbach and the surrounding villages, might occur more frequently, which raises questions regarding damage mitigation, insurance and risk management in flash flood prone regions. 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.

Reviewer 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 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: The aims of the brief communication were stated to be twofold, since we present two major topics. 1. The identification 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. 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 an option to revise the last introduction paragraph and express our aims in a clearer way: “This research paper follows two major

objectives. Using the flash flood in Braunsbach as a case study, it is aimed at identifying, analysing and discussing factors that govern damage caused by flash floods. 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. Since "KoBoCollect" turned out to provide major advantages with regard to the duration of data acquisition, simplicity, effectiveness and in-field handling, we demonstrate the benefits as well as important issues of open source software associated with its use. Within this regard we aim for an increased awareness of open source software and its potential for scientific and public data collection."

Reviewer quote on the methods: 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 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 will be 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 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 -0.11 (p 0.33) between higher ground floor and the damage class 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 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 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 will analyse and discuss all recorded variables (see "Answer on tables and figures"). Further, we will state our motivation and variable choice for particular tests in the beginning.

Reviewer quote on the results: 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 with the process: : :Is it correct to consider it as a defining factor for the intensity?

Answer on the results: With "unbiased" we refer to variations in the dataset caused by intersubjective differences in classification. An alternative description such as "con-

sistency 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. 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. 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" will be revised. We will rather 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.

Reviewer 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 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. 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. Further, the complete survey contains 22 variables, not 21. These mistakes will be corrected. Due to the paper format, not all variables were included in the correlation tests, only those which seem most rewarding with regard to coherences and the desired motivation. 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, to use the full potential of our database, we will analyse all recorded variables in the revised paper. The “process intensity”/”local impact”, which is a combination of the inundation depth measured at the building and the building’s exposition, can be seen as a proxy for local flood related impact forces. Since both variables show the same correlation value to the caused damage and are further rated to be equally important in both developed damage models (RGLM and RF), we chose a combination of these factors, where both contribute to equal extents. While the inun-

dation 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. The calculated “process intensity”/”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 will illustrate our methods with graphics for a better understanding. The “process intensity”/”local impact”-map was created in QGIS (Figure 2) and fills the gaps between buildings with interpolated values to express a hypothetical intensity for hypothetical buildings at that spot. In the framework of the paper, the map is 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.

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