Reply to Reviewer 1

The procedure is applied to the Balkan flood in May 2014 and the plausibility of the results is checked using observed and reported data. In this context also the limitations of the procedure are discussed. In view of an increasing importance of considering consequences within risk oriented flood management the paper addresses a relevant topic and could make a valuable contribution to the field. It is therefore suitable to be published in NHESS.

We thank Reviewer 1 for his/her positive comments on our work.

However, there are a number of points which should be taken into consideration to make the paper stronger. The most important ones are:

1) What is the definition of risk used in the paper? It would be more appropriate to use e.g. impact forecasting, particularly in the title and throughout the manuscript.

*In the manuscript we followed the standard definitions used in flood risk literature, that is, risk = hazard * vulnerability * exposure, and risk = probability * consequences. However, it is true that in the first version of the manuscript the terms "impact" and "risk" were not correctly used. Therefore, we will carefully revise the use of these terms and recall their definition according to literature. In addition, we will discuss how the proposed procedure can be used for flood risk assessment (see the reply to point 'A" for more details).*

2) What is the benchmark you use? I think also this term is not very appropriate in the title because actually no benchmark is available. I would suggest to reword the title 'An operational procedure for rapid flood impact assessment in Europe'

Following the Reviewer's suggestion, we will reword the title of the revised manuscript as 'An operational procedure for rapid flood risk assessment in Europe'.

3) The main achievement of the flood impact forecasts is currently not sufficiently elaborated. The focus shut be on the added value of the impact forecasts: i.e. the evaluation of consequences. Knowing the consequences of the flood in advance allows to take cost-benefit considerations into account which in turn allows to prioritize emergency and response measures. You should then also discuss issues concerning the protection of human life against economic loss.

We will address the remark raised by Reviewer 1 by expanding the analysis of possible uses of the new procedure, highlighting its added value in respect to standard flood forecasting. In particular, we will discuss how risk evaluation (i.e. considering both probability and consequence) can be used to develop cost-benefit analyses, including measures for human safety. In presenting this discussion we will keep a general perspective, because EFAS is a continental scale system and the practical design of any measure, including cost-benefit analyses, would need to be discussed and coordinated with emergency services and policy

makers at local level. Moreover, an accurate uncertainty analysis of EFAS risk forecasts is needed before developing practical applications (see also reply to point "A"), because the use of forecast for activating emergency measures require to take into account the possibility and consequences of acting "in vain", e.g. to issue a false alarm (Coughlan et al., 2016). To this end, we are currently to evaluate the procedure in past flood events recorded in the Copernicus database. As a first step, EFAS risk forecast could be used to activate "low regret" protection measures like monitoring of flood defence structures, warning of population and deployment of emergency services in areas at risk. All these considerations will be included in the revised version of the manuscript.
Regarding the issue of human safety, we will present a brief literature review of the methods for evaluating the risk of fatalities, and discuss the most feasible approaches for the proposed procedure, taking into account the issues previously mentioned. The scale of application of the EFAS risk assessment is not compatible with risk models for personal safety based on precise hydrodynamic analysis, like the one presented by Arrighi et al (2016), whereas probabilistic risk methods (e.g. de Bruijn et al., 2014) and the use of mortality rates calculated form previous flood events (e.g. Tanoue et al., 2016) are more feasible of integration. Again, these considerations will be included in the revised version of the manuscript.

4) Background information on different components of the system is sparse. For instance no information is given on the DEM used. Also, the model approach for flood impact assessment remains obscure. This should be clearly improved.

To address this remark, the revised manuscript will include more information on data and methods used in the study, including exhaustive references about the DEM and the flood impact assessment. For more details we refer to the replies to suggestions provided in the annotated PDF file (Points "G" to "O").

5) Figures 4, 5 and 6 should be combined in a multi panel graph for better comparison between the different settings.

In the revised version we will combine these figures in a single multi-panel graph, as suggested by the Reviewer.

Further remarks are given in the annotated PDF file.

Please find in the following the replies to all the remarks.

P1: suggestion to change the order to be in accordance with previous clause.

We will change the phrase as suggested by the Reviewer.

a) P2 L47: a definition of how the term risk is used in this paper would be useful. The procedure proposed here provides a flood impact forecast. Flood risk (probability*consequences) is not assessed.

As mentioned in the reply to Point 1, in the manuscript we followed the standard definitions used in flood risk literature, and in the revised manuscript we will carefully revise the use of the terms "impact" and "risk". To address the specific issue in L46-48, we will change the paragraph as follows: "While early warning systems are routinely used to predict flood magnitude, there is still a gap in the ability to translate flood forecasts into risk forecasts, that is, to evaluate the possible impacts generated by forecasted events, given their probability of occurrence (e.g. flood prone areas, affected population, flood damages losses). In addition, we will explain in detail why we used the definition "flood risk assessment" for the procedure presented in the manuscript. We reckon that the analysis of results has been mainly focused on impact assessment, whereas the evaluation of flood probability has not been addressed explicitly. However, the procedure does allow to compute the theoretical probability of occurrence of any forecasted event, because EFAS forecasts include the evaluation of discharge return periods at every point of the river network, based on the forecasted flood magnitude. To better illustrate this, in Section 4.3 of the revised manuscript we will evaluate EFAS forecast by comparing forecasted and observed return periods.
On this point, it should be considered that a correct risk evaluation for a forecast would require to estimate the conditional probability of occurrence given the flood forecast itself. For example, if the median of the EFAS ensemble forecast predicts a peak discharge of, say, 20 year return period, the probability that such a discharge will take place during the forecast period will be in theory higher that once every 20 years, depending on the situation and forecast reliability.
However, in order to be useful for emergency management, assessing conditional probability would require an accurate uncertainty analysis of the EFAS risk forecasting procedure, which is beyond the scope of this paper. We will report this discussion in a specific section of the revised paper, and mention the ongoing work aimed evaluating the procedure in past flood events recorded in the EFAS database.

b) P2 L49: please provide context what is meant by static.

We reckon that paragraph in L49-52 was not clearly written. It will be rewritten as follows: "Generally, flood impacts are evaluated considering reference risk scenarios where a fixed return period is used for all the area of interest, for instance based on official maps issued by competent authorities (EC 2007). However, this implies some degree of interpretation to delineate flood prone areas and define impacts in case of a flood forecast."

c) P2 L57: check if repetition is needed

We will delete the repetition as it is not necessary.

d) P2 L60-65: One could argue that these tasks can already be done using flood forecasts. I think you should focus on the real added value of the impact forecast, which is the evaluation of consequences. Knowing the consequences of the flood in advance allows to take cost-benefit considerations into account which in turn allows to prioritize emergency and response measures. You should then also discuss protection of human life against economic loss.

As discussed in the reply to Point 3, the revised manuscript will focus more on the added value given by evaluation of flood probabilities and consequences, highlighting the possibilities offered in respect to standard flood forecasting. Regarding the paragraph in L60-65, we will change it as follows: "At local scale, the joint evaluation of flood probabilities and consequences may not only increase preparedness of emergency services, but also allow cost-benefit considerations for planning and prioritizing response measures (e.g. strengthening flood defences, planning evacuation of people at risk). At European scale, the possibility to receive prior information on expected flood impacts would help the Emergency Response Coordination Centre (ERCC) in prioritizing and coordinating support to national emergency services."

e) P2 L60: s.a. the term impact forecasting seems to be more appropriate than risk forecasting

Please refer to our reply to Points 1 and A.

f) P3 L100: only three components are introduced but four sub-sections are following. You should consider merging 2.1 and 2.2

The separate description of the EFAS and map database was done to improve clarity. However, in order to keep consistency with the scheme in Figure 1, sections 2.1 and 2.2 will be changed into separate subsections 2.1.1 and 2.1.2.

g) P4 L140: The reasoning behind this is not clear. Why don't you use the simulated hydrographs?

The hydrographs simulated in the EFAS reference simulation are not referred to specific return periods, therefore we need to derive synthetic hydrographs for the return periods of interest. The extreme value analysis is used to derive peak discharge values for the return periods of interest, then we extract flow duration curves from the reference simulation which are used to design the shape of the synthetic hydrographs. Since the full procedure was described in Alfieri et al. (2014b) we did not provide a detailed description, however we will add these additional explanations in the revised manuscript.

h) P4 L142: Background information about data sources, e.g. DEM should be added, since this is referred to later on L421

The DEM used is a component of the River and Catchment Database developed at JRC and described in Vogt et al., (2007). We will include this reference in the revised manuscript.

i) P5 L151: is it correct that only some river sections are shown?

The conceptual representation is correct, however it must be noted that there is not a 1:1 correspondence between 5km and 100m river sections, given the different resolution. During the downscaling of discharge information, flood points are linked with the closest 0.1° pixel in the upstream direction where the coarse and high resolution river networks do not overlap. In particular, some 5km sections have no related sections in the 100m river network, while others can have more than one.

j) P5 L163: Is this taken into account in the LISFLOOD-FP simulations in some way?

We could not consider flood protections in LISFLOOD-FP simulations because we don't have information about the location and geometry of flood protection structures (e.g. levees). Therefore, LISFLOOD-FP simulations are run as if there were no protection structures.

k) P6 L168: To which extend are these data available, for which fraction of river reaches from the whle network?

Following a similar request from Reviewer 2, the revised paper will include an appendix with a list of the updates to the flood protection level map developed by Jongman et al. The list will show the regions where values have been updated, the old and new values, and the source of information.

l) P6 L182: Please provide some background information on this approach.

This information is taken from the map of World Cities available in the online ESRI database (http://www.arcgis.com/home/item.html?id=dfab3b294ab24961899b2a98e9e8cd3d).

m) P6 L185: Please add a reference

We will add a reference to the Corine Land Cover webpage on Copernicus website (http://land.copernicus.eu/pan-european/corine-land-cover).

n) P6 L187: The references do not provide sufficient details about these depth-damage functions. The reference Huizinga 2007 is not a scientific publication and not available to the public. Additional information should be given here.

In this study we used normalized damage functions which calculate the damage ratio as a function of water depth. Thus, damage fractions span from zero (no damage) to one (maximum damage). The damage ratio is then multiplied by the maximum damage value, calculated as a function of land use and country's GDP. Besides these additional details, in the revised paper we will refer to a recent JRC report by Huizinga et al. (2017), which describes a novel dataset of depth-damage functions at global scale, including the damage functions for Europe. The report will soon be publicly available.

o) P6 L195: What is the approach to derive these additional curves? Please explain.

In literature, country-specific depth-damage functions based on national data are available only for a limited number of countries. To produce a consistent dataset at European scale, Huizinga et al. (2007) elaborated available damage functions to derive averaged damage functions to be used for countries without specific functions. We therefore applied the same approach for Serbia and Bosnia-Herzegozina. More details can be found in the upcoming report by Huizinga et al. (2017).

p) P7 L216: but in large areas of your test area additional damage curves have been derived, cf. L195, L223. What is this test worth for the European perspective?

As stated in our previous reply (point "O"), the majority of European countries have no specific damage functions, therefore from this point of view the test is representative of the general data availability at European scale.

q) P7 L236: Do you mean Sava river?

The name is correct, the Sana River is a tributary of the Una River.

r) P11 L310: please include references

References to the ISRBC report (described in Section 3.1) will be included.

s) P11 L321: But in the reference simulation also dike failures have been included in the inundation maps, right? cf L269

True, but in real world applications it would not be possible to consider any information on what happened during the event, as forecast-based maps will be by definition produced in advance. Therefore we believe it is more correct to evaluate them without taking into account dyke failures or strengthening.

t) P11 L335: you should introduce this scenario explicitly and explain on which information sources it is based.

This scenario is actually the reference simulation described in Section 3.2, we will correct this.

u) P12 L347: The term validation is not appropriate. You are rather doing plausibility checks on the different components of your system.

We will use the term "evaluation" instead of validation in the revised paper.

v) P12 L353: On which basis have these sections been selected? How many are considered out of the total number of sections?

We used a confusing terminology here and we apologize for this. We considered here those areas in the Sava River basin affected by the flood event and where satellite flood extent maps from Copernicus were available. Areas were grouped considering the main source of flooding, either a tributary (e.g. Bosna) or the Sava River. For the Sava River, we considered two separate areas because of the large extent of the flooded areas, and because flood extent was not continuous. We could not consider other flooded areas for which satellite maps were not available.

w) P12 Table 3: reference simulation

This will be corrected as suggested.

x) P12 L360: The footnotes could be aligned with Table 1.

We will align footnotes as suggested.

y) P12 L363: s.a. (*see above?*)

This will be corrected as reported in the reply to Point "v".

z) P13 L376: withstand

Suggestion accepted.

aa) P13 L392: no details provided on DEM, please add

We will specify that the DEM has a 100m resolution.

bb) P14 Table 6: simulated in reference simulation?

Yes, this will be amended.

cc) P14 L416: suggested to rephrase

We will rephrase this in order to eliminate the repetition.

dd) P14 L426: indicate or estimate

We will replace "report" with "indicate".

ee) P15 L430: but damage curves have been specifically derived for Serbia and Bosnia-Herzegovina (L195). This argument is therefore rather weak. How would such a calibration look like?

The explanation on this point was not clear and we apologize for this. As reported in the reply to point "O", for Serbia and Bosnia- Herzegovina we applied depth-damage functions derived from data for other countries and averaged over all the European countries. However, the availability of detailed, country-specific damage reports at building scale (i.e. indicating the local water depth and the consequent damage for different building categories) would allow to derive specific damage functions.

ff) P15 L433: You should also reflect on the completeness of official damage reports.

We will elaborate on this point and make reference to the paper by Thieken et al. suggested by the Reviewer.

gg) P15 L443: why? It would be interesting to see if the reference simulation is within the range of 25-75 quantiles.

The revised paper will include results from the simulations of 25 and 75 quantiles for May 13.

hh) P17 L476: please state how many days

In the revised paper we will discuss with more details the performance regarding lead time. In fact, the timing of peak flow was variable across the Sava river basin, due to its extent. While in the Kolubara river the highest discharges occurred on 14^{th} and ^{15th} May, peak flows in other tributaries were reached later (between 14^{th} and 16^{th} for Bosna River, on 16^{th} for Drina, 17^{th} May for Sana River), and on the main branch of the Sava River the flood peaks occurred after 17^{th} May. Thus, the majority of affected areas the lead time was at least 2 days, if we consider the EFAS forecast issued on 13^{th} May. In the revised paper we will evaluate the performance considering these additional details, and discussing emergency actions that could be taken base on available lead time.

ii) P17 L491: It would be valuable to refer to the existing international frameworks on impact data collection, see also: Thieken, A. H., Bessel, T., Kienzler, S., Kreibich, H., Müller, M., Pisi, S. and Schröter, K.: The flood of June 2013 in Germany: how much do we know about its impacts?, Nat. Hazards Earth Syst. Sci., 16(6), 1519–1540, doi:10.5194/nhess-16-1519-2016, 2016.

We thank the Reviewer for the suggestion, in the revised paper we will elaborate on this point adding the suggested paper and further references from reports by IRDR (2015) and Corbane et al. (2015) on this topic.

jj) P17 L496: please name the benefits

Following the Reviewer's suggestion in Point 3, we will discuss how the proposed procedure allow to plan and prioritize response measures (e.g. strengthening and monitoring of flood defences, evacuation measures) based on cost-benefit considerations, leading to a considerable improvement in preparedness of emergency services.

Additional references

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