What made the June 2013 flood in Germany an exceptional event? A hydro-meteorological evaluation

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Reply to comments of Massimiliano Zappa

First of all we want to thank Massimiliano Zappa for his valuable and thoughtful comments. Following, we will reply to each of the comments made.

General remarks:

This manuscript is a nice example of (in the words of the Authors') "Forensic disaster analysis" (FDA). This kind of studies is needed in order to understand gaps in the knowledge concerning the triggering and management of extreme (flood) events.

The manuscript uses a solid base of data and nicely combines established evaluation techniques. In the introduction I miss some paragraphs on the methods adopted (See below). The methods adopted are presented and adopted in a straight-forward manner, no sensitivities are assessed. This should be improved, because I have much the impression of reading a cook-book, which is here adopted for assessing the severity of a "random" event. The "hydraulic load" is in my opinion also an aspect that needs to me more highlighted in the introduction (novel to me).

I found that the referencing adequate, but in my opinion some useful paper have been not considered (see minor comments and reference list). Most of the references I missed stem from NHESS, a journal which could also have been an adequate recipient for this manuscript.

Issues to be addressed (Page(s) – Line(s)):

Referee Comment:

Introduction: I completely miss some paragraphs on previous applications of the adopted methodologies (API, Wetness-Index, EVS and so on). I would expect that you introduce them and clarify how novel is the application you realize here (e.g. the specific combination of the approaches).

Authors' response:

We overworked the introduction and also included an overview of the adopted methodologies as suggested.

Referee Comment:

8131-4-13: In the section methods you explain the different measures you use in the assessment. One central question is the selection of the event start date, which varies within the stream network. Now, from an HESS manuscript I expect somewhat less straight-forward application of the methods. I would like you to consider introducing some basic analysis of sensitivities. I really like your Figure 12 and it would be nice to have in there some error-bars (both for API and the wetness index). What if you use API20 instead of API30? What if you do not start the API estimation the day prior to the 3days maximum, but two days prior to the 5 days maximum? These examples should bring you to "experiment" with your methodology and finally tell us that for these kinds of analyses API30 and starting API the day before the 3 days precipitation maximum are a solid way to proceed in these kinds of analyses. Without such contribution is like reading a technical report on the event.

You write on Page 8132 that *"We have performed this analysis for maximum precipitation total of 3 to 7 days duration"*. These analyses should be shown and the sensitivities should be propagated until "Figure 12". You can also vary the "decay" within the API equation (you use 0.9).

Authors' response:

We followed this suggestion and included a sensitivity analysis of several factors and assumptions made within the methodology (see new Section '3.6 Sensitivity Analysis'). This includes varying duration of event precipitation, duration of antecedent precipitation index, different values for the depletion constant for the calculation of API as well as several reference levels for the calculation of severity indices.

For the most sensitive variations – in terms of changes in the according Severity indices (cf. new Figure 13) – we now show the results of the LOWESS interpolation model in additional charts in Figure 12.

Further, we included a new Figure that shows the spatial patterns of 7-day precipitation maxima related return periods and briefly discussed them in the text. Because the differences to the 3-day maxima are not that large (especially the estimated return periods), we put those in the Appendix (Fig. A2).

We mainly considered 3-day precipitation maxima for meteorological reasons. Persistent heavy precipitation may occur on 3 consecutive days, but only extreme rarely on seven days (in Southwest Germany, for example, only once in 30 years). Within 7 days, atmospheric conditions usually change with the effect that the precipitation patterns can hardly be related to ambient conditions (e.g., flow from different directions lead to different locations of orographically-induced precipitation). 3-day totals better represent rainfall associated with floods occurring in summer as it is the case for the three events investigated in this study. In contrast, 7-day precipitation totals are more related winter floods.

Referee Comment:

8133-6: Why 5 year RP? Again I would be interested in the sensitivity of the methodology you use in this “Forensic Disaster Analysis” and I am not very interested in reading a cook-book.

Authors’ response:

We considered a variation of reference levels for calculating the different severity indices (see above). In Uhlemann et al. (2010) the flood severity index was tested for a variety of return periods 1.5 to 20 years). A return period of 2 years refers approximately to bankful discharge in a typical European lowland river. The higher the return period reference level, the more weight is put on extreme runoff in relation to spatial extent which leads to a lower ranking of moderate intensity, large scale winter floods. A 5-years return period is regarded as the best compromise to generate a balanced event set when concentrating on the analysis of very large events.

<u>Minor comments:</u>

Referee Comment:

8127-5-11: When speaking about flood losses you might cite the papers of Hilker et al. (2009) and Barredo (2009)

Authors' response:

We added Barredo (2009) as another suitable reference; Hilker et al. (2009) appear to be more relevant for Switzerland. This reference does not provide additional information for Germany about the 2002 flood damage.

Referee Comment:

8128-6-15: Here you might find also some interesting discussion in Alfieri et al. (2014)

Authors' response:

We included the issues raised by Alfieri et al., 2014 and in other references mentioned therein in the revised introduction.

Referee Comment:

8129-6: You consider a relative long period and this might allow you using the "block maxima" approach. Why you select POT?

Authors' response:

For the extreme value statistics of flood peak discharges we applied a 'block maxima' approach, i.e. we used annual maximum series of mean daily discharges at the 162 gauges. The peak over threshold criterion was used by Uhlemann et al. 2010 to identify potential large scale floods from the spatial time series at 162 gauges. As the use of the term POT in this context might be confusing we changed the text.

Referee Comment:

8130-8: Am I the only one wishing an illustration of "low central Europe (TM)" and "trough central Europe (TRM)"? Add TRM and TM in Figure 1.

Authors' response:

Fig. 1 shows the geopotential height averaged between 16 and 31 May. During that time, both RM and TRM persisted. Thus, we cannot relate this mean to any of the two weather patterns. Anyway, we decided to delete the paragraph with the large-scale weather patterns because it provides no useful insight.

Referee Comment:

8135-5: GEV computations generally allow estimating uncertainty ranges (which in case of RP of 5 years might result very narrow). But again, it would be another piece that can be added for quantifying the sensitivity of this methodology.

Authors' response:

We think that the variation of the different factors addressed within the sensitivity analysis (see above) in particular the variation of return periods chosen as reference levels in calculation of severity indices have a stronger impact on the evaluation results than the uncertainty associated with return period estimates. Therefore we did not include this aspect to the analysis.

Referee Comment:

8136-8137: You make large use of regional geographic terminology. Thank you very much for Figure A1.

Authors' response:

The figure has been updated to include additional locations that were still missing

Referee Comment:

8138-15-20: Is there any literature on LCL, or is it assumed that HESS readers are familiar with this?

Authors' response:

We added an explanation for the LCL: "…the lifting condensation level (LCL), which represents the level of the cloud base in case of synoptic-scale or orographic lifting,…"

Referee Comment:

8139-10: The propagation of this statistical uncertainty up to Figure 12 is what I want to see.

Authors' response:

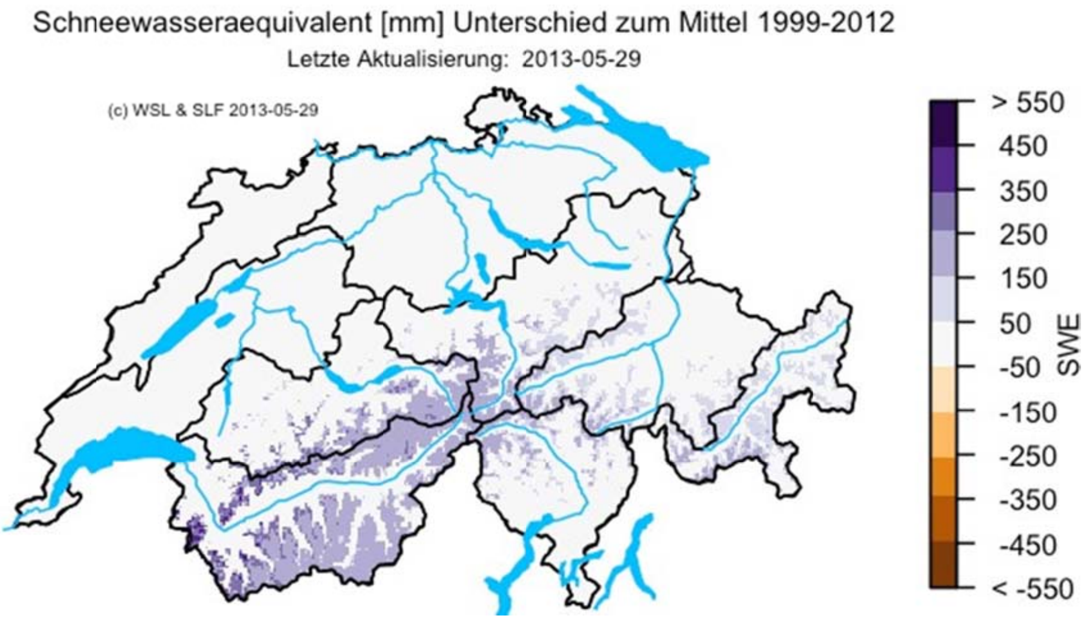
Please refer to our response to the comment on GEV estimation uncertainty above.

Referee Comment:

8141-23: I really like this "Hydraulic load" approach.

Referee Comment:

8142-15-20: It should be possible to access a snow-depth measurement in order to confirm this statement. Here below an assessment of snow-resources anomalies in Switzerland on May 29 2013. Source T. Jonas, SLF (see also Jörg-Hess et al.., 2014 and Zappa et al., 2014). A slight positive anomaly can be seen in the highest areas.



Authors' response:

We agree that snowmelt can play an important role in the generation of floods. However, in the case of summer floods in Germany as in July 1954, August 2002 and June 2013 this was not an important factor. On the contrary, both in June 2013 and in July 1954 snow was accumulated above elevations of 1,600 m and 800 m respectively (e.g. Blöschl et al., 2013), and thus attenuated runoff generation in the Alps. Likewise in August 2002 snow did not play an important role. As the focus area of our analysis is Germany we decided to exclude the aspects of snow melt and accumulation.

Referee Comment:

8144-23: Very interesting section, just add some sensitivity to this as proposed before.

Authors' response:

For the most sensitive variations identified within the sensitivity analysis (see above response to major comment) we added plots for the LOWESS interpolation model to Figure 12 and included some discussion on the variations observed in the text.

Referee Comment:

8145-19: No new line needed.

Authors' response:

This has been changed.

Referee Comment:

Figure 12: Caption: "Upper right corner", I guess.

Authors' response:

This has been corrected.