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

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Reply to Comments of Review C4043

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

Referee statement

In this paper, the 2013 flood is compared to two large-scale summer floods (1954 and 2002) using extreme value statistics and severity indices. The focus of this paper is the floods in Germany, and the analyses are carried out with a consistent data base of precipitation and discharge data was used.

I enjoyed reading the paper; however, some issues were not entirely clear. After reading the other comments in the interactive discussion (which I did after writing down my comments) I realized that some have been mentioned there already.

In my opinion, the scientific significance can be rated 1-2, the scientific quality 1 and the presentation quality 2. As for the scientific significance, I don't know if there are any substantial new concepts or methods, but it is certainly important to understand large scale floods and the processes behind them. I liked the database, even though some issues concerning this data were not entirely clear. As for the presentation quality, there is some improvement possible. Some values were used without any further explanation (e.g., API30,

return period rp5) which should be clarified; also the description of the interpolation of the 1954 precipitation is missing.

I have three larger issues, and several minor which I have listed below.

Major comments

Referee Comment:

You use a number of geographical locations and you also provide a map (Figure A1) in which several of these locations are shown. However, there are a number of stations mentioned in the paper not shown on this map.

Authors' response:

Figure A1 has been completed accordingly.

Referee Comment:

You have used a discharge database from 1952 to 2002. Somewhere you say that you have identified 74 events from 1960-2009. But you analyze the 1954 and 2013 events. Is there some confusion with the years? Or is there a different reason? Please clarify.

Authors' response:

The reference period for long-term analyses is 1960 to 2009 (50 years). The selection of this period was guided by balancing the trade-off between length of reference period and both data quality and consistency:

- For statistical analysis a time frame of 50 years is sufficient. Note that in meteorology usually a 30 years period is used to describe the climatological context.
- For the long-term classification of the three specific events, 1954, 2002, and 2013, it is not necessary that they are within the reference period. We selected these three events because they were that extreme.
- Official discharge data available for most of the 162 gauges have only been checked for plausibility until end of 2009 and thus the update of the flood event set identified by Uhlemann et al. (2010) beyond 2009 would not have been consistent. The data availability and quality varies considerably between the federal states of Germany. For the flood in June 2013 we made an exception and worked with raw data.

- The quality of REGNIE data before 1960 is relatively low due to a reduced number of measurement stations available at that time. For the evaluation of the flood in July 1954 the data are appropriate but we decided not to include this period in the statistical analysis.

We reformulated the second last paragraph in the introduction and also separated between the reference period and the three events in the Sections 2.1 and 2.2 (now 2.1.2 and 2.1.3).

Referee Comment:

How was the precipitation data for the 1954 interpolated? There is no information given. You have used the REGNIE data set for 1960-2009 and 2013.

Authors' response:

See above.

Yes, all the precipitation data were obtained from REGNIE. In Section 2.2 (now 2.1.2) we included a statement ("…and for the single events 2013 (April-June) and 1954 (June-July)…"

Minor comments

Referee Comment:

Page 8126, lines 1-2:.… since at least 1952 the year 1952 is mentioned a few times in the paper. Is this year only mentioned as it is the start of the data base in the Uhlemann et al. (2010) paper? To my knowledge (or at least from the paper) there has been no flood in 1952.

Authors' response:

The year 1952 is referred to as it is the start date of the period examined in Uhlemann et al., 2010.

Referee Comment:

Page 8127, line 14: Blöschl et al. (2013) has been published in HESS

Hydrol. Earth Syst. Sci., 17, 5197–5212, 2013, www.hydrol-earth-syst-sci.net/17/5197/2013/doi:10.5194/hess-17-5197-2013

Authors' response:

This has been changed.

Referee Comment:

Page 8127, Line 28-29: This hypothesis has also been one of the findings of Blöschl et al. (2013)

Authors' response:

This part of the manuscript has been revised; we have included references to the statements concerning the role of initial soil moisture for the June 2013 flood in BfG (2013) and Blöschl et al. (2013).

Referee Comment:

Page 8128, line 15… with the event of Uhlemann …Should probably be paper instead of event.

Authors' response:

Yes, we included event set

Referee Comment:

Page 8129, line 3: Now the first point becomes clear, Uhlemann's data set starts in 1952 and has been expanded to 2009. To my understanding, you updated the database from 2002 to 2009 (and I assume, also the 2013 event). Why did you not include the years 2010-2012? Because it is raw data? Also for the 2013, you have used raw data (see page 8130, line 18).

Authors' response:

See response to major comment above.

Referee Comment:

Page 8129, line 11: You say that there are 74 large scale floods in Germany in the period 1960-2009. Does this number include the 2002 event? Why are the 1954 and 2013 events not included in this number? What is the reason for this? You use the number 74 several times throughout the paper.

Authors' response:

The 2002 event is included, but not the 1954 and 2013 events. The reasons for the reference period are stated above.

Referee Comment:

Page 8129, line 21: The 1954 event is not included in the data set? How did you analyze the precipitation data for this event? Please clarify.

Authors' response:

This is now explained in the manuscript (see answer to major comment 2).

Referee Comment:

Page 8129, line 28: Maybe it should be „underestimates".

Authors' response:

This has been changed.

Referee Comment:

Page 8130, line 9-11: Compared to the past … this persistency is not significant and cannot explain the extraordinary situation in 2013. From this I would say there was at least one other event with a more significant persistency of the weather patterns. Could you clarify and give some more details?

Authors' response:

We decided to delete this paragraph with the large-scale weather patterns because it provides no useful insight.

Referee Comment:

Page 8130 – Section 2.3: In both, sections 2.1 and 2.3, you talk about hydrological data. Maybe you can combine these two sections.

Authors' response:

We agree that both section 2.1 and 2.3 provide information about hydrological data. However, the focus of section 2.1 is to provide background information about the large scale flood data base which provides general guidance for the analysis of meteorological and hydrological data. Section 2.2 and 2.3 provide more specific information on the data used for the evaluation of the June 2013 and the other events. Due to the suggestion of another reviewer the organization of sections has been changed.

Referee Comment:

Page 8132, line 7: What about the 1954 event? And the 2013 event?

Authors' response:

Yes, the two other events are also quantified in the same way. We considered this in the manuscript.

Referee Comment:

Page 8132, line 15: Is there a reason for using API30? Why not API20 or some other period?

Authors' response:

As shown in the time series of Figure 3, the month of May 2013 was extraordinarily wet, which is considered using API30; for API20 we would cut off some precipitation that already contributed to catchment wetness. However, note that the first 10 days account only for 8.3% of the total API (due to the weighting). Thus, the differences between API30 and API20 on average are small. In the revised manuscript we added some sensitivity analysis which also includes a variation of the API duration (30 and 15 days).

Referee Comment:

Page 8132, line 19: Where does the factor 0.9 come from?

Authors' response:

Several Authors use a value of 0.9 for the depletion factor. We added some references to this section. In the revised manuscript we added some sensitivity analyses which also include a variation of the factor k in the calculation of API namely k= 0.8, k=0.9 and k = 0.98 which covers the range of values proposed in the literature.

Referee Comment:

Page 8132, line 24: What about the 1954 event? And the 2013 event?

Authors' response:

Note that our reference period is 1960 to 2009 (reasons for that are stated above).

Referee Comment:

Page 8133, line 5: Why 5 year return period?

Authors' response:

In the revised manuscript we added some sensitivity analyses which also includes a variation of the return period used as the reference level in the calculation of severity indices.

Referee Comment:

Page 8134, line 5: See previous comment.

Authors' response:

Please refer to the answer given above.

Referee Comment:

Page 8134, line 17: Here you use the annual maximum series of daily mean discharge. In section 2.1, the database was compiled using the peak over threshold criterion. Does this mean, you reduced the number of 74 flood events to 60 (annual maximum values)?

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:

Page 8134, line 20: Why 5 year return period?

Authors' response:

We considered a variation of reference levels for calculating the different severity indices. 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.

Referee Comment:

Page 8137, line 12: Could you add some details about the size of the upper Elbe and upper Danube catchments in the figure caption? Or add a table with area of the catchments, mean precipitation, precipitation during the 3 events.

Authors' response:

We included the size of the catchments in the caption of Fig. 3.

Referee Comment:

Page 8137, line 26: If possible, add the location of the station Aschau-Stein in figure A1.

Authors' response:

The location has been included in Figure A1 as meteorological station

Referee Comment:

Page 8138, line 6 (Figure 5): Please use the same legend for all three subfigures, so that in each figure you have the same color for days 1, 2, 3,… 7 from the first day? The right figure will not change, as the difference between day 1 and day 7 is the biggest time difference, but for the middle (only little change) and left figure (big change) it will. I think, the patterns will not change much, but it will be more easily comparable and most likely, the homogeneity will be visible even better.

Authors' response:

We followed this suggestion and used for all three events a 7-day color bar.

Referee Comment:

Page 8138, line 22: Can you give a description of the LCL? What is a very low LCL, what is a high LCL?

Authors' response:

We added a short description: "…the lifting condensation level (LCL), which represents the level of the cloud base in case of synoptic-scale or orographic lifting,…". Furthermore, we provided more details and added the average values for the station of Kümmersbruck (which is located between the two precipitation maxima).

Referee Comment:

Page 8138, line 24: You can tell from the figures where Munich and Stuttgart are. But how about Meiningen and Kümmersbruck? Is it really necessary to name these stations? If possible, add the location in figure A1.

Authors' response:

The location of these stations has been included in Figure A1 as meteorological station

Referee Comment:

Line 8138, line 26ff: … precipitable water pw … was large …What are typical values for pw, why is a pw of 25 mm large? Could you add some details?

… which is far outside the interquartile range …Could you give the values in this paper? I know that I could check the values in Kunz (2011).

Authors' response:

We added a few more details and included the value of the 90% percentiles of the study of Kunz (2011).

Referee Comment:

Page 8139, line 15: Again, where exactly is Aschau-Stein?

Authors' response:

The location of these stations has been included in Figure A1 as meteorological station

Referee Comment:

Page 8140, line 2: Just as the previous comment, where is Zinnwald-Georgenfeld?

Authors' response:

The location has been included in Figure A1 as meteorological station

Referee Comment:

Page 8140, section 3.3.1: You show that the API 30 is high over large parts of Germany, and you give estimates of the return periods of the API, which are on the order of 5-30 years in large parts of Bavaria and 50 and more in the North of Bavaria. In the report of the BfG (Das Juni-Hochwasser des Jahres 2013 in Deutschland. BfG Bericht Nr 1793, Bundesanstalt für Gewässerkunde, Koblenz), there is a figure with results of soil moisture simulation. From this figure I would say that in the Northern parts of Bavaria the soil moisture was the highest value in the period 1962-2012. This would mean that the return period was around 50 years. The numbers correspond approximately.

My question is – are the results of your APIs and the soil moisture values of the BfG comparable?

Authors' response:

Both APIs and soil moisture values provided by BfG indicate a strong wetness anomaly in May 2013. The values provided by BfG refer to a specific date, namely the 31st May. For this specific date the values of 2013 are ranked in comparison to the values from 1962 to 2012.

In contrast, the sample used for the statistical analysis of API in our study is conditioned on the occurrence of a large-scale flood in the reference period (1960 to 2009). Hence our approach targets on the comparison of initial conditions before floods whereas the BfG evaluation is related to a very constrained time window during the year. This means that in our analysis the wetness conditions in May 2013 are compared to wetness conditions for instance in winter or spring if these periods are in advance to a large-scale flood. Given these differences the values are not necessarily comparable.

Referee Comment:

Page 8143, line 5: … comparison to other large-scale summer flood events…Why summer flood events? First, you mentioned POT, then AMS and now summer flood events – did you just concentrate on summer floods?

Authors' response:

This was just a mistake from a previous version, where we actually concentrated on summer floods. But we decided to consider all events. We changed this accordingly.

Referee Comment:

Page 8144, line 12:… less extended in August 2002 …„in" is missing

Authors' response:

This has been corrected.

Referee Comment:

Page 8145, line 23: … above around 40 increase …Increase - should be plural, not singular.

Authors' response:

This has been corrected.

Referee Comment:

Page 8145, line 11, Figure 12: Should be upper right corner.

Authors' response:

This has been corrected.

Referee Comment:

Page 8145, line 27: ERMS=13.2 What does this value say? Where does it come from?

Authors' response:

ERMS is the Root Mean Square Error of the LOWESS-Model interpolation compared to the sample of data used for the interpolation. The Root Mean Square Error can be interpreted as the standard deviation of unexplained variance and thus provides a metric of LOWESS Model accuracy. We provided this context also in the paper.

Referee Comment:

Page 8147, line 4: 1952? Again, the beginning of the Uhlemann data set?

Authors' response:

Yes, this year is mentioned as it is the start date of the period examined in Uhlemann et al., 2010.

Referee Comment:

Page 8147, line 10: In contrast to … Blöschl et al. (2013)…I think this statement needs to be clarified for several reasons.

First, you state that „initial wetness was a minor factor for the 1954 flood in Germany", whereas Blöschl et al. just looked at the Danube Basin. Second, Blöschl et al. said that the defining feature of the event was the spatial distribution with high precipitation (which is in line with your results); however, there was a pre-event which increased soil moisture. E.g., the Inn river had two peaks, one smaller (the pre-event) and the more extreme second event. The Danube in Germany just has one peak during this event. Third, you looked at the API30 and figure 7 clearly shows values of up to 150 mm along the alpine ridge in an area that is even larger than 2013. Your API30 includes the first block of precipitation mentioned before. Could you comment on this and clarify this in the paper?

Authors' response:

We agree that from a more localized perspective initial wetness is an important factor for the flood generation particularly at the Northern ridge of the Alps. We changed the text accordingly.