Hydrol. Earth Syst. Sci. Discuss., 10, C6903–C6907, 2013
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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Large scale analysis of changing frequencies of rain-on-snow events and their impact on floods" *by* D. Freudiger et al.

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Received and published: 26 December 2013

The authors would like to thank the Anonymous Referee 1 for a number of useful comments and two main recommendations to improve the manuscript: (i) to include trends in corresponding discharge observations of the RoS events and (ii) to clarify the analyses of trends in magnitude versus trends in frequencies of RoS events. Both aspects will be implemented in the revised manuscript.

Overall Comment
The paper examines the occurrence and frequency of rain-on-snow events (RoS) in the major German river basins and proposes threshold values for the classification these

events based on an analysis of the rain-on-snow event of January 2011. The analysis shows that upland basins are most influenced by RoS events and that there may be a shift from RoS from late winter to early winter. Overall I think this is a very interesting study on RoS events and a useful contribution to the literature on possible impacts of climate change.

Comment 1: What I do miss in the paper is a trend analysis of the related discharge events to support the conclusions. Using your classification method you can identify the relevant discharge events from the long daily mean discharge series that are available and it would be very interesting to see whether you can detect any changes in these data.

Reply: The authors appreciate this suggestion and agree with the reviewer that a trend analysis of the corresponding discharges in supplement to the trend analysis of the equivalent precipitation depth during RoS events would support the study. It will be added to the revised paper.

Comment 2: I do not understand why you are saying that you need to calculate the runoff (page 13250, lines 21-26) when there are discharge measurements available.

Reply: This paragraph in the discussion refers to the processes a model would need to include if it was to simulate rain-on-snow floods. We will rephrase the paragraph for more clarity in the revised paper. The advantage of our method is that we indeed do not calculate runoff, but only the equivalent precipitation depth, which constitutes potential runoff.

Comment 3: In the abstract you state that the occurrence of ROS events shifted from late to early winter and repeat this in the trend analysis (page 13244, lines 15-17). I think this is not visible in the results shown in Fig. 5, but there is some indication of such behavior in the analysis shown in Fig. 6 and Fig. 7, even though many of the trends are not significant. Showing some analysis of the discharge may support this statement.

Reply: Figure 5 shows the analysis of the trends in the magnitude of RoS events. As the Referee suggested, additional information on the frequency of RoS events is needed which could be given in form of a table. The percentage of RoS events occurring in late and early winter for time slices of 10 years as a fraction of the total number of events is presented in Table 1 (see supplement). The frequency of RoS events in late winter decreased in the upland and lowland, while the frequency of events in early winter stayed rather constant. A more detailed analysis of the frequency of RoS events will be included to the revised paper.

Further comments:

Section 2.3: Did you validate the snow model against snow observations?

Reply: The snow model was compared to the products of the snow model SNOW4 (German Weather Service: DWD) for the winter 2011. Since both simulations had different grid sizes, a frequency analysis was performed on the occurrence and amount of snow per area every day and led to very similar results (shown in Kohn et al. 2013, in press). Snow measurements in Germany are available in few locations only and hence unsuitable to be used in this large-scale study.

Page 13239, line 13-15: I do understand how you define the RoS events, but not the RoS days – which thresholds are you referring to in this case? Please clarify.

Reply: We will clarify the difference better in the revised manuscript. A RoS day is the day when all climatic conditions for a rain-on-snow event are met. Per our definition, this is a day when rainfall, snowmelt, and snowcover exceed 3 mm, 20

Page 13242, lines 7-10: Did you use the response time of 6 days for all basins or did you use different ones (since you state in the next sentence that an event can vary from one to dozens of days). Please clarify.

Reply: The 6 days is the maximum possible response time. This limit was chosen since in the case of January 2011, all basins responded within maximum 6 days. How-

ever, the response time varied for all basins between 1 and 6 days depending on the event, which allows taking into account the antecedent conditions (such as saturated or frozen soils) of different events.

Page 13243, line 1-2: I do not understand this explanation. Is rain not already included in the equivalent precipitation depth?

Reply: Yes it is. The sentence should read " the rainfall component of the equivalent precipitation is more important". The sentence will be rephrased for clarity.

Page 13244, lines 12-18: First you say that the late winter events become more frequent and then that there is a shift from late to early winter. Please clarify.

Reply: Thanks for noticing this inaccuracy. This sentence refers to increased (positive trend) in magnitude, while the frequency of events in late winter decreased. As suggested above, we will provide additional results of the analysis of the frequencies of events in the revised paper for more clarity.

Figure 5: This analysis shows quite contrasting results. You say that there is a shift of events from late to early winter (page 13244, lines 15-18). However, especially for the upland catchments, there seems to be an increase in magnitude in the late winter events, which is also a very interesting phenomenon. Please comment on this in more detail in the paper.

Reply: See above.

Figure 1: Could you please add the river network? Caption: remove the "a" before blue dots.

Reply: The river network will be added to Fig. 1 and the "a" will be removed in the revised paper.

Figure 2: I like this figure, but it is not so easy to read, could you please increase the diagrams a-f. It would also be interesting to see the runoff data for this flood event.

Reply: The size of the diagrams will be increased as suggested. Discharge data is given as the return periods in the map and we argue that this gives enough information about the observed January 2011 event. Adding observed discharge also to the diagrams, however, would make them too busy.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C6903/2013/hessd-10-C6903-2013-supplement.pdf

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 13231, 2013.