Response to reviewer 1

I thank the Anonymous Referee #1 for his comments. I have reproduced those comments below (in normal type), with my responses (in bold).

General comments: The study of Rücker et al. presents an analysis of rain-on-snow events in a Swiss Pre-Alpine catchment for two winters. The focus of this study lies on characterizing the snow conditions at the lysimeter measuring sites and analysing the snowmelt response with respect to the discharge response. Moreover, an isotope based hydrograph separation provides estimates for rainfall vs. snowmelt contributions to stream runoff. In this context, the present work contributes to a better process understanding of rain-on-snow events, being important for flood management and model calibration. The manuscript is well structured and the language quality is appropriate.

Thanks for these remarks.

Although the manuscript sections seem to be well balanced to me, surprisingly, I could not find research hypothesis at the end of the introduction section. These would make the study much stronger and would directly lead to the titles already chosen in the result section.

The fundamental hypothesis of our study is that vegetation and elevation substantially affect the generation and the isotopic composition of snowpack outflow, and thus snowmelt contribution to streamflow. We will include this statement in the revised version of the manuscript.

With respect to the result and discussion section, I noticed that the discussion part is sometimes too short and references could be added. This lack probably results from merging result and discussion section.

We are not sure what specific parts of the results and the discussion section the reviewer refers to. In any case, some of the processes discussed here (e.g., evaporation, sublimation, refreezing) have not been specifically investigated in our study, and thus we cannot go into further detail regarding individual mechanisms that cause changes in snowpack outflow or snowpack isotopic composition.

A last point addresses the use of tenses. I recommend to the authors to check again the when present tense and past tense was used. For example, results are normally described in past tense, which sometimes is not the case.

We will correct the use of tenses in the revised version of the manuscript.

Specific comment:
Page 3, Line 11: provide a reference for the effect of the canopy structure.

We will add the reference Koeniger et al., 2008.

Page 3, Line 21: please comment whether sublimation plays a role in this context as well.

We will include sublimation as a relevant process for isotopic enrichment of the snowpack in the revised manuscript.

Page 3, Line 29: snowmelt contribution.

We will change that in the revised manuscript.

Page 4, Line 1-4: please rephrase;how do you justify the rain snow transition zone?

We will indicate the exact elevation range covered with our snowmelt lysimeter systems. Within this elevation range, precipitation frequently shifts from snow to rainfall (Beniston, 2003; McCabe et al., 2007; Surfleet and Tullos, 2013; Zierl and Bugmann, 2005).

Page 4, Line 8: add more details, such as elevation of these measuring stations

We will add more details concerning the field sites.

Page 5, Line 7: please argue on the representativeness of your lysimeter sites with respect to the catchment (aspect, slope,elevation). What was the reason behind selecting MG and MF sites so close to each other?

The MG and MF sites were installed at official research plots where power supply was available (maintained by the Swiss Federal Institute for Forest, Snow and Landscape Research, WSL). The elevation, slope and aspect of the landscape are similar at the MG and MF sites, so that differences in snowpack outflow generation can be linked to the differences in vegetation cover. Because technical installations were not permitted in the upper part of the Erlenbach catchment, the HG site was installed at a nearby location with similar elevation and line power access.

Page 5, Line 13: 30 m difference in elevation is redundant with line.

We will change that.

8 Page 6,Line 13: please specify the improvements made for this site.

The improvements have already been described in detail in the next paragraph; we will add an introductory sentence to the first paragraph.

Page 6, Line 23: please comment and add in the text on fractionation though evaporation? Could the sampling bottles automatically closed after filling?

We will clarify the effect on fractionation on our sample bottles. The filled sampling bottles remained open until they were replaced with dry bottles once a week. One open sample bottle filled with 400 ml of a water sample of known isotopic composition was placed in the automatic water sampler each week to test whether evaporative fractionation occurred during the one-week sampling period. We did not find a substantial isotopic enrichment effect in these open sample bottles and thus assume that our sampling setup (automatic water sampler inside a protection hut) provides sufficient protection against evaporative fractionation of the snowpack outflow samples. For the automatic water samplers at the snowmelt lysimeter sites, the sample bottles were not modified. However, the sample bottles of the automatic watersampler sampling stream water of the Erlenbach were modified to reduce evaporative fractionation.

Page 7, Line 24: did you use a recognition software to transfer webcam pictures into snow depth data?

No, we did not use recognition software. We analysed the webcam pictures manually; we will clarify this in the manuscript.

Page 7, Line 25: was HG site subject to blowing snow?

We cannot exclude the possibility that wind drift occurred at the HG site, however, we did not observe substantial transport of snow due to wind during our field surveys. If wind drift occurred, it seems likely that wind drift affected all of the three individual lysimeter funnels similarly since they were located in close proximity to each other.

Page 8, Line 3: please use references to support these criteria.

These will be added.

Page 8, Line 15: were collected.

We will clarify this sentence.

Page 10, Line 7: please use a reference for the Gaussian error propagation

A reference to Genereux, 1998 will be added.

Page 11, Line 11: please characterize these cold conditions, how was the mean air temperature?

We will include the specific information: 22 cm of snow depth was reached during 6 days; mean air temperature was -6.6 °C.

Page 12, Line 6: replace “several times” by a number to better quantify.

This will be changed.

Page 14, Line 6: replace by “Further four ROS”.

This will be changed.

Page 15,Line 15: provide some statistics when reporting statistical significance

We do not understand this comment of the reviewer as it refers to the caption of Figure 3: “(a) Rainfall 15 volumes at the MG site (light blue) and snowpack outflow volumes at the HG (red, black-shaded), MG (yellow) and MF (light green: winter 2017; dark green: winter 2018) sites.”

If the reviewer refers to page 15, Line 10, we already provided a definition of statistically significant: “(i.e. larger than two times their pooled standard errors).” In the revised manuscript, we will provide the actual difference between the incoming rainfall and snowpack outflow volumes.

Page 15, Line21: 200-meter is already known and thus redundant, please remove.

This will be removed.

Page 16, Line 9:provide some statistics when reporting no statistical significance

In the revised manuscript, we will provide the actual difference between the incoming rainfall and snowpack outflow volumes.

Page 17, Line 8: to which processes do you refer to? Please rephrase.

We will remove this part of the sentence.

Page 17, Line 21: provide some statistics when reporting no statistical significance.

We will add the p-value.

Page 20, Line 4: be more quantitative with respect to variable responses and lag times.

We will include more information about the ranges of snowpack outflow volumes and lag times between events and sites.

Page 23, Line 4: 200-meter is already known, please remove.

This will be removed.

Page 23, Line 10-11: this is not clear. Is the elevation gradient defined by your sites not large enough to show the elevation effect?

Correct, we argue that a significant effect of elevation on the isotopic composition in bulk snowpack cannot be seen at our field sites, probably because the elevation difference of 220 m was too small.

Page 23,Line 24: provide results from a statistical test to show the similarity in isotopic composition.

We think that the number of data points is too small to facilitate a statistical analysis. Instead, we will rephrase our observation and will say that the isotopic composition of snowpack outflow during ROS events responds to (not reflects) that of incoming rainwater.

Page 30, Line 6: replace by “By using”.

This will be changed in the revised manuscript.

Page 30, Line 10: replace by “compared to that of open grassland”.

This will be changed in the revised manuscript.

Page 30, Line 18: as this is the summary, it would be helpful to repeat the initial criteria how you defined the ROS events (precipitation amount, initial snow depth threshold)

This will be added in the summary.

Page 30, Line 26: IHS is already introduced before.

OK, but we should keep this abbreviation in the summary to improve readability.

Page 31,Line 23: the correct co-author name is McNamara

This will be corrected.

Fig. 1: add a map of Switzerland locating your study site. Why is the forest in the lower part of the map dark green? Shading effect of the underlain hillshade? (in this case, hillshade data not present in the legend) MG seems to lie in the forest.

We will add a map of Switzerland to Figure 1. The shading represents the hillshade and not a change in vegetation cover. We will remove the hillshade and update the figure.

Fig. 2: please make air temperature line thicker and improve grey bars, which are not so visible

We will improve the figure.

Fig. 5: The snow depth subplots could be taller to increase visibility;

The same snowpack data are already shown in Figure 2. The snowpack data in Figure 5 are only shown to indicate the timing of snow-free periods at the sites.

Fig. 7: what is the meaning of the grey dashed line in all subplots?

We will specify this in the figure caption: including grey dashed lines that represent the range between -85 ‰ and -75 ‰.

Fig. 8: why are event #3 and #4 results unrealistic?

The event water fraction resulted in negative results because the isotopic compositions of stream water did not respond to the isotopic composition of the snowpack outflow (event water). We will clarify this in the figure caption.

References

Beniston, M.: Climatic change in mountain regions: A review of possible impacts, edited by H. F. Diaz, Kluwer Academic Publishers, Dordrecht., 2003.

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Koeniger, P., Hubbart, J. A., Link, T. and Marshall, J. D.: Isotopic variation of snow cover and streamflow in response to changes in canopy structure in a snow-dominated mountain catchment, Hydrol. Process., 22(4), 557–566, doi:https://doi.org/10.1002/hyp.6967, 2008.

McCabe, G. J., Clark, M. P. and Hay, L. E.: Rain-on-snow events in the western United States, Am. Meteorol. Soc., 88(3), 319–328, doi:https://10.1175/BAMS-88-3-319, 2007.

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Zierl, B. and Bugmann, H.: Global change impacts on hydrological processes in Alpine catchments, Water Resour. Res., 41(2), 1–13, doi:10.1029/2004WR003447, 2005.