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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Rainwater propagation through snow pack during rain-on-snow events under different snow condition" *by* Roman Juras et al.

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General comments:

The authors present a very interesting study about 4 sprinkling experiments with deuterium enriched water on natural snow covers with different initial conditions. The dynamics of snowpack outflow and the proportions of rainwater and melt water from the snowpack were analyzed using an hydrograph separation approach based on the deuterium signatures of the sprinkled rainwater, the snow cover and the runoff from the snowpack. The results of the study provide some very interesting insights into the dynamics of water flow within the snowpack during the artificial sprinkling experiments and are therefore highly relevant for the process knowledge of runoff generation dur-

ing ROS and consequently the improvement of hydrological models. The focus of the presented study is in the scope of HESS. I like the study very much. However, I recommend some revisions of the manuscript prior to a publication in HESS.

One of my main concerns about the submitted manuscript is the clear separation of experiment 1 from the other 3 experiments and the conclusions based on this one experiment having a cooler snow pack compared to the other experiments. From my point of view a snow pack described as "Snow temperature were mostly below the freezing point. . ." (page 6, lines 32 and 33) and the information from Table 3: Snow temperature -1.0°C with a standard deviation of 0.6°C can not be called a cold snow pack. The use of the term "cool" would be probably better. The results of experiment 1 are of course distinctly different from the other experiments. However, it is just one experiment and the other three experiments show also individual behavior. A clear separation and the conclusions are therefore critical. The authors should think about focusing on the individual behavior of each experiment. This would include a more detailed discussion on the shape of the observed runoff hydrographs in Figure 4 is lacking and would improve the study considerably. Why are the peaks of experiment 1 are decreasing from sprinkling period to sprinkling period, while the peaks in the other experiments tend to increase? Another point in that discussion may be the difference in the peak flows of total runoff and the rainwater fraction in total runoff. Furthermore, I highly motivate the authors to add a correlation analysis to further investigate the influences of snow pack properties (e.g. snow depth) on the observed hydrograph dynamics (e.g. lag times). This analysis would considerably improve the study and will provide further insight into the influences on different snow covers on the internal runoff generation.

The differences in total amounts of rainfall and runoff from the snowpack (page 9, lines 6 and 7 for example and Figure 5) are the reason why ROS events have the potential to generate more runoff than rainfall or snowmelt alone. Although the study in its current form is focused on the snow internal flow processes, please add a few more comments

and think about extending the discussion on that aspect of the study.

There is missing a few words on the scale issue (the experiment was performed on a square meter of snow. What can be expected on a larger scale, what literature is available on the runoff generation during ROS on larger scales?) as well a few words on the effects at the edges of the sprinkled snow block. Please provide also some discussion on the snowmelt energy balance during ROS and the influences this energy (that was certainly not available during the sprinkling experiments may have on the runoff generation within the snowpack. Furthermore, there is missing at least one figure in the results section showing the deuterium signatures during the sprinkling experiments.

Finally, I recommend removing or extending the analysis discussed in section 4.4. In its current form this part is too isolated from the rest of the study. However, the results of using a traditional hydrograph separation approach with snow or snowmelt isotope signature compared to the results with the presented approach would be highly interesting. The signature of the runoff observed prior to the actual sprinkling experiments (that is clearly visible in Figure 4 for all experiments) should be used, since Taylor et al. (2001 and 2002) recommend using the melt water stable isotope signature of the snowpack for an accurate isotope based hydrograph separation.

Specific comments:

I recommend the revision of the title of the presented study. Currently it is misleading, since the results of a number of artificial sprinkling experiments are shown and not the findings during a real ROS event.

In the introduction section there is missing more information about the previous modeling work (page 2, lines 9-12) as well as more details about the different flow concepts (page 2, lines 28-31).

There is missing some important literature (page 3, lines 1-5). Taylor et al. (2001 and

2002) point out that for hydrological applications (in their case isotope based hydrograph separation too) a correct representation of the snow pack is absolutely crucial. They recommend using the melt water stable isotope signature of the snowpack for that purpose.

From my point of view the use of “deuterium content” (page 4, line 9 for example) or “deuterium concentration” (page 4, line 30 for example) are not appropriate. Please use “deuterium signature” or “deuterium value” instead and correct throughout the whole manuscript.

Please provide a few more words about the melt runoff and its isotopic signature that was recorded already before the actual experiment started (page 4, line 9).

There are missing the information about the meteorological conditions prior and during the sprinkling experiments carried out.

Is c-solid (page 5, line 32) the average deuterium signature of the pre-experimental snowpack? Please specify. More information about the isotope signature (page 6, line 25) of the sampled snow profile would be very helpful.

Why was the deuterium value of the sprinkling water +22.61 per-mille VSMOW during experiment 3?

The paragraph on page 8 on lines 8 to 14 is very confuse and hardly understandable. Please revise for more clarity.

Do you refer to a certain experiment or to all experiments on Page 8, line 18?

Please mention clearly that the preferential flow may be due to the rapid development of fast flow paths in the snowpack when rainwater is infiltrating for more clarity (page 9, line 10).

Please provide a more comprehensive discussion on the hydrological response of the snow pack (section 4.2). Please provide more details about the Colbeck (1975) study.

Here some examples that may be relevant, among others of course, in order to improve the discussion on this aspect: Average liquid water holding capacity of 7% of an isothermal snowpack (Singh et al., 1997). Liquid water retention storage between 2% and 52% depending on snowpack conditions (Anderson, 1973). Kattelmann (1997): water outflow from 1 to 2 m snowpack between 4 and 6 hours after onset of rainfall.

The description of the methods are confuse at some points. Please provide the information on the methods used in the study in a very clear way.

There are mixed some results and discussion (page 7, lines 15-17 for example).

I recommend a careful proofreading of the final version of the revised manuscript prior to re-submission.

Technical notes:

Page 3, Line 23: average winter air temperature and mean annual winter precipitation for example.

Page 4, Line 30: Was is the deuterium signature of snow melt water or sampled solid snow later melted in the lab prior to analysis?

Page 5, Line 11: Date analysis would be the more adequate title of this section.

Page 6, Line 9: Please revise equation 5 (Q-rain-in).

Page 5, Line 19: “was” instead of “were”.

Page 8, Line 20: rain water

Page 8, Line 30: deficit instead of deficiency

Page 8, Line 32: “. . .rainwater contribution, however, increased. . .”

Page 9, Line 8: The title of section 4.2 is confused. Please revise.

Page 9, Line 22: Please provide some literature at this point.

Page 9, Line 29: The point at the end of the sentence is missing.

Page 9, Lines 31 and 32: This sentence is too vague. Be careful with statements on the energy exchange processes within the snow pack based on the results of the study. Please revise this sentence.

Page 9, Line 32: Space too large.

Page 10, Line 3: “. . . refrozen or stored as liquid water in the snow pack.” Please revise.

Page 10, Line 9: This sentence is too vague. Please revise.

Page 10, Line 11: Please provide information about were (section) the discussion on piston flow can be found in the manuscript.

Page 15, Table 1: Please revise the dates in table 1 (missing point, space).

Page 15, Table 2: Is this table really needed? Please check if the content can be included to the text or added to another table.

Page 16, Table 3: Please provide SWE of the snowpack in the table. Please provide the information of the structure analysis (grain size etc.) as mentioned in the methods section. Please revise unit of bulk density (kg*cm-3 instead of kg.cm-3). Please provide percentages to allow a better comparison of the different experiments.

Page 16, Table 4: Please provide units (per-mille VSMOW) in the table. Should it be different instead of difference in the header of the table? However, please revise the header text for more clarity.

Page 16, Table 3 and Table 3: Please thick about combining the two tables.

Page 17, Table 5: “. . .events” in the table caption. The peak times (10 min) for sprinkling period 3 and 4 in experiment 3 seem to be wrong. Please check.

Page 20, Figure 1: A real picture of the set-up of experiments would be nice to see.

Page 21, Figure 2: The influence of rainwater isotope signature is missing. Is this figure

really relevant and needed for the study?

References:

Taylor, S., Feng, X., Kirchner, J. W., Osterhuber, R., Klaue, B., and Renshaw, C. E.: Isotopic evolution of a seasonal snowpack and its melt, Water Resources Research, 37, 759-769, doi:10.1029/2000WR900341, 2001.

Taylor, S., Feng, X., Williams, M., and McNamara, J.: How isotopic fractionation of snowmelt affects hydrograph separation, Hydrological Processes, 16, 3683-3690, doi:10.1002/hyp.1232, 2002.

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