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Discussions
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Interactive comment on "Modeling liquid water transport in snow under rain-on-snow conditions – considering preferential flow" *by* Sebastian Würzer et al.

Anonymous Referee #1

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The paper presents a new water transport scheme for the 1-D multi-layer physics-based SNOWPACK model that accounts for preferential flow effects. The model bases on a dual-domain approach and solves Richards equation for matrix and preferential flow. The area of fingers is explicitly parametrized using results from previously available laboratory experiments. Exchange of water between the matrix and the preferential domains is ruled either by water entry pressure head or by water saturation. The approach is evaluated using an extensive dataset of rain-on-snow events (ROS) from two different locations within European Alps and some field experiments. The proposed scheme demonstrates an improved performance at the scale of single ROS events and at the scale of a snow season.

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Including preferential flow in snow models represents an important goal for snow hydrology. This is because it can provide an efficient routing of liquid water through snow and can generate snowmelt runoff earlier than expected. A frequent limitation for snow modelers is that the process understanding is still limited. In this regard, the paper proposes a parsimonious approach that parametrizes the portion of area occupied by fingers and thus takes this process into account without using a full 3-D geometry. The evaluation strategy is extensive and thorough and the paper is generally well written. I have some suggestions for authors that may be included with little effort. I can therefore suggest publication of the paper pending some (minor) revision.

My main suggestion regards Section 3 (Results) and 4 (Discussion). While I generally found both sprinkling experiments and the focus on long-term datasets well motivated and discussed, I am unsure that the two natural ROS events will provide a specific insight into this evaluation. Discussing some “real-world” applications is clearly important, but authors already do that using around 100 ROS events from Davos and Col de Porte. Moreover, results are “partly contradictory” when compared to artificial ROS simulations and this may be understandable as the physics is complex and data may be noisy. This is why focusing on a larger number of events (Section 3.3) is clearly more meaningful. So I suggest that either authors elaborate on the implications of these two specific events, or they remove Section 3.2, move this focus in the Discussion and use it as a starting point for discussing future research.

In the Discussion, I would also try to comment a bit more extensively on the dual-domain approach. For example, Eq. 1 relates the area of preferential flow to grain radius, which is for sure the most important variable ruling heterogeneity of water in snow. Because experimental observations of this process are still limited, may you suggest some directions for future research in order to improve this parametrization? May it also depend on supply rate or other conditions of the snow? More importantly, the model includes a parameter that needs to be calibrated. While calibration is helpful to compensate for a lack of physical understanding (and this is definitely the case with

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preferential flow), it may be interesting for other users to know how did you choose the value of this parameter, or which would be the best calibration protocol for it. This is especially important where lysimeter data are not available. Which is the sensitivity of your results on the value of this parameter?

Specific comments: - Abstract: I found lines 11 – 17 a bit wordy. Could you try to summarize this? Furthermore, I would also specify the meaning of “balanced” (line 24) as it may be unclear for diagonal readers who are not going to screen the entire text;

- Line 29 page 2: may “capillary gradients” work better than “capillarity” alone?

- Line 17 page 3: remains -> remain?;

- Line 20 page 4: may authors include a brief comment about the reason why snow depth is constrained to observed values in a hydrologic application?

- Section 2.2: I would probably be more explicit about the simulated effect of preferential flow on water velocity. In my understanding, the model accelerates liquid water flow in snow because it concentrates water mass in small fingers where unsaturated conductivity is larger than in the matrix domain (and where refreezing is not allowed). Is this a correct interpretation? If yes, I would write something similar in the text in order to clarify this point.

- Eq. 1: should the exponent be negative as in Wever et al. (2016) on TCD?

- Line 19 – 20 page 6: may authors clarify which features of the sprinkler make it “especially developed for sprinkling on snowpack”?

- Line 18 and Table 1: did you choose different portions of snowpack for your experiments at the same sites?

- Line 27 page 7: I think including cumulative plots in Fig. 2 may definitely help to understand this methodology;

- Line 28 page 8: is this Table 1 instead of 2?

- Section 3.3.2: may you include some additional information about the observed variance of these plots? This may be helpful to put these lines in context;

- Lines 4 – 22 page 11: I found this paragraph a bit difficult to read. Could you please try to rephrase it and try to reorganize the information around the most important findings? This is a key step in the paper and therefore I think it should be very clear.

- Lines 24 – 28 page 11: which is the temporal resolution of lysimeter data? May this temporal resolution play a role for this analysis?

- Line 28 page 12: may refreezing be another important process here? This may be also important at lines 6 – 15 page 13.

- Lines 1 – 6 page 14: Katsushima et al. 2013 used a limited range of snow density in their experiments, and this range mostly includes densities greater than 380 kg/m3. May this help to explain this correlation?

- Figure 2: may the bar be above the x-axis?

- Figures 3, 4, etc.: could authors use different colors for the PF or BA approaches? In these figures, they are very similar and this is not very clear;

- Figure 6: is measured runoff black instead of red?

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