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Interactive comment on "Simulating ice layer formation under the presence of preferential flow in layered snowpacks" *by* Nander Wever et al.

Anonymous Referee #2

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The authors have chosen to address a challenging topic and the results of this effort reflect the difficulty of simulating a heterogeneous, three dimensional, multi-process phenomenon in a 1-dimensional framework. While there is certainly much progress and future work to come in this area, the authors have presented a valuable analysis and initial framework that can be adapted and built upon in the future. As such, I am recommending that this work be accepted for publication in The Cryosphere, following some minor revisions that I believe will improve the quality and usefulness of the work.

Much of the framework relies on the interpretation of the results of Katsushima et al. (2013) as interpreted by Hirashima et al. (2014). They found that when water had reached the bottom of the profiles in their laboratory experiments, that the fractional area at 4 cm depth was smaller with larger snow grain size. The wetted fraction was interpreted here as the preferential flow fraction. As grain size decreased the wetted

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fraction increased and this was interpreted as the preferential flow fraction being larger. However, as this extends to the finest grain size, it is stated that no preferential flow was observed, and indeed if slower matric flow was happening, the deepest wetted area would be larger and more uniform. If that is what happened, and matric flow had extended beyond the 4 cm depth, then we have no clear transition defined between the two flow regimes. I would like the authors to discuss the interpretation of the experiment on which Figure 2 is based.

Specific Comments:

P2 line 15: Although I would not expect a through presentation of the work of Colbeck (1979) or Marsh and Woo (1985), the authors have stated that these works were not widely adopted. A couple of sentences summarizing the main concepts presented in these studies, and any weaknesses that may have resulted in their lack of adoption, would help to inform the readers about the need for progress in this area of research.

P2 lines 19-21: I suspect that the specific application suggested in the example would require at least a 2-d model.

The dual-domain approach is a good starting place. Given that the authors point to three flow regimes (matric flow, flow fingering and macropore flow), it would seem appropriate to include multiple flow domains in the future; one step at a time.

P7: I suspect that there would be an interaction between the layer thicknesses (resolution) and the threshold of defining ice lenses / layers. A thicker layer would require more water equivalent to reach a given threshold density, and this would be harder to achieve in terms of water and energy transfer. A higher resolution or finer layers should enable higher threshold density values for defining ice layers.

P8 lines 7-17: This is an honest discussion of the performance issues but also shows that this methodology may be useful for future development.

P9 lines 1-5: Was the precipitation type generally known in the observations or was

this 2003 event a specific example of a known case in which the model misclassified the precipitation type? In any event, if it was known that the precipitation was rain, the model's diagnosis could be overwritten for this event, and if precipitation type was generally known, the model could be fed rainfall and snowfall separately. It would remove a source of uncertainty from the results. If the precipitation type was not generally known, but merely appeared to follow expected patterns save for the 2003 example, then it is not necessary to make any changes, given the size of the dataset.

P9 lines 7-13: I would expect the spread in simulated snow density to be somewhat smaller than observed with such a model, based on the fact that snow pits sample small spatial areas, and the presence of discontinuous ice layers and fingering may increase the number of samples necessary to obtain a reliable estimate of the mean density and its variability at a given depth. The PFP simulations in Figure 6 appears to capture the density distribution slightly better than the Richards equation alone. Have other statistical measures been explored as alternatives or in addition to r^2? A comparison of the mean and variance may show closer agreement with the PFP simulations. There is Willmott's index of agreement or one of the revised formulations. The objective is not to choose the statistic that makes the model appear better, but r^2 has been criticized as being insensitive to important factors of model performance.

In looking at Figures 8 and 9, there are differences in the performance of the REQ and REQ+PF models from year to year. It would be interesting to compare the conditions against a ranking of differences in r^2 (Fig. 8) and arrival date (Fig. 9). Are there specific snowpack or meteorological conditions that are correlated with the differences in performance between years? Knowledge of this may be useful for future model development.

Technical Comments:

P1 line 18: Change 'extend' to 'extent'

P1 line 20-23: Change 'Water may flow... instead (Eiriksson et al., 2013)' to 'Water

may flow laterally over ice layers or crusts, which reduces travel times and has a significant impact on catchment scale hydrology; alternatively, preferential flow in snow may promote vertical percolation instead (Eiriksson et al., 2013)'.

P1 line 23: This reads as if the reader is familiar with the increased melt on the Greenland Ice Sheet, which is likely to be true but, I would add a word or two to indicate the time frame.

P1 line 24: Change 'extends in' to 'extents, on'.

P2 line 6 (possibly elsewhere): I find the use of the term 'snow covers' to be awkward. I suggest the use of the term 'snowpack' or 'snowpacks'.

P2 line 15: I would change 'deployment' to 'adoption'.

P7 line 5: Change '... given the suspicion of problems...' to '... due to suspected problems...'.

P9 lines 8-9: Change '.... is well reproduced...' to '... is reproduced well...'.

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