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Interactive comment on "Solving Richards Equation for snow improves snowpack meltwater runoff estimations" *by* N. Wever et al.

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Wever et al. (2013) introduce a new framework for handling liquid water percolation and associated processes (phase chage, ponding, etc.) in the detailed snowpack model SNOWPACK. Overall, the scientific content of the paper is very good, the paper is well written and surely suitable for publication in The Cryosphere. I have a series of suggestions and comments that aim at making the paper even better. Indeed, I think this publication could become a landmark contribution in snowpack modeling and the authors should be encouraged to reach this level of excellence. Although I found the English pretty good, I encourage the authors to have their article proof-read by independent colleagues (not necessarily native English speaker) to remove the few awkard formulations that can be found in the manuscript, and which are not addressed

below.

General comments

This article is a truly innovative and solid contribution to the field of physically-based modeling of snow. What could make it even stronger is to evaluate the performances of the Richards Equation implementation in SNOWPACK at other sites that Weissfluhjoch. Two other sites come to mind to carry out an extension of the evaluation at other sites : a site in Japan referred to in the article (Page 2391, line 4) could have been used as a further test site. Data from Col de Porte in France contain 18 years of data ready to use including hourly records from two neighbouring lysimeters (Morin et al., 2012), which could be used to test the model in a contrasting site featuring for example rain-on-snow events in the middle of winter, which is not often the case at Weissfluhjoch. Conversely, it would be very appreciated by the snow modeling community that the 14 years data set used here to drive and evaluate various flavours of SNOWPACK are made available publicly for evaluating other models under the high-mountain conditions encountered at Weissfluhjoch. I look forward an upcoming contribution where the impact of the implementation of the RE in SNOWPACK is evaluated in detail not only in terms of snowmelt runoff but in terms of snow stratigraphy, where significant improvements are expected over bucket-like approaches (preliminary results shown at the DACA-13 conference in Davos were extremely encouraging in this respect).

Regarding bucket-approaches, have the authors attempted to study the impact of the model internal time step on the result of the bucket formulation ? Trying a few typical values may be useful the widen the generality range of the conclusions reached here.

Specific comments

Title : The title should better reflect the content of the article. In particular, it should be mentioned that the model was tested at one high-altitude site, which somewhat reduces the generality of the title taken as a firm statement. It could also be mentioned that the Richards Equation was implemented in a detailed multi-layer snowpack model, which is one possible approach among others to model snow for hydrological purposes.

Abstract :

Page 2374, line 4 : “snowpack model” : I think it would be useful to state the name of model in the abstract.
Page 2374, line 5 : “high alpine site” : better name the site in question.

Introduction:

Page 2375, line 18 : “small grains” : It could be precised which grain size metric must be employed for such processes ; later same line : replace “course”‘by “coarse” (?)
Page 2376, line 16 : it is unclear what means “gravitational flow resulting from RE”. While it is true that the original publication describing Crocus (Brun et al., 1989) mentioned an equation explicitly describing the speed of downwards water migration, the bucket approach has been used in all further studies using Crocus and the current formalism (bucket) is described in Vionnet et al. (2012). I don’t know whether such changes over time also occurred in SNTHERM, it may be worth checking with the current managers of the code.
Page 2376, line 25 : the Hirsahima et al. (2010) scheme should be introduced either before or at least a concise explanation of what this scheme is should be placed here. Otherwise, the reader is left to referring to the original publication. Later on, this scheme is referred to as “NIED” if I understood well ... I also think it should be mentioned here that two flavours (i.e., the use of 2 parameterizations of the van

Genuchten model) of the full RE scheme are employed and compared.

Section 2

“LWC production” is mentioned several times in the paper although I didn’t find a precise description of how LWC production was computed, and with which model set-up. Since this term is used in the Results and Discussion section, I think it deserves a description in this section.
Page 2378, line 25 : “grain radius”: please specify how is grain radius defined here.
Page 2379, line 15 : I would suggest to replace “Yamaguchi” and “Danen” by “RE-Yamaguchi”and ‘RE-Danen”, respectively, to avoid confusion with the NIED scheme.
Page 2380, lines 20 to 23 : The compared impact of density and “grain size” evolution of snow permeability is not necessarily always going in the same direction as stated by the authors. Field experiments and model runs recently reported by us (Domine et al., 2013) show that opposite evolutions can be found under the same meteorological conditions depending on the magnitude of the temperature gradient. Also, the use of the Shimizu (1970) regression curve for evaluating snow permeability from snow properties was recently challenged by new tomography-based experiments and new regressions were proposed which could be used here as an alternative to the Shimizu (1970) formalism (not all such studies are quoted here for the sake of brevity - see a description of some of these studies in Domine et al., 2013).

Section 3

Page 2381, line 18 : the range of maximum snow height is given with a high level of precision (1cm resolution), but at this stage it is not said over which time period this range is applicable. This needs some reformulation.
Page 2381, line 20 : I think it should be made more explicit what, within the dataset described, is used to run SNOWPACK, and what is used to evaluate it. There are so

many ways to run SNOWPACK using inputs of various levels of complexity that giving such information is critical to the reader.
Page 2382, line 10 : replace “mm” by “mm w.e.” (or, even better, kg m^{-2})
Page 2384, line 1 : replace “depth” by “thickness” (?)
Page 2386, line 5 “winter snow season” : this needs to be better defined.

Section 4

Page 2389, line 15 : it may be mentioned that the initial publication describing Crocus was already comparing model ouptut with lysimeter data, essentially with the same conclusions (Brun et al., 1989).
Page 2389, line 27 : this sentence will become clearer once “LWC production” is better described in the methods section.

Section 5 / Conclusions

Page 2393, line 22 : errors originating from the model construction can also have varying effects depending on the season.
Page 2394, line 22 : perhaps replace “melt” by “wet”

Appendix

Page 2395, line 10 : the use of “considerable” here is strange. Replace by “deep” ?
Page 2395, line 21 : could you describe a little more how is determined N_{iter} ?

Figures

Figure 1: Since snow seasons are rather independent from each other, maybe the solid lines connecting the individual errors could be removed, and the Runoff sum for each year denoted with a different symbol (without connection from year to year) ?
Figure 2 : why is not LWC production included in panel (b) ?

Figure 4 : is the figure representing one particular year, or all years of simulation ? The reference to this figure in the text is very brief and does not allow to understand exactly how the figure was produced and needs to be interpreted.
Figure 4 : same comment as Figure 1
Figures 6 and 7: it may be mentioned in the caption what is the size of the bins that were used to produce the plot. Also, please replace “mm” by “mm w.e.” at least.

References

Brun, E., Martin, E., Simon, V., Gendre, C., and Coléou, C.: An energy and mass model of snow cover suitable for operational avalanche forecasting, J. Glaciol., 35, 333 – 342, 1989.

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Vionnet, V., Brun, E., Morin, S., Boone, A., Martin, E., Faroux, S., Moigne, P. L., and Willemet, J.-M.: The detailed snowpack scheme Crocus and its implementation in SURFEX v7.2, Geosci. Model. Dev., 5, 773–791, 10.5194/gmd-5-773-2012, 2012.

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Interactive comment on The Cryosphere Discuss., 7, 2373, 2013.