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Interactive comment on "A 2D model for simulating heterogeneous mass and energy fluxes through melting snowpacks" *by* N. R. Leroux and J. W. Pomeroy

Anonymous Referee #1

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In this paper, authors developed new two-dimensional water transport model combining the processes of snow temperature change, snowmelt, refreezing and heterogeneous water transport model. Simulations of preferential flow considering the melt-freeze processes are very important, and this model has a potential to advance modeling studies of heterogeneous water infiltration in the cold snowpack. Components used in this model are basically theories in existence. Water infiltration schemes are almost same with Hirashima et al. (2014). Schemes of temperature and melt-freeze processes are already developed by Illungasekare (1990) and Daanen and Niever (2009). They also simulated interactions between liquid water and snow temperature.

Therefore, analysis of simulation results should show advantage of this combined

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model and provide informative scientific results (e.g. enhanced accuracy or new simulation which cannot be performed by previous model). Authors showed many simulation results in sensitivity analysis, but discussions of sensitivity analysis were just confirm processes that were already known qualitatively. Furthermore, model application in section 6 did not apply to real snowpack observation data but only virtual snow stratigraphy. Due to lack of validation using real data, they could not show the accuracy of this model in the analysis quantitatively. Consequently, despite the model is innovative, this study could neither show availability to reproduce the real snowpack nor suggest additional experiment to improve the accuracy of the model sufficiently. Authors are not necessarily required to perform laboratory experiment or field observation by themselves, but in that case, they need to find any literature of real data to compare with the simulation results. If this model has new idea (e.g. new technic to compute quickly) or shows the new simulation that can be performed only by this model (for example, simulation of ice layer formation), this paper may make informative components even if simulation result is not compared with real data. In my opinion, although this model itself seems to be useful, authors should consider the direction of numerical analysis to produce informative scientific results.

minor comments

P3 L9 the model of Hirashima et al. (2014) is not limited to small artificial snow. Although their model neglected melt freeze processes, their model did not neglect multi layer. Simulations in that paper were performed in single layer snow because laboratory experiments were also performed using single layer column. They performed multi layer simulation in following proceedings although validation was not performed. Therefore, it should not be included as advantage in this model. You should replace with following sentence.

“However, their model was limited to isothermal snow samples, neglecting melting at the surface, and refreezing of liquid water.”

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1) Hirashima, H., S. Yamaguchi, and Y. Ishii, 2014. Simulation of liquid water infiltration into layered snowpacks using multi-dimensional water transport model. ISSW proceedings, 48-54.

2) Hirashima, H., S. Yamaguchi, and Y. Ishii, 2014, Application of a multi-dimensional water transport model to reproduce the temporal change of runoff amount. ISSW proceedings, 541-546.

P5 L10 Eq. (8) is not the equation of dE Rooji and Cho (1999). Katsushima et al (2013) found that the water entry suction of snow was about 1 cm larger than the estimated value by the equation of Baker and Hillel (2000) (hwe(m)=0.0437dˆ-1+0.00074). And then, Hirashima et al. (2014) added 0.01 in their equation. Furthermore, rc is half of d, so (1/2rc) is correct, not (2/rc).

P6 L25 How did you decided to use this boundary condition? What kind of situation were you going to reproduce? (e.g. For laboratory experiment, both right and left hand boundary should be no-flow boundary. For natural snow, both of them should be periodic boundary condition or free drainage boundary.)

P8L11-12 As mentioned in comment P3L9, Hirashima's model can consider multi snow layer. So it should be replaced with following sentence.

"However, their model was limited to an isothermal snowpack. "

P8 L17-25 Both runoff in the graph of Fig.3 are actually impossible. Graph without PFP is simulation result considering water entry suction without heterogeneity. This infiltration condition is different from matrix flow. In reality, the condition with completely homogeneous snow is impossible. Hirashima et al. (2014) showed the simulation of water infiltration in same condition in order to show that considering only water entry suction without heterogeneity is not sufficient to reproduce the preferential flow. The discussion of this impossible phenomenon does not have scientific signification. Graph with PFP also has problem. In the real condition with PFP, it is quite unlikely to occur

such a cyclic pulse in red graph. Isn't it just a fault of this model?

P9-10 Fig. 5 and 6. Irreducible water content, α and n value were determined from the water retention curve in laboratory experiment to optimize the curve. Thus, these values are linked to other parameters each other. Therefore, individual sensitivity experiment with static values of two parameters does not have scientific signification to describe the effect of estimation error. Sensitivity analysis for snow temperature has a potential to show the scientific informative result using this model. However, this result just showed that the low snow temperature leads to delay of runoff by refreezing. It lacks the impact to show advantage of this model.

P10-11 Fig. 7 Applying new numerical model for natural snow is beneficial. However, it was not applied to real data obtained by snowpack observation but to virtual snow layer. If this model applied to real snow using snowpack observations and simulate water infiltration for the duration of interval of two snowpack observations, simulation result can be compared with the real data. If this model can, I expect the reproduction simulation of ice layer formation in the snowpack in this model.

Overall, although the developed model itself is advanced numerical water transport model, numerical analysis could neither show the advantage nor accuracy of this model. Discussion without any validation by real data could lead erroneous opinion such as the case of runoff in Fig. 3. Furthermore, it is necessary to perform numerical analysis to provide scientific informative result. I believe that if this model is validated using real data and show reproduction simulation of ice layer formation, this model can provide scientific informative results.

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