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Interactive comment on "Three-phase numerical model for subsurface hydrology in permafrost-affected regions" *by* S. Karra et al.

Anonymous Referee #2

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General comments

The manuscript presents a non-isothermal, single-component, three phase model for subsurface hydrology. Authors have implemented the presented formulation in massively parallel subsurface flow and reactive transport code PFLOTRAN. With its free availability and open source licensing developed model will be serve as a valuable resource for interested users.

Manuscript is fairly well written, however, some of the simulation results are lacking appropriate discussions. It would be important to discuss the relevant processes and physics of the problem besides showing the results. That would help the readers understand the premise behind the simulations and their results.

Comments on model formulation

While model formulation has been explained in detail in the manuscript it appears to be building upon previously published papers by the authors Painter 2011, Painter 2012 and Painter and Karra 2013. Its not apparent from the manuscript as to what parts of the formulation presented in the current manuscript are new from the previous papers.

van Genuchten, 1980 model has been employed for the soil retention curve (S_*) in Equation 8a. Form of van Genuchten model used in the paper (Equation 9) is for calculation of effective saturation (instead of saturation). It can be inferred from Equation 9 that residual saturation has been assumed to be zero in the formulation. However, manuscript does not mention/discuss any such assumption. For the purpose of clarity it would be helpful to discuss such assumptions in the text.

Comments on model validation/testing (Sections 3, 4, 5)

Section 3 presents the comparison of the model with the experimental data. Comparisons in the Figure 2 has been referred to but without any discussion at all. Differences in the water content at the cold end of the tube has been acknowledged, no explanation for why that's happening in the model has been offered besides references to previous studies with similar observations. While experimental set up has been noted, there is no mention of initial and boundary conditions that were used for the simulations. Please provide appropriate details and discussions for completeness.

Section 4.2 describes the modeled domain with talik in the text but without a visual its very difficul to understand the set up. A figure showing the simulation set up would be helpful for the readers.

Section 5 examines the effect of vapor diffusion using a simulation set up. Due to the poor quality graphics its hard to interpret the plots corresponding to different times. Even with a 3000yr simulation time, the thickness of frozen layer in Figure 6(a) appears to be a really small and not chaging much over time. Temperature at the bottom of the

domain appears to be increasing over time even when a -5C temperature is being applied at the top. Is that because of the geothermal flux boundary at the bottom. Please provide discussions to explain the figures and what may be going on with physics.

Technical corrections

Section 2.4 Page 160 Line 25: Please check if X_g should be X_w^g

Figure 5 and 6 legends are difficult to read. Its to understand the lines corresponding to different times on the plot.

Figure 8 and 9 requires sub-figure captions to explain what they are. They currently are difficult to read. Legends are not legible.

Interactive comment on The Cryosphere Discuss., 8, 149, 2014.