The Cryosphere Discuss., 4, C876–C878, 2010
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The Cryosphere Discussions



# *Interactive comment on* "An energy-conserving model of freezing variably-saturated soil" *by* M. Dall'Amico et al.

**Anonymous Referee #1**

Received and published: 1 October 2010

General comments,

The authors describe an energy conservative model of soil freezing and provide a numerical scheme to compute the soil temperature and moisture content. In the past, this area of research have received a great amount of attention, and hence a wide variety of models have been developed, as discussed in the Introduction. One of the obstacles in the previous studies was to formulate closure relationships that link together the soil temperature, pressure, water flux, volumetric contents, etc. In this paper, the authors use a generalized Clapeyron equation as a closure relationship and consequently link the unfrozen liquid water content and soil temperature. Based on this relationship, the energy and water mass conservation principles can be cast into an easy-to-compute system of partial differential equations. The authors propose a conservative discretiza-

tion and a usage of globally convergent iterations to facilitate computations.

I do have some concerns and suggestions to improve the presented manuscript:

1) The derivation of equation (6) that is THE key to form the closure relationship is not clear to me. How do you integrate equation (4) and obtain the Heaviside function in this equation? The same remark is relevant to the derivation of equation (8). It would be beneficial to the reader to understand how you obtain these equations? I am sorry, but in its present form the derivation of equation (6) does not make sense to me.

2) The governing equations (12) and (16) are not the equations that are being solved. The equations that are actually being solved are scattered among several pages. It would be great to see the final system of equations with the boundary conditions.

Particular comments,

1) Section "Freezing-soil models", p. 1247, Line 10, "...to our knowledge this equation has never been fully derived from a thermodynamical point of view leaving some doubt on its limitations. " An attempt to derive the generalized Clayperon equation from the point of view non-equilibrium thermodynamics was done by M. Mikkola and J. Hartikainen, (2001) "Mathematical model of soil freezing and its numerical implementation", Int. J. Numer. Meth. Engng; 52:543–557

2) Section "Mass balance", p. 1251, Equation (12). The reference is missing. I believe that this equation can be found e.g. in Harlan, R.L., (1973). "Analysis of Coupled Heat-Fluid Transport in Partially Frozen Soil", Water Resource Res., vol. 9, pp. 1314 - 1323.

3) Section "Energy balance", p 1252, Equation (16) The reference is missing again.

4) p 1258, Line 10, " It is important to notice that if the Newton method is solved exactly, energy is preserved . This differentiates the new method from previous work." Could you please run a test and show that the mass and energy are actually conserved in the system? Could you please give references to "the previous work"?



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5) p 1259, Line 15, " A considerable improvement was obtained changing to the so-called globally convergent Newton scheme". A reference is missing.

6) The derivation of the well-known analytical solution in the Appendix is not really necessary, just provide a reference.

7) Figure 3, Could you please plot the solutions by lines with symbols? Otherwise, if this graph is printed in black and white, it is impossible to distinguish between colors. The same remark is valid for Figure 4.

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Interactive comment on The Cryosphere Discuss., 4, 1243, 2010.