**The Cryosphere
Discussions**

Interactive
Comment

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

M. Dall'Amico et al.

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We are grateful for the constructive comments of Referee #3 that have helped to improve the strongly revised manuscript. Below, we have listed the essence of each issue raised together with a short reply and the revised text or its location where appropriate.

Comment: P1245, L10. It is hard to believe that the energy conserving freezing algorithm based on the apparent heat capacity method is the new formulation.

Reply: Actually the novelty of our formulation is not the use of the apparent heat capacity, rather: (i) the notation on the conservation of internal energy rather than the differentiation between sensible and latent term. This allows to: obtain a more general form of the diffusion-advection equation, similar to the mass balance equation. There-

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fore the numerical method used in the energy equation could be further used to the mass balance equation, too. Furthermore, (i) the ice content (i.e. the soil freezing curve) derives from the freezing=drying assumption and from the form of the soil water retention curve. This implies that the ice content depends not only on temperature but also on the total water content. (iii) Finally, the numerical scheme, based on the splitting method, provides new insights in dealing with the high non-linearity typical of the apparent heat capacity.

Comment: P1260, L10. Open acronym SFCC

Reply: With SFCC we intended Soil Freezing Characteristic Curve. Actually we forgot to mention it. In any case, as this acronym is not used throughout the article, we decided not to use it so we removed it from the text.

Comment: Figure 4 (left) the curves of unfrozen water content. The shape of the curves of unfrozen water content looks very similar for various soil structures. Actually, the clay curve is more gently sloping. Assouline and Tartakovsky (2001) tested expressions for relative hydraulic conductivity against different soil types and found that it fits data better than the widely used models of Brooks and Corey (1964) and van Genuchten (1980).

Reply: Thank you for the precious suggestion. Actually, in this paper our objective is to test the improved numerical scheme (coupled water and heat balance) and to point out some problems (oscillations) that arise from the high discontinuity in the apparent heat capacity. Even not done in the paper, it is theoretically possible to change Van Genuchten parameterization with any other. Furthermore, the session regarding the differences in freezing behavior among the various soil types (Fig. 4 and 5 of the original manuscript) was deleted, as it was not totally pertinent with the objectives of the paper.

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