

## ***Interactive comment on “Coupled cellular automata for frozen soil processes” by R. M. Nagare et al.***

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SOILD 1, 119–150, 2014 Nagare et al. – “Coupled cellular automata for frozen soil processes”

RESPONSE TO REVIEWER COMMENTS: REVIEWER # 2 We thank Anonymous Reviewer # 2 for his/her comments. Following is our response to the reviewer comments. The reviewer comment is placed in italic and our response is in normal font. Reviewer Comment: P 122 LL 16-18: Actually, already Cervarolo et al. (2010) considered simultaneous heat and water transport in unsaturated soils (Eq. 42) in order to calculate a component of the surface energy balance (soil heat flux), even though they do not provide many details about coupled T-qw modeling. Author Response: Cervarolo et

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al. (2010) is now cited in the introduction section by introducing the following sentence: “Mendicino et al. (2006) reported a three dimensional CA (direct solving) model to simulate moisture transfer in unsaturated zone. Cervarolo et al. (2010) extended the application of this CA model by coupling it with a surface-vegetation-atmosphere-transfer scheme to simulate water and energy flow dynamics.” Further, we have modified our statement regarding the application of CA to simulate coupled heat and water flow in soils to: “To our knowledge, coupled cellular automata have not yet been used to explore simultaneous heat and water transport in frozen variably saturated porous media.” Reviewer Comment: P 125 LL 21-22: it would be better to tell the reader where Eqs. (2) and (3) are placed (i.e., in the next paragraph). However, it’s not clear at this point why Eqs. 2 and 3 should be applied sequentially. Some explanation can be found only later, in Section 4, in my opinion the sentence related to sequential application of Eqs. (2) and (3) is untimely if placed here, and should be better contextualized. Maybe the period should be rephrased.

Author Response: We have introduced a reference to Section 3 for readers to know where the equations are introduced. Also, we have clarified about sequential application of these two equations in the same sentence. The sequential application of these equations is also highlighted in the next paragraph where the physical meaning of mathematical description of CA is discussed.

Reviewer Comment: Section 4: this is my main point. While describing the flow chart, it’s not easy to follow both references to equation numbers in the text and Fig. 2, especially from Heat Balance Module onwards. In my opinion, the best choice would be adding a box with simplified code lines, such as it is usual in informatics journals. Anyhow, I would suggest at least to modify Fig. 2, explicitly recalling equation numbers in related boxes. Furthermore, it would be interesting to know what programming language and development environment were used. Author Response: We modified the flowchart in Fig. 2 by introducing the corresponding equations. We feel that introducing the code in the paper would divert the focus of the paper, which we feel is

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demonstration of power of CA to model strongly coupled phenomenon. The source code is available on request. The programming language was MATLAB and is now mentioned in the paper at the start of Section 4. Reviewer Comment: Section 6 – Comparison with experimental data: from the cited Nagare et al. (2012) I understand that the authors already investigated effects of freezing in lab. Why did they choose to not use their data? If possible, it would add much value to the manuscript. Author Response: Given the objective of demonstrating the ability of CA to simulate strongly coupled phenomenon of water and heat flow in freezing soils, we chose examples that have been used as benchmarks in the past. Mizoguchi's (1990) experiments have been widely used to verify codes (e.g., Hansson et al., 2004; Painter, 2011; Daanen et al., 2007; Dall'Amico et al. 2011) and the parameters are well established. Therefore, we chose Mizoguchi's (1990) data for verification because it offered a possibility of direct comparison with past modelling exercises. We acknowledge the recommendation by the reviewer and understand the value of simulating our laboratory data. However, Nagare et al. (2012) did not collect total water content data and their experiments ran for more than 2 months. This was one limitation to use the data for code verification at the time. In addition, to simulate Nagare et al. (2012) data, the code required additional modifications, which are currently being implemented (albeit at a slow pace given my commitments to consulting world). Reviewer Comment: Convergence issues are only hinted at (P 123, L 21; P 125, L 17), but this is a central point while dealing with direct explicit methods. Authors should go into more details, trying to better highlight constraints for the choice of the right time step. Conversely, a great advantage of direct explicit methods and, mainly, CA is the ease of parallelization. Of course this advantage cannot be appreciated with simple one column experiments. If not possible already with this paper, it would be very interesting in the future to show computational scalability of more complex 2D/3D test cases.

Author Response: Convergence analysis is presented in Appendix A.

2D/3D expansion of the code is also a current objective. This will be achieved in near

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future.

#### Reviewer Suggested Technical Corrections

P121 L28: variably, not variably. Author Response: Corrected. P 124 Eq.1:  $\phi$  in this equation is written in a different way respect to L6. Author Response: Corrected. P 128 L6: maybe SFCs instead of SFC's? Author Response: Corrected. P 144 Fig. 2 caption: I guess it's "through", not "though". Author Response: Corrected. Fig.3: in the figure there's  $q$ , not  $\theta$ . Author Response: Probably we did not understand this comment. In figure it is  $\theta$  now. P129, L24-25:  $T_i$ ? I think it's not introduced before. Author Response: Has been described in Section 3 now. P 135, L8: it should be Fig.7a and b, not 6. Author Response: Corrected. P 137 L7: not "staright" but "straight" Author Response: Corrected.

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Interactive comment on SOIL Discuss., 1, 119, 2014.

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