Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-345-AC3, 2017


Hydrology and Earth System Sciences
Open Access
Discussions

# *Interactive comment on* "A Simple Temperature-Based Method to Estimate Heterogeneous Frozen Ground within a Distributed Watershed Model" *by* Michael L. Follum et al.

**Michael L. Follum et al.**

michael.l.follum@usace.army.mil

Received and published: 24 October 2017

We would like to thank Referee #3 for their comments and suggestions. We appreciate all their insights about the paper and hope our responses address their suggestions and facilitate further discussion.

Main Issue #1, Introduction unnecessarily complicated: In the revised manuscript we plan to simplify the introduction and better emphasize its goals in relation to the existing literature. The first, second, and third paragraphs in the Introduction will be condensed,



with more focus being placed on the objectives of this study (paragraphs four and five).

Main Issue #2, Relationship between frozen ground index and modified Berggren Equation is unclear.: The reviewer is correct that we use the modified Berggren Equation (as shown in Equation 22) to estimate frost depth once the ground begins to freeze, which in the CFGI and modCFGI models is when the frozen ground index F > F_Threshold. Frost depth continues to deepen as F values become increasingly larger than F_Threshold (Lines 21-23, Page 2). As the F values decrease (due to increased temperatures) so does the thickness of frost depth until no frost is left when F values fall below F_Threshold. In the revised manuscript, we plan to better describe the connection between F values calculated by CFGI / modCFGI and the modified Berggren Equation.

Main Issue #3, Net radiation term is missing from Equation 16.: Equation 16 represents a step in obtaining the radiation-derived proxy temperature (T_rad) for simulation of the snowpack. T_rad is calculated under the assumption that the outgoing long-wave radiation balances the net incoming short-wave and long-wave radiation (Follum et al., 2015). This balance is clearly an approximation, but the implied proxy temperature better represents the available energy than the air temperature. Follum et al. (2015) showed that the use of T_rad can provide a significant improvement in the simulation of snowpack in a temperature index approach. This assumption will be stated directly and discussed on Page 6.

Main Issue #4, Unclear on the inclusion of sublimation of the snowpack.: The RTI snow model (see Section 2.3 on Page 5) maintains the same structure as the TI snow model, which is based on SNOW-17 (Anderson 1973; Anderson 2006). Like SNOW-17, both the RTI and TI models can account for interception / sublimation /condensation through an adjustable factor (SCF) (Anderson 2006; Follum et al., 2015), but this factor is typically applied uniformly to the watershed. Lines 19 and 20 on Page 3 will be modified to better reflect how the TI snow model accounts for interception and sublimation (via the SCF parameter). A clearer statement on page 5 will describe how in watersheds with multiple forest types (deciduous, evergreen, mixed, etc.) the interception, sublimation, and drip from the various canopies can be very different, and therefore a method (as applied in the RTI snow model) is needed to estimate these processes based on land cover type.

Main Issue #5, Ambiguous “residual saturation” term.: This term will be replaced with residual water content. In addition, we will clarify that all soil moisture parameters in Table 3 are volumetric quantities.

Minor Comment #1, Change in Line 4 of Page 23.: We appreciate the correction and will change the text from “require more energy to cool and freeze the soil” to “require more energy loss to cool and freeze the soil” on Line 4 of Page 23.

REFERENCES: Anderson, E.A.: National Weather Service River Forecast System - Snow Accumulation and Ablation Model, Technical Memorandum NWS Hydro-17, November 1973, 217 pp., Silver Spring, Maryland, 1973.

Anderson, E.A.: Snow Accumulation and Ablation Model - SNOW-17, NWSRFS User Documentation, U.S. National Weather Service, Silver Springs, MD, 2006.

Follum, M.L., Downer, C.W., Niemann, J.D., Roylance, S.M., Vuyovich, C.M.: A radiation-derived temperature-index snow routine for the GSSHA hydrologic model, Journal of Hydrology, 529, Part 3, 723-736, 2015.

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-345, 2017.