**Hydrology and
Earth System
Sciences**

Open Access

Discussions

HESSD

Interactive
comment

Interactive comment on "Assessing the influence
of soil freeze-thaw cycles on catchment water
storage – flux – age interactions using a
tracer-aided ecohydrological model" *by*
Aaron A. Smith et al.

Anonymous Referee #2

Received and published: 13 April 2019

The paper by Smith et al., seeks to use a previously developed ecohydrological model
(EcH2O-iso) to further understand the partitioning, water storage, flux and age inter-
actions, particularly in the context of cold, northern catchments. This novelty of this
contribution is that they have adapted the model to include soil freezing, and the im-
pact of soil freezing on water ages. As the authors note, most model estimations of
storage-flux interactions oversimplify vegetation-soil-water interactions, while EcH2O-
iso provides a generic and relatively simplistic (in some parts) modeling approach to
evaluate storage and water ages in cold environments. The model of course has many

limitations related to the process physics and the assumption of complete isotope mixing within each compartment, which may not hold true. However, the authors are transparent as to its shortcomings in most places, and it is of little value to be overly picky with regards to the choices that are made. The manuscript is well written, and the figures are clear and of high quality. I would like the authors to consider the comments below and I believe the manuscript is suitable for publication after minor revisions.

The main conclusion of the work is that soil frost had an early season influence on the ages of transpiration, with less of an influence on water ages of evaporation. Second, that the new module can simulate soil frost dynamics. While I do not dispute this, it is unsurprising that the Stefan-type of equations can simulate frost well, this approach has been used for ages and ages and while perhaps not always a physical realistic representation of ground freezing, it simply works well (as it does here). It would be good for the authors to indicate whey they did not use a more complex thermal scheme, or reference ones. Obviously one would need more soil layers and computational resources would go through the roof, but a bit more on the 'why' this method was used is good.

I would like to focus my comments around the central conclusion re: soil frost and water ages. It would be useful to outline how evaporation and transpiration are partitioned as this would help the reader (although it is likely presented elsewhere) and goes to the central conclusion.

$\sim$Equation 1 simulates the depth of the freezing front, but not the soil temperature. I am curious as to how the model simulates soil temperature. I THINK I understand how the surface temperature is driven, and the authors acknowledge that the thermal routine of the snowpack is simple for various reasons. What I'm trying to get at is: does the model simulate a soil temperature and how does this relate to the position of the zero-degree isotherm. Yes, soils will be identified as frozen or unfrozen base on Eq 1, yet is there a modeled soil temperature that simply has no freezing routine? More clarity is needed.

~The central conclusion that soil freezing affects transpiration is fine, but is it simply because the plants are not 'on' when the soil is frozen and soil evaporation is impeded (it certainly would be). When the module is off, plants can transpire, and soils evaporate? Is it this simple? I'm just not sure. More clarity on what drives the transpiration would be helpful as I'm unsure if there can be no transpiration when the rooting zone is frozen – how does this all work?

~Is there sublimation in the model? I see that latent heat is set at 0 when there is snow – why? What impact does this have when snow is melting and sublimation may be important.

~For Equation 7, what is the basis of the amplification factor C. Does equation 7 preserve an isotope mass balance throughout all time steps (I'm assuming so – but it should be stated).

~The authors use ERA-Interim data to drive the radiative component of the model. For a few years, there was overlap. Did they investigate the bias of the ERA data and correct? I'm assuming ERA-I would work well in this location of Europe, but it's good to check as it can have biases which will propagate through the energy balance calculations. The underestimation in net radiation is a bit concerning – and latent heat as well. So after all this, my question is that if latent heat is in fact greater than simulated, what influence would this have on the age estimates (if any?). I assume some and this should be noted.

~On line 79, I'm not sure that the CRHM reference is correct and the Xie and Gough paper describes the thermal routine that is later incorporated into CRHM (see papers by Krogh for example). The XG method is in CRHM, but this is just slightly incorrect referencing.

~The discussion after line 85 is a bit selective and there are dozens of possible reasons for model errors in turbulent fluxes. First the authors state sensible heat fluxes are underestimated but only show latent fluxes so the discussion should be there or

sensible heat data should be provided. Another reason not stated (and noted above) is the nature of the ERA-I data. I'm also unsure as to how snow processes are incorporated into the canopy module re: unloading, albedo change, etc. All I'm saying is that there are many many reasons here where the model could be improved with physics, and avoid suggesting 'direct calibration' is the best way to improve simulations.

~Figures that highlight the differences between soil moisture at depth would be helpful. A few small typos or unclear statements are outlined below:

~Line 80: under different vegetation communities (forest vs mire). 2) To examine the influence of soil frost on the dynamics and age of water (Comma instead of period after (forest vs mire)

~Line 54: qin → subscript needs to be added

~Line 73: comma needed within coordinates

~Line 95: "Stable isotopes determinations were carried out" → Fix wording

~Table 1: Units of precipitation say m/s → should be moved to wind speed. Units need to be added to other dat. "30 min for Sensible Heat says " 30 in" . Column heading needs to say "Time Period" for top row.

~Line 69: stream isotopes tended to retain a slight "memory" effect from the more enriched late summer... "contributions"? "water"? I think a word is needed here?

~Beginning Line 95: While some work has been conducted on assessing the transit or residence times of ecohydrologic fluxes or their partitioning in northern (e.g. Sprenger et al., 2018a); however, few studies have included the influence of frozen conditions on the water movement, which may be significant for the effective transit times during the spring freshet period (Tetzlaff et al., 2018) and flow path modelling in "cold" regions (Laudon et al., 2007; Sterte et al., 2018).

~Line 99: Traditionally, water ages in stream water at catchment outlets have been the

primary metrics for assessing the transport of tracers. Should this read: Traditionally, isotopic tracers in stream water at catchment outlets have been the primary metrics for assessing water ages.

~Line 29: snow and early spring snowmelt), and snowpack is the amount "weighed" age of solid precipitation (*Should this be weighted)