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Geoscientific Model Development Discussions

Interactive comment on "The Canadian Hydrological Model (CHM): A multi-scale, multi-extent, variable-complexity hydrological model – Design and overview" *by* Christopher B. Marsh et al.

Anonymous Referee #2

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Marsh et al. present an overview of the Canadian Hydrological Model (CHM), a modular modeling framework that specifically aims at cold regions. The manuscript focuses on the main principles of the model rather than the specific process representations (what authors call the "philosophy and design" of the model – line 21 page 1), including how terrain is represented (section 4.2), how parameters for each mesh element are determined (section 4.3), how modules are organized (section 4.4), and how weather inputs like precipitation, temperature, relative humidity, radiation, and wind are distributed (section 4.5). After a discussion on parallelization, point-simulation modules,

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and output visualization, authors also present some examples of model usage for Marmot Creek in the Canadian Rocky Mountains.

CHM has the potential to overcome several issues in the current state of the art of hydrologic models in cold regions. I found of particular interest the use of TINs instead of pixels or HRUs to represent surface topography. While I am lacking full expertise on parallelization, designing a model that is natively and efficiently parallelized is also an asset. Having said that, I do have a few remarks on the current version of this manuscript, which I outline below. I therefore recommend the Editor to reconsider this manuscript after some extensive, but still minor revisions.

After reading the title of this manuscript, I was expecting the description of a full hydrologic model. As far as I was able to understand, the current version of CHM comprises weather-distribution modules, snow modules, and canopy-soil modules related to snow (see Table 1). Ultimately, a hydrologic model should solve the water balance, including evapotranspiration, soil storage, groundwater, surface-runoff generation, and importantly streamflow. Authors say that "the CHM will eventually include the entirety of the hydrological cycle", but only "snow accumulation and surface meteorology processes are currently implemented" (line 4 page 13). I of course agree that a "hydrological model" does not necessarily have to simulate all processes in the water budget, and I also understand that CHM is still under development. At the same time I think that the manuscript title, abstract, and Methods should be revised to be more specific on what CHM simulates at this point and what this manuscript is focusing on.

Related to this, and particularly because the paper is intended to be a discussion of the main "philosophy" of the model, I feel like an outlook section discussing how authors are planning to include "the entirety of the hydrological cycle" would be interesting. For example, it would be interesting to discuss how flow routing will be eventually implemented, since TINs do not necessarily obey to surface-runoff directions and may be (at least partially) decoupled from subsurface-flow direction.

I also suggest authors to clearly define some of the wording in the manuscript. For example, authors say that “there are no explicitly distributed, modular cold regions models”. What is the exact definition of modular here? For example, ALPINE3D is a spatially distributed cold-region model, and it does (to my knowledge) offer several process representations for specific model components (for example, snow hydrology, metamorphism etc). It can also be coupled with a flow-routing scheme (StreamFlow, see https://models.slf.ch). So, to me, ALPINE3D is an explicitly distributed, modular cold regions model.

Also, what do “multi-scale” and ‘multi-extent” mean in this context? TINs are an interesting solution to make spatial discretization computationally more effective, because they refine spatial resolution based on actual topography, but (at least to me) multi-scale models are designed to explicitly address other scale issues besides heterogeneity in surface topography (e.g., multi-scale parameter spaces, see https://doi.org/10.1029/2008WR007327). Some other instances are included in my list of specific comments below.

- Line 10 page 1: maybe “precipitation-runoff” would be better here rather than “rainfall-runoff”, since precipitation is not only liquid in cold regions?

- Line 18 page 1: maybe introducing TINs here would be more informative than just saying that the model “captures spatial heterogeneity in the surface discretization in an efficient manner”?

- Introduction: I think this Section could be revised for conciseness and to better streamline the story. For example, most of the caveats mentioned in the first paragraph are then discussed at pages 4 and 5, while the problems with raster-based models are described both at lines 9ff page 4 and then at lines 6ff page 5.

- Line 6ff page 2: among these limitations, I would also mention that there are processes that we are simply unable to measure and thus to model without some kinds of parameter tuning (e.g., groundwater storage is often poorly constrained).

- Line 30 page 3: could you provide examples of these “next-generation data products”? If UAVs are such an example, then moving the discussion from line 22 page 5 to here could clarify the point.

- Line 22 page 7: remove one “in” before Marsh et al. 2018.

- Section 4.4: I would expand this section to include details of the modules that are currently supported and their main parametrizations. Currently, this is briefly done in Table 1 and at lines 4-5 page 13, but Section 4.4 seems the adequate place to do so to me.

- Line 17 page 10: what does “embarrassingly” mean here?

- Line 13 page 12: maybe remove “in the results”? Also, how does the animation view specifically allow for immediate diagnosis of modeling errors? Maybe provide a couple of qualitative examples to make the point?

- Line 3 page 14: I believe SNOWPACK is generally reported in all caps

- Line 15 page 14: to my knowledge, SNOWPACK allows for many other turbulent-flux schemes (see again https://models.slf.ch)

- Line 26 page 14: maybe report reference to Figure 6 here?

- Line 1 & 5 & 8 page 15: why did you choose 1000 m and 10 steps here? Maybe providing some of your experience here may guide future users.

- Line 8 page 16: is 2007 actually 2008 here?

- Line 22 page 16: I would include here more details on how the other parametrizations performed.

- Conclusion: I think the first two paragraphs could be summarized or removed, while I would expand on the last paragraph to (1) explicitly mention the pros and cons of TINs, (2) include some of your results from Section 6, and maybe (3) add details of future

work (see my general comments above)

- Figure 11: maybe reports dots to highlight speedup values for 1, 2, 4, 6, 8, 16, and 32, which are those measured in your sensitivity test?

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