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Interactive comment on "How Much Cryosphere Model Complexity is Just Right? Exploration Using the Conceptual Cryrosphere Hydrology Framework" *by* Thomas M. Mosier et al.

Anonymous Referee #1

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This MS presents a model framework for simulating snow and glacier melt and related runoff formation. A number of established and partly novel algorithms are implemented and in a calibration-validation study for two different catchments; the authors assess the value of individual concepts. Available models of snow and ice melt almost form a continuum in terms of complexity and data demands and a study shedding light on how much complexity actually is needed, and would come as a highly welcome guidance for the modelling community.

Initially, I was intrigued by the title which poses this timely and relevant question. However, while reading, I became disappointed and find the MS hampered by several, severe deficiencies. These are related to the methodology, the way how the background

is presented, and the discussion of the question asked in the title. In total, the results do not provide sufficient support for the conclusions.

Major comments:

The calibration of conceptual models is often plagued by equifinality, i.e. that several different parameter combinations yield undistinguishable performance. This is a typical problem for models that experience error compensation, such as here. Several 'best performers' will reveal different behavior in a forecast/ validation situation. Hence, picking a single parameter combination, out of potentially several equally valid ones, may yield a low performance when validating, while other members of the ensemble of 'best performers' may perform well. It is misleading to neglect this parameter uncertainty and instead to make when the model concept responsible for the low performance. This shortcoming does compromise the entire conclusions about different concepts. Here, the authors either have to demonstrate that the performance topography has a sharp peak and thereby support the usage of a singular best performing parameter combination. Alternatively, an ensemble of similar best performers should be evaluated to explore the range of uncertainty when validating.

The way how SCA is evaluated is not very useful: the 3 dimensional information (2 spatial dims, 1 temporal) is reduced to a single one. the daily MODIS product lacks spatial completeness which is addressed by temporally aggregating the SCA maps for each month. It is left unclear which timestamp is associated to this aggregated SCAmap and how this is compared to the model results. This way much of the temporal information in the data is lost. In addition, the spatial information is removed by spatially averaging SCA over the domain. This leaves us with a performance measure that is most likely almost insensitive to whatever the model is doing, provided that the model reproduces the snow seasonality. However, severe model misbehavior such as snow in the wrong part of the catchment or missing meltout by 10 days is not at all penalized by averaging procedure.

Confusing presentation of different models implemented, what is new, what not? The original Hock 1999 algorithm does not include albedo but employs 2 different radiation parameters to account for differences between snow and ice. The stated equation here (eq2) is hence not identical to the original but a variant of it. This needs to be clearly stated.

Misleading statement about novelty of the CC approach. Your argumentation is circular by stating P4 L25: "a common concept in snow process modelling. . ." and then later claim "we are not aware of any previous conceptual cryosphere models that incorporate internal energy or 'negative melt' into their formulation". Isn't that a contradiction?

Detailed comments:

It is inappropriate to re-define units of a variable (P9 L3), either introduce a different variable (which would be confusing) or state how it is converted from one unit to another.

Units confusion: for instance M should carry units [m s-1] in water equivalents and is already a specific quantity and does not require repeated normalisation! So the units used here [m/m2 = m-1] are wrong. This applies several places throughout the MS.

Confusing notation: delta is used as operator (e.g. in delta t) but also as concept name (?)

How is the CC determined? Eq 4 suggests it is a function of T but then eq 11 makes Ts a function of CC, isn't that circular?

Redefining variables, eq 17 defines delta t as travel time whereas previously it was used as time step (P9 L13)

Eq 13: I do not get the meaning of H_ice/H, why is that needed? The difference between snow and ice melt would be accounted for by the difference in albedo when calculating H, so what effect is accounted for by this factor?

Eq 15: the units do not work out here, runoff should be in [m3 s-1], but then d_r needs to be converted from [days-1] to [s-1]

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