

### Reviewer #3 (Thorsten Wagener)

#### Comment:

The authors, as always in their papers, have written a well-formulated discussion of relevant current issues in hydrological modeling. While there are many interesting points here, and Hoshin points out quite a few, I have to agree with Ralf Loritz's comment that it becomes hard to keep track of what they key points are in an increasing number of commentaries on (at least seemingly) similar issues. In the case of the present manuscript, I think that there are some issues that can be discussed with more rigour to highlight its uniqueness (though the authors might disagree).

#### Reply:

*We highly appreciate the reviewer's positive assessment of our manuscript. We also agree that the argument needs to be sharpened to more strongly emphasise our intention and main message, which we will try to do in the revised manuscript.*

#### Comment:

One thing that stands out in this commentary is the explicit use of the term top-down modeling. It is not clear to me though what definition the authors use for top-down modeling. My understanding of the manuscript suggests that here this definition includes all conceptual type approaches to hydrologic modeling. So, are all conceptual modeling approaches equivalent to a top-down modeling philosophy? I do not think so, though the authors likely have a different point of view (which would be fine). What definition do the authors follow? Is this defined by the model type I use (ODE vs PDE) or by the mindset/objective I have when developing my model?

Following some of the early definition top-down modeling "provides a systematic framework to learning from data, including the testing of hypotheses at every step of analysis" (Sivapalan et al., 2003). This is often applied in a hierarchical manner (e.g. using signatures), but not necessarily so. If this is the definition the authors use, then I do not think that models such as HBV have been developed following a top-down modeling philosophy. They rather have been developed with a bottom-up mindset I think. Similarly the Sacramento model was not build to just fit the data, but based on an attempt to provide a simple representation of physics. Is there really a common philosophy underlying the modeling approaches used to build HBV, in the top-down papers by Sivapalan and colleagues, and in the FUSE framework? Is it really a binary decision whether an approach is top-down or bottom-up?

#### Reply:

*We indeed started from the premise that top-down modelling "provides a systematic framework to learning from data, including the testing of hypotheses at every step of analysis". However, we realized that the distinction we used in the original manuscript was not precise enough. In fact, we think that much of the misunderstandings between different modelling approaches originate from the fact that terms such as top down, conceptual, bucket, lumped on the one hand and bottom-up, physical and distributed on the other hand are often used interchangeably in spite of having only*

*limited overlap. We will therefore widen the scope of the paper here and provide a framework for a more systematic model taxonomy. This framework will allow to place all model approaches on different positions in the spatial resolution-process complexity spectrum between the two endpoints and will highlight the fact that all models are physical and to some degree conceptual.*

Comment:

If I assume that the definition by Sivapalan above is appropriate, then some important contributions to top-down modeling are missing from this paper. Most notably is the work by Peter Young (e.g. Young, 2003 and much earlier than that), who, with his databased mechanistic approach, has provided one of the few very structured frameworks for top-down modeling. Of course he did so by making some strong assumptions, which limit the generality of his approach. It would be good if the authors could have a wider look at literature in which top-down modeling strategies are investigated (if they use the term more narrowly than simply all conceptual models).

Reply:

*We thank the reviewer for this very good point – of course the databased mechanistic approach needs to be part of such a discussion. We will add relevant references in the revised manuscript.*

Comment:

I think by using a very wide definition of top-down modeling, we miss the opportunity to discuss some important remaining problems. Mainly that hydrology still lacks “a systematic approach to learning from data” as proposed by Siva. For example, how do we assess model complexity (given that information criteria typically do not work for hydrologic models), so that we can identify the simplest model that fits the data? How do we decide that one model structure is better than another one beyond just looking at performance? The data-based mechanistic approach provides a nice strategy to identify the simplest representation (of routing) supported by the data, while also allowing for a hydrological interpretation. I do not think that we have a more general framework of this type yet (i.e. without Peter’s assumption of using linear transfer functions etc.).

Reply:

*We agree that these are important points (which are raised in section 3.2) and we will add these aspects and related papers (such as the work of Patrick Willems) to the relevant discussion.*

Comment:

I am also unclear why a top-down approach should be restricted to catchment scale observations (if that is what the authors suggest). If the approach is focused on learning from data then its philosophy can be applied at any scale. Work by Young and colleagues using their top-down philosophy have not been limited to catchment scale hydrologic data, so why should it be for us in

hydrology? We could actually build distributed models using a top-down strategy for catchments with extensive internal observations.

Reply:

*We fully agree and think that we did not imply otherwise. That is why, throughout the manuscript we tried to speak in terms of “model domain”, which can be e.g. a catchment, a HRU or a grid cell. However, as many conceptual models are formulated as lumped representations, we explicitly referred to as catchments as the model domain in these cases. But quite clearly, the top-down approach in its essence is applicable, and should be applied, at any scale, which would then in term the convergence towards detailed bottom-up models, which we think is necessary. We will clarify that in the revised manuscript.*