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Interactive comment

Interactive comment on "Scaling, Similarity, and the Fourth Paradigm for Hydrology" *by* Christa D. Peters-Lidard et al.

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Please find below the comments of M. Bierkens and our replies (preceded by "»"):

In this synthesis paper the authors make a case to move from the 3th paradigm of computational science to the 4th paradigm of data-intensive science to overcome the challenges to represent hydrological processes in models over a range of scales. After a short review on scaling and similarity in hydrology they propose an existing framework by Nearing et al. (on information theory) for testing new data-driven scaling laws. They also provide an overview of data requirements to do this as well as what is demanded of a modelling framework to provide for this hypothesis testing (SUMMA being a likely candidate). The paper is generally well written. I have three comments that I feel are important to address:

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Discussion paper

»Thank you for your helpful comments

1) I get the idea behind the information theory to test the model/scaling hypotheses as described in Figure 2, but how it works does not become clear from the figure and this paper. I know, I could read the original paper, but I think a paper should be sufficiently self-contained to convey the message by reading it. So please add a bit more details on the method; especially on how to calculate the different information measures with a given model and scaling method.

»More description and discussion have been added.

2) My second comment is the most important one, although it may result from my limited understanding of the Nearing et al. method. The authors take the information content of the observations as a benchmark to compare alternative hypotheses against. However, this may be fundamentally problematic if the data are not intensive enough to properly describe the reality you aim to describe. For instance, if I compare a complex distributed model with a lumped-conceptual model against discharge data only, there is no way I will do it better with my complex model, even though the purpose of my model would possibly be to model the internal states (i.e. runoff generation process or groundwater recharge). So the first question should be: what is the information of the hydrological process I aim to describe. Next, the question than is what data I would need to approximate the necessary information content.

»As described in Nearing et al., there are three requirements for a benchmark: a particular dataset, a particular performance metric, and a particular reference value for that metric. The dataset must contain information about the true process you seek to model, so it would seem that the streamflow example you mention would require many interior streamflow points in addition to that at the outlet. To calculate a benchmark, you first measure the information in the observations themselves (using the entropy metric). In the Nearing example, we used SCAN soil moisture data and FLUXNET for ET. To derive the reference value, you generate a synthetic representation of relationship between the forcing and/or parameters and the metric (using a machine learning such as sparse pseudo-input Gaussian Process Regressions, as in Nearing et al.,) that provides an "upper bound" of information contained in the model about the variable of interest. Then the information contained in a model that conforms to a given hypothesis may be compared to the information contained in this "upper bound", and differences in mutual information indicate losses of information due to model formulation.

3) This is generally an optimistic paper providing a way forward to arrive at multi-scale-consistent parameterizations. However, many of the data sources mentioned as needed to support this path forward are remotely sensed data. These will not provide any information on the subsoil. Also georadar or even airborne EM, albeit promising at the local scale, will not give us this information at larger scales. As long as we do not involve (hydro)geologistists and sedimentologists in large-extent high-resolution hydrogeological mapping, the subsoil will remain closed to us I am afraid.

» The hydrogeophysical techniques described in Binley et al., 2015 (as referenced) do provide some hope for subsurface mapping, although we agree that more work is needed to provide large-scale mapping of the subsurface. We will acknowledge these challenges in the revised manuscript.

Small remark page 4, line 7: also refer to the (improved) ARNO scheme here, e.g. Dumenil, L. and Todini, E., 1992. A rainfall-runoff scheme for use in the Hamburg climate model. Advances in theoretical hydrology. J. P. Kane, (Editor), Elsevier, 129-157. Hagemann, S. and L.D. Gates (2003), Improving a subgrid runoff parame- terization scheme for climate models by the use of high resolution data derived from satellite observations, Climate Dynamics 21, 349–359.

» These references to the improved ARNO scheme have been added.

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