

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 W. R. Berghuijs and our replies (preceded by “»”).

I think the authors address an excellent point by stating that progress in scaling can benefit from utilising data wisely instead of focusing on modelling all the time. While reading the paper I came across a few things that potentially (/hopefully) help to improve the manuscript. This short comment is NOT intended as a full review of the paper. Overall I enjoyed reading the paper, but I refrain from giving an explicit opinion on the suitability of the manuscript for HESS, because: (i) I am not asked to review the paper, (ii) I did not fully review all aspects of the paper, and (iii) one of the authors (Ross Woods) is my current PhD supervisor.

»Thank you for your constructive comments

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- While reading the paper I was expecting a clear definition of “the fourth paradigm”. While the reader will eventually grasp your opinion on this, it seems that the paper can benefit by adding a clear explicit definition of the 4th paradigm early on in the manuscript (e.g. in the final part of the introduction or maybe even in the abstract).

»Agreed...the revised version of the paper adds a definition of the 4th paradigm in the Introduction. The following definition seems appropriate, and perhaps this broader definition also addresses your next point below: “The Fourth Paradigm is a concept that focuses on how science can be advanced by enabling full exploitation of data via new computational methods. The concept is based on the idea that computational science constitutes a new set of methods beyond empiricism, theory, and simulation, and is concerned with data discovery in the sense that researchers and scientists require tools, technologies, and platforms that seamlessly integrate into standard scientific methodologies and processes. By integrating these tools and technologies for research, we provide new opportunities for researchers and scientists to share and analyze data and thereby encourage new scientific discovery.”

- Your definition, or at least emphasis, for the “fourth paradigm for hydrology” seems to be on systematic testing of hypotheses. This is narrower than the definition of the fourth paradigm as discussed by Hey et al. (2009) (which is something like “insights are wrested from vast troves of existing data”). In the latter definition, there is more emphasis on the data-driven discovery of new laws, rather than the focus on testing (existing) concepts. Do you interpret that correctly? If no: addressing the previous comment may resolve my misinterpretation. If yes: is it worth emphasising the difference between the definitions?

»Thank you for helping us clarify this important point. Yes, the definition of the 4th paradigm is much broader than we are using here. However, the key point is that (following on the broad definition above) we need to seamlessly integrate computational methods and data into our scientific methodologies and processes. The point being that we have not adequately exploited the “vast troves of data” in testing existing theo-

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ries and models. We hope this is clarified in the revised version.

- Connected to the previous point: (In my view), it is the combination of the 4 paradigms (empiricism, theory, modeling, systematic testing models/theories with data) that will lead to advances. Should the connection between the four paradigms not be discussed explicitly? Or is there no place for empiricism, new theories and model development in the future of scaling?

»We do not mean that the 4th paradigm supplants the other 3, and similar points were raised by at least one reviewer. We do believe that perhaps the pendulum has swung a bit too far in the area of simulation such that we have lost our way in terms of what is actually knowable from the data and how to properly test hypotheses that might arise from theory or empiricism. For example, how do we know that processes being represented in a “hyper-resolution” model are adequate without using the data to provide an upper bound to describe the information available? Grounding the scientific method in information theory will help to reconcile this issue.

- Very little is said about past work that tried to systematically assess the validity of scaling hypotheses. Especially, since the paper is introduced at a “review” rather than an “opinion paper” I expected to read more about past efforts before you introduce the need for a fourth paradigm.

»Yes, another reviewer also commented on the brevity of the paper—although it is really somewhere between an opinion paper and a review. We expand the discussion of previous work in the revised version.

- Can you summarize the vision of your paper in a Figure? I think the paper will be more appealing with such a figure

»This is a good suggestion. One possibility is a variant of Figure 1 from Gupta et al., HESS, 2014. In this case the diagnostic signatures are based on the patterns in the data as a benchmark and compared with patterns in the model simulations based on

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a particular similarity concept or hypothesis.

Gupta, H. V., Perrin, C., Blöschl, G., Montanari, A., Kumar, R., Clark, M. and Andréassian, V.: Large-sample hydrology: A need to balance depth with breadth, *Hydrol. Earth Syst. Sci.*, 18(2), 463–477, doi:10.5194/hess-18-463-2014, 2014.

Technical comments: Line 14: “larger/longer” suggests that scaling is limited to “up-scaling”. Why not change it to “other” so it refers to both upscaling and downscaling?

»Agreed.

References - In the text there is one citation of Albergel et al (2012). However, in the reference list, there are two articles by Albergel et al (2012).

»This is actually an erroneous repetition of the same article. One has been deleted. - Berghuijs et al. (2014) is listed in the references, but not cited in the main text.

- Köhli et al (2016) does not include the journal it is published in (WRR?)

»Thank you for pointing out these oversights. We now include a citation for Berghuijs et al. (2014) in the main text, and the Köhli et al (2016) reference has been corrected to WRR.

Interactive comment on *Hydrol. Earth Syst. Sci. Discuss.*, doi:10.5194/hess-2016-695, 2017.

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