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Interactive Comment

Interactive comment on "HESS Opinions "The art of hydrology"[1]" by H. H. G. Savenije

H. H. G. Savenije

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Reply to Sivapalan on 'Combining Upward and Downward approaches'

I very much appreciate the comment by Sivapalan on my opinion paper "the Art of Hydrology". Sivapalan is completely right when he states that prediction in ungauged basins requires both a top-down and bottom-up approach. However, as a bottom-up approach I don't advocate the classical reductionist approach that uses upscaling of fundamental laws from the core-scale to the catchment-scale. What I mean with a bottom-up approach is the use of physical theories and laws that relate state variables and fluxes (closure relations) to match observations. This match generally involves some form of calibration or the use of an optimality function. A good example of such

[1]Invited contribution by H. H. G. Savenije, the EGU Henry Darcy Medallist 2008 for outstanding contributions to Hydrology and Water Resources Management.

a bottom-up approach is the method developed by Stan Schymanski who determines transpiration based on biophysical relationships and an optimality function (Schymanski et al. 2007, 2008). But it equally applies to a physically based method to estimate evaporation on the basis of remote sensing information (e.g. SEBAL), or a method that estimates stock variations on the basis of gravity observations (e.g. GRACE) and models.

Fabrizio Fenicia and I are presently working on a method to transfer models from gauged to ungauged catchments through an approach that combines bottom-up and downward thinking. It involves a sequence of activities. Firstly we have developed a method that allows us to treat models (or model architectures) as hypotheses; then we have developed a way to compare models (hypotheses) and to assess which model performs better, based on reducing both parameter and predictive uncertainty and on maximising realism (here the 'art' comes in); subsequently we are working on classifying catchments according to geology, topography, climate and land-use; finally we transfer model architecture and parameter values to similar (ungauged) catchments. Subsequently, parameter values may be refined based on additional, sometimes soft, information (here the 'art' comes in again). We are testing this approach in catchments where we do have information to validate our method. The results look very promising. We shall report on our preliminary results shortly.

Hence, we use a top-down approach to match data with a range of model architectures (hypotheses) and we come up with the model that has the least predictive uncertainty with the best performance. Although this is a top-down approach, a considerable amount of experience (art) and physical knowledge (bottom-up thinking) is involved in defining the range of likely model architectures. Well performing models, in this approach, are generally parsimonious as this approach only uses parameters that are well identifiable. As a result they generally have physical meaning. In addition, a top-down approach is used for catchment classification, but also here knowledge about the criteria for classification that influence hydrological behaviour is important. Finally

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the transfer of model structure and parameters to catchments of the same class can be made. Again, Art is required to adjust model parameters on the basis of possibly available soft or hard information.

So in our approach we have overcome the problem of 'needing guidance to choose an a priori model structure for an ungauged basin' as Sivapalan writes. This still leaves parameter values to be refined, but here, experience can certainly help to assess feasible ranges, particularly since these models are parsimonious with parameters that have a physical meaning. A short field visit can help to reject certain hypotheses and to provide physical constraints on certain parameters. In our research in the Zambezi basin where we have set-up models in poorly gauged or ungauged basins, such short field visits have been invaluable to refine model concepts (Winsemius et al. 2006).

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Winsemius, H.C., H.H.G. Savenije, A.M.J. Gerrits, E.A. Zapreeva, and R. Klees, 2006. Comparison of two model approaches in the Zambezi river basin with regard to model reliability and identifiability . Hydrology and Earth System Sciences, Vol. 10: 339

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