Improving Conceptual Hydrologic Models

Author: Sina Khatami
Email: skhatami@student.unimelb.edu.au
Supervisors : Murray Peel, Tim Peterson, Andrew Western
Department: Infrastructure Engineering

THE UNIVERSITY OF MELBOURNE

Abstract:

The challenge of making accurate predictions in a changing world is one of the most difficult questions facing earth system scientists today. This challenge has significant societal implications for climate change impact assessment and adaptation, water resource management, and policy making. To overcome this challenge we require reliable conceptual hydrologic models that can make accurate predictions in both space and time. A significant barrier to achieving reliable predictions from conceptual hydrologic models is the issue of equifinality, in which a given performance can be reached by many potential model structures and parameter sets. As much as equifinality is an unalienable part of any open system (such as a hydrologic model), it is possible that the degree of inherent equifinality is being increased due to deficient modeling practice/framework. Therefore, this research aims to define and identify equifinality in conceptual hydrologic models and then attempt to develop a framework to minimize equifinality where possible. There is an urgent need for a holistic framework to improve predictions under changing conditions from traditional hydrologic modeling. Such an improvement in classic hydrologic modeling might ultimately facilitate a paradigm shift in water resources climate change impact assessments.

Introduction

There are fundamental difficulties with hydrologic modeling. The world is currently undergoing rapid and large-scale changes. Predicting hydrologic responses under such conditions is one of the most challenging questions for hydrologists (Schaefli, et al., 2011). In addition to 'change', there are further complications to prediction; the chaotic nature of many hydrological processes (Khatami, 2013a, b), numerical daemons of conceptual hydrological modeling (Kavetski & Clark, 2010), ill-conditionedness of environmental mathematical models (Beven, 2006), to name a few. Equifinality arises when the number of unknowns is greater than the number of observations in a mathematical model of a physical phenomenon, the problem becomes ill-conditioned or ill-posed (Hadamard, 1902). A given level of simulation performance can be reached by many potential model structures and parameter sets. Therefore, it is a dilemma in both model identification (best model structure) and prediction from conceptual hydrological models (best parameter set). It is perceived that equifinality is a problem of decidability between feasible models and parameter sets (Beven, 2006). Equifinality seems to be an 'intrinsic' property of any open system like a hydrologic model, due to dependence upon an inductive component—data. Thus, multiple acceptability of models, as representations of hydro-environmental processes, is inevitable. Nonetheless, it is possible that the degree of inherent equifinality is being increased due to deficient modeling practice/framework. In light of the above, in order to improve hydrologic models predictive power, equifinality needs to be addressed systematically through the following research questions:

1. How to quantitatively define and identify equifinality?
2. How to rigorously reduce equifinality?

Methodology

This research aims to outline a framework to improve traditional hydrologic modeling. That is, to develop novel strategies to improve the following:

1. Model-input compatibility (data pre-processing)
2. Model coding (smoothing procedural models)
3. Model results (model output post-processing)

The developed framework will then be evaluated across a wide range of catchments and any change in model performance, relative to a classic model, will be assessed. It is expected that the aforementioned remedies enhance the efficiency and effectiveness of conceptual hydrologic model calibration and performance, and ultimately reduce any artificial/fabricated equifinality within a given model.

Discussion

Climate change represents a challenge to water resources management with potentially significant environmental, socio-economic and political consequences. Hydrologic models are essential to climate change adaptation strategies especially in high water stress countries like Australia with physical and economic water scarcity. Hydrologic models could be used both as a research tool (for understanding hydrological processes) or as an operation tool (for extra-hydrological purposes such as policy making). Therefore, improving the predictive power of models, i.e. their reliability, is crucial not only to the scientific community but more importantly to society. On a larger scheme, this research could serve the problem of model transposability i.e. Prediction in Ungauged Basins and Climate (PUB and PUC) (Peel & Blöschl, 2011). Eventually, this research might be an element of a paradigm shift in water resources climate change impact assessments.

References

Beven, K. (2006). A manifesto for the equifinality thesis. *Journal of hydrology*, 320(1), 18-36.

Kavetski, D., & Clark, M. P. (2010). Ancient numerical daemons of conceptual hydrological modeling: 2. Impact of time stepping schemes on model analysis and prediction. *Water Resources Research*, 46(10).

Hadamard, J. (1902). Sur les problèmes aux dérivées partielles et leur signification physique. *Princeton university bulletin*, 13(49-52), 28.

Khatami, S. (2013a). *Nonlinear Chaotic and Trend Analyses of Water Level at Urmia Lake, Iran.* M.Sc. Thesis report: TVVR 13/5012, ISSN:1101-9824, Lund: Lund University.

Khatami, S. (2013b). *Evidence of Low-dimensional Determinism in Short Time Series of Solute Transport.* Department of Water Resources Engineering, Lund University.

Peel, M. C., & Blöschl, G. (2011). Hydrological modelling in a changing world.*Progress in Physical Geography*, *35*(2), 249-261.

Schaefli, B., Harman, C. J., Sivapalan, M., & Schymanski, S. J. (2011). HESS Opinions: Hydrologic predictions in a changing environment: behavioral modeling. *Hydrology and Earth System Sciences*, 15(2), 635-646.

2014 Infrastructure Engineering Postgraduate Conference