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Virtual Hydrological Laboratories: Developing the next generation of conceptual models to support decision making under change

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Abstract: As hydrological systems are pushed outside the envelope of historical experience, the ability of current hydrological models to serve as a basis for credible prediction and decision-making is increasingly challenged. Conceptual models are the most common type of surface water hydrological model used for decision making, due to suitable predictive performance, ease of use, and computational speed that facilitates scenario analysis, as well as sensitivity and uncertainty analysis. Hence, conceptual model predictions essentially represent the current "shopfront" of hydrological science as seen by practitioners. However, these models have notable limitations in their ability to resolve internal catchment processes, and subsequently capture hydrological change. New thinking is needed to confront the challenges faced by the current generation of conceptual models in dealing with a changing environment. We argue that the next generation of conceptual models should combine the parsimony of conceptual models (CMs) with our best available scientific understanding.

To develop a new strategy we evaluate the principal hydrological lines of evidence (HLE), that have been used to inform process understanding and its incorporation into hydrological models, outlined as follows: (1) Lab-scale experiments, (2) Experimental catchments, (3) Paired catchments, (4) Large Sample Hydrology, and (5) a newly emerging HLE in Virtual Hydrological Laboratories. We evaluate these HLEs to determine if they support the development of new CMs that will be robust (in terms of both predictive ability and hydrological fidelity), by asking the following questions:

1. *Can the HLE evaluate the model for robustness on catchments of practically-relevant size?*
2. *Can the HLE evaluate the model for robustness on a diverse range of catchment properties?*
3. *Can the HLE evaluate the model for robustness on a wide range of processes/predictions?*
4. *Can the HLE evaluate the model for robustness using real data?*
5. *Can the HLE evaluate the model for robustness to "significant" change?*

The evaluation found that the four existing HLEs are unable to provide sufficient information to support the development of CMs that provide robust support for decision-making in the face of hydrological change across the wide range of situations of practical relevance.

A newly emerging, HLE, the Virtual Hydrological Laboratory, has unique strengths that can overcome the weaknesses of existing HLEs. In particular, the ability to undertake a controlled experimental approach will facilitate and accelerate CM development because (1) In a virtual catchment all hydrological components can be observed (albeit virtually), and thus CMs can be subjected to a more comprehensive level of scrutiny than current observational datasets allow; (2) The ability to systematically change catchment characteristics will provide the ability to conduct controlled experiments that isolate the key changes in hydrological process for different catchments types - this is currently not possible with real-world experiments; and (3) The ability to systematically change climate and land cover/use characteristics will provide the opportunity to undertake hydrological change experiments and evaluate CMs on a wide range of future hydrological change scenarios that are outside the envelope of observations. This strategy provides real potential to proactively "future-proof" CMs to be able to support decision making in the face of changes that are yet to be observed.

REFERENCE

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