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Hydrological modelling in a "big data" era: a proof of concept of hydrological models as web services

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Dealing with the massive increase in global data availability of all sorts is increasingly being known as "big data" science. Indeed, largely leveraged by the internet, a new resource of data sets emerges that are so large and heterogeneous that they become awkward to work with. New algorithms, methods and models are needed to filter such data to find trends, test hypotheses, make predictions and quantify uncertainties. As a considerable share of the data relate to environmental processes (e.g., satellite images, distributed sensor networks), this evolution provides exciting challenges for environmental sciences, and hydrology in particular. Web-enabled models are a promising approach to process large and distributed data sets, and to provide tailored products for a variety of end-users. It will also allow hydrological models to be used as building blocks in larger earth system simulation systems. However, in order to do so we need to reconsider the ways that hydrological models are built, results are made available, and uncertainties are quantified.

We present the results of an experimental proof of concept of a hydrological modelling web-service to process heterogeneous hydrological data sets. The hydrological model itself consists of a set of conceptual model routines implemented with on a common platform. This framework is linked to global and local data sets through web standards provided by the Open Geospatial Consortium, as well as to a web interface that enables an end-user to request stream flow simulations from a self-defined location. In essence, the proof-of-concept can be seen as an implementation of the "Models of Everywhere" concept introduced by Beven in 2007.

Although the setup is operational and effectively simulates stream flow, we identify several bottlenecks for optimal hydrological simulation in a web-context. The major challenges we identify are related to (1) model selection; (2) uncertainty quantification, and (3) user interaction and scenario analysis. Model selection is inherent to hydrological modelling, because of the large spatial and temporal variability of processes, which inhibits the use of one optimal model structure. However, in a web context it becomes paramount that such selection is automatic, yet objective and transparent. Similarly, uncertainty quantification is a mainstream practice in hydrological modelling, but in a web-context uncertainty analysis face unprecedented challenges in terms of tracking uncertainties throughout a possibly geographically distributed workflow, as well as dealing with an extreme heterogeneity of data availability. Lastly, the ability of end-users to interact directly with hydrological models poses specific challenges in terms of mapping user scenarios (e.g., a scenario of land-use change) into the model parameter space for prediction and uncertainty quantification.

The setup has been used in several scientific experiments, including the large-scale UK consortium project on an Environmental Virtual Observatory pilot.