# HYDRAULIC MODELLING IN A DATA-RICH WORLD

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The underlying thesis of this paper is that advances in computer power and data collection have, in the last five years, led to a quantum leap in our ability to parameterize, calibrate and validate hydraulic models. In particular, the availability of fine spatial resolution and high accuracy data from remote sensing platforms has transformed hydraulic modelling from a data-poor to a data-rich science with new and exciting opportunities for model development and analysis. The availability of data at a scale and resolution commensurate with, or in many cases in excess of, our hydraulic models will be a key element in developing a new era of computational hydraulics. This paradigm shift is already having consequences for how, where and by whom research in hydraulics is conducted, and may in the future require hydraulics to become a more multi-disciplinary science with less clearly defined boundaries between it and other disciplines. Such changes present a challenge for organisations such as IAHR, but also considerable new opportunities.

Environmental flows vary markedly in space and time, and as a consequence we require hydraulic models that are capable of making dynamic and spatially distributed predictions of key quantities (flood extent, water depth, flow velocity, sediment concentration, solute concentrations etc). These predictions are then used to inform major decisions relating to planning, insurance and infrastructure provision. However, until recently our ability to parameterize, calibrate and validate hydraulic models to produce spatial predictions has been severely limited. For example, even only 10 years ago validation data for reach scale hydraulic models consisted primarily of bulk flow measurements from gauging stations, either at the catchment outlet or at a limited number of stations internal to the model domain. Model validation thus relied on bulk flow data that represented the *aggregate* response of the river system to that point. However, for any given model and discretization, many different spatial patterns of grid square effective parameter values can lead to the same aggregate response, but give different spatial predictions and thus process inferences. In fact, replication of aggregate reach response only requires single values of model parameters spatially lumped at the reach scale and representing aggregate conditions. The consequences of a lack of distributed validation data are therefore equifinality and a tolerance of the physically unrealistic spatial lumping of parameter values and processes. Lack of parameterization data also leads to a requirement to estimate the unknown values, however as these are scale dependent the underlying distribution may not be well known and correct values may be difficult to define *a priori*. Calibration of initial parameter estimates is thus routine practice in hydraulic modelling, but given that insufficient data are usually available to constrain the calibration process this may further reduce the link between the model and reality. Analogous arguments could be made about many types of parameterization and validation data for many scales of hydraulic modelling, and the field as a whole could, until recently, have been characterised as data-poor. The paucity of reliable, consistent and accurate field data sets for almost any aspect of hydraulic modelling thus led to a reliance on idealised analytical solutions and data from laboratory experiments for hydraulic model validation.

Over the last 10 years remote sensing has emerged as a potential solution to many of these problems, and this holds out the possibility of a move towards a true distributed modelling capability in hydraulics. Pixel sizes for remotely sensed data are often the same as distributed model element scales and it is often possible to detect hydraulically significant patterns. This is particularly true of surface hydraulic problems, where we can actually make direct measurements of the relevant processes. Such data are not problem-free, as their conversion to quantities required by the hydraulic modeller may require an interpretative model that may itself be subject to uncertainty. However, such data are at least distributed in time and space and do, in some way, relate to real physical quantities.

Remotely sensed data from a variety of sensors and platforms, from ground-based cameras to satellites orbiting up to 800km above the earth, have now been used within hydraulic modelling and have shown considerable potential. Applications have ranged from modelling through urban areas to large scale modelling of flows through globally significant, yet poorly characterised river systems such as the Amazon. This paper explores a range of such applications and in each case documents the contribution of remote sensing to our developing understanding of hydraulic processes as we move to data-rich modelling environment. Many modelling techniques and theories in hydraulics are based around always having less data than required and the opposite situation may require that we re-think much of what we do. A data-rich environment gives a potential for model re-design to take advantage of this new information, for research into optimal ways to assimilate data into hydraulic models, for investigations of parameter scaling behaviour, for studies of the physical meaning of grid-scale effective parameters in models of different dimensionality or discretization and for an exploration of the ways in which new data sources may reduce uncertainty in model predictions.

The integration of remotely sensed data with hydroinformatics systems makes a true distributed modelling capability in hydraulics a real prospect and brings the ability to conduct significant research in this field to a much wider group of scientists than has hitherto been possible. When hydraulic research required major physical laboratories or mainframe computing the number of scientists able undertake research was limited to those in national level facilities. Whilst cheap desktop computing has transferred the ability to run complex hydraulic models to a much wider group, it is only the recent wide availability of the data necessary to do this that makes such a change successful. As a consequence many more scientists can now get involved in hydraulics research and these people are likely to be drawn from a wider range of disciplines (geography, ecology, hydrology, economics, social policy, environmental engineering, geophysics etc) than those that have traditionally formed the backbone of the hydraulics community. This democratizing and liberalizing effect will likely bring significant changes to the discipline and will require that hydraulics adapts to the challenges and opportunities that this brings. IAHR can potentially benefit from the much wider interest in hydraulic science, but only if it can develop the necessary multi-disciplinary linkages to complement its traditional strengths.