Introduction and Synthesis: Why should hydrologists work on a large number of basin data sets?

VAZKEN ANDRÉASSIAN[1], ALAN HALL[2], NANÉE CHAHINIAN[3] & JOHN SCHAAKE[4]

1 *Cemagref, Hydrosystems and Bioprocesses Research Unit, Antony, France*
vazken.andreassian@cemagref.fr

2 *Water Resources Application Project/GEWEX, Cooma, Australia*

3 *Agrocampus Rennes, Agricultural Engineering Laboratory, Rennes, France*

4 *Office of Hydrologic Development, NOAA/National Weather Service, Silver Spring, USA*

"*Because almost any model with sufficient free parameters can yield good results when applied to a short sample from a single catchment, effective testing requires that models be tried on many catchments of widely differing characteristics, and that each trial cover a period of many years*" (Linsley, 1982).

INTRODUCTION

There is now such a wealth of publications in hydrology, that it seems unlikely that any hydrologist can find the time to read even a decent part of it. Therefore, we have prepared this rapid introduction and summary of the papers that constitute this volume. Our aim is to convince you, the reader, to keep reading in order to discover the original contributions, which we believe are really worth the time you will spend on them. This volume contains 25 papers, many of which follow on from the presentations made at the last two MOPEX workshops (held in July 2004 at ENGREF, Paris, France, and in April 2005 at the IAHS Assembly in Foz do Iguaçu, Brazil. One of the objectives of this volume is to show how valuable it is to work on large data sets in hydrological modelling. The contributions are organized into five sections:

– The first section provides an introduction to the goals of the MOPEX project, and presents the databases that were used by the participants, a part of which is made available to the hydrological community on the DVD accompanying this volume.
– The second section groups four review papers, which were not presented during the MOPEX workshops, and which have been solicited especially for this volume, in order to provide alternative views on the use of large sample basin experiments in hydrology.
– The third and the fourth sections present model parameterization experiments based on samples of a large number of basins: in the third section, the focus is on the databases that were gathered specifically for the MOPEX program, while the fourth section presents regionalization and parameterization studies based on other large hydrometeorological databases.

– Lastly, the fifth section presents a compilation of the most recent results of the project, and discusses its perspectives.

But let us now examine the justifications for the type of research presented here. After all, why is it so important to consider the results of experiments considering a large number of basin data sets, while the trend of the last decade has been towards more and more extremely detailed studies of a single basin or even a single hillslope?

WHY WE BELIEVE THAT HYDROLOGICAL MODELLING RESEARCH SHOULD FOCUS ON A LARGE NUMBER OF BASIN DATA SETS

In the early days of hydrological modelling, computation power was a limiting factor and hydrologists could generally only afford to work on a few flood events on a single basin. Forty years later, this problem of computation power has almost become a detail. However, the work on a single basin or a limited number of basins still remains the rule in most hydrological modelling studies. Instead, we believe that hydrologists can and should take advantage of working on large sets of basins. We detail here a few reasons why this should allow some progress in hydrological research.

Reason 1: Model intercomparisons can definitely be useful … provided they are based on large data sets

An approach proposed over the last three decades to improve basin models is model intercomparison. The successive international intercomparisons organized by WMO since the end of the 1960s (Askew, 1989; WMO, 1975, 1986, 1992) have been very efficient in promoting a sound competitive spirit among research teams and in forcing modellers to question some of their preconceptions. The same applies for intercomparisons organized by single groups (Vandewiele *et al.*, 1992; Perrin *et al.*, 2001).

Some authors have been rather critical of intercomparisons and their possibility to identify guidelines for model selection (Wheater *et al.*, 1993; Woolhiser, 1996). Our opinion is that, as long as the number of basins included in the comparison is limited (as was the case in most of the comparisons published up to now), their conclusions may well be a matter of luck, and so the intercomparison exercise loses most of its interest. What is needed is a statistically significant number of basins (such as in some of the work presented in this volume), to get a robust model assessment, even if it must be acknowledged that such comparisons are still the exception rather than the rule. However, an increasing number of studies based on large data sets have been published recently (Perrin *et al.*, 2001; Merz & Blöschl, 2004; Oudin, 2004; Mouelhi *et al.*, 2006), and this volume will still add some more: for example, the paper by Folton & Lavabre (this issue) based on 880 basins, and that by Rojas Serna *et al.* based on a sample of 1111 basins, are current records (however, that may not last very long).

When based on several hundreds of basins, intercomparisons can be extremely instructive and they can definitely help to improve models and assess their generality (Perrin *et al.*, 2003). However, these intercomparisons can only be implemented when models can be set-up (i.e. structured, parameterized) in a reasonably automated way. Thus, this does not apply to most of the so-called “physically-based” models, since running such models on just one basin usually requires several months of work.

Reason 2: Only large data sets can allow us to move from climate/region-specific towards general catchment models

Some modellers insist on the fact that catchment models should be climate- or region-specific. This is in line with the prescriptions of the "conceptual" school, which advocate keeping in a catchment model only those "driving processes" that the modeller believes to be important in a given basin. As the "driving processes" may vary depending on hydro-climatic zones, it then seems natural to recommend a climate-specific modelling structure.

However, some of the founding fathers of hydrological modelling recommended looking for models with a certain ambition of generality. Ray Linsley (1982), while alluding to the great variety of driving processes which may affect the rainfall–runoff relationship, wrote that "*these differences do not mean that a single model cannot be applied in all cases. The model must represent the various processes with sufficient fidelity so that irrelevant processes can be 'shut off' or will simply not function*". And Linsley concluded that "*it is no longer necessary for each hydrologist to develop his or her own model for each basin, since [...] a new model for every application eliminates the opportunity for learning that comes with repeated applications of the same model*." The MOPEX approach is in line with such a statement.

Reason 3: The application of models on ungauged basins requires parameter estimation methods or laws that must be elaborated and/or calibrated on a wide range of conditions

Ungauged basins pose a formidable challenge to hydrology, as the methods proposed to estimate their parameters are still extremely uncertain. If we are to move forward on this topic during the PUB decade, existing and coming methods should be tested and validated over many basins, representative of a range of climates. This is because any unknown function f can, on a set of basins with similar climate conditions, be reduced to a linear first-order series expansion $y = f(x_0) + (x - x_0)f'(x_0)$. Conversely, if a test set encompasses semi-arid as well as humid basins, x will vary over a wide range of values and the proper structure of function f will be tested effectively.

WHAT ARE THE MAIN CONCLUSIONS OF THIS VOLUME?

This volume is the result of enthusiastic (but sometimes contradictory) exchanges held within a diversified group of modellers. This means that not all of the papers necessarily agree with each other. However, they all look with confidence towards data sets which have a large number of basins and intercomparison studies to guide their future work on model parameterization and regionalization. Let us here try to synthesize the main lessons of each section:

– **Data sets of a large number of basins are becoming widely available (Section 1)** We believe that the data set that comes along with this volume provides a wonderful opportunity for hydrologists all over the world to test their own methods and models. We hope in the future to be able to extend this data set and make it available through ftp.

– **Methods for regionalizing catchment models are still in their infancy (Section 2)** A lot remains to be done for simple lumped models and complex distributed ones as well. The explanation of the model parameter values representative of basin behaviour by basin characteristics remains unsolved. As long as this cannot be determined, it is unlikely we can hope for any progress in model regionalization.

– **Parallel work on the same data set of a large number of basins is extremely instructive (Section 3)** For the individual hydrologist, it is always instructive to read about the experience of his colleagues published in the scientific literature, but working on the same data set is a wonderful opportunity to better understand what others actually do, what assumptions they really make, and what approach or model structure is actually superior to the other.

– **Alternative approaches are emerging that may change the way we look at model regionalization (Section 4)** Though they have to repeatedly face the failure of their past efforts to deal with ungauged basins, hydrologists are not at a loss. Innovative approaches are proposed and tested, either to make the ungauged basins less ungauged, or to make progress with the methods of model parameterization.

– **Large samples of basins, as promoted by MOPEX, have much to contribute towards the success of the PUB decade (Section 5)** There is no consensus yet on the fact that experiments based on data sets of a large number of basins are needed in hydrology, and this volume should be seen as a very partial effort to promote the idea of using large data sets for hydrological studies (science does not necessarily need consensus to move forward!) It is often argued that as the basin sample increases in size, it becomes impossible to perform a detailed validation of the raw input data time series, and this will make the data set unusable. But in a comparative setting, there is no reason why a model would be less sensitive to bad input data than another: poor quality data will undoubtedly equally disadvantage all models. Thus, we believe that it is fallacious to object to the use of a large number of basin data sets on the grounds of the difficulty to control quality. For us, one thing is sure: a large sample of basin data sets and well organized intercomparisons may not be sufficient to ensure progress in hydrology, but at least, they are a necessary condition.

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