1 Model Improvements Through Detailed Process Studies

One of the major sources contributing to large uncertainties in hydrological predictions for ungauged basins comes from inadequate understanding of important physical processes and how to represent/parameterize them adequately in a model framework across different spatial and temporal scales. The goal of this session as part of the PUB Symposium, was to bring together researchers who investigate different aspects of reducing model prediction uncertainties through better understanding of physical processes and better incorporation of this understanding into modelling schemes across different scales. Oral and poster presentations were presented on the following topics:

- field measurement oriented studies in different hydro-climatic regions;
- illustrations of new ground data sources and data utilization to improve the understanding of the physical hydrological processes;
- new frameworks that are used to describe the physical processes mathematically;
- new process-based strategies for improving the model structure of currently used hydrological models; and
- case studies in various hydro-climatic zones showing reductions of model uncertainties through detailed process studies.

Seven papers out of more than 40 abstracts presented at the symposium are published in this proceedings volume. Two papers illustrate nicely the use of the latest techniques to identify hydrological processes at the hillslope and small-catchment scale in mountainous basins using combined tracer and geophysical approaches (Balin *et al.,* Uhlenbrook & Wenninger). This enabled the authors to understand the control of the geology and soil structure on the observed process behaviour. The combined use of different experimental techniques led to the development of conceptual models at the investigated sites that can serve as blueprints for model development. In another experimental study, Abesser *et al.* were using factor analysis and end-member mixing techniques to infer sources of runoff generation in Scottish catchments. High-resolution stream chemistry data from three catchments enabled them to infer sources of iron and manganese-rich runoff and to evaluate their temporal and spatial influence on the streamwater quality.

Four papers deal more with the development of process-based hydrological models. Vache & McDonnell developed process-based strategies for model structural improvement and the reduction of model prediction uncertainty. In particular the incorporation of soft and highly uncertain data in the model evaluation led to a useful rejectionist-based mechanism for incorporating experimental evidence into the modelling. In a tropical Australian catchment, Montanari *et al.* studied the process controls on stream flow response. They explored, in a systematic development of rainfall–runoff models, the appropriate model complexity. Koren *et al.* worked at a significantly larger scale with the modified grid-based Sacramento model. They demonstrate that the model driven by *a priori* parameters performs reasonably well and allows explicit estimation of soil moisture at desired layers. Finally, Cullmann *et al.* present a new strategy for online flood forecasting in mountainous catchments by combining a physically-based model with an ANN. Thus the advantages of both types of model, i.e. physical soundness on the one hand and operational advantages on the other hand are combined.

The papers describe significant progress in the respective fields, and can be seen as steps to improve our ability to make better process-based predictions at the catchment scale. However, there are still significant gaps in our scientific understanding of hydrological processes at all scales. A major limitation is the problem of accurately observing sub-surface fluxes, even with the promising latest developments in hydro-geophysics and tracer hydrology. Other limitations include: how to effectively address spatial heterogeneities; how to adequately generalize our understanding and findings obtained at hillslope or small spatial scales to larger domains; how to adequately quantify the uncertainty of hydrological predictions due to the numerous shortcomings of the input data, model parameter estimations, and the structure of current generation models; and how to validate model structures and results based on limited available point- or small-scale measurements. Incorporation of process driven understanding (often gained at too small scales) and new data sources into the modelling frameworks will continue to be very challenging and keep hydrological science exciting in the years to come.

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