Preface

Every second year since 1992, UNESCO/IHP and IAHS have jointly organized a series of colloquia named after George Kovacs, an outstanding international hydrologist, and President of IAHS from 1983 to 1987, who died in 1988. George Kovacs was a bright and energetic innovator in the fields of groundwater, hydrology and hydrogeology, and a researcher with a broad perspective. His vision and leadership led him to receive international recognition for his scientific contributions far beyond Hungary. Dedication of this colloquium series to George Kovacs is the most appropriate way to commemorate his outstanding role in the international hydrological community.

The first Kovacs Colloquium was devoted to *Space and Time Scale Variability and Interdependence in Various Hydrological Processes*[1] and it is notable that a decade later, the seventh Kovacs Colloquium returns to this fundamental question of Scales in Hydrology. The significant theoretical and application developments that have occurred in hydrology during this decade suggest the need to widen the scope of the question to include Water Management. There is also a need to focus on the possible development of applications from cutting edge research towards Integrated Water Resources Management (IWRM). The topic of scales in the hydrological sciences and in water resources management in general was accepted by the 35th session of the IHP Bureau as a contribution towards IHP-VI. This topic will also strengthen the continuing collaboration between UNESCO-IHP and IAHS, especially in the new Prediction in Ungauged Basins (PUB) initiative.

Indeed, space and time scales are fundamental for both scientific and operational hydrology issues. The question of how different scales interact and how we can transport results from one scale to another is ultimately both fundamental to our understanding, and strategically important for decision-making in an appropriate and timely fashion. The decisions to be made generally concern the storage of water, its allocation and transfer to users, and the treatment and the handling of the wastewater discharge. Because of the continued rise of the global population, the competition for available water is increasing and there is a need to broaden the emphasis of the hydrological sciences towards applications for better land-water management. The two dominating and closely related questions in water resources management (essentially in the terms of water quantity and quality) remain:

- How much of the resources remain for future generations? and
- What is the response of the environment to current management stresses?

To start answering these questions, there is a growing need to understand much better the complex interactions at different scales between the atmosphere, lithosphere, hydrosphere and biosphere, as well as to assess comprehensively our agricultural, urban and industrial activities.

In discussing space scales in hydrology, we must start from the planetary scale with a length scale of about 10^7 m. We generally describe the global evolution of the

[1]Feddes, R. A. (1995) *Space and Time Scale Interdependencies in Hydrological Processes.* International Hydrology Series, Cambridge University Press, UK.

hydrosphere, as well as climatic changes at this macroscale. The planetary scale in fact corresponds to the distance from the pole to the equator along a meridian, and was historically used to define the metre unit. The continental scale of 10^6 m generally corresponds to a few mesh lengths in a general circulation model of the atmosphere. The large catchment scale along with measurements resulting from the hydrological pilot[1] experiments is of the order of 10^5 m. Next the mesoscale generally ranges from about 10^4 m (i.e. the catchment area of approximately 100 km^2) to 10^2 m (i.e. a sub-catchment or a one hectare field). These are the typical scales at which most hydrological data are available. At the microscale, hydrology is linked though fluid mechanics and hydraulics to the physical sciences. For typical soils, the linear scale of a representative elementary volume in hydrogeology is about 10^{-2} m. This scale could be much larger for very heterogeneous media like karsts, and smaller for clays. The scale of about 10^{-5} m corresponds to the limits of the continuum hypothesis forming the basis of classical fluid mechanics.

The question of time scales in hydrology is also highly relevant. For example, millions of years are required for an erosion cycle to evolve through dynamic equilibrium between geology, relief and climate. Whereas in the physical study of hydrological processes we often use time scales shorter than one day and some experimental measurements are available at the time scale of seconds.

An extreme variability over a wide range of space–time scales incorporates the complexity of many natural and societal phenomena. To accommodate this complexity, there has been a common understanding that analytical approaches should strongly depend on the scale of interest. Such approaches may range from strictly deterministic cause–effect relationships to pure statistical considerations. For instance at the microscale, standard physical methods are usually considered as directly applicable to hydrological processes, whereas it is often hoped that macroscale studies could be more concerned with questions of statistical system equilibrium. Between these two extremes it is widely acknowledged that mesoscale fluctuations could correspond to the dynamics of much more complex systems. In particular, there are growing concerns that there may be much more continuity of hydrological phenomena over different scales than was previously believed. As a consequence, rather than obtaining a static understanding of phenomena over narrowly defined scale ranges, the key-problem is to dynamically capture what is flowing across scales: phenomena and characteristics associated with a wider range of scales.

The Seventh Kovacs Colloquium was therefore host to a timely strategic discussion of all the preceding issues in both the science and land–water management at all scales. Thus, the seventh Kovacs proceedings volume, is comprised of a collection of essays contributed by engineers and scientists who have spent much of their recent professional lives investigating issues of scale dependence in hydrological phenomena, with a view towards their application in Integrated Water Resources Management (IWRM).

The first paper in this volume, by Anthony M. Saracino, Jean-Pierre Delhomme and Robert A. Will, entitled *Multiscale information management and decision tools for effective water resource management*, takes on the challenging task of designing information management and decision tools dedicated to water resources management. Particular emphasis is given to drainage basins that display complex multiscale dynamics and where multiple processes are operating concurrently. Then, selected examples of application of the information management system to water resources at all scales in a given region, using a hierarchical data structure and a GIS-driven graphical user interface, are presented. Based on these examples, the authors are able to bridge spatial and temporal scales in order to transform data originally observed at a certain scale, for use at another scale of particular interest. The paper outlines particularly promising approaches for more efficient monitoring, modelling and management of regional water resources.

Scale appropriate modelling: from mechanisms to management by Paul F. Quinn and Caspar J. M. Hewett describes the main principles behind a hydrological modelling framework underpinning Integrated River Basin Management (IRBM) and discusses the key roles and skills required of hydrologists to secure its success. The authors illustrate how the choice of a research tool is related to the scale of interest and to the needs of land management. They demonstrate the possibility of scaling up local processes in order to better inform decision-makers and in turn to then scale down policy for its practical implementation.

Rosa Maria Formiga Johnsson in: *The river basin, a new territorial scale for water resources management in Brazil*, gives an example of a water resources management system that has developed in Brazil since the early 1990s. One of the main novelties of this system is the new administrative scale for planning and management through the use of the river basin scale. The author illustrates why and how the river basin can become the privileged space of institutional renewal, involving the creation of basin committees and agencies, and the institution of a system of bulk water-use charges. By comparing the water management systems of Brazil and France, this paper also reviews the most effective hydrological scale of management that takes into account the socio-economic, political and cultural identities within each basin.

Multiscale approaches to watershed management: land-use impacts on nutrient and sediment dynamics, by Hans Schreier and Sandra Brown discusses excess nutrients and soil erosion as the two most important nonpoint sources of pollution originating from agriculture. The paper examines the scaling problems associated with evaluating the impact of nutrient and soil losses from agriculture on water quality and drainage basin management. Using examples, the authors demonstrate that a multiscale approach, rather than a scaling up approach, is required to successfully address the problem.

Alain Pietroniro, Eric D. Soulis and N. Kouwen in *Scaling soil moisture for hydrological models*, discuss the status of surface soil moisture as a hydrological state variable and its importance for understanding runoff. The paper first gives an overview of some successes and related difficulties with remote sensing techniques in assisting hydrologists to describe and measure surface soil moisture. Then the authors provide an overview of their work which is targeted towards a better understanding of soil moisture variability; and the feasibility of using remotely sensed derived estimates in a meaningful way for hydrological modelling and applications.

Vijay K. Gupta's paper: *Prediction of statistical scaling in peak flows for rainfall–runoff events: a new framework for testing physical hypotheses*, first presents the key elements of a new physical theory that predicts statistical scaling in floods on nested sub-basins for individual rainfall–runoff events. The paper emphasizes that research on flood scaling might provide a helpful alternative for the classic unsolved problem of prediction in ungauged and poorly gauged basins. A discrepancy between model predictions and empirically observed scaling relationships provides a basis for testing physical assumptions without calibrating model parameters; and, at the same time, demonstrates the existence of major gaps between data needs, and data availability for testing scaling theory. Essentially the latter conclusion represents a call for greater attention being given to field measurement at the appropriate scale, and better process understanding through experimental hydrology.

Multiscaling geophysics and sustainable development, by I. Tchiguirinskaia, D. Schertzer, P. Hubert, H. Bendjoudi and S. Lovejoy, focuses on the application of a multifractal formalism to various data for a better understanding of complex interactions between societal impacts and the multiscale variability of natural systems. The authors aim to demonstrate how multifractals can be used for identifying and assessing the causal linkage between nonlinearity in geophysics and multiscaling of inherent geophysical and technological hazards within the natural and man-made environment. The authors suggest that better understanding of this causal linkage is indispensable for sustainable management of natural resources.

Modelling and forecasting rainfall in space and time, by Alan Seed, also discusses the scaling issue, and in particular its application to rainfall distributions. The distributions of rainfall in space and time are well known to be both variable and scale dependent. The latter two factors both affect the ability to forecast rainfall and the appropriate selection of stochastic methods to generate plausible fields of rainfall. This paper describes various methods that are generally used to describe the scaling behaviour of rainfall to achieve short duration rainfall forecasts and stochastic conditional simulations.

The final paper, *Impact of spatial scale on spatial variability in hydrological response: experiments and ideas*, by R. Woods presents a review of conceptual developments on the linkage between spatial variability and spatial scale. He uses the MARVEX project in the North Island of New Zealand to illustrate such linkages. The author argues that hydrology is more complex than a simple scaling approach would suggest and, therefore, expects domains for a scaling law applicability to be limited. This paper directs the readers toward creation of a global, scientifically-based system for classification or definition of similarity variables in hydrological science, that would greatly facilitate the transfer of experimental results around the globe.

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