

Spatial Patterns in Catchment Hydrology

Observations and Modelling

For many years now, modelling tools have been available to simulate spatially distributed hydrological processes. These tools have been used for testing hypotheses about the behaviour of natural systems, for practical applications such as erosion and transport modelling, and for simulation of the effect of land use and climate change. However, so far the quality of the simulations and spatial process representations has been difficult to assess because of a lack of appropriate field data.

Spatial Patterns in Catchment Hydrology: Observations and Modelling brings together a number of recent field exercises in research catchments, that illustrate how the understanding and modelling capability of spatial processes can be improved by the use of observed patterns of hydrological response. In addition the introductory chapters review the nature of the hydrological variability, and introduce basic concepts related to measuring and modelling spatial hydrologic processes. This introductory material provides the conceptual and theoretical background needed to move into this exciting area of research for a general earth sciences/water engineering audience. The book demonstrates that there is rich information in patterns that provide much more stringent tests of the models and much greater insight into hydrological behaviour than traditional methods.

Written in an intuitive and coherent manner, the book is ideal for researchers, graduate students and advanced undergraduates in hydrology, and a range of water related disciplines such as physical geography, earth sciences, and environmental and civil engineering as related to water resources and hydrology.

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Observations and Modelling

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Preface

Our everyday lives are dominated by patterns. The all too persistent temporal pattern of sleep, work, relax; the nightly weather maps and satellite images that might mould the shape of the forthcoming weekend's activities; or the intricate pattern represented by the arrangement of features on a human's face that lets us recognise a friend in a crowd. Some patterns contain simple information like the isobars on a map of surface pressure, while others are breathtakingly rich. Some of this information we can understand and interpret, while some is well beyond us. This book is about patterns. It is about how we measure, interpret and model aspects of spatial hydrological response. It is motivated by a belief that to advance the knowledge base of scientific hydrology, and to answer many of the questions of environmental management that are being asked by the broader community, we have to better exploit the information that resides in the myriad of patterns observable in nature.

For many years now, modelling tools have been available to simulate spatially distributed hydrological processes. The quality of the simulations and spatial process representations has been difficult to assess because of a lack of appropriate field data. In recent years there have been several major field exercises in research catchments, aimed specifically at improving our understanding and modelling capability of spatial processes. This book seeks to bring some of those studies together within the context of reviewing our understanding of spatial hydrological processes and presenting research work aimed at improving that understanding. In addition, we hope it provides a reference and source of motivation for others interested in undertaking detailed spatial data collection in combination with distributed modelling to improve our understanding and prediction of hydrological processes.

Specifically this book seeks to:

- (i) Provide readers with an introduction to the nature and representation of spatial patterns in hydrological processes;
- (ii) Show, through example, how the comparison of measured and simulated spatial patterns of hydrological response can be used both to improve our understanding of processes and to inform model development; and
- (iii) Provide an avenue for expanding upon the experiences of those who have undertaken major collection and collation exercises of spatial field

data, for the purpose of spatial modelling and gaining insight into spatial processes.

This book is aimed at two types of readers. The first will have a general knowledge of catchment hydrology and be keen to develop their understanding of the nature of hydrological variability, and be introduced to some methods and models that can assist in quantifying that variability. We have deliberately kept the introductory chapters free of detailed mathematics, preferring to concentrate on an intuitive understanding of the underlying concepts, many of which are quite rich and complex. We do not intend to provide a complete description of all available techniques or models, rather we seek to equip the reader with the knowledge needed to assess the *types* of tools and models that may be appropriate for their particular application, and to understand the basic approaches to modelling and analysis used in the case-study chapters. The second type of readers will be hydrologists who already have a sound knowledge of methods for spatial data analysis and of distributed modelling, but are thinking of undertaking studies similar to those presented in the book. For these readers, the case studies provide a wide range of measurement techniques, analysis methods, model types used, and approaches to the comparison of observed and simulated patterns, which should help them decide on the best approaches for their own work.

The book is presented in three parts. The first part (Chapters 1–5) starts with three introductory chapters (Chapters 1–3) on fundamentals that are key to putting later chapters in context. Chapters 4 and 5 deal with spatial patterns in precipitation and evaporation, respectively. These two processes were singled out because they are so critical to spatial hydrological response, yet are relatively poorly represented in most models. The two chapters include discussions about the state of the art in measurement and analysis of spatial information and the synthesis of point data. In the second part, case studies in research catchments are presented (Chapters 6–12). These chapters cover a range of environments from the tropics to Alpine regions; a range of dominant processes from Hortonian runoff to surface–groundwater interaction; a range of spatial data including remote sensing and multiple-point measurements; and a range of modelling structures including fully distributed grid and contour-based models of different complexities. An important feature of all the case studies, and something that makes them relatively rare in the hydrological literature, is that they directly compare *observed* with *simulated* spatial patterns. We asked the authors to focus on the collection and interpretation of patterns and their implications for model testing, while providing only a brief description of the models themselves. For full descriptions of the models, references are given in each of the chapters. The final part (Chapters 13 and 14) focuses on implications of the material presented in the earlier chapters. Chapter 13 addresses the implications when one moves away from the small research catchments to larger scales where practical predictions from distributed models are needed, focusing on issues of calibration and validation of these models. The final chapter (Chapter 14) is a

summary of the case studies and a discussion of broader implications from the work, highlighting what we have learnt from pattern comparisons and the challenges that remain.

In preparing this book we are greatly indebted to a large number of people. First and foremost, the contributors, for their dedication in addressing the central theme of the book and for providing their insights for us all to share. Thanks to the reviewers who provided timely feedback, and several colleagues who reviewed sections and were able to see the big picture when we were lost in detail. We are particularly grateful to Erich Plate for his thoughtful comments and willingness to look over the entire manuscript. Andrew Western and Ralf Merz deserve special mention for their help with a range of tasks from stimulating discussions on technical matters, to figure preparation. Dieter Gutknecht and Tom McMahon provided continued support for this project and both the Technical University of Vienna and the University of Melbourne assisted in a number of ways, not least being to help us work in the same office for extended periods of time. It was during these periods that the book really came together, over hours of discussion and friendly argument. Matt Lloyd from Cambridge University Press provided much needed assistance in all matters related to the production of the book.

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Rodger Grayson & Günter Blöschl
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