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Komaragiri Srinivasa Raju
Dasika Nagesh Kumar

Impact of Climate Change on Water Resources

With Modeling Techniques and Case Studies

Springer

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Foreword

A student once asked me after a lecture on climate change impacts to hydrology, 'Sir, What is the problem with increasing temperatures due to global warming. Can't we buy a bigger air conditioner and get back to normal?' The student was correct—one can engineer the effect of temperature rise unless it gets out of hand. The bigger problem is that temperature rise comes with change in rainfall, its intermittency, its distribution in space and in time, and the nature of its extremes that cause floods on one end and droughts on the other. Any change in rainfall will require re-engineering the planet, something that may not even be possible if the change gets too big.

This book by Prof. Srinivasa Raju and Prof. Nagesh Kumar is, to my knowledge, one of the first text-cum-reference books to assess and redesign water resources systems due to our changing climate. It will fill a timely gap to knowledge, given climate change is no longer a topic of debate, but one which countries around the world are learning to adapt to. Part of this adaption requires assessing change to risk for existing water resources infrastructure, put in place to allow us to live in places where water is too much or too little. Part of this adaption is also finding ways of designing new infrastructure that will be needed to combat the new water scarcity or excess a warmer climate will bring. The book draws heavily on the excellent work reported in several PhDs supervized by the authors and their colleagues, along with the considerable literature that has been published on this topic worldwide. The book is meant for those familiar with the principles of water resources systems, their design, management and operation, and for those wishing to learn on how they should be redesigned to cope with the challenges ahead.

The book starts with an explanation of what causes warming, why it is anthropogenic, what changes occur, why they are significant and irrefutable, and what are the implications to hydrology and the design and operation of water resources systems. It then shifts to how one can model future change, the challenges this entails, how climate models should be selected and uncertainty quantified, and how this uncertainty may be reduced through clever combination strategies. Following this, a comprehensive assessment of downscaling approaches is presented, which is needed due to the coarse resolution of climate models. This is followed by

chapters detailing the statistical techniques used in assessing model simulations, the hydrologic models needed to simulate changes in flow, and soil moisture from the changed rainfall and evapotranspiration conditions of the future, as well as a number of carefully selected case studies that articulate the range of problems the techniques presented can be used for.

I was especially pleased to see a set of questions at the end of each chapter, providing lecturers examples of questions that could be posed to students, giving an opportunity to assess for themselves what they have learnt and what remains. It is these questions that push students and the rest of us to devise solutions to what is turning out to be one of the biggest challenges humanity has faced till date. Many of these numerical questions enable better understanding of the theory clearly and systematically. While the climate has been changing since eternity, human-induced change is real and significant, with the bigger changes yet unseen and requiring careful assessment and planning. I feel this book is a step in the right direction, as it will provide the knowledge needed to re-engineer the planet and ensure our water resources systems continue to provide the security we have come to expect over the years.

My congratulations to both authors on this excellent accomplishment, and I hope this book forces its readers to ponder not only on the science behind climate change but also the engineering that is required to combat its effects on our way of life and existence.

March 2017

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Preface

Climate change has been emerging as one of the major challenges in the global scenario. Changes in climate may lead to adverse negative impacts on both natural and human systems. Continued emissions of greenhouse gases would further amplify the existing risks and create new complications for people and ecosystems. To analyze the possible impacts of climate change on a river basin, it is required to predict the future climate changes. This ultimately will help in planning and management of water resources in the basin. Effective decision-making to throttle climate change and its risks can be addressed by broad range of analytical and mathematical approaches by predicting the changes. General Circulation/Global Climate Models (GCMs) are one of the most credible tools presently available for modeling climate change. However, accuracy of GCMs, which generally run at coarse grid resolution, decreases with increasingly finer spatial and temporal scales, rendering them unable to represent sub-grid scale features. In other words, GCMs are not able to effectively model sub-grid scale processes which are of prime interest to hydrologists and water resources planners. Downscaling is one of the approaches where GCM outputs are interpolated to the scale of hydrological modeling or local scale requirement.

Over the years, various experts across the world have brought out a number of books on the above subject. Most of the books published so far are rather theoretically based with limited number of examples and case studies. The present book is an amalgamation of available resources and divided into various chapters and information about the chapters are as follows: Chap. 1 provides introduction to climate change and variability, climate feedback, forcing mechanism, atmospheric chemistry, palaeo records, monsoon variability, Holocene, IPCC scenarios, teleconnections, impact of climate change, and organization and utilization of the book. The chapter concludes with revision questions and exercise problems, advanced review questions, references, and suggested further reading. This sort of exercises is provided to all the chapters in the book with exception of Chap. 6 in which case studies are presented. Chapter 2 describes GCMs and their choice, performance indicators for evaluating GCMs, weight estimation, multicriterion decision-making techniques in deterministic and fuzzy scenario, Spearman rank correlation

coefficient, and group decision-making. Ensembling methodology of GCMs is also discussed. Chapter 3 describes downscaling techniques. Detailed discussion is presented on statistical downscaling techniques such as multiple regression, artificial neural networks, Statistical Downscaling Model (SDSM), change factor technique, and support vector machine. Brief discussion on nested bias correction is also made. Chapter 4 presents data compression techniques, namely, cluster and fuzzy cluster analysis, Kohonen neural networks, and principal component analysis. Trend detection techniques and optimization techniques, namely, linear and non-linear programming and genetic algorithms, are also discussed. Chapter 5 describes hydrological models, SWMM, HEC-HMS, SWAT, and other modeling techniques. Chapter 6 presents various real-world global case studies in AR3 and AR5 perspective that are related to the theories and techniques explained in the earlier chapters. Even through AR3 is relatively older than AR5, case studies are presented to understand the impact of climate change with temperature anomaly equivalent visualization paths, namely, SRES or RCPs.

Appendix A covers procedures for acquiring data from various sources. Appendices B and C provide representative list of journals and books related to climate. Index is also provided for efficient retrieval of topics.

PowerPoint presentations of selected topics are also provided as an additional study material. Interested individuals can contact publishers for PowerPoint presentations.

The present book can help undergraduate as well as postgraduate programs in the field of hydrology, climate change, and allied fields and can be referred as a text book. It can also be used as a reference book or as supplementary study material for researchers working in this upcoming field. The case studies, PowerPoint presentations, extensive references, limited but informative and illustrative problems, and software information render this book as a valuable source of information for researchers, experts, professionals, teachers, and others who are interested in the field of climate, hydrology, and allied fields.

Special acknowledgements to Dr. Ashish Sharma, Professor and Future Fellow (ARC), School of Civil and Environmental Engineering, The University of New South Wales, Sydney, Australia who readily agreed to write a foreword for the book.

The authors are inspired and motivated by the books, reports and publications of esteemed experts, Dr. Ashish Sharma, Dr. B.C. Bates, Dr. Z.W. Kundzewicz, Dr. T. J. Ross, Dr. S. Wu, Dr. J.P. Palutikof, Dr. D.R. Easterling, Dr. F. Johnson, Dr. R.L. Wilby, Dr. Di Luzio M., Dr. G.S. Rao, Dr. R. Srinivasan, Dr. R. Mehrotra, Dr. Sulochana Gadgil, Dr. R.S. Nanjundiah, Dr. V.V. Srinivas, Dr. S.K. Satheesh, Dr. K.C.Patra, Dr. Danielle Costa Morais, Dr. Adiel Teixeira de Almeida, Dr. Chong-yu Xu, Dr. Lankao, Dr. T.I. Eldho and many others and are greatly benefited from various journal papers, Intergovernmental Panel on Climate Change (IPCC) reports, various climate-related homepages such as IPCC, Climate Prediction Center, Climate Research Unit, etc. It will not be surprising, if the reader finds some of their flavor in this book.

The concerned experts and researchers have generously given permission to utilize their study material. We have included in this book some portions of our own publications and publications of other researchers published in various journals (after obtaining copyright permissions) by giving due reference to the journals at the appropriate places. We sincerely thank the publishers of these journals such as Springer, Elsevier, IWA ASCE, Copernicus, De Gruyter, Inter-Research Science Center (Germany), and Prentice Hall of India for giving us specific permissions to reuse the material. Acknowledgements are also due to Dr. A. Anandhi, Dr. Sonali P., and Dr. T.V. Reshmi Devi, Prof. Ajit Pratap Singh, and Ms. Gayam Akshara for permitting us to utilize material from their works. Special Acknowledgements to Ms. V. Swathi for providing numerical problems in the chapter, hydrological modeling.

Even though efforts were made to quote all the sources in the form of acknowledgements or references, a few may have been missed inadvertently. We sincerely apologize for any such inconvenience caused and assure that these will be duly incorporated in the next edition on noticing the same.

Every effort is made to eliminate typographical calculation and methodological errors but still, some may have been left out. We request the readers to bring it to our notice to rectify them in the next edition. The software information provided does not necessarily indicate that the authors are encouraging to use only those particular software. Similar softwares may also be available which may perform as efficiently as those mentioned or even better. Critical suggestions are welcome for improvement of the contents.

The first author is grateful to Prof. G. Sundar, Director, Dr. A. Vasan, Associate Professor, BITS-Pilani, Hyderabad campus, and Prof. A.K. Sarkar, Director, BITS-Pilani, Pilani campus who provided constant motivation and encouragement for preparing the book. The first author acknowledges the support given by his parents Gopala Rao and Varalakshmi, wife Gayathri Devi, daughter Sai Swetha, and son Sai Satvik. The second author acknowledges the support given by his parents Subrahmanyam and Lakshmi, wife Padma, daughter Sruthi, and son Saketh.

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Hyderabad, India
Bangalore, India
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