Climate Variations, Climate Change, and Water Resources Engineering

Edited by
Jürgen D. Garbrecht, Ph.D.

CLIMATE VARIATIONS, CLIMATE CHANGE, AND WATER RESOURCES ENGINEERING

SPONSORED BY
Surface Water Hydrology Technical Committee

Environmental and Water Resources Institute (EWRI)
of the American Society of Civil Engineers

EDITED BY
Jürgen D. Garbrecht, Ph.D.
Thomas C. Piechota, Ph.D., P.E.

Published by the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

Climate variations, climate change, and water resources engineering / edited by Jürgen D. Garbrecht, Thomas C. Piechota ; sponsored by Environmental and Water Resources Institute (EWRI) of the American Society of Civil Engineers, Surface Water Hydrology Technical Committee.
p. cm.
Includes bibliographical references and index.
ISBN 0-7844-0824-6
1. Water resources development--Systems engineering. 2. Water-supply--Management. 3. Water-supply engineering. 4. Climate changes. I. Garbrecht, Jürgen. II. Piechota, Thomas Christopher, 1965- III. Environmental and Water Resources Institute (U.S.)

TD353.C545 2006
628.1--dc22 2005057035

American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4400

www.pubs.asce.org

ISBN 0-7844-0824-6
Manufactured in the United States of America.

11 10 09 08 07 2 3 4 5 6

Preface

The enormous contribution of water to economic development has been recognized for centuries. Sophisticated water resource systems have been developed to ensure a continued safe and reliable water supply, yet seasonal, inter-annual and longer climate variations can stress these systems and even lead to water shortages. Examples of climate variations with water resources impacts include the Dust Bowl of the 1930's that devastated the agricultural economy of the Great Plains; the 1976-1977 and 1987-1992 droughts in California that slowly depleted state water reserves and ultimately affected irrigated agriculture, urban water supply, reservoir operations and natural ecosystems; and the 1980's rise in the Great Salt Lake and the 1993 upper Mississippi River basin flood that caused substantial property and ecological damage. Knowledge of climate variations can be valuable for water resources management in agriculture, urban and industrial water supply, hydro-electric power generation, navigation, recreation and ecosystem maintenance. Forecast of near term climate, or identification of the state of the global climate system and its local consequences can help managers develop adaptive strategies, implement mitigating policies, and make strategic investments in infrastructure and information sources for integrated watershed management.

Many aspects of climate variations and their impact on water resources have been investigated and presented at society conferences, and published in many research reports and journal publications. However, the information is dispersed and makes a comprehensive overview difficult and often impractical for the practicing water resources engineer. A source is needed that provides a general overview of the many interrelated aspects of climate variations and connections to water resources, discusses impacts on water resources variables, and provides references to the literature for details on individual subjects. Recognizing this need, the Surface Water Hydrology Technical Committee under the Water Resources Engineering Division of the Environmental and Water Resources Institute (EWRI) formed a task committee (TC) on Climate Variations, Climate Change and Water Resources Engineering. The purpose of this TC was to advance the understanding of and disseminate information on climate variations and climate change and their significance for water resources engineering. The TC sponsored specialty sessions at annual EWRI Water Resources Engineering conferences, provided an interdisciplinary forum to interact on climate and water resources issues, and produced this TC report. The objectives of this report are to provide a broad overview of our current knowledge of climate variations, discuss their impact on water resources systems, characterize their predictability, and provide examples of their use in water resources management, planning and design.

This report does not pretend to, nor can it be a comprehensive treatment of the subject matter, yet it covers a number of relevant and interrelated aspects that are common to

climate variation and water resource issues. It provides the practicing water resources engineer with an overview of the multiple facets of the subject matter and a source of background information for practical applications. Technical details have intentionally been omitted to maintain focus on underlying issues. The intended audience for this report is water resources planners and managers; flood and drought preparedness agencies; reservoir operators; users of long-range seasonal climate forecasts; agricultural producers; irrigation district managers; and others that rely on water resources budgeting, planning and systems operations.

This report is the result of a joint effort of all members of the EWRI TC on Climate Variations, Climate Change and Water Resources Engineering. The assistance, collaboration, input and time devoted by each and every member of the TC are gratefully acknowledged. Special thanks are extended to Dr. U. Lall who reviewed the contributions to this report and provide valuable suggestions for improvement. The editors also thank the authors for their patience and numerous revisions required by the review process. Contributing authors are C. K. Baldwin, G. O. Brown, L. Cadavid, T. E. Croley, M. D. Dukes, J. M. Jacobs, J. W. Jones, D. C. Garen, B. M. Lofgren, S. M. O'Connell, J. Obeysekera, T. C. Pagano, E. R. Santee, S. R. Satti, J. M. Schneider, R. G. Steger, G. A. Tootle, P. Trimble, M. D. Waage, and D. W. Watkins.

J. Garbrecht and T. C. Piechota
Chair and Co-Chair, EWRI Task Committee on
Climate Variations, Climate Change and Water Resources Engineering

Contents

This page intentionally left blank

Part I

An Overview

This page intentionally left blank

Climate Variability and Climate Change

T.C. Piechota[1], J.D. Garbrecht[2], and J.M. Schneider[2]

[1]University of Nevada, Las Vegas, Department of Civil and Environmental Engineering, 4505 Maryland Parkway, Box 454015, Las Vegas, NV 89154-4015
[2]USDA, Agricultural Research Service, Grazinglands Research Laboratory, 7207 West Cheyenne St., El Reno, OK 73036, USA

INTRODUCTION

Climate change and climate variability has received considerable attention from the scientific community in recent decades and has led to a better understanding of various climate phenomena and driving mechanisms. This increased understanding of climate has also prompted policy makers to ask two important questions: (1) How can an improved understanding of climate variability advance our ability to manage resources such as water, energy, and the environment; (2) What are the potential impacts on our key resources due to projected climate change? These are not easy questions to answer, and probably can not be answered with a high degree of certainty. However, scientists and engineers must make the best assessment of climate impacts given the current state of knowledge. The information presented in this section is meant as a primer of issues related to climate variability and climate change. From an engineer's perspective, the implications may be significant for design of infrastructure (i.e., water supply systems, flood control systems) and for the optimal operation of water systems. This section will review natural climate variations and teleconnections, followed by a brief explanation of anthropogenic climate change, and conclude with an overview of climate predictability and forecasting.

First, some key definitions and concepts commonly used when discussing climate variability and climate change are provided. Weather is the state of the atmosphere, or meteorological conditions, (i.e., temperature, relative humidity, barometric pressure) at a particular time and place (Glantz, 2003). Weather forecasts are made up to 10 days in advance with a decreasing level of skill at longer lead times. Climate is weather averaged over many days (months to years to centuries) and larger spatial scales (Glantz, 2003). The term teleconnections refers to large and persistent ocean-atmospheric anomaly patterns (e.g., El Niño – Southern Oscillation, North Atlantic Oscillation) over large areas, and apparent causal effects on regional climate conditions in adjacent or remote regions. A discussion of well known teleconnections is presented later in this section. These large scale ocean-atmosphere patterns have interannual variations (return periods on the order of 2-10 years), and interdecadal variations (return periods on the order of 10-50 years). In addition, there is evidence