ASCE Manuals and Reports on Engineering Practice No. 139

Radar Rainfall Data Estimation and Use





Surface Water Hydrology Technical Committee Edited by Chandra S. Pathak, Ph.D., P.E., D.WRE Ramesh S. V. Teegavarapu, Ph.D., P.E.





ENVIRONMENTAL & WATER RESOURCES INSTITUTE

Radar Rainfall Data Estimation and Use

Prepared by the Radar Rainfall Data and Application Task Committee of the Surface Water Hydrology Technical Committee of the Watershed Council of the Environmental and Water Resources Institute of the American Society of Civil Engineers

> Edited by Chandra S. Pathak, Ph.D., P.E. and Ramesh S. V. Teegavarapu, Ph.D., P.E.





Published by the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

Names: Pathak, Chandra S., editor. | Teegavarapu, Ramesh S. V., 1970- editor. | Environmental and Water Resources Institute (U.S.). Radar Rainfall Data and Application Task Committee.

Title: Radar rainfall data: estimation and use / prepared by the Radar Rainfall Data and Application Task Committee, of the Surface Water Hydrology Technical Committee, of the Watershed Council, of the Environmental and Water Resources Institute, of the American Society of Civil Engineers; edited by Chandra S. Pathak, Ph.D., P.E., D.WRE [and] Ramesh S.V. Teegavarapu, P.E.

Other titles: Rainfall data Description: Reston, Virginia: American Society of Civil Engineers, [2018] | Series: ASCE manuals and reports on engineering practice; no. 139 | Includes bibliographical references and index. Identifiers: LCCN 2018029381 | ISBN 9780784415115 (hardcover: alk. paper) Subjects: LCSH: Radar meteorology. | Rain and rainfall—Forecasting. | Rain and rainfall. Classification: LCC QC973.5 .R325 2018 | DDC 551.63/53—dc23 LC record available at https://lccn.loc.gov/2018029381

Published by American Society of Civil Engineers 1801 Alexander Bell Drive Reston, Virginia 20191-4382 www.asce.org/bookstore | ascelibrary.org

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers-Registered in U.S. Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be requested by sending an e-mail to permissions@asce.org or by locating a title in the ASCE Library (http://ascelibrary.org) and using the "Permissions" link.

Errata: Errata, if any, can be found at https://doi.org/10.1061/9780784415115.

Copyright © 2018 by the American Society of Civil Engineers. All Rights Reserved. ISBN 978-0-7844-1511-5 (print) ISBN 978-0-7844-8176-9 (PDF) ISBN 978-0-7844-8177-6 (ePub) Manufactured in the United States of America.

24 23 22 21 20 19 18 1 2 3 4 5

Photo credits: — front cover, radar tower: https://www.flickr.com/photos/noaaphotolib/9672381030/in/album-72157638866298193/

— front cover, map and visual of radar data: https://www.flickr.com/photos/noaaphotolib/5278185262/in/photolist-93q5Ab-93mX7K-8QvfYj-8QsbPc

— back cover, weather map: https://www.flickr.com/photos/noaaphotolib/9627283271/in /album-72157625168461902/

MANUALS AND REPORTS ON ENGINEERING PRACTICE

(As developed by the ASCE Technical Procedures Committee, July 1930, and revised March 1935, February 1962, and April 1982)

A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his or her everyday work, rather than findings that may be useful only occasionally or rarely. It is not in any sense a "standard," however; nor is it so elementary or so conclusive as to provide a "rule of thumb" for nonengineers.

Furthermore, material in this series, in distinction from a paper (which expresses only one person's observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable the committee is under the direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of the Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as the basis for improvement. When published, each work shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, so that its merit may be definitely understood.

In February 1962 (and revised in April 1982), the Board of Direction voted to establish a series titled "Manuals and Reports on Engineering Practice," to include the Manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such Manual or Report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past Manuals. Numbering would be consecutive and would be a continuation of present Manual numbers. In some cases of joint committee reports, bypassing of Journal publications may be authorized.

A list of available Manuals of Practice can be found at http://www.asce.org /bookstore.

This page intentionally left blank

CONTENTS

PR	EFAC	Е	ix
AC	CKNO	WLEDGMENTS	xi
1.	RAD	AR RAINFALL ESTIMATION	1
	1.1	Introduction	1
	1.2	Background	2
	1.3	Scope	7
	1.4	Availability of Radar Rainfall Data within the United States References	7 8
2.	RAD CHA	AR RAINFALL DATA: TEMPORAL AND SPATIAL RACTERISTICS	11
	2.1	Native Radar Data Resolution	. 11
	2.2	Radar Rainfall Data Mosaics	12
	2.3	Data Formats and Resolutions	13
	2.4	Radar Rainfall Data QA/QC and Data Management	16
	2.5	Gauge-Adjusted Radar Rainfall Estimates	20
	2.6	Tool for Radar Rainfall Data Analysis (HEC-MetVue)	21
	2.7	Use of Radar Rainfall Data	22
	2.8	Radar Rainfall Data Issues and Future Perspectives	26
	2.9	Conclusions	27
		References	. 28
3.	RAD	AR RAINFALL DATA PROCESSING	. 31
	3.1	Background	. 31
	3.2	Data Acquisition and Processing	. 33
	3.3	Reflectivity-Precipitation Rate Relationships	38
	3.4	Radar QPE Products from the WSR-88D Radar	
		Product Generator	40

CONTENTS

	3.5	Error Distribution of Radar Rainfall Estimates	40			
	3.6	Approaches to Gauge-Radar Adjustment	41			
	3.7	Approaches to Gauge-Radar Observation Merging	43			
	3.8	Applicability of the Gauge-Radar Approaches	45			
	3.9	Use of Daily Precipitation Reports in Combination				
		with Radar QPE	47			
	3.10	Access to Precipitation Observations and Estimates	48			
	3.11	Conclusions	49			
		References	49			
4.	EVALUATION AND IMPROVEMENT OF RADAR					
	RAIN	NFALL DATA	53			
	4.1	Rainfall Measurement Methods, Errors, and Accuracy	53			
	4.2	Rain-Gauge and Radar-Based Measurements	53			
	4.3	Improving Radar-Based Estimation: Optimal Z–R				
		Relationships	54			
	4.4	Conclusions	57			
		References	57			
2	UCE					
5.		ROLOCIC MODELING	50			
	51	Data Requirements for Hydrologic Modeling and Design				
	5.2	Radar-Based Rainfall Data for Hydrologic Modeling	 60			
	53	Conclusions	00			
	0.0	References	02			
6.	EXAMPLES IN RADAR RAINFALL DATA, ANALYSES,					
	AND	APPLICATIONS.	63			
	6.1	Radar Rainfall Estimation—South Florida Water				
		Management District	63			
	6.2	Radar Rainfall Data Analyses	65			
	6.3	Other Radar Rainfall Data Applications	66			
	6.4	Conclusions	69			
		References	69			
7.	ADVANCED TOPIC: FRAMEWORK FOR BIAS					
	ANA	LYSIS OF RADAR DATA	73			
	7.1	Bias Analysis Methods	73			
	7.2	Ideal Performance Measures and Skill Scores	84			
	7.3	Utility of Assessment Indexes and Performance Measures	85			
	7.4	Bias Corrections	89			
	7.5	Bias Corrections with Limited Rain-Gauge Data	90			
	7.6	Bias Corrections: Temporal Resolution Issues	90			
	7.7	Conclusions	91			
		References	91			

CONTENTS

8.	ADV DAT	ANCED TOPIC: RAIN-GAUGE RAINFALL A AUGMENTATION AND RADAR RAINFALL	
	DAT	A ANALYSIS	95
	8.1	Spatial and Temporal Analysis of Rainfall	95
	8.2	Missing Data Estimation	96
	8.3	Use of Radar Data for Infilling Rainfall Data	98
	8.4	Geospatial Grid-Based Transformations of Radar-Based	
		Rainfall Data	102
	8.5	Issues with Filled Precipitation Data Series	105
	8.6	Conclusions	107
		References	107
9.	ADV	ANCED TOPIC: DESIGN OF RAINFALL	
	MON	NITORING NETWORKS	111
	9.1	Design of Rainfall Monitoring Networks	111
	9.2	Rain-Gauge Network Density	111
	9.3	Optimal Rain-Gauge Monitoring Networks	112
	9.4	Optimal Density and Monitoring Networks	113
	9.5	Objectives for Monitoring Network Design	113
	9.6	Optimal Monitoring Network Design	114
	9.6	Optimal Network Design Using Radar Data	116
	9.7	Post-Network Design Recommendations for	
		Rain-Gauge Placements	118
	9.8	Identification of Meteorologically Homogeneous Areas	118
	9.9	Conclusions	119
		References	120
IN	DEX		121

This page intentionally left blank

PREFACE

This manual on radar rainfall data estimation was developed as one of the several tasks that was undertaken by the Radar Rainfall Data and Application Task Committee, under the Surface Water Hydrology Technical Committee within the Watershed Council of Environmental and Water Resources Institute's (EWRI), American Society of Civil Engineers (ASCE).

This manual was developed primarily for use by the practicing water resources engineers in the industry. This manual has nine chapters and their titles and authors are shown as follows.

Chapter 1: Radar Rainfall Estimation, Chandra S. Pathak (US Army Corps of Engineers);

Chapter 2: Radar Rainfall Data: Temporal and Spatial Characteristics, Chandra S. Pathak (US Army Corps of Engineers) and David C. Curtis (WEST Consultants);

Chapter 3: Radar Rainfall Data Processing, David Kitzmiller (National Weather Service);

Chapter 4: Evaluation and Improvement of Radar Rainfall Data, Ramesh S.V. Teegavarapu (Florida Atlantic University);

Chapter 5: Use of Radar Rainfall Data in Hydrologic Modeling, David C. Curtis (WEST Consultants);

Chapter 6: Examples in Radar Rainfall Data, Analyses, and Applications, Chandra S. Pathak (US Army Corps of Engineers);

Chapter 7: Advanced Topic: Framework for Bias Analysis of Radar Data, Ramesh S.V. Teegavarapu (Florida Atlantic University);