Precipitation: Advances in Measurement, Estimation and Prediction

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This book is dedicated to my wife Fyllitsa

Silas Michaelides
Editor

Editorial

This book is the outcome of contributions from scientists who were invited to expose their latest findings on precipitation research and in particular, on the measurement, estimation and prediction of precipitation. In this respect, the book comprises a state-of-the-art coverage of the most modern views and approaches in the study of precipitation. In addition, the 20 Chapters that this book consists of provide an insight into the evolutionary aspects of their respective disciplines; also, many of the authors attempt to project into the future by providing an outlook of the planned and expected developments in their respective areas of research.

The Chapters presented in this book are mostly written by selected scientists who presented their advances in precipitation research during activities at the 2006 and 2007 General Assemblies of the European Geophysical Union (EGU) that I convened, at the kind invitation of its Atmospheric Sciences Division. However, in order to give a more complete picture of the subject, other invited experts were asked to supplement with additional Chapters.

The readers of this volume are presented with a blend of theoretical, mathematical and technical treatise of precipitation science. Large parts of many Chapters are devoted to authentic applications of technological and theoretical advances: from local field experiments to country-scale campaigns and, beyond these, to multinational space endeavors. Also, the book reveals the high level of scientific ingenuity, the systematic exploitation of modern technological knowledge and the extent of scientific collaboration and networking that were employed by the scientific community in tackling a very complex issue.

Bearing in mind the above, the book is addressed to those who are involved in precipitation research, but also to those researchers from the wider area of atmospheric sciences whose interests touch on this extremely important weather phenomenon. Moreover, the book aims at introducing newcomers in the field of precipitation science to the various up-to-date scientific facets of the subject, by exposing the full dimensions of the measurement, estimation and prediction of precipitation. I trust that this volume will become a valuable source of inspiration for the scientific endeavors of all scientists working on the multifaceted physical phenomenon of precipitation.

This book is the result of an intense collaborative effort and close interaction between the Authors and the Editor, on the one hand, and the Editor and the Publishers, on the other hand. In this respect, I wish to express my deepest appreciation to all and each one of the 51 esteemed colleagues, scientists and researchers who contributed to this book for their valuable writings but also for their patience during the compilation of this volume. I also wish to thank the Publishers for their kind invitation to lead and coordinate this effort which turned out to be a great experience for me. Finally, I am grateful to my wife Fyllitsa for her valuable support during the writing and compilation of this book.

Dr. Silas Michaelides
Editor

Prologue

As mankind faces up to the various pressing environmental and climatic problems of the twenty-first century, protecting freshwater resources is to be found at the forefront. The availability of freshwater for human consumption, agriculture and industry is of concern to all nations, particularly those in the arid zones where prolonged droughts have already created immense human suffering, population displacement and erosion of arable resources. Ultimately, precipitation is the foremost source of freshwater. With the exception of ancient artesian deposits and deep aquifers, which themselves can only be recharged by precipitation once depleted, mankind largely depends upon precipitation to supply inland lakes, rivers, wetlands and reservoirs of all types for its freshwater stores – including the buildup of snow in mountains for the eventual Spring runoff. Understanding the physical processes which control and produce precipitation and the development of models to predict precipitation, are responsibilities left to scientists, especially those who are specialists in precipitation physics, measurement, remote sensing estimation, model formulation, and verification.

It is notable than some 60% of the world's population that is impacted by shortages of freshwater live within the 21 countries that surround the Mediterranean Sea – the centerpiece of a basin whose water budget is of central concern to the European Union and even more so to its neighbors to the East and South where current and pending water shortages are extreme. Preserving a fresh water supply to residents of these nations and elsewhere has become a prime responsibility of national and local governments, as well as of individuals – and more recently of international organizations whose well conceived policies are able to help assist governments and individuals to protect, preserve, conserve, and utilize water in the best possible fashion. By the same token, scientists are left with the responsibility of finding the optimal means to measure precipitation, to understand how its production is influenced by climate change, aerosol effects, and land use change – and ultimately to predict its distribution and those additional elements of regional and global water cycles that affect man's life and health. It is easy enough to overlook these issues when conducting research, seeking funding for research, teaching and supervising students concerning precipitation science and running models associated with precipitation and water resources; without scientific commitment in helping solve mankind's central problems with water and water conservation, scientists would not be exercising their very best skills. That is why books such as this up-to-date compendium are so very important.

The book's Chapters are organized into four thematic Parts, entitled: I. Measurement, II. Estimation (via space, ground and underwater remote sensing), III. Prediction, and IV. Integration – with each Part covering a selection of distinct views.

The first Part addresses measurement techniques and quality control based on new technology instruments, including the 2D-Video-Distrometer and the Droplet Spectrometer which obtain measurements of accumulated rainfall by actually counting and integrating the water volumes of individual droplets. Such technology enables diversified quantization and segmentation of rainfall because it resolves the process down to its fundamental unit metric.

The second Part addresses the remote sensing of rainfall- which has traditionally been a problem in transforming backscatter observations (i.e., reflectivity factor measurements) from non-coherent, non-polarimetric, single frequency ground radar systems into estimates of rain rate – but in recent decades has undergone a technology revolution into the use of Doppler, polarimetric, and multi-frequency radar systems operated on the ground, on ships and on aircraft, plus the use of passive microwave radiometers and high frequency radars operating on Earth-pointing spacecraft. New remote sensing technology has even been used in the ocean to estimate rain rates by measurement of under water acoustic waves produced by rainfall noise on the ocean surface. The Chapters in this Part provide a selection of new ideas concerning the remote sensing of precipitation using the newer technologies, including a view to the future.

The third Part then moves to the prediction of precipitation through the use of different types of prognostic modeling systems: (a) the ensemble numerical weather prediction (E-NWP) model, (b) the Limited Area Model (LAM), and (c) the advection-based Nowcasting Model (NM) which can be used with either time-lapse ground radar images or optical-infrared satellite images.

Finally, the fourth Part addresses the integration of precipitation research. Amongst other issues, this Part addresses the research that took place within the *Voltaire Project*, a European-wide project that addressed many of the same issues addressed within this book's compilation of Chapters, but closely focused on verification and validation of precipitation observations.

It is left as a challenge to the reader to help devise and guide future research programs concerning precipitation physics, measurement, estimation, prediction and validation. These remain as imperative research topics for the experimental, applications and operational agencies along with the academic research departments charged with understanding, monitoring and predicting precipitation and the stores of freshwater resources that mankind depends upon for its livelihood, health, food production and commerce. The publication of findings of these research programs is crucial in moving the science forward and in creating understanding of all aspects of precipitation – knowledge that is sublimely important to the world community. Therefore, I offer my gratitude as a scientist and as a friend to Dr. Silas Michaelides for the very fine effort he has put forth to deliver this book and its contents – provided by an international body of scientists – into the open literature.

Professor Eric A. Smith

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Contents

Part I. Measurement of precipitation

1 The 2D-Video-Distrometer

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Table of contents

1.1 Introduction

Detailed knowledge on tropospheric precipitation microstructure is one of the bases in various fields of sciences and applications, like terrestrial and satellite radio transmission, remote sensing of precipitation, generally tropospheric wave propagation and atmospheric sciences.

In the field of telecommunications, precipitation causes several unwanted effects on Earth-satellite as well as on terrestrial links. System design has to consider that and has to take care for appropriate countermeasures. Statistical approaches allow quantitative answers on questions about precipitation's impact on wave propagation. Thus probabilities are given, that e.g., rain induced attenuation or phase delay exceeds a certain threshold for a given set of parameters (location, frequency etc.). Increasingly demanding applications (higher frequencies, frequency re-use and multiple satellite links) require answers on increasingly complex questions.

Remote sensing technologies aim at measuring precipitation parameters at far distances, using either spaceborne or ground-based radars and radiometers. Such observations permit better climatological characterization, on a global as well as on a regional scale. Global keyword terms like greenhouse effect, global atmospheric warming, tropical rainfall, the Earth's energy and water cycle, etc. immediately indicate the urgent need for such observations. Speaking in local scale, short-term climatological considerations play a more important role. Weather fore- and nowcasting help in many various ways in everyday life. To mention only but a few examples of the numerous points of interest: flood and storm warnings, control of air and road traffic, control of hydroelectric power plants, water resources management, etc.

1.2 About distrometer types

Drop size distribution meters are called disdrometers, often with this very spelling being used. Within this Chapter, however, the spelling distrometer is preferred, indicating a device for measuring *distributions*, not limited to raindrops only, but also suited for other particular matter (amongst which are snow flakes and hail stones). The 2D-Video-Distrometer (2DVD) has been produced and marketed under this very name since more than a decade.

Based on different technologies, distrometers have been developed to get detailed information on precipitation microstructure in point monitoring observations. Most distrometer types rely either on measurement of precipitation particles' mechanical impact onto some sensor, or on optical methods. Whereas measurements by electro-mechanical distrometers are restricted to drop size distribution information, optical, especially imaging distrometers, provide more comprehensive information.

A well known electromechanical instrument is the RD69 distrometer (Joss and Waldvogel 1967). The measurement principle of this system is based on the automatic compensation of the force produced by a rain drop falling upon the sensor. This automatic force compensation together with raindrop fall velocities taken from literature models allows obtaining a value for the drop size. On this basis, rain