PRECIPITATION

Theory, Measurement and Distribution

Precipitation plays a very significant role in the climate system, every bit as important as temperature, yet this is the first book that provides a comprehensive examination of the processes involved in the growth of clouds, rain, snow and hail. The book also shows how precipitation is measured and what these measurements tell us about its distribution around the globe.

The book begins by tracing our attempts to understand what precipitation is, starting with the ideas of the ancient Greeks, followed, after a long period of stagnation through the Middle Ages, by the improved insights of seventeenth-century scientists, leading to today's detailed knowledge. The measurement of precipitation with rain gauges, radar and satellites is explained followed by what these measurements tell researchers about global annual means, trends, variability and extremes of precipitation. There are still very few rainfall measurements from any of the oceans, while coverage on land is extremely patchy. The concluding chapter outlines what needs to be done to correct these deficits, thereby making it possible to observe future climate change with more confidence.

Precipitation will be invaluable to researchers in environmental science and climatology, those concerned with water resources and flood management, and those planning action as the climate changes. It will also have an appeal to scientific historians.

IAN STRANGEWAYS is Director of TerraData, a consultancy in meteorological and hydrological instrumentation and data collection. He has also written *Measuring the Natural Environment*, now in its second edition (Cambridge University Press 2003).

PRECIPITATION

Theory, Measurement and Distribution

IAN STRANGEWAYS

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 2RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521851176

First published 2007

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this publication is available from the British Library

ISBN-13 978-0-521-85117-6 hardback

Contents

Preface

I was able to write most of this book directly from personal experience gained at the Institute of Hydrology (now the Centre for Ecology and Hydrology) in Wallingford from 1964 to 1988 and since then as a consultant in the same disciplines. This whole period has also been regularly interspersed with overseas travel, advising on data collection for water resources, flood warning and agricultural projects. These trips have taken me to about as many remote locations around the globe as David Attenborough has visited in his film making, places rarely seen by outsiders. On these many and diverse missions, from the Antarctic to tropical rainforests and deserts, I came face to face with the complex reality of environmental monitoring and the many problems that obtaining good measurements presents.

When it came to writing Part 4, I needed input from those directly involved in collating, homogenising and analysing the data collected by the global network of raingauges, and more recently by satellites. In this I was helped greatly by David Parker, Jen Hardwick and Chris Folland at the Hadley Centre in Exeter, who supplied me with data and graphs showing long-term precipitation trends in England and Wales, and who helped by passing on some of my questions to others with different specialised knowledge. In consequence I also had a useful and interesting exchange of emails with Aiguo Dai, Kevin Trenberth and Ping Ping Xie all at the National Center for Atmospheric Research in Boulder, Colorado. It is always a pleasure to experience the willingness of people working in science to exchange ideas and to do so with enthusiasm, and all of these co-workers lived up to this expectation.

But before getting to the present day I started by looking back to those times when just a handful of Greek philosophers brought a brief glimpse of light into the pervasive darkness of the ancient world to ponder on the nature of things, including rain and snow and clouds, and at their explanation of what they thought they were – their initiatives only to be extinguished very quickly by the dark ages for the next 2000 years. But then came a renaissance in the seventeenth century and the

modern world began, with all its new discoveries; this long history makes interesting reading.

I am grateful to the staff of Cambridge University Press for publishing the book, in particular to Matt Lloyd, who has assisted at every step along the way, and to Dawn Preston, who has managed the production of the book. I would like also in particular to thank my copy-editor, Hugh Brazier, for the way he has been through the book in fine detail, routing out very small, small and not so small errors and suggesting alternative ways of expressing some of the ideas. The result is a book that will be all the more accurate and readable for the close scrutiny it has received.

I should also like to thank the reader for reading the book, and hopefully also for buying it. I can assure you, however, that being an author does not make you rich – unless you write about the adventures of Harry Potter or the private life of a footballer. Fantasy and celebrity pay much better than science. But I would not exchange.

Acronyms and abbreviations

AAO	Antarctic oscillation
ADC	analogue-to-digital conversion
AMS	American Meterological Society
AMSU	advanced microwave sounding unit
AO	Arctic oscillation
ATD	arrival-time difference
ATLAS	autonomous temperature line acquisition system
AVHRR	advanced very high resolution radiometer
AWS	automatic weather station
BT	brightness temperature
CCD	charge-coupled device (image sensor)
CCN	cloud condensation nucleus
CEH	Centre for Ecology and Hydrology (formerly IH)
CERES	clouds and the earth's radiant energy system
CMAP	climate prediction center merged analysis of precipitation
CMIS	conical scanning microwave imager/sounder
CRDF	cathode ray direction finder
CRU	Climatic Research Unit (University of East Anglia)
DCP	data collection platform
DF	direction finder (lightning)
DFIR	double-fence intercomparison reference (snow fence)
DSRT	dual-frequency surface reference technique
DWD	Deutscher Wetterdienst (German National Meteorological Service)
ELF	extra low frequency (radio – lightning)
ENSO	El Niño southern oscillation
ESA	European Space Agency

FRONTIERS	forecasting rain optimised using new techniques of interactively enhanced radar and satellite data
GANDOLF	generating advanced nowcasts for deployment in operational land-surface flood forecasting
GARP	global atmospheric research program
GATE	GARP Atlantic tropical experiment
GCOS	global climate observing system
GEOSS	global earth observation system of systems
GEWEX	global energy and water cycle experiment
GHCN	global historical climatology network
GMI	global precipitation measurement microwave imager
GMS	geostationary meteorological satellite
GOES	geostationary operational environmental satellite
GOMS	geostationary operational meteorological satellite
GPCC	Global Precipitation Climatology Centre
GPCP	global precipitation climatology project
GPI	GOES precipitation index
GPM	global precipitation measurement
GPROF	Goddard profiling algorithm
GPS	global positioning system
GTS	global telecommunication system
ICSU	International Council for Science
IH	Institute of Hydrology (now CEH)
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IR	infrared
JAXA	Japan Aerospace and Exploration Agency
LEO	low-earth orbit
LIS	lightning imaging sensor
LPATS	lightning position and tracking system
MSG-1	Meteosat Second Generation 1
MSS	multispectral scanner
MSU	microwave sounding unit
NAO	North Atlantic oscillation
NASA	National Aeronautical and Space Administration
NCDC	National Climatic Data Center
NOAA	National Oceanographic and Atmospheric Administration
NWS	national weather service
OTD	optical transient detector (lightning)
PIP	precipitation intercomparison project

PIRATA	pilot research moored array in the tropical Atlantic
PR	precipitation radar
RAM	random access memory
RH	relative humidity
RMS	Royal Meteorological Society
RS	remote sensing
SAFIR	(a French lightning direction finding system)
SEVIRI	spinning enhanced visible and infrared imager
SOI	southern oscillation index
SSM/I	special sensor microwave imager
SST	sea surface temperature
SVP	saturation vapour pressure
TAO/TRITON	tropical atmosphere ocean/triangle trans-ocean buoy network
TMI	tropical rainfall measuring mission microwave imager
TOA	time of arrival
TRMM	tropical rainfall measuring mission
UHF	ultra-high frequency
UNEP	United Nations Environment Programme
UV	ultraviolet
VHF	very high frequency
VISSR	visible and IR spin-scan radiometer
VLF	very low frequency (lightning detection)
VP	vapour pressure
WCRP	world climate research programme
WMO	World Meteorological Organization
WV	water vapour

For a fuller list of abbreviations and acronyms, see Padgham, R. C., *A Directory of Acronyms, Abbreviations and Initialisms* (Swindon: Natural Environment Research Council, 1992).