

THE WEATHER OBSERVER'S HANDBOOK

Second Edition

This handbook provides a comprehensive, practical and independent guide to all aspects of making weather observations. The second edition has been fully updated throughout with new material, new instruments and technologies, and the latest reference and research materials. Traditional and modern weather instruments are covered, including how best to choose and to site a weather station, how to get the best out of your equipment, how to store and analyse your records and how to share observations. The book's emphasis is on modern electronic instruments and automatic weather stations. It provides advice on replacing 'traditional' mercury-based thermometers and barometers with modern digital sensors, following implementation of the UN Minamata Convention outlawing mercury in the environment. *The Weather Observer's Handbook* will again prove to be an invaluable resource for both amateur observers choosing their first weather instruments and professional observers looking for a comprehensive and up-to-date guide.

Dr Stephen Burt commenced his professional career in meteorology within the UK Met Office in 1977, followed by a series of private-sector marketing roles within the computer industry before returning to academia, eventually retiring from the Department of Meteorology at the University of Reading in 2018 (where he remains a Visiting Fellow). His meteorological research interests span instruments, observation techniques and methods, climatological data rescue, case studies of notable weather events and long weather records and their sites; in all, he has authored or jointly authored over 50 peer-reviewed journal papers to date, and four other books. Stephen is a Fellow of the UK's Royal Meteorological Society and a member of the American Meteorological Society, the Irish Meteorological Society and the Scientific Instruments Society. He is also an accomplished photographer with several hundred published photographs to his name.

From reviews of the first edition:

‘... a goldmine of information.’

Geoff Jenkins, *Weather*

‘I would highly recommend this comprehensive weather-observing guide to hobbyists, professionals, teachers and college instructors.’

Sytske Kimball, *Bulletin of the American Meteorological Society*

‘... a handy reference for any of its intended users (from backyard enthusiasts to professionals involved in research).’

T. Colleen Farrell, *Bulletin of the Canadian Meteorological and Oceanographic Society*

Endorsement quotes for the second edition:

‘I like this book very much. I am a lifelong weather observer and user of weather data both as an amateur and a career professional. This second edition answers so many of the questions I have had over the decades and the many questions I continue to field. At last, I have a single book that I can point people to, comprehensive, scientifically rigorous, yet very readable.’

Nolan Doesken, Colorado State Climatologist, former President of the American Association of State Climatologists, and founder of the Community Collaborative Rain, Hail and Snow network

‘This is a very informative book for both amateur and professional meteorological observers.’

Steven Colwell, Chair of the Royal Meteorological Society’s Special Interest Group on Meteorological Observing Systems

‘As climate change has an ever-increasing impact on our lives, this book is an essential tool to ensure accuracy and consistency of our weather records. It is difficult to imagine a more useful publication in the world of weather observation. This updated edition of *The Weather Observer's Handbook* is concisely and expertly written, with clear explanations of often complex matters. In Dr Burt’s hands all the weather parameters are explored in detail, but the management of the collected data is particularly well covered. The updated version of *The Weather Observer's Handbook* will meet the demands of amateurs and professionals across the world for the next decade.’

Roger Bailey, Chair, British Standards Technical Committee for Precipitation

‘Stephen is the foremost authority on all aspects of observing the weather. Building upon the successes of its first edition, this newly updated edition of *The Weather Observer's Handbook* is the essential resource for anyone interested in ground-based observational meteorology, whether using the latest equipment or traditional instrumentation, amateur or professional. The handbook provides a fully comprehensive, detailed and practical guide to all aspects of observing the weather.’

Eddy Graham, Atmospheric Scientist and Editor-in-Chief of *Weather*

‘If you still have some doubts about the robustness and reliability of the data on which we base our knowledge of meteorology and climate, this book will definitively and clearly explain how instruments work properly and measurements are accurate. Stephen Burt brings us on a journey across meteorological instrumentation, starting from a very easy approach, let’s say from an “amateur perspective”, up to professional measurement procedures and high-level systems, passing through a variety of users’ needs ... In a world where distributed networks, low-cost sensors and citizens’ science data will increase their role in weather and climate analysis, disseminating good practice in meteorological observation, with a constant taste for “metrological rigour”, is surely a valuable mission, and is fully achieved by this book.’

Andrea Merlone, Research Director at the Italian Institute for Research in Metrology

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Stephen Burt





CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

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www.cambridge.org

Information on this title: www.cambridge.org/9781009260541

DOI: 10.1017/9781009260534

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First published 2012

Second edition 2024

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

A Cataloging-in-Publication data record for this book is available from the Library of Congress

ISBN 978-1-009-26054-1 Hardback

ISBN 978-1-009-26058-9 Paperback

Additional resources for this publication at www.cambridge.org/burt2.

Cambridge University Press & Assessment has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

Cambridge University Press & Assessment
978-1-009-26054-1 — The Weather Observer's Handbook
Stephen Burt
Frontmatter
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For Helen, Fiona and Jennifer

Mr Hook[e] produced a part of his new weather Clock which he had been preparing which was to keep an Account of all the Changes of weather which should happen, namely the Quarters and points in which the wind should blow 2ly the strength of the Wind in that Quarter. 3ly The heat and cold of the Air. 4ly The Gravity and Levity of the Air. 5ly the Dryness and moisture of the Air. 6ly The Quantity of Rain that should fall. 7ly The Quantity of Snow or Hail that shall fall in the winter. 8ly the times of the shining of the Sun. This he was desired to proceed with all to finish he hoped to doe within a month or six weeks.

From Royal Society Journal Book (JBO/6), dated 5 December 1678
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Foreword

I spent the latter half of my career at the UK's National Physical Laboratory (NPL), and one part of my duties there involved making ultra-precision measurements of temperature. Working from the first principles of physics, my colleagues and I created an apparatus the size of a small room that could detect the tiny errors in the temperature measurements made by all the other practical thermometers on Earth. A single temperature measurement might take perhaps three days. The bulk of the work involved making a list of ways in which our apparatus might be in error, and then thinking of ways to evaluate how large that error might be. Few people are fortunate enough to work on such a fascinating and arcane project.

Since historical weather observations play a key role in our understanding of climate change, another strand of my work at NPL involved investigating the uncertainties around *meteorological* temperature measurements. In retrospect, I now understand that my work on ultra-precision measurements may have led me to approach this area from an unhelpfully narrow perspective. Applying the same 'first principles' approach of '*making a list of ways in which meteorological temperature measurements might be in error*' results in a list so long that the endeavour might seem doomed to failure. And yet, somehow weather observers have been busy making measurements day in and day out for hundreds of years. What I had failed to understand is the great value of meteorological measurements *despite* their difficulties and uncertainties.

Thus in 2012, I devoured the first edition of *The Weather Observer's Handbook* with relish. The book uniquely combined Stephen Burt's decades of experience running a weather observatory, his practical first-hand knowledge of modern meteorological techniques, and an outstanding technical and historical perspective. Reading the book, I learned what I should have already known: that to make reliable weather observations one must combine scientific knowledge of the measuring process with an appreciation of engineering reality. It is this multidisciplinary approach which has been at the heart of making reliable and meaningful measurements in the challenging environments to which meteorological instruments are exposed.

For anyone who seeks to make weather observations, either in support of an auxiliary activity or out of a regard for the measurements as an end in themselves, there is no better guide than this *Handbook*. The first edition helped me both in my research activities and also at home, where I maintain a weather station in my garden. In the last few years of my career at NPL I was fortunate enough to work with Stephen Burt, and together we found that, even after hundreds of years, there were still insights to be gained about the relatively simple task of making temperature measurements in air. I am looking forward to the second edition of *The Handbook* in the certainty that there will be new insights and developments in the long story of humanity's observations of the weather.

Michael de Podesta MBE, FInstP.
Teddington, January 2024

Acknowledgements

There have been very many significant developments in meteorological monitoring since the first edition of this book was published in 2012, including once-in-a-lifetime changes in instrument type and function (the statutory withdrawal of mercury-based devices, specifically thermometers and barometers), alongside the continuing rise in capability and deployment of automated systems. These major changes, together with many others of similar import, necessitated a line-by-line revision and update of the existing text, and large sections of this book have been completely rewritten as a result. In doing so, I have been fortunate in being able to draw upon on the willing help and assistance of many individuals and organisations around the world, and it is a great pleasure to be able to acknowledge your contributions – whether helping answer my questions, providing a photograph or reference to published work, or reading and commenting upon draft chapters. I hope and trust you will recognise your input in the pages following: I am most grateful to you all.

There are a few individuals who I would particularly like to thank by name for their contributions and support. Firstly, my Editor Matt Lloyd, of Cambridge University Press in New York: Matt was my Editor for the first edition of this book, and his enthusiasm and commitment provided the motivation to bring this second edition to fruition. Thanks also to tireless copyeditor Bret Workman (in Columbus, Ohio) and project manager Geethanjali Rangaraj (at Integra in Pondicherry, India) together with Jenny van der Meijden (senior content manager, Cambridge University Press in the UK) for their good-natured determination in surmounting the occasional obstacle during the publishing process. This book would have been incomplete without up-to-date information kindly provided from numerous national weather services around the globe, specifically NOAA in the United States, the UK Met Office (particular thanks to Melyssa Wright, at that time Observations Network manager, who went ‘the extra mile’ to answer my questions and to ensure network information and maps were fully up-to-date), Met Éireann in Dublin, Deutsche Wetterdienst, the Hong Kong Observatory, and the Australian Bureau of Meteorology in Melbourne. Thanks are also due to the very many instrument suppliers and manufacturers – too many to list by name here, but full details are given in Appendix 3 – who kindly answered my questions and provided photographs and specifications of their sensors and instruments. Few people know more about Davis Instruments than John Dann from UK reseller Prodata Weather Systems (weatherstations.co.uk), and John’s help was particularly valuable in preparing the all-new Chapter 13. Steve Colwell from the British Antarctic Survey in Cambridge, UK, and Jo Cole and Eloïse Chambers from the British Antarctic Survey base at Rothera, together with Tom Matthews from King’s College, London, provided priceless background information and photographs regarding the difficulties of running weather stations in the most extreme of environments

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(Antarctica and Mount Everest, respectively): at the opposite extreme Christopher C. Burt (US weather historian, Oakland, California – no relation) again provided invaluable background regarding extreme heatwaves and record rainfalls in the United States. Roger Bailey (chairman, British Standards Hydrology working group) and Richard Griffith (private observer, Caithness, Scotland) kindly read through complete early drafts of specialist chapters, providing detailed and constructive feedback – as did others who requested anonymity, who have my gratitude nonetheless. My colleague Giles Harrison within the University of Reading provided many useful discussions and comments on various aspects related to improving the accuracy of air temperature measurements. And to round off, Nolan Doesken (ex-Colorado State University, and co-founder of CoCoRaHS), together with Henry Reges and Steve Hilberg from CoCoRaHS, kept me up-to-date on their organisation, which achieves an enviable and efficient synergy between professional and amateur spheres in meteorology within the United States.

Finally, I owe an enormous debt to my family – my wife Helen and my two daughters, Fiona and Jennifer. Without your tireless love, support, and understanding, I could not have started, far less completed, this latest book project. Thank you.

Stephen Burt
Berkshire, England
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February 2024

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If you use this book to help choose an automatic weather station, or the components of one, please mention this to your reseller or dealer when you make your purchase.

For the latest product information, updated equipment reviews, useful references and downloadable material related to this book, please visit the author's website www.measuringtheweather.net.

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Abbreviations, footnotes and references

Abbreviations are defined within the text when first used; they are listed below only when used in more than one chapter.
Footnotes (indicated by superscripted symbols * † and so on) are given at the foot of the page to which they refer.
References and further reading are indicated within the text by bracketed numerals thus: [9]. They suggest sources of material or further reading for those who seek more detail on the topic. Numbered references are listed after the Appendices.

AMSL	Above Mean Sea Level
ASOS	Automated Surface Observing System
AWS	Automatic weather station
CIMO	Conference on Instruments and Methods of Observation, the WMO committee responsible for defining and publishing global instrumental and observation standard guidelines ('the CIMO guide')
CoCoRaHS	Community Collaborative Rain, Hail and Snow network
COOP	Cooperative Observer Program (US)
DST	Daylight Savings Time
DWD	<i>Deutscher Wetterdienst</i> – the German state weather service
GMT	Greenwich Mean Time, or Z time (equivalent to UTC for all practical purposes)
KNMI	<i>Koninklijk Nederlands Meteorologisch Instituut</i> – the Dutch state weather service
LAT	Local Apparent Time
MMTS	Maximum-Minimum Temperature System (sometimes known as NIMBUS)
MSL	Mean Sea Level (<i>see also</i> AMSL)
NOAA	National Oceanic and Atmospheric Administration (US)
NWS	National Weather Service (US)
PRT	Platinum Resistance Thermometer
RTD	Resistance Temperature Device
SPICE	Solid Precipitation Intercomparison Experiment (WMO)
SRG	Standard Rain Gauge (US)
TBR	Tipping-Bucket Raingauge
USB	Universal Serial Bus (a communications port on computers)
USCRN	US Climate Reference Network
USRCRN	US Regional Climate Reference Network
UTC	Coordinated Universal Time (equivalent to GMT for all practical purposes)
WMO	World Meteorological Organization