HISTORY OF THE METEOROLOGICAL OFFICE

Malcolm Walker tells the story of the UK's national meteorological service – now known simply as the Met Office – from its formation in 1854 with a staff of four and a budget of a few thousand pounds, to its present position as a scientific and technological institution of national and international importance with a staff of nearly 2000 and a turnover of nearly 200 million pounds per year. The Met Office has long been at the forefront of research into atmospheric science and technology and is second to none in providing weather services to the general public and a wide range of customers around the world. The history of the Met Office is therefore largely a history of the development of international weather prediction research in general.

Formed as the Meteorological Department of the Board of Trade with a specifically maritime purpose, the Met Office is now an Executive Agency and Trading Fund responsible to the UK government's Department for Business, Innovation and Skills and serves not only the shipping industry but also many other groups of users. It is at the forefront of pure and applied research in meteorology and related sciences and, moreover, cooperates and interacts with the international meteorological community at administrative, operational and research levels. In addition to being a premier forecasting bureau, it is at the forefront of the modelling of climate change in the modern era.

This volume will be of great interest to meteorologists, atmospheric scientists and historians of science, as well as amateur meteorologists and anyone interested generally in weather prediction.

MALCOLM WALKER was an academic at Cardiff University from 1967 to 1998, first as a Lecturer, then, from 1983, as Senior Lecturer and, from 1996, as Deputy Head of the Department of Maritime Studies and International Transport. He was Education Resources Manager of the Royal Meteorological Society from 1998 to 2007. He is a Fellow of the Royal Meteorological Society and a Member of the American Meteorological Society. He co-authored *The Ocean-Atmosphere System* (1977), with A.H. Perry. He chaired the Royal Meteorological Society's History Group from 1989 to 1999 and again from 2007 to the present. He was awarded the Group's Jehuda Neumann Memorial Prize in 2001 and the Royal Meteorological Society's Outstanding Service Award in 2007. Since 1980 he has had a strong scholarly interest in the history of ideas in meteorology and physical oceanography and the people behind these ideas. He has published numerous articles and lectured many times on this subject.

HISTORY OF THE METEOROLOGICAL OFFICE

MALCOLM WALKER

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

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

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

4843/24, 2nd Floor, Ansari Road, Daryaganj, Delhi - 110002, India

79 Anson Road, #06-04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108445566

First published 2012
First paperback edition 2017

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

Library of Congress Cataloging in Publication data
Walker, J. M. (John Malcolm), 1942–
History of the Meteorological Office / J. M. Walker.
p. cm.
ISBN 978-0-521-85985-1 (hardback)
1. Great Britain. Meteorological Office – History. 2. Meteorology – Great Britain – History. I. Title.
QC989.G69.W35 2012
551.50941–dc23 2011025094

ISBN 978-0-521-85985-1 Hardback
ISBN 978-1-108-44556-6 Paperback

Contents

List of Illustrations *page* ix
Foreword by Lord Hunt of Chesterton, FRS xv
Additional Commentary by Dr David N Axford, CEng, FIET, CMet(ret), FRMetS xxi
Acknowledgements xxiii
Abbreviations xxv

1 Seeds Are Sown 1
Meteorology in Ancient Times 2
The Dawn of Modern Meteorology 3
The Origins and Growth of Marine Meteorology 6
The Emergence of Organized Meteorology 8
Early Attempts to Model Weather Systems 11
Progress through Organized Science 13
Networks of Observers Develop 17
The Outcome of a Conference 19

2 Statistics and Storms 23
A New Government Department Is Born 24
The Great Desiderata of Meteorology 30
The Formation of the Scottish Meteorological Society 32
Progress at the Meteorological Department 34
Operational Storm Warnings 38
Forecasts for the General Public 44
Departmental Growth 45
Criticism and Controversy 47

3 Inquiry and Criticism 55
A New Beginning 55
The Galton Report 60

Reactions and Consequences 65
FitzRoy's Reputation 68
FitzRoy's Successor 71
Under New Management 73

4 The Fight over Forecasts 78
The Campaign in Parliament to Restore Storm Warnings 78
Efforts in the Press to Restore Storm Warnings 83
Resumption of Storm Warnings 85
A New Home for the Meteorological Office 88
An Important New Publication 89
Weather Charts for the Public 90
Owen Rowland – A Notable Amateur Weather Forecaster 92
Trans-Atlantic Weather Warnings 94
A Mid-Atlantic Observatory – An Idea before Its Time 98
Resumption of Weather Forecasts for the Public 100

5 Squalls and Settled Spells 102
Changes in the Role of Kew Observatory 102
An Unsuccessful Proposal from the Astronomer-Royal 104
London and Scotland Disagree 106
The Birth of the International Meteorological Organization 109
Another Change in Management of the Meteorological Office 112
Disappointment and Discontent 116
Science at Last 119
The Value of Weather Forecasts 122
Advances in Theoretical Meteorology 124

6 The Emergence of Science 126
A Scientist with Vision 127
Further Developments at Kew Observatory 133
Glimpses of Everyday Life 136
A Fresh Approach 142
A New Form of Communication 147
Shaw's Early Impact on the Meteorological Office 149

7 A Decade of Change 151
Yet Another Inquiry 151
Yet Another Reorganization 155
A New Home for the Meteorological Office 157
Advances in Research and Education 164
The Budget of the Meteorological Office 169
A New Meteorological Branch in Scotland 173
Communications and Standardization 177
The Continuing Impact of Shaw 178

8 The Great War 180
The Emergence of Aeronautics 180
The Outcome of a Disaster 183
War Breaks Out 185
A Professor of Meteorology at South Farnborough 188
Wartime Field Units of the Meteorological Office 191
Further Wartime Work of Charles Cave 197
Serving the Needs of Wartime 199
Whither the Meteorological Office? 202
The Prospect of a National Meteorological Institute 209
The Meteorological Office Transfers to the Air Ministry 212
Miscellaneous Developments 218

9 The Inter-War Period 223
Meteorological Services Are Resumed 224
Scottish Meteorological Society Difficulties 229
New Directions for Sir Napier Shaw 230
A New Director 233
Under New Management 236
Steady Progress 242
The Rise and Fall of Airships 249
Meteorology from the Air 253
Meteorological Education and Training 256
Further Notable Developments 261

10 The Clouds of War 264
The Pre-War Years 266
War Breaks Out 271
Military Operations during the War 276
Operational Requirements at Home 284
Internal Reorganization 288
Wartime Experiences and Reminiscences 290
Forecasts and Observations 294
Peace Returns 303

11 Aftermath of War to Forecasting by Numbers 307
Further Reorganization of the Meteorological Office 307
Revival of the International Meteorological Organization 311
Research Developments 313
Developments in Weather Forecasting 315
Floating Meteorological Observatories 321
Meteorological Services for the Public 325
Severe Weather Events 328
A New Director 331
The Brabazon Report 334

Progress at Home and Abroad 340
The Office's First Electronic Computer 347
The Move to Bracknell 350

12 Global Meteorology 354
Fahrenheit or Celsius 354
Weather Forecasting Developments 356
A New Director-General 358
Research Developments in the 1960s 365
New Meteorological Services 369
International Developments 378
An Exciting New Era 384
Automatic Systems Develop 387
Developments at Reading 394
End of an Era 397

13 Winds of Change 401
A Host of Environmental Concerns 403
A New Director-General 409
Progress and Storms 415
More Independence for the Met Office 419
Further Important Developments for the Met Office 423
A New Chief Executive 427
Further Changes of Direction for the Met Office 434
Uncertain Times 441
Controversy Continues 447
Epilogue 451
Postscript 453

Index 455

Illustrations

2.1 Robert FitzRoy, Meteorological Statist to the Board of Trade, the first Director of the Meteorological Office. *page* 25
2.2 The first home of the Meteorological Office at 1 and 2 Parliament Street, London, with wind vane and rain gauge on the roof. 27
2.3 Wind star, from FitzRoy's *Weather Book* (1863), showing the directions and strengths of the winds which occurred most frequently between latitudes 20°S and 30°S and longitudes 30°W and 40°W. 30
2.4 Ship's meteorological register (logbook), April 1857. 34
2.5 FitzRoy display in the National Meteorological Library, showing barometers and model of HMS *Beagle*. 37
2.6 Storm-warning signals, from FitzRoy's *Weather Book* (1863), showing cones and drum and the night signals. 43
2.7 The *pendule de voyage* presented to FitzRoy by the French government in 1864. 53
3.1 The upper picture, from FitzRoy's *Weather Book* (1863), shows his analysis of the 1859 *Royal Charter* storm, with flows of cold air from the north and flows of warm air from the south. The lower picture is a meteorological satellite image showing cloud patterns over the British Isles at 11:50 GMT on 2 April 2006. The resemblance between the patterns is striking. 70
3.2 Robert Henry Scott. 71
4.1 South cone, St Ann's Head, Pembrokeshire, 17 September 1965. 87
4.2 The weather chart for 31 March 1875 published in *The Times* on 1 April 1875. The dotted lines indicate the gradations of barometric pressure. Variations of temperature are marked by figures, state of the sea and sky by descriptive words, and direction of the wind by arrows – barbed and feathered according to its force. 91

5.1 Second-order weather station at The Hollies, Hastings, 12 September 1884. 111
5.2 Ben Nevis Observatory, 1890. 121
6.1 William Napier Shaw. 128
6.2 The Meteorological Office headquarters at 63 Victoria Street, London, in the late nineteenth century, showing the display of notice-boards on the first-floor balcony and the pianoforte maker's shop on the ground floor. 137
6.3 Afternoon tea in the Forecast Room of the Meteorological Office at 63 Victoria Street, *c*. 1904. From left to right: R Sargeant, F Snell, W Hayes. 139
6.4 W H Dines and companion launch a box kite in Crinan Bay, Scotland, 1902. 145
7.1 The headquarters of the Meteorological Office at Exhibition Road, London, 1910. 163
7.2 Ernest Gold. 168
7.3 Rudolf Gustav Karl Lempfert. 168
7.4 Meteorological Office annual expenditure in £ from the year ending 31 March 1900 to the year ending 31 March 1939. 170
7.5 The distinctive *KO* mark used on instruments tested at Kew Observatory. 172
8.1 Henry George Lyons. 193
8.2 Ernest Gold's weather diary, France, 24 December 1916. 196
8.3 Wartime humour. Meteorological Office Forecast Division Christmas Card, 1916, with staff identified by their initials added in pencil, including RGKL (Lempfert), JSD (Dines), FJB (Brodie), HH (Harries), RS (Sargeant), WH (Hayes) and 'Jestico' (C F J Jestico). 197
8.4 Meteorological Office staff numbers, 1900–1939. 200
8.5 Lewis Fry Richardson. 219
9.1 George Clarke Simpson. 234
9.2 Shipping forecast sea areas and coastal stations, 1924. 244
9.3 Punching Hollerith cards. 247
9.4 Making an Airmet broadcast in the 1930s. 255
9.5 Chart in the *Daily Weather Report* showing fronts, 2 March 1933, 07:00 GMT. Fronts were first shown on charts the previous day. Warm fronts are shown as dashed lines, cold fronts as lines of open circles, occluded fronts as alternate dashes and open circles. 260
10.1 Nelson King Johnson. 265
10.2 Campbell-Stokes sunshine recorder. The glass sphere focuses the sun's rays onto a graduated card, thus burning a track on it. 270
10.3 Group Captain James Stagg. 280

10.4 Stagg's diary for Sunday 4 June 1944, in which he said that he did not go to bed on the Saturday night but wrote up notes for a conference at 3 a.m. He also noted that "it began to appear that there might be a temporary fair interlude Monday night" and that the assault was "provisionally put in again for 6.30 Tuesday morning". 281
10.5 The weather map for 13:00 GMT on D-Day, 6 June 1944. Note that observations were available from Ireland and other neutral countries and from the Atlantic, Germany, Norway and other parts of occupied Europe. 282
10.6 Appreciative letter from E G Bilham, 6 June 1944, to staff of the Women's Auxiliary Air Force who provided duplicate charts for Douglas and Petterssen. Bilham was Assistant Director (Forecasting). 283
10.7 Meteorological reconnaissance flights, September 1944. 301
11.1 Meteorological Office staff numbers 1947–2010. The figure in August 1945 was 6760. 309
11.2 Weather briefing at Dunstable for senior scientists, *c*. 1946. 310
11.3 C K M Douglas, the greatest British synoptic weather forecaster of all time, early 1950s. 320
11.4 C K M Douglas inspecting work in the Central Forecasting Office at Dunstable, late 1940s. 321
11.5 The teleprinter room at Dunstable. 322
11.6 Oliver Graham Sutton. 333
11.7 Meteorological Office turnover in millions of £ from the year ending 31 March 1950 to the year ending 31 March 2010. 337
11.8 Doppler radar matrix display showing a vertical profile of echoes from precipitation over Worcestershire whilst continuous rain was falling. The display shows raindrops falling with a speed of between 5 and 8 metres per second below a height of about 2.5 kilometres and snowflakes falling with a speed of between 1 and 2 metres per second above a narrow band which contained a mixture of rain drops and melting snowflakes. 342
11.9 London Weather Centre window display of current charts and other meteorological information, Kingsway, 1959. 344
11.10 Making a weather observation on the Air Ministry roof, Kingsway, London, 1959. 345
11.11 Checking a rain-gauge on the Air Ministry roof, Kingsway, London 1959. Weather radar in the background. 345
11.12 Launch of radiosonde at Lerwick Observatory, 1963. 346
11.13 Operating the 'Meteor' computer at Dunstable. 349
11.14 The new headquarters of the Meteorological Office at Bracknell, 1962. 351

11.15 Sir Graham Sutton shows Her Majesty the Queen a component of a Skylark rocket at the Bracknell headquarters of the Meteorological Office, 25 June 1962. 352
12.1 Basil John Mason. 361
12.2 Dr Mason speaking at the Meteorological Office's first-ever press conference, 2 November 1965. 361
12.3 Computer print-out ('zebra chart'), 200 mb analysis for much of the northern hemisphere, 5 October 1966, 12:00 GMT. 362
12.4 The C-130 Hercules aircraft nicknamed 'Snoopy', showing its long nose boom and radar pod. 368
12.5 BBC TV weather presentation by Norman Ellis, early 1960s. 376
12.6 Plotting weather charts in the Central Forecasting Office at Bracknell, 1965. 377
12.7 The headquarters of the Meteorological Office at Bracknell after completion of the Richardson Wing. 387
12.8 Prime Minister Edward Heath opens the Richardson Wing of the Meteorological Office at Bracknell, 6 October 1972, watched by Dr Mason. 388
12.9 Servicing a moored meteorological buoy. 390
12.10 Kew Observatory in the 1960s. 398
13.1 John Theodore Houghton. 411
13.2 The Prime Minister, Mrs Margaret Thatcher, inspecting a poster display at the Hadley Centre after she had opened the Centre, 25 May 1990. 425
13.3 Julian Charles Roland Hunt. 428
13.4 Professor Hunt presenting a barograph to Captain M Bechley, September 1995, continuing a tradition which began in the days of FitzRoy of rewarding mariners whose work at sea for the Meteorological Office was exemplary. 433
13.5 Peter David Ewins. 435
13.6 Met Office logos. 436
13.7 The headquarters of the Met Office at Exeter. 439
13.8 In the National Meteorological Archive, Exeter. 440
13.9 The National Meteorological Library, Exeter. 440
13.10 The instrument development enclosure at the Met Office, Exeter, 2010. 441
13.11 David Rogers. 444
13.12 Mark Hutchinson. 444
13.13 John Raymond Hirst. 445
13.14 How weather forecast accuracy has improved from 1967 to 2009, shown in terms of root mean square barometric pressure error in hectopascals (millibars) over the north-east Atlantic for forecasts 24,

48, 72, 96 and 120 hours ahead, compared with the 72-hour persistence forecast (which has been consistently approximately 11 hPa). The arrow indicates that the forecast for 96 hours ahead is now as accurate as the forecast for 72 hours ahead was in 1999. 452
13.15 Shipping forecast sea areas, 2010. 453
13.16 The Met Office coat of arms, granted in 1991. 454

Foreword

LORD HUNT OF CHESTERTON, FRS

The Met Office is a well-respected and familiar British institution, whose weather forecasts people hear every day. News about its activities and advice are discussed at length in the media and in Parliament. It was founded in 1854 and still goes strong. Queen Victoria had personal weather forecasts from Admiral FitzRoy, the first director, for her three-mile voyage across the Solent to the Isle of Wight. It is not an exaggeration to say that the Office has played an important part in the history of the United Kingdom and of many other countries over this period, in both peace and war. Although it is an institution based on the application of science and technology, its outstanding staff have in fact originated some of the key developments of meteorological science and technology, a tradition that continues today.

This book had its origins in the PhD of the late Dr Jim Burton, a forecaster in the Leeds Weather Centre, who was encouraged by Sir John Houghton, then Director-General of the Met Office. His predecessor, Sir John Mason, helped the project. The necessary financial ingenuity to arrange funding for research into the history of the Office was provided by Martyn Bittlestone, our finance director, when the Office became a Trading Fund in 1996. The Chief Scientist, Professor Julia Slingo, has helped recently with her insights into developments up to 2010. I am very grateful to Malcolm Walker, formerly of Cardiff University, for accepting the invitation not only to write the book but also to listen tactfully to all the inputs from meteorologists and commentators on the text. Stan Cornford's detailed study in 1994 of the Met Office involvement in the D-Day forecast was also a significant contribution.

I was introduced to the familiar names of the shipping forecast areas (Wight, Dover, Thames, etc.) by my grandfather, who liked to sail dinghies in very rough weather, and to the scientific approach to meteorology by my great uncle L F Richardson, who originated numerical weather prediction when he was in the Met Office between 1913 and 1920.

When I was Chief Executive at the Office, I found it instructive to read how FitzRoy was able to push through his scientifically controversial ideas while at the

same time dealing with his political masters. His extraordinary personality was vividly portrayed in the play on FitzRoy and Darwin by Juliet Lacey, which the Royal Society funded in 1997. Napier Shaw, who like other directors came straight from a university position, had a longer and happier time; he demonstrated how the Met Office should always make best use of science and technology and adapt its services to changes in society and politics. He emphasized the importance of involving outside experts and 'stakeholders' in these developments and in the international responsibilities of the Met Office.

This book does not hide the many arguments within the Met Office about scientific and technical questions, but, unlike some other technical agencies of government, the Office has been quite open about these disagreements and then decisive about implementing the best practical method that emerged from the discussions, as with numerical weather prediction using computers (where scepticism continued for more than thirty years), satellites, weather radar, automatic weather stations (a surprisingly controversial technology) and now the Internet. However, it has often been commented that the Office has not been successful in stimulating new businesses in the UK to produce and market these inventions. But that was not an objective given to it by government.

Government agencies and even meteorological offices come and go, and sometimes get moved between different parts of government, as for example with the U.S. weather service. This existential aspect of the Met Office continues to be discussed regularly in the media and in Whitehall. After the UK joined the European Economic Community in 1973, the question asked by officials, anxious to save money, was whether the time had come to merge the UK Met Office with those of other countries or even in a European Met Office. Although a very successful European Centre was established in Reading for Medium-Range Weather Forecasts, Ministers have continued to support a strong national Met Office in order for the UK to have strategic independence. But they also supported progressively closer collaboration in various European initiatives.

After starting in the Board of Trade, the Met Office had a period of being run by a committee of governmental and nongovernmental bodies which included the Royal Society. This was too cumbersome for the new applications of meteorology in modern warfare, so, under Winston Churchill's influence, it was transferred after the First World War to the Air Ministry and merged with the meteorological services of the Army and Royal Air Force and in part with that of the Royal Navy in 1919. Endorsed by subsequent inquiries, notably that of Lord Brabazon in 1955, the Met Office remained there satisfactorily for more than ninety years, while also increasing its collaboration with most other government departments.[1] It has been largely funded by the government through various financial arrangements, culminating in 1996 in its

[1] The Met Office was transferred to the UK government's Department for Business, Innovation and Skills on 18 July 2011.

becoming a 'Trading Fund', which means that it now negotiates financial and service delivery contracts with about thirty government departments and agencies. Its history suggests that a major reason for its survival is that, even as its structure in government has changed, it has been able to provide up-to-date services needed by government, commerce and the public, through its great success in being one of the world's leading services in the effective and economical use of new science and technology.

Other countries still have two or more weather services, typically for civil aviation and defence, which clearly adds to their costs and does not seem to improve their service. Along with the various changed arrangements, the Met Office's buildings and their locations keep changing. From a single office in 1854, receiving data and delivering warnings by the new technology of telegraph, it kept expanding to more than 6000 staff and many hundreds of offices and observing stations worldwide in the Second World War. It is now down to a little under 2000, with a custom-built headquarters at Exeter and fewer than twenty other installations from the Falkland Islands to Cyprus to the Shetland Islands. This reduced network is sufficient as communications have changed from the electric telegraph in the 1850s to the Internet in the 1990s; also, these developments enabled the range of services and advice, both civil and military, to expand continually.

Met Offices are always under scrutiny, but they generally survive. There is one instance of closure when the director of an early meteorological service in France, the famous scientist J B Lamarck, was dismissed on Napoleon's orders in 1810 – an unfortunate overture to his difficulties in the Russian winter of 1812. In the UK, both Houses of Parliament have regularly inquired about and debated the doings of the Met Office, which are well covered in this book. The long speech by the back-bench Lord Wrottesley in 1853, in which he explained why British shipping needed a Met Office to be able to compete with the United States, was followed by the Office's founding in 1854. The book also covers in some detail the debates that led to the forced cessation of forecasting for the public for thirteen years from 1866, because of its alleged inaccuracy. But storm warnings were accurate enough to reduce the number of shipwrecks, which led to Parliamentary complaints that these forecasts were having a damaging effect on the ship salvage businesses of Cornwall and Devon. We have the same story today from some advocates who argue that forecasts of climate change are damaging business and should be ignored or even suppressed.

However, Parliamentary debate has also prompted technical developments, such as when long-range forecasts were initiated after the very cold winter of 1962–1963 and when Prime Minister Ted Heath in 1973 asserted the need to understand global climatic variations, in particular El Niño, in order to understand variations in the prices of food. Parliament has also monitored the Met Office's work on controversial environmental problems, from London smog, acid rain over Scotland and Scandinavia, the ozone hole and the spread of foot-and-mouth disease to the oil fires of the Gulf War. All recent Prime Ministers have actively promoted research on analysing and

predicting climate change by the Hadley Centre, a branch of the Met Office whose leading scientists shared in the award of the Nobel Prize for Peace in 2007 along with other distinguished climate scientists around the world. When Mrs Thatcher was Prime Minister, she devoted most of her speech at the United Nations in 1989 to this subject and made a great impact at the Met Office when she opened the Hadley Centre at Bracknell in 1990.

International collaboration, which has been an essential element of every aspect of the Met Office's work, has been very effective and economical because of the UK's active involvement and financial support of the World Meteorological Organization (WMO), a United Nations agency, which grew out of the International Meteorological Organization set up by directors of Met Offices in 1879. Despite different national policies and political tensions between countries, exchanges of data, weather forecasts and warnings about natural hazards have progressively improved. The passing of 'Resolution 40' brought the agreements up to date at the 1995 WMO Congress, but these arrangements still need extending and also applying to the urgent hydrological problems of warning about floods and droughts, for which the Met Office is also responsible at WMO.

This book reveals how the science of meteorology and its applications has developed over the past 150 years and how it has led to new concepts and techniques. Sometimes developments arose from new technologies and from responses to new user requirements, which have often arisen quite suddenly, such as the recent problem in 2010 of improving the forecasts of how volcanic ash is dispersed in order to advise aircraft where they can fly safely after volcanic eruptions. Some of the innovations of meteorology have had wide ramifications in the worlds of science and technology, notably in the communication of very complex and uncertain information.

It is worth recalling that the Met Office's provision of forecasts and estimations of their accuracy in the 1860s predated the statistical theory and methods that developed later in the century – part of the reason for FitzRoy's problems. L F Richardson had to invent approximate methods for solving the basic equations of fluid flow, starting with uncertain and incomplete measurements in order that forecasts could be made systematically by calculation. Later, Neumann, Lorenz, Charney and others in the United States after the Second World War discovered how to simplify and compute the equations, making use of the new electronic computers, and then proposed a new approach for analysing the chaotic nature of the predicted weather patterns. The computational methods they developed later became the basis of much modern aeronautical design and environmental modelling. Central bankers and economists have finally learnt from meteorology, after about twenty years, how to present the uncertainty of their financial forecasts with multiple curves spreading out into the future.

This history is memorable for its many stories – about great individuals and great team work, some personal tragedies, extraordinary bravery and incredible

perseverance – accounts of which, even now, cannot be told in much detail, such as the secret observers of weather data in war zones and the use of the data in breaking codes and forecasting. The best story of all and the greatest achievement of the Met Office came in June 1944, when Group Captain Stagg provided the right twenty-four-hour forecast of moderate winds and low cloud to General Eisenhower for the perilous crossing of the English Channel by the Allied invasion forces. The forecasting office at Dunstable led by C K M Douglas and assisted by the Norwegian Sverre Petterssen collaborated with teams from the United States and Canada in providing the first 'multi-centre' forecast. There is an interesting postscript. Since 2000, with modern technology and scientific understanding, this collaborative approach is now operational, but now the diplomatic role of Stagg has been taken over by connections between sophisticated computer programs – which of course have their problems too.

I am sure readers will enjoy this history, and I hope that when you listen to your next forecast on the radio or TV you will understand a bit better about what the people do who make it possible.

Julian Hunt

Additional Commentary

DR DAVID N AXFORD, CENG, FIET, CMET(RET), FRMETS

It has been an honour to have provided some small help to Malcolm Walker in the production of this important book, which records the history of the Meteorological Office from its gestation as a mainly data-gathering and -analysing institute through its important role forecasting the weather in the Second World War to its present position, where it is enjoined to act as a semi-commercial enterprise within the boundaries set by the Government. The time and effort in researching and summarizing the essence from the multitude of papers drawn together in this book is much to the credit of the author.

Julian Hunt has provided an excellent overview of the book in his Foreword, and I would not wish to repeat his words. Instead I would like to emphasize the contributions to the international status of the UK in the science of meteorology during the second half of the twentieth century by the three Director-Generals (DGs) that I had the pleasure to serve under during my years in the Office from 1958 to 1989.

These were the 'golden years' to my mind, during which forecasting practice progressed from a science based on intuition (and the plotting of sparse data on a map with two ink pens [one blue-black, one red], drawing up the map and making a guess, based on experience, of the way the atmosphere would change over the next twenty-four hours) to a truly physics-based profession with observations from satellites as well as the land and oceans being analysed by super-computers and the analysis being forecast forward using classical physics-based numerical weather prediction programmes. Nowadays the main job of the human forecaster is to interpret the computer output and to add local knowledge where necessary while packaging the output appropriately for the customer.

When I first joined the Office in 1958, Sir Graham Sutton (DG from 1953 to 1965) was in charge. As recorded in this book, he brought together the various branches of the Office which had been scattered in and around London to a new centre in Bracknell, Berkshire, while also focusing on changing the organizational structure of the Office to bring it into line with the new post-war requirements. Following the

end of the Second World War, meteorological technology, automation and, from the 1950s, the application of electronic computers made rapid progress, and Sir Graham kept the Office focused on a goal of being at the scientific forefront of meteorology.

Under Sir John Mason (DG from 1965 to 1983) the Meteorological Office became internationally recognized as a Centre of Excellence within which staff were active both in providing weather services to the public, the military and the aviation industry, and in conducting front-edge pure and applied research in meteorological science. All staff were encouraged to achieve their potential through regular review and forward planning by the Directorate. High-achieving scientists of international renown were recruited to ensure that fundamental research was carried out in parallel with the development of new and improved operational services. Sir John Mason himself was a leading light on the international stage, too, ensuring that UK meteorologists were fully involved in the first globally supported scientific experiments such as the Global Atmospheric Research Programme (GARP), GARP Atlantic Tropical Experiment (GATE) and others.

Sir John Houghton (DG from 1983 to 1991) continued the work of his predecessor, in particular in the field of satellite meteorology and, later, in the science related to climate forecasting. There was a growing unease amongst international scientists concerning the likelihood of future climate change. In this respect, his role within the international community of national meteorological services at the World Meteorological Organization in Geneva was seminal. He became the first chairman of the Scientific Working Group of the Intergovernmental Panel on Climate Change (IPCC). I was honoured to be present at a lunch that he hosted in Geneva during which he promoted the setting up of the internationally backed Global Climate Observing System (GCOS) which has been an essential component in the scientific understanding of the Earth's climate, and, at a national UK level, he steered through the establishment of the Hadley Centre, which is now internationally recognized as one of the leading centres of expertise in the understanding of climate and climate change.

Looking to the future, it is to be hoped that the UK Meteorological Office maintains its 'centre of excellence' position amongst the world's meteorological services. The pure scientific research conducted during the second half of the twentieth century in areas such as satellite technology, atmospheric chemistry, climate modelling, cloud physics and many other fields has borne serendipitous fruit so that the Office has been well placed to offer the best advice available to the politicians grappling with the new twenty-first-century environmental problems of air pollution, ozone depletion and climate change. May it continue to hold this position of pre-eminence in the future.

David N Axford
Stanford in the Vale

Acknowledgements

The origins of this book lie in the PhD of the late Jim Burton, whose dissertation presented to The Open University in 1988 focused on the history of the Meteorological Office to the year 1905. The then–Chief Executive of the Office, Professor Julian Hunt (now Lord Hunt of Chesterton), commissioned me in 1996 to extend Jim's work and write a book about the history of the Office from its antecedents to the present day. Generous funding from the Office allowed Cardiff University, my employer at the time, to engage a research assistant for two years. Tim Hunt (no relation of Julian) proved an excellent assistant who was particularly skilled at unearthing in archives important information about the Office's development.

Over the years, several members of staff of the National Meteorological Library and Archive have been generous with their time. I am indebted to them all, particularly Maurice Crewe, Mick Wood, Alan Heasman, Graham Bartlett, Sara Osman, Sarah Pankiewicz, Joan Self and Glyn Hughes. I am especially grateful to Steve Jebson, who has not only helped me find material in the Library on numerous occasions but also digitized most of the pictures in the book.

For permission to reproduce images, I am very grateful to the Meteorological Office, the Royal Meteorological Society, the City of Westminster Archives Centre and the NEODAAS/University of Dundee Satellite Receiving Station.

My grateful thanks go also to Steve Poole, grandson of L H G Dines, great-nephew of J S Dines and great-grandson of W H Dines. He has supplied much information about the Dines family, and he has kindly granted me permission to include Figure 8.3 in the book. Others who have assisted by supplying information or helping me get the story right include a number of former and present members of the Office's staff, notably Stan Cornford, Marjory Roy, Brian Booth, Martin Stubbs and Brian Golding.

It has been a great pleasure to have as advisors for the book two distinguished meteorologists, Julian Hunt and David Axford, both of them former members of the Office's staff. Their guidance and support are hugely appreciated. The encouragement and help of the Office's current Chief Scientist, Julia Slingo, is also much appreciated.

Finally, I wish to record my gratitude to Matt Lloyd of Cambridge University Press, who has been very supportive and patient. He has been my editor from the start and must have wondered at times if I would ever complete the book. Indeed, without the encouragement and increasingly persistent urging of my beloved wife, Diane, the book might still be a work in progress.

Malcolm Walker

Abbreviations

AA	The United Kingdom's Automobile Association
AP1134	The official report on the work of the Meteorological Office during the Second World War
BBC	British Broadcasting Corporation
BIS	Department for Business, Innovation and Skills
British Association	British Association for the Advancement of Science
BRO	British Rainfall Organization
CAA	Civil Aviation Authority
CEGB	Central Electricity Generating Board
CFO	Central Forecasting Office
CMet	Chartered Meteorologist
COMESA	Committee on Meteorological Effects of Stratospheric Aircraft
COST	The EEC's scheme for Cooperation in Science and Technology
Defra	Department for Environment, Food and Rural Affairs
DERA	Defence Evaluation and Research Agency
DETR	Department of the Environment, Transport and the Regions
DSIR	Department of Scientific and Industrial Research
ECMWF	European Centre for Medium Range Weather Forecasts
ECOMET	The Economic Interest Grouping of the National Meteorological Services of the European Economic Area
EEC	European Economic Community
ESSA	Environmental Science Services Administration
EUMETSAT	The European Organization for the Exploitation of Meteorological Satellites
FGGE	First GARP Global Experiment
FRONTIERS	Forecasting Rain Optimized using New Techniques of Interactively Enhanced Radar and Satellite
GARP	Global Atmospheric Research Programme
GATE	GARP Atlantic Tropical Experiment
ICSU	International Council of Scientific Unions

IGY	International Geophysical Year
IIOE	International Indian Ocean Expedition
IMC	International Meteorological Committee
IMD	India Meteorological Department
IMO	International Meteorological Organization
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IQSY	International Quiet Sun Year
JASIN	Royal Society Joint Air-Sea Interaction Project
JCMM	Joint Centre for Mesoscale Meteorology
MMU	Mobile Meteorological Unit
MoD	Ministry of Defence
MOLARS	Meteorological Office Library Accessions and Retrieval System
MOSS	Meteorological Office Observing System for Ships
MOWOS	Meteorological Office Weather Observing System
MRC	Meteorological Research Committee
MRF	Meteorological Research Flight
NERC	Natural Environment Research Council
NIO	National Institute of Oceanography
NPL	National Physical Laboratory
NWP	Numerical Weather Prediction
Office	(when used with capital O): Meteorological Office
PMO	Port Meteorological Officer
PWD	Petroleum Warfare Department
RAF	Royal Air Force
RAFVR	RAF Volunteer Reserve
RE	Royal Engineers
RFC	Royal Flying Corps
THUM	Temperature and humidity (in the context of upper-air data obtained by aircraft ascents)
TIROS	Television Infra-Red Observation Satellite
TV	Television
UK	United Kingdom
UM	Unified Model
UN	United Nations
WMO	World Meteorological Organization
WWW	World Weather Watch