ATMOSPHERIC BOUNDARY LAYER
Integrating Air Chemistry and Land Interactions

Based on more than 20 years of research and lecturing, Jordi Vilà-Guerau de Arellano and his team's textbook provides an excellent introduction to the interactions between the atmosphere and the land for advanced undergraduate and graduate students and a reference text for researchers in atmospheric physics and chemistry, hydrology, and plant physiology. The combination of the book, which provides the essential theoretical concepts, and the associated interactive Chemistry Land-surface Atmosphere Soil Slab (CLASS) software, which provides hands-on practical exercises and allows students to design their own numerical experiments, will prove invaluable for learning about many aspects of the soil-vegetation-atmosphere system. This book has a modular and flexible structure, allowing instructors to accommodate it to their own learning-outcome needs.

JORDI VILÀ-GUERAU DE ARELLANO, CHIEL C. VAN HEERWAARDEN, BART J. H. VAN STRATUM, AND KEES VAN DEN DRIES were all members of the Meteorology and Air Quality Section at Wageningen University in the Netherlands at the time of the major development of this book and software. The level of integration achieved in this book and software has only been possible because of the complementary backgrounds and expertise of the authors. Jordi Vilà-Guerau de Arellano has more than 20 years of research and teaching experience in the fields of atmospheric modeling and the atmospheric boundary layer. He has written more than 80 papers, placing special emphasis on cross-disciplinary activities in land and atmospheric science. Chiel van Heerwaarden has made fundamental contributions to integrating our understanding of land and atmospheric processes, with special emphasis on the development of conceptual and numerical models. Bart van Stratum is currently researching several aspects of shallow convection. Kees van den Dries is a specialist in atmospheric chemistry and computer systems.

ATMOSPHERIC BOUNDARY LAYER

Integrating Air Chemistry and Land Interactions

JORDI VILÀ-GUERAU DE ARELLANO
Wageningen University, The Netherlands

CHIEL C. VAN HEERWAARDEN
Max Planck Institute for Meteorology, Germany

BART J. H. VAN STRATUM
Max Planck Institute for Meteorology, Germany

KEES VAN DEN DRIES
Wageningen University, The Netherlands

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

32 Avenue of the Americas, New York, NY 10013-2473, USA

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/9781107090941

First published 2015

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication Data
Vilà-Guerau de Arellano, Jordi, 1962– author.
Atmospheric boundary layer : integrating air chemistry and land interactions / Jordi Vilà-Guerau de Arellano [and three others].
pages cm
Includes bibliographical references and index.
ISBN 978-1-107-09094-1 (hardback)
1. Boundary layer (Meteorology) 2. Boundary layer (Meteorology)–Observations.
3. Atmospheric chemistry. I. Title.
QC880.4.B65V55 2015
551.51′5–dc23 2015003106

ISBN 978-1-107-09094-1 Hardback

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

Contents

CLASS Software

The open-source Chemistry Land-surface Atmosphere Soil Slab (CLASS) model can be downloaded free of charge from [**www.cambridge.org/vila**]. The software runs on default installations of Microsoft Windows (XP, 7 and 8) and Mac OS X (10.6–10.10), and can be compiled on Linux distributions supporting Qt (versions 4 and 5). The source code is hosted by GitHub (**http://classmodel.github.io/**), where incremental updates to the code can be found. Major bug fixes and updates will always be made available through updates on the Cambridge website.

Disclaimer

We make no warranties, express or implied, that the programs supplied with this book are free from error, or are consistent with any particular standard of merchantability, or that they will meet your requirements for any particular application. They should not be relied on to solve a problem whose incorrect solution could result in injury to a person or loss of property. Your use of the programs in such a manner is at your own risk. The authors and publisher disclaim all liability for direct or consequential damages resulting from your use of the programs. All the hands-on exercises have been tested, and any new exercises created by the reader are the sole responsibility of the reader.

Preface

Buffering the free atmospheric conditions from the soil-vegetation properties, the atmospheric boundary layer (ABL) is the region in which the wind, temperature, moisture, and atmospheric constituents change from the large atmospheric scales to the biosphere conditions. Over land, the ABL is characterized by a strong diurnal variability (daylight hours) that presents a challenge to modelling studies and observational interpretation. The first purpose of this book is to introduce the reader systematically to the most important biogeochemical and physical processes that take place in the ABL. A flexible user-friendly model of these processes called Chemistry Land-surface Atmosphere Soil Slab (CLASS) was developed to enable the reader interactively and independently to investigate the behaviour of the diurnal ABL over land. Our second aim is to enable the reader to discover freely the interactions and couplings that occur between the atmosphere and land, and to determine their impact on cloud formation, changes in greenhouse gas concentrations, and atmospheric chemistry. To this end, we decided to represent the main fundamental processes in the atmosphere-biosphere system, while retaining the essential components of the physical and biogeochemical processes involved. We have therefore attempted to move beyond individual disciplines to investigate their mutual interrelationships and feedback, laying special emphasis on the conceptualization of the problem. Finally, the interactivity and modular character of the book will make it very useful as a means of interpreting measurements made during experimental campaigns and deepening our understanding of more complex large-scale biogeochemical atmospheric models.

Acknowledgments

Wageningen University has financially supported the software development and the systematic and extensive testing of the numerical experiments. This support was provided via the bonuses given to the Meteorology and Air Quality (MAQ) section for high quality of the performance of the MAQ section in BSc and MSc courses. Louise Nuijens, David Pino, and Marina Sterk contributed to early versions of the course Clouds and Climate (starting in 2005). This course provided the pioneering concept of this book and of the CLASS software, and thanks to them, the course started on the right track from the very beginning. Chapter 6 greatly benefited from the input provided by Joel Schröter. Critical reviews and input of different chapters by Huug Ouwersloot, Eduardo Barbaro, Marie Combe, and Jisk Attema helped to improve and sharpen the concepts and numerical experiments. Peter Duynkerke, Harm Jonker, Maarten Krol, Wouter Peters, Ryan Teuling, Bert Holtslag, Cor Jacobs, Reinder Ronda, Arnold Moene, and David Fitzjarrald also provided input and ideas through discussion of some of the concepts and experiments. We also thank Hugh M. Allen of AMC for his language and editing skills. Since 2005, large numbers of BSc and MSc students have provided very useful suggestions for improving the syllabus, the course, and the lectures and have suggested improvements to the book and the CLASS software. These students are from different backgrounds and specialties, and took the following courses: Clouds and Climate, Atmospheric Modelling, Interdisciplinary Topics in Earth and Environment, optional tailor-made courses, and international PhD summer schools. By using CLASS in their research projects BSc, MSc, and PhD students have extensively tested it, greatly improving the quality of the book and design of the numerical experiments. Thanks to all for your feedback!