Preface

Clouds, in their various forms, are a vital part of our lives. They are a crucial part of the global hydrological cycle, redistributing water to Earth's surface in the form of precipitation. In addition, they are a key element for the global energy budget since they interact with both shortwave (solar) and longwave (terrestrial) radiation. These so-called cloud–radiation interactions depend strongly on the type of cloud. Clearly, clouds affect the global climate; thus understanding clouds is an important factor for climate projections. The effects on Earth's energy budget and on the hydrological cycle both depend on processes on the microphysical scale, encompassing the formation of cloud droplets, ice crystals, raindrops, snowflakes, graupel, and hailstones.

Establishing an understanding of clouds and precipitation requires a knowledge of the environment in which they form, that is, the atmosphere, with all the gases and airborne particles present. The latter are usually referred to as aerosol particles and encompass a wide range of air-suspended particles of different types and phase state. Some aerosol particles can act as nuclei to form cloud droplets or ice crystals and thus initiate the formation of clouds or precipitation. Thus, they influence the microphysical properties of clouds. In turn, aerosol particles are removed from the atmosphere when clouds precipitate. To gain a complete picture of the behavior of clouds in the atmosphere, the strong interplay between aerosol particles and clouds requires one to tackle the subject with an integrated approach.

This book is intended to offer a fundamental understanding of clouds in the atmosphere, covering their formation, properties, and impacts. Primarily written for students at an advanced undergraduate level, new to the field of atmospheric science, it serves graduate students alike. Indeed, we strive to make this book helpful to students with a multidisciplinary background, as an introduction to cloud physics, and assuming that most readers will have a basic understanding of physics and mathematical concepts.

The content of this book evolved from the BSc course in atmospheric physics at ETH Zurich. The text is organized into 12 chapters, each focusing on a particular topic.

Chapter 1 introduces the major cloud types found in the atmosphere and discusses them from a macroscopic point of view.

Chapter 2 outlines the physical principles of radiative transfer, the global energy budget, and discusses the effects of clouds on it. It also explains some optical phenomena in the atmosphere, that illustrate spectacular examples how aerosols and clouds interact with radiation.

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Chapters 3–5 focus on the thermodynamic principles needed to describe atmospheric processes, and the meteorological conditions and atmospheric dynamics needed for cloud formation.

Chapter 6 treats atmospheric aerosol particles and introduces some of their key physicochemical properties. Aerosol sources and sinks are discussed at the process level, as well as in terms of their global distributions and lifetimes.

Chapters 7–9 cover cloud microphysics. Chapter 7 discusses the fundamental equations that describe the formation of cloud droplets. Chapter 8 introduces the processes that ultimately lead to the formation of raindrops. Conversely, ice crystal formation and other microphysical processes occurring in cold clouds are presented in Chapter 9.

Chapter 10 combines the macroscopic view of Chapter 1 with the microscopic view needed to understand the physics of precipitation, as well as differences between stratiform and convective precipitation. Also, precipitation in a changing climate, extreme precipitation, and weather modification are included.

To understand convective clouds, knowledge about cloud dynamics is needed. This is provided in Chapter 11, where convective clouds at all scales, from isolated thunderstorms with lightning and thunder to multicells, supercells, and mesoscale convective systems, including tropical cyclones, are discussed.

Finally, Chapter 12 brings the reader to the global scale, where we discuss impacts of aerosols and clouds in a changing climate along with possible radiation management methods involving aerosols and clouds.

Throughout the text, essential equations are highlighted, to ease the read and enhance the learning. To strengthen key concepts and to provide the reader with an opportunity to test their understanding, qualitative multiple choice exercises and mathematical problems are provided for each chapter, which can be found in the additional material on the web at www.cambridge.org/lohmann_mahrt. This allows the reader to directly apply the material of the text and provides an opportunity for further learning. To this end, online solutions are provided and can be accessed at www.cambridge.org/lohmann_mahrt. For some of the problem sets the usage of a tephigram will be helpful. This, along with some other material, can be accessed from: www.cambridge.org/lohmann_mahrt.

All quantities are given in SI units unless stated otherwise. However, as we often refer to processes occurring above or below 0 °C, we will use degrees Celsius whenever convenient, keeping in mind that temperatures need to be in kelvins in the equations given (if not noted otherwise).

Our *Introduction to Clouds* is continuously evolving in response to knowledge advancements in the field, evolving interests and approaches in teaching, and valuable users' comments. This second edition is a comprehensive update of the first edition. A change in this edition is the rearrangement of some chapters and sections to improve the overall flow, the update of all chapters to reflect the current state of knowledge, and the addition of new topics to capture the fast-growing fields of aerosol, cloud and climate science.

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We also revised figures, added new ones and now use much more color to improve the understanding of central concepts. One principal change of the second edition is the recession of Felix Lüönd from the author team. We are very sorry to see Felix step down due to other commitments and thank him very much for all his efforts and contributions to the initial version of this textbook, which forms the fundament of the current edition.

Writing this book would not have been possible without the knowledge we received from many pioneers of the field of atmospheric sciences; these are named in the appropriate context throughout the book. Equally important, the development of this book relied on the extraordinary help and support from many colleagues, and we are deeply grateful for help in different aspects. Chief among those who provided excellent support are the members of our research groups, who discussed drafts of different chapters and were a great source of feedback and ideas. A big thanks also goes to students and our overall readership, who stumbled over inconsistencies or errors, which we corrected thanks to them.

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Photographs, illustrating various aspects within our textbook, were kindly provided by many colleagues and friends, each of them acknowledged in the respective image caption.

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An Introduction to Clouds is an evolving text, and we continue to welcome the input and comments from users.

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Additional Resources On The Web

To the textbook user:
We have developed a range of multiple choice questions and mathematical problems for each chapter to encourage you to reflect on the material and to test your grasp of the material.

These can be found at www.cambridge.org/lohmann_mahrt

Lecturers can find the figures and tables of the book in a ready-to-use and download format. In addition, we have also developed solution manuals to both the multiple choice questions and the mathematical problem sets, that can be found at www.cambridge.org/lohmann_mahrt

Furthermore, the resource section includes ready-to-run Python scripts to reproduce key figures from this textbook, as well as selected data sets.

Lecturer resources are available for registered users of this textbook. More information on the registration can be found at www.cambridge.org/lohmann_mahrt

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