

## Preface

Computer models are essential tools for understanding atmospheric phenomena and for making accurate predictions of any changes in the Earth's climate, weather, and resources of renewable energy resulting from anthropogenic activities that generate greenhouse gases and particulates into the atmosphere. Many physical processes that influence Earth's climate and weather occur on spatial (temporal) scales smaller (shorter) than typical grid sizes (time steps) of general circulation models, and thus must be parameterized. This book focuses on the atmospheric subgrid processes — collectively called fast physics — by reviewing and synthesizing relevant physical understanding, parameterization developments, various measurement technologies, and model evaluation framework.

The book is divided into three parts, containing seventeen chapters (Chapters 2-17) to reflect and synthesize the multiple aspects involved. The first chapter briefly introduces the historical development of fast physics parameterizations and the involved complexities; the last chapter summarizes emerging challenges, new opportunities and future research directions.

Part I is devoted to discussing major subgrid processes, with eight chapters (Chapters 2-9) each covering different processes more or less in the conventional compartmentalized format that emphasizes individual processes. Topics covered include, but not limited to, radiative transfer; aerosols, and aerosol direct and indirect effects; entrainment-mixing processes and their microphysical influences; convection and convective clouds; stratiform clouds such as stratus and stratocumulus; planetary boundary layer processes; land surface and its interactions with the atmosphere; and gravity waves. On top of the conventional treatments, some promising ideas/approaches are described that have recently emerged to unify the treatment of individual processes and thus allows for consideration of process interactions.

Part II is devoted to such unifying efforts, with four chapters (Chapters 10-13) covering four different endeavors: the unifying parameterizations based on assumed probability density functions; the EDMF approach that combines the Eddy Diffusivity and Mass Flux approaches to unify turbulence and convection; application of machine learning techniques; and innovative top-down attempts that consider the involved totality by borrowing ideas from systems theory, statistical physics, and non-linear sciences.

Part III (Chapters 14-17) is devoted to assessments, model evaluation, and model-measurement integration, with four chapters that focus on: satellite and airborne remote sensing measurements; surface-based remote sensing measurements; in-situ and laboratory measurements; and model evaluation, and model-measurement integration, respectively.

The development of the book happened around two noteworthy events. The first one is that the 2021 Nobel Prize in Physics was awarded to three pioneers in modeling climate and weather and studying complex systems (*Dr. Syukuro Manabe of Princeton University, Dr. Klaus Hasselmann of the Max Planck Institute for Meteorology, and Dr. Giorgio Parisi of Sapienza University of Rome*). This exciting choice accentuates not only the critical importance of the subject, but also the outstanding challenges of the topics discussed in this book.

The second event is the COVID-19 pandemic, which unfortunately overlapped with the writing of most of the chapters in this book and affected the lives of many of our contributors. We would like to express our special thanks to all the authors and reviewers, as well as to the staff at Wiley and AGU for their hard work and patience. This book is dedicated to two of our dear colleagues and contributing authors who passed away during this period, *Prof. Kuo-Nan Liou* and *Dr. Alexei Belochitski*. The book is also dedicated to Yangang Liu's mother, *Chunlan Sun*, who was hospitalized during the pandemic and passed away in China recently without his company.

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