MESOSCALE-CONVECTIVE PROCESSES IN THE ATMOSPHERE

This modern textbook is devoted to a deep understanding of mesoscale-convective processes in the atmosphere. Mesoscale-convective processes are commonly realized in the form of thunderstorms, which are dynamic, fast evolving, and assume a broad range of sizes and severity. Indeed, convective storms have the potential to spawn tornadoes and generate damaging "straight-line" winds, and are additionally responsible for the rainfall that can be detrimental but also immensely beneficial to society.

To facilitate this understanding, descriptions of the formation, dynamics, and qualitative characteristics of specific convective phenomena such as supercell thunderstorms and mesoscale-convective systems are provided. Although the descriptions pertain largely to the extratropical atmosphere, examples of related tropical phenomena are given for comparison and contrast. To provide a further holistic perspective, separate chapters are included on mesoscale observations and data analysis, numerical modeling, and the theoretical predictability and actual numerical prediction of mesoscale weather. An additional chapter on interactions and feedbacks addresses ways in which convective storms affect and are affected by external processes, particularly on the synoptic and planetary scales.

This textbook provides advanced students, researchers, and weather professionals with a modern, accessible treatment of the convective processes that lie within the range of the atmospheric mesoscale.

ROBERT J. TRAPP received his PhD in Meteorology from The University of Oklahoma in 1994. He was a National Research Council Postdoctoral Fellow, and then was appointed as a research scientist at the Cooperative Institute for Mesoscale Meteorological Studies and the National Severe Storms Laboratory; part of this appointment was served at the National Center for Atmospheric Research. Trapp joined the faculty at Purdue University in 2003, where he is currently Professor and Associate Head of the Department of Earth, Atmospheric, and Planetary Sciences. He is a University Faculty Scholar, which recognizes outstanding faculty members who are on an accelerated path for academic distinction. Professor Trapp has also been recognized as an Outstanding Teacher in the College of Science and has appeared on his departmental teaching honor roll in every semester of his tenure at Purdue. He is an expert on convective storms, their attendant hazards, and their two-way interaction with the larger-scale atmosphere.

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Preface

The primary resource for students enrolled in my early mesoscale meteorology courses at Purdue University was *Mesoscale Meteorology and Forecasting*, the edited collection of review articles published by the American Meteorological Society in 1986. Though still valuable, it was conspicuously missing a number of important developments that had taken place since its publication, including: (1) major field programs such as IHOP (International H2O Project), BAMEX (Bow Echo and Mesoscale Convective Vortex Experiment), and VORTEX (Verification of the Origins of Rotation in Tornadoes Experiment) and its successor VORTEX2; (2) the maturation and implementation of operational Doppler weather radar, and an equivalent advancement of airborne and ground-based mobile radar systems; and (3) the relative proliferation of open-source community models and a concurrent ability to run such models using accessible computing resources, including desktop systems.

In short, these and other developments have led to significant evolution in the understanding of the atmospheric mesoscale since 1986, and motivated my effort to produce an updated resource. The realization of this effort is *Mesoscale-Convective Processes in the Atmosphere*.

As a perusal of the book shows, a major difference between *Mesoscale-Convective Processes in the Atmosphere* and other newly available mesoscale books is its focus on deep moist convection. This limited focus was driven partly by my perception of student interest, and partly by a philosophical choice to provide a concentrated treatment of a few topics, rather than a diluted treatment of all things mesoscale. Of course, it also follows my own interests, which most certainly biased the directions of some explanations (as in my considerable use of numerical modeling results, for example), although I did strive for balance as much as possible.

The discourse is aimed at upper-division undergraduate/beginning graduate students and assumes a basic knowledge of atmospheric dynamics (and a requisite knowledge of vector differential calculus, differential equations, etc.). When I teach a semester-long course based on this book, I typically begin with Chapter 1, and then endeavor to cover the material in Chapters 5 through 8. Specific sections within Chapters 2 through 4 are referenced as needed. I use the material in Chapters 3, 4, 9, and 10 as the basis for special topics courses.

Supplements to each chapter are provided on the companion website. The supplements include problem sets, exercises, and discussion questions that were purposely omitted from the book itself: my desire is to keep these materials fresh and topical, and also to incorporate book-user contributions (which are encouraged). For each relevant chapter, a list of cases is provided so that the reader can apply the theory to real events. Suggested numerical modeling experiments are also given, as are links to appropriate software, datasets, etc.

Mesoscale-Convective Processes in the Atmosphere represents the fruit of my course-developmental labors at Purdue University, but was influenced by multiple external sources. One, of course, is *Mesoscale Meteorology and Forecasting*, which also served as a blueprint for the organization of my topics. Lectures and notes from courses given by Howie Bluestein, Fred Carr, Chuck Doswell, Kelvin Droegemeier, Brian Fiedler, and Tzvi Gal-Chen shaped my thinking while I was a graduate student at the University of Oklahoma, and are reflected either directly or indirectly in the text. During my early career, discussions and debates with Harold Brooks, Bob Davies-Jones, Joe Klemp, Rich Rotunno, and Morris Weisman further shaped my understanding of deep moist convection and attendant phenomena. Additional understanding has come from other people and sources too numerous to list here, but I feel compelled to acknowledge the particular influence of books written by Robert Houze, Kerry Emanuel, and James Holton, which I cite heavily.

I benefited immensely from reviews by George Bryan (Chapter 2), Tammy Weckwerth (Chapter 3), Lou Wicker (Chapter 4), Conrad Ziegler (Chapter 5), Sonia Lasher-Trapp (Chapter 6), Morris Weisman (Chapter 7), Matt Parker (Chapter 8), Dave Stensrud (Chapter 9), and Mike Baldwin (Chapter 10). Dave Schultz, Phil Smith, and John Marsham provided helpful comments along the way.

Several of the chapters were written while I was on sabbatical leave at the University of Leeds, U.K. I am deeply appreciative for the discussions with – and support provided by – Doug Parker and Alan Blyth while I was in the U.K. I am also indebted to the staff of the National Centre for Atmospheric Science, and am forever grateful for the hospitality and friendship of Adrian Kybett and his family.

This project would not have been possible without the patience and support of Matt Lloyd and Cambridge University Press, would not have been undertaken without the opportunities for student engagement provided to me at Purdue University, and would not have been tolerable without the constant source of love and understanding from my wife Sonia and children Noah and Nadine.

Robert J. Trapp