Preface

This book began as lecture notes for an Oregon State University graduate course on instabilities of geophysical fluids, mainly the Earth's atmosphere and oceans. Designed originally for students in physical oceanography, the course is also popular with students of atmospheric dynamics, physics, and mathematics. Besides oceans and atmospheres, flow instabilities are important in rivers, canals, and lakes, hence the course is taken regularly by civil engineers. Additional material has been developed as part of a course at the University of Hamburg.

A defining aspect of the course is its emphasis on the numerical solution of boundary value problems; the student learns techniques whose value extends beyond the present topic. Students develop a collection of software that will allow them to study instabilities and waves in all types of flows, including flows measured observationally. A secondary focus is internal waves, primarily gravity and vorticity waves. These are included for two reasons: first, they arise naturally from the same equations that describe instabilities, and, second, they are often essential parts of the mechanisms that create instability.

In the course and in this book, our main focus is the "big three" instabilities of geophysical flows:

- convection (driven by gravity; Chapter 2),
- shear instability (driven by kinetic energy; Chapter 3), and
- baroclinic instability (controlled by the Earth's rotation; Chapter 8).

The first two of these are foundational: besides describing fundamental mechanisms, which vary and combine to make the assortment of instabilities discussed later, the discussions provide an opportunity to introduce essential ideas and methods in a relatively simple context. We also look at various factors that modify these instabilities such as flow curvature (Chapter 7), viscosity (Chapter 5), and density stratification (Chapters 4 and 6). In the Oregon State course, these main topics are covered in 40 hours of lectures. It is expected that students will devote 80 hours to homework and independent study.

Additional chapters describe specialized mechanisms such as double diffusion (important in the ocean; section 9.2) and conditional convective instability (important in the atmosphere; 9.1), as well as auxiliary topics such as turbulence (Chapter 12) and advanced numerical methods (Chapter 13). These may be included or assigned for independent reading.

Homework exercises are included (Appendix A) and are integral to the course. Much critical information is discovered independently in the course of doing these exercises. Solutions are available from the Cambridge University Press website at www.cambridge.org/iigf, together with example MATLAB codes and authors' contact information. We also include several suggestions for term projects in which a student may explore topics not covered in the main text (Appendix B).

This book is also intended for self-study, with detailed explanations and frequent exercises to confirm understanding. If you take this route, feel free to email the authors with any questions that may arise.

While every effort has been made to ensure that the methods and formulae given in this book are accurate, a healthy skepticism is encouraged. Any statement given here could contain typos, or math errors, or could simply be wrong. Never use a theorem for anything important until you've understood the proof.

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