INTRODUCTION TO ATMOSPHERIC MODELLING

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Prologue

This book has been written specifically for the AIMS Library Series, so its intended audience is students who are attending, have attended, or have backgrounds that would make them eligible to attend the postgraduate programs offered at the African Institute for Mathematical Sciences. The contents of this book could easily be delivered as one of the AIMS postgraduate courses, though it is primarily intended as a self study introductory guide to mathematical modelling in the atmospheric sciences. It has been prepared so that readers with a fairly thorough applied mathematics or physics background can easily, and with little additional reading, understand the main approaches, theoretical and observational underpinnings, intellectual history and challenges of the subject. It is neither a broad introduction to atmospheric science (there exist many such books which serve a very different audience than that intended here), nor is it a review of current research (since that will not serve my intended audience). This book has four distinct, but linked objectives:

- introduce the beauty and wonder of atmospheric phenomena by examining a representative selection;
- explain the importance of scale analysis and scaling arguments in studies of atmospheric phenomena;
- emphasize the power of mathematics in developing an understanding of these phenomena;
- demonstrate how a combination of mathematical modelling, numerical modelling and observations are needed to achieve the understanding.

I start with two rather lengthy introductory chapters designed to introduce the governing equations, their analytical difficulties, and how scale analysis is conducted. The substantive content of this book is organized according to the conventional scale analysis of atmospheric phenomena, and within each scale-specific section I will cover in some detail theoretical (analytical) modelling approaches. Wherever possible and appropriate, I will refer to numerical modelling and observations of the phenomena being discussed. This will be done in order to emphasize the richness of method that characterizes atmospheric science as an academic and professional discipline, but will not constitute a full discussion of atmospheric numerical modelling, or observational meteorology.

Many atmospheric scientists will think that the title implies a book concerned with numerical modelling, and will be surprised that this is not the case. I want to emphasize that intuitive models precede (analytical) mathematical models, which then lead to numerical models. I will not take the second step in that sequence in this book.

In keeping with the spirit of the AIMS Library Series, I will not make extensive reference to research literature, but will rather lean heavily on a small number of selected standard texts listed in my bibliography. These are all texts and colleagues I admire enormously. The colleagues are: Jean-Marie Beckers, Benoit Cushman-Roisin, John Dutton, Solomon Eskinazi and James Holton. I will not include detailed in-text references (since the intended audience will generally not have access to the texts), but will lean heavily on ideas, analyses, approaches and interpretations borrowed from these texts. I here acknowledge the borrowing, and the debt I owe these authors. I acknowledge that any misrepresentations of their ideas are due to my own inadequacies. Furthermore, by this acknowledgement I recognize their ideas as their own, and signal my understanding that not making specific reference leaves me vulnerable to accusations of plagiarism. I am sure they will understand that this has been done because of the nature of books in the AIMS Library Series, and their intended audience. Specifically, Sections 2.1, 4.1, 4.4, 4.5.2 and Chapter 5 follow the approaches taken by Holton, J. R., 1979: *An Introduction to Dynamic Meteorology*, Second Edition, Academic Press, New York. Sections 4.2 and 4.5.1 draw heavily from Cushman-Roisin, B., 1994: *Introduction to Geophysical Fluid Dynamics*, Prentice Hall, NJ. Sections 3.2.1 and 3.2.2 are based on Tennekes, H., 1973: Similarity laws and scale relations in planetary boundary layers. In D. A. Haugen (Ed.), *Workshop on Micrometeorology*, American Meteorological Society, chapter 4. Section 3.3 uses the approach and results of Haurwitz, B., 1947: Comments on the sea breeze circulation. *Journal of Meteorology*, **40** (1), 1–8. Section 3.2.3 draws on Carson, D. J., 1973: The development of a dry, inversion-capped, convectively unstable boundary layer. *Quarterly Journal of the Royal Meteorological Society*, **99**, 450–467.

I am indebted to a stream of remarkable graduate students I taught at UBC in EOSC 571 (Introduction to Research in Atmospheric Science and Physical Oceanography) over the past eight years. Their enthusiastic and always interesting engagement with the subject material made me think hard about many of the ideas contained in this book. I thank Stefano Galmarini who in a strange way bears ultimate responsibility for this book through first telling me about AIMS, and Fritz Hahne and Barry Green for making possible my stay at AIMS in 2010–2011. Alan Beardon suggested this book, and I thank him for persuading me to take up his idea. David Tranah shepherded the manuscript through the labyrinth of CUP. I have drawn heavily on an excellent summary of dimensional analysis by my colleague George Bluman. Susan Allen read an early version of the manuscript and provided wise and critical advice, and Nadya Moisseeva helped with her excellent work on Sardinian sea breezes. Phil Austin and Nico Fameli changed me from a LaTeX neophyte to LaTeX competent. Ultimately, I take full responsibility for the content and the particular perspective which I bring to the subject matter.

Most of all, I could not have done this without the many years of support and encouragement from Margaret. JoHanna is of course responsible for keeping me humble!

Vancouver, September 2014.