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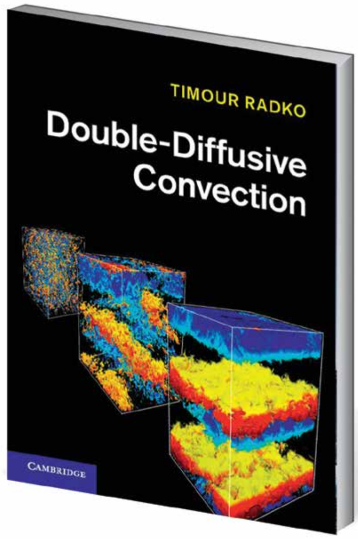

DOUBLE-DIFFUSIVE CONVECTION

By Timour Radko, 2013, Cambridge University Press, 344 pages, ISBN 978-05-218-8074-9, Hardcover $120 US, e-book (Kindle) $80 US

Reviewed by Dan Kelley

INTRODUCTION

Double-diffusive convection (DDC) is a phenomenon that can occur in fluids in which buoyancy is affected by two constituents that diffuse at different rates. Many readers of *Oceanography* magazine will be at least somewhat familiar with the topic of oceanic DDC, probably in the form of "salt fingers" (SF), a variety that can arise when surface waters are warmer and more saline than waters below, as is the case in broad reaches of the ocean, especially in the subtropics. A second variety, called the "diffusive layering" (DL) mode, requires that the warmer water lie below the cooler water, a common situation at high latitudes. In addition, both SF and DL can exist at the boundaries between interleaving water masses, a situation that can occur anywhere that lateral gradients of temperature and salinity occur. Thus, many areas of the ocean appear to be susceptible to DDC, and observations suggest that DDC is commonly present in such regions, especially if background turbulence is relatively low. This would be a mere curiosity but for the fact that the divergence of DDC-mediated fluxes may be large enough to have significant effects on the background system.

Modern research on DDC began with a thought experiment in the 1950s, initiated by Arnold Arons and Henry Stommel, extended by Melvin Stern, and verified (in a sink) by Allan Faller. In an autobiographical essay, Stommel describes this under the heading "Exciting ten minutes at the blackboard" (p. I-11 in Hogg and Wang, 1995). Even today, students who carry out a simple SF experiment experience a similar sense of excitement and become enthusiastic to learn more. Such enthusiasm is a thread that runs through Timour Radko's text entitled *Double-Diffusive Convection*, published in November 2013 by Cambridge University Press.

Radko was a student of the late Melvin Stern, and the book is dedicated to him. (Radko occasionally shows signs of hero worship with respect to Stern, but this will be excused by anyone who met Stern or studied his deeply insightful work.) Oceanographers who follow the DDC literature will be familiar with Radko's influential work on the topic, and will be pleased to see that the book is much more than a survey of his and related recent work. Indeed, it covers most aspects of DDC in a way that should benefit oceanographers and others who seek an overview. The illustrations are clear and useful, with color used only as appropriate. The bibliography is reasonable, but the index is a bit thin. The editorial tone might be described as enthusiastic, with phrasing that is occasionally closer to a tweet than a textbook (e.g., topics being "cool" or "fun"), but the material is treated seriously and often insightfully.

CHAPTER CONTENTS

The Preface includes clear hints as to how various readers might navigate the book. This information is useful, because the chapters are organized somewhat idiosyncratically.

Chapter 1 introduces concepts and history. This chapter reads a bit like a lecture, in which the aim is more to build interest than to connect students to the literature. There is a fair bit of supervisor worship here, and it is surprising that Radko chooses to reference Stern's insights by year of publication instead of by minute of discussion, which is the time scale suggested by Stommel in his recollection of the birth of DDC research (Hogg and Wang, 1995). The theme of the chapter relates mainly to systems in which temperature and salinity vary in the vertical, and this sets the tone for the book: only about 20% of its pages are devoted to the important case of interleaving. (Perhaps we can look forward to a second book on this topic.)

The second chapter deals with instability calculations. The discussion is clear and consistent in notation (to the extent that any of DDC literature is consistent). Perhaps too little is done to explain to readers why they should care about the instability analysis. For example, there is an awkward spot near the end of section 2.1 that says that DL is not predicted to occur under typical oceanic conditions, but that it does occur there. This is one of many spots where my copy of the book has margin notes about the lack of citation to the literature or to other parts of the text.

Chapters 3 and 4 deal with unbounded gradient models and two-layer models. This distinction is useful, given the nature of DDC in the ocean and in the laboratory. After this, Chapter 5 deals with a bounded layer model, and then Chapter 6 with collective instability (another fundamental concept of DDC that was developed by Melvin Stern). One might argue for a rearrangement of some of the material in these three chapters to provide a more integrated treatment, but there is benefit in separating topics so they may be consulted in isolation.

This editorial choice to split rather than to join is reflected in much of the middle part of the book. In Chapter 7, a transition is made to intrusive behavior, and then in Chapter 8, the focus returns to staircases. While these shifts are not problematic, they are still notable. This construction might explain why Radko follows these chapters with a treatment of some integrative ideas in Chapter 9. This chapter is useful but too thin to satisfy readers who are hoping for a generalized theory. Those readers should be made aware that we still lack such a theory, and might thank Radko for this chapter, the remarkable brevity of which could encourage further work.

The last third of the book contains miscellany. Chapter 10 includes a discussion of DDC in active environments, and it should be of particular benefit to readers who are more interested in the ocean than DDC per se. This chapter deals with observations in the ocean and insights that have been gained with numerical experimentation, and it provides a good entry into the literature. And, just like that literature, Chapter 10 deals mainly with the SF case rather than the DL case. On a related theme, Chapter 11 provides material on the effects of DDC on the embedding system, primarily in terms of fluxes. In Chapter 12, Radko moves beyond the ocean to other systems in which DDC can occur. These systems are sometimes separated in the literature, but Radko has made a good choice in addressing them all within this book, for the material is intrinsically interesting, and the study of analogies is often beneficial.

Chapter 13 presents some thoughts on the future. The personal tone of the writing in this chapter is less jarring than in some spots in the book, and the author makes some fine points about the future of DDC research. He argues that DDC research is still at the discovery stage, and that many fundamental questions remain to be answered. This seems undeniable. Part of the challenge is the great mismatch between the small scales at which DDC occurs and the much larger scales that it affects. DDC is simply not a phenomenon that will be solved by gradual refinement of model grids. It requires parameterization, and the first step in developing reliable parameterizations is to establish a firm dynamical understanding. If the history of DDC research is any guide, achieving this understanding will demand careful study along several lines at once. Radko suggests that a key to success may be in establishing more collaborative linkages between researchers, and he may be right.

RECOMMENDATION

Should you buy this book? If you are an expert in double-diffusion, the answer is probably "you already have." Oceanographers working on ocean mixing should also buy the book because they will find it to be an excellent complement to the half-dozen review papers that have appeared in the conventional literature. The wider oceanographic community will also benefit from the book, as a more digestible alternative to those review papers. Undergraduates will find the book gives a good entry to the topic, although its somewhat citation-averse style may frustrate postgraduate students seeking a connection to the literature. The book appears at a good time, with important recent research not yet having been covered in review articles, and it does a laudable job of setting this new work in the context of earlier efforts.

In summary, a wide range of readers will find that this book sits well on their shelves. I have my copy alongside Turner's inspiring (1973) textbook on buoyancy effects and Stern's undercited (1975) book on ocean circulation, and that's about as fine a compliment as Radko's book could receive.

REFERENCES

Hogg, N.G., and R.X. Huang, eds. 1995. *Collected Works of Henry M. Stommel*. American Meteorological Society, Boston, MA, USA, 683 pp.

Stern, M.E. 1975. *Ocean Circulation Physics*. Academic Press, San Diego, CA, 246 pp.

Turner, J.S. 1973. *Buoyancy Effects in Fluids*. Cambridge University Press, Cambridge, UK, http://dx.doi.org/10.1017/CBO9780511608827.

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