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Contemporary Issues in Estuarine Physics

Edited by Arnoldo Valle-Levinson,
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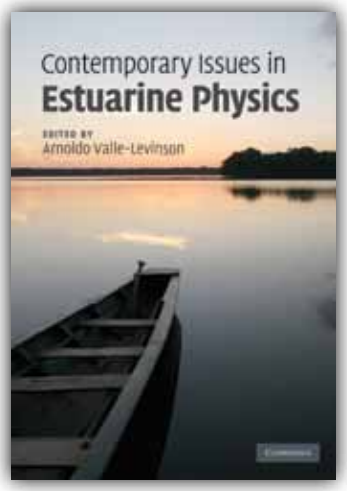
REVIEWED BY MALCOLM SCULLY



In a series of papers published nearly 60 years ago, Donald Pritchard established the basic understanding of estuarine dynamics. Pritchard's elegant and simple representations of the subtidal estuarine circulation and salt balance remain the foundation for modern research on physical oceanography in estuaries. Yet, the simplicity of this early work belies the complexity of physical processes that occur in the estuarine environment, complexity that is well articulated in the recent text *Contemporary Issues in Estuarine Physics*, edited by Arnoldo Valle-Levinson. The book grew out of a 2007 two-week summer program organized by Valle-Levinson through the Pan-American Advanced Studies Institutes (PASI) Program. Leaders in the field of estuarine dynamics were invited to Puerto Morelos, Mexico, to give lectures to graduate and postgraduate researchers from throughout the Americas. Nearly all of the invited lecturers contributed chapters to this book. Consistent with the target audience of the PASI program, this book is intended for graduate students and researchers in the field of oceanography. While some of the information may be relevant to a wider audience, full appreciation of the wealth of information contained in these pages requires at least basic knowledge of physical oceanography. It is assumed that the reader is familiar with fundamental concepts such as conservation of mass and momentum, the role of Earth's rotation, and Reynolds averaging, as well as mathematical concepts ranging from basic calculus to more advanced techniques including differential equations and perturbation theory.

Each chapter does an excellent job of introducing the underlying theory and describing the current state of understanding in the field. More importantly, each author makes an effort to highlight the fundamental gaps in our theoretical understanding. The book begins with several basic definitions and classification schemes for estuarine systems. Rocky Geyer presents subtidal dynamics in Chapter 2, discussing the basic equations for the strength of residual estuarine circulation, stratification, and salt flux. While the overall approach outlined in this chapter follows the original Pritchard work quite closely, significant advances have been made and are included in this chapter, for example, a discussion of the role of time-dependence; a more intuitive parameterization of turbulent mixing, including the influence of density stratification on mixing; and a prognostic classification for estuarine systems.

Carl Friedrichs contributes a comprehensive examination of barotropic tides in Chapter 3. Like many chapters, the theory is derived from the basic governing equations, which are reduced in complexity using scaling arguments based on estuarine morphology. The chapter begins with the simplest cases and builds in complexity, providing a complete framework for understanding the along-channel variation in tidal amplitude and phase for estuaries of varying shapes and sizes. This theory demonstrates the importance of estuarine bathymetry in controlling tidal propagation and provides a more physically sound explanation than the commonly invoked incident and reflected wave for the standing wave relationship between tidal velocity and elevation exhibited by many estuarine systems.

In Chapter 4, David Jay takes on the daunting task of providing a theoretical framework for characterizing estuarine variability, including the role of tidal nonlinearities. This chapter builds on the two previous chapters in describing both tidal and subtidal variations in estuarine circulation. However, unlike the previous chapters, this one focuses significant attention on nonlinear tidal variability. It presents a formal derivation of subtidal circulation driven by the so-called "internal asymmetry" in tidal mixing. This process, which results from tidal variations in density stratification, clearly highlights the complex nature of estuarine dynamics.

Although much of estuarine research to date has focused on along-channel processes, there is increasing interest in the dynamics of lateral or cross-channel flows. Bob Chant provides a

nice overview of estuarine secondary circulation in Chapter 5. He reviews the driving mechanisms of secondary flows, including the importance of channel curvature, the interactions between lateral circulation and estuarine density gradients, and the role of Earth's rotation. This chapter debunks the common misconception that Earth's rotation is not dynamically important in estuarine systems that are narrower than the internal Rossby radius. It also provides a nice discussion of the importance of lateral flows to the subtidal along-channel dynamics, as well as horizontal dispersion.

Clint Winant treats wind and tidally driven flows in Chapter 6. This chapter outlines a theoretical framework for deriving circulation in semi-enclosed basins, which is then used to address both wind-driven and tidally driven estuarine flows. The approach is used to derive the wind-driven response of an enclosed basin with variable bathymetry, as well as the residual circulation driven by tidal rectification of the Stokes drift. The analytical techniques used in this chapter are clearly explained and provide useful tools for examining other oceanographically relevant problems.

By definition, estuaries exist where fresh and salt water are mixed. Stephen Monismith provides an overview of this fundamental concept in Chapter 7. This comprehensive chapter examines mixing at a variety of scales and its implications for the overall dynamics. The chapter begins with an overview of key concepts, including Fickian diffusion, shear-flow dispersion, Reynolds averaging, and the turbulent kinetic energy balance. The role of density stratification on mixing is discussed and presented in terms of the fundamental length scales of turbulence. The chapter concludes with an overview of how mixing that occurs at very small scales ultimately results in the large-scale dispersion of material along the estuary.

While most of the book focuses on processes within estuaries, Jim O'Donnell provides a detailed discussion of where the estuary meets the coastal ocean in the eighth chapter on the dynamics of estuary plumes and fronts. He uses scaling arguments to provide a general classification scheme for river plumes of varying sizes and forcing conditions. The chapter discusses how Earth's rotation, bottom friction, wind forcing, and turbulent mixing all can influence the dynamics of river plume systems. In addition to the discussion of estuarine plumes, this chapter also provides a detailed look at the processes that lead to the development of frontal boundaries within the estuary. Like many chapters in this volume, the variety and complexity of processes associated with river plumes and estuarine fronts could easily be expanded into an entire book.

Chapter 9 focuses on low-inflow and inverse estuaries. Despite the fact that these systems have received comparatively little attention in the scientific literature as compared to "classical" estuaries, John Largier demonstrates that these systems are commonly found throughout the world. The chapter provides a clear explanation of how the water, salt, and heat budgets of these systems result in estuarine water that is denser than the surrounding coastal ocean. In many regards, the dynamics of these systems is similar to their "classical" counterparts; however, as this chapter clearly illustrates, the dynamics of these systems is complicated by the fact they often experience large seasonal changes in both thermal and freshwater forcing.

The final chapter of the text, by Lisa Lucas, highlights the implications of estuarine transport on water quality. Physical processes within estuaries fundamentally impact water-quality issues such as low dissolved oxygen, harmful algal blooms, increased sediment loading, and contaminant transport. This chapter provides an introduction to the issues that many scientists and resource managers care about the most. It introduces basic concepts such as flushing time, residence time, and water age and provides a general framework for analyzing nonconservative constituents using the transport-reaction equation.

As the title suggests, *Contemporary Issues in Estuarine Physics* provides an overview of topics that are at the forefront of research in estuarine physical oceanography. This book offers a thorough treatment of estuarine dynamics and will be a valuable resource to researchers and educators in the field. Although this book is not formatted as a traditional textbook, it surely will be of great value in graduate-level courses in oceanography. In addition to including a thorough review of the literature, the chapters provide numerous examples of the basic analytical approach that is commonly used in physical oceanography. And while there are other texts in the field, few can match the collective experience and breadth of knowledge of the authors assembled here. With such valuable resources available to students and young researchers, a revised edition may be necessary in the near future.

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