INTRODUCTION TO ESTUARINE HYDRODYNAMICS

This textbook provides an in-depth overview of the hydrodynamics of estuaries and semi-enclosed bodies of water. It begins by describing the typical classification of estuaries, followed by a presentation of the quantitative tools needed to study these basins: conservation of mass, salt, heat, momentum, and the thermodynamic equation of seawater. Further topics explore tides in homogeneous basins, including shallow water tides and tidal residual flows, wind-driven flows in homogeneous basins, density-driven flows, as well as interactions among tides, winds and density gradients. The book proposes a classification of semi-enclosed basins that is based on dominant dynamics, comparing forcing agents and restorative or balancing forces. *Introduction to Estuarine Hydrodynamics* provides an introduction for advanced students and researchers across a range of disciplines - Earth science, environmental science, biology, chemistry, geology, hydrology, physics - related to the study of estuarine systems.

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Preface

This text is the result of more than 30 short (1–2 week-long) courses and a handful of semester-long courses on estuarine hydrodynamics. Its production has been encouraged throughout the years by colleagues who have organized some of the short courses: David Salas de Leon and Alex Souza in Mexico, Guto Schettini and Eduardo Siegle in Brazil, and Aldo Sottolichio in France. In the preparation of lectures, Larry Atkinson in the USA has been a great source of inspiration and advice. I am thankful to all of them for their steady encouragement to turn course lectures into a book.

The material in the text has benefited from many colleagues with whom I have interacted throughout the years. Professional meetings and project collaborations often provide opportunities to recognize, refine, and reinforce field underpinnings. In many ways, this text is a community effort spawned from generous and collegial sharing of thoughts. Just like the saying "it takes a village to raise a child," it took the "global estuarine village" to raise this "child."

The presentation level of the material in this text intends to be for *beginner* to *intermediate* skills. To the nonspecialist, however, a rapid page perusal may cause an irascible reaction: "beginner"? "intermediate"? malarkey! I hope that is not the reaction. If indeed it is, it is probably because the perusal triggers sensory overload from many equations, despite efforts to minimize their number. To that, I will respond that equations are your friends. They actually represent lots of words in a few symbols. So they in fact save you time. In some instances, those symbolic expressions even describe a mathematical problem that has a solution. And that solution represents what happens or approximately happens in nature. So cool! My plea is, try to be patient with your friends, the equations; they are helpful.

The text sometimes may be repetitive, either in the same section or in the chapter, or from one chapter to the next. This has been done in an attempt to reinforce concepts. Some passages may present more information than needed, while others might not have enough. The intent is to present topics from an

introductory approach. The focus of the material presented is by no means comprehensive, and it is extremely likely that crucial references are overlooked. Motivated readers are urged to explore literature suggested at the end of each chapter – in additional sources and the studies referenced therein.

The book follows the sequence of topics featured at the short courses mentioned in the first paragraph of this Preface. It starts with an introduction and a typical classification of semienclosed coastal basins influenced by fresh water. This is followed by the presentation of the quantitative tools to study these basins, namely conservation of mass, salt, heat, momentum, and thermodynamic equation of seawater. The first phenomenon treated is tides in homogeneous basins, including shallow water tides and tidal residual flows. The text continues with a treatment of wind-driven flows in homogeneous basins. The following topic is density-driven flows – the typical gravitational circulation. After that, the text explores the interactions among tides, winds, and density gradients. This is the longest chapter and the one with a large number of unresolved research questions. The next topic has to do with fronts, followed by times of water renewal in semienclosed basins, and behavior of basins with low-river discharge. The text ends with a proposed classification of semienclosed basins that is based on dominant dynamics, comparing forcing agents and restorative or balancing forces.

Several of these chapters benefited enormously from relevant books or chapter work by Bruce Parker (shallow water tides), Chunyan Li (tidal residuals), Clinton Winant (wind-driven flows), Jim O'Donnell (fronts), Lisa Lucas (renewal times), and John Largier (low-discharge basins).

Finally, an effort of this nature would be impossible without the inspiration from loved ones. Thank you to my beloved Anne and our wonderful Liliana, Alvaro, and Emiliano for their patience, support, and understanding.