Mathematics of Planet Earth

Volume 9

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The Mathematics of Marine Modelling

Water, Solute and Particle Dynamics in Estuaries and Shallow Seas





Editors Henk Schuttelaars Department of Applied Mathematics Delft University of Technology Delft, The Netherlands

Eric Deleersnijder Institute of Mechanics, Materials and Civil Engineering (IMMC) and Earth and Life Institute (ELI) Université Catholique de Louvain Louvain-la-Neuve, Belgium Arnold Heemink Department of Applied Mathematics Delft University of Technology Delft, The Netherlands

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Preface

Coastal regions are strongly impacted by human interventions and climate change. Sea level rise and increased storminess threaten coastal safety; changes in intensity and duration of rainfall strongly impact intrusion of salt which may endanger the availability of fresh water. Examples of human interventions are the measures to mitigate these adverse climate effects, but also interventions are driven by, for example, economic (e.g., deepening of shipping channels, sand mining) and environmental (e.g., construction of large-scale wind parks) reasons. Unfortunately, such interventions may have unintended negative impacts due to the many conflicting interests in these regions: for example, channel deepening may be an excellent choice from an economic point of view, but it may result in a deterioration of the coastal safety and ecological values of the system under consideration. To oversee the multi-faceted impact of interventions and climate change, the dynamics of coastal seas, estuaries, and tidal inlets have to be well-understood. Only with such understanding, coastal managers can make well-balanced decisions that take all aspects into account. Mathematical modeling of marine systems becomes increasingly important to provide the insights necessary for decision making.

Over the past few decades, the mathematical modeling cycle has become instrumental in understanding the dynamics of coastal seas, estuaries, and tidal inlet systems. In this cycle, new mathematical models are developed or existing models are improved upon, advanced solution techniques are developed and employed to solve these highly complex nonlinear models, and the model outcomes are analyzed using state-of-the-art mathematical techniques and, if possible, compared to field and laboratory observations.

In this contribution, we focus on mathematical techniques available to study various topics from marine sciences in estuaries and coastal seas. Since only a limited number of topics can be treated, we restrict ourselves to the discussion of mathematical models on water motion and transport of pollutants and sediments by the water motion. In the first chapter, the basic mathematical concepts to obtain the governing equations are summarized and the final system of equations to model the water motion in coastal regions is given. In the next chapters, specific aspects of water motion are discussed: water waves in isotropic and anisotropic media, (near-shore) waves, and barotropic tides. This is followed by a detailed review of 2D-turbulence modeling and parameterization of turbulent dispersion. In the final chapters, river plumes, mathematical techniques to model transport phenomena, morphodynamic modeling of the bathymetry and geometry, and accurately model drying and flooding are discussed.

The prerequisite mathematical knowledge varies, but most of the material should be accessible to advanced graduate students and early-stage researchers. In most chapters, there is a clear link with observations and practical challenges, allowing professionals outside academia and decision-makers to get a good insight into the various techniques underpinning the models often used and other methodologies that can be employed to tackle their real-world problems. In each chapter, there is an extensive list of references, ranging from general to highly specialized, allowing the interested reader to further explore these topics independently.

Delft, The Netherlands February, 2022 Eric Deleersnijder Arnold Heemink Henk Schuttelaars

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Contributors

Bokhove Onno School of Mathematics, University of Leeds, LS2 9JT, Leeds, UK

Clercx Herman J. H. Fluid Dynamics Laboratory, Department of Applied Physics, Eindhoven University of Technology, Eindhoven, MB, The Netherlands

Cushman-Roisin Benoit Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, USA

Dawson Clint Oden Institute for Computational Engineering and Sciences, The University of Texas at Austin, Austin, TX, USA

Deleersnijder Eric Université Catholique de Louvain, Ottignies-Louvain-la-Neuve, Belgium

de Swart Huib E. Institute for Marine and Atmospheric research, Department of Physics, Utrecht University, Utrecht, The Netherlands

Fringer Oliver Stanford University, Stanford, CA, USA

Gräwe Ulf Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Rostock, Germany

Heemink Arnold Delft University of Technology, Delft, Netherlands

Hetland Robert D. Department of Oceanography, Texas A &M University, College Station, College Station, TX, USA

Kärnä Tuomas Finnish Meteorological Institute, Helsinki, Finland

Klingbeil Knut Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Rostock, Germany

Lambrechts Jonathan Institute of Mechanics, Materials and Civil Engineering, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Maas Leo R. M. Institute for Marine and Atmospheric Research (IMAU), Utrecht University, Utrecht, Netherlands

Ortleb Sigrun Department of Mathematics, University of Kassel, Kassel, Germany

Roos Pieter C. Water Engineering & Management, University of Twente, Enschede, The Netherlands

Samii Ali Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin, Austin, TX, USA

Schuttelaars H. M. Delft Institute of Applied Mathematics, Delft University of Technology, Delft, The Netherlands

Shah Syed Hyder Ali Muttaqi Sukkur Institute of Business Administration University, Sukkur, Pakistan

Umlauf Lars Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Rostock, Germany

Zitman T. J. Department of Hydraulic Engineering, Delft University of Technology, Delft, The Netherlands