Book Review

"Marine Environmental Characterization": A Practical Book for Marine Scientists and Engineers

Xinyi Kang[1], Bishnupriya Sahoo[1], Miaohua Mao[1], Meng Xia[2*]

[1]Key Laboratory of Coastal Environmental Processes and Ecological Remediation,

Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences,

Yantai, Shandong Province, China, 264003

[2]Department of Natural Science,

University of Maryland Eastern Shore,

Princess Anne, MD, USA, 21853

Correspondence to: mxia@umes.edu

Abstract- The marine environment and its features has been an exciting field of interdisciplinary and multidisciplinary research for oceanographers, environmentalists, marine/coastal engineers, ecologists, geologists, and many more. Moreover, on one hand, diversity and complexity in the oceanographic features openly challenge the scientific community, and on the other hand, voluminous research documents on physical, chemical, and biological features of the marine environment have greatly facilitated understanding and explored the research gaps in the field. The book '*Marine Environmental Characterization*' written by C. Reid Nichols and Kaustubha Raghukumar summarized the current marine environmental characterization tools covering observations and numerical modeling. The book presents oceanic and meteorological phenomena on various temporal and spatial scales with key challenges in operating a sustainable observing system. The authors further point out the importance of numerical models by stating that since the ocean is large and under-sampled, numerical models are an efficient tool to fill the information gap. It is worth mentioning that the authors highlight the environmental sustainability of the observing engineering system before, during, and after the data collection. A comprehensive study observing oceanic and meteorological systems needs to be established all over the world to understand the state of the ocean and provide this essential information to the decision makers.

Keywords: marine environment; oceanography; observation; data; numerical modeling; environmental sustainability

1. Introduction

Marine Environmental Characterization [1] is an introductory book on physical oceanographic processes by C. Reid Nichols and Kaustubha Raghukumar, published under Morgan & Claypool in 2020. The book summarizes divisions of physical oceanography in an engineering aspect where phenomena are described from the open ocean to the nearshore. The authors have inscribed their perception of marine categorization attributed to the research on quantification and classification of atmospheric and marine variables. Broadly, the authors have put forward their insights on oceanic features such as winds, waves, tides, currents, and water quality along with an emphasis on oceanic and atmospheric data collection, assimilation, and broadcast techniques advantageous in navigation, and in coastal and offshore structural designs. The authors never missed mentioning the challenges in marine data sampling, hindcast, nowcast, and forecast techniques. Compared to the standard Ocean Engineering books [2-9], the book explicitly mentions recent data collection techniques such as Remote Sensing and Geographical Information Systems (GIS), data systems and sensors such as Autonomous Underwater Vehicles (AUV), and Coastal-Marine Automatic Network (C-MAN), along with a list of primary international organizations of non-commercial data sources.

The book contains 8 chapters with an introduction note in Chapter 1. The introduction highlights the importance of marine environmental characterization and describes the tools and methods that engineers and scientists use to obtain the data on various spatial and temporal scales. Chapter 2 shows the oceanographic regions on multiple spatial scales from the open ocean, offshore to nearshore with coastal ocean having the information of physical behaviors such as

waves and tides, water quality, and anthropogenic impacts. The authors attempted to convey the extreme wave impacts on the nearshore and offshore structure in Chapter 3. Although the book describes oceanography from various aspects, the depth and breadth of each topic are primary. Chapter 4 describes the ocean observing system that collects the data from the ocean and atmosphere. Chapters 5 and 6 discuss the data quality and data analysis from the perspectives of time series, spectral, and spatial distribution. Chapter 7 lists the key challenges in marine environmental characterization for engineers and scientists to overcome. Chapter 8 makes a concluding remark about the significance of marine environmental characterization and highlights the need for numerical models to provide the spatially extensive information.

2. The global ocean

The ocean is a continuous body of salt water that covers more than 70% of the earth's surface. Governed by the global circulation, different regions of the ocean are interconnected. Winds from the atmosphere generate waves and play an important role in the wind-induced mixing from the water surface. Tides, the rise and fall in sea level resulted from the gravitational attraction of the moon and the sun, lead to tidal currents known as floods and ebbs. Short-wave and long-wave radiation determine the heat content and temperature distribution of the ocean. Precipitation, evaporation, and the freshwater from the large rivers modulate the salt balance of the ocean. Besides physical behaviors of tides, waves, and ocean circulation, the ecosystem balance of the ocean including biological and chemical oceanography is a key research topic constantly studied by researchers all over the world.

In this book, the general information about waves and tides is discussed from different spatial scales from the open ocean, offshore to nearshore. In the nearshore regions, like coastal bays, coastal lagoon systems, and large river mouths, environmental issues are a big concern due to the development of coastal cities and economic mobility. Physical hydrodynamics in the bays are strongly associated with the health of an estuarine ecosystem [10-12]. Excessive nutrients from point sources (i.e., river, industrial, and sewage treatment) due to anthropogenic impacts and non-point sources (i.e., atmospheric deposition) may cause eutrophication in the coastal ocean, and correspondingly deteriorate the water quality and result in hypoxia and other ecological problems such as die-offs of fish, shellfish, and aquatic plants in estuaries [13, 14]. Meanwhile, a series of observed networks has been established around the coasts to collect the data from physical oceanography/biological oceanography and monitor the environmental characterization. Correspondingly, followed by the observed network, a series of research studies have been conducted in different estuaries all over the world to illustrate and understand the linkage between bay hydrodynamics and hypoxia/nutrient dynamics to help people to enhance the management in the future [15-17].

3. Oceanographic data technology development

Oceanographic data collection and predictions initiated with a much bigger extent during the 1st world war for naval activities. Post war, experimental and theoretical understanding on the large-scale ocean circulation held its base during 1940-1960. The advent of moored and satellite instrumentation during 1960 and 1970 eased research on mesoscale ocean dynamics [3]. Thereafter, significant development on marine instrumentation, mathematical and numerical modeling, and remote sensing data collection unveiled the ocean to mankind. Moreover, the

development of prediction methodologies has been beneficial to scientific, engineering, and commercial needs. There is information concealed in the marine environment data, which has immense potential in marine-related fields, such as tsunami and red-tide warning, prevention, and forecasting, disaster inversion, and visualization modeling after disasters from physical, chemical and biological oceanography [18].

This book emphasizes marine instrumentations and systems, numerical models, and data collection and analysis. The authors' notes on the important ocean and coastal engineering projects dealing with design, manufacture, and maintenance of marine instruments are informative for the readers. In context to the spatial extent of the world ocean, precise and continuous marine data collection is challenging [18]. In recent years, deployment and management in adverse sea conditions are avoided using unmanned vehicles and sensors [1]. In such a scenario, remote sensing techniques have been as advantageous for marine as land and atmospheric data. Satellite imageries, drones, radars, altimeters, and aircraft-ship borne data combined with station observations are processed by the scientific organizations such as the National Oceanic and Atmospheric Administration (NOAA) and available for scientific and engineering studies. Advanced GIS techniques allow scientific communities to better interpret data [19]. The authors of this book also specify the importance of numerical models in hindcast, nowcast, and forecast. Continuous development in Global Forecasting Systems (GFS) and Regional Forecasting Systems (RMS) undoubtedly improved the prediction quality. The large scale ocean models such as WWIII (Wave Watch III) and POM (Princeton Ocean Model), along with the coastal ocean models such as SWAN (Simulating Waves Nearshore), ADCIRC (Advanced Circulation Model), and FVCOM (Finite-Volume Community Ocean Model) have

been proved vital in characterizing the ocean waves, tides, currents, coastal flooding, and their interactions which assist in warning the coastal community and navigation engineers prior to the extreme sea conditions. In a reviewers' viewpoint, numerical modeling results together with remote sensing data and ground observations could provide a robust understanding and prediction system when utilized with the recent artificial techniques [20]. There have been sufficient studies illustrating the robustness of AI (Artificial Intelligence) techniques in the oceanic and atmospheric systems [21, 22]. However, a coupled air-sea interaction model integrated with a robust AI technique is always preferred to address the interrelated ocean and atmosphere processes with high degrees of precision.

Furthermore, AI techniques have been proved efficient for quality control of the prediction system [23, 24] and can be implemented for the oceanic and atmospheric models. In context to the spatial extent of ocean and its diversity, quality control of marine data is challenging. Continental shelf interaction, rivers, and estuaries feed crucial variables to the coastal ocean data systems. In Chapter 5, the authors have highlighted several data control and quality assurance processes such as removal of outliers and inconsistencies, data gap filling, and error analysis.

Even with quality-assured data, challenges persist in data management, storage, analysis, and application. In this context, one of the data scientists [18] labeled the marine data a double-edged sword. There have been numerous data analysis techniques developed to unveil the hidden features of the ocean, which include sampling and error handling (e.g., hypothesis testing, interpolation, cone of uncertainty, etc.), spatial analysis (e.g., factor analysis, normal mode analysis, data filter, GIS, etc.), and temporal analysis (e.g., spectral analysis, Fourier analysis,

wavelet analysis, etc.) [25]. The authors of this book inscribed several data analysis techniques for basic engineering studies in Chapter 6. For example, a time series analysis on the sea surface temperature has proved the ocean heat uptake following global warming and rising carbon concentration. Time series analysis has unveiled sea level rise and warns the coastal communities listing out sinking cities and islands [26]. Spectral analysis is essential in engineering studies to scrutinize irregular wind waves' influence on wave heights. In recent years, GIS techniques have grown in importance due to their credibility in spatial data analysis and representation.

4. Key challenges in Marine Environmental Characterization

Going through the whole book, what impressed us most is that authors highlight the environmental sustainability of the observing engineering system before, during, and after the data collection to cope with the various weather events and not to comprise the environment. This needs a lot of work and effort for design, implementation, maintenance, and management, but its significance to the environment is outstanding. There are several key challenges in Marine Environmental Characterization based on the research needs, engineering projects, decision making, and practical usages. We classify them into the following key points:

1. Engineering requirement cycle - elicitation, analysis, specification, validation, and management, need to be considered to ensure that an observing system can operate reliably while during its management.

2. Since the ocean is still under-sampled, engineering projects must use scientific and technological innovation to solve problems related to data scarcity. The unmanned systems with state-of-the-art sensors offer a better chance to fill the gap of the global ocean observed data.

3. Collecting the high-quality data on environmental factors is critical to describe the relationship between variables that affect engineering design and system operation. The application of models can be combined with supplemental observations, which will describe the state of the ocean in the most accurate way.

4. Sustainable engineering is required in engineering projects, especially from the perspective of the environment, which requires detailed planning, designs, and management. Through the processes of data collection, before, during, and after a project, the project should cope with various climate phenomena and not comprise the environment.

The authors in Chapter 7 described the challenges involved in marine data collection, analysis, handling, numerical modeling, and implementation. The spatial extent of the ocean and its diverse and dynamic nature is a crucial constraint in data collection. Extreme value analysis has always been crucial due to their randomness and less predictability. Apart from the environmental factors, uncertainty in the design and performance of the marine instruments is unavoidable. Challenges exist in satellite imagery processing. Scientists believe that there are environmental variables yet to be discovered that constrain the predictability of a system. Model initialization with erroneous data can widen the cone of uncertainty. Lack of understanding in the coupled atmospheric-ocean system can lead to uncertainty in analysis and decision making. In

addition, only a fraction of marine data is accessible by researchers worldwide. Security concerns and data legalization withhold a major portion of the collected data.

5. Conclusion

The book *Marine Environmental Characterization* introduces the general information about oceanic data, highlights the importance of data collection and processing, and lists several key challenges in obtaining, operating, and processing the atmospheric and environmental data. The general lack of oceanographic information can lead to uncertainty in decision making and outcomes analysis. At the end, the authors point out that a comprehensive and sustainable marine environmental monitoring and characterization of observed data networks need to be established all over the world to provide the most accurate oceanic and meteorological data, and this data is a great support to the decision makers. Given that this book clearly illustrates marine instrumentation, data collection, and assimilation techniques, we highly recommend it to project managers, oceanographic engineers, policy decision-makers, and to all those are interested in learning about the basic knowledge of the marine environment.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Nichols, C. R., & Raghukumar K. (2020) Marine Environmental Characterization. Morgan and Claypool Publisher.
2. Pickard, G. L., & Emery, W. J. (2016). Descriptive physical oceanography: an introduction. Elsevier.
3. Talley, L. D. (2011). *Descriptive physical oceanography: an introduction*. Academic press.
4. Sorensen, R. M. (2005). Basic coastal engineering (Vol. 10). Springer Science & Business Media.

5. Vallam, S., & Annamalaisamy, S. S. (2019). Coastal Engineering: Theory And Practice (Vol. 47). World Scientific.
6. Dean, R. G., & Dalrymple, R. A. (1984). Water wave mechanics for engineers and scientists. https://doi.org/10.1029/eo066i024p00490-06
7. Chatfield, C., Bendat, J. S., & Piersol, A. G. (1987). Random Data: Analysis and Measurement Procedures. Journal of the Royal Statistical Society. Series A (General). https://doi.org/10.2307/2981634
8. Eagleson, P. S., Ippen, A. T., & Massachusetts Institute of Technology. Hydrodynamics Laboratory. (1966). Estuary and coastline hydrodynamics. In *Engineering societies monographs*.
9. Kelly, R., Cottrell, R. S., Mackay, M., & Rousseau, Y. (2017). Kathleen Schwerdtner Máñez and Bo Poulsen (eds): Perspectives on oceans past: a handbook of marine environmental history. Reviews in Fish Biology and Fisheries. https://doi.org/10.1007/s11160-016-9462-x
10. Xia, M., Xie, L., Pietrafesa, L.J., & Whitney, M.M. (2011) The ideal response of a Gulf of Mexico estuary plume to wind forcing: Its connection with salt flux and a Lagrangian view. *Journal of Geophysical Research*, *116*, C08035. https://doi.org/10.1029/2010JC006689
11. Kang, X., Xia, M., Pitula, J.S., & Chigbu, P. (2017). Dynamics of water and salt exchange at Maryland Coastal Bays. *Estuarine and Coastal Shelf Science*, *189*, 1-16. https://doi.org/10.1016/j.ecss.2017.03.002
12. Mao, M., & Xia, M. (2018). Wave-current dynamics and interactions near the two inlets of a shallow lagoon-inlet-coastal ocean system under hurricane conditions. Ocean *Modelling*, *129*, 124-144. https://doi.org/10.1016/j.ocemod.2018.08.002
13. Sturdivant, S. K., Diaz, R. J., Llanso, R. J., & Dauer, D. M. (2014). Relationship between Hypoxia and Macrobenthic Production in Chesapeake Bay. *Estuaries and Coasts*, 37(5), 1219-1232. https://doi.org/10.1007/s12237-013-9763-4
14. Hughes, B. B., Levey, M. D., Fountain, M. C., Carlisle, A. B., Chavez, F. P., & Gleason, M. (2015). Climate mediates hypoxic stress on fish diversity and nursery function at the land–sea interface. *Proceedings of the National Academy of Sciences of the United States of America*, 112(26), 8025-8030. https://doi.org/10.1073/pnas.1505815112
15. Scully, M. E. (2013). Physical controls on hypoxia in Chesapeake Bay : a numerical modeling study. *Journal of Geophysical Research*, 118(3), 1239-1256. https://doi.org/10.1002/jgrc.20138
16. Xia, M., & Jiang, L. (2016). Application of an Unstructured Grid-Based Water Quality Model to Chesapeake Bay and Its Adjacent Coastal Ocean. *Journal of Marine Science and Engineering*, 4(3). https://doi.org/ 10.3390/jmse4030052
17. Lu, Z., Gan, J., Dai, M., Zhao, X., & Hui, C. R. (2020). Nutrient transport and dynamics in the South China Sea: A modeling study. *Progress in Oceanography*, 102308. https://doi.org/10.1016/j.pocean.2020.102308
18. Huang, D., Zhao, D., Wei, L., Wang, Z., & Du, Y. (2015). Modeling and analysis in marine big data: Advances and challenges. In Mathematical Problems in Engineering. https://doi.org/10.1155/2015/384742
19. Huisman, O., & De By, R. A. (2009). Principles of geographic information systems. ITC Educational Textbook Series, 1, 17.
20. Haykin, S., (1999). Neural networks: a comprehensive foundation. Prentice Hall.

21. Sahoo, B., & Bhaskaran, P. K. (2019). Prediction of storm surge and inundation using climatological datasets for the Indian coast using soft computing techniques. *Soft Computing*. https://doi.org/10.1007/s00500-019-03775-0
22. Zhang, M., & Scofield, A.R., (1994). Artificial neural network techniques for estimating rainfall and recognizing cloud merger from satellite data. Int. Jour. Remote Sensing, 16, 3241-3262.
23. Ricardo Stemmer, M., Da Costa, C. P. B., Vargas, J., & Lúcio Roloff, M. (2014). Artificial intelligent systems for quality assurance in small series production. Key Engineering Materials. https://doi.org/10.4028/www.scientific.net/KEM.613.279
24. Escobar, C. A., & Morales-Menendez, R. (2018). Machine learning techniques for quality control in high conformance manufacturing environment. Advances in Mechanical Engineering. https://doi.org/10.1177/1687814018755519
25. Erkens, G., Bucx, T., Dam, R., De Lange, G., & Lambert, J. (2015). Sinking coastal cities. Proceedings of the International Association of Hydrological Sciences. https://doi.org/10.5194/piahs-372-189-2015
26. Thomson, R. E., & Emery, W. J. (2014). Data analysis methods in physical oceanography. Newnes.

The work of the Marine Environment Division is, in the main, directed by the Marine Environment Protection Committee, the MEPC in short, which is IMO's senior technical body on marine pollution related matters. It is aided in its work by a number of IMO's Sub-Committees, in particular the Sub-Committee on Pollution Prevention and Response (PPR). The original focus of its work was the prevention of marine pollution by oil, resulting in the adoption of the first ever comprehensive antipollution convention, the International Convention for the Prevention of Pollution from Ships (MARPOL) in 1973. Overall, marine environmental characterization tools, from observational data to numerical. modeling, are critical to todayâ€™s science, engineering, and marine operational disciplines. Nichols â€¢ raghukumar. Marine environmental characterization.Â Marine Environmental Characterization is an introductory geoscience book focusing on physical. oceanographic processes. Science issues that are addressed include sea level rise, coastal erosion.Â Professor, Ocean Engineering and Marine Sciences. Florida Institute of Technology. Melbourne, Florida. The marine environment presents significant challenges for materials due to the potential for corrosion by salt water, extreme pressures when deeply submerged and high stresses arising from variable weather.Â Underwater repair of marine composites is also reviewed. Comprehensively examines all aspects of fibre-reinforced marine composites, including the latest advances in design, manufacturing methods and performance Assesses the environmental impacts of using fibre-reinforced composites in marine environments, including end of life considerations Reviews advanced fibre-reinforced composites for renewable energy devices, rigging, sail textiles, sail shape optimisation and offshore oil and gas applications. Marine scientists are involved in research, analysis and forecasts in relation to the oceans, their life forms and coastal areas. As a marine scientist you'll analyse the sea and its interaction with the land, atmosphere, sea floors, animal life and plants, and use the information gained to predict changes to the earth's infrastructure, inform statutory legislation and encourage environmental protection. Types of marine scientist. Marine science is a broad-ranging field. Within it, you can work in areas as diverse as: biogeochemistry and ecosystems dynamics. Marine Industry is a field of numerous opportunities. No matter what your interest is, you will find something or the other in this field. But if you want to do something unique in the marine world, then check out some interesting career options enumerated in this article.Â These professionals also use tools developed and designed by marine scientists and engineers to explore the aquatic environment. They carry out their research on particular topics of exploration. For instance, they may use magnetic and acoustic remote sensors to find and locate varied sites in order to study those places.