Coastal Hazards

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Charles W. Finkl
Department of Geosciences
Florida Atlantic University
Boca Raton, FL 33431
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Charles W. Finkl
Editor

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Editor
Charles W. Finkl
Department of Geosciences
Florida Atlantic University
Boca Raton, FL, USA

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Preface

With increasing coastal populations worldwide, a greater number of people and infrastructure lie at risk from a wide range of potential hazards. Many coastal environments are salubrious places to live and this fact has not gone unnoticed by people wishing to improve their standard of living and general wellbeing. However, even though enticing sand, sea, and sun may prompt the hoards migrating to coastal realms, there lay many hazards that are seen but soon forgotten. Smith (1994), for example, reports that many coastal dwellers forget the trauma of a severe coastal impact between 100 and 500 days. Then it is business as usual. Perhaps still more risky are coastal hazards that are unseen by the general public because they are not aware of hidden dangers lurking in polluted waters or the repercussions of exotic, invasive species that are beautiful to the eye but deadly to the environment, such as the lionfish along Florida's southeast coast. Still more menacing are deadly reptiles (*e.g.* cobras, green mambas, Burmese pythons) in the Florida Everglades that go unnoticed by the public until they have an unfortunate encounter.

In short, the coastal zone is home to many different kinds of potential hazards, and this book, intended as an update to *Coastal Hazards: Perception, Susceptibility and Mitigation* (Finkl 1994), provides a wide array of chapters to that fact. Much has changed in the last couple of decades since *Coastal Hazards: Perception, Susceptibility and Mitigation* (Finkl 1994) was published, mostly in the area of technological advances for sensing environmental conditions, which have brought a better understanding of the processes and triggers for both high-energy events and incipient exposures to risk. In an edited work of this sort, it is difficult to arrange the topical coverage, as no categorization is truly perfect. Complicating matters is the fact that many coastal hazards partly overlap, are multifaceted, and often reinforced by other processes; as is the case of coastal flooding and erosion, where many contributing factors can be present, such as storm surge, tsunamis, subsidence, high rainfall events, sea-level rise, and so on. Many different types of coastal environments are affected by short-term super-elevations of sea level and long-term inundation. Further complicating the picture are attempts to project phases of storminess and future sea-level rise in many different kinds of probabilistic scenarios. This uncertain future makes it difficult to assess risk, vulnerability,

and the best course for planning remediation of impacts that may or may not occur. With these overlapping problems in mind and for convenience of presentation and discussion, chapters in this book have been grouped under very generalized topical headings in an attempt to highlight the predominant hazard that is discussed with the proviso that ancillary hazards are additionally associated. Knowing that it is impossible to discretize the subject matter into ultimate units, the following parts nevertheless have been identified as a guide for study: Part I: Environmental and Human-Induced Hazards; Part II: Remote Sensing of Coastal Hazards (platforms, methods, and procedures); Part III: Flood Hazards (storm surge, sea-level rise, and populations from risk of coastal flood hazards); Part IV: Hydrologic (groundwater, saltwater intrusion) Hazards; Part V: Coastal Erosion and Sedimentation (detection and measurement of shoreline retreat); Part VI: Coastal Dune Hazards (erosion and management); Part VII: Coastal Storms (tropical cyclones and extra-tropical winter storms); Part VIII: Wave Hazards (extreme coastal waves, storm surge, and runup); Part IX: Coastal Marine Pollution (beach litter and oil spills); and Part X: Beach Safety.

The single chapter in **Part I (Environmental and Human-Induced Hazards)** starts out with an introductory chapter by Charlie Finkl and Chris Makowski that embraces a gamut of hazards in the exemplar of the Southeast Florida Coastal Zone (SFCZ). The highly urbanized SFCZ is susceptible to many different kinds of coastal hazards that often combine into a cascade of risks that now threaten millions of people who are partly aware of obvious dangers, but almost completely oblivious to incipient and mostly unseen hazards.

In **Part II (Remote Sensing of Coastal Hazards)**, Vic Klemas' chapter provides an overview of remote sensing methods that are used to acquire near real-time information to monitor high-energy events and assist in the assembly of post-storm reports that assess damage and plan implementation for recovery. Vic's chapter mostly concentrates on space-borne ocean sensing techniques for a wide variety of hazards. The chapter features by Elif Sertel and Dursun Seker human-induced coastal changes along the Black Sea coast of Turkey. The impacts of intense coastal urbanization are investigated by integrated remote sensing, geographic information systems, and geostatistics in attempts to determine and examine coastal changes that are in effect hazardous to the environment. The main types of change included road construction and urbanization that resulted in coastal erosion and damage to local ecological systems.

Part III (Flood Hazards) features aspects of impacts from storm surge, sea-level rise, and populations at risk of coastal flooding. The seven chapters in this part cover reports of coastal populations at risk from flooding, public perception of flood risks, impacts of storm surges, and a review of sea-level rise. The chapter by Michael Kearney starts out by considering the distinction between vulnerability and risk, a consideration that is often not clearly defined in coastal hazard research. Mike specifically examines how amenable the natural hazard components of coastal disasters are to risk analysis. A broad continental-scale overview of sea-level rise impacts is provided by Sally Brown and colleagues. This perspective considers the age-old problem of how much will sea levels rise in the future as well as discussion

of projected or potential impacts to sandy environments, wetlands and low-lying coasts, developed shorelines, and impacts on infrastructure such as transportation networks and energy production facilities. Mark Crowell and colleagues provide an interesting investigation of 8.6 million permanent residents, about 2.8% of the US population based on the 2010 census, that live in areas subject to the 1% annual chance of flood as defined by FEMA. Consideration of tourists and people working in these areas would increase the number of people whose property and jobs would be affected by the 1% annual chance flood. Lee Lindner and Charles Cockcroft surveyed 200 residents in Charleston, South Carolina, and found some surprising statistics *viz*. over half of the respondents did not realize that the main threat from hurricanes was from storm surge and the majority were not able to translate a standard National Hurricane Center projection of storm surge depth into a realistic appreciation of the risk posed to their lives. Understanding of the risk from storm surge was far higher when a graphic-filled advisory instead of a text-based advisory was used. Nick Coch provides an interesting case study of the amplification of storm surge by viaducts of the Florida East Coast Railway extension to Key West. The 1935 Labor Day hurricane made landfall in the middle section of the Florida Keys with the storm surge killing many people and causing much damage to infrastructure. Nick also reports on how coastal development has increased risk from storm surge by reducing natural flow patterns with the construction of causeways, placement of viaducts, reduction of mangrove areas in favor of canal-type developments, and so on. In another chapter Sotiris Lycourghiotis and Strathos Stiros compare the flooding hazards along low-tidal and high-tidal amplitude coasts, particularly along the north Aegean coast. They found smaller risks of flooding events along high-tidal amplitude coasts because the threat existed only for a few hours a day during high water periods as a result of meteorological events. Threats of flooding are higher along Aegean microtidal coasts because surge amplitudes are not dissipated by astronomic sea-level oscillations. Finally, Jim Houston reviews fluctuations of sea-level over long- and short-term intervals with an emphasis on threats from projected future sea-level rise. In this chapter, Jim considers coastal hazards from future sea-level rise in terms of permanent and episodic inundation, increase shore erosion, and saltwater intrusion. He also summarizes adaptation strategies that should be part of an integrated coastal zone management approach.

Part IV (Hydrologic Hazards) contains two chapters, the first dealing with saltwater intrusion, a hazard along many developed shores and in low-lying islands, and the second with the problem of brine disposal from desalinization plants. The first chapter by Ahmad Aris and Sarva Praveena describes a geochemical modeling approach that can be used for small islands where groundwater is the sole option to meet the water demand. Because groundwater exists as freshwater lenses floating over transition zones, grading into seawater in small islands presents an innate hazard from over use of limited supplies. It is thus necessary to monitor groundwater supplies and create models that can predict future demands and availability of potable water. This study shows how groundwater geochemical modeling assists stakeholders, governmental bodies, and the public to improve the sustainability of groundwater resources that are necessary for survival. The second chapter by

Adrian Ciocanea and colleagues deals with an interesting problem that is increasing along coasts where groundwaters are contaminated by saltwater intrusion. Here, desalinization of seawater provides an alternative to aquifer withdrawal but disposal of waste products from the plants is concerning because of the release of concentrated salt brine, residual chlorine levels, antiscalant and anti-foaming additives, and coagulants. Many desalination plants are located in the Middle East where there is an adequate fuel supply to run the plants. This chapter discusses possible ways to mitigate the concentrate and chemical discharges to the marine environment because they may have adverse effects on water and sediment quality, and impair marine life and the functioning of coastal ecosystems.

Part V (Coastal Erosion and Sedimentation) starts out with an introduction to the worldwide problem of coastal erosion where Robert Dean and colleagues discuss natural and human-induced causes of beach erosion as well as different kinds of remediation efforts. Dean et al. highlight the most pervasive natural causes of beach erosion as being due to sea-level rise, and trapping of sand by natural inlets and migration of inlets. Human-induced causes of erosion are related to the construction of littoral barriers that ironically may include beach renourishment projects. They conclude that it may be possible to maintain some highly developed coastal areas for a century or so with available technology and resources, but some areas will require probably abandonment. Other chapters in this part deal with modern methods of detection and measurement of shoreline retreat that include, for example, the use of aerial photography (photogrammetry), satellite imagery, global positioning system (GPS) ground surveys, and laser scanning. In the chapter by Jay Gao, various geo-informatic means of detecting coastal change are compared and evaluated by reference to different types of coastal morphologies. Here, Gao carefully explains the pros and cons of photogrammetric methods, GPS (combined with RTK), and laser scanning (*e.g.* LiDAR-derived DEM). Combinations of methodologies such as the use of RTK GPS for accurate ground control for photogrammetry enables the changing coastal environment to be monitored at an unprecedented frequency and accuracy. The chapter by Kwasi Appeaning-Addo and Emmanuel Lamptey mirrors concepts advanced in the preceding chapter by providing an actual case study in Accra, Ghana, where shoreline status assessment was studied via an innovative technique that combined dated historic maps, aerial photography, satellite imagery, conventional and global positioning system (GPS) ground surveys, and laser altimetry data. Using these data sets, Appeaning-Addo and Lamptey were able to show that the generic technique involving linear regression was suitable for estimating historic rates of shoreline change. The methodology was also used for long-term forecasting to obtain estimates of the average recession rate of change for Accra and other data-sparse coastal regions in developing countries. The penultimate chapter by Jarba Bonetti and colleagues in this part considers the development of different methodological alternatives to assess and predict coastal risk. The need for new approaches is stimulated by increasing human occupation of the coastal zone and the anticipated intensification in the frequency of meteohydrological events due to global change. Critical hazard areas are identified using this methodology and a numerical index of coastal vulnerability established. Erosional hot spots were identified by calculating longshore sediment

transport rates. The beach erosion model, which quantified the sediment transport rate through simulations, was corroborated field data.

Part V concludes with the chapter by Giovanni Randazzo, Jordi Raventos, and Lanza Stefania that deals with increasing demands on coastal resources and the hazards associated with shore erosion in the European Union (EU). Of the 27 Member States, 22 open directly onto five different seas. At present, the total coastal area lost to marine erosion is estimated to be about 15 km^2/year. Many countries attempt to 'hold the line' and avoid realignment. Cross-border shore protection programs are difficult to implement without a cohesive coastal management plan.

Part VI (Coastal Dune Hazards) primarily deals with aspects of erosion and management. The chapter by Sara Muñoz Vallés and Jesús Cambrollé identifies the main current threats to coastal dunes as expansion of invasive species, anthropogenic impacts associated with development and tourism, and climate change. The decline in frequency of occurrence of coastal dunes is itself a hazard because they form protective coastal barriers, help prevent contamination of fresh groundwater by intrusion of seawater, and preserve natural areas and human settlements from the effects of storm waves, high tides, and wind damage. The chapter by Silvia Cristina Marcomini and Ruben Alvaro López features a summary of the unique and complex systems of dune environments, hazard remediation, and examples from dunes in Buenos Aires, Argentina. Considered here are examples of dune hazards (*e.g.* dune migration, flooding of inter-dunal swales, wave erosion) associated with minor climate change in response to El Niño–La Niña cycles. Examples that are presented here show the benefits of dune stabilization by afforestation. Together both chapters provide a good overview of dune hazards and mitigation measures.

Part VII (Coastal Storms) highlights the impacts of coastal storms (tropical cyclones, extra-tropical winter storms, and flooding). The chapter by S. M. May and colleagues deals with coastal hazards that are derived from impacts of tropical cyclones (tropical storms, hurricanes, typhoons). May et al. take an interesting look at trying to figure out the potential number of prior storms in the Holocene that can be interpreted from storm signatures in landforms and sediments. Although there is a problem of correlating of paleo-events with strong cycles in modern times, these authors point out the advantages of attempting numerical dating along beach ridge systems and in other geo-bioarchives. Such efforts provide a degree of insight into interpretation of present cycles by reference to deduced paleo-event frequencies. The chapter by Paul Komar, Jonathon Allan, and Peter Ruggiero focuses on the US Pacific Northwest coast (Washington, Oregon, and northern California) and deals with meteohydrological events and tectonic processes. The main thrust here is impacts from storms, mostly those that lead to storm-surge flooding, inundation from eustatic sea-level rise, shore (beach, cliff) erosion, and potential tsunamis. Cycles of El Niño, climatic controls on storm surge levels, and increasing storm-generated wave heights since the 1970s constitute a range of coastal hazards for this section of coast. The convergence of geological (subduction earthquakes) and atmospheric phenomena along this coast make for hazardous conditions that must be paid attention to for preparation, prevention, and remediation where feasible.

Part VIII (Wave Hazards) deals with extreme coastal waves (including tsunamis), storm surge, and runup. The chapter by Zai-Jin (Bob) You and Peter

Nielsen focuses on the authors' research experience with extreme waves and elevated water levels along the New South Wales (Australia) coast. These authors consider short-term wave analysis to determine wave heights in deep waters and long-term wave analysis to estimate extreme wave heights from an historical time-series record. The chapter is filled out by discussions of oceanic surges, swash hydrodynamics, wave runup, and extreme wave runup. The chapter by Monzur Imteaz, Fatemeh Mekanik, and Amimul Ahsan deals with tsunamis. They discuss the advantages of an efficient tsunami warning system and then explain the importance of the numerical simulations that are used, providing a newly developed 'stratification number'. They report that as this dimensionless number increases in magnitude, the wave surface and amplitude decrease.

Part IX (Coastal Marine Pollution) contains two chapters that respectively deal with beach litter and oil spills. Both coastal pollution problems are significant and locally important but of entirely different scope and magnitude. Beach litter hazards are discussed by Allan Williams and colleagues, who collectively focus on litter sources, types and composition of litter, and methods for evaluating the impacts of beach litter. This is a growing problem with multifaceted hazards that affect not only humans but wildlife as well. Also considered here are regional variations in sources and densities of litter as well as avoidance procedures. The chapter on hazards from oil spills by Erich Gundlach in a tour de force that considers many aspects of the problem. Legion here are discussions of spill source, risk, and size as they relate to shoreline oiling and impacts. Also highlighted are aspects of oil spill cleanup, biological effects, economic losses and compensation, damages to natural resources, psychological and social impacts, and human health effects.

Part X: Beach Safety deals mostly with rip currents and the hazards associated therewith. The chapter by Stephen Leatherman focuses on beach safety concerns as related to the development, recognition, and response to rip currents. These cross-shore currents are a danger to beachgoers who need to be aware of the hazard before they get jetted offshore by some of these powerful currents. Leatherman recommends public education about the dangers of rip currents through outreach programs. Learning how to recognize the presence of rips and what to do if caught in one can be lifesavers for swimmers.

Although this collection of chapters does not cover all aspects of coastal hazards, it represents an honest attempt to consider most of the major types of coastal hazards as part of disaster research in general. Perhaps the most difficult part of coastal hazard research is to project future courses of human action when natural cycles are incompletely understood, especially as they are affected by anthropogenic activities that further complicate our predictive capabilities. Taking that into consideration, this volume covers the gamut of coastal hazards from various points of view and should provide the interested reader with a base of understanding for the dangers that face coastal dwellers, tourists, and those who work in the coastal zone.

Florida Atlantic University
Boca Raton, Florida, USA

Charles W. Finkl

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Contributors

L. Absalonsen Department of Civil and Coastal Engineering, University of Florida, Gainesville, FL, USA

Amimul Ahsan Faculty of Engineering and Industrial Sciences, Swinburne University of Technology, Hawthorn, Melbourne, VIC, Australia; University Putra Malaysia, Kuala Lumpur, Malaysia

Jonathan C. Allan Coastal Field Office, Oregon Department of Geology and Mineral Industries, Newport, OR, USA

Kwasi Appeaning-Addo Department of Oceanography & Fisheries, University of Ghana, Legon, Ghana

Ahmad Zaharin Aris Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan, Malaysia

Viorel Badescu Candida Oancea Institute, Polytechnic University of Bucharest, Bucharest, Romania; Romanian Academy, Bucharest, Romania

Doug Bellomo Federal Emergency Management Agency, Arlington, VA, USA

Jarbas Bonetti Coastal Oceanography Laboratory, Department of Geosciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

D. Brill Institute of Geography, University of Cologne, Cologne, Germany

Sally Brown Faculty of Engineering and the Environment and the Tyndall Centre for Climate Change Research, University of Southampton, Highfield, Southampton, UK

Jesús Cambrollé Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, Seville, Spain

Richard B. Cathcart Geographos, Burbank, CA, USA

Adrian Ciocanea Department of Hydraulics, Polytechnic University of Bucharest, Bucharest, Romania

Nicholas K. Coch School of Earth and Environmental Sciences, Queens College of C.U.N.Y., Flushing, NY, USA

Charles Cockcroft Physics and Astronomy Department, College of Charleston, Charleston, SC, USA

Kevin Coulton AECOM, Portland, OR, USA

Mark Crowell Federal Emergency Management Agency, Arlington, VA, USA

M.J. Cullis Built Environment, Swansea Metropolitan University, Swansea, Wales, UK

R.G. Dean Department of Civil and Coastal Engineering, University of Florida, Gainesville, FL, USA

M. Engel Institute of Geography, University of Cologne, Cologne, Germany

A. Ergin Civil Engineering Department, Middle East Technical Univeristy, Ankara, Turkey

Charles W. Finkl Department of Geosciences, Charles E. Schmidt College of Science, Florida Atlantic University, Boca Raton, FL, USA; Coastal Education & Research Foundation (CERF), Coconut Creek, FL, USA

Jay Gao School of Environmental, University of Auckland, Auckland, New Zealand

Mauricio González Instituto de Hidráulica Ambiental "IH Cantabria", Universidad de Cantabria, Santander, España, Spain

Erich R. Gundlach E-Tech International, Inc., New Paltz, NY, USA

Susan Hanson Faculty of Engineering and the Environment and the Tyndall Centre for Climate Change Research, University of Southampton, Highfield, Southampton, UK

Jochen Hinkel Global Climate Forum e.V. (GCF), Adaptation and Social Learning, Berlin, Germany; Potsdam Institute for Climate Impact Research (PIK), Transdisciplinary Concepts and Methods, Potsdam, Germany

James R. Houston US Army Engineer Research Center, Vicksburg, MS, USA

Monzur A. Imteaz Faculty of Engineering and Industrial Sciences, Swinburne University of Technology, Hawthorn, Melbourne, VIC, Australia

Michael S. Kearney Department of Environmental Science and Technology, University of Maryland, College Park, MD, USA

Abiy S. Kebede Faculty of Engineering and the Environment and the Tyndall Centre for Climate Change Research, University of Southampton, Highfield, Southampton, UK

D. Kelletat Institute of Geography, University of Cologne, Cologne, Germany

Antonio Henrique da Fontoura Klein Coastal Oceanography Laboratory, Department of Geosciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

Victor V. Klemas School of Marine Science and Policy, University of Delaware, Newark, DE, USA

Paul D. Komar College of Earth, Oceanic & Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

Emmanuel Lamptey Dept. of Oceanography & Fisheries, University of Ghana, Legon, Ghana

Lanza Stefania Dipartimento di Scienze della Terra, Università degli Studi di Messina, Messina, Italy

Stephen P. Leatherman Laboratory for Coastal Research and Department of Earth & Environment, Florida International University, Miami, FL, USA

Bernhard Lee Lindner Physics and Astronomy Department, College of Charleston, Charleston, SC, USA

Rubén Alvaro López Departamento de Geología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires, Argentina

Clarissa Brelinger De Luca Coastal & Port Engineering Master Program, University of Cantabria, Santander - Cantabria, Spain

Sotiris A. Lycourghiotis Geodesy & Geodetic Applications Lab, Department of Civil Engineering, Patras University, Patras, Greece

Tucker Mahoney Federal Emergency Management Agency, Region IV, Atlanta, GA, USA

Christopher Makowski Department of Geosciences, Charles E. Schmidt College of Science, Florida Atlantic University, Boca Raton, FL, USA; Coastal Education & Research Foundation (CERF), West Palm Beach, FL, USA

Silvia Cristina Marcomini Departamento de Geología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires, Argentina

S.M. May Institute of Geography, University of Cologne, Cologne, Germany

Fatemeh Mekanik Faculty of Engineering and Industrial Sciences, Swinburne University of Technology, Hawthorn, Melbourne, VIC, Australia

Mariela Muler Coastal Oceanography Laboratory, Department of Geosciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

Barbara Neumann Coastal Risks and Sea-Level Rise Research Group, Future Ocean Excellence Cluster, Institute of Geography, Christian-Albrechts-University Kiel, Kiel, Germany

Robert J. Nicholls Faculty of Engineering and the Environment and the Tyndall Centre for Climate Change Research, University of Southampton, Highfield, Southampton, UK

Peter Nielsen School of Civil Engineering, University of Queensland, St Lucia, Australia

Susan Phelps AECOM, Greensboro, NC, USA

K. Pond Centre for Public and Environmental Health, University of Surrey, Guildford, UK

Sarva Mangala Praveena Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan, Malaysia

Giovanni Randazzo Dipartimento di Scienze della Terra, Università degli Studi di Messina, Messina, Italy

Jordi Serra Raventos Department d'Estratigrafia, Paleontologia i Geociències Marines, Universitat de Barcelona, Barcelona, Spain

J.D. Rosati Engineer Research and Development Center, U. S. Army Corps of Engineers, Vicksburg, MS, USA

Peter Ruggiero College of Earth, Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

Vanda Claudino Sales Departamento de Geografia, Universidade Federal do Ceará, Fortaleza, CE, Brazil

Anja Scheffers Southern Cross GeoScience, Southern Cross University, Lismore, NSW, Australia

Dursun Zafer Seker Geomatics Engineering Department, Istanbul Technical University, Maslak, Istanbul, Turkey

Elif Sertel Geomatics Engineering Department, ITU-CSCRS Istanbul Technical University Center for Satellite Communications and Remote Sensing, Istanbul Technical University, Maslak, Istanbul, Turkey

Guilherme Vieira da Silva Centro de Estudos de Geologia Costeira e Oceânica - CECO, Instituto de Geociências – IG, Universidade Federal do Rio Grande do Sul – UFRGS, Porto Alegre, RS Brazil

Peter Squire Southern Cross GeoScience, Southern Cross University, Lismore, NSW, Australia

Stathis C. Stiros Geodesy & Geodetic Applications Lab, Department of Civil Engineering, Patras University, Patras, Greece

Elírio E. Toldo Jr Centro de Estudos de Geologia Costeira e Oceânica – CECO, Instituto de Geociências – IG, Universidade Federal do Rio Grande do Sul – UFRGS, Porto Alegre, RS, Brazil

Zai-Jin You Coastal and Marine Science Unit, Science Division, Office of Environment and Heritage, Dangar, NSW, Australia

Athanasios T. Vafeidis Coastal Risks and Sea-level Rise Research Group, Future Ocean Excellence Cluster, Institute of Geography, Christian-Albrechts-University Kiel, Kiel, Germany

Sara Muñoz Vallés Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, Sevilla, Spain

T.L. Walton Beaches and Shores Resource Center, Florida State University, Tallahassee, FL, USA

Jonathan Westcott Federal Emergency Management Agency, Arlington, VA, USA

A.T. Williams Built & Natural Environment, Swansea Metropolitan University, Swansea, Wales, UK; e-GEO Centro de Estudos de Geografia e Planeamento Regional, Faculdade de Ciências Sociais e Humanas, Universidade Nova de Lisboa, Lisbon, Portugal

Colin D. Woodroffe School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW, Australia