

Preface

“I consider this the most successful ocean experiment of all times”

Walter Munk of Scripps Institution of Oceanography, University of California at San Diego
speaking about the TOPEX/Poseidon altimetry mission in front of the U.S. Commission on Ocean
Policy, in April 2002.

The above statement, a tribute from one of the fathers of modern oceanography and a pioneer of revolutionary techniques to sample the sea, is a convincing summary of the immense impact that satellite radar altimetry is having on our knowledge of the oceans. The TOPEX/Poseidon mission (funded by NASA and CNES), its successors Jason-1 and Jason-2, the altimeters on board ESA's ERS-1/2 and Envisat missions and the U.S. Navy's Geosat Follow-On have started and are sustaining one of the most impressive observational records in geophysics, both for its length (currently almost two decades), its synopticity, and its accuracy. The importance of altimetry in capturing the dynamics of the oceans, the intended primary application of the missions, is now paralleled by its role as a global sea level gauge – an application that has become ever more prominent in times of climate change. The by-products of the technique – wind speed and significant wave height – are important variables for climate research and for the independent validation of measurements from other sources. Altimetry's exceptional progress has been made possible by the dedication of many scientists and engineers. Their first-class research on orbit determination and instrumental, atmospheric and surface effects' corrections has improved the precision of the altimetric measurements to levels that were almost unthinkable of at the beginning (~2 cm from a 1,335-km orbit, i.e., slightly more than one part in one hundred million) and ensures accuracy and long-term stability that allow the rate of global sea level rise to be measured with a resolution accuracy better than 1 mm/y. The excellent body of research behind altimetry is comprehensively reviewed in Fu and Cazenave's book *Satellite Altimetry and Earth Sciences* (2001), whose many chapters, authored by some of the leading experts in the field, also illustrate several of the applications of altimetry. Some simple statistics will confirm the impact of altimetry on the oceanographic community: the ISI (Institute for Scientific Information) online library of refereed journals and major conference proceedings cites more than 6,000 papers on ocean altimetry; a search for “TOPEX” on Google Scholar yields more than 15,000 hits (including reports and similar grey literature). A measure of this enormous impact is also the widespread use of altimetry within the modelling community: nowadays, altimetric data are routinely

assimilated into ocean models, both in near-real time for operational forecasting and in delayed time for hindcasts and reanalysis that greatly improve our understanding of many ocean processes. It is not a surprise that GCOS has included Sea Level in its list of Essential Climate Variables (ECVs) required to support the work of the UNFCCC and the IPCC. Ensuring continued support to altimetry is, now more than ever, at the centre of the general political debate on sustaining climate research.

Therefore, altimetry is mature, and is a great success story for satellite-based Earth Observation. At this point the casual reader might conclude that all the technical hurdles have been reasonably overcome, and the future is rosy. Forthcoming techniques (like the delay-Doppler technique) will just bring in more excitement, with their promise to push further the capability of altimeters, and make the picture described in the above paragraph even sharper.

While the above might be true for open-ocean altimetry, there is an important domain where altimetry remains grossly underexploited. This domain coincides, crucially, with the region where changing circulation, sea level and sea state have by far the largest impact on human society: *the coastal zone*. Altimetric data gathered over this coastal strip (up to a few tens of kilometers from the coast) remain unused in the archive, mainly as they are flagged as “bad” or “not reliable” due to contamination of the altimetric waveforms, inadequate corrections, or poorly understood surface effects. The information in the coastal altimetry records ends up being corrupted, and for a long time many satellite oceanographers simply used to throw those records away. But that information would be invaluable for studies of coastal circulation, sea level change and impact on the coastline. And we would have, already, almost two decades of data in the archives. Is that information completely unrecoverable? Many researchers believe this is not the case. They believe that not only coastal altimetry would be very *useful*, but also, and *crucially*, that it is to a large extent *feasible*, and so must be done! This book is an account of their valiant efforts.

The path to coastal altimetry crosses two crucial territories: improvement of the radar measurement retrieval algorithms (retracking) and of the geophysical corrections. First of all, the radar return signals (known as waveforms) are archived, so their conversion to geophysical measurements can be revisited by fitting models of the waveforms (which is what is called retracking) optimized for the coastal zone: this is expected to improve the estimation of height, significant wave height and wind speed, or indeed to make that estimation possible where it was previously not possible at all employing open-ocean waveform models. Then, the other aspects of the whole processing chain from sensor to product, including the various corrections and the quality control, can be largely improved integrating local knowledge; one simple example is the use of local accurate models for the correction of the high-frequency atmospheric pressure effects on the sea level.

The process of extending altimetry to the coastal zone has begun with some early papers (e.g. Crout 1997; Anzenhofer et al. 1999; Vignudelli et al. 2000) around the turn of the century, when several researchers around the world were starting to come up with new ideas and to explore some of the techniques necessary to make it work. A small but significant mark in the history of coastal altimetry was the launch of the ALBICOCCA program

on 2001; this was the precursor of the European INTAS ALTICORE project (2007–2008) where this book had its genesis. Since 2006 there has been a dramatic increase in the research effort on this novel topic, and the coming together of an active international *community of researchers* who are exchanging ideas at regular Coastal Altimetry workshops (Silver Spring 2008; Pisa 2008; Frascati 2009; Porto 2010 – see <http://www.coastalt.eu>) and have contributed a “Community White Paper” on the role of altimetry in Coastal Observing Systems at the recent OceanObs’09 conference (Cipollini et al. 2010). The major space agencies and funding agencies have recognized the importance of the topic and are supporting it via a series of projects (e.g. COASTALT, PISTACH, RECOSETO and some OSTST projects). This book builds on many of the research efforts in the aforementioned projects and across the whole community, with the aim of presenting the current status in this new, challenging and exciting topic.

This peer-reviewed book brings together 20 chapters addressing a wide range of issues in processing and exploiting satellite altimetry from the open ocean to the coasts. The chapters presented describe the state of the art, recent developments on specific issues and practical experience. Chapter 1 gives a historic perspective and shows the current status of satellite altimetry missions. This is immediately followed in Chapter 2 by the illustration of a successful case in which coastal altimetry data have gone from research to operation. Chapter 3 discusses the user requirements for the new coastal altimetry products, i.e. what the users expect to get. The bulk of chapters from Chapter 4 to 9 deals with data processing aspects, particularly those concerning re-tracking and corrections for improving altimeter data, including editing strategy. These are the techniques that truly make coastal altimetry a reality. Chapter 10 extends the content of the book to data dissemination and services. Chapter 11 illustrates the clear link of calibration and validation to coastal altimetry. Following this introduction of how altimeter data are processed and managed is a series of Chapters (12 to 19) that show the gamut of applications in some regional seas (Mediterranean, Black, Caspian, White, Barents), around coasts of some countries (North America, China, Australia) and even lakes that have similar processing challenges. Finally, Chapter 20 explores novel technologies of forthcoming satellite altimetry missions and their expected impact on data retrieval in the coastal zone.

We intend this book for a wide audience of students, researchers, data-integrators with interest in the Coastal Zone who seek a unique, research-centred, up-to-date reference to Coastal Altimetry. Finally, we hope that this book will inspire both young and more experienced researchers, and we hope that it will be seen both as a stimulus to exploit Coastal Altimetry and an invitation to explore further the intricate details of technology, algorithms, processing, in a field that promises to bring significant and long-lasting societal benefits.

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References

- Anzenhofer M, Shum CK, Rentsh M (1999) Coastal altimetry and applications, Tech. Rep. n. 464, Geodetic Science and Surveying, The Ohio State University Columbus, USA
- Cipollini P, Benveniste J, Bouffard J, Emery W, Gommenginger C, Griffin D, Høyer J, Madsen K, Mercier F, Miller L, Pascual A, Ravichandran M, Shillington F, Snaith H, Strub T, Vandemark D, Vignudelli S, Wilkin J, Woodworth P, Zavala-Garay J (2010) The role of altimetry in Coastal Observing Systems, in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306. doi:10.5270/OceanObs09.cwp.16
- Crout R L (1997) Coastal currents from satellite altimetry. *Sea Technology* 8:33–37
- Fu LL, Cazenave A (eds) (2001) Satellite altimetry and earth sciences: a handbook of techniques and applications. Academic Press, San Diego, 463 pp
- Vignudelli S, Cipollini P, Astraldi M, Gasparini GP, Manzella GMR (2000) Integrated use of altimeter and in situ data for understanding the water exchanges between the Tyrrhenian and Ligurian Seas. *J Geophys Res* 105:19,649–19,000

Abbreviations

ALBICOCCA	ALtimeter-Based Investigations in COrsica, Capraia and Contiguous Areas
ALTICORE	Value added satellite ALTImetry for COastal REgions
CNES	Centre National d'Études Spatiales
COASTALT	ESA Development of COASTal ALTImetry
ERS	European Remote Satellite
ESA	European Space Agency
GCOS	Global Climate Observing System
INTAS	International Association for the promotion of co-operation with scientists from the New Independent States of the former Soviet Union
IPCC	Intergovernmental Panel on Climate Change
ISI	Institute for Scientific Information
NASA	National Aeronautics and Space Administration
OSTST	Ocean Surface Topography Science Team
PISTACH	CNES Development of “Prototype Innovant de Système de Traitement pour les Applications Côtières et l'Hydrologie”
RECOSETO	Regional COastal SEa level change and sea surface Topography from altimetry, Oceanography, and tide gauge stations in Europe
UNFCCC	United Nations Framework Convention on Climate Change

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