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Introduction: Special Issue on Advances in Topobathymetric Mapping, Models, and Applications

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ABSTRACT

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Detailed knowledge of near-shore topography and bathymetry is required for many geospatial data applications in the coastal environment. New data sources and processing methods are facilitating development of seamless, regional-scale topobathymetric digital elevation models. These elevation models integrate disparate multi-sensor, multi-temporal topographic and bathymetric datasets to provide a coherent base layer for coastal science applications such as wetlands mapping and monitoring, sea-level rise assessment, benthic habitat mapping, erosion monitoring, and storm impact assessment. The focus of this special issue is on recent advances in the source data, data processing and integration methods, and applications of topobathymetric datasets.

ADDITIONAL INDEX WORDS: *Topography, bathymetry, lidar, storm surge, seacliff, inundation, uncertainty, hydrologic connectivity, benthic habitat, salt marsh.*

INTRODUCTION

Numerous applications of geospatial data in coastal environments require detailed knowledge of near-shore topography and bathymetry. However, because much of the existing topographic and bathymetric data have been collected independently for different purposes, it has been challenging to use them together. An initial difficulty in data integration at the coastal land/water interface arises from the fact that topographic and bathymetric data generally have different vertical reference systems, with topographic data usually referenced to an orthometric datum (based on the geoid) and bathymetric data referenced to a tidal datum, for example mean lower low water. A tool called VDatum (Myers, 2005; Parker *et al*., 2003), developed by the National Oceanic and Atmospheric Administration (NOAA), has solved this problem for conterminous U.S. (CONUS), Puerto Rico, and U.S. Virgin Islands coastlines. VDatum is used to transform disparate datasets into a common vertical datum, which then facilitates generation of hybrid topographic-bathymetric elevation models. Based on successful initial investigations around the year 2000, the U.S. Geological Survey (USGS) and NOAA began collaboratively developing seamless merged coastal elevation datasets, with USGS supplying the topographic component and NOAA's hydrographic survey database supplying the bathymetric component. Hurricane storm surge modeling (Weisberg and Zheng, 2006) and sea-level rise vulnerability assessment (Gesch, 2013) are examples of applications that have benefitted from merged topographic-bathymetric elevation models. The National Research Council (2004) recommended collaborative efforts among federal agencies to produce such products for all U.S. coastal regions, and the National Ocean Council (2013) in its National Ocean Policy Implementation Plan recently renewed the call for a seamless representation of coastal elevations to improve coastal change analysis products. Even with the success attained to date in development of coastal elevation datasets, challenges remain in providing high quality and current data to meet many coastal science requirements (Eakins and Grothe, 2014), and current research and development are addressing many of these challenges.

Detailed knowledge of temporally varying subaerial and submerged topography, as portrayed in topographic-bathymetric models, is needed by scientists and policy makers in heterogeneous coastal zones with high-energy physical processes, complex habitats, steep ecological gradients, focused societal infrastructure investments, and concentrated human populations vulnerable to a range of inundation hazards. The latest topographic-bathymetric (topobathymetric) lidar systems offer greatly enhanced littoral zone mapping capabilities and facilitate generation of merged multi-sensor coastal elevation models with continuous coverage at variable resolution keyed to ecosystem zonation. Recently launched satellite sensors combined with radiative transfer modeling are improving the ability to derive bathymetry from multispectral and hyperspectral imagery. Efficient new methodologies are being developed to allow the assimilation of disparate and voluminous multi-sensor, multi-temporal topographic and bathymetric datasets to create seamless, regional-scale topobathymetric

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digital elevation models (TBDEMs). In parallel, coastal science and coastal zone management communities are devising original applications of these TBDEMs in coastal wetlands mapping and monitoring, storm surge and sea-level rise modeling, benthic habitat mapping, coral reef ecosystem mapping, and a host of related activities. The focus of this special issue is on recent advances in the source data, data processing and integration methods, and applications of topobathymetric datasets.

RESEARCH TOPICS ADDRESSED

In coastal environments, elevation is perhaps the most fundamental and important variable that determines vulnerability. Coastal elevation products are the basis for an integrated geospatial framework at the land/water interface and are critical for characterizing coastal changes and the corresponding effects on coastal resilience. High-resolution, high-accuracy, up-to-date TBDEMs provide the requisite coastal elevation information. Lidar remote sensing has proven to be a key technology for collection of detailed, up-to-date observations of physical characteristics of both the terrestrial and marine sides of the shoreline. In addition to high-accuracy elevation measurements of coastal lands both above and below the water line, lidar and other remote sensing systems enable production of 3-dimensional (3D) data of natural and anthropogenic features in the coastal zone. Because of its high quality, lidar remote sensing has become the primary data source for development of current TBDEMs.

For the bathymetric component of TBDEMs, ship-based hydrographic surveys are still an important source of information, but bathymetric lidar has become critical for accurate representation of intertidal and near-shore areas. Wright *et al*. (this volume) document recent advances in mapping bathymetry with the Experimental Advanced Airborne Research Lidar (EAARL-B), and they detail how substantially increased spatial density of measurements and an improved depth capability are now attainable with such a green laser system. Kim *et al*. (this volume) describe the development of a lidar waveform simulator based on radiative transfer modeling. The work is based on return bathymetric waveforms for the Coastal Zone Mapping and Imaging Lidar (CZMIL), but the model is useful for predicting the general performance of any bathymetric lidar. An advantage of the modeling capability is that advanced waveform processing algorithms can be developed and readily tested. Webster *et al*. (this volume) document how data collection and post-processing with a bathymetric lidar system (in this case, the Chiroptera II) can be optimized and refined to produce improved depth maps and benthic habitat maps. Jasinski *et al*. (this volume) describe recent results with use of the Multiple Altimeter Beam Experimental Lidar (MABEL), a high altitude airborne simulator for developing and testing algorithms for a spaceborne photon counting lidar. They demonstrate the feasibility of retrieving water height statistics from such space-based laser altimeter systems.

While lidar is often the preferred data source for the development of regional TBDEMs, it is not always available for all locations, so multiple data sources must be exploited. For bathymetry, an emerging source is satellite-derived bathymetry (SDB) based on optical satellite imagery. Derivation of bathymetry from optical images has been demonstrated over several decades, but recent advances in both available data and processing approaches have increased its usefulness. Pe'eri *et al*. (this volume) describe a new multi-temporal SDB approach that uses Landsat 7 and Landsat 8 imagery to extract clear water areas acquired on different dates. The approach has been successfully used to update a NOAA navigation chart along Alaska's North Slope.

To address the requirements for improved coastal elevation information, the USGS is developing a new line of science products known as the Coastal National Elevation Database (CoNED). The CoNED builds upon and enhances existing USGS elevation products by integrating recent very high resolution coastal lidar data (both topographic and bathymetric) and by including a temporal component that is captured in coastal lidar collections from multiple dates. Thatcher *et al*. (this volume) provide a useful overview of the CoNED products and an introduction to related applications research. A key component of the CoNED effort is to collaborate with the USGS 3D Elevation Program (3DEP) (Lukas *et al*., 2015), a national initiative to systematically upgrade the nation's elevation data holdings. Danielson *et al*. (this volume) provide a detailed description of recent improvements in the methods used to produce CoNED TBDEMs. These improvements include enhanced interpolation (gridding) techniques for point-based source data and new automated land/water mask delineation methods. Poppenga and Worstell (this volume) describe an important enhancement of the terrestrial elevation data that fill the topographic part of TBDEMs. They detail how hydrologic enforcement of lidar-derived elevation data is conducted, assess the effectiveness of the enforcement, and demonstrate the advantages of the approach for achieving the hydrologic connectivity that is valuable for modeling in coastal regions.

The uncertainty of elevation measurements in TBDEMs is an important consideration for users of such products, and two papers in this special issue address the topic, one each for the topographic and bathymetric components. Salt marshes are critical habitats in many coastal locations, and the physical complexity of these environments poses a challenge to accurate elevation measurements in such a low-relief setting. Rogers *et al*. (this volume) report on an assessment of elevation uncertainty in coastal marshes based on both discrete return and full waveform return lidar systems. Their analysis shows the clear effects of seasonality, species, and lidar processing parameters on elevation uncertainty in salt marshes, and such knowledge is useful for development of data correction methods. Amante and Eakins (this volume) examine the accuracy of interpolation in bathymetric elevation models using three common interpolation methods (inverse distance weighting, spline, and triangulation). Their results indicate that cell size, distance to the nearest measurement, and certain terrain characteristics (slope and curvature) affect accuracy of the interpolated surfaces. Such information is useful in providing cell-level uncertainty information that can be used to better account for error propagation in models that use TBDEMs.

TBDEMs have proven useful for numerous applications, and papers in this special issue specifically address storm surge modeling, seacliff mapping and monitoring, and benthic habitat mapping. Loftis *et al*. (this volume) take advantage of high-resolution lidar elevation measurements to improve hydrodynamic modeling of storm-induced inundation. The high spatial resolution and vertical accuracy of the lidar data help by better resolving ditches and overland drainage. Kress *et al*. (this volume) compare the performance of coarse-scaled grids and fine-scaled grids for modeling inundation by Hurricane Sandy on Staten Island, New York. They conclude that the fine-scale grids based on high-resolution lidar better resolve hydraulic control features so vulnerability to storm surge inundation can be better mapped and understood.

Palaseanu-Lovejoy *et al*. (this volume) use lidar-derived elevation models for automatic delineation of seacliff limits. Their new automated method stands in contrast to labor-intensive, analyst-subjective methods wherein cliff edges are interpreted from imagery and delineated and digitized by hand. The advantages of the developed method are its repeatability, its ability to make use of detailed topographic information in lidar elevation models, and its time savings over manual methods. Johnstone *et al*. (this volume) take advantage of very high-resolution terrestrial lidar data to map seacliff erosion. The terrestrial lidar data, collected with high temporal resolution, are a key to understanding cliff collapse and failures. Such an understanding is important to establish a baseline for future cliff erosion in response to sea-level rise. Olsen *et al*. (this volume) also take advantage of the high spatial and temporal resolution afforded by terrestrial lidar. Comparison of the terrestrial lidar data with water level and climate data help to provide an understanding of the physical mechanisms of cliff failure.

Parrish *et al*. (this volume) use data collected by a topobathymetric lidar system, which, as the term implies, is capable of producing elevation data over land surface as well as depth information over water areas. They applied the lidar data and simultaneously collected imagery to map benthic habitat (seagrass) in Barnegat Bay, New Jersey, an area severely impacted by Hurricane Sandy. They find that the collective use of lidar waveform features, measured bathymetry, and imagery processed with object-based image analysis techniques is effective for mapping benthic habitat. Application of these same procedures to EAARL-B data allows assessment of habitat change resulting from Hurricane Sandy's impact on the area. Pe'eri *et al*. (this volume) also successfully employed imagery and bathymetry data to map benthic habitat, in this case eelgrass. The imagery they used is hyperspectral imagery collected by an airborne sensor.

SUMMARY

The 17 papers presented in this special issue provide a broad array of recent research findings on data, processing methods, applications, and physical processes that are critical for increased understanding of the dynamic coastal environment. It is the hope of the guest editors that this collection not only offers useful information for current work by scientists, coastal zone resource managers, and policy makers, but also provides the impetus for future research and advances in data, methods, models, and applications for the changing coastal environment.

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LITERATURE CITED

Eakins, B.W. and Grothe, P.R., 2014. Challenges in building coastal digital elevation models. *Journal of Coastal Research*, 30(5), 942–953.

Gesch, D.B., 2013. Consideration of vertical uncertainty in elevation-based sea-level rise assessments: Mobile Bay, Alabama case study. *In*: Brock, J.C.; Barras, J.A., and Williams, S.J. (eds.), *Understanding and Predicting Change in the Coastal Ecosystems of the Northern Gulf of Mexico. Journal of Coastal Research*, Special Issue, No. 63, pp. 197–210.

Lukas, V.; Eldridge, D.F.; Jason, A.L.; Saghy, D.L.; Steigerwald, P.R.; Stoker, J.M.; Sugarbaker, L.J., and Thunen, D.R., 2015. *Status report for the 3D Elevation Program, 2013–2014. U.S. Geological Survey Open-File Report 2015–1161*, 17p., http://dx.doi.org/10.3133/ofr20151161.

Myers, E.P., 2005. Review of progress on VDatum, a vertical datum transformation tool. *Proceedings of Oceans 2005 MTS/IEEE Conference* (Washington, DC), pp. 974–980.

National Ocean Council, 2013. National Ocean Policy Implementation Plan Appendix. http://www.whitehouse.gov//sites/default/files/national_ocean_policy_ip_appendix.pdf.

National Research Council, 2004. *A geospatial framework for the coastal zone*. Washington, DC: The National Academies Press, 149p.

Parker, B.; Hess, K.; Milbert D., and Gill, S., 2003. A national vertical datum transformation tool. *Sea Technology*, 44(9), 10–15.

Weisberg, R.H. and Zheng, L., 2006. Hurricane storm surge simulations for Tampa Bay. *Estuaries and Coasts*, 29(6A), 899–913.