Final Report

A research and decision support framework to evaluate sea-level rise impacts in the northeastern U.S.

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Public Summary

We developed a reconnaissance method to distinguish those coastal areas in the northeastern U.S. (~Virginia-Maine) that will likely experience a predominantly inundation (e.g., flooding) response to sea-level rise (SLR) from those that will likely respond dynamically by moving or changing (e.g., landforms such as barrier islands and marshes). Areas that are likely to inundate include urban regions of intense development and/or coastal engineering, as well as bedrock coasts. Areas that are likely to respond dynamically include beaches, unconsolidated cliffs, barrier islands, and wetlands. By distinguishing the response to a variety of sea level projections in these areas, future work can inform appropriate scientific research and decision support efforts.

Technical Summary

We developed a spatially explicit, probabilistic model of coastal response to a variety of sea-level rise scenarios at spatial and temporal scales suitable for guiding landscape management

decisions. We used a Bayesian network approach that includes sea-level rise projections, coastal elevation, vertical land movement, and coastal land cover as input, and produces land cover-specific forecasts of the probability of inundation or dynamic coastal change as output. Output also includes an adjusted land elevation with respect to forecast sea levels. The information provided by predictions and their associated uncertainties can be used to identify where datasets and/or scientific knowledge can be improved.

The original goals of the project were to (1) develop the Bayesian network model and (2) to produce reconnaissance-level map-based products using readily-available datasets. We were able to accomplish the first goal. The second goal will be met through an expanded project, synergized by the initial NECSC work that extended beyond the time and funding constraints originally proposed. The major research accomplishment of this reconnaissance study is the successful development of new technical capabilities that are relevant to this and related efforts to make probabilistic predictions of coastal change impacts at the landscape level. This is markedly different from traditional "bathtub" inundation models that simply submerge existing topography and land classes with higher water levels. This research accomplishment builds on a growing body of work by the PIs and the scientific community to improve the understanding and communication of climate change outcomes and their associated uncertainties.

We also continue to deal with the impacts of hurricane Sandy, which made landfall in the middle of our study area a few months after the start of this project. Hurricane Sandy not only caused major changes to the coastal landscape in the study area, but also redirected a substantial portion of our efforts to support post-storm DOI and other science activities that reduced our ability to fully meet the original goals of the project.

Purpose and Objectives

Landscape change due to sea level rise is a problem facing human developed and natural systems in the coming century. Knowing where coastal land will be available for migration or mitigation is critical for policy makers, land-use planners, and other coastal stakeholders. Previous research to quantify the coastal vulnerability to sea-level rise can be divided into three approaches: 1) simple inundation, such as by “flooding” a digital elevation model; 2) prediction of dynamic coastal change such as shoreline erosion or wetland loss; and 3) a hybrid using attributes of the dominant physical processes and geologic constraints. Each of these approaches has been applied at large spatial scales, such as along the U.S. Atlantic coast (respectively, Weiss et al., 2011; Gutierrez et al., 2011; Thieler and Hammar-Klose, 1999). One of the major shortcomings of these approaches, however, is their broad application to diverse locations and environments where it is possible (likely) that their underlying assumptions are not uniformly valid. As a consequence, their utility for coastal management and land use planning is limited.

Our original objective was to develop a regionally consistent and broadly applicable Bayesian network for sea-level rise impact assessment in the northeastern U.S. (Figure 1) at a resolution commensurate with decision-making at landscape and geomorphic system scales (several hundred meters to tens of kilometers). This objective was met.

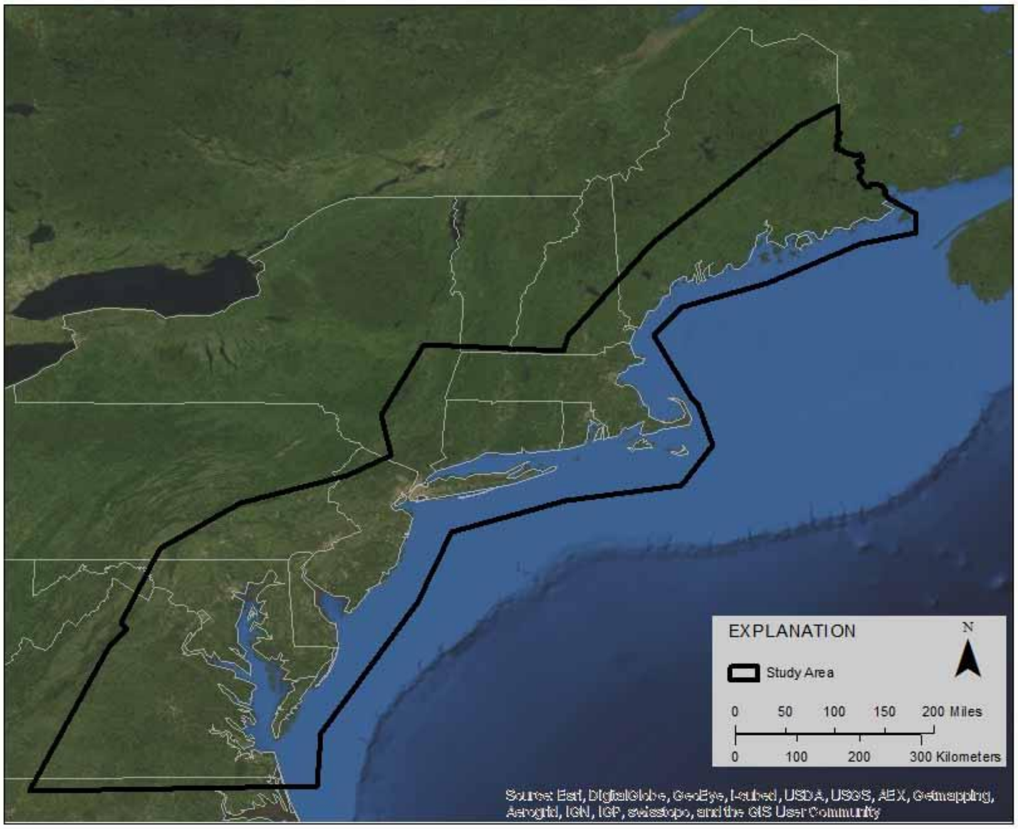

Figure 1. Map showing the northeastern U.S. Outlined area indicates study domain.

Additional objectives to publish geospatial data and interpretive products will be met through ongoing work under the aegis of different DOI projects. Shortly after this initial reconnaissance project was funded, the work attracted significant interest from the USGS and the DOI North Atlantic Landscape Conservation Cooperative (NALCC). Additional USGS funding allowed us to hire a new USGS Mendenhall post-doctoral fellow, as well as to support additional USGS and Columbia University staff. The goal of the expanded project is to provide information that can address conservation objectives defined by NALCC partners using a structured decision-making (SDM) approach (Gregory et al., 2012). To do so, our work will support NALCC and NECSC's Designing Sustainable Landscapes (DSL) project at UMass-Amherst by developing predictions of landscape change using more refined, high-resolution datasets than originally proposed. For example, rather than relatively coarsely resolved C-CAP land cover, we are using DSL landscape data to inform the Bayesian network model that forecasts the probability of static and dynamic coastal change in response to sea-level rise projections developed by Columbia University. The sea-level rise projections were also modified to include the time steps required by the DSL project. The products from this work will subsequently be used by the DSL project to quantify potential future changes in the coastal landscape.

Organization and Approach

Columbia University produced the sea-level rise projections. Future sea-level is estimated using RCP scenarios 4.5 and 8.5 following methods described in Rosenzweig and Solecki (2013).

USGS developed data for vertical land movement rate from a combination of continuously-recording GPS sites and long-term tide gauge data following Sella et al. (2007) and Zervas et al. (2013). USGS compiled high-resolution elevation data from the National Elevation Dataset (NED) following Gesch (2007; 2009) and converted these data from NAVD88 to mean high water (MHW) using VDatum (http://vdatum.noaa.gov/) gridded data. Land cover data were obtained from the DSL project and classified by USGS according to anticipated differences in morphologic and/or ecologic response to sea-level increases (Lentz et al., in prep).

USGS assembled the input data and developed the Bayesian network model. Our framework integrates this knowledge into the corresponding local morphological and landscape impacts. The different degrees of uncertainty associated with the relevant coastal processes as well as with the climate-driven processes are represented in the Bayesian network (Wikle and Berliner, 2007; Gutierrez et al. 2011) and attempt to capture what is known and what is uncertain about these processes and variables. The predictions include likelihood estimates of the predicted outcome that help to indicate the confidence in the predictions and can be used to evaluate probabilistic vulnerabilities. This interdisciplinary approach has been advocated in a number of recent studies (e.g., National Research Council, 2009; Thieler et al., 2009).

Project Results

We developed a new approach to coastal vulnerability assessment that uses probability-based estimates of future sea-level rise to produce probabilistic forecasts of coastal change. The results can be used to inform future science projects and provide decision support for coastal managers. Figure 2 shows an example of how our Bayesian network is constructed, including the inputs and outputs.

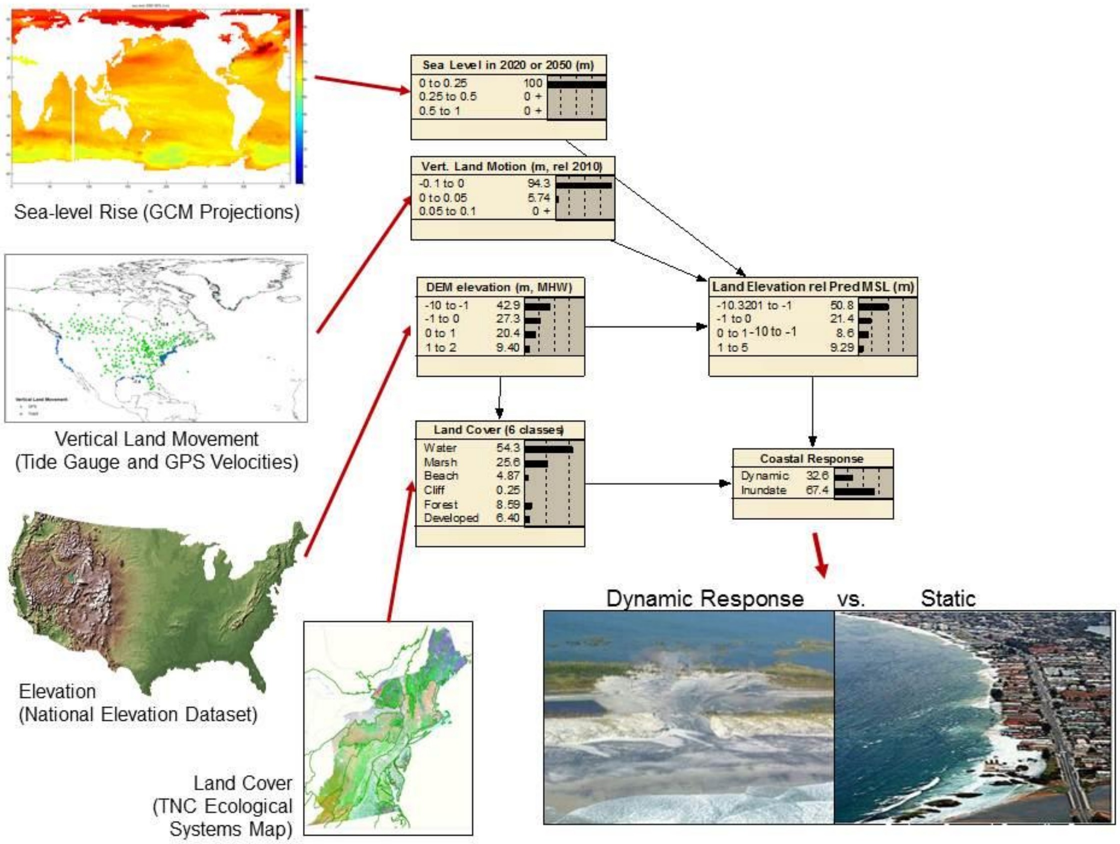

Figure 2. Diagram of a Bayesian network that uses four inputs (sea-level rise projections, vertical land movement, elevation, and land cover) to predict future land elevations and coastal response type. (Lentz et al., in prep.)

Analysis and Findings

The Bayesian network assimilates and captures the different degrees of uncertainty associated with the relevant coastal and climate-driven processes in order to make predictions of future conditions. Specifically, climate projections are especially uncertain at regional scales and farther into the future. There are plausible regional and temporal changes in climate responses that should be considered. As the climate-modeling community provides better understanding of likely changes in regional sea-level change, storminess, and other parameters, our framework integrates this knowledge into the corresponding local morphological and ecological impacts.

Distinguishing which components are relevant to sea-level rise impacts in these areas aids prioritization of scientific research and decision support efforts. For example, we identify where and under what circumstances improved data or fundamental understanding will lead to improved resolution of desired end-point problem identification. Coastal vulnerability predictions and prediction uncertainty are expressed using IPCC likelihood terminology that is common to both the scientific and the decision-making communities and should increase the ability to communicate between scientific and decision making disciplines.

Conclusions and Recommendations

The ambitious scale and scope of the project has driven successful development of new technical capabilities that are relevant to this and related efforts to make probabilistic predictions at the landscape level. The project was able to expand its scope and depth, based on early work that attracted the support of partner institutions. The project serves as a successful example of interdisciplinary science supported through the NECSC and its partners that achieves great synergy through shared support and collaboration. The project team works very well together and has demonstrated a rare ability to share massive data sets and to integrate those data to achieve project objectives.

Outreach

Presentations

University of New Hampshire, ICNet, February 2014, "Forecasting Coastal Impacts Using Uncertain Sea-level Rise Projections", R. Thieler, N. Plant, B. Gutierrez, E. Lentz, M. Fienen, J. Masterson, D. Gesch, S. Stippa, K. Gieder, S. Karpanty, A. Hecht, R. Horton, A. Milliken, K. McGarigal. (webinar, available online at http://www.theicnet.org/webinars/archive/02-26-14)

Northeast Climate Science Center, February 2014, "Sea-level Rise, Coastal Change, and Decision Making in an Uncertain Future", R. Thieler, N. Plant, B. Gutierrez, E. Lentz, M. Fienen, J. Masterson, D. Gesch, S. Stippa, K. Gieder, S. Karpanty, A. Hecht, R. Horton, A. Milliken, K. McGarigal.. (webinar, available online at http://necsc.umass.edu/webinars/sea-level-rise-coastal-change-and-decision-making-uncertain-future)

Northeast Regional Oceans Council Meeting, November 2013, "A Research and Decision Support Framework to Evaluate Sea-Level Rise Impacts in the Northeastern U.S.", E. Lentz, R. Thieler, N. Plant, S. Stippa, D. Gesch, R. Horton. (in-person presentation)

Woods Hole Research Center, Cape Cod and Islands Climate Change and Energy Conference, September 2013, "Sea-level rise and coastal change: likely impacts and possible responses", R. Thieler. (in-person presentation)

North Atlantic Landscape Conservation Cooperative Coastal and Marine Technical Team, February 2013, "Research and Decision Support Framework to Evaluate Sea-Level Rise Impacts for the U.S. Atlantic Coast", E. Lentz, N. Plant, R. Thieler, A. Turecek. (webex presentation)

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