Introduction / Background

One of the most critical scientific issues in the coastal environment today is determining the physical response of the coastal areas to predicted sea-level rise. However, with many natural hazards, the risks associated with sea-level rise remain a challenge. Part of the problem is that the sea-level rise is a long-term, slowly varying process, and the consequences are often not immediately observable.

Topographically, the coastal plain of the eastern U.S. is a classic depositional system of coastal change; therefore, up-to-date, high-resolution, high-accuracy elevation data are required to model the coastal environment. Elevation is only one in a number of interrelated factors that determine the vulnerability of the lands to the effects of sea-level rise. For some areas, improved inundation will be the primary response to SLR. In these areas, the most important factor in assessing potential impacts is the accuracy and resolution with which coastal elevations have been mapped. These reports are critical for adapting or reducing the risks. Likewise, sea-level rise assessments often include statistical summaries of population, infrastructure, and economic impact in the mapped areas; however, this is critical for the mitigation efforts. Many studies have used reduced-quality data in delineating potential impact areas and have had qualitatively different results.

Maps and visualizations, including computer simulations, of the spatial extent of potential sea-level rise are becoming more common methods of attempting to communicate the risk to coastal areas. Often the maps are used to document the regional threat caused by non-governmental organizations, universities, state and local agencies, and other private groups. Numerous Web sites provide maps and/or textual displays of sea-level rise and its impact on land for scientific and general audiences. Few of the level, maps, reports, maps, or Web sites mention anything about the quality of the input data. None address the inherent vertical uncertainty of the elevation data quantitatively, although some do. Mapped elevations of the data that are used for illustrations are not based on generally accepted data and are therefore not used for such illustrations.

A variety of elevation datasets has been used in previous studies to quantify the amount of land and affected population potential inundation from sea-level rise. The scale, or resolution, of the elevation data ranges from a coarse resolution of about 1 km to detailed regional and global resolutions to a fine resolution of a few meters for local studies.

In the last several years, vast amounts of high-quality elevation data derived from light detection and ranging (lidar) have become available, and they are highly suitable for detailed study of the physical processes related to sea-level rise. The significantly improved spatial resolution and vertical accuracy of lidar-derived elevation data provide clear advantages for use in delineating lands subject to given sea-level rise scenarios.

An analysis of four different elevation datasets, including lidar, that have been used to model potential sea-level rise impacts and a demonstration of how the improved quality of lidar data leads to more precise delineation of vulnerable coastal areas, is the focus of this article. Recent advances have greatly enhanced the spatial resolution and temporal availability of lidar data; therefore, new datasets are available to胁安模型 could be considered to quantitatively determine reliable estimates of land areas subject to potential inundation. Model validation is a critical part of the uncertainty associated with a given sea-level rise projected onto the land data can be produced. The following analysis includes a quantitative of the vertical accuracy of the different DEMs that have been used model potential sea-level rise impacts and a demonstration of how the improved quality of lidar data leads to more precise delineation of vulnerable coastal areas.

Data, Study Area, Methods

Elevation data from the following sources were processed and assigned for coastal North Carolina, including the Outer Banks and the Albemarle-Pamlico Sound estuarine system:

- USGS National Elevation Dataset (NED) 3/8-arc-second layer (derived from lidar)
- USGS NED 1/32-arc-second layer (derived from lidar)
- Shuttle Radar Topography Mission (SRTM) 3-arc-second data
- GTOPO30 (horizontal accuracy 50 to 100 meters, vertical accuracy 30 to 40 meters)

The study area is contained within the Pasquotank, Chowan, Reaume, Tar-Pamlico, Roanoke, and White River river basins. The availability of high-quality lidar data over a broad, diverse coastal area provides an excellent opportunity to examine how the resolution and accuracy of elevation data affect sea-level rise analyses.

To properly portray the uncertainty in potential inundation delineated from elevation data, the absolute vertical accuracy of the lidar system must be considered quantitatively to derive reliable estimates of the effects of sea-level rise. For some areas, improved inundation will be the primary response to SLR. In these areas, the most important factor in assessing potential impacts is the accuracy and resolution with which coastal elevations have been mapped. These reports are critical for adapting or reducing the risks. Likewise, sea-level rise assessments often include statistical summaries of population, infrastructure, and economic impact in the mapped areas; however, this information is critical for the mitigation efforts. Many studies have used reduced-quality data in delineating potential impact areas and have had qualitatively different results.

Maps of some subsets of the study area in Beaufort County were developed at a larger scale to observe the differences between two of the elevation sources, namely the 1/8-arc-second NED (derived from lidar) and the 1/32-arc-second NED (derived from lidar). The delineations of the flood only because of the increased spatial resolution of the lidar data but also because of the better vertical accuracy of the lidar, which is reflected in the smaller area of uncertainty (lighter blue tint). The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones. The uncertainty of lidar elevation data affects the delineation of coastal elevation zones.

Results

For the examples in this study, a 1-meter sea-level rise was used to produce maps of potential inundation zones. Calculation of the potential inundation zones accomplished an approach in which raster elevation data are “floated” by identifying the land cells that have an elevation of at least a given sea-level rise scenario and are connected hydrologically to the ocean. For each of the four elevation datasets, maps of potential inundation zones given a 1-meter sea-level rise were produced by extracting the areas from the DEM at or below that elevation and overlaying it on a background image. These are depicted in the lighter blue tint on the maps below. For each dataset, additional areas were delineated by including a spatial representation of the uncertainty of the projected inundation area. This delineation was accomplished by adding the SE, or 95% confidence level, to 1-meter sea-level rise inundation and extracting the areas from this DEM at or below that elevation using the same floating algorithm as before. These additional areas are shown in the lighter blue tint on the maps. The delineation that includes the elevation uncertainty (lighter blue tint) always covers more area than the one with no elevation uncertainty (darker blue tint), but the areas are consistent up to the 1-meter contour.

The level of uncertainty inherent in the topographic map source for the 1/8-arc-second NED, even without any additional error contributed by the elevation model generation process, is nearly the amount of sea-level rise (1.0 m) that is modeled in many studies. Lidar elevation models with accuracies quantified in the 25 centimeter range (95% confidence) are much more appropriate for identification of vulnerabilities at sea-level rise in the coastal range.

The overall findings from this study demonstrate that:

- The quality and characteristics of elevation data used for sea-level rise impact assessments vary greatly among data sources.
- The improved vertical accuracy of lidar elevation data, as well as its increased spatial resolution, provides enhanced topographic information that is necessary for more accurate inundation studies—representing a significant upgrade over datasets previously used in global and regional assessments.
- Spatially explicit vulnerability maps can be produced from highly accurate and detailed lidar elevation data.
- Statistical summaries of impacted population and other socioeconomic variables within the mapped inundation zone also benefit by incorporating the elevation uncertainty information.
- The reliability of estimates of land and population at risk derived from global datasets is questionable because of the inherent vertical uncertainty of the elevation data.

Vertical increments in sea-level rise vulnerability studies should match the elevation data accuracy.

The uncertainty inherent in the inundation zone to the future shoreline—other factors contribute to future shoreline position.

References

