Geospatial and Field Assessment of Sea Level Rise Accomack County, Virginia

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ABSTRACT

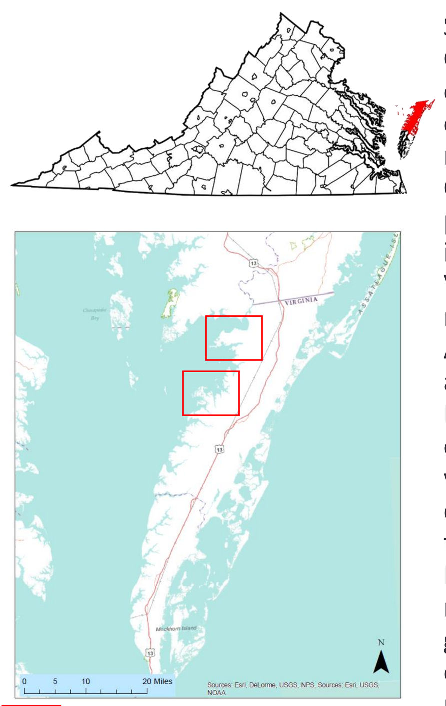
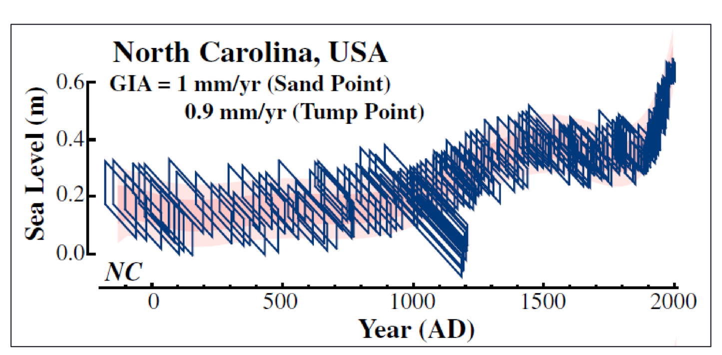


Figure 1. Areas of Concern, Accomack County, Virginia

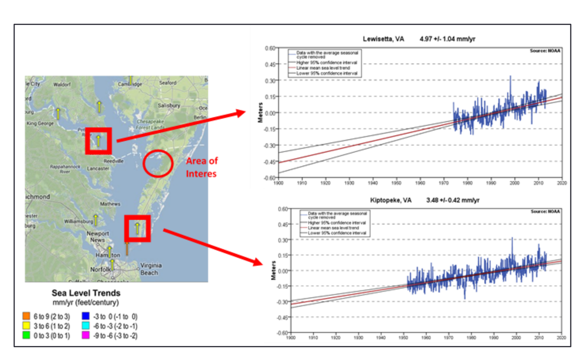
Sea-Level Rise (SLR) is widely discussed as a major consequence of climate change. Global warming has led to the increased melting of glaciers and thermal expansion of ocean water, increasing the volume of water into the world's oceans. There is concern over whether the Atlantic Coast of the United States is experiencing SLR at a more rapid rate than the global average, as more localized SLR models, especially for the Chesapeake Bay region, do not correspond with changes already documented. For this project, we investigated shoreline change, projected SLR, marsh inundation, and the immediate impacts of SLR on Hunting Creek and Saxis Island in Accomack County, Virginia, where rapid inundation threatens communities, livelihoods, and heritage resources. The Digital Coast SLR viewer, developed by National Oceanic and Atmospheric Administration (NOAA), was used to predict areas of Hunting Creek most affected by 1' and 2' of increase. Geospatial data from USGS Earth Explorer and Virginia Institute of Marine Science (VIMS) allowed us to locate current coastal protection zones and severity of erosion along the shore. Well-documented and dated archaeological sites, recorded with the Virginia Department of Historic Resources, were used as landmarks for determining stable Holocene land surfaces. Historic maps collected from the USGS and the Library of Virginia provided a visualization of the shoreline change on Saxis and Hunting Creek over the last 200 years. Overlays of this imagery provide evidence of major changes in Bayside shorelines. Field work on Hunting Creek was conducted to ground-truth the model and determine whether the predicted 1' impacts are already evident. The integration of these varied datasets demonstrates that the NOAA SLR model is inconsistent when applied to localized areas, and in fact, may be too conservative in its estimates of impact.

BACKGROUND

Looking back at the past two millennia, we can measure the variations in regional sea level rise to develop a baseline for more recent changes in Accomack County (Figure 1). SLR measurements taken from Sand Point, North Carolina, just west of the Outer Banks, records SLR over the span of the last 2000 years (Figure 2). From 0 AD to just before mid-900 AD, SLR was relatively stable. Then, from 950 AD to 1350 AD (a 400 year period known as the 'Medieval Warm Period'), sea level rose about 243 mm (or 0.8 ft). Over the course of just 100 years, from 1900 – 2002 A.D., sea level rose 213 mm (or 0.7 ft). This is extremely concerning because now the rate of change is happening four times faster than previous centuries (Kemp 2011). According to NOAA's tidal gauge data, SLR in North Carolina is slower than that of the Chesapeake Bay (Sea Level Trends, n.d.). The Atlantic Coast, in general, is experiencing a larger rate of SLR than the rest of the globe (Sallenger 2012).



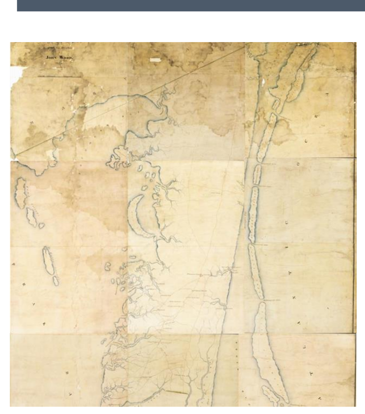
(Figure 2)

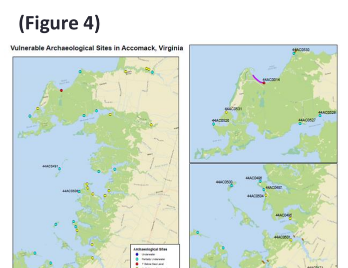

(Figure 3)

Saxis Island and Hunting Creek are our areas of interest at the request of the Virginia Department of Historic Resources, which is concerned about the loss of significant archaeological sites to SLR. Tidal gauges surrounding Saxis Island indicate that sea level is rising here approximately three to five mm/year. At the mouth of the Chesapeake, there is an increase in the trend to about 6 mm per year. Even tidal gauges that are relatively close to each other can read up to a one mm/year difference. Due to this evidence, it is difficult to quantify the amount of SLR from the past or future for an entire region (Sea Level Trends n.d.). Field assessments of SLR have been undertaken in Accomack County and other areas along the Delmarva Peninsula, but no definitive estimate has been given due to the variability along the Chesapeake Bay's shoreline.

Looking more closely at the tidal gauge sites for the Bay (Figure 3), one can visualize this spatial variation in the measurement of SLR. Each of the sites measures the rate of SLR average/year. At all locations, there is a jump in sea level from the mid-20th century. Just north of the Bay's mouth, at the Kiptopeke tidal gauge, the average rate of SLR is measured at 3.48 ± 0.42 mm/year. A tidal gauge at the mouth of the Potomac River measures the average rate at 4.97 ± 1.04 mm/year (Sea Level Trends n.d). Other lines of evidence must be brought to bear on this problem.

METHODS


(Figure 4)


(Figure 5)

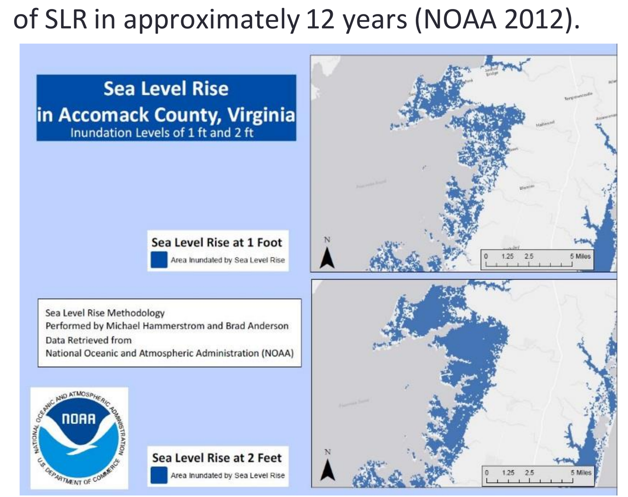
Our research was conducted using a range of geospatial datasets, historic information, and field work. Contemporary imagery from VIMS, the U.S Fish and Wildlife Service, and the USGS was used to establish the condition of the Bay shoreline in the study areas. An 1820 map of Accomack County (Figure 4; Figure 5) was used to visualize and pinpoint areas of concern. A 1904 topographic map was georeferenced to current satellite imagery to accurately measure change within the past century. Both of these datasets allowed us to pinpoint locations to perform our field assessments. Once we identified the areas of concern, we were able to prioritize the archaeological sites to perform field research. Archaeological sites dated to the past 5,000 years were used as a measuring stick for SLR, as they represent a stable land surface.

During our field assessment, Dr. Paul Ewell, founder of the Eastern Shore Watermen's Museum and Professor at Virginia Wesleyan College, helped us navigate to the archaeological sites in his Chincoteague Scow, while providing both background and historical context of the area. The latitude and longitude of prioritized sites were input as waypoints into the Trimble GeoHX hand-held GPS rover, allowing us to navigate to their locations on Hunting Creek. To calculate the elevation of the archaeological sites, we overlaid the site's centroid on top of NOAA's Digital Elevation Model (DEM). Once the overlay was complete, we used a pixel-based geoprocessing technique to automate the elevation calculation. Utilizing the NOAA methodology for SLR, we were able to identify archaeological sites which will be inundated on a water surface rise of 1' to 2' feet. The sites in the most immediate threat or other areas of concern are where we completed our field research. With the GPS, we delineated the shoreline and took GPS points to help measure the amount of shoreline change.

SEA LEVEL RISE MODELING

NOAA's Sea Level Rise Viewer is a popular SLR model (Figure 6) used by coastal planners and managers, and local governments. This tool is a visualization of projected sea level rise and coastal flooding impacts. The criteria used to map the various sea levels on a national scale are the best available elevation datasets, the scholarly consensus levels of SLR, SLR on top of mean higher high water (MHHW), local variation of MHHW for each area, and evaluation of inundation for hydrological connectivity. The MHHW datum represents the level at which the land area is normally inundated by the tide (NOAA 2012).

Modeling SLR in Accomack County is difficult due to the poorly-studied effects of Atlantic Ocean SLR on the Chesapeake Bay. As warming accelerates, the volume of the oceans increases. The various scenarios of the IPCC model illuminate the disparity of the predicted rates of SLR. The conservative projections estimate that one foot of SLR will occur over 76 years. Other projections predict 1 foot of SLR in a less than twenty years. The most extreme scenario predicts one foot of SLR in approximately 12 years (NOAA 2012).



(Figure 6)

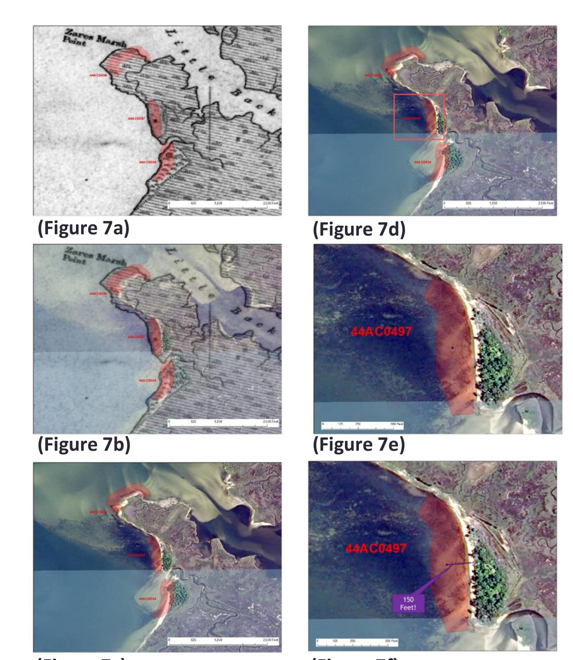
The Sea Level Rise Viewer is based on a modified bathtub or linear superposition model seen in Figure 6, which models SLR as uniform on a national scale. In addition to the uniform SLR, the viewer takes into account the hydroconnectivity of the inundated areas; this is what distinguishes it from a normal bathtub approach. This means that if a part of a marsh would become inundated, the model would show the entire marsh as submerged. In addition to the hydroconnectivty approach, NOAA considers the hydrologic areas that are unconnected and determines whether it is inundated based on the accuracy of the elevation data (NOAA 2012).

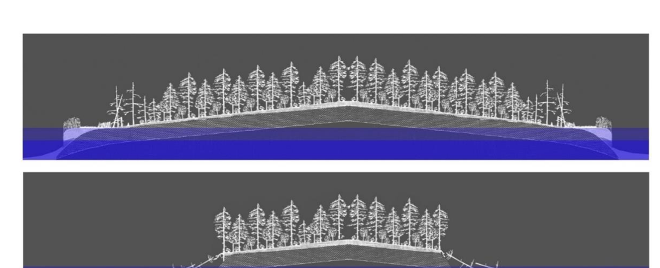
Although the Sea Level Rise Viewer is a helpful resource to visualize projected sea level rise, it does not tell the whole stoy. There are limitations to the modified bathtub approach of SLR. SLR does not happen uniformly across the globe. Eustatic and isostatic/relative sea level change causes discrepancies at all scales. The spatial variations in SLR can be seen throughout the Chesapeake Bay, and there is an even larger disparity when measuring SLR at a national scale. Another factor the model does not take into account is the rate of shoreline erosion. This process, according our calculations, is taking place at a faster rate than SLR itself. Just like SLR, spatial variations of shoreline erosion occur. Other limitations include storm surge occurrences and dataset inaccuracies. Storm surges accelerate the erosion process and impact stable land surfaces along the shore. Also, LiDAR data, used to create mapping surfaces, measures respective land types differently (Ranasinghe 2013).

RESULTS

Figure 7 displays Jacks Island in Hunting Creek from 1904 to 2012 (Figures 7a - 7c). This area of concern shows the erosive tendency of the waves on the Bayside over the past century. Jacks Island is of particular interest to archaeologists, as there are three significant, multi-component sites (44AC0496, 44AC0497, 44AC0504) on the shore. Each site was recorded less than 20 years ago with the Virginia Department of Historic Resources. All of the site's polygons that were once on land are now almost entirely submerged. In particular, Figure 7c shows the soil on the island washed out into Hunting Creek.

During our field assessment, we visited each site to quantify the change first hand. At site 44AC0497 (Figure 7f), we marked a GPS point as close to the centroid as possible. Based on our measurements, there has been at least 150 feet of shoreline erosion and coastal inundation since the site was recorded.


(Figure 7a) (Figure 7d) (Figure 7b) (Figure 7e) (Figure 7c) (Figure 7f)


(Figure 8). Horizontal vegetational shifts to a protected low 'hummock' landscape after minimal sea level rise event.

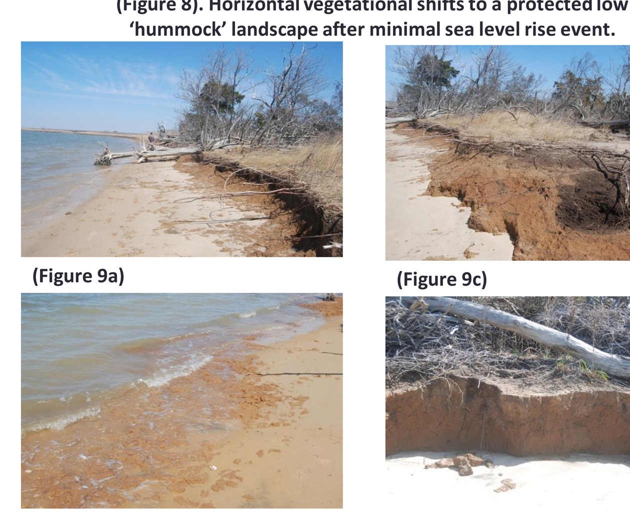
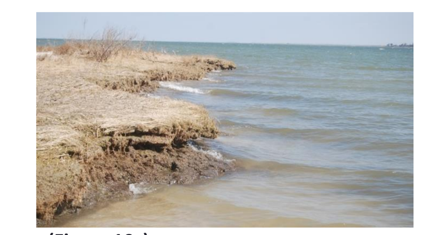

(Figure 9a) (Figure 9c) (Figure 9b) (Figure 9d)

Figure 8 depicts the process of land-loss occurring on Jacks Island (Lowery 2013). Figures 9a – 9d depict the processes at work during ground-truthing in April 2014. Wave action wears away the shoreline profile, pushing back the vegetation and soil. Uprooted trees along the shoreline are the result of the Superstorm Sandy storm surge in 2012. The underlying beach is the foundation of the island and is all that is left after years of erosion. The dark soil in Figure 9c is the root stain from a recently uprooted tree. The aeolian soil layers are more prone to erosion from the wind and water. Figure 9d shows the thickness of this soil layer which is completely exposed in close proximity to the shore. The effects of SLR and shoreline change have had a severe impact on the geomorphological processes for Jacks Island. We estimate the rate of erosion, based on surveyed sites, at approximately 1 foot per year, although this rate of change varies throughout the Bay, much like SLR.


(Figure 10a)


(Figure 10b)


(Figure 10c)

Another study area, Thorofare Hill (Figure 10a), has also seen dramatic change. While in the field, we delineated the shoreline using GPS. In the lab, we created an overlay of the contemporary shoreline on the 1904 historical topographic map to visualize the change. However, because the lack of precise area measurements of the island in 1904, accurate calculations of the amount of land lost over time is subject to error and, due to reprojection techniques utilized in ArcMap, the 1904 land area is difficult to discern. With conservative estimates, however, we calculate the rate of change at about 1000 square feet per year. In 1904, or the black outline in Figure 10a, the land area was estimated at 373,830 square feet. Today, 30 percent of the land mass has been lost (the red outline in Figure 10a), measuring at 267,673 square feet.

Figure 10b (Jacks Island) and Figure 10c (Thorofare Hill) also depict the process of shoreline erosion on Hunting Creek. The wood barrier protecting the shore in Figure 10b is a 19th century bulkhead which has been almost completely destroyed. Without the barrier, the shore is in direct contact with the waves. This direct shoreline erosion magnifies the rate of erosion occurring along the shore. Figure10c depicts direct contact between the waves and the underlying soil layer. The waves are undercutting the intact soil, causing the causes the top layer to hang down, unsupported, and eventually wash out into the creek. This process is not accounted for in the NOAA model: land can be eroded away without the submergence due to SLR.

CONCLUSION

While NOAA's Sea Level Rise Viewer is a useful tool for developing a general idea of the effects of SLR on an area, and may be of some use to those concerned with emergency planning and environmental degradation, it does not take into consideration several factors that are impacting shoreline profiles. For instance, the Sea Level Rise Viewer does not account for the rate of erosion that is occurring. Based on our surveyed areas, the rate of erosion is about one foot a year. Shoreline erosion modeling is becoming more accurate and the processes are becoming better understood (Ranasinghe 2013), and if shoreline modeling was incorporated into the Sea Level Rise Viewer, the model would portray more accurate measurements of land lost. Also, the Sea Level Rise Viewer does not take into consideration the impacts of storm surges, which accelerate the process of eroded land. Locations such as Jacks Island experience a significant topographic change due to large scale storms such as Hurricane Sandy. NOAA's Viewer does not take into account the spatial variance of the rate of SLR. As suggested by tidal gauge data from Lewisetta and Kiptopeke, the amount of SLR varies even within the Bay (Figure 3). Lastly, LiDAR data has its inaccuracies and can lead to a inconsistent sea inundation levels. For these reasons, e conclude that NOAA's Sea Level Rise Viewer is of limited utility for those interested in the complexity of shoreline erosion and SLR.

The impacts of SLR in Accomack are far-reaching. The interruption of coastal geomorphic processes due to accelerated SLR has effects on the local population. The possibility of population displacement for families living along the coast is a real threat. The loss of land in the fishing communities is also a loss of heritage for the families who have lived there for generations. Dr. Ewell told a story about his father pointing out a small strip of land on Jacks Island that used to be a large baseball field when he was a child. This indicates a solid land surface the size of a baseball field was almost completely submerged by the Hunting Creek in just one lifetime.

The threats of accelerated SLR are becoming more evident to local residents. To prevent the loss of heritage and land, actions must be taken soon before it's too late. Models fail to incorporate all the underlying processes and fail to give an accurate portrayal of on-the-ground reality. In the short term, more coastal protection techniques need to be implemented to mitigate risks to these coastal communities. Government at all levels and environmental protection agencies need to act before inundation levels become too large to counteract.

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