Effect of sea level rise and land cover change on future storm surge impacts in the Galveston Bay, Texas region

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Project Overview

Sea level rise (SLR), tropical cyclones, and coastal flooding are a few drivers of environmental change occurring along the Texas coast, and their effects are amplified by local land surface subsidence. Along the Texas flat and low-lying coastal plain, these phenomena are impacting critical coastal wetlands as well as human populations, and industries and infrastructure supporting those populations. Rapid growth in population and impervious cover, and aging and inadequate infrastructure has exacerbated the problem and increased the risk of coastal flooding in the Greater Houston Region.

Given that hazardous flooding from storm surges and rain events is likely to increase in the region as SLR and development continues, this study:

1. explores how sea level rise may affect land cover, including the natural and built environments.
2. provides an assessment of the effects of future landscapes and SLR on storm surge by considering Hurricane Ike as a representative storm making landfall in 2100.
3. analyzes the socio-economic impact due to SLR and storm surge.

Study Area

The study area covers five counties surrounding a large bay-estuary-lagoon system, the Galveston Bay System. These five counties are Brazoria, Chambers, Galveston, Harris and Liberty County, and covers approximately 5,195 square miles of land area. Approximately 5.3 million people reside in these five counties.

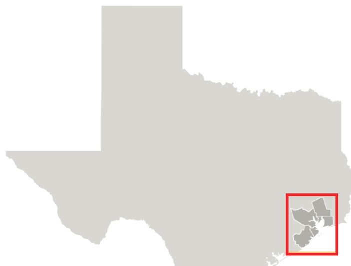


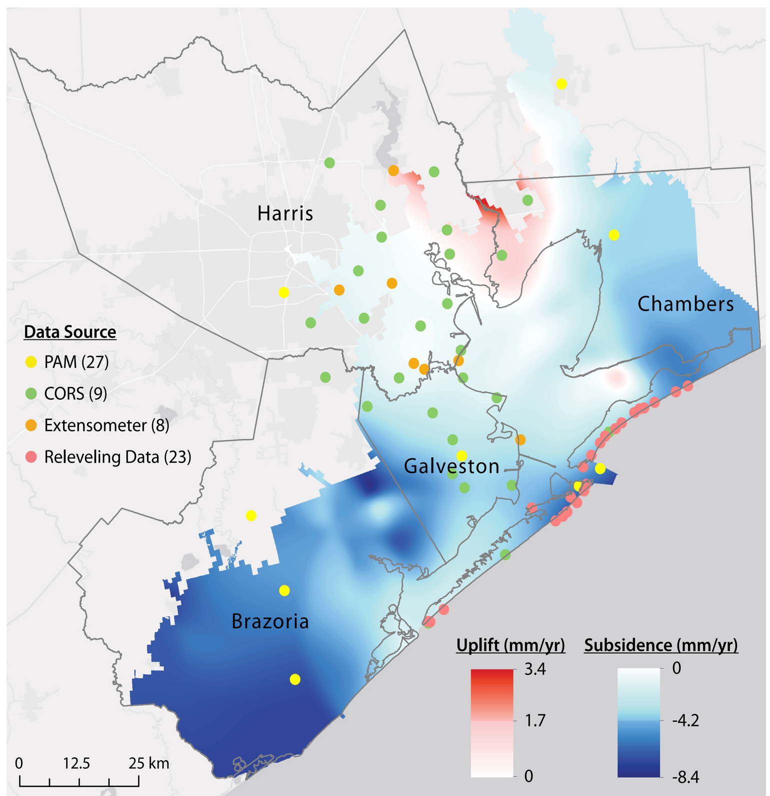
Figure 1. The study area.

The area is vulnerable to flooding due to the low-lying, flat terrain and clay-silt prairie soils that do not drain quickly. In addition to those, the sinking of coastal land called subsidence has increased the frequency and severity of flooding in the region.

Methods

Sea Level Rise Scenario

The sea level rise scenario in this study is based the United Nations' Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The AR5 has defined four Representative Concentration Pathway (RCP) based on the cumulative measure of human emissions of Green House Gases from all sources. The median value of the highest RCP (RCP8.5) is selected for use in this study, which results in 0.74 m of global mean SLR in 2100. A subsidence rate grid developed by Subedee, Dotson & Gibeaut, 2016* was used in order to add the impact of relative sea level rise in the year 2100.



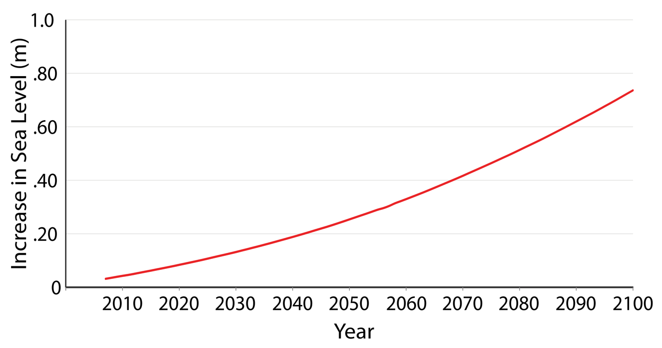


Figure 2. (Left) Subsidence rate grid developed to model relative sea level rise.

* Subedee, M., Dotson, M., Gibeaut, J., 2016. Investigating the Environmental and Socioeconomic Impacts of Sea Level Rise in the Galveston Bay, Texas Region, 2016 Ocean Sciences Meeting, American Geophysical Union (AGU), New Orleans, LA, February 2016.

Figure 3. (Right) The sea level rise amount and rate used in this study from the IPCC AR5 RCP 8.5 median scenario.

Modeling Framework

The Sea Level Affecting Marshes Model (SLAMM) is used to model the possible effects of SLR on coastal habitat transition. It uses digital elevation, land cover and other information to simulate potential impacts of sea level rise on wetlands and shorelines. The 2100 surface and land cover predicted by SLAMM is used as representative of future elevations and land cover type for input to the coupled Advanced CIRculation (ADCIRC) and Simulating Waves in the Nearshore (SWAN) model by considering Hurricane Ike, which struck our study area in 2008, as a representative storm making landfall in 2100.

The sea level in 2100 is applied by increasing the initial water level offset from the geoid in the ADCIRC + SWAN model. The storm surge inundation grid obtained from ADCIRC + SWAN model is input to HAZUS-MH to estimate potential building and infrastructure losses due to the coastal flooding caused by Hurricane Ike in 2100.

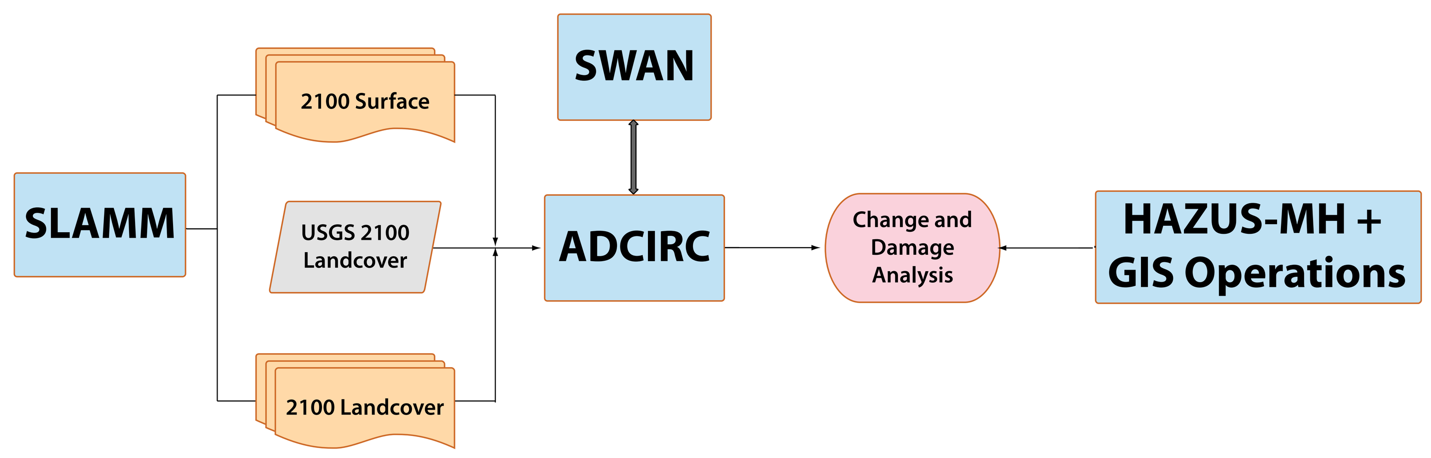


Figure 4. The modeling framework used in this study. Output 2100 surface and landcover from SLAMM was used as input in ADCIRC+SWAN. A change and damage analysis was done on that output by using the HAZUZ-MH model.

Results

SLAMM

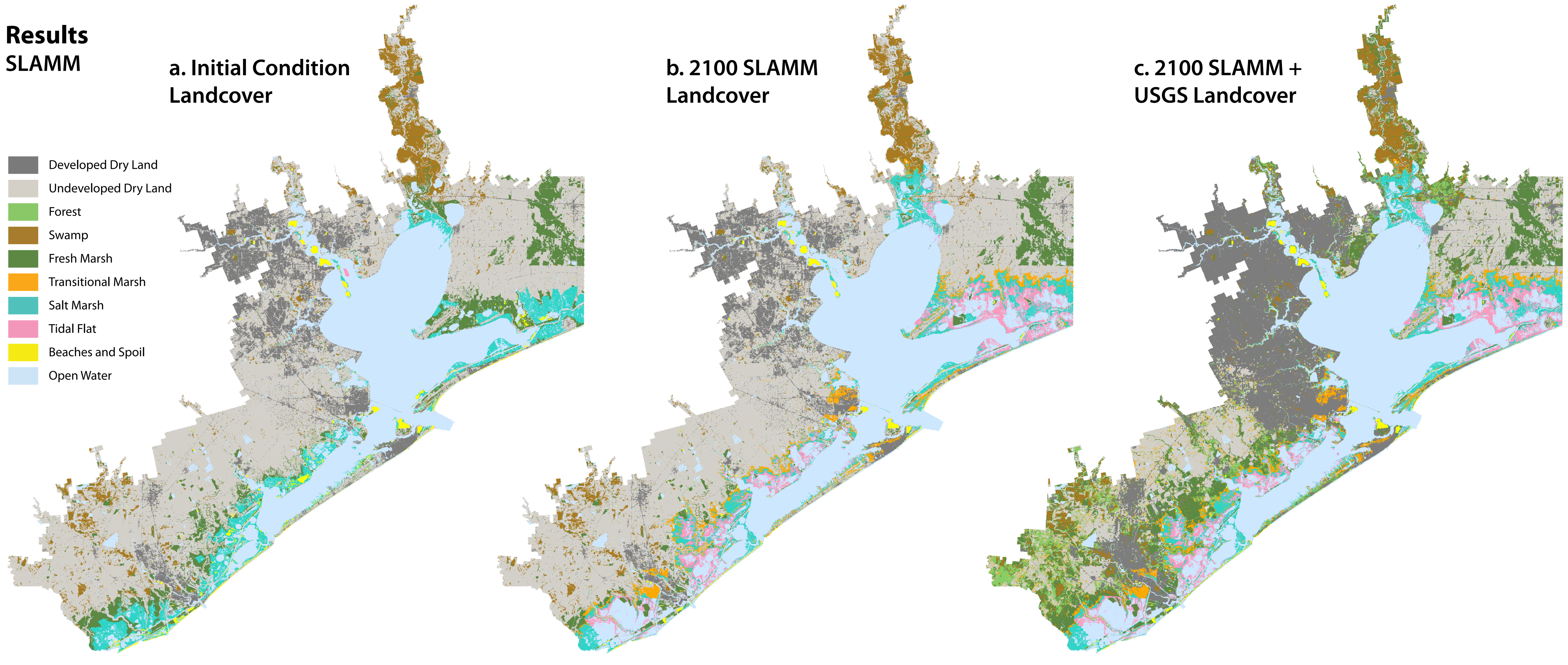


Figure 5. Results from SLAMM modeling. a.) Initial (2007) input landcover. b.) SLAMM 2100 output landcover. c.) Combination of SLAMM 2100 output landcover and classes from 2100 USGS projected landcover changes*.

*Sohl, T.L., et al., 2014. Spatially explicit modeling of 1992–2100 land cover and forest stand age for the conterminous United States. Ecological Applications, 24(5), pp.1015-1036.

ADCIRC and HAZUS-MH

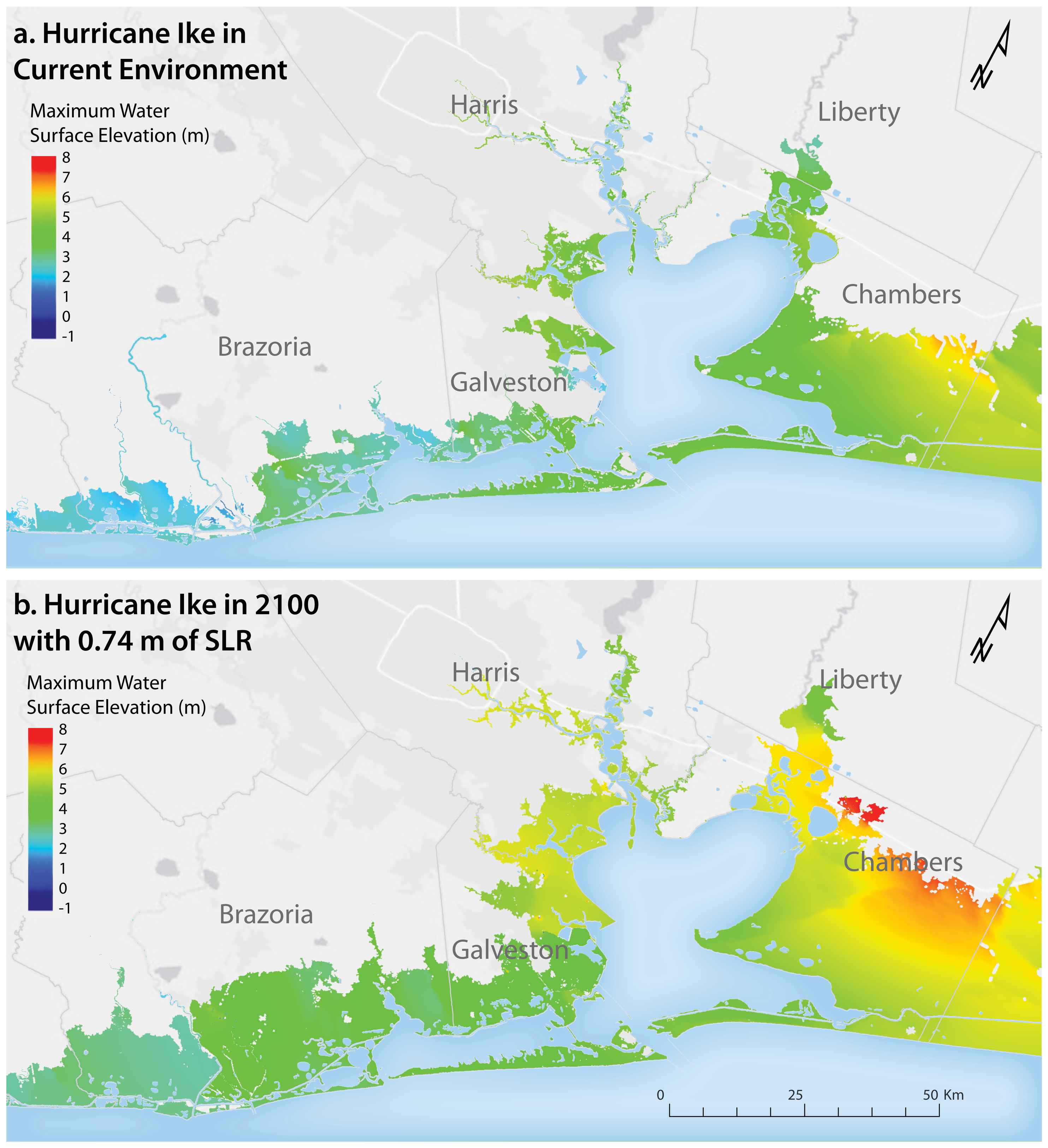


Figure 6. Results from ADCIRC modeling. a.) Maximum water surface elevation from Hurricane Ike in the current environment. b.) Maximum water surface elevation from Hurricane Ike in 2100 after 0.74 meters of SLR and subsidence, including landcover changes.

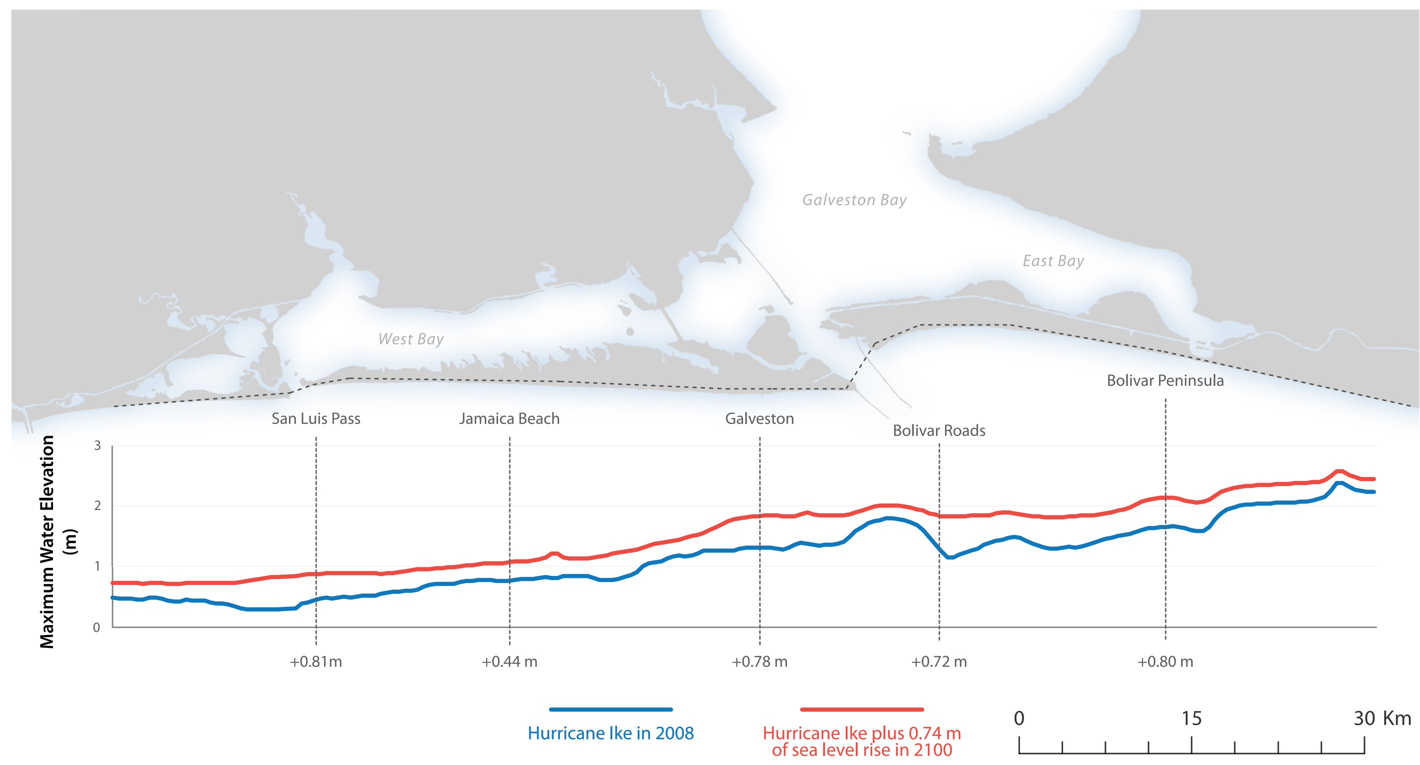
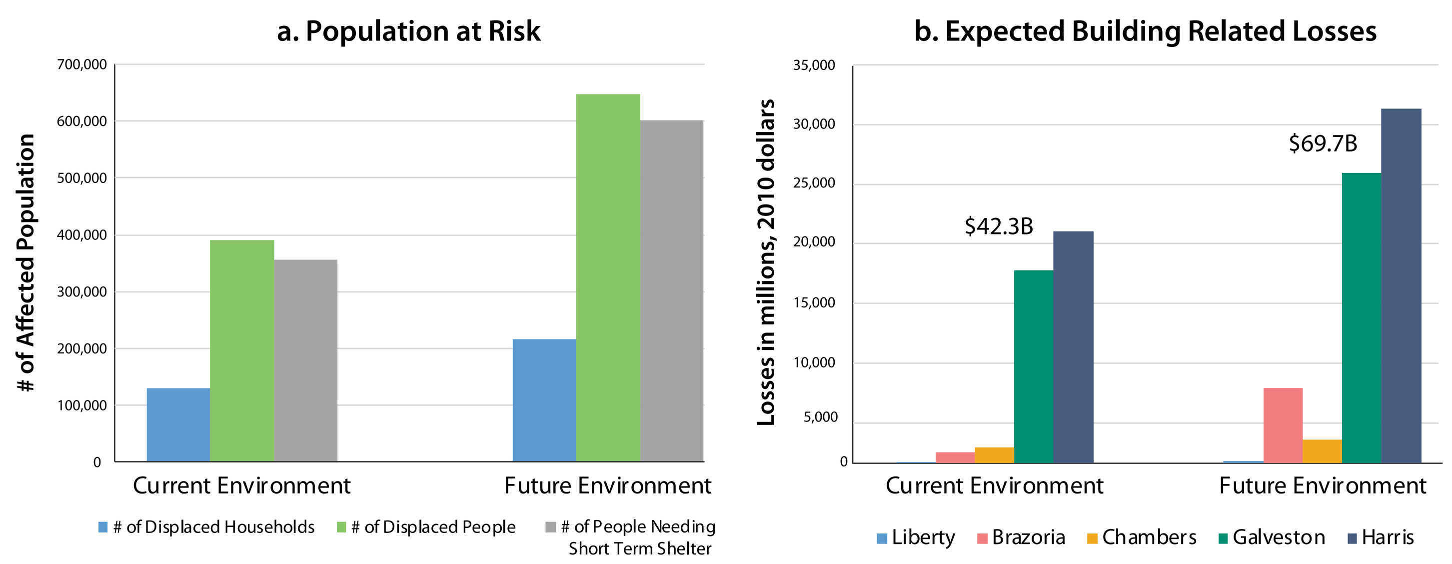


Figure 7. The difference in maximum water elevation across the barrier islands from Hurricane Ike in the current environment and Hurricane Ike in 2100 after 0.74 m of SLR and subsidence, plus landcover changes.



c. Essential Facilities and Infrastructure at Risk							
	Fire Stations	Hospitals	Police Stations	Schools	Emergency Operation Centers	Waste Water Treatment Plant	Oil Refineries
Ike in Current Environment	54	16	84	328	6	52	20
Ike in Future Environment	72	26	118	504	12	64	24

Figure 8. a.) The population at risk from Hurricane Ike in the current environment and in the future environment. b.) Expected building related losses from Hurricane Ike in the current environment and in the future environment. c.) Essential facilities and infrastructure at risk from Hurricane Ike in the current environment and Hurricane Ike in 2100.

Conclusions

Sea level rise will increase coastal flooding as storm surges of a given height are expected to occur more frequently. Similarly, climate change may result in increased intensities and precipitation totals from tropical storms. Therefore, the coastal populations outside of contemporary storm-surge zones are going to be exposed to future hurricanes. The results show that the inundated land area due to Hurricane Ike storm surge in 2100 with 0.74 m of global sea level rise increases by 450 sq. miles in comparison to the current environment. This, eventually, increases the property damage cost by 65% (in 2010 dollars and development level) in comparison to the loss in the current environment.

Finally, this project provides a dynamic modeling framework to assess the combined impact of sea level rise and tropical storm-driven storm surge. The methodology is also applicable for improving the predictive understanding of ecosystem responses to sea level rise and storm surge, and for analyzing the potential socio-economic impacts of climate change along the coast. The results of this study provide a holistic assessment of the coastal system allowing coastal communities and resource managers to develop future adaptation and mitigation strategies. The results and maps of this study are available on the web (http://gomaportal.tamucc.edu/SLR/).