Tsunami Risk Analysis of the East Coast of the United States

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INTRODUCTION

In the wake of the 2004 Indian Ocean tsunami and the 2011 Japan tsunami and corresponding nuclear disaster, much more attention has been focused on coastal vulnerability to tsunamis. Areas near active tectonic margins have a much higher risk of being hit by a tsunami, due to proximity. People who live in these areas are more aware of the danger than their counterparts on passive tectonic margins. It is generally a good assumption that the risk of a tsunami is low in places like the eastern seaboard of the United States.

Despite the low risk, the east coast has been hit by tsunamis in the past. Examples include the Newfoundland tsunami caused by the Grand Banks earthquake. This did not hit the east coast of the United States, but it provides a good example of how tsunami on passive margins can be triggered. The Grand Banks earthquake was fairly small in magnitude, 7.2 where most tsunami causing earthquakes are magnitude 8.0 or above. The quake caused a submarine landslide, which in turn displaced enough water to cause a tsunami.

Since the chance of having a large enough earthquake to trigger a tsunami is very small along a passive margin, submarine landslides and other events that would cause displacement of a large amount of water are the main theoretical causes of passive margin tsunamis. A recent focus of research is La Palma, a volcanic island in the Canary Islands, off the coast of Africa.

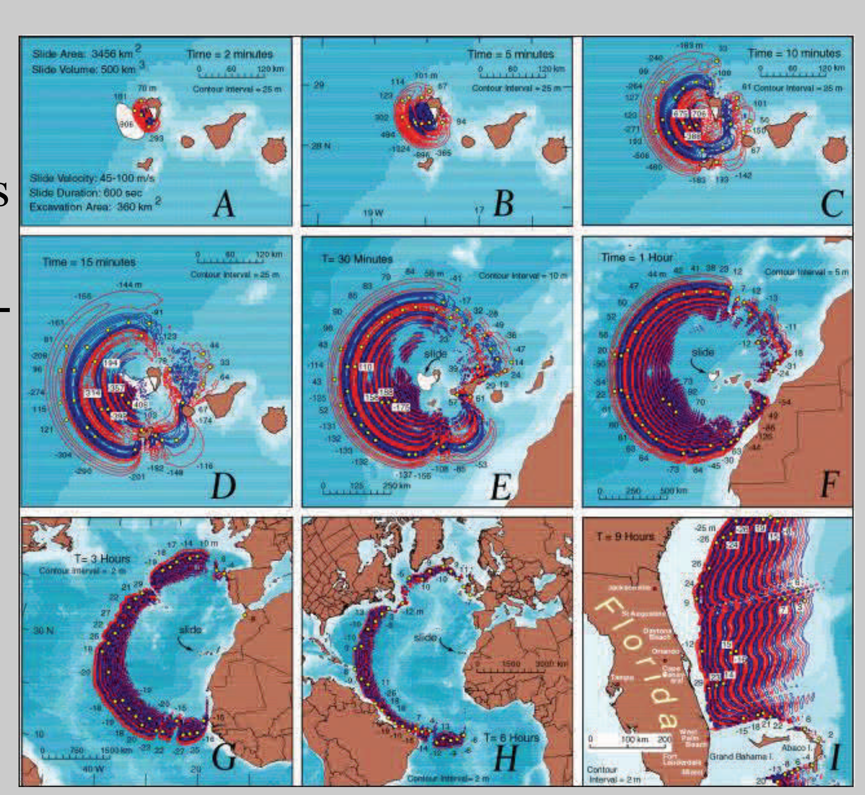
La Palma

La Palma contains the most active volcano in the Canary Islands, Cumbre Vieja. The volcano forms the southern third of La Palma, and reaches two km above sea level with an average slope of 15 to 20 degrees. There indications of movement along a fault on the volcano's west flank. While this fault has been inactive since 1949, Ward and Day (1) hypothesize that an eruption near the summit of Cumbre Vieja could trigger a flank failure. They believe that the slide block could be as large as 15-20km wide and 15-20 km long. Since there is very little data on the detachment surface, it is difficult to determine the thickness of the block. Using a computer model, Ward and Day predict that, in a worst case scenario, the east coast of the United states may be hit by tsunami waves 10 to 25 meters high.

2. Cumbre Vieja

Tsunami Propagation

The image displayed to the right is Ward and Day's model of the path of the tsunami. The model is based off of tsunami propagation equations. As the diagram demonstrates, the tsunami will likely hit the east coast, potentially devastating the coastal population. Image from Ward and Day (1).

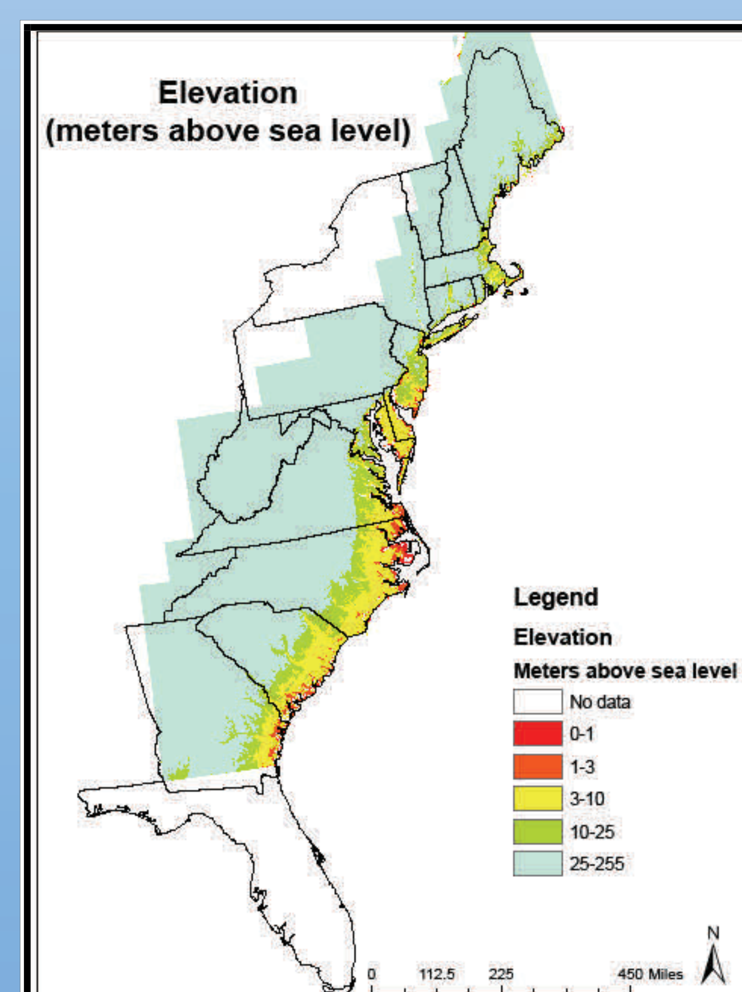


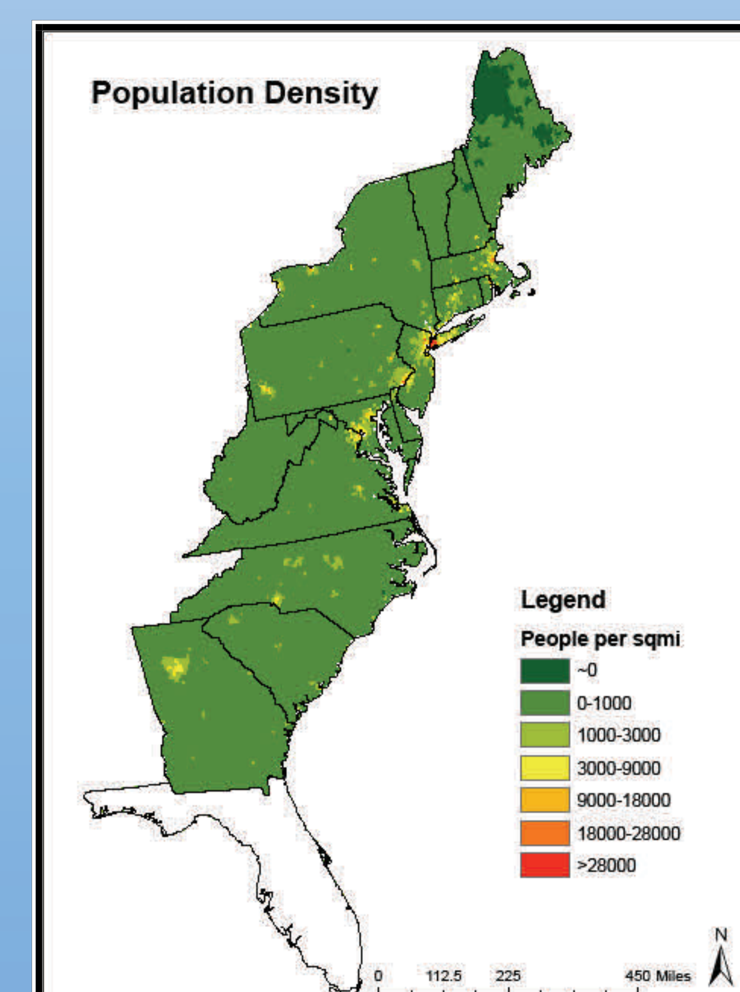
METHODOLOGY

Given the large area of the east coast, a rudimentary analysis was performed. Elevation is the most important factor in analyzing the risk of flooding in a coastal area; the lower the elevation, the greater the potential for damage. Elevation data was reclassified into no risk, medium risk, and high risk zones. These zones were: 25+ m above sea level, 10 to 25 m above sea level, and below 10 m above sea level. Essentially, most land adjacent to the coast that falls in the final category would be badly damaged by a 10m tsunami from the Canary Islands, unless buffered by another portion of land blocking the coast. If a larger tsunami were to occur, up to the max wave height predicted by Ward and Day of 25 m, any land adjacent to the coast that is less than 25 m of elevation would be at risk.

Risk was also classified based on population density. As population increases, there is a corresponding increase in risk, due to the restricted ability to evacuate in case of emergency, and an increased number of people at risk.

The elevation and population data were converted to raster format for the analysis. Once reclassified, a Boolean raster was created from the elevation and population raster. Low elevations and high populations have the highest risk and high elevation and low population areas have low risk. Since elevation and proximity to the coast have a much greater effect on the risk, a weighted Boolean raster was created. More weight was given to low elevation areas that have a higher risk rating. This emphasized the danger of being close to the coast.

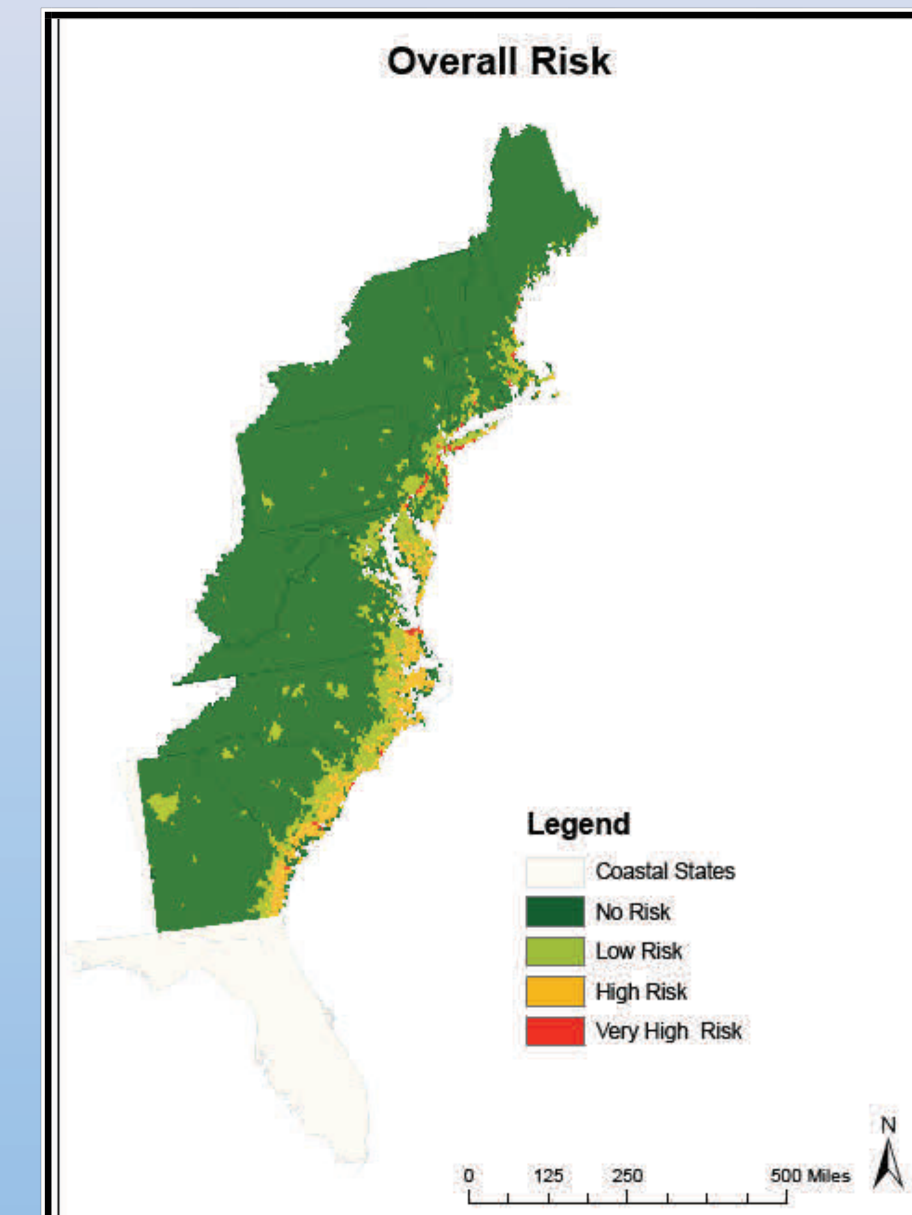


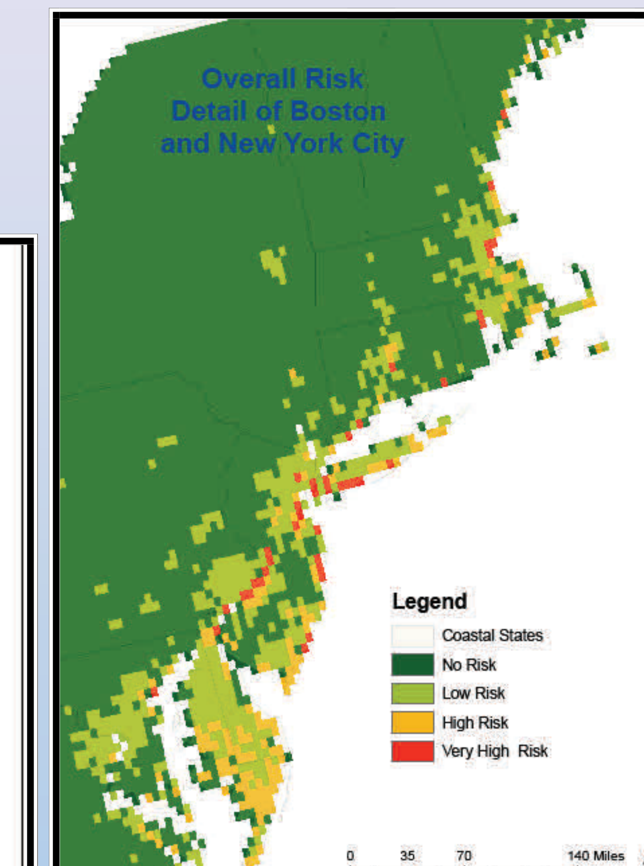


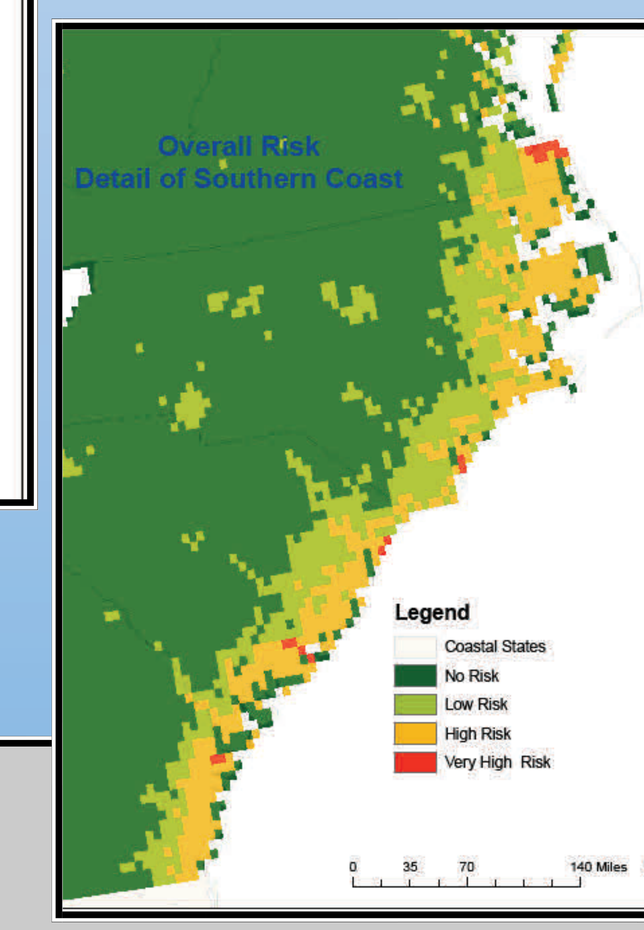
RESULTS

The above maps were combined in a weighted Boolean raster analysis to determine the areas of highest risk. Elevation was given twice as much weight as population. Results were as expected. Urban areas with a high density of population have the most to lose if hit by a tsunami on the scale of the hypothesized La Palma tsunami. New York City is likely to be the most badly effected in terms of total casualties and property loss. However, there will be significant damage along the entire coast. Low lying areas, such as the Outer Banks of North Carolina and Florida will effectively be wiped out.
Note: Areas of very high population remain on the map as areas of low risk. If not near the coast, there areas should be considered no-risk areas.

Compiled by Katherine Lowe
Geo 104-Geological Applications of GIS
Many thanks to Jake Benner for his assistance







CONCLUSION

Although this is not a detailed analysis, it provides a general guide to areas could potentially be damaged by a tsunami. This information can be used by coastal officials in the case that Cumbre Vieja does undergo massive slope failure. Given the distance that the wave must travel, there will be time to warn those in high risk areas. According to the analysis by Ward and Day, the tsunami will start to impact North America (in Newfoundland) around six hours after the slide and will hit Florida around nine hours post-slide. Given this amount of warning, areas that are in danger can be evacuated. The information given allows officials to prioritize those areas at most risk and evacuate the population and protect any vulnerable sites (such as nuclear power plants).

While the likelihood of a tsunami is low because Cumbre Vieja is not very likely to undergo such massive, catastrophic failure, it is still useful to have this information so that a plan of action can be made in advance and casualties can be prevented.

Sources

1. Data accessed from: http://wet.kuleuven.be/wetenschapinbreedbeeld/lesmateriaal_geologie/wardday-lapalmatsunami.pdf (4/22/2012)
2. Data accessed from: http://www.drgeorgepc.com/TsunamiMegaEvaluation.html (5/3/2012)
3. Elevation Data: USGS Seamless Data Warehouse: http://seamless.usgs.gov/website/seamless/viewer.htm
4. Population Data: ESRI, Tele Atlas North America, US Census