Ancient Submarine Landslides and their Numerical Simulations in the Gulf of Mexico
Port Aransas, Texas

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introduction

Hurricanes have greatly impacted the Gulf of Mexico (GOM) and their likelihood are well documented. However, the impact that a tsunami might have on GOM's coastal communities needs to be investigated. Potential tsunami sources for the GOM are local submarine landslides and earthquakes along the Caribbean plate boundary faults. Preliminary modeling results of potential tsunami sources outside the GOM indicated a very low threat and may not pose a tsunami hazard to the GOM's coasts. However, ancient submarine landslides within the GOM may have generated tsunamis as examined by the Atlantic and Gulf of Mexico Tsunami Hazard Assessment Group (THAG), ten Brink *et al.*, (2009). In their findings, they stated that although the likehood is extremely low, submarine landslides in the GOM are considered a potential tsunami hazard for the following reasons:

1. Some dated submarine landslides in the GOM have a post-glacial age.
2. Large landslides in the GOM have been found in the submarine canyons and fan provinces extending from present Mississippi and other former larger rivers that emptied into the GOM. These large submarine landslides were probably active before 7500 years ago.
3. Recent suggestions from seismic records of small-scale energetic submarine landslides in the GOM indicate that there is a probability of recurrence.

Consequently, a detailed tsunami hazard assessment is presented for a specific location in Texas, Port Aransas. In order to estimate the extend and magnitude of inundation by tsunami waves generated from landslide sources, 3-D and 2-D numerical models have been used: a) The landslide generation stage (determination of the tsunami source) is taken by the 3-D Navier-Stokes model developed by the University of Alaska Fairbanks (UAF) and Texas A&M University at Galveston (TAMUG). The numerical model is dubbed

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TSUNAMI3D, for Tsunami Solution Using Navier-Stokes Algorithm with Multiple Interfaces. b) The tsunami wave propagation and inundation stage are carried out by the 2-D non-hydrostatic/hydrostatic model developed by the University of Alaska Fairbanks (UAF) and the University of Hawaii (UH), NEOWAVE for Non-hydrostatic Evolution of Ocean WAVE.

Several scenarios were investigated, resulting in tsunami waves generated by three ancient underwater landslides. The results obtained from the simulation of these landslides were used to construct the first tsunami map to communities in the GOM, which will provide guidance to state emergency managers for hazard mitigation and optimize real-time tsunami warnings.

Landslide Tsunami Hazards in the Gulf of Mexico

According to the THAG report *Regional Assessment of Tsunami Potential in the Gulf of Mexico*, there are not records which accurately date when these landslides occurred in the past, making difficult to determine what environmental or temporal conditions caused them. However, the report provides a detailed description of the geological provinces in the GOM that are likely to be the origin of submarine landslides. These provinces feature the three major ancient scarps or excavations with their respective sediment depositions down slope that were capable of generating large tsunamis in the past: The three underwater landslides are: East-Breaks, Mississippi Canyon and West Florida landslides, see Figure 1.

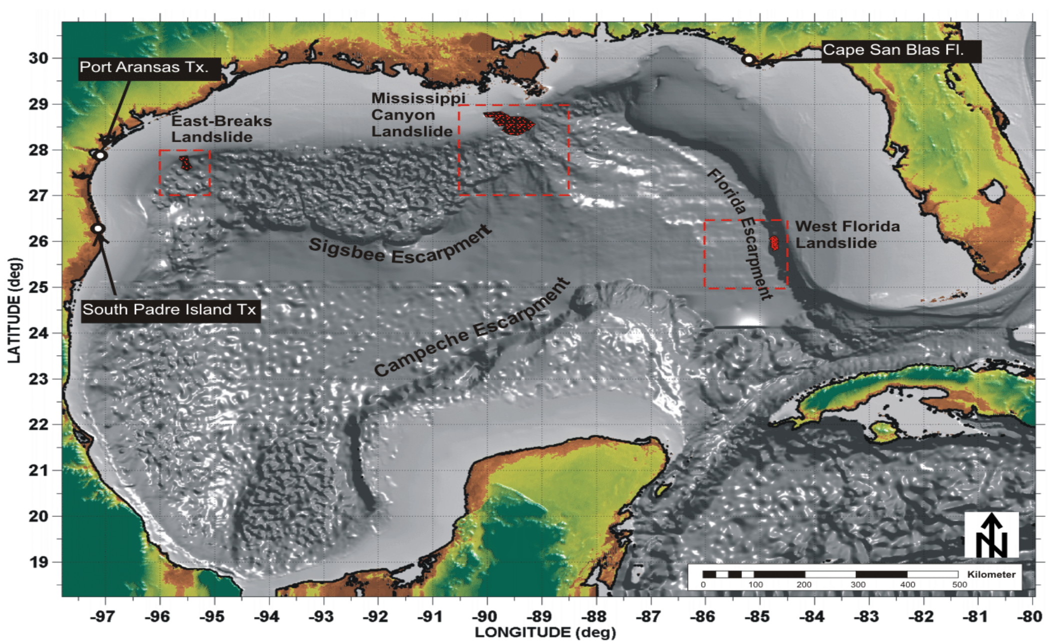

Figure 1: GOM's bathymetry and location of submarine landslides (region hatched in red) used to determine tsunami inundation in Port Aransas, TX. Dashed-red rectangles indicate the domain with 15 arc-second resolution used for 3-D numerical calculation to determine the tsunami source

The East Breaks landslide, which lies offshore of the Rio Grande River system, is located in the salt province in the north-western part of the GOM. The East Breaks landslide (22 km^3) is believed it occurred during the last lowstand of sea level and was the result of the failure of the shelf edge delta, which had accumulated sediment from the Rio Grande River over time. The Mississippi Canyon landslide (425 km^3) is the largest and youngest of the landslides, located in the canyon/fan province, which is at the outflow of the Mississippi River. The West Florida landslide (16 km^3) is located in the West Florida Margins carbonate province, which rims the eastern side of the GOM, and is located on a gentler slope above the Florida Escarpment sourced in Tertiary and Quaternary carbonate deposits.

Model Results

The first set of numerical simulations was carried out using TSUNAMI3D to determine the tsunami source caused by each of the three submarine landslide scenarios described by THAG. The submarine landslide dimensions were based on the volume of material removed from the excavation region using a technique similar to that applied by ten Brink *et al.*(2006). It is important to mention there are some slightly differences between the volumes/areas determined in this study and those reported by the THAG.

The first set of numerical simulations (which determined the tsunami source for each case scenario) was used as input to NEOWAVE to generate a second set of numerical simulations using a coarse grid on the entire GOM to determine maximum wave amplitude and tsunami arrival time. Finally, a set of numerical simulations was carried out using nested grids with finer resolutions to obtain maximum inundation depth, maximum water elevation, maximum momentum flux and direction in Port Aransas, TX. From the results, it was determined that the Mississippi Canyon landslide scenario has the greatest impact on Port Aransas and other regions on the GOM coastline as well. Therefore, a detailed description and discussion of numerical results is presented in the following lines for the Mississippi Canyon landslide scenario.

Mississippi Canyon Submarine Landslide Model Results

A quantitative plot of the Mississippi Canyon's tsunami source (initial configuration) is portrayed in Figure 2. As it can be seen from Figure 2, a maximum wave of approximately 426 ft (130 m) high is recorded after 8 minutes of slide initiation. The outgoing positive wave with amplitude of 210 ft (64 m) is followed by a negative wave or initial surface depression of 216 ft (66 m) caused by the landslide down slope motion.

Figure 3 shows the inundation depth caused by the Mississippi Canyon landslide in Port Aransas. The Mississippi Canyon landslide catastrophically flooded the entire town by overtopping the dune system. The water depth average in the populated area of Port Aransas is around 8 ft (2.4 m).

Figure 4 illustrates the magnitude and direction of the inundation at maximum momentum flux. From Figure 4 it can be seen that most of the water entering the town is the result of

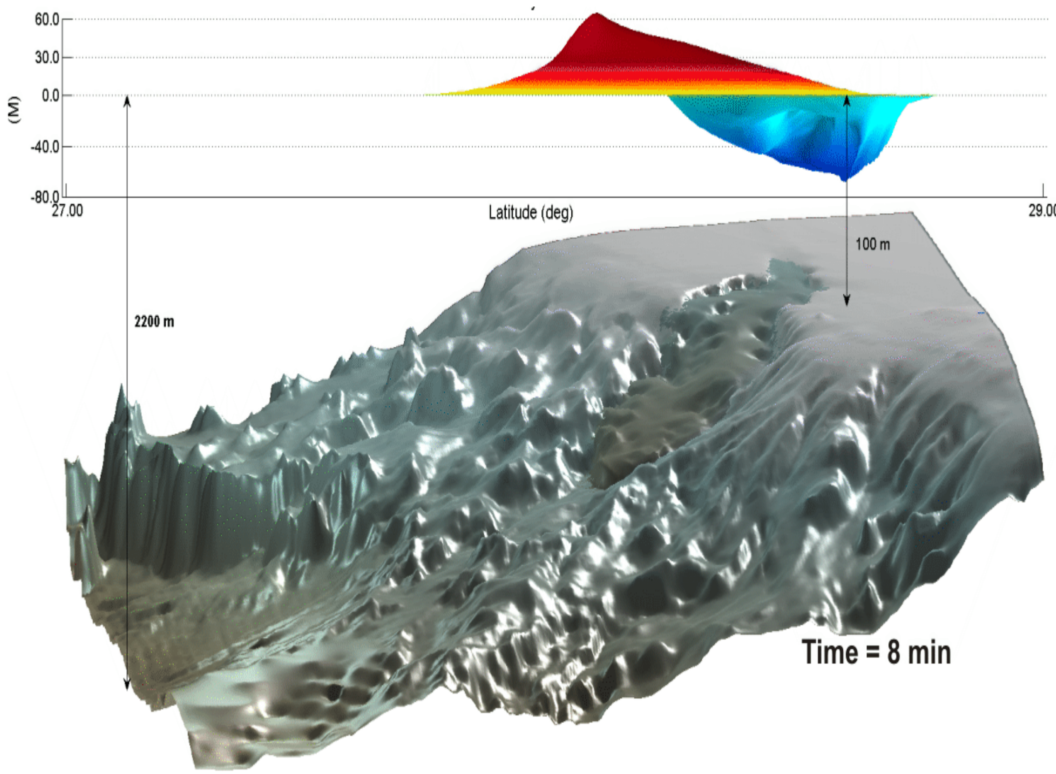

Figure 2: TSUNAMI3D's numerical result side-view for the Mississippi Canyon submarine landslide. Maximum wave height recorded at 8 minute after the landslide initiation

tsunami overtopping through the dune system of Port Aransas. The momentum flux average in the populated area of Port Aransas is approximately 25 m^3/s^2 per unit mass and per unit width. This quantity is important for engineering purposes, and can assist coastal managers in quickly assessing the relative vulnerability of a dunes system and structures.

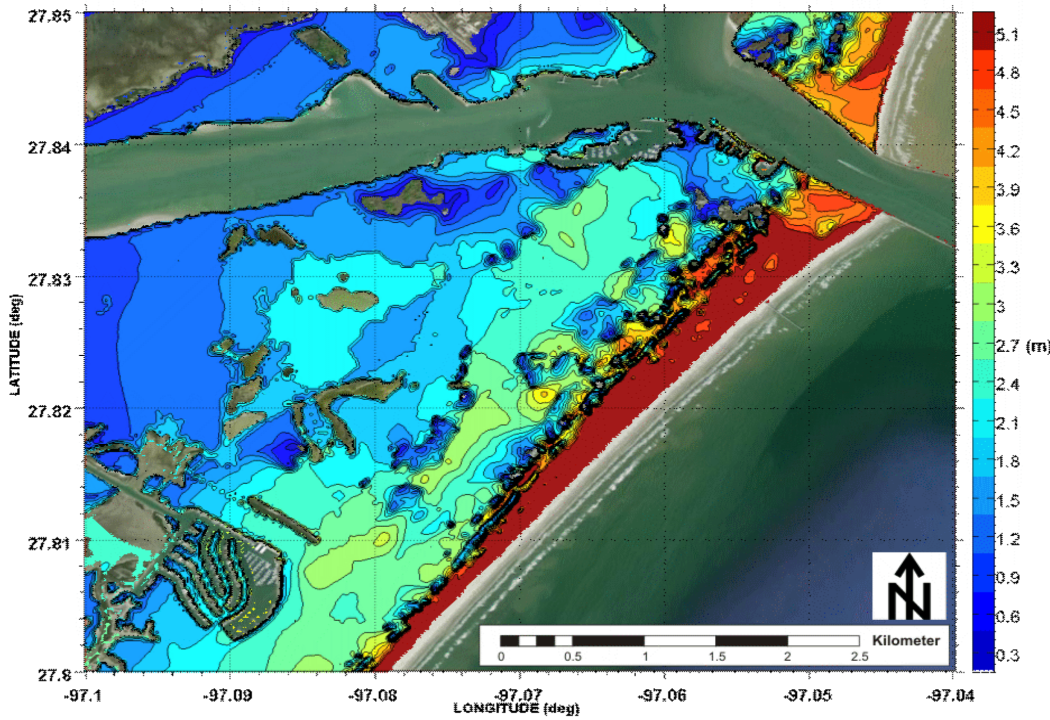

Figure 3: Maximum water depth caused by the Mississippi Canyon landslide in Port Aransas

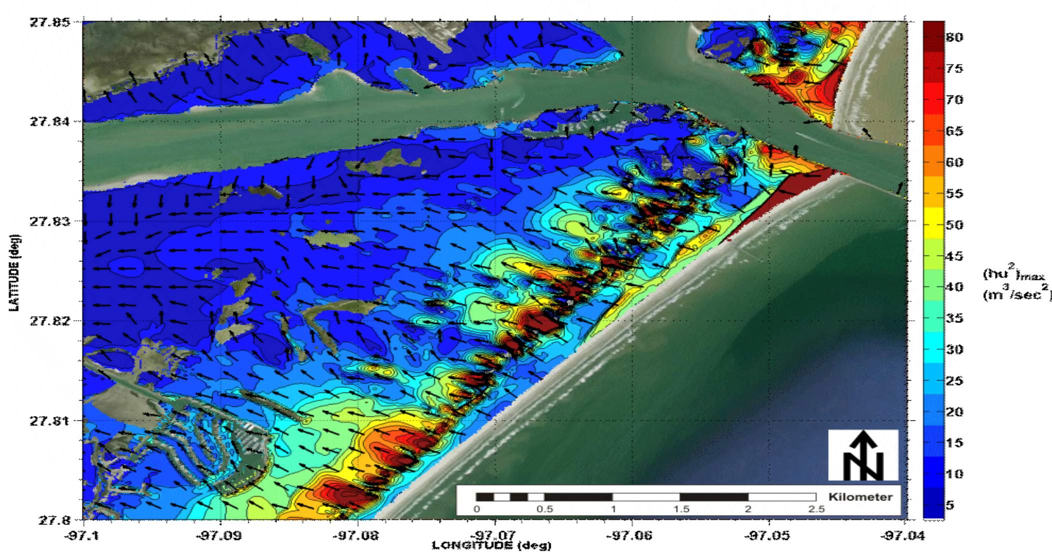

Figure 4: Maximum tsunami momentum flux caused by the Mississippi Canyon landslide in Port Aransas. Arrows represent momentum flux direction

Conclusion

It has been stated that although the likehood of a large landslide event is extremely low in the GOM, its effects could be catastrophic. Such an event can be considered as a potential tsunami hazard for the following reasons: Our study has confirmed that the landslide scenarios investigated have indeed the potential to cause severe flooding and damage to the GOM's coastal communities. Numerical simulations have shown that the tsunami flooding could cover the entire town of Port Aransas with an average water elevation of 7-13ft $(2.1 - 3.9\text{m})$ or average water depth of 3-8ft $(0.9 - 2.4\text{m})$. In terms of flooding the tsunamis generated by these landslides are comparable to storm surges originated by hurricanes of category 2 to 4.

References

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