

# A 3D-2D Hybrid Model for Practical Tsunami Calculations Ancient Submarine Landslides Simulations in the Gulf of Mexico Port Aransas, Texas

Juan J. Horrillo<sup>1</sup>, and Amanda L. Wood<sup>1</sup>

<sup>1</sup>Maritime Systems Engineering, Texas A&M University at Galveston, Galveston, Texas, USA

## Abstract

Hurricanes have greatly impacted the Gulf of Mexico (GOM) and their likelihood is well documented. However, the impact that a tsunami might have on coastline communities within the GOM needs to be investigated. Potential tsunami sources for the GOM are local submarine landslides and earthquakes along the Caribbean plate boundary faults. Preliminary modeling of potential tsunami sources outside the GOM indicated a very low threat and may not pose a tsunami hazard to the GOM 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 likelihood 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 extent and magnitude of inundation by tsunami waves generated from landslide sources, 3D and 2D numerical models have been used. For the calculation of tsunami inundation maps in the GOM two numerical models are used: a) The landslide generation (tsunami source) is taken by the 3D Navier-Stokes model developed by the University of Alaska Fairbanks (UAF) and Texas A&M University at Galveston (TAMUG) dubbed TSUNAMI3D for Tsunami Solution Using Navier-Stokes Algorithm with Multiple Interfaces. b) The tsunami wave propagation and inundation is carried out by the 2D non-hydrostatic/hydrostatic model

---

Received 30 March, 2011; accepted.

Address correspondence to Juan Horrillo, Maritime Systems Engineering, Texas A&M University at Galveston. Galveston, TX 77573, USA. E-mail address: horrillj@tamug.edu

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 East-Breaks landslide, Mississippi Canyon landslide and West Florida landslide. This study determines all elements necessary to construct the first tsunami inundation maps to communities in the GOM, which will provide guidance to state emergency managers 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 no records which accurately date when landslides occurred in the past making it difficult to determine what environmental or temporal conditions that caused them. In addition, the report provided a detailed historical record regarding tsunamis in the Gulf of Mexico and specified three geological provinces in the GOM that are likely to be the origin of submarine landslides. These provinces feature three major ancient scarps or excavations with their respective sediment depositions down slope that were capable of generating large tsunamis in the past. They are recognized as the East Breaks, Mississippi Canyon and the West Florida submarine landslides, see Figure 1.

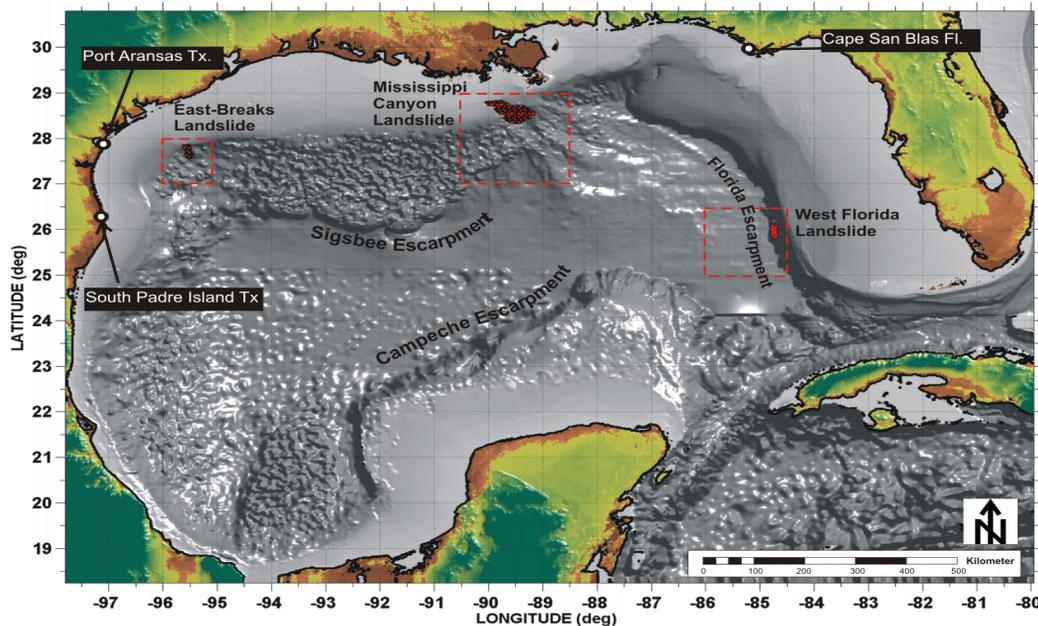


Figure 1: GOM's bathymetry and location of submarine landslides (in red) used to determine tsunami inundation in Port Aransas, TX. Dashed-red rectangles indicate the domain with 15 arc-second resolution used for numerical calculation of the submarine landslide

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 ( $22 \text{ km}^3$ )

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<sup>3</sup>) 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<sup>3</sup>) is located in the West Florida Margins carbonate provinces, 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 were 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 slight 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) were 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. Finally, a set of numerical simulations were carried out using nested grids with a finer resolution 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 of the GOM. Therefore, a detailed description and discussion of numerical results is presented in the following for the Mississippi Canyon landslide scenario.

### Mississippi Canyon Submarine Landslide Model Results

A quantitative plot of the Mississippi Canyon initial tsunami source 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 flooded the entire town catastrophically 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 tsunami overtopping through the dune system of Port Aransas. The momentum flux average in the populated area of Port Aransas is approximately 25 m<sup>3</sup>/s<sup>2</sup> per unit mass and per unit

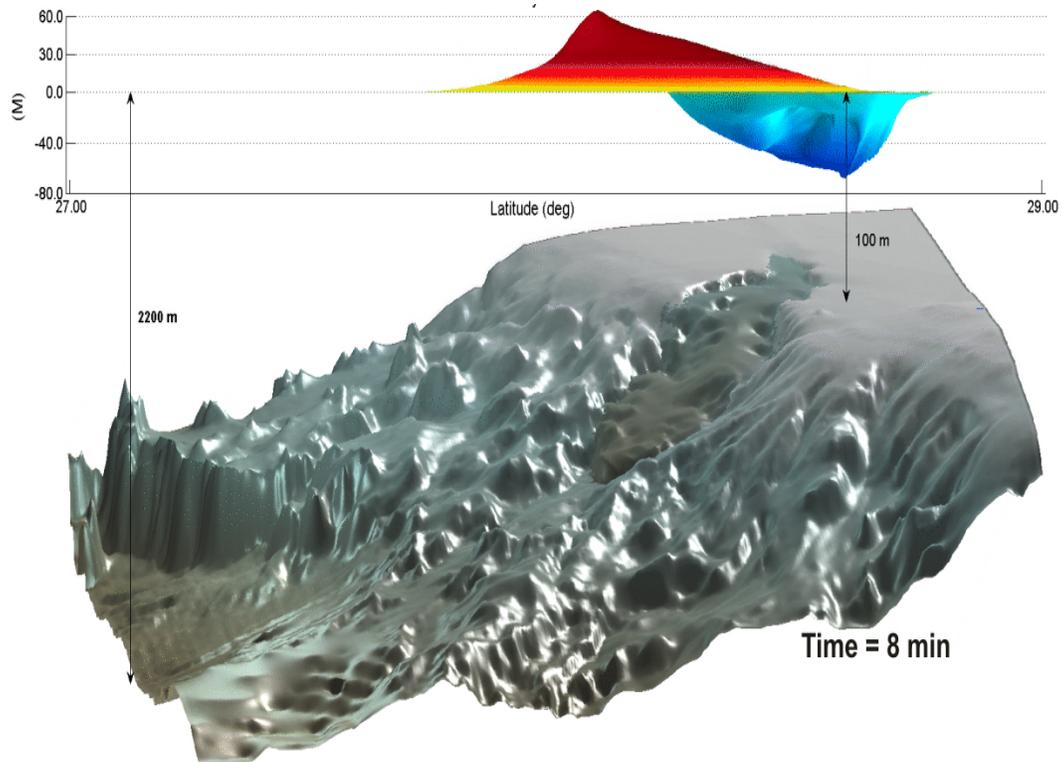


Figure 2: TSUNAMI3D's numerical result side-view for the Mississippi Canyon submarine landslide. Maximum wave height recorded at 8 minute after the landslide initiation

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.

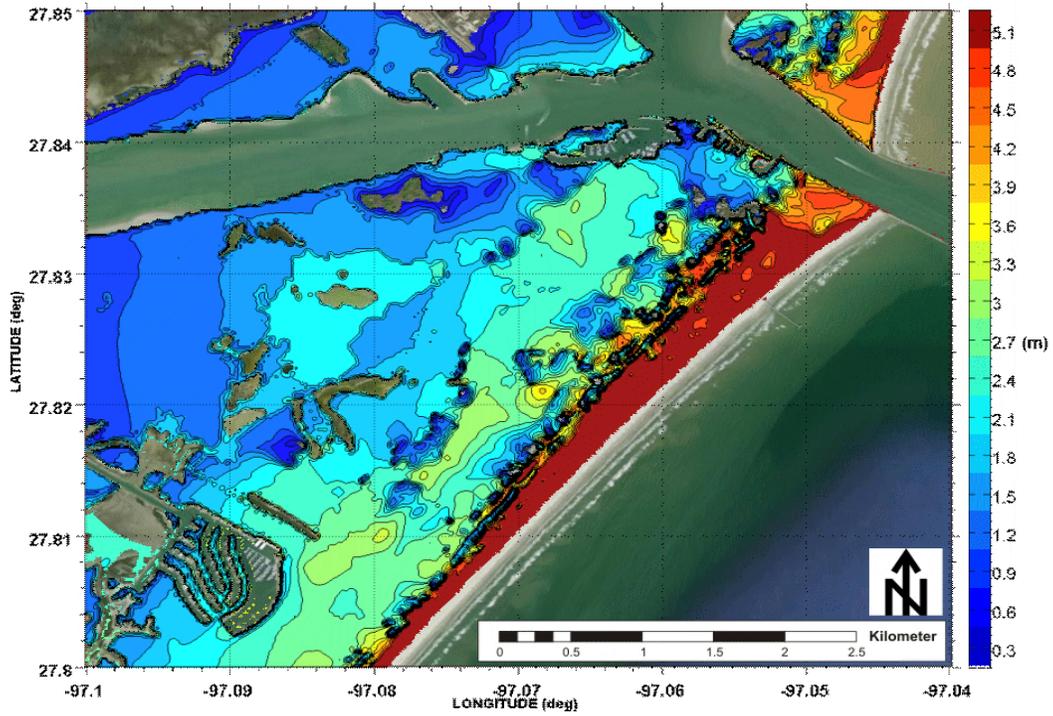


Figure 3: Maximum water depth caused by the Mississippi Canyon landslide in Port Aransas

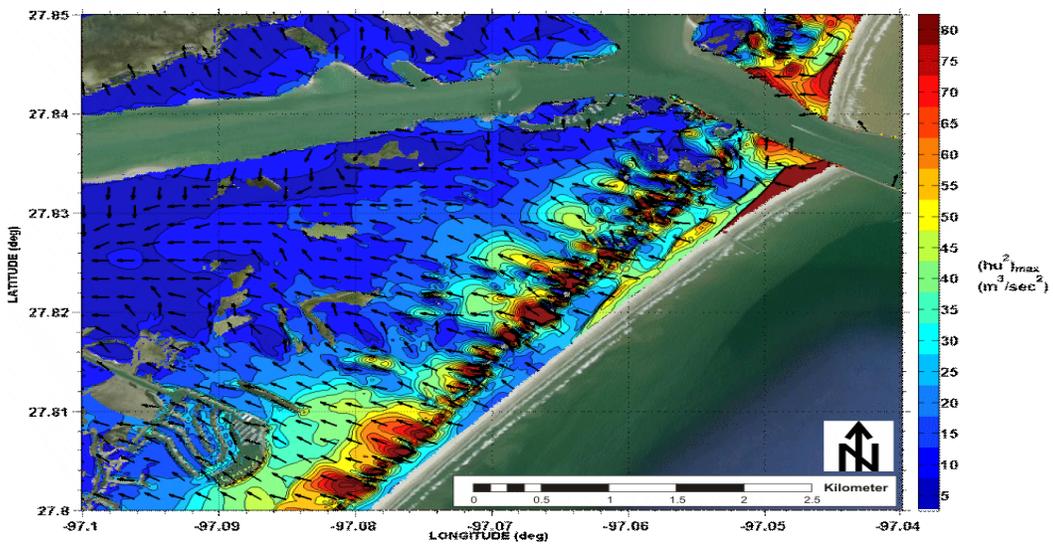


Figure 4: Maximum tsunami momentum flux caused by the Mississippi Canyon landslide in Port Aransas. Arrows represent momentum flux direction

## Conclusion

It has been stated that although the likelihood of a large landslide event is extremely low in the GOM, their effects could be catastrophic and they can be considered as a potential tsunami hazard for the following reasons: Our study has confirmed that these landslide scenarios have indeed the potential to cause severe flooding and damage to the GOM coastal communities. It is proved that such landslide sources can flood the entire town of Port Aransas with an average water elevation of 7 - 13ft (2.1 - 3.9m) or average water depth of 3 -8ft (0.9 - 2.4m). In term of flooding the tsunami generated by these landslide is comparable to storm surges originated by hurricanes of category 2 to 4.

## References

- ten Brink, U., D. Twichell, P. Lynett, E. Geist, J. Chaytor, H. Lee, B. Buczkowski, and C. Flores 2009 *Regional Assessment of Tsunami Potential in the Gulf of Mexico*: U.S. Geological Survey.
- ten Brink, U.S., Geist, E.L., and Andrews, B.D. 2006 Size Distribution of Submarine Landslides and its Implication to Tsunami Hazard in Puerto Rico: *Geophysical Research Letters*, v. 33, p. doi:10.1029/ 2006GL026125.