MODEL PREDICTIONS OF GULF AND SOUTHERN ATLANTIC COAST TSUNAMI IMPACTS FROM A DISTRIBUTION OF SOURCES

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ABSTRACT

The West Coast and Alaska Tsunami Warning Center now issues tsunami warnings for the US Gulf and US /Canadian Atlantic coasts. Because there is less historical data for these regions than for the Pacific, numerical models have been used to make predictions of wave amplitudes, travel time, and "reach". Hypothetical tsunami sources are placed in the Atlantic, the Gulf of Mexico, and in the Caribbean, with the resulting waves advanced forward in time 12 to 24 hours. Model results are presented in relation to warning center procedures.

INTRODUCTION

Four initial sea level disturbances were created using Okada's formulas (1985) in conjunction with their associated hypothetical earthquakes. The model earthquakes are also truly "model" in the sense that they do not necessarily correspond to expected magnitude, likelihood of rupture, or precise location on known thrust faults. They have been chosen in part to excite various ocean basins and to present worst case conditions.

The 2D depth averaged model developed at the University of Alaska, Fairbanks (Kowalik et al., 2005) has been used to propagate the initial disturbance to all points along the US Gulf and Atlantic coasts. All computations were done on a uniform 15 second mesh, and 15 second bathymetric / elevation data was used wherever it was available (NOAA / NGDC). In regions where no data was available, bathymetry values were interpolated from the 1 minute Gebco dataset. The model space was a 40 degree square with radiation conditions applied in the open ocean and run-up conditions at the coast.

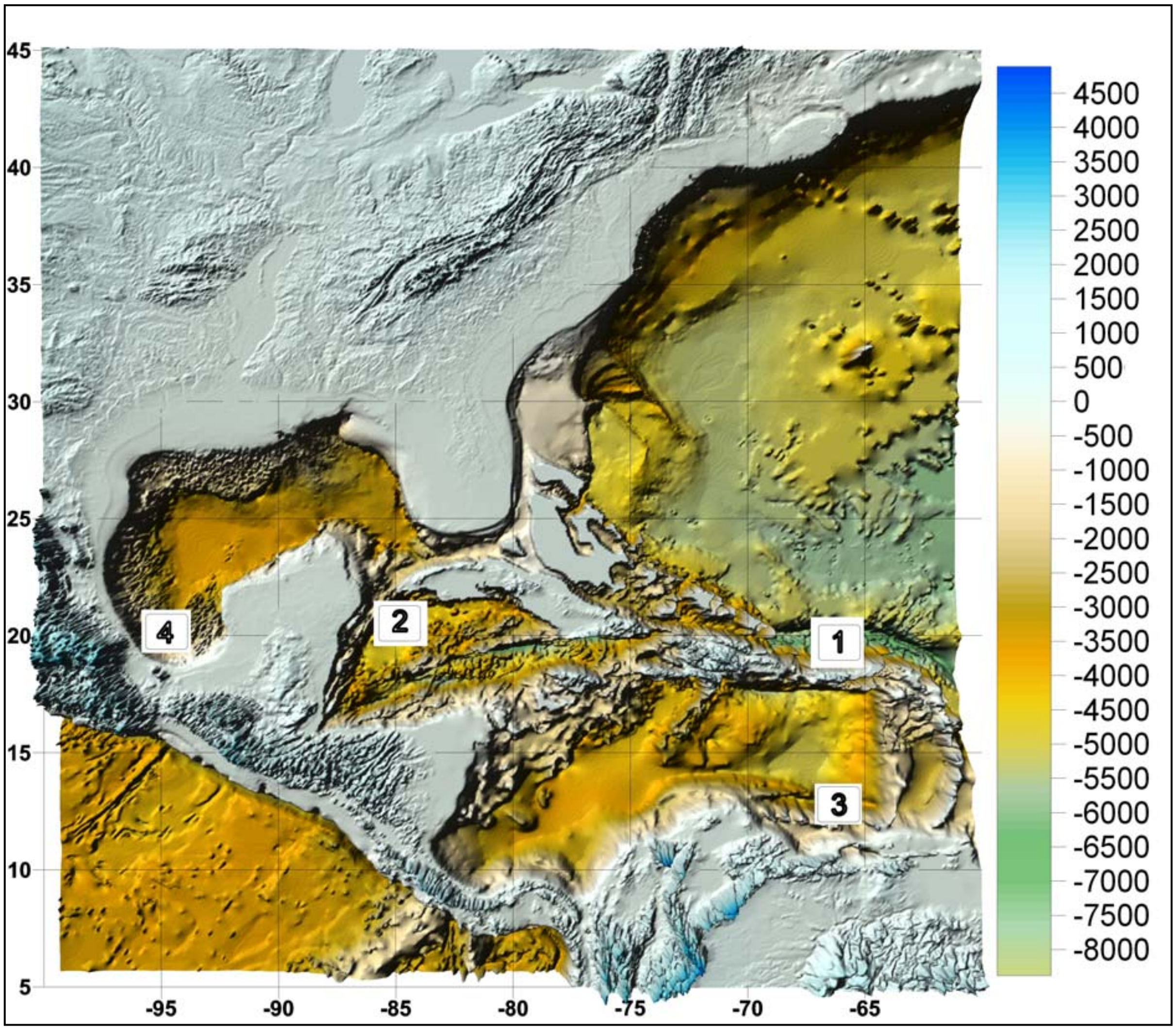
The results presented here were obtained from inspection of approximately 130 synthetic mareograms along the Gulf and Atlantic coasts generated during the model runs. The source summary is shown in Table 1. Numbers also correspond to locations on the model domain map on the following page (Fig 1).

Table I – source summary

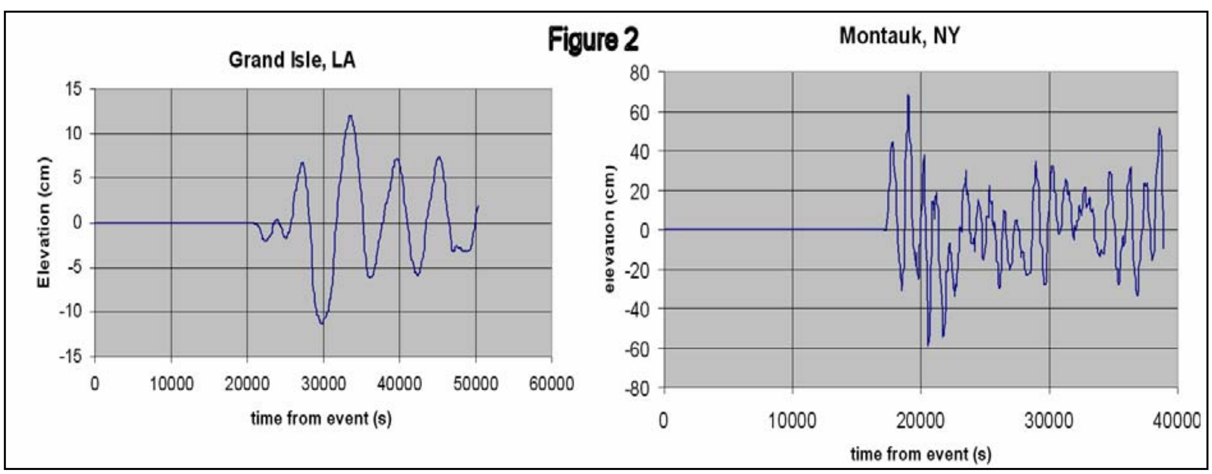
1) *Puerto Rico trench*: 66W, 18N, Mw 9.0
2) *Caribbean Sea*: 85W, 21N, Mw 8.2 – translated from the Swan fault to mouth of Gulf near Cancun
3) *North Panama Deformed Belt*: 66W, 12N, Mw 9.0
4) *Gulf of Mexico*, offshore of Veracruz: 95W, 20N, Mw 8.2 (no known credible source)

The model sources are aligned with local strike where applicable.

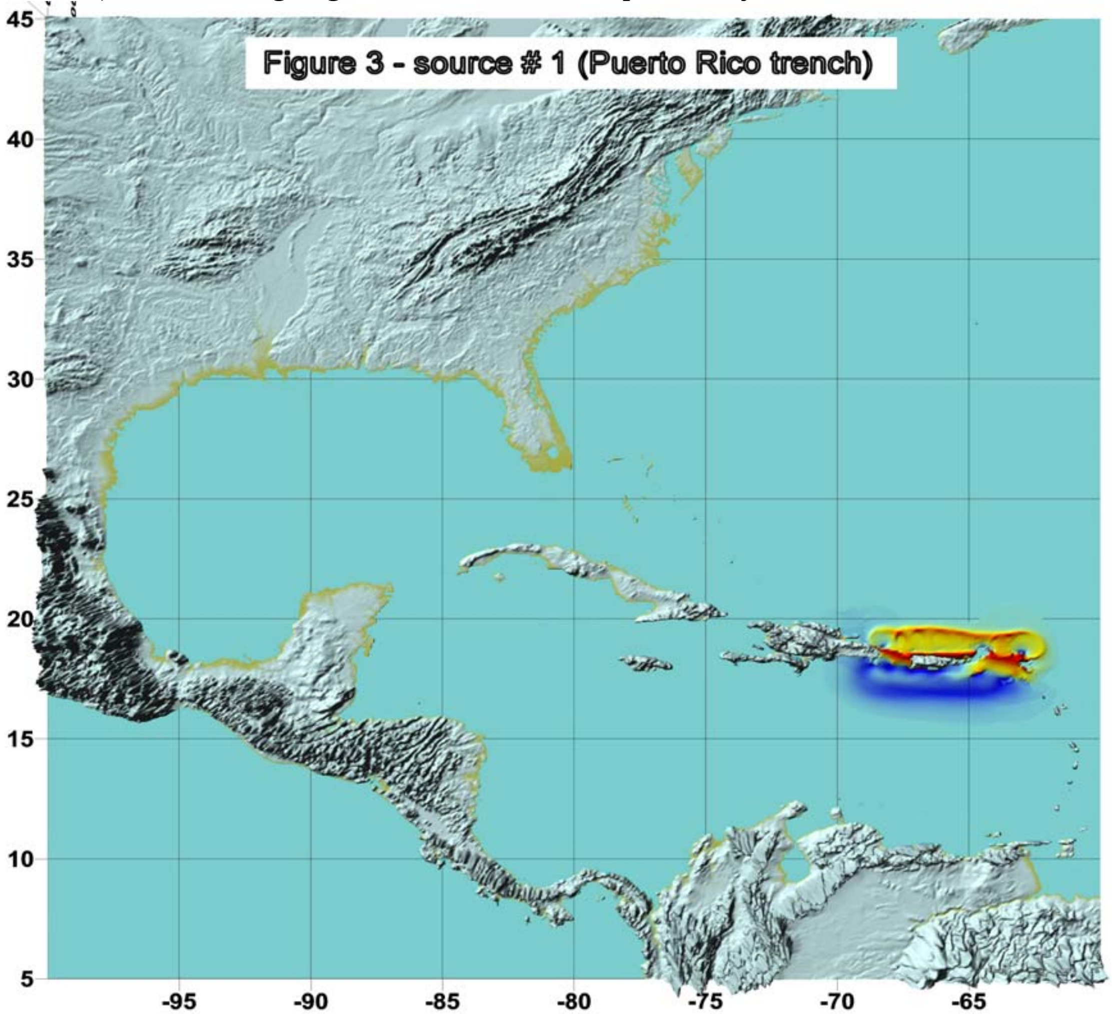
Figure I – model domain with source locations (depths and elevations in Meters)



Source #1 results and discussion:
Typical synthetic mareograms are shown below in Figure 2.



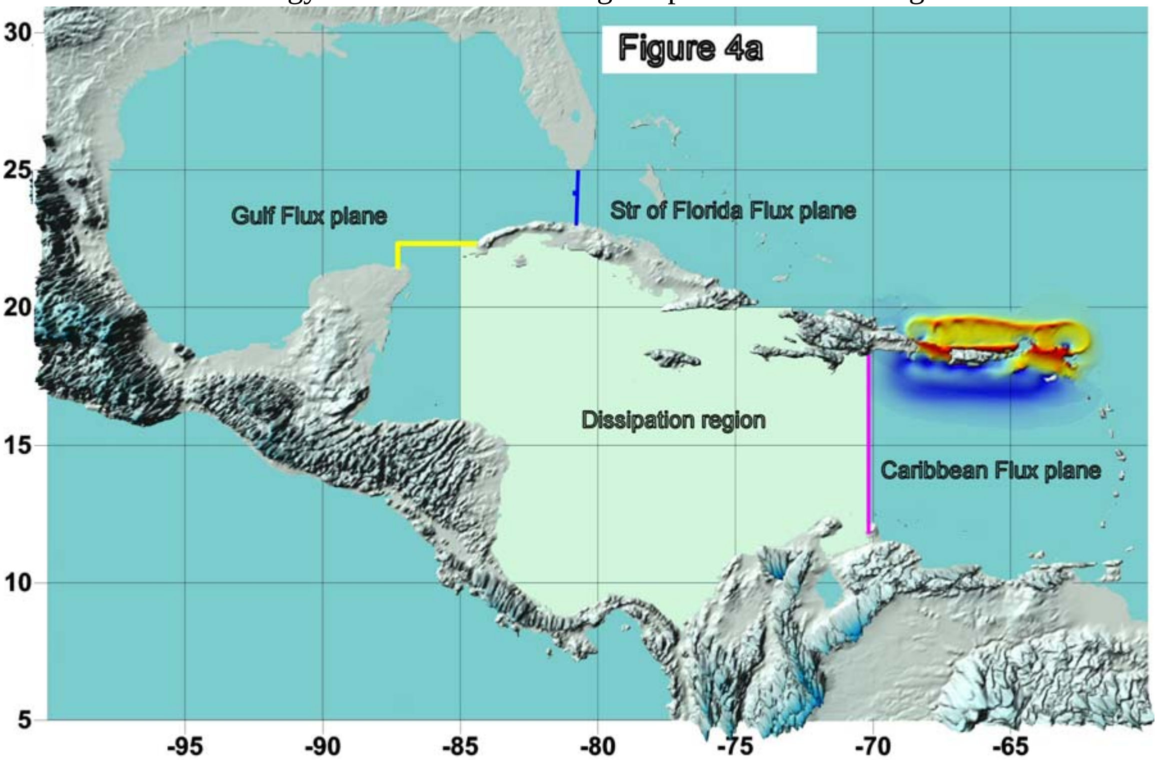
Atlantic and Gulf mareograms form distinct groups that show unique features. Gulf amplitudes are low (under 25 cm) and have leading edge depressions. Wave arrivals along the Atlantic are all leading edge elevations and the amplitudes can be higher (over 150 cm). The leading edge difference can be explained by the orientation of the source.



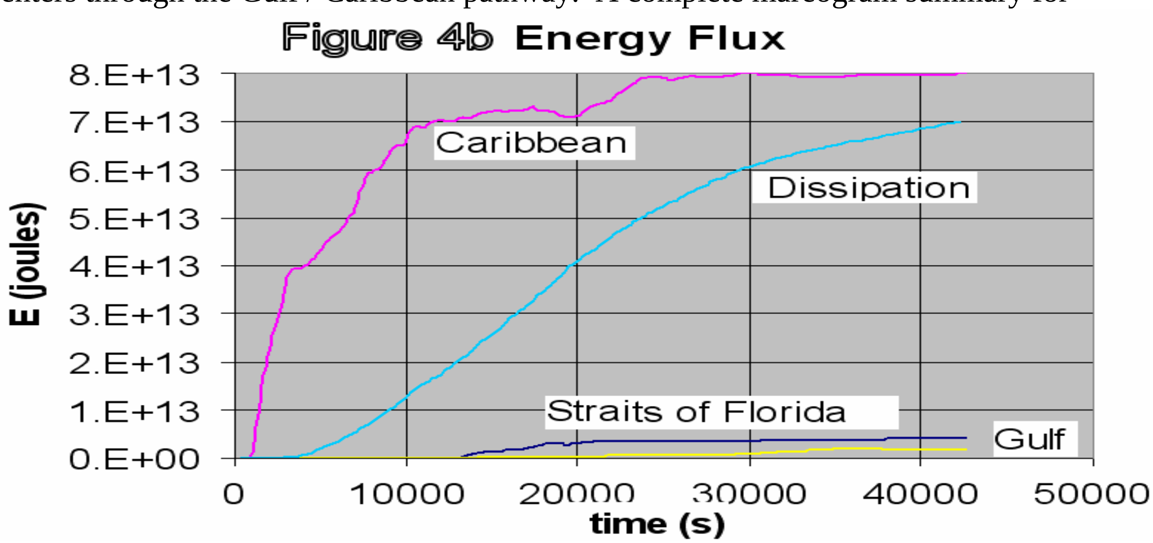
Initial uplift is dipolar as shown in figure 3 above (red is uplifted ocean, blue is down dropped).

Propagation into the Gulf takes two routes, one through the Caribbean and the other through the Straits of Florida. The Caribbean route is faster by about 1 hour, and the first impact is therefore the leading edge depression. Energy transfer into the Gulf is computed with the energy flux vector $\rho d\vec{V}(g\zeta + \frac{1}{2}V^2)$ (Kowalik & Murty, 1993). Evaluating this flux across both the Caribbean and the Straits of Florida shows that more energy moves into the Gulf through the latter pathway, even though it arrives later. This is important because the duration of wave action in the Gulf is increased and because travel times computed from first arrivals may be misleading.

Evaluation of the energy fluxes was done along the planes shown in Figure 4a below.



Energy loss was also computed in the part of the Caribbean Sea labeled "dissipation region" by integration of the bottom friction term over the region and up to time t. Results from the three flux planes along with dissipation are plotted in Figure 4b below. Energy flow into the Atlantic was about 10X larger than the energy entering the Caribbean through the magenta plane, and was not included in the plot. Note that the reduction of energy into the Gulf through the Caribbean is well explained by the dissipation curve. Flux through the Straits of Florida winds up being larger than what enters through the Gulf / Caribbean pathway. A complete mareogram summary for



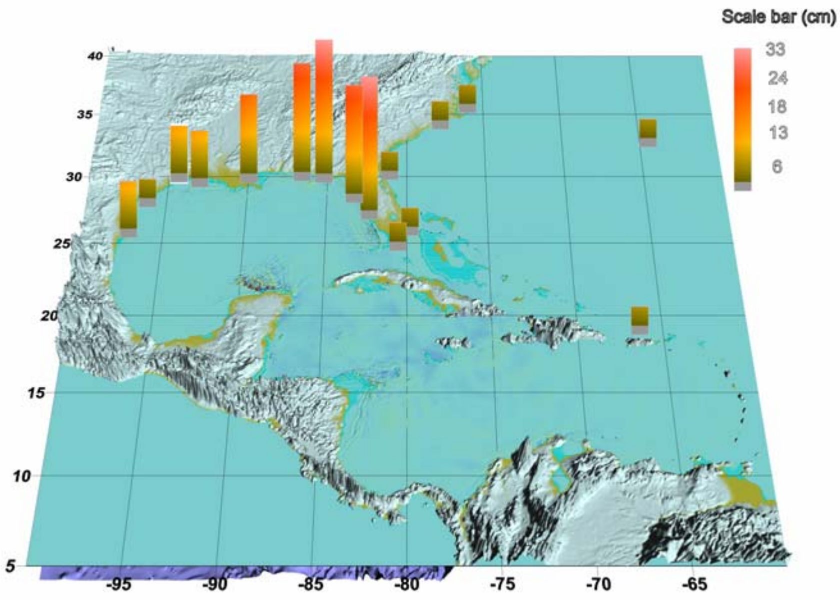
Source 1 is shown in Table 2 on the following page.

Table 2: Source 1 mareogram summary:

Location	Region	Travel Time (hr-min)	Peak Height(cm)	Initial Motion	Period (hr-min)
Brownsville_TX	Gulf	6hours 22min	4	depression	2 hours 3 min
Corpus Christi_TX	Gulf	6 hours 45 min	4	depression	1 hour18 min
Galveston_TX	Gulf	8 hours 2 min	6	depression	1 hour 58 min
High Island_TX	Gulf	8 hours 30 min	3	depression	1 hour 57 min
Eugene Island_LA	Gulf	8 hous 10 min	3	depression	1 hour 56 min
Port Fourchon_LA	Gulf	5 hours 52 min	10	depression	2 hours 3 min
Grand Isle_LA	Gulf	6 hours	12	depression	1 hour 38 min
Waveland_MS	Gulf	10 hours 36 min	1	depression	
Biloxi_MS	Gulf	8 hours 28 min	5	depression	2 hours 5 min
MS_AL Border	Gulf	9 hours 35 min	3	depression	2 hours 2 min
Destin_FL	Gulf	5 hours 38 min	7	depression	1 hour 55 min
Suwanee_FL	Gulf	8 hours 37 min	3	depression	2 hours 2 min
Panama Beach_FL	Gulf	5 hours 47 min	5	depression	1 hour 54 min
Panama City_FL	Gulf	6 hours 20 min	11	depression	2 hours 2 min
Clearwater Bc_FL	Gulf	6 hours 58 min	8	depression	1 hour 6 min
St Petersburg_FL	Gulf	7 hours 48 min	5	depression	2 hours 56 min
Tampa_FL	Gulf	8 hours 28 min	5	depression	2 hours 28 min
Port Manatee_FL	Gulf	7 hours 28 min	5	depression	1 hour 28 min
Bonita_FL	Gulf	7 hours 37 min	25	depression	1 hour 50 min
Naples_FL	Gulf	7 hours 28 min	23	depression	1 hour
Virginia Key_FL	Atlantic	2 hours 57 min	15	elevation	49 min
Ocean Reef_FL	Atlantic	3 hours 13 min	28	elevation	1 hour 40 min
Jupiter_FL	Atlantic	2 hours 47 min	54	elevation	1 hour 2 min
Flagler_FL	Atlantic	4 hours 18 min	117	elevation	1 hour 10 min
Vaca Key_FL	Atlantic	4 hours	13	elevation	1 hour 11 min
St Simons_GA	Atlantic	5 hours 30 min	40	elevation	1 hour 13 min
Altamaha_GA	Atlantic	5 hours 33 min	47	elevation	1 hour 15 min
So Santee_SC	Atlantic	4 hours 32 min	77	elevation	1 hour 22 min
Springmaid_SC	Atlantic	4 hours 57 min	129	elevation	1 hour 8 min
Charleston_SC	Atlantic	4 hours 57 min	49	elevation	1 hour 15 min
Surf City_NC	Atlantic	4 hours 23 min	112	elevation	1 hour 8 min
Beaufort_NC	Atlantic	3 hours 38 min	147	elevation	45 min
Oregon Inlet_NC	Atlantic	3 hours 45 min	38	elevation	42 min
Duck_NC	Atlantic	3 hours 57 min	140	elevation	drained
Curritruck_NC	Atlantic	4 hours 15 min	102	elevation	36 min
Chesapeake B_VA	Atlantic	7 hours 12 min	6	elevation	46 min
Annapolis_MD	Atlantic	10 hours 28 min	3	elevation	~2 hours
Cape Henlopen_DE	Atlantic	4 hours 52 min	64	elevation	42 min
Cape May_NJ	Atlantic	5 hours	68	elevation	45 min
Atlantic City_NJ	Atlantic	4 hours 45 min	155	elevation	45 min
Montauk, NY	Atlantic	4 hours 48 min	68	elevation	16 min
Bar Harbor_ME	Atlantic	5 hours 33 min	71	elevation	6 min
D41424 (32.4N, 73W)	Atlantic	1 hour 52 min	35	elevation	
D41420 (23.3N, 67.6W)	Atlantic	32 min	131	elevation	
D41421 (23.4N, 63.9W)	Atlantic	31 min	175	elevation	
D7-2 (38.6N, 68 W)	Atlantic	2 hours 10 min	78	elevation	
D42407 (23.4N, 63.9W)	Caribbean	10 min	-61	depression	
D8-1 (25.4N, 86.8W)	Gulf	3 hours 27 min	-2	depression	
Bermuda	Atlantic	1 hour 57 min	511	elevation	12 min
Limetree_StCroix	Caribbean	1 min	240	depression	15 min
Punta_Guayanilla	Caribbean	0 min	173	elevation	21 min

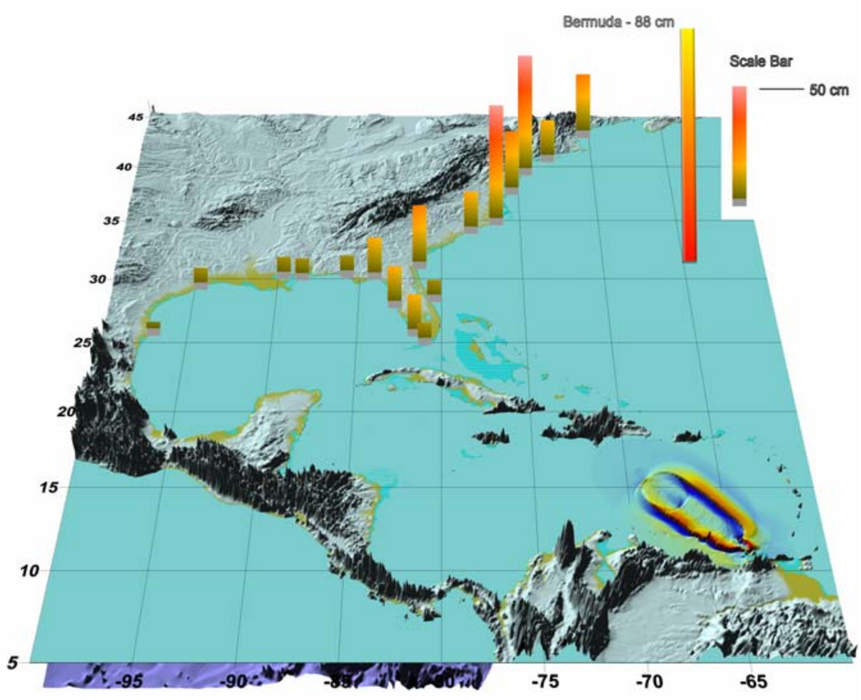
Source2-4 results:
The remaining source mareograms are presented qualitatively as indicator plots.

Source 2 –mareogram summary (source in Caribbean Sea near Cancun)



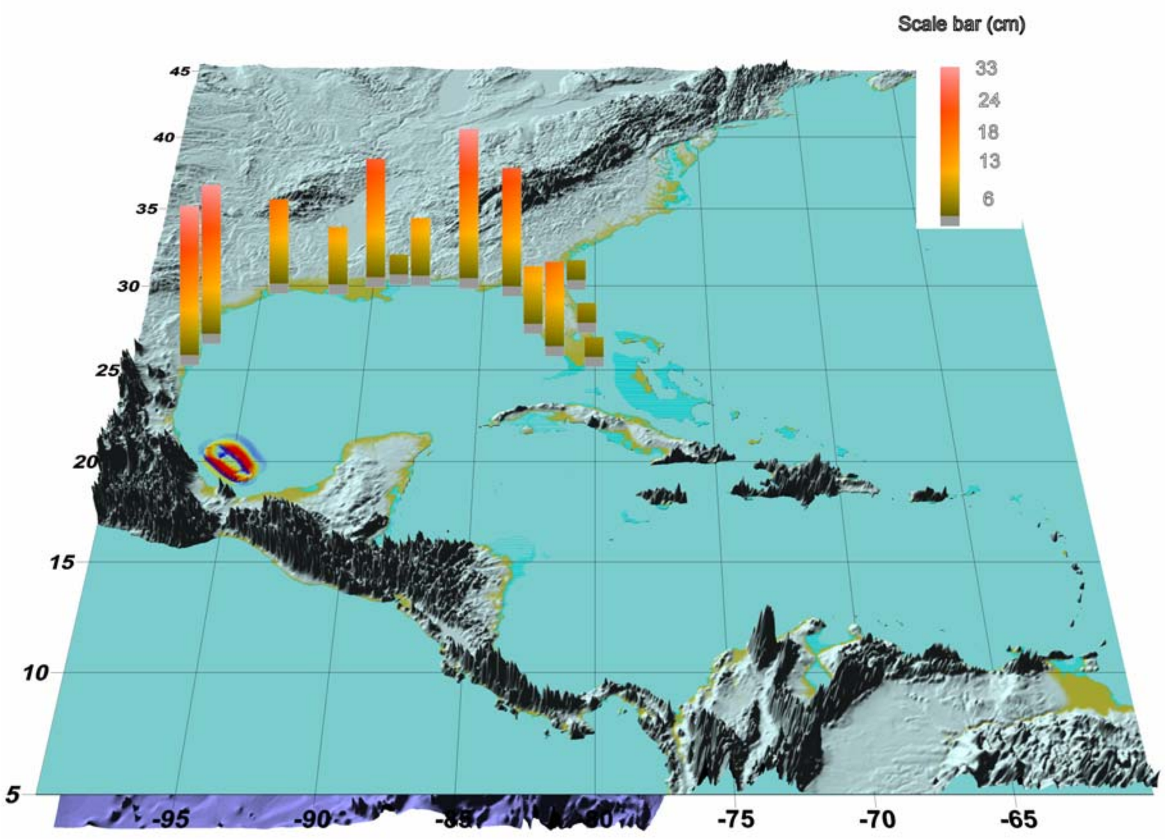
Note that the Gulf amplitudes are all under 30 cm, reflecting in part the fact that significant wave energy is lost to bottom friction in the Caribbean Sea.

Source 3 mareogram summary (source near Venezuela)



The largest Atlantic coast amplitudes are under 50 cm, with the Gulf coast run-ups reduced from these values to a maximum of 15 cm. The wave energy is well dissipated by bottom friction and spread in time by multiple reflections in the Caribbean, resulting in lower than expected amplitudes both on the Gulf and the Atlantic coasts.

Source 4 mareogram summary (Gulf source near Veracruz).
Note the amplitudes are all under 35 cm, and there is very little leakage of wave energy into the Atlantic.



SUMMARY

The Atlantic and Gulf coasts are nearly independent since the hydrodynamic connection between basins is through the narrow Straits of Florida and through the Caribbean, where bottom friction losses appear to be large. Sources outside the Gulf are not expected to create a tsunami threatening to the Gulf coast. Thus the Gulf coast would not need to be included in a warning for a non-Gulf source (unless a Gulf DART buoy records an unexpected large amplitude wave). For Atlantic sources, warnings could be issued for the Atlantic coast alone. Both Gulf and Atlantic coasts appeared to be well shielded from the large model Caribbean source. This would argue for warnings to be issued only with extreme caution for this source region.

The Puerto Rico trench source is the most threatening of the modeled scenarios, but even here, the Gulf should not need to be placed in a warning. The short travel time to Atlantic DART buoys, along with the large amplitude signal and short travel time to Bermuda should provide timely check points for a possible expansion of a tsunami warning to the northern Atlantic states.

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Kowalik, Z, Knight, W., Logan, T., and Whitmore, P.: 2005, NUMERICAL MODELING OF THE GLOBAL TSUNAMI: Indonesian Tsunami of 26 December 2004. *Science of Tsunami Hazards*, 23(1), 40-56

Kowalik, Z. and Murty, T.S.: 1993, *Numerical Modeling of Ocean Dynamics*, World Scientific

http://www.ngdc.noaa.gov/mgg/coastal/coastal.html (download site for US coastal bathymetry and elevation)